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The System Administrator's Guide documents relevant information regarding the deployment, configuration, and administration of Fedora 18. It is oriented towards system administrators with a basic understanding of the system.
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D.2. Directories in the /etc/sysconfig/ Directory
The System Administrator's Guide contains information on how to customize the Fedora 18 system to fit your needs. If you are looking for a comprehensive, task-oriented guide for configuring and customizing your system, this is the manual for you.

This manual discusses many intermediate topics such as the following:

- Installing and managing packages using the graphical PackageKit and command line Yum package managers
- Setting up a network—from establishing an Ethernet connection using NetworkManager to configuring channel bonding interfaces to increase server bandwidth
- Configuring DHCP, BIND, Apache HTTP Server, Postfix, Sendmail and other enterprise-class servers and software
- Gathering information about your system, including obtaining user-space crash data with the Automatic Bug
Reporting Tool, and kernel-space crash data with kdump

Easily working with kernel modules and upgrading the kernel

1. Target Audience
The Deployment Guide assumes you have a basic understanding of the Fedora operating system. If you need help with the installation of this system, refer to the Fedora 18 Installation Guide.

2. How to Read this Book
This manual is divided into the following main categories:

Part I, “Basic System Configuration”
This part covers basic system administration tasks such as keyboard configuration, date and time configuration, installation and initial setup of an NTP server, and managing users and groups.

Chapter 1, Configuring the Language and Keyboard covers basic language and keyboard setup. Read this chapter if you need to configure the language of your desktop, change the keyboard layout, or add the keyboard layout indicator to the panel.

Chapter 2, Configuring the Date and Time covers the configuration of the system date and time. Read this chapter if you need to set or change the date and time.

Chapter 3, Configuring NTP Using the chrony Suite covers the installation and configuration of the chrony suite, a client and a server for the Network Time Protocol (NTP). Read this chapter if you need to configure the system to synchronize the clock with a remote NTP server, or set up an NTP server on this system.

Chapter 4, Managing Users and Groups covers the management of users and groups in a graphical user interface and on the command line. Read this chapter if you need to manage users and groups on your system, or enable password aging.

Part II, “Package Management”
This part describes how to manage software packages on Fedora using both Yum and the PackageKit suite of graphical package management tools.

Chapter 5, Yum describes the Yum package manager. Read this chapter for information how to search, install, update, and uninstall packages on the command line.

Chapter 6, PackageKit describes the PackageKit suite of graphical package management tools. Read this chapter for information how to search, install, update, and uninstall packages using a graphical user interface.

Part III, “Networking”
This part describes how to configure the network on Fedora.

Chapter 7, NetworkManager focuses on NetworkManager, a dynamic network control and configuration system that attempts to keep network devices and connections up and active when they are available. Read this chapter for information how to run the NetworkManager daemon, and how to interact with it using the corresponding applet for the notification area.

Chapter 8, Network Interfaces explores various interface configuration files, interface control scripts, and network function files located in the /etc/sysconfig/network-scripts/ directory. Read this chapter for information how to use these files to configure network interfaces.

Part IV, “Infrastructure Services”
This part provides information how to configure services and daemons, configure authentication, and enable remote logins.

Chapter 9, Services and Daemons covers the configuration of the services to be run when a system is started, and provides information on how to start, stop, and restart the services on the command line using the systemctl utility.

Chapter 10, Configuring Authentication describes how to configure user information retrieval from Lightweight Directory Access Protocol (LDAP), Network Information Service (NIS), and Winbind user account databases, and provides an introduction to the System Security Services Daemon (SSSD). Read this chapter if you need to configure authentication on your system.

Chapter 11, OpenSSH describes how to enable a remote login via the SSH protocol. It covers the configuration of the ssdh service, as well as a basic usage of the ssh, scp, sftp client utilities. Read this chapter if you need a remote access to a machine.

Part V, “Servers”
This part discusses various topics related to servers such as how to set up a Web server or share files and directories over the network.

Chapter 12, DHCP Servers guides you through the installation of a Dynamic Host Configuration Protocol (DHCP) server and client. Read this chapter if you need to configure DHCP on your system.

Chapter 13, DNS Servers introduces you to Domain Name System (DNS), explains how to install, configure, run, and administer the BIND DNS server. Read this chapter if you need to configure a DNS server on your system.

Chapter 14, Web Server focuses on the Apache HTTP Server 2.2, a robust, full-featured open source web server developed by the Apache Software Foundation. Read this chapter if you need to configure a web server on your system.
Chapter 15, Mail Servers reviews modern email protocols in use today, and some of the programs designed to send and receive email, including Postfix, Sendmail, Fetchmail, and Procmail. Read this chapter if you need to configure a mail server on your system.

Chapter 16, Directory Servers covers the installation and configuration of OpenLDAP 2.4, an open source implementation of the LDAPv2 and LDAPv3 protocols. Read this chapter if you need to configure a directory server on your system.

Chapter 17, File and Print Servers guides you through the installation and configuration of Samba, an open source implementation of the Server Message Block (SMB) protocol, and vsftpd, the primary FTP server shipped with Fedora. Additionally, it explains how to use the Printer Configuration tool to configure printers. Read this chapter if you need to configure a file or print server on your system.

Part VI, "Monitoring and Automation"

This part describes various tools that allow system administrators to monitor system performance, automate system tasks, and report bugs.

Chapter 18, System Monitoring Tools discusses applications and commands that can be used to retrieve important information about the system. Read this chapter to learn how to gather essential system information.

Chapter 19, Viewing and Managing Log Files describes the configuration of the rsyslog daemon, and explains how to locate, view, and monitor log files. Read this chapter to learn how to work with log files.

Chapter 20, Automating System Tasks provides an overview of the cron, at, and batch utilities. Read this chapter to learn how to use these utilities to perform automated tasks.

Chapter 21, Automatic Bug Reporting Tool (ABRT) concentrates on ABRT, a system service and a set of tools to collect crash data and send a report to the relevant issue tracker. Read this chapter to learn how to use ABRT on your system.

Chapter 22, OProfile covers OProfile, a low overhead, system-wide performance monitoring tool. Read this chapter for information on how to use OProfile on your system.

Part VII, "Kernel, Module and Driver Configuration"

This part covers various tools that assist administrators with kernel customization.

Chapter 23, Manually Upgrading the Kernel provides important information on how to manually update a kernel package using the rpm command instead of yum. Read this chapter if you cannot update a kernel package with the yum package manager.

Chapter 24, Working with Kernel Modules explains how to display, query, load, and unload kernel modules and their dependencies, and how to set module parameters. Additionally, it covers specific kernel module capabilities such as using multiple Ethernet cards and using channel bonding. Read this chapter if you need to work with kernel modules.

Chapter 25, The kdump Crash Recovery Service explains how to configure, test, and use the kdump service in Fedora, and provides a brief overview of how to analyze the resulting core dump using the crash debugging utility. Read this chapter to learn how to enable kdump on your system.

Appendix A, Consistent Network Device Naming

This appendix covers consistent network device naming for network interfaces, a feature that changes the name of network interfaces on a system in order to make locating and differentiating the interfaces easier. Read this appendix to learn more about this feature and how to enable or disable it.

Appendix B, RPM

This appendix concentrates on the RPM Package Manager (RPM), an open packaging system used by Fedora, and the use of the rpm utility. Read this appendix if you need to use rpm instead of yum.

Appendix C, The X Window System

This appendix covers the configuration of the X Window System, the graphical environment used by Fedora. Read this appendix if you need to adjust the configuration of your X Window System.

Appendix D, The sysconfig Directory

This appendix outlines some of the files and directories located in the /etc/sysconfig/ directory. Read this appendix if you want to learn more about these files and directories, their function, and their contents.

Appendix E, The proc File System

This appendix explains the concept of a virtual file system, and describes some of the top-level files and directories within the proc file system (that is, the /proc/ directory). Read this appendix if you want to learn more about this file system.

3. Document Conventions

This manual uses several conventions to highlight certain words and phrases and draw attention to specific pieces of information.

In PDF and paper editions, this manual uses typefaces drawn from the Liberation Fonts set. The Liberation Fonts set is also used in HTML editions if the set is installed on your system. If not, alternative but equivalent typefaces are displayed. Note: Red Hat Enterprise Linux 5 and later includes the Liberation Fonts set by default.
3.1. Typographic Conventions

Four typographic conventions are used to call attention to specific words and phrases. These conventions, and the circumstances they apply to, are as follows.

**Mono-spaced Bold**

Used to highlight system input, including shell commands, file names and paths. Also used to highlight keycaps and key combinations. For example:

To see the contents of the file `my_next_bestselling_novel` in your current working directory, enter the `cat my_next_bestselling_novel` command at the shell prompt and press `Enter` to execute the command.

The above includes a file name, a shell command and a keycap, all presented in mono-spaced bold and all distinguishable thanks to context.

Key combinations can be distinguished from keycaps by the hyphen connecting each part of a key combination. For example:

Press `Enter` to execute the command.

Press `Ctrl+Alt+F2` to switch to the first virtual terminal. Press `Ctrl+Alt+F1` to return to your X-Windows session.

The first paragraph highlights the particular keycap to press. The second highlights two key combinations (each a set of three keycaps with each set pressed simultaneously).

If source code is discussed, class names, methods, functions, variable names and returned values mentioned within a paragraph will be presented as above, in *mono-spaced bold*. For example:

File-related classes include `<filesystem>` for file systems, `<file>` for files, and `<dir>` for directories. Each class has its own associated set of permissions.

**Proportional Bold**

This denotes words or phrases encountered on a system, including application names; dialog box text; labeled buttons; check-box and radio button labels; menu titles and sub-menu titles. For example:

Choose `System → Preferences → Mouse` from the main menu bar to launch `Mouse Preferences`. In the `Buttons` tab, click the `Left-handed mouse` check box and click `Close` to switch the primary mouse button from the left to the right (making the mouse suitable for use in the left hand).

To insert a special character into a `<gedit>` file, choose `Applications → Accessories → Character Map` from the main menu bar. Next, choose `Search → Find…` from the `Character Map` menu bar, type the name of the character in the `Search` field and click `Next`. The character you sought will be highlighted in the `Character Table`. Double-click this highlighted character to place it in the `Text to copy` field and then click the `Copy` button. Now switch back to your document and choose `Edit → Paste` from the `gedit` menu bar.

The above text includes application names; system-wide menu names and items; application-specific menu names; and buttons and text found within a GUI interface, all presented in proportional bold and all distinguishable by context.

**Mono-spaced Bold Italic** or **Proportional Bold Italic**

Whether mono-spaced bold or proportional bold, the addition of italics indicates replaceable or variable text. Italics denotes text you do not input literally or displayed text that changes depending on circumstance. For example:

To connect to a remote machine using ssh, type `ssh username@domain.name` at a shell prompt. If the remote machine is `example.com` and your username on that machine is john, type `ssh john@example.com`.

The `mount -o remount file-system` command remounts the named file system. For example, to remount the `/home` file system, the command is `mount -o remount /home`.

To see the version of a currently installed package, use the `rpm -q package` command. It will return a result as follows: `package-version-release`.

Note the words in bold italics above — `username`, `domain.name`, `file-system`, `package`, `version` and `release`. Each word is a placeholder, either for text you enter when issuing a command or for text displayed by the system.

Aside from standard usage for presenting the title of a work, italics denotes the first use of a new and important term. For example:

Publican is a DocBook publishing system.

3.2. Pull-quote Conventions

Terminal output and source code listings are set off visually from the surrounding text.

Output sent to a terminal is set in *mono-spaced roman* and presented thus:

```
books   Desktop   documentation drafts  mss   photos   stuff   svn
books_tests Desktop1 downloads  images   notes   scripts  svgs
```

Source-code listings are also set in *mono-spaced roman* but add syntax highlighting as follows:
package org.jboss.book.jca.ex1;

import javax.naming.InitialContext;

public class ExClient {
    public static void main(String args[])
            throws Exception {
        InitialContext iniCtx = new InitialContext();
        Object ref = iniCtx.lookup("EchoBean");
        EchoHome home = (EchoHome) ref;
        Echo echo = home.create();
        System.out.println("Created Echo");
        System.out.println("Echo.echo('Hello') = " + echo.echo("Hello"));
    }
}

3.3. Notes and Warnings

Finally, we use three visual styles to draw attention to information that might otherwise be overlooked.

*Note*

Notes are tips, shortcuts or alternative approaches to the task at hand. Ignoring a note should have no negative consequences, but you might miss out on a trick that makes your life easier.

*Important*

Important boxes detail things that are easily missed: configuration changes that only apply to the current session, or services that need restarting before an update will apply. Ignoring a box labeled 'Important' will not cause data loss but may cause irritation and frustration.

*Warning*

Warnings should not be ignored. Ignoring warnings will most likely cause data loss.

4. We Need Feedback!

If you find a typographical error in this manual, or if you have thought of a way to make this manual better, we would love to hear from you! Please submit a report in Bugzilla: https://bugzilla.redhat.com/enter_bug.cgi?product=Fedora

Documentation&component=system-administrator's-guide

If you have a suggestion for improving the documentation, try to be as specific as possible when describing it. If you have found an error, please include the section number and some of the surrounding text so we can find it easily.

5. Acknowledgments

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Part I. Basic System Configuration

This part covers basic system administration tasks such as keyboard configuration, date and time configuration, installation and initial setup of an NTP server, and managing users and groups.

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2. Configuring the Date and Time
Chapter 1. Configuring the Language and Keyboard

1.1. Changing the Language
1.2. Changing the Date, Time, and Numeric Format

1.3. Changing the Keyboard Layout

1.4. Viewing the Current Configuration

Fedora 18 is shipped with the Region and Language configuration tool, which allows you to configure keyboard layouts, the language of your desktop environment, and other regional settings. To start the tool, open the System Settings window by selecting Applications → System Tools → System Settings from the Activities menu, and click Region and Language.

1.1. Changing the Language

To configure the language of your desktop, select the Language tab of the Region and Language application. You will be presented with a short list of common languages.

![Figure 1.1. Changing the language](image)

By default, this list only contains a few of the available languages. To add another language, click the + (the plus sign) button below the list. A dialog window appears, allowing you to select the desired language. The input field at the bottom part of the dialog window allows you to reduce the number of displayed items by first few letters part of the language name in it (for example, “slov” for the Slovak language). Once you select a language, click the Select button to confirm your choice.
To choose a particular language from the list, click its name to select it. The changes will take effect the next time you log in to the system.

1.2. Changing the Date, Time, and Numeric Format

To change the default date, time, number, and currency format, select the Formats tab of the Region and Language application. You will be presented with a short list of available formats.

By default, this list only contains a few of the available formats. To add another format, click the + (the plus sign) button below the list. A dialog window appears, allowing you to select the desired format according to a region. The input field at the bottom part of the dialog window allows you to reduce the number of displayed items by typing first few letters of the region name in it (for example, “slov” for Slovakia). Once you select a region, click the Select button to confirm your choice.
To choose a particular format from the list, click its name to select it. The changes will take effect the next time you log in to the system.

1.3. Changing the Keyboard Layout

Although the installation program allows a system administrator to configure a keyboard layout during the system installation, the default settings may not always suit your current needs. To change the default keyboard layout, select the Layouts tab of the Region and Language application. You will be presented with a list of currently enabled layouts.

To add a layout to the list, click the + (the plus sign) button below the list. A dialog window appears, allowing you to select the desired keyboard layout. The input field at the bottom part of the dialog window allows you to reduce the number of displayed items by typing first few letters of the layout name in it (for example, “slov” for a Slovak layout). Once you select a layout, click the Add button to confirm your choice.
The first layout in the list is always considered the default. To move a particular layout up or down in the list, select it and click the ↑ (the upwards arrow) or ↓ (the downwards arrow) buttons respectively. To remove a layout, click the − (that is, the minus sign) button. Additionally, by selecting an option button on the right side of the window, you can choose if you want to use different keyboard layouts for individual windows, or a single layout for all windows.

When more than one layout is enabled, a keyboard indicator appears on the panel in order to allow you to switch between the layouts.

To view the current configuration, select the System tab of the Region and Language application. You will be presented with a comparison of your own configuration and system-wide settings.
Chapter 2. Configuring the Date and Time

2.1. Using the Date and Time Configuration Tool

2.2. Using the Command Line Tools

2.2.1. Changing the Date

2.3. Additional Resources

2.3.1. Installed Documentation

This chapter covers setting the system date and time in Fedora, both manually and using the Network Time Protocol (NTP), as well as setting the adequate time zone. Two methods are covered: setting the date and time using the Date and Time configuration tool, and doing so on the command line.

2.1. Using the Date and Time Configuration Tool

Fedora 18 is shipped with the Date and Time configuration tool, which allows you to change the date and time of the system, to configure the time zone used by the system, and to set up the Network Time Protocol daemon to synchronize the system clock with a time server. To start the tool, either select Applications → System Tools → System Settings from the Activities menu and click the Date and Time icon, or click the time in the panel and select Date and Time Settings from the drop-down menu.
By default, the tool only allows you to review the current settings. This is because only root is allowed to set the system date and time. To unlock the configuration tool for changes, click the Unlock button in the top-right corner of the window, and provide the correct password when prompted.

To change the current time of your system, either configure the system to synchronize it over the network by clicking the Network Time switch, or set it manually by clicking the up and down arrows above and below the numbers. You can also select 24-hour or AM/PM to enable or disable the 24-hour time format.

To change the time zone, either click on the map, or select the region and city from the Region and City drop-down lists.

To change the current date of your system, select a month from the drop-down list below the time, and use the up and down arrows to choose the day and year.

The changes take effect immediately.

2.2. Using the Command Line Tools
Fedora 18 provides command line tools that allow you to configure the date and time both manually and using the NTP protocol.

2.2.1. Changing the Date
To change the system date, type the following at a shell prompt as root:

```
  date +%D -s YYYY-MM-DD
```

…where YYYY is a four-digit year, MM is a two-digit month, and DD is a two-digit day of the month. For example, to change the date to 2 June 2010, type:

```
  -]# date +%D -s 2010-06-02
```

You can verify the current settings by running `date` without any additional argument.

2.3. Additional Resources
For more information about the date and time configuration, refer to the following resources.

2.3.1. Installed Documentation

  > `date(1)` — The manual page for the date utility.

Chapter 3. Configuring NTP Using the chrony Suite

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3.6. Additional Resources

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Accurate time keeping is important for a number of reasons in IT. In networking for example, accurate time stamps in packets and logs are required. In Linux systems, the NTP protocol is implemented by a daemon running in user space.

The user space daemon updates the system clock running in the kernel. The system clock can keep time by using various clock sources. Usually, the Time Stamp Counter (TSC) is used. The TSC is a CPU register which counts the number of cycles since it was last reset. It is very fast, has a high resolution, and there are no interrupts.

There is a choice between the daemons ntpd and chronyd, which are available from the repos in the ntp and chrony packages respectively. This section describes the use of the chrony suite of utilities to update the daemon on systems that do not fit into the conventional permanently networked, always on, dedicated server category.

### 3.1. Introduction to the chrony Suite

Chrony consists of chronyd, a daemon that runs in user space, and chronyc, a command line program for making adjustments to chronyd. Systems which are not permanently connected, or not permanently powered up, take a relatively long time to adjust their system clocks using the NTP time protocol. This is because many small corrections are made based on observations of the clocks drift and offset. Temperature changes, which may be significant when powering up a system, affect the stability of hardware clocks. Although adjustments begin within a few milliseconds of booting a system, acceptable accuracy may take anything from ten seconds from a warm restart to a number of hours depending on your requirements, operating environment and hardware. chrony is a different implementation of the NTP protocol than ntpd, it can adjust the system clock more rapidly.

#### 3.1.1. Differences Between ntpd and chronyd

One of the main differences between ntpd and chronyd is in the algorithms used to control the computer's clock. Things chronyd can do better than ntpd are:

- chronyd can work well when external time references are only intermittently accessible whereas ntpd needs regular polling of time reference to work well.
- chronyd can perform well even when the network is congested for longer periods of time.
- chronyd can usually synchronise the clock faster and with better accuracy.
- chronyd quickly adapts to sudden changes in the rate of the clock, for example, due to changes in the temperature of the crystal oscillator, whereas ntpd may need a long time to settle down again.
- chronyd in the default configuration never steps the time, in order not to upset other running programs. ntpd can be configured to never step the time too, but it has to use a different means of adjusting the clock, which has some disadvantages.
- chronyd can adjust the rate of the clock on a Linux system in a larger range, which allows it to operate even on machines with a broken or unstable clock. For example, on some virtual machines.

Things chronyd can do that ntpd cannot do:

- chronyd provides support for isolated networks where the only method of time correction is manual entry. For example, by the administrator looking at a clock. chronyd can look at the errors corrected at different updates to estimate the rate at which the computer gains or loses time, and use this estimate to trim the computer clock subsequently.
- chronyd provides support to work out the rate of gain or loss of the real-time clock, the hardware clock, that maintains the time when the computer is turned off. It can use this data when the system boots to set the system time using an adjusted value of the time taken from the real-time clock. This is, at time of writing, only available in Linux.

Things ntpd can do that chronyd cannot do:

- ntpd fully supports NTP version 4 (RFC5905), including broadcast, multicast, manycast clients and servers, and the orphan mode. It also supports extra authentication schemes based on public-key cryptography (RFC5906). chronyd uses NTP version 3 (RFC1305), which is compatible with version 4.
- ntpd includes drivers for many reference clocks whereas chronyd relies on other programs, for example gpsd, to access the data from the reference clocks.

### 3.2. Understanding chrony and Its Configuration

#### 3.2.1. Understanding chronyd

The chronyd daemon, chronyd, running in user space, makes adjustments to the system clock which is running in the kernel. It does this by consulting external time sources, using the NTP protocol, when ever network access allows it to do so. When external references are not available, chronyd will use the last calculated drift stored in the drift file. It can also be commanded manually to make corrections, by chronyc.

#### 3.2.2. Understanding chronyc
The `chrony` daemon, `chronyd`, can be controlled by the command line utility `chronyc`. This utility provides a command prompt which allows entering of a number of commands to make changes to `chronyd`. The default configuration is for `chronyd` to only accept commands from a local instance of `chronyc`, but `chronyc` can be used to alter the configuration so that `chronyd` will allow external control. That is to say, `chronyc` can be run remotely after first configuring `chronyd` to accept remote connections. The IP addresses allowed to connect to `chronyd` should be tightly controlled.

### 3.2.3. Understanding the chrony Configuration Commands

`chrony`'s default config file is `/etc/chrony.conf`. The `-f` option can be used to specify an alternate config file path. Refer to the `chronyd` man page for further options. We present here a selection of configuration options. For a complete list of the directives that can be used see [http://chrony.tuxfamily.org/manual.html#Configuration-file](http://chrony.tuxfamily.org/manual.html#Configuration-file)

#### Comments

Comments should be preceded by `#`, `%`, `;` or `!`

#### allow

Optionally specify a host, subnet, or network from which to allow NTP connections to a machine acting as NTP server. The default is not to allow connections.

**Examples:**

1. `allow server1.example.com`
   
   Use this form to specify a particular host, by its host name, to be allowed access.

2. `allow 192.0.2.0/24`
   
   Use this form to specify a particular network to be allowed access.

3. `allow 2001:db8::/32`
   
   Use this form to specify an IPv6 address to be allowed access.

#### cmdallow

This is similar to the `allow` directive (see section allow), except that it allows control access (rather than NTP client access) to a particular subnet or host. (By “control access” is meant that `chronyc` can be run on those hosts and successfully connect to `chronyd` on this computer.) The syntax is identical. There is also a `cmddeny` all directive with similar behaviour to the `cmdallow` all directive.

#### dumpdir

Path to the directory to save the measurement history across restarts of `chronyd` (assuming no changes are made to the system clock behaviour whilst it is not running). If this capability is to be used (via the `dumponexit` command in the configuration file, or the `dump` command in `chronyc`), the `dumpdir` command should be used to define the directory where the measurement histories are saved.

#### dumponexit

If this command is present, it indicates that `chronyd` should save the measurement history for each of its time sources recorded whenever the program exits. (See the `dumpdir` command above)

#### local

The `local` keyword is used to allow `chronyd` to appear synchronized to real time (from the viewpoint of clients polling it), even if it has no current synchronization source. This option is normally used on computers in an isolated network, where several computers are required to synchronize to one other, this being the “master” which is kept vaguely in line with real time by manual input.

An example of the command is:

```plaintext
local stratum 10
```

A large value of 10 indicates that the clock is so many hops away from a reference clock that its time is fairly unreliable. Put another way, if the computer ever has access to another computer which is ultimately synchronized to a reference clock, it will almost certainly be at a stratum less than 10. Therefore, the choice of a high value like 10 for the `local` command prevents the machine’s own time from ever being confused with real time, were it ever to leak out to clients that have visibility of real servers.

#### log

The `log` command indicates that certain information is to be logged. It accepts the following options:

- **measurements**
  
  This option logs the raw NTP measurements and related information to a file called `measurements.log`.

- **statistics**
  
  This option logs information about the regression processing to a file called `statistics.log`.

- **tracking**
  
  This option logs changes to the estimate of the system’s gain or loss rate, and any slews made, to a file called `tracking.log`.
rtc
This option logs information about the system’s real-time clock.

refclocks
This option logs the raw and filtered reference clock measurements to a file called refclocks.log.

tempcomp
This option logs the temperature measurements and system rate compensations to a file called tempcomp.log.

refclocks
This option logs the raw and filtered reference clock measurements to a file called refclocks.log.

refclocks
This option logs the raw and filtered reference clock measurements to a file called refclocks.log.

The files are written to the directory specified by the logdir command. An example of the command is:

```
log measurements statistics tracking
```

logdir
This directive allows the directory where log files are written to be specified. An example of the use of this directive is:

```
logdir /var/log/chrony
```

makestep
Normally chronyd will cause the system to gradually correct any time offset, by slowing down or speeding up the clock as required. In certain situations, the system clock may be so far adrift that this slewing process would take a very long time to correct the system clock. This directive forces chronyd to step system clock if the adjustment is larger than a threshold value, but only if there were no more clock updates since chronyd was started than a specified limit (a negative value can be used to disable the limit). This is particularly useful when using reference clocks, because the initstepslew directive only works with NTP sources.

An example of the use of this directive is:

```
makestep 1000 10
```
This would step the system clock if the adjustment is larger than 1000 seconds, but only in the first ten clock updates.

maxchange
This directive sets the maximum allowed offset corrected on a clock update. The check is performed only after the specified number of updates to allow a large initial adjustment of the system clock. When an offset larger than the specified maximum occurs, it will be ignored for the specified number of times and then chronyd will give up and exit (a negative value can be used to never exit). In both cases a message is sent to syslog.

An example of the use of this directive is:

```
maxchange 1000 1 2
```
After the first clock update, chronyd will check the offset on every clock update, it will ignore two adjustments larger than 1000 seconds and exit on another one.

maxupdateskew
One of chronyd's tasks is to work out how fast or slow the computer's clock runs relative to its reference sources. In addition, it computes an estimate of the error bounds around the estimated value. If the range of error is too large, it probably indicates that the measurements have not settled down yet, and that the estimated gain or loss rate is not very reliable. The maxupdateskew parameter allows the threshold for determining whether an estimate may be so unreliable that it should not be used. By default, the threshold is 1000 ppm. The format of the syntax is:

```
maxupdateskew skew-in-ppm
```
Typical values for skew-in-ppm might be 100 for a dial-up connection to servers over a telephone line, and 5 or 10 for a computer on a LAN. It should be noted that this is not the only means of protection against using unreliable estimates. At all times, chronyd keeps track of both the estimated gain or loss rate, and the error bound on the estimate. When a new estimate is generated following another measurement from one of the sources, a weighted combination algorithm is used to update the master estimate. So if chronyd has an existing highly-reliable master estimate and a new estimate is generated which has large error bounds, the existing master estimate will dominate in the new master estimate.

noclientlog
This directive, which takes no arguments, specifies that client accesses are not to be logged. Normally they are logged, allowing statistics to be reported using the clients command in chronyc.

reselectdist
When `chronyd` selects synchronisation source from available sources, it will prefer the one with minimum synchronization distance. However, to avoid frequent reselecting when there are sources with similar distance, a fixed distance is added to the distance for sources that are currently not selected. This can be set with the `reselectdist` option. By default, the distance is 100 microseconds.

The format of the syntax is:

```
reselectdist dist-in-seconds
```

**stratumweight**

The `stratumweight` directive sets how much distance should be added per stratum to the synchronisation distance when `chronyd` selects the synchronisation source from available sources.

The format of the syntax is:

```
stratumweight dist-in-seconds
```

By default, `dist-in-seconds` is 1 second. This usually means that sources with lower stratum will be preferred to sources with higher stratum even when their distance is significantly worse. Setting `stratumweight` to 0 makes `chronyd` ignore stratum when selecting the source.

**rtcfile**

The `rtcfile` directive defines the name of the file in which `chronyd` can save parameters associated with tracking the accuracy of the system’s real-time clock (RTC). The format of the syntax is:

```
rtcfile /etc/chrony.rtc
```

`chronyd` saves information in this file when it exits and when the `writertc` command is issued in `chronyc`. The information saved is the RTC’s error at some epoch, that epoch (in seconds since January 1 1970), and the rate at which the RTC gains or loses time. Not all real-time clocks are supported as their code system-specific.

### 3.2.4. Security with `chronyc`

As access to `chronyc` allows changing `chronyd` just as editing the configuration files would, access to `chronyc` should be limited. Passwords or their hashes can be specified in the key file, to restrict the use of `chronyc`. One of the entries is used to restrict the use of operational commands and is referred to as the command key. In the default configuration, a random command key is generated automatically on start. It should not be necessary to specify or alter it manually.

Other entries in the key file can be used as NTP keys to authenticate packets received from remote NTP servers or peers. The two sides need to share a key with identical ID, hash type and password in their key file. This requires manually creating the keys and copying them over a secure medium, such as SSH. If the key ID was, for example, 10 then the systems that act as clients must have a line in their configuration files in the following format:

```
server w.x.y.z key 10
peer w.x.y.z key 10
```

The location of the key file is specified in the `/etc/chrony.conf` file. The default entry in the configuration file is:

```
keyfile /etc/chrony.keys
```

The command key number is specified in `/etc/chrony.conf` using the `commandkey` directive, it is the key `chronyd` will use for authentication of user commands. The directive in the configuration file takes the following form:

```
commandkey 1
```

An example of the format of the default entry in the key file, `/etc/chrony.keys`, for the command key is:

```
1 SHA1 HEX:A6CFC50C9C93AB6E5A19754C246242FC5471BCDF
```

Where 1 is the key ID, SHA1 is the hash function to use, HEX is the format of the key, and `A6CFC50C9C93AB6E5A19754C246242FC5471BCDF` is the key randomly generated when `chronyc` was started for the first time. The key can be given in hexadecimal or ASCII format (the default).

A manual entry in the key file, used to authenticate packets from certain NTP servers or peers, can be as simple as the following:

```
20 foobar
```

Were 20 is the key ID and `foobar` is the secret authentication key. The default hash is MD5, and ASCII is the default format for the key.

By default, `chronyd` is configured to listen for commands only from localhost (127.0.0.1 and ::1). To access `chronyd` remotely with `chronyc`, any `bindcmdaddress` directives in the `/etc/chrony.conf` file should be removed to enable listening on all interfaces and the `cmdallow` directive should be used to allow commands from the remote IP address, network, or subnet. Note that the `allow` directive is for NTP access whereas the `cmdallow` directive is to enable the receiving of remote commands. It is possible to make these changes temporarily using `chronyc` running locally. Edit the configuration file to make persistent changes.

The communication between `chronyc` and `chronyd` is done over UDP, so it needs to be authorized before issuing operational commands. To authorize, use the `authhash` and `password` commands as follows:

```
authhash
```
Alternatively, you can use the `chrony-helper` wrapper, which will do that automatically. For example, to use the `reselect` command:

```bash
-# /usr/libexec/chrony-helper command reselect
```

Only the following commands can be used without providing a password: `activity`, `authhash`, `dns`, `exit`, `help`, `password`, `quit`, `rtdata`, `sources`, `sourcestats`, `tracking`, `waitsync`.

## 3.3. Using chrony

### 3.3.1. Checking if chrony is Installed

To check if `chrony` is installed, run the following command as root:

```bash
-# yum install chrony
```

The default location for the `chrony` daemon is `/usr/local/sbin/chronyd`.

### 3.3.2. Installing chrony

To install `chrony`, run the following command as root:

```bash
-# yum install chrony -y
```

The default installation directory is `/usr/local/sbin/`.

### 3.3.3. Checking the Status of chronyd

To check the status of `chronyd`, issue the following command:

```bash
-# systemctl status chronyd
```

```
chronyd.service - NTP client/server
Loaded: loaded (/usr/lib/systemd/system/chronyd.service; enabled)
Active: active (running) since Wed 2013-06-12 22:23:16 CEST; 11h ago
```

### 3.3.4. Starting chronyd

To start `chronyd`, issue the following command as root:

```bash
-# systemctl start chronyd
```

To ensure `chronyd` starts automatically at system start, issue the following command as root:

```bash
-# systemctl enable chronyd
```

### 3.3.5. Stopping chronyd

To stop `chronyd`, issue the following command as root:

```bash
-# systemctl stop chronyd
```

To prevent `chronyd` from starting automatically at system start, issue the following command as root:

```bash
-# systemctl disable chronyd
```

### 3.3.6. Checking if chrony is Synchronized

To check if `chrony` is synchronized, make use of the `tracking`, `sources`, and `sourcestats` commands.

#### 3.3.6.1. Checking chrony Tracking

To check chrony tracking, issue the following command:

```bash
-# chronyc tracking
```

```
Reference ID : 1.2.3.4 (a.b.c)  
Stratum : 3  
Ref time (UTC) : Fri Feb 3 15:00:29 2012  
System time : 0.00001501 seconds slow of NTP time  
Last offset : -0.000001632 seconds  
RMS offset : 0.000002360 seconds  
Frequency : 331.898 ppm fast  
Residual freq : 0.004 ppm  
Skew : 0.154 ppm  
Root delay : 0.373169 seconds  
Root dispersion : 0.024780 seconds  
Update interval : 64.2 seconds  
Leap status : Normal
```

The fields are as follows:
Reference ID
This is the refid and name (or IP address) if available, of the server to which the computer is currently synchronised. If this is 127.127.1.1 it means the computer is not synchronised to any external source and that you have the ‘local’ mode operating (via the local command in chronyc (see section local), or the local directive in the ‘/etc/chrony.conf’ file (see section local)).

Stratum
The stratum indicates how many hops away from a computer with an attached reference clock we are. Such a computer is a stratum-1 computer, so the computer in the example is two hops away (i.e. a.b.c is a stratum-2 and is synchronised from a stratum-1).

Ref time
This is the time (UTC) at which the last measurement from the reference source was processed.

System time
In normal operation, chronyd never steps the system clock, because any jump in the timescale can have adverse consequences for certain application programs. Instead, any error in the system clock is corrected by slightly speeding up or slowing down the system clock until the error has been removed, and then returning to the system clock’s normal speed. A consequence of this is that there will be a period when the system clock (as read by other programs using the gettimeofday() system call, or by the date command in the shell) will be different from chronyd’s estimate of the current true time (which it reports to NTP clients when it is operating in server mode). The value reported on this line is the difference due to this effect.

Last offset
This is the estimated local offset on the last clock update.

RMS offset
This is a long-term average of the offset value.

Frequency
The ‘frequency’ is the rate by which the system’s clock would be would be wrong if chronyd was not correcting it. It is expressed in ppm (parts per million). For example, a value of 1ppm would mean that when the system’s clock thinks it has advanced 1 second, it has actually advanced by 1.000001 seconds relative to true time.

Residual freq
This shows the ‘residual frequency’ for the currently selected reference source. This reflects any difference between what the measurements from the reference source indicate the frequency should be and the frequency currently being used. The reason this is not always zero is that a smoothing procedure is applied to the frequency. Each time a measurement from the reference source is obtained and a new residual frequency computed, the estimated accuracy of this residual is compared with the estimated accuracy (see ‘skew’ next) of the existing frequency value. A weighted average is computed for the new frequency, with weights depending on these accuracies. If the measurements from the reference source follow a consistent trend, the residual will be driven to zero over time.

Skew
This is the estimated error bound on the frequency.

Root delay
This is the total of the network path delays to the stratum-1 computer from which the computer is ultimately synchronised. In certain extreme situations, this value can be negative. (This can arise in a symmetric peer arrangement where the computers’ frequencies are not tracking each other and the network delay is very short relative to the turn-around time at each computer.)

Root dispersion
This is the total dispersion accumulated through all the computers back to the stratum-1 computer from which the computer is ultimately synchronised. Dispersion is due to system clock resolution, statistical measurement variations etc.

Leap status
This is the leap status, which can be Normal, Insert second, Delete second or Not synchronised.

3.3.6.2. Checking chrony Sources
The sources command displays information about the current time sources that chronyd is accessing. The optional argument -v can be specified, meaning verbose. In this case, extra caption lines are shown as a reminder of the meanings of the columns.
### chronyc sources

<table>
<thead>
<tr>
<th>MS</th>
<th>Name/IP address</th>
<th>Stratum</th>
<th>Poll</th>
<th>Reach</th>
<th>LastRx</th>
<th>Last sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>#*</td>
<td>GPS0</td>
<td>0</td>
<td>4</td>
<td>377</td>
<td>11</td>
<td>-479ns [-621ns] +/- 134ns</td>
</tr>
<tr>
<td>^?</td>
<td>a.b.c</td>
<td>2</td>
<td>6</td>
<td>377</td>
<td>23</td>
<td>-923us [-924us] +/- 43ms</td>
</tr>
<tr>
<td>^+</td>
<td>d.e.f</td>
<td>1</td>
<td>6</td>
<td>377</td>
<td>21</td>
<td>-2629us [-2619us] +/- 86ms</td>
</tr>
</tbody>
</table>

The columns are as follows:

**M**
- This indicates the mode of the source. ^ means a server, = means a peer and # indicates a locally connected reference clock.

**S**
- This column indicates the state of the sources. * indicates the source to which chronyd is current synchronised. + indicates other acceptable sources. ? indicates sources to which connectivity has been lost. x indicates a clock which chronyd thinks is is a falseticker (i.e. its time is inconsistent with a majority of other sources). ~ indicates a source whose time appears to have too much variability. The ~ condition is also shown at start-up, until at least 3 samples have been gathered from it.

**Name/IP address**
- This shows the name or the IP address of the source, or refid for reference clocks.

**Stratum**
- This shows the stratum of the source, as reported in its most recently received sample. Stratum 1 indicates a computer with a locally attached reference clock. A computer that is synchronised to a stratum 1 computer is at stratum 2. A computer that is synchronised to a stratum 2 computer is at stratum 3, and so on.

**Poll**
- This shows the rate at which the source is being polled, as a base-2 logarithm of the interval in seconds. Thus, a value of 6 would indicate that a measurement is being made every 64 seconds. chronyd automatically varies the polling rate in response to prevailing conditions.

**Reach**
- This shows the source’s reachability register printed as octal number. The register has 8 bits and is updated on every received or missed packet from the source. A value of 377 indicates that a valid reply was received for all from the last eight transmissions.

**LastRx**
- This column shows how long ago the last sample was received from the source. This is normally in seconds. The letters m, h, d or y indicate minutes, hours, days or years. A value of 10 years indicates there were no samples received from this source yet.

**Last sample**
- This column shows the offset between the local clock and the source at the last measurement. The number in the square brackets shows the actual measured offset. This may be suffixed by ns (indicating nanoseconds), us (indicating microseconds), ms (indicating milliseconds), or s (indicating seconds). The number to the left of the square brackets shows the original measurement, adjusted to allow for any slews applied to the local clock since. The number following the +/- indicator shows the margin of error in the measurement. Positive offsets indicate that the local clock is fast of the source.

### 3.3.6.3. Checking chrony Source Statistics

The `sourcestats` command displays information about the drift rate and offset estimation process for each of the sources currently being examined by chronyd. The optional argument `-v` can be specified, meaning verbose. In this case, extra caption lines are shown as a reminder of the meanings of the columns.

```
-]S chronyc sourcestats
```

<table>
<thead>
<tr>
<th>Name/IP address</th>
<th>NP</th>
<th>NR</th>
<th>Span</th>
<th>Frequency</th>
<th>Freq Skew</th>
<th>Offset</th>
<th>Std Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>abc.def.ghi</td>
<td>1</td>
<td>6</td>
<td>377</td>
<td>21</td>
<td>-2629us [-2619us] +/- 86ms</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The columns are as follows:

**Name/IP address**
- This is the name or IP address of the NTP server (or peer) or refid of the refclock to which the rest of the line relates.

**NP**
- This is the number of sample points currently being retained for the server. The drift rate and current offset are estimated by performing a linear regression through these points.
This is the number of runs of residuals having the same sign following the last regression. If this number starts to become too small relative to the number of samples, it indicates that a straight line is no longer a good fit to the data. If the number of runs is too low, `chronyd` discards older samples and re-runs the regression until the number of runs becomes acceptable.

**Span**
This is the interval between the oldest and newest samples. If no unit is shown the value is in seconds. In the example, the interval is 46 minutes.

**Frequency**
This is the estimated residual frequency for the server, in parts per million. In this case, the computer's clock is estimated to be running 1 part in $10^{**9}$ slow relative to the server.

**Freq Skew**
This is the estimated error bounds on Freq (again in parts per million).

**Offset**
This is the estimated offset of the source.

**Std Dev**
This is the estimated sample standard deviation.

### 3.3.7. Manually Adjusting the System Clock
To update, or step, the system clock immediately, bypassing any adjustments in progress by slewing the clock, issue the following commands as root:

```bash
$ chronyc password
200 OK
chrony> makestep
200 OK
```

In Fedora, the real-time clock should not be manually adjusted as this would interfere with `chrony`'s need to measure the rate at which the real-time clock drifts if it was adjusted at random intervals. By default, `rtcsync` will inform the kernel the system clock is synchronized and the kernel will update the real-time clock in 11 minute intervals.

### 3.4. Setting Up `chrony` for Different Environments

#### 3.4.1. Setting Up `chrony` for a System Which is Infrequently Connected
This example is intended for systems which use dial-on-demand connections. The normal configuration should be sufficient for mobile and virtual devices which connect intermittently. First, review and confirm that the default settings in the `/etc/chrony.conf` are similar to the following:

```plaintext
driftfile /var/lib/chrony/drift
commandkey 1
keyfile /etc/chrony.keys
```

The command key ID is generated at install time and should correspond with the `commandkey` value in the key file, `/etc/chrony.keys`.

1. Using your editor running as root, add the addresses of four NTP servers as follows:

```plaintext
server 0.pool.ntp.org offline
server 1.pool.ntp.org offline
server 2.pool.ntp.org offline
server 3.pool.ntp.org offline
```

The `offline` option can be useful in preventing systems from trying to activate connections. The `chrony` daemon will wait for `chronyc` to inform it that the system is connected to the network or Internet.

#### 3.4.1.1. Configuring `chrony` to Connect and Disconnect
Using your editor running as root, add the following to the `/etc/ppp/ip-up` file:

```plaintext
/usr/local/bin/chronyc password commandkey-password online
```

Using your editor running as root, add the following to the `/etc/ppp/ip-down` file:

```plaintext
/usr/local/bin/chronyc password commandkey-password offline
```

The `chrony` daemon, `chronyd`, will now only poll the NTP servers when the Point-To-Point link is activated.
3.4.2. Setting Up chrony for a System in an Isolated Network

For a network that is never connected to the Internet, one computer is selected to be the master timeserver. The other computers are either direct clients of the master, or clients of clients. On the master, the drift file must be manually set with the average rate of drift of the system clock. If the master is rebooted it will obtain the time from surrounding systems and take an average to set its system clock. Thereafter it resumes applying adjustments based on the drift file. The drift file will be updated automatically when the `settime` command is used.

On the system selected to be the master, using a text editor running as root, edit the `/etc/chrony.conf` as follows:

```
  driftfile /var/lib/chrony/drift
  commandkey 1
  keyfile /etc/chrony.keys
  initstepslew 10 client1 client3 client6
  local stratum 8
  manual
  allow 192.0.2.0
```

Where `192.0.2.0` is the network or subnet address from which the clients are allowed to connect.

On the systems selected to be direct clients of the master, using a text editor running as root, edit the `/etc/chrony.conf` as follows:

```
  server master
  driftfile /var/lib/chrony/drift
  logdir /var/log/chrony
  log measurements statistics tracking
  keyfile /etc/chrony.keys
  commandkey 24
  local stratum 10
  initstepslew 20 master
  allow 192.0.2.123
```

Where `192.0.2.123` is the address of the master, and `master` is the host name of the master. These client will resynchronize the master if it restarts.

On the client systems which are not to be direct clients of the master, the `/etc/chrony.conf` file should be the same except that the `local` and `allow` directives should be omitted.

3.5. Using chronyc

3.5.1. Using chronyc to Control cronyd

To make changes using the command line utility `chronyc` in interactive mode, enter the following command as root:

```
~]# chronyc
```

`chronyc` must run as root if some of the restricted commands are to be used.

The `chronyc` command prompt will be displayed as follows:

```
/chronyc>
```

You can type `help` to list all of the commands.

The utility can also be invoked in non-interactive command mode if called together with an option as follows:

```
~]# chronyc option
```

3.5.2. Using chronyc for Remote Administration

To configure `chrony` to connect to a remote instance of `chronyd`, issue a command as root in the following format:

```
~]# chronyc -h hostname
```

Where `hostname` is the `hostname` of a system running `chronyd` to connect to in order to allow remote administration from that host. The default is to connect to the daemon on the localhost.

To configure `chrony` to connect to a remote instance of `chronyd` on a non-default port, issue a command as root in the following format:

```
~]# chronyc -p port
```

Where `port` is the port in use for controlling and monitoring by the instance of `chronyd` to be connected to.

Note that commands issued at the `chrony` command prompt are not persistent. Only commands in the configuration file are persistent.

From the remote systems, the system administrator can issue commands after first using the `password` command at the `chronyc` command prompt as follows:

```
chronyc> password secretpasswordwithnospaces
200 OK
```

Alternatively, the remote system can use the `chrony-helper` wrapper, which will do that automatically. For example, to use the `reselect` command:
The password or hash associated with the command key for a remote system is best obtained by **SSH**. That is to say, an SSH connection should be established to the remote machine and the ID of the command key from `/etc/chrony.conf` and the command key in `/etc/chrony.keys` memorised or stored securely for the duration of the session.

### 3.6. Additional Resources

The following sources of information provide additional resources regarding **chrony**.

#### 3.6.1. Installed Documentation

- **chrony(1)** man page — Introduces the **chrony** daemon and the command-line interface tool.
- **chronyc(1)** man page — Describes the **chronyc** command-line interface tool including commands and command options.
- **chronyd(1)** man page — Describes the **chronyd** daemon including commands and command options.
- **chrony.conf(5)** man page — Describes the **chrony** configuration file.
- **chrony.conf(5)** man page — User guide for the **chrony** suite.
- `/usr/share/doc/chrony*/chrony.txt` — User guide for the **chrony** suite.

#### 3.6.2. Useful Websites


The on-line user guide for **chrony**.

### Chapter 4. Managing Users and Groups

#### 4.1. Introduction to Users and Groups

- **4.1.1. User Private Groups**
- **4.1.2. Shadow Passwords**

#### 4.2. Using the User Accounts Tool

- **4.2.1. Configuring an Account**
- **4.2.2. Adding a New User**
- **4.2.3. Removing a User**

#### 4.3. Using the User Manager Tool

- **4.3.1. Viewing Users and Groups**
- **4.3.2. Adding a New User**
- **4.3.3. Adding a New Group**
- **4.3.4. Modifying User Properties**
- **4.3.5. Modifying Group Properties**

#### 4.4. Using Command Line Tools

- **4.4.1. Adding a New User**
- **4.4.2. Adding a New Group**
- **4.4.3. Enabling Password Aging**
- **4.4.4. Enabling Automatic Logouts**
- **4.4.5. Creating Group Directories**

#### 4.5. Additional Resources

- **4.5.1. Installed Documentation**

The control of users and groups is a core element of Fedora system administration. This chapter explains how to add, manage, and delete users and groups in the graphical user interface and on the command line, and covers advanced topics, such as enabling password aging or creating group directories.

#### 4.1. Introduction to Users and Groups

While users can be either people (meaning accounts tied to physical users) or accounts which exist for specific applications to use, groups are logical expressions of organization, tying users together for a common purpose. Users within a group can read, write, or execute files owned by that group.

Each user is associated with a unique numerical identification number called a **user ID** (UID). Likewise, each group is associated with a **group ID** (GID). A user who creates a file is also the owner and group owner of that file. The file is assigned separate read, write, and execute permissions for the owner, the group, and everyone else. The file owner can be changed only by **root**, and access permissions can be changed by both the **root** user and file owner.

Additionally, Fedora supports **access control lists** (ACLs) for files and directories which allow permissions for specific users outside of the owner to be set. Refer to For more information about this feature, refer to the **Access Control Lists**.
4.1.1. User Private Groups

Fedora uses a user private group (UPG) scheme, which makes UNIX groups easier to manage. A user private group is created whenever a new user is added to the system. It has the same name as the user for which it was created and that user is the only member of the user private group.

User private groups make it safe to set default permissions for a newly created file or directory, allowing both the user and the group of that user to make modifications to the file or directory.

The setting which determines what permissions are applied to a newly created file or directory is called a umask and is configured in the `/etc/bashrc` file. Traditionally on UNIX systems, the umask is set to 022, which allows only the user who created the file or directory to make modifications. Under this scheme, all other users, including members of the creator's group, are not allowed to make any modifications. However, under the UPG scheme, this “group protection” is not necessary since every user has their own private group.

4.1.2. Shadow Passwords

Especially in environments with multiple users, it is very important to use shadow passwords provided by the `shadow-utils` package to enhance the security of system authentication files. For this reason, the installation program enables shadow passwords by default.

The following is a list of the advantages shadow passwords have over the traditional way of storing passwords on UNIX-based systems:

- Shadow passwords improve system security by moving encrypted password hashes from the world-readable `/etc/passwd` file to `/etc/shadow`, which is readable only by the root user.
- Shadow passwords store information about password aging.
- Shadow passwords allow the `/etc/login.defs` file to enforce security policies.

Most utilities provided by the `shadow-utils` package work properly whether or not shadow passwords are enabled. However, since password aging information is stored exclusively in the `/etc/shadow` file, any commands which create or modify password aging information do not work. The following is a list of utilities and commands that do not work without first enabling shadow passwords:

- The `chage` utility.
- The `gpasswd` utility.
- The `usermod` command with the `-e` or `-f` option.
- The `useradd` command with the `-e` or `-f` option.

4.2. Using the User Accounts Tool

The User Accounts configuration tool allows you to view, modify, add, and delete local users. To run the tool, select Applications → System Tools → System Settings from the Activities menu and click the User Accounts icon.

![Figure 4.1. The User Accounts configuration tool](image)

By default, the tool only allows you to change certain settings regarding your account. This is because only the root user is allowed to configure users and groups. To unlock the configuration tool for all kinds of changes, click the Unlock button in the top-right corner of the window, and provide the correct password when prompted.

4.2.1. Configuring an Account
To change the image associated with an account, click the icon next to the account name and either select a picture from the pulldown list, or click **Browse for more pictures...** to use an image from your local drive.

To change the account type, click the text next to the **Account type** label. Note that this change requires the configuration tool to be unlocked even if you are changing your own account.

To change the name associated with an account, click the name next to the icon to edit it.

To change the default language for an account, click the text next to the **Language** label and select a language from the list.

To change the password, click the field next to the **Password** label. A dialog box appears, allowing you to set the new password. Note that the current password must be provided in order to confirm the change. Once done, click the **Change** button to save the change.

![Figure 4.2. Changing the password](image)

**Password security advice**

It is advisable to use a much longer password, as this makes it more difficult for an intruder to guess it and access the account without permission. It is also recommended that the password not be based on a dictionary term: use a combination of letters, numbers and special characters.

Finally, to set up automatic login for a particular account, enable the **Automatic Login** switch. The configuration tool must be unlocked to make this change.

### 4.2.2. Adding a New User

To add a new user, make sure the configuration tool is unlocked, and click the + button (that is, the plus sign) below the account list. A dialog window appears, allowing you to supply user details.

![Figure 4.3. Creating a new account](image)
Take the following steps to create an account:

1. Select an account type from the Account type pulldown list. Available account types are Administrator and Standard (the default option).
2. Fill in the Full name input field to set the name associated with the account. This name will be used by the login manager, and will be displayed on the panel.
3. Either select a suggested username from the Username pulldown list, or fill in the corresponding input field.
4. Click the Create button to confirm the settings.

Fedora uses a user private group (UPG) scheme. The UPG scheme does not add or change anything in the standard UNIX way of handling groups; it offers a new convention. Whenever you create a new user, a unique group with the same name as the user is created.

When a new account is created, default configuration files are copied from the /etc/skel/ directory into the new home directory.

4.2.3. Removing a User

To remove a user, make sure the configuration tool is unlocked, select the desired account from the account list, and click the – button (that is, the minus sign) below the account list. A dialog window appears, allowing you to confirm or cancel the change.

![Image](https://example.com/image.png)

Figure 4.4. Removing an account

To delete files and directories that belong to the user (that is, the home directory, mail spool, and temporary files), click the Delete Files button. To keep these files intact and only delete the user account, click Keep Files. To abort the deletion, click Cancel.

4.3. Using the User Manager Tool

The User Manager application allows you to view, modify, add, and delete local users and groups in the graphical user interface. To start the application, either select Applications → Other → Users and Groups from the Activities menu, or type system-config-users at a shell prompt. Note that unless you have superuser privileges, the application will prompt you to authenticate as root.

4.3.1. Viewing Users and Groups

The main window of the User Manager is divided into two tabs: The Users tab provides a list of local users along with additional information about their user ID, primary group, home directory, login shell, and full name. The Groups tab provides a list of local groups with information about their group ID and group members.

![Table](https://example.com/table.png)

Figure 4.5. Viewing users and groups

To find a specific user or group, type the first few letters of the name in the Search filter field and either press Enter.
or click the apply filter button. You can also sort the items according to any of the available columns by clicking the
column header.

Fedora reserves user and group IDs below 1000 for system users and groups. By default, the User Manager does not
display the system users. To view all users and groups, select Edit → Preferences to open the Preferences dialog box,
and clear the hide system users and groups check box.

4.3.2. Adding a New User

To add a new user, click the Add User button. A window as shown in Figure 4.6, “Adding a new user” appears.

<table>
<thead>
<tr>
<th>User Name:</th>
<th>ekopalova</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Name:</td>
<td>Eva Kopalová</td>
</tr>
<tr>
<td>Password:</td>
<td>**********</td>
</tr>
<tr>
<td>Confirm Password:</td>
<td>**********</td>
</tr>
<tr>
<td>Login Shell:</td>
<td>/bin/bash</td>
</tr>
</tbody>
</table>

Figure 4.6. Adding a new user

The Add New User dialog box allows you to provide information about the newly created user. In order to create a user,
enter the username and full name in the appropriate fields and then type the user's password in the Password and
Confirm Password fields. The password must be at least six characters long.

Password security advice

It is advisable to use a much longer password, as this makes it more difficult for an intruder to guess it and access
the account without permission. It is also recommended that the password not be based on a dictionary term: use
a combination of letters, numbers and special characters.

The Login Shell pulldown list allows you to select a login shell for the user. If you are not sure which shell to select,
accept the default value of /bin/bash.

By default, the User Manager application creates the home directory for a new user in /home/username/. You can
choose not to create the home directory by clearing the Create home directory check box, or change this directory by
editing the content of the Home Directory text box. Note that when the home directory is created, default configuration
files are copied into it from the /etc/skel/ directory.

Fedora uses a user private group (UPG) scheme. Whenever you create a new user, a unique group with the same name
as the user is created by default. If you do not want to create this group, clear the Create a private group for the user
check box.

To specify a user ID for the user, select Specify user ID manually. If the option is not selected, the next available user
ID above 1000 is assigned to the new user. Because Fedora reserves user IDs below 1000 for system users, it is not
advisable to manually assign user IDs 1–999.

Clicking the OK button creates the new user. To configure more advanced user properties, such as password expiration,
modify the user's properties after adding the user.

4.3.3. Adding a New Group

To add a new user group, select Add Group from the toolbar. A window similar to Figure 4.7, “New Group” appears. Type
the name of the new group. To specify a group ID for the new group, select Specify group ID manually and select the
GID. Note that Fedora also reserves group IDs lower than 1000 for system groups.
Click **OK** to create the group. The new group appears in the group list.

### 4.3.4. Modifying User Properties

To view the properties of an existing user, click on the **Users** tab, select the user from the user list, and click **Properties** from the menu (or choose **File** → **Properties** from the pulldown menu). A window similar to Figure 4.8, "User Properties" appears.

![Figure 4.8. User Properties](image)

The **User Properties** window is divided into multiple tabbed pages:

- **User Data** — Shows the basic user information configured when you added the user. Use this tab to change the user's full name, password, home directory, or login shell.
- **Account Info** — Select **Enable account expiration** if you want the account to expire on a certain date. Enter the date in the provided fields. Select **Local password is locked** to lock the user account and prevent the user from logging into the system.
- **Password Info** — Displays the date that the user's password last changed. To force the user to change passwords after a certain number of days, select **Enable password expiration** and enter a desired value in the **Days before change required** field. The number of days before the user's password expires, the number of days before the user is warned to change passwords, and days before the account becomes inactive can also be changed.
- **Groups** — Allows you to view and configure the Primary Group of the user, as well as other groups that you want the user to be a member of.

### 4.3.5. Modifying Group Properties

To view the properties of an existing group, select the group from the group list and click **Properties** from the menu (or choose **File** → **Properties** from the pulldown menu). A window similar to Figure 4.9, "Group Properties" appears.
The Group Users tab displays which users are members of the group. Use this tab to add or remove users from the group. Click OK to save your changes.

### 4.4. Using Command Line Tools

The easiest way to manage users and groups on Fedora is to use the User Manager application as described in Section 4.3, "Using the User Manager Tool". However, if you prefer command line tools or do not have the X Window System installed, you can use command line utilities that are listed in Table 4.1, "Command line utilities for managing users and groups".

#### Table 4.1. Command line utilities for managing users and groups

<table>
<thead>
<tr>
<th>Utilities</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>useradd, usermod, userdel</td>
<td>Standard utilities for adding, modifying, and deleting user accounts.</td>
</tr>
<tr>
<td>groupadd, groupmod, groupdel</td>
<td>Standard utilities for adding, modifying, and deleting groups.</td>
</tr>
<tr>
<td>gpasswd</td>
<td>Standard utility for administering the /etc/group configuration file.</td>
</tr>
<tr>
<td>pwck, grpck</td>
<td>Utilities that can be used for verification of the password, group, and</td>
</tr>
<tr>
<td></td>
<td>associated shadow files.</td>
</tr>
<tr>
<td>pwconv, pwunconv</td>
<td>Utilities that can be used for the conversion of passwords to shadow</td>
</tr>
<tr>
<td></td>
<td>passwords, or back from shadow passwords to standard passwords.</td>
</tr>
</tbody>
</table>

#### 4.4.1. Adding a New User

To add a new user to the system, typing the following at a shell prompt as root:

```
useradd [options] username
```

...where options are command line options as described in Table 4.2, "useradd command line options".

By default, the useradd command creates a locked user account. To unlock the account, run the following command as root to assign a password:

```
passwd username
```

Optionally, you can set password aging policy. Refer to Section 4.4.3, "Enabling Password Aging" for information on how to enable password aging.
### Table 4.2. `useradd` command line options

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>-c comment</code></td>
<td><code>comment</code> can be replaced with any string. This option is generally used to specify the full name of a user.</td>
</tr>
<tr>
<td><code>-d home_directory</code></td>
<td>Home directory to be used instead of default <code>/home/username/</code>.</td>
</tr>
<tr>
<td><code>-e date</code></td>
<td>Date for the account to be disabled in the format YYYY-MM-DD.</td>
</tr>
<tr>
<td><code>-f days</code></td>
<td>Number of days after the password expires until the account is disabled. If 0 is specified, the account is disabled immediately after the password expires. If <code>-1</code> is specified, the account is not be disabled after the password expires.</td>
</tr>
<tr>
<td><code>-g group_name</code></td>
<td>Group name or group number for the user's default group. The group must exist prior to being specified here.</td>
</tr>
<tr>
<td><code>-G group_list</code></td>
<td>List of additional (other than default) group names or group numbers, separated by commas, of which the user is a member. The groups must exist prior to being specified here.</td>
</tr>
<tr>
<td><code>-m</code></td>
<td>Create the home directory if it does not exist.</td>
</tr>
<tr>
<td><code>-M</code></td>
<td>Do not create the home directory.</td>
</tr>
<tr>
<td><code>-N</code></td>
<td>Do not create a user private group for the user.</td>
</tr>
<tr>
<td><code>-p password</code></td>
<td>The password encrypted with <code>crypt</code>.</td>
</tr>
<tr>
<td><code>-r</code></td>
<td>Create a system account with a UID less than 1000 and without a home directory.</td>
</tr>
<tr>
<td><code>-s</code></td>
<td>User's login shell, which defaults to <code>/bin/bash</code>.</td>
</tr>
<tr>
<td><code>-u uid</code></td>
<td>User ID for the user, which must be unique and greater than 999.</td>
</tr>
</tbody>
</table>

### Explaining the Process

The following steps illustrate what happens if the command `useradd juan` is issued on a system that has shadow passwords enabled:

1. A new line for `juan` is created in `/etc/passwd`:

   ```plaintext
   juan:x:501:501::/home/juan:/bin/bash
   ```

   The line has the following characteristics:
   - It begins with the username `juan`.
   - There is an `x` for the password field indicating that the system is using shadow passwords.
   - A UID greater than 999 is created. Under Fedora, UIDs below 1000 are reserved for system use and should not be assigned to users.
   - A GID greater than 999 is created. Under Fedora, GIDs below 1000 are reserved for system use and should not be assigned to users.
   - The optional `GECOS` information is left blank.
   - The home directory for `juan` is set to `/home/juan/`.
   - The default shell is set to `/bin/bash`.

2. A new line for `juan` is created in `/etc/shadow`:

   ```plaintext
   juan:!!:14798:0:99999:7:::
   ```

   The line has the following characteristics:
   - It begins with the username `juan`.
   - Two exclamation marks (`!!`) appear in the password field of the `/etc/shadow` file, which locks the account.

   **Note**

   If an encrypted password is passed using the `-p` flag, it is placed in the `/etc/shadow` file on the new line for the user.

   - The password is set to never expire.

3. A new line for a group named `juan` is created in `/etc/group`:

   ```plaintext
   juan:x:501:
   ```

   A group with the same name as a user is called a user private group. For more information on user private groups, refer to Section 4.1.1, “User Private Groups”.

   The line created in `/etc/group` has the following characteristics:
   - It begins with the group name `juan`.
   - An `x` appears in the password field indicating that the system is using shadow group passwords.
   - The GID matches the one listed for user `juan` in `/etc/passwd`.

4. A new line for a group named `juan` is created in `/etc/gshadow`:

   ```plaintext
   juan:!!:::
   ```

   The line has the following characteristics:
   - It begins with the group name `juan`.
   - An exclamation mark (!) appears in the password field of the `/etc/gshadow` file, which locks the group.
   - All other fields are blank.

5. A directory for user `juan` is created in the `/home/` directory:
This directory is owned by user juan and group juan. It has read, write, and execute privileges only for the user juan. All other permissions are denied.

6. The files within the /etc/skel/ directory (which contain default user settings) are copied into the new /home/juan/ directory:

   ~
   ls -l /home
   total 4
   drwx------.  4 juan juan 4096 Mar  3 18:23 juan

   This directory is owned by user juan and group juan. It has read, write, and execute privileges only for the user juan. All other permissions are denied.

   ~
   ls -l /home/juan
   total 28
   drwx------.  4 juan juan 4096 Mar  3 18:23 .
   drwxr-xr-x.  5 root root 4096 Mar  3 18:23 ..
   -rw-r--r--.  1 juan juan 18 Jun 22 2010 .bash_logout
   -rw-r--r--.  1 juan juan 176 Jun 22 2010 .bash_profile
   -rw-r--r--.  1 juan juan 124 Jun 22 2010 .bashrc
   drwxr-xr-x.  2 juan juan 4096 Jul 14 2010 .gnome2
   drwxr-xr-x.  4 juan juan 4096 Nov 23 15:09 .mozilla

   At this point, a locked account called juan exists on the system. To activate it, the administrator must next assign a password to the account using the passwd command and, optionally, set password aging guidelines.

4.4.2. Adding a New Group

To add a new group to the system, type the following at a shell prompt as root:

   groupadd [options] group_name

   ...where options are command line options as described in Table 4.3, "groupadd command line options".

Table 4.3. groupadd command line options

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>-f</td>
<td>When used with -g gid and gid already exists, groupadd will choose another unique gid for the group.</td>
</tr>
<tr>
<td>-g gid</td>
<td>Group ID for the group, which must be unique and greater than 999.</td>
</tr>
<tr>
<td>-K key=value</td>
<td>Override /etc/login.defs defaults.</td>
</tr>
<tr>
<td>-o</td>
<td>Allow to create groups with duplicate.</td>
</tr>
<tr>
<td>-p</td>
<td>Use this encrypted password for the new group.</td>
</tr>
<tr>
<td>-r</td>
<td>Create a system group with a GID less than 1000.</td>
</tr>
</tbody>
</table>

4.4.3. Enabling Password Aging

For security reasons, it is advisable to require users to change their passwords periodically. This can either be done when adding or editing a user on the Password Info tab of the User Manager application, or by using the chage command.

Shadow passwords must be enabled to use chage

Shadow passwords must be enabled to use the chage command. For more information, see Section 4.1.2, "Shadow Passwords".

To configure password expiration for a user from a shell prompt, run the following command as root:

   chage [options] username

   ...where options are command line options as described in Table 4.4, "chage command line options". When the chage command is followed directly by a username (that is, when no command line options are specified), it displays the current password aging values and allows you to change them interactively.

Table 4.4. chage command line options

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>-d days</td>
<td>Specifies the number of days since January 1, 1970 the password was changed.</td>
</tr>
<tr>
<td>-E date</td>
<td>Specifies the date on which the account is locked, in the format YYYY-MM-DD. Instead of the date, the number of days since January 1, 1970 can also be used.</td>
</tr>
<tr>
<td>-I days</td>
<td>Specifies the number of inactive days after the password expiration before locking the account. If the value is 0, the account is not locked after the password expires.</td>
</tr>
<tr>
<td>-l</td>
<td>Lists current account aging settings.</td>
</tr>
<tr>
<td>-m days</td>
<td>Specify the minimum number of days after which the user must change passwords. If the value is 0, the password does not expire.</td>
</tr>
<tr>
<td>-M days</td>
<td>Specify the maximum number of days for which the password is valid. When the number of days specified by this option plus the number of days specified with the -d option is less than the current day, the user must change passwords before using the account.</td>
</tr>
<tr>
<td>-W days</td>
<td>Specifies the number of days before the password expiration date to warn the user.</td>
</tr>
</tbody>
</table>

You can configure a password to expire the first time a user logs in. This forces users to change passwords immediately.
1. Set up an initial password. There are two common approaches to this step: you can either assign a default password, or you can use a null password.

To assign a default password, type the following at a shell prompt as root:

```
passwd username
```

To assign a null password instead, use the following command:

```
passwd -d username
```

Avoid using null passwords whenever possible

Using a null password, while convenient, is a highly insecure practice, as any third party can log in first and access the system using the insecure username. Always make sure that the user is ready to log in before unlocking an account with a null password.

2. Force immediate password expiration by running the following command as root:

```
chage -d 0 username
```

This command sets the value for the date the password was last changed to the epoch (January 1, 1970). This value forces immediate password expiration no matter what password aging policy, if any, is in place.

Upon the initial log in, the user is now prompted for a new password.

### 4.4.4. Enabling Automatic Logouts

Especially when the user is logged in as root, an unattended login session may pose a significant security risk. To reduce this risk, you can configure the system to automatically log out idle users after a fixed period of time:

1. Make sure the `screen` package is installed. You can do so by running the following command as root:

```
yum install screen
```

For more information on how to install packages in Fedora, refer to Section 5.2.4, “Installing Packages”.

2. As root, add the following line at the beginning of the `~/.profile` file to make sure the processing of this file cannot be interrupted:

```
trap "" 1 2 3 15
```

3. Add the following lines at the end of the `~/.profile` file to start a `screen` session each time a user logs in to a virtual console or remotely:

```
SCREENEXEC="screen"
if [ ! -w $tty ]; then
  trap "exec $SCREENEXEC" 1 2 3 15
  echo -n 'Starting session in 10 seconds'
  sleep 10
echo $SCREENEXEC
fi
```

Note that each time a new session starts, a message will be displayed and the user will have to wait ten seconds.

To adjust the time to wait before starting a session, change the value after the `sleep` command.

4. Add the following lines to the `~/.screenrc` configuration file to close the `screen` session after a given period of inactivity:

```
idle 120 quit
autodetach off
```

This will set the time limit to 120 seconds. To adjust this limit, change the value after the `idle` directive.

Alternatively, you can configure the system to only lock the session by using the following lines instead:

```
idle 120 lockscreen
autodetach off
```

This way, a password will be required to unlock the session.

The changes take effect the next time a user logs in to the system.

### 4.4.5. Creating Group Directories

System administrators usually like to create a group for each major project and assign people to the group when they need to access that project's files. With this traditional scheme, file managing is difficult; when someone creates a file, it is associated with the primary group to which they belong. When a single person works on multiple projects, it becomes difficult to associate the right files with the right group. However, with the UPG scheme, groups are automatically assigned to files created within a directory with the setgid bit set. The setgid bit makes managing group projects that share a common directory very simple because any files a user creates within the directory are owned by the group which owns the directory.

For example, a group of people need to work on files in the `~/opt/myproject/` directory. Some people are trusted to modify the contents of this directory, but not everyone.

1. As root, create the `~/opt/myproject/` directory by typing the following at a shell prompt:

```
mkdir /opt/myproject
```
2. Add the `myproject` group to the system:

   ```bash
groupadd myproject
   ```

3. Associate the contents of the `/opt/myproject/` directory with the `myproject` group:

   ```bash
chown root:myproject /opt/myproject
   ```

4. Allow users to create files within the directory, and set the setgid bit:

   ```bash
chmod 2775 /opt/myproject
   ```

At this point, all members of the `myproject` group can create and edit files in the `/opt/myproject/` directory without the administrator having to change file permissions every time users write new files. To verify that the permissions have been set correctly, run the following command:

```
[-j] ls -l /opt
```
```
total 4
drwxrwsr-x. 3 root myproject 4096 Mar 3 18:31 myproject
```

### 4.5. Additional Resources

Refer to the following resources for more information about managing users and groups.

#### 4.5.1. Installed Documentation

For information about various utilities for managing users and groups, refer to the following manual pages:

- `chage(1)` — A command to modify password aging policies and account expiration.
- `gpasswd(1)` — A command to administer the `/etc/group` file.
- `groupadd(8)` — A command to add groups.
- `grpck(8)` — A command to verify the `/etc/group` file.
- `groupdel(8)` — A command to remove groups.
- `groupmod(8)` — A command to modify group membership.
- `pwck(8)` — A command to verify the `/etc/passwd` and `/etc/shadow` files.
- `pwconv(8)` — A tool to convert standard passwords to shadow passwords.
- `pwunconv(8)` — A tool to convert shadow passwords to standard passwords.
- `useradd(8)` — A command to add users.
- `userdel(8)` — A command to remove users.
- `usermod(8)` — A command to modify users.

For information about related configuration files, see:

- `group(5)` — The file containing group information for the system.
- `passwd(5)` — The file containing user information for the system.
- `shadow(5)` — The file containing passwords and account expiration information for the system.

---

### Part II. Package Management

All software on a Fedora system is divided into RPM packages, which can be installed, upgraded, or removed. This part describes how to manage packages on Fedora using both Yum and the PackageKit suite of graphical package management tools.

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Chapter 5. Yum

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Yum is the The Fedora Project package manager that is able to query for information about packages, fetch packages from repositories, install and uninstall packages using automatic dependency resolution, and update an entire system to the latest available packages. Yum performs automatic dependency resolution on packages you are updating, installing or removing, and thus is able to automatically determine, fetch and install all available dependent packages. Yum can be configured with new, additional repositories, or package sources, and also provides many plug-ins which enhance and extend its capabilities. Yum is able to perform many of the same tasks that RPM can; additionally, many of the command line options are similar. Yum enables easy and simple package management on a single machine or on groups of them.
Secure package management with GPG-signed packages

Yum provides secure package management by enabling GPG (Gnu Privacy Guard; also known as GnuPG) signature verification on GPG-signed packages to be turned on for all package repositories (i.e. package sources), or for individual repositories. When signature verification is enabled, Yum will refuse to install any packages not GPG-signed with the correct key for that repository. This means that you can trust that the RPM packages you download and install on your system are from a trusted source, such as The Fedora Project, and were not modified during transfer. Refer to Section 5.3, “Configuring Yum and Yum Repositories” for details on enabling signature-checking with Yum, or Section B.3, “Checking a Package’s Signature” for information on working with and verifying GPG-signed RPM packages in general.

Yum also enables you to easily set up your own repositories of RPM packages for download and installation on other machines.

Learning Yum is a worthwhile investment because it is often the fastest way to perform system administration tasks, and it provides capabilities beyond those provided by the PackageKit graphical package management tools. Refer to Chapter 6, PackageKit for details on using PackageKit.

Yum and superuser privileges

You must have superuser privileges in order to use yum to install, update or remove packages on your system. All examples in this chapter assume that you have already obtained superuser privileges by using either the su or sudo command.

5.1. Checking For and Updating Packages

5.1.1. Checking For Updates

To see which installed packages on your system have updates available, use the following command:

```
yum check-update
```

For example:

```
$ yum check-update
Loaded plugins: langpacks, presto, refresh-packagekit
PackageKit.x86_64                    0.6.14-2.fc15                 fedora
PackageKit-command-not-found.x86_64  0.6.14-2.fc15                 fedora
PackageKit-device-rebind.x86_64     0.6.14-2.fc15                 fedora
PackageKit-glib.x86_64              0.6.14-2.fc15                 fedora
PackageKit-gstreamer-plugin.x86_64  0.6.14-2.fc15                 fedora
PackageKit-gtk-module.x86_64        0.6.14-2.fc15                 fedora
PackageKit-gtk3-module.x86_64       0.6.14-2.fc15                 fedora
PackageKit-yum.x86_64               0.6.14-2.fc15                 fedora
PackageKit-yum-plugin.x86_64        0.6.14-2.fc15                 fedora
gdb.x86_64                           7.2.90.20110429-36.fc15     fedora
kernel.x86_64                        2.6.38.6-26.fc15              fedora
rpm.x86_64                           4.9.0-6.fc15                  fedora
rpm-libs.x86_64                      4.9.0-6.fc15                  fedora
rpm-python.x86_64                    4.9.0-6.fc15                  fedora
yum.noarch                           3.2.29-5.fc15                 fedora
```

The packages in the above output are listed as having updates available. The first package in the list is PackageKit, the graphical package manager. The line in the example output tells us:

- **PackageKit** — the name of the package
- **x86_64** — the CPU architecture the package was built for
- **0.6.14** — the version of the updated package to be installed
- **fedora** — the repository in which the updated package is located

The output also shows us that we can update the kernel (the kernel package), Yum and RPM themselves (the yum and rpm packages), as well as their dependencies (such as the kernel-firmware, rpm-libs, and rpm-python packages), all using yum.

5.1.2. Updating Packages

You can choose to update a single package, multiple packages, or all packages at once. If any dependencies of the package (or packages) you update have updates available themselves, then they are updated too.

Updating a Single Package

To update a single package, run the following command as root:

```
yum update package_name
```

For example, to update the udev package, type:
yum update udev

-# yum update udev
Loaded plugins: langpacks, presto, refresh-packagekit
Updating Red Hat repositories.
INFO:rhsm-app.repolib:repos updated: 0
Setting up Update Process
Resolving Dependencies
---> Running transaction check
---> Package gdb.x86_64 0:7.2.90.20110411-34.fc15 will be updated
---> Package gdb.x86_64 0:7.2.90.20110429-36.fc15 will be an update
---> Finished Dependency Resolution

Dependencies Resolved

Transaction Summary

-# yum update udev
Transaction Summary

Updating:
Package     Arch         Version                          Repository      Size
gdb         x86_64       7.2.90.20110429-36.fc15          fedora         1.9 M

Transaction Summary

Upgrade       1 Package(s)
Total download size: 1.9 M
Is this ok [y/N]:

This output contains several items of interest:

1. Loaded plugins: — yum always informs you which Yum plug-ins are installed and enabled. Here, yum is using the langpacks, presto, and refresh-packagekit plug-ins. Refer to Section 5.4, “Yum Plug-ins” for general information on Yum plug-ins, or to Section 5.4.3, “Plug-in Descriptions” for descriptions of specific plug-ins.

2. gdb.x86_64 — you can download and install new gdb package.

3. yum presents the update information and then prompts you as to whether you want it to perform the update: yum runs interactively by default. If you already know which transactions yum plans to perform, you can use the -y option to automatically answer yes to any questions yum may ask (in which case it runs non-interactively).
However, you should always examine which changes yum plans to make to the system so that you can easily troubleshoot any problems that might arise.

If a transaction does go awry, you can view Yum’s transaction history by using the yum history command as described in Section 5.2.6, “Working with Transaction History”.

Updating and installing kernels with Yum

yum always installs a new kernel in the same sense that RPM installs a new kernel when you use the command rpm -i kernel. Therefore, you do not need to worry about the distinction between installing and upgrading a kernel package when you use yum: it will do the right thing, regardless of whether you are using the yum update or yum install command.

When using RPM, on the other hand, it is important to use the rpm -i kernel command (which installs a new kernel) instead of rpm -u kernel (which replaces the current kernel).Refer to Section B.2.2, “Installing and Upgrading” for more information on installing/updating kernels with RPM.

Updating All Packages and Their Dependencies
To update all packages and their dependencies, simply enter yum update (without any arguments):

yum update

Updating Security-Related Packages
Discovering which packages have security updates available and then updating those packages quickly and easily is important. Yum provides the plug-in for this purpose. The security plug-in extends the yum command with a set of highly-useful security-centric commands, subcommands and options. Refer to Section 5.4.3, “Plug-in Descriptions” for specific information.

5.1.3. Preserving Configuration File Changes
You will inevitably make changes to the configuration files installed by packages as you use your Fedora system. RPM, which Yum uses to perform changes to the system, provides a mechanism for ensuring their integrity. Refer to Section B.2.2, “Installing and Upgrading” for details on how to manage changes to configuration files across package upgrades.

5.2. Packages and Package Groups

5.2.1. Searching Packages
You can search all RPM package names, descriptions and summaries by using the following command:

yum search term

This command displays the list of matches for each term. For example, to list all packages that match “meld” or “kompare”, type:
The `yum` command is useful for searching for packages you do not know the name of, but for which you know a related term.

5.2.2. Listing Packages

`yum list` and related commands provide information about packages, package groups, and repositories.

All of Yum's list commands allow you to filter the results by appending one or more **glob expressions** as arguments. Glob expressions are normal strings of characters which contain one or more of the wildcard characters `*` (which expands to match any character multiple times) and `?` (which expands to match any one character).

### Filtering results with glob expressions

Be careful to escape the glob expressions when passing them as arguments to a `yum` command, otherwise the Bash shell will interpret these expressions as pathname expansions, and potentially pass all files in the current directory that match the globs to `yum`. To make sure the glob expressions are passed to `yum` as intended, either:

- escape the wildcard characters by preceding them with a backslash character
- double-quote or single-quote the entire glob expression.

Refer to Example 5.1, “Listing all ABRT addons and plug-ins using glob expressions” and Example 5.4, “Listing available packages using a single glob expression with escaped wildcard characters” for an example usage of both these methods.

**Example 5.1. Listing all ABRT addons and plug-ins using glob expressions**

Packages with various ABRT addons and plug-ins either begin with “abrt-addon-”, or “abrt-plugin-”. To list these packages, type the following at a shell prompt:

```bash
~# yum list abrt-addon* abrt-plugin*
```

### Installed Packages

- abrt-addon-ccpp.x86_64 2.0.2-5.fc15 @fedora
- abrt-addon-kerneloops.x86_64 2.0.2-5.fc15 @fedora
- abrt-addon-python.x86_64 2.0.2-5.fc15 @fedora
- abrt-plugin-bugzilla.x86_64 2.0.2-5.fc15 @fedora
- abrt-plugin-logger.x86_64 2.0.2-5.fc15 @fedora

### Available Packages

- abrt-plugin-mailx.x86_64 2.0.2-5.fc15 updates
- abrt-plugin-reportuploader.x86_64 2.0.2-5.fc15 updates
- abrt-plugin-rhtsupport.x86_64 2.0.2-5.fc15 updates

**Example 5.2. Listing all installed and available packages**

```
~# yum list all
```

### Installed Packages

- ConsoleKit.x86_64 0.4.4-1.fc15 @fedora
- ConsoleKit-libs.x86_64 0.4.4-1.fc15 @fedora
- ConsoleKit-x11.x86_64 0.4.4-1.fc15 @fedora
- GConf2.x86_64 2.32.3-1.fc15 @fedora
- GConf2-gtk.x86_64 2.32.3-1.fc15 @fedora
- ModemManager.x86_64 0.4.7.git20110826.fc15 @fedora
- NetworkManager.x86_64 1:0.8.998-4.git20110427.fc15 @fedora
- NetworkManager-glib.x86_64 1:0.8.998-4.git20110427.fc15 @fedora
- NetworkManager-gnome.x86_64 1:0.8.998-4.git20110427.fc15 @fedora
- NetworkManager-openconnect.x86_64 0.8.1-9.git20110649.fc15 @fedora

**Example 5.3. Listing all installed packages**

```
~# yum list installed
```

Lists all packages installed on your system. The rightmost column in the output lists the repository from which the package was retrieved.
Example 5.3. Listing installed packages using a double-quoted glob expression
To list all installed packages that begin with “krb” followed by exactly one character and a hyphen, type:

```
-]# yum list installed "krb?-*"
Loaded plugins: langpacks, presto, refresh-packagekit
Installed Packages
krb5-libs.x86_64    1.9-7.fc15     @fedora
```

**yum list available**
Lists all available packages in all enabled repositories.

Example 5.4. Listing available packages using a single glob expression with escaped wildcard characters
To list all available packages with names that contain “gstreamer” and then “plugin”, run the following command:

```
-]# yum list available gstreamer\"plugin\"*
```

Example 5.5. Listing all package groups
```
-]# yum grouplist
```
```
Installed Groups:
Administration Tools
Design Suite
Dial-up Networking Support
Fonts
GNOME Desktop Environment
```

Example 5.6. Listing enabled repositories
```
-]# yum repolist
```
```
repo id                      repo name                                    status
fedora                       Fedora 15 - i386                             19,365
updates                      Fedora 15 - i386 - Updates                   3,848
repolist: 23,213
```

5.2.3. Displaying Package Information
To display information about one or more packages (glob expressions are valid here as well), use the following command:

```
yum info package_name.
```
For example, to display information about the `abrt` package, type:

```
yum info abrt.
```
The `yum info abrt` command is similar to the `rpm -q --info package_name` command, but provides as additional information the ID of the Yum repository the RPM package is found in (look for the `From repo:` line in the output).

You can also query the Yum database for alternative and useful information about a package by using the following command:

```
]# yumdb info package_name
```

This command provides additional information about a package, including the checksum of the package (and algorithm used to produce it, such as SHA-256), the command given on the command line that was invoked to install the package (if any), and the reason that the package is installed on the system (where `user` indicates it was installed by the user, and `dep` means it was brought in as a dependency). For example, to display additional information about the `yum` package, type:

```
]# yumdb info yum
```

For more information on the `yumdb` command, refer to the `yumdb(8)` manual page.

### 5.2.4. Installing Packages

Yum allows you to install both a single package and multiple packages, as well as a package group of your choice.

#### Installing Individual Packages

To install a single package and all of its non-installed dependencies, enter a command in the following form:

```
yum install package_name
```

You can also install multiple packages simultaneously by appending their names as arguments:

```
yum install package_name package_name...
```

If you are installing packages on a `multilib` system, such as an AMD64 or Intel64 machine, you can specify the architecture of the package (as long as it is available in an enabled repository) by appending `.arch` to the package name. For example, to install the `sqlite2` package for `i586`, type:

```
]# yum install sqlite2.i586
```

You can use glob expressions to quickly install multiple similarly-named packages:

```
]# yum install audacious-plugins-`
```

In addition to package names and glob expressions, you can also provide file names to `yum install`. If you know the name of the binary you want to install, but not its package name, you can give `yum install` the path name:

```
]# yum install /usr/sbin/named
```

`yum` then searches through its package lists, finds the package which provides `/usr/sbin/named`, if any, and prompts you as to whether you want to install it.
Finding which package owns a file

If you know you want to install the package that contains the named binary, but you do not know in which bin or sbin directory is the file installed, use the yum provides command with a glob expression:

```bash
$ yum provides "/bin/named"
```

yum provides "*/file_name" is a common and useful trick to find the packages that contain file_name.

Installing a Package Group

A package group is similar to a package: it is not useful by itself, but installing one pulls a group of dependent packages that serve a common purpose. A package group has a name and a groupid. The yum grouplist -v command lists the names of all package groups, and, next to each of them, their groupid in parentheses. The groupid is always the term in the last pair of parentheses, such as kde-desktop in the following example:

```bash
$ yum -v grouplist kde*
```

You can install a package group by passing its full group name (without the groupid part) to groupinstall:

```bash
yum groupinstall group_name
```

You can also install by groupid:

```bash
yum groupinstall groupid
```

You can even pass the groupid (or quoted name) to the install command if you prepend it with an @-symbol (which tells yum that you want to perform a groupinstall):

```bash
yum install @group
```

For example, the following are alternative but equivalent ways of installing the KDE Desktop group:

```bash
$ yum groupinstall "KDE Desktop"
$ yum groupinstall kde-desktop
$ yum install @kde-desktop
```

5.2.5. Removing Packages

Similarly to package installation, Yum allows you to uninstall (remove in RPM and Yum terminology) both individual packages and a package group.

Removing Individual Packages

To uninstall a particular package, as well as any packages that depend on it, run the following command as root:

```bash
yum remove package_name
```

As when you install multiple packages, you can remove several at once by adding more package names to the command. For example, to remove totem, rhythmbox, and sound-juicer, type the following at a shell prompt:

```bash
$ yum remove totem rhythmbox sound-juicer
```

Similar to install, remove can take these arguments:

- package names
- glob expressions
- file lists
- package provides
Removing a package when other packages depend on it

Yum is not able to remove a package without also removing packages which depend on it. This type of operation can only be performed by RPM, is not advised, and can potentially leave your system in a non-functioning state or cause applications to misbehave and/or crash. For further information, refer to Section B.2.4, “Uninstalling” in the RPM chapter.

Removing a Package Group

You can remove a package group using syntax congruent with the install syntax:

```
yum groupremove group
```

```
yum remove @group
```

The following are alternative but equivalent ways of removing the KDE Desktop group:

```
-# yum groupremove “KDE Desktop”
-# yum groupremove kde-desktop
-# yum remove @kde-desktop
```

Intelligent package group removal

When you tell yum to remove a package group, it will remove every package in that group, even if those packages are members of other package groups or dependencies of other installed packages. However, you can instruct yum to remove only those packages which are not required by any other packages or groups by adding the `groupremove_leaf_only=1` directive to the `[main]` section of the `/etc/yum.conf` configuration file. For more information on this directive, refer to Section 5.3.1, “Setting [main] Options”.

5.2.6. Working with Transaction History

The yum history command allows users to review information about a timeline of Yum transactions, the dates and times on when they occurred, the number of packages affected, whether transactions succeeded or were aborted, and if the RPM database was changed between transactions. Additionally, this command can be used to undo or redo certain transactions.

Listing Transactions

To display a list of twenty most recent transactions, as root, either run yum history with no additional arguments, or type the following at a shell prompt:

```
yum history list
```

To display all transactions, add the all keyword:

```
yum history list all
```

To display only transactions in a given range, use the command in the following form:

```
yum history list start_id..end_id
```

You can also list only transactions regarding a particular package or packages. To do so, use the command with a package name or a glob expression:

```
yum history list glob_expression...
```

For example, the list of first five transactions may look as follows:

```
-# yum history list 1..5
Loaded plugins: langpacks, presto, refresh-packagekit
<table>
<thead>
<tr>
<th>ID</th>
<th>Login user</th>
<th>Date and time</th>
<th>Action(s)</th>
<th>Altered</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Jaromir ... &lt;jhradilek&gt;</td>
<td>2011-07-29 15:33</td>
<td>Install</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Jaromir ... &lt;jhradilek&gt;</td>
<td>2011-07-21 15:10</td>
<td>Install</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Jaromir ... &lt;jhradilek&gt;</td>
<td>2011-07-16 15:27</td>
<td>I, U</td>
<td>73</td>
</tr>
<tr>
<td>2</td>
<td>System &lt;unset&gt;</td>
<td>2011-07-16 15:19</td>
<td>Update</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>System &lt;unset&gt;</td>
<td>2011-07-16 14:38</td>
<td>Install</td>
<td>1186</td>
</tr>
</tbody>
</table>
```

All forms of the yum history list command produce tabular output with each row consisting of the following columns:

- **ID** — an integer value that identifies a particular transaction.
- **Login user** — the name of the user whose login session was used to initiate a transaction. This information is typically presented in the Full Name `<username>` form. For transactions that were not issued by a user (such as an automatic system update), `System <unset>` is used instead.
- **Date and time** — the date and time when a transaction was issued.
- **Action(s)** — a list of actions that were performed during a transaction as described in Table 5.1, “Possible values of the Action(s) field”.
- **Altered** — the number of packages that were affected by a transaction, possibly followed by additional information as described in Table 5.2, “Possible values of the Altered field”.
Table 5.1. Possible values of the Action(s) field

<table>
<thead>
<tr>
<th>Action</th>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Downgrade</td>
<td>D</td>
<td>At least one package has been downgraded to an older version.</td>
</tr>
<tr>
<td>Erase</td>
<td>E</td>
<td>At least one package has been removed.</td>
</tr>
<tr>
<td>Install</td>
<td>I</td>
<td>At least one new package has been installed.</td>
</tr>
<tr>
<td>Obsoleting</td>
<td>O</td>
<td>At least one package has been marked as obsolete.</td>
</tr>
<tr>
<td>Reinstall</td>
<td>R</td>
<td>At least one package has been reinstalled.</td>
</tr>
<tr>
<td>Update</td>
<td>U</td>
<td>At least one package has been updated to a newer version.</td>
</tr>
</tbody>
</table>

Table 5.2. Possible values of the Altered field

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before the transaction finished, the rpmdb database was changed outside Yum.</td>
</tr>
<tr>
<td></td>
<td>After the transaction finished, the rpmdb database was changed outside Yum.</td>
</tr>
<tr>
<td>*</td>
<td>The transaction failed to finish.</td>
</tr>
<tr>
<td>#</td>
<td>The transaction finished successfully, but yum returned a non-zero exit code.</td>
</tr>
<tr>
<td>E</td>
<td>The transaction finished successfully, but an error or a warning was displayed.</td>
</tr>
<tr>
<td>P</td>
<td>The transaction finished successfully, but problems already existed in the rpmdb database.</td>
</tr>
<tr>
<td>s</td>
<td>The transaction finished successfully, but the --skip-broken command line option was used and certain packages were skipped.</td>
</tr>
</tbody>
</table>

Yum also allows you to display a summary of all past transactions. To do so, run the command in the following form as root:

```
yum history summary
```

To display only transactions in a given range, type:

```
yum history summary start_id..end_id
```

Similarly to the `yum history list` command, you can also display a summary of transactions regarding a certain package or packages by supplying a package name or a glob expression:

```
yum history summary glob_expression...
```

For instance, a summary of the transaction history displayed above would look like the following:

```
-]# yum history summary 1..5
```

All forms of the `yum history summary` command produce simplified tabular output similar to the output of `yum history list`. As shown above, both `yum history list` and `yum history summary` are oriented towards transactions, and although they allow you to display only transactions related to a given package or packages, they lack important details, such as package versions. To list transactions from the perspective of a package, run the following command as root:

```
yum history package-list glob_expression...
```

For example, to trace the history of `subscription-manager` and related packages, type the following at a shell prompt:

```
-]# yum history package-list subscription-manager*
```

In this example, three packages were installed during the initial system installation: `subscription-manager`, `subscription-manager-firstboot`, and `subscription-manager-gnome`. In the third transaction, all these packages were updated from version 0.95.11 to version 0.95.17.

**Examining Transactions**

To display the summary of a single transaction, as root, use the `yum history summary` command in the following form:

```
yum history summary id
```

To examine a particular transaction or transactions in more detail, run the following command as root:
yum history info id

The id argument is optional and when you omit it, yum automatically uses the last transaction. Note that when specifying more than one transaction, you can also use a range:

yum history info start_id..end_id

The following is sample output for two transactions, each installing one new package:

```
~]# yum history info 4..5
Loaded plugins: langpacks, presto, refresh-packagekit
Transaction ID: 4..5
Begin time: Thu Jul 21 15:10:46 2011
Begin rpmdb: 1107:0c7c32219c199f9f2ed8ada7572bc6df64edc3a
End time: 15:33:15 2011 (22 minutes)
End rpmdb: 1109:1171025bd9b5bf8db3d0e63598f598f1c1f3242
User: Jaromir Hradilek <jhradilek>
Return-Code: Success
Command Line: install screen
Command Line: install yum-plugin-fs-snapshot
Transaction performed with:
  Installed rpm-4.8.0-16.el6.x86_64
  Installed yum-3.2.29-17.el6.noarch
  Installed yum-metadata-parser-1.1.2-16.el6.x86_64
Packages Altered:
  Install screen-4.0.3-16.el6.x86_64
  Install yum-plugin-fs-snapshot-1.1.30-6.el6.noarch
history info
```

You can also view additional information, such as what configuration options were used at the time of the transaction, or from what repository and why were certain packages installed. To determine what additional information is available for a certain transaction, type the following at a shell prompt as root:

yum history addon-info id

Similarly to yum history info, when no id is provided, yum automatically uses the latest transaction. Another way to refer to the latest transaction is to use the last keyword:

yum history addon-info last

For instance, for the first transaction in the previous example, the yum history addon-info command would provide the following output:

```
~]# yum history addon-info 4
Loaded plugins: langpacks, presto, refresh-packagekit
Transaction ID: 4
Available additional history information:
  config-main
  config-repos
  saved_tx
history addon-info
```

In this example, three types of information are available:

- **config-main** — global Yum options that were in use during the transaction. Refer to Section 5.3.1, “Setting [main] Options” for information on how to change global options.
- **config-repos** — options for individual Yum repositories. Refer to Section 5.3.2, “Setting [repository] Options” for information on how to change options for individual repositories.
- **saved_tx** — the data that can be used by the yum load-transaction command in order to repeat the transaction on another machine (see below).

To display selected type of additional information, run the following command as root:

yum history addon-info id information

Reverting and Repeating Transactions

Apart from reviewing the transaction history, the yum history command provides means to revert or repeat a selected transaction. To revert a transaction, type the following at a shell prompt as root:

yum history undo id

To repeat a particular transaction, as root, run the following command:

yum history redo id

Both commands also accept the last keyword to undo or repeat the latest transaction.

Note that both yum history undo and yum history redo commands merely revert or repeat the steps that were performed during a transaction: if the transaction installed a new package, the yum history undo command will uninstall it, and vice versa. If possible, this command will also attempt to downgrade all updated packages to their previous version, but these older packages may no longer be available. If you need to be able to restore the system to the state before an update, consider using the fs-snapshot plug-in described in Section 5.4.3, “Plug-in Descriptions”.

When managing several identical systems, Yum also allows you to perform a transaction on one of them, store the transaction details in a file, and after a period of testing, repeat the same transaction on the remaining systems as well. To store the transaction details to a file, and type the following at a shell prompt as root:

yum history addon-info last

You can also view additional information, such as what configuration options were used at the time of the transaction, or from what repository and why were certain packages installed. To determine what additional information is available for a certain transaction, type the following at a shell prompt as root:

yum history addon-info id

Similarly to yum history info, when no id is provided, yum automatically uses the latest transaction. Another way to refer to the latest transaction is to use the last keyword:

yum history addon-info last

For instance, for the first transaction in the previous example, the yum history addon-info command would provide the following output:

```
~]# yum history addon-info 4
Loaded plugins: langpacks, presto, refresh-packagekit
Transaction ID: 4
Available additional history information:
  config-main
  config-repos
  saved_tx
history addon-info
```
Once you copy this file to the target system, you can repeat the transaction by using the following command as root:

```bash
yum load-transaction file_name
```

Note, however that the `rpmdb` version stored in the file must be identical to the version on the target system. You can verify the `rpmdb` version by using the `yum version nogroups` command.

### Starting New Transaction History

Yum stores the transaction history in a single SQLite database file. To start new transaction history, run the following command as root:

```bash
yum history new
```

This will create a new, empty database file in the `/var/lib/yum/history/` directory. The old transaction history will be kept, but will not be accessible as long as a newer database file is present in the directory.

### 5.3. Configuring Yum and Yum Repositories

The configuration file for `yum` and related utilities is located at `/etc/yum.conf`. This file contains one mandatory `[main]` section, which allows you to set Yum options that have global effect, and may also contain one or more `[repository]` sections, which allow you to set repository-specific options. However, best practice is to define individual repositories in new or existing `.repo` files in the `/etc/yum.repos.d/` directory. The values you define in the `[main]` section of the `/etc/yum.conf` file may override values set in individual `[repository]` sections.

This section shows you how to:
- set global Yum options by editing the `[main]` section of the `/etc/yum.conf` configuration file;
- set options for individual repositories by editing the `[repository]` sections in `/etc/yum.conf` and `.repo` files in the `/etc/yum.repos.d/` directory;
- use Yum variables in `/etc/yum.conf` and files in the `/etc/yum.repos.d/` directory so that dynamic version and architecture values are handled correctly;
- add, enable, and disable Yum repositories on the command line; and,
- set up your own custom Yum repository.

#### 5.3.1. Setting `[main]` Options

The `/etc/yum.conf` configuration file contains exactly one `[main]` section, and while some of the key-value pairs in this section affect how `yum` operates, others affect how Yum treats repositories. You can add many additional options under the `[main]` section heading in `/etc/yum.conf`.

A sample `/etc/yum.conf` configuration file can look like this:

```bash
[main]
cachedir=/var/cache/yum/$basearch/$releasever
keepcache=0
debuglevel=2
logfile=/var/log/yum.log
exactarch=1
obsoletes=1
gpgcheck=1
plugins=1
installonly_limit=3

[comments abridged]
# PUT YOUR REPOS HERE OR IN separate files named file.repo
# in /etc/yum.repos.d
```

The following are the most commonly-used options in the `[main]` section:

- `assumeyes=value` ...where `value` is one of:
  - `0` — `yum` should prompt for confirmation of critical actions it performs. This is the default.
  - `1` — Do not prompt for confirmation of critical `yum` actions. If `assumeyes=1` is set, `yum` behaves in the same way that the command line option `-y` does.

- `cachedir=directory` ...where `directory` is an absolute path to the directory where Yum should store its cache and database files. By default, Yum's cache directory is `/var/cache/yum/$basearch/$releasever`. Refer to Section 5.3.3, “Using Yum Variables” for descriptions of the `$basearch` and `$releasever` Yum variables.

- `debuglevel=value` ...where `value` is an integer between `1` and `10`. Setting a higher `debuglevel` value causes `yum` to display more detailed debugging output. `debuglevel=0` disables debugging output, while `debuglevel=2` is the default.

- `exactarch=value`
...where value is one of:

0 — Do not take into account the exact architecture when updating packages.

1 — Consider the exact architecture when updating packages. With this setting, **yum** will not install an i686 package to update an i386 package already installed on the system. This is the default.

**exclude=package_name [more_package_names]**

This option allows you to exclude packages by keyword during installation/updates. Listing multiple packages for exclusion can be accomplished by quoting a space-delimited list of packages. Shell globs using wildcards (for example, * and ?) are allowed.

**gpgcheck=value**

...where value is one of:

0 — Disable GPG signature-checking on packages in all repositories, including local package installation.

1 — Enable GPG signature-checking on all packages in all repositories, including local package installation.

**gpgcheck=1** is the default, and thus all packages' signatures are checked.

If this option is set in the [main] section of the /etc/yum.conf file, it sets the GPG-checking rule for all repositories. However, you can also set **gpgcheck=value** for individual repositories instead; that is, you can enable GPG-checking on one repository while disabling it on another. Setting **gpgcheck=value** for an individual repository in its corresponding .repo file overrides the default if it is present in /etc/yum.conf.

For more information on GPG signature-checking, refer to [Section B.3, “Checking a Package’s Signature”](#).

**groupremove_leaf_only=value**

...where value is one of:

0 — **yum** should not check the dependencies of each package when removing a package group. With this setting, **yum** removes all packages in a package group, regardless of whether those packages are required by other packages or groups. **groupremove_leaf_only=0** is the default.

1 — **yum** should check the dependencies of each package when removing a package group, and remove only those packages which are not not required by any other package or group.

For more information on removing packages, refer to [Intelligent package group removal](#).

**installonlypkgs=space separated list of packages**

Here you can provide a space-separated list of packages which **yum** can install, but will never update. Refer to the **yum.conf**(5) manual page for the list of packages which are install-only by default.

If you add the **installonlypkgs** directive to /etc/yum.conf, you should ensure that you list all of the packages that should be install-only, including any of those listed under the **installonlypkgs** section of **yum.conf**(5). In particular, kernel packages should always be listed in **installonlypkgs** (as they are by default), and **installonly_limit** should always be set to a value greater than 2 so that a backup kernel is always available in case the default one fails to boot.

**installonly_limit=value**

...where value is an integer representing the maximum number of versions that can be installed simultaneously for any single package listed in the **installonlypkgs** directive.

The defaults for the **installonlypkgs** directive include several different kernel packages, so be aware that changing the value of **installonly_limit** will also affect the maximum number of installed versions of any single kernel package. The default value listed in /etc/yum.conf is **installonly_limit=3**, and it is not recommended to decrease this value, particularly below 2.

**keepcache=value**

...where value is one of:

0 — Do not retain the cache of headers and packages after a successful installation. This is the default.

1 — Retain the cache after a successful installation.

**logfile=file_name**

...where file_name is an absolute path to the file in which **yum** should write its logging output. By default, **yum** logs to /var/log/yum.log.

**multilib_policy=value**

...where value is one of:

**best** — install the best-choice architecture for this system. For example, setting **multilib_policy=best** on an AMD64 system causes **yum** to install 64-bit versions of all packages.

all — always install every possible architecture for every package. For example, with **multilib_policy** set to **all** on an AMD64 system, **yum** would install both the i586 and AMD64 versions of a package, if both were available.
obsoletes=value
  ...where value is one of:

  0 — Disable yum's obsoletes processing logic when performing updates.

  1 — Enable yum's obsoletes processing logic when performing updates. When one package declares in its spec
      file that it obsoletes another package, the latter package will be replaced by the former package when the former
      package is installed. Obsoletes are declared, for example, when a package is renamed. obsoletes=1 the default.

plugins=value
  ...where value is one of:

  0 — Disable all yum plug-ins globally.

  1 — Enable all yum plug-ins globally. With plugins=1, you can still disable a specific yum plug-in by setting
      enabled=0 in that plug-in's configuration file.

Disabling all plug-ins is not advised

Disabling all plug-ins is not advised because certain plug-ins provide important yum services. Disabling plug-
ins globally is provided as a convenience option, and is generally only recommended when diagnosing a
potential problem with yum.

For more information about various yum plug-ins, refer to Section 5.4, "Yum Plug-ins". For further information on
controlling plug-ins, see Section 5.4.1, "Enabling, Configuring, and Disabling Yum Plug-ins".

reposdir=directory
  ...where directory is an absolute path to the directory where .repo files are located. All .repo files contain
  repository information (similar to the [repository] sections of /etc/yum.conf). yum collects all repository
  information from .repo files and the [repository] section of the /etc/yum.conf file to create a master list of
  repositories to use for transactions. If reposdir is not set, yum uses the default directory /etc/yum.repos.d/.

retries=value
  ...where value is an integer 0 or greater. This value sets the number of times yum should attempt to retrieve a file
  before returning an error. Setting this to 0 makes yum retry forever. The default value is 10.

For a complete list of available [main] options, refer to the [main] OPTIONS section of the yum.conf(5) manual page.

5.3.2. Setting [repository] Options

The [repository] sections, where repository is a unique repository ID such as my_personal_repo (spaces are not
permitted), allow you to define individual yum repositories.

The following is a bare-minimum example of the form a [repository] section takes:

[repository]
name=repository_name
baseurl=repository_url

Every [repository] section must contain the following directives:

name=repository_name
  ...where repository_name is a human-readable string describing the repository.

baseurl=repository_url
  ...where repository_url is a URL to the directory where the repodata directory of a repository is located:

  > If the repository is available over HTTP, use: http://path/to/repo
  > If the repository is available over FTP, use: ftp://path/to/repo
  > If the repository is local to the machine, use: file:///path/to/local/repo
  > If a specific online repository requires basic HTTP authentication, you can specify your username and password
  by prepending it to the URL as username:password@link. For example, if a repository on
  http://www.example.com/repo/ requires a username of "user" and a password of "password", then the baseurl
  link could be specified as http://user:password@www.example.com/repo/.

  Usually this URL is an HTTP link, such as:

  baseurl=http://path/to/repo/releases/$releasever/server/$basearch/os/

  Note that yum always expands the $releasever, $arch, and $basearch variables in URLs. For more information
  about yum variables, refer to Section 5.3.3, "Using Yum Variables".

Another useful [repository] directive is the following:
enabled=value

...where value is one of:

0 — Do not include this repository as a package source when performing updates and installs. This is an easy way of quickly turning repositories on and off, which is useful when you desire a single package from a repository that you do not want to enable for updates or installs.

1 — Include this repository as a package source.

Turning repositories on and off can also be performed by passing either the --enablerepo=repo_name or --disablerepo=repo_name option to yum, or through the Add/Remove Software window of the PackageKit utility.

Many more [repository] options exist. For a complete list, refer to the [repository] OPTIONS section of the yum.conf(5) manual page.

5.3.3. Using Yum Variables

You can use and reference the following built-in variables in yum commands and in all Yum configuration files (that is, /etc/yum.conf and all .repo files in the /etc/yum.repos.d/ directory):

$releasever

You can use this variable to reference the release version of Fedora. Yum obtains the value of $releasever from the distroverpkg=value line in the /etc/yum.conf configuration file. If there is no such line in /etc/yum.conf, then yum infers the correct value by deriving the version number from the redhat-release package.

$arch

You can use this variable to refer to the system's CPU architecture as returned when calling Python's os.uname() function. Valid values for $arch include: i586, i686 and x86_64.

$basearch

You can use $basearch to reference the base architecture of the system. For example, i686 and i586 machines both have a base architecture of i386, and AMD64 and Intel64 machines have a base architecture of x86_64.

$YUM0-9

These ten variables are each replaced with the value of any shell environment variables with the same name. If one of these variables is referenced (in /etc/yum.conf for example) and a shell environment variable with the same name does not exist, then the configuration file variable is not replaced.

To define a custom variable or to override the value of an existing one, create a file with the same name as the variable (without the "$" sign) in the /etc/yum/vars/ directory, and add the desired value on its first line.

For example, repository descriptions often include the operating system name. To define a new variable called $osname, create a new file with "Fedora" on the first line and save it as /etc/yum/vars/osname:

```
~]# echo "Fedora" > /etc/yum/vars/osname
```

Instead of "Fedora 18", you can now use the following in the .repo files:

```
name=$osname $releasever
```

5.3.4. Viewing the Current Configuration

To display the current values of global Yum options (that is, the options specified in the [main] section of the /etc/yum.conf file), run the yum-config-manager with no command line options:

```
yum-config-manager
```

To list the content of a different configuration section or sections, use the command in the following form:

```
yum-config-manager section ...
```

You can also use a glob expression to display the configuration of all matching sections:

```
yum-config-manager glob_expression ...
```

For example, to list all configuration options and their corresponding values, type the following at a shell prompt:

```
~]# yum-config-manager main \
Loaded plugins: langpacks, presto, refresh-packagekit
================================== main ===================================
[main]
alwaysprompt = True
assumeyes = False
bandwidth = 0
bugtracker_url = https://bugzilla.redhat.com/enter_bug.cgi?
product=Red%20Hat%20Enterprise%20Linux%206&component=yum
cache = 0
```

[output truncated]
5.3.5. Adding, Enabling, and Disabling a Yum Repository

Section 5.3.2, "Setting [repository] Options" described various options you can use to define a Yum repository. This section explains how to add, enable, and disable a repository by using the `yum-config-manager` command.

Adding a Yum Repository

To define a new repository, you can either add a `[repository]` section to the `/etc/yum.conf` file, or to a `.repo` file in the `/etc/yum.repos.d/` directory. All files with the `.repo` file extension in this directory are read by `yum`, and best practice is to define your repositories here instead of in `/etc/yum.conf`.

Be careful when using untrusted software sources

Obtaining and installing software packages from unverified or untrusted software sources constitutes a potential security risk, and could lead to security, stability, compatibility maintainability issues.

Yum repositories commonly provide their own `.repo` file. To add such a repository to your system and enable it, run the following command as `root`:

```
$ yum-config-manager --add-repo repository_url
```

...where `repository_url` is a link to the `.repo` file. For example, to add a repository located at `http://www.example.com/example.repo`, type the following at a shell prompt:

```
$ yum-config-manager --add-repo http://www.example.com/example.repo
```

```
Loaded plugins: langpacks, presto, refresh-packagekit
adding repo from: http://www.example.com/example.repo
grabbing file http://www.example.com/example.repo to /etc/yum.repos.d/example.repo
example.repo                                             |  413 B     00:00
repo saved to /etc/yum.repos.d/example.repo
```

Enabling a Yum Repository

To enable a particular repository or repositories, type the following at a shell prompt as `root`:

```
$ yum-config-manager --enable repository
```

...where `repository` is the unique repository ID (use `yum repolist all` to list available repository IDs). Alternatively, you can use a glob expression to enable all matching repositories:

```
$ yum-config-manager --enable glob_expression
```

For example, to disable repositories defined in the `[example]`, `[example-debuginfo]`, and `[example-source]` sections, type:

```
$ yum-config-manager --enable example*
```

When successful, the `yum-config-manager --enable` command displays the current repository configuration.

Disabling a Yum Repository

To disable a Yum repository, run the following command as `root`:

```
$ yum-config-manager --disable repository
```

...where `repository` is the unique repository ID (use `yum repolist all` to list available repository IDs). Similarly to `yum-config-manager --enable`, you can use a glob expression to disable all matching repositories at the same time:

```
$ yum-config-manager --disable glob_expression
```

When successful, the `yum-config-manager --disable` command displays the current configuration.

5.3.6. Creating a Yum Repository

To set up a Yum repository, follow these steps:

1. Install the `createrepo` package:

   ```
   $ yum install createrepo
   ```

2. Copy all of the packages into one directory, such as `/mnt/local_repo/`

3. Run the `createrepo --database` command on that directory:

   ```
   $ createrepo --database /mnt/local_repo
   ```

This creates the necessary metadata for your Yum repository, as well as the `sqlite` database for speeding up `yum` operations.
5.4. Yum Plug-ins

Yum provides plug-ins that extend and enhance its operations. Certain plug-ins are installed by default. Yum always informs you which plug-ins, if any, are loaded and active whenever you call any `yum` command. For example:

```
$ yum info yum
Loaded plugins: langpacks, presto, refresh-packagekit
(output truncated)
```

Note that the plug-in names which follow `Loaded plugins` are the names you can provide to the `--disableplugins=plugin_name` option.

5.4.1. Enabling, Configuring, and Disabling Yum Plug-ins

To enable Yum plug-ins, ensure that a line beginning with `plugins=` is present in the `[main]` section of `/etc/yum.conf`, and that its value is set to `1`:

```
plugins=1
```

You can disable all plug-ins by changing this line to `plugins=0`.

Disabling all plug-ins is not advised because certain plug-ins provide important Yum services. Disabling plug-ins globally is provided as a convenience option, and is generally only recommended when diagnosing a potential problem with Yum.

Every installed plug-in has its own configuration file in the `/etc/yum/pluginconf.d/` directory. You can set plug-in specific options in these files. For example, here is the `refresh-packagekit` plug-in's `refresh-packagekit.conf` configuration file:

```
[main]
enabled=1
```

Plug-in configuration files always contain a `[main]` section (similar to Yum's `/etc/yum.conf` file) in which there is (or you can place if it is missing) an `enabled=` option that controls whether the plug-in is enabled when you run `yum` commands.

If you disable all plug-ins by setting `enabled=0` in `/etc/yum.conf`, then all plug-ins are disabled regardless of whether they are enabled in their individual configuration files.

If you merely want to disable all Yum plug-ins for a single `yum` command, use the `--noplugins` option.

If you want to disable one or more Yum plug-ins for a single `yum` command, add the `--disableplugin=plugin_name` option to the command. For example, to disable the `presto` plug-in while updating a system, type:

```
$ yum update --disableplugin=presto
```

The plug-in names you provide to the `--disableplugin=option` are the same names listed after the `Loaded plugins` line in the output of any `yum` command. You can disable multiple plug-ins by separating their names with commas. In addition, you can match multiple plug-in names or shorten long ones by using glob expressions:

```
$ yum update --disableplugin=presto,refresh-pack*
```

5.4.2. Installing Additional Yum Plug-ins

Yum plug-ins usually adhere to the `yum-plugin-plugin_name` package-naming convention, but not always: the package which provides the `presto` plug-in is named `yum-presto`, for example. You can install a Yum plug-in in the same way you install other packages. For instance, to install the `security` plug-in, type the following at a shell prompt:

```
$ yum install yum-plugin-security
```

5.4.3. Plug-in Descriptions

The following list provides descriptions of a few useful Yum plug-ins:

**fs-snapshot** *(yum-plugin-fs-snapshot)*

The `fs-snapshot` plug-in extends Yum to create a snapshot of a file system before proceeding with a transaction such as a system update or package removal. When a user decides that the changes made by the transaction are unwanted, this mechanism allows the user to roll back to the changes that are stored in a snapshot.

In order for the plug-in to work, the root file system (that is, `/`) must be on an LVM (Logical Volume Manager) or Btrfs volume. To use the `fs-snapshot` plug-in on an LVM volume, take the following steps:

1. Make sure that the volume group with the root file system has enough free extents. The required size is a function of the amount of changes to the original logical volume that is expected during the life of the snapshot. The reasonable default is 50–80% of the original logical volume size.

To display detailed information about a particular volume group, run the `vgdisplay` command in the following form as `root`: `
The number of free extents is listed on the Free PE / Size line.

2. If the volume group with the root file system does not have enough free extents, add a new physical volume:
   a. As root, run the pvcreate command in the following form to initialize a physical volume for use with the Logical Volume Manager:
      
      ```
      pvcreate device
      ```
   b. Use the vgextend command in the following form as root to add the physical volume to the volume group:
      
      ```
      vgextend volume_group physical_volume
      ```

3. Edit the configuration file located in `/etc/yum/pluginconf.d/fs-snapshot.conf`, and make the following changes to the [lvm] section:
   a. Change the value of the enabled option to 1:
      
      ```
      enabled = 1
      ```
   b. Remove the hash sign (that is, #) from the beginning of the lvcreate_size_args line, and adjust the number of logical extents to be allocated for a snapshot. For example, to allocate 80 % of the size of the original logical volume, use:
      
      ```
      lvcreate_size_args = -l 80%ORIGIN
      ```

Refer to Table 5.3, “Supported fs-snapshot.conf directives” for a complete list of available configuration options.

4. Run the desired yum command, and make sure fs-snapshot is included in the list of loaded plug-ins (the Loaded plugins line) before you confirm the changes and proceed with the transaction. The fs-snapshot plug-in displays a line in the following form for each affected logical volume:

   ```
   fs-snapshot: snapshotting file_system (/dev/volume_group/logical_volume):
   logical_volume_yum_timestamp
   ```

5. Verify that the system is working as expected:
   If you decide to keep the changes, remove the snapshot by running the lvremove command as root:

   ```
   lvremove /dev/volume_group/logical_volume_yum_timestamp
   ```

   If you decide to revert the changes and restore the file system to a state that is saved in a snapshot, take the following steps:
   a. As root, run the command in the following form to merge a snapshot into its original logical volume:
      
      ```
      lvconvert --merge /dev/volume_group/logical_volume_yum_timestamp
      ```
      The lvconvert command will inform you that a restart is required in order for the changes to take effect.
   b. Restart the system as instructed. You can do so by typing the following at a shell prompt as root:
      
      ```
      reboot
      ```

To use the fs-snapshot plug-in on a Btrfs file system, take the following steps:

1. Run the desired yum command, and make sure fs-snapshot is included in the list of loaded plug-ins (the Loaded plugins line) before you confirm the changes and proceed with the transaction. The fs-snapshot plug-in displays a line in the following form for each affected file system:

   ```
   fs-snapshot: snapshotting file_system: file_system/yum_timestamp
   ```

2. Verify that the system is working as expected:
   If you decide to keep the changes, you can optionally remove unwanted snapshots. To remove a Btrfs snapshot, use the command in the following form as root:

   ```
   btrfs subvolume delete file_system/yum_timestamp
   ```

   If you decide to revert the changes and restore a file system to a state that is saved in a snapshot, take the following steps:
   a. Determine the identifier of a particular snapshot by using the following command as root:
      
      ```
      btrfs subvolume list file_system
      ```
   b. As root, configure the system to mount this snapshot by default:
      
      ```
      btrfs subvolume set-default id file_system
      ```
   c. Restart the system. You can do so by typing the following at a shell prompt as root:
      
      ```
      reboot
      ```

For more information on logical volume management, Btrfs, and file system snapshots, see the Fedora 18 Storage Administration Guide. For additional information about the plug-in and its configuration, refer to the yum-fs-snapshot(1) and yum-fs-snapshot.conf(5) manual pages.
Refer to the reduce the risk incurred by updating packages as much as possible. You can check for security-related updates as follows:

You can then use either `yum update --security` or `yum update-minimal --security` to update those packages which were affected by security advisories. Both of these commands update all packages on the system for which a security advisory has been issued, `yum update-minimal --security` updates them to the latest packages which were released as part of a security advisory, while `yum update --security` will update all packages affected by a security advisory to the latest version of that package available.

In other words, if:

- the kernel-2.6.38.4-20 package is installed on your system;
- the kernel-2.6.38.6-22 package was released as a security update;
- then kernel-2.6.38.6-26 was released as a bug fix update,

...then `yum update-minimal --security` will update you to kernel-2.6.38.6-22, and `yum update --security` will update you to kernel-2.6.38.6-26. Conservative system administrators may want to use `update-minimal` to reduce the risk incurred by updating packages as much as possible.

Refer to the `yum-security(8)` manual page for usage details and further explanation of the enhancements the `security` plug-in adds to `yum`.

### Table 5.3. Supported fs-snapshot.conf directives

<table>
<thead>
<tr>
<th>Section</th>
<th>Directive</th>
<th>Description</th>
</tr>
</thead>
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<tr>
<td>[main]</td>
<td>enabled=value</td>
<td>Allows you to enable or disable the plug-in. The value must be either 1 (enabled), or 0 (disabled). When installed, the plug-in is enabled by default.</td>
</tr>
<tr>
<td></td>
<td>exclude=list</td>
<td>Allows you to exclude certain file systems. The value must be a space-separated list of mount points you do not want to snapshot (for example, /srv/mnt/backup). This option is not included in the configuration file by default.</td>
</tr>
<tr>
<td>[lvm]</td>
<td>enabled=value</td>
<td>Allows you to enable or disable the use of the plug-in on LVM volumes. The value must be either 1 (enabled), or 0 (disabled). This option is disabled by default.</td>
</tr>
<tr>
<td></td>
<td>lvcreate_size_args=value</td>
<td>Allows you to specify the size of a logical volume snapshot. The value must be the -l or -L command line option for the lvcreate utility followed by a valid argument (for example, -l 80%ORIGIN).</td>
</tr>
</tbody>
</table>

**presto (yum-presto)**

The `presto` plug-in adds support to Yum for downloading delta RPM packages, during updates, from repositories which have `presto` metadata enabled. Delta RPMs contain only the differences between the version of the package installed on the client requesting the RPM package and the updated version in the repository.

Downloading a delta RPM is much quicker than downloading the entire updated package, and can speed up updates considerably. Once the delta RPMs are downloaded, they must be rebuilt to apply the difference to the currently-installed package and thus create the full, updated package. This process takes CPU time on the installing machine. Using delta RPMs is therefore a tradeoff between time-to-download, which depends on the network connection, and time-to-rebuild, which is CPU-bound. Using the `presto` plug-in is recommended for fast machines and systems with slower network connections, while slower machines on very fast connections may benefit more from downloading normal RPM packages, that is, by disabling `presto`.

**refresh-packagekit (PackageKit-yum-plugin)**

The `refresh-packagekit` plug-in updates metadata for `PackageKit` whenever `yum` is run. The `refresh-packagekit` plug-in is installed by default.

**rhnplugin (yum-rhn-plugin)**

The `rhnplugin` provides support for connecting to RHN Classic. This allows systems registered with RHN Classic to update and install packages from this system.

Refer to the `rhnplugin(8)` manual page for more information about the plug-in.

**security (yum-plugin-security)**

Discovering information about and applying security updates easily and often is important to all system administrators. For this reason Yum provides the `security` plug-in, which extends `yum` with a set of highly-useful security-related commands, subcommands and options.

You can check for security-related updates as follows:

```
$ yum check-update --security
Loaded plugins: langpacks, presto, refresh-packagekit, security
Limiting package lists to security relevant ones
updates-testing/updateinfo | 329 kB 00:00
9 package(s) needed for security, out of 270 available

ConsoleKit-x86_64          0.4.6-1.fc15 updates
ConsoleKit-libs.x80_64     0.4.6-1.fc15 updates
ConsoleKit-x11.x86_64      0.4.6-1.fc15 updates
NetworkManager.x86_64      1:0.8.999-2.git20110509.fc15 updates
NetworkManager-glib.x86_64 1:0.8.999-2.git20110509.fc15 updates
[output truncated]
```

You can then use either `yum update --security` or `yum update-minimal --security` to update those packages which were affected by security advisories. Both of these commands update all packages on the system for which a security advisory has been issued, `yum update-minimal --security` updates them to the latest packages which were released as part of a security advisory, while `yum update --security` will update all packages affected by a security advisory to the latest version of that package available.

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Refer to the `yum-security(8)` manual page for usage details and further explanation of the enhancements the `security` plug-in adds to `yum`.  

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</table>
5.5. Additional Resources

http://yum.baseurl.org/wiki/Guides

The Yum Guides section of the Yum wiki contains more documentation.

Chapter 6. PackageKit

6.1. Updating Packages with Software Update

6.1.1. Setting the Update-Checking Interval
6.1.2. Setting the Software Sources

6.2. Using Add/Remove Software

6.2.1. Refreshing Software Sources (Yum Repositories)
6.2.2. Finding Packages with Filters
6.2.3. Installing and Removing Packages (and Dependencies)
6.2.4. Installing and Removing Package Groups
6.2.5. Viewing the Transaction Log

6.3. PackageKit Architecture

6.4. Additional Resources

Fedora provides PackageKit for viewing, managing, updating, installing and un-installing packages compatible with your system. PackageKit consists of several graphical interfaces that can be opened from the GNOME panel menu, or from the Notification Area when PackageKit alerts you that updates are available. For more information on PackageKit's architecture and available front ends, refer to Section 6.3, "PackageKit Architecture".

6.1. Updating Packages with Software Update

You can open Software Updates by clicking Applications → System Tools → Software Update from the Activities menu, or running the `gpk-update-viewer` command at the shell prompt. In the Software Updates window, all available updates are listed along with the names of the packages being updated (minus the `.rpm` suffix, but including the CPU architecture), a short summary of the package, and, usually, short descriptions of the changes the update provides. Any updates you do not wish to install can be de-selected here by un-checking the checkbox corresponding to the update.

![Software Updates window with updates listed](image)

Figure 6.1. Installing updates with Software Update

The updates presented in the Software Updates window only represent the currently-installed packages on your system for which updates are available; dependencies of those packages, whether they are existing packages on your
PackageKit utilizes the fine-grained user authentication capabilities provided by the PolicyKit toolkit whenever you request it to make changes to the system. Whenever you instruct PackageKit to update, install or remove packages, you will be prompted to enter the superuser password before changes are made to the system.

If you instruct PackageKit to update the kernel package, then it will prompt you after installation, asking you whether you want to reboot the system and thereby boot into the newly-installed kernel.

### 6.1.1. Setting the Update-Checking Interval

Selecting Applications → Other → Software Updates from the Activities menu opens the Software Update Preferences window. The Update Settings tab allows you to define the interval at which PackageKit checks for package updates, as well as whether or not to automatically install all updates or only security updates. Leaving the Check for updates when using mobile broadband box unchecked is handy for avoiding extraneous bandwidth usage when using a wireless connection on which you are charged for the amount of data you download.

![Image of PackageKit's update-checking interval settings](image)

**Figure 6.2. Setting PackageKit’s update-checking interval**

### 6.1.2. Setting the Software Sources

To select which package repositories to use to install software updates, select Applications → Other → Software Updates from the Activities menu, and click the Software Sources tab of the Software Update Preferences window.

![Image of PackageKit's software sources](image)

**Figure 6.3. Setting PackageKit’s software sources**

PackageKit refers to Yum repositories as software sources. It obtains all packages from enabled software sources. The Software Sources tab shows the repository name, as written on the `name=` field of all `repository` sections in the `/etc/yum.conf` configuration file, and in all `repository.repo` files in the `/etc/yum.repos.d/` directory.

Entries which are checked in the Enabled column indicate that the corresponding repository will be used to locate packages to satisfy all update and installation requests (including dependency resolution). The Enabled column corresponds to the `enabled=<1 or 0>` field in `repository` sections. Checking an unchecked box enables the Yum repository, and unchecking it disables it. Performing either function causes PolicyKit to prompt for superuser authentication to enable or disable the repository. PackageKit actually inserts the `enabled=<1 or 0>` line into the correct `repository` section if it does not exist, or changes the value if it does. This means that enabling or disabling a repository through the Software Sources window causes that change to persist after closing the window or rebooting the system. The ability to quickly enable and disable repositories based on our needs is a highly-convenient feature of PackageKit.
Note that it is not possible to add or remove Yum repositories through PackageKit.

### Showing source RPM, test, and debuginfo repositories

Checking the box at the bottom of the Software Sources tab causes PackageKit to display source RPM, testing and debuginfo repositories as well. This box is unchecked by default.

### 6.2. Using Add/Remove Software

PackageKit's Software Update GUI window is a separate application from its Add/Remove Software application, although the two have intuitively similar interfaces. To find and install a new package, select Applications → System Tools → Add/Remove Software from the Activities menu, or run the `gpk-application` command at the shell prompt.

![Figure 6.4. PackageKit's Add/Remove Software window](image)

### 6.2.1. Refreshing Software Sources (Yum Repositories)

To enable or disable a Yum repository, open a dialog box by clicking System → Software Sources, and select the Software Sources tab. Refer to Section 6.1.2, “Setting the Software Sources” for more information on available configuration options.

After enabling and/or disabling the correct Yum repositories, make sure that you have the latest list of available packages. Click on System → Refresh Package Lists and PackageKit will obtain the latest lists of packages from all enabled software sources, that is, Yum repositories.

### 6.2.2. Finding Packages with Filters

You can view the list of all configured and unfiltered (see below) Yum repositories by opening Add/Remove Software and clicking System → Software Sources. Once the software sources have been updated, it is often beneficial to apply some filters so that PackageKit retrieves the results of our Find queries faster. This is especially helpful when performing many package searches. Four of the filters in the Filters drop-down menu are used to split results by matching or not matching a single criterion. By default when PackageKit starts, these filters are all unapplied (No Filter), but once you do filter by one of them, that filter remains set until you either change it or close PackageKit.

Because you are usually searching for available packages that are not installed on the system, click Filters → Installed and select the Only Available radio button.
Also, unless we require development files such as C header files, we can filter for **Only End User Files** and, in doing so, filter out all of the `package_name-devel` packages we are not interested in.

The two remaining filters with submenus are:

**Graphical**

Narrows the search to either applications which provide a GUI interface (**only** **Graphical**) or those that do not. This filter is useful when browsing for GUI applications that perform a specific function.

**Free**

Search for packages which are considered to be free software. Refer to the **Fedora Licensing List** for details on approved licenses.

The remaining checkbox filters are always either checked or unchecked. They are:

**Hide Subpackages**

Checking the **Hide Subpackages** checkbox filters out generally-uninteresting packages that are typically only dependencies of other packages that we want. For example, checking Hide Subpackages and searching for `package` would cause the following related packages to be filtered out of the Find results (if it exists):

- `package-devel`
- `package-libs`
- `package-libs-devel`
- `package-debuginfo`

**Only Newest Packages**

Checking **Only Newest Packages** filters out all older versions of the same package from the list of results, which is generally what we want.

---

**Using the Only Newest Packages filter**

Checking **Only Newest Packages** filters out all but the most recent version of any package from the results list. This filter is often combined with the **Only Available** filter to search for the latest available versions of new (not installed) packages.

---

**Only native packages**

Checking the **Only Native Packages** box on a multilib system causes **PackageKit** to omit listing results for packages compiled for the architecture that runs in compatibility mode. For example, enabling this filter on a 64-bit system with...
an AMD64 CPU would cause all packages built for the 32-bit x86 CPU architecture not to be shown in the list of results, even though those packages are able to run on an AMD64 machine. Packages which are architecture-agnostic (i.e., noarch packages such as crontabs-1.10-32.1.e16.noarch.rpm) are never filtered out by checking Only Native Packages. This filter has no affect on non-multilib systems, such as x86 machines.

6.2.3. Installing and Removing Packages (and Dependencies)

With the two filters selected, Only Available and Only End User Files, search for the htop interactive process viewer and highlight the package. You now have access to some very useful information about it, including: a clickable link to the project homepage; the Yum package group it is found in, if any; the license of the package; a pointer to the GNOME menu location from where the application can be opened, if applicable; and the size of the package, which is relevant when we download and install it.

Figure 6.7. Viewing and installing a package with PackageKit's Add/Remove Software window

When the checkbox next to a package or group is checked, then that item is already installed on the system. Checking an unchecked box causes it to be marked for installation, which only occurs when the Apply button is clicked. In this way, you can search for and select multiple packages or package groups before performing the actual installation transactions. Additionally, you can remove installed packages by unchecking the checked box, and the removal will occur along with any pending installations when Apply is pressed. Dependency resolution, which may add additional packages to be installed or removed, is performed after pressing Apply. PackageKit will then display a window listing those additional packages to install or remove, and ask for confirmation to proceed.

Check htop and click the Apply button. You will then be prompted for the superuser password; enter it, and PackageKit will install htop. One nice feature of PackageKit is that, following installation, it sometimes presents you with a list of your newly-installed applications and offer you the choice of running them immediately. Alternatively, you will remember that finding a package and selecting it in the Add/Remove Software window shows you the Location of where in the GNOME menus its application shortcut is located, which is helpful when you want to run it.

Once it is installed, you can run htop, a colorful and enhanced version of the top process viewer, by opening a shell prompt and entering:

```bash
htop
```

htop is nifty, but we decide that top is good enough for us and we want to uninstall it. Remembering that we need to change the Only Available filter we recently used to install it to Only Installed in Filters → Installed, we search for htop again and uncheck it. The program did not install any dependencies of its own; if it had, those would be automatically removed as well, as long as they were not also dependencies of any other packages still installed on our system.

Although PackageKit automatically resolves dependencies during package installation and removal, it is unable to remove a package without also removing packages which depend on it. This type of operation can only be performed by RPM, is not advised, and can potentially leave your system in a non-functioning state or cause applications to misbehave and/or crash.
6.2.4. Installing and Removing Package Groups

PackageKit also has the ability to install Yum package groups, which it calls Package collections. Clicking on Package collections in the top-left list of categories in the Software Updates window allows us to scroll through and find the package group we want to install. In this case, we want to install Czech language support (the Czech Support group). Checking the box and clicking Apply informs us how many additional packages must be installed in order to fulfill the dependencies of the package group.

Similarly, installed package groups can be uninstalled by selecting Package collections, unchecking the appropriate checkbox, and applying.

6.2.5. Viewing the Transaction Log

PackageKit maintains a log of the transactions that it performs. To view the log, from the Add/Remove Software window, click System → Software Log, or run the gpk-log command at the shell prompt.

The Software Log Viewer shows the Action, such as Updated Packages or Installed Packages, the Date on which that action was performed, the Username of the user who performed the action, and the front end Application the user used (such as Add/Remove Software, or Update System). The Details column provides the types of the transactions, such as Updated, Installed, or Removed, as well as the list of packages the transactions were performed on.
Typing the name of a package in the top text entry field filters the list of transactions to those which affected that package.

6.3. PackageKit Architecture

Fedora provides the PackageKit suite of applications for viewing, updating, installing and uninstalling packages and package groups compatible with your system. Architecturally, PackageKit consists of several graphical front ends that communicate with the packagekitd daemon back end, which communicates with a package manager-specific back end that utilizes Yum to perform the actual transactions, such as installing and removing packages, etc.

Table 6.1, “PackageKit GUI windows, menu locations, and shell prompt commands” shows the name of the GUI window, how to start the window from the GNOME desktop or from the Add/Remove Software window, and the name of the command line application that opens that window.

<table>
<thead>
<tr>
<th>Window Title</th>
<th>Function</th>
<th>How to Open</th>
<th>Shell Command</th>
</tr>
</thead>
<tbody>
<tr>
<td>Add/Remove Software</td>
<td>Install, remove or view package info</td>
<td>From the GNOME panel: System → Administration → Add/Remove Software</td>
<td>gpk-application</td>
</tr>
<tr>
<td>Software Update</td>
<td>Perform package updates</td>
<td>From the GNOME panel: System → Administration → Software Update</td>
<td>gpk-update-viewer</td>
</tr>
<tr>
<td>Software Sources</td>
<td>Enable and disable Yum repositories</td>
<td>From Add/Remove Software: System → Software Sources</td>
<td>gpk-repo</td>
</tr>
<tr>
<td>Software Log Viewer</td>
<td>View the transaction log</td>
<td>From Add/Remove Software: System → Software Log</td>
<td>gpk-log</td>
</tr>
<tr>
<td>Software Update Preferences</td>
<td>Set PackageKit preferences</td>
<td>gpk-prefs</td>
<td></td>
</tr>
<tr>
<td>(Notification Area Alert)</td>
<td>Alerts you when updates are available</td>
<td>From the GNOME panel: System → Preferences → Startup Applications, Startup Programs tab</td>
<td>gpk-update-icon</td>
</tr>
</tbody>
</table>

The packagekitd daemon runs outside the user session and communicates with the various graphical front ends. The packagekitd daemon communicates via the DBus system message bus with another back end, which utilizes Yum's Python API to perform queries and make changes to the system. On Linux systems other than Red Hat Enterprise Linux and Fedora, packagekitd can communicate with other back ends that are able to utilize the native package manager for that system. This modular architecture provides the abstraction necessary for the graphical interfaces to work with many different package managers to perform essentially the same types of package management tasks. Learning how to use the PackageKit front ends means that you can use the same familiar graphical interface across many different Linux distributions, even when they utilize a native package manager other than Yum.

In addition, PackageKit's separation of concerns provides reliability in that a crash of one of the GUI windows—or even the user's X Window session—will not affect any package management tasks being supervised by the packagekitd daemon, which runs outside of the user session.

All of the front end graphical applications discussed in this chapter are provided by the gnome-packagekit package instead of by PackageKit and its dependencies. Users working in a KDE environment may prefer to install the kpackagekit package, which provides a KDE interface for PackageKit.

Finally, PackageKit also comes with a console-based front end called pkcon.

6.4. Additional Resources


Information about and mailing lists for PackageKit.


An informative list of Frequently Asked Questions for the PackageKit software suite.
Part III. Networking

This part describes how to configure the network on Fedora.

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Chapter 7. NetworkManager

System daemons are typically long-running processes that provide services to the user or to other programs, and which are started, often at boot time. Daemons respond to the \texttt{systemctl} command and can be turned on or off permanently by using the \texttt{systemctl enable} or \texttt{systemctl disable} commands. They can typically be recognized by a “d” appended to their name, such as the \texttt{packagekitd} daemon. Refer to Chapter 9, Services and Daemons for information about system services.
7.1. The NetworkManager Daemon

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7.5. NetworkManager Architecture

NetworkManager is a dynamic network control and configuration system that attempts to keep network devices and connections up and active when they are available. NetworkManager consists of a core daemon, a GNOME Notification Area applet that provides network status information, and graphical configuration tools that can create, edit and remove connections and interfaces. NetworkManager can be used to configure the following types of connections: Ethernet, wireless, mobile broadband (such as cellular 3G), and DSL and PPPoE (Point-to-Point over Ethernet). In addition, NetworkManager allows for the configuration of network aliases, static routes, DNS information and VPN connections, as well as many connection-specific parameters. Finally, NetworkManager provides a rich API via D-Bus which allows applications to query and control network configuration and state.

Previous versions of Fedora included the Network Administration Tool, which was commonly known as system-config-network after its command line invocation. In Fedora 18, NetworkManager replaces the former Network Administration Tool while providing enhanced functionality, such as user-specific and mobile broadband configuration. It is also possible to configure the network in Fedora 18 by editing interface configuration files; refer to Chapter 8, Network Interfaces for more information.

NetworkManager may be installed by default on Fedora. To ensure that it is, first run the following command as the root user:

```bash
-# yum install NetworkManager
```

7.1. The NetworkManager Daemon

The NetworkManager daemon runs with root privileges and is usually configured to start up at boot time. You can determine whether the NetworkManager daemon is running by entering this command:

```bash
-# systemctl status NetworkManager.service
```

The `systemctl status` command will report NetworkManager as `Active: inactive (dead)` if the NetworkManager service is not running. To start it for the current session run the following command as the root user:

```bash
-# systemctl start NetworkManager.service
```

Run the `systemctl enable` command to ensure that NetworkManager starts up every time the system boots:

```bash
-# systemctl enable NetworkManager.service
```

For more information on starting, stopping and managing services and runlevels, refer to Chapter 9, Services and Daemons.

7.2. Interacting with NetworkManager

Users do not interact with the NetworkManager system service directly. Instead, you can perform network configuration tasks via NetworkManager's Notification Area applet. The applet has multiple states that serve as visual indicators for the type of connection you are currently using.

![NetworkManager applet states](image)

If you do not see the NetworkManager applet in the GNOME panel, and assuming that the NetworkManager package is installed on your system, you can start the applet by running the following command as a normal user (not root):
After running this command, the applet appears in your Notification Area.

7.2.1. Connecting to a Network
When you click on the applet icon, you are presented with:

- a list of categorized networks you are currently connected to (such as Wired and Wireless);
- a list of all Available Networks that NetworkManager has detected;
- options for connecting to any configured Virtual Private Networks (VPNs); and,
- options for connecting to hidden or new wireless networks.

If you are connected to a network, its name is presented first under its network type, such as Wired or Wireless with a bulletpoint to the left. When many networks are available, such as wireless access points, the More networks expandable menu entry appears.

![NetworkManager applet's drop-down menu, showing all available and connected-to networks](image)

Figure 7.2. The NetworkManager applet’s drop-down menu, showing all available and connected-to networks

7.2.2. Configuring New and Editing Existing Connections
Click on the NetworkManager applet to open the drop-down menu, this is the main point of entry for interacting with NetworkManager to configure connections.

If the system has detected a wired connection, the Wired menu entry will appear. If the system has detected a wireless card, then you will also see a Wireless menu entry. Clicking the Wired and Wireless labels or the associated ON OFF indicator to the right will toggle the status between ON and OFF.

Finally, clicking on the Network Settings menu entry opens the Network window, from where you can view some basic network configuration information and initiate configuration tasks.

Then, to configure:

- wired Ethernet connections, click on Wired followed by Options and proceed to Section 7.3.1, "Establishing a Wired (Ethernet) Connection";
- wireless connections, click on Wireless followed by Options and proceed to Section 7.3.2, "Establishing a Wireless Connection"; or,
- mobile broadband connections, proceed to Section 7.3.3, "Establishing a Mobile Broadband Connection"; or,
- VPN connections, click on the VPN menu entry followed by Options and proceed to Section 7.3.4, "Establishing a VPN Connection". If there is no VPN menu entry click on the plus sign at the bottom. A dialog box appears. Ensure the interface is set to VPN. Click the Create button to open the Choose a VPN Connection Type assistant. Proceed to Step 5.

7.2.3. Connecting to a Network Automatically
For any connection type you add or configure, you can choose whether you want NetworkManager to try to connect to that network automatically when it is available.

Procedure 7.1. Configuring NetworkManager to Connect to a Network Automatically When Detected

1. Click on the NetworkManager applet icon in the Notification Area.
2. Click Network Settings.
   The Network window appears.
3. Select the type of connection from the left-hand-side menu.
4. Click on Options. The Editing window appears.
5. Click on the General tab.
6. Select Automatically connect to this network when it is available to cause NetworkManager to auto-connect to the connection whenever NetworkManager detects that it is available. Unselect the checkbox if you do not want NetworkManager to connect automatically. If the box is unchecked, you will have to select that...
7.2.4. User and System Connections

NetworkManager connections are always either user connections or system connections. Depending on the system-specific policy that the administrator has configured, users may need root privileges to create and modify system connections. NetworkManager's default policy enables users to create and modify user connections, but requires them to have root privileges to add, modify or delete system connections.

User connections are so-called because they are specific to the user who creates them. In contrast to system connections, whose configurations are stored under the `/etc/sysconfig/network-scripts/` directory (mainly in `ifcfg-<network_type>` interface configuration files), user connection settings are stored in the GConf configuration database and the GNOME keyring, and are only available during login sessions for the user who created them. Thus, logging out of the desktop session causes user-specific connections to become unavailable.

System connections, on the other hand, become available at boot time and can be used by other users on the system without first logging in to a desktop session. NetworkManager can quickly and conveniently convert user to system connections and vice versa. Converting a user connection to a system connection causes NetworkManager to create the relevant interface configuration files under the `/etc/sysconfig/network-scripts/` directory, and to delete the GConf settings from the user's session. Conversely, converting a system to a user-specific connection causes NetworkManager to remove the system-wide configuration files and create the corresponding GConf/GNOME keyring settings.

Procedure 7.2. Changing a Connection to be User-Specific instead of System-Wide, or Vice-Versa

Depending on the system's policy, you may need root privileges on the system in order to change whether a connection is user-specific or system-wide.

1. Click on the NetworkManager applet icon in the Notification Area and click Network Settings. The Network window appears.
2. Select the menu entry for the type of network connection you want to configure.
3. Select the Options button.
4. Select the General tab.
5. Check the All users may connect to this network checkbox to ask NetworkManager to make the connection a system-wide connection. Depending on system policy, you may then be prompted for the root password by the PolicyKit application. If so, enter the root password to finalize the change. Conversely, uncheck the All users may connect to this network checkbox to make the connection user-specific.

7.3. Establishing Connections

7.3.1. Establishing a Wired (Ethernet) Connection

To establish a wired network connection, click on the NetworkManager applet to open its menu, then click on Network Settings. This opens the Network window.

Select the Wired menu entry and then click Options.

The system startup scripts create and configure a single wired connection called `eth1` by default on all systems. Although you can edit the default connection, creating a new wired connection for your custom settings is recommended. You can create a new wired connection by changing the connection name and clicking the Save button.

When you add a new connection by clicking the Save button, NetworkManager creates a new configuration file for that connection and uses the same dialog that is used for editing an existing connection. There is no difference between these dialogs. In effect, you are always editing a connection; the difference only lies in whether that connection previously existed or was just created by NetworkManager when you clicked Save.

Configuring the Connection Name, Auto-Connect Behavior, and Availability Settings

Three settings in the Editing dialog are common to all connection types:

- At the top of the window, above the tabs: Connection name — Enter a descriptive name for your network connection. This name will be used to list this connection in the Network window.
- On the General tab: Automatically connect to this network when it is available — Check this box if you want NetworkManager to auto-connect to this connection when it is available. Refer to Section 7.2.3. "Connecting..."
If more about wireless security, refer to Connect Certain password types, such as a 40-bit WEP or 128-bit WPA key, are invalid unless they are of a requisite length. The using. If you are unsure, try connecting to each type in turn. Finally, enter the key or passphrase in the are multiple choices, click the NetworkManager prompts you for authentication. The easiest way to connect to an available access point is to click on the Quick Connecting to an Available Access Point. To configure a mobile broadband (such as 3G) connection, refer to connection to an Access Point. This section explains how to use NetworkManager to configure a wireless (also known as Wi-Fi or 802.1a/b/g/n) connection to an Access Point. To configure a mobile broadband (such as 3G) connection, refer to Section 7.3.3, "Establishing a Mobile Broadband Connection".

Quickly Connecting to an Available Access Point
The easiest way to connect to an available access point is to click on the NetworkManager applet, locate the Service Set Identifier (SSID) of the access point in the list of available networks, and click on it. If the access point is secured, a dialog prompts you for authentication. NetworkManager tries to auto-detect the type of security used by the access point. If there are multiple possibilities, NetworkManager guesses the security type and presents it in the Wireless security dropdown menu. To see if there are multiple choices, click the Wireless security dropdown menu and select the type of security the access point is using. If you are unsure, try connecting to each type in turn. Finally, enter the key or passphrase in the Password field. Certain password types, such as a 40-bit WEP or 128-bit WPA key, are invalid unless they are of a requisite length. The Connect button will remain inactive until you enter a key of the length required for the selected security type. To learn more about wireless security, refer to Section 7.4.2, "Configuring Wireless Security".

If NetworkManager connects to the access point successfully, its applet icon will change into a graphical indicator of the...
Connecting to a Hidden Wireless Network

All access points have a Service Set Identifier (SSID) to identify them. However, an access point may be configured not to broadcast its SSID, in which case it is hidden, and will not show up in NetworkManager's list of Available networks. You can still connect to a wireless access point that is hiding its SSID as long as you know its SSID, authentication method, and secrets.

To connect to a hidden wireless network, click NetworkManager's applet icon and then click Network Settings. The Network window appears. Select the Wireless menu entry and then the Wireless connections are displayed. Select Connect to a Hidden Network. The Hidden Wi-Fi network dialog window appears.

![Hidden wireless network dialog window](image)

If you have connected to the hidden network before, use the Connection drop-down list to select it, and click Connect. If you have not, leave the Connection dropdown as New..., enter the SSID of the hidden network, select its Wireless security method, enter the correct authentication secrets, and click Connect.

For more information on wireless security settings, refer to Section 7.4.2, “Configuring Wireless Security”.

Editing a Connection, or Creating a Completely New One

You can create a new connection by clicking on the NetworkManager applet to open its menu.

1. Click on the NetworkManager applet icon in the Notification Area and click Network Settings. The Network window appears.
2. Select the Wireless menu entry. The list of available SSIDs appears
3. Select the SSID you want to connect to. You may be prompted for a password or encryption keys.
4. Click the arrow to the right of the SSID to configure the connection. The Network window displays connection status and essential information for the connection.
5. Select the Settings button. The Editing window appears.

Configuring the Connection Name, Auto-Connect Behavior, and Availability Settings

Three settings in the Editing dialog are common to all connection types:

- **At the top of the window, above the tabs:** Connection name — Enter a descriptive name for your network connection. This name will be used to list this connection in the Network window. By default, wireless connections are named the same as the SSID of the wireless access point. You can rename the wireless connection without affecting its ability to connect, as in the example above, but it is recommended to retain the SSID name.
- **On the General tab:** Automatically connect to this network when it is available — Check this box if you want NetworkManager to auto-connect to this connection when it is available. Refer to Section 7.2.3, “Connecting to a Network Automatically” for more information.
- **On the General tab:** All users may connect to this network — Check this box to create a connection available to all users on the system. Changing this setting may require root privileges. Refer to Section 7.2.4, “User and System Connections” for details.

Configuring the Wireless Tab

**SSID**

All access points have a Service Set Identifier to identify them. However, an access point may be configured not to broadcast its SSID, in which case it is hidden, and will not show up in NetworkManager's list of Available networks. You can still connect to a wireless access point that is hiding its SSID as long as you know its SSID (and authentication secrets).

For information on connecting to a hidden wireless network, refer to the section called “Connecting to a Hidden Wireless Network”. 

Mode
Infrastructure — Set Mode to Infrastructure if you are connecting to a dedicated wireless access point or one built into a network device such as a router or a switch.

Ad-hoc — Set Mode to Ad-hoc if you are creating a peer-to-peer network for two or more mobile devices to communicate directly with each other. If you use Ad-hoc mode, referred to as Independent Basic Service Set (IBSS) in the 802.11 standard, you must ensure that the same SSID is set for all participating wireless devices, and that they are all communicating over the same channel.

**BSSID**

The Basic Service Set Identifier (BSSID) is the MAC address of the specific wireless access point you are connecting to when in **Infrastructure** mode. This field is blank by default, and you are able to connect to a wireless access point by **SSID** without having to specify its **BSSID**. If the BSSID is specified, it will force the system to associate to a specific access point only.

For ad-hoc networks, the **BSSID** is generated randomly by the mac80211 subsystem when the ad-hoc network is created. It is not displayed by NetworkManager.

**MAC address**

Like an Ethernet Network Interface Card (NIC), a wireless adapter has a unique MAC address (Media Access Control; also known as a **hardware address**) that identifies it to the system. Running the `ip addr` command will show the MAC address associated with each interface. For example, in the following `ip addr` output, the MAC address for the `wlan0` interface (which is `00:1c:bf:02:f8:70`) immediately follows the `link/ether` keyword:

```
-]# ip addr
1: lo <LOOPBACK,UP,LOWER_UP> mtu 16436 qdisc noqueue state UNKNOWN
   link/loopback 00:00:00:00:00:00 brd 00:00:00:00:00:00
   inet 127.0.0.1/8 scope host lo
   inet6 ::1/128 scope host
   valid_lft forever preferred_lft forever
2: eth0 <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc pfifo_fast state UNKNOWN qlen 1024
   link/slot 52:54:00:26:9e:f1 brd ff:ff:ff:ff:ff:ff
   inet 192.168.122.251/24 brd 192.168.122.255 scope global eth0
   inet6 fe80::5054:ff:fe26:9ef1/64 scope link
   valid_lft forever preferred_lft forever
3: wlan0 <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc mq state UNKNOWN qlen 1000
   link/ether 52:54:00:26:9e:f1 brd ff:ff:ff:ff:ff:ff
   inet 10.200.130.67/24 brd 10.200.130.255 scope global wlan0
   inet6 fe80::21c:bfff:fe02:f870/64 scope link
   valid_lft forever preferred_lft forever
```

A single system could have one or more wireless network adapters connected to it. The **MAC address** field therefore allows you to associate a specific wireless adapter with a specific connection (or connections). As mentioned, you can determine the MAC address using the `ip addr` command, and then copy and paste that value into the **MAC address** text-entry field.

**MTU**

The MTU (Maximum Transmission Unit) value represents the size in bytes of the largest packet that the connection will use to transmit. If set to a non-zero number, only packets of the specified size or smaller will be transmitted. Larger packets are broken up into multiple Ethernet frames. It is recommended to leave this setting on automatic.

**Saving Your New (or Modified) Connection and Making Further Configurations**

Once you have finished editing the wireless connection, click the **Apply** button and NetworkManager will immediately save your customized configuration. Given a correct configuration, you can successfully connect to your modified connection by selecting it from the NetworkManager Notification Area applet. See Section 7.2.1, “Connecting to a Network” for details on selecting and connecting to a network.

You can further configure an existing connection by selecting it in the **Network Connections** window and clicking **Edit** to return to the **Editing** dialog.

Then, to configure:

- **security authentication** for the wireless connection, click the **Wireless Security** tab and proceed to Section 7.4.2, “Configuring Wireless Security”;
- **IPv4 settings** for the connection, click the **IPv4 Settings** tab and proceed to Section 7.4.4, “Configuring IPv4 Settings”;
- **IPv6 settings** for the connection, click the **IPv6 Settings** tab and proceed to Section 7.4.5, “Configuring IPv6 Settings”.

**7.3.3. Establishing a Mobile Broadband Connection**

You can use NetworkManager’s mobile broadband connection abilities to connect to the following 2G and 3G services:

- **2G** — GPRS (General Packet Radio Service) or EDGE (Enhanced Data Rates for GSM Evolution)
- **3G** — UMTS (Universal Mobile Telecommunications System) or HSPA (High Speed Packet Access)

Your computer must have a mobile broadband device (modem), which the system has discovered and recognized, in order to create the connection. Such a device may be built into your computer (as is the case on many notebooks and netbooks), or may be provided separately as internal or external hardware. Examples include PC card, USB Modem or Dongle, mobile or cellular telephone capable of acting as a modem.
Procedure 7.3. Adding a New Mobile Broadband Connection
You can configure a mobile broadband connection by opening the Network Connections window and selecting the Mobile Broadband tab.

1. Open the Network Connections window by running, as a normal user:

```
-]$: mm-connection-editor &
```

The Network Connections window appears.

2. Select the Mobile Broadband tab.

3. Click the Add button to open the Set up a Mobile Broadband Connection assistant.

4. Under Create a connection for this mobile broadband device, choose the 2G- or 3G-capable device you want to use with the connection. If the dropdown menu is inactive, this indicates that the system was unable to detect a device capable of mobile broadband. In this case, click Cancel, ensure that you do have a mobile broadband-capable device attached and recognized by the computer and then retry this procedure. Click the Forward button.

5. Select the country where your service provider is located from the list and click the Forward button.

6. Select your provider from the list or enter it manually. Click the Forward button.

7. Select your payment plan from the dropdown menu and confirm the Access Point Name (APN) is correct. Click the Forward button.

8. Review and confirm the settings and then click the Apply button.

9. Edit the mobile broadband-specific settings by referring to the Configuring the Mobile Broadband Tab description below.

Procedure 7.4. Editing an Existing Mobile Broadband Connection
Follow these steps to edit an existing mobile broadband connection.

1. Open the Network Connections window by running, as a normal user:

```
-]$: mm-connection-editor &
```

The Network Connections window appears.

2. Select the Mobile Broadband tab.

3. Select the connection you wish to edit and click the Edit button.

4. Configure the connection name, auto-connect behavior, and availability settings. Three settings in the Editing dialog are common to all connection types:

   - **Connection name** — Enter a descriptive name for your network connection. This name will be used to list this connection in the Mobile Broadband tab of the Network Connections window.

   - **Connect automatically** — Check this box if you want NetworkManager to auto-connect to this connection when it is available. Refer to Section 7.2.3, “Connecting to a Network Automatically” for more information.

   - **Available to all users** — Check this box to create a connection available to all users on the system. Changing this setting may require root privileges. Refer to Section 7.2.4, “User and System Connections” for details.

5. Edit the mobile broadband-specific settings by referring to the Configuring the Mobile Broadband Tab description below.

Saving Your New (or Modified) Connection and Making Further Configurations
Once you have finished editing your mobile broadband connection, click the Apply button and NetworkManager will immediately save your customized configuration. Given a correct configuration, you can connect to your new or customized connection by selecting it from the NetworkManager Notification Area applet. See Section 7.2.1, “Connecting to a Network” for information on using your new or altered connection.

You can further configure an existing connection by selecting it in the Network Connections window and clicking Edit to return to the Editing dialog.

Then, to configure:

- Point-to-point settings for the connection, click the PPP Settings tab and proceed to Section 7.4.3, “Configuring PPP (Point-to-Point) Settings”;
- IPv4 settings for the connection, click the IPv4 Settings tab and proceed to Section 7.4.4, “Configuring IPv4 Settings”; or,
- IPv6 settings for the connection, click the IPv6 Settings tab and proceed to Section 7.4.5, “Configuring IPv6 Settings”.

Configuring the Mobile Broadband Tab
If you have already added a new mobile broadband connection using the assistant (refer to Procedure 7.3, “Adding a New Mobile Broadband Connection” for instructions), you can edit the Mobile Broadband tab to disable roaming if home network is not available, assign a network ID, or instruct NetworkManager to prefer a certain technology (such as 3G or 2G) when using the connection.

**Number**

The number that is dialed to establish a PPP connection with the GSM-based mobile broadband network. This field may be automatically populated during the initial installation of the broadband device. You can usually leave this field blank and enter the APN instead.

**Username**

Enter the username used to authenticate with the network. Some providers do not provide a username, or accept any username when connecting to the network.
Password
Enter the password used to authenticate with the network. Some providers do not provide a password, or accept any password.

APN
Enter the Access Point Name (APN) used to establish a connection with the GSM-based network. Entering the correct APN for a connection is important because it often determines:

- how the user is billed for their network usage; and/or
- whether the user has access to the Internet, an intranet, or a subnetwork.

Network ID
Entering a Network ID causes NetworkManager to force the device to register only to a specific network. This can be used to ensure the connection does not roam when it is not possible to control roaming directly.

Type
- Any — The default value of Any leaves the modem to select the fastest network.
- 3G (UMTS/HSPA) — Force the connection to use only 3G network technologies.
- 2G (GPRS/EDGE) — Force the connection to use only 2G network technologies.
- Prefer 3G (UMTS/HSPA) — First attempt to connect using a 3G technology such as HSPA or UMTS, and fall back to GPRS or EDGE only upon failure.
- Prefer 2G (GPRS/EDGE) — First attempt to connect using a 2G technology such as GPRS or EDGE, and fall back to HSPA or UMTS only upon failure.

Allow roaming if home network is not available
Uncheck this box if you want NetworkManager to terminate the connection rather than transition from the home network to a roaming one, thereby avoiding possible roaming charges. If the box is checked, NetworkManager will attempt to maintain a good connection by transitioning from the home network to a roaming one, and vice versa.

PIN
If your device's SIM (Subscriber Identity Module) is locked with a PIN (Personal Identification Number), enter the PIN so that NetworkManager can unlock the device. NetworkManager must unlock the SIM if a PIN is required in order to use the device for any purpose.

7.3.4. Establishing a VPN Connection
Establishing an encrypted Virtual Private Network (VPN) enables you to communicate securely between your Local Area Network (LAN), and another, remote LAN. After successfully establishing a VPN connection, a VPN router or gateway performs the following actions upon the packets you transmit:

1. it adds an Authentication Header for routing and authentication purposes;
2. it encrypts the packet data; and,
3. it encloses the data with an Encapsulating Security Payload (ESP), which constitutes the decryption and handling instructions.

The receiving VPN router strips the header information, decrypts the data, and routes it to its intended destination (either a workstation or other node on a network). Using a network-to-network connection, the receiving node on the local network receives the packets already decrypted and ready for processing. The encryption/decryption process in a network-to-network VPN connection is therefore transparent to clients.

Because they employ several layers of authentication and encryption, VPNs are a secure and effective means of connecting multiple remote nodes to act as a unified intranet.

Procedure 7.5. Adding a New VPN Connection

1. You can configure a new VPN connection by opening the Network window and selecting the VPN menu entry.
2. Click on the NetworkManager applet icon in the Notification Area. Clicking on the Network Settings menu entry opens the Network window, from where you can view some basic network configuration information and initiate configuration tasks.
3. Click on the VPN menu entry followed by Configure and proceed to Section 7.3.4, “Establishing a VPN Connection”. If there is no VPN menu entry click on the plus sign at the bottom. A dialog box appears. Ensure the interface is set to VPN.

A VPN plug-in is required

The appropriate NetworkManager VPN plug-in for the VPN type you wish to configure must be installed. (refer to Section 5.2.4, “Installing Packages” for more information on how to install new packages in Fedora 18).

4. Click the Create button to open the Choose a VPN Connection Type assistant.
5. Select the VPN protocol for the gateway you are connecting to from the dropdown menu. The VPN protocols available for selection in the dropdown menu corresponds to the NetworkManager VPN plug-ins installed. For example, if the NetworkManager VPN plug-in for openswan is installed then the IPsec based VPN will be selectable from the dropdown menu.

After selecting the correct one, press the Create... button.

6. The Editing VPN Connection 1 window then appears. This window presents settings customized for the type of VPN connection you selected in Step 5.

You can configure an existing VPN connection by opening the Network window and selecting the VPN menu entry.

1. Click on the NetworkManager applet icon in the Notification Area and click Network Settings. The Network window appears.
2. Select the VPN menu entry.
3. Select the connection you wish to edit and click the Configure button.

![Editing VPN Connection 1](image)

**Figure 7.5. Editing the newly-created VPN connection 1.**

**Configuring the Connection Name, Auto-Connect Behavior, and Availability Settings**

Three settings in the Editing dialog are common to all connection types:

- **Connection name** — Enter a descriptive name for your network connection. This name will be used to list this connection in the VPN tab of the Network Connections window.
- **Connect automatically** — Check this box if you want NetworkManager to auto-connect to this connection when it is available. Refer to Section 7.2.3, "Connecting to a Network Automatically" for more information.
- **Available to all users** — Check this box to create a connection available to all users on the system. Changing this setting may require root privileges. Refer to Section 7.2.4, "User and System Connections" for details.

**Configuring the VPN Tab**

**Gateway**

The name or IP address of the remote VPN gateway.

**Group name**

The name of a VPN group configured on the remote gateway.

**User password**

If required, enter the password used to authenticate with the VPN.

**Group password**

If required, enter the password used to authenticate with the VPN.
User name

If required, enter the username used to authenticate with the VPN.

Phase1 Algorithms

If required, enter the algorithms to be used to authenticate and set up an encrypted channel.

Phase2 Algorithms

If required, enter the algorithms to be used for the IPsec negotiations.

Domain

If required, enter the Domain Name.

NAT traversal

Cisco UDP (default) — IPsec over UDP.

NAT-T — ESP encapsulation and IKE extensions are used to handle NAT Traversal.

Disabled — No special NAT measures required.

Disable Dead Peer Detection — Disable the sending of probes to the remote gateway or endpoint.

Saving Your New (or Modified) Connection and Making Further Configurations

Once you have finished editing your new VPN connection, click the Apply button and NetworkManager will immediately save your customized configuration. Given a correct configuration, you can connect to your new or customized connection by selecting it from the NetworkManager Notification Area applet. See Section 7.2.1, “Connecting to a Network” for information on using your new or altered connection.

You can further configure an existing connection by selecting it in the Network Connections window and clicking Edit to return to the Editing dialog.

Then, to configure:

» IPv4 settings for the connection, click the IPv4 Settings tab and proceed to Section 7.4.4, “Configuring IPv4 Settings”.

7.3.5. Establishing a DSL Connection

This section is intended for those installations which have a DSL card fitted within a host rather than the external combined DSL modem router combinations typical of private consumer or SOHO installations.

Procedure 7.6. Adding a New DSL Connection

1. Open the Network Connections window by running, as a normal user:

   ```bash
   $ nm-connection-editor &
   ```

2. Select the DSL tab and click Add.

3. The Editing DSL Connection window appears.

Procedure 7.7. Editing an Existing DSL Connection

You can further configure an existing connection by selecting it in the Network Connections window and clicking Edit to return to the Editing dialog.

1. Open the Network Connections window by running, as a normal user:

   ```bash
   $ nm-connection-editor &
   ```

2. Select the DSL tab.

3. Select the connection you wish to edit and click the Edit button.

4. The Editing DSL Connection window appears.

Configuring the Connection Name, Auto-Connect Behavior, and Availability Settings

Three settings in the Editing dialog are common to all connection types:

» Connection name — Enter a descriptive name for your network connection. This name will be used to list this connection in the DSL section of the Network Connections window.

» Connect automatically — Check this box if you want NetworkManager to auto-connect to this connection when it is available. Refer to Section 7.2.3, ”Connecting to a Network Automatically” for more information.

» Available to all users — Check this box to create a connection available to all users on the system. Changing this setting may require root privileges. Refer to Section 7.2.4, ”User and System Connections” for details.

Configuring the DSL Tab

Username

Enter the username used to authenticate with the service provider.

Service
Password
Enter the password supplied by the service provider.

Saving Your New (or Modified) Connection and Making Further Configurations
Once you have finished editing your DSL connection, click the Save button to save your customized configuration. Given a correct configuration, you can connect to your new or customized connection by selecting it from the NetworkManager Notification Area applet. See Section 7.2.1, “Connecting to a Network” for information on using your new or altered connection.

You can further configure an existing connection by selecting it in the Network Connections window and clicking Edit to return to the Editing dialog.

Then, to configure:
- The MAC address and MTU settings, click the Wired tab and proceed to the section called “Configuring the Wired Tab”;
- Point-to-point settings for the connection, click the PPP Settings tab and proceed to Section 7.4.3, “Configuring PPP (Point-to-Point) Settings”;
- IPv4 settings for the connection, click the IPv4 Settings tab and proceed to Section 7.4.4, “Configuring IPv4 Settings”.

7.4. Configuring Connection Settings

7.4.1. Configuring 802.1x Security
802.1x security is the name of the IEEE standard for port-based Network Access Control (PNAC). Simply put, 802.1x security is a way of defining a logical network out of a physical one. All clients who want to join the logical network must authenticate with the server (a router, for example) using the correct 802.1x authentication method.

802.1x security is most often associated with securing wireless networks (WLANs), but can also be used to prevent intruders with physical access to the network (LAN) from gaining entry. In the past, DHCP servers were configured not to lease IP addresses to unauthorized users, but for various reasons this practice is both impractical and insecure, and thus is no longer recommended. Instead, 802.1x security is used to ensure a logically-secure network through port-based authentication.

802.1x provides a framework for WLAN and LAN access control and serves as an envelope for carrying one of the Extensible Authentication Protocol (EAP) types. An EAP type is a protocol that defines how WLAN security is achieved on the network.

You can configure 802.1x security for a wired or wireless connection type by opening the Network Connections window (refer to Section 7.2.2, “Configuring New and Editing Existing Connections”) and following the applicable procedure:

Procedure 7.8. For a wired connection...
1. Select the Wired tab.
2. Either click on Add to add a new network connection for which you want to configure 802.1x security, or select an existing connection and click Edit.
3. Then select the 802.1x Security tab and check the Use 802.1x security for this connection checkbox to enable settings configuration.
4. Proceed to Section 7.4.1.1, “Configuring TLS (Transport Layer Security) Settings”.

Procedure 7.9. For a wireless connection...
1. Select the Wireless tab.
2. Either click on Add to add a new network connection for which you want to configure 802.1x security, or select an existing connection and click Edit.
3. Then click the Security dropdown and choose one of the following security methods: LEAP, Dynamic WEP (802.1x), or WPA & WPA2 Enterprise.
4. Refer to Section 7.4.1.1, “Configuring TLS (Transport Layer Security) Settings” for descriptions of which EAP types correspond to your selection in the Security dropdown.

7.4.1.1. Configuring TLS (Transport Layer Security) Settings
With Transport Layer Security, the client and server mutually authenticate using the TLS protocol. The server demonstrates that it holds a digital certificate, the client proves its own identity using its client-side certificate, and key information is exchanged. Once authentication is complete, the TLS tunnel is no longer used. Instead, the client and server use the exchanged keys to encrypt data using AES, TKIP or WEP.

The fact that certificates must be distributed to all clients who want to authenticate means that the EAP-TLS authentication method is very strong, but also more complicated to set up. Using TLS security requires the overhead of a public key infrastructure (PKI) to manage certificates. The benefit of using TLS security is that a compromised password does not allow access to the (W)LAN: an intruder must also have access to the authenticating client's private key.

Network Manager does not determine the version of TLS supported. Network Manager gathers the parameters entered by the user and passes them to the daemon, wpa_supplicant, that handles the procedure. It, in turn, uses OpenSSL to establish the TLS tunnel. OpenSSL itself negotiates the SSL/TLS protocol version. It uses the highest version both ends support.
Identity
Identity string for EAP authentication methods, such as a username or login name.

User certificate
Click to browse for, and select, a user's certificate.

CA certificate
Click to browse for, and select, a Certificate Authority's certificate.

Private key
Click to browse for, and select, a user's private key file.

Private key password
Enter the user password corresponding to the user's private key.

7.4.1.2. Configuring Tunneled TLS Settings
Anonymous identity
This value is used as the unencrypted identity.

CA certificate
Click to browse for, and select, a Certificate Authority's certificate.

Inner authentication
PAP — Password Authentication Protocol.

Username
Enter the username to be used in the authentication process.

Password
Enter the password to be used in the authentication process.

7.4.1.3. Configuring Protected EAP (PEAP) Settings
Anonymous Identity
This value is used as the unencrypted identity.

CA certificate
Click to browse for, and select, a Certificate Authority's certificate.

PEAP version
The version of Protected EAP to use. Automatic, 0 or 1.

Inner authentication
MD5 — Message Digest 5, a cryptographic hash function.
GTC — Generic Token Card.

Username
Enter the username to be used in the authentication process.

Password
Enter the password to be used in the authentication process.

7.4.2. Configuring Wireless Security
Security
None — Do not encrypt the Wi-Fi connection.
WEP 40/128-bit Key — Wired Equivalent Privacy (WEP), from the IEEE 802.11 standard. Uses a single pre-shared key (PSK).

WEP 128-bit Passphrase — An MD5 hash of the passphrase will be used to derive a WEP key.

LEAP — Lightweight Extensible Authentication Protocol, from Cisco Systems.

Dynamic WEP (802.1x) — WEP keys are changed dynamically.

WPA & WPA2 Personal — Wi-Fi Protected Access (WPA), from the draft IEEE 802.11i standard. A replacement for WEP. Wi-Fi Protected Access II (WPA2), from the 802.11i-2004 standard. Personal mode uses a pre-shared key (WPA-PSK).

WPA & WPA2 Enterprise — WPA for use with a RADIUS authentication server to provide IEEE 802.1x network access control.

Password
Enter the password to be used in the authentication process.

7.4.3. Configuring PPP (Point-to-Point) Settings

Configure Methods

Use point-to-point encryption (MPPE)
Microsoft Point-To-Point Encryption protocol (RFC 3078).

Allow BSD data compression

Allow Deflate data compression

Use TCP header compression
Compressing TCP/IP Headers for Low-Speed Serial Links (RFC 1144).

Send PPP echo packets
LCP Echo-Request and Echo-Reply Codes for loopback tests (RFC 1661).

7.4.4. Configuring IPv4 Settings
The **IPv4 Settings** tab allows you to configure the method by which you connect to the Internet and enter IP address, route, and DNS information as required. The **IPv4 Settings** tab is available when you create and modify one of the following connection types: wired, wireless, mobile broadband, VPN or DSL.

If you are using DHCP to obtain a dynamic IP address from a DHCP server, you can simply set **Method** to **Automatic (DHCP)**.

**Setting the Method**

**Available IPv4 Methods by Connection Type**

When you click the **Method** dropdown menu, depending on the type of connection you are configuring, you are able to select one of the following IPv4 connection methods. All of the methods are listed here according to which connection type or types they are associated with.

- **Method**
  - **Automatic (DHCP)** — Choose this option if the network you are connecting to uses a DHCP server to assign IP addresses. You do not need to fill in the **DHCP client ID** field.
  - **Automatic (DHCP) addresses only** — Choose this option if the network you are connecting to uses a DHCP server to assign IP addresses but you want to assign DNS servers manually.
  - **Link-Local Only** — Choose this option if the network you are connecting to does not have a DHCP server and you do not want to assign IP addresses manually. Random addresses will be selected as per RFC 3927.
  - **Shared to other computers** — Choose this option if the interface you are configuring is for sharing an Internet or WAN connection.

- **Wired, Wireless and DSL Connection Methods**
  - **Manual** — Choose this option if the network you are connecting to does not have a DHCP server and you want to assign IP addresses manually.

- **Mobile Broadband Connection Methods**
  - **Automatic (PPP)** — Choose this option if the network you are connecting to uses a DHCP server to assign IP addresses.
  - **Automatic (PPP) addresses only** — Choose this option if the network you are connecting to uses a DHCP server to assign IP addresses but you want to assign DNS servers manually.

- **VPN Connection Methods**
  - **Automatic (VPN)** — Choose this option if the network you are connecting to uses a DHCP server to assign IP addresses.
  - **Automatic (VPN) addresses only** — Choose this option if the network you are connecting to uses a DHCP server to assign IP addresses but you want to assign DNS servers manually.
assign IP addresses but you want to assign DNS servers manually.

**DSL Connection Methods**

- **Automatic (PPPoE)** — Choose this option if the network you are connecting to uses a DHCP server to assign IP addresses.
- **Automatic (PPPoE) addresses only** — Choose this option if the network you are connecting to uses a DHCP server to assign IP addresses but you want to assign DNS servers manually.

**7.4.5. Configuring IPv6 Settings**

**Method**

- **Ignore** — Choose this option if you want to disable IPv6 settings.
- **Automatic** — Choose this option if the network you are connecting to uses a DHCP server to assign IP addresses.
- **Automatic, addresses only** — Choose this option if the network you are connecting to uses a DHCP server to assign IP addresses but you want to assign DNS servers manually.
- **Manual** — Choose this option if the network you are connecting to does not have a DHCP server and you want to assign IP addresses manually.
- **Link-Local Only** — Choose this option if the network you are connecting to does not have a DHCP server and you do not want to assign IP addresses manually. Random addresses will be selected as per RFC 4862.
- **Shared to other computers** — Choose this option if the interface you are configuring is for sharing an Internet or WAN connection.

**Addresses**

- **DNS servers** — Enter a comma separated list of DNS servers.
- **Search domains** — Enter a comma separated list of domain controllers.

For information on configuring static routes for the network connection, go to Section 7.4.6, “Configuring Routes”.

**7.4.6. Configuring Routes**

A hosts routing table will be automatically populated with routes to directly connected networks. The routes are learned by observing the network interfaces when they are “up”. This section is for entering static routes to networks or hosts which can be reached by traversing an intermediate network or connection, such as a VPN or leased line.
Figure 7.7. Configuring static network routes

Addresses
- **Address** — The IP address of a network, sub-net or host.
- **Netmask** — The netmask or prefix length of the IP address just entered.
- **Gateway** — The IP address of the gateway leading to the network, sub-net or host.
- **Metric** — A network cost, that is to say a preference value to give to this route. Lower values will be preferred over higher values.

Ignore automatically obtained routes
Select this check box to only use manually entered routes for this connection.

Use this connection only for resources on its network
Select this checkbox to prevent the connection from becoming the default route. Typical examples are where a connection is a VPN or a leased line to a head office and you do not want any Internet bound traffic to pass over the connection. Selecting this option means that only traffic specifically destined for routes learned automatically over the connection or entered here manually will be routed over the connection.

7.5. NetworkManager Architecture
See [http://live.gnome.org/NetworkManagerConfiguration](http://live.gnome.org/NetworkManagerConfiguration)

Chapter 8. Network Interfaces

8.1. Network Configuration Files

8.2. Interface Configuration Files
- 8.2.1. Ethernet Interfaces
- 8.2.2. Ethtool
- 8.2.3. Channel Bonding Interfaces
- 8.2.4. Network Bridge
- 8.2.5. Setting Up 802.1q VLAN Tagging
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8.3. Interface Control Scripts

8.4. Using Hostnamed
- 8.4.1. View all the Hostnames
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8.5. Static Routes and the Default Gateway

8.6. Network Function Files

8.7. Additional Resources
- 8.7.1. Installed Documentation
- 8.7.2. Useful Websites

Under Fedora, all network communications occur between configured software interfaces and physical networking devices connected to the system.

The configuration files for network interfaces are located in the `/etc/sysconfig/network-scripts/` directory. The scripts used to activate and deactivate these network interfaces are also located here. Although the number and type of interface files can differ from system to system, there are three categories of files that exist in this directory:

1. Interface configuration files
2. Interface control scripts
3. Network function files

The files in each of these categories work together to enable various network devices.

This chapter explores the relationship between these files and how they are used.

8.1. Network Configuration Files

Before delving into the interface configuration files, let us first itemize the primary configuration files used in network
configuration. Understanding the role these files play in setting up the network stack can be helpful when customizing a Fedora system.

The primary network configuration files are as follows:

/etc/hosts
The main purpose of this file is to resolve hostnames that cannot be resolved any other way. It can also be used to resolve hostnames on small networks with no DNS server. Regardless of the type of network the computer is on, this file should contain a line specifying the IP address of the loopback device (127.0.0.1) as localhost.localdomain. For more information, refer to the hosts(5) manual page.

/etc/hostname
There are three separate classes of hostnames in use on a given system. The pretty hostname is the high level hostname often presented to users by their desktop environment or shell. The static hostname is used by the kernel at boot, and is usually the system’s fully qualified domain name. A system may also have a transient hostname assigned by a dhcp server, hostnamectl is provided for administering these hostnames. For more information on hostnames, see man hostname and man hostnamectl.

/etc/resolv.conf
This file specifies the IP addresses of DNS servers and the search domain. Unless configured to do otherwise, the network initialization scripts populate this file. For more information about this file, refer to the resolv.conf(5) manual page.

/etc/sysconfig/network
This file specifies routing and host information for all network interfaces. For more information about this file and the directives it accepts, refer to Section D.1.13, “/etc/sysconfig/network”.

/etc/sysconfig/network-scripts/ifcfg-interface-name
For each network interface, there is a corresponding interface configuration script. Each of these files provide information specific to a particular network interface. Refer to Section 8.2, “Interface Configuration Files” for more information on this type of file and the directives it accepts.

### Network interface names

Network interface names may be different on different hardware types. Refer to Appendix A, Consistent Network Device Naming for more information.

### The /etc/sysconfig/networking/ directory

The /etc/sysconfig/networking/ directory is used by the now deprecated Network Administration Tool (system-config-network). Its contents should not be edited manually. Using only one method for network configuration is strongly encouraged, due to the risk of configuration deletion. For more information about configuring network interfaces using graphical configuration tools, refer to Chapter 7, NetworkManager.

8.2. Interface Configuration Files

Interface configuration files control the software interfaces for individual network devices. As the system boots, it uses these files to determine what interfaces to bring up and how to configure them. These files are usually named ifcfg-name, where name refers to the name of the device that the configuration file controls.

8.2.1. Ethernet Interfaces

One of the most common interface files is /etc/sysconfig/network-scripts/ifcfg-eth0, which controls the first Ethernet network interface card or NIC in the system. In a system with multiple NICs, there are multiple ifcfg-ethX files (where X is a unique number corresponding to a specific interface). Because each device has its own configuration file, an administrator can control how each interface functions individually.

The following is a sample ifcfg-eth0 file for a system using a fixed IP address:

```
DEVICE=eth0
BOOTPROTO=none
ONBOOT=yes
NETMASK=255.255.255.0
IPADDR=10.0.1.27
USERCTL=no
```

The values required in an interface configuration file can change based on other values. For example, the ifcfg-eth0 file for an interface using DHCP looks different because IP information is provided by the DHCP server:

```
DEVICE=eth0
BOOTPROTO= dhcp
ONBOOT=yes
```

NetworkManager is graphical configuration tool which provides an easy way to make changes to the various network interface configuration files (refer to Chapter 7, NetworkManager for detailed instructions on using this tool).
However, it is also possible to manually edit the configuration files for a given network interface.

Below is a listing of the configurable parameters in an Ethernet interface configuration file:

**BONDING_OPTS=parameters**

sets the configuration parameters for the bonding device, and is used in `/etc/sysconfig/network-scripts/ifcfg-bond` (see Section 8.2.3, “Channel Bonding Interfaces”). These parameters are identical to those used for bonding devices in `/sys/class/net/bonding_device/bonding`, and the module parameters for the bonding driver as described in bonding Module Directives.

This configuration method is used so that multiple bonding devices can have different configurations. It is highly recommended to place all of your bonding options after the BONDING_OPTS directive in `ifcfg-name`. Do not specify options for the bonding device in `/etc/modprobe.d/bonding.conf`, or in the deprecated `/etc/modprobe.conf` file.

**BOOTPROTO=protocol**

where `protocol` is one of the following:

- `none` — No boot-time protocol should be used.
- `bootp` — The BOOTP protocol should be used.
- `dhcp` — The DHCP protocol should be used.

**BROADCAST=address**

where `address` is the broadcast address. This directive is deprecated, as the value is calculated automatically with `ipcalc`.

**DEVICE=name**

where `name` is the name of the physical device (except for dynamically-allocated PPP devices where it is the logical name).

**DHCP_HOSTNAME=name**

where `name` is a short hostname to be sent to the DHCP server. Use this option only if the DHCP server requires the client to specify a hostname before receiving an IP address.

**DHCPV6C=answer**

where `answer` is one of the following:

- `yes` — Use DHCP to obtain an IPv6 address for this interface.
- `no` — Do not use DHCP to obtain an IPv6 address for this interface. This is the default value.

An IPv6 link-local address will still be assigned by default. The link-local address is based on the MAC address of the interface as per RFC 4862.

**DHCPV6C_OPTIONS=answer**

where `answer` is one of the following:

- `-P` — Enable IPv6 prefix delegation.
- `-S` — Use DHCP to obtain stateless configuration only, not addresses, for this interface.
- `-N` — Restore normal operation after using the -T or -P options.
- `-T` — Use DHCP to obtain a temporary IPv6 address for this interface.
- `-D` — Override the default when selecting the type of DHCP Unique Identifier (DUID) to use.

By default, the DHCPv6 client (dhclient) creates a DHCP Unique Identifier (DUID) based on the link-layer address (DUID-LL) if it is running in stateless mode (with the -S option, to not request an address), or it creates an identifier based on the link-layer address plus a timestamp (DUID-LLT) if it is running in stateful mode (without -S, requesting an address). The -D option overrides this default, with a value of either LL or LLT.

**DNS{1,2}=address**

where `address` is a name server address to be placed in `/etc/resolv.conf` if the PEERDNS directive is set to `yes`.

**ETHTOOL_OPTS=options**

where `options` are any device-specific options supported by `ethtool`. For example, if you wanted to force 100Mb, full duplex:

```
ETHTOOL_OPTS="autoneg off speed 100 duplex full"
```

Instead of a custom initscript, use ETHTOOL_OPTS to set the interface speed and duplex settings. Custom initscripts run outside of the network init script lead to unpredictable results during a post-boot network service restart.

Set “autoneg off” before changing speed or duplex settings

Changing speed or duplex settings almost always requires disabling autonegotiation with the autoneg off option. This option needs to be stated first, as the option entries are order-dependent.
Refer to Section 8.2.2, "Ethtool" for more Ethtool options.

**HOTPLUG=** *answer*

where *answer* is one of the following:

- **yes** — This device should be activated when it is hot-plugged (this is the default option).
- **no** — This device should not be activated when it is hot-plugged.

The **HOTPLUG=no** option can be used to prevent a channel bonding interface from being activated when a bonding kernel module is loaded.

Refer to Section 8.2.3, "Channel Bonding Interfaces" for more information about channel bonding interfaces.

**HWADDR=** *MAC-address*

where *MAC-address* is the hardware address of the Ethernet device in the form **AA:BB:CC:DD:EE:FF**. This directive must be used in machines containing more than one NIC to ensure that the interfaces are assigned the correct device names regardless of the configured load order for each NIC's module. This directive should not be used in conjunction with **MACADDR**.

**IPADDR=** *address*

where *address* is the IPv4 address.

**IPV6ADDR=** *address*

where *address* is the first static, or primary, IPv6 address on an interface.

The format is Address/Prefix-length. If no prefix length is specified, /64 is assumed. Note that this setting depends on IPV6INIT being enabled.

**IPV6ADDR_SECONDARIES=** *address*

where *address* is one or more, space separated, additional IPv6 addresses.

The format is Address/Prefix-length. If no prefix length is specified, /64 is assumed. Note that this setting depends on IPV6INIT being enabled.

**IPV6_PRIVACY_PREFER_PUBLIC_IP=** *answer*

where *answer* is one of the following:

- **yes** — Prefer the public IP address.
- **no** — Do not prefer the public IP address, prefer a temporary address.

**LINKDELAY=** *time*

where *time* is the number of seconds to wait for link negotiation before configuring the device.

**MACADDR=** *MAC-address*

where *MAC-address* is the hardware address of the Ethernet device in the form **AA:BB:CC:DD:EE:FF**.

This directive is used to assign a MAC address to an interface, overriding the one assigned to the physical NIC. This directive should not be used in conjunction with the **HWADDR** directive.

**MASTER=** *bond-interface*

where *bond-interface* is the channel bonding interface to which the Ethernet interface is linked.

This directive is used in conjunction with the **SLAVE** directive.

Refer to Section 8.2.3, "Channel Bonding Interfaces" for more information about channel bonding interfaces.

**NETMASK=** *mask*

where *mask* is the netmask value.

**NETWORK=** *address*

where *address* is the network address. This directive is deprecated, as the value is calculated automatically with **ipcalc**.

**NM_CONTROLLED=** *answer*

where *answer* is one of the following:

- **yes** — NetworkManager is permitted to configure this device. This is the default behavior and can be omitted.
ONBOOT=answer
where answer is one of the following:
  > yes — This device should be activated at boot-time.
  > no — This device should not be activated at boot-time.

PEERDNS=answer
where answer is one of the following:
  > yes — Modify /etc/resolv.conf if the DNS directive is set. If using DHCP, then yes is the default.
  > no — Do not modify /etc/resolv.conf.

SLAVE=answer
where answer is one of the following:
  > yes — This device is controlled by the channel bonding interface specified in the MASTER directive.
  > no — This device is not controlled by the channel bonding interface specified in the MASTER directive.

This directive is used in conjunction with the MASTER directive.
Refer to Section 8.2.3, "Channel Bonding Interfaces" for more about channel bonding interfaces.

SRCADDR=address
where address is the specified source IP address for outgoing packets.

USERCTL=answer
where answer is one of the following:
  > yes — Non-root users are allowed to control this device.
  > no — Non-root users are not allowed to control this device.

8.2.2. Ethtool
Ethtool is a utility for configuration of Network Interface Cards (NICs). This utility allows querying and changing settings such as speed, port, auto-negotiation, PCI locations and checksum offload on many network devices, especially Ethernet devices.

We present here a short selection of often used Ethtool commands together with some useful commands that are not well known. For a full list of commands type ethtool -h or refer to the man page, ethtool(8), for a more verbose list and explanation. The first two examples are information queries and show the use of the different formats of the command.

But first, the command structure:

```
ethtool [option...] devname
```

where option is none or more options, and devname is your Network Interface Card (NIC). For example eth0 or em1.

```
ethtool
```

The ethtool command with only a device name as an option is used to query a network device for NIC and driver statistics. It takes the following form:

```
ethtool -S, --statistics devname
```

where devname is your NIC. For example eth0 or em1.

Some values can only be obtained when the command is run as root. Here is an example of the output when the command is run as root:
ethtool em1

Settings for em1:
Supported ports: [ TP ]
Supported link modes: 10baseT/Half 10baseT/Full
100baseT/Half 100baseT/Full
1000baseT/Full
Supported pause frame use: No
Supports auto-negotiation: Yes
Advertised link modes: 10baseT/Half 10baseT/Full
100baseT/Half 100baseT/Full
1000baseT/Full
Advertised pause frame use: No
Advertised auto-negotiation: Yes
Speed: 1000Mb/s
Duplex: Full
Port: Twisted Pair
PHYAD: 2
Transceiver: internal
Auto-negotiation: on
MDI-X: on
Supports Wake-on: pumbg
Wake-on: g
Current message level: 0x00000007 (7)

drv probe link
Link detected: yes

Issue the following command, using the short or long form of the argument, to query the specified network device for associated driver information:

```bash
ethtool -i, --driver devname
```

where `devname` is your Network Interface Card (NIC). For example `eth0` or `em1`.

Here is an example of the output:

```bash
ethtool -i em1
```

driver: e1000e
version: 2.0.0-k
firmware-version: 0.13-3
bus-info: 0000:00:19.0
supports-statistics: yes
supports-test: yes
supports-eeprom-access: yes
supports-register-dump: yes

Here follows a list of commands to query, identify or reset the device. They are in the usual -short and --long form:

**--statistics**
The `--statistics` or `-S` queries the specified network device for NIC and driver statistics. It takes the following form:

```bash
ethtool -S, --statistics devname
```

where `devname` is your NIC.

**--identify**
The `--identify` or `-p` option initiates adapter-specific action intended to enable an operator to easily identify the adapter by sight. Typically this involves blinking one or more LEDs on the specified network port. It takes the following form:

```bash
-p, --identify devname integer
```

where `integer` is length of time in seconds to perform the action,
and `devname` is your NIC.

**--test**
The `--test` or `-t` option is used to perform tests on a Network Interface Card. It takes the following form:

```bash
-t, --test word devname
```

where `word` is one of the following:

- **offline** — Perform a comprehensive set of tests. Service will be interrupted.
- **online** — Perform a reduced set of tests. Service should not be interrupted.
- **external_lb** — Perform full set of tests including loopback tests while fitted with a loopback cable.

and `devname` is your NIC.

Changing some or all settings of the specified network device requires the -s or --change option. All the following options are only applied if the -s or --change option is also specified. For the sake of clarity we will omit it here.

To make these settings permanent you can make use of the ETHTOOL_OPTS directive. It can be used in interface configuration files to set the desired options when the network interface is brought up. Refer to Section 8.2.1, "Ethernet Interfaces" for more details on how to use this directive.
---speed

The `--speed` option is used to set the speed in megabits per second (Mb/s). Omitting the speed value will show the supported device speeds. It takes the following form:

```bash
--speed number devname
```

where `number` is the speed in megabits per second (Mb/s),

and `devname` is your NIC.

---duplex

The `--duplex` option is used to set the transmit and receive mode of operation. It takes the following form:

```bash
--duplex word devname
```

where `word` is one of the following:

- `half` — Sets half-duplex mode. Usually used when connected to a hub.
- `full` — Sets full-duplex mode. Usually used when connected to a switch or another host.

and `devname` is your NIC.

---port

The `--port` option is used to select the device port. It takes the following form:

```bash
--port value devname
```

where `value` is one of the following:

- `tp` — An Ethernet interface using Twisted-Pair cable as the medium.
- `aui` — Attachment Unit Interface (AUI). Normally used with hubs.
- `bnc` — An Ethernet interface using BNC connectors and co-axial cable.
- `mii` — An Ethernet interface using a Media Independent Interface (MII).
- `fibre` — An Ethernet interface using Optical Fibre as the medium.

and `devname` is your NIC.

---autoneg

The `--autoneg` option is used to control auto-negotiation of network speed and mode of operation (full-duplex or half-duplex mode). If auto-negotiation is enabled you can initiate re-negotiation of network speeds and mode of operation by using the `-r, --negotiate` option. You can display the auto-negotiation state using the `--a, --show-pause` option.

It takes the following form:

```bash
--autoneg value devname
```

where `value` is one of the following:

- `yes` — Allow auto-negotiating of network speed and mode of operation.
- `no` — Do not allow auto-negotiating of network speed and mode of operation.

and `devname` is your NIC.

---advertise

The `--advertise` option is used to set what speeds and modes of operation (duplex mode) are advertised for auto-negotiation. The argument is one or more hexadecimal values from Table 8.1, "Ethtool advertise options: speed and mode of operation".

It takes the following form:

```bash
--advertise HEX-VALUE devname
```

where `HEX-VALUE` is one or more of the hexadecimal values from the table below and `devname` is your NIC.
Table 8.1. Ethtool advertise options: speed and mode of operation

<table>
<thead>
<tr>
<th>Hex Value</th>
<th>Speed</th>
<th>Duplex Mode</th>
<th>IEEE standard?</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x001</td>
<td>10</td>
<td>Half</td>
<td>Yes</td>
</tr>
<tr>
<td>0x002</td>
<td>10</td>
<td>Full</td>
<td>Yes</td>
</tr>
<tr>
<td>0x004</td>
<td>100</td>
<td>Half</td>
<td>Yes</td>
</tr>
<tr>
<td>0x008</td>
<td>100</td>
<td>Full</td>
<td>Yes</td>
</tr>
<tr>
<td>0x010</td>
<td>1000</td>
<td>Half</td>
<td>No</td>
</tr>
<tr>
<td>0x020</td>
<td>1000</td>
<td>Full</td>
<td>Yes</td>
</tr>
<tr>
<td>0x8000</td>
<td>2500</td>
<td>Full</td>
<td>Yes</td>
</tr>
<tr>
<td>0x1000</td>
<td>10000</td>
<td>Full</td>
<td>Yes</td>
</tr>
<tr>
<td>0x20000</td>
<td>20000MLD2</td>
<td>Full</td>
<td>No</td>
</tr>
<tr>
<td>0x20000</td>
<td>20000MLD2</td>
<td>Full</td>
<td>No</td>
</tr>
<tr>
<td>0x40000</td>
<td>20000KR2</td>
<td>Full</td>
<td>No</td>
</tr>
</tbody>
</table>

---phyad

The --phyad option is used to change the physical address. Often referred to as the MAC or hardware address but in this context referred to as the physical address.

It takes the following form:

```
--phyad HEX-VALUE devname
```

where HEX-VALUE is the physical address in hexadecimal format and devname is your NIC.

---xcvr

The --xcvr option is used to select the transceiver type. Currently only "internal" and "external" can be specified. In the future other types might be added.

It takes the following form:

```
--xcvr word devname
```

where word is one of the following:

> internal — Use internal transceiver.
> external — Use external transceiver.

and devname is your NIC.

---wol

The --wol option is used to set "Wake-on-LAN" options. Not all devices support this. The argument to this option is a string of characters specifying which options to enable.

It takes the following form:

```
--wol value devname
```

where value is one or more of the following:

> p — Wake on PHY activity.
> u — Wake on unicast messages.
> m — Wake on multicast messages.
> b — Wake on broadcast messages.
> g — Wake-on-Lan; wake on receipt of a "magic packet".
> s — Enable security function using password for Wake-on-Lan.
> d — Disable Wake-on-Lan and clear all settings.

and devname is your NIC.

---sopass

The --sopass option is used to set the "SecureOn" password. The argument to this option must be 6 bytes in Ethernet MAC hexadecimal format (xx:yy:zz:aa:bb:cc).

It takes the following form:

```
--sopass xx:yy:zz:aa:bb:cc devname
```

where xx:yy:zz:aa:bb:cc is the password in the same format as a MAC address and devname is your NIC.

---msglvl

The --msglvl option is used to set the driver message-type flags by name or number. The precise meanings of these type flags differ between drivers.

It takes the following form:

```
--msglvl value devname
```
where value is one of:

- **HEX-VALUE** — Hexadecimal value indicating message type.

- **message-type** — The message type name in plain text.

and **devname** is your NIC.

The defined message type names and numbers are shown in the table below:

<table>
<thead>
<tr>
<th>Message Type</th>
<th>Hex Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>drv</td>
<td>0x0001</td>
<td>General driver status</td>
</tr>
<tr>
<td>probe</td>
<td>0x0002</td>
<td>Hardware probing</td>
</tr>
<tr>
<td>link</td>
<td>0x0004</td>
<td>Link state</td>
</tr>
<tr>
<td>timer</td>
<td>0x0008</td>
<td>Periodic status check</td>
</tr>
<tr>
<td>ifdown</td>
<td>0x0010</td>
<td>Interface being brought down</td>
</tr>
<tr>
<td>ifup</td>
<td>0x0020</td>
<td>Interface being brought up</td>
</tr>
<tr>
<td>rx_err</td>
<td>0x0040</td>
<td>Receive error</td>
</tr>
<tr>
<td>tx_err</td>
<td>0x0080</td>
<td>Transmit error</td>
</tr>
<tr>
<td>intr</td>
<td>0x0200</td>
<td>Interrupt handling</td>
</tr>
<tr>
<td>tx_done</td>
<td>0x0400</td>
<td>Transmit completion</td>
</tr>
<tr>
<td>rx_status</td>
<td>0x0800</td>
<td>Receive completion</td>
</tr>
<tr>
<td>pktdata</td>
<td>0x1000</td>
<td>Packet contents</td>
</tr>
<tr>
<td>hw</td>
<td>0x2000</td>
<td>Hardware status</td>
</tr>
<tr>
<td>wol</td>
<td>0x4000</td>
<td>Wake-on-LAN status</td>
</tr>
</tbody>
</table>

### 8.2.3. Channel Bonding Interfaces

Fedora allows administrators to bind multiple network interfaces together into a single channel using the **bonding** kernel module and a special network interface called a **channel bonding interface**. Channel bonding enables two or more network interfaces to act as one, simultaneously increasing the bandwidth and providing redundancy.

To create a channel bonding interface, create a file in the `/etc/sysconfig/network-scripts/` directory called `ifcfg-bondN`, replacing `N` with the number for the interface, such as `0`.

The contents of the file can be identical to whatever type of interface is getting bonded, such as an Ethernet interface. The only difference is that the **DEVICE** directive is `bondN`, replacing `N` with the number for the interface.

The following is a sample channel bonding configuration file:

```
DEVICE=bond0
IPADDR=192.168.1.1
NETMASK=255.255.255.0
ONBOOT=yes
BOOTPROTO=None
USERCTL=no
BONDING_OPTS="bonding parameters separated by spaces"
```

After the channel bonding interface is created, the network interfaces to be bound together must be configured by adding the **MASTER** and **SLAVE** directives to their configuration files. The configuration files for each of the channel-bonded interfaces can be nearly identical.

For example, if two Ethernet interfaces are being channel bonded, both `eth0` and `eth1` may look like the following example:

```
DEVICE=eth0
BOOTPROTO=None
ONBOOT=yes
MASTER=bond0
SLAVE=eth1
USERCTL=no
```

In this example, replace `N` with the numerical value for the interface.

For a channel bonding interface to be valid, the kernel module must be loaded. To ensure that the module is loaded when the channel bonding interface is brought up, create a new file as root named **bonding.conf** in the `/etc/modprobe.d/` directory. Note that you can name this file anything you like as long as it ends with a `.conf` extension. Insert the following line in this new file:

```ini
alias bondN bonding
```

Replace `N` with the interface number, such as `0`. For each configured channel bonding interface, there must be a corresponding entry in your new `/etc/modprobe.d/bonding.conf` file.
Put all bonding module parameters in ifcfg-bondN files

Parameters for the bonding kernel module must be specified as a space-separated list in the
BONDING_OPTS="bonding parameters" directive in the ifcfg-bondN interface file. Do not specify options for
the bonding device in /etc/modprobe.d/bonding.conf, or in the deprecated /etc/modprobe.conf file. For
further instructions and advice on configuring the bonding module and to view the list of bonding parameters, refer
to Section 24.7.2, “Using Channel Bonding”.

8.2.4. Network Bridge

A network bridge is a Link Layer device which forwards traffic between networks based on MAC addresses and is
therefore also referred to as a Layer 2 device. It makes forwarding decisions based on tables of MAC addresses which it
builds by learning what hosts are connected to each network. A software bridge can be used within a Linux host in order
to emulate a hardware bridge, for example in virtualization applications for sharing a NIC with one or more virtual NICs.
This case will be illustrated here as an example.

To create a network bridge, create a file in the /etc/sysconfig/network-scripts/ directory called ifcfg-brN,
replacing N with the number for the interface, such as 0.

The contents of the file is similar to whatever type of interface is getting bridged to, such as an Ethernet interface. The
differences in this example are as follows:

- The DEVICE directive is given an interface name as its argument in the format brN, where N is replaced with
  the number of the interface.
- The TYPE directive is given an argument Bridge or Ethernet. This directive determines the device type and the
  argument is case sensitive.
- The bridge interface configuration file now has the IP address and the physical interface has only a MAC address.
- An extra directive, DELAY=0, is added to prevent the bridge from waiting while it monitors traffic, learns where hosts are
  located, and builds a table of MAC addresses on which to base its filtering decisions. The default delay of 30 seconds
  is not needed if no routing loops are possible.
- The NM_CONTROLLED=no should be added to the Ethernet interface to prevent NetworkManager from altering the file.
  It can also be added to the bridge configuration file in case future versions of NetworkManager support bridge
  configuration.

The following is a sample bridge interface configuration file using a static IP address:

Example 8.2. Sample ifcfg-br0 interface configuration file

DEVICE=br0
TYPE=Bridge
IPADDR=192.168.1.1
NETMASK=255.255.255.0
ONBOOT=yes
BOOTPROTO=static
NM_CONTROLLED=no
DELAY=0

To complete the bridge another interface is created, or an existing interface is modified, and pointed to the bridge
interface. The following is a sample Ethernet interface configuration file pointing to a bridge interface. Configure your
physical interface in /etc/sysconfig/network-scripts/ifcfg-ethX, where X is a unique number corresponding to
a specific interface, as follows:

Example 8.3. Sample ifcfg-ethX interface configuration file

DEVICE=ethX
TYPE=Ethernet
HWADDR=AA:BB:CC:DD:EE:FF
BOOTPROTO=none
ONBOOT=yes
NM_CONTROLLED=no
BRIDGE=br0

For the DEVICE directive, almost any interface name could be used as it does not determine the device type. Other
commonly used names include tap, dummy and bond for example. TYPE=Ethernet is not strictly required. If the
TYPE directive is not set, the device is treated as an Ethernet device (unless its name explicitly matches a different
interface configuration file.)

Note

You can refer to Section 8.2, “Interface Configuration Files” for a review of the directives and options used in network
interface config files.
Warning

If you are configuring bridging on a remote host, and you are connected to that host over the physical NIC you are configuring, please consider the implications of losing connectivity before proceeding. You will lose connectivity when restarting the service and may not be able to regain connectivity if any errors have been made. Console, or out-of-band access is advised.

Restart the networking service, in order for the changes to take effect by running as root:

```
systemctl restart network.service
```

An example of a network bridge formed from two or more bonded Ethernet interfaces will now be given as this is another common application in a virtualization environment. If you are not very familiar with the configuration files for bonded interfaces then please refer to Section 8.2.3, “Channel Bonding Interfaces”.

Create or edit two or more Ethernet interface configuration files, which are to be bonded, as follows:

```
DEVICE=ethX
TYPE=Ethernet
USERCTL=no
SLAVE=yes
MASTER=bond0
BOOTPROTO=none
HWADDR=AA:BB:CC:DD:EE:FF
NM_CONTROLLED=no
```

Note

Using `ethX` as the interface name is common practice but almost any name could be used. Names such as `tap`, `dummy` and `bond` are commonly used.

Create or edit one interface configuration file, `/etc/sysconfig/network-scripts/ifcfg-bond0`, as follows:

```
DEVICE=bond0
ONBOOT=yes
BONDING_OPTS='mode=1 miimon=100'
BRIDGE=brbond0
NM_CONTROLLED=no
```

For further instructions and advice on configuring the bonding module and to view the list of bonding parameters, refer to Section 24.7.2, “Using Channel Bonding”.

Create or edit one interface configuration file, `/etc/sysconfig/network-scripts/ifcfg-brbond0`, as follows:

```
DEVICE=brbond0
ONBOOT=yes
TYPE=Bridge
IPADDR=192.168.1.1
NETMASK=255.255.255.0
NM_CONTROLLED=no
```
We now have two or more interface configuration files with the \texttt{MASTER=bond0} directive. These point to the configuration file named \texttt{/etc/sysconfig/network-scripts/ifcfg-bond0}, which contains the \texttt{DEVICE=bond0} directive. This \texttt{ifcfg-bond0} in turn points to the \texttt{/etc/sysconfig/network-scripts/ifcfg-brbond0} configuration file, which contains the IP address, and acts as an interface to the virtual networks inside the host.

Restart the networking service, in order for the changes to take effect by running as \texttt{root}:

\begin{verbatim}
systemctl restart network.service
\end{verbatim}

\section*{8.2.5. Setting Up 802.1q VLAN Tagging}

1. Ensure that the module is loaded by entering the following command:

\begin{verbatim}
lsmod | grep 8021q
\end{verbatim}

2. If the module is not loaded, load it with the following command:

\begin{verbatim}
modprobe 8021q
\end{verbatim}

3. Configure your physical interface in \texttt{/etc/sysconfig/network-scripts/ifcfg-ethX}, where \texttt{X} is a unique number corresponding to a specific interface, as follows:

\begin{verbatim}
DEVICE=ethX
TYPE=Ethernet
BOOTPROTO=none
ONBOOT=yes
\end{verbatim}

4. Configure the VLAN interface configuration in \texttt{/etc/sysconfig/network-scripts}. The configuration filename should be the physical interface plus a . character plus the VLAN ID number. For example, if the VLAN ID is 192, and the physical interface is \texttt{eth0}, then the configuration filename should be \texttt{ifcfg-eth0.192}:

\begin{verbatim}
DEVICE=ethX.192
BOOTPROTO=static
ONBOOT=yes
IPADDR=192.168.1.1
NETMASK=255.255.255.0
USERCTL=no
NETWORK=192.168.1.0
VLAN=yes
\end{verbatim}

If there is a need to configure a second VLAN, with for example, VLAN ID 193, on the same interface, \texttt{eth0}, add a new file with the name \texttt{eth0.193} with the VLAN configuration details.

5. Restart the networking service, in order for the changes to take effect by running as \texttt{root}:

\begin{verbatim}
systemctl restart network.service
\end{verbatim}

\section*{8.2.6. Alias and Clone Files}
Two lesser-used types of interface configuration files are alias and clone files. As the `ip` command of the `iproute` package now supports assigning multiple address to the same interface it is no longer necessary to use this method of binding multiple addresses to the same interface.

**Note**

At the time of writing, NetworkManager does not detect IP aliases in `ifcfg` files. For example, if `ifcfg-eth0` and `ifcfg-eth0:1` files are present, NetworkManager creates two connections, which will cause confusion.

For new installations, users should select the Manual method on the IPv4 or IPv6 tab in NetworkManager to assign multiple IP address to the same interface. For more information on using this tool, refer to Chapter 7, NetworkManager.

Alias interface configuration files, which are used to bind multiple addresses to a single interface, use the `ifcfg-if-name:alias-value` naming scheme.

For example, an `ifcfg-eth0:0` file could be configured to specify `DEVICE=eth0:0` and a static IP address of `10.0.0.2`, serving as an alias of an Ethernet interface already configured to receive its IP information via DHCP in `ifcfg-eth0`. Under this configuration, `eth0` is bound to a dynamic IP address, but the same physical network card can receive requests via the fixed, `10.0.0.2` IP address.

### Warning

Alias interfaces do not support DHCP.

A clone interface configuration file should use the following naming convention: `ifcfg-if-name-clone-name`. While an alias file allows multiple addresses for an existing interface, a clone file is used to specify additional options for an interface. For example, a standard DHCP Ethernet interface called `eth0`, may look similar to this:

```
DEVICE=eth0
ONBOOT=yes
BOOTPROTO=dhcp
```

Since the default value for the `USERCTL` directive is `no` if it is not specified, users cannot bring this interface up and down.

To give users the ability to control the interface, create a clone by copying `ifcfg-eth0` to `ifcfg-eth0-user` and add the following line to `ifcfg-eth0-user`:

```
USERCTL=yes
```

This way a user can bring up the `eth0` interface using the `/sbin/ifup eth0-user` command because the configuration options from `ifcfg-eth0` and `ifcfg-eth0-user` are combined. While this is a very basic example, this method can be used with a variety of options and interfaces.

It is no longer possible to create alias and clone interface configuration files using a graphical tool. However, as explained at the beginning of this section, it is no longer necessary to use this method as it is now possible to directly assign multiple IP address to the same interface. For new installations, users should select the Manual method on the IPv4 or IPv6 tab in NetworkManager to assign multiple IP address to the same interface. For more information on using this tool, refer to Chapter 7, NetworkManager.

### 8.2.7. Dialup Interfaces

If you are connecting to the Internet via a dialup connection, a configuration file is necessary for the interface.

PPP interface files are named using the following format:

`ifcfg-pppX`

where `X` is a unique number corresponding to a specific interface.

The PPP interface configuration file is created automatically when `wvdial`, the Network Administration Tool or Kppp is used to create a dialup account. It is also possible to create and edit this file manually.

The following is a typical `ifcfg-ppp0` file:

```
DEVICE=ppp0
NAME=test
WVDIALSECT=test
MODEMPORT=/dev/modem
LINESPEED=115200
PAPNAME=test
USERCTL=true
ONBOOT=no
PERSIST=no
DEFROUTE=yes
PEERDNS=yes
DEMAND=no
IDLETIMEOUT=600
```

Serial Line Internet Protocol (SLIP) is another dialup interface, although it is used less frequently. SLIP files have interface configuration file names such as `ifcfg-sl0`.

Other options that may be used in these files include:
DEFROUTE=answer
  where answer is one of the following:
  > yes — Set this interface as the default route.
  > no — Do not set this interface as the default route.

DEMAND=answer
  where answer is one of the following:
  > yes — This interface allows pppd to initiate a connection when someone attempts to use it.
  > no — A connection must be manually established for this interface.

IDLETIMEOUT=value
  where value is the number of seconds of idle activity before the interface disconnects itself.

INITSTRING=string
  where string is the initialization string passed to the modem device. This option is primarily used in conjunction with SLIP interfaces.

LINESPEED=value
  where value is the baud rate of the device. Possible standard values include 57600, 38400, 19200, and 9600.

MODEMPORT=device
  where device is the name of the serial device that is used to establish the connection for the interface.

MTU=value
  where value is the Maximum Transfer Unit (MTU) setting for the interface. The MTU refers to the largest number of bytes of data a frame can carry, not counting its header information. In some dialup situations, setting this to a value of 576 results in fewer packets dropped and a slight improvement to the throughput for a connection.

NAME=name
  where name is the reference to the title given to a collection of dialup connection configurations.

PAPNAME=name
  where name is the username given during the Password Authentication Protocol (PAP) exchange that occurs to allow connections to a remote system.

PERSIST=answer
  where answer is one of the following:
  > yes — This interface should be kept active at all times, even if deactivated after a modem hang up.
  > no — This interface should not be kept active at all times.

REMIP=address
  where address is the IP address of the remote system. This is usually left unspecified.

WVDIALSEC=name
  where name associates this interface with a dialer configuration in /etc/wvdial.conf. This file contains the phone number to be dialed and other important information for the interface.

8.2.8. Other Interfaces
Other common interface configuration files include the following:

ifcfg-lo
  A local loopback interface is often used in testing, as well as being used in a variety of applications that require an IP address pointing back to the same system. Any data sent to the loopback device is immediately returned to the host's network layer.

Do not manually edit the ifcfg-lo script

The loopback interface script /etc/sysconfig/network-scripts/ifcfg-lo, should never be edited manually. Doing so can prevent the system from operating correctly.

ifcfg-irlan0
  An infrared interface allows information between devices, such as a laptop and a printer, to flow over an infrared link. This works in a similar way to an Ethernet device except that it commonly occurs over a peer-to-peer connection.
8.3. Interface Control Scripts

The interface control scripts activate and deactivate system interfaces. There are two primary interface control scripts that call on control scripts located in the `/etc/sysconfig/network-scripts/` directory: `/sbin/ifdown` and `/sbin/ifup`.

The `ifup` and `ifdown` interface scripts are symbolic links to scripts in the `/sbin/` directory. When either of these scripts are called, they require the value of the interface to be specified, such as:

```
ifup eth0
```

Two files used to perform a variety of network initialization tasks during the process of bringing up a network interface are `/etc/rc.d/init.d/functions` and `/etc/sysconfig/network-scripts/network-functions`. Refer to Section 8.6, "Network Function Files" for more information.

After verifying that an interface has been specified and that the user executing the request is allowed to control the interface, the correct script brings the interface up or down. The following are common interface control scripts found within the `/etc/sysconfig/network-scripts/` directory:

- `ifup-aliases`  
  Configures IP aliases from interface configuration files when more than one IP address is associated with an interface.

- `ifup-ipp` and `ifdown-ipp`  
  Brings ISDN interfaces up and down.

- `ifup-ipv6` and `ifdown-ipv6`  
  Brings IPv6 interfaces up and down.

- `ifup-plip`  
  Brings up a PLIP interface.

- `ifup-plusb`  
  Brings up a USB interface for network connections.

- `ifup-post` and `ifdown-post`  
  Contains commands to be executed after an interface is brought up or down.

- `ifup-ppp` and `ifdown-ppp`  
  Brings a PPP interface up or down.

- `ifup-routes`  
  Adds static routes for a device as its interface is brought up.

- `ifdown-sit` and `ifup-sit`  
  Contains function calls related to bringing up and down an IPv6 tunnel within an IPv4 connection.

- `ifup-wireless`  
  Brings up a wireless interface.

Be careful when removing or modifying network scripts!

Removing or modifying any scripts in the `/etc/sysconfig/network-scripts/` directory can cause interface connections to act irregularly or fail. Only advanced users should modify scripts related to a network interface.

The easiest way to manipulate all network scripts simultaneously is to use the `systemctl` command on the network service (`/etc/rc.d/init.d/network`), as illustrated by the following command:

```
systemctl action network.service
```
Here, action can be either start, stop, or restart.

To view a list of configured devices and currently active network interfaces, use the following command:

```
systemctl status network.service
```

8.4. Using Hostnamectl
The hostnamectl tool is provided for administering the three separate classes of host names in use on a given system. The three classes of hostname are: static, pretty, and transient.

The static host name is the traditional hostname, which can be chosen by the user, and is stored in the /etc/hostname file. The "transient" hostname is a dynamic host name maintained by the kernel. It is initialized to the static host name by default, whose value defaults to "localhost". It can be changed by DHCP or nDNS at runtime. The pretty hostname is a free-form UTF8 host name for presentation to the user.

Note
A host name can be a free-form string up to 64 characters in length, however it is recommended that the static and transient names consists only of 7 bit ASCII lower-case characters, no spaces or dots, and limits itself to the format allowed for DNS domain name labels, even though this is not a strict requirement. The hostnamectl tool will enforce the following: Static and transient host names to consist of a-z, A-Z, 0-9, \-, \., \_ and \., only, to not begin or end in a dot, and to not have two dots immediately following each other. The size limit of 64 characters is enforced.

8.4.1. View all the Hostnames
To view all the current host names, enter the following command:

```
 hostnamectl status
```

The status option is implied by default if no option is given.

8.4.2. Set All The Hostnames
To set all the host names on a system, enter the following command as root:

```
 hostnamectl set-hostname name
```

This will alter the pretty, static, and transient host names alike. The static and transient host names will be simplified forms of the pretty host name. Spaces will be replaced with \- and special characters will be removed.

8.4.3. Set A Particular Hostname
To set a particular host name, enter the following command as root with the relevant option:

```
 hostnamectl set-hostname name option
```

Where option is one or more of: \-pretty, \-static, and \-transient.

If the static or transient options are used together with the pretty option, the static and transient host names will be simplified forms of the pretty host name. Spaces will be replaced with \- and special characters will be removed. If the \-pretty option is not given, no simplification takes place.

8.4.4. Clear A Particular Hostname
To clear a particular host name and to allow it to revert to the default, enter the following command as root with the relevant option:

```
 hostnamectl set-hostname "" option
```

Where "" is a quoted empty string and where option is one or more of: \-pretty, \-static, and \-transient.

8.4.5. Changing Host Names Remotely
To execute a hostnamectl command on a remote system, use the \-H, \-host option as follows:

```
 hostnamectl set-hostname \-H username@hostname
```

Where hostname is the remote host you wish to configure. The username is optional. The hostnamectl tool will use SSH to connect to the remote system.

8.4.6. Additional Resources
The following sources of information provide additional resources regarding hostnamectl.
8.4.6.1. Installed Documentation

- `hostnamectl(1)` man page — Describes `hostnamectl` including the commands and command options.
- `hostname(1)` man page — Contains an explanation of the `hostname` and `domainname` command.
- `hostname(5)` man page — Contains an explanation of the host name file, its contents, and use.
- `hostname(7)` man page — Contains an explanation of host name resolution.
- `machine-info(5)` man page — Describes the local machine information file and the environment variables it contains.
- `machine-id(5)` man page — Describes the local machine ID configuration file.
- `systemd-hostnamed.service` man page — Describes the `systemd-hostnamed` system service used by `hostnamectl`.

8.4.6.2. Useful Websites

http://www.freedesktop.org/wiki/Software/systemd/hostnamed

Information on `systemd-hostnamed`.

8.5. Static Routes and the Default Gateway

Static routes are for traffic that must not, or should not, go through the default gateway. Routing is usually handled by routing devices and therefore it is often not necessary to configure static routes on Red Hat Enterprise Linux servers or clients. Exceptions include traffic that must pass through an encrypted VPN tunnel or traffic that should take a less costly route. The default gateway is for any and all traffic which is not destined for the local network and for which no preferred route is specified in the routing table. The default gateway is traditionally a dedicated network router.

**Static Routes**

Use the `ip route` command to display the IP routing table. If static routes are required, they can be added to the routing table by means of the `ip route add` command and removed using the `ip route del` command. To add a static route to a host address, that is to say to a single IP address, issue the following command as `root`:

```
ip route add X.X.X.X
```

where X.X.X.X is the IP address of the host in dotted decimal notation. To add a static route to a network, that is to say to an IP address representing a range of IP addresses, issue the following command as `root`:

```
ip route add X.X.X.X/Y
```

where X.X.X.X is the IP address of the network in dotted decimal notation and Y is the network prefix. The network prefix is the number of enabled bits in the subnet mask. This format of network address slash prefix length is referred to as CIDR notation.

Static route configuration is stored per-interface in a `/etc/sysconfig/network-scripts/route-interface` file. For example, static routes for the `eth0` interface would be stored in the `/etc/sysconfig/network-scripts/route-eth0` file. The `route-interface` file has two formats: IP command arguments and network/netmask directives. These are described below.

**The Default Gateway**

The default gateway is specified by means of the `GATEWAY` directive and can be specified either globally or in interface-specific configuration files. Specifying the default gateway globally has certain advantages especially if more than one network interface is present and it can make fault finding simpler if applied consistently. There is also the `GATEWAYDEV` directive, which is a global option. If multiple devices specify `GATEWAY`, and one interface uses the `GATEWAYDEV` directive, that directive will take precedence. This option is not recommend as it can have unexpected consequences if an interface goes down and it can complicate fault finding.

Global default gateway configuration is stored in the `/etc/sysconfig/network` file. For more information about this file and the directives it accepts, refer to Section D.1.13, "/etc/sysconfig/network ".

**IP Command Arguments Format**

If required in a per-interface configuration file, define a default gateway on the first line. This is only required if the default gateway is not set via DHCP and is not set globally as mentioned above:

```
default via X.X.X.X dev interface
```

X.X.X.X is the IP address of the default gateway. The `interface` is the interface that is connected to, or can reach, the default gateway. The `dev` option can be omitted, it is optional.

Define a static route. Each line is parsed as an individual route:

```
X.X.X.Y via X.X.X.X dev interface
```

X.X.X.Y is the network address and netmask for the static route. X.X.X.X and `interface` are the IP address and interface for the default gateway respectively. The X.X.X.X address does not have to be the default gateway IP address. In most cases, X.X.X.X will be an IP address in a different subnet, and `interface` will be the interface that is connected to, or can reach, that subnet. Add as many static routes as required.
The following is a sample route-eth0 file using the IP command arguments format. The default gateway is 192.168.0.1, interface eth0. The two static routes are for the 10.10.10.0/24 and 172.16.1.0/24 networks:

```
default via 192.168.0.1 dev eth0
10.10.10.0/24 via 192.168.0.1 dev eth0
172.16.1.0/24 via 192.168.0.1 dev eth0
```

Static routes should only be configured for other subnets. The above example is not necessary, since packets going to the 10.10.10.0/24 and 172.16.1.0/24 networks will use the default gateway anyway. Below is an example of setting static routes to a different subnet, on a machine in a 192.168.0.0/24 subnet. The example machine has an eth0 interface in the 192.168.0.0/24 subnet, and an eth1 interface (10.10.10.1) in the 10.10.10.0/24 subnet:

```
10.10.10.0/24 via 10.10.10.1 dev eth1
```

Specifying an exit interface is optional. It can be useful if you want to force traffic out of a specific interface. For example, in the case of a VPN, you can force traffic to a remote network to pass through a tun0 interface even when the interface is in a different sub-net to the destination network.

**Duplicate default gateways**

If the default gateway is already assigned from DHCP, the IP command arguments format can cause one of two errors during start-up, or when bringing up an interface from the down state using the ifup command: "RTNETLINK answers: File exists" or 'Error: either "to" is a duplicate, or "X.X.X.X" is a garbage.', where X.X.X.X is the gateway, or a different IP address. These errors can also occur if you have another route to another network using the default gateway. Both of these errors are safe to ignore.

**Network/Netmask Directives Format**

You can also use the network/netmask directives format for route-interface files. The following is a template for the network/netmask format, with instructions following afterwards:

```
ADDRESS0=X.X.X.X NETMASK0=X.X.X.X GATEWAY0=X.X.X.X
ADDRESS0=X.X.X.X NETMASK0=X.X.X.X GATEWAY0=X.X.X.X
ADDRESS0=X.X.X.X NETMASK0=X.X.X.X GATEWAY0=X.X.X.X
```

ADDRESS0=X.X.X.X is the network number for the static route.
NETMASK0=X.X.X.X is the netmask for the network number defined with ADDRESS0=X.X.X.X.
GATEWAY0=X.X.X.X is the default gateway, or an IP address that can be used to reach ADDRESS0=X.X.X.X.

The following is a sample route-eth0 file using the network/netmask directives format. The default gateway is 192.168.0.1, interface eth0. The two static routes are for the 10.10.10.0/24 and 172.16.1.0/24 networks. However, as mentioned before, this example is not necessary as the 10.10.10.0/24 and 172.16.1.0/24 networks would use the default gateway anyway:

```
ADDRESS0=10.10.10.0 NETMASK0=255.255.255.0 GATEWAY0=192.168.0.1
ADDRESS1=172.16.1.0 NETMASK1=255.255.255.0 GATEWAY1=192.168.0.1
```

Subsequent static routes must be numbered sequentially, and must not skip any values. For example, ADDRESS0, ADDRESS1, ADDRESS2, and so on.

Below is an example of setting static routes to a different subnet, on a machine in the 192.168.0.0/24 subnet. The example machine has an eth0 interface in the 192.168.0.0/24 subnet, and an eth1 interface (10.10.10.1) in the 10.10.10.0/24 subnet:

```
ADDRESS0=10.10.10.0 NETMASK0=255.255.255.0 GATEWAY0=10.10.10.1
```

Note that if DHCP is used, it can assign these settings automatically.

### 8.6. Network Function Files

Fedora makes use of several files that contain important common functions used to bring interfaces up and down. Rather than forcing each interface control file to contain these functions, they are grouped together in a few files that are called upon when necessary.

The /etc/sysconfig/network-scripts/network-functions file contains the most commonly used IPv4 functions, which are useful to many interface control scripts. These functions include contacting running programs that have requested information about changes in the status of an interface, setting hostnames, finding a gateway device, verifying whether or not a particular device is down, and adding a default route.

As the functions required for IPv6 interfaces are different from IPv4 interfaces, a /etc/sysconfig/network-scripts/network-functions-ipv6 file exists specifically to hold this information. The functions in this file configure and delete static IPv6 routes, create and remove tunnels, add and remove IPv6 addresses to an interface, and test for the existence of an IPv6 address on an interface.

### 8.7. Additional Resources

The following are resources which explain more about network interfaces.
8.7.1. Installed Documentation

`/usr/share/doc/initscripts-version/sysconfig.txt`

A guide to available options for network configuration files, including IPv6 options not covered in this chapter.

8.7.2. Useful Websites

[http://linux-ip.net/ip/cref/](http://linux-ip.net/ip/cref/)

This document contains a wealth of information about the `ip` command, which can be used to manipulate routing tables, among other things.

Part IV. Infrastructure Services

This part provides information how to configure services and daemons, configure authentication, and enable remote logins.

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Maintaining security on your system is extremely important, and one approach for this task is to manage access to system services carefully. Your system may need to provide open access to particular services (for example, `httpd` if you are running a web server). However, if you do not need to provide a service, you should turn it off to minimize your exposure to possible bug exploits.

This chapter covers the configuration of the services to be run when a system is started, and provides information on how to start, stop, and restart the services on the command line using the `systemctl` utility.

Keep the system secure

When you allow access for new services, always remember that both the firewall and SELinux need to be configured as well. One of the most common mistakes committed when configuring a new service is neglecting to implement the necessary firewall configuration and SELinux policies to allow access for it. For more information, refer to the Fedora 18 Security Guide.

9.1. Configuring Services

To allow you to configure which services are started at boot time, Fedora is shipped with the `systemctl` command line tool.

Do not use the ntsysv and chkconfig utilities

Although it is still possible to use the `ntsysv` and `chkconfig` utilities to manage services that have init scripts installed in the `/etc/rc.d/init.d/` directory, it is advised that you use the `systemctl` utility.

Enabling the irqbalance service

To ensure optimal performance on POWER architecture, it is recommended that the `irqbalance` service is enabled. In most cases, this service is installed and configured to run during the Fedora 18 installation. To verify that `irqbalance` is running, type the following at a shell prompt:

```
systemctl status irqbalance.service
```

9.1.1. Enabling the Service

To configure a service to be automatically started at boot time, use the `systemctl` command in the following form:

```
systemctl enable service_name.service
```

The service will be started the next time you boot the system. For information on how to start the service immediately, refer to Section 9.2.2, "Running the Service".
Example 9.1. Enabling the httpd service
Imagine you want to run the Apache HTTP Server on your system. Provided that you have the httpd package installed, you can enable the httpd service by typing the following at a shell prompt as root:

```
[~]# systemctl enable httpd.service
```

9.1.2. Disabling the Service
To disable starting a service at boot time, use the `systemctl` command in the following form:

```
systemctl disable service_name.service
```

The next time you boot the system, the service will not be started. For information on how to stop the service immediately, refer to Section 9.2.3, "Stopping the Service".

Example 9.2. Disabling the telnet service
In order to secure the system, users are advised to disable insecure connection protocols such as Telnet. You can make sure that the telnet service is disabled by running the following command as root:

```
[~]# systemctl disable telnet.service
```

9.2. Running Services
The `systemctl` utility also allows you to determine the status of a particular service, as well as to start, stop, or restart a service.

**Do not use the service utility**
Although it is still possible to use the `service` utility to manage services that have init scripts installed in the `/etc/rc.d/init.d/` directory, it is advised that you use the `systemctl` utility.

9.2.1. Checking the Service Status
To determine the status of a particular service, use the `systemctl` command in the following form:

```
systemctl status service_name.service
```

This command provides detailed information on the service's status. However, if you merely need to verify that a service is running, you can use the `systemctl` command in the following form instead:

```
systemctl is-active service_name.service
```

Example 9.3. Checking the status of the httpd service
Example 9.1, "Enabling the httpd service" illustrated how to enable starting the httpd service at boot time. Imagine that the system has been restarted and you need to verify that the service is really running. You can do so by typing the following at a shell prompt:

```
[~]$ systemctl is-active httpd.service
active
```

You can also display detailed information about the service by running the following command:

```
[~]$ systemctl status httpd.service
```

```
httpd.service - LSB: start and stop Apache HTTP Server
   Loaded: loaded (/etc/rc.d/init.d/httpd)
  Active: active (running) since Mon, 23 May 2011 21:38:57 +0200; 27s ago
   Process: 2997 ExecStart=/etc/rc.d/init.d/httpd start (code=exited, status=0/SUCCESS)
Main PID: 3002 (httpd)
   CGroup: name=systemd:/system/httpd.service
   └ 3002 /usr/sbin/httpd
```

To display a list of all active system services, use the following command:

```
systemctl list-units --type=service
```

This command provides a tabular output with each line consisting of the following columns:

- **UNIT** — A `systemd` unit name. In this case, a service name.
Example 9.4. Listing all active services
You can list all active services by using the following command:

```
~$ systemctl list-units --type=service

UNIT                      LOAD   ACTIVE SUB     JOB DESCRIPTION
abrt-ccpp.service         loaded active exited      LSB: Installs coredump handler which saves segfault data
abrt-oops.service         loaded active running     LSB: Watches system log for oops messages, creates ABRT dump directories for each oops
abrtd.service             loaded active running     ABRT Automated Bug Reporting Tool
accounts-daemon.service   loaded active running     Accounts Service
atd.service               loaded active running     Job spooling tools
[output truncated]
```

In the example above, the abrtd service is loaded, active, and running, and it does not have any pending jobs.

9.2.2. Running the Service
To run a service, use the `systemctl` command in the following form:

```
systemctl start service_name.service
```

This will start the service in the current session. To configure the service to be started at boot time, refer to Section 9.1.1, "Enabling the Service".

Example 9.5. Running the httpd service
Example 9.1, "Enabling the httpd service" illustrated how to run the httpd service at boot time. You can start the service immediately by typing the following at a shell prompt as root:

```
~# systemctl start httpd.service
```

9.2.3. Stopping the Service
To stop a service, use the `systemctl` command in the following form:

```
systemctl stop service_name.service
```

This will stop the service in the current session. To disable starting the service at boot time, refer to Section 9.1.1, "Enabling the Service".

Example 9.6. Stopping the telnet service
Example 9.2, "Disabling the telnet service" illustrated how to disable starting the telnet service at boot time. You can stop the service immediately by running the following command as root:

```
~# systemctl stop telnet.service
```

9.2.4. Restarting the Service
To restart a service, use the `systemctl` command in the following form:

```
systemctl restart service_name.service
```

Example 9.7. Restarting the sshd service
For any changes in the /etc/ssh/sshd_config configuration file to take effect, it is required that you restart the sshd service. You can do so by typing the following at a shell prompt as root:

```
~# systemctl restart sshd.service
```

9.3. Additional Resources

9.3.1. Installed Documentation

» `systemctl(1)` — The manual page for the systemctl utility.
9.3.2. Related Books

Fedora 18 Security Guide
A guide to securing Fedora. It contains valuable information on how to set up the firewall, as well as the configuration of SELinux.

Chapter 10. Configuring Authentication

10.1. Configuring System Authentication

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10.2.10. Troubleshooting SSSD

Authentication is the way that a user is identified and verified to a system. The authentication process requires presenting some sort of identity and credentials, like a username and password. The credentials are then compared to information stored in some data store on the system. In Fedora, the Authentication Configuration Tool helps configure what kind of data store to use for user credentials, such as LDAP.

For convenience and potentially part of single sign-on, Fedora can use a central daemon to store user credentials for a number of different data stores. The System Security Services Daemon (SSSD) can interact with LDAP, Kerberos, and external applications to verify user credentials. The Authentication Configuration Tool can configure SSSD along with NIS, Winbind, and LDAP, so that authentication processing and caching can be combined.

10.1. Configuring System Authentication

When a user logs into a Fedora system, that user presents some sort of credential to establish the user identity. The system then checks those credentials against the configured authentication service. If the credentials match and the user account is active, then the user is authenticated. (Once a user is authenticated, then the information is passed to the access control service to determine what the user is permitted to do. Those are the resources the user is authorized to access.)

The information to verify the user can be located on the local system or the local system can reference a user database on a remote system, such as LDAP or Kerberos.

The system must have a configured list of valid account databases for it to check for user authentication. On Fedora, the Authentication Configuration Tool has both GUI and command-line options to configure any user data stores.

A local system can use a variety of different data stores for user information, including Lightweight Directory Access Protocol (LDAP), Network Information Service (NIS), and Winbind. Additionally, both LDAP and NIS data stores can use Kerberos to authenticate users.

Important If a medium or high security level is set during installation or with the Security Level Configuration Tool, then the firewall prevents NIS authentication. For more information about firewalls, see the "Firewalls" section of the Security Guide.

10.1.1. Launching the Authentication Configuration Tool UI

1. Log into the system as root.
2. Open the System.
3. Select the Administration menu.
4. Select the Authentication item.

Alternatively, run the system-config-authentication command.
Any changes take effect immediately when the Authentication Configuration Tool UI is closed.

There are two configuration tabs in the Authentication dialog box:

- **Identity & Authentication**, which configures the resource used as the identity store (the data repository where the user IDs and corresponding credentials are stored).
- **Advanced Options**, which allows authentication methods other than passwords or certificates, like smart cards and fingerprint.

### 10.1.2. Selecting the Identity Store for Authentication

The **Identity & Authentication** tab sets how users should be authenticated. The default is to use local system authentication, meaning the users and their passwords are checked against local system accounts. A Fedora machine can also use external resources which contain the users and credentials, including LDAP, NIS, and Winbind.

#### Figure 10.1. Local Authentication

#### 10.1.2.1. Configuring LDAP Authentication

Either the **openldap-clients** package or the **sssd** package is used to configure an LDAP server for the user database. Both packages are installed by default.

1. Open the Authentication Configuration Tool, as in Section 10.1.1, “Launching the Authentication Configuration Tool UI”.
2. Select **LDAP** in the **User Account Database** drop-down menu.

3. Set the information that is required to connect to the LDAP server.
   - **LDAP Search Base DN** gives the root suffix or distinguished name (DN) for the user directory. All of the user entries used for identity/authentication will exist below this parent entry. For example, `ou=people,dc=example,dc=com`. This field is optional. If it is not specified, then SSSD attempts to detect the search base using the `namingContexts` and `defaultNamingContext` attributes in the LDAP server's configuration entry.
   - **LDAP Server** gives the URL of the LDAP server. This usually requires both the hostname and port number of the LDAP server, such as `ldap://ldap.example.com:389`. Entering the secure protocol in the URL, ldaps://, enables the **Download CA Certificate** button. Use TLS to encrypt connections sets whether to use Start TLS to encrypt the connections to the LDAP server. This enables a secure connection over a standard port. Selecting TLS enables the **Download CA Certificate** button, which retrieves the issuing CA certificate for the LDAP server from whatever certificate authority issued it. The CA certificate must be in the privacy enhanced mail (PEM) format.

#### Important

Do not select **Use TLS to encrypt connections** if the server URL uses a secure protocol (ldaps). This option uses Start TLS, which initiates a secure connection over a standard port; if a secure port is specified, then a protocol like SSL must be used instead of Start TLS.

4. Select the authentication method. LDAP allows simple password authentication or Kerberos authentication. Using Kerberos is described in Section 10.1.2.4, “Using Kerberos with LDAP or NIS Authentication”.

#### 10.1.2.2. Configuring NIS Authentication

1. Install the **ypbind** package. This is required for NIS services, but is not installed by default.

   ```
   [root@server ~]# yum install ypbind
   ```

   When the **ypbind** service is installed, the **portmap** and **ypbind** services are started and enabled to start at boot time.
2. Open the Authentication Configuration Tool, as in Section 10.1.1, “Launching the Authentication Configuration Tool UI”.
3. Select **NIS** in the **User Account Database** drop-down menu.

4. Set the information to connect to the NIS server, meaning the NIS domain name and the server hostname. If the
NIS server is not specified, the authconfig daemon scans for the NIS server.

5. Select the authentication method. NIS allows simple password authentication or Kerberos authentication.

Using Kerberos is described in Section 10.1.2.4, “Using Kerberos with LDAP or NIS Authentication”.

For more information about NIS, see the “Securing NIS” section of the Security Guide.

10.1.2.3. Configuring Winbind Authentication

Using Winbind as an authentication provider requires the samba-winbind package, which is installed by default.

1. Open the Authentication Configuration Tool, as in Section 10.1.1, “Launching the Authentication Configuration Tool UI”.

2. Select Winbind in the User Account Database drop-down menu.

3. Set the information that is required to connect to the Microsoft Active Directory domain controller.

   - **Winbind Domain** gives the Windows domain to connect to. This should be in the Windows 2000 format, such as DOMAIN.
   - **Security Model** sets the security model to use for Samba clients. authconfig supports four types of security models:
     - **ads** configures Samba to act as a domain member in an Active Directory Server realm. To operate in this mode, the krb5-server package must be installed and Kerberos must be configured properly.
     - **domain** has Samba validate the username/password by authenticating it through a Windows primary or backup domain controller, much like a Windows server.
     - **server** has a local Samba server validate the username/password by authenticating it through another server, such as a Windows server. If the server authentication attempt fails, the system then attempts to authenticate using user mode.
     - **user** requires a client to log in with a valid username and password. This mode does support encrypted passwords.

   The username format must be domain\user, such as EXAMPLE\jsmith.

   **Note**

   When verifying that a given user exists in the Windows domain, always use Windows 2000-style formats and escape the backslash (\) character. For example:

   ```bash
   [root@server ~]# getent passwd domain\user
   DOMAIN\user:*:16777216:16777216:Name Surname:/home/DOMAIN/user:/bin/bash
   ```

   This is the default option.

   - **Winbind ADS Realm** gives the Active Directory realm that the Samba server will join. This is only used with the ads security model.
   - **Winbind Domain Controllers** gives the domain controller to use. For more information about domain controllers, refer to Section 17.1.6.3, “Domain Controller”.
   - **Template Shell** sets which login shell to use for Windows user account settings.
   - **Allow offline login** allows authentication information to be stored in a local cache. The cache is referenced when a user attempts to authenticate to system resources while the system is offline.

   For more information about the winbind service, refer to Section 17.1.2, “Samba Daemons and Related Services”.

10.1.2.4. Using Kerberos with LDAP or NIS Authentication

Both LDAP and NIS authentication stores support Kerberos authentication methods. Using Kerberos has a couple of benefits:

- It uses a security layer for communication while still allowing connections over standard ports.
- It automatically uses credentials caching with SSSD, which allows offline logins.

Using Kerberos authentication requires the krb5-libs and krb5-workstation packages.

The Kerberos password option from the Authentication Method drop-down menu automatically opens the fields required to connect to the Kerberos realm.
Figure 10.2. Kerberos Fields

- **Realm** gives the name for the realm for the Kerberos server. The realm is the network that uses Kerberos, composed of one or more **key distribution centers** (KDC) and a potentially large number of clients.
- **KDCs** gives a comma-separated list of servers that issue Kerberos tickets.
- **Admin Servers** gives a list of administration servers running the **kadmind** process in the realm.
- Optionally, use DNS to resolve server hostname and to find additional KDCs within the realm.

For more information about Kerberos, refer to section "Using Kerberos" of the Fedora 18 Managing Single Sign-On and Smart Cards guide.

### 10.1.3. Configuring Alternative Authentication Features

The Authentication Configuration Tool also configures settings related to authentication behavior, apart from the identity store. This includes entirely different authentication methods (fingerprint scans and smart cards) or local authentication rules. These alternative authentication options are configured in the **Advanced Options** tab.
10.1.3.1. Using Fingerprint Authentication
When there is appropriate hardware available, the **Enable fingerprint reader support** option allows fingerprint scans to be used to authenticate local users in addition to other credentials.

10.1.3.2. Setting Local Authentication Parameters
There are two options in the **Local Authentication Options** area which define authentication behavior on the local system:

- **Enable local access control** instructs the `/etc/security/access.conf` file to check for local user authorization rules.
- **Password Hashing Algorithm** sets the hashing algorithm to use to encrypt locally-stored passwords.

10.1.3.3. Enabling Smart Card Authentication
When there are appropriate smart card readers available, a system can accept smart cards (or tokens) instead of other user credentials to authenticate.

Once the **Enable smart card support** option is selected, then the behaviors of smart card authentication can be defined:

- **Card Removal Action** tells the system how to respond when the card is removed from the card reader during an active session. A system can either ignore the removal and allow the user to access resources as normal, or a system can immediately lock until the smart card is supplied.
- **Require smart card login** sets whether a smart card is required for logins or simply allowed for logins. When this option is selected, all other methods of authentication are immediately blocked.

**Warning**
Do not select this option until you have successfully authenticated to the system using a smart card.

Using smart cards requires the **pam_pkcs11** package.

10.1.3.4. Creating User Home Directories
There is an option (**Create home directories on the first login**) to create a home directory automatically the first time that a user logs in.

This option is beneficial with accounts that are managed centrally, such as with LDAP. However, this option should not be selected if a system like automount is used to manage user home directories.
10.1.4. Configuring Authentication from the Command Line

The `authconfig` command-line tool updates all of the configuration files and services required for system authentication, according to the settings passed to the script. Along with allowing all of the identity and authentication configuration options that can be set through the UI, the `authconfig` tool can also be used to create backup and kickstart files.

For a complete list of `authconfig` options, check the help output and the man page.

10.1.4.1. Tips for Using authconfig

There are some things to remember when running `authconfig`:

- With every command, use either the `--update` or `--test` option. One of those options is required for the command to run successfully. Using `--update` writes the configuration changes. `--test` prints the changes to stdout but does not apply the changes to the configuration.
- Each enable option has a corresponding disable option.

10.1.4.2. Configuring LDAP User Stores

To use an LDAP identity store, use the `--enableldap`. To use LDAP as the authentication source, use `--enableldapauth` and then the requisite connection information, like the LDAP server name, base DN for the user suffix, and (optionally) whether to use TLS. The `authconfig` command also has options to enable or disable RFC 2307bis schema for user entries, which is not possible through the Authentication Configuration UI.

Be sure to use the full LDAP URL, including the protocol (``ldap`` or ``ldaps``) and the port number. Do not use a secure LDAP URL (``ldaps``) with the `--enableldaptls` option.

```
authconfig --enableldap --enableldapauth -- ldapserver=ldap://ldap.example.com:389,ldap://ldap2.example.com:389 -- ldapbasedn="ou=people,dc=example,dc=com" --enableldaptds -- ldapproxydn=ou=people,dc=example,dc=com --enableldaptls -- ldaploadcacert=https://ca.server.example.com/caCert.crt --update
```

Instead of using `--ldapauth` for LDAP password authentication, it is possible to use Kerberos with the LDAP user store. These options are described in Section 10.1.4.5, “Configuring Kerberos Authentication”.

10.1.4.3. Configuring NIS User Stores

To use a NIS identity store, use the `--enablenis`. This automatically uses NIS authentication, unless the Kerberos parameters are explicitly set, so it uses Kerberos authentication (Section 10.1.4.5, “Configuring Kerberos Authentication”). The only parameters are to identify the NIS server and NIS domain; if these are not used, then the `authconfig` service scans the network for NIS servers.

```
authconfig --enablenis --nisdomain=EXAMPLE --nisserver=nis.example.com --update
```

10.1.4.4. Configuring Winbind User Stores

Windows domains have several different security models, and the security model used in the domain determines the authentication configuration for the local system.

For user and server security models, the Winbind configuration requires only the domain (or workgroup) name and the domain controller hostnames.

```
authconfig --enablewinbind --enablewinbindauth --smbsecurity=user|server -- enablewinbindoffline --smbservers=ad.example.com --smbworkgroup=EXAMPLE --enablewinbindoffline --smbrealm=EXAMPLE.COM --winbindtemplateshell=/bin/sh --update
```

There are a lot of other options for configuring Windows-based authentication and the information for Windows user accounts, such as name formats, whether to require the domain name with the username, and UID ranges. These options are listed in the `authconfig` help.

10.1.4.5. Configuring Kerberos Authentication

Both LDAP and NIS allow Kerberos authentication to be used in place of their native authentication mechanisms. At a minimum, using Kerberos authentication requires specifying the realm, the KDC, and the administrative server. There are also options to use DNS to resolve client names and to find additional admin servers.
10.1.4.6. Configuring Local Authentication Settings
The Authentication Configuration Tool can also control some user settings that relate to security, such as creating home directories, setting password hash algorithms, and authorization. These settings are done independently of identity/user store settings.

For example, to create user home directories:

```bash
authconfig --enablemkhomedir --update
```

To set or change the hash algorithm used to encrypt user passwords:

```bash
authconfig --passalgo=sha512 --update
```

10.1.4.7. Configuring Fingerprint Authentication
There is one option to enable support for fingerprint readers. This option can be used alone or in conjunction with other `authconfig` settings, like LDAP user stores.

```bash
authconfig --enablefingerprint --update
```

10.1.4.8. Configuring Smart Card Authentication
All that is required to use smart cards with a system is to set the `--enablesmartcard` option:

```bash
authconfig --enablesmartcard --update
```

There are other configuration options for smart cards, such as changing the default smart card module, setting the behavior of the system when the smart card is removed, and requiring smart cards for login.

For example, this command instructs the system to lock out a user immediately if the smart card is removed (a setting of 1 ignores it if the smart card is removed):  

```bash
authconfig --enablesmartcard --smartcardaction=0 --update
```

Once smart card authentication has been successfully configured and tested, then the system can be configured to require smart card authentication for users rather than simple password-based authentication.

```bash
authconfig --enablerequiresmartcard --update
```

**Warning**

Do not use the `--enablerequiresmartcard` option until you have successfully authenticated to the system using a smart card. Otherwise, users may be unable to log into the system.

10.1.4.9. Managing Kickstart and Configuration Files
The `--update` option updates all of the configuration files with the configuration changes. There are a couple of alternative options with slightly different behavior:

- `--kickstart` writes the updated configuration to a kickstart file.
- `--test` prints the full configuration, with changes, to stdout but does not edit any configuration files.

Additionally, `authconfig` can be used to back up and restore previous configurations. All archives are saved to a unique subdirectory in the `/var/lib/authconfig/` directory. For example, the `--savebackup` option gives the backup directory as `2011-07-01`:

```bash
authconfig --savebackup=2011-07-01
```

This backs up all of the authentication configuration files beneath the `/var/lib/authconfig/backup-2011-07-01` directory.

Any of the saved backups can be used to restore the configuration using the `--restorebackup` option, giving the name of the manually-saved configuration:

```bash
authconfig --restorebackup=2011-07-01
```

Additionally, `authconfig` automatically makes a backup of the configuration before it applies any changes (with the `--update` option). The configuration can be restored from the most recent automatic backup, without having to specify the exact backup, using the `--restorelastbackup` option.

10.1.5. Using Custom Home Directories
If LDAP users have home directories that are not in `/home` and the system is configured to create home directories the first time users log in, then these directories are created with the wrong permissions.

1. Apply the correct SELinux context and permissions from the `/home` directory to the home directory that is created on the local system. For example:
2. Install the `oddjob-mkhomedir` package on the system.
   This package provides the `pam_oddjob_mkhomedir.so` library, which the Authentication Configuration Tool uses to create home directories. The `pam_oddjob_mkhomedir.so` library, unlike the default `pam_mkhomedir.so` library, can create SELinux labels. The Authentication Configuration Tool automatically uses the `pam_oddjob_mkhomedir.so` library if it is available. Otherwise, it will default to using `pam_mkhomedir.so`.

3. Make sure the `oddjobd` service is running.

4. Re-run the Authentication Configuration Tool and enable home directories, as in Section 10.1.3, "Configuring Alternative Authentication Features".

If home directories were created before the home directory configuration was changed, then correct the permissions and SELinux contexts. For example:

```
# semanage fcontext -a -e /home /home/locale
# restorecon -R -v /home/locale
```

10.2. Using and Caching Credentials with SSSD

The System Security Services Daemon (SSSD) provides access to different identity and authentication providers. SSSD is an intermediary between local clients and any configured data store. The local clients connect to SSSD and then SSSD contacts the external providers. This brings a number of benefits for administrators:

- **Reducing the load on identification/authentication servers.** Rather than having every client service attempt to contact the identification server directly, all of the local clients can contact SSSD which can connect to the identification server or check its cache.

- **Permitting offline authentication.** SSSD can optionally keep a cache of user identities and credentials that it retrieves from remote services. This allows users to authenticate to resources successfully, even if the remote identification server is offline or the local machine is offline.

- **Using a single user account.** Remote users frequently have two (or even more) user accounts, such as one for their local system and one for the organizational system. This is necessary to connect to a virtual private network (VPN). Because SSSD supports caching and offline authentication, remote users can connect to network resources simply by authenticating to their local machine and then SSSD maintains their network credentials.

The System Security Services Daemon does not require any additional configuration or tuning to work with the Authentication Configuration Tool. However, SSSD can work with other applications, and the daemon may require configuration changes to improve the performance of those applications.

10.2.1. About the sssd.conf File

SSSD services and domains are configured in a `.conf` file. The default file is `/etc/sssd/sssd.conf`, although alternative files can be passed to SSSD by using the `-c` option with the `sssd` command:

```
# sssd -c /etc/sssd/customfile.conf
```

Both services and domains are configured individually, in separate sections on the configuration identified by `[type/name]` divisions, such as `[domain/LDAP]`. The configuration file uses simple `key = value` lines to set the configuration. Comment lines are set by either a hash sign (#) or a semicolon (;)

For example:

```
[section]
  # Comment line
  key1 = val1
  key10 = val1,val2
```

10.2.2. Starting and Stopping SSSD

Either the `service` command or the `/etc/init.d/sssd` script can start SSSD. For example:

```
# service sssd start
```

By default, SSSD is configured not to start automatically. There are two ways to change this behavior:

- **Using the `authconfig` command:**
  
  ```
  [root@server ~]# authconfig --enablesssd --enablesssdauth --update
  ```

- **Using the `chkconfig` command:**
  
  ```
  [root@server ~]# chkconfig sssd on
  ```

10.2.3. Configuring SSSD to Work with System Services

SSSD worked with specialized services that run in tandem with the SSSD process itself. SSSD and its associated services
are configured in the `sssd.conf` file. The `[sssd]` section also lists the services that are active and should be started when `sssd` starts within the `services` directive.

SSSD currently provides several services:

- A Name Service Switch (NSS) provider service that answers name service requests from the `sssd_nss` module. This is configured in the `[nss]` section of the SSSD configuration.
- A PAM provider service that manages a PAM conversation through the `sssd_pam` module. This is configured in the `[pam]` section of the configuration.
- `monitor`, a special service that monitors and starts or restarts all other SSSD services. Its options are specified in the `[sssd]` section of the `/etc/sssd/sssd.conf` configuration file.

**Note**

If a DNS lookup fails to return an IPv4 address for a hostname, SSSD attempts to look up an IPv6 address before returning a failure. This only ensures that the asynchronous resolver identifies the correct address. The hostname resolution behavior is configured in the `lookup family order` option in the `sssd.conf` configuration file.

10.2.3.1. Configuring NSS Services

SSSD provides an NSS module, `sssd_nss`, which instructs the system to use SSSD to retrieve user information. The NSS configuration must include a reference to the SSSD module, and then the SSSD configuration sets how SSSD interacts with NSS.

10.2.3.1.1. About NSS Service Maps and SSSD

The Name Service Switch (NSS) provides a central configuration for services to look up a number of configuration and name resolution services. NSS provides one method of mapping system identities and services with configuration sources.

SSSD works with NSS as a provider services for several types of NSS maps:

- Passwords (`passwd`)
- User groups (`shadow`)
- Groups (`groups`)
- Netgroups (`netgroups`)
- Services (`services`)

10.2.3.1.2. Configuring NSS Services to Use SSSD

NSS can use multiple identity and configuration providers for any and all of its service maps. The default is to use system files for services; for SSSD to be included, the `nss_sss` module has to be included for the desired service type.

1. Use the Authentication Configuration tool to enable SSSD. This automatically configured the `nsswitch.conf` file to use SSSD as a provider.

   ```bash
   [root@server ~]# authconfig --enablesssd --update
   ```

   This automatically configures the password, shadow, group, and netgroups services maps to use the SSSD module:

   ```
   passwd:     files sss
   shadow:     files sss
   group:      files sss
   netgroup:   files sss
   ```

2. The services map is not enabled by default when SSSD is enabled with `authconfig`. To include that map, open the `nsswitch.conf` file and add the `sss` module to the `services` map:

   ```bash
   [root@server ~]# vim /etc/nsswitch.conf
   ...
   services: file sss
   ```

10.2.3.1.3. Configuring SSSD to Work with NSS

The options and configuration that SSSD uses to service NSS requests are configured in the SSSD configuration file, in the `[nss]` services section.

1. Open the `sssd.conf` file.

   ```bash
   [root@server ~]# vim /etc/sssd/sssd.conf
   ```

2. Make sure that NSS is listed as one of the services that works with SSSD.

   ```
   [sssd]
   config_file_version = 2
   reconnection_retries = 3
   sbus_timeout = 30
   services = nss, pam
   ```
3. In the [nss] section, change any of the NSS parameters. These are listed in Table 10.1, “SSSD [nss] Configuration Parameters”:

```plaintext
[nss]
    filter_groups = root
    filter_users = root
    reconnection_retries = 3
    entry_cache_timeout = 300
    entry_cache_nowait_percentage = 75
```

4. Restart SSSD.

   ```plaintext
   [root@server ~]# service sssd restart
   ```

---

### Table 10.1. SSSD [nss] Configuration Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>enum_cache_timeout</td>
<td>integer</td>
<td>Specifies how long, in seconds, <code>sssd_nss</code> should cache requests for information about all users (enumerations).</td>
</tr>
<tr>
<td>entry_cache_nowait_percentage</td>
<td>integer</td>
<td>Specifies how long <code>sssd_nss</code> should return cached entries before refreshing the cache. Setting this to zero (0) disables the entry cache refresh. This configures the entry cache to update entries in the background automatically if they are requested if the time before the next update is a certain percentage of the next interval. For example, if the interval is 300 seconds and the cache percentage is 75, then the entry cache will begin refreshing when a request comes in at 225 seconds — 75% of the interval. The allowed values for this option are 0 to 99, which sets the percentage based on the <code>entry_cache_timeout</code> value. The default value is 50%.</td>
</tr>
<tr>
<td>entry_negative_timeout</td>
<td>integer</td>
<td>Specifies how long, in seconds, <code>sssd_nss</code> should cache negative cache hits. A negative cache hit is a query for an invalid database entries, including non-existent entries.</td>
</tr>
<tr>
<td>filter_users, filter_groups</td>
<td>string</td>
<td>Tells SSSD to exclude certain users from being fetched from the NSS database. This is particularly useful for system accounts such as root.</td>
</tr>
<tr>
<td>filter_users_in_groups</td>
<td>Boolean</td>
<td>Sets whether users listed in the <code>filter_users</code> list appear in group memberships when performing group lookups. If set to <code>FALSE</code>, group lookups return all users that are members of that group. If not specified, this value defaults to <code>true</code>, which filters the group member lists.</td>
</tr>
<tr>
<td>debug_level</td>
<td>integer, 0 - 9</td>
<td>Sets a debug logging level.</td>
</tr>
</tbody>
</table>

---

### 10.2.3.2. Configuring the PAM Service

**Warning**

A mistake in the PAM configuration file can lock users out of the system completely. Always back up the configuration files before performing any changes, and keep a session open so that any changes can be reverted.

SSSD provides a PAM module, `sssd_pam`, which instructs the system to use SSSD to retrieve user information. The PAM configuration must include a reference to the SSSD module, and then the SSSD configuration sets how SSSD interacts with PAM.

To configure the PAM service:

1. Use `authconfig` to enable SSSD for system authentication.

   ```bash
   # authconfig --update --enablesssd --enablesssdauth
   ```

   This automatically updates the PAM configuration to reference all of the SSSD modules:
These modules can be set to include statements, as necessary.

2. Open the `sssd.conf` file.

   ```bash
   # vim /etc/sssd/sssd.conf
   ```

3. Make sure that PAM is listed as one of the services that works with SSSD.

   ```ini
   [sssd]
   config_file_version = 2
   reconnection_retries = 3
   sbus_timeout = 30
   services = nss, pam
   ```

4. In the `[pam]` section, change any of the PAM parameters. These are listed in Table 10.2, "SSSD [pam] Configuration Parameters".

   ```ini
   [pam]
   reconnection_retries = 3
   offline_credentialsExpiration = 2
   offline_failed_login_attempts = 3
   offline_failed_login_delay = 5
   ```

5. Restart SSSD.

   ```bash
   [root@server ~]# service sssd restart
   ```

### Table 10.2. SSSD [pam] Configuration Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>offline_credentialsExpiration</td>
<td>integer</td>
<td>Sets how long, in days, to allow cached logins if the authentication</td>
</tr>
<tr>
<td></td>
<td></td>
<td>provider is offline. This value is measured from the last successful</td>
</tr>
<tr>
<td></td>
<td></td>
<td>online login. If not specified, this defaults to zero (0), which is</td>
</tr>
<tr>
<td></td>
<td></td>
<td>unlimited.</td>
</tr>
<tr>
<td>offline_failed_login_attempts</td>
<td>integer</td>
<td>Sets how many failed login attempts are allowed if the authentication</td>
</tr>
<tr>
<td></td>
<td></td>
<td>provider is offline. If not specified, this defaults to zero (0), which is</td>
</tr>
<tr>
<td></td>
<td></td>
<td>unlimited.</td>
</tr>
<tr>
<td>offline_failed_login_delay</td>
<td>integer</td>
<td>Sets how long to prevent login attempts if a user hits the failed login</td>
</tr>
<tr>
<td></td>
<td></td>
<td>attempt limit. Only a successful online authentication can re-enable offline</td>
</tr>
<tr>
<td></td>
<td></td>
<td>authentication. If not specified, this defaults to five (5).</td>
</tr>
</tbody>
</table>

### 10.2.4. Creating Domains

SSSD recognizes domains, which are associated with the different identity servers. Domains are a combination of an identity provider and an authentication method. SSSD works with LDAP identity providers (including OpenLDAP, Red Hat Directory Server, and Microsoft Active Directory) and can use native LDAP authentication or Kerberos authentication.

As long as they belong to different domains, SSSD can recognize different users with the same username. For example, SSSD can successfully authenticate both `jsmith` in the `ldap.example.com` domain and `jsmith` in the `ldap.otherexample.com` domain. SSSD allows requests using fully-qualified domain names, so requesting information...
for jsmith@ldap.example.com returns the proper user account. Specifying only the username returns the user for whichever domain comes first in the lookup order.

Tip

SSSD has a filter_users option, which excludes the specified users from being returned in a search.

Configuring a domain defines both where user information is stored and how those users are allowed to authenticate to the system. The possible combinations are listed in Table 10.3, “Identity Store and Authentication Type Combinations”.

Section 10.2.4.1, “General Rules and Options for Configuring a Domain”
Section 10.2.4.2, “Configuring an LDAP Domain”
Section 10.2.4.3, “Configuring Kerberos Authentication with a Domain”
Section 10.2.4.4, “Configuring a Proxy Domain”

Table 10.3. Identity Store and Authentication Type Combinations

<table>
<thead>
<tr>
<th>Identification Provider</th>
<th>Authentication Provider</th>
</tr>
</thead>
<tbody>
<tr>
<td>LDAP</td>
<td>LDAP</td>
</tr>
<tr>
<td>LDAP</td>
<td>Kerberos</td>
</tr>
<tr>
<td>proxy</td>
<td>LDAP</td>
</tr>
<tr>
<td>proxy</td>
<td>Kerberos</td>
</tr>
<tr>
<td>proxy</td>
<td>proxy</td>
</tr>
</tbody>
</table>

10.2.4.1. General Rules and Options for Configuring a Domain

A domain configuration defines the identity provider, the authentication provider, and any specific configuration to access the information in those providers. There are two types of identity providers — LDAP and proxy —three types of authentication providers — LDAP, Kerberos, and proxy. The identity and authentication providers can be configured in any combination in a domain entry.

Along with the domain entry itself, the domain name must be added to the list of domains that SSSD will query. For example:

domains = LOCAL, Name

[domain/Name]
id_provider = type
auth_provider = type
provider_specific = value
global = value

global attributes are available to any type of domain, such as cache and time out settings. Each identity and authentication provider has its own set of required and optional configuration parameters.

Table 10.4. General [domain] Configuration Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>id_provider</td>
<td>string</td>
<td>Specifies the data provider identity backend to use for this domain. The supported identity backends are:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- ldap</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- ipa, compatible with FreeIPA version 2.x and Identity Management in Fedora</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- proxy for a legacy NSS provider, such as nss_nis. Using a proxy ID provider also requires specifying the legacy NSS library to load to start successfully, set in the proxy_lib_name option.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- local, the SSSD internal local provider</td>
</tr>
<tr>
<td>auth_provider</td>
<td>string</td>
<td>Sets the authentication provider used for the domain. The default value for this option is the value of id_provider. The supported authentication providers are ldap, ipa, krb5 (Kerberos), proxy, and none.</td>
</tr>
<tr>
<td>min_id,max_id</td>
<td>integer</td>
<td>Optional. Specifies the UID and GID range for the domain. If a domain contains entries that are outside that range, they are ignored. The default value for min_id is 1, the default value for max_id is 0, which is unlimited.</td>
</tr>
</tbody>
</table>
### Important

The default **min_id** value is the same for all types of identity provider. If LDAP directories are using UID numbers that start at one, it could cause conflicts with users in the local `/etc/passwd` file. To avoid these conflicts, set **min_id** to **1000** or higher as possible.

---

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>enumerate</td>
<td>Boolean</td>
<td>Optional. Specifies whether to list the users and groups of a domain.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Enumeration means that the entire set of available users and groups on the remote source is cached on the local machine. When enumeration is disabled, users and groups are only cached as they are requested.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Warning</strong> When enumeration is enabled, reinitializing a client results in a complete refresh of the entire set of available users and groups from the remote source. Similarly, when SSSD is connected to a new server, the entire set of available users and groups from the remote source is pulled and cached on the local machine. In a domain with a large number of clients connected to a remote source, this refresh process can harm the network performance because of frequent queries from the clients. If the set of available users and groups is large enough, it degrades client performance as well.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The default value for this parameter is <strong>false</strong>, which disables enumeration.</td>
</tr>
<tr>
<td>cache_credentials</td>
<td>Boolean</td>
<td>Optional. Specifies whether to store user credentials in the local SSSD domain database cache. The default value for this parameter is <strong>false</strong>. Set this value to <strong>true</strong> for domains other than the LOCAL domain to enable offline authentication.</td>
</tr>
<tr>
<td>entry_cache_timeout</td>
<td>integer</td>
<td>Optional. Specifies how long, in seconds, SSSD should cache positive cache hits. A positive cache hit is a successful query.</td>
</tr>
<tr>
<td>use_fully_qualified_names</td>
<td>Boolean</td>
<td>Optional. Specifies whether requests to this domain require fully-qualified domain names. If set to <strong>true</strong>, all requests to this domain must use fully-qualified domain names. It also means that the output from the request displays the fully-qualified name. Restricting requests to fully-qualified user names allows SSSD to differentiate between domains with users with conflicting usernames. If <strong>use_fully_qualified_names</strong> is set to <strong>false</strong>, it is possible to use the fully-qualified name in the requests, but only the simplified version is displayed in the output. SSSD can only parse names based on the domain name, not the realm name. The same name can be used for both domains and realms.</td>
</tr>
</tbody>
</table>
10.2.4.2. Configuring an LDAP Domain

An LDAP domain simply means that SSSD uses an LDAP directory as the identity provider (and, optionally, also as an authentication provider). SSSD supports several major directory services:

- Red Hat Directory Server
- OpenLDAP
- Microsoft Active Directory 2008, with Subsystem for UNIX-based Applications

**Note**

DNS service discovery allows the LDAP backend to find the appropriate DNS servers to connect to automatically using a special DNS query.

**10.2.4.2.1. Parameters for Configuring an LDAP Domain**

An LDAP directory can function as both an identity provider and an authentication provider. The configuration requires enough information to identify and connect to the user directory in the LDAP server, but the way that those connection parameters are defined is flexible.

Other options are available to provide more fine-grained control, like specifying a user account to use to connect to the LDAP server or using different LDAP servers for password operations. The most common options are listed in Table 10.5, "LDAP Domain Configuration Parameters". All of the options listed in Section 10.2.4.1, "General Rules and Options for Configuring a Domain" are also available for LDAP domains.

**Tip**

Many other options are listed in the man page for LDAP domain configuration, `sssd-ldap(5)`.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ldap_uri</td>
<td>Gives a comma-separated list of the URIs of the LDAP servers to which SSSD will connect. The list is given in order of preference, so the first server in the list is tried first. Listing additional servers provides failover protection. This can be detected from the DNS SRV records if it is not given.</td>
</tr>
<tr>
<td>ldap_search_base</td>
<td>Gives the base DN to use for performing LDAP user operations.</td>
</tr>
<tr>
<td>ldap_tls_reqcert</td>
<td>Specifies how to check for SSL server certificates in a TLS session. There are four options:</td>
</tr>
<tr>
<td></td>
<td>- never disables requests for certificates.</td>
</tr>
<tr>
<td></td>
<td>- allow requests a certificate, but proceeds normally even if no certificate is given or a bad certificate is given.</td>
</tr>
<tr>
<td></td>
<td>- try requests a certificate and proceeds normally if no certificate is given. If a bad certificate is given, the session terminates.</td>
</tr>
<tr>
<td></td>
<td>- demand and hard are the same option. This requires a valid certificate or the session is terminated.</td>
</tr>
<tr>
<td></td>
<td>The default is hard.</td>
</tr>
<tr>
<td>ldap_tls_cacert</td>
<td>Gives the full path and file name to the file that contains the CA certificates for all of the CAs that SSSD recognizes. SSSD will accept any certificate issued by these CAs. This uses the OpenLDAP system defaults if it is not given explicitly.</td>
</tr>
<tr>
<td>ldap_referrals</td>
<td>Sets whether SSSD will use LDAP referrals, meaning forwarding queries from one LDAP database to another. SSSD supports database-level and subtree referrals. For referrals within the same LDAP server, SSSD will adjust the DN of the entry being queried. For referrals that go to different LDAP servers, SSSD does an exact match on the DN. Setting this value to true enables referrals; this is the default.</td>
</tr>
<tr>
<td>ldap_schema</td>
<td>Sets what version of schema to use when searching for user entries. This can be either rfc2307 or rfc2307bis. The default is rfc2307. In RFC 2307, group objects use a multi-valued attribute, memberuid, which lists the names of the users that belong to that group. In RFC 2307bis, group objects use the member attribute, which contains the full distinguished name (DN) of a user or group entry. RFC 2307bis allows nested groups using the member attribute. Because these different schema use different definitions for group membership, using the wrong LDAP schema with SSSD can affect both viewing and managing network resources, even if the appropriate permissions are in place. For example, with RFC 2307bis, all groups are returned when using nested groups or primary/secondary groups.</td>
</tr>
<tr>
<td></td>
<td>$ id  uid=500(myserver) gid=500(myserver)</td>
</tr>
<tr>
<td></td>
<td>groups=500(myserver),510(myothergroup)</td>
</tr>
<tr>
<td></td>
<td>If SSSD is using RFC 2307 schema, only the primary group is returned.</td>
</tr>
<tr>
<td></td>
<td>This setting only affects how SSSD determines the group members. It does not change the actual user data.</td>
</tr>
<tr>
<td>ldap_search_timeout</td>
<td>Sets the time, in seconds, that LDAP searches are allowed to run before they are canceled and cached results are returned. This defaults to five when the enumerate value is false and defaults to 30 when enumerate is true. When an LDAP search times out, SSSD automatically switches to offline mode.</td>
</tr>
<tr>
<td>ldap_network_timeout</td>
<td>Sets the time, in seconds, SSSD attempts to poll an LDAP server after a connection attempt fails. The default is six seconds.</td>
</tr>
<tr>
<td>ldap_opt_timeout</td>
<td>Sets the time, in seconds, to wait before aborting synchronous LDAP operations if no response is received from the server. This option also controls the timeout when communicating with the KDC in case of a SASL bind. The default is five seconds.</td>
</tr>
</tbody>
</table>
**10.2.4.2.2. LDAP Domain Example**

The LDAP configuration is very flexible, depending on your specific environment and the SSSD behavior. These are some common examples of an LDAP domain, but the SSSD configuration is not limited to these examples.

### Note

Along with creating the domain entry, add the new domain to the list of domains for SSSD to query in the `sssd.conf` file. For example:

```
domains = LOCAL,LDAP1,AD,PROXYNIS
```

#### Example 10.1. A Basic LDAP Domain Configuration

An LDAP domain requires three things:

- An LDAP server
- The search base
- A way to establish a secure connection

The last item depends on the LDAP environment. SSSD requires a secure connection since it handles sensitive information. This connection can be a dedicated TLS/SSL connection or it can use Start TLS.

Using a dedicated TLS/SSL connection simply uses an LDAPS connection to connect to the server and is therefore set as part of the `ldap_uri` option:

```
# An LDAP domain
[domain/LDAP]
enumerate = false
cache_credentials = true
id_provider = ldap
auth_provider = ldap
ldap_uri = ldaps://ldap.example.com:636
ldap_search_base = dc=example,dc=com
```

Using Start TLS requires a way to input the certificate information to establish a secure connection dynamically over an insecure port. This is done using the `ldap_id_use_start_tls` option to use Start TLS and then `ldap_tls_cacert` to identify the CA certificate which issued the SSL server certificates.

```
# An LDAP domain
[domain/LDAP]
enumerate = false
cache_credentials = true
id_provider = ldap
auth_provider = ldap
ldap_uri = ldap://ldap.example.com
ldap_search_base = dc=example,dc=com
ldap_id_use_start_tls = true
ldap_tls_reqcert = demand
ldap_tls_cacert = /etc/pki/tls/certs/ca-bundle.crt
```

### 10.2.4.2.3. Active Directory Domain Example

For SSSD to work with an Active Directory domain, both the Active Directory domain and the local system have to be configured specially to communicate with one another.

#### Note

The Microsoft Active Directory documentation has complete procedures for configuring the Active Directory domain.

1. Using `authconfig`, set the Linux client to use Active Directory as its LDAP identity provider. For example:

   ```
   authconfig --enableldap --enableldaps --ldapserver=ldap://ad.example.com:389 --enablekrb5 --krb5realm AD-REALM.EXAMPLE.COM --krb5kdc ad-kdc.example.com:88 --krb5adminserver ad-kdc.example.com:749 --update
   ```

   The `authconfig` command is described in Section 10.1, "Configuring System Authentication".

2. Create the Active Directory Domain Services role.

3. Add the Identity Management for UNIX service to the Active Directory Domain Services role. Use the Unix NIS domain as the domain name in the configuration.

4. On the Active Directory server, create a new **Computer** object with the name of the Linux client.

   a. In the **Administrative Tools** menu, select the **Active Directory Users and Computers** application.
   
   b. Expand the Active Directory root object, such as `ad.example.com`.
   
   c. Right-click **Computers**, and select the **New** and the **Computer** item.
d. Enter the name for the Linux client, such as `rhel-server`, and click **OK**.

e. Expand the **Computers** object.

f. Right-click the **rhel-server** object, and select **Properties**.

g. In the **UNIX Attributes**, enter the name of the Linux NIS domain and the IP address of the Linux server. Click **OK**.

5. From the command prompt on the Active Directory server, create a machine account, password, and UPN for the Linux host principal.

```
C:\> setspn -A host/rhel-server.example.com@AD-REALM.EXAMPLE.COM rhel-server
Registering ServicePrincipalNames for CN=rhel server,CN=Computers,DC=ad,DC=example,DC=com
   host/rhel server.example.com@AD-REALM.EXAMPLE.COM
Updated object
```

```
C:\> setspn -L rhel-server
Registered ServicePrincipalNames for CN=rhel server,CN=Computers,DC=ad,DC=example,DC=com:
   host/rhel server.example.com@AD-REALM.EXAMPLE.COM
```

```
C:\> ktpass /princ host/rhel-server.example.com@AD-REALM.EXAMPLE.COM /out rhel-server.keytab /crypto all /ptype KRB5_NT_PRINCIPAL -desonly /mapuser AD\rhel-server$ +rndPass
Targeting domain controller: ad.example.com
Using legacy password setting method
Successfully mapped host/rhel server.redhat.com
```

6. Copy the keytab from the Active Directory server to the Linux client, and save it as `/etc/krb5.keytab`.

7. On the Linux system, reset the permissions and owner for the keytab file.

```
[root@rhel-server ~]# chown root:root /etc/krb5.keytab
[root@rhel-server ~]# chmod 0600 /etc/krb5.keytab
```

8. Restore the SELinux file permissions for the keytab.

```
[root@rhel-server ~]# restorecon /etc/krb5.keytab
```

9. Verify that the host can connect to the Active Directory domain.

```
[root@rhel-server ~]# kinit -k -t /etc/krb5.keytab host/rhel-server.example.com@AD-REALM.EXAMPLE.COM
```

10. On the Active Directory server, create a a group for the Linux users.

a. Create a new group named `unixusers`.

b. Open the `unixusers` group and open the **Unix Attributes** tab.

c. Configure the Unix settings:

   - The **NIS domain**
   - The **UID**
   - The login shell, to `/bin/bash`
   - The home directory, to `/home/aduser`
   - The primary group name, to `unixusers`

11. Then, configure the SSSD domain on the Linux machine.
Example 10.2. An Active Directory 2008 Domain

```bash
[root@rhel-server ~]# vim /etc/sssd/sssd.conf
[sssd]
config_file_version = 2
domains = ad.example.com
services = nss, pam

[nss]
[pam]
[domain/ad.example.com]
cache_credentials = true
enumerate = false
id_provider = ldap
auth_provider = krb5
chpass_provider = krb5
access_provider = ldap
ldap_sasl_mech = GSSAPI
ldap_sasl_authid = host/rhel-server.example.com@AD-REALM.EXAMPLE.COM
ldap_schema = rfc2307bis
ldap_user_search_base = ou=user accounts,dc=ad,dc=example,dc=com
ldap_user_object_class = user
ldap_user_home_directory = unixHomeDirectory
ldap_user_name = sAMAccountName
ldap_group_search_base = ou=groups,dc=ad,dc=example,dc=com
ldap_group_object_class = group
ldap_access_order = expire
ldap_account_expire_policy = ad
ldap_force_upper_case.realm = true
ldap_disable_referrals = true
#krb5_server = server.ad.example.com
krb5_realm = AD-REALM.EXAMPLE.COM
```

These options are described in the man page for LDAP domain configuration, `sssd-ldap(5)`.

12. Restart SSSD.

```bash
[root@rhel-server ~]# service sssd restart
```

10.2.4.2.4. Using IP Addresses in Certificate Subject Names

Using an IP address in the `ldap_uri` option instead of the server name may cause the TLS/SSL connection to fail. TLS/SSL certificates contain the server name, not the IP address. However, the `subject alternative name` field in the certificate can be used to include the IP address of the server, which allows a successful secure connection using an IP address.

1. Convert an existing certificate into a certificate request. The signing key (`-signkey`) is the key of the issuer of whatever CA originally issued the certificate. If this is done by an external CA, it requires a separate PEM file; if the certificate is self-signed, then this is the certificate itself. For example:

```bash
openssl x509 -x509toreq -in old_cert.pem -out req.pem -signkey key.pem
```

With a self-signed certificate:

```bash
openssl x509 -x509toreq -in old_cert.pem -out req.pem -signkey old_cert.pem
```

2. Edit the `/etc/pki/tls/openssl.cnf` configuration file to include the server's IP address under the `[ v3_ca ]` section:

```bash
subjectAltName = IP:10.0.0.10
```

3. Use the generated certificate request to generate a new self-signed certificate with the specified IP address:

```bash
openssl x509 -req -in req.pem -out new_cert.pem -extfile ./openssl.cnf -extensions v3_ca -signkey old_cert.pem
```

The `-extensions` option sets which extensions to use with the certificate. For this, it should be `v3_ca` to load the appropriate section.

4. Copy the private key block from the `old_cert.pem` file into the `new_cert.pem` file to keep all relevant information in one file.

When creating a certificate through the `certutil` utility provided by the `nss-utils` package, note that `certutil` supports DNS subject alternative names for certificate creation only.

10.2.4.3. Configuring Kerberos Authentication with a Domain

Both LDAP and proxy identity providers can use a separate Kerberos domain to supply authentication. Configuring a Kerberos authentication provider requires the key distribution center (KDC) and the Kerberos domain. All of the principal
names must be available in the specified identity provider; if they are not, SSSD constructs the principals using the format username@REALM.

**Note**

Kerberos can only provide authentication; it cannot provide an identity database.

SSSD assumes that the Kerberos KDC is also a Kerberos kadmin server. However, production environments commonly have multiple, read-only replicas of the KDC and only a single kadmin server. Use the `krb5_kpasswd` option to specify where the password changing service is running or if it is running on a non-default port. If the `krb5_kpasswd` option is not defined, SSSD tries to use the Kerberos KDC to change the password.

The basic Kerberos configuration options are listed in Table 10.6, "Kerberos Authentication Configuration Parameters". The `sssd-krb5(5)` man page has more information about Kerberos configuration options.

**Example 10.3. Basic Kerberos Authentication**

```bash
# A domain with identities provided by LDAP and authentication by Kerberos
[domain/KRBDOMAIN]
enumerate = false
id_provider = ldap
chpass_provider = krb5
ldap_uri = ldap://ldap.example.com
ldap_search_base = dc=example,dc=com
ldap_tls_reqcert = demand
ldap_tls_cacert = /etc/pki/tls/certs/ca-bundle.crt
auth_provider = krb5
krb5_server = 192.168.1.1, kerberos.example.com
krb5_realm = EXAMPLE.COM
krb5_kpasswd = kerberos.admin.example.com
krb5_auth_timeout = 15
```
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>chpass_provider</td>
<td>Specifies which service to use for password change operations. This is assumed to be the same as the authentication provider. To use Kerberos, set this to krb5.</td>
</tr>
<tr>
<td>krb5_server</td>
<td>Gives a comma-separated list of IP addresses or hostnames of Kerberos servers to which SSSD will connect. The list is given in order of preference, so the first server in the list is tried first. Listing additional servers provides failover protection. When using service discovery for KDC or kpasswd servers, SSSD first searches for DNS entries that specify UDP as the connection protocol, and then falls back to TCP.</td>
</tr>
<tr>
<td>krb5_realm</td>
<td>Identifies the Kerberos realm served by the KDC.</td>
</tr>
<tr>
<td>krb5_lifetime</td>
<td>Requests a Kerberos ticket with the specified lifetime in seconds (s), minutes (m), hours (h) or days (d).</td>
</tr>
<tr>
<td>krb5_renewable_lifetime</td>
<td>Requests a renewable Kerberos ticket with a total lifetime that is specified in seconds (s), minutes (m), hours (h) or days (d).</td>
</tr>
<tr>
<td>krb5_renew_interval</td>
<td>Sets the time, in seconds, for SSSD to check if tickets should be renewed. Tickets are renewed automatically once they exceed half their lifetime. If this option is missing or set to zero, then automatic ticket renewal is disabled.</td>
</tr>
<tr>
<td>krb5_store_password_if_offline</td>
<td>Sets whether to store user passwords if the Kerberos authentication provider is offline, and then to use that cache to request tickets when the provider is back online. The default is false, which does not store passwords.</td>
</tr>
<tr>
<td>krb5_kpasswd</td>
<td>Lists alternate Kerberos kadmin servers to use if the change password service is not running on the KDC.</td>
</tr>
<tr>
<td>krb5_ccname_template</td>
<td>Gives the directory to use to store the user's credential cache. This can be templatized, and the following tokens are supported:</td>
</tr>
<tr>
<td></td>
<td>%u, the user's login name</td>
</tr>
<tr>
<td></td>
<td>%U, the user's login UID</td>
</tr>
<tr>
<td></td>
<td>%p, the user's principal name</td>
</tr>
<tr>
<td></td>
<td>%r, the realm name</td>
</tr>
<tr>
<td></td>
<td>%h, the user's home directory</td>
</tr>
<tr>
<td></td>
<td>%d, the value of the krb5ccache_dir parameter</td>
</tr>
<tr>
<td></td>
<td>%P, the process ID of the SSSD client.</td>
</tr>
<tr>
<td></td>
<td>%%, a literal percent sign (%)</td>
</tr>
<tr>
<td></td>
<td>XXXXXXX, a string at the end of the template which instructs SSSD to create a unique filename safely</td>
</tr>
<tr>
<td></td>
<td>For example:</td>
</tr>
<tr>
<td></td>
<td>krb5_ccname_template = FILE:%d/krb5cc_%U_XXXXXX</td>
</tr>
<tr>
<td>krb5_ccachedir</td>
<td>Specifies the directory to store credential caches. This can be templatized, using the same tokens as krb5_ccname_template, except for %d and %P. If %u, %U, %p, or %h are used, then SSSD creates a private directory for each user; otherwise, it creates a public directory.</td>
</tr>
<tr>
<td>krb5_auth_timeout</td>
<td>Gives the time, in seconds, before an online authentication or change password request is aborted. If possible, the authentication request is continued offline. The default is 15 seconds.</td>
</tr>
</tbody>
</table>

### 10.2.4.4 Configuring a Proxy Domain
A proxy with SSSD is just a relay, an intermediary configuration. SSSD connects to its proxy service, and then that proxy loads the specified libraries. This allows SSSD to use some resources that it otherwise would not be able to use. For example, SSSD only supports LDAP and Kerberos as authentication providers, but using a proxy allows SSSD to use alternative authentication methods like a fingerprint scanner or smart card.
Table 10.7. Proxy Domain Configuration Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>proxy_pam_target</td>
<td>Specifies the target to which PAM must proxy as an authentication provider.</td>
</tr>
<tr>
<td></td>
<td>The PAM target is a file containing PAM stack information in the default PAM directory, /etc/pam.d/.</td>
</tr>
<tr>
<td></td>
<td>This is used to proxy an authentication provider.</td>
</tr>
<tr>
<td></td>
<td><strong>Important</strong></td>
</tr>
<tr>
<td></td>
<td>Ensure that the proxy PAM stack does not recursively include pam_sss.so.</td>
</tr>
<tr>
<td>proxy_lib_name</td>
<td>Specifies which existing NSS library to proxy identity requests through.</td>
</tr>
<tr>
<td></td>
<td>This is used to proxy an identity provider.</td>
</tr>
</tbody>
</table>

**Example 10.4. Proxy Identity and Kerberos Authentication**

The proxy library is loaded using the `proxy_lib_name` parameter. This library can be anything as long as it is compatible with the given authentication service. For a Kerberos authentication provider, it must be a Kerberos-compatible library, like NIS.

```
[domain/PROXY_KRB5]
auth_provider = krb5
krb5_server = 192.168.1.1
krb5_realm = EXAMPLE.COM
id_provider = proxy
proxy_lib_name = nis
enumerate = true
cache_credentials = true
```

**Example 10.5. LDAP Identity and Proxy Authentication**

The proxy library is loaded using the `proxy_pam_target` parameter. This library must be a PAM module that is compatible with the given identity provider. For example, this uses a PAM fingerprint module with LDAP:

```
[domain/LDAP_PROXY]
id_provider = ldap
ldap_uri = ldap://example.com
ldap_search_base = dc=example,dc=com
auth_provider = proxy
proxy_pam_target = sssdpamproxy
enumerate = true
cache_credentials = true
```

After the SSSD domain is configured, make sure that the specified PAM files are configured. In this example, the target is `sssdpamproxy`, so create a `/etc/pam.d/sssdpamproxy` file and load the PAM/LDAP modules:

```
auth required pam_fprint.so
account required pam_fprint.so
password required pam_fprint.so
session required pam_fprint.so
```
Example 10.6. Proxy Identity and Authentication
SSSD can have a domain with both identity and authentication proxies. The only configuration given then are the proxy
settings, \texttt{proxy\_pam\_target} for the authentication PAM module and \texttt{proxy\_lib\_name} for the service, like NIS or
LDAP.

This example illustrates a possible configuration, but this is not a realistic configuration. If LDAP is used for identity and
authentication, then both the identity and authentication providers should be set to the LDAP configuration, not a proxy.

\begin{verbatim}
[domain/PROXY_PROXY]
auth\_provider = proxy
id\_provider = proxy
proxy\_lib\_name = ldap
proxy\_pam\_target = sssdproxyldap
enumerate = true
cache\_credentials = true
\end{verbatim}

Once the SSSD domain is added, then update the system settings to configure the proxy service:

1. Create a \texttt{/etc/pam.d/sssdproxyldap} file which requires the \texttt{pam\_ldap.so} module:

\begin{verbatim}
auth          required      pam\_ldap.so
account       required      pam\_ldap.so
password      required      pam\_ldap.so
session       required      pam\_ldap.so
\end{verbatim}

2. Make sure the \texttt{nss-pam-ldap} package is installed.

3. Edit the \texttt{/etc/nslcd.conf} file, the configuration file for the LDAP name service daemon, to contain the
information for the LDAP directory:

\begin{verbatim}
uid nslcd
gid ldap
uri ldaps://ldap.example.com:636
base dc=example,dc=com
ssl on
tls\_cacertdir /etc/openldap/cacerts
\end{verbatim}

10.2.5. Configuring Access Control for SSSD Domains
SSSD provides a rudimentary access control for domain configuration, allowing either simple user allow/deny lists or
using the LDAP backend itself.

10.2.5.1. Using the Simple Access Provider
The Simple Access Provider allows or denies access based on a list of usernames or groups.

The Simple Access Provider is a way to restrict access to certain, specific machines. For example, if a company uses
laptops, the Simple Access Provider can be used to restrict access to only a specific user or a specific group, even if a
different user authenticated successfully against the same authentication provider.

The most common options are \texttt{simple\_allow\_users} and \texttt{simple\_allow\_groups}, which grant access explicitly to
specific users (either the given users or group members) and deny access to everyone else. It is also possible to create
deny lists (which deny access only to explicit people and implicitly allow everyone else access).

The Simple Access Provider adheres to the following four rules to determine which users should or should not be granted
access:

\begin{itemize}
  \item If both the allow and deny lists are empty, access is granted.
  \item If any list is provided, allow rules are evaluated first, and then deny rules. Practically, this means that deny rules
       supersede allow rules.
  \item If an allowed list is provided, then all users are denied access unless they are in the list.
  \item If only deny lists are provided, then all users are allowed access unless they are in the list.
\end{itemize}

This example grants access to two users and anyone who belongs to the IT group; implicitly, all other users are denied:

\begin{verbatim}
[domain/example.com]
access\_provider = simple
simple\_allow\_users = jsmith,bjensen
simple\_allow\_groups = itgroup
\end{verbatim}

\textbf{Note}

The LOCAL domain in SSSD does not support \texttt{simple} as an access provider.

Other options are listed in the \texttt{sssd\_simple} man page, but these are rarely used.

10.2.5.2. Using the LDAP Access Filter
The LDAP server itself can provide the access control rules. The associated filter option \texttt{(ldap\_access\_filter)} specifies
which users are granted access to the specified host. The user filter must be used or all users are denied access.
For example:

```
[domain/example.com]
access_provider = ldap
ldap_access_filter = memberOf=cn=allowedusers,ou=Groups,dc=example,dc=com
```

**Note**
Offline caching for LDAP access providers is limited to determining whether the user’s last online login attempt was successful. Users that were granted access during their last login will continue to be granted access while offline.

SSSD can also check results by the account expiration policy and the `authorizedService` attribute.

### 10.2.6. Configuring Domain Failover

SSSD attempts to connect to machines and to services separately.

When SSSD tries to connect to one of its domain backends, it first tries to resolve the hostname of a given machine. If this resolution attempt fails, the machine is considered offline, and SSSD no longer attempts to connect to this machine for any other service.

If the resolution attempt succeeds, the backend tries to connect to a service on this machine. If the service connection attempt fails, then only this particular service is considered offline and the backend automatically switches over to the next service. The machine is still considered online and might still be tried for another service.

SSSD only tries the first IP address given in the DNS A record. To find multiple servers with a single request, SSSD relies on SRV records.

Connections are retried to offline machines or services every 30 seconds, until SSSD can successfully connect to the backend.

#### 10.2.6.1. Configuring Failover

Configuring failover allows SSSD to switch automatically to a different server if the primary server fails. These servers are entered as a case-insensitive, comma-separated list in the `[domain/Name]` sections of the `/etc/sssd/sssd.conf` file. The servers are listed in order of preference. This list can contain any number of servers.

For example, for a native LDAP domain:

```
ldap_uri = ldap://ldap0.example.com, ldap://ldap1.example.com, ldap://ldap2.example.com
```

The first entry, `ldap://ldap0.example.com`, is the primary server. If this server fails, SSSD first attempts to connect to `ldap1.example.com` and then `ldap2.example.com`.

If the server parameter is not specified, then SSSD uses service discovery to try to find another server on the network.

**Important**

The failover servers must be entered as a comma-separated list of values for a single key. If there are multiple keys, SSSD only recognizes the last entry.

#### 10.2.6.2. Using SRV Records with Failover

SSSD supports SRV records in its failover configuration. The SSSD configuration can specify a server that is later resolved into a list of specific servers using SRV requests.

For every service with which to use service discovery, add a special DNS record to the DNS server:

```
_service._protocol._domain TTL priority weight port hostname
```

The priority and weight attributes of SRV records provide fine-grained control over which servers to contact first if the primary server fails.

A typical configuration contains multiple such records, each with a different priority for failover and different weights for load balancing.

For more information on SRV records, see RFC 2782.

### 10.2.7. Managing the SSSD Cache

SSSD can define multiple domains of the same type and different types of domain. SSSD maintains a separate database file for each domain, meaning each domain has its own cache. These cache files are stored in the `/var/lib/sss/db/` directory.

#### 10.2.7.1. Purging the SSSD Cache

As LDAP updates are made to the identity provider for the domains, it can be necessary to clear the cache to reload the new information quickly.

The cache purge utility, `sss_cache`, invalidates records in the SSSD cache for a user, a domain, or a group. Invalidating the current records forces the cache to retrieve the updated records from the identity provider, so changes can be realized quickly.
Most commonly, this is used to clear the cache and update the records for an entire domain:

```
Example 10.7. Purging Domain Records
[root@server ~]# sss_cache -d LDAP1
```

If the administrator knows that a specific record (user, group, or netgroup) has been updated, then `sss_cache` can purge the records for that specific account, and leave the rest of the cache intact.

```
Example 10.8. Purging a User Record
[root@server ~]# sss_cache -u jsmith
```

### Table 10.8. sss_cache Options

<table>
<thead>
<tr>
<th>Short Argument</th>
<th>Long Argument</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>-d name</td>
<td>--domain name</td>
<td>Invalidates cache entries for users, groups, and other entries only within</td>
</tr>
<tr>
<td></td>
<td></td>
<td>the specified domain.</td>
</tr>
<tr>
<td>-G</td>
<td>--groups</td>
<td>Invalidates all group records. If <code>-g</code> is also used, <code>-G</code> takes precedence</td>
</tr>
<tr>
<td></td>
<td></td>
<td>and <code>-G</code> is ignored.</td>
</tr>
<tr>
<td>-g name</td>
<td>--group name</td>
<td>Invalidates the cache entry for the specified group.</td>
</tr>
<tr>
<td>-N</td>
<td>--netgroups</td>
<td>Invalidates cache entries for all netgroup cache records. If <code>-n</code> is also</td>
</tr>
<tr>
<td></td>
<td></td>
<td>used, <code>-N</code> takes precedence and <code>-n</code> is ignored.</td>
</tr>
<tr>
<td>-n name</td>
<td>--netgroup name</td>
<td>Invalidates the cache entry for the specified netgroup.</td>
</tr>
<tr>
<td>-U</td>
<td>--users</td>
<td>Invalidates cache entries for all user records. If the <code>-u</code> option is also</td>
</tr>
<tr>
<td></td>
<td></td>
<td>used, <code>-U</code> takes precedence and <code>-u</code> is ignored.</td>
</tr>
<tr>
<td>-u name</td>
<td>--user name</td>
<td>Invalidates the cache entry for the specified user.</td>
</tr>
</tbody>
</table>

### 10.2.7.2. Deleting Domain Cache Files

All cache files are named for the domain. For example, for a domain named `exampleldap`, the cache file is named `cache_exampleldap.ldb`.

**Be careful when you delete a cache file.** This operation has significant effects:

- Deleting the cache file deletes all user data, both identification and cached credentials. Consequently, do not delete a cache file unless the system is online and can authenticate with a username against the domain's servers. Without a credentials cache, offline authentication will fail.
- If the configuration is changed to reference a different identity provider, SSSD will recognize users from both providers until the cached entries from the original provider time out.

It is possible to avoid this by purging the cache, but the better option is to use a different domain name for the new provider. When SSSD is restarted, it creates a new cache file with the new name and the old file is ignored.

### 10.2.8. Configuring OpenSSH to Check SSSD for Cached Keys (TECH PREVIEW)

OpenSSH creates secure, encrypted connections between two systems. One machine authenticates to another machine to allow access; the authentication can be of the machine itself for server connections or of a user on that machine. OpenSSH is described in more detail in Chapter 11, OpenSSH.

This authentication is performed through **public-private key pairs** that identify the authenticating user or machine. The remote machine or user attempting to access the machine presents a key pair. The local machine then elects whether to trust that remote entity; if it is trusted, the public key for that remote machine is stored in the `known_hosts` file or for the remote user in `authorized_keys`. Whenever that remote machine or user attempts to authenticate again, the local system simply checks the `known_hosts` or `authorized_keys` file first to see if that remote entity is recognized and trusted. If it is, then access is granted.

The first problem comes in verifying those identities reliably.

The `known_hosts` file is a triplet of the machine name, its IP address, and its public key:

```
server.example.com,255.255.255.255 ssh-rsa
AbcdEfG1234ZYX98776/AbcdEfG1234ZYX98776/AbcdEfG1234ZYX98776=
```

The `known_hosts` file can quickly become outdated for a number of different reasons: systems using DHCP cycle through IP addresses, new keys can be re-issued periodically, or virtual machines or services can be brought online and removed. This changes the hostname, IP address, and key triplet.

Administrators have to clean and maintain a current `known_hosts` file to maintain security. (Or system users get in the habit of simply accepting any machine and key presented, which negates the security benefits of key-based security.)
Additionally, problem for both machines and users is distributing keys in a scalable way. Machines can send their keys are part of establishing an encrypted session, but users have to supply their keys in advance. Simply propagating and then updating keys consistently is a difficult administrative task.

Lastly, SSH key and machine information are only maintained locally. There may be machines or users on the network which are recognized and trusted by some systems and not by others because the known_hosts file has not been updated uniformly.

The goal of SSSD is to server as a credentials cache. This includes working as a credentials cache for SSH public keys for machines and users. OpenSSH is configured to reference SSSD to check for cached keys; SSSD uses Red Hat Linux’s Identity Management (IPA) domain as an identity, and IPA actually stores the public keys and host information.

NOTE

Only Linux machines enrolled, or joined, in the IPA domain can use SSSD as a key cache for OpenSSH. Other Unix machines and Windows machines must use the regular authentication mechanisms with the known_hosts file.

10.2.8.1. Configuring OpenSSH to Use SSSD for Host Keys

OpenSSH is configured in either a user-specific configuration file (~/.ssh/config) or a system-wide configuration file (/etc/ssh/ssh_config). The user file has precedence over the system settings and the first obtained value for a parameter is used. The formatting and conventions for this file are covered in Chapter 11, OpenSSH.

In order to manage host keys, SSSD has a tool, sss_ssh_knownhostsproxy, which performs three operations:

1. Retrieves the public host key from the enrolled Linux system.
2. Stores the host key in a custom hosts file, .ssh/sss_known_hosts.
3. Establishes a connection with the host machine, either a socket (the default) or a secure connection.

This tool has the format:

```
sss_ssh_knownhostsproxy [-d sssd_domain] [-p ssh_port] HOST [PROXY_COMMAND]
```

Table 10.9. sss_ssh_knownhostsproxy Options

<table>
<thead>
<tr>
<th>Short Argument</th>
<th>Long Argument</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>HOSTNAME</td>
<td></td>
<td>Gives the hostname of the host to check and connect to. In the OpenSSH configuration file, this can be a token, %h.</td>
</tr>
<tr>
<td>PROXY_COMMAND</td>
<td></td>
<td>Passes a proxy command to use to connect to the SSH client. This is similar to running ssh -o ProxyCommand=value. This option is used when running sss_ssh_knownhostsproxy from the command line or through another script, but is not necessary in the OpenSSH configuration file.</td>
</tr>
<tr>
<td>-d sssd_domain</td>
<td>--domain sssd_domain</td>
<td>Only searches for public keys in entries in the specified domain. If not given, SSSD searches for keys in all configured domains.</td>
</tr>
<tr>
<td>-p port</td>
<td>--port port</td>
<td>Uses this port to connect to the SSH client. By default, this is port 22.</td>
</tr>
</tbody>
</table>

To use this SSSD tool, add or edit two parameters to the ssh_config or ~/.ssh/config file:

- Specify the command to use to connect to the SSH client (ProxyCommand). This is the sss_ssh_knownhostsproxy, with the desired arguments and hostname.
- Specify the location of the SSSD hosts file, rather than the default known_hosts file (UserKnownHostsFile). The SSSD hosts file is .ssh/sss_known_hosts.

For example, this looks for public keys in the IPA SSSD domain and connects over whatever port and host are supplied:

```
ProxyCommand /usr/bin/sss_ssh_knownhostsproxy -p %p -d IPA1 %h
UserKnownHostsFile2 .ssh/sss_known_hosts
```

10.2.8.2. Configuring OpenSSH to Use SSSD for User Keys

User keys are stored on a local system in the authorized_keys file for OpenSSH. As with hosts, SSSD can maintain and automatically update a separate cache of user public keys for OpenSSH to refer to. This is kept in the .ssh/sss_authorized_keys file.

OpenSSH is configured in either a user-specific configuration file (~/.ssh/config) or a system-wide configuration file (/etc/ssh/ssh_config). The user file has precedence over the system settings and the first obtained value for a parameter is used. The formatting and conventions for this file are covered in Chapter 11, OpenSSH.

In order to manage user keys, SSSD has a tool, sss_ssh_authorizedkeys, which performs two operations:
1. Retrieves the user's public key from the user entries in the Identity Management (IPA) domain.
2. Stores the user key in a custom file, `.ssh/sss_authorized_keys`, in the standard authorized keys format.

This tool has the format:

```bash
sss_ssh_authorizedkeys [-d sssd_domain] USER
```

<table>
<thead>
<tr>
<th>Short Argument</th>
<th>Long Argument</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>USER</td>
<td></td>
<td>Gives the username or account name for which to obtain the public key. In the OpenSSH configuration file, this can be represented by a token, <code>%u</code>.</td>
</tr>
<tr>
<td>-d sssd_domain</td>
<td>--domain sssd_domain</td>
<td>Only searches for public keys in entries in the specified domain. If not given, SSSD searches for keys in all configured domains.</td>
</tr>
</tbody>
</table>

There are two possible options for how to configure OpenSSH to use SSSD for user keys, depending on the SSH deployment:

- Most commonly, SSH supports the authorized key command. In that case, it is necessary only to specify the command to run to retrieve user keys. For example:

  ```bash
  AuthorizedKeysCommand /usr/bin/sss_ssh_authorizedkeys
  ```

- SSH can also support a public key agent. In that case, give the command to use to retrieve agent keys, including tokens for required arguments (such as the username):

  ```bash
  PubKeyAgent /usr/bin/sss_ssh_authorizedkeys %u
  ```

### 10.2.9. Using NSCD with SSSD

SSSD is not designed to be used with the NSCD daemon. Even though SSSD does not directly conflict with NSCD, using both services can result in unexpected behavior, especially with how long entries are cached.

The most common evidence of a problem is conflicts with NFS. When using Network Manager to manage network connections, it may take several minutes for the network interface to come up. During this time, various services attempt to start. If these services start before the network is up and the DNS servers are available, these services fail to identify the forward or reverse DNS entries they need. These services will read an incorrect or possibly empty `resolv.conf` file. This file is typically only read once, and so any changes made to this file are not automatically applied. This can cause NFS locking to fail on the machine where the NSCD service is running, unless that service is manually restarted.

To avoid this problem, enable caching for hosts and services in the `/etc/nscd.conf` file and rely on the SSSD cache for the `passwd`, `group`, and `netgroup` entries.

Change the `/etc/nscd.conf` file:

```conf
enable-cache hosts yes
enable-cache passwd no
enable-cache group no
enable-cache netgroup no
```

With NSCD answering hosts requests, these entries will be cached by NSCD and returned by NSCD during the boot process. All other entries are handled by SSSD.

### 10.2.10. Troubleshooting SSSD

#### 10.2.10.1. Setting Debug Logs for SSSD Domains

Each domain sets its own debug log level. Increasing the log level can provide more information about problems with SSSD or with the domain configuration.

To change the log level, set the `debug_level` parameter for each section in the `sssd.conf` file for which to produce extra logs. For example:

```conf
[domain/LDAP]
enumerate = false
cache_credentials = true
d debug_level = 9
```
### Table 10.11. Debug Log Levels

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Fatal failures. Anything that would prevent SSSD from starting up or causes it to cease running.</td>
</tr>
<tr>
<td>1</td>
<td>Critical failures. An error that doesn't kill the SSSD, but one that indicates that at least one major feature is not going to work properly.</td>
</tr>
<tr>
<td>2</td>
<td>Serious failures. An error announcing that a particular request or operation has failed.</td>
</tr>
<tr>
<td>3</td>
<td>Minor failures. These are the errors that would percolate down to cause the operation failure of 2.</td>
</tr>
<tr>
<td>4</td>
<td>Configuration settings.</td>
</tr>
<tr>
<td>5</td>
<td>Function data.</td>
</tr>
<tr>
<td>6</td>
<td>Trace messages for operation functions.</td>
</tr>
<tr>
<td>7</td>
<td>Trace messages for internal control functions.</td>
</tr>
<tr>
<td>8</td>
<td>Contents of function-internal variables that may be interesting.</td>
</tr>
<tr>
<td>9</td>
<td>Extremely low-level tracing information.</td>
</tr>
</tbody>
</table>

**NOTE**
In versions of SSSD older than 1.8, debug log levels could be set globally in the [sssd] section. Now, each domain and service must configure its own debug log level.

To copy the global SSSD debug log levels into each configuration area in the SSSD configuration file, use the `sssd_update_debug_levels.py` script.

```
python /usr/lib/python2.6/site-packages/sssd_update_debug_levels.py
```

### 10.2.10.2. Checking SSSD Log Files

SSSD uses a number of log files to report information about its operation, located in the `/var/log/sssd/` directory. SSSD produces a log file for each domain, as well as an `sssd_pam.log` and an `sssd_nss.log` file.

Additionally, the `/var/log/secure` file logs authentication failures and the reason for the failure.

### 10.2.10.3. Problems with SSSD Configuration

**SSSD fails to start**

- SSSD requires that the configuration file be properly set up, with all the required entries, before the daemon will start.

  - Without a domain, attempting to start SSSD returns an error that no domains are configured:

    ```
    # sssd -d4
    [sssd] [ldb] (3): server_sort:Unable to register control with rootdse!
    [sssd] [confdb.get_domains] (0): No domains configured, fatal error!
    [sssd] [get_monitor_config] (0): No domains configured.
    ```

    Edit the `/etc/sssd/sssd.conf` file and create at least one domain.

- SSSD also requires at least one available service provider before it will start. If the problem is with the service provider configuration, the error message indicates that there are no services configured:

  ```
  [sssd] [get_monitor_config] (0): No services configured!
  ```

  Edit the `/etc/sssd/sssd.conf` file and configure at least one service provider.

**Important**

SSSD requires that service providers be configured as a comma-separated list in a single `services` entry in the `/etc/sssd/sssd.conf` file. If services are listed in multiple entries, only the last entry is recognized by SSSD.

**I don't see any groups with 'id' or group members with 'getent group'.**

This may be due to an incorrect `ldap_schema` setting in the `[domain/DOMAINNAME]` section of `sssd.conf`.

SSSD supports RFC 2307 and RFC 2307bis schema types. By default, SSSD uses the more common RFC 2307 schema.

The difference between RFC 2307 and RFC 2307bis is the way which group membership is stored in the LDAP server. In an RFC 2307 domain, group members are stored as the multi-valued `memberuid` attribute, which contains the name of the users that are members. In an RFC2307bis server, group members are stored as the multi-valued `member` or `uniqueMember` attribute which contains the DN of the user or group that is a member of this group. RFC2307bis allows nested groups to be maintained as well.
If group lookups are not returning any information:

1. Set `ldap_schema` to `rfc2307bis`.
2. Delete `/var/lib/sss/db/cache_DOMAINNAME.ldb`.
3. Restarting SSSD.

If that doesn’t work, add this line to `sssd.conf`:

```
ldap_group_name = uniqueMember
```

Then delete the cache and restart SSSD again.

**Authentication fails against LDAP.**

To perform authentication, SSSD requires that the communication channel be encrypted. This means that if `sssd.conf` is configured to connect over a standard protocol (`ldap://`), it attempts to encrypt the communication channel with StartTLS. If `sssd.conf` is configured to connect over a secure protocol (`ldaps://`), then SSSD uses SSL.

This means that the LDAP server must be configured to run in SSL or TLS. TLS must be enabled for the standard LDAP port (389) or SSL enabled on the secure LDAPS port (636). With either SSL or TLS, the LDAP server must also be configured with a valid certificate trust.

An invalid certificate trust is one of the most common issues with authenticating against LDAP. If the client does not have proper trust of the LDAP server certificate, it is unable to validate the connection, and SSSD refuses to send the password. The LDAP protocol requires that the password be sent in plaintext to the LDAP server. Sending the password in plaintext over an unencrypted connection is a security problem.

If the certificate is not trusted, a `syslog` message is written, indicating that TLS encryption could not be started. The certificate configuration can be tested by checking if the LDAP server is accessible apart from SSSD. For example, this tests an anonymous bind over a TLS connection to `test.example.com`:

```
$ ldapsearch -x -ZZ -h test.example.com -b dc=example,dc=com
```

If the certificate trust is not properly configured, the test fails with this error:

```
ldap_start_tls: Connect error (-11) additional info: TLS error -8179:Unknown code ___f 13
```

To trust the certificate:

1. Obtain a copy of the public CA certificate for the certificate authority used to sign the LDAP server certificate and save it to the local system.
2. Add a line to the `sssd.conf` file that points to the CA certificate on the filesystem.

```
ldap_tls_cacert = /path/to/cacert
```
3. If the LDAP server uses a self-signed certificate, remove the `ldap_tls_reqcert` line from the `sssd.conf` file.

This parameter directs SSSD to trust any certificate issued by the CA certificate, which is a security risk with a self-signed CA certificate.

**Connecting to LDAP servers on non-standard ports fail.**

When running SELinux in enforcing mode, the client's SELinux policy has to be modified to connect to the LDAP server over the non-standard port. For example:

```
# semanage port -a -t ldap_port_t -p tcp 1389
```

**NSS fails to return user information**

This usually means that SSSD cannot connect to the NSS service.

- Ensure that NSS is running:

```
# service sssd status
```
- If NSS is running, make sure that the provider is properly configured in the `[nss]` section of the `/etc/sssd/sssd.conf` file. Especially check the `filter_users` and `filter_groups` attributes.
- Make sure that NSS is included in the list of services that SSSD uses.
- Check the configuration in the `/etc/nsswitch.conf` file.

**NSS returns incorrect user information**

If searches are returning the incorrect user information, check that there are not conflicting usernames in separate domains. When there are multiple domains, set the `use_fully_qualified_domains` attribute to `true` in the `/etc/sssd/sssd.conf` file. This differentiates between different users in different domains with the same name.

**Setting the password for the local SSSD user prompts twice for the password**

When attempting to change a local SSSD user's password, it may prompt for the password twice:
Chapter 11. OpenSSH

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11.1.2. Main Features

11.1.3. Protocol Versions

11.1.4. Event Sequence of an SSH Connection

11.2. An OpenSSH Configuration

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SSH (Secure Shell) is a protocol which facilitates secure communications between two systems using a client/server architecture and allows users to log into server host systems remotely. Unlike other remote communication protocols, such as FTP or Telnet, SSH encrypts the login session, rendering the connection difficult for intruders to collect unencrypted passwords.

The ssh program is designed to replace older, less secure terminal applications used to log into remote hosts, such as telnet or rsh. A related program called scp replaces older programs designed to copy files between hosts, such as rcp. Because these older applications do not encrypt passwords transmitted between the client and the server, avoid them whenever possible. Using secure methods to log into remote systems decreases the risks for both the client system and the remote host.

Fedora includes the general OpenSSH package (openssh) as well as the OpenSSH server (openssh-server) and client (openssh-clients) packages. Note that the OpenSSH packages require the OpenSSL package (openssl), which installs several important cryptographic libraries, enabling OpenSSH to provide encrypted communications.

11.1. The SSH Protocol

11.1.1. Why Use SSH?

Potential intruders have a variety of tools at their disposal enabling them to disrupt, intercept, and re-route network traffic in an effort to gain access to a system. In general terms, these threats can be categorized as follows:

Interception of communication between two systems

The attacker can be somewhere on the network between the communicating parties, copying any information passed between them. He may intercept and keep the information, or alter the information and send it on to the intended recipient.

This attack is usually performed using a packet sniffer, a rather common network utility that captures each packet flowing through the network, and analyzes its content.

Impersonation of a particular host

Attacker's system is configured to pose as the intended recipient of a transmission. If this strategy works, the user's system remains unaware that it is communicating with the wrong host.

This attack can be performed using a technique known as DNS poisoning, or via so-called IP spoofing. In the first case, the intruder uses a cracked DNS server to point client systems to a maliciously duplicated host. In the second case, the intruder sends falsified network packets that appear to be from a trusted host.
Both techniques intercept potentially sensitive information and, if the interception is made for hostile reasons, the results can be disastrous. If SSH is used for remote shell login and file copying, these security threats can be greatly diminished. This is because the SSH client and server use digital signatures to verify their identity. Additionally, all communication between the client and server systems is encrypted. Attempts to spoof the identity of either side of a communication does not work, since each packet is encrypted using a key known only by the local and remote systems.

11.1.2. Main Features
The SSH protocol provides the following safeguards:

No one can pose as the intended server
After an initial connection, the client can verify that it is connecting to the same server it had connected to previously.

No one can capture the authentication information
The client transmits its authentication information to the server using strong, 128-bit encryption.

No one can intercept the communication
All data sent and received during a session is transferred using 128-bit encryption, making intercepted transmissions extremely difficult to decrypt and read.

Additionally, it also offers the following options:

It provides secure means to use graphical applications over a network
Using a technique called X11 forwarding, the client can forward X11 (X Window System) applications from the server.

It provides a way to secure otherwise insecure protocols
The SSH protocol encrypts everything it sends and receives. Using a technique called port forwarding, an SSH server can become a conduit to securing otherwise insecure protocols, like POP, and increasing overall system and data security.

It can be used to create a secure channel
The OpenSSH server and client can be configured to create a tunnel similar to a virtual private network for traffic between server and client machines.

It supports the Kerberos authentication
OpenSSH servers and clients can be configured to authenticate using the GSSAPI (Generic Security Services Application Program Interface) implementation of the Kerberos network authentication protocol.

11.1.3. Protocol Versions
Two varieties of SSH currently exist: version 1, and newer version 2. The OpenSSH suite under Fedora uses SSH version 2, which has an enhanced key exchange algorithm not vulnerable to the known exploit in version 1. However, for compatibility reasons, the OpenSSH suite does support version 1 connections as well.

Avoid using SSH version 1
To ensure maximum security for your connection, it is recommended that only SSH version 2-compatible servers and clients are used whenever possible.

11.1.4. Event Sequence of an SSH Connection
The following series of events help protect the integrity of SSH communication between two hosts.

1. A cryptographic handshake is made so that the client can verify that it is communicating with the correct server.
2. The transport layer of the connection between the client and remote host is encrypted using a symmetric cipher.
3. The client authenticates itself to the server.
4. The remote client interacts with the remote host over the encrypted connection.

11.1.4.1. Transport Layer
The primary role of the transport layer is to facilitate safe and secure communication between the two hosts at the time of authentication and during subsequent communication. The transport layer accomplishes this by handling the encryption and decryption of data, and by providing integrity protection of data packets as they are sent and received. The transport layer also provides compression, speeding the transfer of information.

Once an SSH client contacts a server, key information is exchanged so that the two systems can correctly construct the transport layer. The following steps occur during this exchange:

- Keys are exchanged
- The public key encryption algorithm is determined
- The symmetric encryption algorithm is determined
- The message authentication algorithm is determined
- The hash algorithm is determined
During the key exchange, the server identifies itself to the client with a unique host key. If the client has never communicated with this particular server before, the server's host key is unknown to the client and it does not connect. OpenSSH gets around this problem by accepting the server's host key. This is done after the user is notified and has both accepted and verified the new host key. In subsequent connections, the server's host key is checked against the saved version on the client, providing confidence that the client is indeed communicating with the intended server. If, in the future, the host key no longer matches, the user must remove the client's saved version before a connection can occur.

Always verify the integrity of a new SSH server

It is possible for an attacker to masquerade as an SSH server during the initial contact since the local system does not know the difference between the intended server and a false one set up by an attacker. To help prevent this, verify the integrity of a new SSH server by contacting the server administrator before connecting for the first time or in the event of a host key mismatch.

SSH is designed to work with almost any kind of public key algorithm or encoding format. After an initial key exchange creates a hash value used for exchanges and a shared secret value, the two systems immediately begin calculating new keys and algorithms to protect authentication and future data sent over the connection.

After a certain amount of data has been transmitted using a given key and algorithm (the exact amount depends on the SSH implementation), another key exchange occurs, generating another set of hash values and a new shared secret value. Even if an attacker is able to determine the hash and shared secret value, this information is only useful for a limited period of time.

11.1.4.2. Authentication

Once the transport layer has constructed a secure tunnel to pass information between the two systems, the server tells the client the different authentication methods supported, such as using a private key-encoded signature or typing a password. The client then tries to authenticate itself to the server using one of these supported methods.

SSH servers and clients can be configured to allow different types of authentication, which gives each side the optimal amount of control. The server can decide which encryption methods it supports based on its security model, and the client can choose the order of authentication methods to attempt from the available options.

11.1.4.3. Channels

After a successful authentication over the SSH transport layer, multiple channels are opened via a technique called multiplexing. Each of these channels handles communication for different terminal sessions and for forwarded X11 sessions.

Both clients and servers can create a new channel. Each channel is then assigned a different number on each end of the connection. When the client attempts to open a new channel, the client sends the channel number along with the request. This information is stored by the server and is used to direct communication to that channel. This is done so that different types of sessions do not affect one another and so that when a given session ends, its channel can be closed without disrupting the primary SSH connection.

Channels also support flow-control, which allows them to send and receive data in an orderly fashion. In this way, data is not sent over the channel until the client receives a message that the channel is open.

The client and server negotiate the characteristics of each channel automatically, depending on the type of service the client requests and the way the user is connected to the network. This allows great flexibility in handling different types of remote connections without having to change the basic infrastructure of the protocol.

11.2. An OpenSSH Configuration

In order to perform tasks described in this section, you must have superuser privileges. To obtain them, log in as root by typing:

```
su -
```

11.2.1. Configuration Files

There are two different sets of configuration files: those for client programs (that is, ssh, scp, and sftp), and those for the server (the sshd daemon).

System-wide SSH configuration information is stored in the /etc/ssh/ directory. See Table 11.1, “System-wide configuration files” for a description of its content.
### Table 11.1. System-wide configuration files

<table>
<thead>
<tr>
<th>Configuration File</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>/etc/ssh/moduli</td>
<td>Contains Diffie-Hellman groups used for the Diffie-Hellman key exchange which is critical for constructing a secure transport layer. When keys are exchanged at the beginning of an SSH session, a shared, secret value is created which cannot be determined by either party alone. This value is then used to provide host authentication.</td>
</tr>
<tr>
<td>/etc/ssh/ssh_config</td>
<td>The default SSH client configuration file. Note that it is overridden by <code>~/.ssh/config</code> if it exists.</td>
</tr>
<tr>
<td>/etc/ssh/sshd_config</td>
<td>The configuration file for the <code>sshd</code> daemon.</td>
</tr>
<tr>
<td>/etc/ssh/ssh_host_dsa_key</td>
<td>The DSA private key used by the <code>sshd</code> daemon.</td>
</tr>
<tr>
<td>/etc/ssh/ssh_host_dsa_key.pub</td>
<td>The DSA public key used by the <code>sshd</code> daemon.</td>
</tr>
<tr>
<td>/etc/ssh/ssh_host_key</td>
<td>The RSA private key used by the <code>sshd</code> daemon for version 1 of the SSH protocol.</td>
</tr>
<tr>
<td>/etc/ssh/ssh_host_key.pub</td>
<td>The RSA public key used by the <code>sshd</code> daemon for version 1 of the SSH protocol.</td>
</tr>
<tr>
<td>/etc/ssh/ssh_host_rsa_key</td>
<td>The RSA private key used by the <code>sshd</code> daemon for version 2 of the SSH protocol.</td>
</tr>
<tr>
<td>/etc/ssh/ssh_host_rsa_key.pub</td>
<td>The RSA public key used by the <code>sshd</code> for version 2 of the SSH protocol.</td>
</tr>
</tbody>
</table>

User-specific SSH configuration information is stored in the user's home directory within the `~/.ssh/` directory. See Table 11.2, “User-specific configuration files” for a description of its content.

### Table 11.2. User-specific configuration files

<table>
<thead>
<tr>
<th>Configuration File</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>~/.ssh/authorized_keys</code></td>
<td>Holds a list of authorized public keys for servers. When the client connects to a server, the server authenticates the client by checking its signed public key stored within this file.</td>
</tr>
<tr>
<td><code>~/.ssh/id_dsa</code></td>
<td>Contains the DSA private key of the user.</td>
</tr>
<tr>
<td><code>~/.ssh/id_dsa.pub</code></td>
<td>The DSA public key of the user.</td>
</tr>
<tr>
<td><code>~/.ssh/id_rsa</code></td>
<td>The RSA private key used by <code>ssh</code> for version 2 of the SSH protocol.</td>
</tr>
<tr>
<td><code>~/.ssh/id_rsa.pub</code></td>
<td>The RSA public key used by <code>ssh</code> for version 2 of the SSH protocol.</td>
</tr>
<tr>
<td><code>~/.ssh/identity</code></td>
<td>The RSA private key used by <code>ssh</code> for version 1 of the SSH protocol.</td>
</tr>
<tr>
<td><code>~/.ssh/identity.pub</code></td>
<td>The RSA public key used by <code>ssh</code> for version 1 of the SSH protocol.</td>
</tr>
<tr>
<td><code>~/.ssh/known_hosts</code></td>
<td>Contains DSA host keys of SSH servers accessed by the user. This file is very important for ensuring that the SSH client is connecting the correct SSH server.</td>
</tr>
</tbody>
</table>

Refer to the `ssh_config` and `sshd_config` man pages for information concerning the various directives available in the SSH configuration files.

#### 11.2.2. Starting an OpenSSH Server

**Make sure you have relevant packages installed**

To run an OpenSSH server, you must have the `openssh-server` and `openssh` packages installed. Refer to Section 5.2.4, “Installing Packages” for more information on how to install new packages in Fedora.

To start the `sshd` daemon, type the following at a shell prompt:

```bash
systemctl start sshd.service
```

To stop the running `sshd` daemon, use the following command:

```bash
systemctl stop sshd.service
```

If you want the daemon to start automatically at the boot time, type:

```bash
systemctl enable sshd.service
```

Refer to Chapter 9, Services and Daemons for more information on how to configure services in Fedora.

Note that if you reinstall the system, a new set of identification keys will be created. As a result, clients who had connected to the system with any of the OpenSSH tools before the reinstall will see the following message:

```
@    WARNING: REMOTE HOST IDENTIFICATION HAS CHANGED!@
IT IS POSSIBLE THAT SOMEONE IS DOING SOMETHING NASTY!
IT IS ALSO POSSIBLE THAT SOMEONE IS DOING SOMETHING NASTY!
Someone could be eavesdropping on you right now (man-in-the-middle attack)!
```

To prevent this, you can back up the relevant files from the `/etc/ssh/` directory (see Table 11.1, “System-wide configuration files” for a complete list), and restore them whenever you reinstall the system.

#### 11.2.3. Requiring SSH for Remote Connections

For SSH to be truly effective, using insecure connection protocols should be prohibited. Otherwise, a user's password may
be protected using SSH for one session, only to be captured later while logging in using Telnet. Some services to disable include telnet, rsh, rlogin, and vsftpd.

To make sure these services are not running, type the following commands at a shell prompt:

```
systemctl stop telnet.service
systemctl stop rsh.service
systemctl stop rlogin.service
systemctl stop vsftpd.service
```

To disable running these services at startup, type:

```
systemctl disable telnet.service
systemctl disable rsh.service
systemctl disable rlogin.service
systemctl disable vsftpd.service
```

Refer to Chapter 9, Services and Daemons for more information on how to configure services in Fedora.

11.2.4. Using a Key-Based Authentication

To improve the system security even further, you can enforce the key-based authentication by disabling the standard password authentication. To do so, open the `/etc/ssh/sshd_config` configuration file in a text editor, and change the `PasswordAuthentication` option as follows:

```
PasswordAuthentication no
```

To be able to use `ssh`, `scp`, or `sftp` to connect to the server from a client machine, generate an authorization key pair by following the steps below. Note that keys must be generated for each user separately.

Fedora 18 uses SSH Protocol 2 and RSA keys by default (see Section 11.1.3, “Protocol Versions” for more information).

---

**Do not generate key pairs as root**

If you complete the steps as root, only root will be able to use the keys.

**Backup your ~/.ssh/ directory**

If you reinstall your system and want to keep previously generated key pair, backup the `~/.ssh/` directory. After reinstalling, copy it back to your home directory. This process can be done for all users on your system, including root.

11.2.4.1. Generating Key Pairs

To generate an RSA key pair for version 2 of the SSH protocol, follow these steps:

1. Generate an RSA key pair by typing the following at a shell prompt:

   ```bash
   ~$ ssh-keygen -t rsa
   Generating public/private rsa key pair.
   Enter file in which to save the key (/home/john/.ssh/id_rsa):
   2. Press Enter to confirm the default location (that is, `~/.ssh/id_rsa`) for the newly created key.
   3. Enter a passphrase, and confirm it by entering it again when prompted to do so. For security reasons, avoid using the same password as you use to log in to your account.
   After this, you will be presented with a message similar to this:

   ```
   Your identification has been saved in /home/john/.ssh/id_rsa.
   Your public key has been saved in /home/john/.ssh/id_rsa.pub.
   The key fingerprint is:
   The key's randomart image is:
   +--[ RSA 2048]----+
   |             E.  |
   |            . .  |
   |             o . |
   |              . .|
   |        S .    . |
   |         + o o ..|
   |          * * +oo|
   |           O +..=|
   |           o*  o.|
   +-----------------+
   ```

4. Change the permissions of the `~/.ssh/` directory:

   ```bash
   ~$ chmod 755 ~/.ssh
   ```

5. Copy the content of `~/.ssh/id_rsa.pub` into the `~/.ssh/authorized_keys` on the machine to which you want to connect, appending it to its end if the file already exists.

6. Change the permissions of the `~/.ssh/authorized_keys` file using the following command:

   ```bash
   ~$ chmod 644 ~/.ssh/authorized_keys
   ```
To generate a DSA key pair for version 2 of the SSH protocol, follow these steps:

1. Generate a DSA key pair by typing the following at a shell prompt:

   ```
   ~$ ssh-keygen -t dsa
   Generating public/private dsa key pair.
   Enter file in which to save the key (/home/john/.ssh/id_dsa):
   ```

2. Press Enter to confirm the default location (that is, `.ssh/id_dsa`) for the newly created key.

3. Enter a passphrase, and confirm it by entering it again when prompted to do so. For security reasons, avoid using the same password as you use to log in to your account.

   After this, you will be presented with a message similar to this:

   ```
   Your identification has been saved in /home/john/.ssh/id_dsa.
   Your public key has been saved in /home/john/.ssh/id_dsa.pub.
   The key fingerprint is:
   The key's randomart image is:
   +--[- DSA 1024]-----+
   |   .oo*o.        |
   |...o Bo         |
   | .. . + o.      |
   |.  . + S        |
   |. o= .          |
   |. +             |
   |.               |
   |                 |
   +-----------------+
   ```

4. Change the permissions of the `~/.ssh` directory:

   ```
   ~$ chmod 775 ~/.ssh
   ```

5. Copy the content of `~/.ssh/id_dsa.pub` into the `~/.ssh/authorized_keys` on the machine to which you want to connect, appending it to its end if the file already exists.

6. Change the permissions of the `~/.ssh/authorized_keys` file using the following command:

   ```
   ~$ chmod 644 ~/.ssh/authorized_keys
   ```

To generate an RSA key pair for version 1 of the SSH protocol, follow these steps:

1. Generate an RSA key pair by typing the following at a shell prompt:

   ```
   ~$ ssh-keygen -t rsa
   Generating public/private rsa1 key pair.
   Enter file in which to save the key (/home/john/.ssh/identity):
   ```

2. Press Enter to confirm the default location (that is, `~/.ssh/identity`) for the newly created key.

3. Enter a passphrase, and confirm it by entering it again when prompted to do so. For security reasons, avoid using the same password as you use to log in to your account.

   After this, you will be presented with a message similar to this:

   ```
   Your identification has been saved in /home/john/.ssh/identity.
   Your public key has been saved in /home/john/.ssh/identity.pub.
   The key fingerprint is:
   The key's randomart image is:
   +--[- RSA1 2048]-----+
   |                 |
   |     . .         |
   |    o o          |
   |     + o E       |
   |    . o S        |
   |       = +   .   |
   |      . = . o . .|
   |       .o o  o=o.|
   |       . = o o..|
   |       .o o  o=o.|
   |                 |
   +-----------------+
   ```

4. Change the permissions of the `~/.ssh` directory:

   ```
   ~$ chmod 755 ~/.ssh
   ```

5. Copy the content of `~/.ssh/identity.pub` into the `~/.ssh/authorized_keys` on the machine to which you want to connect, appending it to its end if the file already exists.

6. Change the permissions of the `~/.ssh/authorized_keys` file using the following command:

   ```
   ~$ chmod 644 ~/.ssh/authorized_keys
   ```

Refer to Section 11.2.4.2, “Configuring ssh-agent” for information on how to set up your system to remember the passphrase.

**Never share your private key**

The private key is for your personal use only, and it is important that you never give it to anyone.
11.2.4.2 Configuring ssh-agent
To store your passphrase so that you do not have to enter it each time you initiate a connection with a remote machine, you can use the ssh-agent authentication agent. To save your passphrase for a certain shell prompt, use the following command:

```bash
$ ssh-add
Enter passphrase for /home/john/.ssh/id_rsa:
```

Note that when you log out, your passphrase will be forgotten. You must execute the command each time you log in to a virtual console or a terminal window.

11.3. OpenSSH Clients

Make sure you have relevant packages installed
To connect to an OpenSSH server from a client machine, you must have the openssh-clients and openssh packages installed. Refer to Section 5.2.4, “Installing Packages” for more information on how to install new packages in Fedora.

11.3.1. Using the ssh Utility

ssh allows you to log in to a remote machine and execute commands there. It is a secure replacement for the rlogin, rsh, and telnet programs.

Similarly to telnet, to log in to a remote machine named penguin.example.com, type the following command at a shell prompt:

```bash
$ ssh penguin.example.com
```

This will log you in with the same username you are using on a local machine. If you want to specify a different one, use a command in the ssh username@hostname form. For example, to log in as john, type:

```bash
$ ssh john@penguin.example.com
```

The first time you initiate a connection, you will be presented with a message similar to this:

```
The authenticity of host 'penguin.example.com' can't be established.
Are you sure you want to continue connecting (yes/no)?
```

Type yes to confirm. You will see a notice that the server has been added to the list of known hosts, and a prompt asking for your password:

```
Warning: Permanently added 'penguin.example.com' (RSA) to the list of known hosts.
john@penguin.example.com's password:
```

After entering the password, you will be provided with a shell prompt for the remote machine.

Alternatively, the ssh program can be used to execute a command on the remote machine without logging in to a shell prompt. The syntax for this is ssh [username@]hostname command. For example, if you want to execute the whoami command on penguin.example.com, type:

```bash
$ ssh john@penguin.example.com whoami
```

After you enter the correct password, the username will be displayed, and you will return to your local shell prompt.

11.3.2. Using the scp Utility

scp can be used to transfer files between machines over a secure, encrypted connection. In its design, it is very similar to rcp.

To transfer a local file to a remote system, use a command in the following form:

```bash
cp localfile username@hostname:remotefile
```

For example, if you want to transfer taglist.vim to a remote machine named penguin.example.com, type the following at a shell prompt:

```bash
$ scp taglist.vim john@penguin.example.com:.vim/plugin/taglist.vim
```

After you enter the correct password, the transfer will proceed.
Multiple files can be specified at once. To transfer the contents of `.vim/plugin/` to the same directory on the remote machine `penguin.example.com`, type the following command:

```
$ scp .vim/plugin/* john@penguin.example.com:.vim/plugin/
```

To transfer a remote file to the local system, use the following syntax:

```
scp username@hostname:remotefile localfile
```

For instance, to download the `.vimrc` configuration file from the remote machine, type:

```
$ scp john@penguin.example.com:.vimrc .vimrc
```

### Using the sftp Utility

The `sftp` utility can be used to open a secure, interactive FTP session. In its design, it is similar to `ftp` except that it uses a secure, encrypted connection.

To connect to a remote system, use a command in the following form:

```
sftp username@hostname
```

For example, to log in to a remote machine named `penguin.example.com` with `john` as a username, type:

```
~]$ sftp john@penguin.example.com
```

After you enter the correct password, you will be presented with a prompt. The `sftp` utility accepts a set of commands similar to those used by `ftp` (see Table 11.3, "A selection of available sftp commands").

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>ls [directory]</code></td>
<td>List the content of a remote directory. If none is supplied, a current working directory is used by default.</td>
</tr>
<tr>
<td><code>cd directory</code></td>
<td>Change the remote working directory to <code>directory</code>.</td>
</tr>
<tr>
<td><code>mkdir directory</code></td>
<td>Create a remote <code>directory</code>.</td>
</tr>
<tr>
<td><code>rmdir path</code></td>
<td>Remove a remote <code>directory</code>.</td>
</tr>
<tr>
<td><code>put localfile [remotefile]</code></td>
<td>Transfer <code>localfile</code> to a remote machine.</td>
</tr>
<tr>
<td><code>get remotefile [localfile]</code></td>
<td>Transfer <code>remotefile</code> from a remote machine.</td>
</tr>
</tbody>
</table>

For a complete list of available commands, refer to the `sftp` man page.

### More Than a Secure Shell

A secure command line interface is just the beginning of the many ways SSH can be used. Given the proper amount of bandwidth, X11 sessions can be directed over an SSH channel. Or, by using TCP/IP forwarding, previously insecure port connections between systems can be mapped to specific SSH channels.

#### X11 Forwarding

To open an X11 session over an SSH connection, use a command in the following form:

```
ssh -Y username@hostname
```

For example, to log in to a remote machine named `penguin.example.com` with `john` as a username, type:

```
~]$ ssh -Y john@penguin.example.com
```

When an X program is run from the secure shell prompt, the SSH client and server create a new secure channel, and the X program data is sent over that channel to the client machine transparently.

X11 forwarding can be very useful. For example, X11 forwarding can be used to create a secure, interactive session of the Printer Configuration utility. To do this, connect to the server using `ssh` and type:

```
$ system-config-printer &
```

The Printer Configuration Tool will appear, allowing the remote user to safely configure printing on the remote system.

#### Port Forwarding

SSH can secure otherwise insecure TCP/IP protocols via port forwarding. When using this technique, the SSH server becomes an encrypted conduit to the SSH client.

Port forwarding works by mapping a local port on the client to a remote port on the server. SSH can map any port from the server to any port on the client. Port numbers do not need to match for this technique to work.
To create a TCP/IP port forwarding channel which listens for connections on the localhost, use a command in the following form:

```
ssh -L local-port:remote-hostname:remote-port username@hostname
```

For example, to check email on a server called mail.example.com using POP3 through an encrypted connection, use the following command:

```
~]$ ssh -L 1100:mail.example.com:110 mail.example.com
```

Once the port forwarding channel is in place between the client machine and the mail server, direct a POP3 mail client to use port 1100 on the localhost to check for new email. Any requests sent to port 1100 on the client system will be directed securely to the mail.example.com server.

If mail.example.com is not running an SSH server, but another machine on the same network is, SSSH can still be used to secure part of the connection. However, a slightly different command is necessary:

```
~]$ ssh -L 1100:mail.example.com:110 other.example.com
```

In this example, POP3 requests from port 1100 on the client machine are forwarded through the SSH connection on port 22 to the SSH server, other.example.com. Then, other.example.com connects to port 110 on mail.example.com to check for new email. Note that when using this technique, only the connection between the client system and other.example.com SSH server is secure.

Port forwarding can also be used to get information securely through network firewalls. If the firewall is configured to allow SSH traffic via its standard port (that is, port 22) but blocks access to other ports, a connection between two hosts using the blocked ports is still possible by redirecting their communication over an established SSH connection.

A connection is only as secure as a client system

Using port forwarding to forward connections in this manner allows any user on the client system to connect to that service. If the client system becomes compromised, the attacker also has access to forwarded services. System administrators concerned about port forwarding can disable this functionality on the server by specifying a No parameter for the AllowTcpForwarding line in /etc/ssh/sshd_config and restarting the sshd service.

11.5. Additional Resources

The OpenSSH and OpenSSL projects are in constant development, and the most up-to-date information for them is available from their websites. The man pages for OpenSSH and OpenSSL tools are also good sources of detailed information.

11.5.1. Installed Documentation

```
man ssh
```
The manual page for ssh containing the full documentation on its usage.

```
man scp
```
The manual page for scp containing the full documentation on its usage.

```
man sftp
```
The manual page for sftp containing the full documentation on its usage.

```
man sshd
```
The manual page for sshd containing the full documentation on its usage.

```
man ssh-keygen
```
The manual page for ssh-keygen containing the full documentation on its usage.

```
man ssh_config
```
The manual page with full description of available SSH client configuration options.

```
man sshd_config
```
The manual page with full description of available SSH daemon configuration options.

11.5.2. Useful Websites

http://www.openssh.com/
The OpenSSH home page containing further documentation, frequently asked questions, links to the mailing lists, bug reports, and other useful resources.

http://www.openssl.org/
The OpenSSL home page containing further documentation, frequently asked questions, links to the mailing lists, and other useful resources.

http://www.freesshd.com/
Another implementation of an SSH server.

---

Part V. Servers

This part discusses various topics related to servers such as how to set up a Web server or share files and directories over the network.

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Dynamic Host Configuration Protocol (DHCP) is a network protocol that automatically assigns TCP/IP information to client machines. Each DHCP client connects to the centrally located DHCP server, which returns that client’s network configuration (including the IP address, gateway, and DNS servers).

12.1. Why Use DHCP?

DHCP is useful for automatic configuration of client network interfaces. When configuring the client system, the administrator chooses DHCP instead of specifying an IP address, netmask, gateway, or DNS servers. The client retrieves this information from the DHCP server. DHCP is also useful if an administrator wants to change the IP addresses of a large number of systems. Instead of reconfiguring all the systems, he can just edit one DHCP configuration file on the server for the new set of IP addresses. If the DNS servers for an organization changes, the changes are made on the DHCP server, not on the DHCP clients. When the administrator restarts the network or reboots the clients, the changes will go into effect.

If an organization has a functional DHCP server properly connected to a network, laptops and other mobile computer users can move these devices from office to office.

12.2. Configuring a DHCP Server

The `dhcp` package contains an ISC DHCP server. First, install the package as `root`:

```
yum install dhcp
```

Installing the `dhcp` package creates a file, `/etc/dhcp/dhcpd.conf`, which is merely an empty configuration file:

```
# DHCP Server Configuration file.
# see /usr/share/doc/dhcp*/dhcpd.conf.sample
# see dhcpd.conf(5) man page
```

The sample configuration file can be found at `/usr/share/doc/dhcp*/dhcpd.conf.sample`. You should use this file to help you configure `/etc/dhcp/dhcpd.conf`, which is explained in detail below.

DHCP also uses the file `/var/lib/dhcpd/dhcpd.leases` to store the client lease database. Refer to Section 12.2.2, “Lease Database” for more information.

12.2.1. Configuration File

The first step in configuring a DHCP server is to create the configuration file that stores the network information for the clients. Use this file to declare options and global options for client systems.

The configuration file can contain extra tabs or blank lines for easier formatting. Keywords are case-insensitive and lines beginning with a hash sign (#) are considered comments.

There are two types of statements in the configuration file:

- Parameters — State how to perform a task, whether to perform a task, or what network configuration options to send to the client.
- Declarations — Describe the topology of the network, describe the clients, provide addresses for the clients, or apply a group of parameters to a group of declarations.

The parameters that start with the keyword `option` are referred to as `options`. These options control DHCP options; whereas, parameters configure values that are not optional or control how the DHCP server behaves.

Parameters (including options) declared before a section enclosed in curly brackets ({ }) are considered global parameters. Global parameters apply to all the sections below it.
Restart the DHCP daemon for the changes to take effect

If the configuration file is changed, the changes do not take effect until the DHCP daemon is restarted. To do so, type the following at a shell prompt as root:

```
systemctl restart dhcpd.service
```

Use the omshell command

Instead of changing a DHCP configuration file and restarting the service each time, using the `omshell` command provides an interactive way to connect to, query, and change the configuration of a DHCP server. By using `omshell`, all changes can be made while the server is running. For more information on `omshell`, refer to the `omshell` man page.

In Example 12.1, “Subnet declaration”, the `routers`, `subnet-mask`, `domain-search`, `domain-name-servers`, and `time-offset` options are used for any `host` statements declared below it.

Additionally, a `subnet` can be declared, a `subnet` declaration must be included for every subnet in the network. If it is not, the DHCP server fails to start.

In this example, there are global options for every DHCP client in the subnet and a `range` declared. Clients are assigned an IP address within the `range`.

**Example 12.1. Subnet declaration**

```plaintext
subnet 192.168.1.0 netmask 255.255.255.0 {
    option routers                  192.168.1.254;
    option subnet-mask              255.255.255.0;
    option domain-search              "example.com";
    option domain-name-servers       192.168.1.1;
    option time-offset              -18000;     # Eastern Standard Time
    range 192.168.1.10 192.168.1.100;
}
```

To configure a DHCP server that leases a dynamic IP address to a system within a subnet, modify Example 12.2, “Range parameter” with your values. It declares a default lease time, maximum lease time, and network configuration values for the clients. This example assigns IP addresses in the `range` 192.168.1.10 and 192.168.1.100 to client systems.

**Example 12.2. Range parameter**

```plaintext
default-lease-time 600;
max-lease-time 7200;
option subnet-mask 255.255.255.0;
option broadcast-address 192.168.1.255;
option routers 192.168.1.254;
option domain-name-servers 192.168.1.1, 192.168.1.2;
option domain-search "example.com";
subnet 192.168.1.0 netmask 255.255.255.0 {
    range 192.168.1.10 192.168.1.100;
}
```

To assign an IP address to a client based on the MAC address of the network interface card, use the `hardware ethernet` parameter within a `host` declaration. As demonstrated in Example 12.3, “Static IP address using DHCP”, the `host apex` declaration specifies that the network interface card with the MAC address 00:A0:78:8E:9E:AA always receives the IP address 192.168.1.4.

**Example 12.3. Static IP address using DHCP**

```plaintext
host apex {
    option host-name "apex.example.com";
    hardware ethernet 00:A0:78:8E:9E:AA;
    fixed-address 192.168.1.4;
}
```

All subnets that share the same physical network should be declared within a `shared-network` declaration as shown in Example 12.4, “Shared-network declaration”. Parameters within the `shared-network`, but outside the enclosed `subnet` declarations, are considered to be global parameters. The name of the `shared-network` must be a descriptive title for the network, such as using the title 'test-lab' to describe all the subnets in a test lab environment.
Example 12.4. Shared-network declaration

```plaintext
shared-network name {
    option domain-search "test.redhat.com";
    option domain-name-servers ns1.redhat.com, ns2.redhat.com;
    option routers 192.168.0.254;
    more parameters for EXAMPLE shared-network
    subnet 192.168.1.0 netmask 255.255.252.0 {
        parameters for subnet
        range 192.168.1.1 192.168.1.254;
    }
    subnet 192.168.2.0 netmask 255.255.252.0 {
        parameters for subnet
        range 192.168.2.1 192.168.2.254;
    }
}
```

As demonstrated in Example 12.5, "Group declaration", the group declaration is used to apply global parameters to a group of declarations. For example, shared networks, subnets, and hosts can be grouped.

Example 12.5. Group declaration

```plaintext
group {
    option routers 192.168.1.254;
    option subnet-mask 255.255.255.0;
    option domain-search "example.com";
    option domain-name-servers 192.168.1.1;
    option time-offset -18000; # Eastern Standard Time
    host apex {
        option host-name "apex.example.com";
        hardware ethernet 00:A0:78:8E:9E:AA;
        fixed-address 192.168.1.4;
    }
    host raleigh {
        option host-name "raleigh.example.com";
        hardware ethernet 00:A1:DD:74:C3:F2;
        fixed-address 192.168.1.6;
    }
}
```

Using the sample configuration file

The sample configuration file provided can be used as a starting point and custom configuration options can be added to it. To copy it to the proper location, use the following command:

```
cp /usr/share/doc/dhcp-version-number/dhcp.conf.sample /etc/dhcp/dhcpd.conf
```

... where version-number is the DHCP version number.

For a complete list of option statements and what they do, refer to the dhcp-options man page.

12.2.2. Lease Database

On the DHCP server, the file `/var/lib/dhcpd/dhcpd.leases` stores the DHCP client lease database. Do not change this file. DHCP lease information for each recently assigned IP address is automatically stored in the lease database. The information includes the length of the lease, to whom the IP address has been assigned, the start and end dates for the lease, and the MAC address of the network interface card that was used to retrieve the lease.

All times in the lease database are in Coordinated Universal Time (UTC), not local time.

The lease database is recreated from time to time so that it is not too large. First, all known leases are saved in a temporary lease database. The `dhcpd.leases` file is renamed `dhcpd.leases~` and the temporary lease database is written to `dhcpd.leases`.

The DHCP daemon could be killed or the system could crash after the lease database has been renamed to the backup file but before the new file has been written. If this happens, the `dhcpd.leases` file does not exist, but it is required to start the service. Do not create a new lease file. If you do, all old leases are lost which causes many problems. The correct solution is to rename the `dhcpd.leases~` backup file to `dhcpd.leases` and then start the daemon.

12.2.3. Starting and Stopping the Server

Starting the DHCP server for the first time

When the DHCP server is started for the first time, it fails unless the `dhcpd.leases` file exists. Use the command `touch /var/lib/dhcpd/dhcpd.leases` to create the file if it does not exist. If the same server is also running BIND as a DNS server, this step is not necessary, as starting the named service automatically checks for a `dhcpd.leases` file.

To start the DHCP service, use the following command:

```
systemctl start dhcpd.service
```
To stop the DHCP server, type:

```
systemctl stop dhcpd.service
```

By default, the DHCP service does not start at boot time. To configure the daemon to start automatically at boot time, run:

```
systemctl enable dhcpd.service
```

Refer to Chapter 9, Services and Daemons for more information on how to configure services in Fedora.

If more than one network interface is attached to the system, but the DHCP server should only be started on one of the interfaces, configure the DHCP server to start only on that device. In `/etc/sysconfig/dhcpd`, add the name of the interface to the list of `DHCPDARGS`:

```
# Command line options here
DHCPDARGS=eth0
```

This is useful for a firewall machine with two network cards. One network card can be configured as a DHCP client to retrieve an IP address to the Internet. The other network card can be used as a DHCP server for the internal network behind the firewall. Specifying only the network card connected to the internal network makes the system more secure because users can not connect to the daemon via the Internet.

Other command line options that can be specified in `/etc/sysconfig/dhcpd` include:

- `-p portnum` — Specifies the UDP port number on which `dhcpd` should listen. The default is port 67. The DHCP server transmits responses to the DHCP clients at a port number one greater than the UDP port specified. For example, if the default port 67 is used, the server listens on port 67 for requests and responses to the client on port 68. If a port is specified here and the DHCP relay agent is used, the same port on which the DHCP relay agent should listen must be specified. Refer to Section 12.2.4, “DHCP Relay Agent” for details.
- `-f` — Runs the daemon as a foreground process. This is mostly used for debugging.
- `-d` — Logs the DHCP server daemon to the standard error descriptor. This is mostly used for debugging. If this is not specified, the log is written to `/var/log/messages`.
- `-cf filename` — Specifies the location of the configuration file. The default location is `/etc/dhcp/dhcpd.conf`.
- `-lf filename` — Specifies the location of the lease database file. If a lease database file already exists, it is very important that the same file be used every time the DHCP server is started. It is strongly recommended that this option only be used for debugging purposes on non-production machines. The default location is `/var/lib/dhcpd/dhcpd.leases`.
- `-q` — Do not print the entire copyright message when starting the daemon.

12.2.4. DHCP Relay Agent

The DHCP Relay Agent (`dhcrelay`) allows for the relay of DHCP and BOOTP requests from a subnet with no DHCP server on it to one or more DHCP servers on other subnets.

When a DHCP client requests information, the DHCP Relay Agent forwards the request to the list of DHCP servers specified when the DHCP Relay Agent is started. When a DHCP server returns a reply, the reply is broadcast or unicast on the network that sent the original request.

The DHCP Relay Agent listens for DHCP requests on all interfaces unless the interfaces are specified in `/etc/sysconfig/dhcrelay` with the `INTERFACES` directive.

To start the DHCP Relay Agent, use the following command:

```
systemctl start dhcrelay.service
```

12.3. Configuring a DHCP Client

To configure a DHCP client manually, modify the `/etc/sysconfig/network` file to enable networking and the configuration file for each network device in the `/etc/sysconfig/network-scripts` directory. In this directory, each device should have a configuration file named `ifcfg-eth0`, where `eth0` is the network device name.

The `/etc/sysconfig/network-scripts/ifcfg-eth0` file should contain the following lines:

```
DEVICE=eth0
BOOTPROTO=dhcp
ONBOOT=yes
```

A configuration file is needed for each device to be configured to use DHCP.

Other options for the network script includes:

- `DHCP_HOSTNAME` — Only use this option if the DHCP server requires the client to specify a hostname before receiving an IP address. (The DHCP server daemon in Fedora does not support this feature.)
- `PEERDNS=answer`, where `answer` is one of the following:
  - `yes` — Modify `/etc/resolv.conf` with information from the server. If using DHCP, then `yes` is the default.
  - `no` — Do not modify `/etc/resolv.conf`.
Advanced configurations

For advanced configurations of client DHCP options such as protocol timing, lease requirements and requests, dynamic DNS support, aliases, as well as a wide variety of values to override, prepend, or append to client-side configurations, refer to the `dhclient` and `dhclient.conf` man pages.

12.4. Configuring a Multihomed DHCP Server

A multihomed DHCP server serves multiple networks, that is, multiple subnets. The examples in these sections detail how to configure a DHCP server to serve multiple networks, select which network interfaces to listen on, and how to define network settings for systems that move networks.

Before making any changes, back up the existing `/etc/sysconfig/dhcpd` and `/etc/dhcp/dhcpd.conf` files.

The DHCP daemon listens on all network interfaces unless otherwise specified. Use the `/etc/sysconfig/dhcpd` file to specify which network interfaces the DHCP daemon listens on. The following `/etc/sysconfig/dhcpd` example specifies that the DHCP daemon listens on the `eth0` and `eth1` interfaces:

```
DHCPDARGS="eth0 eth1";
```

If a system has three network interfaces cards -- `eth0`, `eth1`, and `eth2` -- and it is only desired that the DHCP daemon listens on `eth0`, then only specify `eth0` in `/etc/sysconfig/dhcpd`:

```
DHCPDARGS="eth0";
```

The following is a basic `/etc/dhcp/dhcpd.conf` file, for a server that has two network interfaces, `eth0` in a 10.0.0.0/24 network, and `eth1` in a 172.16.0.0/24 network. Multiple `subnet` declarations allow different settings to be defined for multiple networks:

```
default-lease-time 600;
max-lease-time 7200;
subnet 10.0.0.0 netmask 255.255.255.0 {
  option subnet-mask 255.255.255.0;
  option routers 10.0.0.1;
  range 10.0.0.5 10.0.0.15;
}
subnet 172.16.0.0 netmask 255.255.255.0 {
  option subnet-mask 255.255.255.0;
  option routers 172.16.0.1;
  range 172.16.0.5 172.16.0.15;
}
```

A `subnet` declaration is required for every network your DHCP server is serving. Multiple subnets require multiple `subnet` declarations. If the DHCP server does not have a network interface in a range of a `subnet` declaration, the DHCP server does not serve that network.

If there is only one `subnet` declaration, and no network interfaces are in the range of that subnet, the DHCP daemon fails to start, and an error such as the following is logged to `/var/log/messages`:

```
dhcpd: No subnet declaration for eth0 (0.0.0.0).
dhcpd: " Ignoring requests on eth0. If this is not what
dhcpd: you want, please write a subnet declaration
dhcpd: in your dhcpd.conf file for the network segment
dhcpd: to which interface eth1 is attached. "
dhcpd:
dhcpd: Not configured to listen on any interfaces!
```

```
option subnet-mask 255.255.255.0;
```

The `option subnet-mask` option defines a subnet mask, and overrides the `netmask` value in the `subnet` declaration. In simple cases, the subnet and netmask values are the same.

```
option routers 10.0.0.1;
```

The `option routers` option defines the default gateway for the subnet. This is required for systems to reach internal networks on a different subnet, as well as external networks.

```
range 10.0.0.5 10.0.0.15;
```

The `range` option specifies the pool of available IP addresses. Systems are assigned an address from the range of specified IP addresses.

For further information, refer to the `dhcpd.conf(5)` man page.

12.4.1. Host Configuration

Before making any changes, back up the existing `/etc/sysconfig/dhcpd` and `/etc/dhcp/dhcpd.conf` files.

Configuring a single system for multiple networks
The following `/etc/dhcp/dhcpd.conf` example creates two subnets, and configures an IP address for the same system, depending on which network it connects to:

```plaintext
default-lease-time 600;
max-lease-time 7200;
subnet 10.0.0.0 netmask 255.255.255.0 {
  option subnet-mask 255.255.255.0;
  option routers 10.0.0.1;
  range 10.0.0.5 10.0.0.15;
}
subnet 172.16.0.0 netmask 255.255.255.0 {
  option subnet-mask 255.255.255.0;
  option routers 172.16.0.1;
  range 172.16.0.5 172.16.0.16;
}
host example0 {
  hardware ethernet 00:1A:6B:6A:2E:0B;
  fixed-address 10.0.0.20;
}
host example1 {
  hardware ethernet 00:1A:6B:6A:2E:0B;
  fixed-address 172.16.0.20;
}
```

**host example0**

The `host` declaration defines specific parameters for a single system, such as an IP address. To configure specific parameters for multiple hosts, use multiple `host` declarations.

Most DHCP clients ignore the name in `host` declarations, and as such, this name can anything, as long as it is unique to other `host` declarations. To configure the same system for multiple networks, use a different name for each `host` declaration, otherwise the DHCP daemon fails to start. Systems are identified by the `hardware ethernet` option, not the name in the `host` declaration.

`hardware ethernet 00:1A:6B:6A:2E:0B;`

The `hardware ethernet` option identifies the system. To find this address, run the `ip link` command.

`fixed-address 10.0.0.20;`

The `fixed-address` option assigns a valid IP address to the system specified by the `hardware ethernet` option. This address must be outside the IP address pool specified with the `range` option.

If `option` statements do not end with a semicolon, the DHCP daemon fails to start, and an error such as the following is logged to `/var/log/messages`:

```
/etc/dhcp/dhcpd.conf line 20: semicolon expected.
dhcpd: }
dhcpd: };
dhcpd: /etc/dhcp/dhcpd.conf line 38: unexpected end of file
dhcpd: }
dhcpd: ^
dhcpd: Configuration file errors encountered -- exiting
```

### Configuring systems with multiple network interfaces

The following `host` declarations configure a single system, that has multiple network interfaces, so that each interface receives the same IP address. This configuration will not work if both network interfaces are connected to the same network at the same time:

```plaintext
host interface0 {
  hardware ethernet 00:1A:6B:6A:2E:0B;
  fixed-address 10.0.0.18;
}
host interface1 {
  hardware ethernet 00:1A:6B:6A:27:3A;
  fixed-address 10.0.0.18;
}
```

For this example, `interface0` is the first network interface, and `interface1` is the second interface. The different `hardware ethernet` options identify each interface.

If such a system connects to another network, add more `host` declarations, remembering to:

- assign a valid `fixed-address` for the network the host is connecting to.
- make the name in the `host` declaration unique.

When a name given in a `host` declaration is not unique, the DHCP daemon fails to start, and an error such as the following is logged to `/var/log/messages`:

```
dhcpd: /etc/dhcp/dhcpd.conf line 31: host interface0: already exists
dhcpd: }
dhcpd: ^
dhcpd: Configuration file errors encountered -- exiting
```

This error was caused by having multiple `host interface0` declarations defined in `/etc/dhcp/dhcpd.conf`. 
12.5. DHCP for IPv6 (DHCPv6)

The ISC DHCP includes support for IPv6 (DHCPv6) since the 4.x release with a DHCPv6 server, client and relay agent functionality. The server, client and relay agents support both IPv4 and IPv6. However, the client and the server can only manage one protocol at a time — for dual support they must be started separately for IPv4 and IPv6.

The DHCPv6 server configuration file can be found at `/etc/dhcp/dhcpd6.conf`.

The sample server configuration file can be found at `/usr/share/doc/dhcp-version/dhcpd6.conf.sample`.

To start the DHCPv6 service, use the following command:

```
systemctl start dhcpd6.service
```

A simple DHCPv6 server configuration file can look like this:

```
subnet6 2001:db8:0:1::/64 {
    range6 2001:db8:0:1::129 2001:db8:0:1::254;
    option dhcp6.name-servers fec0:0:0:1::1;
    option dhcp6.domain-search "domain.example";
}
```

12.6. Additional Resources

For additional information, refer to The DHCP Handbook; Ralph Droms and Ted Lemon; 2003 or the following resources.

12.6.1. Installed Documentation

- `dhcpd man page` — Describes how the DHCP daemon works.
- `dhcpd.conf man page` — Explains how to configure the DHCP configuration file; includes some examples.
- `dhcpd.leases man page` — Describes a persistent database of leases.
- `dhcp-options man page` — Explains the syntax for declaring DHCP options in `dhcpd.conf`; includes some examples.
- `dhcrelay man page` — Explains the DHCP Relay Agent and its configuration options.

Chapter 13. DNS Servers

13.1. Introduction to DNS

13.1.1. Nameserver Zones
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13.1.3. BIND as a Nameserver

13.2. BIND

13.2.1. Configuring the named Service
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13.2.5. Advanced Features of BIND
13.2.6. Common Mistakes to Avoid
13.2.7. Additional Resources

DNS (Domain Name System), also known as a nameserver, is a network system that associates hostnames with their respective IP addresses. For users, this has the advantage that they can refer to machines on the network by names that are usually easier to remember than the numerical network addresses. For system administrators, using the nameserver allows them to change the IP address for a host without ever affecting the name-based queries, or to decide which machines handle these queries.

13.1. Introduction to DNS

DNS is usually implemented using one or more centralized servers that are authoritative for certain domains. When a client host requests information from a nameserver, it usually connects to port 53. The nameserver then attempts to resolve the name requested. If it does not have an authoritative answer, or does not already have the answer cached from an earlier query, it queries other nameservers, called root nameservers, to determine which nameservers are authoritative for the name in question, and then queries them to get the requested name.

13.1.1. Nameserver Zones

In a DNS server such as BIND, all information is stored in basic data elements called resource records (RR). The resource record is usually a fully qualified domain name (FQDN) of a host, and is broken down into multiple sections organized into a tree-like hierarchy. This hierarchy consists of a main trunk, primary branches, secondary branches, and so on. The following is an example of a resource record:

```
bob.sales.example.com
```

Each level of the hierarchy is divided by a period (that is, .). In the example above, `com` defines the top-level domain,
example its subdomain, and sales the subdomain of example. In this case, bob identifies a resource record that is part of the sales.example.com domain. With the exception of the part furthest to the left (that is, bob), each of these sections is called a zone and defines a specific namespace.

Zones are defined on authoritative nameservers through the use of zone files, which contain definitions of the resource records in each zone. Zone files are stored on primary nameservers (also called master nameservers), where changes are made to the files, and secondary nameservers (also called slave nameservers), which receive zone definitions from the primary nameservers. Both primary and secondary nameservers are authoritative for the zone and look the same to clients. Depending on the configuration, any nameserver can also serve as a primary or secondary server for multiple zones at the same time.

13.1.2. Nameserver Types

There are two nameserver configuration types:

authoritative

Authoritative nameservers answer to resource records that are part of their zones only. This category includes both primary (master) and secondary (slave) nameservers.

recursive

Recursive nameservers offer resolution services, but they are not authoritative for any zone. Answers for all resolutions are cached in a memory for a fixed period of time, which is specified by the retrieved resource record.

Although a nameserver can be both authoritative and recursive at the same time, it is recommended not to combine the configuration types. To be able to perform their work, authoritative servers should be available to all clients all the time. On the other hand, since the recursive lookup takes far more time than authoritative responses, recursive servers should be available to a restricted number of clients only, otherwise they are prone to distributed denial of service (DDoS) attacks.

13.1.3. BIND as a Nameserver

BIND consists of a set of DNS-related programs. It contains a monolithic nameserver called named, an administration utility called rndc, and a debugging tool called dig. Refer to Chapter 9, Services and Daemons for more information on how to configure services in Fedora.

13.2. BIND

This chapter covers BIND (Berkeley Internet Name Domain), the DNS server included in Fedora. It focuses on the structure of its configuration files, and describes how to administer it both locally and remotely.

13.2.1. Configuring the named Service

When the named service is started, it reads the configuration from the files as described in Table 13.1, “The named service configuration files”.

Table 13.1. The named service configuration files

<table>
<thead>
<tr>
<th>Path</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>/etc/named.conf</td>
<td>The main configuration file.</td>
</tr>
<tr>
<td>/etc/named/</td>
<td>An auxiliary directory for configuration files that are included in the main configuration file.</td>
</tr>
</tbody>
</table>

The configuration file consists of a collection of statements with nested options surrounded by opening and closing curly brackets (that is, { and }). Note that when editing the file, you have to be careful not to make any syntax error, otherwise the named service will not start. A typical /etc/named.conf file is organized as follows:

```
statement-1 ["statement-1-name"] [statement-1-class] {
  option-1;
  option-2;
  option-N;
};
statement-2 ["statement-2-name"] [statement-2-class] {
  option-1;
  option-2;
  option-N;
};
statement-N ["statement-N-name"] [statement-N-class] {
  option-1;
  option-2;
  option-N;
};
```

Running BIND in a chroot environment

If you have installed the bind-chroot package, the BIND service will run in the /var/named/chroot environment. In that case, the initialization script will mount the above configuration files using the mount --bind command, so that you can manage the configuration outside this environment.

13.2.1.1. Installing BIND In A Chroot Environment

To install BIND to run in a chroot environment, issue the following commands as root:
To enable the named-chroot service, first check if the named service is running by issuing the following command:

```
[-]# systemctl status named
```

If it is running, it must be disabled.

To disable named, issue the following commands as root:

```
[-]# systemctl stop named
[-]# systemctl disable named
```

Then, to enable the named-chroot service, issue the following commands as root:

```
[-]# systemctl enable named-chroot
[-]# systemctl start named-chroot
```

To check the status of the named-chroot service, issue the following command as root:

```
[-]# systemctl status named-chroot
```

### 13.2.1.2. Common Statement Types

The following types of statements are commonly used in `/etc/named.conf`:

**acl**

The `acl` (Access Control List) statement allows you to define groups of hosts, so that they can be permitted or denied access to the nameserver. It takes the following form:

```plaintext
acl acl-name {
    match-element;
    ...;
};
```

The `acl-name` statement name is the name of the access control list, and the `match-element` option is usually an individual IP address (such as `10.0.1.1`) or a CIDR network notation (for example, `10.0.1.0/24`). For a list of already defined keywords, see Table 13.2, “Predefined access control lists”.

<table>
<thead>
<tr>
<th>Keyword</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>any</td>
<td>Matches every IP address.</td>
</tr>
<tr>
<td>localhost</td>
<td>Matches any IP address that is in use by the local system.</td>
</tr>
<tr>
<td>localnets</td>
<td>Matches any IP address on any network to which the local system is connected.</td>
</tr>
<tr>
<td>none</td>
<td>Does not match any IP address.</td>
</tr>
</tbody>
</table>

The `acl` statement can be especially useful with conjunction with other statements such as `options`. Example 13.1, “Using acl in conjunction with options” defines two access control lists, `black-hats` and `red-hats`, and adds `black-hats` on the blacklist while granting `red-hats` a normal access.

**Example 13.1. Using acl in conjunction with options**

```plaintext
acl black-hats {
    10.0.2.0/24;
    192.168.0.0/24;
    1234:5678::9abc/24;
};

acl red-hats {
    10.0.1.0/24;
};

options {
    blackhole { black-hats; };
    allow-query { red-hats; };
    allow-query-cache { red-hats; };
};
```

**include**

The `include` statement allows you to include files in the `/etc/named.conf`, so that potentially sensitive data can be placed in a separate file with restricted permissions. It takes the following form:

```plaintext
include "file-name"
```

The `file-name` statement name is an absolute path to a file.

**Example 13.2. Including a file to /etc/named.conf**

```plaintext
include "/etc/named.rfc1912.zones";
```
The `options` statement allows you to define global server configuration options as well as to set defaults for other statements. It can be used to specify the location of the `named` working directory, the types of queries allowed, and much more. It takes the following form:

```plaintext
options {
    option;
    ...
};
```

For a list of frequently used `option` directives, see Table 13.3, "Commonly used options" below.

### Table 13.3. Commonly used options

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>allow-query</code></td>
<td>Specifies which hosts are allowed to query the nameserver for authoritative resource records. It accepts an access control lists, a collection of IP addresses, or networks in the CIDR notation. All hosts are allowed by default.</td>
</tr>
<tr>
<td><code>allow-query-cache</code></td>
<td>Specifies which hosts are allowed to query the nameserver for non-authoritative data such as recursive queries. Only <code>localhost</code> and <code>localnets</code> are allowed by default.</td>
</tr>
<tr>
<td><code>blackhole</code></td>
<td>Specifies which hosts are not allowed to query the nameserver. This option should be used when particular host or network floods the server with requests. The default option is <code>none</code>.</td>
</tr>
<tr>
<td><code>directory</code></td>
<td>Specifies a working directory for the <code>named</code> service. The default option is <code>/var/named/</code>.</td>
</tr>
<tr>
<td><code>dnssec-enable</code></td>
<td>Specifies whether to return DNSSEC related resource records. The default option is <code>yes</code>.</td>
</tr>
<tr>
<td><code>dnssec-validation</code></td>
<td>Specifies whether to prove that resource records are authentic via DNSSEC. The default option is <code>yes</code>.</td>
</tr>
<tr>
<td><code>forwards</code></td>
<td>Specifies a list of valid IP addresses for nameservers to which the requests should be forwarded for resolution.</td>
</tr>
<tr>
<td><code>forward</code></td>
<td>Specifies the behavior of the <code>forwards</code> directive. It accepts the following options:</td>
</tr>
<tr>
<td></td>
<td>» <code>first</code> — The server will query the nameservers listed in the <code>forwards</code> directive before attempting to resolve the name on its own.</td>
</tr>
<tr>
<td></td>
<td>» <code>only</code> — When unable to query the nameservers listed in the <code>forwards</code> directive, the server will not attempt to resolve the name on its own.</td>
</tr>
<tr>
<td><code>listen-on</code></td>
<td>Specifies the IPv4 network interface on which to listen for queries. On a DNS server that also acts as a gateway, you can use this option to answer queries originating from a single network only. All IPv4 interfaces are used by default.</td>
</tr>
<tr>
<td><code>listen-on-v6</code></td>
<td>Specifies the IPv6 network interface on which to listen for queries. On a DNS server that also acts as a gateway, you can use this option to answer queries originating from a single network only. All IPv6 interfaces are used by default.</td>
</tr>
<tr>
<td><code>max-cache-size</code></td>
<td>Specifies the maximum amount of memory to be used for server caches. When the limit is reached, the server causes records to expire prematurely so that the limit is not exceeded. In a server with multiple views, the limit applies separately to the cache of each view. The default option is <code>32M</code>.</td>
</tr>
<tr>
<td><code>notify</code></td>
<td>Specifies whether to notify the secondary nameservers when a zone is updated. It accepts the following options:</td>
</tr>
<tr>
<td></td>
<td>» <code>yes</code> — The server will notify all secondary nameservers.</td>
</tr>
<tr>
<td></td>
<td>» <code>no</code> — The server will <code>not</code> notify any secondary nameserver.</td>
</tr>
<tr>
<td></td>
<td>» <code>master-only</code> — The server will notify primary server for the zone only.</td>
</tr>
<tr>
<td></td>
<td>» <code>explicit</code> — The server will notify only the secondary servers that are specified in the <code>also-notify</code> list within a zone statement.</td>
</tr>
<tr>
<td><code>pid-file</code></td>
<td>Specifies the location of the process ID file created by the <code>named</code> service.</td>
</tr>
<tr>
<td><code>recursion</code></td>
<td>Specifies whether to act as a recursive server. The default option is <code>yes</code>.</td>
</tr>
<tr>
<td><code>statistics-file</code></td>
<td>Specifies an alternate location for statistics files. The <code>/var/named/named.stats</code> file is used by default.</td>
</tr>
</tbody>
</table>

---

**Restrict recursive servers to selected clients only**

To prevent distributed denial of service (DDoS) attacks, it is recommended that you use the `allow-query-cache` option to restrict recursive DNS services for a particular subset of clients only.

Refer to the *BIND 9 Administrator Reference Manual* referenced in Section 13.2.7.1, "Installed Documentation", and the `named.conf` manual page for a complete list of available options.
Example 13.3. Using the options statement

```plaintext
options {
  allow-query       { localhost;   ;
  listen-on port    53 [ 127.0.0.1; ];
  listen-on-v6 port 53 [ :1; ];
  max-cache-size   256M;
  directory        "/var/named";
  statistics-file   "/var/named/data/named_stats.txt";
  recursion        yes;
  dnssec-enable    yes;
  dnssec-validation yes;
};
```

The `zone` statement allows you to define the characteristics of a zone, such as the location of its configuration file and zone-specific options, and can be used to override the global `options` statements. It takes the following form:

```plaintext
zone zone-name [zone-class] {
  option;
  ...
};
```

The `zone-name` attribute is the name of the zone, `zone-class` is the optional class of the zone, and `option` is a zone statement option as described in Table 13.4, "Commonly used options".

The `zone-name` attribute is particularly important, as it is the default value assigned for the `$ORIGIN` directive used within the corresponding zone file located in the `/var/named/` directory. The `named` daemon appends the name of the zone to any non-fully qualified domain name listed in the zone file. For example, if a `zone` statement defines the namespace for `example.com`, use `example.com` as the `zone-name` so that it is placed at the end of hostnames within the `example.com` zone file.

For more information about zone files, refer to Section 13.2.2, "Editing Zone Files".

Table 13.4. Commonly used options

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>allow-query</td>
<td>Specifies which clients are allowed to request information about this zone. This option overrides global <code>allow-query</code> option. All query requests are allowed by default.</td>
</tr>
<tr>
<td>allow-transfer</td>
<td>Specifies which secondary servers are allowed to request a transfer of the zone's information. All transfer requests are allowed by default.</td>
</tr>
<tr>
<td>allow-update</td>
<td>Specifies which hosts are allowed to dynamically update information in their zone. The default option is to deny all dynamic update requests. Note that you should be careful when allowing hosts to update information about their zone. Do not set IP addresses in this option unless the server is in the trusted network. Instead, use TSIG key as described in Section 13.2.5.3, &quot;Transaction SIGNatures (TSIG)&quot;.</td>
</tr>
<tr>
<td>file</td>
<td>Specifies the name of the file in the <code>named</code> working directory that contains the zone's configuration data.</td>
</tr>
<tr>
<td>masters</td>
<td>Specifies from which IP addresses to request authoritative zone information. This option is used only if the zone is defined as <code>type slave</code>.</td>
</tr>
<tr>
<td>notify</td>
<td>Specifies whether to notify the secondary nameservers when a zone is updated. It accepts the following options:</td>
</tr>
<tr>
<td></td>
<td>» yes — The server will notify all secondary nameservers.</td>
</tr>
<tr>
<td></td>
<td>» no — The server will not notify any secondary nameserver.</td>
</tr>
<tr>
<td></td>
<td>» master-only — The server will notify primary server for the zone only.</td>
</tr>
<tr>
<td></td>
<td>» explicit — The server will notify only the secondary servers that are specified in the <code>also-notify</code> list within a zone statement.</td>
</tr>
<tr>
<td>type</td>
<td>Specifies the zone type. It accepts the following options:</td>
</tr>
<tr>
<td></td>
<td>» delegation-only — Enforces the delegation status of infrastructure zones such as COM, NET, or ORG. Any answer that is received without an explicit or implicit delegation is treated as <code>NXDOMAIN</code>. This option is only applicable in TLDs or root zone files used in recursive or caching implementations.</td>
</tr>
<tr>
<td></td>
<td>» forward — Forwards all requests for information about this zone to other nameservers.</td>
</tr>
<tr>
<td></td>
<td>» hint — A special type of zone used to point to the root nameservers which resolve queries when a zone is not otherwise known. No configuration beyond the default is necessary with a <code>hint</code> zone.</td>
</tr>
<tr>
<td></td>
<td>» master — Designates the nameserver as authoritative for this zone. A zone should be set as the <code>master</code> if the zone's configuration files reside on the system.</td>
</tr>
<tr>
<td></td>
<td>» slave — Designates the nameserver as a slave server for this zone. Master server is specified in <code>masters</code> directive.</td>
</tr>
</tbody>
</table>
Most changes to the `/etc/named.conf` file of a primary or secondary nameserver involve adding, modifying, or deleting `zone` statements, and only a small subset of `zone` statement options is usually needed for a nameserver to work efficiently.

In Example 13.4, "A zone statement for a primary nameserver", the zone is identified as `example.com`, the type is set to `master`, and the `named` service is instructed to read the `/var/named/example.com.zone` file. It also allows only a secondary nameserver (192.168.0.2) to transfer the zone.

```
Example 13.4. A zone statement for a primary nameserver

zone "example.com" IN {
    type master;
    file "example.com.zone";
    allow-transfer { 192.168.0.2; };
};
```

A secondary server's `zone` statement is slightly different. The type is set to `slave`, and the `masters` directive is telling `named` the IP address of the master server.

In Example 13.5, "A zone statement for a secondary nameserver", the `named` service is configured to query the primary server at the 192.168.0.1 IP address for information about the `example.com` zone. The received information is then saved to the `/var/named/slaves/example.com.zone` file. Note that you have to put all slave zones to `/var/named/slaves` directory, otherwise the service will fail to transfer the zone.

```
Example 13.5. A zone statement for a secondary nameserver

zone "example.com" {
    type slave;
    file "slaves/example.com.zone";
    masters { 192.168.0.1; };
};
```

### 13.2.1.3. Other Statement Types

The following types of statements are less commonly used in `/etc/named.conf`:

- **controls**
  
  The `controls` statement allows you to configure various security requirements necessary to use the `rndc` command to administer the `named` service.

  Refer to Section 13.2.3, "Using the rndc Utility" for more information on the `rndc` utility and its usage.

- **key**
  
  The `key` statement allows you to define a particular key by name. Keys are used to authenticate various actions, such as secure updates or the use of the `rndc` command. Two options are used with `key`:
  
  - `algorithm algorithm-name` — The type of algorithm to be used (for example, `hmac-md5`).
  - `secret "key-value"` — The encrypted key.

  Refer to Section 13.2.3, "Using the rndc Utility" for more information on the `rndc` utility and its usage.

- **logging**
  
  The `logging` statement allows you to use multiple types of logs, so called channels. By using the `channel` option within the statement, you can construct a customized type of log with its own file name (`file`), size limit (`size`), versioning (`version`), and level of importance (`severity`). Once a customized channel is defined, a `category` option is used to categorize the channel and begin logging when the `named` service is restarted.

  By default, `named` sends standard messages to the `rsyslog` daemon, which places them in `/var/log/messages`. Several standard channels are built into BIND with various severity levels, such as `default_syslog` (which handles informational logging messages) and `default_debug` (which specifically handles debugging messages). A default category, called `default`, uses the built-in channels to do normal logging without any special configuration.

  Customizing the logging process can be a very detailed process and is beyond the scope of this chapter. For information on creating custom BIND logs, refer to the `BIND 9 Administrator Reference Manual` referenced in Section 13.2.7.1, “Installed Documentation”.

- **server**
  
  The `server` statement allows you to specify options that affect how the `named` service should respond to remote nameservers, especially with regard to notifications and zone transfers.

  The `transfer-format` option controls the number of resource records that are sent with each message. It can be either `one-answer` (only one resource record), or `many-answers` (multiple resource records). Note that while the `many-answers` option is more efficient, it is not supported by older versions of BIND.

- **trusted-keys**
  
  The `trusted-keys` statement allows you to specify assorted public keys used for secure DNS (DNSSEC). Refer to
Section 13.2.5.4, "DNS Security Extensions (DNSSEC)" for more information on this topic.

view
The view statement allows you to create special views depending upon which network the host querying the nameserver is on. This allows some hosts to receive one answer regarding a zone while other hosts receive totally different information. Alternatively, certain zones may only be made available to particular trusted hosts while non-trusted hosts can only make queries for other zones.

Multiple views can be used as long as their names are unique. The match-clients option allows you to specify the IP addresses that apply to a particular view. If the options statement is used within a view, it overrides the already configured global options. Finally, most view statements contain multiple zone statements that apply to the match-clients list.

Note that the order in which the view statements are listed is important, as the first statement that matches a particular client's IP address is used. For more information on this topic, refer to Section 13.2.5.1, "Multiple Views".

13.2.1.4. Comment Tags
Additionally to statements, the /etc/named.conf file can also contain comments. Comments are ignored by the named service, but can prove useful when providing additional information to a user. The following are valid comment tags:

//
Any text after the // characters to the end of the line is considered a comment. For example:

```
notify yes;  // notify all secondary nameservers
```

#
Any text after the # character to the end of the line is considered a comment. For example:

```
notify yes;  # notify all secondary nameservers
```

/\* and */
Any block of text enclosed in /* and */ is considered a comment. For example:

```
notify yes;  /* notify all secondary nameservers */
```

13.2.2. Editing Zone Files
As outlined in Section 13.1.1, "Nameserver Zones", zone files contain information about a namespace. They are stored in the named working directory located in /var/named/ by default, and each zone file is named according to the file option in the zone statement, usually in a way that relates to the domain in question and identifies the file as containing zone data, such as example.com.zone.

Table 13.5. The named service zone files

<table>
<thead>
<tr>
<th>Path</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>/var/named/</td>
<td>The working directory for the named service. The nameserver is not allowed to write to this directory.</td>
</tr>
<tr>
<td>/var/named/slaves/</td>
<td>The directory for secondary zones. This directory is writable by the named service.</td>
</tr>
<tr>
<td>/var/named/dynamic/</td>
<td>The directory for other files, such as dynamic DNS (DDNS) zones or managed DNSSEC keys. This directory is writable by the named service.</td>
</tr>
<tr>
<td>/var/named/data/</td>
<td>The directory for various statistics and debugging files. This directory is writable by the named service.</td>
</tr>
</tbody>
</table>

A zone file consists of directives and resource records. Directives tell the nameserver to perform tasks or apply special settings to the zone, resource records define the parameters of the zone and assign identities to individual hosts. While the directives are optional, the resource records are required in order to provide name service to a zone.

All directives and resource records should be entered on individual lines.

13.2.2.1. Common Directives
Directives begin with the dollar sign character (that is, $) followed by the name of the directive, and usually appear at the top of the file. The following directives are commonly used in zone files:

$INCLUDE
The $INCLUDE directive allows you to include another file at the place where it appears, so that other zone settings can be stored in a separate zone file.

Example 13.6. Using the $INCLUDE directive

```
$INCLUDE /var/named/penguin.example.com
```
The $ORIGIN directive allows you to append the domain name to unqualified records, such as those with the hostname only. Note that the use of this directive is not necessary if the zone is specified in `/etc/named.conf`, since the zone name is used by default.

In Example 13.7, “Using the $ORIGIN directive”, any names used in resource records that do not end in a trailing period (that is, the . character) are appended with `example.com`.

Example 13.7. Using the $ORIGIN directive

```
$ORIGIN example.com.
```

The $TTL directive allows you to set the default Time to Live (TTL) value for the zone, that is, how long is a zone record valid. Each resource record can contain its own TTL value, which overrides this directive.

Increasing this value allows remote nameservers to cache the zone information for a longer period of time, reducing the number of queries for the zone and lengthening the amount of time required to proliferate resource record changes.

Example 13.8. Using the $TTL directive

```
$TTL 1D
```

### 13.2.2.2. Common Resource Records

The following resource records are commonly used in zone files:

#### A

The Address record specifies an IP address to be assigned to a name. It takes the following form:

```
hostname IN A IP-address
```

If the `hostname` value is omitted, the record will point to the last specified `hostname`.

In Example 13.9, “Using the A resource record”, the requests for `server1.example.com` are pointed to `10.0.1.3` or `10.0.1.5`.

Example 13.9. Using the A resource record

```
server1  IN  A  10.0.1.3
IN  A  10.0.1.5
```

#### CNAME

The Canonical Name record maps one name to another. Because of this, this type of record is sometimes referred to as an alias record. It takes the following form:

```
alias-name IN CNAME real-name
```

CNAME records are most commonly used to point to services that use a common naming scheme, such as `www` for Web servers. However, there are multiple restrictions for their usage:

- CNAME records should not point to other CNAME records. This is mainly to avoid possible infinite loops.
- CNAME records should not contain other resource record types (such as A, NS, MX, etc.). The only exception are DNSSEC related records (that is, RRSIG, NSEC, etc.) when the zone is signed.
- Other resource record that point to the fully qualified domain name (FQDN) of a host (that is, NS, MX, PTR) should not point to a CNAME record.

In Example 13.10, “Using the CNAME resource record”, the A record binds a hostname to an IP address, while the CNAME record points the commonly used `www` hostname to it.

Example 13.10. Using the CNAME resource record

```
server1 IN A 10.0.1.5
www IN CNAME server1
```

#### MX

The Mail Exchange record specifies where the mail sent to a particular namespace controlled by this zone should go. It takes the following form:

```
IN MX preference-value email-server-name
```

The `email-server-name` is a fully qualified domain name (FQDN). The `preference-value` allows numerical ranking of the email servers for a namespace, giving preference to some email systems over others. The MX resource
record with the lowest preference-value is preferred over the others. However, multiple email servers can possess the same value to distribute email traffic evenly among them. In Example 13.11, “Using the MX resource record”, the first mail.example.com email server is preferred to the mail2.example.com email server when receiving email destined for the example.com domain.

Example 13.11. Using the MX resource record

<table>
<thead>
<tr>
<th>Domain</th>
<th>Class</th>
<th>Type</th>
<th>Preference Value</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>example.com</td>
<td>MX</td>
<td>10</td>
<td></td>
<td>mail.example.com</td>
</tr>
<tr>
<td></td>
<td>MX</td>
<td>20</td>
<td></td>
<td>mail2.example.com</td>
</tr>
</tbody>
</table>

NS

The Nameserver record announces authoritative nameservers for a particular zone. It takes the following form:

```
IN NS nameserver-name
```

The nameserver-name should be a fully qualified domain name (FQDN). Note that when two nameservers are listed as authoritative for the domain, it is not important whether these nameservers are secondary nameservers, or if one of them is a primary server. They are both still considered authoritative.

Example 13.12. Using the NS resource record

<table>
<thead>
<tr>
<th>Domain</th>
<th>Class</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>example.com</td>
<td>NS</td>
<td>dns1.example.com</td>
</tr>
<tr>
<td></td>
<td>NS</td>
<td>dns2.example.com</td>
</tr>
</tbody>
</table>

PTR

The Pointer record points to another part of the namespace. It takes the following form:

```
last-IP-digit IN PTR FQDN-of-system
```

The last-IP-digit directive is the last number in an IP address, and the FQDN-of-system is a fully qualified domain name (FQDN).

PTR records are primarily used for reverse name resolution, as they point IP addresses back to a particular name. Refer to Section 13.2.2.4.2, “A Reverse Name Resolution Zone File” for more examples of PTR records in use.

SOA

The Start of Authority record announces important authoritative information about a namespace to the nameserver. Located after the directives, it is the first resource record in a zone file. It takes the following form:

```
@ IN SOA primary-name-server hostmaster-email {
  serial-number
  time-to-refresh
  time-to-retry
  time-to-expire
  minimum-TTL
}
```

The directives are as follows:

- The @ symbol places the SORIGIN directive (or the zone's name if the SORIGIN directive is not set) as the namespace being defined by this SOA resource record.
- The primary-name-server directive is the hostname of the primary nameserver that is authoritative for this domain.
- The hostmaster-email directive is the email of the person to contact about the namespace.
- The serial-number directive is a numerical value incremented every time the zone file is altered to indicate it is time for the named service to reload the zone.
- The time-to-refresh directive is the numerical value secondary nameservers use to determine how long to wait before asking the primary nameserver if any changes have been made to the zone.
- The time-to-retry directive is a numerical value used by secondary nameservers to determine the length of time to wait before issuing a refresh request in the event that the primary nameserver is not answering. If the primary server has not replied to a refresh request before the amount of time specified in the time-to-expire directive elapses, the secondary servers stop responding as an authority for requests concerning that namespace.
- In BIND 4 and 8, the minimum-TTL directive is the amount of time other nameservers cache the zone's information. In BIND 9, it defines how long negative answers are cached for. Caching of negative answers can be set to a maximum of 3 hours (that is, 3H).

When configuring BIND, all times are specified in seconds. However, it is possible to use abbreviations when specifying units of time other than seconds, such as minutes (M), hours (H), days (D), and weeks (W). Table 13.6, “Seconds compared to other time units” shows an amount of time in seconds and the equivalent time in another format.
### Table 13.6. Seconds compared to other time units

<table>
<thead>
<tr>
<th>Seconds</th>
<th>Other Time Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>1M</td>
</tr>
<tr>
<td>3600</td>
<td>1H</td>
</tr>
<tr>
<td>10800</td>
<td>3H</td>
</tr>
<tr>
<td>21600</td>
<td>6H</td>
</tr>
<tr>
<td>43200</td>
<td>12H</td>
</tr>
<tr>
<td>86400</td>
<td>1D</td>
</tr>
<tr>
<td>360000</td>
<td>12H</td>
</tr>
<tr>
<td>10800</td>
<td>3H</td>
</tr>
<tr>
<td>108000</td>
<td>1W</td>
</tr>
<tr>
<td>259200</td>
<td>3D</td>
</tr>
<tr>
<td>3153600</td>
<td>365D</td>
</tr>
</tbody>
</table>

---

**Example 13.13. Using the SOA resource record**

```plaintext
@ IN SOA dns1.example.com. hostmaster.example.com. ( 2001062501 ; serial 21600 ; refresh after 6 hours 3600 ; retry after 1 hour 604800 ; expire after 1 week 86400 ) ; minimum TTL of 1 day
```

---

**13.2.2.3. Comment Tags**

Additionally to resource records and directives, a zone file can also contain comments. Comments are ignored by the named service, but can prove useful when providing additional information to the user. Any text after the semicolon character (that is, ;) to the end of the line is considered a comment. For example:

```plaintext
604800 ; expire after 1 week
```

---

**13.2.2.4. Example Usage**

The following examples show the basic usage of zone files.

#### 13.2.2.4.1. A Simple Zone File


```plaintext
$ORIGIN example.com.
$TTL 86400

@ IN SOA dns1.example.com. hostmaster.example.com. ( 2001062501 ; serial 21600 ; refresh after 6 hours 3600 ; retry after 1 hour 604800 ; expire after 1 week 86400 ) ; minimum TTL of 1 day
;
;
IN NS dns1.example.com.
IN NS dns2.example.com.
dns1 IN A 10.0.1.1
IN AAAA aaaa:bbbb::1
dns2 IN A 10.0.1.2
IN AAA aaaa:bbbb::2
;
@
IN MX 10 mail.example.com.
IN MX 20 mail2.example.com.
mail IN A 10.0.1.5
IN AAA aaaa:bbbb::5
mail2 IN A 10.0.1.6
IN AAA aaaa:bbbb::6
;
; This sample zone file illustrates sharing the same IP addresses
; for multiple services:
;
services IN A 10.0.1.10
IN AAA aaaa:bbbb::10
IN A 10.0.1.11
IN AAA aaaa:bbbb::11

ftp IN CNAME services.example.com.
www IN CNAME services.example.com.
;
```

In this example, the authoritative nameservers are set as `dns1.example.com` and `dns2.example.com`, and are tied to the **10.0.1.1** and **10.0.1.2** IP addresses respectively using the **A** record.
The email servers configured with the MX records point to mail and mail2 via A records. Since these names do not end in a trailing period (that is, the . character), the $ORIGIN domain is placed after them, expanding them to mail.example.com and mail2.example.com.

Services available at the standard names, such as www.example.com (WWW), are pointed at the appropriate servers using the CNAME record.

This zone file would be called into service with a zone statement in the /etc/named.conf similar to the following:

```plaintext
zone "example.com" IN {
    type master;
    file "example.com.zone";
    allow-update { none; };
};
```

### 13.2.2.4.2. A Reverse Name Resolution Zone File

A reverse name resolution zone file is used to translate an IP address in a particular namespace into a fully qualified domain name (FQDN). It looks very similar to a standard zone file, except that the PTR resource records are used to link the IP addresses to a fully qualified domain name as shown in Example 13.15, “A reverse name resolution zone file”.

**Example 13.15. A reverse name resolution zone file**

```plaintext
$ORIGIN 1.0.10.in-addr.arpa.
$TTL 86400
@     IN  SOA  dns1.example.com.  hostmaster.example.com. (2001062501 ; serial
21600 ; refresh after 6 hours
3600 ; retry after 1 hour
604800 ; expire after 1 week
86400 ) ; minimum TTL of 1 day
;
@     IN  NS   dns1.example.com.
;
1     IN  PTR  dns1.example.com.
2     IN  PTR  dns2.example.com.
;
5     IN  PTR  server1.example.com.
6     IN  PTR  server2.example.com.
;
3     IN  PTR  ftp1.example.com.
4     IN  PTR  ftp2.example.com.
```

In this example, IP addresses 10.0.1.1 through 10.0.1.6 are pointed to the corresponding fully qualified domain name.

This zone file would be called into service with a zone statement in the /etc/named.conf file similar to the following:

```plaintext
zone "1.0.10.in-addr.arpa" IN {
    type master;
    file "example.com.rr.zone";
    allow-update { none; };
};
```

There is very little difference between this example and a standard zone statement, except for the zone name. Note that a reverse name resolution zone requires the first three blocks of the IP address reversed followed by .in-addr.arpa. This allows the single block of IP numbers used in the reverse name resolution zone file to be associated with the zone.

### 13.2.3. Using the rndc Utility

The **rndc** utility is a command line tool that allows you to administer the named service, both locally and from a remote machine. Its usage is as follows:

```
rnc [option...] command [command-option]
```

#### 13.2.3.1. Configuring the Utility

To prevent unauthorized access to the service, named must be configured to listen on the selected port (that is, 953 by default), and an identical key must be used by both the service and the rndc utility.

<table>
<thead>
<tr>
<th>Path</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>/etc/named.conf</td>
<td>The default configuration file for the named service.</td>
</tr>
<tr>
<td>/etc/rndc.conf</td>
<td>The default configuration file for the rndc utility.</td>
</tr>
<tr>
<td>/etc/rndc.key</td>
<td>The default key location.</td>
</tr>
</tbody>
</table>

The rndc configuration is located in /etc/rndc.conf. If the file does not exist, the utility will use the key located in /etc/rndc.key, which was generated automatically during the installation process using the `rndc-confgen -a` command.

The named service is configured using the controls statement in the /etc/named.conf configuration file as described in Section 13.2.1.3, “Other Statement Types”. Unless this statement is present, only the connections from the loopback address (that is, 127.0.0.1) will be allowed, and the key located in /etc/rndc.key will be used.
Set the correct permissions

To prevent unprivileged users from sending control commands to the service, make sure only root is allowed to read the /etc/rndc.key file:

```
$ chmod o-rwx /etc/rndc.key
```

13.2.3.2. Checking the Service Status

To check the current status of the named service, use the following command:

```
$ rndc status
version: 9.7.0-P2-RedHat-9.7.0-5.P2.el6
CPUs found: 1
worker threads: 1
number of zones: 16
debu level: 0
xfers running: 0
xfers deferred: 0
soa queries in progress: 0
query logging is OFF
recursive clients: 0/0/1000
tcp clients: 0/100
server is up and running
```

13.2.3.3. Reloading the Configuration and Zones

To reload both the configuration file and zones, type the following at a shell prompt:

```
$ rndc reload
server reload successful
```

This will reload the zones while keeping all previously cached responses, so that you can make changes to the zone files without losing all stored name resolutions.

To reload a single zone, specify its name after the `reload` command, for example:

```
$ rndc reload localhost
zone reload up-to-date
```

Finally, to reload the configuration file and newly added zones only, type:

```
$ rndc reconfig
```

13.2.3.4. Updating Zone Keys

To update the DNSSEC keys and sign the zone, use the `sign` command. For example:

```
$ rndc sign localhost
```

Note that to sign a zone with the above command, the `auto-dnssec` option has to be set to `maintain` in the zone statement. For instance:

```
zone "localhost" IN {
    type master;
    file "named.localhost";
    allow-update { none; };
    auto-dnssec maintain;
};
```

13.2.3.5. Enabling the DNSSEC Validation

To enable the DNSSEC validation, type the following at a shell prompt:

```
$ rndc validation on
```

Similarly, to disable this option, type:
13.2.3.6. Enabling the Query Logging
To enable (or disable in case it is currently enabled) the query logging, run the following command:

```bash
rndc querylog
```

To check the current setting, use the `status` command as described in Section 13.2.3.2, “Checking the Service Status”.

13.2.4. Using the dig Utility
The `dig` utility is a command line tool that allows you to perform DNS lookups and debug a nameserver configuration. Its typical usage is as follows:

```bash
dig [@server] [option...] name type
```

Refer to Section 13.2.2.2, “Common Resource Records” for a list of common types.

13.2.4.1. Looking Up a Nameserver
To look up a nameserver for a particular domain, use the command in the following form:

```bash
dig name NS
```

Example 13.16. A sample nameserver lookup

```
$ dig example.com NS
; <<>> DiG 9.7.1-P2-RedHat-9.7.1-2.P2.fc13 <<>> example.com NS
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 57883
;; flags: qr rd ra; QUERY: 1, ANSWER: 2, AUTHORITY: 0, ADDITIONAL: 0
;; QUESTION SECTION:
;example.com.       IN      NS
;; ANSWER SECTION:
example.com.     99374   IN      NS      a.iana-servers.net.
example.com.     99374   IN      NS      b.iana-servers.net.
;; Query time: 1 msec
;; SERVER: 10.34.255.7#53(10.34.255.7)
;; WHEN: Wed Aug 18 18:04:06 2010
;; MSG SIZE  rcvd: 77
```

13.2.4.2. Looking Up an IP Address
To look up an IP address assigned to a particular domain, use the command in the following form:

```bash
dig name A
```

Example 13.17. A sample IP address lookup

```
$ dig example.com A
; <<>> DiG 9.7.1-P2-RedHat-9.7.1-2.P2.fc13 <<>> example.com A
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 4849
;; flags: qr rd ra; QUERY: 1, ANSWER: 1, AUTHORITY: 2, ADDITIONAL: 0
;; QUESTION SECTION:
;example.com.       IN      A
;; ANSWER SECTION:
example.com.     155606  IN      A       192.0.32.10
;; AUTHORITY SECTION:
example.com.     99175   IN      NS      a.iana-servers.net.
example.com.     99175   IN      NS      b.iana-servers.net.
;; Query time: 1 msec
;; SERVER: 10.34.255.7#53(10.34.255.7)
;; WHEN: Wed Aug 18 18:04:46 2010
;; MSG SIZE  rcvd: 93
```
13.2.4.3. Looking Up a Hostname

To look up a hostname for a particular IP address, use the command in the following form:

```
dig -x address
```

In Example 13.18, “A sample hostname lookup”, the `dig` utility is used to display the hostname assigned to 192.0.32.10.

**Example 13.18. A sample hostname lookup**

```
[-] $ dig -x 192.0.32.10
;; Got answer:
;; QUESTION SECTION:
;10.32.0.192.in-addr.arpa.      IN      PTR
;; ANSWER SECTION:
10.32.0.192.in-addr.arpa. 21600 IN PTR www.example.com.
;; AUTHORITY SECTION:
32.0.192.in-addr.arpa. 21600 IN NS b.iana-servers.org.
32.0.192.in-addr.arpa. 21600 IN NS c.iana-servers.net.
32.0.192.in-addr.arpa. 21600 IN NS d.iana-servers.net.
32.0.192.in-addr.arpa. 21600 IN NS ns.icann.org.
32.0.192.in-addr.arpa. 21600 IN NS a.iana-servers.net.
;; ADDITIONAL SECTION:
a.iana-servers.net. 13688 IN A 192.0.34.43
b.iana-servers.org. 5844 IN A 193.0.0.236
b.iana-servers.org. 5844 IN AAAA 2001:610:240:2::c100:ec
c.iana-servers.net. 12173 IN A 139.91.1.10
c.iana-servers.net. 12173 IN AAAA 2001:648:2c30::1:10
ns.icann.org. 12884 IN A 192.0.34.126
```

13.2.5. Advanced Features of BIND

Most BIND implementations only use the `named` service to provide name resolution services or to act as an authority for a particular domain. However, BIND version 9 has a number of advanced features that allow for a more secure and efficient DNS service.

**Make sure the feature is supported**

Before attempting to use advanced features like DNSSEC, TSIG, or IXFR, make sure that the particular feature is supported by all nameservers in the network environment, especially when you use older versions of BIND or non-BIND servers.

All of the features mentioned are discussed in greater detail in the BIND 9 Administrator Reference Manual referenced in Section 13.2.7.1, “Installed Documentation”.

13.2.5.1. Multiple Views

Optionally, different information can be presented to a client depending on the network a request originates from. This is primarily used to deny sensitive DNS entries from clients outside of the local network, while allowing queries from clients inside the local network.

To configure multiple views, add the `view` statement to the `/etc/named.conf` configuration file. Use the `match-clients` option to match IP addresses or entire networks and give them special options and zone data.

13.2.5.2. Incremental Zone Transfers (IXFR)

Incremental Zone Transfers (IXFR) allow a secondary nameserver to only download the updated portions of a zone modified on a primary nameserver. Compared to the standard transfer process, this makes the notification and update process much more efficient.

Note that IXFR is only available when using dynamic updating to make changes to master zone records. If manually editing zone files to make changes, Automatic Zone Transfer (AXFR) is used.

13.2.5.3. Transaction SIGnatures (TSIG)

Transaction SIGnatures (TSIG) ensure that a shared secret key exists on both primary and secondary nameserver before allowing a transfer. This strengthens the standard IP address-based method of transfer authorization, since attackers would not only need to have access to the IP address to transfer the zone, but they would also need to know the secret key.
Since version 9, BIND also supports TKEY, which is another shared secret key method of authorizing zone transfers.

**Secure the transfer**

When communicating over an insecure network, do not rely on IP address-based authentication only.

13.2.5.4. DNS Security Extensions (DNSSEC)

Domain Name System Security Extensions (DNSSEC) provide origin authentication of DNS data, authenticated denial of existence, and data integrity. When a particular domain is marked as secure, the SERVFAIL response is returned for each resource record that fails the validation.

Note that to debug a DNSSEC-signed domain or a DNSSEC-aware resolver, you can use the dig utility as described in Section 13.2.4, “Using the dig Utility”. Useful options are +dnssec (requests DNSSEC-related resource records by setting the DNSSEC OK bit), +cd (tells recursive nameserver not to validate the response), and +bufsize=512 (changes the packet size to 512B to get through some firewalls).

13.2.5.5. Internet Protocol version 6 (IPv6)

Internet Protocol version 6 (IPv6) is supported through the use of AAAA resource records, and the listen-on-v6 directive as described in Table 13.3, “Commonly used options”.

13.2.6. Common Mistakes to Avoid

The following is a list of advices how to avoid common mistakes users make when configuring a nameserver:

**Use semicolons and curly brackets correctly**

An omitted semicolon or unmatched curly bracket in the /etc/named.conf file can prevent the named service from starting.

**Use period (that is, the . character) correctly**

In zone files, a period at the end of a domain name denotes a fully qualified domain name. If omitted, the named service will append the name of the zone or the value of $ORIGIN to complete it.

**Increment the serial number when editing a zone file**

If the serial number is not incremented, the primary nameserver will have the correct, new information, but the secondary nameservers will never be notified of the change, and will not attempt to refresh their data of that zone.

**Configure the firewall**

If a firewall is blocking connections from the named service to other nameservers, the recommended best practice is to change the firewall settings whenever possible.

Avoid using fixed UDP source ports

According to the recent research in DNS security, using a fixed UDP source port for DNS queries is a potential security vulnerability that could allow an attacker to conduct cache-poisoning attacks more easily. To prevent this, configure your firewall to allow queries from a random UDP source port.

13.2.7. Additional Resources

The following sources of information provide additional resources regarding BIND.

13.2.7.1. Installed Documentation

BIND features a full range of installed documentation covering many different topics, each placed in its own subject directory. For each item below, replace version with the version of the bind package installed on the system:

/usr/share/doc/bind-version/

The main directory containing the most recent documentation.

/usr/share/doc/bind-version/arm/

The directory containing the BIND 9 Administrator Reference Manual in HTML and SGML formats, which details BIND resource requirements, how to configure different types of nameservers, how to perform load balancing, and other advanced topics. For most new users of BIND, this is the best place to start.

/usr/share/doc/bind-version/draft/

The directory containing assorted technical documents that review issues related to the DNS service, and propose some methods to address them.

/usr/share/doc/bind-version/misc/

The directory designed to address specific advanced issues. Users of BIND version 8 should consult the migration document for specific changes they must make when moving to BIND 9. The options file lists all of the options
implemented in BIND 9 that are used in /etc/named.conf.

/usr/share/doc/bind-version/rfc/
The directory providing every RFC document related to BIND.

There is also a number of man pages for the various applications and configuration files involved with BIND:

man rndc
The manual page for rndc containing the full documentation on its usage.

man named
The manual page for named containing the documentation on assorted arguments that can be used to control the BIND nameserver daemon.

man lwresd
The manual page for lwresd containing the full documentation on the lightweight resolver daemon and its usage.

man named.conf
The manual page with a comprehensive list of options available within the named configuration file.

man rndc.conf
The manual page with a comprehensive list of options available within the rndc configuration file.

13.2.7.2. Useful Websites

http://www.isc.org/software/bind
The home page of the BIND project containing information about current releases as well as a PDF version of the BIND 9 Administrator Reference Manual.

13.2.7.3. Related Books

DNS and BIND by Paul Albitz and Cricket Liu; O'Reilly & Associates
A popular reference that explains both common and esoteric BIND configuration options, and provides strategies for securing a DNS server.

The Concise Guide to DNS and BIND by Nicolai Langfeldt; Que
Looks at the connection between multiple network services and BIND, with an emphasis on task-oriented, technical topics.

Chapter 14. Web Servers

14.1. The Apache HTTP Server

14.1.1. New Features
14.1.2. Notable Changes
14.1.3. Updating the Configuration
14.1.4. Running the httpd Service
14.1.5. Editing the Configuration Files
14.1.6. Working with Modules
14.1.7. Setting Up Virtual Hosts
14.1.8. Setting Up an SSL Server
14.1.9. Additional Resources

HTTP (Hypertext Transfer Protocol) server, or a web server, is a network service that serves content to a client over the web. This typically means web pages, but any other documents can be served as well.

14.1. The Apache HTTP Server

This section focuses on the Apache HTTP Server 2.2, a robust, full-featured open source web server developed by the Apache Software Foundation, that is included in Fedora 18. It describes the basic configuration of the httpd service, and covers advanced topics such as adding server modules, setting up virtual hosts, or configuring the secure HTTP server.

There are important differences between the Apache HTTP Server 2.2 and version 2.0, and if you are upgrading from a previous release of Fedora, you will need to update the httpd service configuration accordingly. This section reviews some of the newly added features, outlines important changes, and guides you through the update of older configuration files.
14.1.1. New Features
The Apache HTTP Server version 2.2 introduces the following enhancements:

- Improved caching modules, that is, `mod_cache` and `mod_disk_cache`.
- Support for proxy load balancing, that is, the `mod_proxy_balancer` module.
- Support for large files on 32-bit architectures, allowing the web server to handle files greater than 2GB.
- A new structure for authentication and authorization support, replacing the authentication modules provided in previous versions.

14.1.2. Notable Changes
Since version 2.0, few changes have been made to the default `httpd` service configuration:

- The following modules are no longer loaded by default: `mod_cern_meta` and `mod_asis`.
- The following module is newly loaded by default: `mod_ext_filter`.

14.1.3. Updating the Configuration
To update the configuration files from the Apache HTTP Server version 2.0, take the following steps:

1. Make sure all module names are correct, since they may have changed. Adjust the `LoadModule` directive for each module that has been renamed.
2. Recompile all third party modules before attempting to load them. This typically means authentication and authorization modules.
3. If you use the `mod_userdir` module, make sure the `UserDir` directive indicating a directory name (typically `public_html`) is provided.
4. If you use the Apache HTTP Secure Server, edit the `/etc/httpd/conf.d/ssl.conf` to enable the Secure Sockets Layer (SSL) protocol.

Note that you can check the configuration for possible errors by using the following command:

```
service httpd configtest
```

For more information on upgrading the Apache HTTP Server configuration from version 2.0 to 2.2, refer to [http://httpd.apache.org/docs/2.2/upgrading.html](http://httpd.apache.org/docs/2.2/upgrading.html).

14.1.4. Running the `httpd` Service
This section describes how to start, stop, restart, and check the current status of the Apache HTTP Server. To be able to use the `httpd` service, make sure you have the `httpd` installed. You can do so by using the following command as `root`:

```
yum install httpd
```

For more information on the concept of runlevels and how to manage system services in Fedora in general, refer to [Chapter 9, Services and Daemons](#).

14.1.4.1. Starting the Service
To run the `httpd` service, type the following at a shell prompt as `root`:

```
systemctl start httpd.service
```

If you want the service to start automatically at the boot time, use the following command:

```
systemctl enable httpd.service
```

Refer to [Chapter 9, Services and Daemons](#) for more information on how to configure services in Fedora.

Using the secure server

If running the Apache HTTP Server as a secure server, a password may be required after the machine boots if using an encrypted private SSL key.

14.1.4.2. Stopping the Service
To stop the running `httpd` service, type the following at a shell prompt as `root`:

```
systemctl stop httpd.service
```

To prevent the service from starting automatically at the boot time, type:

```
systemctl disable httpd.service
```

Refer to [Chapter 9, Services and Daemons](#) for more information on how to configure services in Fedora.

14.1.4.3. Restarting the Service
There are two different ways to restart the running `httpd` service:

1. To restart the service completely, type the following at a shell prompt as `root`:

```
service httpd restart
```

For more information on how to restart services, refer to [Chapter 9, Services and Daemons](#).
To check whether the service is running, type the following at a shell prompt:

```
systemctl is-active httpd.service
```

To make the recovery from mistakes easier, it is recommended that you make a copy of the original file before editing it.

**14.1.5.1. Common httpd.conf Directives**

The following directives are commonly used in the `/etc/httpd/conf/httpd.conf` configuration file:

```<Directory>`
The `<Directory>` directive allows you to apply certain directives to a particular directory only. It takes the following form:

```
<Directory directory>
directive
</Directory>
```

The `directory` can be either a full path to an existing directory in the local file system, or a wildcard expression.

This directive can be used to configure additional `cgi-bin` directories for server-side scripts located outside the directory that is specified by `ScriptAlias`. In this case, the `ExecCGI` and `AddHandler` directives must be supplied, and the permissions on the target directory must be set correctly (that is, 0755).

**Example 14.1. Using the `<Directory>` directive**

```
<Directory /var/www/html>
    Options Indexes FollowSymLinks
    AllowOverride None
    Order allow,deny
    Allow from all
</Directory>
```

**`<IfDefine>`**
The `<IfDefine>` directive allows you to use certain directives only when a particular parameter is supplied on the command line. It takes the following form:
The parameter can be supplied at a shell prompt using the `-D` parameter command line option (for example, `httpd -DEnableHome`). If the optional exclamation mark (that is, `!`) is present, the enclosed directives are used only when the parameter is not specified.

Example 14.2. Using the `<IfDefine>` directive

```xml
<IfDefine EnableHome>
  UserDir public_html
</IfDefine>
```

The `<IfModule>` directive allows you to use certain directive only when a particular module is loaded. It takes the following form:

```xml
<IfModule ![module]>
  directive
</IfModule>
```

The module can be identified either by its name, or by the file name. If the optional exclamation mark (that is, `!`) is present, the enclosed directives are used only when the module is not loaded.

Example 14.3. Using the `<IfModule>` directive

```xml
<IfModule mod_disk_cache.c>
  CacheEnable disk / CacheRoot /var/cache/mod_proxy
</IfModule>
```

The `<Location>` directive allows you to apply certain directives to a particular URL only. It takes the following form:

```xml
<Location ![url]>
  directive
</Location>
```

The `url` can be either a path relative to the directory specified by the `DocumentRoot` directive (for example, `/server-info`), or an external URL such as `http://example.com/server-info`.

Example 14.4. Using the `<Location>` directive

```xml
<Location /server-info>
  SetHandler server-info
  Order deny,allow
  Deny from all
  Allow from .example.com
</Location>
```

The `<Proxy>` directive allows you to apply certain directives to the proxy server only. It takes the following form:

```xml
<Proxy ![pattern]>
  directive
</Proxy>
```

The `pattern` can be an external URL, or a wildcard expression (for example, `http://example.com/*`).

Example 14.5. Using the `<Proxy>` directive

```xml
<Proxy />
  Order deny,allow
  Deny from all
  Allow from .example.com
</Proxy>
```

The `<VirtualHost>` directive allows you apply certain directives to particular virtual hosts only. It takes the following form:
The address can be an IP address, a fully qualified domain name, or a special form as described in Table 14.2, "Available <VirtualHost> options".

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>*</td>
<td>Represents all IP addresses.</td>
</tr>
<tr>
<td><em>default</em></td>
<td>Represents unmatched IP addresses.</td>
</tr>
</tbody>
</table>

Example 14.7. Using the AccessFileName directive

AccessFileName .htaccess

<table>
<thead>
<tr>
<th>Action content-type path</th>
</tr>
</thead>
<tbody>
<tr>
<td>The content-type has to be a valid MIME type such as text/html, image/png, or application/pdf. The path refers to an existing CGI script, and must be relative to the directory specified by the DocumentRoot directive (for example, /cgi-bin/process-image.cgi).</td>
</tr>
</tbody>
</table>

Example 14.8. Using the Action directive

<table>
<thead>
<tr>
<th>AddDescription &quot;description&quot; filename.</th>
</tr>
</thead>
<tbody>
<tr>
<td>The description should be a short text enclosed in double quotes (that is, &quot;&quot;). The filename can be a full file name, a file extension, or a wildcard expression.</td>
</tr>
</tbody>
</table>

Example 14.9. Using the AddDescription directive

<table>
<thead>
<tr>
<th>AddEncoding</th>
</tr>
</thead>
<tbody>
<tr>
<td>The AddEncoding directive allows you to specify an encoding type for a particular file extension. It takes the following form:</td>
</tr>
</tbody>
</table>
The `AddEncoding` directive allows you to specify an icon to be displayed for a particular file in server-generated directory listings. It takes the following form:

```html
AddEncoding encoding extension...
```

The `encoding` has to be a valid MIME encoding such as `x-compress`, `x-gzip`, etc. The `extension` is a case sensitive file extension, and is conventionally written with a leading dot (for example, `.gz`).

This directive is typically used to instruct web browsers to decompress certain file types as they are downloaded.

Example 14.10. Using the `AddEncoding` directive

```html
AddEncoding x-gzip .gz .tgz
```

### AddHandler

The `AddHandler` directive allows you to map certain file extensions to a selected handler. It takes the following form:

```html
AddHandler handler extension...
```

The `handler` has to be a name of previously defined handler. The `extension` is a case sensitive file extension, and is conventionally written with a leading dot (for example, `.cgi`).

This directive is typically used to treat files with the `.cgi` extension as CGI scripts regardless of the directory they are in. Additionally, it is also commonly used to process server-parsed HTML and image-map files.

Example 14.11. Using the `AddHandler` option

```html
AddHandler cgi-script .cgi
```

### AddIcon

The `AddIcon` directive allows you to specify an icon to be displayed for a particular file in server-generated directory listings. It takes the following form:

```html
AddIcon path pattern...
```

The `path` refers to an existing icon file, and must be relative to the directory specified by the `DocumentRoot` directive (for example, `/icons/folder.png`). The `pattern` can be a file name, a file extension, a wildcard expression, or a special form as described in the following table:

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>^^DIRECTORY^^</td>
<td>Represents a directory.</td>
</tr>
<tr>
<td>^^BLANKICON^^</td>
<td>Represents a blank line.</td>
</tr>
</tbody>
</table>

Example 14.12. Using the `AddIcon` directive

```html
AddIcon /icons/text.png .txt README
```

### AddIconByEncoding

The `AddIconByEncoding` directive allows you to specify an icon to be displayed for a particular encoding type in server-generated directory listings. It takes the following form:

```html
AddIconByEncoding path encoding...
```

The `path` refers to an existing icon file, and must be relative to the directory specified by the `DocumentRoot` directive (for example, `/icons/compressed.png`). The `encoding` has to be a valid MIME encoding such as `x-compress`, `x-gzip`, etc.

Example 14.13. Using the `AddIconByEncoding` directive

```html
AddIconByEncoding /icons/compressed.png x-compress x-gzip
```

### AddIconByType

The `AddIconByType` directive allows you to specify an icon to be displayed for a particular media type in server-generated directory listings. It takes the following form:

```html
AddIconByType path content-type...
```

The `path` refers to an existing icon file, and must be relative to the directory specified by the `DocumentRoot` directive (for example, `/icons/text.png`). The `content-type` has to be either a valid MIME type (for example, `text/html` or `image/png`), or a wildcard expression such as `text/*`, `image/*`, etc.

Example 14.14. Using the `AddIconByType` directive

```html
AddIconByType /icons/video.png video/*
```
AddLanguage

The **AddLanguage** directive allows you to associate a file extension with a specific language. It takes the following form:

```
AddLanguage language extension...
```

The *language* has to be a valid MIME language such as `cs`, `en`, or `fr`. The *extension* is a case sensitive file extension, and is conventionally written with a leading dot (for example, `.cs`).

This directive is especially useful for web servers that serve content in multiple languages based on the client's language settings.

**Example 14.15. Using the AddLanguage directive**

```
AddLanguage cs .cs .cz
```

AddType

The **AddType** directive allows you to define or override the media type for a particular file extension. It takes the following form:

```
AddType content-type extension...
```

The *content-type* has to be a valid MIME type such as `text/html`, `image/png`, etc. The *extension* is a case sensitive file extension, and is conventionally written with a leading dot (for example, `.cs`).

**Example 14.16. Using the AddType directive**

```
AddType application/x-gzip .gz .tgz
```

Alias

The **Alias** directive allows you to refer to files and directories outside the default directory specified by the **DocumentRoot** directive. It takes the following form:

```
Alias url-path real-path
```

The *url-path* must be relative to the directory specified by the **DocumentRoot** directive (for example, `/images/`). The *real-path* is a full path to a file or directory in the local file system.

This directive is typically followed by the **Directory** tag with additional permissions to access the target directory. By default, the `/icons/` alias is created so that the icons from `/var/www/icons/` are displayed in server-generated directory listings.

**Example 14.17. Using the Alias directive**

```
Options Indexes MultiViews FollowSymLinks
AllowOverride None
Order allow,deny
Allow from all

<Directory "/var/www/icons/"

Alias /icons/ /var/www/icons/
```

Allow

The **Allow** directive allows you to specify which clients have permission to access a given directory. It takes the following form:

```
Allow from client.
```

The *client* can be a domain name, an IP address (both full and partial), a network/netmask pair, or all for all clients.

**Example 14.18. Using the Allow directive**

```
Allow from 192.168.1.0/255.255.255.0
```

AllowOverride

The **AllowOverride** directive allows you to specify which directives in a `.htaccess` file can override the default configuration. It takes the following form:

```
AllowOverride type.
```

The *type* has to be one of the available grouping options as described in Table 14.4, "Available AllowOverride options".
Table 14.4. Available AllowOverride options

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>All directives in .htaccess are allowed to override earlier configuration settings.</td>
</tr>
<tr>
<td>None</td>
<td>No directive in .htaccess is allowed to override earlier configuration settings.</td>
</tr>
<tr>
<td>AuthConfig</td>
<td>Allows the use of authorization directives such as AuthName, AuthType, or Require.</td>
</tr>
<tr>
<td>FileInfo</td>
<td>Allows the use of file type, metadata, and mod_rewrite directives such as DefaultType, RequestHeader, or RewriteEngine, as well as the Action directive.</td>
</tr>
<tr>
<td>Indexes</td>
<td>Allows the use of directory indexing directives such as AddDescription, AddIcon, or FancyIndexing.</td>
</tr>
<tr>
<td>Limit</td>
<td>Allows the use of host access directives, that is, Allow, Deny, and Order.</td>
</tr>
<tr>
<td>Options...</td>
<td>Allows the use of the Options directive. Additionally, you can provide a comma-separated list of options to customize which options can be set using this directive.</td>
</tr>
</tbody>
</table>

Example 14.19. Using the AllowOverride directive

```
AllowOverride FileInfo AuthConfig Limit
```

BrowserMatch

The BrowserMatch directive allows you to modify the server behavior based on the client's web browser type. It takes the following form:

```
BrowserMatch pattern variable...
```

The `pattern` is a regular expression to match the User-Agent HTTP header field. The `variable` is an environment variable that is set when the header field matches the pattern.

By default, this directive is used to deny connections to specific browsers with known issues, and to disable keepalives and HTTP header flushes for browsers that are known to have problems with these actions.

Example 14.20. Using the BrowserMatch directive

```
BrowserMatch "Mozilla/2" nokeepalive
```

CacheDefaultExpire

The CacheDefaultExpire option allows you to set how long to cache a document that does not have any expiration date or the date of its last modification specified. It takes the following form:

```
CacheDefaultExpire time
```

The `time` is specified in seconds. The default option is 3600 (that is, one hour).

Example 14.21. Using the CacheDefaultExpire directive

```
CacheDefaultExpire 3600
```

CacheDisable

The CacheDisable directive allows you to disable caching of certain URLs. It takes the following form:

```
CacheDisable path
```

The `path` must be relative to the directory specified by the DocumentRoot directive (for example, /files/).

Example 14.22. Using the CacheDisable directive

```
CacheDisable /temporary
```

CacheEnable

The CacheEnable directive allows you to specify a cache type to be used for certain URLs. It takes the following form:

```
CacheEnable type url
```

The `type` has to be a valid cache type as described in Table 14.5, "Available cache types". The `url` can be a path relative to the directory specified by the DocumentRoot directive (for example, /images/), a protocol (for example, ftp://), or an external URL such as http://example.com/.

Table 14.5. Available cache types

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>mem</td>
<td>The memory-based storage manager.</td>
</tr>
<tr>
<td>disk</td>
<td>The disk-based storage manager.</td>
</tr>
<tr>
<td>fd</td>
<td>The file descriptor cache.</td>
</tr>
</tbody>
</table>
CacheLastModifiedFactor
The **CacheLastModifiedFactor** directive allows you to customize how long to cache a document that does not have any expiration date specified, but that provides information about the date of its last modification. It takes the following form:

```
CacheLastModifiedFactor number
```

The *number* is a coefficient to be used to multiply the time that passed since the last modification of the document. The default option is **0.1** (that is, one tenth).

**Example 14.24. Using the CacheLastModifiedFactor directive**

```
CacheLastModifiedFactor 0.1
```

CacheMaxExpire
The **CacheMaxExpire** directive allows you to specify the maximum amount of time to cache a document. It takes the following form:

```
CacheMaxExpire time
```

The *time* is specified in seconds. The default option is **86400** (that is, one day).

**Example 14.25. Using the CacheMaxExpire directive**

```
CacheMaxExpire 86400
```

CacheNegotiatedDocs
The **CacheNegotiatedDocs** directive allows you to enable caching of the documents that were negotiated on the basis of content. It takes the following form:

```
CacheNegotiatedDocs option
```

The *option* has to be a valid keyword as described in Table 14.6, "Available CacheNegotiatedDocs options". Since the content-negotiated documents may change over time or because of the input from the requester, the default option is **Off**.

**Table 14.6. Available CacheNegotiatedDocs options**

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>On</td>
<td>Enables caching the content-negotiated documents.</td>
</tr>
<tr>
<td>Off</td>
<td>Disables caching the content-negotiated documents.</td>
</tr>
</tbody>
</table>

**Example 14.26. Using the CacheNegotiatedDocs directive**

```
CacheNegotiatedDocs On
```

CacheRoot
The **CacheRoot** directive allows you to specify the directory to store cache files in. It takes the following form:

```
CacheRoot directory
```

The *directory* must be a full path to an existing directory in the local file system. The default option is `/var/cache/mod_proxy/`.

**Example 14.27. Using the CacheRoot directive**

```
CacheRoot /var/cache/mod_proxy
```

CustomLog
The **CustomLog** directive allows you to specify the log file name and the log file format. It takes the following form:

```
CustomLog path format
```

The *path* refers to a log file, and must be relative to the directory that is specified by the **ServerRoot** directive (that is, `/etc/httpd/` by default). The *format* has to be either an explicit format string, or a format name that was previously defined using the **LogFormat** directive.
Example 14.28. Using the CustomLog directive

CustomLog logs/access_log combined

DefaultIcon

The `DefaultIcon` directive allows you to specify an icon to be displayed for a file in server-generated directory listings when no other icon is associated with it. It takes the following form:

```
DefaultIcon path
```

The `path` refers to an existing icon file, and must be relative to the directory specified by the `DocumentRoot` directive (for example, `/icons/unknown.png`).

Example 14.29. Using the DefaultIcon directive

```
DefaultIcon /icons/unknown.png
```

DefaultType

The `DefaultType` directive allows you to specify a media type to be used in case the proper MIME type cannot be determined by the server. It takes the following form:

```
DefaultType content-type
```

The `content-type` has to be a valid MIME type such as `text/html`, `image/png`, `application/pdf`, etc.

Example 14.30. Using the DefaultType directive

```
DefaultType text/plain
```

Deny

The `Deny` directive allows you to specify which clients are denied access to a given directory. It takes the following form:

```
Deny from client
```

The `client` can be a domain name, an IP address (both full and partial), a `network/netmask` pair, or `all` for all clients.

Example 14.31. Using the Deny directive

```
Deny from 192.168.1.1
```

DirectoryIndex

The `DirectoryIndex` directive allows you to specify a document to be served to a client when a directory is requested (that is, when the URL ends with the `/` character). It takes the following form:

```
DirectoryIndex filename...
```

The `filename` is a name of the file to look for in the requested directory. By default, the server looks for `index.html`, and `index.html.var`.

Example 14.32. Using the DirectoryIndex directive

```
DirectoryIndex index.html index.html.var
```

DocumentRoot

The `DocumentRoot` directive allows you to specify the main directory from which the content is served. It takes the following form:

```
DocumentRoot directory
```

The `directory` must be a full path to an existing directory in the local file system. The default option is `/var/www/html/`.

Example 14.33. Using the DocumentRoot directive

```
DocumentRoot /var/www/html
```

ErrorDocument

The `ErrorDocument` directive allows you to specify a document or a message to be displayed as a response to a
particular error. It takes the following form:

```
ErrorDocument error-code action
```

The `error-code` has to be a valid code such as 403 (Forbidden), 404 (Not Found), or 500 (Internal Server Error). The `action` can be either a URL (both local and external), or a message string enclosed in double quotes (that is, "").

**Example 14.34. Using the ErrorDocument directive**

```
ErrorDocument 403 "Access Denied"
ErrorDocument 404 /404-not_found.html
```

**ErrorLog**

The `ErrorLog` directive allows you to specify a file to which the server errors are logged. It takes the following form:

```
ErrorLog path
```

The `path` refers to a log file, and can be either absolute, or relative to the directory that is specified by the `ServerRoot` directive (that is, /etc/httpd/ by default). The default option is `logs/error_log`

**Example 14.35. Using the ErrorLog directive**

```
ErrorLog logs/error_log
```

**ExtendedStatus**

The `ExtendedStatus` directive allows you to enable detailed server status information. It takes the following form:

```
ExtendedStatus option
```

The `option` has to be a valid keyword as described in Table 14.7, "Available ExtendedStatus options". The default option is `Off`.

**Table 14.7. Available ExtendedStatus options**

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>On</td>
<td>Enables generating the detailed server status.</td>
</tr>
<tr>
<td>Off</td>
<td>Disables generating the detailed server status.</td>
</tr>
</tbody>
</table>

**Example 14.36. Using the ExtendedStatus directive**

```
ExtendedStatus On
```

**Group**

The `Group` directive allows you to specify the group under which the `httpd` service will run. It takes the following form:

```
Group group
```

The `group` has to be an existing UNIX group. The default option is `apache`.

Note that `Group` is no longer supported inside `<VirtualHost>`, and has been replaced by the `SuexecUserGroup` directive.

**Example 14.37. Using the Group directive**

```
Group apache
```

**HeaderName**

The `HeaderName` directive allows you to specify a file to be prepended to the beginning of the server-generated directory listing. It takes the following form:

```
HeaderName filename
```

The `filename` is a name of the file to look for in the requested directory. By default, the server looks for `HEADER.html`.

**Example 14.38. Using the HeaderName directive**

```
HeaderName HEADER.html
```

**HostnameLookups**

The `HostnameLookups` directive allows you to enable automatic resolving of IP addresses. It takes the following form:
HostnameLookups option

The option has to be a valid keyword as described in Table 14.8, "Available HostnameLookups options". To conserve resources on the server, the default option is Off.

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>On</td>
<td>Enables resolving the IP address for each connection so that the hostname can be logged. However, this also adds a significant processing overhead.</td>
</tr>
<tr>
<td>Double</td>
<td>Enables performing the double-reverse DNS lookup. In comparison to the above option, this adds even more processing overhead.</td>
</tr>
<tr>
<td>Off</td>
<td>Disables resolving the IP address for each connection.</td>
</tr>
</tbody>
</table>

Table 14.8. Available HostnameLookups options

Note that when the presence of hostnames is required in server log files, it is often possible to use one of the many log analyzer tools that perform the DNS lookups more efficiently.

Example 14.39. Using the HostnameLookups directive

HostnameLookups Off

Include

The Include directive allows you to include other configuration files. It takes the following form:

```
Include filename
```

The filename can be an absolute path, a path relative to the directory specified by the ServerRoot directive, or a wildcard expression. All configuration files from the `/etc/httpd/conf.d/` directory are loaded by default.

Example 14.40. Using the Include directive

```
Include conf.d/*.conf
```

IndexIgnore

The IndexIgnore directive allows you to specify a list of file names to be omitted from the server-generated directory listings. It takes the following form:

```
IndexIgnore filename...
```

The filename option can be either a full file name, or a wildcard expression.

Example 14.41. Using the IndexIgnore directive

```
IndexIgnore .** ~- *# HEADER* README* RCS CVS *,v *,t
```

IndexOptions

The IndexOptions directive allows you to customize the behavior of server-generated directory listings. It takes the following form:

```
IndexOptions option...
```

The option has to be a valid keyword as described in Table 14.9, "Available directory listing options". The default options are Charset=UTF-8, FancyIndexing, HTMLTable, NameWidth=*, and VersionSort.
### Table 14.9. Available directory listing options

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charset:encoding</td>
<td>Specifies the character set of a generated web page. The <strong>encoding</strong> has to be a valid character set such as UTF-8 or ISO-8859-2.</td>
</tr>
<tr>
<td>Type:content-type</td>
<td>Specifies the media type of a generated web page. The <strong>content-type</strong> has to be a valid MIME type such as text/html or text/plain.</td>
</tr>
<tr>
<td>DescriptionWidth:value</td>
<td>Specifies the width of the description column. The <strong>value</strong> can be either a number of characters, or an asterisk (that is, <code>*</code>) to adjust the width automatically.</td>
</tr>
<tr>
<td>FancyIndexing:value</td>
<td>Enables advanced features such as different icons for certain files or possibility to re-sort a directory listing by clicking on a column header.</td>
</tr>
<tr>
<td>FolderFirst</td>
<td>Enables listing directories first, always placing them above files.</td>
</tr>
<tr>
<td>HTMLTable</td>
<td>Enables the use of HTML tables for directory listings.</td>
</tr>
<tr>
<td>IconsAreLinks</td>
<td>Enables using the icons as links.</td>
</tr>
<tr>
<td>IconHeight:value</td>
<td>Specifies an icon height. The <strong>value</strong> is a number of pixels.</td>
</tr>
<tr>
<td>IconWidth:value</td>
<td>Specifies an icon width. The <strong>value</strong> is a number of pixels.</td>
</tr>
<tr>
<td>IgnoreCase</td>
<td>Enables sorting files and directories in a case-sensitive manner.</td>
</tr>
<tr>
<td>IgnoreClient</td>
<td>Disables accepting query variables from a client.</td>
</tr>
<tr>
<td>NameWidth:value</td>
<td>Specifies the width of the file name column. The <strong>value</strong> can be either a number of characters, or an asterisk (that is, <code>*</code>) to adjust the width automatically.</td>
</tr>
<tr>
<td>ScanHTMLTitles</td>
<td>Enables parsing the file for a description (that is, the <strong>title</strong> element) in case it is not provided by the AddDescription directive.</td>
</tr>
<tr>
<td>ShowForbidden</td>
<td>Enables listing the files with otherwise restricted access.</td>
</tr>
<tr>
<td>SuppressColumnSorting</td>
<td>Disables re-sorting a directory listing by clicking on a column header.</td>
</tr>
<tr>
<td>SuppressDescription</td>
<td>Disables reserving a space for file descriptions.</td>
</tr>
<tr>
<td>SuppressHTMLPreamble</td>
<td>Disables the use of standard HTML preamble when a file specified by the HeaderName directive is present.</td>
</tr>
<tr>
<td>SuppressIcon</td>
<td>Disables the use of icons in directory listings.</td>
</tr>
<tr>
<td>SuppressLastModified</td>
<td>Disables displaying the date of the last modification in directory listings.</td>
</tr>
<tr>
<td>SuppressRules</td>
<td>Disables the use of horizontal lines in directory listings.</td>
</tr>
<tr>
<td>SuppressSize</td>
<td>Disables displaying the file size field in directory listings.</td>
</tr>
<tr>
<td>TrackModified</td>
<td>Enables returning the Last-Modified and ETag values in the HTTP header.</td>
</tr>
<tr>
<td>VersionSort</td>
<td>Enables sorting files that contain a version number in the expected manner.</td>
</tr>
<tr>
<td>XHTML</td>
<td>Enables the use of XHTML 1.0 instead of the default HTML 3.2.</td>
</tr>
</tbody>
</table>

#### Example 14.42. Using the IndexOptions directive
```
IndexOptions FancyIndexing VersionSort NameWidth=* HTMLTable Charset=UTF-8
```

### KeepAlive

The **KeepAlive** directive allows you to enable persistent connections. It takes the following form:

```
KeepAlive option
```

The **option** has to be a valid keyword as described in **Table 14.10. Available KeepAlive options**. The default option is **Off**.

#### Table 14.10. Available KeepAlive options

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>On</td>
<td>Enables the persistent connections. In this case, the server will accept more than one request per connection.</td>
</tr>
<tr>
<td>Off</td>
<td>Disables the keep-alive connections.</td>
</tr>
</tbody>
</table>

Note that when the persistent connections are enabled, on a busy server, the number of child processes can increase rapidly and eventually reach the maximum limit, slowing down the server significantly. To reduce the risk, it is recommended that you set KeepAliveTimeout to a low number, and monitor the `/var/log/httpd/logs/error_log` log file carefully.

#### Example 14.43. Using the KeepAlive directive
```
KeepAlive Off
```

### KeepAliveTimeout

The **KeepAliveTimeout** directive allows you to specify the amount of time to wait for another request before closing the connection. It takes the following form:

```
KeepAliveTimeout time
```

The **time** is specified in seconds. The default option is **15**.

Example 14.44. Using the `KeepAliveTimeout` directive

```
KeepAliveTimeout 15
```

**LanguagePriority**

The **LanguagePriority** directive allows you to customize the precedence of languages. It takes the following form:

```
LanguagePriority language...
```

The **language** has to be a valid MIME language such as `cs`, `en`, or `fr`.

This directive is especially useful for web servers that serve content in multiple languages based on the client's language settings.

Example 14.45. Using the `LanguagePriority` directive

```
LanguagePriority sk cs en
```

**Listen**

The **Listen** directive allows you to specify IP addresses or ports to listen to. It takes the following form:

```
Listen [ip-address:]port [protocol]
```

The **ip-address** is optional and unless supplied, the server will accept incoming requests on a given **port** from all IP addresses. Since the **protocol** is determined automatically from the port number, it can be usually omitted. The default option is to listen to port **80**.

Note that if the server is configured to listen to a port under 1024, only superuser will be able to start the **httpd** service.

Example 14.46. Using the `Listen` directive

```
Listen 80
```

**LoadModule**

The **LoadModule** directive allows you to load a **Dynamic Shared Object (DSO)** module. It takes the following form:

```
LoadModule name path
```

The **name** has to be a valid identifier of the required module. The **path** refers to an existing module file, and must be relative to the directory in which the libraries are placed (that is, `/usr/lib/httpd/` on 32-bit and `/usr/lib64/httpd/` on 64-bit systems by default).

Refer to **Section 14.1.6, “Working with Modules”** for more information on the Apache HTTP Server's DSO support.

Example 14.47. Using the `LoadModule` directive

```
LoadModule php5_module modules/libphp5.so
```

**LogFormat**

The **LogFormat** directive allows you to specify a log file format. It takes the following form:

```
LogFormat format name
```

The **format** is a string consisting of options as described in **Table 14.11, “Common LogFormat options”**. The **name** can be used instead of the format string in the **CustomLog** directive.

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>%b</td>
<td>Represents the size of the response in bytes.</td>
</tr>
<tr>
<td>%h</td>
<td>Represents the IP address or hostname of a remote client.</td>
</tr>
<tr>
<td>%l</td>
<td>Represents the remote log name if supplied. If not, a hyphen (that is, -) is used instead.</td>
</tr>
<tr>
<td>%r</td>
<td>Represents the first line of the request string as it came from the browser or client.</td>
</tr>
<tr>
<td>%s</td>
<td>Represents the status code.</td>
</tr>
<tr>
<td>%t</td>
<td>Represents the date and time of the request.</td>
</tr>
<tr>
<td>%u</td>
<td>If the authentication is required, it represents the remote user. If not, a hyphen (that is, -) is used instead.</td>
</tr>
<tr>
<td>%F[field]</td>
<td>Represents the content of the HTTP header field. The common options include %F[Referer] (the URL of the web page that referred the client to the server) and %F[User-Agent] (the type of the web browser making the request).</td>
</tr>
</tbody>
</table>
Example 14.48. Using the LogFormat directive

```
LogFormat "%h %l %u %t "%r" %>s %b" common
```

LogLevel

The `LogLevel` directive allows you to customize the verbosity level of the error log. It takes the following form:

```
LogLevel option
```

The `option` has to be a valid keyword as described in Table 14.12, "Available LogLevel options". The default option is `warn`.

**Table 14.12. Available LogLevel options**

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>emerg</td>
<td>Only the emergency situations when the server cannot perform its work are logged.</td>
</tr>
<tr>
<td>alert</td>
<td>All situations when an immediate action is required are logged.</td>
</tr>
<tr>
<td>crit</td>
<td>All critical conditions are logged.</td>
</tr>
<tr>
<td>error</td>
<td>All error messages are logged.</td>
</tr>
<tr>
<td>warn</td>
<td>All warning messages are logged.</td>
</tr>
<tr>
<td>notice</td>
<td>Even normal, but still significant situations are logged.</td>
</tr>
<tr>
<td>info</td>
<td>Various informational messages are logged.</td>
</tr>
<tr>
<td>debug</td>
<td>Various debugging messages are logged.</td>
</tr>
</tbody>
</table>

Example 14.49. Using the LogLevel directive

```
LogLevel warn
```

MaxKeepAliveRequests

The `MaxKeepAliveRequests` directive allows you to specify the maximum number of requests for a persistent connection. It takes the following form:

```
MaxKeepAliveRequests number
```

A high `number` can improve the performance of the server. Note that using 0 allows unlimited number of requests. The default option is 100.

Example 14.50. Using the MaxKeepAliveRequests option

```
MaxKeepAliveRequests 100
```

NameVirtualHost

The `NameVirtualHost` directive allows you to specify the IP address and port number for a name-based virtual host. It takes the following form:

```
NameVirtualHost ip-address[:port]
```

The `ip-address` can be either a full IP address, or an asterisk (that is, *) representing all interfaces. Note that IPv6 addresses have to be enclosed in square brackets (that is, [ and ]). The `port` is optional.

Name-based virtual hosting allows one Apache HTTP Server to serve different domains without using multiple IP addresses.

**Using secure HTTP connections**

Name-based virtual hosts only work with non-secure HTTP connections. If using virtual hosts with a secure server, use IP address-based virtual hosts instead.

Example 14.51. Using the NameVirtualHost directive

```
NameVirtualHost "*:80"
```

Options

The `Options` directive allows you to specify which server features are available in a particular directory. It takes the following form:

```
Options option...
```

The `option` has to be a valid keyword as described in Table 14.13, "Available server features".
Table 14.13. Available server features

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ExecCGI</td>
<td>Enables the execution of CGI scripts.</td>
</tr>
<tr>
<td>FollowSymLinks</td>
<td>Enables following symbolic links in the directory.</td>
</tr>
<tr>
<td>Includes</td>
<td>Enables server-side includes.</td>
</tr>
<tr>
<td>IncludesNOEXEC</td>
<td>Enables server-side includes, but does not allow the execution of commands.</td>
</tr>
<tr>
<td>Indexes</td>
<td>Enables server-generated directory listings.</td>
</tr>
<tr>
<td>MultiViews</td>
<td>Enables content-negotiated &quot;MultiViews&quot;.</td>
</tr>
<tr>
<td>SymLinksIFOwnerMatch</td>
<td>Enables following symbolic links in the directory when both the link and the target file have the same owner.</td>
</tr>
<tr>
<td>All</td>
<td>Enables all of the features above with the exception of MultiViews.</td>
</tr>
<tr>
<td>None</td>
<td>Disables all of the features above.</td>
</tr>
</tbody>
</table>

Example 14.52. Using the Options directive

```
Options Indexes FollowSymLinks
```

Order

The `Order` directive allows you to specify the order in which the `Allow` and `Deny` directives are evaluated. It takes the following form:

```
Order option
```

The `option` has to be a valid keyword as described in Table 14.14, "Available Order options". The default option is `allow, deny`.

Table 14.14. Available Order options

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>allow, deny</td>
<td>Allow directives are evaluated first.</td>
</tr>
<tr>
<td>deny, allow</td>
<td>Deny directives are evaluated first.</td>
</tr>
</tbody>
</table>

Example 14.53. Using the Order directive

```
Order allow,deny
```

PidFile

The `PidFile` directive allows you to specify a file to which the process ID (PID) of the server is stored. It takes the following form:

```
PidFile path
```

The `path` refers to a pid file, and can be either absolute, or relative to the directory that is specified by the `ServerRoot` directive (that is, `/etc/httpd/` by default). The default option is `run/httpd.pid`.

Example 14.54. Using the PidFile directive

```
PidFile run/httpd.pid
```

ProxyRequests

The `ProxyRequests` directive allows you to enable forward proxy requests. It takes the following form:

```
ProxyRequests option
```

The `option` has to be a valid keyword as described in Table 14.15, "Available ProxyRequests options". The default option is `Off`.

Table 14.15. Available ProxyRequests options

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>On</td>
<td>Enables forward proxy requests.</td>
</tr>
<tr>
<td>off</td>
<td>Disables forward proxy requests.</td>
</tr>
</tbody>
</table>

Example 14.55. Using the ProxyRequests directive

```
ProxyRequests On
```

ReadmeName

The `ReadmeName` directive allows you to specify a file to be appended to the end of the server-generated directory listing. It takes the following form:
ReadmeName *filename*

The *filename* is a name of the file to look for in the requested directory. By default, the server looks for README.html.

**Example 14.56. Using the ReadmeName directive**

```
ReadmeName README.html
```

### Redirect

The **Redirect** directive allows you to redirect a client to another URL. It takes the following form:

```
Redirect [status] path url
```

The *status* is optional, and if provided, it has to be a valid keyword as described in Table 14.16, "Available status options". The *path* refers to the old location, and must be relative to the directory specified by the **DocumentRoot** directive (for example, /docs). The *url* refers to the current location of the content (for example, http://docs.example.com).

**Table 14.16. Available status options**

<table>
<thead>
<tr>
<th>Status</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>permanent</td>
<td>Indicates that the requested resource has been moved permanently. The 301 (Moved Permanently) status code is returned to a client.</td>
</tr>
<tr>
<td>temp</td>
<td>Indicates that the requested resource has been moved only temporarily. The 302 (Found) status code is returned to a client.</td>
</tr>
<tr>
<td>seeother</td>
<td>Indicates that the requested resource has been replaced. The 303 (See Other) status code is returned to a client.</td>
</tr>
<tr>
<td>gone</td>
<td>Indicates that the requested resource has been removed permanently. The 410 (Gone) status is returned to a client.</td>
</tr>
</tbody>
</table>

Note that for more advanced redirection techniques, you can use the **mod_rewrite** module that is part of the Apache HTTP Server installation.

**Example 14.57. Using the Redirect directive**

```
Redirect permanent /docs http://docs.example.com
```

### ScriptAlias

The **ScriptAlias** directive allows you to specify the location of CGI scripts. It takes the following form:

```
ScriptAlias url-path real-path
```

The *url-path* must be relative to the directory specified by the **DocumentRoot** directive (for example, /cgi-bin/). The *real-path* is a full path to a file or directory in the local file system.

This directive is typically followed by the **Directory** tag with additional permissions to access the target directory. By default, the /cgi-bin/ alias is created so that the scripts located in the /var/www/cgi-bin/ are accessible.

The **ScriptAlias** directive is used for security reasons to prevent CGI scripts from being viewed as ordinary text documents.

**Example 14.58. Using the ScriptAlias directive**

```
<Directory "/var/www/cgi-bin"/
  AllowOverride None
  Options None
  Order allow,deny
  Allow from all
</Directory>
```

### ServerAdmin

The **ServerAdmin** directive allows you to specify the email address of the server administrator to be displayed in server-generated web pages. It takes the following form:

```
ServerAdmin email
```

The default option is root@localhost.

This directive is commonly set to webmaster@hostname, where hostname is the address of the server. Once set, alias webmaster to the person responsible for the web server in /etc/aliases, and as superuser, run the `newaliases` command.
Example 14.59. Using the ServerAdmin directive

```
ServerAdmin webmaster@penguin.example.com
```

**ServerName**

The **ServerName** directive allows you to specify the hostname and the port number of a web server. It takes the following form:

```
ServerName hostname[:port]
```

The **hostname** has to be a fully qualified domain name (FQDN) of the server. The **port** is optional, but when supplied, it has to match the number specified by the **Listen** directive.

When using this directive, make sure that the IP address and server name pair are included in the `/etc/hosts` file.

Example 14.60. Using the ServerName directive

```
ServerName penguin.example.com:80
```

**ServerRoot**

The **ServerRoot** directive allows you to specify the directory in which the server operates. It takes the following form:

```
ServerRoot directory
```

The **directory** must be a full path to an existing directory in the local file system. The default option is `/etc/httpd/`.

Example 14.61. Using the ServerRoot directive

```
ServerRoot /etc/httpd
```

**ServerSignature**

The **ServerSignature** directive allows you to enable displaying information about the server on server-generated documents. It takes the following form:

```
ServerSignature option
```

The **option** has to be a valid keyword as described in Table 14.17, "Available ServerSignature options". The default option is **On**.

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>On</td>
<td>Enables appending the server name and version to server-generated pages.</td>
</tr>
<tr>
<td>Off</td>
<td>Disables appending the server name and version to server-generated pages.</td>
</tr>
<tr>
<td>EMai</td>
<td>Enables appending the server name, version, and the email address of the system administrator as specified by the <strong>ServerAdmin</strong> directive to server-generated pages.</td>
</tr>
</tbody>
</table>

Example 14.62. Using the ServerSignature directive

```
ServerSignature On
```

**ServerTokens**

The **ServerTokens** directive allows you to customize what information are included in the Server response header. It takes the following form:

```
ServerTokens option
```

The **option** has to be a valid keyword as described in Table 14.18, "Available ServerTokens options". The default option is **OS**.

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prod</td>
<td>Includes the product name only (that is, Apache).</td>
</tr>
<tr>
<td>Major</td>
<td>Includes the product name and the major version of the server (for example, 2).</td>
</tr>
<tr>
<td>Minor</td>
<td>Includes the product name and the minor version of the server (for example, 2.2).</td>
</tr>
<tr>
<td>Min</td>
<td>Includes the product name and the minimal version of the server (for example, 2.2.15).</td>
</tr>
<tr>
<td>OS</td>
<td>Includes the product name, the minimal version of the server, and the type of the operating system it is running on (for example, Red Hat).</td>
</tr>
<tr>
<td>Full</td>
<td>Includes all the information above along with the list of loaded modules.</td>
</tr>
</tbody>
</table>
Note that for security reasons, it is recommended to reveal as little information about the server as possible.

**Example 14.63. Using the ServerTokens directive**
```
ServerTokens Prod
```

**SuexecUserGroup**

The `SuexecUserGroup` directive allows you to specify the user and group under which the CGI scripts will be run. It takes the following form:
```
SuexecUserGroup user group
```

The *user* has to be an existing user, and the *group* must be a valid UNIX group.

For security reasons, the CGI scripts should not be run with *root* privileges. Note that in `<VirtualHost>`, `SuexecUserGroup` replaces the *User* and *Group* directives.

**Example 14.64. Using the SuexecUserGroup directive**
```
SuexecUserGroup apache apache
```

**Timeout**

The `Timeout` directive allows you to specify the amount of time to wait for an event before closing a connection. It takes the following form:
```
Timeout time
```

The *time* is specified in seconds. The default option is 60.

**Example 14.65. Using the Timeout directive**
```
Timeout 60
```

**TypesConfig**

The `TypesConfig` allows you to specify the location of the MIME types configuration file. It takes the following form:
```
TypesConfig path
```

The *path* refers to an existing MIME types configuration file, and can be either absolute, or relative to the directory that is specified by the `ServerRoot` directive (that is, `/etc/httpd/` by default). The default option is `/etc/mime.types`.

Note that instead of editing `/etc/mime.types`, the recommended way to add MIME type mapping to the Apache HTTP Server is to use the `AddType` directive.

**Example 14.66. Using the TypesConfig directive**
```
TypesConfig /etc/mime.types
```

**UseCanonicalName**

The `UseCanonicalName` allows you to specify the way the server refers to itself. It takes the following form:
```
UseCanonicalName option
```

The *option* has to be a valid keyword as described in Table 14.19, "Available UseCanonicalName options". The default option is *Off*.

**Table 14.19. Available UseCanonicalName options**

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>On</td>
<td>Enables the use of the name that is specified by the <code>ServerName</code> directive.</td>
</tr>
<tr>
<td>Off</td>
<td>Disables the use of the name that is specified by the <code>ServerName</code> directive. The hostname and port number provided by the requesting client are used instead.</td>
</tr>
<tr>
<td>DNS</td>
<td>Disables the use of the name that is specified by the <code>ServerName</code> directive. The hostname determined by a reverse DNS lookup is used instead.</td>
</tr>
</tbody>
</table>

**Example 14.67. Using the UseCanonicalName directive**
```
UseCanonicalName Off
```

**User**

The `User` directive allows you to specify the user under which the *httpd* service will run. It takes the following form:
```
User
```
The user has to be an existing UNIX user. The default option is apache.

For security reasons, the httpd service should not be run with root privileges. Note that User is no longer supported inside <VirtualHost>, and has been replaced by the SuexecUserGroup directive.

Example 14.68. Using the User directive

```
User apache
```

UserDir

The UserDir directive allows you to enable serving content from users' home directories. It takes the following form:

```
UserDir option
```

The option can be either a name of the directory to look for in user's home directory (typically public_html), or a valid keyword as described in Table 14.20, “Available UserDir options”. The default option is disabled.

Table 14.20. Available UserDir options

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>enabled user...</td>
<td>Enables serving content from home directories of given users.</td>
</tr>
<tr>
<td>disabled [user...]</td>
<td>Disables serving content from home directories, either for all users, or, if a space separated list of users is supplied, for given users only.</td>
</tr>
</tbody>
</table>

Set the correct permissions

In order for the web server to access the content, the permissions on relevant directories and files must be set correctly. Make sure that all users are able to access the home directories, and that they can access and read the content of the directory specified by the UserDir directive. For example, to allow access to public_html/ in the home directory of user joe, type the following at a shell prompt as root:

```
~]# chmod a+x /home/joe/
~]# chmod a+rx /home/joe/public_html/
```

All files in this directory must be set accordingly.

Example 14.69. Using the UserDir directive

```
UserDir public_html
```

14.1.5.2. Common ssl.conf Directives

The Secure Sockets Layer (SSL) directives allow you to customize the behavior of the Apache HTTP Secure Server, and in most cases, they are configured appropriately during the installation. Be careful when changing these settings, as incorrect configuration can lead to security vulnerabilities.

The following directive is commonly used in /etc/httpd/conf.d/ssl.conf:

SetEnvIf

The SetEnvIf directive allows you to set environment variables based on the headers of incoming connections. It takes the following form:

```
SetEnvIf option pattern [!]variable[=value]...
```

The option can be either a HTTP header field, a previously defined environment variable name, or a valid keyword as described in Table 14.21, “Available SetEnvIf options”. The pattern is a regular expression. The variable is an environment variable that is set when the option matches the pattern. If the optional exclamation mark (that is, !) is present, the variable is removed instead of being set.

Table 14.21. Available SetEnvIf options

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remote_Host</td>
<td>Refers to the client's hostname.</td>
</tr>
<tr>
<td>Remote.Addr</td>
<td>Refers to the client's IP address.</td>
</tr>
<tr>
<td>Server.Addr</td>
<td>Refers to the server's IP address.</td>
</tr>
<tr>
<td>Request_Method</td>
<td>Refers to the request method (for example, GET).</td>
</tr>
<tr>
<td>Request_Protocol</td>
<td>Refers to the protocol name and version (for example, HTTP/1.1).</td>
</tr>
<tr>
<td>Request_URI</td>
<td>Refers to the requested resource.</td>
</tr>
</tbody>
</table>

The SetEnvIf directive is used to disable HTTP keepalives, and to allow SSL to close the connection without a closing notification from the client browser. This is necessary for certain web browsers that do not reliably shut down the SSL connection.
Example 14.70. Using the SetEnvIf directive

SetEnvIf User-Agent ".*MSIE.*" nokeepalive ssl-unclean-shutdown downgrade-1.0 force-response-1.0

Note that for the /etc/httpd/conf.d/ssl.conf file to be present, the mod_ssl needs to be installed. Refer to Section 14.1.8, "Setting Up an SSL Server" for more information on how to install and configure an SSL server.

14.1.5.3. Common Multi-Processing Module Directives

The Multi-Processing Module (MPM) directives allow you to customize the behavior of a particular MPM specific server-pool. Since its characteristics differ depending on which MPM is used, the directives are embedded in IfModule. By default, the server-pool is defined for both the prefork and worker MPMs.

The following MPM directives are commonly used in /etc/httpd/conf/httpd.conf:

MaxClients
The MaxClients directive allows you to specify the maximum number of simultaneously connected clients to process at one time. It takes the following form:

MaxClients number

A high number can improve the performance of the server, although it is not recommended to exceed 256 when using the prefork MPM.

Example 14.71. Using the MaxClients directive

MaxClients 256

MaxRequestsPerChild
The MaxRequestsPerChild directive allows you to specify the maximum number of request a child process can serve before it dies. It takes the following form:

MaxRequestsPerChild number

Setting the number to 0 allows unlimited number of requests.

The MaxRequestsPerChild directive is used to prevent long-lived processes from causing memory leaks.

Example 14.72. Using the MaxRequestsPerChild directive

MaxRequestsPerChild 4000

MaxSpareServers
The MaxSpareServers directive allows you to specify the maximum number of spare child processes. It takes the following form:

MaxSpareServers number

This directive is used by the prefork MPM only.

Example 14.73. Using the MaxSpareServers directive

MaxSpareServers 20

MaxSpareThreads
The MaxSpareThreads directive allows you to specify the maximum number of spare server threads. It takes the following form:

MaxSpareThreads number

The number must be greater than or equal to the sum of MinSpareThreads and ThreadsPerChild. This directive is used by the worker MPM only.

Example 14.74. Using the MaxSpareThreads directive

MaxSpareThreads 75

MinSpareServers
The MinSpareServers directive allows you to specify the minimum number of spare child processes. It takes the following form:
MinSpareServers number
Note that a high number can create a heavy processing load on the server. This directive is used by the prefork MPM only.

Example 14.75. Using the MinSpareServers directive
MinSpareServers 5

MinSpareThreads
The MinSpareThreads directive allows you to specify the minimum number of spare server threads. It takes the following form:

MinSpareThreads number
This directive is used by the worker MPM only.

Example 14.76. Using the MinSpareThreads directive
MinSpareThreads 75

StartServers
The StartServers directive allows you to specify the number of child processes to create when the service is started. It takes the following form:

StartServers number
Since the child processes are dynamically created and terminated according to the current traffic load, it is usually not necessary to change this value.

Example 14.77. Using the StartServers directive
StartServers 8

ThreadsPerChild
The ThreadsPerChild directive allows you to specify the number of threads a child process can create. It takes the following form:

ThreadsPerChild number
This directive is used by the worker MPM only.

Example 14.78. Using the ThreadsPerChild directive
ThreadsPerChild 25

14.1.6. Working with Modules
Being a modular application, the httpd service is distributed along with a number of Dynamic Shared Objects (DSOs), which can be dynamically loaded or unloaded at runtime as necessary. By default, these modules are located in /usr/lib/httpd/modules/ on 32-bit and in /usr/lib64/httpd/modules/ on 64-bit systems.

14.1.6.1. Loading a Module
To load a particular DSO module, use the LoadModule directive as described in Section 14.1.5.1, "Common httpd.conf Directives". Note that modules provided by a separate package often have their own configuration file in the /etc/httpd/conf.d/ directory.

Example 14.79. Loading the mod_ssl DSO
LoadModule ssl_module modules/mod_ssl.so

Once you are finished, restart the web server to reload the configuration. Refer to Section 14.1.4.3, "Restarting the Service" for more information on how to restart the httpd service.

14.1.6.2. Writing a Module
If you intend to create a new DSO module, make sure you have the httpd-devel package installed. To do so, type the following at a shell prompt as root:

yum install httpd-devel

This package contains the include files, the header files, and the Apache eXtenSion (apxs) utility required to compile a
module.

Once written, you can build the module with the following command:

```bash
apxs -i -a -c module_name.c
```

If the build was successful, you should be able to load the module the same way as any other module that is distributed with the Apache HTTP Server.

14.1.7. Setting Up Virtual Hosts

The Apache HTTP Server's built-in virtual hosting allows the server to provide different information based on which IP address, hostname, or port is being requested.

To create a name-based virtual host, find the virtual host container provided in `/etc/httpd/conf/httpd.conf` as an example, remove the hash sign (that is, #) from the beginning of each line, and customize the options according to your requirements as shown in Example 14.80, "Sample virtual host configuration".

**Example 14.80. Sample virtual host configuration**

```html
NameVirtualHost penguin.example.com:80
<VirtualHost penguin.example.com:80>
  ServerAdmin webmaster@penguin.example.com
  DocumentRoot /www/docs/penguin.example.com
  ServerName penguin.example.com:80
  ErrorLog logs/penguin.example.com-error_log
  CustomLog logs/penguin.example.com-access_log common
</VirtualHost>
```

Note that `ServerName` must be a valid DNS name assigned to the machine. The `<VirtualHost>` container is highly customizable, and accepts most of the directives available within the main server configuration. Directives that are not supported within this container include `User` and `Group`, which were replaced by `SuexecUserGroup`.

Changing the port number

If you configure a virtual host to listen on a non-default port, make sure you update the `Listen` directive in the global settings section of the `/etc/httpd/conf/httpd.conf` file accordingly.

To activate a newly created virtual host, the web server has to be restarted first. Refer to Section 14.1.4.3, "Restarting the Service" for more information on how to restart the `httpd` service.

14.1.8. Setting Up an SSL Server

Secure Sockets Layer (SSL) is a cryptographic protocol that allows a server and a client to communicate securely. Along with its extended and improved version called Transport Layer Security (TLS), it ensures both privacy and data integrity.

The Apache HTTP Server in combination with `mod_ssl`, a module that uses the OpenSSL toolkit to provide the SSL/TLS support, is commonly referred to as the SSL server.

Unlike a regular HTTP connection that can be read and possibly modified by anybody who is able to intercept it, the use of `mod_ssl` prevents any inspection or modification of the transmitted content. This section provides basic information on how to enable this module in the Apache HTTP Server configuration, and guides you through the process of generating private keys and self-signed certificates.

14.1.8.1. An Overview of Certificates and Security

Secure communication is based on the use of keys. In conventional or symmetric cryptography, both ends of the transaction have the same key they can use to decode each other's transmissions. On the other hand, in public or asymmetric cryptography, two keys co-exist: a private key that is kept a secret, and a public key that is usually shared with the public. While the data encoded with the public key can only be decoded with the private key, data encoded with the private key can in turn only be decoded with the public key.

To provide secure communications using SSL, an SSL server must use a digital certificate signed by a Certificate Authority (CA). The certificate lists various attributes of the server (that is, the server hostname, the name of the company, its location, etc.), and the signature produced using the CA's private key. This signature ensures that a particular certificate authority has issued the certificate, and that the certificate has not been modified in any way.

When a web browser establishes a new SSL connection, it checks the certificate provided by the web server. If the certificate does not have a signature from a trusted CA, or if the hostname listed in the certificate does not match the hostname used to establish the connection, it refuses to communicate with the server and usually presents a user with an appropriate error message.

By default, most web browsers are configured to trust a set of widely used certificate authorities. Because of this, an appropriate CA should be chosen when setting up a secure server, so that target users can trust the connection, otherwise they will be presented with an error message, and will have to accept the certificate manually. Since encouraging users to override certificate errors can allow an attacker to intercept the connection, you should use a trusted CA whenever possible. For more information on this, see Table 14.22, "CA lists for most common web browsers".
### Table 14.22. CA lists for most common web browsers

<table>
<thead>
<tr>
<th>Web Browser</th>
<th>Link</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mozilla Firefox</td>
<td>Mozilla root CA list</td>
</tr>
<tr>
<td>Opera</td>
<td>The Opera Rootstore</td>
</tr>
<tr>
<td>Internet Explorer</td>
<td>Windows root certificate program members</td>
</tr>
</tbody>
</table>

When setting up an SSL server, you need to generate a certificate request and a private key, and then send the certificate request, proof of the company's identity, and payment to a certificate authority. Once the CA verifies the certificate request and your identity, it will send you a signed certificate you can use with your server. Alternatively, you can create a self-signed certificate that does not contain a CA signature, and thus should be used for testing purposes only.

#### 14.1.8.2. Enabling the mod_ssl Module

If you intend to set up an SSL server, make sure you have the `mod_ssl` (the `mod_ssl` module) and `openssl` (the OpenSSL toolkit) packages installed. To do so, type the following at a shell prompt as `root`:

```bash
yum install mod_ssl openssl
```

This will create the `mod_ssl` configuration file at `/etc/httpd/conf.d/ssl.conf`, which is included in the main Apache HTTP Server configuration file by default. For the module to be loaded, restart the `httpd` service as described in Section 14.1.4.3, "Restarting the Service".

#### 14.1.8.3. Using an Existing Key and Certificate

If you have a previously created key and certificate, you can configure the SSL server to use these files instead of generating new ones. There are only two situations where this is not possible:

1. **You are changing the IP address or domain name.**
   
   Certificates are issued for a particular IP address and domain name pair. If one of these values changes, the certificate becomes invalid.

2. **You have a certificate from VeriSign, and you are changing the server software.**
   
   VeriSign, a widely used certificate authority, issues certificates for a particular software product, IP address, and domain name. Changing the software product renders the certificate invalid.

In either of the above cases, you will need to obtain a new certificate. For more information on this topic, refer to Section 14.1.8.4, "Generating a New Key and Certificate".

If you wish to use an existing key and certificate, move the relevant files to the `/etc/pki/tls/private/` and `/etc/pki/tls/certs/` directories respectively. You can do so by running the following commands as `root`:

```bash
mv key_file.key /etc/pki/tls/private/hostname.key
mv certificate.crt /etc/pki/tls/certs/hostname.crt
```

Then add the following lines to the `/etc/httpd/conf.d/ssl.conf` configuration file:

```conf
SSLCertificateFile /etc/pki/tls/certs/hostname.crt
SSLCertificateKeyFile /etc/pki/tls/private/hostname.key
```

To load the updated configuration, restart the `httpd` service as described in Section 14.1.4.3, "Restarting the Service".

#### Example 14.81. Using a key and certificate from the Red Hat Secure Web Server

```bash
~]# mv /etc/httpd/conf/httpsd.key /etc/pki/tls/private/penguin.example.com.key
~]# mv /etc/httpd/conf/httpsd.crt /etc/pki/tls/certs/penguin.example.com.crt
```

#### 14.1.8.4. Generating a New Key and Certificate

In order to generate a new key and certificate pair, you must to have the `crypto-utils` package installed in your system. As `root`, you can install it by typing the following at a shell prompt:

```bash
yum install crypto-utils
```

This package provides a set of tools to generate and manage SSL certificates and private keys, and includes `genkey`, the Red Hat Keypair Generation utility that will guide you through the key generation process.

### Replacing an existing certificate

If the server already has a valid certificate and you are replacing it with a new one, specify a different serial number. This ensures that client browsers are notified of this change, update to this new certificate as expected, and do not fail to access the page. To create a new certificate with a custom serial number, as `root`, use the following command instead of `genkey`:

```bash
openssl req -x509 -new -set_serial_number -key hostname.key -out hostname.crt
```
Remove a previously created key

If there already is a key file for a particular hostname in your system, `genkey` will refuse to start. In this case, remove the existing file using the following command as `root`:

```bash
rm /etc/pki/tls/private/hostname.key
```

To run the utility, as `root`, run the `genkey` command followed by the appropriate hostname (for example, `penguin.example.com`):

```
genkey hostname
```

To complete the key and certificate creation, take the following steps:

1. Review the target locations in which the key and certificate will be stored.

   ![Figure 14.1. Running the genkey utility](image)

   Use the Tab key to select the Next button, and press Enter to proceed to the next screen.

2. Using the Up and down arrow keys, select the suitable key size. Note that while the large key increases the security, it also increases the response time of your server. Because of this, the recommended option is **1024 bits**.

   ![Figure 14.2. Selecting the key size](image)

   Once finished, use the Tab key to select the Next button, and press Enter to initiate the random bits generation process. Depending on the selected key size, this may take some time.

3. Decide whether you wish to send a certificate request to a certificate authority.
Use the Tab key to select Yes to compose a certificate request, or No to generate a self-signed certificate. Then press Enter to confirm your choice.

4. Using the Spacebar key, enable ([*]) or disable ([ ] ) the encryption of the private key.

Use the Tab key to select the Next button, and press Enter to proceed to the next screen.

5. If you have enabled the private key encryption, enter an adequate passphrase. Note that for security reasons, it is not displayed as you type, and it must be at least five characters long.

Use the Tab key to select the Next button, and press Enter to proceed to the next screen.

Do not forget the passphrase

Entering the correct passphrase is required in order for the server to start. If you lose it, you will need to generate a new key and certificate.

6. Customize the certificate details.
Use the Tab key to select the Next button, and press Enter to finish the key generation.

7. If you have previously enabled the certificate request generation, you will be prompted to send it to a certificate authority.

Once generated, add the key and certificate locations to the /etc/httpd/conf.d/ssl.conf configuration file:

SSLCertificateFile /etc/pki/tls/certs/hostname.crt
SSLCertificateKeyFile /etc/pki/tls/private/hostname.key

Finally, restart the httpd service as described in Section 14.1.4.3, "Restarting the Service", so that the updated configuration is loaded.

14.1.9. Additional Resources

To learn more about the Apache HTTP Server, refer to the following resources.

14.1.9.1. Installed Documentation

http://localhost/manual/

The official documentation for the Apache HTTP Server with the full description of its directives and available modules. Note that in order to access this documentation, you must have the httpd-manual package installed, and the web server must be running.

man httpd

The manual page for the httpd service containing the complete list of its command line options.

man genkey

The manual page for genkey containing the full documentation on its usage.

14.1.9.2. Useful Websites

http://httpd.apache.org/

The official website for the Apache HTTP Server with documentation on all the directives and default modules.

http://www.modssl.org/
Email was born in the 1960s. The mailbox was a file in a user's home directory that was readable only by that user. Primitive mail applications appended new text messages to the bottom of the file, making the user wade through the constantly growing file to find any particular message. This system was only capable of sending messages to users on the same system.

The first network transfer of an electronic mail message file took place in 1971 when a computer engineer named Ray Tomlinson sent a test message between two machines via ARPANET—the precursor to the Internet. Communication via email soon became very popular, comprising 75 percent of ARPANET's traffic in less than two years.

Today, email systems based on standardized network protocols have evolved into some of the most widely used services on the Internet. Fedora offers many advanced applications to serve and access email.

This chapter reviews modern email protocols in use today, and some of the programs designed to send and receive email.

15.1. Email Protocols

Today, email is delivered using a client/server architecture. An email message is created using a mail client program. This program then sends the message to a server. The server then forwards the message to the recipient's email server, where the message is then supplied to the recipient's email client.

To enable this process, a variety of standard network protocols allow different machines, often running different operating systems and using different email programs, to send and receive email.

The following protocols discussed are the most commonly used in the transfer of email.

15.1.1. Mail Transport Protocols

Mail delivery from a client application to the server, and from an originating server to the destination server, is handled by the Simple Mail Transfer Protocol (SMTP).

15.1.1.1. SMTP

The primary purpose of SMTP is to transfer email between mail servers. However, it is critical for email clients as well. To send email, the client sends the message to an outgoing mail server, which in turn contacts the destination mail server for delivery. For this reason, it is necessary to specify an SMTP server when configuring an email client.

Under Fedora, a user can configure an SMTP server on the local machine to handle mail delivery. However, it is also possible to configure remote SMTP servers for outgoing mail.
One important point to make about the SMTP protocol is that it does not require authentication. This allows anyone on the Internet to send email to anyone else or even to large groups of people. It is this characteristic of SMTP that makes junk email or spam possible. Imposing relay restrictions limits random users on the Internet from sending email through your SMTP server, to other servers on the Internet. Servers that do not impose such restrictions are called open relay servers. Fedora provides the Postfix and Sendmail SMTP programs.

### 15.1.2. Mail Access Protocols

There are two primary protocols used by email client applications to retrieve email from mail servers: the Post Office Protocol (POP) and the Internet Message Access Protocol (IMAP).

#### 15.1.2.1. POP

The default POP server under Fedora is **Dovecot** and is provided by the dovecot package.

**Installing the dovecot package**

In order to use **Dovecot**, first ensure the **dovecot** package is installed on your system by running, as **root**:

```
yum install dovecot
```

For more information on installing packages with Yum, refer to Section 5.2.4, “Installing Packages”.

When using a POP server, email messages are downloaded by email client applications. By default, most POP email clients are automatically configured to delete the message on the email server after it has been successfully transferred, however this setting usually can be changed.

POP is fully compatible with important Internet messaging standards, such as **Multipurpose Internet Mail Extensions (MIME)**, which allow for email attachments.

POP works best for users who have one system on which to read email. It also works well for users who do not have a persistent connection to the Internet or the network containing the mail server. Unfortunately for those with slow network connections, POP requires client programs upon authentication to download the entire content of each message. This can take a long time if any messages have large attachments.

The most current version of the standard POP protocol is **POP3**.

There are, however, a variety of lesser-used POP protocol variants:

- **APOP** — POP3 with **MDS** (Monash Directory Service) authentication. An encoded hash of the user's password is sent from the email client to the server rather than sending an unencrypted password.
- **KPOP** — POP3 with Kerberos authentication.
- **RPOP** — POP3 with **RPOP** authentication. This uses a per-user ID, similar to a password, to authenticate POP requests. However, this ID is not encrypted, so RPOP is no more secure than standard POP.

For added security, it is possible to use **Secure Socket Layer (SSL)** encryption for client authentication and data transfer sessions. This can be enabled by using the **pop3s** service, or by using the `/usr/sbin/stunnel` application. For more information on securing email communication, refer to Section 15.5.1, “Securing Communication”.

#### 15.1.2.2. IMAP

The default **IMAP** server under Fedora is **Dovecot** and is provided by the dovecot package. Refer to Section 15.1.2.1, “POP” for information on how to install **Dovecot**.

When using an IMAP mail server, email messages remain on the server where users can read or delete them. IMAP also allows client applications to create, rename, or delete mail directories on the server to organize and store email.

**IMAP** is particularly useful for users who access their email using multiple machines. The protocol is also convenient for users connecting to the mail server via a slow connection, because only the email header information is downloaded for messages until opened, saving bandwidth. The user also has the ability to delete messages without viewing or downloading them.

For convenience, IMAP client applications are capable of caching copies of messages locally, so the user can browse previously read messages when not directly connected to the IMAP server.

**IMAP**, like POP, is fully compatible with important Internet messaging standards, such as MIME, which allow for email attachments.

For added security, it is possible to use **SSL** encryption for client authentication and data transfer sessions. This can be enabled by using the **imaps** service, or by using the `/usr/sbin/stunnel` program. For more information on securing email communication, refer to Section 15.5.1, “Securing Communication”.

Other free, as well as commercial, IMAP clients and servers are available, many of which extend the IMAP protocol and provide additional functionality.

#### 15.1.2.3. Dovecot

The **imap-login** and **pop3-login** processes which implement the **IMAP** and **POP3** protocols are spawned by the master **dovecot** daemon included in the dovecot package. The use of **IMAP** and **POP** is configured through the `/etc/dovecot/dovecot.conf` configuration file; by default **dovecot** runs **IMAP** and **POP3** together with their secure versions using **SSL**. To configure **dovecot** to use **POP**, complete the following steps:
MUAs may be graphical, such as applications to access.

A program to access.

A Mail User Agent (MUA) is synonymous with an email client application. An MUA is a program that, at the very least, allows a user to read and compose email messages. Many MUAs are capable of retrieving messages via the POP or IMAP protocols, setting up mailboxes to store messages, and sending outbound messages to an MTA.

MUAs may be graphical, such as Evolution, or have simple text-based interfaces, such as pine.

15.2. Email Program Classifications

In general, all email applications fall into at least one of three classifications. Each classification plays a specific role in the process of moving and managing email messages. While most users are only aware of the specific email program they use to receive and send messages, each one is important for ensuring that email arrives at the correct destination.

15.2.1. Mail Transport Agent

A Mail Transport Agent (MTA) transports email messages between hosts using SMTP. A message may involve several MTAs as it moves to its intended destination.

While the delivery of messages between machines may seem rather straightforward, the entire process of deciding if a particular MTA can or should accept a message for delivery is quite complicated. In addition, due to problems from spam, use of a particular MTA is usually restricted by the MTA's configuration or the access configuration for the network on which the MTA resides.

Many modern email client programs can act as an MTA when sending email. However, this action should not be confused with the role of a true MTA. The sole reason email client programs are capable of sending email like an MTA is because the host running the application does not have its own MTA. This is particularly true for email client programs on non-UNIX-based operating systems. However, these client programs only send outbound messages to an MTA they are authorized to use and do not directly deliver the message to the intended recipient's email server.

Since Fedora offers two MTAs—Postfix and Sendmail—email client programs are often not required to act as an MTA. Fedora also includes a special purpose MTA called Fetchmail.

For more information on Postfix, Sendmail, and Fetchmail, refer to Section 15.3, "Mail Transport Agents".

15.2.2. Mail Delivery Agent

A Mail Delivery Agent (MDA) is invoked by the MTA to file incoming email in the proper user's mailbox. In many cases, the MDA is actually a Local Delivery Agent (LDA), such as Mail or Procmail.

Any program that actually handles a message for delivery to the point where it can be read by an email client application can be considered an MDA. For this reason, some MTAs (such as Sendmail and Postfix) can fill the role of an MDA when they append new email messages to a local user's mail spool file. In general, MDAs do not transport messages between systems nor do they provide a user interface; MDAs distribute and sort messages on the local machine for an email client application to access.

15.2.3. Mail User Agent

A Mail User Agent (MUA) is a program that, at the very least, allows a user to read and compose email messages. Many MUAs are capable of retrieving messages via the POP or IMAP protocols, setting up mailboxes to store messages, and sending outbound messages to an MTA.

MUAs may be graphical, such as Evolution, or have simple text-based interfaces, such as pine.
15.3. Mail Transport Agents
Fedora offers two primary MTAs: Postfix and Sendmail. Postfix is configured as the default MTA, although it is easy to switch the default MTA to Sendmail. To switch the default MTA to Sendmail, as root, you can either uninstall Postfix or use the following command to switch to Sendmail:

```
alternatives --config mta
```

You can also use the following command to enable/disable the desired service:

```
systemctl enable|disable service.service
```

15.3.1. Postfix
Originally developed at IBM by security expert and programmer Wietse Venema, Postfix is a Sendmail-compatible MTA that is designed to be secure, fast, and easy to configure.

To improve security, Postfix uses a modular design, where small processes with limited privileges are launched by a master daemon. The smaller, less privileged processes perform very specific tasks related to the various stages of mail delivery and run in a change rooted environment to limit the effects of attacks.

Configuring Postfix to accept network connections from hosts other than the local computer takes only a few minor changes in its configuration file. Yet for those with more complex needs, Postfix provides a variety of configuration options, as well as third party add-ons that make it a very versatile and full-featured MTA.

The configuration files for Postfix are human-readable and support upward of 250 directives. Unlike Sendmail, no macro processing is required for changes to take effect and the majority of the most commonly used options are described in the heavily commented files.

15.3.1.1. The Default Postfix Installation
The Postfix executable is `/usr/sbin/postfix`. This daemon launches all related processes needed to handle mail delivery.

Postfix stores its configuration files in the `/etc/postfix/` directory. The following is a list of the more commonly used files:

- **access** — Used for access control, this file specifies which hosts are allowed to connect to Postfix.
- **main.cf** — The global Postfix configuration file. The majority of configuration options are specified in this file.
- **master.cf** — Specifies how Postfix interacts with various processes to accomplish mail delivery.
- **transport** — Maps email addresses to relay hosts.

The **aliases** file can be found in the `/etc/` directory. This file is shared between Postfix and Sendmail. It is a configurable list required by the mail protocol that describes user ID aliases.

### Configuring Postfix as a server for other clients
The default `/etc/postfix/main.cf` file does not allow Postfix to accept network connections from a host other than the local computer. For instructions on configuring Postfix as a server for other clients, refer to Section 15.3.1.2, "Basic Postfix Configuration".

```
systemctl restart postfix.service
```

15.3.1.2. Basic Postfix Configuration
By default, Postfix does not accept network connections from any host other than the local host. Perform the following steps as root to enable mail delivery for other hosts on the network:

- **Edit** the `/etc/postfix/main.cf` file with a text editor, such as `vi`
- **Uncomment** the `mydomain` line by removing the hash sign (`#`), and replace `domain.tld` with the domain the mail server is servicing, such as `example.com`.
- **Uncomment** the `myorigin = $mydomain` line.
- **Uncomment** the `myhostname` line, and replace `host.domain.tld` with the hostname for the machine.
- **Uncomment** the `mydestination = $myhostname, localhost.$mydomain` line.
- **Uncomment** the `mynetworks` line, and replace `168.100.189.0/28` with a valid network setting for hosts that can connect to the server.
- **Uncomment** the `inet_interfaces = all` line.
- **Comment** the `inet_interfaces = localhost` line.
- **Uncomment** the `inet_interfaces = all` line.
- **Comment** the `inet_interfaces = localhost` line.
- **Restart** the `postfix` service.

Once these steps are complete, the host accepts outside emails for delivery.

Postfix has a large assortment of configuration options. One of the best ways to learn how to configure Postfix is to read the comments within the `/etc/postfix/main.cf` configuration file. Additional resources including information about Postfix configuration, SpamAssassin integration, or detailed descriptions of the `/etc/postfix/main.cf` parameters are...
15.3.1.3. Using Postfix with LDAP
Postfix can use an LDAP directory as a source for various lookup tables (e.g. aliases, virtual, canonical, etc.). This allows LDAP to store hierarchical user information and Postfix to only be given the result of LDAP queries when needed. By not storing this information locally, administrators can easily maintain it.

15.3.1.3.1. The /etc/aliases lookup example
The following is a basic example for using LDAP to look up the /etc/aliases file. Make sure your /etc/postfix/main.cf contains the following:

```
alias_maps = hash:/etc/aliases, ldap:/etc/postfix/ldap-aliases.cf
```

Create a /etc/postfix/ldap-aliases.cf file if you do not have one created already and make sure it contains the following:

```
server_host = ldap.example.com
search_base = dc=example, dc=com
```

where ldap.example.com, and com are parameters that need to be replaced with specification of an existing available LDAP server.

**The /etc/postfix/ldap-aliases.cf file**

The /etc/postfix/ldap-aliases.cf file can specify various parameters, including parameters that enable LDAP SSL and STARTTLS. For more information, refer to the ldap_table(5) man page.

For more information on LDAP, refer to Section 16.1, "OpenLDAP".

15.3.2. Sendmail
Sendmail's core purpose, like other MTAs, is to safely transfer email among hosts, usually using the SMTP protocol. However, Sendmail is highly configurable, allowing control over almost every aspect of how email is handled, including the protocol used. Many system administrators elect to use Sendmail as their MTA due to its power and scalability.

15.3.2.1. Purpose and Limitations
It is important to be aware of what Sendmail is and what it can do, as opposed to what it is not. In these days of monolithic applications that fulfill multiple roles, Sendmail may seem like the only application needed to run an email server within an organization. Technically, this is true, as Sendmail can spool mail to each users' directory and deliver outbound mail for users. However, most users actually require much more than simple email delivery. Users usually want to interact with their email using an MUA, that uses POP or IMAP, to download their messages to their local machine. Or, they may prefer a Web interface to gain access to their mailbox. These other applications can work in conjunction with Sendmail, but they actually exist for different reasons and can operate separately from one another.

It is beyond the scope of this section to go into all that Sendmail should or could be configured to do. With literally hundreds of different options and rule sets, entire volumes have been dedicated to helping explain everything that can be done and how to fix things that go wrong. Refer to the Section 15.6, "Additional Resources" for a list of Sendmail resources.

This section reviews the files installed with Sendmail by default and reviews basic configuration changes, including how to stop unwanted email (spam) and how to extend Sendmail with the Lightweight Directory Access Protocol (LDAP).

15.3.2.2. The Default Sendmail Installation
In order to use Sendmail, first ensure the sendmail package is installed on your system by running, as root:

```
yum install sendmail
cy
di
```n
In order to configure Sendmail, ensure the sendmail-cf package is installed on your system by running, as root:

```
yum install sendmail-cf
cy
di
```n
For more information on installing packages with Yum, refer to Section 5.2.4, "Installing Packages".

Before using Sendmail, the default MTA has to be switched from Postfix. For more information how to switch the default MTA refer to Section 15.3, "Mail Transport Agents".

The Sendmail executable is /usr/sbin/sendmail.

Sendmail's lengthy and detailed configuration file is /etc/mail/sendmail.cf. Avoid editing the sendmail.cf file directly. To make configuration changes to Sendmail, edit the /etc/mail/sendmail.mc file, back up the original /etc/mail/sendmail.cf, and use the following alternatives to generate a new configuration file:

- Use the included makemap in /etc/mail/(-j) make all -C /etc/mail/ to create a new /etc/mail/sendmail.cf configuration file. All other generated files in /etc/mail (db files) will be regenerated if needed. The old makemap commands are still usable. The make command will automatically be used by systemctl start|restart|reload sendmail.service.
- Alternatively you may use the m4 macro processor to create a new /etc/mail/sendmail.cf. The m4 macro processor is not installed by default. Before using it to create /etc/mail/sendmail.cf, install the m4 package as root:
yum install m4

More information on configuring Sendmail can be found in Section 15.3.2.3, "Common Sendmail Configuration Changes".

Various Sendmail configuration files are installed in the /etc/mail/ directory including:

- **access** — Specifies which systems can use Sendmail for outbound email.
- **domaintable** — Specifies domain name mapping.
- **local-host-names** — Specifies aliases for the host.
- **mailertable** — Specifies instructions that override routing for particular domains.
- **virtusertable** — Specifies a domain-specific form of aliasing, allowing multiple virtual domains to be hosted on one machine.

Several of the configuration files in /etc/mail/, such as access, domaintable, mailertable and virtusertable, must actually store their information in database files before Sendmail can use any configuration changes. To include any changes made to these configurations in their database files, run the following command, as root:

```
makemap hash /etc/mail/name < /etc/mail/name
```

where name represents the name of the configuration file to be updated. You may also restart the sendmail service for the changes to take effect by running:

```
systemctl restart sendmail.service
```

For example, to have all emails addressed to the example.com domain delivered to bob@other-example.com, add the following line to the virtusertable file:

```
@example.com bob@other-example.com
```

To finalize the change, the virtusertable.db file must be updated:

```
makemap hash /etc/mail/virtusertable < /etc/mail/virtusertable
```

Sendmail will create an updated virtusertable.db file containing the new configuration.

### 15.3.2.3. Common Sendmail Configuration Changes

When altering the Sendmail configuration file, it is best not to edit an existing file, but to generate an entirely new /etc/mail/sendmail.cf file.

**Backup the sendmail.cf file before changing its content**

Before changing the sendmail.cf file, it is a good idea to create a backup copy.

To add the desired functionality to Sendmail, edit the /etc/mail/sendmail.mc file as root. Once you are finished, restart the sendmail service and, if the m4 package is installed, the m4 macro processor will automatically generate a new sendmail.cf configuration file:

```
systemctl restart sendmail.service
```

### Configuring Sendmail as a server for other clients

The default sendmail.cf file does not allow Sendmail to accept network connections from any host other than the local computer. To configure Sendmail as a server for other clients, edit the /etc/mail/sendmail.mc file, and either change the address specified in the Addr= option of the DAEMON_OPTIONS directive from 127.0.0.1 to the IP address of an active network device or comment out the DAEMON_OPTIONS directive altogether by placing dnl at the beginning of the line. When finished, regenerate /etc/mail/sendmail.cf by restarting the service:

```
systemctl restart sendmail.service
```

The default configuration which ships with Fedora works for most SMTP-only sites. However, it does not work for UUCP (UNIX-to-UNIX Copy Protocol) sites. If using UUCP mail transfers, the /etc/mail/sendmail.mc file must be reconfigured and a new /etc/mail/sendmail.cf file must be generated.

Consult the /usr/share/sendmail-cf/README file before editing any files in the directories under the /usr/share/sendmail-cf directory, as they can affect the future configuration of the /etc/mail/sendmail.cf file.

### 15.3.2.4. Masquerading

One common Sendmail configuration is to have a single machine act as a mail gateway for all machines on the network. For instance, a company may want to have a machine called mail.example.com that handles all of their email and assigns a consistent return address to all outgoing mail.

In this situation, the Sendmail server must masquerade the machine names on the company network so that their return address is user@example.com instead of user@host.example.com.

To do this, add the following lines to /etc/mail/sendmail.mc:
Refer to Section 15.3.2.5, "Stopping Spam"

Email spam can be defined as unnecessary and unwanted email received by a user who never requested the communication. It is a disruptive, costly, and widespread abuse of Internet communication standards.

Sendmail makes it relatively easy to block new spamming techniques being employed to send junk email. It even blocks many of the more usual spamming methods by default. Main anti-spam features available in sendmail are header checks, relayed denial (default from version 8.9), access database and sender information checks.

For example, forwarding of SMTP messages, also called relaying, has been disabled by default since Sendmail version 8.9. Before this change occurred, Sendmail directed the mail host (x.edu) to accept messages from one party (y.com) and sent them to a different party (z.net). Now, however, Sendmail must be configured to permit any domain to relay mail through the server. To configure relay domains, edit the /etc/mail/relay-domains file and restart Sendmail:

```
systemctl restart sendmail.service
```

However, many times users are bombarded with spam from other servers throughout the Internet. In these instances, Sendmail's access control features available through the /etc/mail/access file can be used to prevent connections from unwanted hosts. The following example illustrates how this file can be used to both block and specifically allow access to the Sendmail server:

```
FEATURE(always_add_domain)dnl
FEATURE('masquerade_entire_domain')dnl
FEATURE('masquerade_envelope')dnl
FEATURE('allmasquerade')dnl
MASQUERADE_AS(\bigcorp.com.'dnl
MASQUERADE_DOMAIN(\bigcorp.com.'dnl
MASQUERADE_AS(\bigcorp.com.dnl

After generating a new sendmail.cf using the m4 macro processor, this configuration makes all mail from inside the network appear as if it were sent from bigcorp.com.

```
makemap hash /etc/mail/access < /etc/mail/access
```

Message header analysis allows you to reject mail based on header contents. SMTP servers store information about an email’s journey in the message header. As the message travels from one MTA to another, each puts in a Received header above all the other Received headers. It is important to note that this information may be altered by spammers.

The above examples only represent a small part of what Sendmail can do in terms of allowing or blocking access. Refer to the /usr/share/sendmail-cf/README for more information and examples.

Since Sendmail calls the Procmail MDA when delivering mail, it is also possible to use a spam filtering program, such as SpamAssassin, to identify and file spam for users. Refer to Section 15.4.2.6, "Spam Filters" for more information about using SpamAssassin.

15.3.2.6. Using Sendmail with LDAP

Using LDAP is a very quick and powerful way to find specific information about a particular user from a much larger group. For example, an LDAP server can be used to look up a particular email address from a common corporate directory by the user’s last name. In this kind of implementation, LDAP is largely separate from Sendmail, with LDAP storing the hierarchical user information and Sendmail only being given the result of LDAP queries in pre-addressed email messages.

However, Sendmail supports a much greater integration with LDAP, where it uses LDAP to replace separately maintained files, such as /etc/aliases and /etc/mail/virtusertables, on different mail servers that work together to support a medium- to enterprise-level organization. In short, LDAP abstracts the mail routing level from Sendmail and its separate configuration files to a powerful LDAP cluster that can be leveraged by many different applications.

The current version of Sendmail contains support for LDAP. To extend the Sendmail server using LDAP, first get an LDAP server, such as OpenLDAP, running and properly configured. Then edit the /etc/mail/sendmail.mc to include the following:

```
FEATURE('ldap_routing')dnl
```

This is only for a very basic configuration of Sendmail with LDAP. The configuration can differ greatly from this depending on the implementation of LDAP, especially when configuring several Sendmail machines to use a common LDAP server. Consult /usr/share/sendmail-cf/README for detailed LDAP routing configuration instructions and examples.

Next, recreate the /etc/mail/sendmail.cf file by running the m4 macro processor and again restarting Sendmail. Refer to Section 15.3.2.3, "Common Sendmail Configuration Changes" for instructions.
15.3.3. Fetchmail
Fetchmail is an MTA which retrieves email from remote servers and delivers it to the local MTA. Many users appreciate the ability to separate the process of downloading their messages located on a remote server from the process of reading and organizing their email in an MUA. Designed with the needs of dial-up users in mind, Fetchmail connects and quickly downloads all of the email messages to the mail spool file using any number of protocols, including POP3 and IMAP. It can even forward email messages to an SMTP server, if necessary.

Installing the fetchmail package

In order to use Fetchmail, first ensure the fetchmail package is installed on your system by running, as root:

```bash
yum install fetchmail
```
For more information on installing packages with Yum, refer to Section 5.2.4, “Installing Packages”.

Fetchmail is configured for each user through the use of a .fetchmailrc file in the user’s home directory. If it does not already exist, create the .fetchmailrc file in your home directory.

Using preferences in the .fetchmailrc file, Fetchmail checks for email on a remote server and downloads it. It then delivers it to port 25 on the local machine, using the local MTA to place the email in the correct user’s spool file. If Procmail is available, it is launched to filter the email and place it in a mailbox so that it can be read by an MUA.

15.3.3.1. Fetchmail Configuration Options
Although it is possible to pass all necessary options on the command line to check for email on a remote server when executing Fetchmail, using a .fetchmailrc file is much easier. Place any desired configuration options in the .fetchmailrc file for those options to be used each time the fetchmail command is issued. It is possible to override these at the time Fetchmail is run by specifying that option on the command line.

A user’s .fetchmailrc file contains three classes of configuration options:

- **global options** — Gives Fetchmail instructions that control the operation of the program or provide settings for every connection that checks for email.
- **server options** — Specifies necessary information about the server being polled, such as the hostname, as well as preferences for specific email servers, such as the port to check or number of seconds to wait before timing out. These options affect every user using that server.
- **user options** — Contains information, such as username and password, necessary to authenticate and check for email using a specified email server.

Global options appear at the top of the .fetchmailrc file, followed by one or more server options, each of which designate a different email server that Fetchmail should check. User options follow server options for each user account checking that email server. Like server options, multiple user options may be specified for use with a particular server as well as to check multiple email accounts on the same server.

Server options are called into service in the .fetchmailrc file by the use of a special option verb, poll or skip, that precedes any of the server information. The poll action tells Fetchmail to use this server option when it is run, which checks for email using the specified user options. Any server options after a skip action, however, are not checked unless this server’s hostname is specified when Fetchmail is invoked. The skip option is useful when testing configurations in the .fetchmailrc file because it only checks skipped servers when specifically invoked, and does not affect any currently working configurations.

The following is a sample example of a .fetchmailrc file:

```bash
set postmaster "user1"
set bouncemail
   poll pop.domain.com proto pop3
      user 'user1' there with password 'secret' is user1 here
      poll mail.domain2.com
      user 'user1' there with password 'secret2' is user1 here
      user 'user1' there with password 'secret3' is user1 here
```

In this example, the global options specify that the user is sent email as a last resort (postmaster option) and all email errors are sent to the postmaster instead of the sender (bouncemail option). The set action tells Fetchmail that this line contains a global option. Then, two email servers are specified, one set to check using POP3, the other for trying various protocols to find one that works. Two users are checked using the second server option, but all email found for any user is sent to user1’s mail spool. This allows multiple mailboxes to be checked on multiple servers, while appearing in a single MUA inbox. Each user’s specific information begins with the user action.

Omitting the password from the configuration

Users are not required to place their password in the .fetchmailrc file. Omitting the with password 'password' section causes Fetchmail to ask for a password when it is launched.

Fetchmail has numerous global, server, and local options. Many of these options are rarely used or only apply to very specific situations. The Fetchmail man page explains each option in detail, but the most common ones are listed in the following three sections.
15.3.3.2. Global Options
Each global option should be placed on a single line after a set action.

- **daemon seconds** — Specifies daemon-mode, where Fetchmail stays in the background. Replace seconds with the number of seconds Fetchmail is to wait before polling the server.
- **postmaster** — Specifies a local user to send mail to in case of delivery problems.
- **syslog** — Specifies the log file for errors and status messages. By default, this is /var/log/maillog.

15.3.3.3. Server Options
Server options must be placed on their own line in fetchmailrc after a poll or skip action.

- **auth auth-type** — Replace auth-type with the type of authentication to be used. By default, password authentication is used, but some protocols support other types of authentication, including kerberos_v5, kerberos_v4, and ssh. If the any authentication type is used, Fetchmail first tries methods that do not require a password, then methods that mask the password, and finally attempts to send the password unencrypted to authenticate to the server.
- **interval number** — Polls the specified server every number of times that it checks for email on all configured servers. This option is generally used for email servers where the user rarely receives messages.
- **port port-number** — Replace port-number with the port number. This value overrides the default port number for the specified protocol.
- **proto protocol** — Replace protocol with the protocol, such as pop3 or imap, to use when checking for messages on the server.
- **timeout seconds** — Replace seconds with the number of seconds of server inactivity after which Fetchmail gives up on a connection attempt. If this value is not set, a default of 300 seconds is assumed.

15.3.3.4. User Options
User options may be placed on their own lines beneath a server option or on the same line as the server option. In either case, the defined options must follow the user option (defined below).

- **fetchall** — Orders Fetchmail to download all messages in the queue, including messages that have already been viewed. By default, Fetchmail only pulls down new messages.
- **fetchlimit number** — Replace number with the number of messages to be retrieved before stopping.
- **flush** — Deletes all previously viewed messages in the queue before retrieving new messages.
- **limit max-number-bytes** — Replace max-number-bytes with the maximum size in bytes that messages are allowed to be when retrieved by Fetchmail. This option is useful with slow network links, when a large message takes too long to download.
- **password 'password'** — Replace password with the user's password.
- **preconnect "command"** — Replace command with a command to be executed before retrieving messages for the user.
- **postconnect "command"** — Replace command with a command to be executed after retrieving messages for the user.
- **ssl** — Activates SSL encryption.
- **user "username"** — Replace username with the username used by Fetchmail to retrieve messages. This option must precede all other user options.

15.3.3.5. Fetchmail Command Options
Most Fetchmail options used on the command line when executing the fetchmail command mirror the .fetchmailrc configuration options. In this way, Fetchmail may be used with or without a configuration file. These options are not used on the command line by most users because it is easier to leave them in the .fetchmailrc file.

There may be times when it is desirable to run the fetchmail command with other options for a particular purpose. It is possible to issue command options to temporarily override a .fetchmailrc setting that is causing an error, as any options specified at the command line override configuration file options.

15.3.3.6. Informational or Debugging Options
Certain options used after the fetchmail command can supply important information.

- **--configdump** — Displays every possible option based on information from .fetchmailrc and Fetchmail defaults. No email is retrieved for any users when using this option.
- **s** — Executes Fetchmail in silent mode, preventing any messages, other than errors, from appearing after the fetchmail command.
- **v** — Executes Fetchmail in verbose mode, displaying every communication between Fetchmail and remote email servers.
- **V** — Displays detailed version information, lists its global options, and shows settings to be used with each user, including the email protocol and authentication method. No email is retrieved for any users when using this option.

15.3.3.7. Special Options
These options are occasionally useful for overriding defaults often found in the .fetchmailrc file.

- **a** — Fetchmail downloads all messages from the remote email server, whether new or previously viewed. By default, Fetchmail only downloads new messages.
- **k** — Fetchmail leaves the messages on the remote email server after downloading them. This option overrides the
Variables are already defined by a default value. Most of the time, the following variables are used:

- `mailrc` — Specifies the original mailbox, or another place to put the messages if they cannot be placed in the default mailbox.
- `INCLUDERC` — Specifies additional `.procmailrc` files containing more recipes for messages to be checked against. This breaks up the Procmail recipe lists into individual files that fulfill different roles, such as blocking spam and managing email addresses.
- `LOGFILE` — The file to which any Procmail information or error messages are written.
- `MAILDIR` — Sets the current working directory for Procmail. If set, all other Procmail paths are relative to this directory.
- `MAILDIR=$HOME/Msgs INCLUDERC=$MAILDIR/lists.rc INCLUDERC=$MAILDIR/spam.rc`

More commands and `.fetchmailrc` options can be found in the `fetchmail` man page.

### 15.3.4. Mail Delivery Agent (MTA) Configuration

A Mail Delivery Agent (MTA) is essential for sending email. A Mail User Agent (MUA) such as Evolution, Thunderbird, and Mutt, is used to read and compose email. When a user sends an email from an MUA, the message is handed off to the MTA, which sends the message through a series of MTAs until it reaches its destination.

Even if a user does not plan to send email from the system, some automated tasks or system programs might use the `/bin/mail` command to send email containing log messages to the root user of the local system.

Fedora 18 provides two MTAs: Postfix and Sendmail. If both are installed, Postfix is the default MTA.

### 15.4. Mail Delivery Agents

Fedora includes two primary MDAs, Procmail and mail. Both of the applications are considered LDAs and both move email from the MTA’s spool file into the user’s mailbox. However, Procmail provides a robust filtering system.

This section details only Procmail. For information on the `mail` command, consult its man page (man mail).

Procmail delivers and filters email as it is placed in the mail spool file of the localhost. It is powerful, gentle on system resources, and widely used. Procmail can play a critical role in delivering email to be read by email client applications.

Procmail can be invoked in several different ways. Whenever an MTA places an email into the mail spool file, Procmail is launched. Procmail then filters and files the email for the MUA and quits. Alternatively, the MUA can be configured to execute Procmail any time a message is received so that messages are moved into their correct mailboxes. By default, the presence of `etc/procmailrc` or of a `~/.procmailrc` file (also called an `rc` file) in the user’s home directory invokes Procmail whenever an MTA receives a new message.

By default, no system-wide `rc` files exist in the `/etc/` directory and no `etc/procmailrc` files exist in any user's home directory. Therefore, to use Procmail, each user must construct a `.procmailrc` file with specific environment variables and rules.

Whether Procmail acts upon an email message depends upon whether the message matches a specified set of conditions or recipes in the `rc` file. If a message matches a recipe, then the email is placed in a specified file, is deleted, or is otherwise processed.

When Procmail starts, it reads the email message and separates the body from the header information. Next, Procmail looks for a `etc/procmailrc` file and `rc` files in the `etc/procmailrcs` directory for default, system-wide, Procmail environmental variables and recipes. Procmail then searches for a `.procmailrc` file in the user’s home directory. Many users also create additional `rc` files for Procmail that are referred to within the `.procmailrc` file in their home directory.

### 15.4.1. Procmail Configuration

The Procmail configuration file contains important environmental variables. These variables specify things such as which messages to sort and what to do with the messages that do not match any recipes.

These environmental variables usually appear at the beginning of the `~/.procmailrc` file in the following format:

```
env-variable="value"
```

In this example, `env-variable` is the name of the variable and `value` defines the variable.

There are many environment variables not used by most Procmail users and many of the more important environment variables are already defined by a default value. Most of the time, the following variables are used:

- `DEFAULT` — Sets the default mailbox where messages that do not match any recipes are placed. The default `DEFAULT` value is the same as `SORGMAIL`.
- `INCLUDERC` — Specifies additional `rc` files containing more recipes for messages to be checked against. This breaks up the Procmail recipe lists into individual files that fulfill different roles, such as blocking spam and managing email addresses, that can then be turned off or on by using comment characters in the user's `~/.procmailrc` file.

For example, lines in a user's `.procmailrc` file may look like this:

```
MAILDIR=$HOME/Msgs INCLUDERC=$MAILDIR/lists.rc INCLUDERC=$MAILDIR/spam.rc
```

To turn off Procmail filtering of email lists but leaving spam control in place, comment out the first `INCLUDERC` line with a hash sign (`#`).

- `LOCKTIMEOUT` — Sets the amount of time, in seconds, that must pass after a lockfile was last modified before Procmail assumes that the lockfile is old and can be deleted. The default is 1024 seconds.
- `LOGFILE` — The file to which any Procmail information or error messages are written.
- `MAILDIR` — Sets the current working directory for Procmail. If set, all other Procmail paths are relative to this directory.
- `ORGMAIL` — Specifies the original mailbox, or another place to put the messages if they cannot be placed in the default or recipe-required location.

By default, a value of `/var/spool/mail/SLOGNAME` is used.
### Flags

Flags are essential to determine how or if a recipe's conditions are compared to a message. The following flags are commonly used:

- **A** — Specifies that this recipe is only used if the previous recipe without an A or a flag also matched this message.
- **a** — Specifies that this recipe is only used if the previous recipe with an A or a flag also matched this message and was successfully completed.
- **B** — Parses the body of the message and looks for matching conditions.
- **b** — Uses the body in any resulting action, such as writing the message to a file or forwarding it. This is the default behavior.
- **c** — Generates a carbon copy of the email. This is useful with delivering recipes, since the required action can be performed on the message and a copy of the message can continue being processed in the rc files.
- **D** — Makes the egrep comparison case-sensitive. By default, the comparison process is not case-sensitive.
- **E** — While similar to the A flag, the conditions in the recipe are only compared to the message if the immediately preceding recipe without an E flag did not match. This is comparable to an else action.
- **e** — The recipe is compared to the message only if the action specified in the immediately preceding recipe fails.
- **f** — Uses the pipe as a filter.
- **H** — Parses the header of the message and looks for matching conditions. This is the default behavior.
- **h** — Uses the header in a resulting action. This is the default behavior.
- **w** — Tells Procmail to wait for the specified filter or program to finish, and reports whether or not it was successful before considering the message filtered.
- **W** — Is identical to w except that "Program failure" messages are suppressed.

### Delivering vs. Non-Delivering Recipes

The action used if the recipe matches a particular message determines whether it is considered a delivering or non-delivering recipe. A delivering recipe contains an action that writes the message to a file, sends the message to another program, or forwards the message to another email address. A non-delivering recipe covers any other actions, such as a lockfile is created, the name can be specified by replacing lockfile-name .

### Procmail Recipes

New users often find the construction of recipes the most difficult part of learning to use Procmail. To some extent, this is understandable, as recipes do their message matching using regular expressions, which is a particular format used to specify qualifications for a matching string. However, regular expressions are not very difficult to construct and even less understandable, as recipes do their message matching using regular expressions, makes it easy to learn by example. To see example Procmail recipes, refer to Section 15.4.2.5, "Recipe Examples".

Procmail recipes take the following form:

```
:flags: lockfile-name ' special-condition-character
    condition-1 ' special-condition-character
    condition-2 ' special-condition-character
    condition-N ' special-action-character
    action-to-perform
```

The first two characters in a Procmail recipe are a colon and a zero. Various flags can be placed after the zero to control how Procmail processes the recipe. A colon after the **flags** section specifies that a lockfile is created for this message. If a lockfile is created, the name can be specified by replacing **lockfile-name**.

A recipe can contain several conditions to match against the message. If it has no conditions, every message matches the recipe. Regular expressions are placed in some conditions to facilitate message matching. If multiple conditions are used, they must all match for the action to be performed. Conditions are checked based on the flags set in the recipe's first line. Optional special characters placed after the asterisk character (\*) can further control the condition.

The **action-to-perform** argument specifies the action taken when the message matches one of the conditions. There can only be one action per recipe. In many cases, the name of a mailbox is used here to direct matching messages into that file, effectively sorting the email. Special action characters may also be used before the action is specified. Refer to Section 15.4.2.4, "Special Conditions and Actions" for more information.

### Delivering vs. Non-Delivering Recipes

The action used if the recipe matches a particular message determines whether it is considered a delivering or non-delivering recipe. A delivering recipe contains an action that writes the message to a file, sends the message to another program, or forwards the message to another email address. A non-delivering recipe covers any other actions, such as a lockfile is created for this message. If a lockfile is created, the name can be specified by replacing **lockfile-name**.

When messages match a delivering recipe, Procmail performs the specified action and stops comparing the message against other recipes. Messages that match non-delivering recipes continue to be compared against other recipes.

### Flags

Flags are essential to determine how or if a recipe's conditions are compared to a message. The following flags are commonly used:

- **A** — Specifies that this recipe is only used if the previous recipe without an A or a flag also matched this message.
- **a** — Specifies that this recipe is only used if the previous recipe with an A or a flag also matched this message and was successfully completed.
- **B** — Parses the body of the message and looks for matching conditions.
- **b** — Uses the body in any resulting action, such as writing the message to a file or forwarding it. This is the default behavior.
- **c** — Generates a carbon copy of the email. This is useful with delivering recipes, since the required action can be performed on the message and a copy of the message can continue being processed in the rc files.
- **D** — Makes the egrep comparison case-sensitive. By default, the comparison process is not case-sensitive.
- **E** — While similar to the A flag, the conditions in the recipe are only compared to the message if the immediately preceding recipe without an E flag did not match. This is comparable to an else action.
- **e** — The recipe is compared to the message only if the action specified in the immediately preceding recipe fails.
- **f** — Uses the pipe as a filter.
- **H** — Parses the header of the message and looks for matching conditions. This is the default behavior.
- **h** — Uses the header in a resulting action. This is the default behavior.
- **w** — Tells Procmail to wait for the specified filter or program to finish, and reports whether or not it was successful before considering the message filtered.
- **W** — Is identical to w except that "Program failure" messages are suppressed.
For a detailed list of additional flags, refer to the `procmailrc` man page.

15.4.2.3. Specifying a Local Lockfile
Lockfiles are very useful with Procmail to ensure that more than one process does not try to alter a message simultaneously. Specify a local lockfile by placing a colon (:) after any flags on a recipe’s first line. This creates a local lockfile based on the destination file name plus whatever has been set in the `LOCKEXT` global environment variable.

Alternatively, specify the name of the local lockfile to be used with this recipe after the colon.

15.4.2.4. Special Conditions and Actions
Special characters used before Procmail recipe conditions and actions change the way they are interpreted.

The following characters may be used after the asterisk character (*) at the beginning of a recipe’s condition line:

- ! — In the condition line, this character inverts the condition, causing a match to occur only if the condition does not match the message.
- < — Checks if the message is under a specified number of bytes.
- > — Checks if the message is over a specified number of bytes.

The following characters are used to perform special actions:

- ! — In the action line, this character tells Procmail to forward the message to the specified email addresses.
- $ — Refers to a variable set earlier in the `rc` file. This is often used to set a common mailbox that is referred to by various recipes.
- I — Starts a specified program to process the message.
- { and } — Constructs a nesting block, used to contain additional recipes to apply to matching messages.

If no special character is used at the beginning of the action line, Procmail assumes that the action line is specifying the mailbox in which to write the message.

15.4.2.5. Recipe Examples
Procmail is an extremely flexible program, but as a result of this flexibility, composing Procmail recipes from scratch can be difficult for new users.

The best way to develop the skills to build Procmail recipe conditions stems from a strong understanding of regular expressions combined with looking at many examples built by others. A thorough explanation of regular expressions is beyond the scope of this section. The structure of Procmail recipes and useful sample Procmail recipes can be found at various places on the Internet (such as [http://www.iki.fi/era/procmail/links.html](http://www.iki.fi/era/procmail/links.html)). The proper use and adaptation of regular expressions can be derived by viewing these recipe examples. In addition, introductory information about basic regular expression rules can be found in the `grep` man page.

The following simple examples demonstrate the basic structure of Procmail recipes and can provide the foundation for more intricate constructions.

A basic recipe may not even contain conditions, as is illustrated in the following example:

```
:0: new-mail.spool
```

The first line specifies that a local lockfile is to be created but does not specify a name, so Procmail uses the destination file name and appends the value specified in the `LOCKEXT` environment variable. No condition is specified, so every message matches this recipe and is placed in the single spool file called `new-mail.spool`, located within the directory specified by the `MAILDIR` environment variable. An MUA can then view messages in this file.

A basic recipe, such as this, can be placed at the end of all `rc` files to direct messages to a default location.

The following example matched messages from a specific email address and throws them away.

```
:0 * ^From: spammer@domain.com /dev/null
```

With this example, any messages sent by `spammer@domain.com` are sent to the `/dev/null` device, deleting them.

### Sending messages to /dev/null

Be certain that rules are working as intended before sending messages to `/dev/null` for permanent deletion. If a recipe inadvertently catches unintended messages, and those messages disappear, it becomes difficult to troubleshoot the rule.

A better solution is to point the recipe’s action to a special mailbox, which can be checked from time to time to look for false positives. Once satisfied that no messages are accidentally being matched, delete the mailbox and direct the action to send the messages to `/dev/null`.

The following recipe grabs email sent from a particular mailing list and places it in a specified folder.

```
:0 * ^{From|Cc|To}.tux-lug tuxlug
```

Any messages sent from the `tux-lug@domain.com` mailing list are placed in the `tuxlug` mailbox automatically for the MUA. Note that the condition in this example matches the message if it has the mailing list's email address on the `From`, `Cc`, or `To` lines.

Consult the many Procmail online resources available in Section 15.6, "Additional Resources" for more detailed and powerful recipes.
15.4.2.6. Spam Filters
Because it is called by Sendmail, Postfix, and Fetchmail upon receiving new emails, Procmail can be used as a powerful tool for combating spam.

This is particularly true when Procmail is used in conjunction with SpamAssassin. When used together, these two applications can quickly identify spam emails, and sort or destroy them.

SpamAssassin uses header analysis, text analysis, blacklists, a spam-tracking database, and self-learning Bayesian spam analysis to quickly and accurately identify and tag spam.

### Installing the spamassassin package

In order to use SpamAssassin, first ensure the spamassassin package is installed on your system by running, as root:

```
yum install spamassassin
```

For more information on installing packages with Yum, refer to [Section 5.2.4, “Installing Packages”](#).

The easiest way for a local user to use SpamAssassin is to place the following line near the top of the `~/.procmailrc` file:

```
INCLUDERC=/etc/mail/spamassassin/spamassassin-default.rc
```

The `/etc/mail/spamassassin/spamassassin-default.rc` contains a simple Procmail rule that activates SpamAssassin for all incoming email. If an email is determined to be spam, it is tagged in the header as such and the title is prepended with the following pattern:

```
*****SPAM*****
```

The message body of the email is also prepended with a running tally of what elements caused it to be diagnosed as spam.

To file email tagged as spam, a rule similar to the following can be used:

```
:0 Hw * ^X-Spam-Status: Yes spam
```

This rule files all email tagged in the header as spam into a mailbox called `spam`.

Since SpamAssassin is a Perl script, it may be necessary on busy servers to use the binary SpamAssassin daemon (`spamd`) and the client application (`spamc`). Configuring SpamAssassin this way, however, requires root access to the host.

To start the `spamd` daemon, type the following command:

```
systemctl start spamassassin.service
```

To start the SpamAssassin daemon when the system is booted, run:

```
systemctl enable spamassassin.service
```

Refer to [Chapter 9, Services and Daemons](#) for more information on how to configure services in Fedora.

To configure Procmail to use the SpamAssassin client application instead of the Perl script, place the following line near the top of the `~/.procmailrc` file. For a system-wide configuration, place it in `/etc/procmailrc`:

```
INCLUDERC=/etc/mail/spamassassin/spamassassin-spamc.rc
```

15.5. Mail User Agents
Fedora offers a variety of email programs, both, graphical email client programs, such as Evolution, and text-based email programs such as mutt.

The remainder of this section focuses on securing communication between a client and a server.

15.5.1. Securing Communication

Popular MUAs included with Fedora, such as Evolution and mutt offer SSL-encrypted email sessions.

Like any other service that flows over a network unencrypted, important email information, such as usernames, passwords, and entire messages, may be intercepted and viewed by users on the network. Additionally, since the standard POP and IMAP protocols pass authentication information unencrypted, it is possible for an attacker to gain access to user accounts by collecting usernames and passwords as they are passed over the network.

15.5.1.1. Secure Email Clients

Most Linux MUAs designed to check email on remote servers support SSL encryption. To use SSL when retrieving email, it must be enabled on both the email client and the server.

SSL is easy to enable on the client-side, often done with the click of a button in the MUA's configuration window or via an option in the MUA's configuration file. Secure IMAP and POP have known port numbers (993 and 995, respectively) that the MUA uses to authenticate and download messages.
15.5.1.2. Securing Email Client Communications
Offering SSL encryption to IMAP and POP users on the email server is a simple matter.

First, create an SSL certificate. This can be done in two ways: by applying to a Certificate Authority (CA) for an SSL certificate or by creating a self-signed certificate.

Avoid using self-signed certificates
Self-signed certificates should be used for testing purposes only. Any server used in a production environment should use an SSL certificate granted by a CA.

To create a self-signed SSL certificate for IMAP or POP, change to the /etc/pki/dovecot/ directory, edit the certificate parameters in the /etc/pki/dovecot/dovecot-openssl.conf configuration file as you prefer, and type the following commands, as root:

dovecot]
rm -f certs/dovecot.pem private/dovecot.pem
/usr/libexec/dovecot/mkcert.sh

Once finished, make sure you have the following configurations in your /etc/dovecot/conf.d/10-ssl.conf file:

ssl_cert = </etc/pki/dovecot/certs/dovecot.pem
ssl_key = </etc/pki/dovecot/private/dovecot.pem

Execute the systemctl restart dovecot.service command to restart the dovecot daemon.

Alternatively, the stunnel command can be used as an SSL encryption wrapper around the standard, non-secure connections to IMAP or POP services.

The stunnel utility uses external OpenSSL libraries included with Fedora to provide strong cryptography and to protect the network connections. It is recommended to apply to a CA to obtain an SSL certificate, but it is also possible to create a self-signed certificate.

Installing the stunnel package
In order to use stunnel, first ensure the stunnel package is installed on your system by running, as root:

yum install stunnel

For more information on installing packages with Yum, refer to Section 5.2.4, “Installing Packages”.

To create a self-signed SSL certificate, change to the /etc/pki/tls/certs/ directory, and type the following command:

certs]# make stunnel.pem

Answer all of the questions to complete the process.

Once the certificate is generated, create an stunnel configuration file, for example /etc/stunnel/mail.conf, with the following content:

cert = /etc/pki/tls/certs/stunnel.pem

[pop3s]
accept = 995
connect = 110

[imaps]
accept = 993
connect = 143

Once you start stunnel with the created configuration file using the /usr/bin/stunnel /etc/stunnel/mail.conf command, it will be possible to use an IMAP or a POP email client and connect to the email server using SSL encryption.

For more information on stunnel, refer to the stunnel man page or the documents in the /usr/share/doc/stunnel-version-number/ directory, where version-number is the version number of stunnel.

15.6. Additional Resources
The following is a list of additional documentation about email applications.

15.6.1. Installed Documentation
- Information on configuring Sendmail is included with the sendmail and sendmail-cf packages.
  - /usr/share/sendmail-cf/README — Contains information on the m4 macro processor, file locations for Sendmail, supported mailers, how to access enhanced features, and more.
  - In addition, the sendmail and aliases man pages contain helpful information covering various Sendmail options and the proper configuration of the Sendmail /etc/mail/aliases file.
- /usr/share/doc/postfix-version-number — Contains a large amount of information about ways to configure Postfix. Replace version-number with the version number of Postfix.
- /usr/share/doc/fetchmail-version-number — Contains a full list of Fetchmail features in the FEATURES file and an introductory FAQ document. Replace version-number with the version number of Fetchmail.
LDAP (Lightweight Directory Access Protocol) is a set of open protocols used to access centrally stored information over a network. It is based on the X.500 standard for directory sharing, but is less complex and resource-intensive. For this reason, LDAP is sometimes referred to as “X.500 Lite”.

Like X.500, LDAP organizes information in a hierarchical manner using directories. These directories can store a variety of information such as names, addresses, or phone numbers, and can even be used in a manner similar to the Network Information Service (NIS), enabling anyone to access their account from any machine on the LDAP enabled network.

LDAP is commonly used for centrally managed users and groups, user authentication, or system configuration. It can also serve as a virtual phone directory, allowing users to easily access contact information for other users. Additionally, it can refer a user to other LDAP servers throughout the world, and thus provide an ad-hoc global repository of information. However, it is most frequently used within individual organizations such as universities, government departments, and private companies.

This section covers the installation and configuration of OpenLDAP 2.4, an open source implementation of the LDAPv2 and LDAPv3 protocols.
16.1.1. Introduction to LDAP
Using a client/server architecture, LDAP provides reliable means to create a central information directory accessible from the network. When a client attempts to modify information within this directory, the server verifies the user has permission to make the change, and then adds or updates the entry as requested. To ensure the communication is secure, the Secure Sockets Layer (SSL) or Transport Layer Security (TLS) cryptographic protocols can be used to prevent an attacker from intercepting the transmission.

Using Mozilla NSS

The OpenLDAP suite in Fedora 18 no longer uses OpenSSL. Instead, it uses the Mozilla implementation of Network Security Services (NSS). OpenLDAP continues to work with existing certificates, keys, and other TLS configuration. For more information on how to configure it to use Mozilla certificate and key database, refer to How do I use TLS/SSL with Mozilla NSS.

The LDAP server supports several database systems, which gives administrators the flexibility to choose the best suited solution for the type of information they are planning to serve. Because of a well-defined client Application Programming Interface (API), the number of applications able to communicate with an LDAP server is numerous, and increasing in both quantity and quality.

16.1.1.1. LDAP Terminology
The following is a list of LDAP-specific terms that are used within this chapter:

**entry**
A single unit within an LDAP directory. Each entry is identified by its unique Distinguished Name (DN).

**attribute**
Information directly associated with an entry. For example, if an organization is represented as an LDAP entry, attributes associated with this organization might include an address, a fax number, etc. Similarly, people can be represented as entries with common attributes such as personal telephone number or email address.

An attribute can either have a single value, or an unordered space-separated list of values. While certain attributes are optional, other are required. Required attributes are specified using the objectClass definition, and can be found in schema files located in the `/etc/openldap/slapd.d/cn=config/cn=schema/` directory.

The assertion of an attribute and its corresponding value is also referred to as a Relative Distinguished Name (RDN). Unlike distinguished names that are unique globally, a relative distinguished name is only unique per entry.

**LDIF**
The LDAP Data Interchange Format (LDIF) is a plain text representation of an LDAP entry. It takes the following form:

```
[id] dn: distinguished_name
attribute_type: attribute_value...
attribute_type: attribute_value...
```

The optional `id` is a number determined by the application that is used to edit the entry. Each entry can contain as many `attribute_type` and `attribute_value` pairs as needed, as long as they are all defined in a corresponding schema file. A blank line indicates the end of an entry.

16.1.1.2. OpenLDAP Features
OpenLDAP suite provides a number of important features:

- **LDAPv3 Support** — Many of the changes in the protocol since LDAP version 2 are designed to make LDAP more secure. Among other improvements, this includes the support for Simple Authentication and Security Layer (SASL), Transport Layer Security (TLS), and Secure Sockets Layer (SSL) protocols.
- **LDAP Over IPC** — The use of inter-process communication (IPC) enhances security by eliminating the need to communicate over a network.
- **IPv6 Support** — OpenLDAP is compliant with Internet Protocol version 6 (IPv6), the next generation of the Internet Protocol.
- **LDIFv1 Support** — OpenLDAP is fully compliant with LDIF version 1.
- **Updated C API** — The current C API improves the way programmers can connect to and use LDAP directory servers.
- **Enhanced Standalone LDAP Server** — This includes an updated access control system, thread pooling, better tools, and much more.

16.1.1.3. OpenLDAP Server Setup
The typical steps to set up an LDAP server on Fedora are as follows:

1. Install the OpenLDAP suite. Refer to Section 16.1.2, “Installing the OpenLDAP Suite” for more information on required packages.
2. Customize the configuration as described in Section 16.1.3, “Configuring an OpenLDAP Server”.
3. Start the `slapd` service as described in Section 16.1.4, “Running an OpenLDAP Server”.
4. Use the `ldapadd` utility to add entries to the LDAP directory.
5. Use the `ldaps` utility to verify that the `slapd` service is accessing the information correctly.
16.1.2. Installing the OpenLDAP Suite

The suite of OpenLDAP libraries and tools is provided by the following packages:

<table>
<thead>
<tr>
<th>Package</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>openldap</td>
<td>A package containing the libraries necessary to run the OpenLDAP server and client applications.</td>
</tr>
<tr>
<td>openldap-clients</td>
<td>A package containing the command line utilities for viewing and modifying directories on an LDAP server.</td>
</tr>
<tr>
<td>openldap-servers</td>
<td>A package containing both the services and utilities to configure and run an LDAP server. This includes the Standalone LDAP Daemon, slapd.</td>
</tr>
<tr>
<td>openldap-servers-sql</td>
<td>A package containing the SQL support module.</td>
</tr>
</tbody>
</table>

Additionally, the following packages are commonly used along with the LDAP server:

<table>
<thead>
<tr>
<th>Package</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>nss-pam-ldapd</td>
<td>A package containing nslcd, a local LDAP name service that allows a user to perform local LDAP queries.</td>
</tr>
<tr>
<td>mod_authz_ldap</td>
<td>A package containing mod_authz_ldap, the LDAP authorization module for the Apache HTTP Server. This module uses the short form of the distinguished name for a subject and the issuer of the client SSL certificate to determine the distinguished name of the user within an LDAP directory. It is also capable of authorizing users based on attributes of that user's LDAP directory entry, determining access to assets based on the user and group privileges of the asset, and denying access for users with expired passwords. Note that the mod_ssl module is required when using the mod_authz_ldap module.</td>
</tr>
</tbody>
</table>

To install these packages, use the `yum` command in the following form:

```
yum install package...
```

For example, to perform the basic LDAP server installation, type the following at a shell prompt as root:

```
yum install openldap openldap-clients openldap-servers
```

Note that you must have superuser privileges (that is, you must be logged in as root) to run this command. For more information on how to install new packages in Fedora, refer to Section 5.2.4, "Installing Packages".

16.1.2.1. Overview of OpenLDAP Server Utilities

To perform administrative tasks, the openldap-servers package installs the following utilities along with the slapd service:

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>slapacl</td>
<td>Allows you to check the access to a list of attributes.</td>
</tr>
<tr>
<td>slapadd</td>
<td>Allows you to add entries from an LDIF file to an LDAP directory.</td>
</tr>
<tr>
<td>slapauth</td>
<td>Allows you to check a list of IDs for authentication and authorization permissions.</td>
</tr>
<tr>
<td>slapcat</td>
<td>Allows you to pull entries from an LDAP directory in the default format and save them in an LDIF file.</td>
</tr>
<tr>
<td>slapdn</td>
<td>Allows you to check a list of Distinguished Names (DNs) based on available schema syntax.</td>
</tr>
<tr>
<td>slapindex</td>
<td>Allows you to re-index the slapd directory based on the current content. Run this utility whenever you change indexing options in the configuration file.</td>
</tr>
<tr>
<td>slappasswd</td>
<td>Allows you to create an encrypted user password to be used with the ldapmodify utility, or in the slapd configuration file.</td>
</tr>
<tr>
<td>slapschema</td>
<td>Allows you to check the compliance of a database with the corresponding schema.</td>
</tr>
<tr>
<td>slaptest</td>
<td>Allows you to check the LDAP server configuration.</td>
</tr>
</tbody>
</table>

For a detailed description of these utilities and their usage, refer to the corresponding manual pages as referred to in Section 16.1.6.1, "Installed Documentation".

Make sure the files have correct owner

Although only root can run slapadd, the slapd service runs as the ldap user. Because of this, the directory server is unable to modify any files created by slapadd. To correct this issue, after running the slapadd utility, type the following at a shell prompt:

```
chown -R ldap:ldap /var/lib/ldap
```
Stop slapd before using these utilities

To preserve the data integrity, stop the slapd service before using slapadd, slapcat, or slapindex. You can do so by typing the following at a shell prompt as root:

```
systemctl stop slapd.service
```

For more information on how to start, stop, restart, and check the current status of the slapd service, refer to Section 16.1.4, “Running an OpenLDAP Server”.

### 16.1.2.2. Overview of OpenLDAP Client Utilities

The openldap-clients package installs the following utilities which can be used to add, modify, and delete entries in an LDAP directory:

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ldapadd</td>
<td>Allows you to add entries to an LDAP directory, either from a file, or from standard input. It is a symbolic link to ldapmodify -a.</td>
</tr>
<tr>
<td>ldapcompare</td>
<td>Allows you to compare given attribute with an LDAP directory entry.</td>
</tr>
<tr>
<td>ldapdelete</td>
<td>Allows you to delete entries from an LDAP directory.</td>
</tr>
<tr>
<td>ldapexop</td>
<td>Allows you to perform extended LDAP operations.</td>
</tr>
<tr>
<td>ldapmodify</td>
<td>Allows you to modify entries in an LDAP directory, either from a file, or from standard input.</td>
</tr>
<tr>
<td>ldapmodify</td>
<td>Allows you to modify the RDN value of an LDAP directory entry.</td>
</tr>
<tr>
<td>ldappassword</td>
<td>Allows you to set or change the password for an LDAP user.</td>
</tr>
<tr>
<td>ldapsearch</td>
<td>Allows you to search LDAP directory entries.</td>
</tr>
<tr>
<td>ldapurl</td>
<td>Allows you to compose or decompose LDAP URLs.</td>
</tr>
<tr>
<td>ldaphoami</td>
<td>Allows you to perform a whoami operation on an LDAP server.</td>
</tr>
</tbody>
</table>

With the exception of ldapsearch, each of these utilities is more easily used by referencing a file containing the changes to be made rather than typing a command for each entry to be changed within an LDAP directory. The format of such a file is outlined in the man page for each utility.

### 16.1.2.3. Overview of Common LDAP Client Applications

Although there are various graphical LDAP clients capable of creating and modifying directories on the server, none of them is included in Fedora. Popular applications that can access directories in a read-only mode include Mozilla Thunderbird, Evolution, or Ekiga.

### 16.1.3. Configuring an OpenLDAP Server

By default, the OpenLDAP configuration is stored in the `/etc/openldap/` directory. The following table highlights the most important directories and files within this directory:

<table>
<thead>
<tr>
<th>Path</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>/etc/openldap/ldap.conf</code></td>
<td>The configuration file for client applications that use the OpenLDAP libraries. This includes ldapadd, ldapsearch, Evolution, etc.</td>
</tr>
<tr>
<td><code>/etc/openldap/slapd.d/</code></td>
<td>The directory containing the slapd configuration.</td>
</tr>
</tbody>
</table>

Note that OpenLDAP no longer reads its configuration from the `/etc/openldap/slapd.conf` file. Instead, it uses a configuration database located in the `/etc/openldap/slapd.d/` directory. If you have an existing slapd.conf file from a previous installation, you can convert it to the new format by running the following command as root:

```
slaptest -f /etc/openldap/slapd.conf -F /etc/openldap/slapd.d/
```

The slapd configuration consists of LDIF entries organized in a hierarchical directory structure, and the recommended way to edit these entries is to use the server utilities described in Section 16.1.2.1, “Overview of OpenLDAP Server Utilities”.

Do not edit LDIF files directly

An error in an LDIF file can render the slapd service unable to start. Because of this, it is strongly advised that you avoid editing the LDIF files within the `/etc/openldap/slapd.d/` directory directly.

### 16.1.3.1. Changing the Global Configuration

Global configuration options for the LDAP server are stored in the `/etc/openldap/slapd.d/cn=config.ldif` file. The following directives are commonly used:

**olcAllows**

The olcAllows directive allows you to specify which features to enable. It takes the following form:

```
olcAllows: feature...
```
It accepts a space-separated list of features as described in Table 16.6, “Available olcAllows options”. The default option is `bind_v2`.

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>bind_v2</code></td>
<td>Enables the acceptance of LDAP version 2 bind requests.</td>
</tr>
<tr>
<td><code>bind_anon_cred</code></td>
<td>Enables an anonymous bind when the Distinguished Name (DN) is empty.</td>
</tr>
<tr>
<td><code>bind_anon_dn</code></td>
<td>Enables an anonymous bind when the Distinguished Name (DN) is not empty.</td>
</tr>
<tr>
<td><code>update_anon</code></td>
<td>Enables processing of anonymous update operations.</td>
</tr>
<tr>
<td><code>proxy_authz_anon</code></td>
<td>Enables processing of anonymous proxy authorization control.</td>
</tr>
</tbody>
</table>

Example 16.1. Using the olcAllows directive

```
olcAllows: bind_v2 update_anon
```

The `olcConnMaxPending` directive allows you to specify the maximum number of pending requests for an anonymous session. It takes the following form:

```
olcConnMaxPending: number
```

The default option is 100.

Example 16.2. Using the olcConnMaxPending directive

```
olcConnMaxPending: 100
```

The `olcConnMaxPendingAuth` directive allows you to specify the maximum number of pending requests for an authenticated session. It takes the following form:

```
olcConnMaxPendingAuth: number
```

The default option is 1000.

Example 16.3. Using the olcConnMaxPendingAuth directive

```
olcConnMaxPendingAuth: 1000
```

The `olcDisallows` directive allows you to specify which features to disable. It takes the following form:

```
olcDisallows: feature...
```

It accepts a space-separated list of features as described in Table 16.7, “Available olcDisallows options”. No features are disabled by default.

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>bind_anon</code></td>
<td>Disables the acceptance of anonymous bind requests.</td>
</tr>
<tr>
<td><code>bind_simple</code></td>
<td>Disables the simple bind authentication mechanism.</td>
</tr>
<tr>
<td><code>tls_2_anon</code></td>
<td>Disables the enforcing of an anonymous session when the STARTTLS command is received.</td>
</tr>
<tr>
<td><code>tls_authc</code></td>
<td>Disallows the STARTTLS command when authenticated.</td>
</tr>
</tbody>
</table>

Example 16.4. Using the olcDisallows directive

```
olcDisallows: bind_anon
```

The `olcIdleTimeout` directive allows you to specify how many seconds to wait before closing an idle connection. It takes the following form:

```
olcIdleTimeout: number
```

This option is disabled by default (that is, set to 0).

Example 16.5. Using the olcIdleTimeout directive

```
olcIdleTimeout: 180
```
**olcLogFile**
The `olcLogFile` directive allows you to specify a file in which to write log messages. It takes the following form:

```
olcLogFile: file_name
```
The log messages are written to standard error by default.

**Example 16.6. Using the olcLogFile directive**

```
olcLogFile: /var/log/slapd.log
```

**olcReferral**
The `olcReferral` option allows you to specify a URL of a server to process the request in case the server is not able to handle it. It takes the following form:

```
olcReferral: URL
```
This option is disabled by default.

**Example 16.7. Using the olcReferral directive**

```
olcReferral: ldap://root.openldap.org
```

**olcWriteTimeout**
The `olcWriteTimeout` option allows you to specify how many seconds to wait before closing a connection with an outstanding write request. It takes the following form:

```
olcWriteTimeout
```
This option is disabled by default (that is, set to 0).

**Example 16.8. Using the olcWriteTimeout directive**

```
olcWriteTimeout: 180
```

16.1.3.2. Changing the Database-Specific Configuration
By default, the OpenLDAP server uses Berkeley DB (BDB) as a database back end. The configuration for this database is stored in the `/etc/openldap/slapd.d/cn=config/olcDatabase={1}bdb.ldif` file. The following directives are commonly used in a database-specific configuration:

**olcReadOnly**
The `olcReadOnly` directive allows you to use the database in a read-only mode. It takes the following form:

```
olcReadOnly: boolean
```
It accepts either `TRUE` (enable the read-only mode), or `FALSE` (enable modifications of the database). The default option is `FALSE`.

**Example 16.9. Using the olcReadOnly directive**

```
olcReadOnly: TRUE
```

**olcRootDN**
The `olcRootDN` directive allows you to specify the user that is unrestricted by access controls or administrative limit parameters set for operations on the LDAP directory. It takes the following form:

```
olcRootDN: distinguished_name
```
It accepts a `Distinguished Name` (DN). The default option is `cn=Manager, dn=my-domain, dc=com`.

**Example 16.10. Using the olcRootDN directive**

```
olcRootDN: cn=root, dn=my-example, dc=com
```

**olcRootPW**
The `olcRootPW` directive allows you to set a password for the user that is specified using the `olcRootDN` directive. It takes the following form:

```
olcRootPW: password
```
It accepts either a plain text string, or a hash. To generate a hash, use the `slappasswd` utility, for example:
Example 16.11. Using the olcRootPW directive

```
olcRootPW: {SSHA}WczWsyPEnMchFf1GRTweq2q7XJcvmSxD
```

```
Example 16.12. Using the olcSuffix directive

```
olcSuffix: dc=example,dc=com
```

16.1.3.3. Extending Schema

Since OpenLDAP 2.3, the `/etc/openldap/slapd.d/` directory also contains LDAP definitions that were previously located in `/etc/openldap/schema/`. It is possible to extend the schema used by OpenLDAP to support additional attribute types and object classes using the default schema files as a guide. However, this task is beyond the scope of this chapter. For more information on this topic, refer to [http://www.openldap.org/doc/admin/schema.html](http://www.openldap.org/doc/admin/schema.html).

16.1.4. Running an OpenLDAP Server

This section describes how to start, stop, restart, and check the current status of the Standalone LDAP Daemon. For more information on how to manage system services in general, refer to Chapter 9, Services and Daemons.

16.1.4.1. Starting the Service

To run the `slapd` service, type the following at a shell prompt as `root`:

```
systemctl start slapd.service
```

To prevent the service from starting automatically at the boot time, type:

```
systemctl disable slapd.service
```

Refer to Chapter 9, Services and Daemons for more information on how to configure services in Fedora.

16.1.4.2. Stopping the Service

To stop the running `slapd` service, type the following at a shell prompt as `root`:

```
systemctl stop slapd.service
```

16.1.4.3. Restarting the Service

To restart the running `slapd` service, type the following at a shell prompt as `root`:

```
systemctl restart slapd.service
```

This stops the service, and then starts it again. Use this command to reload the configuration.

16.1.4.4. Checking the Service Status

To check whether the service is running, type the following at a shell prompt:

```
systemctl is-active slapd.service
```

16.1.5. Configuring a System to Authenticate Using OpenLDAP

In order to configure a system to authenticate using OpenLDAP, make sure that the appropriate packages are installed on both LDAP server and client machines. For information on how to set up the server, follow the instructions in Section 16.1.2, “Installing the OpenLDAP Suite” and Section 16.1.3, “Configuring an OpenLDAP Server”. On a client, type the following at a shell prompt as `root`:

```
yum install openldap openldap-clients nss-pam-ldapd
```
Chapter 10, Configuring Authentication provides detailed instructions on how to configure applications to use LDAP for authentication.

16.1.5.1. Migrating Old Authentication Information to LDAP Format
The migrationtools package provides a set of shell and Perl scripts to help you migrate authentication information into an LDAP format. To install this package, type the following at a shell prompt as root:

```
yum install migrationtools
```

This will install the scripts to the `/usr/share/migrationtools/` directory. Once installed, edit the `/usr/share/migrationtools/migrate_common.ph` file and change the following lines to reflect the correct domain, for example:

```
# Default DNS domain
$DEFAULT_MAIL_DOMAIN = "example.com";

# Default base
$DEFAULT_BASE = "dc=example,dc=com";
```

Alternatively, you can specify the environment variables directly on the command line. For example, to run the `migrate_all_online.sh` script with the default base set to `dc=example,dc=com`, type:

```
export DEFAULT_BASE="dc=example,dc=com" \ 
/usr/share/migrationtools/migrate_all_online.sh
```

To decide which script to run in order to migrate the user database, refer to Table 16.8, "Commonly used LDAP migration scripts".

**Table 16.8. Commonly used LDAP migration scripts**

<table>
<thead>
<tr>
<th>Existing Name Service</th>
<th>Is LDAP Running?</th>
<th>Script to Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>/etc flat files</td>
<td>yes</td>
<td>migrate_all_online.sh</td>
</tr>
<tr>
<td>/etc flat files</td>
<td>no</td>
<td>migrate_all_offline.sh</td>
</tr>
<tr>
<td>Netinfo</td>
<td>yes</td>
<td>migrate_all_netinfo_online.sh</td>
</tr>
<tr>
<td>Netinfo</td>
<td>no</td>
<td>migrate_all_netinfo_offline.sh</td>
</tr>
<tr>
<td>NIS (YP)</td>
<td>yes</td>
<td>migrate_all_nis_online.sh</td>
</tr>
<tr>
<td>NIS (YP)</td>
<td>no</td>
<td>migrate_all_nis_offline.sh</td>
</tr>
</tbody>
</table>

For more information on how to use these scripts, refer to the README and the migration-tools.txt files in the `/usr/share/doc/migrationtools-version/` directory.

16.1.6. Additional Resources
The following resources offer additional information on the Lightweight Directory Access Protocol. Before configuring LDAP on your system, it is highly recommended that you review these resources, especially the OpenLDAP Software Administrator's Guide.

16.1.6.1. Installed Documentation
The following documentation is installed with the openldap-servers package:

```
/usr/share/doc/openldap-servers-version/guide.html
```

A copy of the OpenLDAP Software Administrator's Guide.

```
/usr/share/doc/openldap-servers-version/README.schema
```

A README file containing the description of installed schema files.

Additionally, there is also a number of manual pages that are installed with the openldap, openldap-servers, and openldap-clients packages:

**Client Applications**

- `man ldapadd` — Describes how to add entries to an LDAP directory.
- `man ldapdelete` — Describes how to delete entries within an LDAP directory.
- `man ldapmodify` — Describes how to modify entries within an LDAP directory.
- `man ldapsearch` — Describes how to search for entries within an LDAP directory.
- `man ldappasswd` — Describes how to set or change the password of an LDAP user.
- `man ldapcompare` — Describes how to use the `ldapcompare` tool.
- `man ldapwhoami` — Describes how to use the `ldapwhoami` tool.
- `man ldapmodrdn` — Describes how to modify the RDNs of entries.

**Server Applications**

- `man slapd` — Describes command line options for the LDAP server.

**Administrative Applications**
> man slapadd — Describes command line options used to add entries to a slapd database.
> man slapcat — Describes command line options used to generate an LDIF file from a slapd database.
> man slapindex — Describes command line options used to regenerate an index based upon the contents of a slapd database.
> man slappasswd — Describes command line options used to generate user passwords for LDAP directories.

**Configuration Files**

> man ldap.conf — Describes the format and options available within the configuration file for LDAP clients.
> man slapd-config — Describes the format and options available within the configuration directory.

16.1.6.2. Useful Websites

http://www.openldap.org/doc/admin24/

The current version of the OpenLDAP Software Administrator's Guide.

http://www.kingsmountain.com/ldapRoadmap.shtml

Jeff Hodges' LDAP Roadmap & FAQ containing links to several useful resources and emerging news concerning the LDAP protocol.

http://www.ldapman.org/articles/

A collection of articles that offer a good introduction to LDAP, including methods to design a directory tree and customizing directory structures.

http://www.padl.com/

A website of developers of several useful LDAP tools.

16.1.6.3. Related Books

OpenLDAP by Example by John Terpstra and Benjamin Coles; Prentice Hall.

A collection of practical exercises in the OpenLDAP deployment.

Implementing LDAP by Mark Wilcox; Wrox Press, Inc.

A book covering LDAP from both the system administrator's and software developer's perspective.


A book covering LDAP design principles, as well as its deployment in a production environment.

Chapter 17. File and Print Servers

17.1. Samba

17.1.1. Introduction to Samba
17.1.2. Samba Daemons and Related Services
17.1.3. Connecting to a Samba Share
17.1.4. Configuring a Samba Server
17.1.5. Starting and Stopping Samba
17.1.6. Samba Server Types and the smb.conf File
17.1.7. Samba Security Modes
17.1.8. Samba Account Information Databases
17.1.9. Samba Network Browsing
17.1.10. Samba with CUPS Printing Support
17.1.11. Samba Distribution Programs
17.1.12. Additional Resources

17.2. FTP

17.2.1. The File Transfer Protocol
17.2.2. FTP Servers
17.2.3. Files Installed with vsftpd
17.2.4. Starting and Stopping vsftpd
17.2.5. vsftpd Configuration Options
17.2.6. Additional Resources

17.3. Printer Configuration

17.3.1. Starting the Printer Configuration Tool
17.3.2. Starting Printer Setup
17.3.3. Adding a Local Printer
17.3.4. Adding an AppSocket/HP JetDirect printer
17.3.5. Adding an IPP Printer
17.3.6. Adding an LPD/LPR Host or Printer
17.3.7. Adding a Samba (SMB) printer
17.3.8. Selecting the Printer Model and Finishing
17.3.9. Printing a test page
17.3.10. Modifying Existing Printers
17.3.11. Additional Resources

This chapter guides you through the installation and configuration of Samba, an open source implementation of the Server Message Block (SMB) protocol, and vsftpd, the primary FTP server shipped with Fedora. Additionally, it explains how to use the Printer Configuration tool to configure printers.

17.1. Samba

Samba is an open source implementation of the Server Message Block (SMB) protocol. It allows the networking of Microsoft Windows®, Linux, UNIX, and other operating systems together, enabling access to Windows-based file and printer shares. Samba's use of SMB allows it to appear as a Windows server to Windows clients.

Installing the samba package

In order to use Samba, first ensure the samba package is installed on your system by running, as root:

```
yum install samba
```

For more information on installing packages with Yum, refer to Section 5.2.4, "Installing Packages".

17.1.1. Introduction to Samba

The third major release of Samba, version 3.0.0, introduced numerous improvements from prior versions, including:

- The ability to join an Active Directory domain by means of the Lightweight Directory Access Protocol (LDAP) and Kerberos
- Built in Unicode support for internationalization
- Support for all recent Microsoft Windows server and client versions to connect to Samba servers without needing local registry hacking
- Two new documents developed by the Samba.org team, which include a 400+ page reference manual, and a 300+ page implementation and integration manual. For more information about these published titles, refer to Section 17.1.12.2, "Related Books".

17.1.1.1. Samba Features

Samba is a powerful and versatile server application. Even seasoned system administrators must know its abilities and limitations before attempting installation and configuration.

What Samba can do:

- Serve directory trees and printers to Linux, UNIX, and Windows clients
- Assist in network browsing (with or without NetBIOS)
- Authenticate Windows domain logins
- Provide Windows Internet Name Service (WINS) name server resolution
- Act as a Windows NT®-style Primary Domain Controller (PDC)
- Act as a Backup Domain Controller (BDC) for a Samba-based PDC
- Act as an Active Directory domain member server
- Join a Windows NT/2000/2003/2008 PDC

What Samba cannot do:

- Act as a BDC for a Windows PDC (and vice versa)
- Act as an Active Directory domain controller

17.1.2. Samba Daemons and Related Services

The following is a brief introduction to the individual Samba daemons and services.

17.1.2.1. Samba Daemons

Samba is comprised of three daemons (smbd, nmbd, and winbindd). Three services (smb, nmb, and winbind) control how the daemons are started, stopped, and other service-related features. These services act as different init scripts. Each daemon is listed in detail below, as well as which specific service has control over it.

smbd

The smbd server daemon provides file sharing and printing services to Windows clients. In addition, it is responsible for user authentication, resource locking, and data sharing through the SMB protocol. The default ports on which the server listens for SMB traffic are TCP ports 139 and 445.

The smbd daemon is controlled by the smb service.

nmbd
The nmbd server daemon understands and replies to NetBIOS name service requests such as those produced by SMB/Common Internet File System (CIFS) in Windows-based systems. These systems include Windows 95/98/ME, Windows NT, Windows 2000, Windows XP, and LanManager clients. It also participates in the browsing protocols that make up the Windows Network Neighborhood view. The default port that the server listens to for NMB traffic is UDP port 137.

The nmbd daemon is controlled by the nmb service.

winbindd

The winbind service resolves user and group information on a server running Windows NT, 2000, 2003 or Windows Server 2008. This makes Windows user / group information understandable by UNIX platforms. This is achieved by using Microsoft RPC calls, Pluggable Authentication Modules (PAM), and the Name Service Switch (NSS). This allows Windows NT domain users to appear and operate as UNIX users on a UNIX machine. Though bundled with the Samba distribution, the winbind service is controlled separately from the smb service.

The winbindd daemon is controlled by the winbind service and does not require the smb service to be started in order to operate. winbind is also used when Samba is an Active Directory member, and may also be used on a Samba domain controller (to implement nested groups and/or interdomain trust). Because winbind is a client-side service used to connect to Windows NT-based servers, further discussion of winbind is beyond the scope of this chapter.

Obtaining a list of utilities that are shipped with Samba

You may refer to Section 17.1.11, “Samba Distribution Programs” for a list of utilities included in the Samba distribution.

17.1.3. Connecting to a Samba Share

You can use Nautilus to view available Samba shares on your network. To view a list of Samba workgroups and domains on your network, select Applications → Accessories → Files from the Activities menu, and click Browse Network at the sidebar.

An icon appears for each available SMB workgroup or domain on the network. Double-click one of the workgroup/domain icons to view a list of computers within the workgroup/domain.

Each machine within the workgroup is represented by its own icon. Double-click on an icon to view the Samba shares on the machine. If a username and password combination is required, you are prompted for them.

Alternately, you can also specify the Samba server and sharename in the Location: bar for Nautilus using the following syntax (replace servername and sharename with the appropriate values):

smb://servername/sharename

17.1.3.1. Command Line

To query the network for Samba servers, use the findsmb command. For each server found, it displays its IP address, NetBIOS name, workgroup name, operating system, and SMB server version.

To connect to a Samba share from a shell prompt, type the following command:
smbclient //hostname/sharename -U username

Replace hostname with the hostname or IP address of the Samba server you want to connect to, sharename with the name of the shared directory you want to browse, and username with the Samba username for the system. Enter the correct password or press Enter if no password is required for the user.

If you see the smb:/> prompt, you have successfully logged in. Once you are logged in, type help for a list of commands. If you wish to browse the contents of your home directory, replace sharename with your username. If the -U switch is not used, the username of the current user is passed to the Samba server.

To exit smbclient, type exit at the smb:/> prompt.

17.1.3.2. Mounting the Share

Sometimes it is useful to mount a Samba share to a directory so that the files in the directory can be treated as if they are part of the local file system.

To mount a Samba share to a directory, create a directory to mount it to (if it does not already exist), and execute the following command as root:

cat -t cifs //servername/sharename /mnt/point/ -o username=username, password=password

This command mounts sharename from servername in the local directory /mnt/point/.

Installing cifs-utils package

The mount.cifs utility is a separate RPM (independent from Samba). In order to use mount.cifs, first ensure the cifs-utils package is installed on your system by running, as root:

yum install cifs-utils

For more information on installing packages with Yum, refer to Section 5.2.4, “Installing Packages”.

For more information about mounting a samba share, refer to man mount.cifs.

CIFS servers that require plain text passwords

Some CIFS servers require plain text passwords for authentication. Support for plain text password authentication can be enabled using the following command as root:

echo 0x37 > /proc/fs/cifs/SecurityFlags

WARNING: This operation can expose passwords by removing password encryption.

17.1.4. Configuring a Samba Server

The default configuration file (/etc/samba/smb.conf) allows users to view their home directories as a Samba share. It also shares all printers configured for the system as Samba shared printers. In other words, you can attach a printer to the system and print to it from the Windows machines on your network.

17.1.4.1. Graphical Configuration

To configure Samba using a graphical interface, use one of the available Samba graphical user interfaces. A list of available GUIs can be found at http://www.samba.org/samba/GUI/.

17.1.4.2. Command Line Configuration

Samba uses /etc/samba/smb.conf as its configuration file. If you change this configuration file, the changes do not take effect until you restart the Samba daemon with the following command, as root:

systemctl restart smb.service

To specify the Windows workgroup and a brief description of the Samba server, edit the following lines in your
/etc/samba/smb.conf file:

workgroup = WORKGROUPNAME
server string = BRIEF COMMENT ABOUT SERVER

Replace WORKGROUPNAME with the name of the Windows workgroup to which this machine should belong. The BRIEF COMMENT ABOUT SERVER is optional and is used as the Windows comment about the Samba system.

To create a Samba share directory on your Linux system, add the following section to your /etc/samba/smb.conf file (after modifying it to reflect your needs and your system):
Encrypted Passwords

Encrypted passwords are enabled by default because it is more secure to do so. To create a user with an encrypted password, use the command `smbpasswd -a username`.

Starting and Stopping Samba

To start a Samba server, type the following command in a shell prompt, as `root`:

```
systemctl start smb.service
```

To stop the server, type the following command in a shell prompt, as `root`:

```
systemctl stop smb.service
```

Setting up a domain member server

To set up a domain member server, you must first join the domain or Active Directory using the `net join` command before starting the `smb` service.

The restart option is a quick way of stopping and then starting Samba. This is the most reliable way to make configuration changes take effect after editing the configuration file for Samba. Note that the restart option starts the daemon even if it was not running originally.

To restart the server, type the following command in a shell prompt, as `root`:

```
systemctl restart smb.service
```

The condrestart (conditional restart) option only starts `smb` on the condition that it is currently running. This option is useful for scripts, because it does not start the daemon if it is not running.

Applying the changes to the configuration

When the `/etc/samba/smb.conf` file is changed, Samba automatically reloads it after a few minutes. Issuing a manual `restart` or `reload` is just as effective.

To conditionally restart the server, type the following command, as `root`:

```
systemctl condrestart smb.service
```

To conditionally reload the server configuration file, type the following command as `root`:

```
systemctl reload smb.service
```

A manual reload of the `/etc/samba/smb.conf` file can be useful in case of a failed automatic reload by the `smb` service. To ensure that the Samba server configuration file is reloaded without restarting the service, type the following command, as `root`:

```
systemctl reload smb.service
```

By default, the `smb` service does not start automatically at boot time. To configure Samba to start at boot time, use a service manager such as `systemctl`. Refer to Chapter 9, Services and Daemons for more information regarding this tool.

Samba Server Types and the `smb.conf` File

Samba configuration is straightforward. All modifications to Samba are done in the `/etc/samba/smb.conf` configuration file. Although the default `smb.conf` file is well documented, it does not address complex topics such as LDAP, Active Directory, and the numerous domain controller implementations.

The following sections describe the different ways a Samba server can be configured. Keep in mind your needs and the changes required to the `/etc/samba/smb.conf` file for a successful configuration.

### Stand-alone Server

A stand-alone server can be a workgroup server or a member of a workgroup environment. A stand-alone server is not a domain controller and does not participate in a domain in any way. The following examples include several anonymous share-level security configurations and one user-level security configuration. For more information on share-level and user-level security modes, refer to Section 17.1.7, “Samba Security Modes”.

### Anonymous Read-Only

The following `/etc/samba/smb.conf` file shows a sample configuration needed to implement anonymous read-only file sharing. The `security = share` parameter makes a share anonymous. Note, security levels for a single Samba server cannot be mixed. The `security` directive is a global Samba parameter located in the `[global]` configuration section of the `/etc/samba/smb.conf` file. 

```
[sharename]
comment = Insert a comment here
path = /home/share/
valid users = tfox carole
public = no
writable = yes
printable = no
create mask = 0765
```

The above example allows the users `tfox` and `carole` to read and write to the directory `/home/share`, on the Samba server, from a Samba client.
the `/etc/samba/smb.conf` file.

```
[global]
workgroup = DOCS
netbios name = DOCS_SRV
security = share
[data]
comment = Documentation Samba Server
path = /export
read only = Yes
guest only = Yes
```

17.1.6.1.2. Anonymous ReadWrite

The following `/etc/samba/smb.conf` file shows a sample configuration needed to implement anonymous read/write file sharing. To enable anonymous read/write file sharing, set the `read only` directive to `no`. The `force user` and `force group` directives are also added to enforce the ownership of any newly placed files specified in the share.

```
[global]
workgroup = DOCS
netbios name = DOCS_SRV
security = share
[data]
comment = Documentation Samba Server
path = /export
read only = Yes
guest only = Yes
```

**Do not use anonymous read/write servers**

Although having an anonymous read/write server is possible, it is not recommended. Any files placed in the share space, regardless of user, are assigned the user/group combination as specified by a generic user (`force user`) and group (`force group`) in the `/etc/samba/smb.conf` file.

```
[global]
workgroup = DOCS
netbios name = DOCS_SRV
security = share
[data]
comment = Data
path = /export
force user = docsbot
force group = users
read only = No
guest ok = Yes
```

17.1.6.1.3. Anonymous Print Server

The following `/etc/samba/smb.conf` file shows a sample configuration needed to implement an anonymous print server. Setting `browseable` to `no` as shown does not list the printer in Windows `Network Neighborhood`. Although hidden from browsing, configuring the printer explicitly is possible. By connecting to `DOCS_SRV` using NetBIOS, the client can have access to the printer if the client is also part of the `DOCS` workgroup. It is also assumed that the client has the correct local printer driver installed, as the `use client driver` directive is set to `Yes`. In this case, the Samba server has no responsibility for sharing printer drivers to the client.

```
[global]
workgroup = DOCS
netbios name = DOCS_SRV
security = share
printcap name = cups
disable spools= Yes
show add printer wizard = No
printing = cups
[printers]
comment = All Printers
path = /var/spool/samba
guest ok = Yes
printable = Yes
use client driver = Yes
browseable = Yes
```

17.1.6.1.4. Secure ReadWrite File and Print Server

The following `/etc/samba/smb.conf` file shows a sample configuration needed to implement a secure read/write print server. Setting the `security` directive to `user` forces Samba to authenticate client connections. Notice the `[homes]` share does not have a `force user` or `force group` directive as the `[public]` share does. The `[homes]` share uses the authenticated user details for any files created as opposed to the `force user` and `force group` in `[public]`.

```
[global]
workgroup = DOCS
netbios name = DOCS_SRV
security = share
```

```
[printers]
comment = Samba Printer
path = /var/spool/samba
guest ok = Yes
printable = Yes
use client driver = Yes
browseable = Yes
```

```
[homes]
comment = Home
capabilities = rw
path = /home/
read only = Yes
guest ok = Yes
```

```
[printers]
comment = All Printers
path = /var/spool/samba
guest ok = Yes
printable = Yes
use client driver = Yes
browseable = Yes
```

```
[public]
comment = Public
path = /export
read only = Yes
guest ok = Yes
```
[global]
    workgroup = DOCS
    netbios name = DOCS_SRV
    security = user
    printcap name = cups
    disable spools = Yes
    show add printer wizard = No
    printing = cups
[homes]
    comment = Home Directories
    valid users = %S
    read only = No
    browseable = No
[public]
    comment = Data
    path = /export
    force user = docsbot
    force group = users
    guest ok = Yes
[printers]
    comment = All Printers
    path = /var/spool/samba
    printer admin = john, ed, @admins
    create mask = 0600
    guest ok = Yes
    printable = Yes
    use client driver = Yes
    browseable = Yes

17.1.6.2. Domain Member Server
A domain member, while similar to a stand-alone server, is logged into a domain controller (either Windows or Samba) and is subject to the domain's security rules. An example of a domain member server would be a departmental server running Samba that has a machine account on the Primary Domain Controller (PDC). All of the department's clients still authenticate with the PDC, and desktop profiles and all network policy files are included. The difference is that the departmental server has the ability to control printer and network shares.

17.1.6.2.1. Active Directory Domain Member Server
The following /etc/samba/smb.conf file shows a sample configuration needed to implement an Active Directory domain member server. In this example, Samba authenticates users for services being run locally but is also a client of the Active Directory. Ensure that your kerberos realm parameter is shown in all caps (for example realm = EXAMPLE.COM). Since Windows 2000/2003/2008 requires Kerberos for Active Directory authentication, the realm directive is required. If Active Directory and Kerberos are running on different servers, the password server directive may be required to help the distinction.

[global]
    realm = EXAMPLE.COM
    security = ADS
    encrypt passwords = yes
    # Optional. Use only if Samba cannot determine the Kerberos server automatically.
    password server = kerberos.example.com

In order to join a member server to an Active Directory domain, the following steps must be completed:

- Configuration of the /etc/samba/smb.conf file on the member server
- Configuration of Kerberos, including the /etc/krb5.conf file, on the member server
- Creation of the machine account on the Active Directory domain server
- Association of the member server to the Active Directory domain

To create the machine account and join the Windows 2000/2003/2008 Active Directory, Kerberos must first be initialized for the member server wishing to join the Active Directory domain. To create an administrative Kerberos ticket, type the following command as root on the member server:

```
    kinit administrator@EXAMPLE.COM
```

The kinit command is a Kerberos initialization script that references the Active Directory administrator account and Kerberos realm. Since Active Directory requires Kerberos tickets, kinit obtains and caches a Kerberos ticket-granting ticket for client/server authentication. For more information on Kerberos, the /etc/krb5.conf file, and the kinit command, refer to the Using Kerberos section of the Red Hat Enterprise Linux 6 Managing Single Sign-On and Smart Cards guide.

To join an Active Directory server (windows1.example.com), type the following command as root on the member server:

```
    net ads join -S windows1.example.com -U administrator%password
```

Since the machine windows1 was automatically found in the corresponding Kerberos realm (the kinit command succeeded), the net command connects to the Active Directory server using its required administrator account and password. This creates the appropriate machine account on the Active Directory and grants permissions to the Samba domain member server to join the domain.
The security option

Since security = ads and not security = user is used, a local password back end such as smbd is not needed. Older clients that do not support security = ads are authenticated as if security = domain had been set. This change does not affect functionality and allows local users not previously in the domain.

17.1.6.2.2. Windows NT4-based Domain Member Server

The following /etc/samba/smb.conf file shows a sample configuration needed to implement a Windows NT4-based domain member server. Becoming a member server of an NT4-based domain is similar to connecting to an Active Directory. The main difference is NT4-based domains do not use Kerberos in their authentication method, making the /etc/samba/smb.conf file simpler. In this instance, the Samba member server functions as a pass through to the NT4-based domain server.

```
[global]
workgroup = DOCS
netbios name = DOCS_SRV
security = domain

[homes]
comment = Home Directories
valid users = %S
read only = No
browseable = No

[public]
comment = Data
path = /export
force user = docsbot
force group = users
guest ok = Yes
```

Having Samba as a domain member server can be useful in many situations. There are times where the Samba server can have other uses besides file and printer sharing. It may be beneficial to make Samba a domain member server in instances where Linux-only applications are required for use in the domain environment. Administrators appreciate keeping track of all machines in the domain, even if not Windows-based. In the event the Windows-based server hardware is deprecated, it is quite easy to modify the /etc/samba/smb.conf file to convert the server to a Samba-based PDC. If Windows NT-based servers are upgraded to Windows 2000/2003/2008, the /etc/samba/smb.conf file is easily modifiable to incorporate the infrastructure change to Active Directory if needed.

Make sure you join the domain before starting Samba

After configuring the /etc/samba/smb.conf file, join the domain before starting Samba by typing the following command as root:

```
net rpc join -U administrator%password
```

Note that the -S option, which specifies the domain server hostname, does not need to be stated in the net rpc join command. Samba uses the hostname specified by the workgroup directive in the /etc/samba/smb.conf file instead of it being stated explicitly.

17.1.6.3. Domain Controller

A domain controller in Windows NT is functionally similar to a Network Information Service (NIS) server in a Linux environment. Domain controllers and NIS servers both host user/group information databases as well as related services. Domain controllers are mainly used for security, including the authentication of users accessing domain resources. The service that maintains the user/group database integrity is called the Security Account Manager (SAM). The SAM database is stored differently between Windows and Linux Samba-based systems, therefore SAM replication cannot be achieved and platforms cannot be mixed in a PDC/BDC environment.

In a Samba environment, there can be only one PDC and zero or more BDCs.

A mixed Samba/Windows domain controller environment

Samba cannot exist in a mixed Samba/Windows domain controller environment (Samba cannot be a BDC of a Windows PDC or vice versa). Alternatively, Samba PDCs and BDCs can coexist.

17.1.6.3.1. Primary Domain Controller (PDC) using tdbsam

The simplest and most common implementation of a Samba PDC uses the new default tdbsam password database back end. Replacing the aging smbd back end, tdbsam has numerous improvements that are explained in more detail in Section 17.1.8, “Samba Account Information Databases”. The passwd backend directive controls which back end is to be used for the PDC.

The following /etc/samba/smb.conf file shows a sample configuration needed to implement a tdbsam password database back end.
To provide a functional PDC system which uses the *tdbsam* follow these steps:

1. Use a configuration of the *smb.conf* file as shown in the example above.
2. Add the root user to the Samba password database:

   ```bash
   smbpasswd -a root
   ```
3. Start the *smb* service.
4. Make sure all profile, user, and netlogon directories are created.
5. Add groups that users can be members of:

   ```bash
   groupadd -f users
   groupadd -f nobody
   groupadd -f ntadmins
   ```
6. Associate the UNIX groups with their respective Windows groups:

   ```bash
   net groupmap add ntgroup="Domain Users" unixgroup=users
   net groupmap add ntgroup="Domain Guests" unixgroup=nobody
   net groupmap add ntgroup="Domain Admins" unixgroup=ntadmins
   ```
7. Grant access rights to a user or a group. For example, to grant the right to add client machines to the domain on a Samba domain controller, to the members to the Domain Admins group, execute the following command:

   ```bash
   net rpc rights grant 'DOCS\Domain Admins' SetMachineAccountPrivilege -S PDC -U root
   ```

Keep in mind that Windows systems prefer to have a primary group which is mapped to a domain group such as Domain Users.

Windows groups and users use the same namespace thus not allowing the existence of a group and a user with the same name like in UNIX.

### Limitations of the *tdbsam* authentication back end

If you need more than one domain controller or have more than 250 users, do not use a *tdbsam* authentication back end. LDAP is recommended in these cases.

#### 17.1.6.3.2. Primary Domain Controller (PDC) with Active Directory

Although it is possible for Samba to be a member of an Active Directory, it is not possible for Samba to operate as an Active Directory domain controller.

#### 17.1.7. Samba Security Modes

There are only two types of security modes for Samba, *share-level* and *user-level*, which are collectively known as *security levels*. Share-level security can only be implemented in one way, while user-level security can be implemented...
in one of four different ways. The different ways of implementing a security level are called **security modes**.

### 17.1.7.1. User-Level Security

User-level security is the default setting for Samba. Even if the `security = user` directive is not listed in the `/etc/samba/smb.conf` file, it is used by Samba. If the server accepts the client's username/password, the client can then mount multiple shares without specifying a password for each instance. Samba can also accept session-based username/password requests. The client maintains multiple authentication contexts by using a unique UID for each logon.

In the `/etc/samba/smb.conf` file, the `security = user` directive that sets user-level security is:

```
[GLOBAL]
...
security = user
...
```

The following sections describe other implementations of user-level security.

#### 17.1.7.1.1. Domain Security Mode (User-Level Security)

In domain security mode, the Samba server has a machine account (domain security trust account) and causes all authentication requests to be passed through to the domain controllers. The Samba server is made into a domain member server by using the following directives in the `/etc/samba/smb.conf` file:

```
[GLOBAL]
...
security = domain
workgroup = MARKETING
...
```

#### 17.1.7.1.2. Active Directory Security Mode (User-Level Security)

If you have an Active Directory environment, it is possible to join the domain as a native Active Directory member. Even if a security policy restricts the use of NT-compatible authentication protocols, the Samba server can join an ADS using Kerberos. Samba in Active Directory member mode can accept Kerberos tickets.

In the `/etc/samba/smb.conf` file, the following directives make Samba an Active Directory member server:

```
[GLOBAL]
...
security = ADS
realm = EXAMPLE.COM
password server = kerberos.example.com
...
```

#### 17.1.7.1.3. Server Security Mode (User-Level Security)

Server security mode was previously used when Samba was not capable of acting as a domain member server. It is highly recommended to not use this mode since there are numerous security drawbacks.

In the `/etc/samba/smb.conf`, the following directives enable Samba to operate in server security mode:

```
[GLOBAL]
...
encrypt passwords = Yes
security = server
password server = "NetBIOS_of_Domain_Controller"
...
```

#### 17.1.7.2. Share-Level Security

With share-level security, the server accepts only a password without an explicit username from the client. The server expects a password for each share, independent of the username. There have been recent reports that Microsoft Windows clients have compatibility issues with share-level security servers. Samba developers strongly discourage use of share-level security.

In the `/etc/samba/smb.conf` file, the `security = share` directive that sets share-level security is:

```
[GLOBAL]
...
security = share
...
```

### 17.1.8. Samba Account Information Databases

The latest release of Samba offers many new features including new password database back ends not previously available. Samba version 3.0.0 fully supports all databases used in previous versions of Samba. However, although supported, many back ends may not be suitable for production use.

The following is a list different back ends you can use with Samba. Other back ends not listed here may also be available.
Plain Text
Plain text back ends are nothing more than the /etc/passwd type back ends. With a plain text back end, all usernames and passwords are sent unencrypted between the client and the Samba server. This method is very unsecure and is not recommended for use by any means. It is possible that different Windows clients connecting to the Samba server with plain text passwords cannot support such an authentication method.

smbpasswd
A popular back end used in previous Samba packages, the smbpasswd back end utilizes a plain ASCII text layout that includes the MS Windows LanMan and NT account, and encrypted password information. The smbpasswd back end lacks the storage of the Windows NT2000/2003 SAM extended controls. The smbpasswd back end is not recommended because it does not scale well or hold any Windows information, such as RIDs for NT-based groups. The tdbsam back end solves these issues for use in a smaller database (250 users), but is still not an enterprise-class solution.

ldapsam_compat
The ldapsam_compat back end allows continued OpenLDAP support for use with upgraded versions of Samba. This option is normally used when migrating to Samba 3.0.

dlbsam
The new default tdbsam password back end provides an ideal database back end for local servers, servers that do not need built-in database replication, and servers that do not require the scalability or complexity of LDAP. The tdbsam back end includes all of the smbpasswd database information as well as the previously-excluded SAM information. The inclusion of the extended SAM data allows Samba to implement the same account and system access controls as seen with Windows NT2000/2003/2008-based systems.

The tdbsam back end is recommended for 250 users at most. Larger organizations should require Active Directory or LDAP integration due to scalability and possible network infrastructure concerns.

ldapsam
The ldapsam back end provides an optimal distributed account installation method for Samba. LDAP is optimal because of its ability to replicate its database to any number of servers such as the Red Hat Directory Server or an OpenLDAP Server. LDAP databases are light-weight and scalable, and as such are preferred by large enterprises. Installation and configuration of directory servers is beyond the scope of this chapter. For more information on the Red Hat Directory Server, refer to the Red Hat Directory Server 8.2 Deployment Guide. For more information on LDAP, refer to Section 16.1, “OpenLDAP”.

If you are upgrading from a previous version of Samba to 3.0, note that the OpenLDAP schema file (/usr/share/doc/samba-version/LDAP/samba.schema) and the Red Hat Directory Server schema file (/usr/share/doc/samba-version/LDAP/samba-schema-FDS.ldif) have changed. These files contain the attribute syntax definitions and objectclass definitions that the ldapsam back end needs in order to function properly.

As such, if you are using the ldapsam back end for your Samba server, you will need to configure slapd to include one of these schema file. Refer to Section 16.1.3.3, “Extending Schema” for directions on how to do this.

Make sure the openldap-server package is installed
You need to have the openldap-server package installed if you want to use the ldapsam back end.

17.1.9. Samba Network Browsing
Network browsing enables Windows and Samba servers to appear in the Windows Network Neighborhood. Inside the Network Neighborhood, icons are represented as servers and if opened, the server's shares and printers that are available are displayed.

Network browsing capabilities require NetBIOS over TCP/IP. NetBIOS-based networking uses broadcast (UDP) messaging to accomplish browse list management. Without NetBIOS and WINS as the primary method for TCP/IP hostname resolution, other methods such as static files (/etc/hosts) or DNS, must be used.

A domain master browser collates the browse lists from local master browsers on all subnets so that browsing can occur between workgroups and subnets. Also, the domain master browser should preferably be the local master browser for its own subnet.

17.1.9.1. Domain Browsing
By default, a Windows server PDC for a domain is also the domain master browser for that domain. A Samba server must not be set up as a domain master server in this type of situation.

For subnets that do not include the Windows server PDC, a Samba server can be implemented as a local master browser. Configuring the /etc/samba/smb.conf file for a local master browser (or no browsing at all) in a domain controller environment is the same as workgroup configuration.

17.1.9.2. WINS (Windows Internet Name Server)
Either a Samba server or a Windows NT server can function as a WINS server. When a WINS server is used with NetBIOS enabled, UDP unicasts can be routed which allows name resolution across networks. Without a WINS server, the UDP broadcast is limited to the local subnet and therefore cannot be routed to other subnets, workgroups, or domains. If WINS
replication is necessary, do not use Samba as your primary WINS server, as Samba does not currently support WINS replication.

In a mixed NT/2000/2003/2008 server and Samba environment, it is recommended that you use the Microsoft WINS capabilities. In a Samba-only environment, it is recommended that you use only one Samba server for WINS.

The following is an example of the `/etc/samba/smb.conf` file in which the Samba server is serving as a WINS server:

```plaintext
[global]
  wins support = Yes
```

### Using WINS

All servers (including Samba) should connect to a WINS server to resolve NetBIOS names. Without WINS, browsing only occurs on the local subnet. Furthermore, even if a domain-wide list is somehow obtained, hosts cannot be resolved for the client without WINS.

17.1.10. Samba with CUPS Printing Support

Samba allows client machines to share printers connected to the Samba server. In addition, Samba also allows client machines to send documents built in Linux to Windows printer shares. Although there are other printing systems that function with Fedora, CUPS (Common UNIX Print System) is the recommended printing system due to its close integration with Samba.

#### 17.1.10.1. Simple smb.conf Settings

The following example shows a very basic `/etc/samba/smb.conf` configuration for CUPS support:

```plaintext
[global]
  load printers = Yes
  printing = cups
  printcap name = cups
  [printers]
  comment = All Printers
  path = /var.spool/samba
  browseable = No
  public = Yes
  guest ok = Yes
  writable = No
  printable = Yes
  printer admin = @ntadmins
  [print$]
  comment = Printer Drivers Share
  path = /var/lib/samba/drivers
  write list = ed, john
  printer admin = ed, john
```

Other printing configurations are also possible. To add additional security and privacy for printing confidential documents, users can have their own print spooler not located in a public path. If a job fails, other users would not have access to the file.

The `print$` directive contains printer drivers for clients to access if not available locally. The `print$` directive is optional and may not be required depending on the organization.

Setting `browseable` to `Yes` enables the printer to be viewed in the Windows Network Neighborhood, provided the Samba server is set up correctly in the domain/workgroup.

17.1.11. Samba Distribution Programs

**findsmb**

The `findsmb` program is a Perl script which reports information about SMB-aware systems on a specific subnet. If no subnet is specified the local subnet is used. Items displayed include IP address, NetBIOS name, workgroup or domain name, operating system, and version.

The following example shows the output of executing `findsmb` as any valid user on a system:

```
IP ADDR         NETBIOS NAME  WORKGROUP/OS/VERSION
----------------- ----------------------------
10.1.59.25      VERVE           [MYGROUP] [Unix] [Samba 3.0.0-15]
10.1.59.26      STATION22      [MYGROUP] [Unix] [Samba 3.0.2-7.FC1]
10.1.59.56      TREK            [WORKGROUP] [Windows 5.0] [Windows 2000 LAN Manager]
10.1.57.94      PIXEL           [MYGROUP] [Unix] [Samba 3.0.0-15]
10.1.57.137     MOBILE001      [MYGROUP] [Unix] [Samba 2.2.7-security-rollup-fix]
10.1.57.141     JAWS            [Kwikmart] [Unix] [Samba 2.2.7a-security-rollup-fix]
10.1.56.159     FRED            +[MYGROUP] [Unix] [Samba 3.0.0-14.3E]
10.1.59.192     LEGION          +[MYGROUP] [Unix] [Samba 2.2.7-security-rollup-fix]
10.1.56.205     NANCYN         +[MYGROUP] [Unix] [Samba 2.2.7a-security-rollup-fix]
```

**net**

The `net` utility is similar to the `net` utility used for Windows and MS-DOS. The first argument is used to specify the protocol
to use when executing a command. The protocol option can be ads, rap, or rpc for specifying the type of server connection. Active Directory uses ads, Win9x/NT3 uses rap, and Windows NT4/2000/2003/2008 uses rpc. If the protocol is omitted, net automatically tries to determine it.

The following example displays a list the available shares for a host named wakko:

```
~]$ net -l share -S wakko
Password:
Enumerating shared resources (exports) on remote server:
<table>
<thead>
<tr>
<th>Share name</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>data</td>
<td>Disk</td>
<td>Wakko data share</td>
</tr>
<tr>
<td>tmp</td>
<td>Disk</td>
<td>Wakko tmp share</td>
</tr>
<tr>
<td>IPC$</td>
<td>IPC</td>
<td>IPC Service (Samba Server)</td>
</tr>
<tr>
<td>ADMIN$</td>
<td>IPC</td>
<td>IPC Service (Samba Server)</td>
</tr>
</tbody>
</table>
```

The following example displays a list of Samba users for a host named wakko:

```
~]$ net -l user -S wakko
root password:
<table>
<thead>
<tr>
<th>User name</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>andriusb</td>
<td>Documentation</td>
</tr>
<tr>
<td>joe</td>
<td>Marketing</td>
</tr>
<tr>
<td>lisa</td>
<td>Sales</td>
</tr>
</tbody>
</table>
```

**nmblookup**

```
nmblookup options netbios_name
```

The nmblookup program resolves NetBIOS names into IP addresses. The program broadcasts its query on the local subnet until the target machine replies.

Here is an example:

```
~]$ nmblookup trek
querying trek on 10.1.59.255
10.1.56.45 trek<00>
```

**pdbedit**

```
pdbedit options
```

The pdbedit program manages accounts located in the SAM database. All back ends are supported including smbpasswd, LDAP, and the tdb database library.

The following are examples of adding, deleting, and listing users:
new password:
retype new password:
Unix username: kristin
NT username: 
Account Flags: [U ]
User SID: S-1-5-21-1210235352-3884200048-1474406118-2012
Primary Group SID: S-1-5-21-1210235352-3884200048-1474406118-2077
Full Name: \wakko\kristin
HomeDir Drive: Logon Script: Profile Path: \wakko\kristin\profile
Account desc: Workstations: Munged
dial: Logon time: 0 Logoff time: Mon, 18 Jan 2038 22:14:07 GMT
Kickoff time: Mon, 18 Jan 2038 22:14:07 GMT
Password last set: Thu, 29 Jan 2004 08:29:28 GMT
Password can change: Thu, 29 Jan 2004 08:29:28 GMT
Password must change: Mon, 18 Jan 2038 22:14:07 GMT
Unix username: kristin
NT username: 
Account Flags: [U ]
User SID: S-1-5-21-1210235352-3884200048-1474406118-2012
Primary Group SID: S-1-5-21-1210235352-3884200048-1474406118-2077
Full Name: \wakko\kristin
HomeDir Drive: Logon Script: Profile Path: \wakko\kristin\profile
Account desc: Workstations: Munged
dial: Logon time: 0 Logoff time: Mon, 18 Jan 2038 22:14:07 GMT
Kickoff time: Mon, 18 Jan 2038 22:14:07 GMT
Password last set: Thu, 29 Jan 2004 08:29:28 GMT
Password can change: Thu, 29 Jan 2004 08:29:28 GMT
Password must change: Mon, 18 Jan 2038 22:14:07 GMT
}$ pdbedit -a kristin
new password:
retype new password:
Unix username: kristin
NT username: 
Account Flags: [U ]
User SID: S-1-5-21-1210235352-3884200048-1474406118-2012
Primary Group SID: S-1-5-21-1210235352-3884200048-1474406118-2077
Full Name: \wakko\kristin
HomeDir Drive: Logon Script: Profile Path: \wakko\kristin\profile
Account desc: Workstations: Munged
dial: Logon time: 0 Logoff time: Mon, 18 Jan 2038 22:14:07 GMT
Kickoff time: Mon, 18 Jan 2038 22:14:07 GMT
Password last set: Thu, 29 Jan 2004 08:29:28 GMT
Password can change: Thu, 29 Jan 2004 08:29:28 GMT
Password must change: Mon, 18 Jan 2038 22:14:07 GMT
}$ pdbedit -v -L kristin
Unix username: kristin
NT username: 
Account Flags: [U ]
User SID: S-1-5-21-1210235352-3884200048-1474406118-2012
Primary Group SID: S-1-5-21-1210235352-3884200048-1474406118-2077
Full Name: \wakko\kristin
HomeDir Drive: Logon Script: Profile Path: \wakko\kristin\profile
Account desc: Workstations: Munged
dial: Logon time: 0 Logoff time: Mon, 18 Jan 2038 22:14:07 GMT
Kickoff time: Mon, 18 Jan 2038 22:14:07 GMT
Password last set: Thu, 29 Jan 2004 08:29:28 GMT
Password can change: Thu, 29 Jan 2004 08:29:28 GMT
Password must change: Mon, 18 Jan 2038 22:14:07 GMT
}$ pdbedit -L
andriusb:505:
joe:503:
lisa:504:
kristin:506:
}$ pdbedit -x joe
}$ pdbedit -L
andriusb:505: lisa:504: kristin:506:
rpcclient

rpcclient server options
The rpcclient program issues administrative commands using Microsoft RPCs, which provide access to the Windows administration graphical user interfaces (GUIs) for system management. This is most often used by advanced users that understand the full complexity of Microsoft RPCs.
smbcacls

smbcacls //server/share filename options
The smbcacls program modifies Windows ACLs on files and directories shared by a Samba server or a Windows server.
smbclient

smbclient //server/share password options
The smbclient program is a versatile UNIX client which provides functionality similar to ftp.
smbcontrol

smbcontrol -i options
smbcontrol options destination messagetype parameters
The smbcontrol program sends control messages to running smbd, nmbd, or winbindd daemons. Executing smbcontrol -i runs commands interactively until a blank line or a 'q' is entered.
smbpasswd

smbpasswd options username password
The smbpasswd program manages encrypted passwords. This program can be run by a superuser to change any user's password as well as by an ordinary user to change their own Samba password.
smbspool

smbspool job user title copies options filename
The **smbpool** program is a CUPS-compatible printing interface to Samba. Although designed for use with CUPS printers, **smbpool** can work with non-CUPS printers as well.

### smbstatus

**smbstatus options**

The **smbstatus** program displays the status of current connections to a Samba server.

### smbtar

**smbtar options**

The **smbtar** program performs backup and restores of Windows-based share files and directories to a local tape archive. Though similar to the **tar** command, the two are not compatible.

### testparm

**testparm options filename hostname IP_address**

The **testparm** program checks the syntax of the `/etc/samba/smb.conf` file. If your `/etc/samba/smb.conf` file is in the default location (`/etc/samba/smb.conf`) you do not need to specify the location. Specifying the hostname and IP address to the **testparm** program verifies that the `hosts.allow` and `host.deny` files are configured correctly. The **testparm** program also displays a summary of your `/etc/samba/smb.conf` file and the server's role (stand-alone, domain, etc.) after testing. This is convenient when debugging as it excludes comments and concisely presents information for experienced administrators to read.

For example:

```
$ testparm
Load smb config files from /etc/samba/smb.conf
Processing section "[homes]"
Processing section "[printers]"
Processing section "[tmp]"
Processing section "[html]"
Loaded services file OK.
Server role: ROLE_STANDALONE
Press enter to see a dump of your service definitions
<enter>
# Global parameters
[global]
  workgroup = MYGROUP
  server string = Samba Server
  security = SHARE
  log file = /var/log/samba/%m.log
  max log size = 50
  socket options = TCP_NODELAY SO_RCVBUF=8192 SO_SNDBUF=8192
timeout = 30
  dns proxy = No

[homes]
  comment = Home Directories
  read only = No
  browseable = No

[printers]
  comment = All Printers
  path = /var/spool/samba
  printable = Yes
  browseable = No

[tmp]
  comment = Wakko tmp
  path = /tmp
  guest only = Yes

[html]
  comment = Wakko www
  path = /var/www/html
  force user = andriusb
  force group = users
  read only = No
  guest only = Yes
```

### wbinfo

**wbinfo options**

The **wbinfo** program displays information from the **winbindd** daemon. The **winbindd** daemon must be running for **wbinfo** to work.

#### 17.1.12. Additional Resources

The following sections give you the means to explore Samba in greater detail.

##### 17.1.12.1. Installed Documentation

> `/usr/share/doc/samba-version-number/` — All additional files included with the Samba distribution. This includes all helper scripts, sample configuration files, and documentation. This directory also contains online versions of *The Official Samba-3 HOWTO-Collection* and *Samba-3 by Example*, both of which are cited below.
Make sure you have the samba-doc package installed

In order to use the Samba documentation, first ensure the samba-doc package is installed on your system by running, as root:

```bash
yum install samba-doc
```

For more information on installing packages with Yum, refer to Section 5.2.4, "Installing Packages".

Refer to the following manual pages for detailed information specific Samba features:

- `smb.conf`
- `samba`
- `smbd`
- `nmbd`
- `winbind`

17.1.12.2. Related Books

- *The Official Samba-3 HOWTO-Collection* by John H. Terpstra and Jelmer R. Vernooij; Prentice Hall — The official Samba-3 documentation as issued by the Samba development team. This is more of a reference guide than a step-by-step guide.
- *Samba-3 by Example* by John H. Terpstra; Prentice Hall — This is another official release issued by the Samba development team which discusses detailed examples of OpenLDAP, DNS, DHCP, and printing configuration files. This has step-by-step related information that helps in real-world implementations.
- *Using Samba, 2nd Edition* by Jay T's, Robert Eckstein, and David Collier-Brown; O'Reilly — A good resource for novice to advanced users, which includes comprehensive reference material.

17.1.12.3. Useful Websites

- [http://www.samba.org/](http://www.samba.org/) — Homepage for the Samba distribution and all official documentation created by the Samba development team. Many resources are available in HTML and PDF formats, while others are only available for purchase. Although many of these links are not Fedora specific, some concepts may apply.
- [http://samba.org/samba/archives.html](http://samba.org/samba/archives.html) — Active email lists for the Samba community. Enabling digest mode is recommended due to high levels of list activity.
- Samba newsgroups — Samba threaded newsgroups, such as gmane.org, that use the NNTP protocol are also available. This an alternative to receiving mailing list emails.

17.2. FTP

File Transfer Protocol (FTP) is one of the oldest and most commonly used protocols found on the Internet today. Its purpose is to reliably transfer files between computer hosts on a network without requiring the user to log directly into the remote host or have knowledge of how to use the remote system. It allows users to access files on remote systems using a standard set of simple commands.

This section outlines the basics of the FTP protocol, as well as configuration options for the primary FTP server shipped with Fedora, vsftpd.

17.2.1. The File Transfer Protocol

However, because FTP is so prevalent on the Internet, it is often required to share files to the public. System administrators, therefore, should be aware of the FTP protocol's unique characteristics.

17.2.1.1. Multiple Ports, Multiple Modes

Unlike most protocols used on the Internet, FTP requires multiple network ports to work properly. When an FTP client application initiates a connection to an FTP server, it opens port 21 on the server — known as the command port. This port is used to issue all commands to the server. Any data requested from the server is returned to the client via a data port. The port number for data connections, and the way in which data connections are initialized, vary depending upon whether the client requests the data in active or passive mode.

The following defines these modes:

**active mode**

Active mode is the original method used by the FTP protocol for transferring data to the client application. When an active mode data transfer is initiated by the FTP client, the server opens a connection from port 20 on the server to the IP address and a random, unprivileged port (greater than 1024) specified by the client. This arrangement means that the client machine must be allowed to accept connections over any port above 1024. With the growth of insecure networks, such as the Internet, the use of firewalls to protect client machines is now prevalent. Because these client-side firewalls often deny incoming connections from active mode FTP servers, passive mode was devised.

**passive mode**

Passive mode, like active mode, is initiated by the FTP client application. When requesting data from the server, the FTP client indicates it wants to access the data in passive mode and the server provides the IP address and a random, unprivileged port (greater than 1024) on the server. The client then connects to that port on the server to download the requested information.
While passive mode resolves issues for client-side firewall interference with data connections, it can complicate administration of the server-side firewall. You can reduce the number of open ports on a server by limiting the range of unprivileged ports on the FTP server. This also simplifies the process of configuring firewall rules for the server. For more information about limiting passive ports, refer to Section 17.2.5.8, "Network Options".

17.2.2. FTP Servers

Fedora ships with two different FTP servers:

- **Red Hat Content Accelerator** — A kernel-based Web server that delivers high performance Web server and FTP services. Since speed is its primary design goal, it has limited functionality and runs only as an anonymous FTP server. For more information about configuring and administering Red Hat Content Accelerator, consult the documentation available online at [http://www.redhat.com/docs/manuals/lux/](http://www.redhat.com/docs/manuals/lux/).
- **vsftpd** — A last, secure FTP daemon which is the preferred FTP server for Fedora. The remainder of this section focuses on vsftpd.

17.2.2.1. vsftpd

The Very Secure FTP Daemon (vsftpd) is designed from the ground up to be fast, stable, and, most importantly, secure. vsftpd is the only stand-alone FTP server distributed with Fedora, due to its ability to handle large numbers of connections efficiently and securely.

The security model used by vsftpd has three primary aspects:

- **Strong separation of privileged and non-privileged processes** — Separate processes handle different tasks, and each of these processes run with the minimal privileges required for the task.
- **Tasks requiring elevated privileges are handled by processes with the minimal privilege necessary** — By leveraging compatibilities found in the `libcap` library, tasks that usually require full root privileges can be executed more safely from a less privileged process.
- **Most processes run in a chroot jail** — Whenever possible, processes are change-rooted to the directory being shared; this directory is then considered a chroot jail. For example, if the directory `/var/ftp/` is the primary shared directory, vsftpd reassigns `/var/ftp/` to the new root directory, known as `/`. This disallows any potential malicious hacker activities for any directories not contained below the new root directory.

Use of these security practices has the following effect on how vsftpd deals with requests:

- **The parent process runs with the least privileges required** — The parent process dynamically calculates the level of privileges it requires to minimize the level of risk. Child processes handle direct interaction with the FTP clients and run with as close to no privileges as possible.
- **All operations requiring elevated privileges are handled by a small parent process** — Much like the Apache HTTP Server, vsftpd launches unprivileged child processes to handle incoming connections. This allows the privileged, parent process to be as small as possible and handle relatively few tasks.
- **All requests from unprivileged child processes are distorted by the parent process** — Communication with child processes are received over a socket, and the validity of any information from child processes is checked before being acted on.
- **Most interaction with FTP clients is handled by unprivileged child processes in a chroot jail** — Because these child processes are unprivileged and only have access to the directory being shared, any crashed processes only allows the attacker access to the shared files.

17.2.2.3. Files Installed with vsftpd

The vsftpd RPM installs the daemon (`/usr/sbin/vsftpd`), its configuration and related files, as well as FTP directories onto the system. The following lists the files and directories related to vsftpd configuration:

- `/etc/rc.d/init.d/vsftpd` — The initialization script (`initscript`) used by the `systemctl` command to start, stop, or reload vsftpd. Refer to Section 17.2.4, "Starting and Stopping vsftpd," for more information about using this script.
- `/etc/pam.d/vsftpd` — The Pluggable Authentication Modules (PAM) configuration file for vsftpd. This file specifies the requirements a user must meet to login to the FTP server. For more information on PAM, refer to the Using Pluggable Authentication Modules (PAM) chapter of the Fedora 18 Managing Single Sign-On and Smart Cards guide.
- `/etc/vsftpd/vsftpd.conf` — The configuration file for vsftpd. Refer to Section 17.2.5, "vsftpd Configuration Options" for a list of important options contained within this file.
- `/etc/vsftpd/ftpusers` — A list of users not allowed to log into vsftpd. By default, this list includes the root, bin, and daemon users, among others.
- `/etc/vsftpd/user_list` — This file can be configured to either deny or allow access to the users listed, depending on whether the `userlist_deny` directive is set to YES (default) or NO in `/etc/vsftpd/vsftpd.conf`. If `/etc/vsftpd/user_list` is used to grant access to users, the usernames listed must not appear in `/etc/vsftpd/ftpusers`.
- `/var/ftp/` — The directory containing files served by vsftpd. It also contains the `/var/ftp/pub/` directory for anonymous users. Both directories are world-readable, but writable only by the root user.

17.2.4. Starting and Stopping vsftpd

The vsftpd RPM installs the `/etc/rc.d/init.d/vsftpd` script, which can be accessed using the `systemctl` command.

To start the server, as root type:
To stop the server, as root type:

```bash
systemctl stop vsftpd.service
```

The `restart` option is a shorthand way of stopping and then starting `vsftpd`. This is the most efficient way to make configuration changes take effect after editing the configuration file for `vsftpd`.

To restart the server, as root type:

```bash
systemctl restart vsftpd.service
```

The `condrestart` (conditional restart) option only starts `vsftpd` if it is currently running. This option is useful for scripts, because it does not start the daemon if it is not running.

To conditionally restart the server, as root type:

```bash
systemctl condrestart vsftpd.service
```

By default, the `vsftpd` service does not start automatically at boot time. To configure the `vsftpd` service to start at boot time, use a service manager such as `systemctl`. Refer to Chapter 9, Services and Daemons for more information on how to configure services in Fedora.

### 17.2.4.1. Starting Multiple Copies of vsftpd

Sometimes one computer is used to serve multiple FTP domains. This is a technique called multihoming. One way to multihome using `vsftpd` is by running multiple copies of the daemon, each with its own configuration file.

To do this, first assign all relevant IP addresses to network devices or alias network devices on the system. Additional information about network configuration scripts can be found in Chapter 8, Network Interfaces.

Next, the DNS server for the FTP domains must be configured to reference the correct machine. For information about BIND and its configuration files, refer to Section 13.2, "BIND".

If there is more configuration files present in the `/etc/vsftpd` directory, calling `systemctl start vsftpd.service` results in the `/etc/rc.d/init.d/vsftpd` initscript starting the same number of processes as the number of configuration files. Each configuration file must have a unique name in the `/etc/vsftpd/` directory and must be readable and writable only by root.

### 17.2.5. vsftpd Configuration Options

Although `vsftpd` may not offer the level of customization other widely available FTP servers have, it offers enough options to fill most administrator's needs. The fact that it is not overly feature-laden limits configuration and programmatic errors.

All configuration of `vsftpd` is handled by its configuration file, `/etc/vsftpd/vsftpd.conf`. Each directive is on its own line within the file and follows the following format:

```
directive=value
```

For each directive, replace `directive` with a valid directive and `value` with a valid value.

**Do not use spaces**

There must not be any spaces between the `directive`, equal symbol, and the `value` in a directive.

Comment lines must be preceded by a hash sign (`#`) and are ignored by the daemon.

For a complete list of all directives available, refer to the man page for `vsftpd.conf`.

**Securing the vsftpd service**

For an overview of ways to secure `vsftpd`, refer to the Fedora 18 Security Guide.

The following is a list of some of the more important directives within `/etc/vsftpd/vsftpd.conf`. All directives not explicitly found or commented out within `vsftpd`'s configuration file are set to their default value.

#### 17.2.5.1. Daemon Options

The following is a list of directives which control the overall behavior of the `vsftpd` daemon.

- **listen** — When enabled, `vsftpd` runs in stand-alone mode. Fedora sets this value to `YES`. This directive cannot be used in conjunction with the `listen_ipv6` directive.
  
  The default value is `NO`.

- **listen_ipv6** — When enabled, `vsftpd` runs in stand-alone mode, but listens only to IPv6 sockets. This directive cannot be used in conjunction with the `listen` directive.
  
  The default value is `NO`.

- **session_support** — When enabled, `vsftpd` attempts to maintain login sessions for each user through Pluggable Authentication Modules (PAM). For more information, refer to the Using Pluggable Authentication Modules (PAM).
The following lists directives which control anonymous user access to the server. To use these options, the

17.2.5.3. Anonymous User Options

The following is a list of directives which control the login behavior and access control mechanisms.

- **anonymous_enable** — When enabled, anonymous users are allowed to log in. The usernames anonymous and ftp are accepted.
  - The default value is YES.
  - Refer to Section 17.2.5.3, “Anonymous User Options” for a list of directives affecting anonymous users.

- **banned_email_file** — If the deny_email_enable directive is set to YES, this directive specifies the file containing a list of anonymous email passwords which are not permitted access to the server.
  - The default value is /etc/vsftpd/banned_emails.

- **banner_file** — Specifies the file containing text displayed when a connection is established to the server. This option overrides any text specified in the ftpd_banner directive.
  - There is no default value for this directive.

- **cmds_allowed** — Specifies a comma-delimited list of FTP commands allowed by the server. All other commands are rejected.
  - There is no default value for this directive.

- **deny_email_enable** — When enabled, any anonymous user utilizing email passwords specified in the /etc/vsftpd/banned_emails are denied access to the server. The name of the file referenced by this directive can be specified using the banned_email_file directive.
  - The default value is NO.

- **ftpd_banner** — When enabled, the string specified within this directive is displayed when a connection is established to the server. This option can be overridden by the banner_file directive.
  - By default vsftpd displays its standard banner.

- **local_enable** — When enabled, local users are allowed to log into the system.
  - The default value is YES.
  - Refer to Section 17.2.5.4, “Local User Options” for a list of directives affecting local users.

- **pam_service_name** — Specifies the PAM service name for vsftpd.
  - The default value is ftp. Note, in Fedora, the value is set to vsftpd.
  - The default value is NO. Note, in Fedora, the value is set to YES.

- **userlistdeny** — When used in conjunction with the userlist_enable directive and set to NO, all local users are denied access unless the username is listed in the file specified by the userlist_file directive. Because access is denied before the client is asked for a password, setting this directive to NO prevents local users from submitting unencrypted passwords over the network.
  - The default value is YES.

- **userlist_enable** — When enabled, the users listed in the file specified by the userlist_file directive are denied access. Because access is denied before the client is asked for a password, users are prevented from submitting unencrypted passwords over the network.
  - The default value is NO, however under Fedora the value is set to YES.

- **userlist_file** — Specifies the file referenced by vsftpd when the userlist_enable directive is enabled.
  - The default value is /etc/vsftpd/user_list and is created during installation.

17.2.5.4. Local User Options

The following lists directives which control anonymous user access to the server. To use these options, the anonymous_enable directive must be set to YES.

- **anondir_writeenable** — When enabled in conjunction with the write_enable directive, anonymous users are allowed to create new directories within a parent directory which has write permissions.
  - The default value is NO.

- **anon_root** — Specifies the directory vsftpd changes to after an anonymous user logs in.
  - There is no default value for this directive.

- **anon_upload_enable** — When enabled in conjunction with the write_enable directive, anonymous users are allowed to upload files within a parent directory which has write permissions.
  - The default value is NO.

- **anon_world_readable_only** — When enabled, anonymous users are only allowed to download world-readable files.
  - The default value is YES.

- **ftppassword** — Specifies the local user account (listed in /etc/passwd) used for the anonymous FTP user. The home directory specified in /etc/passwd for the user is the root directory of the anonymous FTP user.
  - The default value is ANON.

- **no_anon_password** — When enabled, the anonymous user is not asked for a password.
  - The default value is NO.

- **secure_email_list_enable** — When enabled, only a specified list of email passwords for anonymous logins is accepted. This is a convenient way to offer limited security to public content without the need for virtual users. Anonymous logins are prevented unless the password provided is listed in /etc/vsftpd/email_passwords. The file format is one password per line, with no trailing white spaces.
  - The default value is NO.
17.2.5.4. Local User Options
The following lists directives which characterize the way local users access the server. To use these options, the `local_enable` directive must be set to YES.

- **chmod_enable** — When enabled, the FTP command SITE CHMOD is allowed for local users. This command allows the users to change the permissions on files.
  - The default value is YES.
- **chroot_list_enable** — When enabled, the local users listed in the file specified in the `chroot_list_file` directive are placed in a chroot jail upon log in.
  - If enabled in conjunction with the `chroot_local_user` directive, the local users listed in the file specified in the `chroot_list_file` directive are not placed in a chroot jail upon log in.
  - The default value is NO.
- **chroot_list_file** — Specifies the file containing a list of local users referenced when the `chroot_list_enable` directive is set to YES.
  - The default value is `/etc/vsftpd/chroot_list`.
- **chroot_local_user** — When enabled, local users are change-rooted to their home directories after logging in.
  - The default value is NO.

**Avoid enabling the chroot_local_user option**
Enabling `chroot_local_user` opens up a number of security issues, especially for users with upload privileges. For this reason, it is not recommended.

- **guest_enable** — When enabled, all non-anonymous users are logged in as the user `guest`, which is the local user specified in the `guest_username` directive.
  - The default value is NO.
- **guest_username** — Specifies the username the guest user is mapped to.
  - The default value is ftp.
- **local_root** — Specifies the directory vsftpd changes to after a local user logs in.
  - There is no default value for this directive.
- **local_umask** — Specifies the umask value for file creation. Note that the default value is in octal form (a numerical system with a base of eight), which includes a "0" prefix. Otherwise the value is treated as a base-10 integer.
  - The default value is 022.
- **passwd_chroot_enable** — When enabled in conjunction with the `chroot_local_user` directive, vsftpd changes-roots local users based on the occurrence of the `./` in the home directory field within `/etc/passwd`.
  - The default value is NO.
- **user_config_dir** — Specifies the path to a directory containing configuration files bearing the name of local system users that contain specific setting for that user. Any directive in the user's configuration file overrides those found in `/etc/vsftpd/vsftpd.conf`.
  - There is no default value for this directive.

17.2.5.5. Directory Options
The following lists directives which affect directories.

- **dirlist_enable** — When enabled, users are allowed to view directory lists.
  - The default value is YES.
- **dirmessage_enable** — When enabled, a message is displayed whenever a user enters a directory with a message file. This message resides within the current directory. The name of this file is specified in the `message_file` directive and is .message by default.
  - The default value is NO. Note, in Fedora, the value is set to YES.
- **force_dot_files** — When enabled, files beginning with a dot (.) are listed in directory listings, with the exception of the . and .. files.
  - The default value is NO.
- **hide_ids** — When enabled, all directory listings show ftp as the user and group for each file.
  - The default value is NO.
- **message_file** — Specifies the name of the message file when using the `dirmessage_enable` directive.
  - The default value is .message.
- **text_userdb_names** — When enabled, text usernames and group names are used in place of UID and GID entries. Enabling this option may slow performance of the server.
  - The default value is NO.
- **use_localtime** — When enabled, directory listings reveal the local time for the computer instead of GMT.
  - The default value is NO.

17.2.5.6. File Transfer Options
The following lists directives which affect directories.

- **download_enable** — When enabled, file downloads are permitted.
  - The default value is YES.
- **chown_uploads** — When enabled, all files uploaded by anonymous users are owned by the user specified in the
chown_username directive.
The default value is NO.

- **chown_username** — Specifies the ownership of anonymously uploaded files if the chown_uploads directive is enabled.
The default value is root.

- **write_enable** — When enabled, FTP commands which can change the file system are allowed, such as DELE, RNFR, and STOR.
The default value is YES.

### 17.2.5.7. Logging Options
The following lists directives which affect vsftpd's logging behavior.

- **dual_log_enable** — When enabled in conjunction with xferlog_enable, vsftpd writes two files simultaneously: a wu-ftpd-compatible log to the file specified in the xferlog_file directive (/var/log/xferlog by default) and a standard vsftpd log file specified in the vsftpd_log_file directive (/var/log/vsftpd.log by default).
The default value is NO.

- **log_ftp_protocol** — When enabled in conjunction with xferlog_enable and with xferlog_std_format set to NO, all FTP commands and responses are logged. This directive is useful for debugging.
The default value is NO.

- **syslog_enable** — When enabled in conjunction with xferlog_enable, all logging normally written to the standard vsftpd log file specified in the vsftpd_log_file directive (/var/log/vsftpd.log by default) is sent to the system logger instead under the FTPD facility.
The default value is NO.

- **vsftpd_log_file** — Specifies the vsftpd log file. For this file to be used, xferlog_enable must be enabled and xferlog_std_format must either be set to NO or, if xferlog_std_format is set to YES dual_log_enable must be enabled. It is important to note that if syslog_enable is set to YES, the system log is used instead of the file specified in this directive.
The default value is /var/log/vsftpd.log.

- **xferlog_enable** — When enabled, vsftpd logs connections (vsftpd format only) and file transfer information to the log file specified in the vsftpd_log_file directive (/var/log/vsftpd.log by default). If xferlog_std_format is set to YES, file transfer information is logged but connections are not, and the log file specified in xferlog_file (/var/log/vsftpd.log by default) is used instead. It is important to note that both log files and log formats are used if dual_log_enable is set to YES.
The default value is NO. Note, in Fedora, the value is set to YES.

- **xferlog_file** — Specifies the wu-ftpd-compatible log file. For this file to be used, xferlog_enable must be enabled and xferlog_std_format must be set to YES. It is also used if dual_log_enable is set to YES.
The default value is /var/log/xferlog.

- **xferlog_std_format** — When enabled in conjunction with xferlog_enable, only a wu-ftpd-compatible file transfer log is written to the file specified in the xferlog_file directive (/var/log/xferlog by default). It is important to note that this file only logs file transfers and does not log connections to the server.
The default value is NO. Note, in Fedora, the value is set to YES.

---

### Maintaining compatibility with older log file formats

To maintain compatibility with log files written by the older wu-ftpd FTP server, the xferlog_std_format directive is set to YES under Fedora. However, this setting means that connections to the server are not logged.

To both log connections in vsftpd format and maintain a wu-ftpd-compatible file transfer log, set dual_log_enable to YES.

If maintaining a wu-ftpd-compatible file transfer log is not important, either set xferlog_std_format to NO, comment the line with a hash sign (#), or delete the line entirely.

### 17.2.5.8. Network Options
The following lists directives which affect how vsftpd interacts with the network.

- **accept_timeout** — Specifies the amount of time for a client using passive mode to establish a connection.
The default value is 60.

- **anon_max_rate** — Specifies the maximum data transfer rate for anonymous users in bytes per second.
The default value is 0, which does not limit the transfer rate.

- **connect_from_port_20** When enabled, vsftpd runs with enough privileges to open port 20 on the server during active mode data transfers. Disabling this option allows vsftpd to run with less privileges, but may be incompatible with some FTP clients.
The default value is NO. Note, in Fedora, the value is set to YES.

- **connect_timeout** — Specifies the maximum amount of time a client using active mode has to respond to a data connection, in seconds.
The default value is 60.

- **data_connection_timeout** — Specifies maximum amount of time data transfers are allowed to stall, in seconds. Once triggered, the connection to the remote client is closed.
The default value is 300.

- **ftp_data_port** — Specifies the port used for active data connections when connect_from_port_20 is set to YES.
The default value is 20.
17.2.6.1. Installed Documentation

For more information about
17.2.6. Additional Resources

Server Applications
  • man vsftpd — Describes available command line options for vsftpd.

Running multiple copies of vsftpd

If running multiple copies of vsftpd serving different IP addresses, the configuration file for each copy of the vsftpd daemon must have a different value for this directive. Refer to Section 17.2.4.1, “Starting Multiple Copies of vsftpd”, for more information about multithomed FTP servers.

Running multiple copies of vsftpd

If running multiple copies of vsftpd serving different IP addresses, the configuration file for each copy of the vsftpd daemon must have a different value for this directive. Refer to Section 17.2.4.1, “Starting Multiple Copies of vsftpd”, for more information about multithomed FTP servers.

Avoid enabling the pasv_promiscuous option

Do not enable this option unless absolutely necessary as it disables an important security feature which verifies that passive mode connections originate from the same IP address as the control connection that initiates the data transfer.

The default value is NO.

port_enable — When enabled, active mode connects are allowed.

The default value is YES.

17.2.6. Additional Resources

For more information about vsftpd, refer to the following resources.
17.2.6.2. Useful Websites

- [http://vsftpd.beasts.org/](http://vsftpd.beasts.org/) — The vsftpd project page is a great place to locate the latest documentation and to contact the author of the software.
- [http://slacksite.com/other/ftp.html](http://slacksite.com/other/ftp.html) — This website provides a concise explanation of the differences between active and passive mode FTP.
- [http://www.ietf.org/rfc/rfc0959.txt](http://www.ietf.org/rfc/rfc0959.txt) — The original Request for Comments (RFC) of the FTP protocol from the IETF.

17.3. Printer Configuration

The Printer Configuration tool serves for printer configuring, maintenance of printer configuration files, print spool directories and print filters, and printer classes management.

The tool is based on the Common Unix Printing System (CUPS). If you upgraded the system from a previous Fedora version that used CUPS, the upgrade process preserved the configured printers.

### Using the CUPS web application or command line tools

You can perform the same and additional operations on printers directly from the CUPS web application or command line. To access the application, in a web browser, go to [http://localhost:631/](http://localhost:631/). For CUPS manuals refer to the links on the Home tab of the web site.

17.3.1. Starting the Printer Configuration Tool

With the Printer Configuration tool you can perform various operations on existing printers and set up new printers.

On the upper panel, go to Activities, choose Applications and click Printing. Alternatively, run the `system-config-printer` command from the command line to start the tool.

The Printer Configuration window depicted in Figure 17.2, “Printer Configuration window” appears.

![Printer Configuration window](image)

**Figure 17.2. Printer Configuration window**

17.3.2. Starting Printer Setup

Printer setup process varies depending on the printer queue type.

If you are setting up a local printer connected with USB, the printer is discovered and added automatically. You will be prompted to confirm the packages to be installed and provide the root password. Local printers connected with other port types and network printers need to be set up manually.

Follow this procedure to start a manual printer setup:

1. Start the Printer Configuration tool (refer to Section 17.3.1, “Starting the Printer Configuration Tool”).
2. Go to Server → New → Printer.
3. In the Authentication Required box, type the root user password and confirm.
4. Select the printer connection type and provide its details in the area on the right.

17.3.3. Adding a Local Printer

Follow this procedure to add a local printer connected with other than a serial port:

1. Open the New Printer dialog (refer to Section 17.3.2, “Starting Printer Setup”).
2. If the device does not appear automatically, select the port to which the printer is connected in the list on the left (such as Serial Port #1 or LPT #1).

3. On the right, enter the connection properties:

   **for Enter URI**
   - URI (for example file:/dev/lp0)

   **for Serial Port**
   - Baud Rate
   - Parity
   - Data Bits
   - Flow Control

![Select Device and Settings of the serial port](image)

4. Click Forward.

5. Select the printer model. Refer to Section 17.3.8, “Selecting the Printer Model and Finishing” for details.

### 17.3.4. Adding an AppSocket/HP JetDirect printer

Follow this procedure to add an AppSocket/HP JetDirect printer:

1. Open the New Printer dialog (refer to Section 17.3.1, “Starting the Printer Configuration Tool”).
2. In the list on the left, select Network Printer → AppSocket/HP JetDirect.
3. On the right, enter the connection settings:

   **Hostname**
   - printer hostname or IP address

   **Port Number**
   - printer port listening for print jobs (9100 by default)
17.3.5. Adding an IPP Printer

An IPP printer is a printer attached to a different system on the same TCP/IP network. The system this printer is attached to may either be running CUPS or simply configured to use IPP.

If a firewall is enabled on the printer server, then the firewall must be configured to allow incoming TCP connections on port 631. Note that the CUPS browsing protocol allows client machines to discover shared CUPS queues automatically. To enable this, the firewall on the client machine must be configured to allow incoming UDP packets on port 631.

Follow this procedure to add an IPP printer:

1. Open the New Printer dialog (refer to Section 17.3.2, "Starting Printer Setup").
2. In the list of devices on the left, select Network Printer and Internet Printing Protocol (ipp) or Internet Printing Protocol (https).
3. On the right, enter the connection settings:

   **Host**
   - the hostname for the system that controls the printer

   **Queue**
   - the queue name to be given to the new queue (if the box is left empty, a name based on the device node will be used)
4. Optionally, click **Verify** to detect the printer.
5. Click **Forward** to continue.
6. Select the printer model. Refer to **Section 17.3.8, “Selecting the Printer Model and Finishing”** for details.

### 17.3.6. Adding an LPD/LPR Host or Printer

Follow this procedure to add an LPD/LPR host or printer:

1. Open the **New Printer** dialog (refer to **Section 17.3.2, “Starting Printer Setup”**).
2. In the list of devices on the left, select **Network Printer → LPD/LPR Host or Printer**.
3. On the right, enter the connection settings:

   **Host**
   
   - the hostname of the LPD/LPR printer or host
   - Optionally, click **Probe** to find queues on the LPD host.

   **Queue**
   
   - the queue name to be given to the new queue (if the box is left empty, a name based on the device node will be used)

---

For example:

- `ipp://cups-server/printers/printer-queue`
- `ipp://printer.mydomain/ipp`
4. Click Forward to continue.
5. Select the printer model. Refer to Section 17.3.8, “Selecting the Printer Model and Finishing” for details.

17.3.7. Adding a Samba (SMB) printer

Follow this procedure to add a Samba printer:

**Installing the samba-client package**

Note that in order to add a Samba printer, you need to have the samba-client package installed. You can do so by running, as root:

```
yum install samba-client
```

For more information on installing packages with Yum, refer to Section 5.2.4, “Installing Packages”.

1. Open the New Printer dialog (refer to Section 17.3.2, “Starting Printer Setup”).
2. In the list on the left, select Network Printer → Windows Printer via SAMBA.
3. Enter the SMB address in the smb:// field. Use the format `computer name/printer share`. In Figure 17.7, “Adding a SMB printer”, the `computer name` is dellbox and the `printer share` is r2.
4. Click **Browse** to see the available workgroups/domains. To display only queues of a particular host, type in the host name (NetBios name) and click **Browse**.

5. Select either of the options:
   - **Prompt user if authentication is required**: username and password are collected from the user when printing a document.
   - **Set authentication details now**: provide authentication information now so it is not required later. In the **Username** field, enter the username to access the printer. This user must exist on the SMB system, and the user must have permission to access the printer. The default user name is typically `guest` for Windows servers, or `nobody` for Samba servers.

6. Enter the **Password** (if required) for the user specified in the **Username** field.

   **Be careful when choosing a password**

   Samba printer usernames and passwords are stored in the printer server as unencrypted files readable by root and lpd. Thus, other users that have root access to the printer server can view the username and password you use to access the Samba printer.

   As such, when you choose a username and password to access a Samba printer, it is advisable that you choose a password that is different from what you use to access your local Fedora system.

   If there are files shared on the Samba print server, it is recommended that they also use a password different from what is used by the print queue.

7. Click **Verify** to test the connection. Upon successful verification, a dialog box appears confirming printer share accessibility.

8. Click **Forward**.

9. Select the printer model. Refer to **Section 17.3.8, “Selecting the Printer Model and Finishing”** for details.

**17.3.8. Selecting the Printer Model and Finishing**

Once you have properly selected a printer connection type, the system attempts to acquire a driver. If the process fails, you can locate or search for the driver resources manually.

Follow this procedure to provide the printer driver and finish the installation:

1. In the window displayed after the automatic driver detection has failed, select one of the following options:
   - **Select printer from database** — the system chooses a driver based on the selected make of your printer from the list of Makes. If your printer model is not listed, choose **Generic**.
   - **Provide PPD file** — the system uses the provided PostScript Printer Description (PPD) file for installation. A PPD file may also be delivered with your printer as being normally provided by the manufacturer. If the PPD file is available, you can choose this option and use the browser bar below the option description to select the PPD file.
Search for a printer driver to download — enter the make and model of your printer into the Make and model field to search on OpenPrinting.org for the appropriate packages.

2. Depending on your previous choice provide details in the area displayed below:
   - Printer brand for the Select printer from database option
   - PPD file location for the Provide PPD file option
   - Printer make and model for the Search for a printer driver to download option

3. Click Forward to continue.

4. If applicable for your option, window shown in Figure 17.9, "Selecting a printer model" appears. Choose the corresponding model in the Models column on the left.

On the right, the recommended printed driver is automatically selected; however, you can select another available driver. The print driver processes the data that you want to print into a format the printer can understand. Since a local printer is attached directly to your computer, you need a printer driver to process the data that is sent to the printer.
5. Click **Forward**.

6. Under the **Describe Printer** enter a unique name for the printer in the **Printer Name** field. The printer name can contain letters, numbers, dashes (-), and underscores (_); it must not contain any spaces. You can also use the **Description** and **Location** fields to add further printer information. Both fields are optional, and may contain spaces.
7. Click **Apply** to confirm your printer configuration and add the print queue if the settings are correct. Click **Back** to modify the printer configuration.

8. After the changes are applied, a dialog box appears allowing you to print a test page. Click **Print Test Page** to print a test page now. Alternatively, you can print a test page also later, refer to Section 17.3.9, “Printing a test page” for details.

### 17.3.9. Printing a test page

After you have set up a printer or changed a printer configuration, print a test page to make sure the printer is functioning properly:

1. Right-click the printer in the **Printing** window and click **Properties**.
2. In the Properties window, click **Settings** on the left.
3. On the displayed **Settings** tab, click the **Print Test Page** button.

### 17.3.10. Modifying Existing Printers

To delete an existing printer, in the **Printer Configuration** window, select the printer and go to **Printer → Delete**. Confirm the printer deletion. Alternatively, press the **Delete** key.

To set the default printer, right-click the printer in the printer list and click the **Set As Default** button in the context menu.

#### 17.3.10.1. The Settings Page

To change printer driver configuration, double-click the corresponding name in the **Printer** list and click the **Settings** label on the left to display the **Settings** page.

You can modify printer settings such as make and model, print a test page, change the device location (URI), and more.
17.3.10.2. The Policies Page

Click the **Policies** button on the left to change settings in printer state and print output.

You can select the printer states, configure the **Error Policy** of the printer (you can decide to abort the print job, retry, or stop it if an error occurs).

You can also create a **banner page** (a page that describes aspects of the print job such as the originating printer, the username from which the job originated, and the security status of the document being printed): click the **Starting Banner** or **Ending Banner** drop-menu and choose the option that best describes the nature of the print jobs (such as *topsecret*, *classified*, or *confidential*).

17.3.10.2.1. Sharing Printers

On the **Policies** page, you can mark a printer as shared: if a printer is shared, users published on the network can use it. To allow the sharing function for printers, go to **Server → Settings** and select **Publish shared printers connected to this system**.

Finally, ensure that the firewall allows incoming TCP connections to port 631, which is Network Printing Server (IPP) in `system-config-firewall`. 

---

![Figure 17.11. Settings page](image-url)
17.3.10.2.2. The Access Control Page

You can change user-level access to the configured printer on the **Access Control** page. Click the **Access Control** label on the left to display the page. Select either **Allow printing for everyone except these users** or **Deny printing for everyone except these users** and define the user set below: enter the user name in the text box and click the **Add** button to add the user to the user set.
17.3.10.2.3. The Printer Options Page

The Printer Options page contains various configuration options for the printer media and output, and its content may vary from printer to printer. It contains general printing, paper, quality, and printing size settings.

![Printer Options page]

17.3.10.2.4. Job Options Page

On the Job Options page, you can detail the printer job options. Click the Job Options label on the left to display the page. Edit the default settings to apply custom job options, such as number of copies, orientation, pages per side, scaling (increase or decrease the size of the printable area, which can be used to fit an oversize print area onto a smaller physical sheet of print medium), detailed text options, and custom job options.
17.3.10.2.5. Ink/Toner Levels Page

The **Ink/Toner Levels** page contains details on toner status if available and printer status messages. Click the **Ink/Toner Levels** label on the left to display the page.
17.3.10.3. Managing Print Jobs

When you send a print job to the printer daemon, such as printing a text file from Emacs or printing an image from GIMP, the print job is added to the print spool queue. The print spool queue is a list of print jobs that have been sent to the printer and information about each print request, such as the status of the request, the job number, and more.

During the printing process, messages informing about the process appear in the notification area.

```
processing / pending: 1 / 1
```

To cancel, hold, release, reprint or authenticate a print job, select the job in the GNOME Print Status and on the Job menu, click the respective command.

To view the list of print jobs in the print spool from a shell prompt, type the command `lpstat -o`. The last few lines look similar to the following:

```
Example 17.1. Example of lpstat -o output

$ lpstat -o
Charlie-60  twaugh  1024  Tue 08 Feb 2011 16:42:11 GMT
Aaron-61    twaugh  1024  Tue 08 Feb 2011 16:42:44 GMT
Ben-62      root    1024  Tue 08 Feb 2011 16:45:42 GMT
```

If you want to cancel a print job, find the job number of the request with the command `lpstat -o` and then use the command `cancel job number`. For example, `cancel 60` would cancel the print job in Example 17.1, “Example of lpstat -o output”. You cannot cancel print jobs that were started by other users with the cancel command. However, you can enforce deletion of such job by issuing the `cancel -U root job_number` command. To prevent such canceling, change the printer operation policy to Authenticated to force root authentication.

You can also print a file directly from a shell prompt. For example, the command `lp sample.txt` prints the text file...
The print filter determines what type of file it is and converts it into a format the printer can understand.

17.3.11. Additional Resources
To learn more about printing on Fedora, refer to the following resources.

17.3.11.1. Installed Documentation

man lp
The manual page for the `lpr` command that allows you to print files from the command line.

man cancel
The manual page for the command line utility to remove print jobs from the print queue.

man mpage
The manual page for the command line utility to print multiple pages on one sheet of paper.

man cupsd
The manual page for the CUPS printer daemon.

man cupsd.conf
The manual page for the CUPS printer daemon configuration file.

man classes.conf
The manual page for the class configuration file for CUPS.

man lpstat
The manual page for the `lpstat` command, which displays status information about classes, jobs, and printers.

17.3.11.2. Useful Websites

http://www.linuxprinting.org/
`GNU/Linux Printing` contains a large amount of information about printing in Linux.

http://www.cups.org/
Documentation, FAQs, and newsgroups about CUPS.

Part VI. Monitoring and Automation
This part describes various tools that allow system administrators to monitor system performance, automate system tasks, and report bugs.

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In order to configure the system, system administrators often need to determine the amount of free memory, how much free disk space is available, how the hard drive is partitioned, or what processes are running.
18.1. Viewing System Processes

18.1.1. Using the ps Command

The `ps` command allows you to display information about running processes. It produces a static list, that is, a snapshot of what is running when you execute the command. If you want a constantly updated list of running processes, use the `top` command or the System Monitor application instead.

To list all processes that are currently running on the system including processes owned by other users, type the following at a shell prompt:

```
ps ax
```

For each listed process, the `ps ax` command displays the process ID (`PID`), the terminal that is associated with it (`TTY`), the current status (`STAT`), the cumulated CPU time (`TIME`), and the name of the executable file (`COMMAND`). For example:

```
~]$ ps ax
PID TTY      STAT   TIME COMMAND
1 ?        Ss     0:02 /usr/lib/systemd/systemd --system --deserialize 20
2 ?        S      0:00 [kthreadd]
3 ?        S      0:00 [ksoftirqd/0]
5 ?        S      0:00 [kworker/u:0]
6 ?        S      0:00 [migration/0]
[output truncated]
```

To display the owner alongside each process, use the following command:

```
ps aux
```

Apart from the information provided by the `ps ax` command, `ps aux` displays the effective username of the process owner (`USER`), the percentage of the CPU (`%CPU`) and memory (`%MEM`) usage, the virtual memory size in kilobytes (`VSZ`), the non-swapped physical memory size in kilobytes (`RSS`), and the time or date the process was started. For instance:

```
~]$ ps aux
USER       PID %CPU %MEM    VSZ   RSS TTY      STAT START   TIME COMMAND
root         1  0.0  0.3  53128  2988 ?        Ss   13:28   0:02 /usr/lib/systemd/systemd -system --deserialize 20
root         2  0.0  0.0      0     0 ?        S    13:28   0:00 [kthreadd]
root         3  0.0  0.0      0     0 ?        S    13:28   0:00 [ksoftirqd/0]
root         5  0.0  0.0      0     0 ?        S    13:28   0:00 [kworker/u:0]
root         6  0.0  0.0      0     0 ?        S    13:28   0:00 [migration/0]
[output truncated]
```

You can also use the `ps` command in a combination with `grep` to see if a particular process is running. For example, to determine if Emacs is running, type:

```
~]$ ps ax | grep emacs
2625 ?        0:00 emacs
```

For a complete list of available command line options, refer to the `ps(1)` manual page.

18.1.2. Using the top Command

The `top` command displays a real-time list of processes that are running on the system. It also displays additional information about the system uptime, current CPU and memory usage, or total number of running processes, and allows you to perform actions such as sorting the list or killing a process.

To run the `top` command, type the following at a shell prompt:

```
top
```

For each listed process, the `top` command displays the process ID (`PID`), the effective username of the process owner (`USER`), the priority (`PR`), the nice value (`NI`), the amount of virtual memory the process uses (`VIRT`), the amount of non-swapped physical memory the process uses (`RES`), the amount of shared memory the process uses (`SHR`), the percentage of the CPU (`%CPU`) and memory (`%MEM`) usage, the cumulated CPU time (`TIME+`), and the name of the executable file (`COMMAND`). For example:
Table 18.1, “Interactive top commands” contains useful interactive commands that you can use with top. For more information, refer to the top(1) manual page.

Table 18.1. Interactive top commands

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enter, Space</td>
<td>Immediately refreshes the display.</td>
</tr>
<tr>
<td>h, ?</td>
<td>Displays a help screen.</td>
</tr>
<tr>
<td>k</td>
<td>Kills a process. You are prompted for the process ID and the signal to send to it.</td>
</tr>
<tr>
<td>n</td>
<td>Changes the number of displayed processes. You are prompted to enter the number.</td>
</tr>
<tr>
<td>u</td>
<td>Sorts the list by user.</td>
</tr>
<tr>
<td>M</td>
<td>Sorts the list by memory usage.</td>
</tr>
<tr>
<td>P</td>
<td>Sorts the list by CPU usage.</td>
</tr>
<tr>
<td>q</td>
<td>Terminates the utility and returns to the shell prompt.</td>
</tr>
</tbody>
</table>

18.1.3. Using the System Monitor Tool

The Processes tab of the System Monitor tool allows you to view, search for, change the priority of, and kill processes from the graphical user interface.

To start the System Monitor tool, either select Applications → System Tools → System Monitor from the Activities menu, or type gnome-system-monitor at a shell prompt. Then click the Processes tab to view the list of running processes.
For each listed process, the System Monitor tool displays its name (Process Name), current status (Status), percentage of the memory usage (% CPU), nice value (Nice), process ID (ID), memory usage (Memory), the channel the process is waiting in (Waiting Channel), and additional details about the session (Session). To sort the information by a specific column in ascending order, click the name of that column. Click the name of the column again to toggle the sort between ascending and descending order.

By default, the System Monitor tool displays a list of processes that are owned by the current user. Selecting various options from the View menu allows you to:

- view only active processes,
- view all processes,
- view your processes,
- view process dependencies,
- view a memory map of a selected process,
- view the files opened by a selected process, and
- refresh the list of processes.

Additionally, various options in the Edit menu allows you to:

- stop a process,
- continue running a stopped process,
- end a process,
- kill a process,
- change the priority of a selected process, and
- edit the System Monitor preferences, such as the refresh interval for the list of processes, or what information to show.

You can also end a process by selecting it from the list and clicking the End Process button.

18.2. Viewing Memory Usage

18.2.1. Using the free Command

The `free` command allows you to display the amount of free and used memory on the system. To do so, type the following at a shell prompt:

```
free
```

The `free` command provides information about both the physical memory (Mem) and swap space (Swap). It displays the total amount of memory (total), as well as the amount of memory that is in use (used), free (free), shared (shared), in kernel buffers (buffers), and cached (cached). For example:
By default, `free` displays the values in kilobytes. To display the values in megabytes, supply the `-m` command line option:

```
free -m
```

For instance:

```
Mem:           744        593        150          0         36        152
      -/+ buffers/cache:        404        339
Swap:         1503         82       1421
```

For a complete list of available command line options, refer to the `free(1)` manual page.

18.2.2. Using the System Monitor Tool

The `Resources` tab of the System Monitor tool allows you to view the amount of free and used memory on the system.

To start the System Monitor tool, either select `Applications → System Tools → System Monitor` from the Activities menu, or type `gnome-system-monitor` at a shell prompt. Then click the `Resources` tab to view the system's memory usage.

![System Monitor — Resources](image)

In the `Memory and Swap History` section, the System Monitor tool displays a graphical representation of the memory and swap usage history, as well as the total amount of the physical memory (Memory) and swap space (Swap) and how much of it is in use.

18.3. Viewing CPU Usage

18.3.1. Using the System Monitor Tool

The `Resources` tab of the System Monitor tool allows you to view the current CPU usage on the system.

To start the System Monitor tool, either select `Applications → System Tools → System Monitor` from the Activities menu, or type `gnome-system-monitor` at a shell prompt. Then click the `Resources` tab to view the system's CPU usage.
In the CPU History section, the System Monitor tool displays a graphical representation of the CPU usage history and shows the percentage of how much CPU is currently in use.

18.4. Viewing Block Devices and File Systems

18.4.1. Using the lsblk Command

The `lsblk` command allows you to display a list of available block devices. To do so, type the following at a shell prompt:

```
lsblk
```

For each listed block device, the `lsblk` command displays the device name (`NAME`), major and minor device number (`MAJ:MIN`), if the device is removable (`RM`), what is its size (`SIZE`), if the device is read-only (`RO`), what type is it (`TYPE`), and where the device is mounted (`MOUNTPOINT`). For example:

```
NAME                         MAJ:MIN RM   SIZE RO TYPE MOUNTPOINT
sr0                           11:0    1  1024M  0 rom
vda                          252:0    0   20G  0 disk
  |-vda1                       252:1    0   500M  0 part /boot
  `--vda2                      252:2    0  19.5G  0 part
    `--vg_fedora-lv_swap (dm-0) 253:0    0  1.5G  0 lvm  [SWAP]
    `--vg_fedora-lv_root (dm-1) 253:1    0  18G  0 lvm  /
```

By default, `lsblk` lists block devices in a tree-like format. To display the information as an ordinary list, add the `-l` command line option:

```
lsblk -l
```

For instance:

```
NAME                           MAJ:MIN RM   SIZE RO TYPE MOUNTPOINT
sr0                            11:0    1  1024M  0 rom
vda                            252:0    0   20G  0 disk
vda1                           252:1    0  500M  0 part /boot
vda2                           252:2    0   19G  0 part
  `--vg_fedora-lv_swap (dm-0) 253:0    0  1.5G  0 lvm  [SWAP]
  `--vg_fedora-lv_root (dm-1) 253:1    0  18G  0 lvm  /
```

For a complete list of available command line options, refer to the `lsblk(8)` manual page.

18.4.2. Using the blkid Command

The `blkid` command allows you to display information about available block devices. To do so, type the following at a shell prompt as `root`:

```
blkid
```

For each listed block device, the `blkid` command displays the device name (`NAME`), major and minor device number (`MAJ:MIN`), if the device is removable (`RM`), what is its size (`SIZE`), if the device is read-only (`RO`), what type is it (`TYPE`), and where the device is mounted (`MOUNTPOINT`). For example:

```
NAME                   MAJ:MIN RM  SIZE RO TYPE MOUNTPOINT
sr0                    11:0    1   1024M  0 rom
vda                    252:0    0  20G  0 disk
  |-vda1                252:1    0   500M  0 part /boot
  `--vda2               252:2    0  19G  0 part
    `--vg_fedora-lv_swap (dm-0) 253:0    0  1.5G  0 lvm  [SWAP]
    `--vg_fedora-lv_root (dm-1) 253:1    0  18G  0 lvm  /
```

For a complete list of available command line options, refer to the `blkid(8)` manual page.
For each listed block device, the `blkid` command displays available attributes such as its universally unique identifier (UUID), file system type (TYPE), or volume label (LABEL). For example:

```bash
[-]# blkid /dev/vda1: UUID="4ea24c68-ab10-47d4-8a6b-b8d3a002acba" TYPE="ext4"
/dev/vda2: UUID="iJ9YwJ-leFf-A1zb-VVaK-H9t1-raLW-HoqlUG" TYPE="LVM2_member"
/dev/mapper/vg_fedora-lv_swap: UUID="d6d755bc-3e3e-4e8f-9bb5-a5e7f4d86fffd" TYPE="swap"
/dev/mapper/vg_fedora-lv_root: LABEL="_Fedora-17-x86_6" UUID="77ba9149-751a-48e0-974f-ad9491174b9" TYPE="ext4"
```

By default, the `lsblk` command lists all available block devices. To display information about a particular device only, specify the device name on the command line:

```
blkid device_name
```

For instance, to display information about `/dev/vda1`, type:

```
[-]# blkid /dev/vda1
/dev/vda1: UUID="4ea24c68-ab10-47d4-8a6b-b8d3a002acba" TYPE="ext4"
```

You can also use the above command with the `-p` and `-o udev` command line options to obtain more detailed information. Note that root privileges are required to run this command:

```
blkid -po udev device_name
```

For example:

```
[-]# blkid -po udev /dev/vda1
ID_FS_UUID=4ea24c68-ab10-47d4-8a6b-b8d3a002acba
ID_FS_UUID_ENC=4ea24c68-ab10-47d4-8a6b-b8d3a002acba
ID_FS_VERSION=1.0
ID_FS_TYPE=ext4
ID_FS_USAGE=filesystem
ID_PART_ENTRY_SCHEME=dos
ID_PART_ENTRY_TYPE=0x83
ID_PART_ENTRY_FLAGS=0x80
ID_PART_ENTRY_NUMBER=1
ID_PART_ENTRY_OFFSET=2048
ID_PART_ENTRY_SIZE=1024000
ID_PART_ENTRY_DISK=252:0
```

For a complete list of available command line options, refer to the `blkid`(8) manual page.

### 18.4.3. Using the `partx` Command

The `partx` command allows you to display a list of disk partitions. To list the partition table of a particular disk, as root, run this command with the `-s` option followed by the device name:

```
partx -s device_name
```

For example, to list partitions on `/dev/vda`, type:

```
[-]# partx -s /dev/vda
NR START END SECTORS SIZE NAME UUID
1 2048 1026047 1024000 500M
2 1026048 41943039 40916992 19.5G
```

For a complete list of available command line options, refer to the `partx`(8) manual page.

### 18.4.4. Using the `findmnt` Command

The `findmnt` command allows you to display a list of currently mounted file systems. To do so, type the following at a shell prompt:

```
findmnt
```

For each listed file system, the `findmnt` command displays the target mount point (TARGET), source device (SOURCE), file system type (FSTYPE), and relevant mount options (OPTIONS). For example:
### 18.4.5. Using the df Command

The **df** command allows you to display a detailed report on the system's disk space usage. To do so, type the following at a shell prompt:

```
$ df
```

For each listed file system, the **df** command displays its name (**Filesystem**), size (**1K-blocks** or **Size**), how much space is used (**Used**), how much space is still available (**Available**), the percentage of space usage (**Use%**), and where is the file system mounted (**Mounted on**). For example:

```
Filesystem  1K-blocks  Used  Available  Use%  Mounted on
/           18877356 4605476 14082844    25%     /
```

By default, the **df** command shows the partition size in 1 kilobyte blocks and the amount of used and available disk space in kilobytes. To view the information in megabytes and gigabytes, supply the `-h` command line option, which causes **df** to display the values in a human-readable format:

```
$ df -h
```

For instance:
\begin{itemize}
\item Note that the \texttt{/dev/shm} entry represents the system's virtual memory file system, \texttt{/sys/fs/cgroup} is a cgroup file system, and \texttt{/run} contains information about the running system.
\end{itemize}

For a complete list of available command line options, refer to the \texttt{df(1)} manual page.

### 18.4.6. Using the \texttt{du} Command

The \texttt{du} command allows you to display the amount of space that is being used by files in a directory. To display the disk usage for each of the subdirectories in the current working directory, run the command with no additional command line options:

\begin{verbatim}
$ du
\end{verbatim}

For example:

\begin{verbatim}
8       ./.gconf/apps/gnome-terminal/profiles/Default
12      ./.gconf/apps/gnome-terminal/profiles
16      ./.gconf/apps/gnome-terminal
[output truncated]
460     ./.gimp-2.6
68828   .
\end{verbatim}

By default, the \texttt{du} command displays the disk usage in kilobytes. To view the information in megabytes and gigabytes, supply the \texttt{-h} command line option, which causes the utility to display the values in a human-readable format:

\begin{verbatim}
$ du -h
\end{verbatim}

For example:

\begin{verbatim}
8.0K    ./.gconf/apps/gnome-terminal/profiles/Default
12K     ./.gconf/apps/gnome-terminal/profiles
16K     ./.gconf/apps/gnome-terminal
[output truncated]
460K    ./.gimp-2.6
68M     .
\end{verbatim}

At the end of the list, the \texttt{du} command always shows the grand total for the current directory. To display only this information, supply the \texttt{-s} command line option:

\begin{verbatim}
$ du -sh
\end{verbatim}

For example:

\begin{verbatim}
68M     .
\end{verbatim}

For a complete list of available command line options, refer to the \texttt{du(1)} manual page.

### 18.4.7. Using the System Monitor Tool

The File Systems tab of the System Monitor tool allows you to view file systems and disk space usage in the graphical user interface.

To start the System Monitor tool, either select \textbf{Applications} \rightarrow \textbf{System Tools} \rightarrow \textbf{System Monitor} from the Activities menu, or type \texttt{gnome-system-monitor} at a shell prompt. Then click the File Systems tab to view a list of file systems.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure18.4.png}
\caption{System Monitor — File Systems}
\end{figure}

For each listed file system, the System Monitor tool displays the source device (Device), target mount point (Directory), file system type (Type), total size (Total), free space (Free), and available space (Available).
18.5. Viewing Hardware Information

18.5.1. Using the lspci Command

The `lspci` command lists all PCI devices that are present in the system:

```
18.5.2. Using the lsusb Command

The `lsusb` command allows you to display information about USB buses and devices that are attached to them. To list all USB devices that are in the system, type the following at a shell prompt:

```
You can also use the `-v` command line option to display more verbose output:

For instance, to determine the manufacturer, model, and memory size of a system's video card, type:

```
For a complete list of available command line options, refer to the `lspci(8)` manual page.

18.5.2. Using the lsusb Command

The `lsusb` command allows you to display information about USB buses and devices that are attached to them. To list all USB devices that are in the system, type the following at a shell prompt:

```
This displays a simple list of devices, for example:

```
You can also use the `-v` command line option to display more verbose output:

For instance:
For a complete list of available command line options, refer to the \texttt{lsusb(8)} manual page.

\subsection*{18.5.3. Using the \texttt{lspcmcia} Command}

The \texttt{lspcmcia} command allows you to list all PCMCIA devices that are present in the system. To do so, type the following at a shell prompt:

\begin{verbatim}
\$ lspcmcia -v
\end{verbatim}

For example:

\begin{verbatim}
Socket @ Bridge: [yenta_cardbus] (bus ID: 0000:15:00.0)
\end{verbatim}

You can also use the \texttt{-v} command line option to display more verbose information, or \texttt{-vv} to increase the verbosity level even further:

\begin{verbatim}
\$ lspcmcia -v -vv
\end{verbatim}

For instance:

\begin{verbatim}
Socket @ Bridge: [yenta_cardbus] (bus ID: 0000:15:00.0)
Configuration: state: on ready: unknown
\end{verbatim}

For a complete list of available command line options, refer to the \texttt{pcardctl(8)} manual page.

\subsection*{18.5.4. Using the \texttt{lscpu} Command}

The \texttt{lscpu} command allows you to list information about CPUs that are present in the system, including the number of CPUs, their architecture, vendor, family, model, CPU caches, etc. To do so, type the following at a shell prompt:

\begin{verbatim}
\$ lscpu
\end{verbatim}

For example:

\begin{verbatim}
Architecture: x86_64
CPU op-mode(s): 32-bit, 64-bit
Byte Order: Little Endian
CPU(s): 4
On-line CPU(s) list: 0-3
Thread(s) per core: 1
Core(s) per socket: 4
Socket(s): 1
NUMA node(s): 1
Vendor ID: GenuineIntel
CPU family: 6
Model: 23
Stepping: 7
CPU MHz: 1998.000
BogoMIPS: 4999.98
Virtualization: VT-x
L1d cache: 32K
L1i cache: 32K
L2 cache: 3072K
NUMA node@ CPU(s): 0-3
\end{verbatim}

For a complete list of available command line options, refer to the \texttt{lscpu(1)} manual page.

\subsection*{18.6. Monitoring Performance with Net-SNMP}

Fedora 18 includes the \texttt{Net-SNMP} software suite, which includes a flexible and extensible \textit{Simple Network Management Protocol} (SNMP) agent. This agent and its associated utilities can be used to provide performance data from a large number of systems to a variety of tools which support polling over the SNMP protocol.

This section provides information on configuring the Net-SNMP agent to securely provide performance data over the
network, retrieving the data using the SNMP protocol, and extending the SNMP agent to provide custom performance metrics.

### 18.6.1. Installing Net-SNMP

The Net-SNMP software suite is available as a set of RPM packages in the Fedora software distribution. Table 18.2, “Available Net-SNMP packages” summarizes each of the packages and their contents.

<table>
<thead>
<tr>
<th>Package</th>
<th>Provides</th>
</tr>
</thead>
<tbody>
<tr>
<td>net-snmp</td>
<td>The SNMP Agent Daemon and documentation. This package is required for exporting performance data.</td>
</tr>
<tr>
<td>net-snmp-libs</td>
<td>The netsnmp library and the bundled management information bases (MIBs). This package is required for exporting performance data.</td>
</tr>
<tr>
<td>net-snmp-utils</td>
<td>SNMP clients such as snmpget and snmpwalk. This package is required in order to query a system’s performance data over SNMP.</td>
</tr>
<tr>
<td>net-snmp-perl</td>
<td>The mib2c utility and the NetSNMP Perl module.</td>
</tr>
<tr>
<td>net-snmp-python</td>
<td>An SNMP client library for Python.</td>
</tr>
</tbody>
</table>

To install any of these packages, use the **yum** command in the following form:

```bash
yum install package...
```

For example, to install the SNMP Agent Daemon and SNMP clients used in the rest of this section, type the following at a shell prompt:

```
~# yum install net-snmp net-snmp-libs net-snmp-utils
```

Note that you must have superuser privileges (that is, you must be logged in as **root**) to run this command. For more information on how to install new packages in Fedora, refer to Section 5.2.4, "Installing Packages".

### 18.6.2. Running the Net-SNMP Daemon

The **net-snmp** package contains **snmpd**, the SNMP Agent Daemon. This section provides information on how to start, stop, and restart the **snmpd** service, and shows how to enable or disable it in the **multi-user** target unit. For more information on the concept of target units and how to manage system services in Fedora in general, refer to Chapter 9, Services and Daemons.

#### 18.6.2.1. Starting the Service

To run the **snmpd** service in the current session, type the following at a shell prompt as **root**:

```
systemctl start snmpd.service
```

To configure the service to be automatically started at boot time, use the following command:

```
systemctl enable snmpd.service
```

This will enable the service in the **multi-user** target unit.

#### 18.6.2.2. Stopping the Service

To stop the running **snmpd** service, type the following at a shell prompt as **root**:

```
systemctl stop snmpd.service
```

To disable starting the service at boot time, use the following command:

```
systemctl disable snmpd.service
```

This will disable the service in the **multi-user** target unit.

#### 18.6.2.3. Restarting the Service

To restart the running **snmpd** service, type the following at a shell prompt:

```
systemctl restart snmpd.service
```

This will stop the service and start it again in quick succession. To only reload the configuration without stopping the service, run the following command instead:

```
systemctl reload snmpd.service
```

This will cause the running **snmpd** service to reload the configuration.

### 18.6.3. Configuring Net-SNMP

To change the Net-SNMP Agent Daemon configuration, edit the **/etc/snmp/snmpd.conf** configuration file. The default **snmpd.conf** file shipped with Fedora 18 is heavily commented and serves as a good starting point for agent configuration.

This section focuses on two common tasks: setting system information and configuring authentication. For more information about available configuration directives, refer to the **snmpd.conf**(5) manual page. Additionally, there is a utility in the **net-snmp** package named **snmpconf** which can be used to interactively generate a valid agent configuration.
Note that the net-snmp-utils package must be installed in order to use the `snmpwalk` utility described in this section.

Applying the changes

For any changes to the configuration file to take effect, force the `snmpd` service to re-read the configuration by running the following command as `root`:

```
systemctl reload snmpd.service
```

18.6.3.1. Setting System Information

Net-SNMP provides some rudimentary system information via the `system` tree. For example, the following `snmpwalk` command shows the `system` tree with a default agent configuration.

```
[-]# snmpwalk -v2c -c public localhost system
SNMPv2-MIB::sysDescr.0 = STRING: Linux localhost.localdomain 2.6.32-122.el6.x86_64 #1 SMP
SNMPv2-MIB::sysObjectId.0 = OID: NET-SNMP-MIB::netSnmpAgentOIDs.10
DISMAN-EVENT-MIB::sysUpTimeInstance = Timeticks: (99554) 0:16:35.54
SNMPv2-MIB::sysContact.0 = STRING: Root <root@localhost> (configure /etc/snmp/snmpd.conf)
SNMPv2-MIB::sysLocation.0 = STRING: Unknown (edit /etc/snmp/snmpd.conf)
```

By default, the `sysName` object is set to the hostname. The `sysLocation` and `sysContact` objects can be configured in the `/etc/snmp/snmpd.conf` file by changing the value of the `syslocation` and `syscontact` directives, for example:

```
syslocation Datacenter, Row 3, Rack 2
syscontact UNIX Admin <admin@example.com>
```

After making changes to the configuration file, reload the configuration and test it by running the `snmpwalk` command again:

```
[-]# systemctl reload snmpd.service
[-]# snmpwalk -v2c -c public localhost system
```

18.6.3.2. Configuring Authentication

The Net-SNMP Agent Daemon supports all three versions of the SNMP protocol. The first two versions (1 and 2c) provide for simple authentication using a community string. This string is a shared secret between the agent and any client utilities. The string is passed in clear text over the network however and is not considered secure. Version 3 of the SNMP protocol supports user authentication and message encryption using a variety of protocols. The Net-SNMP agent also supports tunneling over SSH, TLS authentication with X.509 certificates, and Kerberos authentication.

Configuring SNMP Version 2c Community

To configure an SNMP version 2c community, use either the `rocommunity` or `rwcommunity` directive in the `/etc/snmp/snmpd.conf` configuration file. The format of the directives is the following:

```
directive community [source [OID]]
```

... where `community` is the community string to use, `source` is an IP address or subnet, and `OID` is the SNMP tree to provide access to. For example, the following directive provides read-only access to the `system` tree to a client using the community string "redhat" on the local machine:

```
rocommunity redhat 127.0.0.1 .1.3.6.1.2.1.1
```

To test the configuration, use the `snmpwalk` command with the `-v` and `-c` options.

```
[-]# snmpwalk -v2c -c redhat localhost system
SNMPv2-MIB::sysDescr.0 = STRING: Linux localhost.localdomain 2.6.32-122.el6.x86_64 #1 SMP
SNMPv2-MIB::sysObjectId.0 = OID: NET-SNMP-MIB::netSnmpAgentOIDs.10
DISMAN-EVENT-MIB::sysUpTimeInstance = Timeticks: (158357) 0:26:23.57
SNMPv2-MIB::sysContact.0 = STRING: UNIX Admin <admin@example.com>
SNMPv2-MIB::sysLocation.0 = STRING: Datacenter, Row 3, Rack 2
```

Configuring SNMP Version 3 User

To configure an SNMP version 3 user, use the `net-snmp-create-v3-user` command. This command adds entries to the `/var/lib/net-snmp/snmpd.conf` and `/etc/snmp/snmpd.conf` files which create the user and grant access to the user. Note that the `net-snmp-create-v3-user` command may only be run when the agent is not running. The following example creates the "sysadmin" user with the password "redhatsnmp":

```
```
```bash
[-]# systemctl stop snmpd.service
[-]# net-snmp-create-v3-user
Enter a SNMPv3 user name to create: admin
Enter authentication pass-phrase: redhatsnmp
Enter encryption pass-phrase: [press return to reuse the authentication pass-phrase]
adding the following line to /var/lib/net-snmp/snmpd.conf:
    createUser admin MD5 "redhatsnmp" DES
adding the following line to /etc/snmp/snmpd.conf:
    rwuser admin
[-]# systemctl start snmpd.service
```

The `rwuser` directive (or `rouser` when the `-ro` command line option is supplied) that `net-snmp-create-v3-user` adds to `/etc/snmp/snmpd.conf` has a similar format to the `rwcommunity` and `rocommunity` directives:

```
directive user [noauth|auth|priv] [OID]
```

... where `user` is a username and `OID` is the SNMP tree to provide access to. By default, the Net-SNMP Agent Daemon allows only authenticated requests (the `auth` option). The `noauth` option allows you to permit unauthenticated requests, and the `priv` option enforces the use of encryption. The `authpriv` option specifies that requests must be authenticated and replies should be encrypted.

For example, the following line grants the user “admin” read-write access to the entire tree:

```
rwuser admin authpriv .1
```

To test the configuration, create a `.snmp` directory in your user’s home directory and a configuration file named `snmp.conf` in that directory (`~/.snmp/snmp.conf`) with the following lines:

```bash
defVersion 3
defSecurityLevel authPriv
defSecurityName admin
defPassphrase redhatsnmp
```

The `snmpwalk` command will now use these authentication settings when querying the agent:

```
$ snmpwalk -v3 localhost system
SNMPv2-MIB::sysDescr.0 = STRING: Linux localhost.localdomain 2.6.32-122.el6.x86_64 #1 SMP
Wed Mar 9 23:54:34 EST 2011 x86_64
[output truncated]
```

### 18.6.4. Retrieving Performance Data over SNMP

The Net-SNMP Agent in Fedora provides a wide variety of performance information over the SNMP protocol. In addition, the agent can be queried for a listing of the installed RPM packages on the system, a listing of currently running processes on the system, or the network configuration of the system.

This section provides an overview of OIDs related to performance tuning available over SNMP. It assumes that the `net-snmp-utils` package is installed and that the user is granted access to the SNMP tree as described in Section 18.6.3.2, “Configuring Authentication”.

#### 18.6.4.1. Hardware Configuration

The Host Resources MIB included with Net-SNMP presents information about the current hardware and software configuration of a host to a client utility. Table 18.3, “Available OIDs” summarizes the different OIDs available under that MIB.

<table>
<thead>
<tr>
<th>OID</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>HOST-RESOURCES-MIB::hrSystem</td>
<td>Contains general system information such as uptime, number of users, and number of running processes.</td>
</tr>
<tr>
<td>HOST-RESOURCES-MIB::hrStorage</td>
<td>Contains data on memory and file system usage.</td>
</tr>
<tr>
<td>HOST-RESOURCES-MIB::hrDevices</td>
<td>Contains a listing of all processors, network devices, and file systems.</td>
</tr>
<tr>
<td>HOST-RESOURCES-MIB::hrSWRun</td>
<td>Contains a listing of all running processes.</td>
</tr>
<tr>
<td>HOST-RESOURCES-MIB::hrSWRunPerf</td>
<td>Contains memory and CPU statistics on the process table from HOST-RESOURCES-MIB::hrSWRun.</td>
</tr>
<tr>
<td>HOST-RESOURCES-MIB::hrSWInstalled</td>
<td>Contains a listing of the RPM database.</td>
</tr>
</tbody>
</table>

There are also a number of SNMP tables available in the Host Resources MIB which can be used to retrieve a summary of the available information. The following example displays `HOST-RESOURCES-MIB::hrFSTable`: ...
For more information about HOST-RESOURCES-MIB, see the /usr/share/snmp/mibs/HOST-RESOURCES-MIB.txt file.

18.6.4.2. CPU and Memory Information

Most system performance data is available in the UCD SNMP MIB. The systemStats OID provides a number of counters around processor usage:

In particular, the ssCpuRawUser, ssCpuRawSystem, ssCpuRawWait, and ssCpuRawIdle OIDs provide counters which are helpful when determining whether a system is spending most of its processor time in kernel space, user space, or I/O. ssRawSwapIn and ssRawSwapOut can be helpful when determining whether a system is suffering from memory exhaustion.

More memory information is available under the UCD-SNMP-MIB::memory OID, which provides similar data to the free command:

Load averages are also available in the UCD SNMP MIB. The SNMP table UCD-SNMP-MIB::laTable has a listing of the 1, 5, and 15 minute load averages:

18.6.4.3. File System and Disk Information

The Host Resources MIB provides information on file system size and usage. Each file system (and also each memory pool) has an entry in the HOST-RESOURCES-MIB::hrStorageTable table:
### 18.6.4. Network Information

Information on network devices is provided by the Interfaces MIB. \texttt{IF-MIB::ifTable} provides an SNMP table with an entry for each interface on the system, the configuration of the interface, and various packet counters for the interface. The following example shows the first few columns of \texttt{ifTable} on a system with two physical network interfaces:

```bash
- $ snmpwalk localhost IF-MIB::ifTable
SNMP table: IF-MIB::ifTable

Index  Description  Type  Flags AdminStatus
1  ether0  ethernetCsmacd 1500 0  up
2  ether1  ethernetCsmacd 1500 0  up
3  lo    softwareLoopback 16436 10000000 up
```

Network traffic is available under the OIDs \texttt{IF-MIB::ifInOctets} and \texttt{IF-MIB::ifOutOctets}. The following SNMP queries will retrieve network traffic for each of the interfaces on this system:

```bash
- $ snmpwalk localhost IF-MIB::ifInOctets
- $ snmpwalk localhost IF-MIB::ifOutOctets
```

### 18.6.5. Extending Net-SNMP

The Net-SNMP Agent can be extended to provide application metrics in addition to raw system metrics. This allows for capacity planning as well as performance issue troubleshooting. For example, it may be helpful to know that an email system had a 5-minute load average of 15 while being tested, but it may be more helpful to know that the email system has a load average of 15 while processing 80,000 messages a second. When application metrics are available via the same interface as the system metrics, this also allows for the visualization of the impact of different load scenarios on system performance.

The Net-SNMP Agent can be extended to provide application metrics in addition to raw system metrics. This allows for performance (for example, each additional 10,000 messages increases the load average linearly until 100,000).

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### 18.6.4.1. Network Information

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```bash
- $ snmpwalk localhost IF-MIB::ifTable
SNMP table: IF-MIB::ifTable

Index  Description  Type  Flags AdminStatus
1  ether0  ethernetCsmacd 1500 0  up
2  ether1  ethernetCsmacd 1500 0  up
3  lo    softwareLoopback 16436 10000000 up
```

Network traffic is available under the OIDs \texttt{IF-MIB::ifInOctets} and \texttt{IF-MIB::ifOutOctets}. The following SNMP queries will retrieve network traffic for each of the interfaces on this system:

```bash
- $ snmpwalk localhost IF-MIB::ifInOctets
- $ snmpwalk localhost IF-MIB::ifOutOctets
```

### 18.6.5. Extending Net-SNMP

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A number of applications that ship with Fedora extend the Net-SNMP Agent to provide application metrics over SNMP. There are several ways to extend the agent for custom applications as well. This section describes extending the agent with shell scripts and Perl plug-ins. It assumes that the net-snmp-utils and net-snmp-perl packages are installed, and that the user is granted access to the SNMP tree as described in Section 18.6.3.2, “Configuring Authentication”.

### 18.6.5.1. Extending Net-SNMP with Shell Scripts

The Net-SNMP Agent provides an extension MIB (\texttt{NET-SNMP-EXTEND-MIB}) that can be used to query arbitrary shell scripts. To specify the shell script to run, use the \texttt{extend} directive in the \texttt{/etc/snmp/snmpd.conf} file. Once defined, the Agent will provide the exit code and any output of the command over SNMP. The example below demonstrates this.
mechanism with a script which determines the number of httpd processes in the process table.

Using the proc directive

The Net-SNMP Agent also provides a built-in mechanism for checking the process table via the proc directive. Refer to the snmpd.conf(5) manual page for more information.

The exit code of the following shell script is the number of httpd processes running on the system at a given point in time:

```
#!/bin/sh
NUMPIDS=`pgrep httpd | wc -l`
exit $NUMPIDS
```

To make this script available over SNMP, copy the script to a location on the system path, set the executable bit, and add an extend directive to the /etc/snmp/snmpd.conf file. The format of the extend directive is the following:

```
extend name prog args
```

... where name is an identifying string for the extension, prog is the program to run, and args are the arguments to give the program. For instance, if the above shell script is copied to /usr/local/bin/check_apache.sh, the following directive will add the script to the SNMP tree:

```
extend httpd_pids /bin/sh /usr/local/bin/check_apache.sh
```

The script can then be queried at NET-SNMP-EXTEND-MIB::nsExtendObjects:

```
~]$ snmpwalk localhost NET-SNMP-EXTEND-MIB::nsExtendObjects
```

```
NET-SNMP-EXTEND-MIB::nsExtendNumEntries.0 = INTEGER: 1
NET-SNMP-EXTEND-MIB::nsExtendCommand."httpd_pids" = STRING: /bin/sh
NET-SNMP-EXTEND-MIB::nsExtendInput."httpd_pids" = STRING:
NET-SNMP-EXTEND-MIB::nsExtendCacheTime."httpd_pids" = INTEGER: 5
NET-SNMP-EXTEND-MIB::nsExtendExecType."httpd_pids" = INTEGER: exec(1)
NET-SNMP-EXTEND-MIB::nsExtendRunType."httpd_pids" = INTEGER: run-on-read(1)
NET-SNMP-EXTEND-MIB::nsExtendStorage."httpd_pids" = INTEGER: permanent(4)
NET-SNMP-EXTEND-MIB::nsExtendStatus."httpd_pids" = INTEGER: active(1)
NET-SNMP-EXTEND-MIB::nsExtendOutPutLine."httpd_pids" = STRING:
NET-SNMP-EXTEND-MIB::nsExtendOutNumLines."httpd_pids" = INTEGER: 1
NET-SNMP-EXTEND-MIB::nsExtendResult."httpd_pids" = INTEGER: 8
NET-SNMP-EXTEND-MIB::nsExtendOutLine."httpd_pids".1 = STRING: There are 8 httpd processes.
```

Note that the exit code ("8" in this example) is provided as an INTEGER type and any output is provided as a STRING type. To expose multiple metrics as integers, supply different arguments to the script using the extend directive. For example, the following shell script can be used to determine the number of processes matching an arbitrary string, and will also output a text string giving the number of processes:

```
#!/bin/sh
PATTERN=$1
NUMPIDS=`pgrep $PATTERN | wc -l`
echo "There are $NUMPIDS $PATTERN processes."
exit $NUMPIDS
```

The following /etc/snmp/snmpd.conf directives will give both the number of httpd PIDs as well as the number of snmpd PIDs when the above script is copied to /usr/local/bin/check_proc.sh:

```
extend httpd_pids /bin/sh /usr/local/bin/check_proc.sh httpd
extend snmpd_pids /bin/sh /usr/local/bin/check_proc.sh snmpd
```

The following example shows the output of an snmpwalk of the nsExtendObjects OID:

```
~]$ snmpwalk localhost NET-SNMP-EXTEND-MIB::nsExtendObjects
```

```
NET-SNMP-EXTEND-MIB::nsExtendNumEntries.0 = INTEGER: 2
NET-SNMP-EXTEND-MIB::nsExtendCommand."snmpd_pids" = STRING: /bin/sh
NET-SNMP-EXTEND-MIB::nsExtendArgs."snmpd_pids" = STRING: /usr/local/bin/check_proc.sh httpd
NET-SNMP-EXTEND-MIB::nsExtendInput."httpd_pids" = STRING:
NET-SNMP-EXTEND-MIB::nsExtendInput."snmpd_pids" = STRING:
NET-SNMP-EXTEND-MIB::nsExtendOutPutLine."httpd_pids" = STRING:
NET-SNMP-EXTEND-MIB::nsExtendOutPutLine."snmpd_pids" = STRING:
... 
NET-SNMP-EXTEND-MIB::nsExtendResult."httpd_pids" = INTEGER: 8
NET-SNMP-EXTEND-MIB::nsExtendResult."httpd_pids" = INTEGER: 8
NET-SNMP-EXTEND-MIB::nsExtendResult."snmpd_pids" = INTEGER: 1
NET-SNMP-EXTEND-MIB::nsExtendResult."snmpd_pids" = INTEGER: There are 8 httpd processes.
NET-SNMP-EXTEND-MIB::nsExtendOutLine."snmpd_pids".1 = STRING: There are 1 snmpd processes.
```

Integer exit codes are limited

Integer exit codes are limited to a range of 0–255. For values that are likely to exceed 256, either use the standard output of the script (which will be typed as a string) or a different method of extending the agent.

This last example shows a query for the free memory of the system and the number of httpd processes. This query could be used during a performance test to determine the impact of the number of processes on memory pressure:
18.5.2. Extending Net-SNMP with Perl

Executing shell scripts using the `extend` directive is a fairly limited method for exposing custom application metrics over SNMP. The Net-SNMP Agent also provides an embedded Perl interface for exposing custom objects. The `net-snmp-perl` package provides the `NetSNMP::agent` Perl module that is used to write embedded Perl plug-ins on Fedora.

The `NetSNMP::agent` Perl module provides an `agent` object which is used to handle requests for a part of the agent's OID tree. The `agent` object's constructor has options for running the agent as a sub-agent of `snmpd` or a standalone agent. No arguments are necessary to create an embedded agent:

```perl
use NetSNMP::agent ('all');
my $agent = new NetSNMP::agent();
```

The `agent` object has a `register` method which is used to register a callback function with a particular OID. The `register` function takes a name, OID, and pointer to the callback function. The following example will register a callback function named `hello_handler` with the SNMP Agent which will handle requests under the OID `.1.3.6.1.4.1.8072.9999.9999`:

```perl
$agent->register('hello_world', '.1.3.6.1.4.1.8072.9999.9999', \&hello_handler);
```

Obtaining a root OID

The OID `.1.3.6.1.4.1.8072.9999.9999` (NET-SNMP-MIB:::netSnmpPlaypen) is typically used for demonstration purposes only. If your organization does not already have a root OID, you can obtain one by contacting your Name Registration Authority (ANSI in the United States).

The handler function will be called with four parameters, `HANDLER, REGISTRATION_INFO, REQUEST_INFO, and REQUESTS.` The `REQUESTS` parameter contains a list of requests in the current call and should be iterated over and populated with data. The `REQUESTS` object's list have get and set methods which allow for manipulating the OID and value of the request. For example, the following call will set the value of a request object to the string "hello world":

```perl
$request->setValue(ASN_OCTET_STR, "hello world");
```

The handler function should respond to two types of SNMP requests: the GET request and the GETNEXT request. The type of request is determined by calling the `getMode` method on the `REQUEST_INFO` object passed as the third parameter to the handler function. If the request is a GET request, the caller will expect the handler to set the value of the request object, depending on the OID of the request. If the request is a GETNEXT request, the caller will also expect the handler to set the OID of the request to the next available OID in the tree. This is illustrated in the following code example:

```perl
my $request;
my $string_value = "hello world";
my $integer_value = 8675309;
for($request = $requests; $request; $request = $request->next()) {
  my $oid = $request->getOID();
  if ($request_info->getMode() == MODE_GET) {
    if ($oid == new NetSNMP::OID('.1.3.6.1.4.1.8072.9999.9999.1.0')) {
      $request->setValue(ASN_OCTET_STR, $string_value);
    } elsif ($oid == new NetSNMP::OID('.1.3.6.1.4.1.8072.9999.9999.1.1')) {
      $request->setValue(ASN_INTEGER, $integer_value);
    } elsif ($request_info->getMode() == MODE_GETNEXT) {
      if ($oid == new NetSNMP::OID('.1.3.6.1.4.1.8072.9999.9999.1.0')) {
        $request->setOID('.1.3.6.1.4.1.8072.9999.9999.1.1');
        $request->setValue(ASN_INTEGER, $integer_value);
      } elsif ($oid < new NetSNMP::OID('.1.3.6.1.4.1.8072.9999.9999.1.0')) {
        $request->setOID('.1.3.6.1.4.1.8072.9999.9999.1.0');
        $request->setValue(ASN_OCTET_STR, $string_value);
      } else {
        # Handle other cases...
      }
    } else {
      # Handle other cases...
    }
  }
  else {
    # Handle other cases...
  }
}
```

When `getMode` returns `MODE_GET`, the handler analyzes the value of the `getOID` call on the `REQUEST_INFO` object. The value of the `REQUEST_INFO` object is to either `string_value` if the OID ends in "1.0", or to `integer_value` if the OID ends in "1.1". If the `getMode` returns `MODE_GETNEXT`, the handler determines whether the OID of the request is "1.0", and then sets the OID and value for "1.1". If the request is higher on the tree than "1.0", the OID and value for "1.0" is set. This is in effect returns the "next" value in the tree so that a program like `snmpwalk` can traverse the tree without prior knowledge of the structure.

The type of the variable is set using constants from `NetSNMP::ASN`. See the `perldoc` for `NetSNMP::ASN` for a full list of available constants.

The entire code listing for this example Perl plug-in is as follows:

```perl
#!/usr/bin/perl

use NetSNMP::agent ('all');
my $agent = new NetSNMP::agent();

$agent->register('hello_world', '.1.3.6.1.4.1.8072.9999.9999', \&hello_handler);

sub hello_handler {
  my ($oid, $string_value, $integer_value) = @_

  return if $oid->getMode != MODE_GET;

  if ($oid == new NetSNMP::OID('.1.3.6.1.4.1.8072.9999.9999.1.0')) {
    $string_value = "hello world";
  } elsif ($oid == new NetSNMP::OID('.1.3.6.1.4.1.8072.9999.9999.1.1')) {
    $integer_value = 8675309;
  } elsif ($oid < new NetSNMP::OID('.1.3.6.1.4.1.8072.9999.9999.1.0')) {
    $oid = new NetSNMP::OID('.1.3.6.1.4.1.8072.9999.9999.1.0');
    $string_value = "hello world";
    $integer_value = 8675309;
  }
}
```

Example usage:

```bash
$ snmpget localhost \n  'NET-SNMP-EXTEND-MIB::nsExtendResult "httpd.pids"' \nUČD-SNMP-MIB::memAvailReal.0 = INTEGER: 799664 kB
```

```
~]$ snmpget localhost \n  'NET-SNMP-EXTEND-MIB::nsExtendResult "httpd.pids"' \nUČD-SNMP-MIB::memAvailReal.0 = INTEGER: 799664 kB
```

```bash
~]$ snmpwalk localhost \n  'NET-SNMP-EXTEND-MIB::nsExtendResult "httpd.pids"'
```

```
~]$ snmpwalk localhost \n  'NET-SNMP-EXTEND-MIB::nsExtendResult "httpd.pids"'
```

```bash
~]$ snmpwalk localhost \n  'NET-SNMP-EXTEND-MIB::nsExtendResult "httpd.pids"'
```

```bash
~]$ snmpwalk localhost \n  'NET-SNMP-EXTEND-MIB::nsExtendResult "httpd.pids"'
```

```bash
~]$ snmpwalk localhost \n  'NET-SNMP-EXTEND-MIB::nsExtendResult "httpd.pids"'
```
#!/usr/bin/perl

use NetSNMP::agent ('all');
use NetSNMP::ASN qw(ASN_OCTET_STR ASN_INTEGER);

sub hello_handler {
  my ($handler, $registration_info, $request_info, $requests) = @_; 
  my $request;
  my $string_value = "hello world";
  my $integer_value = 8675309;

  for($request = @requests; $request; $request = $request->next()) {
    my $oid = $request->getOID();
    if ($request_info->getMode() == MODE_GET) {
      if ($oid == new NetSNMP::OID(".1.3.6.1.4.1.8072.9999.9999.1.0")) {
        $request->setValue(ASN_OCTET_STR, $string_value);
      }
      elsif ($oid == new NetSNMP::OID(".1.3.6.1.4.1.8072.9999.9999.1.1")) {
        $request->setValue(ASN_INTEGER, $integer_value);
      }
    }
    elsif ($oid < new NetSNMP::OID(".1.3.6.1.4.1.8072.9999.9999.1.0")) {
      $request->setOID(".1.3.6.1.4.1.8072.9999.9999.1.0");
      $request->setValue(ASN_OCTET_STR, $string_value);
    }
    $agent = new NetSNMP::agent();
    $agent->register("hello_world", 
    
    &hello_handler);

  }
  my $agent = new NetSNMP::agent();
  $agent->register("hello_world", 

  
  
  
  &hello_handler);

  To test the plug-in, copy the above program to 
  /usr/share/snmp/hello_world.pl and add the following line to the 
  /etc/snmp/snmpd.conf configuration file:

  perl do "/usr/share/snmp/hello_world.pl"

  The SNMP Agent Daemon will need to be restarted to load the new Perl plug-in. Once it has been restarted, an snmpwalk should return the new data:

  ```
  $ snmpwalk localhost NET-SNMP-MIB::netSnmpPlaypen
  NET-SNMP-MIB::netSnmpPlaypen.1.0 = STRING: "hello world"
  NET-SNMP-MIB::netSnmpPlaypen.1.1 = INTEGER: 8675309
  ```

  The snmpget should also be used to exercise the other mode of the handler:

  ```
  $ snmpget localhost 
  NET-SNMP-MIB::netSnmpPlaypen.1.0 
  NET-SNMP-MIB::netSnmpPlaypen.1.1
  NET-SNMP-MIB::netSnmpPlaypen.1.0 = STRING: "hello world"
  NET-SNMP-MIB::netSnmpPlaypen.1.1 = INTEGER: 8675309
  ```

18.7. Additional Resources

To learn more about gathering system information, refer to the following resources.

18.7.1. Installed Documentation

» ps(1) — The manual page for the ps command.
» top(1) — The manual page for the top command.
» free(1) — The manual page for the free command.
» df(1) — The manual page for the df command.
» du(1) — The manual page for the du command.
» lspci(8) — The manual page for the lspci command.
» snmpd(8) — The manual page for the snmpd service.
» snmpd.conf(5) — The manual page for the /etc/snmp/snmpd.conf file containing full documentation of available configuration directives.

Chapter 19. Viewing and Managing Log Files

19.1. Configuring rsyslog

19.1.1. Global Directives
19.1.2. Modules
19.1.3. Rules
19.1.4. rsyslog Command Line Configuration

19.2. Locating Log Files
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19.4. Adding a Log File

19.5. Monitoring Log Files

19.6. Additional Resources

19.6.1. Installed Documentation

19.6.2. Useful Websites

Log files are files that contain messages about the system, including the kernel, services, and applications running on it. There are different log files for different information. For example, there is a default system log file, a log file just for security messages, and a log file for cron tasks.

Log files can be very useful when trying to troubleshoot a problem with the system such as trying to load a kernel driver or when looking for unauthorized login attempts to the system. This chapter discusses where to find log files, how to view log files, and what to look for in log files.

Some log files are controlled by a daemon called **rsyslog**. A list of log files maintained by **rsyslog** can be found in the `/etc/rsyslog.conf` configuration file.

**rsyslog** is an enhanced, multi-threaded syslog daemon which replaced the **sysklogd** daemon. **rsyslog** supports the same functionality as **sysklogd** and extends it with enhanced filtering, encryption protected relaying of messages, various configuration options, or support for transportation via the TCP or UDP protocols. Note that **rsyslog** is compatible with **sysklogd**.

19.1. Configuring rsyslog

The main configuration file for **rsyslog** is `/etc/rsyslog.conf`. It consists of global directives, rules or comments (any empty lines or any text following a hash sign (#)). Both, global directives and rules are extensively described in the sections below.

19.1.1. Global Directives

Global directives specify configuration options that apply to the **rsyslogd** daemon. They usually specify a value for a specific pre-defined variable that affects the behavior of the **rsyslogd** daemon or a rule that follows. All of the global directives must start with a dollar sign ($). Only one directive can be specified per line. The following is an example of a global directive that specifies the maximum size of the syslog message queue:

```
$MainMsgQueueSize 50000
```

The default size defined for this directive (10,000 messages) can be overridden by specifying a different value (as shown in the example above).

You may define multiple directives in your `/etc/rsyslog.conf` configuration file. A directive affects the behavior of all configuration options until another occurrence of that same directive is detected.

A comprehensive list of all available configuration directives and their detailed description can be found in `/usr/share/doc/rsyslog-<version-number>/rsyslog_conf_global.html`.

19.1.2. Modules

Due to its modular design, **rsyslog** offers a variety of modules which provide dynamic functionality. Note that modules can be written by third parties. Most modules provide additional inputs (see Input Modules below) or outputs (see Output Modules below). Other modules provide special functionality specific to each module. The modules may provide additional configuration directives that become available after a module is loaded. To load a module, use the following syntax:

```
$ModLoad <MODULE>
```

where `$ModLoad` is the global directive that loads the specified module and `<MODULE>` represents your desired module. For example, if you want to load the Text File Input Module (`imfile` — enables **rsyslog** to convert any standard text files into syslog messages), specify the following line in your `/etc/rsyslog.conf` configuration file:

```
$ModLoad imfile
```

**rsyslog** offers a number of modules which are split into these main categories:

- **Input Modules** — Input modules gather messages from various sources. The name of an input module always starts with the `im` prefix, such as `imfile`, `imrelp`, etc.
- **Output Modules** — Output modules provide a facility to store messages into various targets such as sending them across network, storing them in a database or encrypting them. The name of an output module always starts with the `om` prefix, such as `omsnmp`, `omrelp`, etc.
- **Filter Modules** — Filter modules provide the ability to filter messages according to specified rules. The name of a filter module always starts with the `fm` prefix.
- **Parser Modules** — Parser modules use the message parsers to parse message content of any received messages. The name of a parser module always starts with the `pm` prefix, such as `pmrfc5424`, `pmrfc3164`, etc.
- **Message Modification Modules** — Message modification modules change the content of a syslog message. The message modification modules only differ in their implementation from the output and filter modules but share the same interface.
19.1.3. Rules

A rule is specified by a filter part, which selects a subset of syslog messages, and an action part, which specifies what to do with the selected messages. To define a rule in your `/etc/rsyslog.conf` configuration file, define both, a filter and an action, on one line and separate them with one or more spaces or tabs. For more information on filters, refer to Section 19.1.3.1, “Filter Conditions”, and for information on actions, refer to Section 19.1.3.2, “Actions”.

19.1.3.1. Filter Conditions

rsyslog offers various ways to filter syslog messages according to various properties. This sections sums up the most used filter conditions.

**Facility/Priority-based filters**

The most used and well-known way to filter syslog messages is to use the facility/priority-based filters which filter syslog messages based on two conditions: facility and priority. To create a selector, use the following syntax:

```
<facility>, <priority>
```

where:

- `<facility>` specifies the subsystem that produces a specific syslog message. For example, the `mail` subsystem handles all mail related syslog messages. `<facility>` can be represented by one of these keywords: `auth`, `authpriv`, `cron`, `daemon`, `kern`, `lpr`, `mail`, `news`, `syslog`, `user`, `uucp`, and `local0` through `local7`.
- `<priority>` specifies a priority of a syslog message. `<priority>` can be represented by one of these keywords (listed in an ascending order): `debug`, `info`, `notice`, `warning`, `err`, `crit`, `alert`, and `emerg`.

By preceding any priority with an equal sign (=), you specify that only syslog messages with that priority will be selected. All other priorities will be ignored. Conversely, preceding a priority with an exclamation mark (!) selects all syslog messages but those with the defined priority. By not using either of these two extensions, you specify a selection of syslog messages with the defined or higher priority.

In addition to the keywords specified above, you may also use an asterisk (*) to define all facilities or priorities (depending on where you place the asterisk, before or after the dot). Specifying the keyword `none` serves for facilities with no given priorities.

To define multiple facilities and priorities, simply separate them with a comma (,). To define multiple filters on one line, separate them with a semi-colon (;).

The following are a few examples of simple facility/priority-based filters:

```
kern.*    # Selects all kernel syslog messages with any priority
mail.crit  # Selects all mail syslog messages with priority crit and higher.
cron.info,!debug    # Selects all cron syslog messages except those with the info or debug priority.
```

**Property-based filters**

Property-based filters let you filter syslog messages by any property, such as `timegenerated` or `syslogtag`. For more information on properties, refer to Section 19.1.3.3.2, “Properties”. Each of the properties specified in the filters lets you compare it to a specific value using one of the compare-operations listed in Table 19.1, “Property-based compare-operations”.

<table>
<thead>
<tr>
<th>Compare-operation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>contains</code></td>
<td>Checks whether the provided string matches any part of the text provided by the property.</td>
</tr>
<tr>
<td><code>isequal</code></td>
<td>Compares the provided string against all of the text provided by the property.</td>
</tr>
<tr>
<td><code>startswith</code></td>
<td>Checks whether the provided string matches a prefix of the text provided by the property.</td>
</tr>
<tr>
<td><code>regex</code></td>
<td>Compares the provided POSIX BRE (Basic Regular Expression) regular expression against the text provided by the property.</td>
</tr>
<tr>
<td><code>ereregex</code></td>
<td>Compares the provided POSIX ERE (Extended Regular Expression) regular expression against the text provided by the property.</td>
</tr>
</tbody>
</table>

A comprehensive list of all available modules and their detailed description can be found at http://www.rsyslog.com/doc/rsyslog_conf_modules.html.
To define a property-based filter, use the following syntax:

```
<PROPERTY>, ![<COMPARE_OPERATION>>, "<STRING>"
```

where:

- The `<PROPERTY>` attribute specifies the desired property (for example, `timegenerated`, `hostname`, etc.).
- The optional exclamation point (!) negates the output of the compare-operation (if prefixing the compare-operation).
- The `<COMPARE_OPERATION>` attribute specifies one of the compare-operations listed in Table 19.1, “Property-based compare-operations”.
- The `<STRING>` attribute specifies the value that the text provided by the property is compared to. To escape certain character (for example a quotation mark (")), use the backslash character (\).

The following are few examples of property-based filters:

- The following filter selects syslog messages which contain the string `error` in their message text:
  
  ```
  :msg, contains, "error"
  ```

- The following filter selects syslog messages received from the hostname `host1`:
  
  ```
  :hostname, isequal, "host1"
  ```

- The following filter selects syslog messages which do not contain any mention of the words `fatal` and `error` with any or no text between them (for example, `fatal lib error`):
  
  ```
  :msg, !regex, "fatal .* error"
  ```

**Expression-based filters**

Expression-based filters select syslog messages according to defined arithmetic, boolean or string operations. Expression-based filters use `rsyslog`'s own scripting language. The syntax of this language is defined in `/usr/share/doc/rsyslog-<version-number>/rscript_abnf.html` along with examples of various expression-based filters.

To define an expression-based filter, use the following syntax:

```
if <EXPRESSION> then <ACTION>
```

where:

- The `<EXPRESSION>` attribute represents an expression to be evaluated, for example: `$msg startswith 'DEVNAME'` or `$syslogfacility-text == 'local0'`.
- The `<ACTION>` attribute represents an action to be performed if the expression returns the value `true`.

**Define an expression-based filter on a single line**

When defining an expression-based filter, it must be defined on a single line.

**Do not use regular expressions**

Regular expressions are currently not supported in expression-based filters.

**BSD-style blocks**

`rsyslog` supports BSD-style blocks inside the `/etc/rsyslog.conf` configuration file. Each block consists of rules which are preceded with a program or hostname label. Use the `<PROGRAM>` or `<HOSTNAME>` labels to include or exclude programs, respectively. Use the `!<HOSTNAME>` or `<HOSTNAME>` labels to include or exclude hostnames, respectively.

**Example 19.1, “BSD-style block”** shows a BSD-style block that saves all messages generated by `yum` to a file.

```
Example 19.1. BSD-style block

!yum
  *. * /var/log/named.log
```

**19.1.3.2. Actions**

Actions specify what is to be done with the messages filtered out by an already-defined selector. The following are some of the actions you can define in your rule:

**Saving syslog messages to log files**

The majority of actions specify to which log file a syslog message is saved. This is done by specifying a file path after your already-defined selector. The following is a rule comprised of a selector that selects all `cron` syslog messages and an action that saves them into the `/var/log/cron.log` log file:

```
Example 19.2. Saving syslog messages to log files

<@<LOCATION>><@<обытие>>
  /var/log/cron.log
```
cron.* /var/log/cron.log

Use a dash mark (-) as a prefix of the file path you specified if you want to omit syncing the desired log file after every syslog message is generated.

Your specified file path can be either static or dynamic. Static files are represented by a simple file path as was shown in the example above. Dynamic files are represented by a template and a question mark (?) prefix. For more information on templates, refer to Section 19.1.3.3.1, "Generating dynamic file names".

If the file you specified is an existing tty or /dev/console device, syslog messages are sent to standard output (using special tty-handling) or your console (using special /dev/console-handling) when using the X Window System, respectively.

Sending syslog messages over the network

rsyslog allows you to send and receive syslog messages over the network. This feature allows to administer syslog messages of multiple hosts on one machine. To forward syslog messages to a remote machine, use the following syntax:

```
@([<OPTION>])<HOST>:[<PORT>]
```

where:

- The at sign (@) indicates that the syslog messages are forwarded to a host using the UDP protocol. To use the TCP protocol, use two at signs with no space between them (@@).
- The `<OPTION>` attribute can be replaced with an option such as z<NUMBER> . This option enables zlib compression for syslog messages; the `<NUMBER>` attribute specifies the level of compression. To define multiple options, simply separate each one of them with a comma (,).
- The `<HOST>` attribute specifies the host which receives the selected syslog messages.
- The `<PORT>` attribute specifies the host machine's port.

When specifying an IPv6 address as the host, enclose the address in square brackets ([ ]).

The following are some examples of actions that forward syslog messages over the network (note that all actions are preceded with a selector that selects all messages with any priority):

```
*.@192.168.0.1    # Forwards messages to 192.168.0.1 via the UDP protocol

*.@example.com:18    # Forwards messages to "example.com" using port 18 and the TCP protocol

*.@([z9][2001::1])    # Compresses messages with zlib (level 9 compression) and forwards them to 2001::1 using the UDP protocol
```

Output channels

Output channels are primarily used for log file rotation (for more info on log file rotation, refer to Section 19.2.1, "Configuring logrotate"), that is, to specify the maximum size a log file can grow to. To define an output channel, use the following syntax:

```
$outchannel <NAME>, <FILE_NAME>, <MAX_SIZE>, <ACTION>
```

where:

- The `<NAME>` attribute specifies the name of the output channel.
- The `<FILE_NAME>` attribute specifies the name of the output file.
- The `<MAX_SIZE>` attribute represents the maximum size the specified file (in `<FILE_NAME>`) can grow to. This value is specified in bytes.
- The `<ACTION>` attribute specifies the action that is taken when the maximum size, defined in `<MAX_SIZE>`, is hit.

Example 19.2, "Output channel log rotation" shows a simple log rotation through the use of an output channel. First, the output channel is defined via the $outchannel directive and then used in a rule which selects every syslog message with any priority and executes the previously-defined output channel on the acquired syslog messages. Once the limit (in the example 100 MB) is hit, the /home/joe/log_rotation_script is executed. This script can contain anything from moving the file into a different folder, editing specific content out of it, or simply removing it.

```
Example 19.2. Output channel log rotation
$outchannel log_rotation, /var/log/test_log.log, 104857600, /home/joe/log_rotation_script

```

Sending syslog messages to specific users

rsyslog can send syslog messages to specific users by simply specifying a username of the user you wish to send
the messages to. To specify more than one user, separate each username with a comma (,). To send messages to every user that is currently logged on, use an asterisk (*).

Executing a program

rsyslog lets you execute a program for selected syslog messages and uses the system() call to execute the program in shell. To specify a program to be executed, prefix it with a caret character (^). Consequently, specify a template that formats the received message and passes it to the specified executable as a one line parameter (for more information on templates, refer to Section 19.1.3.3, “Templates”). In the following example, any syslog message with any priority is selected, formatted with the template template and passed as a parameter to the test-program program, which is then executed with the provided parameter:

```
*.* ^test-program;template
```

Be careful when using the shell execute action

When accepting messages from any host, and using the shell execute action, you may be vulnerable to command injection. An attacker may try to inject and execute commands specified by the attacker in the program you specified (in your action) to be executed. To avoid any possible security threats, thoroughly consider the use of the shell execute action.

Inputting syslog messages in a database

Selected syslog messages can be directly written into a database table using the database writer action. The database writer uses the following syntax:

```
<PLUGIN>,<DB_HOST>,<DB_NAME>,<DB_USER>,<DB_PASSWORD>;[<TEMPLATE>]
```

where:

- The <PLUGIN> calls the specified plug-in that handles the database writing (for example, the ommysql plug-in).
- The <DB_HOST> attribute specifies the database hostname.
- The <DB_NAME> attribute specifies the name of the database.
- The <DB_USER> attribute specifies the database user.
- The <DB_PASSWORD> attribute specifies the password used with the aforementioned database user.
- The <TEMPLATE> attribute specifies an optional use of a template that modifies the syslog message. For more information on templates, refer to Section 19.1.3.3, "Templates".

Using MySQL and PostgreSQL

Currently, rsyslog provides support for MySQL (for more information, refer to /usr/share/doc/rsyslog-[version-number]/rsyslog_mysql.html) and PostgreSQL databases only. In order to use the MySQL and PostgreSQL database writer functionality, install the rsyslog-mysql and rsyslog-pgsql packages installed, respectively. Also, make sure you load the appropriate modules in your /etc/rsyslog.conf configuration file:

```
$ModLoad ommysql    # Output module for MySQL support
$ModLoad ompgsql    # Output module for PostgreSQL support
```

For more information on rsyslog modules, refer to Section 19.1.2, "Modules". Alternatively, you may use a generic database interface provided by the on11dbb module. However, this module is currently not compiled.

Discarding syslog messages

To discard your selected messages, use the tilde character (~). The following rule discards any cron syslog messages:

```
cron.* ~
```

For each selector, you are allowed to specify multiple actions. To specify multiple actions for one selector, write each action on a separate line and precede it with an ampersand character (&). Only the first action is allowed to have a selector specified on its line. The following is an example of a rule with multiple actions:

```
kern.=crit joe
& ^test-program;temp
& @192.168.0.1
```

In the example above, all kernel syslog messages with the critical priority (crit) are send to user joe, processed by the template temp and passed on to the test-program executable, and forwarded to 192.168.0.1 via the UDP protocol.

Specifying multiple actions improves the overall performance of the desired outcome since the specified selector has to be evaluated only once.

Note that any action can be followed by a template that formats the message. To specify a template, suffix an action with a semicolon (;) and specify the name of the template.
Using templates

A template must be defined before it is used in an action, otherwise, it is ignored.

For more information on templates, refer to Section 19.1.3.3, “Templates”.

19.1.3.3. Templates

Any output that is generated by rsyslog can be modified and formatted according to your needs through the use of templates. To create a template use the following syntax:

```
$template <TEMPLATE_NAME>,"text %<PROPERTY>% more text", [<OPTION>]
```

where:

> **<TEMPLATE_NAME>** is the name of the template. Use this name to refer to the template.
> Anything between the two quotation marks ("…") is the actual template text. Within this text, you are allowed to escape characters in order to use their functionality, such as \n for new line or \r for carriage return. Other characters, such as % or \, have to be escaped in case you want to those characters literally.
> The text specified within two percent signs (\%) specifies a property that is consequently replaced with the property's actual value. For more information on properties, refer to Section 19.1.3.3.2, “Properties”.
> The <OPTION> attribute specifies any options that modify the template functionality. Do not mistake these for property options, which are defined inside the template text (between "…"). The currently supported template options are sql and stdsql used for formatting the text as an SQL query.

The sql and stdsql options

Note that the database writer (for more information, refer to section Inputting syslog messages in a database in Section 19.1.3.2, “Actions”) checks whether the sql and stdsql options are specified in the template. If they are not, the database writer does not perform any action. This is to prevent any possible security threats, such as SQL injection.

19.1.3.3.1. Generating dynamic file names

Templates can be used to generate dynamic file names. By specifying a property as a part of the file path, a new file will be created for each unique property. For example, use the timegenerated property to generate a unique file name for each syslog message:

```
$template DynamicFile,"/var/log/test_logs/%timegenerated%-test.log"
```

Keep in mind that the **template** directive only specifies the template. You must use it inside a rule for it to take effect:

```
".*" ?DynamicFile
```

19.1.3.3.2. Properties

Properties defined inside a template (within two percent signs (\%)) allow you to access various contents of a syslog message through the use of a property replacer. To define a property inside a template (between the two quotation marks ("…")), use the following syntax:

```
%<PROPERTY_NAME>[[:<FROM_CHAR>:<TO_CHAR>:<OPTION>]]%
```

where:

> The <PROPERTY_NAME> attribute specifies the name of a property. A comprehensible list of all available properties and their detailed description can be found in /usr/share/doc/rsyslog-<version-number>/property_replacer.html under the section Available Properties.
> <FROM_CHAR> and <TO_CHAR> attributes denote a range of characters that the specified property will act upon. Alternatively, regular expressions can be used to specify a range of characters. To do so, specify the letter R as the <FROM_CHAR> attribute and specify your desired regular expression as the <TO_CHAR> attribute.
> The <OPTION> attribute specifies any property options. A comprehensible list of all available properties and their detailed description can be found in /usr/share/doc/rsyslog-<version-number>/property_replacer.html under the section Property Options.

The following are some examples of simple properties:

> The following property simply obtains the whole message text of a syslog message:

```
%msg%
```

> The following property obtains the first two characters of the message text of a syslog message:

```
%msg:1:2%
```

> The following property obtains the whole message text of a syslog message and drops its last line feed character:

```
%msg::drop-last-lf%
```

> The following property obtains the first 10 characters of the timestamp that is generated when the syslog message is received and formats it according to the RFC 3999 date standard.
19.1.3.3. Template Examples
This section presents few examples of rsyslog templates.

Example 19.3, “A verbose syslog message template” shows a template that formats a syslog message so that it outputs the message’s severity, facility, the timestamp of when the message was received, the hostname, the message tag, the message text, and ends with a new line.

```
$template verbose,"%syslogseverity%,%syslogfacility%,%timegenerated%,%HOSTNAME%,%syslogtag%,%msg\n"
```

Example 19.4, “A wall message template” shows a template that resembles a traditional wall message (a message that is send to every user that is logged in and has their msg(1) permission set to yes). This template outputs the message text, along with a hostname, message tag and a timestamp, on a new line (using \r and \n) and rings the bell (using \7).

```
$template wallmsg,\r\n\7Message from syslogd@%HOSTNAME% at %timegenerated% ...
%syslogtag% %msg\n\r"
```

Example 19.5, “A database formatted message template” shows a template that formats a syslog message so that it can be used as a database query. Notice the use of the sql option at the end of the template specified as the template option. It tells the database writer to format the message as an MySQL SQL query.

```
$template dbFormat,"insert into SystemEvents (Message, Facility,FromHost, Priority, DeviceReportedTime, ReceivedAt, InfoUnitID, SysLogTag) values ('%msg%', %syslogfacility%, '%HOSTNAME%',%syslogpriority%, '%timereported:::date-mysql%', '%timegenerated:::date-mysql%', %iut%, '%syslogtag%')",sql
```

rsyslog also contains a set of predefined templates identified by the RSYSLOG_ prefix. It is advisable to not create a template using this prefix to avoid any conflicts. The following list shows these predefined templates along with their definitions.

**RSYSLOG_DebugFormat**

"Debug line with all properties:

**RSYSLOG_SyslogProtocol23Format**

"<%PRI%>1 %TIMESTAMP:::date-rfc3339% %HOSTNAME% %APP-NAME% %PROCID% %MSGID% %STRUCTURED-DATA% %msg%\n"

**RSYSLOG_FileFormat**

"%TIMESTAMP:::date-rfc3339% %HOSTNAME% %syslogtag%\nmsg:::sp-if-no-1st-sp%%msg:::drop-last-lf%\n"

**RSYSLOG_TraditionalFileFormat**

"%TIMESTAMP% %HOSTNAME% %syslogtag%\nmsg:::sp-if-no-1st-sp%%msg:::drop-last-lf%\n"

**RSYSLOG_ForwardFormat**

"<%PRI%>%TIMESTAMP:::date-rfc3339% %HOSTNAME% %syslogtag%\nmsg:::drop-if-no-1st-sp%\n"

**RSYSLOG_TraditionalForwardFormat**

"<%PRI%>%TIMESTAMP% %HOSTNAME% %syslogtag%\nmsg:::drop-if-no-1st-sp%\n"

19.1.4. rsyslog Command Line Configuration

Some of rsyslog’s functionality can be configured through the command line options, as sysklogd can. Note that as of version 3 of rsyslog, this method was deprecated. To enable some of these options, you must specify the compatibility mode rsyslog should run in. However, configuring rsyslog through the command line options should be avoided.
To specify the compatibility mode `rsyslog` should run in, use the `-c` option. When no parameter is specified, `rsyslog` tries to be compatible with `sysklogd`. This is partially achieved by activating configuration directives that modify your configuration accordingly. Therefore, it is advisable to supply this option with a number that matches the major version of `rsyslog` that is in use and update your `/etc/rsyslog.conf` configuration file accordingly. If you want to, for example, use `sysklogd` options (which were deprecated in version 3 of `rsyslog`), you can specify so by executing the following command:

```bash
[-]# rsyslogd -c 2
```

Options that are passed to the `rsyslogd` daemon, including the backward compatibility mode, can be specified in the `/etc/sysconfig/rsyslog` configuration file.

For more information on various `rsyslogd` options, refer to `man rsyslogd`.

### 19.2. Locating Log Files

Most log files are located in the `/var/log/` directory. Some applications such as `httpd` and `samba` have a directory within `/var/log/` for their log files.

You may notice multiple files in the `/var/log/` directory with numbers after them (for example, `cron-20100906`). These numbers represent a timestamp that has been added to a rotated log file. Log files are rotated so their file sizes do not become too large. The `logrotate` package contains a cron task that automatically rotates log files according to the `/etc/logrotate.conf` configuration file and the configuration files in the `/etc/logrotate.d/` directory.

#### 19.2.1. Configuring logrotate

The following is a sample `/etc/logrotate.conf` configuration file:

```conf
# rotate log files weekly
weekly
# keep 4 weeks worth of backlogs
rotate 4
# uncomment this if you want your log files compressed
compress
```

All of the lines in the sample configuration file define global options that apply to every log file. In our example, log files are rotated weekly, rotated log files are kept for the duration of 4 weeks, and all rotated log files are compressed by `gzip` into the `.gz` format. Any lines that begin with a hash sign (`#`) are comments and are not processed.

You may define configuration options for a specific log file and place it under the global options. However, it is advisable to create a separate configuration file for any specific log file in the `/etc/logrotate.d/` directory and define any configuration options there.

The following is an example of a configuration file placed in the `/etc/logrotate.d/` directory:

```conf
/var/log/messages {
    rotate 5
    weekly
    postrotate
    /usr/bin/killall -HUP syslogd
    endscript
}
```

The configuration options in this file are specific for the `/var/log/messages` log file only. The settings specified here override the global settings where possible. Thus the rotated `/var/log/messages` log file will be kept for five weeks instead of four weeks as was defined in the global options.

The following is a list of some of the directives you can specify in your `logrotate` configuration file:

- `weekly` — Specifies the rotation of log files on a weekly basis. Similar directives include:
  - `daily`
  - `monthly`
  - `yearly`
- `compress` — Enables compression of rotated log files. Similar directives include:
  - `nocompress`
  - `compresscmd` — Specifies the command to be used for compressing.
  - `uncompresscmd` — Specifies what extension is to be used for compressing.
  - `compressoptions` — Lets you specify any options that may be passed to the used compression program.
  - `delaycompress` — Postpones the compression of log files to the next rotation of log files.
- `rotate <INTEGER>` — Specifies the number of rotations a log file undergoes before it is removed or mailed to a specific address. If the value 0 is specified, old log files are removed instead of rotated.
- `mail <ADDRESS>` — This option enables mailing of log files that have been rotated as many times as is defined by the `rotate` directive to the specified address. Similar directives include:
  - `nomail`
  - `mailfirst` — Specifies that the just-rotated log files are to be mailed, instead of the about-to-expire log files.
  - `maillast` — Specifies that the just-rotated log files are to be mailed, instead of the about-to-expire log files. This is the default option when `mail` is enabled.

For the full list of directives and various configuration options, refer to the `logrotate` man page (`man logrotate`).
19.3. Viewing Log Files

Most log files are in plain text format. You can view them with any text editor such as **Vi** or **Emacs**. Some log files are readable by all users on the system; however, **root** privileges are required to read most log files.

To view system log files in an interactive, real-time application, use the **Log File Viewer**.

![Image](49x702 to 78x726)

---

### Installing the gnome-system-log package

In order to use the **Log File Viewer**, first ensure the `gnome-system-log` package is installed on your system by running, as **root**:

```bash
yum install gnome-system-log
```

For more information on installing packages with Yum, refer to Section 5.2.4, “Installing Packages”.

After you have installed the `gnome-system-log` package, you can open the **Log File Viewer** by selecting **Applications** → **System Tools** → **Log File Viewer** from the **Activities** menu, or type the following command at a shell prompt:

```bash
gnome-system-log
```

The application only displays log files that exist; thus, the list might differ from the one shown in **Figure 19.1, "Log File Viewer"**.

![Figure 19.1. Log File Viewer](46x144 to 197x279)

The **Log File Viewer** application lets you filter any existing log file. Click on **Filters** from the menu and select **Manage Filters** to define or edit your desired filter.

![Figure 19.2. Log File Viewer — filters](46x774)

Adding or editing a filter lets you define its parameters as is shown in **Figure 19.3, "Log File Viewer — defining a filter"**.
When defining a filter, you can edit the following parameters:

- **Name** — Specifies the name of the filter.
- **Regular Expression** — Specifies the regular expression that will be applied to the log file and will attempt to match any possible strings of text in it.
- **Effect**
  - **Highlight** — If checked, the found results will be highlighted with the selected color. You may select whether to highlight the background or the foreground of the text.
  - **Hide** — If checked, the found results will be hidden from the log file you are viewing.

When you have at least one filter defined, you may select it from the **Filters** menu and it will automatically search for the strings you have defined in the filter and highlight/hide every successful match in the log file you are currently viewing.

When you check the **Show matches only** option, only the matched strings will be shown in the log file you are currently viewing.

### 19.4. Adding a Log File

To add a log file you wish to view in the list, select **File → Open**. This will display the **Open Log** window where you can select the directory and file name of the log file you wish to view. Figure 19.5, "Log File Viewer — adding a log file" illustrates the **Open Log** window.
Click on the **Open** button to open the file. The file is immediately added to the viewing list where you can select it and view its contents.

19.5. Monitoring Log Files

**Log File Viewer** monitors all opened logs by default. If a new line is added to a monitored log file, the log name appears in bold in the log list. If the log file is selected or displayed, the new lines appear in bold at the bottom of the log file. Figure 19.6, "Log File Viewer — new log alert" illustrates a new alert in the `yum.log` log file and in the `messages` log file. Clicking on the `messages` log file displays the logs in the file with the new lines in bold.

19.6. Additional Resources

To learn more about **rsyslog**, **logrotate**, and log files in general, refer to the following resources.

19.6.1. Installed Documentation

- **rsyslogd** manual page — Type `man rsyslogd` to learn more about **rsyslogd** and its many options.
- **rsyslog.conf** manual page — Type `man rsyslog.conf` to learn more about the `/etc/rsyslog.conf` configuration file and its many options.
- `/usr/share/doc/rsyslog-<version-number>/` — After installing the **rsyslog** package, this directory contains extensive documentation in the **html** format.
Chapter 20. Automating System Tasks

20.1. Cron and Anacron

20.1.1. Starting and Stopping the Service

20.1.2. Configuring Anacron Jobs

20.1.3. Configuring Cron Jobs

20.1.4. Controlling Access to Cron

20.1.5. Black/White Listing of Cron Jobs

20.2. At and Batch

20.2.1. Configuring At Jobs

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20.2.3. Viewing Pending Jobs

20.2.4. Additional Command Line Options

20.2.5. Controlling Access to At and Batch

20.2.6. Starting and Stopping the Service

20.3. Additional Resources

20.3.1. Installed Documentation

In Linux, tasks, which are also known as jobs, can be configured to run automatically within a specified period of time, on a specified date, or when the system load average is below a specified number. Fedora is pre-configured to run important system tasks to keep the system updated. For example, the slocate database used by the `locate` command is updated daily. A system administrator can use automated tasks to perform periodic backups, monitor the system, run custom scripts, and more.

Fedora comes with several automated tasks utilities: `cron`, `at`, and `batch`.

20.1. Cron and Anacron

Both, Cron and Anacron, are daemons that can be used to schedule the execution of recurring tasks according to a combination of the time, day of the month, month, day of the week, and week.

Cron assumes that the system is on continuously. If the system is not on when a job is scheduled, it is not executed. Cron allows jobs to be run as often as every minute. Anacron does not assume the system is always on, remembers every scheduled job, and executes it the next time the system is up. However, Anacron can only run a job once a day. To schedule recurring jobs, refer to Section 20.1.2, “Configuring Anacron Jobs” or Section 20.1.3, “Configuring Cron Jobs”. To schedule one-time jobs, refer to Section 20.2, “At and Batch”.

To use the cron service, the `cronie` RPM package must be installed and the `crond` service must be running. `anacron` is a sub-package of `cronie`. To determine if these packages are installed, use the `rpm -q cronie cronie-anacron` command.

20.1.1. Starting and Stopping the Service

To determine if the service is running, use the following command:

```bash
systemctl is-active crond.service
```

To start the cron service, type the following at a shell prompt as `root`:

```bash
systemctl start crond.service
```

To stop the service, run the following command as `root`:

```bash
systemctl stop crond.service
```

It is recommended that you start the service at boot time. To do so, use the following command as `root`:

```bash
systemctl enable crond.service
```

Refer to Chapter 9, Services and Daemons for more information on how to configure services in Fedora.

20.1.2. Configuring Anacron Jobs

The main configuration file to schedule jobs is `/etc/anacrontab` (only `root` is allowed to modify this file), which contains the following lines:

SHELL=/bin/sh
PATH=/sbin:/bin:/usr/sbin:/usr/bin
MAILTO=root

# the maximal random delay added to the base delay of the jobs
RANDOM_DELAY=45
# the jobs will be started during the following hours only
START_HOURS_RANGE=3-22

#period in days delay in minutes job-identifier command
1 5 cron.daily nice run-parts /etc/cron.daily
7 25 cron.weekly nice run-parts /etc/cron.weekly
@monthly 45 cron.monthly nice run-parts /etc/cron.monthly

The first three lines are variables used to configure the environment in which the anacron tasks are run. The SHELL variable tells the system which shell environment to use (in this example the bash shell). The PATH variable defines the path used to execute commands. The output of the anacron jobs are emailed to the username defined with the MAILTO variable. If the MAILTO variable is not defined, (i.e. is empty, MAILTO=), email is not sent.

The next two lines are variables that modify the time for each scheduled job. The RANDOM_DELAY variable denotes the maximum number of minutes that will be added to the delay in minutes variable which is specified for each job. The minimum delay value is set, by default, to 6 minutes. A RANDOM_DELAY set to 12 would therefore add, randomly, between 6 and 12 minutes to the delay in minutes for each job in that particular anacrontab. RANDOM_DELAY can also be set to a value below 6, or even 0. When set to 0, no random delay is added. This proves to be useful when, for example, more computers that share one network connection need to download the same data every day. The START_HOURS_RANGE variable defines an interval (in hours) when scheduled jobs can be run. In case this time interval is missed, for example, due to a power down, then scheduled jobs are not executed that day.

The rest of the lines in the /etc/anacrontab file represent scheduled jobs and have the following format:

```
#period in days delay in minutes job-identifier command
1 5 cron.daily nice run-parts /etc/cron.daily
7 25 cron.weekly nice run-parts /etc/cron.weekly
@monthly 45 cron.monthly nice run-parts /etc/cron.monthly
```

Any lines that begin with a hash sign (#) are comments and are not processed.

20.1.2.1. Disabling Anacron
In case your system is continuously on and you do not require anacron to run your scheduled jobs, you may uninstall the cronie-anacron package. Thus, you will be able to define jobs using crontabs only.

20.1.3. Configuring Cron Jobs
The configuration file to configure cron jobs, /etc/crontab (only root is allowed to modify this file), contains the following lines:

```
SHELL=/bin/sh
PATH=/sbin:/bin:/usr/sbin:/usr/bin
MAILTO=root

# the maximal random delay added to the base delay of the jobs
RANDOM_DELAY=30
# the jobs will be started during the following hours only
START_HOURS_RANGE=16-20

#period in days delay in minutes job-identifier command
1 20 dailyjob nice run-parts /etc/cron.daily
7 25 weeklyjob /etc/weeklyjob.bash
@monthly 45 monthlyjob ls /proc >> /tmp/proc
```

All jobs defined in this anacrontab file are randomly delayed by 6-30 minutes and can be executed between 16:00 and 20:00. Thus, the first defined job will run anywhere between 16:26 and 16:50 every day. The command specified for this job will execute all present programs in the /etc/cron.daily directory (using the run-parts script which takes a directory as a command-line argument and sequentially executes every program within that directory). The second specified job will be executed once a week and will execute the weeklyjob.bash script in the /etc directory. The third job is executed once a month and runs a command to write the contents of the /proc directory to the /tmp/proc file (e.g. ls /proc >> /tmp/proc).

20.1.2.1.1. Disabling Anacron
In case your system is continuously on and you do not require anacron to run your scheduled jobs, you may uninstall the cronie-anacron package. Thus, you will be able to define jobs using crontabs only.

20.1.3. Configuring Cron Jobs
The configuration file to configure cron jobs, /etc/crontab (only root is allowed to modify this file), contains the following lines:
SHELL=/bin/bash
PATH=/sbin:/bin:/usr/sbin:/usr/bin
MAILTO=root
HOME=/

# For details see man 4 crontabs
# Example of job definition:
# | | | | | |
# | | | | | |
# | | | | | |
# | | | | | |
# 0 0 1 1 * user command to be executed

The first three lines contain the same variables as an anacrontab file, SHELL, PATH, and MAILTO. For more information about these variables, refer to Section 20.1.2, “Configuring Anacron Jobs.” The fourth line contains the HOME variable. The HOME variable can be used to set the home directory to use when executing commands or scripts.

The rest of the lines in the /etc/crontab file represent scheduled jobs and have the following format:

```
minute   hour   day   month   day of week   user   command
```

- **minute** — any integer from 0 to 59
- **hour** — any integer from 0 to 23
- **day** — any integer from 1 to 31 (must be a valid day if a month is specified)
- **month** — any integer from 1 to 12 (or the short name of the month such as jan or feb)
- **day of week** — any integer from 0 to 7, where 0 or 7 represents Sunday (or the short name of the week such as sun or mon)
- **user** — specifies the user under which the jobs are run
- **command** — the command to execute (the command can either be a command such as `ls /proc >> /tmp/proc` or the command to execute a custom script)

For any of the above values, an asterisk (*) can be used to specify all valid values. For example, an asterisk for the month value means execute the command every month within the constraints of the other values.

A hyphen (-) between integers specifies a range of integers. For example, 1-4 means the integers 1, 2, 3, and 4.

A list of values separated by commas (,) specifies a list. For example, 3, 4, 6, 8 indicates those four specific integers.

The forward slash (/) can be used to specify step values. The value of an integer can be skipped within a range by following the range with `/integer`. For example, 0-59/2 can be used to define every other minute in the minute field.

Step values can also be used with an asterisk. For instance, the value */3` can be used in the month field to run the task every third month.

Any lines that begin with a hash sign (#) are comments and are not processed.

Users other than root can configure cron tasks by using the crontab utility. All user-defined crontabs are stored in the /var/spool/cron/ directory and are executed using the usernames of the users that created them. To create a crontab as a user, login as that user and type the command `crontab -e` to edit the user's crontab using the editor specified by the VISUAL or EDITOR environment variable. The file uses the same format as /etc/crontab. When the changes to the crontab are saved, the crontab is stored according to username and written to the file /var/spool/cron/username. To list the contents of your own personal crontab file, use the `crontab -l` command.

**Do not specify a user**

When using the crontab utility, there is no need to specify a user when defining a job.

**Do not restart the daemon to apply the changes**

The cron daemon checks the /etc/anacrontab file, the /etc/crontab file, the /etc/cron.d/ directory, and the /var/spool/cron/ directory every minute for any changes. If any changes are found, they are loaded into memory. Thus, the daemon does not need to be restarted if an anacrontab or a crontab file is changed.

### 20.1.4. Controlling Access to Cron

The /etc/cron.d/ directory contains files that have the same syntax as the /etc/crontab file. Only root is allowed to create and modify files in this directory.

The cron daemon checks the /etc/anacrontab file, the /etc/crontab file, the /etc/cron.d/ directory, and the /var/spool/cron/ directory every minute for any changes. If any changes are found, they are loaded into memory. Thus, the daemon does not need to be restarted if an anacrontab or a crontab file is changed.
If the set of commands or script tries to display information to standard out, the output is emailed to the user.

As the load average is below 0.8, the set of commands or script is executed.

The load average is used in the shell set in the user's environment, the user's login shell, or /bin/sh (whichever is found first). As soon as the load average is below 0.8, the set of commands or script is executed.

20.15. Black/White Listing of Cron Jobs

Black/White listing of jobs is used to omit parts of the defined jobs that do not need to be executed. When calling the run-parts script on a cron folder, such as /etc/cron.daily, we can define which of the programs in this folder will not be executed by run-parts.

To define a black list, create a jobs.deny file in the folder that run-parts will be executing from. For example, if we need to omit a particular program from /etc/cron.daily, then, a file /etc/cron.daily/jobs.deny has to be created. In this file, specify the names of the omitted programs from the same directory. These will not be executed when a command, such as run-parts /etc/cron.daily, is executed by a specific job.

To define a white list, create a jobs.allow file.

The principles of jobs.deny and jobs.allow are the same as those of cron.deny and cron.allow described in section Section 20.1.4, "Controlling Access to Cron".

20.2. At and Batch

While cron is used to schedule recurring tasks, the at command is used to schedule a one-time task at a specific time and the batch command is used to schedule a one-time task to be executed when the system's load average drops below 0.8.

To use at or batch, the at RPM package must be installed, and the atd service must be running. To determine if the package is installed, use the rpm -q at command. To determine if the service is running, use the following command:

```
systemctl is-active atd.service
```

20.2.1. Configuring At Jobs

To schedule a one-time job at a specific time, type the command at time, where time is the time to execute the command.

The argument time can be one of the following:

- HH:MM format — For example, 04:00 specifies 4:00 a.m. If the time is already past, it is executed at the specified time the next day.
- midnight — Specifies 12:00 a.m.
- noon — Specifies 12:00 p.m.
- teatime — Specifies 4:00 p.m.
- month-name day year format — For example, January 15 2002 specifies the 15th day of January in the year 2002.
- MM/DD/YY, MM/DD/YY, or MM.DD.YY formats — For example, 011502 for the 15th day of January in the year 2002.
- now + time — time is in minutes, hours, days, or weeks. For example, now + 5 days specifies that the command should be executed at the same time five days from now.

The time must be specified first, followed by the optional date. For more information about the time format, read the /usr/share/doc/at-timespec file.

After typing the at command with the time argument, the at> prompt is displayed. Type the command to execute, press Enter, and press Ctrl+D. Multiple commands can be specified by typing each command followed by the Enter key.

After typing all the commands, press Enter to go to a blank line and press Ctrl+D. Alternatively, a shell script can be entered at the prompt, pressing Enter after each line in the script, and pressing Ctrl+D on a blank line to exit. If a script is entered, the shell used is the shell set in the user's SHELL environment, the user's login shell, or /bin/sh (whichever is found first).

If the set of commands or script tries to display information to standard output, the output is emailed to the user.

Use the command atq to view pending jobs. Refer to Section 20.2.3, "Viewing Pending Jobs" for more information.

Usage of the at command can be restricted. For more information, refer to Section 20.2.5, "Controlling Access to At and Batch" for details.

20.2.2. Configuring Batch Jobs

To execute a one-time task when the load average is below 0.8, use the batch command.

After typing the batch command, the at> prompt is displayed. Type the command to execute, press Enter, and press Ctrl+D. Multiple commands can be specified by typing each command followed by the Enter key. After typing all the commands, press Enter to go to a blank line and press Ctrl+D. Alternatively, a shell script can be entered at the prompt, pressing Enter after each line in the script, and pressing Ctrl+D on a blank line to exit. If a script is entered, the shell used is the shell set in the user's SHELL environment, the user's login shell, or /bin/sh (whichever is found first). As soon as the load average is below 0.8, the set of commands or script is executed.

If the set of commands or script tries to display information to standard out, the output is emailed to the user.
20.2.3. Viewing Pending Jobs

To view pending at and batch jobs, use the `atq` command. The `atq` command displays a list of pending jobs, with each job on a line. Each line follows the job number, date, hour, job class, and username format. Users can only view their own jobs. If the root user executes the `atq` command, all jobs for all users are displayed.

Table 20.1. Additional Command Line Options

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>-f</td>
<td>Read the commands or shell script from a file instead of specifying them at the prompt.</td>
</tr>
<tr>
<td>-m</td>
<td>Send email to the user when the job has been completed.</td>
</tr>
<tr>
<td>-v</td>
<td>Display the time that the job is executed.</td>
</tr>
</tbody>
</table>

20.2.5. Controlling Access to At and Batch

The `/etc/at.allow` and `/etc/at.deny` files can be used to restrict access to the at and batch commands. The format of both access control files is one username on each line. Whitespace is not permitted in either file. The at daemon (atd) does not have to be restarted if the access control files are modified. The access control files are read each time a user tries to execute the at or batch commands.

The root user can always execute at and batch commands, regardless of the access control files.

If the file at.allow exists, only users listed in it are allowed to use at or batch, and the at.deny file is ignored.

If at.allow does not exist, users listed in at.deny are not allowed to use at or batch.

20.2.6. Starting and Stopping the Service

To start the at service, use the following command as root:

```
systemctl start atd.service
```

To stop the service, as root, type the following at a shell prompt:

```
systemctl stop atd.service
```

It is recommended that you start the service at boot time. To do so, run the following command as root:

```
systemctl enable atd.service
```

Refer to Chapter 9, Services and Daemons for more information on how to configure services in Fedora.

20.3. Additional Resources

To learn more about configuring automated tasks, refer to the following resources.

20.3.1. Installed Documentation

- cron man page — contains an overview of cron.
- crontab man pages in sections 1 and 5 — The man page in section 1 contains an overview of the crontab file. The man page in section 5 contains the format for the file and some example entries.
- anacron man page — contains an overview of anacron.
- anacrontab man page — contains an overview of the anacrontab file.
- `/usr/share/doc/at-version/timespec` contains more detailed information about the times that can be specified for cron jobs.
- at man page — description of at and batch and their command line options.

Chapter 21. Automatic Bug Reporting Tool (ABRT)

21.1. Overview

21.2. Installing ABRT and Starting its Services

21.3. Running ABRT

21.3.1. Using the Graphical User Interface

21.3.2. Using the Command Line Interface
21.1. Overview

Migration to ABRT version 2.0

For Red Hat Enterprise Linux 6.2, the Automatic Bug Reporting Tool has been upgraded to version 2.0. The ABRT 2-series brings major improvements to automatic bug detection and reporting.

ABRT is the Automatic Bug Reporting Tool. ABRT consists of a daemon, abrtd, which runs silently in the background most of the time. It springs into action when an application crashes, or a kernel oops is detected. The daemon then collects the relevant problem data such as a core file if there is one, the crashing application's command line parameters, and other data of forensic utility.

ABRT currently supports detection of crashes in applications written in the C/C++ and Python languages, as well as kernel oopses.

ABRT is capable of reporting problems to a remote issue tracker. Reporting can be configured to happen automatically whenever an issue is detected, or problem data can be stored locally, reviewed, reported, and deleted manually by a user. The reporting tools can send problem data to a Bugzilla database, a Red Hat Technical Support (RHTSupport) site, upload it using FTP/SCP, email it, or write it to a file.

The part of ABRT which handles already-existing problem data (as opposed to, for example, creation of new problem data) has been factored out into a separate project, libreport. The libreport library provides a generic mechanism for analyzing and reporting problems, and it is used by applications other than ABRT. However, ABRT and libreport operation and configuration is closely integrated. They are therefore discussed as one in this document.

The ABRT packages provide the following crucial components, among others:

- abrtd — The ABRT daemon which runs under root as a background service.
- abrt-applet — The program that receives messages from abrtd and informs you whenever a new problem occurs.
- abrt-gui — The GUI application that shows collected problem data and allows you to further process it.
- abrt-cli — The command line interface, which provides similar functionality to the GUI.
- abrt-ccpp — The ABRT service that provides the C/C++ problems analyzer
- abrt-oops — The ABRT service that provides the kernel oopses analyzer.

21.2. Installing ABRT and Starting its Services

As the first step in order to use ABRT, you should ensure that the abrtdesktop package is installed on your system by running the following command as the root user:

```
~]# yum install abrtdesktop
```

With abrtdesktop installed, you will be able to use ABRT only in its graphical interface. If you intend to use ABRT on the command line, install the abrt-cli package:

```
~]# yum install abrt-cli
```

For more information on how to install packages with the Yum package manager, refer to Section 5.2.4, "Installing Packages".

Your next step should be to verify that abrtd is running. The daemon is typically configured to start up at boot time. You can use the following command as root to verify its current status:

```
~]# service abrtd status
abrtd (pid 1535) is running...
```

If the service command returns the abrtd is stopped message, the daemon is not running. It can be started for the current session by entering this command:

```
~]# service abrtd start
Starting abrtd daemon:  [ OK ]
```

You can run the following chkconfig command to ensure that the abrtd service initializes every time the system starts up:

```
~]# chkconfig abrtd on
```
Similarly, you can follow the same steps to check and configure the `abrt-ccpp` service if you want ABRT to catch C/C++ crashes. To set ABRT to detect kernel oopses, use the same steps for the `abrt-oops` service. Note that this service cannot catch kernel oopses which cause the system to fail to become unresponsive or to reboot immediately.

Finally, you can verify that the ABRT notification applet is running:

```
~]$ ps -el | grep abrt-applet
 0 S   500  2036  1824  0  80   0 - 61604 poll_s ?       00:00:00 abrt-applet
```

If the ABRT notification applet is not running, you can start it manually in your current desktop session by running the `abrt-applet` program:

```
~]$ abrt-applet &
[1] 2261
```

The applet can be configured to start automatically when your graphical desktop session starts. For example, on the GNOME desktop this can be achieved by accessing the System → Preferences → Startup Applications menu and ensuring that the ABRT notification applet is added to the list of programs and selected to run on at system startup.

21.3. Running ABRT

Whenever a problem is detected, ABRT compares it with all existing problem data and determines whether that same
problem has been recorded. If it has been, the existing problem data is updated and the most recent (duplicate) problem is not recorded again. If this problem is not recognized by ABRT, a problem data directory is created. A problem data directory typically consists of files such as:

- analyzer
- architecture
- coredump
- cmdline
- executable
- kernel
- os_release
- reason
- time
- uid

Other files, such as backtrace, can be created during analysis depending on which analyzer method is used and its configuration settings. Each of these files holds specific information about the system and the problem itself. For example, the kernel file records the version of the crashed kernel.

### 21.3.1. Using the Graphical User Interface

The ABRT daemon sends a broadcast D-Bus message whenever a problem report is created. If the ABRT notification applet is running, it catches this message and displays an orange alarm icon in the Notification Area. You can open the ABRT GUI application using this icon. As an alternative, you can display the ABRT GUI by selecting the Application → System Tools → Automatic Bug Reporting Tool menu item.

![Figure 21.3. Running the ABRT GUI from the Applications menu.](image)

Alternatively, you can run the ABRT GUI from the command line as follows:

```bash
$ abrt-gui &
```

The ABRT GUI provides an easy and intuitive way of viewing, reporting and deleting of reported problems. The ABRT window displays a list of detected problems. Each problem entry consists of the name of the failing application, the reason why the application crashed, and the date of the last occurrence of the problem.
If you double-click on a problem report line, you can access the detailed problem description and proceed with the process of determining how the problem should be analyzed, and where it should be reported.

You are first asked to provide additional information about the problem which occurred. You should provide detailed information on how the problem happened and what steps should be done in order to reproduce it. In the next steps, choose how the problem will be analyzed and generate a backtrace depending on your configuration. You can skip the analysis and backtrace-generation steps but remember that developers need as much information about the problem as possible. You can always modify the backtrace and remove any sensitive information you do not want to provide before you send the problem data out.
Next, choose how you want to report the issue. If you are using Red Hat Enterprise Linux, Red Hat Customer Support is the preferred choice.
If you choose to report to Red Hat Customer Support, and you have not configured this event yet, you will be warned that this event is not configured properly and you will be offered an option to do so.

Here, you need to provide your Red Hat login information (Refer to Section 21.4.3, "Event Configuration in ABRT GUI" for more information on how to acquire it and how to set this event), otherwise you will fail to report the problem.

After you have chosen a reporting method and have it set up correctly, review the backtrace and confirm the data to be reported.
Finally, the problem data is sent to the chosen destination, and you can now decide whether to continue with reporting the problem using another available method or finish your work on this problem. If you have reported your problem to the Red Hat Customer Support database, a problem case is filed in the database. From now on, you will be informed about the problem resolution progress via email you provided during the process of reporting. You can also oversee the problem case using the URL that is provided to you by ABRT GUI when the problem case is created, or via emails received from Red Hat Support.
21.3.2. Using the Command Line Interface

Problem data saved by `abrt` can be viewed, reported, and deleted using the command line interface.

General usage of the `abrt-cli` tool can be described using the following syntax:

```
abrt-cli [--version] <command> [args]
```

...where `<args>` stands for a problem data directory and/or options modifying the commands, and `<command>` is one of the following sub-commands:

- `list` — lists problems and views the problem data.
- `report` — analyzes and reports problems.
- `rm` — removes unneeded problems.
- `info` — provides information about a particular problem.

To display help on particular `abrt-cli` command use:

```
abrt-cli <command> --help
```

The rest of the commands used with `abrt-cli` are described in the following sections.

21.3.2.1. Viewing Problems

To view detected problems, enter the `abrt-cli list` command:

```
-]# abrt-cli list
  count: 2
  executable: /usr/bin/gdb
  package: gdb-7.2-48.e16
  time: Tue 13 Sep 2011 10:18:14 AM CEST
  uid: 500

  count: 1
  executable: /bin/bash
  package: bash-4.1.2-8.e16
  time: Wed 21 Sep 2011 06:18:07 PM CEST
  uid: 500
```

- `Directory` — Shows the problem data directory that contains all information about the problem.
- `count` — Shows how many times this particular problem occurred.
- `executable` — Indicates which binary or executable script crashed.
- `package` — Shows the name of the package that contains the program that caused the problem.
- `time` — Shows the date and time of the last occurrence of the problem.
- `uid` — Shows the ID of the user which ran the program that crashed.

The following table shows options available with the `abrt-cli list` command. All options are mutually inclusive so you can combine them according to your need. The command output will be the most comprehensive if you combine all options, and you will receive the least details if you use no additional options.
Table 21.1. The `abrt-cli list` command options

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>With no additional option, the <code>abrt-cli list</code> command displays only basic information for problems that have not been reported yet.</td>
</tr>
<tr>
<td><code>-d</code>, <code>--detailed</code></td>
<td>Displays all stored information about problems listed, including a backtrace if it has already been generated.</td>
</tr>
<tr>
<td><code>-f</code>, <code>--full</code></td>
<td>Displays basic information for all problems including the already-reported ones.</td>
</tr>
<tr>
<td><code>-v</code>, <code>--verbose</code></td>
<td>Provides additional information on its actions.</td>
</tr>
</tbody>
</table>

If you want to view information just about one particular problem, you can use the command:

```
abrt-cli info <DIR>
```

...where `<DIR>` stands for the problem data directory of the problem that is being viewed. The following table shows options available with the `abrt-cli info` command. All options are mutually exclusive so you can combine them according to your need. The command output will be the most comprehensive if you combine all options, and you will receive the least details if you use no additional options.

Table 21.2. The `abrt-cli info` command options

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>With no additional option, the <code>abrt-cli info</code> command displays only basic information for the problem specified by the problem data directory argument.</td>
</tr>
<tr>
<td><code>-d</code>, <code>--detailed</code></td>
<td>Displays all stored information for the problem specified by the problem data directory argument, including a backtrace if it has already been generated.</td>
</tr>
<tr>
<td><code>-v</code>, <code>--verbose</code></td>
<td><code>abrt-cli info</code> provides additional information on its actions.</td>
</tr>
</tbody>
</table>

21.3.2.2. Reporting Problems

To report a certain problem, use the command:

```
abrt-cli report <DIR>
```

...where `<DIR>` stands for the problem data directory of the problem that is being reported. For example:

```
```

ABRT prompts you to select an analyzer event for the problem that is being reported. After selecting an event, the problem is analyzed. This can take a considerable amount of time. When the problem report is ready, `abrt-cli` opens a text editor with the content of the report. You can see what is being reported, and you can fill in instructions on how to reproduce the crash and other comments. You should also check the backtrace, because the backtrace might be sent to a public server and viewed by anyone, depending on the problem reporter event settings.

Selecting a preferred text editor

You can choose which text editor is used to check the reports. `abrt-cli` uses the editor defined in the `ABRT_EDITOR` environment variable. If the variable is not defined, it checks the `VISUAL` and `EDITOR` variables. If none of these variables is set, `vi` is used. You can set the preferred editor in your `.bashrc` configuration file. For example, if you prefer GNU Emacs, add the following line to the file:

```
export VISUAL=emacs
```

When you are done with the report, save your changes and close the editor. You will be asked which of the configured ABRT reporter events you want to use to send the report.

```
How would you like to report the problem?
1) Logger
2) Red Hat Customer Support
Select reporter(s): _
```

After selecting a reporting method, you can proceed with reviewing data to be sent with the report. The following table shows options available with the `abrt-cli report` command.

Table 21.3. The `abrt-cli report` command options

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>-v</code>, <code>--verbose</code></td>
<td>With no additional option, the <code>abrt-cli report</code> command provides the usual output.</td>
</tr>
<tr>
<td><code>-v</code>, <code>--verbose</code></td>
<td><code>abrt-cli report</code> provides additional information on its actions.</td>
</tr>
</tbody>
</table>

21.3.2.3. Deleting Problems

If you are certain that you do not want to report a particular problem, you can delete it. To delete a problem so ABRT does not keep information about it, use the command:
Deletion of a problem can lead to frequent ABRT notification

Note that ABRT performs a detection of duplicate problems by comparing new problems with all locally saved problems. For a repeating crash, ABRT requires you to act upon it only once. However, if you delete the crash dump of that problem, the next time this specific problem occurs, ABRT will treat it as a new crash: ABRT will alert you about it, prompt you to fill in a description, and report it. To avoid having ABRT notifying you about a recurring problem, do not delete its problem data.

The following table shows options available with the `abrt-cli rm` command.

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>-v, --verbose</code></td>
<td><code>abrt-cli rm</code> provides additional information on its actions.</td>
</tr>
</tbody>
</table>

21.4. Configuring ABRT

A problem life cycle is driven by events in ABRT. For example:

- Event 1 — a problem data directory is created.
- Event 2 — problem data is analyzed.
- Event 3 — a problem is reported to Bugzilla.

When a problem is detected and its defining data is stored, the problem is processed by running events on the problem's data directory. For more information on events and how to define one, refer to Section 21.4.1, "ABRT Events". Standard ABRT installation currently supports several default events that can be selected and used during problem reporting process. Refer to Section 21.4.2, "Standard ABRT Installation Supported Events" to see the list of these events.

Upon installation, ABRT and libreport place their respective configuration files into the several directories on a system:

- `/etc/libreport/` — contains the `report_event.conf` main configuration file. More information about this configuration file can be found in Section 21.4.1, "ABRT Events".
- `/etc/libreport/events/` — holds files specifying the default setting of predefined events.
- `/etc/libreport/events.d/` — keeps configuration files defining events.
- `/etc/libreport/plugins/` — contains configuration files of programs that take part in events.
- `/etc/abrt/` — holds ABRT specific configuration files used to modify the behavior of ABRT's services and programs.
- `/etc/abrt/plugins/` — keeps configuration files used to override the default setting of ABRT's services and programs. For more information on some specific configuration files refer to Section 21.4.4, "ABRT Specific Configuration".

21.4.1. ABRT Events

Each event is defined by one rule structure in a respective configuration file. The configuration files are typically stored in the `/etc/libreport/events.d/` directory. These configuration files are used by the main configuration file, `/etc/libreport/report_event.conf`.

The `/etc/libreport/report_event.conf` file consists of `include` directives and rules. Rules are typically stored in other configuration files in the `/etc/libreport/events.d/` directory. In the standard installation, the `/etc/libreport/report_event.conf` file contains only one include directive:

```
include events.d/*.conf
```

If you would like to modify this file, please note that it respects shell metacharacters (`*`, `$`, etc.) and interprets relative paths relatively to its location.

Each rule starts with a line with a non-space leading character, all subsequent lines starting with the `space` character or the `tab` character are considered a part of this rule. Each rule consists of two parts, a `condition` part and a `program` part.

The condition part contains conditions in one of the following forms:

- `VAR=VAL`
- `VAR!=VAL` or `VAL~REGEX`

where:

- `VAR` is either the `EVENT` key word or a name of a problem data directory element (such as `executable`, `package`, `hostname`, etc.).
- `VAL` is either a name of an event or a problem data element, and
- `REGEX` is a regular expression.
The program part consists of program names and shell interpretable code. If all conditions in the condition part are valid, the program part is run in the shell. The following is an event example:

```bash
EVENT=post-create
date > /tmp/dt
echo $HOSTNAME 'uname -r'
```

This event would overwrite the contents of the `/tmp/dt` file with the current date and time, and print the hostname of the machine and its kernel version on the standard output.

Here is an example of a yet more complex event which is actually one of the predefined events. It saves relevant lines from the `~/.xsession-errors` file to the problem report for any problem for which the `abrt-ccpp` service has been used to process that problem, and the crashed application has loaded any X11 libraries at the time of crash:

```bash
EVENT=analyze_xsession_errors
 analyzer=CCpp
dso_list=./libX11.*
 test -f ~/.xsession-errors || { echo "No ~/.xsession-errors"; exit 1; }
 test -r ~/.xsession-errors || { echo "Can't read ~/.xsession-errors"; exit 1; }
 executable='cat executable' &&
 base_executable=${executables%/}
 grep -F -e "@base_executable" ~/.xsession-errors
 tail -999 xsession_errors &&
 echo "Element 'xsession_errors' saved"
```

The set of possible events is not hard-set. System administrators can add events according to their need. Currently, the following event names are provided with standard ABRT and libreport installation:

- **post-create**
  - This event is run by `abrtd` on newly created problem data directories. When the `post-create` event is run, `abrtd` checks whether the UUID identifier of the new problem data matches the UUID of any already existing problem directories. If such a problem directory exists, the new problem data is deleted.

- **analyze_<NAME_SUFFIX>**
  - Where `<NAME_SUFFIX>` is the adjustable part of the event name. This event is used to process collected data. For example, the `analyze_LocalGDB` runs the GNU Debugger (GDB) utility on a core dump of an application and produces a backtrace of a program. You can view the list of analyze events and choose from it using `abrt-gui`.

- **collect_<NAME_SUFFIX>**
  - Where `<NAME_SUFFIX>` is the adjustable part of the event name. This event is used to collect additional information on a problem. You can view the list of collect events and choose from it using `abrt-gui`.

- **report_<NAME_SUFFIX>**
  - Where `<NAME_SUFFIX>` is the adjustable part of the event name. This event is used to report a problem. You can view the list of report events and choose from it using `abrt-gui`.

Additional information about events (such as their description, names and types of parameters which can be passed to them as environment variables, and other properties) is stored in the `/etc/libreport/events/<event_name>.xml` files. These files are used by `abrt-gui` and `abrt-cli` to make the user interface more friendly. Do not edit these files unless you want to modify the standard installation.

### 21.4.2. Standard ABRT Installation Supported Events

Standard ABRT installation currently provides a number of default analyzing, collecting and reporting events. Some of these events are also configurable using the ABRT GUI application (for more information on event configuration using ABRT GUI refer to Section 21.4.3, "Event Configuration in ABRT GUI"). ABRT GUI only shows the event's unique part of the name which is more readable the user, instead of the complete event name. For example, the `analyze_xsession_errors` event is shown as `Collect .xsession-errors` in ABRT GUI. The following is a list of default analyzing, collecting and reporting events provided by the standard installation of ABRT:

- **analyze_LocalGDB**
  - Local GNU Debugger
  - Runs GDB (the GNU debugger) on problem data of an application and generates a backtrace of a program. It is defined in the `/etc/libreport/events.d/ccpp_event.conf` configuration file.

- **analyze_xsession_errors**
  - Collect .xsession-errors
  - Saves relevant lines from the `~/.xsession-errors` file to the problem report. It is defined in the `/etc/libreport/events.d/ccpp_event.conf` configuration file.

- **report_Logger**
  - Logger
  - Creates a problem report and saves it to a specified local file. It is defined in the `/etc/libreport/events.d/print_event.conf` configuration file.

- **report_RHTSupport**
  - Red Hat Customer Support
  - Reports problems to the Red Hat Technical Support system. This possibility is intended for users of Red Hat Enterprise Linux. It is defined in the `/etc/libreport/events.d/rhtsupport_event.conf` configuration file.

- **report_Mailx**
  - Mailx
  - Sends a problem report via the Mailx utility to a specified email address. It is defined in the `/etc/libreport/events.d/mailx_event.conf` configuration file.
21.4.3. Event Configuration in ABRT GUI

Events can use parameters passed to them as environment variables (for example, the report_Logger event accepts an output file name as a parameter). Using the respective /etc/libreport/events/<event_name>.xml file, ABRT GUI determines which parameters can be specified for a selected event and allows a user to set the values for these parameters. These values are saved by ABRT GUI and reused on subsequent invocations of these events.

Open the Event Configuration window by clicking Edit → Preferences. This window shows a list of all available events that can be selected during the reporting process. When you select one of the configurable events, you can click the Configure Event button and you will be able to configure settings for that event. If you change any of the events' parameters, they are saved in the Gnome keyring and will be used in the future GUI sessions.

Do not store sensitive data in global configuration files

All files in the /etc/libreport/ directory hierarchy are world readable and are meant to be used as global settings. Thus, it is not advisable to store usernames, passwords or any other sensitive data in them. The per-user settings (set in the GUI application and readable by the owner of $HOME only) are stored in the Gnome keyring or can be stored in a text file in $HOME/.abrt/*.conf for use in abrt-cli.

<table>
<thead>
<tr>
<th>Event</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logger</td>
<td>In the Logger event configuration window, you can configure the following parameter:</td>
</tr>
<tr>
<td></td>
<td>&gt;&gt; Log file — Specifies a file into which the crash reports are saved (by default, set to /var/log/abrt.log).</td>
</tr>
<tr>
<td></td>
<td>When the Append option is checked, the Logger event will append new crash reports to the log file specified in the Log file option. When unchecked, the new crash report always replaces the previous one.</td>
</tr>
<tr>
<td>Collect .xsession-errors</td>
<td>Save relevant lines from ~/.xsession-errors file.</td>
</tr>
<tr>
<td>Local GNU Debugger</td>
<td>Download debuginfo packages and generate backtrace locally using GDB.</td>
</tr>
<tr>
<td>Mailx</td>
<td>Send via email.</td>
</tr>
<tr>
<td>Kerneloops.org</td>
<td>Send kernel problems to oops tracker.</td>
</tr>
<tr>
<td>Report uploader</td>
<td>Upload compressed report to url of choice.</td>
</tr>
</tbody>
</table>

Figure 21.14. The Event Configuration Window.

The following is a list of all configuration options available for each predefined event that is configurable in the ABRT GUI application.

Logger

In the Logger event configuration window, you can configure the following parameter:

>> Log file — Specifies a file into which the crash reports are saved (by default, set to /var/log/abrt.log).

When the Append option is checked, the Logger event will append new crash reports to the log file specified in the Log file option. When unchecked, the new crash report always replaces the previous one.

Red Hat Customer Support

In the Red Hat Customer Support event configuration window, you can configure the following parameters:

>> RH Portal URL — Specifies the Red Hat Customer Support URL where crash dumps are sent (by default, set to https://api.access.redhat.com/rs).
>> Username — User login which is used to log into Red Hat Customer Support and create a Red Hat Customer Support database entry for a reported crash. Use your Red Hat Login acquired by creating an account on http://www.redhat.com/, the Red Hat Customer Portal (https://access.redhat.com/home) or the Red Hat Network (https://rhn.redhat.com/).
>> Password — Password used to log into Red Hat Customer Support (that is, password associated with your Red Hat Login).
When the SSL verify option is checked, the SSL protocol is used when sending the data over the network.

MailX
In the MailX event configuration window, you can configure the following parameters:

- **Subject** — A string that appears in the Subject field of a problem report email sent by Mailx (by default, set to "[abrt] detected a crash").
- **Sender** — A string that appears in the From field of a problem report email.
- **Recipient** — Email address of the recipient of a problem report email.

When the Send Binary Data option is checked, the problem report email will also contain all binary files associated with the problem in an attachment. The core dump file is also sent as an attachment.

Kerneloops.org
In the Kerneloops.org event configuration window, you can configure the following parameter:

- **Kerneloops URL** — Specifies the URL where Kernel problems are reported to (by default, set to http://submit.kerneloops.org/submitoops.php)

Report Uploader
In the Report Uploader event configuration window, you can configure the following parameter:

- **URL** — Specifies the URL where a tarball containing compressed problem data is uploaded using the FTP or SCP protocol (by default, set to ftp://localhost:/tmp/upload).

21.4.4. ABRT Specific Configuration
Standard ABRT installation currently provides the following ABRT specific configuration files:

- `/etc/abrt/abrt.conf` — allows you to modify the behavior of the abrtd service.
- `/etc/abrt/abrt-action-save-package-data.conf` — allows you to modify the behavior of the abrtaction-save-package-data program.
- `/etc/abrt/plugins/CCpp.conf` — allows you to modify the behavior of ABRT's core catching hook.

The following configuration directives are supported in the `/etc/abrt/abrt.conf` file:

- **WatchCrashdumpArchiveDir** = `/var/spool/abrt-upload`
  This directive is commented out by default. Enable it if you want abrtd to auto-unpack crashdump tarball archives (.tar.gz) which are located in the specified directory. In the example above, it is the `/var/spool/abrt-upload/` directory. Whichever directory you specify in this directive, you must ensure that it exists and it is writable for abrtd. The ABRT daemon will not create it automatically.

  **Do not modify this option in SELinux**

  If you are using SELinux, do not modify the default setting of this option unless you reflect the change in SELinux rules. Changing the location for crashdump archives without previous modification of respective rules will cause SELinux denials. See the abrt_selinux(8) manual page for more information on running ABRT in SELinux. Remember that if you enable this option when using SELinux, you need to execute the following command in order to set the appropriate boolean allowing ABRT to write into the public_content_rw_t domain:

  ```
  setsebool -P abrt_anon_write 1
  ```

- **MaxCrashReportsSize** = `<size_in_megabytes>`
  This option sets the amount of storage space, in megabytes, used by ABRT to store all problem information from all users. The default setting is 1000 MB. Once the quota specified here has been met, ABRT will continue catching problems, and in order to make room for the new crash dumps, it will delete the oldest and largest ones.

- **DumpLocation** = `/var/spool/abrt`
  This directive is commented out by default. It specifies the location where problem data directories are created and in which problem core dumps and all other problem data are stored. The default location is set to the `/var/spool/abrt` directory. Whichever directory you specify in this directive, you must ensure that it exists and it is writable for abrtd.
Do not modify this option in SELinux

Do not modify the default setting of this option if you are using SELinux. Changing the dump location will cause SELinux denials unless you reflect the change in respective SELinux rules first. See the `abrt_selinux(8)` manual page for more information on running ABRT in SELinux.

Remember that if you enable this option when using SELinux, you need to execute the following command in order to set the appropriate boolean allowing ABRT to write into the public_content_rw_t domain:

```
setsebool -P abrt_anon_write 1
```

The following configuration directives are supported in the `/etc/abrt/abrt-action-save-package-data.conf` file:

**OpenGPGCheck** = **yes/no**

Setting the `OpenGPGCheck` directive to yes (the default setting) tells ABRT to only analyze and handle crashes in applications provided by packages which are signed by the GPG keys whose locations are listed in the `/etc/abrt/gpg_keys` file. Setting `OpenGPGCheck` to no tells ABRT to catch crashes in all programs.

**BlackList** = nspluginwrapper, valgrind, strace, [MORE_PACKAGES]

Crashes in packages and binaries listed after the `BlackList` directive will not be handled by ABRT. If you want ABRT to ignore other packages and binaries, list them here separated by commas.

**ProcessUnpackaged** = **yes/no**

This directive tells ABRT whether to process crashes in executables that do not belong to any package. The default setting is no.

**BlackListedPaths** = /usr/share/doc/*, */example*

Crashes in executables in these paths will be ignored by ABRT.

The following configuration directives are supported in the `/etc/abrt/plugins/CCpp.conf` file:

**MakeCompatCore** = **yes/no**

This directive specifies whether ABRT's core catching hook should create a core file, as it could be done if ABRT would not be installed. The core file is typically created in the current directory of the crashed program but only if the `ulimit -c` setting allows it. The directive is set to yes by default.

**SaveBinaryImage** = **yes/no**

This directive specifies whether ABRT's core catching hook should save a binary image to a core dump. It is useful when debugging crashes which occurred in binaries that were deleted. The default setting is no.

### 21.4.5. Configuring Automatic Reporting

ABRT can be configured to report any detected issues or crashes automatically without any user interaction. This can be achieved by specifying an analyze-and-report rule as a post-create rule. For example, you can instruct ABRT to report Python crashes to Bugzilla immediately without any user interaction by enabling the rule and replacing the `EVENT=report_Bugzilla` condition with the `EVENT=post-create` condition in the `/etc/libreport/events.d/python_event.conf` file:

```
EVENT=post-create analyzer=Python
test -f component || abrt-action-save-package-data
reporter-bugzilla -c /etc/abrt/plugins/Bugzilla.conf
```

**post-create runs with root privileges**

Please note that the `post-create` event is run by `abrtd`, which usually runs with root privileges.

### 21.4.6. Uploading and reporting using a proxy server

The `reporter-bugzilla` and the `reporter-upload` tools respect the `http_proxy` and the `ftp_proxy` environment variables. When you use environment variables as a part of a reporting event, they inherit their values from the process which performs reporting, usually `abrtd` or `abrt-cli`. Therefore, you can specify HTTP or FTP proxy servers by using these variables in your working environment.

If you arrange these tools to be a part of the `post-create` event, they will run as children of the `abrtd` process. You should either adjust the environment of `abrtd` or modify the rules to set these variables. For example:

```
EVENT=post-create analyzer=Python
test -f component || abrt-action-save-package-data
export http_proxy=http://proxy.server:8888/
reporter-bugzilla -c /etc/abrt/plugins/Bugzilla.conf
```
21.5. Configuring Centralized Crash Collection

You can set up ABRT so that crash reports are collected from multiple systems and sent to a dedicated system for further processing. This is useful when an administrator does not want to log into hundreds of systems and manually check for crashes found by ABRT. In order to use this method, you need to install the `libreport-plugin-reportuploader` plug-in (yum install libreport-plugin-reportuploader). See the following sections on how to configure systems to use ABRT's centralized crash collection.

21.5.1. Configuration Steps Required on a Dedicated System

Complete the following steps on a dedicated (server) system:

1. Create a directory to which you want the crash reports to be uploaded to. Usually, `/var/spool/abrt-upload/` is used (the rest of the document assumes you are using this directory). Make sure this directory is writable by the `abrt` user.

   ![The abrt user and group](image)

   When the `abrt-desktop` package is installed, it creates a new system user and a group, both named `abrt`. This user is used by the `abrd` daemon, for example, as the owner/group of `/var/spool/abrt/*` directories.

2. In the `/etc/abrt/abrt.conf` configuration file, set the `WatchCrashdumpArchiveDir` directive to the following:

   ```
   WatchCrashdumpArchiveDir = /var/spool/abrt-upload/
   ```

3. Choose your preferred upload mechanism; for example, FTP or SCP. For more information on how to configure FTP, refer to Section 17.2, “FTP”. For more information on how to configure SCP, refer to Section 11.3.2, “Using the scp Utility.”

   It is advisable to check whether your upload method works. For example, if you use FTP, upload a file using an interactive FTP client:

   ```
   -]$ ftp
   ftp> open SERVERNAME
   Name: USERNAME
   Password: PASSWORD
   ftp> cd /var/spool/abrt-upload
   250 Operation successful
   ftp> put TESTFILE
   ftp> quit
   ```

   Check whether `TESTFILE` appeared in the correct directory on the server system.

4. The `MaxCrashReportsSize` directive (in the `/etc/abrt/abrt.conf` configuration file) needs to be set to a larger value if the expected volume of crash data is larger than the default 1000 MB.

5. Consider whether you would like to generate a backtrace of C/C++ crashes.

   You can disable backtrace generation on the server if you do not wish to generate backtraces at all, or if you decide to create them locally on the machine where a problem occurred. In the standard ABRT installation, a backtrace of a C/C++ crash is generated using the following rule in the `/etc/libreport/events.d/ccpp_events.conf` configuration file:

   ```
   EVENT=analyze_LocalGDB analyzer=Cpp
   abrt-action-analyze-core.py --core=coredump -o build_ids &
   abrt-action-install-debuginfo-to-abrt-cache --size_mb=4896 &
   abrt-action-generate-backtrace &
   abrt-action-analyze-backtrace
   ```

   You can ensure that this rule is not applied for uploaded problem data by adding the `remote!=1` condition to the rule.

6. Decide whether you want to collect package information (the `package` and the `component` elements) in the problem data. Refer to Section 21.5.3, “Saving Package Information” to find out whether you need to collect package information in your centralized crash collection configuration and how to configure it properly.

21.5.2. Configuration Steps Required on a Client System

Complete the following steps on every client system which will use the central management method:

1. If you do not wish to generate a backtrace, or if you decided to generate it on a server system, you need to delete or comment out the corresponding rules in the `/etc/libreport/events.d/ccpp_events.conf` file. Refer to Section 21.5.1, “Configuration Steps Required on a Dedicated System” for an example of such a rule.

2. If you decided to not collect package information on client machines, delete, comment out or modify the rule which runs `abrt-action-save-package-data` in the `/etc/libreport/events.d/abrt_event.conf` file. Refer to Section 21.5.3, “Saving Package Information” to find out whether you need to collect package information in your centralized crash collection configuration and how to configure it properly.

3. Add a rule for uploading problem reports to the server system in the corresponding configuration file. For example, if you want to upload all problems automatically as soon as they are detected, you can use the following rule in the `/etc/libreport/events.d/abrt_event.conf` configuration file:

   ```
   EVENT=analyze_LocalGDB analyzer=Cpp
   abrt-action-analyze-core.py --core=coredump -o build_ids &
   abrt-action-install-debuginfo-to-abrt-cache --size_mb=4896 &
   abrt-action-generate-backtrace &
   abrt-action-analyze-backtrace
   ```

   Alternatively, you can use a similar rule that runs the reporter-upload program as the `report_SFX` event if you want to store problem data locally on clients and upload it later using ABRT GUI/CLI. The following is an example of such an event.

21.5.3. Saving Package Information
In a single-machine ABRT installation, problems are usually reported to external bug databases such as RHTSupport or Bugzilla. Reporting to these bug databases usually requires knowledge about the component and package in which the problem occurred. The post-create event runs the abrt-action-save-package-data tool (among other steps) in order to provide this information in the standard ABRT installation.

If you are setting up a centralized crash collection system, your requirements may be significantly different. Depending on your needs, you have two options:

**Internal analysis of problems**

After collecting problem data, you do not need to collect package information if you plan to analyze problems in-house, without reporting them to any external bug databases. You might be also interested in collecting crashes that occur in programs written by your organization. Such programs do not belong to any package in the first place. In this case take the following steps on both, client systems and a dedicated crash collecting system:

- Remove the following rule from the /etc/libreport/events.d/abrt_event.conf file:
  ```
  ProcessUnpackaged = yes
  ```

---

**Reporting to external bug database**

Alternatively, you may want to report crashes to RHTSupport or Bugzilla. In this case, you need to collect package information. Generally, client machines and dedicated crash collecting systems have non-identical sets of installed packages. Therefore, it may happen that problem data uploaded from a client does not correspond to any package installed on the dedicated crash collecting system. In the standard ABRT configuration, this will lead to deletion of problem data (ABRT will consider it to be a crash in an unpackaged executable). To prevent this from happening, it is necessary to modify ABRT's configuration on the dedicated system in the following way:

- Prevent inadvertent collection of package information for problem data uploaded from client machines, by adding the remote!=1 condition in the /etc/libreport/events.d/abrt_event.conf file:
  ```
  ProcessUnpackaged = yes
  ```

---

Note

Note that in this case, no such modifications are necessary on client systems: they continue to collect package information, and continue to ignore crashes in unpackaged executables.

---

**21.5.4. Testing ABRT's Crash Detection**

After completing all the steps of the configuration process, the basic setup is finished. To test that this setup works properly use the `kill -s SEGV PID` command to terminate a process on a client system. For example, start a `sleep` process and terminate it with the `kill` command in the following way:

```
$ sleep 100 &
[1] 2823
$ kill -s SEGV 2823
```

ABRT should detect a crash shortly after executing the `kill` command. Check that the crash was detected by ABRT on the client system (this can be checked by examining the appropriate syslog file, by running the `abrt-cli list --full` command, or by examining the crash dump created in the `/var/spool/abrt` directory, copied to the server system, unpacked on the server system and can be seen and acted upon using `abrt-cli` or `abrt-gui` on the server system.

---

**Chapter 22. OProfile**

22.1. Overview of Tools

22.2. Configuring OProfile

  22.2.1. Specifying the Kernel
  22.2.2. Setting Events to Monitor
  22.2.3. Separating Kernel and User-space Profiles

22.3. Starting and Stopping OProfile

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22.5. Analyzing the Data

  22.5.1. Using oreport
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  22.5.3. Getting more detailed output on the modules
  22.5.4. Using oannotate

22.6. Understanding /dev/oprofile/
OProfile is a low overhead, system-wide performance monitoring tool. It uses the performance monitoring hardware on the processor to retrieve information about the kernel and executables on the system, such as when memory is referenced, the number of L2 cache requests, and the number of hardware interrupts received. On a Fedora system, the `oprofile` package must be installed to use this tool.

Many processors include dedicated performance monitoring hardware. This hardware makes it possible to detect when certain events happen (such as the requested data not being in cache). The hardware normally takes the form of one or more counters that are incremented each time an event takes place. When the counter value, essentially rolls over, an interrupt is generated, making it possible to control the amount of detail (and therefore, overhead) produced by performance monitoring.

OProfile uses this hardware (or a timer-based substitute in cases where performance monitoring hardware is not present) to collect samples of performance-related data each time a counter generates an interrupt. These samples are periodically written out to disk; later, the data contained in these samples can then be used to generate reports on system-level and application-level performance.

OProfile is a useful tool, but be aware of some limitations when using it:

- **Use of shared libraries** — Samples for code in shared libraries are not attributed to the particular application unless the `--separate=library` option is used.
- **Performance monitoring samples are inexact** — When a performance monitoring register triggers a sample, the interrupt handling is not precise like a divide by zero exception. Due to the out-of-order execution of instructions by the processor, the sample may be recorded on a nearby instruction.
- **opreport does not associate samples for inline functions properly** — `opreport` uses a simple address range mechanism to determine which function an address is in. Inline function samples are not attributed to the inline function but rather to the function the inline function was inserted into.
- **OProfile accumulates data from multiple runs** — OProfile is a system-wide profiler and expects processes to start up and shut down multiple times. Thus, samples from multiple runs accumulate. Use the command `opcontrol --reset` to clear out the samples from previous runs.
- **Hardware performance counters do not work on guest virtual machines** — Because the hardware performance counters are not available on virtual systems, you need to use the `timer` mode. Run the command `opcontrol --deinit`, and then execute `modprobe oprofile timer=1` to enable the `timer` mode.
- **Non-CPU-limited performance problems** — OProfile is oriented to finding problems with CPU-limited processes. OProfile does not identify processes that are asleep because they are waiting on locks or for some other event to occur (for example an I/O device to finish an operation).

### 22.1. Overview of Tools

Table 22.1, "OProfile Commands" provides a brief overview of the tools provided with the `oprofile` package.

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ophelp</td>
<td>Displays available events for the system's processor along with a brief description of each.</td>
</tr>
<tr>
<td>opimport</td>
<td>Converts sample database files from a foreign binary format to the native format for the system. Only use this option when analyzing a sample database from a different architecture.</td>
</tr>
<tr>
<td>opannotate</td>
<td>Creates annotated source for an executable if the application was compiled with debugging symbols. Refer to Section 22.5.4, &quot;Using opannotate&quot; for details.</td>
</tr>
<tr>
<td>opcontrol</td>
<td>Configures what data is collected. Refer to Section 22.2, &quot;Configuring OProfile&quot; for details.</td>
</tr>
<tr>
<td>opreport</td>
<td>Retrieves profile data. Refer to Section 22.5.1, &quot;Using opreport&quot; for details.</td>
</tr>
<tr>
<td>oprofiled</td>
<td>Runs as a daemon to periodically write sample data to disk.</td>
</tr>
</tbody>
</table>

### 22.2. Configuring OProfile

Before OProfile can be run, it must be configured. At a minimum, selecting to monitor the kernel (or selecting not to monitor the kernel) is required. The following sections describe how to use the `opcontrol` utility to configure OProfile. As the `opcontrol` commands are executed, the setup options are saved to the `/root/.oprofile/daemonrc` file.

#### 22.2.1. Specifying the Kernel

First, configure whether OProfile should monitor the kernel. This is the only configuration option that is required before starting OProfile. All others are optional.
To monitor the kernel, execute the following command as root:

```bash
[-]# opcontrol --setup --vmlinux=/usr/lib/debug/lib/modules/`uname -r`/vmlinux
```

Install the debuginfo package

The `debuginfo` package for the kernel must be installed (which contains the uncompressed kernel) in order to monitor the kernel.

To configure OProfile not to monitor the kernel, execute the following command as root:

```bash
[-]# opcontrol --setup --no-vmlinux
```

This command also loads the `oprofile` kernel module, if it is not already loaded, and creates the `/dev/oprofile/` directory, if it does not already exist. Refer to Section 22.6, "Understanding `/dev/oprofile/" for details about this directory.

Setting whether samples should be collected within the kernel only changes what data is collected, not how or where the collected data is stored. To generate different sample files for the kernel and application libraries, refer to Section 22.2.3, "Separating Kernel and User-space Profiles".

### 22.2.2. Setting Events to Monitor

Most processors contain counters, which are used by OProfile to monitor specific events. As shown in Table 22.2, "OProfile Processors and Counters", the number of counters available depends on the processor.

<table>
<thead>
<tr>
<th>Processor</th>
<th>cpu_type</th>
<th>Number of Counters</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMD64</td>
<td>x86-64/hammer</td>
<td>4</td>
</tr>
<tr>
<td>AMD Athlon</td>
<td>i386/athlon</td>
<td>4</td>
</tr>
<tr>
<td>AMD Family 10h</td>
<td>x86-64/family10</td>
<td>4</td>
</tr>
<tr>
<td>AMD Family 11h</td>
<td>x86-64/family11</td>
<td>4</td>
</tr>
<tr>
<td>AMD Family 12h</td>
<td>x86-64/family12</td>
<td>4</td>
</tr>
<tr>
<td>AMD Family 14h</td>
<td>x86-64/family14</td>
<td>4</td>
</tr>
<tr>
<td>AMD Family 15h</td>
<td>x86-64/family15</td>
<td>6</td>
</tr>
<tr>
<td>IBM eServer System i and IBM eServer System p</td>
<td>timer</td>
<td>1</td>
</tr>
<tr>
<td>IBM POWER4</td>
<td>ppc64/power4</td>
<td>8</td>
</tr>
<tr>
<td>IBM POWER5</td>
<td>ppc64/power5</td>
<td>6</td>
</tr>
<tr>
<td>IBM PowerPC 970</td>
<td>ppc64/970</td>
<td>8</td>
</tr>
<tr>
<td>IBM S/390 and IBM System z</td>
<td>timer</td>
<td>1</td>
</tr>
<tr>
<td>Intel Core i7</td>
<td>i386/core_i7</td>
<td>4</td>
</tr>
<tr>
<td>Intel Nehalem microarchitecture</td>
<td>i386/nehalem</td>
<td>4</td>
</tr>
<tr>
<td>Intel Pentium 4 (non-hyper-threaded)</td>
<td>i386/p4</td>
<td>8</td>
</tr>
<tr>
<td>Intel Pentium 4 (hyper-threaded)</td>
<td>i386/p4-h</td>
<td>4</td>
</tr>
<tr>
<td>Intel Westmere microarchitecture</td>
<td>i386/westmere</td>
<td>4</td>
</tr>
<tr>
<td>TIMER_INT</td>
<td>timer</td>
<td>1</td>
</tr>
</tbody>
</table>

Use Table 22.2, "OProfile Processors and Counters" to verify that the correct processor type was detected and to determine the number of events that can be monitored simultaneously. `timer` is used as the processor type if the processor does not have supported performance monitoring hardware.

If `timer` is used, events cannot be set for any processor because the hardware does not have support for hardware performance counters. Instead, the timer interrupt is used for profiling.

If `timer` is not used as the processor type, the events monitored can be changed, and counter 0 for the processor is set to a time-based event by default. If more than one counter exists on the processor, the counters other than counter 0 are not set to an event by default. The default events monitored are shown in Table 22.3, "Default Events".
### Table 22.3. Default Events

<table>
<thead>
<tr>
<th>Processor</th>
<th>Default Event for Counter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMD Athlon and AMD64</td>
<td>CPU_CLK_UNHALTED</td>
<td>The processor's clock is not halted</td>
</tr>
<tr>
<td>AMD Family 10h, AMD Family 11h, AMD Family 12h</td>
<td>CPU_CLK_UNHALTED</td>
<td>The processor's clock is not halted</td>
</tr>
<tr>
<td>AMD Family 14h, AMD Family 15h</td>
<td>CPU_CLK_UNHALTED</td>
<td>The processor's clock is not halted</td>
</tr>
<tr>
<td>IBM POWER4</td>
<td>CYCLES</td>
<td>Processor Cycles</td>
</tr>
<tr>
<td>IBM POWER5</td>
<td>CYCLES</td>
<td>Processor Cycles</td>
</tr>
<tr>
<td>IBM PowerPC 970</td>
<td>CYCLES</td>
<td>Processor Cycles</td>
</tr>
<tr>
<td>Intel Core i7</td>
<td>CPU_CLK_UNHALTED</td>
<td>The processor's clock is not halted</td>
</tr>
<tr>
<td>Intel Nehalem microarchitecture</td>
<td>CPU_CLK_UNHALTED</td>
<td>The processor's clock is not halted</td>
</tr>
<tr>
<td>Intel Pentium 4 (hyper-threaded and non-hyper-threaded)</td>
<td>GLOBAL_POWER_EVENTS</td>
<td>The time during which the processor is not stopped</td>
</tr>
<tr>
<td>Intel Westmere microarchitecture</td>
<td>CPU_CLK_UNHALTED</td>
<td>The processor's clock is not halted</td>
</tr>
<tr>
<td>TIMER_INT</td>
<td>(none)</td>
<td>Sample for each timer interrupt</td>
</tr>
</tbody>
</table>

The number of events that can be monitored at one time is determined by the number of counters for the processor. However, it is not a one-to-one correlation; on some processors, certain events must be mapped to specific counters. To determine the number of counters available, execute the following command:

```
$ ls -d /dev/oprofile/[0-9]*
```

The events available vary depending on the processor type. To determine the events available for profiling, execute the following command as root (the list is specific to the system's processor type):

```
$ ophelp
```

The events for each counter can be configured via the command line or with a graphical interface. For more information on the graphical interface, refer to Section 22.9, "Graphical Interface". If the counter cannot be set to a specific event, an error message is displayed.

To set the event for each configurable counter via the command line, use `opcontrol`:

```
$ opcontrol --event=event-name:sample-rate
```

Replace `event-name` with the exact name of the event from `ophelp`, and replace `sample-rate` with the number of events between samples.

#### 22.2.2.1. Sampling Rate

By default, a time-based event set is selected. It creates a sample every 100,000 clock cycles per processor. If the timer interrupt is used, the timer is set to whatever the jiffy rate is and is not user-settable. If the `cpu_type` is not `timer`, each event can have a sampling rate set for it. The sampling rate is the number of events between each sample snapshot.

When setting the event for the counter, a sample rate can also be specified:

```
$ opcontrol --event=event-name:sample-rate:unit-mask
```

Replace `sample-rate` with the number of events to wait before sampling again. The smaller the count, the more frequent the samples. For events that do not happen frequently, a lower count may be needed to capture the event instances.

**Sampling too frequently can overload the system**

Be extremely careful when setting sampling rates. Sampling too frequently can overload the system, causing the system to appear as if it is frozen or causing the system to actually freeze.

#### 22.2.2.2. Unit Masks

Some user performance monitoring events may also require unit masks to further define the event.

Unit masks for each event are listed with the `ophelp` command. The values for each unit mask are listed in hexadecimal format. To specify more than one unit mask, the hexadecimal values must be combined using a bitwise operation.

```
$ opcontrol --event=event-name:sample-rate:unit-mask
```

#### 22.2.3. Separating Kernel and User-space Profiles

By default, kernel mode and user mode information is gathered for each event. To configure OProfile to ignore events in kernel mode for a specific counter, execute the following command:

```
$ opcontrol --event=event-name:sample-rate:unit-mask:0
```

Execute the following command to start profiling kernel mode for the counter again:

```
$ opcontrol --event=event-name:sample-rate:unit-mask:1
```
To configure OProfile to ignore events in user mode for a specific counter, execute the following command:

```
~ ]# opcontrol --event=event-name:sample-rate:unit-mask:kernel:0
```

Execute the following command to start profiling user mode for the counter again:

```
~ ]# opcontrol --event=event-name:sample-rate:unit-mask:kernel:1
```

When the OProfile daemon writes the profile data to sample files, it can separate the kernel and library profile data into separate sample files. To configure how the daemon writes to sample files, execute the following command as root:

```
~ ]# opcontrol --separate=choice
```

`choice` can be one of the following:

- none — do not separate the profiles (default)
- library — generate per-application profiles for libraries
- kernel — generate per-application profiles for the kernel and kernel modules
- all — generate per-application profiles for libraries and per-application profiles for the kernel and kernel modules

If `--separate=library` is used, the sample file name includes the name of the executable as well as the name of the library.

**Restart the OProfile profiler**

These configuration changes will take effect when the OProfile profiler is restarted.

### 22.3. Starting and Stopping OProfile

To start monitoring the system with OProfile, execute the following command as root:

```
~ ]# opcontrol --start
```

Output similar to the following is displayed:

```
```

The settings in `/root/.oprofile/daemonrc` are used.

The OProfile daemon, `oprofiled`, is started; it periodically writes the sample data to the `/var/lib/oprofile/samples/` directory. The log file for the daemon is located at `/var/lib/oprofile/oprofiled.log`.

**Disable the nmi_watchdog registers**

On a Fedora 18 system, the `nmi_watchdog` registers with the `perf` subsystem. Due to this, the `perf` subsystem grabs control of the performance counter registers at boot time, blocking OProfile from working.

To resolve this, either boot with the `nmi_watchdog=0` kernel parameter set, or run the following command to disable `nmi_watchdog` at run time:

```
~ ]# echo 0 > /proc/sys/kernel/nmi_watchdog
```

To re-enable `nmi_watchdog`, use the following command:

```
~ ]# echo 1 > /proc/sys/kernel/nmi_watchdog
```

To stop the profiler, execute the following command as root:

```
~ ]# opcontrol --shutdown
```

### 22.4. Saving Data

Sometimes it is useful to save samples at a specific time. For example, when profiling an executable, it may be useful to gather different samples based on different input data sets. If the number of events to be monitored exceeds the number of counters available for the processor, multiple runs of OProfile can be used to collect data, saving the sample data to different files each time.

To save the current set of sample files, execute the following command, replacing `name` with a unique descriptive name for the current session.

```
~ ]# opcontrol --save=name
```

The directory `/var/lib/oprofile/samples/name/` is created and the current sample files are copied to it.

### 22.5. Analyzing the Data

Periodically, the OProfile daemon, `oprofiled`, collects the samples and writes them to the `/var/lib/oprofile/samples/` directory. Before reading the data, make sure all data has been written to this directory by executing the following command as root:

```
~ ]# opcontrol --dump
```

To read the data, execute the following command:

```
~ ]# opcontrol --read
```

This will display the sample data in a human-readable format.
Each sample file name is based on the name of the executable. For example, the samples for the default event on a
Pentium III processor for /bin/bash becomes:

```
[root]/bin/bash\([dep]\)\([root]\)/bin/bash/CPU_CLK_UNHALTED.100000
```

The following tools are available to profile the sample data once it has been collected:

- `opreport`
- `opannotate`

Use these tools, along with the binaries profiled, to generate reports that can be further analyzed.

### Back up the executable and the sample files

The executable being profiled must be used with these tools to analyze the data. If it must change after the data is
collected, back up the executable used to create the samples as well as the sample files. Please note that the
sample file and the binary have to agree. Making a backup is not going to work if they do not match. `oparchive`
can be used to address this problem.

Samples for each executable are written to a single sample file. Samples from each dynamically linked library are also
written to a single sample file. While OProfile is running, if the executable being monitored changes and a sample file for
the executable exists, the existing sample file is automatically deleted. Thus, if the existing sample file is needed, it must
be backed up, along with the executable used to create it before replacing the executable with a new version. The
OProfile analysis tools use the executable file that created the samples during analysis. If the executable changes the
analysis tools will be unable to analyze the associated samples. Refer to Section 22.4, "Saving Data" for details on how to
back up the sample file.

#### 22.5.1. Using opreport

The `opreport` tool provides an overview of all the executables being profiled.

The following is part of a sample output:

```
Proiling through timer interrupt
TIMER:8| samples|  %|
------------------
25926 97.5212 no-vmlinux
359  1.3584 pi
65  0.2445 Xorg
62  0.2332 libvte.so.4.4.0
56  0.2106 libgc-2.3.4.so
34  0.1279 libglib-2.0.so.0.400.7
19  0.0715 libAft.so.2.1.2
17  0.0639 bash
8  0.0301 ld-2.3.4.so
8  0.0301 libgd-x11-2.0.so.0.400.13
6  0.0226 libgobject-2.0.so.0.400.7
5  0.0188 oprofiled
4  0.0158 libpthread-2.3.4.so
4  0.0158 libtk-x11-2.0.so.0.400.13
3  0.0113 librender.so.1.2.2
3  0.0113 du
1  0.0038 libcrypto.so.0.9.7a
1  0.0038 libgmp.so.0.77
1  0.0038 libncmcap.so.2.0.8
1  0.0038 libx11.so.6.2
1  0.0038 libpthread-2.6.so.0.400.7
1  0.0038 libnm-1.so.4.9.0
```

Each executable is listed on its own line. The first column is the number of samples recorded for the executable. The
second column is the percentage of samples relative to the total number of samples. The third column is the name of the
executable.

Refer to the `opreport` man page for a list of available command line options, such as the `-r` option used to sort the
output from the executable with the smallest number of samples to the one with the largest number of samples.

#### 22.5.2. Using opreport on a Single Executable

To retrieve more detailed profiled information about a specific executable, use `opreport`:

```
[-]# opreport mode executable
```

`executable` must be the full path to the executable to be analyzed. `mode` must be one of the following:

- `-l`

List sample data by symbols. For example, the following is part of the output from running the command `opreport`:

```
[-]# opreport -l /lib/tls/libc-version.so
```
### 22.5.3. Getting more detailed output on the modules

OProfile collects data on a system-wide basis for kernel- and user-space code running on the machine. However, once a module is loaded into the kernel, the information about the origin of the kernel module is lost. The module could have come from the initrd file on boot up, the directory with the various kernel modules, or a locally created kernel module. As a result, when OProfile records sample for a module, it just lists the samples for the modules for an executable in the root directory, but this is unlikely to be the place with the actual code for the module. You will need to take some steps to make sure that analysis tools get the executable.

To get a more detailed view of the actions of the module, you will need to either have the module “unstripped” (that is installed from a custom build) or have the debuginfo package installed for the kernel.
Find out which kernel is running with the `uname -a` command, obtain the appropriate `debuginfo` package and install it on the machine.

Then proceed with clearing out the samples from previous runs with the following command:

```
[-]# opcontrol --reset
```

To start the monitoring process, for example, on a machine with Westmere processor, run the following command:

```
[-]# opcontrol --setup --vmlinux=/usr/lib/debug/lib/modules/`uname -r`/vmlinux \
--event=CPU_CLK_UNHALTED:500000
```

Then the detailed information, for instance, for the `ext4` module can be obtained with:

```
[-]# opreport /ext4 -l --image-path /lib/modules/`uname -r`/kernel
```

CPU: Intel Westmere microarchitecture, speed 2.667e+06 MHz (estimated)
Counted CPU_CLK_UNHALTED events (Clock cycles when not halted) with a unit mask of 0x00 (No unit mask) count 500000
warning: could not check that the binary file /lib/modules/2.6.32-191.el6.x86_64/kernel/fs/ext4/ext4.ko has not been modified since the profile was taken.
Results may be inaccurate.
samples % symbol name
1622 9.8381 ext4_iget
1591 9.6500 ext4_find_entry
1231 7.4665 __ext4_get_inode_loc
783 4.7492 ext4_ext_get_blocks
752 4.5612 ext4_check_dir_entry
644 3.9061 ext4_mark_iloc_dirty
583 3.5361 ext4_get_blocks
583 3.5361 ext4_xattr_get
479 2.8447 ext4_htree_store_dirent
469 2.8447 ext4_get_group_desc
414 2.5111 ext4_xf_find_entry

22.5.4. Using `opannotate`

The `opannotate` tool tries to match the samples for particular instructions to the corresponding lines in the source code. The resulting files generated should have the samples for the lines at the left. It also puts in a comment at the beginning of each function listing the total samples for the function.

For this utility to work, the appropriate `debuginfo` package for the executable must be installed on the system. By default, Fedora `debuginfo` packages are not installed together with their corresponding packages, which contain the executable, so that you have to obtain and install the `debuginfo` packages separately.

The general syntax for `opannotate` is as follows:

```
[-]# opannotate --search-dirs src-dir --source executable
```

The directory containing the source code and the executable to be analyzed must be specified. Refer to the `opannotate` man page for a list of additional command line options.

22.6. Understanding `/dev/oprofile/`

The `/dev/oprofile/` directory contains the file system for OProfile. Use the `cat` command to display the values of the virtual files in this file system. For example, the following command displays the type of processor OProfile detected:

```
[-]# cat /dev/oprofile/cpu_type
```

A directory exists in `/dev/oprofile/` for each counter. For example, if there are 2 counters, the directories `/dev/oprofile/0/` and `/dev/oprofile/1/` exist.

Each directory for a counter contains the following files:

- `count` — The interval between samples.
- `enabled` — If 0, the counter is off and no samples are collected for it; if 1, the counter is on and samples are being collected for it.
- `event` — The event to monitor.
- `extra` — Used on machines with Nehalem processors to further specify the event to monitor.
- `kernel` — If 0, samples are not collected for this counter event when the processor is in kernel-space; if 1, samples are collected even if the processor is in kernel-space.
- `unit_mask` — Defines which unit masks are enabled for the counter.
- `user` — If 0, samples are not collected for the counter event when the processor is in user-space; if 1, samples are collected even if the processor is in user-space.

The values of these files can be retrieved with the `cat` command. For example:

```
[-]# cat /dev/oprofile/0/count
```

22.7. Example Usage

While OProfile can be used by developers to analyze application performance, it can also be used by system administrators to perform system analysis. For example:

- **Determine which applications and services are used the most on a system** — `opreport` can be used to determine
how much processor time an application or service uses. If the system is used for multiple services but is under
performing, the services consuming the most processor time can be moved to dedicated systems.

Determine processor usage — The CPU_CLK_UNHALTED event can be monitored to determine the processor load over
a given period of time. This data can then be used to determine if additional processors or a faster processor might
improve system performance.

22.8. OProfile Support for Java

OProfile allows you to profile dynamically compiled code (also known as “just-in-time” or JIT code) of the Java Virtual
Machine (JVM). OProfile in Fedora 18 includes build-in support for the JVM Tools Interface (JVMTI) agent library, which
supports Java 1.5 and higher.

22.8.1. Profiling Java Code

To profile JIT code from the Java Virtual Machine with the JVMTI agent, add the following to the JVM startup parameters:

-agentlib:jvmti_oprofile

Install the oprofile-jit package

The oprofile-jit package must be installed on the system in order to profile JIT code with OProfile.

To learn more about Java support in OProfile, refer to the OProfile Manual, which is linked from Section 22.11, “Additional
Resources”.

22.9. Graphical Interface

Some OProfile preferences can be set with a graphical interface. To start it, execute the oprof_start command as root
at a shell prompt. To use the graphical interface, you will need to have the oprofile_gui package installed.

After changing any of the options, save them by clicking the Save and quit button. The preferences are written to
/root/.oprofile/daemonrc, and the application exits. Exiting the application does not stop OProfile from sampling.

On the Setup tab, to set events for the processor counters as discussed in Section 22.2.2, “Setting Events to Monitor”,
select the counter from the pulldown menu and select the event from the list. A brief description of the event appears in
the text box below the list. Only events available for the specific counter and the specific architecture are displayed. The
interface also displays whether the profiler is running and some brief statistics about it.
On the right side of the tab, select the **Profile kernel** option to count events in kernel mode for the currently selected event, as discussed in Section 22.2.3, “Separating Kernel and User-space Profiles”. If this option is unselected, no samples are collected for the kernel.

Select the **Profile user binaries** option to count events in user mode for the currently selected event, as discussed in Section 22.2.3, “Separating Kernel and User-space Profiles”. If this option is unselected, no samples are collected for user applications.

Use the **Count** text field to set the sampling rate for the currently selected event as discussed in Section 22.2.2.1, “Sampling Rate”. If any unit masks are available for the currently selected event, as discussed in Section 22.2.2.2, “Unit Masks”, they are displayed in the **Unit Masks** area on the right side of the **Setup** tab. Select the checkbox beside the unit mask to enable it for the event.

On the **Configuration** tab, to profile the kernel, enter the name and location of the `vmlinux` file for the kernel to monitor in the **Kernel image file** text field. To configure OProfile not to monitor the kernel, select **No kernel image**.

If the **Verbose** option is selected, the `oprofiled` daemon log includes more information.

If **Per-application profiles** is selected, OProfile generates per-application profiles for libraries. This is equivalent to the `opcontrol --separate=library` command. If **Per-application profiles, including kernel** is selected, OProfile generates per-application profiles for the kernel and kernel modules as discussed in Section 22.2.3, “Separating Kernel and User-space Profiles”. This is equivalent to the `opcontrol --separate=kernel` command.

To force data to be written to samples files as discussed in Section 22.5, “Analyzing the Data”, click the **Flush** button. This is equivalent to the `opcontrol --dump` command.

To start OProfile from the graphical interface, click **Start**. To stop the profiler, click **Stop**. Exiting the application does not stop OProfile from sampling.

**22.10. OProfile and SystemTap**

SystemTap is a tracing and probing tool that allows users to study and monitor the activities of the operating system in fine detail. It provides information similar to the output of tools like `netstat`, `ps`, `top`, and `iostat`; however, SystemTap is designed to provide more filtering and analysis options for collected information.
While using OProfile is suggested in cases of collecting data on where and why the processor spends time in a particular area of code, it is less usable when finding out why the processor stays idle.

You might want to use SystemTap when instrumenting specific places in code. Because SystemTap allows you to run the code instrumentation without having to stop and restart the instrumentation, it is particularly useful for instrumenting the kernel and daemons.

For more information on SystemTap, refer to Section 22.11.2, "Useful Websites" for the relevant SystemTap documentation.

22.11. Additional Resources
This chapter only highlights OProfile and how to configure and use it. To learn more, refer to the following resources.

22.11.1. Installed Docs

> oprofile man page — Discusses opcontrol, oreport, opannotate, and ophelp

22.11.2. Useful Websites

> http://oprofile.sourceforge.net/ — Contains the latest documentation, mailing lists, IRC channels, and more.
> SystemTap Beginners Guide — Provides basic instructions on how to use SystemTap to monitor different subsystems of Fedora in finer detail.

Part VII. Kernel, Module and Driver Configuration
This part covers various tools that assist administrators with kernel customization.

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Chapter 23. Manually Upgrading the Kernel

23.1. Overview of Kernel Packages

Fedora contains the following kernel packages:

- **kernel** — Contains the kernel for single, multicore and multiprocessor systems.
- **kernel-debug** — Contains a kernel with numerous debugging options enabled for kernel diagnosis, at the expense of reduced performance.
- **kernel-devel** — Contains the kernel headers and makefiles sufficient to build modules against the kernel package.
- **kernel-debug-devel** — Contains the development version of the kernel with numerous debugging options enabled for kernel diagnosis, at the expense of reduced performance.
- **kernel-doc** — Documentation files from the kernel source. Various portions of the Linux kernel and the device drivers shipped with it are documented in these files. Installation of this package provides a reference to the options that can be passed to Linux kernel modules at load time. By default, these files are placed in the `/usr/share/doc/kernel-doc-kernel_version/` directory.
- **kernel-headers** — Includes the C header files that specify the interface between the Linux kernel and user-space libraries and programs. The header files define structures and constants that are needed for building most standard programs.
- **linux-firmware** — Contains all of the firmware files that are required by various devices to operate.
- **perf** — This package contains supporting scripts and documentation for the `perf` tool shipped in each kernel image subpackage.

23.2. Preparing to Upgrade

Before upgrading the kernel, it is recommended that you take some precautionary steps.

First, ensure that working boot media exists for the system in case a problem occurs. If the boot loader is not configured properly to boot the new kernel, the system cannot be booted into Fedora without working boot media.

USB media often comes in the form of flash devices sometimes called pen drives, thumb disks, or keys, or as an externally-connected hard disk device. Almost all media of this type is formatted as a VFAT file system. You can create

Use Yum to install kernels whenever possible

Whenever possible, use either the Yum or PackageKit package manager to install a new kernel because they always install a new kernel instead of replacing the current one, which could potentially leave your system unable to boot.

For more information on installing kernel packages with Yum, refer to Section 5.1.2, “Updating Packages”.

23.4. Performing the Upgrade

23.5. Verifying the Initial RAM Disk Image

23.6. Verifying the Boot Loader

### 23.6.1. Configuring the GRUB 2 Boot Loader

### 23.6.2. Configuring the OS/400 Boot Loader

### 23.6.3. Configuring the YABOOT Boot Loader

The Fedora kernel is custom-built by the Fedora kernel team to ensure its integrity and compatibility with supported hardware. Before a kernel is released, it must first pass a rigorous set of quality assurance tests.

Fedora kernels are packaged in the RPM format so that they are easy to upgrade and verify using the Yum or PackageKit package managers. PackageKit automatically queries the Yum repositories and informs you of packages with available updates, including kernel packages.

This chapter is therefore only useful for users who need to manually update a kernel package using the `rpm` command instead of `yum`.

For more information on installing kernel packages with Yum, refer to Section 5.1.2, “Updating Packages”.

23.1. Overview of Kernel Packages

Fedora contains the following kernel packages:

- **kernel** — Contains the kernel for single, multicore and multiprocessor systems.
- **kernel-debug** — Contains a kernel with numerous debugging options enabled for kernel diagnosis, at the expense of reduced performance.
- **kernel-devel** — Contains the kernel headers and makefiles sufficient to build modules against the kernel package.
- **kernel-debug-devel** — Contains the development version of the kernel with numerous debugging options enabled for kernel diagnosis, at the expense of reduced performance.
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- **kernel-headers** — Includes the C header files that specify the interface between the Linux kernel and user-space libraries and programs. The header files define structures and constants that are needed for building most standard programs.
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23.2. Preparing to Upgrade

Before upgrading the kernel, it is recommended that you take some precautionary steps.

First, ensure that working boot media exists for the system in case a problem occurs. If the boot loader is not configured properly to boot the new kernel, the system cannot be booted into Fedora without working boot media.

USB media often comes in the form of flash devices sometimes called pen drives, thumb disks, or keys, or as an externally-connected hard disk device. Almost all media of this type is formatted as a VFAT file system. You can create
bootable USB media on media formatted as ext2, ext3, ext4, or VFAT.

You can transfer a distribution image file or a minimal boot media image file to USB media. Make sure that sufficient free space is available on the device. Around 4 GB is required for a distribution DVD image, around 700 MB for a distribution CD image, or around 10 MB for a minimal boot media image.

You must have a copy of the boot.iso file from a Fedora installation DVD, or installation CD-ROM, and you need a USB storage device formatted with the VFAT file system and around 16 MB of free space. The following procedure will not affect existing files on the USB storage device unless they have the same path names as the files that you copy onto it. To create USB boot media, perform the following commands as the root user:

1. Install the SYSLINUX bootloader on the USB storage device:
   ```bash
   syslinux /dev/sdX1
   ...
   ``
   where sdX is the device name.

2. Create mount points for boot.iso and the USB storage device:
   ```bash
   mkdir /mnt/isoboot /mnt/diskboot
   ```

3. Mount boot.iso:
   ```bash
   mount -o loop boot.iso /mnt/isoboot
   ```

4. Mount the USB storage device:
   ```bash
   mount /dev/sdX1 /mnt/diskboot
   ```

5. Copy the ISOLINUX files from the boot.iso to the USB storage device:
   ```bash
   cp /mnt/isoboot/isolinux/* /mnt/diskboot
   ```

6. Use the isolinux.cfg file from boot.iso as the syslinux.cfg file for the USB device:
   ```bash
   grep -v local /mnt/isoboot/isolinux/isolinux.cfg > /mnt/diskboot/syslinux.cfg
   ```

7. Unmount boot.iso and the USB storage device:
   ```bash
   umount /mnt/isoboot /mnt/diskboot
   ```

8. You should reboot the machine with the boot media and verify that you are able to boot with it before continuing.

Alternatively, on systems with a floppy drive, you can create a boot diskette by installing the mkbootdisk package and running the mkbootdisk command as root. Refer to man mkbootdisk man page after installing the package for usage information.

To determine which kernel packages are installed, execute the command `yum list installed "kernel-***"` at a shell prompt. The output will comprise some or all of the following packages, depending on the system's architecture, and the version numbers may differ:

```bash
-]# yum list installed "kernel-***"
Loaded plugins: langpacks, preston, refresh-packagekit
Installed Packages
kernel.x86_64            3.1.0-0.rc6.git0.3.fc16        @updates-testing
kernel.x86_64            3.1.0-0.rc9.git0.0.fc16        @updates-testing
kernel-doc.x86_64        3.1.0-0.rc6.git0.3.fc16        @updates-testing
kernel-doc.x86_64        3.1.0-0.rc9.git0.0.fc16        @updates-testing
kernel-headers.x86_64    3.1.0-0.rc6.git0.3.fc16        @updates-testing
kernel-headers.x86_64    3.1.0-0.rc9.git0.0.fc16        @updates-testing
```

From the output, determine which packages need to be downloaded for the kernel upgrade. For a single processor system, the only required package is the kernel package. Refer to Section 23.1, "Overview of Kernel Packages" for descriptions of the different packages.

23.3. Downloading the Upgraded Kernel

There are several ways to determine if an updated kernel is available for the system.

- Security Advisories — Refer to http://fedoraproject.org/wiki/FSA for information on Security Advisories, including kernel upgrades that fix security issues.
- Via Fedora Update System — Download and install the kernel RPM packages. For more information, refer to http://admin.fedoraproject.org/updates/.

To install the kernel manually, continue to Section 23.4, "Performing the Upgrade".

23.4. Performing the Upgrade

After retrieving all of the necessary packages, it is time to upgrade the existing kernel.

Keep the old kernel when performing the upgrade

It is strongly recommended that you keep the old kernel in case there are problems with the new kernel.

At a shell prompt, change to the directory that contains the kernel RPM packages. Use `-i` argument with the `rpm` command to keep the old kernel. Do not use the `-U` option, since it overwrites the currently installed kernel, which creates
boot loader problems. For example:

```bash
rpm -ivh kernel-kernel_version.arch.rpm
```

The next step is to verify that the initial RAM disk image has been created. Refer to Section 23.3.5, "Verifying the Initial RAM Disk Image" for details.

### 23.5. Verifying the Initial RAM Disk Image

The job of the initial RAM disk image is to preload the block device modules, such as for IDE, SCSI or RAID, so that the root file system, on which those modules normally reside, can then be accessed and mounted. On Fedora 18 systems, whenever a new kernel is installed using either the Yum, PackageKit, or RPM package manager, the Dracut utility is always called by the installation scripts to create an initramfs (initial RAM disk image).

On all architectures other than IBM eServer System i (see the section called "Verifying the Initial RAM Disk Image and Kernel on IBM eServer System i"), you can create an initramfs by running the dracut command. However, you usually don't need to create an initramfs manually: this step is automatically performed if the kernel and its associated packages are installed or upgraded from RPM packages distributed by The Fedora Project.

On architectures that use the GRUB 2 boot loader, you can verify that an initramfs corresponding to your current kernel version exists and is specified correctly in the `/boot/grub2/grub.cfg` configuration file by following this procedure:

#### Procedure 23.1. Verifying the Initial RAM Disk Image

1. As root, list the contents in the `/boot` directory and find the kernel (`vmlinuz-kernel_version`) and initramfs-kernel_version with the latest (most recent) version number:

   ```sh
   ~[ ]# ls /boot
   config-3.1.0-0.rc6.git0.3.fc16.x86_64
   config-3.1.0-0.rc9.git0.0.fc16.x86_64
   elf-memtest86+-4.20
   grub
   grub2
   initramfs-3.1.0-0.rc6.git0.3.fc16.x86_64.img
   initramfs-3.1.0-0.rc9.git0.0.fc16.x86_64.img
   initrd-plymouth.img
   memtest86+-4.20
   System.map-3.1.0-0.rc6.git0.3.fc16.x86_64
   System.map-3.1.0-0.rc9.git0.0.fc16.x86_64
   vmlinuz-3.1.0-0.rc6.git0.3.fc16.x86_64
   vmlinuz-3.1.0-0.rc9.git0.0.fc16.x86_64
   ```

   The example above shows that:
   
   - we have two kernels installed (or, more correctly, two kernel files are present in the `/boot` directory),
   - the latest kernel is `vmlinuz-vmlinuz-3.1.0-0.rc9.git0.0.fc16.x86_64`, and
   - an initramfs file matching our kernel version, `initramfs-3.1.0-0.rc9.git0.0.fc16.x86_64.img`, also exists.

   ![initrd files in the /boot directory are not the same as initramfs files](image)

   In the `/boot` directory you may find several `initrd-<kernel_version>kdump.img` files. These are special files created by the kdump mechanism for kernel debugging purposes, are not used to boot the system, and can safely be ignored. For more information on kdump, refer to Chapter 25, The kdump Crash Recovery Service.

2. (Optional) If your `initramfs-kernel_version` file does not match the version of the latest kernel in `/boot`, or in certain other situations, you may need to generate an initramfs file with the Dracut utility. Simply invoking `dracut` as root without options causes it to generate an initramfs file in the `/boot` directory for the latest kernel present in that directory:

   ```sh
   ~[ ]# dracut
   ```

   You must use the `--force` option if you want `dracut` to overwrite an existing initramfs (for example, if your initramfs has become corrupt). Otherwise `dracut` will refuse to overwrite the existing initramfs file:

   ```sh
   ~[ ]# dracut
   F: Will not override existing initramfs (/boot/initramfs-3.1.0-0.rc9.git0.0.fc16.x86_64.img) without --force
   ```

   You can create an initramfs in the current directory by calling `dracut initramfs_name kernel_version`, for example:

   ```sh
   ~[ ]# dracut "initramfs-$[uname -r].img" "$[uname -r]
   ```

   If you need to specify specific kernel modules to be preloaded, add the names of those modules (minus any file name suffixes such as `.ko`) inside the parentheses of the `add_dracutmodules="module [more modules]"` directive of the `/etc/dracut.conf` configuration file. You can list the file contents of an initramfs image file created by dracut by using the `lsinitrd initramfs_file` command:
3. Examine the `/boot/grub2/grub.cfg` configuration file to ensure that an `initrd` file exists for the kernel version you are booting. For example:

```
ls -l /boot
```

The `kernel_version` should match the version of the kernel just installed.

### 23.6. Verifying the Boot Loader

When you install a kernel using `rpm`, the kernel package creates an entry in the boot loader configuration file for that new kernel. However, `rpm` does not configure the new kernel to boot as the default kernel. You must do this manually when installing a new kernel with `rpm`.

It is always recommended to double-check the boot loader configuration file after installing a new kernel with `rpm` to ensure that the configuration is correct. Otherwise, the system may not be able to boot into Fedora properly. If this happens, boot the system with the boot media created earlier and re-configure the boot loader.

In the following table, find your system’s architecture to determine the boot loader it uses, and then click on the “Refer to” link to jump to the correct instructions for your system.

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<tr>
<th>Architecture</th>
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#### 23.6.1. Configuring the GRUB 2 Boot Loader

Fedora 18 is distributed with GRUB 2, which reads its configuration from the `/boot/grub2/grub.cfg` file. This file is generated by the `grub2-mkconfig` utility based on Linux kernels located in the `/boot` directory, template files located in `/etc/grub.d/`, and custom settings in the `/etc/default/grub` file and is automatically updated each time you install a new kernel from an RPM package. To update this configuration file manually, type the following at a shell prompt as `root`:

```
grub2-mkconfig -o /boot/grub2/grub.cfg
```

Among various code snippets and directives, the `/boot/grub2/grub.cfg` configuration file contains one or more `menuentry` blocks, each representing a single GRUB 2 boot menu entry. These blocks always start with the `menuentry` keyword followed by a title, list of options, and opening curly bracket, and end with a closing curly bracket. Anything between the opening and closing bracket should be indented. For example, the following is a sample `menuentry` block for Fedora 17 with Linux kernel 3.4.0-1.fc17.x86_64:
menuentry 'Fedora (3.4.0-1.fc17.x86_64)' --class fedora --class gnu-linux --class gnu --class os $menuentry_id_option 'gnulinux-simple-77ba9149-751a-48e0-974f-ad94911734b9' {
  load_video
  gfxpayload=keep
  insmod gzio
  insmod part_msdos
  insmod ext2
  set root='hd0,msdos1'
  if [ x$feature_platform_search_hint = xy ]; then
    search --no-floppy --fs-uuid --set=root --hint='hd0,msdos1' 4ea24c68-ab10-47d4-8a6b-b8d3a802acba
  else
    search --no-floppy --fs-uuid --set=root 4ea24c68-ab10-47d4-8a6b-b8d3a802acba
  fi
  echo 'Loading Fedora (3.4.0-1.fc17.x86_64)'
  linux /vmlinuz-3.4.0-1.fc17.x86_64 root=/dev/mapper/vg_fedora-lv_root ro rd.md=0 rs.lvm.lv=vg_fedora/lv_swap
  KEYTABLE=True rd.lvm.lv=vg_fedora/lv_root
  LANG=en_US.UTF-8 rhgb quiet
  echo 'Loading initial ramdisk ...'
  initrd /initramfs-3.4.0-1.fc17.x86_64.img
}

Each menuentry block that represents an installed Linux kernel contains linux and initrd directives followed by the path to the kernel and the initramfs image respectively. If a separate /boot partition was created, the paths to the kernel and the initramfs image are relative to /boot. In the example above, the initrd /initramfs-3.4.0-1.fc17.x86_64.img line means that the initramfs image is actually located at /boot/initramfs-3.4.0-1.fc17.x86_64.img when the root file system is mounted, and likewise for the kernel path.

The kernel version number as given on the linux /vmlinuz-kernel_version line must match the version number of the initramfs image given on the initrd /initramfs-kernel_version.img line of each menuentry block. For more information on how to verify the initial RAM disk image, refer to Procedure 23.1, “Verifying the Initial RAM Disk Image”.

The initrd directive in grub.cfg refers to an initramfs image

In menuentry blocks, the initrd directive must point to the location (relative to the /boot directory if it is on a separate partition) of the initramfs file corresponding to the same kernel version. This directive is called initrd because the previous tool which created initial RAM disk images, mkinitrd, created what were known as initrd files. The grub.cfg directive remains initrd to maintain compatibility with other tools. The file-naming convention of systems using the dracut utility to create the initial RAM disk image is initramfs-kernel_version.img. For information on using Dracut, refer to Section 23.5, “Verifying the Initial RAM Disk Image”.

After installing a new kernel with rpm, verify that /boot/grub2/grub.cfg is correct and reboot the computer into the new kernel. Ensure your hardware is detected by watching the boot process output. If GRUB 2 presents an error and is unable to boot into the new kernel, it is often easiest to try to boot into an alternative or older kernel so that you can fix the problem. Alternatively, use the boot media you created earlier to boot the system.

Causing the GRUB 2 boot menu to display

If you set the GRUB_TIMEOUT option in the /etc/default/grub file to 0, GRUB 2 will not display its list of bootable kernels when the system starts up. In order to display this list when booting, press and hold any alphanumeric key while and immediately after BIOS information is displayed, and GRUB 2 will present you with the GRUB menu.

23.6.2. Configuring the OS/400 Boot Loader

The /boot/vmlinitrd-kernel-version file is installed when you upgrade the kernel. However, you must use the dd command to configure the system to boot the new kernel.

1. As root, issue the command cat /proc/iSeries/mf/side to determine the default side (either A, B, or C).
2. As root, issue the following command, where kernel-version is the version of the new kernel and side is the side from the previous command:

   ```
   dd if=/boot/vmlinitrd-kernel-version of=/proc/iSeries/mf/side/vmlinux bs=8k
   ```

Begin testing the new kernel by rebooting the computer and watching the messages to ensure that the hardware is detected properly.

23.6.3. Configuring the YABOOT Boot Loader

IBM eServer System p uses YABOOT as its boot loader. YABOOT uses /etc/aboot.conf as its configuration file. Confirm that the file contains an image section with the same version as the kernel package just installed, and likewise for the initramfs image:
Notice that the default is not set to the new kernel. The kernel in the first image is booted by default. To change the default kernel to boot either move its image stanza so that it is the first one listed or add the directive default and set it to the label of the image stanza that contains the new kernel.

Begin testing the new kernel by rebooting the computer and watching the messages to ensure that the hardware is detected properly.

Chapter 24. Working with Kernel Modules

24.1. Listing Currently-Loaded Modules

24.2. Displaying Information About a Module

24.3. Loading a Module

24.4. Unloading a Module

24.5. Setting Module Parameters

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24.7. Specific Kernel Module Capabilities

24.7.1. Using Multiple Ethernet Cards

24.7.2. Using Channel Bonding

24.8. Additional Resources

24.8.1. Installed Documentation

24.8.2. Useful Websites

The Linux kernel is modular, which means it can extend its capabilities through the use of dynamically-loaded kernel modules. A kernel module can provide:

- a device driver which adds support for new hardware; or,
- support for a file system such as btrfs or NFS.

Like the kernel itself, modules can take parameters that customize their behavior, though the default parameters work well in most cases. User-space tools can list the modules currently loaded into a running kernel; query all available modules for available parameters and module-specific information; and load or unload (remove) modules dynamically into or from a running kernel. Many of these utilities, which are provided by the module-init-tools package, take module dependencies into account when performing operations so that manual dependency-tracking is rarely necessary.

On modern systems, kernel modules are automatically loaded by various mechanisms when the conditions call for it. However, there are occasions when is it necessary to load and/or unload modules manually, such as when a module provides optional functionality, one module should be preferred over another although either could provide basic functionality, or when a module is misbehaving, among other situations.

This chapter explains how to:

- use the user-space module-init-tools package to display, query, load and unload kernel modules and their dependencies;
- set module parameters both dynamically on the command line and permanently so that you can customize the behavior of your kernel modules; and,
- load modules at boot time.

Installing the module-init-tools package

In order to use the kernel module utilities described in this chapter, first ensure the module-init-tools package is installed on your system by running, as root:

```bash
yum install module-init-tools
```

For more information on installing packages with Yum, refer to Section 5.2.4, “Installing Packages”.

24.1. Listing Currently-Loaded Modules

You can list all kernel modules that are currently loaded into the kernel by running the `lsmod` command, for example:
Each row of `lsmod` output specifies:

- the name of a kernel module currently loaded in memory;
- the amount of memory it uses; and,
- the sum total of processes that are using the module and other modules which depend on it, followed by a list of the names of those modules, if there are any. Using this list, you can first unload all the modules depending the module you want to unload. For more information, refer to Section 24.4, "Unloading a Module".

Finally, note that `lsmod` output is less verbose and considerably easier to read than the content of the `/proc/modules` pseudo-file.

### 24.2. Displaying Information About a Module

You can display detailed information about a kernel module by running the `modinfo module_name` command.

#### Module names do not end in `.ko`

When entering the name of a kernel module as an argument to one of the `module-init-tools` utilities, do not append a `.ko` extension to the end of the name. Kernel module names do not have extensions: their corresponding files do.

#### Example 24.1. Listing information about a kernel module with `lsmod`

To display information about the `e1000e` module, which is the Intel PRO/1000 network driver, run:

```bash
modinfo e1000e
```

```bash
filename:       /lib/modules/2.6.32-71.el6.x86_64/kernel/drivers/net/e1000e/e1000e.ko
version:        1.2.7-k2
license:        GPL
description:    Intel(R) PRO/1000 Network Driver
author:         Intel Corporation, <linux.nics@intel.com>
srcversion:     93CB73D3995B501872B2982
alias:          pci:v00008086d00001503sv*sd*bc*sc*i*
alias:          pci:v00008086d00001502sv*sd*bc*sc*i*
alias:          pci:v00008086d0000105Ev*sd*bc*sc*i*
alias:          pci:v000080860d00001503sv’d’bc’s’c’i’
alias:          pci:v000080860d00001502sv’d’bc’s’c’i’
alias:          pci:v000080860d0000105Ev’d’bc’s’c’i’
alias:          pci:v000080860d00001503sv’d’bc’s’c’i’
depends:
vermagic:       2.6.32-71.el6.x86_64 SMP mod_unload modversions
parm:           copybreak:Maximum size of packet that is copied to a new buffer on receive (uint)
parm:           TxIntDelay:Transmit Interrupt Delay (array of int)
parm:           TxAbsIntDelay:Transmit Absolute Interrupt Delay (array of int)
parm:           RxIntDelay:Receive Interrupt Delay (array of int)
parm:           RxAbsIntDelay:Receive Absolute Interrupt Delay (array of int)
parm:           InterruptThrottleRate:Interrupt Throttling Rate (array of int)
parm:           IntMode:Interrupt Mode (array of int)
parm:           SmartPowerDownEnable:Enable PHY smart power down (array of int)
parm:           KumeranLockless:Enable Kumeran lock loss workaround (array of int)
parm:           WriteProtectNVM:Write-protect NVM [WARNING: disabling this can lead to corrupted NVM] (array of int)
parm:           EEE:Enable/disable on parts that support the feature (array of int)
```
Here are descriptions of a few of the fields in `modinfo` output:

**filename**

The absolute path to the .ko kernel object file. You can use `modinfo -n` as a shortcut command for printing only the `filename` field.

**description**

A short description of the module. You can use `modinfo -d` as a shortcut command for printing only the `description` field.

**alias**

The `alias` field appears as many times as there are aliases for a module, or is omitted entirely if there are none.

**depends**

This field contains a comma-separated list of all the modules this module depends on.

---

**Omitting the depends field**

If a module has no dependencies, the `depends` field may be omitted from the output.

---

**parm**

Each `parm` field presents one module parameter in the form `parameter_name: description`, where:

- `parameter_name` is the exact syntax you should use when using it as a module parameter on the command line, or in an option line in a `.conf` file in the `/etc/modprobe.d/` directory; and,
- `description` is a brief explanation of what the parameter does, along with an expectation for the type of value the parameter accepts (such as int, unit or array of int) in parentheses.

**Example 24.2. Listing module parameters**

You can list all parameters that the module supports by using the `-p` option. However, because useful value type information is omitted from `modinfo -p` output, it is more useful to run:

```
～# modinfo e1000e | grep "^parm" | sort
parm:           copybreak:Maximum size of packet that is copied to a new buffer on receive (uint)
parm:           CrcStripping:Enable CRC Stripping, disable if your BMC needs the CRC (array of int)
parm:           EEE:Enable/disable on parts that support the feature (array of int)
parm:           InterruptThrottleRate:Interrupt Throttling Rate (array of int)
parm:           IntMode:Interrupt Mode (array of int)
parm:           KumeranLockLoss:Enable Kumeran lock loss workaround (array of int)
parm:           RxAbsIntDelay:Receive Absolute Interrupt Delay (array of int)
parm:           SmartPowerDownEnable:Enable PHY smart power down (array of int)
parm:           TxAbsIntDelay:Transmit Absolute Interrupt Delay (array of int)
parm:           WriteProtectNVM:Write-protect NVM [WARNING: disabling this can lead to corrupted NVM] (array of int)
```

---

**24.3. Loading a Module**

To load a kernel module, run `modprobe module_name` as root. For example, to load the `wacom` module, run:

```
～# modprobe wacom
```

By default, `modprobe` attempts to load the module from `/lib/modules/kernel_version/kernel/drivers/`. In this directory, each type of module has its own subdirectory, such as `net/` and `scsi/`, for network and SCSI interface drivers respectively.

Some modules have dependencies, which are other kernel modules that must be loaded before the module in question can be loaded. The `modprobe` command always takes dependencies into account when performing operations. When you ask `modprobe` to load a specific kernel module, it first examines the dependencies of that module, if there are any, and loads them if they are not already loaded into the kernel. `modprobe` resolves dependencies recursively: it will load all dependencies of dependencies, and so on, if necessary, thus ensuring that all dependencies are always met.

You can use the `-v` (or `-v verbose`) option to cause `modprobe` to display detailed information about what it is doing, which may include loading module dependencies.
Example 24.3. modprobe -v shows module dependencies as they are loaded
You can load the Fibre Channel over Ethernet module verbose by typing the following at a shell prompt:

```bash
[~]# modprobe -v fcoe
insmod /lib/modules/2.6.32-71.el6.x86_64/kernel/drivers/scsi/scsi_tgt.ko
insmod /lib/modules/2.6.32-71.el6.x86_64/kernel/drivers/scsi/scsi_transport_fc.ko
insmod /lib/modules/2.6.32-71.el6.x86_64/kernel/drivers/scsi/libfc/libfc.ko
insmod /lib/modules/2.6.32-71.el6.x86_64/kernel/drivers/scsi/fcoe/libfcoe.ko
insmod /lib/modules/2.6.32-71.el6.x86_64/kernel/drivers/scsi/fcoe/fcoe.ko
```

In this example, you can see that modprobe loaded the scsi_tgt, scsi_transport_fc, libfc and libfcoe modules as dependencies before finally loading fcoe. Also note that modprobe used the more "primitive" insmod command to insert the modules into the running kernel.

Always use modprobe instead of insmod!

Although the insmod command can also be used to load kernel modules, it does not resolve dependencies. Because of this, you should always load modules using modprobe instead.

24.4. Unloading a Module
You can unload a kernel module by running modprobe -r module_name as root. For example, assuming that the wacom module is already loaded into the kernel, you can unload it by running:

```
[~]# modprobe -r wacom
```

However, this command will fail if a process is using:

- the wacom module,
- a module that wacom directly depends on, or,
- any module that wacom—through the dependency tree—depends on indirectly.

Refer to Section 24.1, "Listing Currently-Loaded Modules" for more information about using lsmod to obtain the names of the modules which are preventing you from unloading a certain module.

Example 24.4. Unloading a kernel module
For example, if you want to unload the firewire_ohci module (because you believe there is a bug in it that is affecting system stability, for example), your terminal session might look similar to this:

```bash
[~]# modinfo -F depends firewire_ohci
depends:        firewire-core
[~]# modinfo -F depends firewire_core
depends:        crc-itu-t
[~]# modinfo -F depends crc-itu-t
depends:        
```

You have figured out the dependency tree (which does not branch in this example) for the loaded Firewire modules: firewire_ohci depends on firewire_core, which itself depends on crc-itu-t.

You can unload firewire_ohci using the modprobe -v -r module_name command, where -r is short for --remove and -v for --verbose:

```
[~]# modprobe -r -v firewire_ohci
rmmod /lib/modules/2.6.32-71.el6.x86_64/kernel/drivers/firewire/firewire-ohci.ko
rmmod /lib/modules/2.6.32-71.el6.x86_64/kernel/drivers/firewire/firewire-core.ko
rmmod /lib/modules/2.6.32-71.el6.x86_64/kernel/lib/crc-itu-t.ko
```

The output shows that modules are unloaded in the reverse order that they are loaded, given that no processes depend on any of the modules being unloaded.

Do not use rmmod directly!

Although the rmmod command can be used to unload kernel modules, it is recommended to use modprobe -r instead.

24.5. Setting Module Parameters
Like the kernel itself, modules can also take parameters that change their behavior. Most of the time, the default ones work well, but occasionally it is necessary or desirable to set custom parameters for a module. Because parameters cannot be dynamically set for a module that is already loaded into a running kernel, there are two different methods for setting them.

1. You can unload all dependencies of the module you want to set parameters for, unload the module using modprobe -r, and then load it with modprobe along with a list of customized parameters. This method is often used when the module does not have many dependencies, or to test different combinations of parameters without making them persistent, and is the method covered in this section.

2. Alternatively, you can list the new parameters in an existing or newly-created file in the /etc/modprobe.d/
You can use `modprobe` to load a kernel module with custom parameters using the following command line format:

```
modprobe module_name [parameter=value]
```

When loading a module with custom parameters on the command line, be aware of the following:

- You can enter multiple parameters and values by separating them with spaces.
- Some module parameters expect a list of comma-separated values as their argument. When entering the list of values, do not insert a space after each comma, or `modprobe` will incorrectly interpret the values following spaces as additional parameters.
- The `modprobe` command silently succeeds with an exit status of 0 if:
  - it successfully loads the module, or
  - the module is already loaded into the kernel.

Thus, you must ensure that the module is not already loaded before attempting to load it with custom parameters. The `modprobe` command does not automatically reload the module, or alert you that it is already loaded.

Here are the recommended steps for setting custom parameters and then loading a kernel module. This procedure illustrates the steps using the `e1000e` module, which is the network driver for Intel PRO/1000 network adapters, as an example:

### Procedure 24.1. Loading a Kernel Module with Custom Parameters

1. First, ensure the module is not already loaded into the kernel. For example:

```
~]# lsmod | grep e1000e
~]#
```

Output indicates that the module is already loaded into the kernel, in which case you must first unload it before proceeding. Refer to Section 24.4, "Unloading a Module" for instructions on safely unloading it.

2. Load the module and list all custom parameters after the module name. For example, if you wanted to load the Intel PRO/1000 network driver with the interrupt throttle rate set to 3000 interrupts per second for the first, second and third instances of the driver, and Energy Efficient Ethernet (EEE) turned on, you would run, as root:

```
~]# modprobe e1000e InterruptThrottleRate=3000,3000,3000 EEE=1
```

This example illustrates passing multiple valued to a single parameter by separating them with commas and omitting any spaces between them.

### 24.6. Persistent Module Loading

As shown in Example 24.1, "Listing information about a kernel module with lsmod", many kernel modules are loaded automatically at boot time. You can specify additional modules to be loaded by creating a new `file_name.modules` file in the `/etc/sysconfig/modules/` directory, where `file_name` is any descriptive name of your choice. Your `file_name.modules` files are treated by the system startup scripts as shell scripts, and as such should begin with an interpreter directive (also called a "bang line") as their first line:

```
#!/bin/sh
```

Additionally, the `file_name.modules` file should be executable. You can make it executable by running:

```
modules]# chmod +x file_name.modules
```

Example 24.5. /etc/sysconfig/modules/bluez-uinput.modules

The following `bluez-uinput.modules` script loads the `uinput` module:

```
#!/bin/sh
if [ ! -c /dev/input/uinput ]; then
  exec /sbin/modprobe uinput >/dev/null 2>&1
fi
```

The `if`-conditional statement on the third line ensures that the `/dev/input/uinput` file does not already exist (the `!` symbol negates the condition), and, if that is the case, loads the `uinput` module by calling `exec /sbin/modprobe uinput`. Note that the `uinput` module creates the `/dev/input/uinput` file, so testing to see if that file exists serves as verification of whether the `uinput` module is loaded into the kernel.

The following `>/dev/null 2>&1` clause at the end of that line redirects any output to `/dev/null` so that the `modprobe` command remains quiet.

### 24.7. Specific Kernel Module Capabilities

This section explains how to enable specific kernel capabilities using various kernel modules.

#### 24.7.1. Using Multiple Ethernet Cards

It is possible to use multiple Ethernet cards on a single machine. For each card there must be an `alias` and, possibly, `options` lines for each card in a user-created `module_name.conf` file in the `/etc/modprobe.d/` directory.
For additional information about using multiple Ethernet cards, refer to the **Linux Ethernet-HOWTO** online at http://www.redhat.com/mirrors/LDP/HOWTO/Ethernet-HOWTO.html.

### 24.7.2. Using Channel Bonding

Fedora allows administrators to bind NICs together into a single channel using the **bonding** kernel module and a special network interface, called a **channel bonding interface**. Channel bonding enables two or more network interfaces to act as one, simultaneously increasing the bandwidth and providing redundancy.

To channel bond multiple network interfaces, the administrator must perform the following steps:

1. As **root**, create a new file named `bonding.conf` in the `/etc/modprobe.d/` directory. Note that you can name this file anything you like as long as it ends with a `.conf` extension. Insert the following line in this new file:

   ```
   alias bondN bonding
   ```

   Replace `N` with the interface number, such as `0`. For each configured channel bonding interface, there must be a corresponding entry in your new `/etc/modprobe.d/bonding.conf` file.

2. Configure a channel bonding interface as outlined in [Section 8.2.3, “Channel Bonding Interfaces”](#).

3. To enhance performance, adjust available module options to ascertain what combination works best. Pay particular attention to the `miimon` or `arp_interval` and the `arp_ip_target` parameters. Refer to [Section 24.7.2.1, “Bonding Module Directives”](#) for a list of available options and how to quickly determine the best ones for your bonded interface.

#### 24.7.2.1. Bonding Module Directives

It is a good idea to test which channel bonding module parameters work best for your bonded interfaces before adding them to the `BONDING_OPTS="bonding parameters"` directive in your bonding interface configuration file (`ifcfg-bond0` for example). Parameters to bonded interfaces can be configured without unloading (and reloading) the bonding module by manipulating files in the **sysfs** file system.

**sysfs** is a virtual file system that represents kernel objects as directories, files and symbolic links. **sysfs** can be used to query for information about kernel objects, and can also manipulate those objects through the use of normal file system commands. The **sysfs** virtual file system has a line in `/etc/fstab`, and is mounted under the `/sys/` directory. All bonding interfaces can be configured dynamically by interacting with and manipulating files under the `/sys/class/net/` directory.

In order to determine the best parameters for your bonding interface, create a channel bonding interface file such as `ifcfg-bond0` by following the instructions in [Section 8.2.3, “Channel Bonding Interfaces”](#). Insert the `SLAVE=yes` and `MASTER=bond0` directives in the configuration files for each interface bonded to `bond0`. Once this is completed, you can proceed to testing the parameters.

First, bring up the bond you created by running `ifconfig bond0 up as root`:

```
-]# ifconfig bond0 up
```

If you have correctly created the `ifcfg-bond0` bonding interface file, you will be able to see `bond0` listed in the output of running `ifconfig` (without any options):

```
-]# ifconfig
bond0 Link encap:Ethernet HWaddr 00:00:00:00:00:00
    UP BROADCAST RUNNING MASTER MULTICAST  MTU:1500  Metric:1
    RX packets:0 errors:0 dropped:0 overruns:0 frame:0
    TX packets:0 errors:0 dropped:0 overruns:0 carrier:0
    collisions:0 txqueuelen:0
    RX bytes:0 (0.0 b)  TX bytes:0 (0.0 b)
eth0 Link encap:Ethernet HWaddr 52:54:00:26:9E:F1
    inet addr:192.168.122.251  Bcast:192.168.122.255  Mask:255.255.255.0
    inet6 addr: fe80::5054:ff:fe26:9ef1/64 Scope:Link
    UP BROADCAST RUNNING MULTICAST  MTU:1500 Metric:1
    RX packets:207 errors:0 dropped:0 overruns:0 frame:0
    TX packets:205 errors:0 dropped:0 overruns:0 carrier:0
    collisions:0 txqueuelen:1000
    RX bytes:70374 (68.7 KiB) TX bytes:25298 (24.7 KiB)
```

To view all existing bonds, even if they are not up, run:

```
-]# cat /sys/class/net/bonding_masters
```

You can configure each bond individually by manipulating the files located in the `/sys/class/net/bond0/bonding/` directory. First, the bond you are configuring must be taken down:

```
-]# ifconfig bond0 down
```

As an example, to enable MII monitoring on bond0 with a 1 second interval, you could run (as **root**):

```
-]# echo 1000 > /sys/class/net/bond0/bonding/miimon
```

To configure bond0 for **balance-alb** mode, you could run either:

```
-]# echo 6 > /sys/class/net/bond0/bonding/mode
-]# or, using the name of the mode:
-]# echo balance-alb > /sys/class/net/bond0/bonding/mode
```
After configuring options for the bond in question, you can bring it up and test it by running `ifconfig bondW up`. If you decide to change the options, take the interface down, modify its parameters using `sysfs`, bring it back up, and re-test.

Once you have determined the best set of parameters for your bond, add those parameters as a space-separated list to the `BONDING_OPTS=` directive of the `/etc/sysconfig/network-scripts/ifcfg-bond` file for the bonding interface you are configuring. Whenever that bond is brought up (for example, by the system during the boot sequence if the `ONBOOT=yes` directive is set), the bonding options specified in the `BONDING_OPTS` will take effect for that bond. For more information on configuring bonding interfaces (and `BONDING_OPTS`), refer to Section 8.2.3, "Channel Bonding Interfaces".

The following list provides the names of many of the more common channel bonding parameters, along with a description of what they do. For more information, refer to the brief descriptions for each `parm` in `modinfo bonding` output, or the exhaustive descriptions in the `bonding.txt` file in the `kernel-doc` package (see Section 24.8, "Additional Resources").

### Bonding Interface Parameters

**arp_interval=time_in_milliseconds**

Specifies (in milliseconds) how often ARP monitoring occurs.

**arp_ip_target=ip_address [, ip_address_2,...,ip_address_16]**

Specifies the target IP address of ARP requests when the `arp_interval` parameter is enabled. Up to 16 IP addresses can be specified in a comma separated list.

**arp_validate=value**

Validate source/distribution of ARP probes; default is `none`. Other valid values are `active`, `backup`, and `all`.

**debug=number**

Enables debug messages. Possible values are:

- `0` — Debug messages are disabled. This is the default.
- `1` — Debug messages are enabled.

**downdelay=time_in_milliseconds**

Specifies (in milliseconds) how long to wait after link failure before disabling the link. The value must be a multiple of the value specified in the `miimon` parameter. The value is set to `0` by default, which disables it.

**lacp_rate=value**

Specifies the rate at which link partners should transmit LACPDU packets in 802.3ad mode. Possible values are:

- `slow` or `0` — Default setting. This specifies that partners should transmit LACPDUs every 30 seconds.
- `fast` or `1` — Specifies that partners should transmit LACPDUs every 1 second.

**miimon=time_in_milliseconds**

Specifies (in milliseconds) how often MII link monitoring occurs. This is useful if high availability is required because MI is used to verify that the NIC is active. To verify that the driver for a particular NIC supports the MII tool, type the following command as `root`:

```bash
[-]# ethtool interface_name | grep "Link detected:"
```

In this command, replace `interface_name` with the name of the device interface, such as `eth0`, not the bond interface. If MII is supported, the command returns:

```
link detected: yes
```

If using a bonded interface for high availability, the module for each NIC must support MII. Setting the value to `0` (the default), turns this feature off. When configuring this setting, a good starting point for this parameter is `100`.

---

Make sure you specify all required parameters

It is essential that both `arp_interval` and `arp_ip_target` parameters are specified, or, alternatively, the `miimon` parameter is specified. Failure to do so can cause degradation of network performance in the event that a link fails.

---
mode=value

Allows you to specify the bonding policy. The value can be one of:

- **balance-rr** or **0** — Sets a round-robin policy for fault tolerance and load balancing. Transmissions are received and sent out sequentially on each bonded slave interface beginning with the first one available.
- **active-backup** or **1** — Sets an active-backup policy for fault tolerance. Transmissions are received and sent out via the first available bonded slave interface. Another bonded slave interface is only used if the active bonded slave interface fails.
- **balance-xor** or **2** — Sets an XOR (exclusive-or) policy for fault tolerance and load balancing. Using this method, the interface matches up the incoming request's MAC address with the MAC address for one of the slave NICs. Once this link is established, transmissions are sent out sequentially beginning with the first available interface.
- **broadcast** or **3** — Sets a broadcast policy for fault tolerance. All transmissions are sent on all slave interfaces.
- **802.3ad** or **4** — Sets an IEEE 802.3ad dynamic link aggregation policy. Creates aggregation groups that share the same speed and duplex settings. Transmits and receives on all slaves in the active aggregator. Requires a switch that is 802.3ad compliant.
- **balance-tlb** or **5** — Sets a Transmit Load Balancing (TLB) policy for fault tolerance and load balancing. The outgoing traffic is distributed according to the current load on each slave interface. Incoming traffic is received by the current slave. If the receiving slave fails, another slave takes over the MAC address of the failed slave.
- **balance-alb** or **6** — Sets an Active Load Balancing (ALB) policy for fault tolerance and load balancing. Includes transmit and receive load balancing for IPv4 traffic. Receive load balancing is achieved through ARP negotiation.

num_unsol_na=number

Specifies the number of unsolicited IPv6 Neighbor Advertisements to be issued after a failover event. One unsolicited NA is issued immediately after the failover.

The valid range is **0 - 255**; the default value is **1**. This parameter affects only the active-backup mode.

primary=interface_name

Specifies the interface name, such as **eth0**, of the primary device. The primary device is the first of the bonding interfaces to be used and is not abandoned unless it fails. This setting is particularly useful when one NIC in the bonding interface is faster and, therefore, able to handle a bigger load.

This setting is only valid when the bonding interface is in **active-backup** mode. Refer to

https://www.kernel.org/doc/Documentation/networking/bonding.txt

for more information.

primary_reselect=value

Specifies the reselection policy for the primary slave. This affects how the primary slave is chosen to become the active slave when failure of the active slave or recovery of the primary slave occurs. This parameter is designed to prevent flip-flopping between the primary slave and other slaves. Possible values are:

- **always** or **0** (default) — The primary slave becomes the active slave whenever it comes back up.
- **better** or **1** — The primary slave becomes the active slave when it comes back up, if the speed and duplex of the primary slave is better than the speed and duplex of the current active slave.
- **failure** or **2** — The primary slave becomes the active slave only if the current active slave fails and the primary slave is up.

The **primary_reselect** setting is ignored in two cases:

- If no slaves are active, the first slave to recover is made the active slave.
- When initially enslaved, the primary slave is always made the active slave.

Changing the **primary_reselect** policy via **sysfs** will cause an immediate selection of the best active slave according to the new policy. This may or may not result in a change of the active slave, depending upon the circumstances.

updelay=time_in_milliseconds

Specifies (in milliseconds) how long to wait before enabling a link. The value must be a multiple of the value specified in the **miimon** parameter. The value is set to **0** by default, which disables it.

use_carrier=number

Specifies whether or not **miimon** should use **MII/ETHTOOL** ioctls or **netif_carrier_ok()** to determine the link state. The **netif_carrier_ok()** function relies on the device driver to maintain its state with **netif_carrier_on/off**; most device drivers support this function.

The **MII/ETHTOOL** ioctls tools utilize a deprecated calling sequence within the kernel. However, this is still configurable in case your device driver does not support **netif_carrier_on/off**.

Valid values are:

- **1** — Default setting. Enables the use of **netif_carrier_ok()**.
- **0** — Enables the use of **MII/ETHTOOL** ioctls.
Note

If the bonding interface insists that the link is up when it should not be, it is possible that your network device driver does not support netif_carrier_on/off.

xmit_hash_policy=value

Selects the transmit hash policy used for slave selection in balance-xor and 802.3ad modes. Possible values are:

- 0 or layer2 — Default setting. This parameter uses the XOR of hardware MAC addresses to generate the hash. The formula used is:

  \[(\text{source_MAC_address} \oplus \text{destination_MAC}) \bmod \text{slave_count}\]

  This algorithm will place all traffic to a particular network peer on the same slave, and is 802.3ad compliant.

- 1 or layer3+4 — Uses upper layer protocol information (when available) to generate the hash. This allows for traffic to a particular network peer to span multiple slaves, although a single connection will not span multiple slaves.

  The formula for unfragmented TCP and UDP packets used is:

  \[
  ((\text{source_port} \oplus \text{dest_port}) \oplus ((\text{source_IP} \oplus \text{dest_IP}) \wedge 0xffff)) \bmod \text{slave_count}
  \]

  For fragmented TCP or UDP packets and all other IP protocol traffic, the source and destination port information is omitted. For non-IP traffic, the formula is the same as the layer2 transmit hash policy.

  This policy intends to mimic the behavior of certain switches, particularly, Cisco switches with PFC2 as well as some Foundry and IBM products.

  The algorithm used by this policy is not 802.3ad compliant.

- 2 or layer2+3 — Uses a combination of layer2 and layer3 protocol information to generate the hash.

  Uses XOR of hardware MAC addresses and IP addresses to generate the hash. The formula is:

  \[
  (((\text{source_IP} \oplus \text{dest_IP}) \wedge 0xffff) \oplus (\text{source_MAC} \oplus \text{destination_MAC})) \bmod \text{slave_count}
  \]

  This algorithm will place all traffic to a particular network peer on the same slave. For non-IP traffic, the formula is the same as for the layer2 transmit hash policy.

  This policy is intended to provide a more balanced distribution of traffic than layer2 alone, especially in environments where a layer3 gateway device is required to reach most destinations.

  This algorithm is 802.3ad compliant.

24.8. Additional Resources

For more information on kernel modules and their utilities, refer to the following resources.

24.8.1. Installed Documentation

There is a number of manual pages for various utilities related to the kernel modules:

man lsmod

The manual page for the lsmod command.

man modinfo

The manual page for the modinfo command.

man modprobe

The manual page for the modprobe command.

man rmmod

The manual page for the rmmod command.

man ethtool

The manual page for the ethtool command.

man mii-tool

The manual page for the mii-tool command.

Additionally, you can refer to the documentation provided by the kernel-doc package:

/usr/share/doc/kernel-doc-kernel_version/Documentation/

This directory contains information on the kernel, kernel modules, and their respective parameters. Note that before accessing the kernel documentation, you must run the following command as root:
yum install kernel-doc

24.8.2. Useful Websites

Linux Loadable Kernel Module HOWTO

The Linux Loadable Kernel Module HOWTO from the Linux Documentation Project contains further information on working with kernel modules.

Chapter 25. The kdump Crash Recovery Service

25.1. Installing the kdump Service

In order to use the kdump service on your system, make sure you have the kexec-tools package installed. To do so, type the following at a shell prompt as root:

```
yum install kexec-tools
```

For more information on how to install new packages in Fedora, refer to Section 5.2.4, “Installing Packages”.

25.2. Configuring the kdump Service

There are three common means of configuring the kdump service: at the first boot, using the Kernel Dump Configuration utility, and doing so manually on the command line.

Enable IOMMU on Intel chipsets

A limitation in the current implementation of the Intel IOMMU driver can occasionally prevent the kdump service from capturing the core dump image. To use kdump on Intel architectures reliably, it is advised that the IOMMU support is disabled.

25.2.1. Configuring the kdump at First Boot

When the system boots for the first time, the firstboot application is launched to guide the user through the initial configuration of the freshly installed system. To configure kdump, navigate to the Kdump section and follow the instructions below.
25.2.1. Enabling the Service
To allow the `kdump` daemon to start at boot time, select the `Enable kdump?` checkbox. This will enable the service and start it for the current session. Similarly, unselecting the checkbox will disable it and stop the service immediately.

25.2.2.1. Enabling the Service
To start the `kdump` daemon at boot time, click the `Enable` button on the toolbar. This will enable the service and start it for the current session. Similarly, clicking the `Disable` button will disable it and stop the service immediately.

For more information on system services and their configuration, refer to Chapter 9, Services and Daemons.

25.2.2.2. The Basic Settings Tab
The Basic Settings tab enables you to configure the amount of memory that is reserved for the `kdump` kernel. To do so, select the Manual `kdump` memory settings radio button, and click the up and down arrow buttons next to the `New kdump Memory` field to increase or decrease the value. Notice that the `Usable Memory` field changes accordingly showing you the remaining memory that will be available to the system.

25.2.2.3. The Target Settings Tab
The Target Settings tab enables you to specify the target location for the `vmcore` dump. It can be either stored as a file in a local file system, written directly to a device, or sent over a network using the NFS (Network File System) or SSH (Secure Shell) protocol.
To save the dump to the local file system, select the **Local filesystem** radio button. Optionally, you can customize the settings by choosing a different partition from the **Partition** pulldown list and a target directory from the **Path** pulldown list.

To write the dump directly to a device, select the **Raw device** radio button, and choose the desired target device from the pulldown list next to it.

To store the dump to a remote machine, select the **Network** radio button. To use the NFS protocol, select the **NFS** radio button, and fill the **Server name**, **Path to directory**, and **User name** fields with the remote server address, target directory, and a valid remote user name respectively. Refer to Chapter 11, **OpenSSH** for information on how to configure an SSH server, and how to set up a key-based authentication.

For a complete list of currently supported targets, see Table 25.1, "Supported kdump targets".

### Table 25.1. Supported kdump targets

<table>
<thead>
<tr>
<th>Type</th>
<th>Supported Targets</th>
<th>Unsupported Targets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw device</td>
<td>All locally attached raw disks and partitions.</td>
<td></td>
</tr>
<tr>
<td>Local filesystem</td>
<td>ext2, ext3, ext4, minix file systems on directly attached disk drives, hardware RAID logical drives, LVM devices, and mdraid arrays.</td>
<td>The eCryptfs file system.</td>
</tr>
<tr>
<td></td>
<td>Remote directories accessed using the iSCSI protocol over hardware initiators.</td>
<td>Remote directories accessed using the iSCSI protocol over software initiators.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Remote directories accessed using the IPv6.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Remote directories accessed using the SMB/CIFS protocol.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Remote directories accessed using the FCoE (Fibre Channel over Ethernet) protocol.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Remote directories accessed using wireless network interfaces.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Multipath-based storages.</td>
</tr>
</tbody>
</table>

### 25.2.2.4. The Filtering Settings Tab

The **Filtering Settings** tab enables you to select the filtering level for the vmcore dump.
To exclude the zero page, cache page, cache private, user data, or free page from the dump, select the checkbox next to the appropriate label.

25.2.2.5. The Expert Settings Tab

The Expert Settings tab enables you to choose which kernel and initial RAM disk to use, as well as to customize the options that are passed to the kernel and the core collector program.

![Figure 25.4. Expert Settings](image)

To use a different initial RAM disk, select the Custom initrd radio button, and choose the desired RAM disk from the pulldown list next to it.

To adjust the list of options that are passed to the kernel at boot time, edit the content of the Edited text field. Note that you can always revert your changes by clicking the Refresh button.

To choose what action to perform when kdump fails to create a core dump, select an appropriate option from the Default action pulldown list. Available options are mount rootfs and run/sbin/init (the default action), reboot (to reboot the system), shell (to present a user with an interactive shell prompt), halt (to halt the system), and poweroff (to power the system off).

25.2.3. Configuring kdump on the Command Line

25.2.3.1. Configuring the Memory Usage

To configure the amount of memory that is reserved for the kdump kernel, as root, edit the /etc/default/grub file and add the crashkernel=<size>M (or crashkernel=auto) parameter to the list of kernel options (the GRUB_CMDLINE_LINUX line). For example, to reserve 128 MB of memory, use:

```
GRUB_CMDLINE_LINUX="crashkernel=128M quiet rhgb"
```

Then update the configuration file for the GRUB 2 boot loader by typing the following at a shell prompt as root:

```
grub2-mkconfig -o /boot/grub2/grub.cfg
```

Make sure the system has enough memory

Unless the system has enough memory, this option will not be available. For the information on minimum memory requirements, refer to the Hardware Overview section of the Fedora 18 Release Notes. When the kdump crash recovery is enabled, the minimum memory requirements increase by the amount of memory reserved for it. This value is determined by the user, and defaults to 128 MB plus 64 MB for each TB of physical memory (that is, a total of 192 MB for a system with 1 TB of physical memory).

Using the crashkernel=auto parameter

In Fedora 18, the crashkernel=auto only reserves memory if the system has 4 GB of physical memory or more.

25.2.3.2. Configuring the Target Type

When a kernel crash is captured, the core dump can be either stored as a file in a local file system, written directly to a device, or sent over a network using the NFS (Network File System) or SSH (Secure Shell) protocol. Only one of these options can be set at the moment, and the default option is to store the vmcore file in the /var/crash/ directory of the local file system. To change this, as root, open the /etc/kdump.conf configuration file in a text editor and edit the options as described below.
To change the local directory in which the core dump is to be saved, remove the hash sign ("#") from the beginning of the `#path /var/crash` line, and replace the value with a desired directory path. Optionally, if you wish to write the file to a different partition, follow the same procedure with the `#ext4 /dev/sda3` line as well, and change both the file system type and the device (a device name, a file system label, and UUID are all supported) accordingly. For example:

```
#ext3 /dev/sda4
path /usr/local/cores
```

To write the dump directly to a device, remove the hash sign ("#") from the beginning of the `#raw /dev/sda5` line, and replace the value with a desired device name. For example:

```
raw /dev/sdb1
```

To store the dump to a remote machine using the NFS protocol, remove the hash sign ("#") from the beginning of the `#net my.server.com:/export/tmp` line, and replace the value with a valid hostname and directory path. For example:

```
net penguin.example.com:/export/cores
```

To store the dump to a remote machine using the SSH protocol, remove the hash sign ("#") from the beginning of the `#net user@my.server.com` line, and replace the value with a valid username and hostname. For example:

```
net john@penguin.example.com
```

Refer to Chapter 11, OpenSSH for information on how to configure an SSH server, and how to set up a key-based authentication.

For a complete list of currently supported targets, see Table 25.1, "Supported kdump targets".

25.2.3.3. Configuring the Core Collector

To reduce the size of the `vmcore` dump file, `kdump` allows you to specify an external application (that is, a core collector) to compress the data, and optionally leave out all irrelevant information. Currently, the only fully supported core collector is `makedumpfile`.

To enable the core collector, as `root`, open the `/etc/kdump.conf` configuration file in a text editor, remove the hash sign ("#") from the beginning of the `#core_collector makedumpfile -c --message-level 1 -d 31` line, and edit the command line options as described below.

To enable the dump file compression, add the `-c` parameter. For example:

```
core_collector makedumpfile -c
```

To remove certain pages from the dump, add the `-d value` parameter, where `value` is a sum of values of pages you want to omit as described in Table 25.2, "Supported filtering levels". For example, to remove both zero and free pages, use the following:

```
core_collector makedumpfile -d 17 -c
```

Refer to the manual page for `makedumpfile` for a complete list of available options.

Table 25.2. Supported filtering levels

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Zero pages</td>
</tr>
<tr>
<td>2</td>
<td>Cache pages</td>
</tr>
<tr>
<td>4</td>
<td>Cache private</td>
</tr>
<tr>
<td>8</td>
<td>User pages</td>
</tr>
<tr>
<td>16</td>
<td>Free pages</td>
</tr>
</tbody>
</table>

25.2.3.4. Changing the Default Action

By default, when `kdump` fails to create a core dump, the root file system is mounted and `/sbin/init` is run. To change this behavior, as `root`, open the `/etc/kdUMP.conf` configuration file in a text editor, remove the hash sign ("#") from the beginning of the `#default shell` line, and replace the value with a desired action as described in Table 25.3, "Supported actions".

```
default halt
```

25.2.3.5. Enabling the Service

To start the `kdUMP` daemon at boot time, type the following at a shell prompt as `root`:

```
```
Similarly, typing `systemctl disable kdump.service` will disable it. To start the service in the current session, use the following command as `root`:

```
systemctl start kdump.service
```

For more information on services and their configuration, refer to Chapter 9, Services and Daemons.

### 25.2.4. Testing the Configuration

> **Be careful when using these commands**
>
> The commands below will cause the kernel to crash. Use caution when following these steps, and by no means use them on a production machine.

To test the configuration, reboot the system with kdump enabled, and make sure that the service is running (refer to Section 9.2, “Running Services” for more information on how to run a service in Fedora):

```
systemctl is-active kdump.service
```

Then type the following commands at a shell prompt:

```
echo 1 > /proc/sys/kernel/sysrq
echo c > /proc/sysrq-trigger
```

This will force the Linux kernel to crash, and the `address-YYYY-MM-DD-HH:MM:SS/vmcore` file will be copied to the location you have selected in the configuration (that is, to `/var/crash/` by default).

### 25.3. Analyzing the Core Dump

To determine the cause of the system crash, you can use the `crash` utility, which provides an interactive prompt very similar to the GNU Debugger (GDB). This utility allows you to interactively analyze a running Linux system as well as a core dump created by `netdump`, `diskdump`, `xendump`, or `kdump`.

> **Make sure you have relevant packages installed**
>
> To analyze the `vmcore` dump file, you must have the `crash` and `kernel-debuginfo` packages installed. To install these packages, type the following at a shell prompt as `root`:

```
yum install crash
dependinfo-install kernel
```

For more information on how to install new packages in Fedora, refer to Section 5.2.4, “Installing Packages”.

### 25.3.1. Running the crash Utility

To start the utility, type the command in the following form at a shell prompt:

```
crash /var/crash/timestamp/vmcore /usr/lib/debug/lib/modules/kernel/vmlinux
```

Note that the `kernel` version should be the same that was captured by `kdump`. To find out which kernel you are currently running, use the `uname -r` command.
Example 25.1. Running the crash utility

```
-# crash /usr/lib/debug/lib/modules/2.6.32-69.el6.i686/vmlinux \
   /var/crash/127.0.0.1-2010-08-25:08:45:02/vmcORE
```

```
5.0.0-23.el6
Copyright (C) 2002-2010  Red Hat, Inc.
Copyright (C) 2004, 2005, 2006 IBM Corporation
Copyright (C) 1999-2006  Hewlett-Packard Co
Copyright (C) 2005, 2006  Fujitsu Limited
Copyright (C) 2006, 2007 VA Linux Systems Japan K.K.
Copyright (C) 2005  NEC Corporation
This program is free software, covered by the GNU General Public License,
and you are welcome to change it and/or distribute copies of it under
some conditions. Enter "help copying" to see the conditions.
This program has absolutely no warranty. Enter "help warranty" for details.

GNU gdb (GDB) 7.0
Copyright (C) 2009 Free Software Foundation, Inc.
License GPLv3+: GNU GPL version 3 or later <http://gnu.org/licenses/gpl.html>
This is free software: you are free to change and redistribute it.
There is NO WARRANTY, to the extent permitted by law. Type "show copying"
and "show warranty" for details.
This GDB was configured as "i686-pc-linux-gnu"...
```

 KERNEL: /usr/lib/debug/lib/modules/2.6.32-69.el6.i686/vmlinux
 DUMPFILE: /var/crash/127.0.0.1-2010-08-25-08:45:02/vmcORE  
 CPUS: 4
 LOAD AVERAGE: 0.00, 0.01, 0.00
 TASKS: 140
 NODENAME: hp-dl320g5-02.lab.bos.redhat.com
 RELEASE: 2.6.32-69.el6.i686
 VERSION: #1 SMP Tue Aug 24 10:31:45 EDT 2010
 MACHINE: i686  (2394 Mhz)
 MEMORY: 8 GB
 PANIC: "Oops: 0002 [s1] SMP " (check log for details)
 PID: 5591
 COMMAND: "bash"
 TASK: f196d560  
 CPU: 2
 STATE: TASK_RUNNING (PANIC)

```
crash>
```

25.3.2. Displaying the Message Buffer

To display the kernel message buffer, type the `log` command at the interactive prompt.

```
Example 25.2. Displaying the kernel message buffer

```

```
crash> log
... several lines omitted ...
EIP: 0060:[<c068124f>] EFLAGS: 00010096 CPU: 2
EAX: 00000063 EBX: 00000063 ECX: c09e1c8c EDX: 00000000
ESI: c0a09ca0 EDI: 00000286 EBP: 00000000 ESP: ef4dbf24
DS: 007b ES: 007b FS: 00d8 GS: 00e0 SS: 0068
Process bash (pid: 5591, ti=ef4da000 task=f196d560 task.ti=ef4da000)
Stack:
Call Trace:
```
```
crash>
```
```
```

Type `help log` for more information on the command usage.

25.3.3. Displaying a Backtrace

To display the kernel stack trace, type the `bt` command at the interactive prompt. You can use `bt pid` to display the backtrace of the selected process.
Example 25.3. Displaying the kernel stack trace

```
crash> bt
PID: 5591 TASK: f196d560 CPU: 2 COMMAND: "bash"
#0 [ef4dbdcc] crash_kexec at c0494922
#1 [ef4dbe20] oops_end at c080e402
#2 [ef4dbe34] no_context at c043089d
#3 [ef4dbe58] bad_area at c0438b26
#4 [ef4dbe6c] do_page_fault at c080fb9b
#5 [ef4dbbe4] error_code (via page_fault) at c080f09b
DS: 007b ESI: c09e1c8c EDX: 00000000 EBP: 00000000
crash>
```

Type `help bt` for more information on the command usage.

25.3.4. Displaying a Process Status

To display status of processes in the system, type the `ps` command at the interactive prompt. You can use `ps pid` to display the status of the selected process.

Example 25.4. Displaying status of processes in the system

```
crash> ps
PID    PPID  CPU   TASK    ST  %MEM     VSZ    RSS  COMM
>     0      0   0  c09dc560  RU   0.0       0      0  [swapper]
>     0      0   1  f7072030  RU   0.0       0      0  [swapper]
>     0      0   2  f70a3a90  RU   0.0       0      0  [swapper]
>     0      0   3  f70ac560  RU   0.0       0      0  [swapper]
1      0   1  f705ba90  IN   0.0    2828   1424  init
... several lines omitted ...
5566 5132   0  f196d560  IN   0.0   11064   3184  sshd
5591 5587   2  f196d560  RU   0.0    5084   1648  bash
```

Type `help ps` for more information on the command usage.

25.3.5. Displaying Virtual Memory Information

To display basic virtual memory information, type the `vm` command at the interactive prompt. You can use `vm pid` to display information on the selected process.

Example 25.5. Displaying virtual memory information of the current context

```
crash> vm
PID: 5591 TASK: f196d560 CPU: 2 COMMAND: "bash"
MM PIDG PGSZ MM        RSS  TOTAL_VM
f1bb31d 242000 260000 0000075 /lib/libc-2.12.so
f26af098 260000 261000 0180071 /lib/libc-2.12.so
fbc2a1b 260000 0000075 /lib/libc-2.12.so
fbc2b3d 3ed000 0000070 /lib/libc-2.12.so
fbc2b58 3ed000 0000070 /lib/libc-2.12.so
fbc2be8 3ed000 0000070 /lib/libc-2.12.so
fbc2c9c 3ed000 0000070 /lib/libc-2.12.so
fbc2d2c 3ed000 0000070 /lib/libc-2.12.so
fbc2d68 0000070 /lib/libc.so.1
fbc2e8a 0000070 /lib/libc.so.1
fbc2ef8 0000070 /lib/libc.so.1
fbc32b8 0000070 /lib/libc.so.1
fbc352c 0000070 /lib/libc.so.1
fbc35e8 0000070 /lib/libc.so.1
fbc36c0 0000070 /lib/libc.so.1
fbc36e0 0000070 /lib/libc.so.1
fbc37f8 0000070 /lib/libc.so.1
fbc384c 0000070 /lib/libc.so.1
fbc38a8 0000070 /lib/libc.so.1
fbc393c 0000070 /lib/libc.so.1
fbc3990 0000070 /lib/libc.so.1
fbc39e8 0000070 /lib/libc.so.1
fbc3a2c 0000070 /lib/libc.so.1
fbc3a88 0000070 /lib/libc.so.1
fbc3b4c 0000070 /lib/libc.so.1
fbc3c00 0000070 /lib/libc.so.1
fbc3c5c 0000070 /lib/libc.so.1
fbc3d00 0000070 /lib/libc.so.1
fbc3e88 0000070 /lib/libc.so.1
fbc3f4c 0000070 /lib/libc.so.1
fbc3f90 0000070 /lib/libc.so.1
fbc3f90 0000070 /lib/libc.so.1
fbc3f90 0000070 /lib/libc.so.1
fbc3f90 0000070 /lib/libc.so.1
fbc3f90 0000070 /lib/libc.so.1
fbc3f90 0000070 /lib/libc.so.1
fbc3f90 0000070 /lib/libc.so.1
fbc3f90 0000070 /lib/libc.so.1
fbc3f90 0000070 /lib/libc.so.1
fbc3f90 0000070 /lib/libc.so.1
fbc3f90 0000070 /lib/libc.so.1
... several lines omitted ...
```

Type `help vm` for more information on the command usage.
25.3.6. Displaying Open Files
To display information about open files, type the `files` command at the interactive prompt. You can use `files pid` to display files opened by the selected process.

```
Example 25.6. Displaying information about open files of the current context

```
crash> files
PID: 5591   TASK: f196d560  CPU: 2   COMMAND: "bash"
ROOT: /    CWD: /root
FD   FILE     DENTRY    INODE    TYPE  PATH
 0  f734f640  eedc2c6c  eecd6048  CHR   /pts/0
 1  efade5c0  eee14090  f00431d4  REG   /proc/sysrq-trigger
 2  f734f640  eedc2c6c  eecd6048  CHR   /pts/0
10  f734f640  eedc2c6c  eecd6048  CHR   /pts/0
255 f734f640  eedc2c6c  eecd6048  CHR   /pts/0
```

Type `help files` for more information on the command usage.

25.3.7. Exiting the Utility
To exit the interactive prompt and terminate `crash`, type `exit` or `q`.

```
Example 25.7. Exiting the crash utility

```
crash> exit
~]#
```

25.4. Additional Resources

25.4.1. Installed Documentation
- `kdump.conf(5)` — a manual page for the `/etc/kdump.conf` configuration file containing the full documentation of available options.
- `makedumpfile(8)` — a manual page for the `makedumpfile` core collector.
- `kexec(8)` — a manual page for `kexec`.
- `crash(8)` — a manual page for the `crash` utility.

25.4.2. Useful Websites
- [https://access.redhat.com/kb/docs/DOC-6039](https://access.redhat.com/kb/docs/DOC-6039)
  The Red Hat Knowledgebase article about the `kexec` and `kdump` configuration.
- [https://access.redhat.com/kb/docs/DOC-45183](https://access.redhat.com/kb/docs/DOC-45183)
  The Red Hat Knowledgebase article about supported `kdump` targets.
- [http://people.redhat.com/anderson/](http://people.redhat.com/anderson/)
  The `crash` utility homepage.

**Consistent Network Device Naming**

Fedora 18 provides consistent network device naming for network interfaces. This feature changes the name of network interfaces on a system in order to make locating and differentiating the interfaces easier.

Traditionally, network interfaces in Linux are enumerated as `eth[0123...]`, but these names do not necessarily correspond to actual labels on the chassis. Modern server platforms with multiple network adapters can encounter non-deterministic and counter-intuitive naming of these interfaces. This affects both network adapters embedded on the motherboard (Lan-on-Motherboard, or LOM) and add-in (single and multiport) adapters.

The new naming convention assigns names to network interfaces based on their physical location, whether embedded or in PCI slots. By converting to this naming convention, system administrators will no longer have to guess at the physical location of a network port, or modify each system to rename them into some consistent order.

This feature, implemented via the `biosdevname` program, will change the name of all embedded network interfaces, PCI card network interfaces, and virtual function network interfaces from the existing `eth[0123...]` to the new naming convention as shown in Table A.1, "The new naming convention".
Table A.1. The new naming convention

<table>
<thead>
<tr>
<th>Device</th>
<th>Old Name</th>
<th>New Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Embedded network interface (LOM)</td>
<td>eth[0123...&gt;</td>
<td>em[1234...&gt;</td>
</tr>
<tr>
<td>PCI card network interface</td>
<td>eth[0123...&gt;</td>
<td>p&lt;slot&gt;p&lt;ethernet port&gt;</td>
</tr>
<tr>
<td>Virtual function</td>
<td>eth[0123...&gt;</td>
<td>p&lt;slot&gt;p&lt;ethernet port&gt;_&lt;virtual interface&gt;</td>
</tr>
</tbody>
</table>

- New enumeration starts at 1
- For example: p3p4
- For example: p3p4_1

A.1. System Requirements

The biosdevname program uses information from the system's BIOS, specifically the type 9 (System Slot) and type 41 (Onboard Devices Extended Information) fields contained within the SMBIOS. If the system's BIOS does not have SMBIOS version 2.6 or higher and this data, the new naming convention will not be used. Most older hardware does not support this feature because of a lack of BIOSes with the correct SMBIOS version and field information. For BIOS or SMBIOS version information, contact your hardware vendor.

For this feature to take effect, the biosdevname package must also be installed. The biosdevname package is part of the base package group in Fedora 18. All install options, except for Minimal Install, include this package.

A.2. Enabling and Disabling the Feature

To disable the consistent network device naming on systems that would normally have it on by default, pass the following option on the boot command line, both during and after installation:

- biosdevname=0

To enable this feature, pass the following option on the boot command line, both during and after installation:

- biosdevname=1

Unless the system meets the minimum requirements (see Section A.1, “System Requirements”), this option will be ignored and the system will boot with the traditional network interface name format.

If the biosdevname install option is specified, it must remain as a boot option for the lifetime of the system.

A.3. Notes for Administrators

Many system customization files can include network interface names, and thus will require updates if moving a system from the old convention to the new convention. If you use the new naming convention, you will also need to update network interface names in areas such as custom iptables rules, scripts altering irqbalance, and other similar configuration files. Also, enabling this change for installation will require modification to existing kickstart files that use device names via the ksdevice parameter; these kickstart files will need to be updated to use the network device's MAC address or the network device's new name.

RPM

The RPM Package Manager (RPM) is an open packaging system, which runs on Fedora as well as other Linux and UNIX systems. Red Hat, Inc. and the Fedora Project encourage other vendors to use RPM for their own products. RPM is distributed under the terms of the GPL (GNU General Public License).

The RPM Package Manager only works with packages built to work with the RPM format. RPM is itself provided as a pre-installed rpm package. For the end user, RPM makes system updates easy. Installing, uninstalling and upgrading RPM packages can be accomplished with short commands. RPM maintains a database of installed packages and their files, so you can invoke powerful queries and verifications on your system.

The RPM package format has been improved for Fedora 18. RPM packages are now compressed using the XZ lossless data compression format, which has the benefit of greater compression and less CPU usage during decompression, and support multiple strong hash algorithms, such as SHA-256, for package signing and verification.

Use Yum Instead of RPM Whenever Possible

For most package management tasks, the Yum package manager offers equal and often greater capabilities and utility than RPM. Yum also performs and tracks complicated system dependency resolution, and will complain and force system integrity checks if you use RPM as well to install and remove packages. For these reasons, it is highly recommended that you use Yum instead of RPM whenever possible to perform package management tasks. Refer to Chapter 5, Yum.

If you prefer a graphical interface, you can use the PackageKit GUI application, which uses Yum as its back end, to manage your system's packages. Refer to Chapter 6, PackageKit for details.
Install RPM packages with the correct architecture!

When installing a package, ensure it is compatible with your operating system and processor architecture. This can usually be determined by checking the package name. Many of the following examples show RPM packages compiled for the AMD64/Intel 64 computer architectures; thus, the RPM file name ends in `x86_64.rpm`.

During upgrades, RPM handles configuration files carefully, so that you never lose your customizations—something that you cannot accomplish with regular `.tar.gz` files.

For the developer, RPM allows you to take software source code and package it into source and binary packages for end users. This process is quite simple and is driven from a single file and optional patches that you create. This clear delineation between pristine sources and your patches along with build instructions eases the maintenance of the package as new versions of the software are released.

Running rpm commands must be performed as root

Because RPM makes changes to your system, you must be logged in as root to install, remove, or upgrade an RPM package.

B.1. RPM Design Goals

To understand how to use RPM, it can be helpful to understand the design goals of RPM:

**Upgradability**

With RPM, you can upgrade individual components of your system without completely reinstalling. When you get a new release of an operating system based on RPM, such as Fedora, you do not need to reinstall a fresh copy of the operating system your machine (as you might need to with operating systems based on other packaging systems). RPM allows intelligent, fully-automated, in-place upgrades of your system. In addition, configuration files in packages are preserved across upgrades, so you do not lose your customizations. There are no special upgrade files needed to upgrade a package because the same RPM file is used to both install and upgrade the package on your system.

**Powerful Querying**

RPM is designed to provide powerful querying options. You can perform searches on your entire database for packages or even just certain files. You can also easily find out what package a file belongs to and from where the package came. The files an RPM package contains are in a compressed archive, with a custom binary header containing useful information about the package and its contents, allowing you to query individual packages quickly and easily.

**System Verification**

Another powerful RPM feature is the ability to verify packages. If you are worried that you deleted an important file for some package, you can verify the package. You are then notified of anomalies, if any—at which point you can reinstall the package, if necessary. Any configuration files that you modified are preserved during reinstallation.

**Pristine Sources**

A crucial design goal was to allow the use of pristine software sources, as distributed by the original authors of the software. With RPM, you have the pristine sources along with any patches that were used, plus complete build instructions. This is an important advantage for several reasons. For instance, if a new version of a program is released, you do not necessarily have to start from scratch to get it to compile. You can look at the patch to see what you might need to do. All the compiled-in defaults, and all of the changes that were made to get the software to build properly, are easily visible using this technique.

The goal of keeping sources pristine may seem important only for developers, but it results in higher quality software for end users, too.

B.2. Using RPM

RPM has five basic modes of operation (not counting package building): installing, uninstalling, upgrading, querying, and verifying. This section contains an overview of each mode. For complete details and options, try `rpm --help` or `man rpm`. You can also refer to Section B.5, “Additional Resources” for more information on RPM.

B.2.1. Finding RPM Packages

Before using any RPM packages, you must know where to find them. An internet search returns many RPM repositories, but if you are looking for Red Hat RPM packages, they can be found at the following locations:

- The Fedora installation media contain many installable RPMs.
- The initial RPM repositories provided with the YUM package manager. Refer to Chapter 5, Yum for details on how to use the official Fedora package repositories.
- The active Fedora mirrors contains many installable RPMs: [http://mirrors.fedoraproject.org/publiclist/](http://mirrors.fedoraproject.org/publiclist/).
- Unofficial, third-party repositories not affiliated with The Fedora Project also provide RPM packages.
When considering third-party repositories for use with your Fedora system, pay close attention to the repository's web site with regard to package compatibility before adding the repository as a package source. Alternate package repositories may offer different, incompatible versions of the same software, including packages already included in the Fedora repositories.

B.2.2. Installing and Upgrading

RPM packages typically have file names like `tree-1.5.3-2.fc18.x86_64.rpm`. The file name includes the package name (`tree`), version (1.5.3), release (2), operating system major version (`fc18`) and CPU architecture (`x86_64`).

You can use `rpm` `-U` option to:

- upgrade an existing but older package on the system to a newer version, or
- install the package even if an older version is not already installed.

That is, `rpm -U <rpm_file>` is able to perform the function of either upgrading or installing as is appropriate for the package.

Assuming the `tree-1.5.3-2.fc18.x86_64.rpm` package is in the current directory, log in as root and type the following command at a shell prompt to either upgrade or install the `tree` package as determined by `rpm`:

```
rpm -Uvh tree-1.5.3-2.fc18.x86_64.rpm
```

Use `-Uvh` for nicely-formatted RPM installs

The `-v` and `-h` options (which are combined with `-U`) cause `rpm` to print more verbose output and display a progress meter using hash signs.

If the upgrade/installation is successful, the following output is displayed:

```
Preparing...                ########################################### [100%]
1:tree                   ########################################### [100%]
```

Always use the `-i` (install) option to install new kernel packages!

`rpm` provides two different options for installing packages: the aforementioned `-U` option (which historically stands for upgrade), and the `-i` option, historically standing for install. Because the `-U` option subsumes both install and upgrade functions, we recommend to use `rpm` `-Uvh` with all packages except kernel packages.

You should always use the `-i` option to simply install a new kernel package instead of upgrading it. This is because using the `-U` option to upgrade a kernel package removes the previous (older) kernel package, which could render the system unable to boot if there is a problem with the new kernel. Therefore, use the `rpm -i <kernel_package>` command to install a new kernel without replacing any older kernel packages. For more information on installing kernel packages, refer to Chapter 23, Manually Upgrading the Kernel.

The signature of a package is checked automatically when installing or upgrading a package. The signature confirms that the package was signed by an authorized party. For example, if the verification of the signature fails, an error message such as the following is displayed:

```
error: tree-1.5.2.2-4.fc18.x86_64.rpm: Header V3 RSA/SHA256 signature: BAD, key ID d22e77f2
```

If it is a new, header-only, signature, an error message such as the following is displayed:

```
error: tree-1.5.2.2-4.fc18.x86_64.rpm: Header V3 RSA/SHA256 signature: BAD, key ID d22e77f2
```

If you do not have the appropriate key installed to verify the signature, the message contains the word `NOKEY`:

```
warning: tree-1.5.2.2-4.fc18.x86_64.rpm: Header V3 RSA/SHA1 signature: NOKEY, key ID 57bbccba
```

Refer to Section B.3, "Checking a Package's Signature" for more information on checking a package's signature.

B.2.2.1. Package Already Installed

If a package of the same name and version is already installed, the following output is displayed:

```
Preparing...                ########################################### [100%]
package tree-1.5.3-2.fc18.x86_64 is already installed
```

However, if you want to install the package anyway, you can use the `--replacepkgs` option, which tells RPM to ignore the error:

```
rpm -Uvh --replacepkgs tree-1.5.3-2.fc18.x86_64.rpm
```

This option is helpful if files installed from the RPM were deleted or if you want the original configuration files from the RPM to be installed.
B.2.2.2. Conflicting Files
If you attempt to install a package that contains a file which has already been installed by another package, the following is displayed:

```
Preparing... ##################################################
file /usr/bin/foobar from install of foo-1.0-1.fc18.x86_64 conflicts
with file from package bar-3.1.1.fc18.x86_64
```

To make RPM ignore this error, use the `--replacefiles` option:

```
rpm -Uvh --replacefiles foo-1.0-1.fc18.x86_64.rpm
```

B.2.2.3. Unresolved Dependency
RPM packages may sometimes depend on other packages, which means that they require other packages to be installed to run properly. If you try to install a package which has an unresolved dependency, output similar to the following is displayed:

```
error: Failed dependencies:
  bar.so.3()(64bit) is needed by foo-1.0-1.fc18.x86_64
```

If you are installing a package from the Fedora installation media, such as from a CD-ROM or DVD, the dependencies may be available. Find the suggested package(s) on the Fedora installation media or on one of the active Fedora mirrors and add it to the command:

```
rpm -Uvh foo-1.0-1.fc18.x86_64.rpm    bar-3.1.1.fc18.x86_64.rpm
```

If installation of both packages is successful, output similar to the following is displayed:

```
Preparing...                ########################################### [100%]
1:foo                   ########################################### [ 50%]
2:bar                   ########################################### [100%]
```

You can try the `--whatprovides` option to determine which package contains the required file.

```
rpm -q --whatprovides "bar.so.3"
```

If the package that contains `bar.so.3` is in the RPM database, the name of the package is displayed:

```
bar-3.1.1.fc18.i586.rpm
```

Warning: Forcing Package Installation
Although we can force rpm to install a package that gives us a `Failed dependencies` error (using the `--nodeps` option), this is not recommended, and will usually result in the installed package failing to run. Installing or removing packages with `rpm --nodeps` can cause applications to misbehave and/or crash, and can cause serious package management problems or, possibly, system failure. For these reasons, it is best to heed such warnings; the package manager—whether RPM, Yum or PackageKit—shows us these warnings and suggests possible fixes because accounting for dependencies is critical. The Yum package manager can perform dependency resolution and fetch dependencies from online repositories, making it safer, easier and smarter than forcing rpm to carry out actions without regard to resolving dependencies.

B.2.3. Configuration File Changes
Because RPM performs intelligent upgrading of packages with configuration files, you may see one or the other of the following messages:

```
saving /etc/foo.conf as /etc/foo.conf.rpmsave
```

This message means that changes you made to the configuration file may not be `forward-compatible` with the new configuration file in the package, so RPM saved your original file and installed a new one. You should investigate the differences between the two configuration files and resolve them as soon as possible, to ensure that your system continues to function properly.

Alternatively, RPM may save the package’s `new` configuration file as, for example, `foo.conf.rpmnew`, and leave the configuration file you modified untouched. You should still resolve any conflicts between your modified configuration file and the new one, usually by merging changes from the old one to the new one with a `diff` program.

If you attempt to upgrade to a package with an `older` version number (that is, if a higher version of the package is already installed), the output is similar to the following:

```
package foo-2.0-1.fc18.x86_64.rpm (which is newer than foo-1.0-1) is already installed
```

To force RPM to upgrade anyway, use the `--oldpackage` option:

```
rpm -Uvh --oldpackage foo-1.0-1.fc18.x86_64.rpm
```

B.2.4. Uninstalling
Uninstalling a package is just as simple as installing one. Type the following command at a shell prompt:

```
rpm -e foo
```
Notice that we used the package name foo, not the name of the original package file, foo-1.0-1.fc18.x86_64.
If you attempt to uninstall a package using the rpm -e command and the original full file name, you will receive a package name error.

You can encounter dependency errors when uninstalling a package if another installed package depends on the one you are trying to remove. For example:

```
rpm -e ghostscript
error: Failed dependencies:
  libgs.so.8()(64bit) is needed by (installed) libspectre-0.2.2-3.fc18.x86_64
  libgs.so.8()(64bit) is needed by (installed) foomatic-4.0.3-1.fc18.x86_64
  libijs-0.35.so()(64bit) is needed by (installed) gutenprint-5.2.4-5.fc18.x86_64
  ghostscript is needed by (installed) printer-filters-1.1-4.fc18.noarch
```

Similar to how we searched for a shared object library (i.e. a `<library_name>.so.<number>` file) in Section B.2.2.3, "Unresolved Dependency", we can search for a 64-bit shared object library using this exact syntax (and making sure to quote the file name):

```
% rpm -q --whatprovides "libgs.so.8()(64bit)"
ghostscript-8.70-1.fc18.x86_64
```

Warning: Forcing Package Installation

Although we can force rpm to remove a package that gives us a Failed dependencies error (using the --nodeps option), this is not recommended, and may cause harm to other installed applications. Installing or removing packages with rpm --nodeps can cause applications to misbehave and/or crash, and can cause serious package management problems or, possibly, system failure. For these reasons, it is best to heed such warnings; the package manager—whether RPM, Yum or PackageKit—shows us these warnings and suggests possible fixes because accounting for dependencies is critical. The Yum package manager can perform dependency resolution and fetch dependencies from online repositories, making it safer, easier and smarter than forcing rpm to carry out actions without regard to resolving dependencies.

B.2.5. Freshening

Freshening is similar to upgrading, except that only existent packages are upgraded. Type the following command at a shell prompt:

```
rpm -Fvh foo-2.0-1.fc18.x86_64.rpm
```

RPM's freshen option checks the versions of the packages specified on the command line against the versions of packages that have already been installed on your system. When a newer version of an already-installed package is processed by RPM's freshen option, it is upgraded to the newer version. However, RPM's freshen option does not install a package if no previously-installed package of the same name exists. This differs from RPM's upgrade option, as an upgrade does install packages whether or not an older version of the package was already installed.

Freshening works for single packages or package groups. If you have just downloaded a large number of different packages, and you only want to upgrade those packages that are already installed on your system, freshening does the job. Thus, you do not have to delete any unwanted packages from the group that you downloaded before using RPM.

In this case, issue the following with the *.*.rpm glob:

```
rpm -Fvh *.rpm
```

RPM then automatically upgrades only those packages that are already installed.

B.2.6. Querying

The RPM database stores information about all RPM packages installed in your system. It is stored in the directory `/var/lib/rpm/`, and is used to query what packages are installed, what versions each package is, and to calculate any changes to any files in the package since installation, among other use cases.

To query this database, use the -q option. The rpm -q package name command displays the package name, version, and release number of the installed package `<package_name>`. For example, using rpm -q tree to query installed package tree might generate the following output:

```
tree-1.5.2.2-4.fc18.x86_64
```

You can also use the following Package Selection Options (which is a subheading in the RPM man page: see man rpm for details) to further refine or qualify your query:

```
  -a — queries all currently installed packages.
  -f <file_name> — queries the RPM database for which package owns <file_name> . Specify the absolute path of the file (for example, rpm -qf /bin/ls instead of rpm -qf ls).
  -p <package_file> — queries the uninstalled package <package_file> .
```

There are a number of ways to specify what information to display about queried packages. The following options are used to select the type of information for which you are searching. These are called the Package Query Options:

```
  -i displays package information including name, description, release, size, build date, install date, vendor, and other
```
miscellaneous information.

- -l displays the list of files that the package contains.
- -s displays the state of all the files in the package.
- -d displays a list of files marked as documentation (man pages, info pages, READMEs, etc.) in the package.
- -c displays a list of files marked as configuration files. These are the files you edit after installation to adapt and customize the package to your system (for example, sendmail.cf, passwd, inittab, etc.).

For options that display lists of files, add -v to the command to display the lists in a familiar ls -l format.

**B.2.7. Verifying**

Verifying a package compares information about files installed from a package with the same information from the original package. Among other things, verifying compares the file size, MD5 sum, permissions, type, owner, and group of each file.

The command rpm -V verifies a package. You can use any of the Verify Options listed for querying to specify the packages you wish to verify. A simple use of verifying is rpm -V tree, which verifies that all the files in the tree package are as they were when they were originally installed. For example:

```bash
rpm -Vf /usr/bin/tree
```

In this example, /usr/bin/tree is the absolute path to the file used to query a package.

> To verify ALL installed packages throughout the system (which will take some time):

```bash
rpm -Va
```

> To verify an installed package against an RPM package file:

```bash
rpm -Vp tree-1.5.2.2-4.fc18.x86_64.rpm
```

This command can be useful if you suspect that your RPM database is corrupt.

If everything verified properly, there is no output. If there are any discrepancies, they are displayed. The format of the output is a string of eight characters (a "c" denotes a configuration file) and then the file name. Each of the eight characters denotes the result of a comparison of one attribute of the file to the value of that attribute recorded in the RPM database. A single period (.) means the test passed. The following characters denote specific discrepancies:

- S — MD5 checksum
- S — file size
- L — symbolic link
- T — file modification time
- D — device
- U — user
- G — group
- M — mode (includes permissions and file type)
- ? — unreadable file (file permission errors, for example)

If you see any output, use your best judgment to determine if you should remove the package, reinstall it, or fix the problem in another way.

**B.3. Checking a Package's Signature**

To verify that a package has not been corrupted or tampered with, examine the checksum by typing the following command at a shell prompt (where `<rpm_file>` is the file name of the RPM package):

```bash
rpm -K --nosignature <rpm_file>
```

If the message `<rpm_file>`: sha1 md5 OK (specifically the OK part of it) is displayed, the file was not corrupted during download. To see a more verbose message, replace -K with -Kv in the command.

On the other hand, how trustworthy is the developer who created the package? If the package is signed with the developer's GnuPG key, you know that the developer really is who they say they are.

An RPM package can be signed using GNU Privacy Guard (or GnuPG), to help you make certain your downloaded package is trustworthy.

GnuPG is a tool for secure communication; it is a complete and free replacement for the encryption technology of PGP, an electronic privacy program. With GnuPG, you can authenticate the validity of documents and encrypt/decrypt data to and from other recipients. GnuPG is capable of decrypting and verifying PGP 5.x files as well.

During installation, GnuPG is installed by default, which enables you to immediately start using it to verify any packages that you download from the Fedora Project. Before doing so, you first need to import the correct Fedora key.

**B.3.1. Importing Keys**

Fedora GnuPG keys are located in the `/etc/pki/rpm-gpg/` directory. To verify a Fedora Project package, first import the correct key based on your processor architecture:
To display a list of all keys installed for RPM verification, execute the command:

```
 rpm --import /etc/pki/rpm-gpg/RPM-GPG-KEY-fedora-x86_64
```

For the Fedora Project key, the output states:

```
gpg-pubkey-57bbccba-4a6f97af
```

To display details about a specific key, use `rpm -qi` followed by the output from the previous command:

```
rpm -qi gpg-pubkey-57bbccba-4a6f97af
```

### B.3.2. Verifying Signature of Packages

To check the GnuPG signature of an RPM file after importing the builder's GnuPG key, use the following command (replace `<rpm_file>` with the file name of the RPM package):

```
rpm -K <rpm_file>
```

If all goes well, the following message is displayed: `rsa sha1 (md5) pgp md5 OK`. This means that the signature of the package has been verified, that it is not corrupt, and is therefore safe to install and use.

For more information, including a list of currently-used Fedora Project keys and their fingerprints, refer to [http://fedoraproject.org/en/keys](http://fedoraproject.org/en/keys).

### B.4. Practical and Common Examples of RPM Usage

RPM is a useful tool for both managing your system and diagnosing and fixing problems. The best way to make sense of all its options is to look at some examples.

- **Perhaps you have deleted some files by accident, but you are not sure what you deleted. To verify your entire system and see what might be missing, you could try the following command:**

  ```
rpm -Va
  ```

  If some files are missing or appear to have been corrupted, you should probably either re-install the package or uninstall and then re-install the package.

- **At some point, you might see a file that you do not recognize. To find out which package owns it, enter:**

  ```
rpm -qf /usr/bin/ghostscript
  ```

  The output would look like the following:

  ```
  ghostscript-8.70-1.fc18.x86_64
  ```

- **We can combine the above two examples in the following scenario. Say you are having problems with `/usr/bin/paste`. You would like to verify the package that owns that program, but you do not know which package owns `paste`. Enter the following command,**

  ```
rpm -Vf /usr/bin/paste
  ```

  and the appropriate package is verified.

- **Do you want to find out more information about a particular program? You can try the following command to locate the documentation which came with the package that owns that program:**

  ```
rpm -qdf /usr/bin/free
  ```

  The output would be similar to the following:

  ```
  /usr/share/doc/procps-3.2.8/BUGS
  /usr/share/doc/procps-3.2.8/FAQ
  /usr/share/doc/procps-3.2.8/NEWS
  /usr/share/doc/procps-3.2.8/TODD
  /usr/share/man/man1/free.1.gz
  /usr/share/man/man1/pgrep.1.gz
  /usr/share/man/man1/pkill.1.gz
  /usr/share/man/man1/pmap.1.gz
  /usr/share/man/man1/pfax.1.gz
  /usr/share/man/man1/pwdx.1.gz
  /usr/share/man/man1/slabtop.1.gz
  /usr/share/man/man1/snice.1.gz
  /usr/share/man/man1/tload.1.gz
  /usr/share/man/man1/top.1.gz
  /usr/share/man/man1/uptime.1.gz
  /usr/share/man/man1/w.1.gz
  /usr/share/man/man1/watch.1.gz
  /usr/share/man/man5/sysctl.conf.5.gz
  /usr/share/man/man8/sysctl.8.gz
  /usr/share/man8/vmstat.8.gz
  ```

- **You may find a new RPM, but you do not know what it does. To find information about it, use the following command:**

  ```
rpm -qip crontabs-1.10-31.fc18.noarch.rpm
  ```
The output would be similar to the following:

```
Name        : crontabs                     Relocations: (not relocatable)
Size        : 2486                             License: Public Domain and GPLv2
Signature   : RSA/SHA1, Tue 11 Aug 2009 01:11:19 PM CEST, Key ID 9d1cc34857baccba
Packager    : Fedora Project
Summary     : Root crontab files used to schedule the execution of programs
Description :
The crontabs package contains root crontab files and directories. You will need to install cron daemon to run the jobs from the crontabs. The cron daemon such as cronie or fcron checks the crontab files to see when particular commands are scheduled to be executed. If commands are scheduled, it executes them. Crontabs handles a basic system function, so it should be installed on your system.
```

Perhaps you now want to see what files the crontabs RPM package installs. You would enter the following:

```
rpm -qlp crontabs-1.10-31.fc18.noarch.rpm
```

The output is similar to the following:

```
/etc/cron.daily
/etc/cron.hourly
/etc/cron.monthly
/etc/cron.weekly
/etc/crontab
/usr/bin/run-parts
/usr/share/man/man4/crontabs.4.gz
```

These are just a few examples. As you use RPM, you may find more uses for it.

B.5. Additional Resources

RPM is an extremely complex utility with many options and methods for querying, installing, upgrading, and removing packages. Refer to the following resources to learn more about RPM.

B.5.1. Installed Documentation

```
rpm --help
```

This command displays a quick reference of RPM parameters.

```
man rpm
```

The RPM man page gives more detail about RPM parameters than the `rpm --help` command.

B.5.2. Useful Websites

```
The RPM website — http://www.rpm.org/
The RPM mailing list can be subscribed to, and its archives read from, here — https://lists.rpm.org/mailman/listinfo/rpm-list
```

B.5.3. Related Books

Maximum RPM — http://www.rpm.org/max-rpm/

The Maximum RPM book, which you can read online, covers everything from general RPM usage to building your own RPMs to programming with rpmlib.

The X Window System

While the heart of Fedora is the kernel, for many users, the face of the operating system is the graphical environment provided by the X Window System, also called X.

Other windowing environments have existed in the UNIX world, including some that predate the release of the X Window System in June 1984. Nonetheless, X has been the default graphical environment for most UNIX-like operating systems, including Fedora, for many years.

The graphical environment for Fedora is supplied by the X.Org Foundation, an open source organization created to manage development and strategy for the X Window System and related technologies. X.Org is a large-scale, rapid-developing project with hundreds of developers around the world. It features a wide degree of support for a variety of hardware devices and architectures, and runs on myriad operating systems and platforms.

The X Window System uses a client-server architecture. Its main purpose is to provide network transparent window system, which runs on a wide range of computing and graphics machines. The X server (the Xorg binary) listens for connections from X client applications via a network or local loopback interface. The server communicates with the hardware, such as the video card, monitor, keyboard, and mouse. X client applications exist in the user space, creating a graphical user interface (GUI) for the user and passing user requests to the X server.
C.1. The X Server

Fedora 18 uses X server version, which includes several video drivers, EXA, and platform support enhancements over the previous release, among others. In addition, this release includes several automatic configuration features for the X server, as well as the generic input driver, *evdev*, that supports all input devices that the kernel knows about, including most mice and keyboards.

X11R7.1 was the first release to take specific advantage of the modularization of the X Window System. With it, X is split into logically distinct modules, which make it easier for open source developers to contribute code to the system.

In the current release, all libraries, headers, and binaries live under the `/usr/` directory. The `/etc/X11/` directory contains configuration files for X client and server applications. This includes configuration files for the X server itself, the X display managers, and many other base components.

The configuration file for the newer Fontconfig-based font architecture is still `/etc/fonts/fonts.conf`. For more information on configuring and adding fonts, refer to Section C.4, “Fonts”.

Because the X server performs advanced tasks on a wide array of hardware, it requires detailed information about the hardware it works on. The X server is able to automatically detect most of the hardware that it runs on and configure itself accordingly. Alternatively, hardware can be manually specified in configuration files.

The Fedora system installer, Anaconda, installs and configures X automatically, unless the X packages are not selected for installation. If there are any changes to the monitor, video card or other devices managed by the X server, most of the time, X detects and reconfigures these changes automatically. In rare cases, X must be reconfigured manually.

C.2. Desktop Environments and Window Managers

Once an X server is running, X client applications can connect to it and create a GUI for the user. A range of GUIs are available with Fedora, from the rudimentary *Tab Window Manager* (twm) to the highly developed and interactive desktop environment (such as GNOME or KDE) that most Fedora users are familiar with.

To create the latter, more comprehensive GUI, two main classes of X client application must connect to the X server: a window manager and a desktop environment.

C.2.1. Desktop Environments

A desktop environment integrates various X clients to create a common graphical user environment and a development platform.

Desktop environments have advanced features allowing X clients and other running processes to communicate with one another, while also allowing all applications written to work in that environment to perform advanced tasks, such as drag-and-drop operations.

Fedora provides two desktop environments:

- **GNOME** — The default desktop environment for Fedora based on the GTK+ 2 graphical toolkit.
- **KDE** — An alternative desktop environment based on the Qt 4 graphical toolkit.

Both GNOME and KDE have advanced-productivity applications, such as word processors, spreadsheets, and Web browsers; both also provide tools to customize the look and feel of the GUI. Additionally, if both the GTK+ 2 and the Qt libraries are present, KDE applications can run in GNOME and vice versa.

C.2.2. Window Managers

Window managers are X client programs which are either part of a desktop environment or, in some cases, stand-alone. Their primary purpose is to control the way graphical windows are positioned, resized, or moved. Window managers also control title bars, window focus behavior, and user-specified key and mouse button bindings.

The Fedora repositories provide five different window managers:

- **metacity**
  
  The Metacity window manager is the default window manager for GNOME. It is a simple and efficient window manager which supports custom themes. This window manager is automatically pulled in as a dependency when the GNOME desktop is installed.

- **kwin**
  
  The KWin window manager is the default window manager for KDE. It is an efficient window manager which supports custom themes. This window manager is automatically pulled in as a dependency when the KDE desktop is installed.

- **compiz**
  
  The Compiz compositing window manager is based on OpenGL and can use 3D graphics hardware to create fast compositing desktop effects for window management. Advanced features, such as a cube workspace, are implemented as loadable plug-ins. To run this window manager, you need to install the **compiz** package.

**mwm**

The Motif Window Manager (**mwm**) is a basic, stand-alone window manager. Since it is designed to be stand-alone, it...
C.3. X Server Configuration Files

The X server is a single binary executable /usr/bin/Xorg; a symbolic link pointing to this file is also provided. Associated configuration files are stored in the /etc/X11/ and /usr/share/X11/ directories.

The X Window System supports two different configuration schemes. Configuration files in the xorg.conf file contain preconfigured settings from vendors and from distribution, and these files should not be edited by hand. Configuration in the xorg.conf file, on the other hand, is done completely by hand but is not necessary in most scenarios.

When do you need the xorg.conf file?

All necessary parameters for a display and peripherals are auto-detected and configured during installation. The configuration file for the X server, /etc/X11/xorg.conf, that was necessary in previous releases, is not supplied with the current release of the X Window System. It can still be useful to create the file manually to configure new hardware, to set up an environment with multiple video cards, or for debugging purposes.

The /usr/lib/xorg/modules/ (or /usr/lib64/xorg/modules/) directory contains X server modules that can be loaded dynamically at runtime. By default, only some modules in /usr/lib/xorg/modules/ are automatically loaded by the X server.

When Fedora 18 is installed, the configuration files for X are created using information gathered about the system hardware during the installation process by the HAL (Hardware Abstraction Layer) configuration back end. Whenever the X server is started, it asks HAL for the list of input devices and adds each of them with their respective driver. Whenever a new input device is plugged in, or an existing input device is removed, HAL notifies the X server about the change. Because of this notification system, devices using the mouse, kbd, or vmmouse driver configured in the xorg.conf file are, by default, ignored by the X server. Refer to Section C.3.3.3, “The ServerFlags section” for further details. Additional configuration is provided in the /etc/X11/xorg.conf.d/ directory and it can override or augment any configuration that has been obtained through HAL.

C.3.1. The Structure of the Configuration

The format of the X configuration files is comprised of many different sections which address specific aspects of the system hardware. Each section begins with a Section “section-name” line, where “section-name” is the title for the section, and ends with an EndSection line. Each section contains lines that include option names and one or more option values. Some of these are sometimes enclosed in double quotes (").

Some options within the /etc/X11/xorg.conf file accept a boolean switch which turns the feature on or off. The acceptable values are:

- 1, on, true, or yes — Turns the option on.
- 0, off, false, or no — Turns the option off.

The following shows a typical configuration file for the keyboard. Lines beginning with a hash sign (#) are not read by the X server and are used for human-readable comments.

```
# This file is autogenerated by system-setup-keyboard. Any
# modifications will be lost.

Section "InputClass"
  Identifier "system-setup-keyboard"
  MatchIsKeyboard "on"
  Option "XkbModel" "pc105"
  Option "XkbLayout" "cz,us"
# Option "XkbVariant" "(null)"
  Option "XkbOptions" "terminate:ctrl_alt_bksp,grp:shifts_toggle,grp_led:scroll"
EndSection
```

C.3.2. The xorg.conf.d Directory

The X server supports two configuration directories. The /usr/share/X11/xorg.conf.d/ provides separate configuration files from vendors or third-party packages; changes to these files in this directory may be overwritten by settings specified in the /etc/X11/xorg.conf file. The /etc/X11/xorg.conf.d/ directory stores user-specific configuration.

Files with the suffix .conf in configuration directories are parsed by the X server upon startup and are treated like part of the traditional xorg.conf configuration file. These files may contain one or more sections; for a description of the options in a section and the general layout of the configuration file, refer to Section C.3.3, “The xorg.conf File” or to the xorg.conf(5) man page. The X server essentially treats the collection of configuration files as one big file with entries from xorg.conf at the end. Users are encouraged to put custom configuration into /etc/xorg.conf and leave the

---

twm

The minimalist Tab Window Manager (twm), which provides the most basic tool set among the available window managers, can be used either as a stand-alone or with a desktop environment. To run this window manager, you need to install the xorg-x11-twm package.
The following entries are commonly used in the xorg.conf file.

C.3.3. The xorg.conf File

In previous releases of the X Window System, /etc/X11/xorg.conf file was used to store initial setup for X. When a change occurred with the monitor, video card or other device managed by X, the file needed to be edited manually. In Fedora, there is rarely a need to manually create and edit the /etc/X11/xorg.conf file. Nevertheless, it is still useful to understand various sections and optional parameters available, especially when troubleshooting or setting up unusual hardware configuration.

In the following, some important sections are described in the order in which they appear in a typical /etc/X11/xorg.conf file. More detailed information about the X server configuration file can be found in the xorg.conf(5) man page. This section is mostly intended for advanced users as most configuration options described below are not needed in typical configuration scenarios.

C.3.3.1. The InputClass section

InputClass is a new type of configuration section that does not apply to a single device but rather to a class of devices, including hot-plugged devices. An InputClass section’s scope is limited by the matches specified; in order to apply to an input device, all matches must apply to the device as seen in the example below:

```plaintext
Section "InputClass"
    Identifier "touchpad catchall"
    MatchIsTouchpad "on"
    Driver "synaptics"
EndSection
```

If this snippet is present in an xorg.conf file or an xorg.conf.d directory, any touchpad present in the system is assigned the synaptics driver.

Alphanumeric sorting in xorg.conf

Note that due to alphanumeric sorting of configuration files in the xorg.conf.d directory, the Driver setting in the example above overwrites previously set driver options. The more generic the class, the earlier it should be listed.

The match options specify which devices a section may apply to. To match a device, all match options must correspond. The following options are commonly used in the InputClass section:

- `MatchIsPointer`, `MatchIsKeyboard`, `MatchIsTouchpad`, `MatchIsTouchscreen`, `MatchIsJoystick` — boolean options to specify a type of a device.
- `MatchProduct "product_name"` — this option matches if the product_name substring occurs in the product name of the device.
- `MatchVendor "vendor_name"` — this option matches if the vendor_name substring occurs in the vendor name of the device.
- `MatchDevicePath "path/to/device"` — this option matches any device if its device path corresponds to the patterns given in the "path/to/device" template, for example /dev/input/event*.
- `MatchTag "tag_pattern"` — this option matches if at least one tag assigned by the HAL configuration back end matches the tag_pattern pattern.

A configuration file may have multiple InputClass sections. These sections are optional and are used to configure a class of input devices as they are automatically added. An input device can match more than one InputClass section. When arranging these sections, it is recommended to put generic matches above specific ones because each input class can override settings from a previous one if an overlap occurs.

C.3.3.2. The InputDevice section

Each InputDevice section configures one input device for the X server. Previously, systems typically had at least one InputDevice section for the keyboard, and most mouse settings were automatically detected.

With Fedora 18, no InputDevice configuration is needed for most setups, and the xorg-x11-drv-* input driver packages provide the automatic configuration through HAL. The default driver for both keyboards and mice is evdev.

The following example shows a typical InputDevice section for a keyboard:

```plaintext
Section "InputDevice"
    Identifier "Keyboard0"
    Driver "kbd"
    Option "XkbModel" "pc105"
    Option "XkbLayout" "us"
EndSection
```

The following entries are commonly used in the InputDevice section:

- `Identifier` — Specifies a unique name for this InputDevice section. This is a required entry.
- `Driver` — Specifies the name of the device driver X must load for the device. If the AutoAddDevices option is enabled (which is the default setting), any input device section with Driver "mouse" or Driver "kbd" will be ignored. This is necessary due to conflicts between the legacy mouse and keyboard drivers and the new evdev generic driver. Instead, the server will use the information from the back end for any input devices. Any custom input device configuration in the xorg.conf should be moved to the back end. In most cases, the back end will be HAL and the configuration location will be the /etc/X11/xorg.conf.d directory.
Option — Specifies necessary options pertaining to the device. A mouse may also be specified to override any auto-detected values for the device. The following options are typically included when adding a mouse in the xorg.conf file:

- **Protocol** — Specifies the protocol used by the mouse, such as IMPS/2.
- **Device** — Specifies the location of the physical device.
- **Emulate3Buttons** — Specifies whether to allow a two-button mouse to act like a three-button mouse when both mouse buttons are pressed simultaneously.

Consult the xorg.conf(5) man page for a complete list of valid options for this section.

### C.3.3.3. The ServerFlags section

The optional ServerFlags section contains miscellaneous global X server settings. Any settings in this section may be overridden by options placed in the ServerLayout section (refer to Section C.3.3.4, "ServerLayout," for details).

Each entry within the ServerFlags section occupies a single line and begins with the term Option followed by an option enclosed in double quotation marks (".

The following is a sample ServerFlags section:

```plaintext
Section "ServerFlags"
  Option "DontZap" "true"
EndSection
```

The following lists some of the most useful options:

- **"DontZap" "boolean"** — When the value of <boolean> is set to true, this setting prevents the use of the Ctrl-Alt+Backspace key combination to immediately terminate the X server.

#### X keyboard extension

Even if this option is enabled, the key combination still must be configured in the X Keyboard Extension (XKB) map before it can be used. One way how to add the key combination to the map is to run the following command:

```plaintext
setxkbmap -option "terminate:ctrl_alt_bksp"
```

- **"DontZoom" "boolean"** — When the value of <boolean> is set to true, this setting prevents cycling through configured video resolutions using the Ctrl+Alt+Keypad-Plus and Ctrl+Alt+Keypad-Minus key combinations.

- **"AutoAddDevices" "boolean"** — When the value of <boolean> is set to false, the server will not hot plug input devices and instead rely solely on devices configured in the xorg.conf file. Refer to Section C.3.3.2, "The InputDevice section," for more information concerning input devices. This option is enabled by default and HAL (hardware abstraction layer) is used as a back end for device discovery.

### C.3.3.4. ServerLayout

The ServerLayout section binds together the input and output devices controlled by the X server. At a minimum, this section must specify one input device and one output device. By default, a monitor (output device) and a keyboard (input device) are specified.

The following example shows a typical ServerLayout section:

```plaintext
Section "ServerLayout"
  Identifier "Default Layout"
  Screen 0 "Screen0" 0 0
    InputDevice "Mouse0" "CorePointer"
    InputDevice "Keyboard0" "CoreKeyboard"
EndSection
```

The following entries are commonly used in the ServerLayout section:

- **Identifier** — Specifies a unique name for this ServerLayout section.
- **Screen** — Specifies the name of a Screen section to be used with the X server. More than one Screen option may be present.

The following is an example of a typical Screen entry:

```plaintext
Screen 0 "Screen0" 0 0
```

The first number in this example Screen entry (0) indicates that the first monitor connector, or head on the video card, uses the configuration specified in the Screen section with the identifier "Screen0".

An example of a Screen section with the identifier "Screen0" can be found in Section C.3.3.8, "The Screen section." If the video card has more than one head, another Screen entry with a different number and a different Screen section identifier is necessary.

The numbers to the right of "Screen0" give the absolute X and Y coordinates for the upper left corner of the screen (0 0 by default).

- **InputDevice** — Specifies the name of an InputDevice section to be used with the X server.

It is advisable that there be at least two InputDevice entries: one for the default mouse and one for the default keyboard. The options CorePointer and CoreKeyboard indicate that these are the primary mouse and keyboard. If the AutoAddDevices option is enabled, this entry needs not to be specified in the ServerLayout section. If the AutoAddDevices option is disabled, both mouse and keyboard are auto-detected with the default values.
Option "option-name" — An optional entry which specifies extra parameters for the section. Any options listed here override those listed in the ServerFlags section.

Replace <option-name> with a valid option listed for this section in the xorg.conf(5) man page.

It is possible to put more than one ServerLayout section in the /etc/X11/xorg.conf file. By default, the server only reads the first one it encounters, however. If there is an alternative ServerLayout section, it can be specified as a command line argument when starting an X session; as in the Xorg -layout <layoutname> command.

C.3.3.5. The Files section
The Files section sets paths for services vital to the X server, such as the font path. This is an optional section, as these paths are normally detected automatically. This section can be used to override automatically detected values.

The following example shows a typical Files section:

```
Section "Files"
    RgbPath "/usr/share/X11/rgb.txt"
    FontPath "unix:/7100"
EndSection
```

The following entries are commonly used in the Files section:

- ModulePath — An optional parameter which specifies alternate directories which store X server modules.

C.3.3.6. The Monitor section
Each Monitor section configures one type of monitor used by the system. This is an optional entry as most monitors are now detected automatically.

This example shows a typical Monitor section for a monitor:

```
Section "Monitor"
    Identifier "Monitor0"
    VendorName "Monitor Vendor"
    ModelName "DDC Probed Monitor - ViewSonic G773-2"
    DisplaySize 320 240
    HorizSync 30.0 - 70.0
    VertRefresh 50.0 - 180.0
EndSection
```

The following entries are commonly used in the Monitor section:

- Identifier — Specifies a unique name for this Monitor section. This is a required entry.
- VendorName — An optional parameter which specifies the vendor of the monitor.
- ModelName — An optional parameter which specifies the monitor's model name.
- DisplaySize — An optional parameter which specifies, in millimeters, the physical size of the monitor's picture area.
- HorizSync — Specifies the range of horizontal sync frequencies compatible with the monitor, in kHz. These values help the X server determine the validity of built-in or specified Modeline entries for the monitor.
- VertRefresh — Specifies the range of vertical refresh frequencies supported by the monitor, in kHz. These values help the X server determine the validity of built-in or specified Modeline entries for the monitor.
- Modeline — An optional parameter which specifies additional video modes for the monitor at particular resolutions, with certain horizontal sync and vertical refresh resolutions. Refer to the xorg.conf(5) man page for a more detailed explanation of Modeline entries.
- Option "option-name" — An optional entry which specifies extra parameters for the section. Replace <option-name> with a valid option listed for this section in the xorg.conf(5) man page.

C.3.3.7. The Device section
Each Device section configures one video card on the system. While one Device section is the minimum, additional instances may occur for each video card installed on the machine.

The following example shows a typical Device section for a video card:

```
Section "Device"
    Identifier "Videocard0"
    Driver "mga"
    VendorName "Videocard vendor"
    BoardName "Matrox Millennium G200"
    VideoRam 8192
    Option "dpms"
EndSection
```

The following entries are commonly used in the Device section:

- Identifier — Specifies a unique name for this Device section. This is a required entry.
- Driver — Specifies which driver the X server must load to utilize the video card. A list of drivers can be found in /usr/share/hwdata/videodrivers, which is installed with the hwdata package.
- VendorName — An optional parameter which specifies the vendor of the video card.
- BoardName — An optional parameter which specifies the name of the video card.
- VideoRam — An optional parameter which specifies the amount of RAM available on the video card, in kilobytes. This setting is only necessary for video cards the X server cannot probe to detect the amount of video RAM.
- BusID — An entry which specifies the bus location of the video card. On systems with only one video card a BusID
entry is optional and may not even be present in the default /etc/X11/xorg.conf file. On systems with more than one video card, however, a BusID entry is required.

- Screen — An optional entry which specifies which monitor connector or head on the video card the Device section configures. This option is only useful for video cards with multiple heads. If multiple monitors are connected to different heads on the same video card, separate Device sections must exist and each of these sections must have a different Screen value.

Values for the Screen entry must be an integer. The first head on the video card has a value of 0. The value for each additional head increments this value by one.

- Option "option-name" — An optional entry which specifies extra parameters for the section. Replace <option-name> with a valid option listed for this section in the xorg.conf(5) man page.

One of the more common options is "dpms" (for Display Power Management Signaling, a VESA standard), which activates the Service Star energy compliance setting for the monitor.

C.3.3.8. The Screen section

Each Screen section binds one video card (or video card head) to one monitor by referencing the Device section and the Monitor section for each. While one Screen section is the minimum, additional instances may occur for each video card and monitor combination present on the machine.

The following example shows a typical Screen section:

```plaintext
Section "Screen"
  Identifier "Screen0"
  Device "Videocard0"
  Monitor "Monitor0"
  DefaultDepth 16

SubSection "Display"
  Depth 24
  Modes "1280x1024" "1280x960" "1152x864" "1024x768" "800x600" "640x480"
EndSubSection

SubSection "Display"
  Depth 16
  Modes "1152x864" "1024x768" "800x600" "640x480"
EndSubSection
EndSection
```

The following entries are commonly used in the Screen section:

- Identifier — Specifies a unique name for this Screen section. This is a required entry.
- Device — Specifies the unique name of a Device section. This is a required entry.
- Monitor — Specifies the unique name of a Monitor section. This is only required if a specific Monitor section is defined in the xorg.conf file. Normally, monitors are detected automatically.

- DefaultDepth — Specifies the default color depth in bits. In the previous example, 16 (which provides thousands of colors) is the default. Only one DefaultDepth entry is permitted, although this can be overridden with the Xorg command line option -depth <n>, where <n> is any additional depth specified.

- SubSection "Display" — Specifies the screen modes available at a particular color depth. The Screen section can have multiple Display subsections, which are entirely optional since screen modes are detected automatically.
  This subsection is normally used to override auto-detected modes.

- Option "option-name" — An optional entry which specifies extra parameters for the section. Replace <option-name> with a valid option listed for this section in the xorg.conf(5) man page.

C.3.3.9. The DRI section

The optional DRI section specifies parameters for the Direct Rendering Infrastructure (DRI). DRI is an interface which allows 3D software applications to take advantage of 3D hardware acceleration capabilities built into most modern video hardware. In addition, DRI can improve 2D performance via hardware acceleration, if supported by the video card driver.

This section is rarely used, as the DRI Group and Mode are automatically initialized to default values. If a different Group or Mode is needed, then adding this section to the xorg.conf file will override the default values.

The following example shows a typical DRI section:

```plaintext
Section "DRI"
  Group 0
  Mode 0666
EndSection
```

Since different video cards use DRI in different ways, do not add to this section without first referring to http://dri.freedesktop.org/wiki/.

C.4. Fonts

Fedora uses Fontconfig subsystem to manage and display fonts under the X Window System. It simplifies font management and provides advanced display features, such as anti-aliasing. This system is used automatically for applications programmed using the Qt 3 or GTK+ 2 graphical toolkits, or their newer versions.

The Fontconfig font subsystem allows applications to directly access fonts on the system and use the X FreeType interface library (Xft) or other rendering mechanisms to render Fontconfig fonts with advanced features such as anti-aliasing.

Graphical applications can use the Xft library with Fontconfig to draw text to the screen.
Font configuration

Fontconfig uses the /etc/fonts/fonts.conf configuration file, which should not be edited by hand.

Fonts group

Any system where the user expects to run remote X applications needs to have the fonts group installed. This can be done by selecting the group in the installer, and also by running the yum groupinstall fonts command after installation.

C.4.1. Adding Fonts to Fontconfig

Adding new fonts to the Fontconfig subsystem is a straightforward process:

1. To add fonts for an individual user, copy the new fonts into the .fonts/ directory in the user's home directory.
2. To add fonts system-wide, copy the new fonts into the /usr/share/fonts/ directory. It is a good idea to create a new subdirectory, such as local/ or similar, to help distinguish between user-installed and default fonts.
3. Run the fc-cache command as root to update the font information cache:

   fc-cache <path-to-font-directory>

   In this command, replace <path-to-font-directory> with the directory containing the new fonts (either /usr/share/fonts/local/ or /home/<user>/.fonts/).

Interactive font installation

Individual users may also install fonts interactively, by typing fonts:/// into the Nautilus address bar, and dragging the new font files there.

C.5. Runlevels and X

In most cases, the Fedora installer configures a machine to boot into a graphical login environment, known as runlevel 5. It is possible, however, to boot into a text-only multi-user mode called runlevel 3 and begin an X session from there.

The following subsections review how X starts up in both runlevel 3 and runlevel 5.

C.5.1. Runlevel 3

When in runlevel 3, the best way to start an X session is to log in and type startx. The startx command is a front-end to the xinit command, which launches the X server (Xorg) and connects X client applications to it. Because the user is already logged into the system at runlevel 3, startx does not launch a display manager or authenticate users. Refer to Section C.5.2, "Runlevel 5" for more information about display managers.

1. When the startx command is executed, it searches for the .xinitrc file in the user's home directory to define the desktop environment and possibly other X client applications to run. If no .xinitrc file is present, it uses the system default /etc/X11/xinit/xinitrc file instead.
2. The default xinitrc script then searches for user-defined files and default system files, including .Xresources, .Xmodmap, and .Xkbmap in the user's home directory, and Xresources, Xmodmap, and Xkbmap in the /etc/X11/ directory. The Xmodmap and Xkbmap files, if they exist, are used by the xmodmap utility to configure the keyboard. The Xresources file is read to assign specific preference values to applications.
3. After setting the above options, the xinitrc script executes all scripts located in the /etc/X11/xinit/xinitrc.d/ directory. One important script in this directory is xinput.sh, which configures settings such as the default language.
4. The xinitrc script attempts to execute .Xclients in the user's home directory and turns to /etc/X11/xinit/Xclients if it cannot be found. The purpose of the Xclients file is to start the desktop environment or, possibly, just a basic window manager. The .Xclients script in the user's home directory starts the user-specified desktop environment in the .Xclients-default file. If .Xclients does not exist in the user's home directory, the standard /etc/X11/xinit/Xclients script attempts to start another desktop environment, trying GNOME first, then KDE, followed by twm.

When in runlevel 3, the user is returned to a text mode user session after ending an X session.

C.5.2. Runlevel 5

When the system boots into runlevel 5, a special X client application called a display manager is launched. A user must authenticate using the display manager before any desktop environment or window managers are launched.

Depending on the desktop environments installed on the system, three different display managers are available to handle user authentication.

> GDM (GNOME Display Manager) — The default display manager for Fedora. GNOME allows the user to configure language settings, shutdown, restart or log in to the system.
> KDM — KDE's display manager which allows the user to shutdown, restart or log in to the system.
When booting into runlevel 5, the /etc/X11/prefdm script determines the preferred display manager by referencing the /etc/sysconfig/desktop file. A list of options for this file is available in this file:

```
/usr/share/doc/initscripts-<version-number>/sysconfig.txt
```

where `<version-number>` is the version number of the initscripts package.

Each of the display managers reference the /etc/X11/xdm/Xsetup_0 file to set up the login screen. Once the user logs into the system, the /etc/X11/xdm/GiveConsole script runs to assign ownership of the console to the user. Then, the /etc/X11/xdm/Xsession script runs to accomplish many of the tasks normally performed by the xinitrc script when starting X from runlevel 3, including setting system and user resources, as well as running the scripts in the /etc/X11/xinit/xinitrc.d/ directory.

Users can specify which desktop environment they want to use when they authenticate using the GNOME or KDE display managers by selecting it from the Sessions menu item accessed by selecting System → Preferences → More Preferences → Sessions. If the desktop environment is not specified in the display manager, the /etc/X11/xdm/Xsession script checks the .xsession and .Xclients files in the user's home directory to decide which desktop environment to load. As a last resort, the /etc/X11/xdm/Xclients file is used to select a desktop environment or window manager to use in the same way as runlevel 3.

When the user finishes an X session on the default display (:0) and logs out, the /etc/X11/xdm/TakeConsole script runs and reassigns ownership of the console to the root user. The original display manager, which continues running after the user logged in, takes control by spawning a new display manager. This restarts the X server, displays a new login window, and starts the entire process over again.

The user is returned to the display manager after logging out of X from runlevel 5.

For more information on how display managers control user authentication, refer to the /usr/share/doc/gdm-<version-number>/README, where `<version-number>` is the version number for the gdm package installed, or the xdm man page.

### C.6. Additional Resources

There is a large amount of detailed information available about the X server, the clients that connect to it, and the assorted desktop environments and window managers.

#### C.6.1. Installed Documentation

- `/usr/share/X11/doc/` — contains detailed documentation on the X Window System architecture, as well as how to get additional information about the Xorg project as a new user.
- `/usr/share/doc/gdm-<version-number>/README` — contains information on how display managers control user authentication.
- `man xorg.conf` — Contains information about the xorg.conf configuration files, including the meaning and syntax for the different sections within the files.
- `man Xorg` — Describes the Xorg display server.

#### C.6.2. Useful Websites

- [http://www.X.org/](http://www.X.org/) — Home page of the X.Org Foundation, which produces major releases of the X Window System bundled with Fedora to control the necessary hardware and provide a GUI environment.
- [http://dri.sourceforge.net/](http://dri.sourceforge.net/) — Home page of the DRI (Direct Rendering Infrastructure) project. The DRI is the core hardware 3D acceleration component of X.

### The sysconfig Directory

This appendix outlines some of the files and directories found in the /etc/sysconfig/ directory, their function, and their contents. The information in this appendix is not intended to be complete, as many of these files have a variety of options that are only used in very specific or rare circumstances.

The actual content of your /etc/sysconfig/ directory depends on the programs you have installed on your machine. To find the name of the package the configuration file belongs to, type the following at a shell prompt:

```
$ yum provides /etc/sysconfig/filename
```

Refer to Section 5.2.4, “Installing Packages” for more information on how to install new packages in Fedora.
D.1. Files in the /etc/sysconfig/ Directory

The following sections offer descriptions of files normally found in the /etc/sysconfig/ directory.

D.1.1. /etc/sysconfig/arpwatch

The /etc/sysconfig/arpwatch file is used to pass arguments to the arpwatch daemon at boot time. By default, it contains the following option:

```
OPTIONS=value
```

Additional options to be passed to the arpwatch daemon. For example:

```
OPTIONS=-u arpwatch -e root -s 'root (Arpwatch)'
```

D.1.2. /etc/sysconfig/authconfig

The /etc/sysconfig/authconfig file sets the authorization to be used on the host. By default, it contains the following options:

```
USEMHOMEDIR=boolean
```

A boolean to enable (yes) or disable (no) creating a home directory for a user on the first login. For example:

```
USEMHOMEDIR=no
```

```
USEPAMACCESS=boolean
```

A boolean to enable (yes) or disable (no) the PAM authentication. For example:

```
USEPAMACCESS=no
```

```
USESSSDAUTH=boolean
```

A boolean to enable (yes) or disable (no) the SSSD authentication. For example:

```
USESSSDAUTH=no
```

```
USESHADOW=boolean
```

A boolean to enable (yes) or disable (no) shadow passwords. For example:

```
USESHADOW=yes
```

```
USEWINBIND=boolean
```

A boolean to enable (yes) or disable (no) using Winbind for user account configuration. For example:

```
USEWINBIND=no
```

```
USEDB=boolean
```

A boolean to enable (yes) or disable (no) the FAS authentication. For example:

```
USEDB=no
```

```
USEFPRINTD=boolean
```

A boolean to enable (yes) or disable (no) the fingerprint authentication. For example:

```
USEFPRINTD=yes
```

```
FORCESMARTCARD=boolean
```

A boolean to enable (yes) or disable (no) enforcing the smart card authentication. For example:

```
FORCESMARTCARD=no
```

```
PASSWDALGORITHM=value
```

The password algorithm. The value can be `bigcrypt`, `descript`, `md5`, `sha256`, or `sha512`. For example:

```
PASSWDALGORITHM=sha512
```

```
USELDAPAUTH=boolean
```

A boolean to enable (yes) or disable (no) the LDAP authentication. For example:

```
USELDAPAUTH=no
```

```
USELOCAUTHORIZE=boolean
```

A boolean to enable (yes) or disable (no) the local authorization for local users. For example:

```
USELOCAUTHORIZE=yes
```
USECRACKLIB=boolean
A boolean to enable (yes) or disable (no) using the CrackLib. For example:

USEWINBINDAUTH=boolean
A boolean to enable (yes) or disable (no) the Winbind authentication. For example:

USESMARTCARD=boolean
A boolean to enable (yes) or disable (no) the smart card authentication. For example:

USELDAP=boolean
A boolean to enable (yes) or disable (no) using LDAP for user account configuration. For example:

USENIS=boolean
A boolean to enable (yes) or disable (no) using NIS for user account configuration. For example:

USEKERBEROS=boolean
A boolean to enable (yes) or disable (no) the Kerberos authentication. For example:

USESYSNETAUTH=boolean
A boolean to enable (yes) or disable (no) authenticating system accounts with network services. For example:

USESMBAUTH=boolean
A boolean to enable (yes) or disable (no) the SMB authentication. For example:

USESSSD=boolean
A boolean to enable (yes) or disable (no) using SSSD for obtaining user information. For example:

USEHESIOD=boolean
A boolean to enable (yes) or disable (no) using the Hesoid name service. For example:

Refer to Chapter 10, Configuring Authentication for more information on this topic.

D.1.3. /etc/sysconfig/autofs
The /etc/sysconfig/autofs file defines custom options for the automatic mounting of devices. This file controls the operation of the automount daemons, which automatically mount file systems when you use them and unmount them after a period of inactivity. File systems can include network file systems, CD-ROM drives, diskettes, and other media.

By default, it contains the following options:

MASTER_MAP_NAME=value
The default name for the master map. For example:

TIMEOUT=value
The default mount timeout. For example:

NEGATIVE_TIMEOUT=value
The default negative timeout for unsuccessful mount attempts. For example:
NEGATIVE_TIMEOUT=60

MOUNT_WAIT=value
The time to wait for a response from mount. For example:
MOUNT_WAIT=-1

UMOUNT_WAIT=value
The time to wait for a response from umount. For example:
UMOUNT_WAIT=12

BROWSE_MODE=boolean
A boolean to enable (yes) or disable (no) browsing the maps. For example:
BROWSE_MODE="no"

MOUNT_NFS_DEFAULT_PROTOCOL=value
The default protocol to be used by mount.nfs. For example:
MOUNT_NFS_DEFAULT_PROTOCOL=4

APPEND_OPTIONS=boolean
A boolean to enable (yes) or disable (no) appending the global options instead of replacing them. For example:
APPEND_OPTIONS="yes"

LOGGING=value
The default logging level. The value has to be either none, verbose, or debug. For example:
LOGGING="none"

LDAP_URI=value
A space-separated list of server URIs in the form of protocol://server. For example:
LDAP_URI="ldaps://ldap.example.com/"

LDAP_TIMEOUT=value
The synchronous API calls timeout. For example:
LDAP_TIMEOUT=-1

LDAP_NETWORK_TIMEOUT=value
The network response timeout. For example:
LDAP_NETWORK_TIMEOUT=8

SEARCH_BASE=value
The base Distinguished Name (DN) for the map search. For example:
SEARCH_BASE=""

AUTH_CONF_FILE=value
The default location of the SASL authentication configuration file. For example:
AUTH_CONF_FILE="/etc/autofs_ldap_auth.conf"

MAP_HASH_TABLE_SIZE=value
The hash table size for the map cache. For example:
MAP_HASH_TABLE_SIZE=1024

USE_MISCDEVICE=boolean
A boolean to enable (yes) or disable (no) using the autofs miscellaneous device. For example:
USE_MISCDEVICE="yes"

OPTIONS=value
Additional options to be passed to the LDAP daemon. For example:
OPTIONS=""
D.1.4. /etc/sysconfig/clock

The /etc/sysconfig/clock file controls the interpretation of values read from the system hardware clock. It is used by the Date and Time configuration tool, and should not be edited by hand. By default, it contains the following option:

ZONE=value
The time zone file under /usr/share/zoneinfo that /etc/localtime is a copy of. For example:

ZONE="Europe/Prague"

Refer to Section 2.1, "Using the Date and Time Configuration Tool" for more information on the Date and Time configuration tool and its usage.

D.1.5. /etc/sysconfig/dhcpd

The /etc/sysconfig/dhcpd file is used to pass arguments to the dhcpd daemon at boot time. By default, it contains the following options:

DHCPDARGS=value
Additional options to be passed to the dhcpd daemon. For example:

DHCPDARGS=

Refer to Chapter 12, DHCP Servers for more information on DHCP and its usage.

D.1.6. /etc/sysconfig/firstboot

The /etc/sysconfig/firstboot file defines whether to run the firstboot utility. By default, it contains the following option:

RUN_FIRSTBOOT=boolean
A boolean to enable (YES) or disable (NO) running the firstboot program. For example:

RUN_FIRSTBOOT=NO

The first time the system boots, the init program calls the /etc/rc.d/init.d/firstboot script, which looks for the /etc/sysconfig/firstboot file. If this file does not contain the RUN_FIRSTBOOT=NO option, the firstboot program is run, guiding a user through the initial configuration of the system.

You can run the firstboot program again

To start the firstboot program the next time the system boots, change the value of RUN_FIRSTBOOT option to YES, and type the following at a shell prompt as root:

~]# systemctl enable firstboot.service

D.1.7. /etc/sysconfig/i18n

The /etc/sysconfig/i18n configuration file defines the default language, any supported languages, and the default system font. By default, it contains the following options:

LANG=value
The default language. For example:

LANG="en_US.UTF-8"

SUPPORTED=value
A colon-separated list of supported languages. For example:

SUPPORTED="en_US.UTF-8:en_US:en"

SYSFONT=value
The default system font. For example:

SYSFONT="latarcyrheb-sun16"

D.1.8. /etc/sysconfig/init

The /etc/sysconfig/init file controls how the system appears and functions during the boot process. By default, it contains the following options:

BOOTUP=value
The bootup style. The value has to be either color (the standard color boot display), verbose (an old style display which provides more information), or anything else for the new style display, but without ANSI formatting. For example:

```plaintext
BOOTUP=color
```

RES_COL=value

The number of the column in which the status labels start. For example:

```plaintext
RES_COL=60
```

MOVE_TO_COL=value

The terminal sequence to move the cursor to the column specified in RES_COL (see above). For example:

```plaintext
MOVE_TO_COL="echo -en \033[\${RES_COL}G"
```

SETCOLOR_SUCCESS=value

The terminal sequence to set the success color. For example:

```plaintext
SETCOLOR_SUCCESS="echo -en \033[0;32m"
```

SETCOLOR_FAILURE=value

The terminal sequence to set the failure color. For example:

```plaintext
SETCOLOR_FAILURE="echo -en \033[0;31m"
```

SETCOLOR_WARNING=value

The terminal sequence to set the warning color. For example:

```plaintext
SETCOLOR_WARNING="echo -en \033[0;33m"
```

SETCOLOR_NORMAL=value

The terminal sequence to set the default color. For example:

```plaintext
SETCOLOR_NORMAL="echo -en \033[0;39m"
```

LOGLEVEL=value

The initial console logging level. The value has to be in the range from 1 (kernel panics only) to 8 (everything, including the debugging information). For example:

```plaintext
LOGLEVEL=3
```

PROMPT=boolean

A boolean to enable (yes) or disable (no) the hotkey interactive startup. For example:

```plaintext
PROMPT=yes
```

AUTOSWAP=boolean

A boolean to enable (yes) or disable (no) probing for devices with swap signatures. For example:

```plaintext
AUTOSWAP=no
```

ACTIVE_CONSOLES=value

The list of active consoles. For example:

```plaintext
ACTIVE_CONSOLES=/dev/tty[1-6]
```

SINGLE=value

The single-user mode type. The value has to be either /sbin/sulogin (a user will be prompted for a password to log in), or /sbin/sushell (the user will be logged in directly). For example:

```plaintext
SINGLE=/sbin/sushell
```

---

**D.1.9. /etc/sysconfig/ip6tables-config**

The `/etc/sysconfig/ip6tables-config` file stores information used by the kernel to set up IPv6 packet filtering at boot time or whenever the `ip6tables` service is started. Note that you should not modify it unless you are familiar with `ip6tables` rules. By default, it contains the following options:

`IP6TABLES_MODULES=value`

A space-separated list of helpers to be loaded after the firewall rules are applied. For example:

```plaintext
IP6TABLES_MODULES="ip_nat_ftp ip_nat_irc"
```
IP6TABLES_MODULES_UNLOAD=boolean
A boolean to enable (yes) or disable (no) module unloading when the firewall is stopped or restarted. For example:

```
IP6TABLES_MODULES_UNLOAD="yes"
```

IP6TABLES_SAVE_ON_STOP=boolean
A boolean to enable (yes) or disable (no) saving the current firewall rules when the firewall is stopped. For example:

```
IP6TABLES_SAVE_ON_STOP="no"
```

IP6TABLES_SAVE_ON_RESTART=boolean
A boolean to enable (yes) or disable (no) saving the current firewall rules when the firewall is restarted. For example:

```
IP6TABLES_SAVE_ON_RESTART="no"
```

IP6TABLES_SAVE_COUNTER=boolean
A boolean to enable (yes) or disable (no) saving the rule and chain counters. For example:

```
IP6TABLES_SAVE_COUNTER="no"
```

IP6TABLES_STATUS_NUMERIC=boolean
A boolean to enable (yes) or disable (no) printing IP addresses and port numbers in a numeric format in the status output. For example:

```
IP6TABLES_STATUS_NUMERIC="yes"
```

IP6TABLES_STATUS_VERBOSE=boolean
A boolean to enable (yes) or disable (no) printing information about the number of packets and bytes in the status output. For example:

```
IP6TABLES_STATUS_VERBOSE="no"
```

IP6TABLES_STATUS_LINENUMBERS=boolean
A boolean to enable (yes) or disable (no) printing line numbers in the status output. For example:

```
IP6TABLES_STATUS_LINENUMBERS="yes"
```

Use the ip6tables command to create the rules
You can create the rules manually using the ip6tables command. Once created, type the following at a shell prompt:

```
~# service ip6tables save
```
This will add the rules to /etc/sysconfig/ip6tables. Once this file exists, any firewall rules saved in it persist through a system reboot or a service restart.

D.1.10. /etc/sysconfig/keyboard
The /etc/sysconfig/keyboard file controls the behavior of the keyboard. By default, it contains the following options:

KEYTABLE=value
The name of a keytable file. The files that can be used as keytables start in the /lib/kbd/keymaps/i386/ directory, and branch into different keyboard layouts from there, all labeled value.kmap.gz. The first file name that matches the KEYTABLE setting is used. For example:

```
KEYTABLE="us"
```

MODEL=value
The keyboard model. For example:

```
MODEL="pc105+inet"
```

LAYOUT=value
The keyboard layout. For example:

```
LAYOUT="us"
```

KEYBOARDTYPE=value
The keyboard type. Allowed values are pc (a PS/2 keyboard), or sun (a Sun keyboard). For example:
D.1.11. /etc/sysconfig/ldap

The /etc/sysconfig/ldap file holds the basic configuration for the LDAP server. By default, it contains the following options:

**SLAPD_OPTIONS=value**
Additional options to be passed to the **slapd** daemon. For example:

```
SLAPD_OPTIONS="-4"
```

**SLURPD_OPTIONS=value**
Additional options to be passed to the **slurpd** daemon. For example:

```
SLURPD_OPTIONS=""
```

**SLAPD_LDAP=boolean**
A boolean to enable (yes) or disable (no) using the LDAP over TCP (that is, **ldap:///**). For example:

```
SLAPD_LDAP="yes"
```

**SLAPD_LDAPI=boolean**
A boolean to enable (yes) or disable (no) using the LDAP over IPC (that is, **ldapi:///**). For example:

```
SLAPD_LDAPI="no"
```

**SLAPD_LDAPS=boolean**
A boolean to enable (yes) or disable (no) using the LDAP over TLS (that is, **ldaps:///**). For example:

```
SLAPD_LDAPS="no"
```

**SLAPD_URLS=value**
A space-separated list of URLs. For example:

```
SLAPD_URLS="ldapi:///var/lib/ldap_root/ldapi ldapi:/// ldaps:///
```

**SLAPD_SHUTDOWN_TIMEOUT=value**
The time to wait for **slapd** to shut down. For example:

```
SLAPD_SHUTDOWN_TIMEOUT=3
```

**SLAPD_ULIMIT_SETTINGS=value**
The parameters to be passed to **ulimit** before the **slapd** daemon is started. For example:

```
SLAPD_ULIMIT_SETTINGS=""
```

Refer to Section 16.1, “OpenLDAP” for more information on LDAP and its configuration.

D.1.12. /etc/sysconfig/named

The /etc/sysconfig/named file is used to pass arguments to the **named** daemon at boot time. By default, it contains the following options:

**ROOTDIR=value**
The chroot environment under which the **named** daemon runs. The **value** has to be a full directory path. For example:

```
ROOTDIR="/var/named/chroot"
```

Note that the chroot environment has to be configured first (type **info chroot** at a shell prompt for more information).

**OPTIONS=value**
Additional options to be passed to **named**. For example:

```
OPTIONS="-6"
```

Note that you should not use the **-t** option. Instead, use **ROOTDIR** as described above.

**KEYTAB_FILE=value**
The keytab file name. For example:

```
KEYTAB_FILE="/etc/named.keytab"
```
Refer to Section 13.2, “BIND” for more information on the BIND DNS server and its configuration.

D.1.13. `/etc/sysconfig/network`

The `/etc/sysconfig/network` file is used to specify information about the desired network configuration. By default, it contains the following options:

**NETWORKING=boolean**

A boolean to enable (yes) or disable (no) the networking. For example:

```bash
NETWORKING=yes
```

**GATEWAY=value**

The IP address of the network’s gateway. For example:

```bash
GATEWAY=192.168.1.1
```

This is used as the default value when there is no `GATEWAY` directive in an interface's `ifcfg` file.

**Note**

If you want to completely disable IPv6, you should add these lines to `/etc/sysctl.conf`:

```bash
net.ipv6.conf.all.disable_ipv6=1
net.ipv6.conf.default.disable_ipv6=1
```

In addition, adding `ipv6.disable=1` to the kernel command line will disable the kernel module `net-pf-10` which implements IPv6.

**Avoid using custom init scripts**

Do not use custom init scripts to configure network settings. When performing a post-boot network service restart, custom init scripts configuring network settings that are run outside of the network init script lead to unpredictable results.

D.1.14. `/etc/sysconfig/quagga`

The `/etc/sysconfig/quagga` file holds the basic configuration for Quagga daemons. By default, it contains the following options:

**QCONFDIR=value**

The directory with the configuration files for Quagga daemons. For example:

```bash
QCONFDIR="/etc/quagga"
```

**BGPD_OPTS=value**

Additional options to be passed to the `bgpd` daemon. For example:

```bash
BGPD_OPTS="-A 127.0.0.1 -f ${QCONFDIR}/bgpd.conf"
```

**OSPF6D_OPTS=value**

Additional options to be passed to the `ospf6d` daemon. For example:

```bash
OSPF6D_OPTS="-A ::1 -f ${QCONFDIR}/ospf6d.conf"
```

**OSPFD_OPTS=value**

Additional options to be passed to the `ospfd` daemon. For example:

```bash
OSPFD_OPTS="-A 127.0.0.1 -f ${QCONFDIR}/ospfd.conf"
```

**RIPD_OPTS=value**

Additional options to be passed to the `ripd` daemon. For example:

```bash
RIPD_OPTS="-A 127.0.0.1 -f ${QCONFDIR}/ripd.conf"
```

**RIPNGD_OPTS=value**

Additional options to be passed to the `ripngd` daemon. For example:

```bash
RIPNGD_OPTS="-A ::1 -f ${QCONFDIR}/ripngd.conf"
```
**ZEBRA_OPTS=value**  
Additional options to be passed to the *zebra* daemon. For example:

```
ZEBRA_OPTS="-A 127.0.0.1 -f ${QCONFDIR}/zebra.conf"
```

**ISISD_OPTS=value**  
Additional options to be passed to the *isisd* daemon. For example:

```
ISISD_OPTS="-A ::1 -f ${QCONFDIR}/isisd.conf"
```

**WATCH_OPTS=value**  
Additional options to be passed to the *watchquagga* daemon. For example:

```
WATCH_OPTS="-Az -b_ -r/sbin/service_%s_restart -s/sbin/service_%s_start -k/sbin/service_%s_stop"
```

**WATCH_DAEMONS=value**  
A space separated list of monitored daemons. For example:

```
WATCH_DAEMONS="zebra bgpd ospfd ospf6d ripd ripngd"
```

---

**D.1.15. /etc/sysconfig/radvd**

The `/etc/sysconfig/radvd` file is used to pass arguments to the *radvd* daemon at boot time. By default, it contains the following option:

**OPTIONS=value**  
Additional options to be passed to the *radvd* daemon. For example:

```
OPTIONS="-u radvd"
```

---

**D.1.16. /etc/sysconfig/samba**

The `/etc/sysconfig/samba` file is used to pass arguments to the Samba daemons at boot time. By default, it contains the following options:

**SMBOPTIONS=value**  
Additional options to be passed to *smbd*. For example:

```
SMBOPTIONS="-D"
```

**NMBOPTIONS=value**  
Additional options to be passed to *nmbd*. For example:

```
NMBOPTIONS="-D"
```

**WINBINDOPTIONS=value**  
Additional options to be passed to *winbindd*. For example:

```
WINBINDOPTIONS=""
```

Refer to Section 17.1, "Samba" for more information on Samba and its configuration.

---

**D.1.17. /etc/sysconfig/sendmail**

---

**D.1.18. /etc/sysconfig/sendmail**

---
The `/etc/sysconfig/sendmail` is used to set the default values for the `Sendmail` application. By default, it contains the following values:

**DAEMON=boolean**
A boolean to enable (yes) or disable (no) running `sendmail` as a daemon. For example:

```
DAEMON=yes
```

**QUEUE=value**
The interval at which the messages are to be processed. For example:

```
QUEUE=1h
```

Refer to Section 15.3.2, "Sendmail" for more information on Sendmail and its configuration.

**D.1.19. `/etc/sysconfig/spamassassin`**
The `/etc/sysconfig/spamassassin` file is used to pass arguments to the `spamd` daemon (a daemonized version of `Spamassassin`) at boot time. By default, it contains the following option:

**SPAMDOPTIONS=value**
Additional options to be passed to the `spamd` daemon. For example:

```
SPAMDOPTIONS="-d -c -m5 -H"
```

Refer to Section 15.4.2.6, "Spam Filters" for more information on Spamassassin and its configuration.

**D.1.20. `/etc/sysconfig/squid`**
The `/etc/sysconfig/squid` file is used to pass arguments to the `squid` daemon at boot time. By default, it contains the following options:

**SQUID_OPTS=value**
Additional options to be passed to the `squid` daemon. For example:

```
SQUID_OPTS=""
```

**SQUID_SHUTDOWN_TIMEOUT=value**
The time to wait for `squid` daemon to shut down. For example:

```
SQUID_SHUTDOWN_TIMEOUT=100
```

**SQUID_CONF=value**
The default configuration file. For example:

```
SQUID_CONF="/etc/squid/squid.conf"
```

**D.1.21. `/etc/sysconfig/system-config-users`**
The `/etc/sysconfig/system-config-users` file is the configuration file for the `User Manager` utility, and should not be edited by hand. By default, it contains the following options:

**FILTER=boolean**
A boolean to enable (true) or disable (false) filtering of system users. For example:

```
FILTER=true
```

**ASSIGN_HIGHEST_UID=boolean**
A boolean to enable (true) or disable (false) assigning the highest available UID to newly added users. For example:

```
ASSIGN_HIGHEST_UID=true
```

**ASSIGN_HIGHEST_GID=boolean**
A boolean to enable (true) or disable (false) assigning the highest available GID to newly added groups. For example:

```
ASSIGN_HIGHEST_GID=true
```

**PREFER_SAME_UID_GID=boolean**
A boolean to enable (true) or disable (false) using the same UID and GID for newly added users when possible. For example:
PREFER_SAME_UID_GID=true

Refer to Section 4.3, "Using the User Manager Tool" for more information on User Manager and its usage.

**D.1.22. `/etc/sysconfig/vncservers`**

The `/etc/sysconfig/vncservers` file configures the way the Virtual Network Computing (VNC) server starts up. By default, it contains the following options:

**VNCSERVERS=value**
A list of space separated `display:username` pairs. For example:

```
VNCSERVERS="2:myusername"
```

**VNCSERVERARGS[display]=value**
Additional arguments to be passed to the VNC server running on the specified `display`. For example:

```
VNCSERVERARGS[2]="-geometry 800x600 -nolisten tcp -localhost"
```

**D.1.23. `/etc/sysconfig/xinetd`**

The `/etc/sysconfig/xinetd` file is used to pass arguments to the `xinetd` daemon at boot time. By default, it contains the following options:

**EXTRAOPTIONS=value**
Additional options to be passed to `xinetd`. For example:

```
EXTRAOPTIONS=""
```

**XINETD_LANG=value**
The locale information to be passed to every service started by `xinetd`. Note that to remove locale information from the `xinetd` environment, you can use an empty string (""") or `none`. For example:

```
XINETD_LANG="en_US"
```

Refer to Chapter 9, Services and Daemons for more information on how to configure the `xinetd` services.

**D.2. Directories in the `/etc/sysconfig/` Directory**

The following directories are normally found in `/etc/sysconfig/`.

- `/etc/sysconfig/cbq/`
  This directory contains the configuration files needed to do Class Based Queuing for bandwidth management on network interfaces. CBQ divides user traffic into a hierarchy of classes based on any combination of IP addresses, protocols, and application types.

- `/etc/sysconfig/networking/`
  This directory is used by the Network Administration Tool (system-config-network), and its contents should not be edited manually.

- `/etc/sysconfig/network-scripts/`
  This directory contains the following network-related configuration files:
  - Network configuration files for each configured network interface, such as `ifcfg-eth0` for the `eth0` Ethernet interface.
  - Scripts used to bring network interfaces up and down, such as `ifup` and `ifdown`.
  - Scripts used to bring ISDN interfaces up and down, such as `ifup-isdn` and `ifdown-isdn`.
  - Various shared network function scripts which should not be edited directly.

  For more information on the `/etc/sysconfig/network-scripts/` directory, refer to Chapter 8, Network Interfaces.

**D.3. Additional Resources**

This chapter is only intended as an introduction to the files in the `/etc/sysconfig/` directory. The following source contains more comprehensive information.

**D.3.1. Installed Documentation**
The proc File System

The Linux kernel has two primary functions: to control access to physical devices on the computer and to schedule when and how processes interact with these devices. The /proc/ directory (also called the proc file system) contains a hierarchy of special files which represent the current state of the kernel, allowing applications and users to peer into the kernel's view of the system.

The /proc/ directory contains a wealth of information detailing system hardware and any running processes. In addition, some of the files within /proc/ can be manipulated by users and applications to communicate configuration changes to the kernel.

The /proc/idle/ and /proc/pci/ directories

Later versions of the 2.6 kernel have made the /proc/idle/ and /proc/pci/ directories obsolete. The /proc/idle/ file system is now superseded by files in sysfs; to retrieve information on PCI devices, use lspci instead. For more information on sysfs or lspci, refer to their respective man pages.

E.1. A Virtual File System

Linux systems store all data as files. Most users are familiar with the two primary types of files: text and binary. But the /proc/ directory contains another type of file called a virtual file. As such, /proc/ is often referred to as a virtual file system.

Virtual files have unique qualities. Most of them are listed as zero bytes in size, but can still contain a large amount of information when viewed. In addition, most of the time and date stamps on virtual files reflect the current time and date, indicative of the fact they are constantly updated.

Virtual files such as /proc/interrupts, /proc/meminfo, /proc/mounts, and /proc/partitions provide an up-to-the-moment glimpse of the system’s hardware. Others, like the /proc/filesystems file and the /proc/sys/ directory provide system configuration information and interfaces.

For organizational purposes, files containing information on a similar topic are grouped into virtual directories and sub-directories. Process directories contain information about each running process on the system.

WAS: For organizational purposes, files containing information on a similar topic are grouped into virtual directories and sub-directories. For instance, /proc/idle/ contains information for all physical IDE devices. Likewise, process directories contain information about each running process on the system.

E.1.1. Viewing Virtual Files

Most files within /proc/ files operate similarly to text files, storing useful system and hardware data in human-readable text format. As such, you can use cat, more, or less to view them. For example, to display information about the system’s CPU, run cat /proc/cpuinfo. This will return output similar to the following:

```
processor : 0
vendor_id : AuthenticAMD
cpu family : 5
model : 0
model name : AMD-K6(tm) 3D+
Processor stepping : 1 cpu
MHz : 400.919
cache size : 256 KB
fdiv_bug : no
hlt_bug : no
f00f_bug : no
coma_bug : no
fpu : yes
fpu_exception : yes
cpuid level : 1
wp : yes
flags : fpu vme de pse tsc msr mce cx8 pge mmx syscall 3dnow k6_mtrr
bogomips : 799.53
```

Some files in /proc/ contain information that is not human-readable. To retrieve information from such files, use tools such as lspci, apm, free, and top.

Certain files can only be accessed with root privileges

Some of the virtual files in the /proc/ directory are readable only by the root user.
E.1.2. Changing Virtual Files

As a general rule, most virtual files within the `/proc/` directory are read-only. However, some can be used to adjust settings in the kernel. This is especially true for files in the `/proc/sys/` subdirectory.

To change the value of a virtual file, use the following command:

```
echo value > /proc/file
```

For example, to change the hostname on the fly, run:

```
echo www.example.com > /proc/sys/kernel/hostname
```

Other files act as binary or Boolean switches. Typing `cat /proc/sys/net/ipv4/ip_forward` returns either a 0 (off or false) or a 1 (on or true). A 0 indicates that the kernel is not forwarding network packets. To turn packet forwarding on, run `echo 1 > /proc/sys/net/ipv4/ip_forward`.

The `sysctl` command

Another command used to alter settings in the `/proc/sys/` subdirectory is `/sbin/sysctl`. For more information on this command, refer to Section E.4, “Using the `sysctl` Command”.

For a listing of some of the kernel configuration files available in the `/proc/sys/` subdirectory, refer to Section E.3.9, “/proc/sys/”.

E.2. Top-level Files within the proc File System

Below is a list of some of the more useful virtual files in the top-level of the `/proc/` directory.

The content of your files may differ

In most cases, the content of the files listed in this section are not the same as those installed on your machine. This is because much of the information is specific to the hardware on which Fedora is running for this documentation effort.

E.2.1. `/proc/buddyinfo`

This file is used primarily for diagnosing memory fragmentation issues. Using the buddy algorithm, each column represents the number of pages of a certain order (a certain size) that are available at any given time. For example, for zone direct memory access (DMA), there are 90 of $2^{0 \times \text{PAGE SIZE}}$ chunks of memory. Similarly, there are 6 of $2^{1 \times \text{PAGE SIZE}}$ chunks and 2 of $2^{2 \times \text{PAGE SIZE}}$ chunks of memory available.

The `DMA` row references the first 16 MB on a system, the `HighMem` row references all memory greater than 4 GB on a system, and the `Normal` row references all memory in between.

The following is an example of the output typical of `/proc/buddyinfo`:

```
Node 0, zone   DMA     90      6      2      1      1      ...  
Node 0, zone   Normal 1650    310      5      0      0      ...  
Node 0, zone   HighMem      2      0      0      1      1      ...  
```

E.2.2. `/proc/cmdline`

This file shows the parameters passed to the kernel at the time it is started. A sample `/proc/cmdline` file looks like the following:

```
ro root=/dev/VolGroup00/LogVol00 rhgb quiet 3
```

This tells us that the kernel is mounted read-only (signified by `{ro}`), located on the first logical volume (LogVol00) of the first volume group (/dev/VolGroup00). LogVol00 is the equivalent of a disk partition in a non-LVM system (Logical Volume Management), just as /dev/VolGroup00 is similar in concept to /dev/hda1, but much more extensible.

For more information on LVM used in Fedora, refer to [http://www.tldp.org/HOWTO/LVM-HOWTO/index.html](http://www.tldp.org/HOWTO/LVM-HOWTO/index.html).

Next, `rhgb` signals that the `rhgb` package has been installed, and graphical booting is supported, assuming `/etc/initrd` shows a default runlevel set to `id:3:default`.

Finally, `quiet` indicates all verbose kernel messages are suppressed at boot time.

E.2.3. `/proc/cpuinfo`

This virtual file identifies the type of processor used by your system. The following is an example of the output typical of `/proc/cpuinfo`:

```
```
processor : 0
timestamp: 0
vendor_id : GenuineIntel
cpu family : 15
model : 2
model name : Intel(R) Xeon(TM) CPU 2.40GHz
stepping : 7
cpu MHz : 2392.371
Physical id : 0
siblings : 2
runqueue : 0
fdiv_bug : no
hlt_bug : no
f00f_bug : no
coma_bug : no
fpu : yes
fpu_exception : yes
cpu id level : 2
wp : yes
flags : fpu vme de pse tsc msr pae mce cmov pat pse36 clflush
dts acpi mmx fxsr sse sse2 ss ht tm
bogomips : 4771.62
processor
— Provides each processor with an identifying number. On systems that have one processor, only a 0 is present.
cpu family — Authoritatively identifies the type of processor in the system. For an Intel-based system, place the
type in front of “86” to determine the value. This is particularly helpful for those attempting to identify the
architecture of an older system such as a 586, 486, or 386. Because some RPM packages are compiled for each of
these particular architectures, this value also helps users determine which packages to install.
model name — Displays the common name of the processor, including its project name.
cpu MHz — Shows the precise speed in megahertz for the processor to the thousandths decimal place.
cache size — Displays the amount of level 2 memory cache available to the processor.
siblings — Displays the number of sibling CPUs on the same physical CPU for architectures which use hyper-
threading.
flags — Defines a number of different qualities about the processor, such as the presence of a floating point unit
(FPU) and the ability to process MMX instructions.

E.2.4. /proc/crypto
This file lists all installed cryptographic ciphers used by the Linux kernel, including additional details for each. A sample
/proc/crypto file looks like the following:

| name         | :sha1          |
| module       | :kernel       |
| type         | :digest       |
| blocksize    | :64           |
| digestsize   | :20           |
| name         | :md5          |
| module       | :md5          |
| type         | :digest       |
| blocksize    | :64           |
| digestsize   | :16           |

E.2.5. /proc/devices
This file displays the various character and block devices currently configured (not including devices whose modules are
not loaded). Below is a sample output from this file:

Character devices:
1 mem
4 /dev/vc/0
4 tty
4 ttyS
5 /dev/tty
5 /dev/console
5 /dev/ptmx
7 vcs
18 misc
13 input
29 fb
36 netlink
128 ptm
136 pts
180 usb
110 audio
249 ac97
121 ide0

Block devices:
1 ramdisk
3 ide0
9 md
22 ide1
253 device-mapper
254 adp

The output from /proc/devices includes the major number and name of the device, and is broken into two major
sections: Character devices and Block devices.

Character devices are similar to block devices, except for two basic differences:
1. Character devices do not require buffering. Block devices have a buffer available, allowing them to order requests before addressing them. This is important for devices designed to store information — such as hard drives — because the ability to order the information before writing it to the device allows it to be placed in a more efficient order.

2. Character devices send data with no preconfigured size. Block devices can send and receive information in blocks of a size configured per device.

For more information about devices refer to the following installed documentation:

```
/usr/share/doc/kernel-doc-<kernel_version>/Documentation/devices.txt
```

### E.2.6. /proc/dma

This file contains a list of the registered ISA DMA channels in use. A sample `/proc/dma` file looks like the following:

```
4: cascade
```

### E.2.7. /proc/execdomains

This file lists the execution domains currently supported by the Linux kernel, along with the range of personalities they support.

```
0-0   Linux           [kernel]
```

Think of execution domains as the “personality” for an operating system. Because other binary formats, such as Solaris, UnixWare, and FreeBSD, can be used with Linux, programmers can change the way the operating system treats system calls from these binaries by changing the personality of the task. Except for the `PER_LINUX` execution domain, different personalities can be implemented as dynamically loadable modules.

### E.2.8. /proc/fb

This file contains a list of frame buffer devices, with the frame buffer device number and the driver that controls it. Typical output of `/proc/fb` for systems which contain frame buffer devices looks similar to the following:

```
0 VESA VGA
```

### E.2.9. /proc/filesystems

This file displays a list of the file system types currently supported by the kernel. Sample output from a generic `/proc/filesystems` file looks similar to the following:

```
nodev   sysfs
nodev   rootfs
nodev   bdev
nodev   proc
nodev   sockfs
nodev   binfmt_misc
nodev   usbfs
nodev   usbdevfs
nodev   futexfs
nodev   tmpfs
nodev   pipes
nodev   eventpollfs
nodev   devpts
ext2    ramfs
nodev   hugetlbfs
iso9660
nodev   mqueue
ext3    rpc_pipefs
nodev   autofs
```

The first column signifies whether the file system is mounted on a block device. Those beginning with `nodev` are not mounted on a device. The second column lists the names of the file systems supported.

The `mount` command cycles through the file systems listed here when one is not specified as an argument.

### E.2.10. /proc/interrupts

This file records the number of interrupts per IRQ on the x86 architecture. A standard `/proc/interrupts` looks similar to the following:

```
CPU0
  0:  88448940          XT-PIC  timer
  1:  374412           XT-PIC  keyboard
  2:     0              XT-PIC  cascade
  8:     0              XT-PIC  rtc
10:    410964          XT-PIC  eth0
12:    60330           XT-PIC  PS/2 Mouse
14:   1314121          XT-PIC  ide0
15:   5195422          XT-PIC  ide1
NMI:    0
ERR:    0
```

For a multi-processor machine, this file may look slightly different:
<table>
<thead>
<tr>
<th>CPU0</th>
<th>CPU1</th>
<th>0</th>
<th>XT-PIC timer</th>
</tr>
</thead>
<tbody>
<tr>
<td>0: 1366814704</td>
<td>0</td>
<td>XT-PIC cascade</td>
<td></td>
</tr>
<tr>
<td>1: 128</td>
<td>349</td>
<td>IO-APIC-edge keyboard</td>
<td></td>
</tr>
<tr>
<td>2: 0</td>
<td>0</td>
<td>XT-PIC cascade</td>
<td></td>
</tr>
<tr>
<td>8: 0</td>
<td>1</td>
<td>IO-APIC-edge rtc</td>
<td></td>
</tr>
<tr>
<td>12: 5323</td>
<td>5793</td>
<td>IO-APIC-edge PS/2 Mouse</td>
<td></td>
</tr>
<tr>
<td>13: 1</td>
<td>0</td>
<td>XT-PIC fpu</td>
<td></td>
</tr>
<tr>
<td>16: 11184294</td>
<td>15940594</td>
<td>IO-APIC-level Intel EtherExpress Pro 10/100 Ethernet</td>
<td></td>
</tr>
<tr>
<td>20: 8450043</td>
<td>11120093</td>
<td>IO-APIC-level megaraid</td>
<td></td>
</tr>
<tr>
<td>30: 18432</td>
<td>10722</td>
<td>IO-APIC-level aic7xxx</td>
<td></td>
</tr>
<tr>
<td>31: 23</td>
<td>22</td>
<td>IO-APIC-level aic7xxx</td>
<td></td>
</tr>
</tbody>
</table>

The first column refers to the IRQ number. Each CPU in the system has its own column and its own number of interrupts per IRQ. The next column reports the type of interrupt, and the last column contains the name of the device that is located at that IRQ.

Each of the types of interrupts seen in this file, which are architecture-specific, mean something different. For x86 machines, the following values are common:

- **XT-PIC** — This is the old AT computer interrupts.
- **IO-APIC-edge** — The voltage signal on this interrupt transitions from low to high, creating an edge, where the interrupt occurs and is only signaled once. This kind of interrupt, as well as the **IO-APIC-level** interrupt, are only seen on systems with processors from the 586 family and higher.
- **IO-APIC-level** — Generates interrupts when its voltage signal is high until the signal is low again.

### E.2.11. /proc/iomem

This file shows you the current map of the system's memory for each physical device:

<table>
<thead>
<tr>
<th>Memory Address</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>00000000-0009fbff</td>
<td>System RAM</td>
</tr>
<tr>
<td>0009fc00-0009ffffff</td>
<td>reserved</td>
</tr>
<tr>
<td>000a0000-000bffff</td>
<td>Video RAM area</td>
</tr>
<tr>
<td>000cc0000-000c7fff</td>
<td>Video ROM</td>
</tr>
<tr>
<td>000f0000-000fffffff</td>
<td>System ROM</td>
</tr>
<tr>
<td>00100000-0010ffffff</td>
<td>System RAM</td>
</tr>
<tr>
<td>00100000-00291ba8</td>
<td>Kernel code</td>
</tr>
<tr>
<td>00291ba9-002e09cb</td>
<td>Kernel data</td>
</tr>
<tr>
<td>e0000000-e3ffffff</td>
<td>VIA Technologies, Inc. VT82C597 [Apollo VP3]</td>
</tr>
<tr>
<td>e4000000-e7ffffff</td>
<td>PCI Bus #01</td>
</tr>
<tr>
<td>e4000000-e4003fff</td>
<td>Matrox Graphics, Inc. MGA G200 AGP</td>
</tr>
<tr>
<td>e5000000-e57ffff</td>
<td>Matrox Graphics, Inc. MGA G200 AGP</td>
</tr>
<tr>
<td>e8000000-e8ffffff</td>
<td>Matrox Graphics, Inc. MGA G200 AGP</td>
</tr>
<tr>
<td>ea000000-ea00007f</td>
<td>Digital Equipment Corporation DECchip 21140 [FasterNet]</td>
</tr>
<tr>
<td>ea000000-ea00007f</td>
<td>tulp ffff0000-ffffff</td>
</tr>
</tbody>
</table>

The first column displays the memory registers used by each of the different types of memory. The second column lists the kind of memory located within those registers and displays which memory registers are used by the kernel within the system RAM or, if the network interface card has multiple Ethernet ports, the memory registers assigned for each port.

### E.2.12. /proc/ioports

The output of `/proc/ioports` provides a list of currently registered port regions used for input or output communication with a device. This file can be quite long. The following is a partial listing:

<table>
<thead>
<tr>
<th>Port Address</th>
<th>Device</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000-001f</td>
<td>dma1</td>
</tr>
<tr>
<td>0020-003f</td>
<td>pic1</td>
</tr>
<tr>
<td>0040-005f</td>
<td>timer</td>
</tr>
<tr>
<td>0060-006f</td>
<td>keyboard</td>
</tr>
<tr>
<td>0070-007f</td>
<td>rtc</td>
</tr>
<tr>
<td>0080-008f</td>
<td>dma page reg</td>
</tr>
<tr>
<td>00a0-00bf</td>
<td>pic2</td>
</tr>
<tr>
<td>00c0-00df</td>
<td>dma2</td>
</tr>
<tr>
<td>00f0-00ff</td>
<td>fpu</td>
</tr>
<tr>
<td>0170-017f</td>
<td>ide1</td>
</tr>
<tr>
<td>01f0-01ff</td>
<td>ide0</td>
</tr>
<tr>
<td>02f0-02ff</td>
<td>serial(auto)</td>
</tr>
<tr>
<td>0370-037f</td>
<td>ide1</td>
</tr>
<tr>
<td>03c0-03df</td>
<td>vga+</td>
</tr>
<tr>
<td>03f0-03ff</td>
<td>ide0</td>
</tr>
<tr>
<td>03f0-03ff</td>
<td>serial(auto)</td>
</tr>
<tr>
<td>0cf0-0cff</td>
<td>PCI conf1</td>
</tr>
<tr>
<td>d000-ffff</td>
<td>PCI Bus #01</td>
</tr>
<tr>
<td>e000-e00f</td>
<td>VIA Technologies, Inc. Bus Master IDE</td>
</tr>
<tr>
<td>e000-e00f</td>
<td>ide0</td>
</tr>
<tr>
<td>e000-e00f</td>
<td>ide1</td>
</tr>
<tr>
<td>e000-e87f</td>
<td>Digital Equipment Corporation DECchip 21140 [FasterNet]</td>
</tr>
<tr>
<td>e000-e87f</td>
<td>tulp</td>
</tr>
</tbody>
</table>

The first column gives the I/O port address range reserved for the device listed in the second column.

### E.2.13. /proc/kcore

This file represents the physical memory of the system and is stored in the core file format. Unlike most `/proc/` files, `kcore` displays a size. This value is given in bytes and is equal to the size of the physical memory (RAM) used plus 4 KB.

The contents of this file are designed to be examined by a debugger, such as `gdb`, and is not human readable.
Do not attempt to view the content of /proc/kcore

Do not attempt to view the /Proc/kcore virtual file. The contents of the file scramble text output on the terminal. If this file is accidentally viewed, press Ctrl+C to stop the process and then type reset to bring back the command line prompt.

E.2.14. /proc/kmsg

This file is used to hold messages generated by the kernel. These messages are then picked up by other programs, such as /sbin/klogd or /bin/dmesg.

E.2.15. /proc/loadavg

This file provides a look at the load average in regard to both the CPU and IO over time, as well as additional data used by uptime and other commands. A sample /proc/loadavg file looks similar to the following:

```
0.20 0.18 0.12 1/80 11206
```

The first three columns measure CPU and IO utilization of the last one, five, and 15 minute periods. The fourth column shows the number of currently running processes and the total number of processes. The last column displays the last process ID used.

In addition, load average also refers to the number of processes ready to run (i.e. in the run queue, waiting for a CPU share).

E.2.16. /proc/locks

This file displays the files currently locked by the kernel. The contents of this file contain internal kernel debugging data and can vary tremendously, depending on the use of the system. A sample /proc/locks file for a lightly loaded system looks similar to the following:

```
1: POSIX ADVISORY WRITE 3568 fd:00:2531452 0 EOF
2: FLOCK ADVISORY WRITE 3517 fd:00:2531448 0 EOF
3: POSIX ADVISORY WRITE 3452 fd:00:2531442 0 EOF
4: POSIX ADVISORY WRITE 3443 fd:00:2531448 0 EOF
5: POSIX ADVISORY WRITE 3326 fd:00:2531430 0 EOF
6: POSIX ADVISORY WRITE 3175 fd:00:2531425 0 EOF
7: POSIX ADVISORY WRITE 3056 fd:00:2548663 0 EOF
```

Each lock has its own line which starts with a unique number. The second column refers to the class of lock used, with FLOCK signifying the older-style UNIX file locks from a flock system call and POSIX representing the newer POSIX locks from the lockf system call.

The third column can have two values: ADVISORY or MANDATORY. ADVISORY means that the lock does not prevent other people from accessing the data; it only prevents other attempts to lock it. MANDATORY means that no other access to the data is permitted while the lock is held. The fourth column reveals whether the lock is allowing the holder READ or WRITE access to the file. The fifth column shows the ID of the process holding the lock. The sixth column shows the ID of the file being locked, in the format of MAJOR-DEVICE:MINOR-DEVICE:INODE-NUMBER. The seventh and eighth column shows the start and end of the file's locked region.

E.2.17. /proc/mdstat

This file contains the current information for multiple-disk, RAID configurations. If the system does not contain such a configuration, then /proc/mdstat looks similar to the following:

```
Personalities : read_ahead not set unused devices: <none>
```

This file remains in the same state as seen above unless a software RAID or nd device is present. In that case, view /proc/mdstat to find the current status of mdX RAID devices.

The /proc/mdstat file below shows a system with its md0 configured as a RAID 1 device, while it is currently re-syncing the disks:

```
Personalities : [linear] [raid1] read_ahead 1824 sectors
unused devices: <none>
```

E.2.18. /proc/meminfo

This is one of the more commonly used files in the /proc/ directory, as it reports a large amount of valuable information about the systems RAM usage.

The following sample /proc/meminfo virtual file is from a system with 256 MB of RAM and 512 MB of swap space:
MemTotal:       255908 kB
MemFree:         69936 kB
Buffers:         15812 kB
Cached:         115124 kB
SwapCached:          0 kB
Active:          92700 kB
Inactive:        63792 kB
HighTotal:           0 kB
HighFree:            0 kB
LowTotal:       255908 kB
LowFree:         69936 kB
SwapTotal:      524280 kB
SwapFree:        524280 kB
Dirty:                4 kB
Writeback:          0 kB
Mapped:          42236 kB
Slab:            25912 kB
Committed_AS:    118680 kB
PageTables:       1236 kB
VmallocTotal:  3874808 kB
VmallocUsed:      1416 kB
VmallocChunk:  3872908 kB
HugePages_Total:     0
HugePages_Free:      0
Hugepagesize:     4096 kB

Much of the information here is used by the `free`, `top`, and `ps` commands. In fact, the output of the `free` command is similar in appearance to the contents and structure of `/proc/meminfo`. But by looking directly at `/proc/meminfo`, more details are revealed:

- **MemTotal** — Total amount of physical RAM, in kilobytes.
- **MemFree** — The amount of physical RAM, in kilobytes, left unused by the system.
- **Buffers** — The amount of physical RAM, in kilobytes, used for file buffers.
- **Cached** — The amount of physical RAM, in kilobytes, used as cache memory.
- **SwapCached** — The amount of swap, in kilobytes, used as cache memory.
- **Active** — The total amount of buffer or page cache memory, in kilobytes, that is in active use. This is memory that has been recently used and is usually not reclaimed for other purposes.
- **Inactive** — The total amount of buffer or page cache memory, in kilobytes, that are free and available. This is memory that has not been recently used and can be reclaimed for other purposes.
- **HighTotal** and **HighFree** — The total and free amount of memory, in kilobytes, that is not directly mapped into kernel space. The **HighTotal** value can vary based on the type of kernel used.
- **LowTotal** and **LowFree** — The total and free amount of memory, in kilobytes, that is directly mapped into kernel space. The **LowTotal** value can vary based on the type of kernel used.
- **SwapTotal** — The total amount of swap available, in kilobytes.
- **SwapFree** — The total amount of swap free, in kilobytes.
- **Dirty** — The total amount of memory, in kilobytes, waiting to be written back to the disk.
- **Writeback** — The total amount of memory, in kilobytes, actively being written back to the disk.
- **Mapped** — The total amount of memory, in kilobytes, which have been used to map devices, files, or libraries using the `mmap` command.
- **Slab** — The total amount of memory, in kilobytes, used by the kernel to cache data structures for its own use.
- **Committed_AS** — The total amount of memory, in kilobytes, estimated to complete the workload. This value represents the worst case scenario value, and also includes swap memory.
- **PageTables** — The total amount of memory, in kilobytes, dedicated to the lowest page table level.
- **VmallocTotal** — The total amount of memory, in kilobytes, of total allocated virtual address space.
- **VmallocUsed** — The total amount of memory, in kilobytes, of used virtual address space.
- **VmallocChunk** — The largest contiguous block of memory, in kilobytes, of available virtual address space.
- **HugePages_Total** — The total number of hugepages for the system. The number is derived by dividing `Hugepagesize` by the megabytes set aside for hugepages specified in `/proc/sys/vm/hugetlb_pool`. This statistic only appears on the x86, Itanium, and AMD64 architectures.
- **HugePages_Free** — The total number of hugepages available for the system. This statistic only appears on the x86, Itanium, and AMD64 architectures.
- **Hugepagesize** — The size for each hugepages unit in kilobytes. By default, the value is 4096 KB on uniprocessor kernels for 32 bit architectures. For SMP, hugemem kernels, and AMD64, the default is 2048 KB. For Itanium architectures, the default is 262144 KB. This statistic only appears on the x86, Itanium, and AMD64 architectures.

### E.2.19. /proc/misc

This file lists miscellaneous drivers registered on the miscellaneous major device, which is device number 10:

```
  63 device-mapper 175 agpgart 135 rtc 134 apm_bios
```

The first column is the minor number of each device, while the second column shows the driver in use.

### E.2.20. /proc/modules

This file displays a list of all modules loaded into the kernel. Its contents vary based on the configuration and use of your system, but it should be organized in a similar manner to this sample `/proc/modules` file output:
The content of /proc/modules

This example has been reformatted into a readable format. Most of this information can also be viewed via the /sbin/lsmod command.

<table>
<thead>
<tr>
<th>Module</th>
<th>Usage</th>
<th>Load State</th>
<th>Memory Offset</th>
</tr>
</thead>
<tbody>
<tr>
<td>nfs</td>
<td>170109</td>
<td>Live</td>
<td>0x129b0000</td>
</tr>
<tr>
<td>lockd</td>
<td>51593</td>
<td>Live</td>
<td>0x128b0000</td>
</tr>
<tr>
<td>nfs_utf8</td>
<td>1729</td>
<td>Live</td>
<td>0x12830000</td>
</tr>
<tr>
<td>vfat</td>
<td>32697</td>
<td>Live</td>
<td>0x12833000</td>
</tr>
<tr>
<td>fat</td>
<td>38881</td>
<td>Live</td>
<td>0x1287b0000</td>
</tr>
<tr>
<td>autofs4</td>
<td>20293</td>
<td>Live</td>
<td>0x1284f0000</td>
</tr>
<tr>
<td>sunrpc</td>
<td>140453</td>
<td>Live</td>
<td>0x12954000</td>
</tr>
<tr>
<td>3c59x</td>
<td>33257</td>
<td>Live</td>
<td>0x12871000</td>
</tr>
<tr>
<td>uhci_hcd</td>
<td>28377</td>
<td>Live</td>
<td>0x12869000</td>
</tr>
<tr>
<td>md5</td>
<td>3777</td>
<td>Live</td>
<td>0x1282c0000</td>
</tr>
<tr>
<td>ipv6</td>
<td>211845</td>
<td>Live</td>
<td>0x12869000</td>
</tr>
<tr>
<td>ext3</td>
<td>92585</td>
<td>Live</td>
<td>0x12857000</td>
</tr>
<tr>
<td>jbd</td>
<td>20293</td>
<td>Live</td>
<td>0x1284f0000</td>
</tr>
<tr>
<td>dm_mod</td>
<td>5677</td>
<td>Live</td>
<td>0x12833000</td>
</tr>
</tbody>
</table>

The first column contains the name of the module.
The second column refers to the memory size of the module, in bytes.
The fourth column lists how many instances of the module are currently loaded. A value of zero represents an unloaded module.
The fifth column states if the module depends upon another module to be present in order to function, and lists those other modules.
The sixth column lists what load state the module is in: Live, Loading, or Unloading are the only possible values.
The sixth column lists the current kernel memory offset for the loaded module. This information can be useful for debugging purposes, or for profiling tools such asoprofile.

E.2.21. /proc/mounts

This file provides a list of all mounts in use by the system:

```
rootfs / rootfs rw 0 0
/proc /proc proc rw,nodiratime 0 0 none
/dev/ramfs /dev/ramfs rw 0 0
/dev/volGroup00-LogVol00 /ext3 rw 0 0 none
/dev/pts /dev/pts rw 0 0
/sys /sys sysfs rw 0 0
/usr/bin /proc/bin bw 0 0
/sunrpc/var/lib/nfs/rpc_pipefs rw 0 0
```

The output found here is similar to the contents of /etc/mtab, except that /proc/mounts is more up-to-date.
The first column specifies the device that is mounted, the second column reveals the mount point, and the third column tells the file system type, and the fourth column tells you if it is mounted read-only (ro) or read-write (rw). The fifth and sixth columns are dummy values designed to match the format used in /etc/mtab.

E.2.22. /proc/mtrr

This file refers to the current Memory Type Range Registers (MTRRs) in use with the system. If the system architecture supports MTRRs, then the /proc/mtrr file may look similar to the following:

```
reg00: base=0x00000000 ( 0MB), size= 256MB: write-back, count=1
reg01: base=0x00000000 (3712MB) size= 32MB: write-combining, count=1
```

MTRRs are used with the Intel P6 family of processors (Pentium II and higher) and control processor access to memory ranges. When using a video card on a PCI or AGP bus, a properly configured /proc/mtrr file can increase performance more than 150%.

Most of the time, this value is properly configured by default. More information on manually configuring this file can be found locally at the following location:

/usr/share/doc/kernel-doc-<kernel_version>/Documentation/<arch>/mtrr.txt

E.2.23. /proc/partitions

This file contains partition block allocation information. A sampling of this file from a basic system looks similar to the following:
Most of the information here is of little importance to the user, except for the following columns:

- **major** — The major number of the device with this partition. The major number in the `/proc/partitions` file corresponds with the block device `/dev/ide0` in the `/proc/devices` file.
- **minor** — The minor number of the device with this partition. This serves to separate the partitions into different physical devices and relates to the number at the end of the name of the partition.
- **#blocks** — Lists the number of physical disk blocks contained in a particular partition.
- **name** — The name of the partition.

### E.2.24. `/proc/slabinfo`

This file gives full information about memory usage on the slab level. Linux kernels greater than version 2.2 use slab pools to manage memory above the page level. Commonly used objects have their own slab pools.

Instead of parsing the highly verbose `/proc/slabinfo` file manually, the `/usr/bin/slabtop` program displays kernel slab cache information in real time. This program allows for custom configurations, including column sorting and screen refreshing.

A sample screen shot of `/usr/bin/slabtop` usually looks like the following example:

<table>
<thead>
<tr>
<th>OBJS</th>
<th>Active</th>
<th>Total</th>
<th>Objects (% used)</th>
<th>OBJ SIZE</th>
<th>SLABS</th>
<th>OBJ/SLAB</th>
<th>CACHE SIZE</th>
<th>NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>44814</td>
<td>43159</td>
<td>96%</td>
<td>0.62K</td>
<td>7469</td>
<td></td>
<td></td>
<td>29876K</td>
<td>ext3_inode_cache</td>
</tr>
<tr>
<td>36900</td>
<td>34614</td>
<td>93%</td>
<td>0.05K</td>
<td>492</td>
<td>75</td>
<td></td>
<td>1968K</td>
<td>buffer_head</td>
</tr>
<tr>
<td>35213</td>
<td>33124</td>
<td>94%</td>
<td>0.16K</td>
<td>1531</td>
<td>23</td>
<td></td>
<td>6124K</td>
<td>dentry_cache</td>
</tr>
<tr>
<td>2585</td>
<td>1781</td>
<td>68%</td>
<td>0.08K</td>
<td>55</td>
<td>47</td>
<td></td>
<td>220K</td>
<td>vm_area_struct</td>
</tr>
<tr>
<td>1904</td>
<td>1125</td>
<td>59%</td>
<td>0.12K</td>
<td>16</td>
<td>119</td>
<td></td>
<td>64K</td>
<td>size-32</td>
</tr>
<tr>
<td>1866</td>
<td>768</td>
<td>46%</td>
<td>0.03K</td>
<td>14</td>
<td>119</td>
<td></td>
<td>56K</td>
<td>size-64</td>
</tr>
<tr>
<td>1512</td>
<td>1482</td>
<td>98%</td>
<td>0.44K</td>
<td>168</td>
<td>9</td>
<td></td>
<td>672K</td>
<td>inode_cache</td>
</tr>
</tbody>
</table>

Some of the more commonly used statistics in `/proc/slabinfo` that are included into `/usr/bin/slabtop` include:

- **OBJS** — The total number of objects (memory blocks), including those in use (allocated), and some spares not in use.
- **ACTIVE** — The number of objects (memory blocks) that are in use (allocated).
- **USE** — Percentage of total objects that are active. ((ACTIVE/OBJS)(100))
- **OBJ SIZE** — The size of the objects.
- **SLABS** — The total number of slabs.
- **OBJ/SLAB** — The number of objects that fit into a slab.
- **CACHE SIZE** — The cache size of the slab.
- **NAME** — The name of the slab.

For more information on the `/usr/bin/slabtop` program, refer to the `slabtop` man page.

### E.2.25. `/proc/stat`

This file keeps track of a variety of different statistics about the system since it was last restarted. The contents of `/proc/stat`, which can be quite long, usually begins like the following example:
Some of the more commonly used statistics include:

- **cpu** — Measures the number of jiffies (1/100 of a second for x86 systems) that the system has been in user mode, user mode with low priority (nice), system mode, idle task, I/O wait, IRQ (hardirq), and softirq respectively. The IRQ (hardirq) is the direct response to a hardware event. The IRQ takes minimal work for queuing the "heavy" work up for the softirq to execute. The softirq runs at a lower priority than the IRQ and therefore may be interrupted more frequently. The total for all CPUs is given at the top, while each individual CPU is listed below with its own statistics. The following example is a 4-way Intel Pentium Xeon configuration with multi-threading enabled, therefore showing four physical processors and four virtual processors totaling eight processors.

- **page** — The number of memory pages the system has written in and out to disk.

- **swap** — The number of swap pages the system has brought in and out.

- **intr** — The number of interrupts the system has experienced.

- **btime** — The boot time, measured in the number of seconds since January 1, 1970, otherwise known as the epoch.

### E.2.26. /proc/swaps

This file measures swap space and its utilization. For a system with only one swap partition, the output of /proc/swaps may look similar to the following:

<table>
<thead>
<tr>
<th>Filename</th>
<th>Type</th>
<th>Size</th>
<th>Used</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>/dev/mapper/VolGroup00-LogVol01</td>
<td>partition</td>
<td>524280</td>
<td>0</td>
<td>-1</td>
</tr>
</tbody>
</table>

While some of this information can be found in other files in the /proc/ directory, /proc/swap provides a snapshot of every swap file name, the type of swap space, the total size, and the amount of space in use (in kilobytes). The priority column is useful when multiple swap files are in use. The lower the priority, the more likely the swap file is to be used.

### E.2.27. /proc/sysrq-trigger

Using the `echo` command to write to this file, a remote root user can execute most System Request Key commands remotely as if at the local terminal. To `echo` values to this file, the /proc/sys/kernel/sysrq must be set to a value other than 0. For more information about the System Request Key, refer to Section E.3.9.3, "/proc/sys/kernel/".

Although it is possible to write to this file, it cannot be read, even by the root user.

### E.2.28. /proc/uptime

This file contains information detailing how long the system has been on since its last restart. The output of /proc/uptime is quite minimal:

```
350735.47 234388.90
```

The first number is the total number of seconds the system has been up. The second number is how much of that time the machine has spent idle, in seconds.

### E.2.29. /proc/version

This file specifies the version of the Linux kernel, the version of gcc used to compile the kernel, and the time of kernel compilation. It also contains the kernel compiler’s user name (in parentheses).

```
Linux version 2.6.8-1.523 (user@foo.redhat.com) (gcc version 3.4.1 20040714 \ (Red Hat Enterprise Linux 3.4.1-7)) #1 Mon Aug 16 12:27:03 EDT 2004
```

This information is used for a variety of purposes, including the version data presented when a user logs in.

### E.3. Directories within /proc/

Common groups of information concerning the kernel are grouped into directories and subdirectories within the /proc/ directory.
E.3.1. Process Directories

Every `/proc/` directory contains a number of directories with numerical names. A listing of them may be similar to the following:

<table>
<thead>
<tr>
<th>Mode</th>
<th>Owner</th>
<th>Group</th>
<th>Size</th>
<th>Mode</th>
<th>Owner</th>
<th>Group</th>
<th>Size</th>
<th>Mode</th>
<th>Owner</th>
<th>Group</th>
<th>Size</th>
<th>Mode</th>
<th>Owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>dr-xr-xr-x</td>
<td>root</td>
<td>root</td>
<td>0</td>
<td>Feb 13 01:28</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>dr-xr-xr-x</td>
<td>root</td>
<td>root</td>
<td>0</td>
<td>Feb 13 01:28</td>
<td>1010</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>dr-xr-xr-x</td>
<td>daemon</td>
<td>daemon</td>
<td>0</td>
<td>Feb 13 01:28</td>
<td>1123</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>dr-xr-xr-x</td>
<td>root</td>
<td>root</td>
<td>0</td>
<td>Feb 13 01:28</td>
<td>11807</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>dr-xr-xr-x</td>
<td>apache</td>
<td>apache</td>
<td>0</td>
<td>Feb 13 01:28</td>
<td>12660</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>dr-xr-xr-x</td>
<td>rpc</td>
<td>rpc</td>
<td>0</td>
<td>Feb 13 01:28</td>
<td>637</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>dr-xr-xr-x</td>
<td>rpcuser</td>
<td>rpcuser</td>
<td>0</td>
<td>Feb 13 01:28</td>
<td>666</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

These directories are called process directories, as they are named after a program's process ID and contain information specific to that process. The owner and group of each process directory is set to the user running the process. When the process is terminated, its `/proc/` process directory vanishes.

Each process directory contains the following files:

- `cmdline` — Contains the command issued when starting the process.
- `cwd` — A symbolic link to the current working directory for the process.
- `environ` — A list of the environment variables for the process. The environment variable is given in all upper-case characters, and the value is in lower-case characters.
- `exe` — A symbolic link to the executable of this process.
- `fd` — A directory containing all of the file descriptors for a particular process. These are given in numbered links:
  - `total` 0
  - `lrwx------` 1 root root 64 May 8 11:31 0 -> /dev/null
  - `lrwx------` 1 root root 64 May 8 11:31 1 -> /dev/null
  - `lrwx------` 1 root root 64 May 8 11:31 2 -> /dev/null
  - `lrwx------` 1 root root 64 May 8 11:31 3 -> /dev/ptmx
  - `lrwx------` 1 root root 64 May 8 11:31 4 -> socket:[7774817]
  - `lrwx------` 1 root root 64 May 8 11:31 5 -> /dev/ptmx
  - `lrwx------` 1 root root 64 May 8 11:31 6 -> socket:[7774829]
  - `lrwx------` 1 root root 64 May 8 11:31 7 -> /dev/ptmx
- `maps` — A list of memory maps to the various executables and library files associated with this process. This file can be rather long, depending upon the complexity of the process, but sample output from the `sshd` process begins like the following:
  - `08048000-08086000 r-xp 00000000 03:03 391479 /usr/sbin/sshd`
  - `08086000-08088000 rw-p 0003e000 03:03 391479 /usr/sbin/sshd`
  - `08088000-08095000 rwxp 00000000 00:00 0 40000000-40013000 r-xp 00000000 03:03 293205 /lib/ld-2.2.5.so`
  - `40013000-40014000 rw-p 00013000 03:03 293205 /lib/ld-2.2.5.so`
  - `40014000-40015000 r-xp 00000000 03:03 293205 /lib/ld-2.2.5.so`
  - `40015000-40016000 rw-p 00000000 03:03 293228 /lib/libpam.so.0.75`
  - `40020000-40023000 r-xp 00000000 03:03 293228 /lib/libpam.so.0.75`
  - `40023000-40025000 rw-p 00000000 03:03 293228 /lib/libpam.so.0.75`
  - `40025000-40026000 rw-p 00000000 03:03 293228 /lib/libpam.so.0.75`
- `mem` — The memory held by the process. This file cannot be read by the user.
- `root` — A link to the root directory of the process.
- `stat` — The status of the process.
- `statm` — The status of the memory in use by the process. Below is a sample `/proc/statm` file:

```
263 216 218 5 0 285 0
```

The seven columns relate to different memory statistics for the process. From left to right, they report the following aspects of the memory used:

1. Total program size, in kilobytes.
2. Size of memory portions, in kilobytes.
3. Number of pages that are shared.
4. Number of pages that are code.
5. Number of pages of data/stack.
6. Number of library pages.
7. Number of dirty pages.

- `status` — The status of the process in a more readable form than `stat` or `statm`. Sample output for `sshd` looks similar to the following:
Name: sshd
State: S (sleeping)
Tgid: 797
Pid: 797
PPid: 1
TracerPid: 0
Uid: 0 0 0 0
Gid: 0 0 0 0
FDSize: 32
Groups:
  VmSize: 3072 kB
  VmLck: 0 kB
  VmRSS: 840 kB
  VmData: 104 kB
  VmStk: 12 kB
  VmExe: 300 kB
  VmLib: 2528 kB
  SigPnd: 0000000000000000
  SigBlk: 0000000000000000
  SigIgn: 8000000000001000
  SigCgt: 0000000000014005
  CapInh: 0000000000000000
  CapPrm: 00000000fffffeff
  CapEff: 00000000fffffeff

The information in this output includes the process name and ID, the state (such as S (sleeping) or R (running)), user/group ID running the process, and detailed data regarding memory usage.

E.3.1.1. /proc/self/
The `/proc/self/` directory is a link to the currently running process. This allows a process to look at itself without having to know its process ID.

Within a shell environment, a listing of the `/proc/self/` directory produces the same contents as listing the process directory for that process.

E.3.2. /proc/bus/
This directory contains information specific to the various buses available on the system. For example, on a standard system containing PCI and USB buses, current data on each of these buses is available within a subdirectory within `/proc/bus/` by the same name, such as `/proc/bus/pci/`.

The subdirectories and files available within `/proc/bus/` vary depending on the devices connected to the system. However, each bus type has at least one directory. Within these bus directories are normally at least one subdirectory with a numerical name, such as `001`, which contain binary files.

For example, the `/proc/bus/usb/` subdirectory contains files that track the various devices on any USB buses, as well as the drivers required for them. The following is a sample listing of a `/proc/bus/usb/` directory:

```
total 0 dr-xr-xr-x 1 root root 0 May  3 16:25 001
-r--r--r-- 1 root root 0 May  3 16:25 devices
-r--r--r-- 1 root root 0 May  3 16:25 drivers
```

The `/proc/bus/usb/001/` directory contains all devices on the first USB bus and the `devices` file identifies the USB root hub on the motherboard.

The following is a example of a `/proc/bus/usb/devices` file:

```
T:  Bus=01 Lev=00 Prnt=00 Port=00 Cnt=00 Dev=  1 Spd=12  MxCh=  2
B:  Alloc=  0/900 us ( 0%), #Int=  0, #Iso=  0
D:  Ver= 1.00 Cls=09(hub    ) Sub=00 Prot=00 MxPS= 8 #Cfgs=  1
P:  Vendor=0000 ProdID=0000 Rev= 0.00
S:  Product=USB UHCI Root Hub
S:  SerialNumber=d400
C:* #Ifs= 1 Cfg= 1 Atr=40 MxPwr= 0mA
I:  Ifs= 0 Alt= 0 #EPs= 1 Cls=09(hub    ) Sub=00 Prot=00 Driver=hub
   Ad=01(1) Atr=03(Inf.) MxPS= 8 lvl=255ms
```

E.3.3. /proc/bus/pci/
Later versions of the 2.6 Linux kernel have obsoleted the `/proc/pci` directory in favor of the `/proc/bus/pci` directory.

Although you can get a list of all PCI devices present on the system using the command `cat /proc/bus/pci/devices`, the output is difficult to read and interpret.

For a human-readable list of PCI devices, run the following command:
The output is a sorted list of all IRQ numbers and addresses as seen by the cards on the PCI bus instead of as seen by the kernel. Beyond providing the name and version of the device, this list also gives detailed IRQ information so an administrator can quickly look for conflicts.

E.3.4. /proc/driver/

This directory contains information for specific drivers in use by the kernel.  

A common file found here is rtc which provides output from the driver for the system's Real Time Clock (RTC), the device that keeps the time while the system is switched off. Sample output from /proc/driver/rtc looks like the following:

```
rtc_time: 16:21:00
rtc_date: 2004-08-31
rtc_epoch: 1900
alarm: 21:16:27
DST_enable: no
BCD: yes
24hr: yes
square_wave: no
alarm_IRQ: no
update_IRQ: no
periodic_IRQ: no
periodic_freq: 1024
batt_status: okay
```

For more information about the RTC, refer to the following installed documentation:

```
/usr/share/doc/kernel-doc-<kernel_version>/Documentation/rtc.txt
```

E.3.5. /proc/fs

This directory shows which file systems are exported.  If running an NFS server, typing `cat /proc/fs/nfsd/exports` displays the file systems being shared and the permissions granted for those file systems.  For more on file system sharing with NFS, refer to the Network File System (NFS) chapter of the Storage Administration Guide.

E.3.6. /proc/irq/

This directory is used to set IRQ to CPU affinity, which allows the system to connect a particular IRQ to only one CPU. Alternatively, it can exclude a CPU from handling any IRQs.

Each IRQ has its own directory, allowing for the individual configuration of each IRQ. The `/proc/irq/prof_cpu_mask` file is a bitmask that contains the default values for the `smp_affinity` file in the IRQ directory. The values in `smp_affinity` specify which CPUs handle that particular IRQ.

For more information about the `/proc/irq/` directory, refer to the following installed documentation:

```
/usr/share/doc/kernel-doc-<kernel_version>/Documentation/filesystems/proc.txt
```

E.3.7. /proc/net/

This directory provides a comprehensive look at various networking parameters and statistics. Each directory and virtual file within this directory describes aspects of the system’s network configuration. Below is a partial list of the `/proc/net/` directory:

- `arp` — Lists the kernel's ARP table. This file is particularly useful for connecting a hardware address to an IP address on a system.
- `atm/` directory — The files within this directory contain Asynchronous Transfer Mode (ATM) settings and statistics. This
The primary file in this directory is `/proc/scsi/scsi`, which contains a list of every recognized SCSI device. From this listing, the type of device, as well as the model name, vendor, SCSI channel and ID data is available.

For example, if a system contains a SCSI CD-ROM, a tape drive, a hard drive, and a RAID controller, this file looks similar to the following:

```
Attached devices:
Host: scsi1
 Channel: 00
  Id: 05
  Lun: 00
  Vendor: NEC
  Model: CD-ROM DRIVE:466
  Rev: 1.06
  Type:   CD-ROM
  ANSI SCSI revision: 02
Host: scsi1
 Channel: 00
  Id: 06
  Lun: 00
  Vendor: ARCHIVE
  Model: Python 04186-XXX
  Rev: 7350
  Type:   Sequential-Access
  ANSI SCSI revision: 02
Host: scsi2
 Channel: 00
  Id: 06
  Lun: 00
  Vendor: DELL
  Model: 1x6 U2W SCSI BP
  Rev: 5.35
  Type:   Processor
  ANSI SCSI revision: 02
Host: scsi2
 Channel: 02
  Id: 00
  Lun: 0
  Vendor: MegaRAID
  Model: LD8 RAID5 34556R
  Rev: 1.81
  Type:   Direct-Access
  ANSI SCSI revision: 02
```

Each SCSI driver used by the system has its own directory within `/proc/scsi`, which contains files specific to each SCSI controller using that driver. From the previous example, `aic7xxx/` and `megaraid/` directories are present, since two drivers are in use. The files in each of the directories typically contain an I/O address range, IRQ information, and statistics for the SCSI controller using that driver. Each controller can report a different type and amount of information. The Adaptec AIC-7880 Ultra SCSI host adapter's file in this example system produces the following output:
Adaptec AIC7xxx driver version: 5.1.20/3.2.4

Compile Options:
TCQ Enabled By Default : Disabled
AIC7XXX_PROC_STATS     : Enabled
AIC7XXX_RESET_DELAY    : 5

Adapter Configuration:
SCSI Adapter: Adaptec AIC-7880 Ultra SCSI host adapter
I/O Base: 0xffe000
Adapter SEEPROM Config: SEEPROM found and used.
Adaptec SCSI BIOS: Enabled
IRQ: 30
SCBs: Active 0, Max Active 1, Allocated 15, HW 16, Page 256
Interrupts: 33726
BIOS Control Word: 0x18a6
Adapter Control Word: 0x1c5f
Extended Translation: Enabled
Disconnect Enable Flags: 0x00ff
Ultra Enable Flags: 0x0020
Tag Queue Enable Flags: 0x0000
Ordered Queue Tag Flags: 0x0000
Default Tag Queue Depth: 0
Tagged Queue By Device array for aic7xxx
Actual queue depth per device for aic7xxx host instance 1:
{1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1}

Statistics:
(scsl1:8:5:0) Device using Narrow/Non transfers at 20.0 MByte/sec, offset 15
Transinfo settings: current(12/15/0/0), goal(12/15/0/0), user(12/15/0/0)
Total transfers 0 (0 reads and 0 writes)
< 2K 2K+ 4K+ 8K+ 16K+ 32K+ 64K+ 128K+
Reads: 0 0 0 0 0 0 0 0
Writes: 0 0 0 0 0 0 0 0

(scsl1:8:6:0) Device using Narrow/Non transfers at 10.0 MByte/sec, offset 15
Transinfo settings: current(25/15/0/0), goal(12/15/0/0), user(12/15/0/0)
Total transfers 132 (0 reads and 132 writes)
< 2K 2K+ 4K+ 8K+ 16K+ 32K+ 64K+ 128K+
Reads: 0 0 4 1 31 0 0 0
Writes: 0 0 1 1 1 0 0 0

This output reveals the transfer speed to the SCSI devices connected to the controller based on channel ID, as well as detailed statistics concerning the amount and sizes of files read or written by that device. For example, this controller is communicating with the CD-ROM at 20 megabytes per second, while the tape drive is only communicating at 10 megabytes per second.

E.3.9. /proc/sys/

The /proc/sys/ directory is different from others in /proc/ because it not only provides information about the system but also allows the system administrator to immediately enable and disable kernel features.

Be careful when changing the content of /proc/sys/

Use caution when changing settings on a production system using the various files in the /proc/sys/ directory. Changing the wrong setting may render the kernel unstable, requiring a system reboot.

For this reason, be sure the options are valid for that file before attempting to change any value in /proc/sys/.

A good way to determine if a particular file can be configured, or if it is only designed to provide information, is to list it with the -l option at the shell prompt. If the file is writable, it may be used to configure the kernel. For example, a partial listing of /proc/sys/fs looks like the following:

-r--r--r--    1 root     root            0 May 10 16:14 dentry-state
-rw-r--r--    1 root     root            0 May 10 16:14 dir-notify-enable
-rw-r--r--    1 root     root            0 May 10 16:14 file-max
-r-r-r-r-r-r-r  1 root     root            0 May 10 16:14 file-nr

In this listing, the files dir-notify-enable and file-max can be written to and, therefore, can be used to configure the kernel. The other files only provide feedback on current settings.

Changing a value within a /proc/sys/ file is done by echoing the new value into the file. For example, to enable the System Request Key on a running kernel, type the command:

```
echo 1 > /proc/sys/kernel/sysrq
```

This changes the value for sysrq from 0 (off) to 1 (on).

A few /proc/sys/ configuration files contain more than one value. To correctly send new values to them, place a space character between each value passed with the echo command, such as is done in this example:

```
echo 4 2 45 > /proc/sys/kernelacct
```

Changes made using the echo command are not persistent

Any configuration changes made using the echo command disappear when the system is restarted. To make configuration changes take effect after the system is rebooted, refer to Section E.4, "Using the sysctl Command".
The `/proc/sys/` directory contains several subdirectories controlling different aspects of a running kernel.

### E.3.9.1. `/proc/sys/dev/`

This directory provides parameters for particular devices on the system. Most systems have at least two directories, `cdrom/` and `raid/`. Customized kernels can have other directories, such as `parport/`, which provides the ability to share one parallel port between multiple device drivers.

The `cdrom/` directory contains a file called `info`, which reveals a number of important CD-ROM parameters:

```
CD-ROM information, Id: cdrom.c 3.20 2003/12/17
drive name:       hdc
drive speed:      48
drive # of slots: 1
Can close tray:   1
Can open tray:    1
Can lock tray:    1
Can change speed: 1
Can select disk:  0
Can read multisession: 1
Can read MCN:     1
Can play audio:   1
Can write CD-R:   0
Can write CD-RW:  0
Can read DVD:     0
Can write DVD-R:  0
Can write DVD-RAM: 0
Can read MRW:     0
Can write MRW:    0
Can write RAM:    0
```

This file can be quickly scanned to discover the qualities of an unknown CD-ROM. If multiple CD-ROMs are available on a system, each device is given its own column of information.

Various files in `/proc/sys/dev/cdrom`, such as `autoclose` and `checkmedia`, can be used to control the system's CD-ROM. Use the `echo` command to enable or disable these features.

If RAID support is compiled into the kernel, a `/proc/sys/dev/raid/` directory becomes available with at least two files in it: `speed_limit_min` and `speed_limit_max`. These settings determine the acceleration of RAID devices for I/O intensive tasks, such as resyncing the disks.

### E.3.9.2. `/proc/sys/fs/`

This directory contains an array of options and information concerning various aspects of the file system, including quota, file handle, inode, and dentry information.

The `binfmt_misc/` directory is used to provide kernel support for miscellaneous binary formats.

The important files in `/proc/sys/fs/` include:

- `dentry-state` — Provides the status of the directory cache. The file looks similar to the following:

  ```
  57411 52939 45 0 0 0
  ```

  The first number reveals the total number of directory cache entries, while the second number displays the number of unused entries. The third number tells the number of seconds between when a directory has been freed and when it can be reclaimed, and the fourth measures the pages currently requested by the system. The last two numbers are not used and display only zeros.

- `file-max` — Lists the maximum number of file handles that the kernel allocates. Raising the value in this file can resolve errors caused by a lack of available file handles.

- `file-nr` — Lists the number of allocated file handles, used file handles, and the maximum number of file handles.

- `overflowgid` and `overflowuid` — Defines the fixed group ID and user ID, respectively, for use with file systems that only support 16-bit group and user IDs.

### E.3.9.3. `/proc/sys/kernel/`

This directory contains a variety of different configuration files that directly affect the operation of the kernel. Some of the most important files include:

- `acct` — Controls the suspension of process accounting based on the percentage of free space available on the file system containing the log. By default, the file looks like the following:

  ```
  4 2 30
  ```

  The first value dictates the percentage of free space required for logging to resume, while the second value sets the threshold percentage of free space when logging is suspended. The third value sets the interval, in seconds, that the kernel polls the file system to see if logging should be suspended or resumed.

- `ctrl-alt-del` — Controls whether Ctrl+Alt+Delete gracefully restarts the computer using `init (0)` or forces an immediate reboot without syncing the dirty buffers to disk (1).

- `domainname` — Configures the system domain name, such as `example.com`.

- `exec-shield` — Configures the Exec Shield feature of the kernel. Exec Shield provides protection against certain types of buffer overflow attacks.

There are two possible values for this virtual file:

- **0** — Disables Exec Shield.
Using Exec Shield

If a system is running security-sensitive applications that were started while Exec Shield was disabled, these applications must be restarted when Exec Shield is enabled in order for Exec Shield to take effect.

- hostname — Configures the system hostname, such as www.example.com.
- hotplug — Configures the utility to be used when a configuration change is detected by the system. This is primarily used with USB and Cardbus PCI. The default value of /sbin/hotplug should not be changed unless testing a new program to fulfill this role.
- modprobe — Sets the location of the program used to load kernel modules. The default value is /sbin/modprobe which means kmod calls it to load the module when a kernel thread calls kmod.
- maxsize — Sets the maximum size of an active process, in bytes. By default, this value is 8192 bytes by default. Be careful when raising this value, as queued messages between processes are stored in non-swappable kernel memory. Any increase in msgmax would increase RAM requirements for the system.
- msgnum — Sets the maximum number of bytes in a single message queue. The default is 4096.
- msgnum1 — Sets the maximum number of message queue identifiers. The default is 4096.
- osrelease — Lists the Linux kernel release number. This file can only be altered by changing the kernel source and recompiling.
- ostype — Displays the type of operating system. By default, this file is set to Linux, and this value can only be changed by changing the kernel source and recompiling.
- overlowgid and overlowuid — Defines the fixed group ID and user ID, respectively, for use with system calls on architectures that only support 16-bit group and user IDs.
- panic — Defines the number of seconds the kernel postpones rebooting when the system experiences a kernel panic. By default, the value is set to 0, which disables automatic rebooting after a panic.
- printk — This file controls a variety of settings related to printing or logging error messages. Each error message reported by the kernel has a loglevel associated with it that defines the importance of the message. The loglevel values break down in this order:
  - 0 — Kernel emergency. The system is unusable.
  - 1 — Kernel alert. Action must be taken immediately.
  - 2 — Condition of the kernel is considered critical.
  - 3 — General kernel error condition.
  - 4 — General kernel warning condition.
  - 5 — Kernel notice of a normal but significant condition.
  - 6 — Kernel informational message.
  - 7 — Kernel debug-level messages.

Four values are found in the printk file:

<table>
<thead>
<tr>
<th>6</th>
<th>4</th>
<th>1</th>
<th>7</th>
</tr>
</thead>
</table>

Each of these values defines a different rule for dealing with error messages. The first value, called the console loglevel, defines the lowest priority of messages printed to the console. (Note that, the lower the priority, the higher the loglevel number.) The second value sets the default loglevel for messages without an explicit loglevel attached to them. The third value sets the lowest possible loglevel configuration for the console loglevel. The last value sets the default value for the console loglevel.

- random/ directory — Lists a number of values related to generating random numbers for the kernel.
- sem — Configures semaphore settings within the kernel. A semaphore is a System V IPC object that is used to control utilization of a particular process.
- shmall — Sets the total amount of shared memory that can be used at one time on the system, in bytes. By default, this value is 2997152.
- shmax — Sets the largest shared memory segment size allowed by the kernel. By default, this value is 33554432. However, the kernel supports much larger values than this.
- shmmul — Sets the maximum number of shared memory segments for the whole system. By default, this value is 4096.
- sysrq — Activates the System Request Key, if this value is set to anything other than zero (0), the default. The System Request Key allows immediate input to the kernel through simple key combinations. For example, the System Request Key can be used to immediately shut down or restart a system, sync all mounted file systems, or dump important information to the console. To initiate a System Request Key, type `Alt+SysRq`.
  - r — Disables raw mode for the keyboard and sets it to XSTATE (a limited keyboard mode which does not recognize modifiers such as Alt, Ctrl, or Shift for all keys).
  - k — Kills all processes active in a virtual console. Also called Secure Access Key (SAK), it is often used to verify that the login prompt is spawned from init and not a trojan copy designed to capture usernames and passwords.
  - b — Reboots the kernel without first unmounting file systems or syncing disks attached to the system.
  - c — Crashes the system without first unmounting file systems or syncing disks attached to the system.
  - o — Shuts off the system.
  - s — Attempts to sync disks attached to the system.
  - u — Attempts to unmount and remount all file systems as read-only.
  - p — Outputs all flags and registers to the console.
The following is a list of some of the more important files within the system:

- **tcp_syn_retries**: The number of times a kernel was built from the source base.
- **version**: Displays the date and time the kernel was last compiled. The first field in this file, such as #3, relates to the number of times a kernel was built from the source base.
- **threads-max**: Sets the maximum number of threads to be used by the kernel, with a default value of 2048.
- **message_burst**: Sets the amount of time in tenths of a second required to write a new warning message. This setting is used to mitigate DoS (Denial of Service) attacks. The default setting is 10.
- **message_cost**: Sets a cost on every warning message. The higher the value of this file (default of 5), the more likely the warning message is ignored. This setting is used to mitigate DoS attacks.
- **ip_local_port_range**: Specifies the range of ports to be used by TCP or UDP when a local port is needed. The first number is the lowest port to be used and the second number specifies the highest port. Any systems that expect to require more ports than the default 1024 to 4999 should use a range from 32768 to 61000.
- **ip_forward**: Permits interfaces on the system to forward packets to one other. By default, this file is set to 0. Setting this file to 1 enables network packet forwarding.
- **ipx/**, **ipv4/**, and **ipv6/**: By altering the files within these directories, system administrators are able to adjust the network configuration on a running system.

The **/proc/sys/net/ipv4/* directory** contains a variety of settings that control the interaction between the kernel and networking layers. The most important of these files are:

- **message_burst**: Sets the amount of time in tenths of a second required to write a new warning message. This setting is used to mitigate DoS attacks. The default setting is 10.
- **message_cost**: Sets a cost on every warning message. The higher the value of this file (default of 5), the more likely the warning message is ignored. This setting is used to mitigate DoS attacks. The idea of a DoS attack is to bombard the targeted system with requests that generate errors and fill up disk partitions with log files or require all of the system's resources to handle the error logging. The settings in **message_burst** and **message_cost** are designed to be modified based on the system's acceptable risk versus the need for comprehensive logging.
- **netdev_max_backlog**: Sets the maximum number of packets allowed to queue when a particular interface receives packets faster than the kernel can process them. The default value for this file is 1000.
- **optmem_max**: Configures the maximum ancillary buffer size allowed per socket.
- **rmem_default**: Sets the receive socket buffer default size in bytes.
- **rmmem**: Sets the receive socket buffer maximum size in bytes.
- **wmem_default**: Sets the send socket buffer default size in bytes.
- **wmem_max**: Sets the send socket buffer maximum size in bytes.

The **/proc/sys/net/ipv6/* directory** contains additional networking settings. Many of these settings, used in conjunction with one another, are useful in preventing attacks on the system or when using the system to act as a router.

Be careful when enabling the System Request Key feature

The System Request Key feature is considered a security risk because an unattended console provides an attacker with access to the system. For this reason, it is turned off by default. Be careful when changing these files

An erroneous change to these files may affect remote connectivity to the system.
The following files are commonly found in the `/proc/sys` directory. This directory facilitates the configuration of the Linux kernel's virtual memory (VM) subsystem. The kernel makes many of these settings, such as `overcommit_memory` and `nr_pdflush_threads`, automatically.

The file called `/usr/share/doc/kernel-doc-<version>/Documentation/networking/ip-sysctl.txt` contains a complete list of files and options available in the `/proc/sys/net/ipv4` directory.

A number of other directories exist within the `/proc/sys/net/ipv4` directory and each covers a different aspect of the network stack. The `/proc/sys/net/ipv4/conf/` directory allows each system interface to be configured in different ways, including the use of default settings for unconfigured devices (in the `/proc/sys/net/ipv4/conf/default` subdirectory) and settings that override all special configurations (in the `/proc/sys/net/ipv4/conf/all` subdirectory).

The `/proc/sys/net/ipv4/neigh/` directory contains settings for communicating with a host directly connected to the system (called a network neighbor) and also contains different settings for systems more than one hop away.

Routing over IPV4 also has its own directory, `/proc/sys/net/ipv4/conf/`. Unlike `conf/` and `neigh/`, the `/proc/sys/net/ipv4/conf/` directory contains specifications that apply to routing with any interfaces on the system. Many of these settings, such as `max_size`, `max_delay`, and `min_delay`, relate to controlling the size of the routing cache.

To clear the routing cache, write any value to the `flush` file.

Additional information about these directories and the possible values for their configuration files can be found in:

`/usr/share/doc/kernel-doc-<version>/Documentation/filesystems/proc.txt`

### 3.9.5. `/proc/sys/vm`

This directory facilitates the configuration of the Linux kernel's virtual memory (VM) subsystem. The kernel makes extensive and intelligent use of virtual memory, which is commonly referred to as swap space.

The following files are commonly found in the `/proc/sys/vm/` directory:

- **block_dump** — Configures block I/O debugging when enabled. All read/write and block dirtying operations done to files are logged accordingly. This can be useful if diagnosing disk spin up and spin downs for laptop battery conservation. All output when `block_dump` is enabled can be retrieved via `dmesg`. The default value is 0.

#### Stopping the klogd daemon

If `block_dump` is enabled at the same time as kernel debugging, it is prudent to stop the `klogd` daemon, as it generates erroneous disk activity caused by `block_dump`.

- **dirty_background_ratio** — Starts background writeback of dirty data at this percentage of total memory, via a `pdflush` daemon. The default value is 0.
- **dirty_expire_centisecs** — Defines when dirty in-memory data is old enough to be eligible for writeout. Data which has been dirty in-memory for longer than this interval is written out next time a `pdflush` daemon wakes up. The default value is 3000, expressed in hundredths of a second.
- **dirty_ratio** — Starts active writeback of dirty data at this percentage of total memory for the generator of dirty data, via `pdflush`. The default value is 0.
- **dirty_writeback_centisecs** — Defines the interval between `pdflush` daemon wakesups, which periodically writes dirty in-memory data out to disk. The default value is 500, expressed in hundredths of a second.
- **laptop_mode** — Minimizes the number of times that a hard disk needs to spin up by keeping the disk spun down for as long as possible, therefore conserving battery power on laptops. This increases efficiency by combining all future I/O processes together, reducing the frequency of spin ups. The default value is 0, but is automatically enabled in case a battery on a laptop is used.

This value is controlled automatically by the `acpid` daemon once a user is notified battery power is enabled. No user modifications or interactions are necessary if the laptop supports the ACPI (Advanced Configuration and Power Interface) specification.

For more information, refer to the following installed documentation:

`/usr/share/doc/kernel-doc-<version>/Documentation/laptop-mode.txt`

- **max_map_count** — Configures the maximum number of memory map areas a process may have. In most cases, the default value of 65536 is appropriate.
- **min_free_kbytes** — Forces the Linux VM (virtual memory manager) to keep a minimum number of kilobytes free. The VM uses this number to compute a `pages_min` value for each `lowmem` zone in the system. The default value is in respect to the total memory on the machine.
- **nr_hugepages** — Indicates the current number of configured `hugetlb` pages in the kernel.

For more information, refer to the following installed documentation:

`/usr/share/doc/kernel-doc-<version>/Documentation/vm/hugetlbpage.txt`

- **nr_pflush_threads** — Indicates the number of `pdflush` daemons that are currently running. This file is read-only, and should not be changed by the user. Under heavy I/O loads, the default value of two is increased by the kernel.
- **overcommit_memory** — Configures the conditions under which a large memory request is accepted or denied. The following three modes are available:
  - 0 — The kernel performs heuristic memory over commit handling by estimating the amount of memory available and failing requests that are blatantly invalid. Unfortunately, since memory is allocated using a heuristic rather than
a precise algorithm, this setting can sometimes allow available memory on the system to be overloaded. This is
the default setting.

1 — The kernel performs no memory over commit handling. Under this setting, the potential for memory overload
is increased, but so is performance for memory intensive tasks (such as those executed by some scientific
software).

2 — The kernel fails requests for memory that add up to all of swap plus the percent of physical RAM specified in
/proc/sys/vm/overcommit_ratio. This setting is best for those who desire less risk of memory
overcommitment.

Using this setting
This setting is only recommended for systems with swap areas larger than physical memory.

- overcommit_ratio — Specifies the percentage of physical RAM considered when
  /proc/sys/vm/overcommit_memory is set to 2. The default value is 50.
- page-cluster — Sets the number of pages read in a single attempt. The default value of 3, which actually relates to
  16 pages, is appropriate for most systems.
- swappiness — Determines how much a machine should swap. The higher the value, the more swapping occurs. The
default value, as a percentage, is set to 60.

All kernel-based documentation can be found in the following locally installed location:

/usr/share/doc/kernel-doc-
kernel_version/Documentation/, which contains additional information.

E.3.10. /proc/sysvipc/
This directory contains information about System V IPC resources. The files in this directory relate to System V IPC calls
for messages (msg), semaphores (sem), and shared memory (shm).

E.3.11. /proc/tty/
This directory contains information about the available and currently used tty devices on the system. Originally called
teletype devices, any character-based data terminals are called tty devices.

In Linux, there are three different kinds of tty devices. Serial devices are used with serial connections, such as over a
modern or using a serial cable. Virtual terminals create the common console connection, such as the virtual consoles
available when pressing Alt+<F-key> at the system console. Pseudo terminals create a two-way communication that is
used by some higher level applications, such as XFree86. The drivers file is a list of the current tty devices in use, as in
the following example:

```
serial               /dev/cua        5  64-127 serial:callout
serial               /dev/ttyS       4  64-127 serial
pty_slave            /dev/pts      136   0-255 pty:slave
pty_master           /dev/ptm      128   0-255 pty:master
pty_slave            /dev/ttyp       3   0-255 pty:slave
pty_master           /dev/pty        2   0-255 pty:master
/dev/vc/0            /dev/vc/0       4       0 system:vtmaster
/dev/ptmx            /dev/ptmx       5       2 system
/dev/console         /dev/console    5       1 system:console
/dev/tty             /dev/tty        5       0 system:/dev/tty
unknown              /dev/vc/%d      4    1-63 console
```

The /proc/tty/driver/serial file lists the usage statistics and status of each of the serial tty lines.

In order for tty devices to be used as network devices, the Linux kernel enforces line discipline on the device. This allows
the driver to place a specific type of header with every block of data transmitted over the device, making it possible for the
remote end of the connection to a block of data as just one in a stream of data blocks. SLIP and PPP are common line
disciplines, and each are commonly used to connect systems to one other over a serial link.

E.3.12. /proc/PID/
Out of Memory (OOM) refers to a computing state where all available memory, including swap space, has been allocated.
When this situation occurs, it will cause the system to panic and stop functioning as expected. There is a switch that
controls OOM behavior in /proc/sys/vm/panic_on_oom. When set to 1 the kernel will panic on OOM. A setting of 0
instructs the kernel to call a function named oom_killer on an OOM. Usually, oom_killer can kill rogue processes and
the system will survive.

The easiest way to change this is to echo the new value to /proc/sys/vm/panic_on_oom.

```
# cat /proc/sys/vm/panic_on_oom
1
# echo 0 > /proc/sys/vm/panic_on_oom
# cat /proc/sys/vm/panic_on_oom
0
```

It is also possible to prioritize which processes get killed by adjusting the oom_killer score. In /proc/PID/ there are two
tools labeled oom_adj and oom_score. Valid scores for oom_adj are in the range -16 to +15. To see the current
oom_killer score, view the oom_score for the process. oom_killer will kill processes with the highest scores first.

This example adjusts the oom_score of a process with a PID of 12465 to make it less likely that oom_killer will kill it.
There is also a special value of -17, which disables oom_killer for that process. In the example below, oom_score returns a value of 0, indicating that this process would not be killed.

A function called badness() is used to determine the actual score for each process. This is done by adding up 'points' for each examined process. The process scoring is done in the following way:

1. The basis of each process's score is its memory size.
2. The memory size of any of the process's children (not including a kernel thread) is also added to the score
3. The process's score is increased for 'niced' processes and decreased for long running processes.
4. Processes with the CAP_SYS_ADMIN and CAP_SYS_RAWIO capabilities have their scores reduced.
5. The final score is then bitshifted by the value saved in the oom_adj file.

Thus, a process with the highest oom_score value will most probably be a non-priviliged, recently started process that, along with its children, uses a large amount of memory, has been 'niced', and handles no raw I/O.

### E.4. Using the sysctl Command

The /sbin/sysctl command is used to view, set, and automate kernel settings in the /proc/sys/ directory.

For a quick overview of all settings configurable in the /proc/sys/ directory, type the /sbin/sysctl -a command as root. This creates a large, comprehensive list, a small portion of which looks something like the following:

```
net.ipv4.route.min_delay = 2
kernel.sysrq = 0
kernel.sem = 250     32000     32     128
```

This is the same information seen if each of the files were viewed individually. The only difference is the file location. For example, the /proc/sys/net/ipv4/route/min_delay file is listed as net.ipv4.route.min_delay, with the directory slashes replaced by dots and the proc.sys portion assumed.

The sysctl command can be used in place of echo to assign values to writable files in the /proc/sys/ directory. For example, instead of using the command

```
echo 1 > /proc/sys/kernel/sysrq
```

use the equivalent sysctl command as follows:

```
sysctl -w kernel.sysrq="1"
kern.log.sysrq = 1
```

While quickly setting single values like this in /proc/sys/ is helpful during testing, this method does not work as well on a production system as special settings within /proc/sys/ are lost when the machine is rebooted. To preserve custom settings, add them to the /etc/sysctl.conf file.

Each time the system boots, systemd executes sysctl using the /etc/sysctl.conf configuration file to determine the values passed to the kernel. Any values added to /etc/sysctl.conf therefore take effect each time the system boots.

Additionally, systemd determines the contents of several directories including /etc/sysctl.d/ and reads values from any file with the .conf extension. The /etc/sysctl.d/ directory can be used to organize values into different files, and also permits them to be disabled by changing the extension of the file. For a complete list of directories read by systemd, refer to the sysctl.d(5) manual page.

### E.5. References

Below are additional sources of information about proc file system.

#### Installed Documentation

Some of the best documentation about the proc file system is installed on the system by default.

- `/usr/share/doc/kernel-doc-kernel_version/Documentation/filesystems/proc.txt` — Contains assorted, but limited, information about all aspects of the /proc/ directory.
- `/usr/share/doc/kernel-doc-kernel_version/Documentation/sysctl/` — A directory containing a variety of sysctl tips, including modifying values that concern the kernel (kernel.txt), accessing file systems (fs.txt), and
virtual memory use (vm.txt).


**Useful Websites**

> http://www.linuxhq.com/ — This website maintains a complete database of source, patches, and documentation for various versions of the Linux kernel.

**Revision History**

Revision 1-0 Mon 01 Jul 2013 Jaromír Hradílek

Fedora 18 release of the System Administrator's Guide.

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