

# *Red Hat Enterprise Linux 3*

## Reference Guide



# Red Hat Enterprise Linux 3: Reference Guide

Copyright © 2003 by Red Hat, Inc.



Red Hat, Inc.

1801 Varsity Drive  
Raleigh NC 27606-2072 USA  
Phone: +1 919 754 3700  
Phone: 888 733 4281  
Fax: +1 919 754 3701  
PO Box 13588  
Research Triangle Park NC 27709 USA

rhel-rg(EN)-3-Print-RHI(2003-07-25T17:13)

Copyright © 2003 by Red Hat, Inc. This material may be distributed only subject to the terms and conditions set forth in the Open Publication License, V1.0 or later (the latest version is presently available at <http://www.opencontent.org/openpub/>). Distribution of substantively modified versions of this document is prohibited without the explicit permission of the copyright holder.

Distribution of the work or derivative of the work in any standard (paper) book form for commercial purposes is prohibited unless prior permission is obtained from the copyright holder.

Red Hat, Red Hat Network, the Red Hat "Shadow Man" logo, RPM, Maximum RPM, the RPM logo, Linux Library, PowerTools, Linux Undercover, RHmember, RHmember More, Rough Cuts, Rawhide and all Red Hat-based trademarks and logos are trademarks or registered trademarks of Red Hat, Inc. in the United States and other countries.

Linux is a registered trademark of Linus Torvalds.

Motif and UNIX are registered trademarks of The Open Group.

Intel and Pentium are a registered trademarks of Intel Corporation. Itanium and Celeron are trademarks of Intel Corporation.

AMD, Opteron, Athlon, Duron, and K6 are registered trademarks of Advanced Micro Devices, Inc.

Netscape is a registered trademark of Netscape Communications Corporation in the United States and other countries.

Windows is a registered trademark of Microsoft Corporation.

SSH and Secure Shell are trademarks of SSH Communications Security, Inc.

FireWire is a trademark of Apple Computer Corporation.

IBM, AS/400, OS/400, RS/6000, S/390, and zSeries are registered trademarks of International Business Machines Corporation. eServer, iSeries, and pSeries are trademarks of International Business Machines Corporation.

All other trademarks and copyrights referred to are the property of their respective owners.

The GPG fingerprint of the security@redhat.com key is:

CA 20 86 86 2B D6 9D FC 65 F6 EC C4 21 91 80 CD DB 42 A6 0E

# Table of Contents

<b>Introduction</b> .....	<b>i</b>
1. Changes To This Manual .....	i
2. Finding Appropriate Documentation .....	ii
2.1. Documentation For First-Time Linux Users.....	ii
2.2. For the More Experienced .....	iv
2.3. Documentation for Linux Gurus.....	v
3. Document Conventions.....	v
4. Using the Mouse .....	vii
5. Copying and Pasting Text With X.....	viii
6. More to Come .....	viii
6.1. We Need Feedback! .....	viii
7. Sign Up for Support.....	viii
<b>I. System Reference</b> .....	<b>i</b>
1. Boot Process, Init, and Shutdown .....	1
1.1. The Boot Process .....	1
1.2. A Detailed Look at the Boot Process .....	1
1.3. Running Additional Programs at Boot Time .....	6
1.4. SysV Init Runlevels .....	7
1.5. Shutting Down .....	8
2. Boot Loaders.....	11
2.1. Boot Loaders and System Architecture .....	11
2.2. GRUB.....	11
2.3. Installing GRUB .....	12
2.4. GRUB Terminology.....	13
2.5. GRUB Interfaces.....	15
2.6. GRUB Commands .....	16
2.7. GRUB Menu Configuration File.....	17
2.8. LILO .....	19
2.9. The LILO Configuration File.....	20
2.10. Changing Runlevels at Boot Time .....	22
2.11. Additional Resources.....	22
3. File System Structure.....	25
3.1. Why Share a Common Structure?.....	25
3.2. Overview of File System Hierarchy Standard (FHS) .....	25
3.3. Special File Locations Under Red Hat Enterprise Linux.....	29
4. The <code>sysconfig</code> Directory.....	31
4.1. Files in the <code>/etc/sysconfig/</code> Directory .....	31
4.2. Directories in the <code>/etc/sysconfig/</code> Directory .....	42
4.3. Additional Resources.....	43
5. The <code>proc</code> File System.....	45
5.1. A Virtual File System.....	45
5.2. Top-level Files within the <code>proc</code> File System.....	46
5.3. Directories within <code>/proc/</code> .....	60
5.4. Using the <code>sysctl</code> Command .....	76
5.5. Additional Resources.....	77
6. Users and Groups.....	79
6.1. User and Group Management Tools .....	79
6.2. Standard Users .....	79
6.3. Standard Groups.....	81
6.4. User Private Groups.....	83
6.5. Shadow Passwords.....	84
6.6. Additional Resources .....	84
7. The X Window System .....	87
7.1. XFree86.....	87

7.2. Desktop Environments and Window Managers .....	88
7.3. XFree86 Server Configuration Files .....	89
7.4. Fonts .....	95
7.5. Runlevels and XFree86 .....	98
7.6. Additional Resources .....	99

## II. Network Services Reference..... 101

8. Network Interfaces .....	103
8.1. Network Configuration Files .....	103
8.2. Interface Configuration Files .....	103
8.3. Interface Control Scripts .....	110
8.4. Network Function Files .....	111
8.5. Additional Resources .....	112
9. Network File System (NFS) .....	113
9.1. How It Works .....	113
9.2. Starting and Stopping NFS .....	115
9.3. NFS Server Configuration .....	116
9.4. NFS Client Configuration Files .....	119
9.5. Securing NFS .....	121
9.6. Additional Resources .....	122
10. Apache HTTP Server .....	125
10.1. Apache HTTP Server 2.0 .....	125
10.2. Migrating Apache HTTP Server 1.3 Configuration Files .....	126
10.3. After Installation .....	136
10.4. Starting and Stopping <code>httpd</code> .....	136
10.5. Configuration Directives in <code>httpd.conf</code> .....	137
10.6. Default Modules .....	153
10.7. Adding Modules .....	154
10.8. Virtual Hosts .....	154
10.9. Additional Resources .....	156
11. FTP .....	157
11.1. The File Transport Protocol .....	157
11.2. FTP Servers .....	158
11.3. Files Installed with <code>vsftpd</code> .....	158
11.4. Starting and Stopping <code>vsftpd</code> .....	159
11.5. <code>vsftpd</code> Configuration Options .....	160
11.6. Additional Resources .....	168
12. Email .....	171
12.1. Email Protocols .....	171
12.2. Email Program Classifications .....	173
12.3. Mail Transport Agents .....	174
12.4. Mail Delivery Agents .....	183
12.5. Mail User Agents .....	188
12.6. Additional Resources .....	190
13. Berkeley Internet Name Domain (BIND) .....	193
13.1. Introduction to DNS .....	193
13.2. <code>/etc/named.conf</code> .....	194
13.3. Zone Files .....	200
13.4. Using <code>rndc</code> .....	205
13.5. Advanced Features of BIND .....	207
13.6. Common Mistakes to Avoid .....	209
13.7. Additional Resources .....	209
14. Lightweight Directory Access Protocol (LDAP) .....	213
14.1. Why Use LDAP? .....	213
14.2. LDAP Terminology .....	214
14.3. OpenLDAP Daemons and Utilities .....	214

14.4. OpenLDAP Configuration Files.....	216
14.5. The <code>/etc/openldap/schema/Directory</code> .....	217
14.6. OpenLDAP Setup Overview.....	217
14.7. Configuring a System to Authenticate Using OpenLDAP.....	219
14.8. Migrating Directories from Earlier Releases.....	221
14.9. Additional Resources.....	222
<b>III. Security Reference.....</b>	<b>225</b>
15. Pluggable Authentication Modules (PAM).....	227
15.1. Advantages of PAM.....	227
15.2. PAM Configuration Files.....	227
15.3. PAM Configuration File Format.....	227
15.4. Sample PAM Configuration Files.....	230
15.5. Creating PAM Modules.....	232
15.6. PAM and Administrative Credential Caching.....	232
15.7. PAM and Device Ownership.....	233
15.8. Additional Resources.....	234
16. TCP Wrappers and <code>xinetd</code> .....	237
16.1. TCP Wrappers.....	237
16.2. TCP Wrappers Configuration Files.....	238
16.3. <code>xinetd</code> .....	244
16.4. <code>xinetd</code> Configuration Files.....	245
16.5. Additional Resources.....	249
17. <code>iptables</code> .....	251
17.1. Packet Filtering.....	251
17.2. Differences between <code>iptables</code> and <code>ipchains</code> .....	252
17.3. Options Used within <code>iptables</code> Commands.....	253
17.4. Saving <code>iptables</code> Rules.....	259
17.5. <code>iptables</code> Control Scripts.....	259
17.6. <code>ip6tables</code> and IPv6.....	261
17.7. Additional Resources.....	261
18. Kerberos.....	263
18.1. What is Kerberos?.....	263
18.2. Kerberos Terminology.....	264
18.3. How Kerberos Works.....	266
18.4. Kerberos and PAM.....	267
18.5. Configuring a Kerberos 5 Server.....	267
18.6. Configuring a Kerberos 5 Client.....	269
18.7. Additional Resources.....	270
19. SSH Protocol.....	273
19.1. Features of SSH.....	273
19.2. SSH Protocol Versions.....	274
19.3. Event Sequence of an SSH Connection.....	274
19.4. OpenSSH Configuration Files.....	276
19.5. More Than a Secure Shell.....	277
19.6. Requiring SSH for Remote Connections.....	278
19.7. Additional Resources.....	279
<b>IV. Appendixes.....</b>	<b>281</b>
A. General Parameters and Modules.....	283
A.1. Specifying Module Parameters.....	283
A.2. SCSI parameters.....	283
A.3. Ethernet Parameters.....	284
<b>Index.....</b>	<b>289</b>
<b>Colophon.....</b>	<b>303</b>



Welcome to the *Red Hat Enterprise Linux Reference Guide*.

The *Red Hat Enterprise Linux Reference Guide* contains useful information about the Red Hat Enterprise Linux system. From fundamental concepts, such as the structure of the file system, to the finer points of system security and authentication control, we hope you find this book to be a valuable resource.

This guide is for you if you want to learn a bit more about how the Red Hat Enterprise Linux system works. Topics that you can explore within this manual include the following:

- The boot process
- The file system structure
- The X Window System
- Network services
- Security tools

## 1. Changes To This Manual

This manual has been reorganized for clarity and updated for the latest features of Red Hat Enterprise Linux 3. Some of the changes include:

### *A New FTP Chapter*

The new *FTP* chapter explains the FTP protocol and provides a detailed list of configuration options for the default FTP server, `vsftpd`.

### *An Updated Network File System (NFS) Chapter*

The *Network File System (NFS)* chapter has been completely revised and reorganized for clarity. Also, new features, such as TCP and access control list support have been added.

### *An Updated Modules Appendix*

The *Modules* appendix has been completely overhauled. Instructions for the `bonding` module have been added which enable users to bind multiple network interface cards together as if they are one.

### *Updated Network Interfaces Chapter*

The *Network Interfaces* chapter has been updated to include IPSec and bonding interfaces.

### *An Updated Apache HTTP Server Chapter*

The guide for migrating from version 1.3 to version 2.0 of the Apache HTTP Server has been updated. The list of server configuration options has been further updated and reorganized. Special thanks to **Gary Benson** and **Joe Orton** for their hard work on the Apache HTTP Server migration guide.

### *An Updated The X Window System Chapter*

*The X Window System* has been completely revised and reorganized for clarity. New font configuration instructions were added as well.

### *Updated Users and Groups Chapter*

The *Users and Groups* chapter has been updated.

Before reading this guide, you should be familiar with the contents of the *Red Hat Enterprise Linux Installation Guide* concerning installation issues, the *Red Hat Enterprise Linux Introduction to System Administration* for basic administration concepts, the *Red Hat Enterprise Linux System Administration Guide* for general customization instructions, and the *Red Hat Enterprise Linux Security Guide* for security related instructions. The *Red Hat Enterprise Linux Reference Guide* contains information about topics for advanced users.

HTML, PDF, and RPM versions of the manuals are available on the Red Hat Enterprise Linux Documentation CD and online at <http://www.redhat.com/docs/>.



#### **Note**

Although this manual reflects the most current information possible, read the *Red Hat Enterprise Linux Release Notes* for information that may not have been available prior to our documentation being finalized. They can be found on the Red Hat Enterprise Linux CD #1 and online at <http://www.redhat.com/docs/>.

## **2. Finding Appropriate Documentation**

You need documentation that is appropriate to your level of Linux expertise. Otherwise, you might feel overwhelmed or may not find the necessary information to answer any questions. The *Red Hat Enterprise Linux Reference Guide* deals with the more technical aspects and options of a Red Hat Enterprise Linux system. This section helps you decide whether to look in this manual for the information you need or consider other Red Hat Enterprise Linux manuals, including online sources, in your search.

Three different categories of people use Red Hat Enterprise Linux, and each of these categories require different sets of documentation and informative sources. To help you figure out where you should start, determine your own experience level:

### *New to Linux*

This type of user has never used any Linux (or Linux-like) operating system before or has had only limited exposure to Linux. They may or may not have experience using other operating systems (such as Windows). Is this you? If so, skip ahead to Section 2.1 *Documentation For First-Time Linux Users*.

### *Some Linux Experience*

This type of user has installed and successfully used Linux (but not Red Hat Enterprise Linux) before or may have equivalent experience with other Linux-like operating systems. Does this describe you? If so, turn to Section 2.2 *For the More Experienced*.

### *Experienced User*

This type of user has installed and successfully used Red Hat Enterprise Linux before. If this describes you, turn to Section 2.3 *Documentation for Linux Gurus*.



## 2.1. Documentation For First-Time Linux Users

For someone new to Linux, the amount of information available on any particular subject, such as printing, starting up the system or partitioning a hard drive, can be overwhelming. It helps to initially step back and gain a decent base of information centered around how Linux works before tackling these kinds of advanced issues.

Your first goal should be to obtain some useful documentation. This cannot be stressed enough. Without documentation, you only become frustrated at your inability to get a Red Hat Enterprise Linux system working the way you want.

You should acquire the following types of Linux documentation:

- *A brief history of Linux* — Many aspects of Linux are the way they are because of historical precedent. The Linux culture is also based on past events, needs or requirements. A basic understanding of the history of Linux help you figure out how to solve many potential problems before you actually see them.
- *An explanation of how Linux works* — While delving into the most arcane aspects of the Linux kernel is not necessary, it is a good idea to know something about how Linux is put together. This is particularly important if you have been working with other operating systems, as some of the assumptions you currently hold about how computers work may not transfer from that operating system to Linux.
- *An introductory command overview (with examples)* — This is probably the most important thing to look for in Linux documentation. The underlying design philosophy for Linux is that it is better to use many small commands connected together in different ways than it is to have a few large (and complex) commands that do the whole job themselves. Without examples that illustrate this approach to doing things, you may find yourself intimidated by the sheer number of commands available on a Red Hat Enterprise Linux system.

Keep in mind that you do not have to memorize all of the available Linux commands. Different techniques exist to help you find the specific command you need to accomplish a task. You only need to know the general way in which Linux functions, what you need to accomplish, and how to access the tool that give you the exact instructions you need to execute the command.

The *Red Hat Enterprise Linux Installation Guide* is a excellent reference for helping you get a Red Hat Enterprise Linux system successfully installed and initially configured. The *Red Hat Enterprise Linux Introduction to System Administration* is an excellent place to start for those learning the basics of system administration. You should start with these two books and use them to build the base of your knowledge of Red Hat Enterprise Linux. Before long, more complicated concepts begin to make sense because you already grasp the general ideas.

Beyond reading Red Hat Enterprise Linux manuals, several other excellent documentation resources are available for little or no cost:

### 2.1.1. Introduction to Linux Websites

- <http://www.redhat.com/> — On the Red Hat website, you find links to the Linux Documentation Project (LDP), online versions of the Red Hat Enterprise Linux manuals, FAQs (Frequently Asked Questions), a database which can help you find a Linux Users Group near you, technical information in the Red Hat Support Knowledge Base, and more.
- <http://www.linuxheadquarters.com/> — The Linux Headquarters website features easy to follow, step-by-step guides for a variety of Linux tasks.

### 2.1.2. Introduction to Linux Newsgroups

You can participate in newsgroups by watching the discussions of others attempting to solve problems, or by actively asking or answering questions. Experienced Linux users are known to be extremely helpful when trying to assist new users with various Linux issues — especially if you are posing questions in the right venue. If you do not have access to a news reader application, you can access this information via the Web at <http://groups.google.com/>. Dozens of Linux-related newsgroups exist, including the following:

- `linux.help` — A great place to get help from fellow Linux users.
- `linux.redhat` — This newsgroup primarily covers Red Hat Enterprise Linux-specific issues.
- `linux.redhat.install` — Pose installation questions to this newsgroup or search it to see how others solved similar problems.
- `linux.redhat.misc` — Questions or requests for help that do not really fit into traditional categories go here.
- `linux.redhat.rpm` — A good place to go if you are having trouble using RPM to accomplish particular objectives.

### 2.1.3. Beginning Linux Books

- *Red Hat Linux for Dummies, 2nd Edition* by Jon "maddog" Hall; IDG
- *Special Edition Using Red Hat Linux* by Alan Simpson, John Ray and Neal Jamison; Que
- *Running Linux* by Matt Welsh and Lar Kaufman; O'Reilly & Associates
- *Red Hat Linux 9 Unleashed* by Bill Ball and Hoyle Duff; Pearson Education

The books suggested here are excellent primary sources of information for basic knowledge about a Red Hat Enterprise Linux system. For more in-depth information concerning the various topics discussed throughout this book, many of the chapters list specific book titles, usually in an *Additional Resources* area.

One excellent resource for aspiring system administrators is the *Red Hat Enterprise Linux Introduction to System Administration*. This book is designed to explain strategies for administering Red Hat Enterprise Linux and is an excellent place to start for those learning the basics of system administration.

## 2.2. For the More Experienced

If you have used other Linux distributions, you probably already have a basic grasp of the most frequently used commands. You may have installed your own Linux system, and maybe you have even downloaded and built software you found on the Internet. After installing Linux, however, configuration issues can be very confusing.

The *Red Hat Enterprise Linux System Administration Guide* is designed to help explain the various ways a Red Hat Enterprise Linux system can be configured to meet specific objectives. Use this manual to learn about specific configuration options and how to put them into effect.

When you are installing software that is not covered in the *Red Hat Enterprise Linux System Administration Guide*, it is often helpful to see what other people in similar circumstances have done. HOWTO documents from the Linux Documentation Project, available at <http://www.redhat.com/mirrors/LDP/HOWTO/HOWTO-INDEX/howtos.html>, document particular aspects of Linux, from low-level kernel esoteric changes to using Linux for amateur radio station work.

If you are concerned about security issues, the *Red Hat Enterprise Linux Security Guide* is a great resource — explaining in concise terms best strategies and practices for securing Red Hat Enterprise Linux.

### 2.3. Documentation for Linux Gurus

If you are a long-time Red Hat Enterprise Linux user, you probably already know that one of the best ways to understand a particular program is to read its source code and/or configuration files. A major advantage of Red Hat Enterprise Linux is the availability of the source code for anyone to read.

Obviously, not everyone is a programmer, so the source code may not be helpful for you. However, if you have the knowledge and skills necessary to read it, the source code holds all of the answers.

## 3. Document Conventions

When you read this manual, certain words are represented in different fonts, typefaces, sizes, and weights. This highlighting is systematic; different words are represented in the same style to indicate their inclusion in a specific category. The types of words that are represented this way include the following:

`command`

Linux commands (and other operating system commands, when used) are represented this way. This style should indicate to you that you can type the word or phrase on the command line and press [Enter] to invoke a command. Sometimes a command contains words that would be displayed in a different style on their own (such as file names). In these cases, they are considered to be part of the command, so the entire phrase is displayed as a command. For example:

Use the `cat testfile` command to view the contents of a file, named `testfile`, in the current working directory.

`file name`

File names, directory names, paths, and RPM package names are represented this way. This style should indicate that a particular file or directory exists by that name on your system. Examples:

The `.bashrc` file in your home directory contains bash shell definitions and aliases for your own use.

The `/etc/fstab` file contains information about different system devices and file systems.

Install the `webalizer` RPM if you want to use a Web server log file analysis program.

### application

This style indicates that the program is an end-user application (as opposed to system software). For example:

Use **Mozilla** to browse the Web.

[key]

A key on the keyboard is shown in this style. For example:

To use [Tab] completion, type in a character and then press the [Tab] key. Your terminal displays the list of files in the directory that start with that letter.

[key]-[combination]

A combination of keystrokes is represented in this way. For example:

The [Ctrl]-[Alt]-[Backspace] key combination exits your graphical session and return you to the graphical login screen or the console.

### text found on a GUI interface

A title, word, or phrase found on a GUI interface screen or window is shown in this style. Text shown in this style is being used to identify a particular GUI screen or an element on a GUI screen (such as text associated with a checkbox or field). Example:

Select the **Require Password** checkbox if you would like your screensaver to require a password before stopping.

### top level of a menu on a GUI screen or window

A word in this style indicates that the word is the top level of a pulldown menu. If you click on the word on the GUI screen, the rest of the menu should appear. For example:

Under **File** on a GNOME terminal, the **New Tab** option allows you to open multiple shell prompts in the same window.

If you need to type in a sequence of commands from a GUI menu, they are shown like the following example:

Go to **Main Menu Button** (on the Panel) => **Programming** => **Emacs** to start the **Emacs** text editor.

### button on a GUI screen or window

This style indicates that the text can be found on a clickable button on a GUI screen. For example:

Click on the **Back** button to return to the webpage you last viewed.

computer output

Text in this style indicates text displayed to a shell prompt such as error messages and responses to commands. For example:

The `ls` command displays the contents of a directory. For example:

```
Desktop          about.html      logs            paulwesterberg.png
Mail             backupfiles    mail            reports
```

The output returned in response to the command (in this case, the contents of the directory) is shown in this style.

prompt

A prompt, which is a computer's way of signifying that it is ready for you to input something, is shown in this style. Examples:

```
$
#
[stephen@maturin stephen]$
leopard login:
```

### user input

Text that the user has to type, either on the command line, or into a text box on a GUI screen, is displayed in this style. In the following example, **text** is displayed in this style:

To boot your system into the text based installation program, you must type in the **text** command at the `boot:` prompt.

*replaceable*

Text used for examples which is meant to be replaced with data provided by the user is displayed in this style. In the following example, `<version-number>` is displayed in this style:

The directory for the kernel source is `/usr/src/<version-number>/`, where `<version-number>` is the version of the kernel installed on this system.

Additionally, we use several different strategies to draw your attention to certain pieces of information. In order of how critical the information is to your system, these items are marked as note, tip, important, caution, or a warning. For example:



#### Note

Remember that Linux is case sensitive. In other words, a rose is not a ROSE is not a rOsE.



#### Tip

The directory `/usr/share/doc/` contains additional documentation for packages installed on your system.



#### Important

If you modify the DHCP configuration file, the changes will not take effect until you restart the DHCP daemon.



#### Caution

Do not perform routine tasks as root — use a regular user account unless you need to use the root account for system administration tasks.



#### Warning

Be careful to remove only the necessary Red Hat Enterprise Linux partitions. Removing other partitions could result in data loss or a corrupted system environment.

## 4. Using the Mouse

Red Hat Enterprise Linux is designed to use a three-button mouse. If you have a two-button mouse, you should have selected three-button emulation during the installation process. If you're using three-button emulation, pressing both mouse buttons at the same time equates to pressing the missing third (middle) button.

In this document, if you are instructed to click with the mouse on something, that means click the left mouse button. If you need to use the middle or right mouse button, that will be explicitly stated. (This will be reversed if you've configured your mouse to be used by a left handed person.)

The phrase "drag and drop" may be familiar to you. If you're instructed to drag and drop an item on your GUI desktop, click on something and hold the mouse button down. While continuing to hold down the mouse button, drag the item by moving the mouse to a new location. When you've reached the desired location, release the mouse button to drop the item.

## 5. Copying and Pasting Text With X

Copying and pasting text is easy using your mouse and the X Window System. To copy text, simply click and drag your mouse over the text to highlight it. To paste the text somewhere, click the middle mouse button in the spot where the text should be placed.

## 6. More to Come

The *Red Hat Enterprise Linux Reference Guide* is part of Red Hat's commitment to provide useful and timely support to Red Hat Enterprise Linux users. Future editions feature expanded information on changes to system structure and organization, new and powerful security tools, and other resources to help you extend the power of the Red Hat Enterprise Linux system — and your ability to use it.

That is where you can help.

### 6.1. We Need Feedback!

If you find an error in the *Red Hat Enterprise Linux Reference Guide*, 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 (<http://bugzilla.redhat.com/bugzilla/>) against the component *rhel-rg*.

Be sure to mention the manual's identifier:

```
rhel-rg(EN)-3-Print-RHI (2003-07-25T17:13)
```

If you mention the manual's identifier, we know exactly which version of the guide you have.

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.

## 7. Sign Up for Support

If you have an edition of Red Hat Enterprise Linux 3, please remember to sign up for the benefits you are entitled to as a Red Hat customer.

You will be entitled to any or all of the following benefits, depending upon the product you purchased:

- Red Hat support — Get help with your installation questions from Red Hat, Inc.'s support team.

- Red Hat Network — Easily update your packages and receive security notices that are customized for your system. Go to <http://rhn.redhat.com/> for more details.
- *Under the Brim: The Red Hat E-Newsletter* — Every month, get the latest news and product information directly from Red Hat.

To sign up, go to <http://www.redhat.com/apps/activate/>. You will find your Product ID on a black, red, and white card in your Red Hat Enterprise Linux box.

To read more about technical support for Red Hat Enterprise Linux, refer to the *Getting Technical Support* Appendix in the *Red Hat Enterprise Linux Installation Guide*.

Good luck, and thank you for choosing Red Hat Enterprise Linux!

*The Red Hat Documentation Team*





# I. System Reference

To manage the system effectively, it is crucial to know about its components and how they fit together. This part outlines many important aspects of the system. It covers the boot process, the basic file system layout, the location of crucial system files and file systems, and the basic concepts behind users and groups. Additionally, the X Window System is explained in detail.

## Table of Contents

1. Boot Process, Init, and Shutdown.....	1
2. Boot Loaders.....	11
3. File System Structure .....	25
4. The <code>sysconfig</code> Directory .....	31
5. The <code>proc</code> File System.....	45
6. Users and Groups.....	79
7. The X Window System .....	87



# Boot Process, Init, and Shutdown

An important and powerful aspect of Red Hat Enterprise Linux is the open, user-configurable method it uses for starting the operating system. Users are free to configure many aspects of the boot process, including specifying the programs launched at boot-time. Similarly, system shutdown gracefully terminates processes in an organized and configurable way, although customization of this process is rarely required.

Understanding how the boot and shutdown processes work not only allows customization, but also makes it easier to troubleshoot problems related to starting or shutting down the system.

## 1.1. The Boot Process

Below are the basic stages of the boot process for an x86 system:

1. The system BIOS checks the system and launches the first stage boot loader on the MBR of the primary hard disk.
2. The first stage boot loader loads itself into memory and launches the second stage boot loader from the `/boot/` partition.
3. The second stage boot loader loads the kernel into memory, which in turn loads any necessary modules and mounts the root partition read-only.
4. The kernel transfers control of the boot process to the `/sbin/init` program.
5. The `/sbin/init` program loads all services and user-space tools, and mounts all partitions listed in `/etc/fstab`.
6. The user is presented with a login screen for the freshly booted Linux system.

Because configuration of the boot process is more common than the customization of the shutdown process, the remainder of this chapter discusses in detail how the boot process works and how it can be customized to suite specific needs.

## 1.2. A Detailed Look at the Boot Process

The beginning of the boot process varies depending on the hardware platform being used. However, once the kernel is found and loaded by the boot loader, the default boot process is identical across all architectures. This chapter focuses primarily on the x86 architecture.

### 1.2.1. The BIOS

When an x86 computer is booted, the processor looks at the end of system memory for the *Basic Input/Output System* or *BIOS* program and runs it. The BIOS controls not only the first step of the boot process, but also provides the lowest level interface to peripheral devices. For this reason it is written into read-only, permanent memory and is always available for use.

Other platforms use different programs to perform low-level tasks roughly equivalent to those of the BIOS on an x86 system. For instance, Itanium-based computers use the *Extensible Firmware Interface (EFI) Shell*, while Alpha systems use the *SRM console*.

Once loaded, the BIOS tests the system, looks for and checks peripherals, and then locates a valid device with which to boot the system. Usually, it checks any diskette drives and CD-ROM drives present for bootable media, then, failing that, looks to the system's hard drives. In most cases, the

order of the drives searched while booting is controlled with a setting in BIOS, and it looks on the master IDE device on the primary IDE bus. The BIOS then loads into memory whatever program is residing in the first sector of this device, called the *Master Boot Record* or *MBR*. The MBR is only 512 bytes in size and contains machine code instructions for booting the machine, called a boot loader, along with the partition table. Once the BIOS finds and loads the boot loader program into memory, it yields control of the boot process to it.

## 1.2.2. The Boot Loader

This section looks at the boot loaders for the x86 platform. Depending on the system's architecture, the boot process may differ slightly. Refer to Section 1.2.2.1 *Boot Loaders for Other Architectures* for a brief overview of non-x86 boot loaders.

When using Red Hat Enterprise Linux, two boot loaders are available: *GRUB* or *LILO*. GRUB is the default boot loader, but LILO is available for those who require or prefer it. For more information about configuring and using GRUB or LILO, see Chapter 2 *Boot Loaders*.

Both boot loaders for the x86 platform are broken into at least two stages. The first stage is a small machine code binary on the MBR. Its sole job is to locate the second stage boot loader and load the first part of it into memory.

GRUB is the newer boot loader and has the advantage of being able read ext2 and ext3<sup>1</sup> partitions and load its configuration file — `/boot/grub/grub.conf` — at boot time. Refer to Section 2.7 *GRUB Menu Configuration File* for information on how to edit this file.

With LILO, the second stage boot loader uses information on the MBR to determine the boot options available to the user. This means that any time a configuration change is made or kernel is manually upgraded, the `/sbin/lilo -v -v` command must be executed to write the appropriate information to the MBR. For details about doing this, refer to Section 2.8 *LILO*.



### Tip

If upgrading the kernel using the **Red Hat Update Agent**, the boot loader configuration file is updated automatically. More information on Red Hat Network can be found online at the following URL: <https://rhn.redhat.com>.

Once the second stage boot loader is in memory, it presents the user with a graphical screen showing the different operating systems or kernels it has been configured to boot. On this screen a user can use the arrow keys to choose which operating system or kernel they wish to boot and press [Enter]. If no key is pressed, the boot loader loads the default selection after a configurable period of time has passed.



### Note

If Symmetric Multi-Processor (SMP) kernel support is installed, there will be more than one option present the first time the system is booted. In this situation, LILO will display `linux`, which is the SMP kernel, and `linux-up`, which is for single processors. GRUB displays `Red Hat Enterprise Linux (<kernel-version>-smp)`, which is the SMP kernel, and `Red Hat Enterprise Linux (<kernel-version>)`, which is for single processors.

---

1. GRUB reads ext3 file systems as ext2, disregarding the journal file. Refer to the chapter titled *The ext3 File System* in the *Red Hat Enterprise Linux System Administration Guide* for more information on the ext3 file system.

If any problems occur using the SMP kernel, try selecting the a non-SMP kernel upon rebooting.

Once the second stage boot loader has determined which kernel to boot, it locates the corresponding kernel binary in the `/boot/` directory. The kernel binary is named using the following format — `/boot/vmlinuz-<kernel-version>` file (where `<kernel-version>` corresponds to the kernel version specified in the boot loader's settings).

For instructions on using the boot loader to supply command line arguments to the kernel, refer to Chapter 2 *Boot Loaders*. For information on changing the runlevel at the GRUB or LILO prompt, refer Section 2.10 *Changing Runlevels at Boot Time*.

The boot loader then places the appropriate *initial RAM disk* image, called an `initrd`, into memory. The `initrd` is used by the kernel to load drivers necessary to boot the system. This is particularly important if SCSI hard drives are present or if the systems uses the ext3 file system<sup>2</sup>.



### Warning

Do not remove the `/initrd/` directory from the file system for any reason. Removing this directory will cause the system to fail with a kernel panic error message at boot time.

Once the kernel and the `initrd` image are loaded into memory, the boot loader hands control of the boot process to the kernel.

For a more detailed overview of the GRUB and LILO boot loaders, refer to Chapter 2 *Boot Loaders*.

#### 1.2.2.1. Boot Loaders for Other Architectures

Once the kernel loads and hands off the boot process to the `init` command, the same sequence of events occurs on every architecture. So the main difference between each architecture's boot process is in the application used to find and load the kernel.

For example, the Alpha architecture uses the `aboot` boot loader, the Itanium architecture uses the ELILO boot loader, IBM pSeries uses YABOOT, and IBM s390 systems use the `z/IPL` boot loader.

Consult the *Red Hat Enterprise Linux Installation Guide* specific to these platforms for information on configuring their boot loaders.

### 1.2.3. The Kernel

When the kernel is loaded, it immediately initializes and configures the computer's memory and configures the various hardware attached to the system, including all processors, I/O subsystems, and storage devices. It then looks for the compressed `initrd` image in a predetermined location in memory, decompresses it, mounts it, and loads all necessary drivers. Next, it initializes virtual devices related to the file system, such as LVM or software RAID before unmounting the `initrd` disk image and freeing up all the memory the disk image once occupied.

The kernel then creates a root device, mounts the root partition read-only, and frees any unused memory.

At this point, the kernel is loaded into memory and operational. However, since there are no user applications that allow meaningful input to the system, not much can be done with the system.

---

2. For details on making an `initrd`, refer to the chapter titled *The ext3 File System* in the *Red Hat Enterprise Linux System Administration Guide*.

To set up the user environment, the kernel executes the `/sbin/init` program.

### 1.2.4. The `/sbin/init` Program

The `/sbin/init` program (also called `init`) coordinates the rest of the boot process and configures the environment for the user.

When the `init` command starts, it becomes the parent or grandparent of all of the processes that start up automatically on the system. First, it runs the `/etc/rc.d/rc.sysinit` script, which sets the environment path, starts `swap`, checks the file systems, and executes all other steps required for system initialization. For example, most systems use a clock, so on them `rc.sysinit` reads the `/etc/sysconfig/clock` configuration file to initialize the hardware clock. Another example is if there are special serial port processes which must be initialized, `rc.sysinit` will execute the `/etc/rc.serial` file.

The `init` command then runs the `/etc/inittab` script, which describes how the system should be set up in each `SysV init runlevel`<sup>3</sup>. Among other things, the `/etc/inittab` sets the default runlevel and dictates that `/sbin/update` should be run whenever it starts a given runlevel<sup>4</sup>.

Next, the `init` command sets the source function library, `/etc/rc.d/init.d/functions`, for the system, which configures how to start, kill, and determine the PID of a program.

The `init` program starts all of the background processes by looking in the appropriate `rc` directory for the runlevel specified as default in `/etc/inittab`. The `rc` directories are numbered to correspond to the runlevel they represent. For instance, `/etc/rc.d/rc5.d/` is the directory for runlevel 5.

When booting to runlevel 5, the `init` program looks in the `/etc/rc.d/rc5.d/` directory to determine which processes to start and stop.

Below is an example listing of the `/etc/rc.d/rc5.d/` directory:

```
K05innd -> ../init.d/innd
K05saslauthd -> ../init.d/saslauthd
K10psacct -> ../init.d/psacct
K10radiusd -> ../init.d/radiusd
K12mysqld -> ../init.d/mysqld
K15httpd -> ../init.d/httpd
K15postgresql -> ../init.d/postgresql
K16rarpd -> ../init.d/rarpd
K20iscsi -> ../init.d/iscsi
K20netdump-server -> ../init.d/netdump-server
K20nfs -> ../init.d/nfs
K20tomcat -> ../init.d/tomcat
K24irda -> ../init.d/irda
K25squid -> ../init.d/squid
K28amd -> ../init.d/amd
K34dhcrelay -> ../init.d/dhcrelay
K34yppasswdd -> ../init.d/yppasswdd
K35dhcpcd -> ../init.d/dhcpcd
K35smb -> ../init.d/smb
K35vncserver -> ../init.d/vncserver
K35winbind -> ../init.d/winbind
K36lisa -> ../init.d/lisa
K45arpwatch -> ../init.d/arpwatch
K45named -> ../init.d/named
K45smartd -> ../init.d/smartd
```

3. For more information on SysV `init` runlevels, refer to Section 1.4 *SysV Init Runlevels*.

4. The `update` command is used to flush dirty buffers back to disk.

```
K46radvd -> ../init.d/radvd
K50netdump -> ../init.d/netdump
K50snmpd -> ../init.d/snmpd
K50snmptrapd -> ../init.d/snmptrapd
K50tux -> ../init.d/tux
K50vsftpd -> ../init.d/vsftpd
K54pxe -> ../init.d/pxe
K61ldap -> ../init.d/ldap
K65kadmin -> ../init.d/kadmin
K65kprop -> ../init.d/kprop
K65krb524 -> ../init.d/krb524
K65krb5kdc -> ../init.d/krb5kdc
K70aep1000 -> ../init.d/aep1000
K70bcm5820 -> ../init.d/bcm5820
K74ntpd -> ../init.d/ntpd
K74ypserv -> ../init.d/ypserv
K74ypxfrd -> ../init.d/ypxfrd
K84bgpd -> ../init.d/bgpd
K84ospf6d -> ../init.d/ospf6d
K84ospfd -> ../init.d/ospfd
K84ripd -> ../init.d/ripd
K84ripngd -> ../init.d/ripngd
K85zebra -> ../init.d/zebra
K92ipvsadm -> ../init.d/ipvsadm
K95firstboot -> ../init.d/firstboot
S00microcode_ctl -> ../init.d/microcode_ctl
S08ip6tables -> ../init.d/ip6tables
S08iptables -> ../init.d/iptables
S09isdn -> ../init.d/isdn
S10network -> ../init.d/network
S12syslog -> ../init.d/syslog
S13irqbalance -> ../init.d/irqbalance
S13portmap -> ../init.d/portmap
S14nfslock -> ../init.d/nfslock
S17keytable -> ../init.d/keytable
S20random -> ../init.d/random
S24pcmcia -> ../init.d/pcmcia
S25netfs -> ../init.d/netfs
S26apmd -> ../init.d/apmd
S28autofs -> ../init.d/autofs
S44acpid -> ../init.d/acpid
S55sshd -> ../init.d/sshd
S56rawdevices -> ../init.d/rawdevices
S56xinetd -> ../init.d/xinetd
S59hpoj -> ../init.d/hpoj
S80sendmail -> ../init.d/sendmail
S85gpm -> ../init.d/gpm
S90canna -> ../init.d/canna
S90crond -> ../init.d/crond
S90cups -> ../init.d/cups
S90FreeWnn -> ../init.d/FreeWnn
S90xfs -> ../init.d/xfs
S95atd -> ../init.d/atd
S97rhnssd -> ../init.d/rhnssd
S99local -> ../rc.local
S99mdmonitor -> ../init.d/mdmonitor
```

As illustrated in this listing, none of the scripts that actually start and stop the services are located in the `/etc/rc.d/rc5.d/` directory. Rather, all of the files in `/etc/rc.d/rc5.d/` are *symbolic links* pointing to scripts located in the `/etc/rc.d/init.d/` directory. Symbolic links are used in each of the `rc` directories so that the runlevels can be reconfigured by creating, modifying, and deleting the symbolic links without affecting the actual scripts they reference.

The name of each symbolic link begin with either a `K` or an `S`. The `K` links are processes that are killed on that runlevel, while those beginning with an `S` are started.

The `init` command first stops all of the `K` symbolic links in the directory by issuing the `/etc/rc.d/init.d/<command> stop` command, where `<command>` is the process to be killed. It then starts all of the `S` symbolic links by issuing `/etc/rc.d/init.d/<command> start`.



#### Tip

After the system is finished booting, it is possible to log in as root and execute these same scripts to start and stop services. For instance, the command `/etc/rc.d/init.d/httpd stop` stops the Apache HTTP Server.

Each of the symbolic links are numbered to dictate start order. The order in which the services are started or stopped can be altered by changing this number. The lower the number, the earlier it is started. Those symbolic links with the same number are started alphabetically.



#### Note

One of the last things the `init` program executes is the `/etc/rc.d/rc.local` file. This file is useful for system customization. Refer to Section 1.3 *Running Additional Programs at Boot Time* for more information about using the `rc.local` file.

After the `init` command has progressed through the appropriate `rc` directory for the runlevel, the `/etc/inittab` script forks an `/sbin/mingetty` process for each virtual console (login prompt) allocated to the runlevel. Runlevels 2 through 5 has all six virtual consoles, while runlevel 1 (single user mode) has one and runlevels 0 and 6 have none. The `/sbin/mingetty` process opens communication pathways to `tty` devices<sup>5</sup>, sets their modes, prints the login prompt, accepts the user's username and password and initiates the login process.

In runlevel 5, the `/etc/inittab` runs a script called `/etc/X11/prefdm`. The `prefdm` script executes the preferred X display manager<sup>6</sup> — `gdm`, `kdm`, or `xdm`, depending on the contents of the `/etc/sysconfig/desktop` file.

Once finished, the system is operating on runlevel 5 and displaying a login screen.

### 1.3. Running Additional Programs at Boot Time

The `/etc/rc.d/rc.local` script is executed by the `init` command at boot time or when changing runlevels. Adding commands to the bottom of this script is an easy way to perform necessary tasks like starting special services or initialize devices without writing complex initialization scripts in the `/etc/rc.d/init.d/` directory and creating symbolic links.

5. Refer to Section 5.3.11 */proc/tty/* for more information about `tty` devices.

6. Refer to Section 7.5.2 *Runlevel 5* for more information about display managers.



The `/etc/rc.serial` script is used if serial ports must be setup at boot time. This script runs `setserial` commands to configure the system's serial ports. Refer to the `setserial` man page for more information.

## 1.4. SysV Init Runlevels

The SysV init runlevel system provides a standard process for controlling which programs `init` launches or halts when initializing a runlevel. SysV init was chosen because it is easier to use and more flexible than the traditional BSD-style init process.

The configuration files for SysV init are located in the `/etc/rc.d/` directory. Within this directory, are the `rc`, `rc.local`, `rc.sysinit`, and, optionally, the `rc.serial` scripts as well as the following directories:

```
init.d/  
rc0.d/  
rc1.d/  
rc2.d/  
rc3.d/  
rc4.d/  
rc5.d/  
rc6.d/
```

The `init.d/` directory contains the scripts used by the `/sbin/init` command when controlling services. Each of the numbered directories represent the six default runlevels configured by default under Red Hat Enterprise Linux.

### 1.4.1. Runlevels

Runlevels are a state, or *mode*, defined by the services listed in the SysV `/etc/rc.d/rc<x>.d/` directory, where `<x>` is the number of the runlevel.

The idea behind SysV init runlevels revolves around the idea that different systems can be used in different ways. For example, a server runs more efficiently without the drag on system resources created by the X Window System. Or there may be times when a system administrator may need to operate the system at a lower runlevel to perform diagnostic tasks, like fixing disk corruption in runlevel 1.

The characteristics of a given runlevel determines which services are halted and started by `init`. For instance, runlevel 1 (single user mode) halts any network services, while runlevel 3 starts these services. By assigning specific services to be halted or started on a given runlevel, `init` can quickly change the mode of the machine without the user manually stopping and starting services.

The following runlevels are defined by default for Red Hat Enterprise Linux:

- 0 — Halt
- 1 — Single-user text mode
- 2 — Not used (user-definable)
- 3 — Full multi-user text mode
- 4 — Not used (user-definable)
- 5 — Full multi-user graphical mode (with an X-based login screen)
- 6 — Reboot

In general, users operate Red Hat Enterprise Linux at runlevel 3 or runlevel 5 — both full multi-user modes. Users sometimes customize runlevels 2 and 4 to meet specific needs, since they are not used.

The default runlevel for the system is listed in `/etc/inittab`. To find out the default runlevel for a system, look for the line similar to the one below near the top of `/etc/inittab`:

```
id:5:initdefault:
```

The default runlevel listed in the example above is five, as the number after the first colon indicates. To change it, edit `/etc/inittab` as root.



### Warning

Be very careful when editing `/etc/inittab`. Simple typos can cause the system to become unbootable. If this happens, either use a boot diskette, enter single-user mode, or enter rescue mode to boot the computer and repair the file.

For more information on single-user and rescue mode, refer to the chapter titled *Basic System Recovery* in the *Red Hat Enterprise Linux System Administration Guide*.

It is possible to change the default runlevel at boot-time by modifying the arguments passed by the boot loader to the kernel. For information on changing the runlevel at boot time, refer to Section 2.10 *Changing Runlevels at Boot Time*.

## 1.4.2. Runlevel Utilities

One of the best ways to configure runlevels is to use an *initscript utility*. These tools are designed to simplify the task of maintaining files in the SysV init directory hierarchy and relieves system administrators from having to directly manipulate the numerous symbolic links in the subdirectories of `/etc/rc.d/`.

Red Hat Enterprise Linux provides three such utilities:

- `/sbin/chkconfig` — The `/sbin/chkconfig` utility is a simple command-line tool for maintaining the `/etc/rc.d/init.d` directory hierarchy.
- `/sbin/ntsysv` — The ncurses-based `/sbin/ntsysv` utility provides an interactive text-based interface, which some find easier to use than `chkconfig`.
- **Services Configuration Tool** — The graphical **Services Configuration Tool** (`redhat-config-services`) program is a flexible utility for configuring runlevels.

Refer to the chapter titled *Controlling Access to Services* in the *Red Hat Enterprise Linux System Administration Guide* for more information regarding these tools.

## 1.5. Shutting Down

To shut down Red Hat Enterprise Linux, the root user may issue the `/sbin/shutdown` command. The `shutdown` man page has a complete list of options, but the two most common uses are:

```
/sbin/shutdown -h now
/sbin/shutdown -r now
```

After shutting everything down, the `-h` option halts the machine, and the `-r` option reboots.

PAM console users can use the `reboot` and `halt` commands to shut down the system while in run-levels 1 through 5. For more information about PAM console users, refer to Section 15.7 *PAM and Device Ownership*.

If the computer does not power itself down, be careful not to turn off the computer until a message appears indicating that the system is halted.

Failure to wait for this message can mean that not all the hard drive partitions are unmounted, which can lead to file system corruption.



When a computer with Red Hat Enterprise Linux is turned on, the operating system is loaded into memory by a special program called a *boot loader*. A boot loader usually exists on the system's primary hard drive (or other media device) and has the sole responsibility of loading the Linux kernel with its required files or (in some cases) other operating systems into memory.

### 2.1. Boot Loaders and System Architecture

Each architecture capable of running Red Hat Enterprise Linux uses a different boot loader. The following table lists the boot loaders available for each architecture:

Architecture	Boot Loaders
AMD® AMD64	GRUB
IBM® eServer™ iSeries™	OS/400®
IBM® eServer™ pSeries™	YABOOT
IBM® S/390®	z/IPL
IBM® eServer™ zSeries®	z/IPL
Intel® Itanium™	ELILO
x86	GRUB or LILO

**Table 2-1. Boot Loaders by Architecture**

This chapter discusses commands and configuration options for the two boot loaders supplied with Red Hat Enterprise Linux for the x86 architecture: GRUB and LILO.

### 2.2. GRUB

*GNU GRand Unified Boot loader* or GRUB is a program which enables the user to select which installed operating system or kernel to load at system boot time. It also allows the user to pass arguments to the kernel.

#### 2.2.1. GRUB and the x86 Boot Process

This section discusses the specific role GRUB plays when booting an x86 system. For a look at the overall boot process, refer to Section 1.2 *A Detailed Look at the Boot Process*.

GRUB loads itself into memory in the following stages:

1. *The Stage 1 or primary boot loader is read into memory by the BIOS from the MBR<sup>1</sup>. The primary boot loader exists on less than 512 bytes of disk space within the MBR and is capable of loading either the Stage 1.5 or Stage 2 boot loader.*
2. *The Stage 1.5 boot loader is read into memory by the Stage 1 boot loader, if necessary. Some hardware requires an intermediate step to get to the Stage 2 boot loader. This is sometimes true*

---

1. For more on the system BIOS and the MBR, refer to Section 1.2.1 *The BIOS*.

when the `/boot/` partition is above the 1024 cylinder head of the hard drive or when using LBA mode. The Stage 1.5 boot loader is found either on the `/boot/` partition or on a small part of the MBR and the `/boot/` partition.

3. *The Stage 2 or secondary boot loader is read into memory.* The secondary boot loader displays the GRUB menu and command environment. This interface allows selection of the kernel or operating system to boot, pass arguments to the kernel, or look at system parameters.
4. *The secondary boot loader reads the operating system or kernel and `initrd` into memory.* Once GRUB determines which operating system to start, it loads it into memory and transfers control of the machine to that operating system.

The boot method used to boot Red Hat Enterprise Linux is called *direct loading* because the boot loader loads the operating system directly. There is no intermediary between the boot loader and the kernel.

The boot process used by other operating systems may differ. For example,; the Microsoft® Windows® operating system, as well as other operating systems, are loaded using *chain loading*. Under this method, the MBR points to the first sector of the partition holding the operating system, where it finds the files necessary to actually boot that operating system.

GRUB supports both direct and chain loading boot methods, allowing it to boot almost any operating system.



### Warning

During installation, Microsoft's DOS and Windows installation programs completely overwrite the MBR, destroying any existing boot loaders. If creating a dual-boot system, it is best to install the Microsoft operating system first.

## 2.2.2. Features of GRUB

GRUB contains several features that make it preferable to other boot loaders available for the x86 architecture. Below is a partial list of some of the more important features:

- *GRUB provides a true command-based, pre-OS environment on x86 machines.* This feature affords the user maximum flexibility in loading operating systems with specified options or gathering information about the system. For years, many non-x86 architectures have employed pre-OS environments that allow system booting from a command line. While some command features are available with LILO and other x86 boot loaders, GRUB is more feature rich.
- *GRUB supports Logical Block Addressing (LBA) mode.* LBA places the addressing conversion used to find files in the hard drive's firmware, and is used on many IDE and all SCSI hard devices. Before LBA, boot loaders could encounter the 1024-cylinder BIOS limitation, where the BIOS could not find a file after the 1024 cylinder head of the disk. LBA support allows GRUB to boot operating systems from partitions beyond the 1024-cylinder limit, so long as the system BIOS supports LBA mode. Most modern BIOS revisions support LBA mode.
- *GRUB can read ext2 partitions.* This functionality allows GRUB to access its configuration file, `/boot/grub/grub.conf`, every time the system boots, eliminating the need for the user to write a new version of the first stage boot loader to the MBR when configuration changes are made. The only time a user needs to reinstall GRUB on the MBR is if the physical location of the `/boot/` partition is moved on the disk. For details on installing GRUB to the MBR, refer to Section 2.3 *Installing GRUB*.

## 2.3. Installing GRUB

If GRUB was not installed during the installation process, it can be installed afterward. Once installed, it automatically becomes the default boot loader.

Before installing GRUB, make sure to use the latest GRUB package available or use the GRUB package from the installation CD-ROMs. For instructions on installing packages, refer to the chapter titled *Package Management with RPM* in the *Red Hat Enterprise Linux System Administration Guide*.

Once the GRUB package is installed, open a root shell prompt and run the command `/sbin/grub-install <location>`, where `<location>` is the location that the GRUB Stage 1 boot loader should be installed. For example, the following command installs GRUB to the MBR of the master IDE device on the primary IDE bus:

```
/sbin/grub-install /dev/hda
```

The next time the system boots, the GRUB graphical boot loader menu appears before the kernel loads into memory.



### Important

If GRUB is installed on a RAID 1 array, the system may become unbootable in the event of disk failure. An unsupported workaround is provided online at the following URL:

[http://www.dur.ac.uk/a.d.stribblehill/mirrored\\_grub.html](http://www.dur.ac.uk/a.d.stribblehill/mirrored_grub.html)

## 2.4. GRUB Terminology

One of the most important things to understand before using GRUB is how the program refers to devices, such as hard drives and partitions. This information is particularly important when configuring GRUB to boot multiple operating systems.

### 2.4.1. Device Names

When referring to a specific device with GRUB, do so using the following format (note that the parentheses and comma are very important syntactically):

```
(<type-of-device><bios-device-number>,<partition-number>)
```

The `<type-of-device>` specifies the type of device GRUB is booting from. The two most common options are `hd` for a hard disk or `fd` for a 3.5 diskette. A lesser used device type is also available called `nd` for a network disk. Instructions on configuring GRUB to boot over the network are available online at <http://www.gnu.org/manual/grub/>.

The `<bios-device-number>` is the BIOS device number. The primary IDE hard drive is numbered `0` and a secondary IDE hard drive is numbered `1`. This syntax is roughly equivalent to that used for devices by the kernel. For example, the `a` in `hda` for the kernel is analogous to the `0` in `hd0` for GRUB, the `b` in `hdb` is analogous to the `1` in `hd1`, and so on.

The `<partition-number>` specifies the number of a partition on a device. Like the `<bios-device-number>`, most types of partitions are numbered starting at `0`. However, BSD partitions are specified using letters, with `a` corresponding to `0`, `b` corresponding to `1`, and so on.

**Tip**

The numbering system for devices under GRUB always begins with 0, not 1. Failing to make this distinction is one of the most common mistakes made by new users.

To give an example, if a system has more than one hard drive, GRUB refers to the first hard drive as `(hd0)` and the second as `(hd1)`. Likewise, GRUB refers to the first partition on the first drive as `(hd0,0)` and the third partition on the second hard drive as `(hd1,2)`.

In general the following rules apply when naming devices and partitions under GRUB:

- It does not matter if system hard drives are IDE or SCSI, all hard drives begin with the letters `hd`. The letters `fd` are used to specify 3.5 diskettes.
- To specify an entire device without respect to partitions, leave off the comma and the partition number. This is important when telling GRUB to configure the MBR for a particular disk. For example, `(hd0)` specifies the MBR on the first device and `(hd3)` specifies the MBR on the fourth device.
- If a system has multiple drive devices, it is very important to know the drive boot order set in the BIOS. This is a simple task if a system has only IDE or SCSI drives, but if there is a mix of devices, it becomes critical that the type of drive with the boot partition be accessed first.

### 2.4.2. File Names and Blocklists

When typing commands to GRUB that reference a file, such as a menu list, it is necessary to specify an absolute file path immediately after the device and partition numbers.

The following illustrates the structure of such a command:

```
<device-type><device-number>,<partition-number> </path/to/file>
```

In this example, replace `<device-type>` with `hd`, `fd`, or `nd`. Replace `<device-number>` with the integer for the device. Replace `</path/to/file>` with an absolute path relative to the top-level of the device.

It is also possible to specify files to GRUB that do not actually appear in the file system, such as a chain loader that appears in the first few blocks of a partition. To load such files, provide a *blocklist* that specifies block by block where the file is located in the partition. Since a file is often comprised of several different sets of blocks, blocklists use a special syntax. Each block containing the file is specified by an offset number of blocks followed by the number of blocks from that offset point. Block offsets are listed sequentially in a comma-delimited list.

The following is a sample blocklist:

```
0+50,100+25,200+1
```

This sample blocklist specifies a file that starts at the first block on the partition and uses blocks 0 through 49, 99 through 124, and 199.

Knowing how to write blocklists is useful when using GRUB to load operating systems which require chain loading. It is possible to leave off the offset number of blocks if starting at block 0. As an example, the chain loading file in the first partition of the first hard drive would have the following name:

```
(hd0,0)+1
```



The following shows the `chainloader` command with a similar blocklist designation at the GRUB command line after setting the correct device and partition as root:

```
chainloader +1
```

### 2.4.3. The Root File System and GRUB

The use of the term *root file system* has a different meaning in regard to GRUB. It is important to remember that GRUB's root file system has nothing to do with the Linux root file system.

The GRUB root file system is the top level of the specified device. For example, the image file `(hd0,0)/grub/splash.xpm.gz` is located within the `/grub/` directory at the top-level (or root) of the `(hd0,0)` partition (which is actually the `/boot/` partition for the system).

Once GRUB has loaded its root partition (which equates to the `/boot` partition and contains the Linux kernel), the `kernel` command can be executed with the location of the kernel file as an option. Once the Linux kernel boots, it sets up the root file system that Linux users are familiar with. The original GRUB root file system and its mounts are forgotten; they only existed to boot the kernel file.

Refer to the `root` and `kernel` commands in Section 2.6 *GRUB Commands* for more information.

## 2.5. GRUB Interfaces

GRUB features three interfaces which provide different levels of functionality. Each of these interfaces allows users to boot the Linux kernel or another operating system.

The interfaces are as follows:

### *Menu Interface*

This is the default interface shown when GRUB is configured by the installation program, this is the interface shown by default. A menu of operating systems or kernels preconfigured are displayed as a list, ordered by name. Use the arrow keys to select an option other than the default selection and press the [Enter] key to boot it. Alternatively, a timeout period is set, after which GRUB loads the default option.

Press the [e] key to enter the entry editor interface or the [c] key to load a command line interface.

Refer to Section 2.7 *GRUB Menu Configuration File* for more information on configuring this interface.

### *Menu Entry Editor Interface*

To access the menu entry editor, press the [e] key from the boot loader menu. The GRUB commands for that entry are displayed here, and users may alter these command lines before booting the operating system by adding a command line ([o] inserts a new line after the current line and [O] inserts a new line before it), editing one ([e]), or deleting one ([d]).

After all changes are made, the [b] key executes the commands and boots the operating system. The [Esc] key discards any changes and reloads the standard menu interface. The [c] key loads the command line interface.



#### Tip

For information about changing runlevels with GRUB using the menu entry editor, refer to Section 2.10 *Changing Runlevels at Boot Time*.

### Command Line Interface

The command line interface is the most basic of the GRUB interfaces, but it is also the one that grants the most control. The command line makes it possible to type any relevant GRUB commands followed by the [Enter] key to execute them. This interface features some advanced shell-like features, including [Tab] key completion, based on context, and [Ctrl] key combinations when typing commands, such as [Ctrl]-[a] to move to the beginning of a line and [Ctrl]-[e] to move to the end of a line. In addition, the arrow, [Home], [End], and [Delete] keys work as they do in the `bash` shell.

Refer to Section 2.6 *GRUB Commands*, for a list of common commands.

### 2.5.1. Interfaces Load Order

When GRUB loads its second stage boot loader, it first searches for its configuration file. Once found, it builds a menu list and displays the menu interface.

If the configuration file cannot be found, or if the configuration file is unreadable, GRUB loads the command line interface, allowing the user to type commands to complete the boot process.

If the configuration file is not valid, GRUB prints out the error and asks for input. This helps the user see precisely where the problem occurred. Pressing any key reloads the menu interface, where it is then possible to edit the menu option and correct the problem based on the error reported by GRUB. If the correction fails, GRUB reports an error and reloads the menu interface.

## 2.6. GRUB Commands

GRUB allows a number of useful commands in its command line interface. Some of the commands accept options after their name; these options should be separated from the command and other options on that line by space characters.

The following is a list of useful commands:

- `boot` — Boots the operating system or chain loader that was last loaded.
- `chainloader </path/to/file>` — Loads the specified file as a chain loader. If the file is located on the first sector of the specified partition, use the blocklist notation, `+1`, instead of the filename.

The following is an example `chainloader` command:

```
chainloader +1
```

- `displaymem` — Displays the current use of memory, based on information from the BIOS. This is useful to determine how much RAM a system has prior to booting it.
- `initrd </path/to/initrd>` — Enables users to specify an initial RAM disk to use when booting. An `initrd` is necessary when the kernel needs certain modules in order to boot properly, such as when the root partition is formatted with the ext3 file system.

The following is an example `initrd` command:

```
initrd /initrd-2.4.21.ent.img
```

- `install <stage-1> <install-disk> <stage-2> p config-file` — Installs GRUB to the system MBR.
  - `<stage-1>` — Signifies a device, partition, and file where the first boot loader image can be found, such as `(hd0,0)/grub/stage1`.
  - `<install-disk>` — Specifies the disk where the stage 1 boot loader should be installed, such as `(hd0)`.

- `<stage-2>` — Passes the stage 2 boot loader location to the stage 1 boot loader, such as `(hd0,0)/grub/stage2`.
- `p <config-file>` — This option tells the `install` command to look for the menu configuration file specified by `<config-file>`, such as `(hd0,0)/grub/grub.conf`.



### Warning

The `install` command overwrites any information already located on the MBR.

- `kernel </path/to/kernel> <option-1> <option-N> ...` — Specifies the kernel file to load when booting the operating system. Replace `</path/to/kernel>` with an absolute path from the partition specified by the root command. Replace `<option-1>` with options for the Linux kernel, such as `root=/dev/hda5` to specify the device on which the root partition for the system is located. Multiple options can be passed to the kernel in a space separated list.

The following is an example `kernel` command:

```
kernel /vmlinuz-2.4.21 root=/dev/hda5
```

The option in the previous example specifies that the root file system for Linux is located on the `hda5` partition.

- `root (<device-type><device-number>,<partition>)` — Configures the root partition for GRUB, such as `(hd0,0)`, and mounts the partition.

The following is an example `root` command:

```
root (hd0,0)
```

- `rootnoverify (<device-type><device-number>,<partition>)` — Configures the root partition for GRUB, just like the `root` command, but does not mount the partition.

Other commands are also available; type `info grub` for a full list of commands. For a description of all GRUB commands, refer to the documentation available online at <http://www.gnu.org/manual/grub/>.

## 2.7. GRUB Menu Configuration File

The configuration file (`/boot/grub/grub.conf`), which is used to create the list of operating systems to boot in GRUB's menu interface, essentially allows the user to select a pre-set group of commands to execute. The commands given in Section 2.6 *GRUB Commands* can be used, as well as some special commands that are only available in the configuration file.

### 2.7.1. Configuration File Structure

The GRUB menu interface configuration file is `/boot/grub/grub.conf`. The commands to set the global preferences for the menu interface are placed at the top of the file, followed by stanzas for each operating kernel or operating system listed in the menu.

The following is a very basic GRUB menu configuration file designed to boot either Red Hat Enterprise Linux or Microsoft Windows 2000:

```
default=0
timeout=10
splashimage=(hd0,0)/grub/splash.xpm.gz

# section to load Linux
title Red Hat Enterprise Linux (2.4.21-1.ent)
    root (hd0,0)
    kernel /vmlinuz-2.4.21-1 ro root=/dev/sda2
    initrd /initrd-2.4.21-1.img
```

```
# section to load Windows
title Windows
    rootnoverify (hd0,0)
    chainloader +1
```

This file configures GRUB to build a menu with Red Hat Enterprise Linux as the default operating system and sets it to autoboot after 10 seconds. Two sections are given, one for each operating system entry, with commands specific to the system disk partition table.



### Note

Note that the default is specified as an integer. This refers to the first `title` line in the GRUB configuration file. For the `Windows` section to be set as the default in the previous example, change the `default=0` to `default=1`.

Configuring a GRUB menu configuration file to boot multiple operating systems is beyond the scope of this chapter. Consult Section 2.11 *Additional Resources* for a list of additional resources.

## 2.7.2. Configuration File Directives

The following are directives commonly used in the GRUB menu configuration file:

- `chainloader </path/to/file>` — Loads the specified file as a chain loader. Replace `</path/to/file>` with the absolute path to the chain loader. If the file is located on the first sector of the specified partition, use the blocklist notation, `+1`.
- `color <normal-color> <selected-color>` — Allows specific colors to be used in the menu, where two colors are configured as the foreground and background. Use simple color names such as `red/black`. For example:  
`color red/black green/blue`
- `default=<integer>` — Replace `<integer>` with the default entry title number to be loaded if the menu interface times out.
- `fallback=<integer>` — Replace `<integer>` with the entry title number to try if the first attempt fails.
- `hiddenmenu` — Prevents the GRUB menu interface from being displayed, loading the default entry when the `timeout` period expires. The user can see the standard GRUB menu by pressing the [Esc] key.
- `initrd </path/to/initrd>` — Enables users to specify an initial RAM disk to use when booting. Replace `</path/to/initrd>` with the absolute path to the initial RAM disk.
- `kernel </path/to/kernel> <option-1> <option-N>` — Specifies the kernel file to load when booting the operating system. Replace `</path/to/kernel>` with an absolute path from the partition specified by the root directive. Multiple options can be passed to the kernel when it is loaded.
- `password=<password>` — Prevents a user who does not know the password from editing the entries for this menu option.

Optionally, it is possible to specify an alternate menu configuration file after the `password=<password>` directive. In this case, GRUB restarts the second stage boot loader and uses the specified alternate configuration file to build the menu. If an alternate menu configuration

file is left out of the command, a user who knows the password is allowed to edit the current configuration file.

For more information about securing GRUB, refer to the chapter titled *Workstation Security* in the *Red Hat Enterprise Linux Security Guide*.

- `root (<device-type><device-number>, <partition>)` — Configures the root partition for GRUB, such as `(hd0,0)`, and mounts the partition.
- `rootnoverify (<device-type><device-number>, <partition>)` — Configures the root partition for GRUB, just like the `root` command, but does not mount the partition.
- `timeout=<integer>` — Specifies the interval, in seconds, that GRUB waits before loading the entry designated in the default command.
- `splashimage=<path-to-image>` — Specifies the location of the splash screen image to be used when GRUB boots.
- `title group-title` — Specifies a title to be used with a particular group of commands used to load a kernel or operating system.

To add human-readable comments to the menu configuration file, begin the line with the hash mark character (`#`).

## 2.8. LILO

*LILO* is an acronym for the *L*inux *L*oader and has been used to boot Linux on x86 systems for many years. Although GRUB is now the default boot loader, some users prefer to use LILO because it is more familiar to them and others use it out of necessity, since GRUB may have trouble booting some hardware.

### 2.8.1. LILO and the x86 Boot Process

This section discusses in detail the specific role LILO plays when booting an x86 system. For a detailed look at the overall boot process, refer to Section 1.2 *A Detailed Look at the Boot Process*.

LILO loads itself into memory almost identically to GRUB, with the exception that it is only a two stage loader.

1. *The Stage 1 or primary boot loader is read into memory by the BIOS from the MBR<sup>2</sup>.* The primary boot loader exists on less than 512 bytes of disk space within the MBR. It only loads the Stage 2 boot loader and passes disk geometry information to it.
2. *The Stage 2 or secondary boot loader is read into memory.* The secondary boot loader displays the Red Hat Enterprise Linux initial screen. This screen allows you to select which operating system or Linux kernel to boot.
3. *The Stage 2 boot loader reads the operating system or kernel and `initrd` into memory.* Once LILO determines which operating system to start, it loads it into memory and transfers control of the machine to that operating system.

Once the Stage 2 boot loader is in memory, LILO displays the initial Red Hat Enterprise Linux screen with the different operating systems or kernels it has been configured to boot. By default, if Red Hat Enterprise Linux is the only operating system installed, `linux` is the only available option. If the system has multiple processors, a `linux-up` option appears for the single processor kernel and a `linux` option appears for the multiple processor (SMP) kernel. If LILO is configured to boot other operating systems, those boot entries also appear on this screen.

---

2. For more on the system BIOS and the MBR, refer to Section 1.2.1 *The BIOS*.

The arrow keys allow a user to highlight the desired operating system and the [Enter] key begins the boot process.

To access a `boot :` prompt, press [Ctrl]-[X].

### 2.8.2. LILO versus GRUB

In general, LILO works similarly to GRUB except for three major differences:

- It has no interactive command interface.
- It stores information about the location of the kernel or other operating system it is to load on the MBR.
- It cannot read ext2 partitions.

The first point means the command prompt for LILO is not interactive and only allows one command with arguments.

The last two points mean that if LILO's configuration file is changed or if a new kernel is installed, LILO must be reinstalled on the MBR by using the following command:

```
/sbin/lilo -v -v
```

This method is more risky than the method used by GRUB because a misconfigured MBR leaves the system unbootable. With GRUB, if the configuration file is erroneously configured, it defaults to its command line interface where the user can boot the system manually. Refer to Section 2.5 *GRUB Interfaces* for more information about the GRUB command line interface.



#### Tip

If upgrading the kernel using the **Red Hat Update Agent**, the MBR is updated automatically. More information about RHN is available online at <https://rhn.redhat.com/>.

## 2.9. The LILO Configuration File

The LILO configuration file is `/etc/lilo.conf`. The `/sbin/lilo` command uses this file to determine what information to write to the MBR.



#### Warning

Before editing `/etc/lilo.conf`, be sure to make a backup copy of the file. Also, have a working boot disk available so that changes can be made to the MBR if there is a problem. Refer To the man page for `mkbootdisk` for more information on creating a boot disk.

The `/etc/lilo.conf` file is used by the `/sbin/lilo` command to determine which operating system or kernel to load and where it should be installed.

### 2.9.1. Sample `/etc/lilo.conf`

The following is a sample `/etc/lilo.conf` for a system configured to boot two operating systems, Red Hat Enterprise Linux and DOS:

```
boot=/dev/hda
map=/boot/map
install=/boot/boot.b
prompt
timeout=50
message=/boot/message
lba32
default=linux

image=/boot/vmlinuz-2.4.0-0.43.6
label=linux
initrd=/boot/initrd-2.4.0-0.43.6.img
read-only
root=/dev/hda5

other=/dev/hda1
label=dos
```

The following is a more detailed look at the lines of this file:

- `boot=/dev/hda` — Instructs LILO to be installed on the first hard disk of the first IDE controller.
- `map=/boot/map` — Locates the map file. In normal use, this should not be modified.
- `install=/boot/boot.b` — Instructs LILO to install the specified file as the new boot sector. In normal use, this should not be altered. If the `install` line is missing, LILO assumes a default of `/boot/boot.b` as the file to be used.
- `prompt` — Instructs LILO to show you whatever is referenced in the `message` line. While it is not recommended that you remove the `prompt` line, if you do remove it, you can still access a prompt by holding down the [Shift] key while your machine starts to boot.
- `timeout=50` — Sets the amount of time that LILO waits for user input before proceeding with booting the `default` line entry. This is measured in tenths of a second, with 50 as the default.
- `message=/boot/message` — Refers to the screen that LILO displays to let you select the operating system or kernel to boot.
- `lba32` — Describes the hard disk geometry to LILO. Another common entry here is `linear`. You should not change this line unless you are very aware of what you are doing. Otherwise, you could put your system in an unbootable state.
- `default=linux` — Refers to the default operating system for LILO to boot as seen in the options listed below this line. The name `linux` refers to the `label` line below in each of the boot options.
- `image=/boot/vmlinuz-2.4.0-0.43.6` — Specifies which Linux kernel to boot with this particular boot option.
- `label=linux` — Names the operating system option in the LILO screen. In this case, it is also the name referred to by the `default` line.
- `initrd=/boot/initrd-2.4.0-0.43.6.img` — Refers to the *initial ram disk* image that is used at boot time to initialize and start the devices that makes booting the kernel possible. The initial ram disk is a collection of machine-specific drivers necessary to operate a SCSI card, hard drive, or any other device needed to load the kernel. You should never try to share initial ram disks between machines.

- `read-only` — Specifies that the root partition (refer to the `root` line below) is read-only and cannot be altered during the boot process.
- `root=/dev/hda5` — Specifies which disk partition to use as the root partition.
- `other=/dev/hda1` — Specifies the partition containing DOS.

## 2.10. Changing Runlevels at Boot Time

Under Red Hat Enterprise Linux, it is possible to change the default runlevel at boot time.

If using LILO, access the `boot:` prompt by typing `[Ctrl]-[X]`. Then type:

```
linux <runlevel-number>
```

In this command, replace `<runlevel-number>` with either the number of the runlevel to boot into (1 through 5), or the words `single` or `emergency`.

If using GRUB, follow these steps:

- In the graphical GRUB boot loader screen, select the **Red Hat Enterprise Linux** boot label and press `[e]` to edit it.
- Arrow down to the kernel line and press `[e]` to edit it.
- At the prompt, type the number of the runlevel you wish to boot into (1 through 5), or the words `single` or `emergency` and press `[Enter]`.
- The GRUB screen reappears with the kernel information. Press the `[b]` key to boot the system.

For more information about runlevels, refer to Section 1.4.1 *Runlevels*.

## 2.11. Additional Resources

This chapter is only intended as an introduction to GRUB and LILO. Consult the following resources to discover more about how GRUB and LILO work.

### 2.11.1. Installed Documentation

- `/usr/share/doc/grub-<version-number>/` — This directory contains good information about using and configuring GRUB, where `<version-number>` corresponds to the version of the GRUB package installed.
- `info grub` — The GRUB info page contains a tutorial, a user reference manual, a programmer reference manual, and a FAQ document about GRUB and its usage.
- `/usr/share/doc/lilo-<version-number>/` — This directory contains a wealth of information about using and configuring LILO. In particular, the `doc/` subdirectory contains a postscript file called `User_Guide.ps` that is highly informative. Here, `<version-number>` corresponds to the version of the LILO package installed.

### 2.11.2. Useful Websites

- <http://www.gnu.org/software/grub/> — The home page of the GNU GRUB project. This site contains information concerning the state of GRUB development and a FAQ.



- <http://www.uruk.org/orig-grub/> — The original GRUB documentation before the project was handed off to the Free Software Foundation for further development.
- <http://www.redhat.com/mirrors/LDP/HOWTO/mini/Multiboot-with-GRUB.html> — Investigates various uses for GRUB, including booting operating systems other than Linux.
- <http://www.linuxgazette.com/issue64/kohli.html> — An introductory article discussing the configuration of GRUB on a system from scratch, including an overview of GRUB command line options.
- <http://www.tldp.org/HOWTO/mini/LILO.html> — This mini-HOWTO discusses various uses for LILO, including booting operating systems other than Linux.

### 2.11.3. Related Books

- *Red Hat Enterprise Linux Security Guide*; Red Hat, Inc. — The *Workstation Security* chapter explains, in a concise manner, how to secure the GRUB and LILO boot loaders.



## File System Structure

### 3.1. Why Share a Common Structure?

An operating system's file system structure is its most basic level of organization. Almost all of the ways an operating system interacts with its users, applications, and security model are dependent upon the way it organizes files on storage devices. Providing a common file system structure ensures users and programs are able to access and write files.

Files systems break files down into two logical categories:

- Shareable vs. unsharable files
- Variable vs. static files

*Shareable* files are those that can be accessed locally and by remote hosts; *unsharable* files are only available locally. *Variable* files, such as documents, can be changed at any time; *static* files, such as binaries, do not change without an action from the system administrator.

The reason for looking at files in this manner is to help correlate the function of the file with the permissions assigned to the directories which hold them. The way in which the operating system and its users interact with a given file determines the directory in which it is placed, whether that directory is mounted with read-only or read/write permissions, and the level of access each user has to that file. The top level of this organization is crucial. Access to the underlying directories can be restricted or security problems could manifest themselves if, from the top level down, it does not adhere to a rigid structure.

### 3.2. Overview of File System Hierarchy Standard (FHS)

Red Hat Enterprise Linux uses the *Filesystem Hierarchy Standard (FHS)* file system structure, which defines the names, locations, and permissions for many file types and directories.

The FHS document is the authoritative reference to any FHS-compliant file system, but the standard leaves many areas undefined or extensible. This section is an overview of the standard and a description of the parts of the file system not covered by the standard.

Compliance with the standard means many things, but the two most important are compatibility with other compliant systems and the ability to mount a `/usr/` partition as read-only. This second point is important because the directory contains common executables and should not be changed by users. Also, since the `/usr/` directory is mounted as read-only, it can be mounted from the CD-ROM or from another machine via a read-only NFS mount.

#### 3.2.1. FHS Organization

The directories and files noted here are a small subset of those specified by the FHS document. Refer to the latest FHS document for the most complete information.

The complete standard is available online at <http://www.pathname.com/fhs/>.

### 3.2.1.1. The `/boot/` Directory

The `/boot/` directory contains static files required to boot the system, such as the Linux kernel. These files are essential for the system to boot properly.



#### Warning

Do not remove the `/boot/` directory. Doing so will render the system unbootable.

### 3.2.1.2. The `/dev/` Directory

The `/dev/` directory contains file system entries which represent devices that are attached to the system. These files are essential for the system to function properly.

### 3.2.1.3. The `/etc/` Directory

The `/etc/` directory is reserved for configuration files that are local to the machine. No binaries are to be put in `/etc/`. Any binaries that were once located in `/etc/` should be placed into `/sbin/` or `/bin/`.

The `X11/` and `skel/` directories are subdirectories of the `/etc/` directory:

```
/etc
|- X11/
|- skel/
```

The `/etc/X11/` directory is for X Window System configuration files such as `XF86Config`. The `/etc/skel/` directory is for "skeleton" user files, which are used to populate a home directory when a user is first created.

### 3.2.1.4. The `/lib/` Directory

The `/lib/` directory should contain only those libraries needed to execute the binaries in `/bin/` and `/sbin/`. These shared library images are particularly important for booting the system and executing commands within the root file system.

### 3.2.1.5. The `/mnt/` Directory

The `/mnt/` directory is for temporarily mounted file systems, such as CD-ROMs and 3.5 diskettes.

### 3.2.1.6. The `/opt/` Directory

The `/opt/` directory provides storage for large, static application software packages.

A package placing files in the `/opt/` directory creates a directory bearing the same name as the package. This directory, in turn, holds files that otherwise would be scattered throughout the file system, giving the system administrator an easy way to determine the role of each file within a particular package.

For example, if `sample` is the name of a particular software package located within the `/opt/` directory, then all of its files are placed in directories inside the `/opt/sample/` directory, such as `/opt/sample/bin/` for binaries and `/opt/sample/man/` for manual pages.

Large packages that encompass many different sub-packages, each of which accomplish a particular task, are also located in the `/opt/` directory, giving that large package a way to organize itself. In this way, our `sample` package may have different tools that each go in their own sub-directories, such as `/opt/sample/tool1/` and `/opt/sample/tool2/`, each of which can have their own `bin/`, `man/`, and other similar directories.

### 3.2.1.7. The `/proc/` Directory

The `/proc/` directory contains special files that either extract information from or send information to the kernel.

Due to the great variety of data available within `/proc/` and the many ways this directory can be used to communicate with the kernel, an entire chapter has been devoted to the subject. For more information, please refer to Chapter 5 *The `proc` File System*.

### 3.2.1.8. The `/sbin/` Directory

The `/sbin/` directory stores executables used by the root user. The executables in `/sbin/` are only used at boot time and perform system recovery operations. Of this directory, the FHS says:

*/sbin* contains binaries essential for booting, restoring, recovering, and/or repairing the system in addition to the binaries in */bin*. Programs executed after */usr/* is known to be mounted (when there are no problems) are generally placed into */usr/sbin*. Locally-installed system administration programs should be placed into */usr/local/sbin*.

At a minimum, the following programs should be in `/sbin/`:

```
arp, clock,  
halt, init,  
fsck.*, grub  
ifconfig, lilo,  
mingetty, mkfs.*,  
mkswap, reboot,  
route, shutdown,  
swapoff, swapon
```

### 3.2.1.9. The `/usr/` Directory

The `/usr/` directory is for files that can be shared across multiple machines. The `/usr/` directory is often on its own partition and is mounted read-only. At minimum, the following directories should be subdirectories of `/usr/`:

```
/usr  
|- bin/  
|- dict/  
|- doc/  
|- etc/  
|- games/  
|- include/  
|- kerberos/  
|- lib/  
|- libexec/  
|- local/  
|- sbin/
```

```

|- share/
|- src/
|- tmp -> ../var/tmp/
|- X11R6/

```

Under the `/usr/` directory, the `bin/` directory contains executables, `dict/` contains non-FHS compliant documentation pages, `etc/` contains system-wide configuration files, `games` is for games, `include/` contains C header files, `kerberos/` contains binaries and other Kerberos-related files, and `lib/` contains object files and libraries that are not designed to be directly utilized by users or shell scripts. The `libexec/` directory contains small helper programs called by other programs, `sbin/` is for system administration binaries (those that do not belong in the `/sbin/` directory), `share/` contains files that are not architecture-specific, `src/` is for source code, and `X11R6/` is for the X Window System (XFree86 on Red Hat Enterprise Linux).

### 3.2.1.10. The `/usr/local/` Directory

The FHS says:

The `/usr/local` hierarchy is for use by the system administrator when installing software locally. It needs to be safe from being overwritten when the system software is updated. It may be used for programs and data that are shareable among a group of hosts, but not found in `/usr`.

The `/usr/local/` directory is similar in structure to the `/usr/` directory. It has the following subdirectories, which are similar in purpose to those in the `/usr/` directory:

```

/usr/local
|- bin/
|- doc/
|- etc/
|- games/
|- include/
|- lib/
|- libexec/
|- sbin/
|- share/
|- src/

```

In Red Hat Enterprise Linux, the intended use for the `/usr/local/` directory is slightly different from that specified by the FHS. The FHS says that `/usr/local/` should be where software that is to remain safe from system software upgrades is stored. Since software upgrades can be performed safely with *Red Hat Package Manager (RPM)*, it is not necessary to protect files by putting them in `/usr/local/`. Instead, the `/usr/local/` directory is used for software that is local to the machine.

For instance, if the `/usr/` directory is mounted as a read-only NFS share from a remote host, it is still possible to install a package or program under the `/usr/local/` directory.

### 3.2.1.11. The `/var/` Directory

Since the FHS requires Linux to mount `/usr/` as read-only, any programs that write log files or need `spool/` or `lock/` directories should write them to the `/var/` directory. The FHS states `/var/` is for:

...variable data files. This includes spool directories and files, administrative and logging data, and transient and temporary files.

Below are some of the directories found within the `/var/` directory:

```
/var
|- account/
|- arpwatch/
|- cache/
|- crash/
|- db/
|- empty/
|- ftp/
|- gdm/
|- kerberos/
|- lib/
|- local/
|- lock/
|- log/
|- mail -> spool/mail/
|- mailman/
|- named/
|- nis/
|- opt/
|- preserve/
|- run/
+- spool/
    |- at/
    |- clientmqueue/
    |- cron/
    |- cups/
    |- lpd/
    |- mail/
    |- mqueue/
    |- news/
    |- postfix/
    |- repackage/
    |- rwho/
    |- samba/
    |- squid/
    |- squirrelmail/
    |- up2date/
    |- uucppublic/
    |- vbox/
|- tmp/
|- tux/
|- www/
|- yp/
```

System log files such as `messages/` and `lastlog/` go in the `/var/log/` directory. The `/var/lib/rpm/` directory contains RPM system databases. Lock files go in the `/var/lock/` directory, usually in directories for the program using the file. The `/var/spool/` directory has subdirectories for programs in which data files are stored.

### 3.3. Special File Locations Under Red Hat Enterprise Linux

Red Hat Enterprise Linux extends the FHS structure slightly to accommodate special files.

Most files pertaining to RPM are kept in the `/var/lib/rpm/` directory. For more information on RPM refer to the chapter titled *Package Management with RPM* in the *Red Hat Enterprise Linux System Administration Guide*.

The `/var/spool/updates/` directory contains files used by **Red Hat Update Agent**, including RPM header information for the system. This location may also be used to temporarily store RPMs downloaded while updating the system. For more information about Red Hat Network, refer to the documentation online at <https://rhn.redhat.com/>.

Another location specific to Red Hat Enterprise Linux is the `/etc/sysconfig/` directory. This directory stores a variety of configuration information. Many scripts that run at boot time use the files in this directory. Refer to Chapter 4 *The sysconfig Directory* for more information about what is within this directory and the role these files play in the boot process.

Finally, one more directory worth noting is the `/initrd/` directory. It is empty, but is used as a critical mount point during the boot process.



#### Warning

Do not remove the `/initrd/` directory for any reason. Removing this directory causes the system to fail to boot with a kernel panic error message.



## The `sysconfig` Directory

The `/etc/sysconfig/` directory is where a variety of system configuration files for Red Hat Enterprise Linux are stored.

This chapter outlines some of the files found in the `/etc/sysconfig/` directory, their function, and their contents. The information in this chapter 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.

### 4.1. Files in the `/etc/sysconfig/` Directory

The following files are normally found in the `/etc/sysconfig/` directory:

- `amd`
- `apmd`
- `authconfig`
- `clock`
- `desktop`
- `devlabel`
- `dhcpcd`
- `firstboot`
- `gpm`
- `harddisks`
- `hwconf`
- `i18n`
- `init`
- `ip6tables-config`
- `iptables-config`
- `irda`
- `keyboard`
- `kudzu`
- `mouse`
- `named`
- `netdump`
- `network`
- `ntpd`
- `pcmcia`
- `radvd`
- `rawdevices`
- `redhat-config-securitylevel`

- `redhat-config-users`
- `redhat-logviewer`
- `samba`
- `sendmail`
- `spamassassin`
- `squid`
- `tux`
- `vncservers`
- `xinetd`



#### Note

If some of the files listed here are not present in the `/etc/sysconfig/` directory, the corresponding program may not be installed.

The following are descriptions of these files. Files not listed here as well as extra options for files that are can be found in the `/usr/share/doc/initscripts-<version-number>/sysconfig.txt` file (replace `<version-number>` with the version of the `initscripts` package). Alternatively, looking through the `initscripts` in the `/etc/rc.d/` directory can prove helpful.

#### 4.1.1. `/etc/sysconfig/amd`

The `/etc/sysconfig/amd` file contains various parameters used by `amd`, which allow for the automatic mounting and unmounting of file systems.

#### 4.1.2. `/etc/sysconfig/apmd`

The `/etc/sysconfig/apmd` file is used by `apmd` as a way to configure what power settings to start/stop/change on suspend or resume. It is configured to turn on or off `apmd` at boot time, depending on whether the hardware supports *Advanced Power Management (APM)* or whether the user has configured the system to use it. The `apm` daemon is a monitoring program that works with power management code within the Linux kernel. It capable of alerting users to low battery power on laptops and other power-related settings.

#### 4.1.3. `/etc/sysconfig/authconfig`

The `/etc/sysconfig/authconfig` file sets the kind of authorization to be used on the host. It contains one or more of the following lines:

- `USEMD5=<value>`, where `<value>` is one of the following:
  - `yes` — MD5 is used for authentication.
  - `no` — MD5 is not used for authentication.
- `USEKERBEROS=<value>`, where `<value>` is one of the following:
  - `yes` — Kerberos is used for authentication.

- `no` — Kerberos is not used for authentication.
- `USELDAPAUTH=<value>`, where `<value>` is one of the following:
  - `yes` — LDAP is used for authentication.
  - `no` — LDAP is not used for authentication.

#### 4.1.4. `/etc/sysconfig/clock`

The `/etc/sysconfig/clock` file controls the interpretation of values read from the system hardware clock.

The correct values are:

- `UTC=<value>`, where `<value>` is one of the following boolean values:
  - `true` or `yes` — The hardware clock is set to Universal Time.
  - `false` or `no` — The hardware clock is set to local time.
- `ARC=<value>`, where `<value>` is the following:
  - `true` or `yes` — The ARC console's 42-year time offset is in effect. This setting is only for ARC- or AlphaBIOS-based Alpha systems. Any other value indicates that the normal UNIX epoch is in use.
- `SRM=<value>`, where `<value>` is the following:
  - `true` or `yes` — The SRM console's 1900 epoch is in effect. This setting is only for SRM-based Alpha systems. Any other value indicates that the normal UNIX epoch is in use.
- `ZONE=<filename>` — The time zone file under `/usr/share/zoneinfo` that `/etc/localtime` is a copy of. The file contains information such as:
 

```
ZONE="America/New York"
```

Earlier releases of Red Hat Linux and Red Hat Enterprise Linux used the following values (which are deprecated):

- `CLOCKMODE=<value>`, where `<value>` is one of the following:
  - `GMT` — The clock is set to Universal Time (Greenwich Mean Time).
  - `ARC` — The ARC console's 42-year time offset is in effect (for Alpha-based systems only).

#### 4.1.5. `/etc/sysconfig/desktop`

The `/etc/sysconfig/desktop` file specifies the desktop for new users and the display manager to be run when entering runlevel 5.

Correct values are:

- `DISPLAY=<value>`, where `<value>` is one of the following:
  - `GNOME` — Selects the GNOME desktop environment.

- `KDE` — Selects the KDE desktop environment.
- `DISPLAYMANAGER=<value>`, where `<value>` is one of the following:
  - `GDM` — Selects the GNOME display manager.
  - `KDM` — Selects the KDE display manager.
  - `XDM` — Selects the XFree86 display manager.

For more about the X Window System under Red Hat Enterprise Linux, refer to Chapter 7 *The X Window System*.

#### 4.1.6. `/etc/sysconfig/devlabel`

The `/etc/sysconfig/devlabel` is the `devlabel` configuration file. It should not be modified by hand, but rather, configured using the `/sbin/devlabel` command.

For instructions on using the `devlabel` command, refer to the chapter titled *User-Defined Device Names* in the *Red Hat Enterprise Linux System Administration Guide*.

#### 4.1.7. `/etc/sysconfig/dhcpd`

The `/etc/sysconfig/dhcpd` file is used to pass arguments to the `dhcpd` daemon at boot time. The `dhcpd` daemon implements the Dynamic Host Configuration Protocol (DHCP) and the Internet Bootstrap Protocol (BOOTP). DHCP and BOOTP assign hostnames to machines on the network. For more information about what parameters are available in this file, refer to the `dhcpd` man page.

#### 4.1.8. `/etc/sysconfig/firstboot`

Beginning with Red Hat Linux 8.0, the first time the system boots, the `/sbin/init` program calls the `etc/rc.d/init.d/firstboot` script, which in turn launches **Setup Agent**. This application allows the user to install the latest updates as well as additional applications and documentation.

The `/etc/sysconfig/firstboot` file tells the **Setup Agent** application not to run on subsequent reboots. To run it the next time the system boots, remove `/etc/sysconfig/firstboot` and execute `chkconfig --level 5 firstboot on`.

#### 4.1.9. `/etc/sysconfig/gpm`

The `/etc/sysconfig/gpm` file is used to pass arguments to the `gpm` daemon at boot time. The `gpm` daemon is the mouse server which allows mouse acceleration and middle-click pasting. For more information about what parameters are available for this file, refer to the `gpm` man page. By default, it sets the mouse device to `/dev/mouse`.

#### 4.1.10. `/etc/sysconfig/harddisks`

The `/etc/sysconfig/harddisks` file tunes the hard drive(s). The administrator can also use `/etc/sysconfig/hardiskhd[a-h]` to configure parameters for specific drives.

**Warning**

Do not make changes to this file without careful consideration. By changing the default values, it is possible to corrupt all of the data on the hard drive(s).

The `/etc/sysconfig/harddisks` file may contain the following:

- `USE_DMA=1`, where setting this value to 1 enables DMA. However, with some chipsets and hard drive combinations, DMA can cause data corruption. *Check the hard drive documentation or with the manufacturer before enabling this option.*
- `Multiple_IO=16`, where a setting of 16 allows for multiple sectors per I/O interrupt. When enabled, this feature reduces operating system overhead by 30-50%. *Use with caution.*
- `EIDE_32BIT=3` enables (E)IDE 32-bit I/O support to an interface card.
- `LOOKAHEAD=1` enables drive read-lookahead.
- `EXTRA_PARAMS=` specifies where extra parameters can be added.

**4.1.11. `/etc/sysconfig/hwconf`**

The `/etc/sysconfig/hwconf` file lists all the hardware that `kudzu` detected on the system, as well as the drivers used, vendor ID, and device ID information. The `kudzu` program detects and configures new and/or changed hardware on a system. The `/etc/sysconfig/hwconf` file is not meant to be manually edited. If edited, devices could suddenly show up as being added or removed.

**4.1.12. `/etc/sysconfig/i18n`**

The `/etc/sysconfig/i18n` file sets the default language, any supported languages, and the default system font. For example:

```
LANG="en_US.UTF-8"
SUPPORTED="en_US.UTF-8:en_US:en"
SYSFONT="latarcyrheb-sun16"
```

**4.1.13. `/etc/sysconfig/init`**

The `/etc/sysconfig/init` file controls how the system appears and functions during the boot process.

The following values may be used:

- `BOOTUP=<value>`, where `<value>` is one of the following:
  - `BOOTUP=color` means the standard color boot display, where the success or failure of devices and services starting up is shown in different colors.
  - `BOOTUP=verbose` means an old style display, which provides more information than purely a message of success or failure.
  - Anything else means a new display, but without ANSI-formatting.
- `RES_COL=<value>`, where `<value>` is the number of the column of the screen to start status labels. Defaults to 60.

- `MOVE_TO_COL=<value>`, where `<value>` moves the cursor to the value in the `RES_COL` line via the `echo -en` command.
- `SETCOLOR_SUCCESS=<value>`, where `<value>` sets the color to a color indicating success via the `echo -en` command. The default color is set to green.
- `SETCOLOR_FAILURE=<value>`, where `<value>` sets the color to a color indicating failure via the `echo -en` command. The default color is set to red.
- `SETCOLOR_WARNING=<value>`, where `<value>` sets the warning color via the `echo -en` command. The default color is set to yellow.
- `SETCOLOR_NORMAL=<value>`, where `<value>` resets the color to "normal" via the `echo -en`.
- `LOGLEVEL=<value>`, where `<value>` sets the initial console logging level for the kernel. The default is 3; 8 means everything (including debugging); 1 means nothing except kernel panics. The `syslogd` daemon overrides this setting once started.
- `PROMPT=<value>`, where `<value>` is one of the following boolean values:
  - `yes` — Enables the key check for interactive mode.
  - `no` — Disables the key check for interactive mode.

#### 4.1.14. `/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 service `ip6tables` is started.

Do not modify this file by hand unless familiar with how to construct `ip6tables` rules. Rules also can be created manually using the `/sbin/ip6tables` command. Once created, add the rules to the `/etc/sysconfig/ip6tables` file by typing the following command:

```
/sbin/service ip6tables save
```

Once this file exists, any firewall rules saved in it persists through a system reboot or a service restart.

For more information on `ip6tables`, refer to Chapter 17 *iptables*.

#### 4.1.15. `/etc/sysconfig/iptables-config`

The `/etc/sysconfig/iptables` file stores information used by the kernel to set up packet filtering services at boot time or whenever the service is started.

Do not modify this file by hand unless familiar with how to construct `iptables` rules. The easiest way to add rules is to use the **Security Level Configuration Tool** (`redhat-config-securitylevel`) application to create a firewall. These applications automatically edit this file at the end of the process.

Rules can also be created manually using the `/sbin/iptables` command. Once created, add the rules to the `/etc/sysconfig/iptables` file by typing the following command:

```
/sbin/service iptables save
```

Once this file exists, any firewall rules saved in it persists through a system reboot or a service restart.

For more information on `iptables`, refer to Chapter 17 *iptables*.

#### 4.1.16. `/etc/sysconfig/irda`

The `/etc/sysconfig/irda` file controls how infrared devices on the system are configured at startup.

The following values may be used:

- `IRDA=<value>`, where `<value>` is one of the following boolean values:
  - `yes` — `irattach` is run, which periodically checks to see if anything is trying to connect to the infrared port, such as another notebook computer trying to make a network connection. For infrared devices to work on the system, this line must be set to `yes`.
  - `no` — `irattach` is not run, preventing infrared device communication.
- `DEVICE=<value>`, where `<value>` is the device (usually a serial port) that handles infrared connections.
- `DONGLE=<value>`, where `<value>` specifies the type of dongle being used for infrared communication. This setting exists for people who use serial dongles rather than real infrared ports. A dongle is a device that is attached to a traditional serial port to communicate via infrared. This line is commented out by default because notebooks with real infrared ports are far more common than computers with add-on dongles.
- `DISCOVERY=<value>`, where `<value>` is one of the following boolean values:
  - `yes` — Starts `irattach` in discovery mode, meaning it actively checks for other infrared devices. This must be turned on for the machine to actively looking for an infrared connection (meaning the peer that does not initiate the connection).
  - `no` — Does not start `irattach` in discovery mode.

#### 4.1.17. `/etc/sysconfig/keyboard`

The `/etc/sysconfig/keyboard` file controls the behavior of the keyboard. The following values may be used:

- `KEYBOARDTYPE=sun|pc`, which is used on SPARCs only. `sun` means a Sun keyboard is attached on `/dev/kbd`, and `pc` means a PS/2 keyboard connected to a PS/2 port.
- `KEYTABLE=<file>`, where `<file>` is the name of a keytable file.

For example: `KEYTABLE="us"`. The files that can be used as keytables start in `/lib/kbd/keymaps/i386` and branch into different keyboard layouts from there, all labeled `<file>.kmap.gz`. The first file found beneath `/lib/kbd/keymaps/i386` that matches the `KEYTABLE` setting is used.

#### 4.1.18. `/etc/sysconfig/kudzu`

The `/etc/sysconfig/kudzu` file triggers a safe probe of the system hardware by `kudzu` at boot time. A safe probe is one that disables serial port probing.

- `SAFE=<value>`, where `<value>` is one of the following:
  - `yes` — `kudzu` does a safe probe.
  - `no` — `kudzu` does a normal probe.

#### 4.1.19. `/etc/sysconfig/mouse`

The `/etc/sysconfig/mouse` file is used to specify information about the available mouse. The following values may be used:

- `FULLNAME=<value>`, where `<value>` refers to the full name of the kind of mouse being used.
- `MOUSETYPE=<value>`, where `<value>` is one of the following:
  - `imps2` — A generic USB wheel mouse.
  - `microsoft` — A Microsoft™ mouse.
  - `mouseman` — A MouseMan™ mouse.
  - `mousesystems` — A Mouse Systems™ mouse.
  - `ps/2` — A PS/2 mouse.
  - `msbm` — A Microsoft™ bus mouse.
  - `logibm` — A Logitech™ bus mouse.
  - `atibm` — An AT™ bus mouse.
  - `logitech` — A Logitech™ mouse.
  - `mmseries` — An older MouseMan™ mouse.
  - `mmhittab` — An mmhittab mouse.
- `XEMU3=<value>`, where `<value>` is one of the following boolean values:
  - `yes` — The mouse only has two buttons, but three mouse buttons should be emulated.
  - `no` — The mouse already has three buttons.
- `XMOUSETYPE=<value>`, where `<value>` refers to the kind of mouse used when X is running. The options here are the same as the `MOUSETYPE` setting in this same file.
- `DEVICE=<value>`, where `<value>` is the mouse device.

In addition, `/dev/mouse` is a symbolic link that points to the actual mouse device.

#### 4.1.20. `/etc/sysconfig/named`

The `/etc/sysconfig/named` file is used to pass arguments to the `named` daemon at boot time. The `named` daemon is a *Domain Name System (DNS)* server which implements the *Berkeley Internet Name Domain (BIND)* version 9 distribution. This server maintains a table of which hostnames are associated with IP addresses on the network.

Currently, only the following values may be used:

- `ROOTDIR="</some/where>"`, where `</some/where>` refers to the full directory path of a configured chroot environment under which `named` runs. This chroot environment must first be configured. Type `info chroot` for more information.
- `OPTIONS="<value>"`, where `<value>` is any option listed in the man page for `named` except `-t`. In place of `-t`, use the `ROOTDIR` line above.



For more information about what parameters are available for this file, refer to the `named` man page. For detailed information on how to configure a BIND DNS server, refer to Chapter 13 *Berkeley Internet Name Domain (BIND)*. By default, the file contains no parameters.

#### 4.1.21. `/etc/sysconfig/netdump`

The `/etc/sysconfig/netdump` file is the configuration file for the `/etc/init.d/netdump` service. The `netdump` service sends both oops data and memory dumps over the network. In general, `netdump` is not a required service; only run it if absolutely necessary. For more information about what parameters are available for this file, refer to the `netdump` man page.

#### 4.1.22. `/etc/sysconfig/network`

The `/etc/sysconfig/network` file is used to specify information about the desired network configuration. The following values may be used:

- `NETWORKING=<value>`, where `<value>` is one of the following boolean values:
  - `yes` — Networking should be configured.
  - `no` — Networking should not be configured.
- `HOSTNAME=<value>`, where `<value>` should be the *Fully Qualified Domain Name (FQDN)*, such as `hostname.example.com`, but can be whatever hostname is necessary.



#### Note

For compatibility with older software that people might install (such as `trn`), the `/etc/HOSTNAME` file should contain the same value as here.

- `GATEWAY=<value>`, where `<value>` is the IP address of the network's gateway.
- `GATEWAYDEV=<value>`, where `<value>` is the gateway device, such as `eth0`.
- `NISDOMAIN=<value>`, where `<value>` is the NIS domain name.

#### 4.1.23. `/etc/sysconfig/ntp`

The `/etc/sysconfig/ntp` file is used to pass arguments to the `ntpd` daemon at boot time. The `ntpd` daemon sets and maintains the system clock to synchronize with an Internet standard time server. It implements version 4 of the Network Time Protocol (NTP). For more information about what parameters are available for this file, point a Web browser at the following file: `/usr/share/doc/ntp-<version>/ntpd.htm` (where `<version>` is the version number of `ntpd`). By default, this file sets the owner of the `ntpd` process to the user `ntp`.

#### 4.1.24. `/etc/sysconfig/pcmcia`

The `/etc/sysconfig/pcmcia` file is used to specify PCMCIA configuration information. The following values may be used:

- `PCMCIA=<value>`, where `<value>` is one of the following:

- `yes` — PCMCIA support should be enabled.
- `no` — PCMCIA support should not be enabled.
- `PCIC=<value>`, where `<value>` is one of the following:
  - `i82365` — The computer has an i82365-style PCMCIA socket chipset.
  - `tcic` — The computer has a tcic-style PCMCIA socket chipset.
- `PCIC_OPTS=<value>`, where `<value>` is the socket driver (i82365 or tcic) timing parameters.
- `CORE_OPTS=<value>`, where `<value>` is the list of `pcmcia_core` options.
- `CARDMGR_OPTS=<value>`, where `<value>` is the list of options for the PCMCIA `cardmgr` (such as `-q` for quiet mode; `-m` to look for loadable kernel modules in the specified directory, and so on). Read the `cardmgr` man page for more information.

#### 4.1.25. `/etc/sysconfig/radvd`

The `/etc/sysconfig/radvd` file is used to pass arguments to the `radvd` daemon at boot time. The `radvd` daemon listens to for router requests and sends router advertisements for the IP version 6 protocol. This service allows hosts on a network to dynamically change their default routers based on these router advertisements. For more information about what parameters are available for this file, refer to the `radvd` man page. By default, this file sets the owner of the `radvd` process to the user `radvd`.

#### 4.1.26. `/etc/sysconfig/rawdevices`

The `/etc/sysconfig/rawdevices` file is used to configure raw device bindings, such as:

```
/dev/raw/raw1 /dev/sda1
/dev/raw/raw2 8 5
```

#### 4.1.27. `/etc/sysconfig/redhat-config-securitylevel`

The `/etc/sysconfig/redhat-config-securitylevel` file contains all options chosen by the user the last time the **Security Level Configuration Tool** (`redhat-config-securitylevel`) was run. Users should not modify this file by hand. For more information about the **Security Level Configuration Tool**, refer to the chapter titled *Basic Firewall Configuration* in the *Red Hat Enterprise Linux System Administration Guide*.

#### 4.1.28. `/etc/sysconfig/redhat-config-users`

The `/etc/sysconfig/redhat-config-users` file is the configuration file for the graphical application, **User Manager**. This file is used to filter out system users such as `root`, `daemon`, or `lp`. This file is edited by the **Preferences => Filter system users and groups** pull-down menu in the **User Manager** application and should never be edited by hand. For more information on using this application, refer to the chapter called *User and Group Configuration* in the *Red Hat Enterprise Linux System Administration Guide*.

#### 4.1.29. `/etc/sysconfig/redhat-logviewer`

The `/etc/sysconfig/redhat-logviewer` file is the configuration file for the graphical, interactive log viewing application, **Log Viewer**. This file is edited by the **Edit => Preferences** pull-down menu in the **Log Viewer** application and should not be edited by hand. For more information on using this application, refer to the chapter called *Log Files* in the *Red Hat Enterprise Linux System Administration Guide*.

#### 4.1.30. `/etc/sysconfig/samba`

The `/etc/sysconfig/samba` file is used to pass arguments to the `smbd` and the `nmbd` daemons at boot time. The `smbd` daemon offers file sharing connectivity for Windows clients on the network. The `nmbd` daemon offers NetBIOS over IP naming services. For more information about what parameters are available for this file, refer to the `smbd` man page. By default, this file sets `smbd` and `nmbd` to run in daemon mode.

#### 4.1.31. `/etc/sysconfig/sendmail`

The `/etc/sysconfig/sendmail` file allows messages to be sent to one or more clients, routing the message over whatever networks are necessary. The file sets the default values for the Sendmail application to run. Its default values are to run as a background daemon and to check its queue once an hour in case something has backed up.

The following values may be used:

- `DAEMON=<value>`, where `<value>` is one of the following boolean values:
  - `yes` — Sendmail should be configured to listen to port 25 for incoming mail. `yes` implies the use of Sendmail's `-bd` options.
  - `no` — Sendmail should not be configured to listen to port 25 for incoming mail.
- `QUEUE=1h` which is given to Sendmail as `-q$QUEUE`. The `-q` option is not given to Sendmail if `/etc/sysconfig/sendmail` exists and `QUEUE` is empty or undefined.

#### 4.1.32. `/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. Spamassassin is an email spam filter application. For a list of available options, refer to the `spamd` man page. By default, it configures `spamd` to run in daemon mode, create user preferences, and auto-create whitelists.

For more information about Spamassassin, refer to Section 12.4.2.6 *Spam Filters*.

#### 4.1.33. `/etc/sysconfig/squid`

The `/etc/sysconfig/squid` file is used to pass arguments to the `squid` daemon at boot time. The `squid` daemon is a proxy caching server for Web client applications. For more information on configuring a `squid` proxy server, use a Web browser to open the `/usr/share/doc/squid-<version>/` directory (replace `<version>` with the `squid` version number installed on the system). By default, this file sets `squid` to start in daemon mode and sets the amount of time before it shuts itself down.

#### 4.1.34. `/etc/sysconfig/tux`

The `/etc/sysconfig/tux` file is the configuration file for the Red Hat Content Accelerator (formerly known as TUX), the kernel-based Web server. For more information on configuring the Red Hat Content Accelerator, use a Web browser to open the `/usr/share/doc/tux-<version>/tux/index.html` (replace `<version>` with the version number of TUX installed on the system). The parameters available for this file are listed in `/usr/share/doc/tux-<version>/tux/parameters.html`.

#### 4.1.35. `/etc/sysconfig/vncservers`

The `/etc/sysconfig/vncservers` file configures the way the *Virtual Network Computing* (VNC) server starts up.

VNC is a remote display system which allows users to view the desktop environment not only on the machine where it is running but across different networks on a variety of architectures.

It may contain the following:

- `VNCSERVERS=<value>`, where `<value>` is set to something like `"1:fred"`, to indicate that a VNC server should be started for user fred on display :1. User fred must have set a VNC password using `vncpasswd` before attempting to connect to the remote VNC server.

Note that when using a VNC server, communication with it is unencrypted, and it should not be used on an untrusted network. For specific instructions concerning the use of SSH to secure the VNC communication, read the information found online at <http://www.uk.research.att.com/vnc/sshvnc.html>. To find out more about SSH, refer to Chapter 19 *SSH Protocol* or in the *Red Hat Enterprise Linux System Administration Guide*.

#### 4.1.36. `/etc/sysconfig/xinetd`

The `/etc/sysconfig/xinetd` file is used to pass arguments to the `xinetd` daemon at boot time. The `xinetd` daemon starts programs that provide Internet services when a request to the port for that service is received. For more information about the parameters available for this file, refer to the `xinetd` man page. For more information on the `xinetd` service, refer to Section 16.3 *xinetd*.

## 4.2. Directories in the `/etc/sysconfig/` Directory

The following directories are normally found in `/etc/sysconfig/`.

- `apm-scripts/` — This directory contains the Red Hat APM suspend/resume script. Do not edit the files directly. If customization is necessary, create a file called `/etc/sysconfig/apm-scripts/apmcontinue` and it is called at the end of the script. It is also possible to control the script by editing `/etc/sysconfig/apmd`.
- `cbq/` — This directory contains the configuration files needed to do Class Based Queuing for bandwidth management on network interfaces.
- `networking/` — This directory is used by the **Network Administration Tool** (`redhat-config-network`), and its contents should not be edited manually. For more information about configuring network interfaces using the **Network Administration Tool**, refer to the chapter called *Network Configuration* in the *Red Hat Enterprise Linux System Administration Guide*.
- `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 up and down network interfaces, such as `ifup` and `ifdown`.
- Scripts used to bring up and down ISDN interfaces, such as `ifup-isdn` and `ifdown-isdn`.
- Various shared network function scripts which should not be edited directly.

For more information on the `network-scripts` directory, refer to Chapter 8 *Network Interfaces*.

- `rhn/` — This directory contains the configuration files and GPG keys for the Red Hat Network. No files in this directory should be edited by hand. For more information on the Red Hat Network, refer to the Red Hat Network website online at <https://rhn.redhat.com/>.

## 4.3. 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.

### 4.3.1. Installed Documentation

- `/usr/share/doc/initscripts-<version-number>/sysconfig.txt` — This file contains a more authoritative listing of the files found in the `/etc/sysconfig/` directory and the configuration options available for them. The `<version-number>` in the path to this file corresponds to the version of the `initscripts` package installed.



## 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.

Within the `/proc/` directory, one can find a wealth of information detailing the system hardware and any processes currently running. In addition, some of the files within the `/proc/` directory tree can be manipulated by users and applications to communicate configuration changes to the kernel.

### 5.1. A Virtual File System

Under Linux, all data are stored 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*. It is for this reason that `/proc/` is often referred to as a *virtual file system*.

These virtual files have unique qualities. Most of them are listed as zero bytes in size and yet when one is viewed, it can contain a large amount of information. In addition, most of the time and date settings 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. For instance, `/proc/ide/` contains information for all physical IDE devices. Likewise, process directories contain information about each running process on the system.

#### 5.1.1. Viewing Virtual Files

By using the `cat`, `more`, or `less` commands on files within the `/proc/` directory, users can immediately access enormous amounts of information about the system. For example, to display the type of CPU a computer has, type `cat /proc/cpuinfo` to receive output similar to the following:

```
processor : 0
vendor_id : AuthenticAMD
cpu family : 5
model : 9
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
```

When viewing different virtual files in the `/proc/` file system, some of the information is easily understandable while some is not human-readable. This is in part why utilities exist to pull data from virtual files and display it in a useful way. Examples of these utilities include `lspci`, `apm`, `free`, and `top`.

**Note**

Some of the virtual files in the `/proc/` directory are readable only by the root user.

### 5.1.2. 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 `echo` command and a greater than symbol (`>`) symbol to redirect the new value to the file. For example, to change the hostname on the fly, type:

```
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 or a 1. A 0 indicates that the kernel is not forwarding network packets. Using the `echo` command to change the value of the `ip_forward` file to 1 immediately turns packet forwarding on.

**Tip**

Another command used to alter settings in the `/proc/sys/` subdirectory is `/sbin/sysctl`. For more information on this command, refer to Section 5.4 *Using the `sysctl` Command*

For a listing of some of the kernel configuration files available in the `/proc/sys/`, refer to Section 5.3.9 */proc/sys/*.

## 5.2. 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.

**Note**

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 Red Hat Enterprise Linux is running.



### 5.2.1. `/proc/apm`

This file provides information about the state of the *Advanced Power Management (APM)* system and is used by the `apm` command. If a system with no battery is connected to an AC power source, this virtual file would look similar to the following:

```
1.16 1.2 0x07 0x01 0xff 0x80 -1% -1 ?
```

Running the `apm -v` command on such a system results in output similar to the following:

```
APM BIOS 1.2 (kernel driver 1.16)
AC on-line, no system battery
```

For systems which do not use a battery as a power source, `apm` is able do little more than put the machine in standby mode. The `apm` command is much more useful on laptops. For example, the following output is from the command `cat /proc/apm` on a laptop while plugged into a power outlet:

```
1.16 1.2 0x03 0x01 0x03 0x09 100% -1 ?
```

When the same laptop is unplugged from its power source for a few minutes, the contents of the `apm` file change to something like the following:

```
1.16 1.2 0x03 0x00 0x00 0x01 99% 1792 min
```

The `apm -v` command now yields more useful data, such as the following:

```
APM BIOS 1.2 (kernel driver 1.16)
AC off-line, battery status high: 99% (1 day, 5:52)
```

### 5.2.2. `/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/hda2
```

This tells us that the kernel is mounted read-only (signified by `(ro)`) off of the second partition on the first IDE device (`/dev/hda2`).

### 5.2.3. `/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
vendor_id : GenuineIntel
cpu family : 15
model : 2
model name : Intel(R) Xeon(TM) CPU 2.40GHz
stepping : 7
cpu MHz : 2392.371
cache size : 512 KB
physical id : 0
siblings : 2
```

```

runqueue : 0
fddiv_bug : no
hlt_bug : no
f00f_bug : no
coma_bug : no
fpu : yes
fpu_exception : yes
cpuid level : 2
wp : yes
flags : fpu vme de pse tsc msr pae mce cx8 apic sep mtrr pge mca
cmov pat pse36 clflush dts acpi mmx fxsr sse sse2 ss ht tm
bogomips : 4771.02

```

- `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 number 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 thousandth decimal point.
- `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.

#### 5.2.4. `/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
 2 pty
 3 tty
 4 ttyS
 5 cua
 7 vcs
10 misc
14 sound
29 fb
36 netlink
128 ptm
129 ptm
136 pts
137 pts
162 raw
254 iscsictl

```

```
Block devices:
 1 ramdisk
 2 fd
 3 ide0
 9 md
22 ide1
```

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. 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. Character devices do not require buffering.
2. Block devices can send and receive information in blocks of a size configured per device. Character devices send data with no preconfigured size.

For more information about devices refer to the following installed documentation:

```
/usr/src/linux-2.4/Documentation/devices.txt
```

### 5.2.5. `/proc/dma`

This file contains a list of the registered ISA direct memory access (DMA) channels in use. A sample `/proc/dma` files looks like the following:

```
4: cascade
```

### 5.2.6. `/proc/execd domains`

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.

### 5.2.7. `/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
```

### 5.2.8. `/proc/filesystems`

This file displays a list of the file system types currently supported by the kernel. Sample output from a generic `/proc/filesystems` looks similar to the following:

```
nodev rootfs
nodev bdev
nodev proc
nodev sockfs
nodev tmpfs
nodev shm
nodev pipefs
  ext2
nodev ramfs
  iso9660
nodev devpts
  ext3
nodev autofs
nodev binfmt_misc
```

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.

### 5.2.9. `/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: 80448940      XT-PIC timer
1: 174412       XT-PIC keyboard
2: 0            XT-PIC cascade
8: 1           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:

```
          CPU0          CPU1
0: 1366814704         0      XT-PIC timer
1: 128              340    IO-APIC-edge keyboard
2: 0                0      XT-PIC cascade
8: 0                1     IO-APIC-edge rtc
12: 5323            5793   IO-APIC-edge PS/2 Mouse
13: 1                0      XT-PIC fpu
16: 11184294       15940594 IO-APIC-level Intel EtherExpress Pro 10/100 Ethernet
20: 8450043       11120093 IO-APIC-level megaraid
30: 10432          10722   IO-APIC-level aic7xxx
31: 23             22     IO-APIC-level aic7xxx
NMI: 0
ERR: 0
```

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.

### 5.2.10. `/proc/iomem`

This file shows you the current map of the system's memory for each physical device:

```
00000000-0009fbff : System RAM
0009fc00-0009ffff : reserved
000a0000-000bffff : Video RAM area
000c0000-000c7fff : Video ROM
000f0000-000fffff : System ROM
00100000-07ffffff : System RAM
    00100000-00291ba8 : Kernel code
    00291ba9-002e09cb : Kernel data
e0000000-e3ffffff : VIA Technologies, Inc. VT82C597 [Apollo VP3]
e4000000-e7ffffff : PCI Bus #01
    e4000000-e4003fff : Matrox Graphics, Inc. MGA G200 AGP
    e5000000-e57ffffff : Matrox Graphics, Inc. MGA G200 AGP
e8000000-e8ffffff : PCI Bus #01
    e8000000-e8ffffff : Matrox Graphics, Inc. MGA G200 AGP
ea000000-ea00007f : Digital Equipment Corporation DECchip 21140 [FasterNet]
    ea000000-ea00007f : tulip
ffff0000-ffffffff : reserved
```

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.

### 5.2.11. `/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:

```
0000-001f : dma1
0020-003f : pic1
0040-005f : timer
0060-006f : keyboard
0070-007f : rtc
0080-008f : dma page reg
00a0-00bf : pic2
00c0-00df : dma2
```

```

00f0-00ff : fpu
0170-0177 : ide1
01f0-01f7 : ide0
02f8-02ff : serial(auto)
0376-0376 : ide1
03c0-03df : vga+
03f6-03f6 : ide0
03f8-03ff : serial(auto)
0cf8-0cff : PCI confl
d000-dfff : PCI Bus #01
e000-e00f : VIA Technologies, Inc. Bus Master IDE
    e000-e007 : ide0
    e008-e00f : ide1
e800-e87f : Digital Equipment Corporation DECchip 21140 [FasterNet]
    e800-e87f : tulip

```

The first column gives the I/O port address range reserved for the device listed in the second column.

### 5.2.12. `/proc/isapnp`

This file lists installed *Plug and Play (PnP)* cards in ISA slots on the system. This is most often seen with sound cards but may include any number of devices. The following is an example `/proc/isapnp` file with a sound card installed:

```

Card 1 'CTL0070:Creative ViBRA16C PnP' PnP version 1.0 Product version 1.0
Logical device 0 'CTL0001:Audio'
Device is not active
Active port 0x220,0x330,0x388
Active IRQ 5 [0x2]
Active DMA 1,5
Resources 0
Priority preferred
Port 0x220-0x220, align 0x0, size 0x10, 16-bit address decoding
Port 0x330-0x330, align 0x0, size 0x2, 16-bit address decoding
Port 0x388-0x3f8, align 0x0, size 0x4, 16-bit address decoding
IRQ 5 High-Edge
DMA 1 8-bit byte-count compatible
DMA 5 16-bit word-count compatible
Alternate resources 0:1
Priority acceptable
Port 0x220-0x280, align 0x1f, size 0x10, 16-bit address decoding
Port 0x300-0x330, align 0x2f, size 0x2, 16-bit address decoding
Port 0x388-0x3f8, align 0x0, size 0x4, 16-bit address decoding
IRQ 5,7,2/9,10 High-Edge
DMA 1,3 8-bit byte-count compatible
DMA 5,7 16-bit word-count compatible

```

This file can be quite long, depending on the number of devices displayed and their resource requirements.

Each card lists its name, PnP version number, and product version number. If the device is active and configured, this file also reveals the port and IRQ numbers for the device. In addition, to ensure better compatibility, the card specifies preferred and acceptable values for a number of different parameters. The goal here is to allow the PnP cards to work around one another and avoid IRQ and port conflicts.

### 5.2.13. `/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 4KB.

The contents of this file are designed to be examined by a debugger, such as `gdb`, and is not human readable.



#### Warning

Do not view the `/proc/kcore` virtual file. The contents of the file scrambles 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.

### 5.2.14. `/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`.

### 5.2.15. `/proc/ksyms`

This file contains the symbol definitions used by the module tools to dynamically link and bind kernel modules.

```
e003def4 speedo_debug [eeepro100]
e003b04c eeepro100_init [eeepro100]
e00390c0 st_template [st]
e002104c RDINDOOR [megaraid]
e00210a4 callDone [megaraid]
e00226cc megaraid_detect [megaraid]
```

The first column lists the memory address for the kernel function, the second column refers to the name of the function, and the last column reveals the name of the loaded module.

### 5.2.16. `/proc/loadavg`

This file provides a look the load average in regards 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 1, 5, and 10 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.

### 5.2.17. `/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: FLOCK  ADVISORY  WRITE 807 03:05:308731 0 EOF c2a260c0 c025aa48 c2a26120
2: POSIX  ADVISORY  WRITE 708 03:05:308720 0 EOF c2a2611c c2a260c4 c025aa48
```

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 column shows the start and end of the file's locked region. The remaining columns point to internal kernel data structures used for specialized debugging and can be ignored.

### 5.2.18. `/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 `md` 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 1024 sectors
md0: active raid1 sda2[1] sdb2[0] 9940 blocks [2/2] [UU] resync=1% finish=12.3min
algorithm 2 [3/3] [UUU]
unused devices: <none>
```

### 5.2.19. `/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 256MB of RAM and 384MB of swap space:

```
total:      used:      free:      shared:    buffers:    cached:
Mem: 128692224 121212928 7479296    0 9293824 47964160
Swap: 1103093760 32772096 1070321664
MemTotal:    125676 kB
MemFree:     7304 kB
MemShared:   0 kB
```



```

Buffers:          9076 kB
Cached:          34204 kB
SwapCached:      12636 kB
Active:          79352 kB
ActiveAnon:      57308 kB
ActiveCache:     22044 kB
Inact_dirty:     240 kB
Inact_laundry:   17468 kB
Inact_clean:     984 kB
Inact_target:    19608 kB
HighTotal:       0 kB
HighFree:        0 kB
LowTotal:        125676 kB
LowFree:         7304 kB
SwapTotal:       1077240 kB
SwapFree:        1045236 kB
HugePages_Total: 2
HugePages_Free:  2
Hugepagesize:    2096 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:

- `Mem` — The current state of physical RAM in the system, including a full breakdown of total, used, free, shared, buffered, and cached memory utilization in bytes.
- `Swap` — The total, used, and free amounts of swap space, in bytes.
- `MemTotal` — Total amount of physical RAM, in kilobytes.
- `MemFree` — The amount of physical RAM, in kilobytes, left unused by the system.
- `MemShared` — Unused with 2.4 and higher kernels but left in for compatibility with earlier kernel versions.
- `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.
- `Inact_dirty` — The total amount of buffer or cache pages, in kilobytes, estimated to be free and available.
- `Inact_laundry` — The total amount of buffer or cache pages, in kilobytes, that are about to become free and available, possibly after disk IO for these pages has finished.
- `Inact_clean` — The total amount of buffer or cache pages, in kilobytes, that are free and available.
- `Inact_target` — The net amount of allocations per second, in kilobytes, averaged over one minute. This is a deprecated statistic which has little meaning on modern systems.
- `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.

- `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 and hugemem kernels, the default is 2048 KB. For 64 bit architectures, the default is 262144 KB. This statistic only appears on the x86, Itanium, and AMD64 architectures.

### 5.2.20. `/proc/misc`

This file lists miscellaneous drivers registered on the miscellaneous major device, which is device number 10:

```
135 rtc
    1 psaux
134 apm_bios
```

The first column is the minor number of each device, while the second column shows the driver in use.

### 5.2.21. `/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:

```
ide-cd          27008    0 (autoclean)
cdrom          28960    0 (autoclean) [ide-cd]
soundcore       4100    0 (autoclean)
agpgart        31072    0 (unused)
binfmt_misc     5956    1
iscsi          32672    0 (unused)
scsi_mod       94424    1 [iscsi]
autofs         10628    0 (autoclean) (unused)
tulip          48608    1
ext3           60352    2
jbd            39192    2 [ext3]
```

The first column contains the name of the module. The second column refers to the memory size of the module, in bytes. The third column lists whether the module is currently loaded (1) or unloaded (0). The final column states if the module can unload itself automatically after a period without use (`autoclean`) or if it is not being utilized (`unused`). A module with a line containing a name listed in brackets (`[ ]`) indicates that the module depends upon another module to be present in order to function.

This information can also be viewed via the `/sbin/lsmmod` command.

### 5.2.22. `/proc/mounts`

This file provides a list of all mounts in use by the system:

```
rootfs / rootfs rw 0 0
/dev/hda2 / ext3 rw 0 0
/proc /proc proc rw 0 0
/dev/hda1 /boot ext3 rw 0 0
none /dev/pts devpts rw 0 0
none /dev/shm tmpfs rw 0 0
none /proc/sys/fs/binfmt_misc binfmt_misc rw 0 0
```

The output found here is similar to contents of `/etc/mtab`, except that `/proc/mount` 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`.

### 5.2.23. `/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= 64MB: write-back, 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 online at the following URL:

<http://web1.linuxhq.com/kernel/v2.3/doc/mtrr.txt.html>

### 5.2.24. `/proc/partitions`

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 our example (3) corresponds with the block device `ide0` in `/proc/devices`.
- `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.

### 5.2.25. `/proc/pci`

This file contains a full listing of every PCI device on the system. Depending on the number of PCI devices, `/proc/pci` can be rather long. A sampling of this file from a basic system looks similar to the following:

```

Bus 0, device 0, function 0:
  Host bridge: Intel Corporation 440BX/ZX - 82443BX/ZX Host bridge (rev 3).
  Master Capable. Latency=64.
  Prefetchable 32 bit memory at 0xe4000000 [0xe7ffffff].
Bus 0, device 1, function 0:
  PCI bridge: Intel Corporation 440BX/ZX - 82443BX/ZX AGP bridge (rev 3).
  Master Capable. Latency=64. Min Gnt=128.
Bus 0, device 4, function 0:
  ISA bridge: Intel Corporation 82371AB PIIX4 ISA (rev 2).
Bus 0, device 4, function 1:
  IDE interface: Intel Corporation 82371AB PIIX4 IDE (rev 1).
  Master Capable. Latency=32.
  I/O at 0xd800 [0xd80f].
Bus 0, device 4, function 2:
  USB Controller: Intel Corporation 82371AB PIIX4 USB (rev 1).
  IRQ 5.
  Master Capable. Latency=32.
  I/O at 0xd400 [0xd41f].
Bus 0, device 4, function 3:
  Bridge: Intel Corporation 82371AB PIIX4 ACPI (rev 2).
  IRQ 9.
Bus 0, device 9, function 0:
  Ethernet controller: Lite-On Communications Inc LNE100TX (rev 33).
  IRQ 5.
  Master Capable. Latency=32.
  I/O at 0xd000 [0xd0ff].
  Non-prefetchable 32 bit memory at 0xe3000000 [0xe30000ff].
Bus 0, device 12, function 0:
  VGA compatible controller: S3 Inc. ViRGE/DX or /GX (rev 1).
  IRQ 11.
  Master Capable. Latency=32. Min Gnt=4.Max Lat=255.
  Non-prefetchable 32 bit memory at 0xdc000000 [0xdfffffff].

```

This output shows a list of all PCI devices, sorted in the order of bus, device, and function. Beyond providing the name and version of the device, this list also gives detailed IRQ information so an administrator can quickly look for conflicts.



### Tip

To get a more readable version of this information, type:

```
/sbin/lspci -vb
```

## 5.2.26. `/proc/slabinfo`

This file gives 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. The following is a portion of a typical `/proc/slabinfo` virtual file:

```

slabinfo - version: 1.1 (statistics)
kmem_cache      64      68    112      2      2      1
nfs_write_data   0         0    384      0      0      1
nfs_read_data    0      160    384      0     16      1
nfs_page         0      200     96      0      5      1

```

```

ip_fib_hash      10    113    32    1    1    1
journal_head    51   7020    48    2   90    1
revoke_table     2    253    12    1    1    1
revoke_record    0     0    32    0    0    1
clip_arp_cache   0     0   128    0    0    1
ip_mrt_cache     0     0    96    0    0    1

```

The values in this file occur in the following order: cache name, number of active objects, number of total objects, size of the object, number of active slabs (blocks) of the objects, total number of slabs of the objects, and the number of pages per slab.

Note that *active* in this case means an object is in use.

### 5.2.27. `/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:

```

cpu 1139111 3689 234449 84378914
cpu0 1139111 3689 234449 84378914
page 2675248 8567956
swap 10022 19226
intr 93326523 85756163 174412 0 3 3 0 6 0 1 0 428620 0 60330 0 1368304 5538681
disk_io: (3,0): (1408049,445601,5349480,962448,17135856)
ctxt 27269477
btime 886490134
processes 206458

```

Some of the more commonly used statistics include:

- `cpu` — Measures the number of *jiffies* (1/100 of a second) that the system has been in user mode, user mode with low priority (*nice*), system mode, and in idle task, respectively. The total for all CPUs is given at the top, while each individual CPU is listed below with its own statistics.
- `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*.

### 5.2.28. `/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 5.3.9.3 `/proc/sys/kernel/`.

Although it is possible to write to this file, it cannot be read, even by the root user.

### 5.2.29. `/proc/swaps`

This file measures swap space and its utilization. For a system with only one swap partition, the output of `/proc/swap` may look similar to the following:

```
Filename      Type      Size      Used      Priority
/dev/hda6     partition 136512    20024     -1
```

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 is 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.

### 5.2.30. `/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.

### 5.2.31. `/proc/version`

This file specifies the version of the Linux kernel and `gcc` in use, as well as the version of Red Hat Enterprise Linux installed on the system:

```
Linux version 2.4.20-1.1931.2.231.2.12.ent (user@foo.redhat.com) (gcc version 3.2.3 200
(Red Hat Enterprise Linux 3.2.3-7)) #1 Thu Jun 19 14:57:04 EDT 2003
```

This information is used for a variety of purposes, including the version data presented when a user logs in.

## 5.3. Directories within `/proc/`

Common groups of information concerning the kernel are grouped into directories and subdirectories within the `/proc/` directory.

### 5.3.1. Process Directories

Every `/proc/` directory contains a number of directories with numerical names. A listing of them may be similar to the following:

```
dr-xr-xr-x  3 root    root          0 Feb 13 01:28 1
dr-xr-xr-x  3 root    root          0 Feb 13 01:28 1010
dr-xr-xr-x  3 xfs     xfs           0 Feb 13 01:28 1087
dr-xr-xr-x  3 daemon  daemon       0 Feb 13 01:28 1123
dr-xr-xr-x  3 root    root          0 Feb 13 01:28 11307
dr-xr-xr-x  3 apache  apache       0 Feb 13 01:28 13660
dr-xr-xr-x  3 rpc     rpc           0 Feb 13 01:28 637
dr-xr-xr-x  3 rpcuser rpcuser      0 Feb 13 01:28 666
```

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.
- `cpu` — Provides specific information about the utilization of each of the system's CPUs. A process running on a dual CPU system produces output similar to the following:
 

```
cpu 11 3
cpu0 0 0
cpu1 11 3
```
- `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
40031000-40038000 r-xp 00000000 03:03 293282      /lib/libpam.so.0.75
40038000-40039000 rw-p 00006000 03:03 293282      /lib/libpam.so.0.75
40039000-4003a000 rw-p 00000000 00:00 0
4003a000-4003c000 r-xp 00000000 03:03 293218      /lib/libdl-2.2.5.so
4003c000-4003d000 rw-p 00001000 03:03 293218      /lib/libdl-2.2.5.so
```

- `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:
 

```
263 210 210 5 0 205 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: 00000000ffffffef
CapEff: 00000000ffffffef
```

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.

### 5.3.1.1. `/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.

### 5.3.2. `/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 busses, 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 an 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: If#= 0 Alt= 0 #EPs= 1 Cls=09(hub ) Sub=00 Prot=00 Driver=hub
E: Ad=81(I) Atr=03(Int.) MxPS= 8 Iv1=255ms
```

### 5.3.3. `/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 : 01:38:43
rtc_date : 1998-02-13
rtc_epoch : 1900
alarm    : 00:00:00
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, review `/usr/src/linux-2.4/Documentation/rtc.txt`.

### 5.3.4. `/proc/fs`

This directory shows which file systems are exported. If running an NFS server, typing `cat /proc/fs/nfs/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 Chapter 9 *Network File System (NFS)*.

### 5.3.5. `/proc/ide/`

This directory contains information about IDE devices on the system. Each IDE channel is represented as a separate directory, such as `/proc/ide/ide0` and `/proc/ide/ide1`. In addition, a `drivers` file is available, providing the version number of the various drivers used on the IDE channels:

```
ide-cdrom version 4.59
ide-floppy version 0.97
ide-disk version 1.10
```

Many chipsets also provide a file in this directory with additional data concerning the drives connected through the channels. For example, a generic Intel PIIX4 Ultra 33 chipset produces the `/proc/ide/piix` file which reveal whether DMA or UDMA is enabled for the devices on the IDE channels:

```

                                Intel PIIX4 Ultra 33 Chipset.
----- Primary Channel ----- Secondary Channel -----
                    enabled                    enabled
----- drive0 ----- drive1 ----- drive0 ----- drive1 -----
DMA enabled:   yes           no           yes           no
UDMA enabled:  yes           no           no            no
UDMA enabled:  2             X           X             X
UDMA
DMA
PIO
```

Navigating into the directory for an IDE channel, such as `ide0`, provides additional information. The `channel` file provides the channel number, while the `model` identifies the bus type for the channel (such as `pci`).

#### 5.3.5.1. Device Directories

Within each IDE channel directory is a device directory. The name of the device directory corresponds to the drive letter in the `/dev/` directory. For instance, the first IDE drive on `ide0` would be `hda`.



#### Note

There is a symbolic link to each of these device directories in the `/proc/ide/` directory.

Each device directory contains a collection of information and statistics. The contents of these directories vary according to the type of device connected. Some of the more useful files common to many devices include:

- `cache` — The device cache.
- `capacity` — The capacity of the device, in 512 byte blocks.
- `driver` — The driver and version used to control the device.
- `geometry` — The physical and logical geometry of the device.
- `media` — The type of device, such as a `disk`.
- `model` — The model name or number of the device.

- `settings` — A collection of current parameters of the device. This file usually contains quite a bit of useful, technical information. A sample `settings` file for a standard IDE hard disk looks similar to the following:

name	value	min	max	mode
----	-----	---	---	----
<code>bios_cyl</code>	784	0	65535	<code>rw</code>
<code>bios_head</code>	255	0	255	<code>rw</code>
<code>bios_sect</code>	63	0	63	<code>rw</code>
<code>breada_readahead</code>	4	0	127	<code>rw</code>
<code>bswap</code>	0	0	1	<code>r</code>
<code>current_speed</code>	66	0	69	<code>rw</code>
<code>file_readahead</code>	0	0	2097151	<code>rw</code>
<code>ide_scsi</code>	0	0	1	<code>rw</code>
<code>init_speed</code>	66	0	69	<code>rw</code>
<code>io_32bit</code>	0	0	3	<code>rw</code>
<code>keepsettings</code>	0	0	1	<code>rw</code>
<code>lun</code>	0	0	7	<code>rw</code>
<code>max_kb_per_request</code>	64	1	127	<code>rw</code>
<code>multcount</code>	8	0	8	<code>rw</code>
<code>nicel</code>	1	0	1	<code>rw</code>
<code>nowerr</code>	0	0	1	<code>rw</code>
<code>number</code>	0	0	3	<code>rw</code>
<code>pio_mode</code>	<code>write-only</code>	0	255	<code>w</code>
<code>slow</code>	0	0	1	<code>rw</code>
<code>unmaskirq</code>	0	0	1	<code>rw</code>
<code>using_dma</code>	1	0	1	<code>rw</code>

### 5.3.6. `/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:

`/usr/src/linux-2.4/Documentation/filesystems/proc.txt`

### 5.3.7. `/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 directory is primarily used with ATM networking and ADSL cards.
- `dev` — Lists the various network devices configured on the system, complete with transmit and receive statistics. This file lists the number of bytes each interface has sent and received, the number

of packets inbound and outbound, the number of errors seen, the number of packets dropped, and more.

- `dev_mcast` — Lists Layer2 multicast groups on which each device is listening.
- `igmp` — Lists the IP multicast addresses which this system joined.
- `ip_conntrack` — Lists tracked network connections for machines that are forwarding IP connections.
- `ip_tables_names` — Lists the types of `iptables` in use. This file is only present if `iptables` are active on the system and contain one or more of the following values: `filter`, `mangle`, or `nat`.
- `ip_mr_cache` — Lists the multicast routing cache.
- `ip_mr_vif` — Lists multicast virtual interfaces.
- `netstat` — Contains a broad yet detailed collection of networking statistics, including TCP timeouts, SYN cookies sent and received, and much more.
- `psched` — Lists global packet scheduler parameters.
- `raw` — Lists raw device statistics.
- `route` — Lists the kernel's routing table.
- `rt_cache` — Contains the current routing cache.
- `snmp` — List of Simple Network Management Protocol (SNMP) data for various networking protocols in use.
- `sockstat` — Provides socket statistics.
- `tcp` — Contains detailed TCP socket information.
- `tr_rif` — Lists the token ring RIF routing table.
- `udp` — Contains detailed UDP socket information.
- `unix` — Lists UNIX domain sockets currently in use.
- `wireless` — Lists wireless interface data.

### 5.3.8. `/proc/scsi/`

This directory is analogous to the `/proc/ide/` directory, but it is for connected SCSI devices.

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 04106-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: 00
  Vendor: MegaRAID     Model: LD0 RAID5 34556R Rev: 1.01
  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

Adaptec Configuration:
  SCSI Adapter: Adaptec AIC-7880 Ultra SCSI host adapter
                Ultra Narrow Controller
  PCI MMAPed I/O Base: 0xfcffe000
  Adapter SEEPROM Config: SEEPROM found and used.
  Adaptec SCSI BIOS: Enabled
                    IRQ: 30
                    SCBs: Active 0, Max Active 1,
                          Allocated 15, HW 16, Page 255
                    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: 8
  Tagged Queue By Device array for aic7xxx host instance 1:
    {255,255,255,255,255,255,255,255,255,255,255,255,255,255}
  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}

Statistics:

(scsl1:0:5:0)
  Device using Narrow/Sync 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

(scsl1:0:6:0)
  Device using Narrow/Sync 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      0      0      0      0      0      0
  Writes:   0      0      0      1     131     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.

### 5.3.9. `/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.



#### Warning

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
-r--r--r-- 1 root root 0 May 10 16:14 dquot-nr
-rw-r--r-- 1 root root 0 May 10 16:14 file-max
-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/kernel/acct
```



#### Note

Any configuration changes made using the `echo` command disappears when the system is restarted. To make configuration changes take effect after the system is rebooted, refer to Section 5.4 *Using the `sysctl` Command*.

The `/proc/sys/` directory contains several subdirectories controlling different aspects of a running kernel.

### 5.3.9.1. `/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 3.12 2000/10/18
```

```
drive name: hdc
drive speed: 32
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
Reports media changed: 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
```

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.

### 5.3.9.2. `/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.

- `dquot-nr` — Lists the maximum number of cached disk quota entries.
- `file-max` — Lists the maximum number of file handles that the kernel will allocate. 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.
- `super-max` — Controls the maximum number of superblocks available.
- `super-nr` — Displays the current number of superblocks in use.

### 5.3.9.3. `/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 second value sets the threshold percentage of free space when logging is suspended, while the first value dictates the percentage of free space required for logging to resume. The third value sets the interval, in seconds, that the kernel polls the file system to see if logging should be suspended or resumed.

- `cap-bound` — Controls the *capability bounding* settings, which provides a list of capabilities for any process on the system. If a capability is not listed here, then no process, no matter how privileged, can do it. The idea is to make the system more secure by ensuring that certain things cannot happen, at least beyond a certain point in the boot process.

For a valid list of values for this virtual file, can be found in `/usr/src/linux-2.4/include/linux/capability.h`. More information on capability bounding is available online at the following URL:

<http://lwn.net/1999/1202/kernel.php3>

- `ctrl-alt-del` — Controls whether [Ctrl]-[Alt]-[Delete] gracefully restarts the computer using `init (0)` or force an immediate reboot without syncing the dirty buffers to disk (1).
- `domainname` — Configures the system domain name, such as `example.com`.
- `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`.
- `msgmax` — Sets the maximum size of any message sent from one process to another and is set to 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.
- `msgmnb` — Sets the maximum number of bytes in a single message queue. The default is 16384.
- `msgmni` — Sets the maximum number of message queue identifiers. The default is 16.
- `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.



- `overflowgid` and `overflowuid` — 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:

```
6      4      1      7
```

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.
- `rtsig-max` — Configures the maximum number of POSIX realtime signals that the system may have queued at any one time. The default value is 1024.
- `rtsig-nr` — Lists the current number of POSIX realtime signals queued by 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 2097152.
- `shmmax` — Sets the largest shared memory segment size allowed by the kernel, in bytes. By default, this value is 33554432. However, the kernel supports much larger values than this.
- `shmmni` — Sets the maximum number of shared memory segments for the whole system, in bytes. By default, this value is 4096
- `sysrq` — Activates the System Request Key, if this value is set to anything other than the 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]-[<system request code>]`. Replace `<system request code>` with one of the following system request codes:

- `r` — Disables raw mode for the keyboard and sets it to XLATE (a more 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 the *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 read-only.
- `p` — Outputs all flags and registers to the console.
- `t` — Outputs a list of processes to the console.
- `m` — Outputs memory statistics to the console.
- `0` through `9` — Sets the log level for the console.
- `e` — Kills all processes except `init` using `SIGTERM`.
- `i` — Kills all processes except `init` using `SIGKILL`.
- `l` — Kills all processes using `SIGKILL` (including `init`). The system is unusable after issuing this System Request Key code.
- `h` — Displays help text.

This feature is most useful when using a development kernel or when experiencing system freezes.



### Caution

The System Request Key feature is considered a security risk because an unattended console allows an attacker to gain access to the system. For this reason, it is turned off by default.

Refer to `/usr/src/linux-2.4/Documentation/sysrq.txt` for more information about the System Request Key.

- `sysrq-key` — Defines the key code for the System Request Key (84 is the default).
- `sysrq-sticky` — Defines whether or not the System Request Key is a chorded key combination. The accepted values are as follows:
  - `0` — `[Alt]-[SysRq]` and the system request code must be pressed simultaneously. This is the default value.
  - `1` — `[Alt]-[SysRq]` must be pressed simultaneously, but the system request code can be pressed anytime before the number of seconds specified in `/proc/sys/kernel/sysrq-timer`.
- `sysrq-timer` — Specifies the number of seconds allowed to pass before the system request code must be pressed. The default value is 10.
- `tainted` — Indicates whether or not a non-GPL module is loaded.
  - `0` — No non-GPL modules are loaded.
  - `1` — At least one module without a GPL license (including modules with no license) is loaded.
  - `2` — At least one module was force-loaded with the command `insmod -f`.
- `threads-max` — Sets the maximum number of threads to be used by the kernel, with a default value of 2048.

- `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.

#### 5.3.9.4. `/proc/sys/net/`

This directory contains subdirectories concerning various networking topics. Various configurations at the time of kernel compilation make different directories available here, such as `appletalk/`, `ethernet/`, `ipv4/`, `ipx/`, and `ipv6/`. By altering the files within these directories, system administrators are able to adjust the network configuration on a running system.

Given the wide variety of possible networking options available with Linux, only the most common `/proc/sys/net/` directories are discussed.

The `/proc/sys/net/core/` 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 *Denial of Service (DoS)* attacks. The default setting is 50.
- `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 300.
- `optmem_max` — Configures the maximum ancillary buffer size allowed per socket.
- `rmem_default` — Sets the receive socket buffer default size in bytes.
- `rmem_max` — 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/ipv4/` 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.



#### Caution

An erroneous change to these files may affect remote connectivity to the system.

The following is a list of some of the more important files within the `/proc/sys/net/ipv4/` directory:

- `icmp_destunreach_rate`, `icmp_echo_reply_rate`, `icmp_paramprob_rate`, and `icmp_timeexceed_rate` — Set the maximum ICMP send packet rate, in 1/100 of a second, to hosts under certain conditions. A setting of 0 removes any delay and is not a good idea.
- `icmp_echo_ignore_all` and `icmp_echo_ignore_broadcasts` — Allows the kernel to ignore ICMP ECHO packets from every host or only those originating from broadcast and multicast ad-

dresses, respectively. A value of 0 allows the kernel to respond, while a value of 1 ignores the packets.

- `ip_default_ttl` — Sets the default *Time To Live (TTL)*, which limits the number of hops a packet may make before reaching its destination. Increasing this value can diminish system performance.
- `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.
- `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.
- `tcp_syn_retries` — Provides a limit on the number of times the system re-transmits a SYN packet when attempting to make a connection.
- `tcp_retries1` — Sets the number of permitted re-transmissions attempting to answer an incoming connection. Default of 3.
- `tcp_retries2` — Sets the number of permitted re-transmissions of TCP packets. Default of 15.

The `/usr/src/linux-2.4/Documentation/networking/ip-sysctl.txt` file 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/neighbor/` 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/route/`. Unlike `conf/` and `neighbor/`, the `/proc/sys/net/ipv4/route/` 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/src/linux-2.4/Documentation/filesystems/proc.txt
```

### 5.3.9.5. `/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 called swap space.

The following files are commonly found in the `/proc/sys/vm/` directory:

- `bdflush` — Sets values related to the `bdflush` kernel daemon.
- `kswapd` — Sets values for the kernel swap-out daemon, `kswapd`. This file has three values:  
512 32 8

The first value sets the maximum number of pages that `kswapd` attempts to free in a single attempt. The larger this number, the more aggressively the kernel can move to free pages. The second value sets the minimum number of times that `kswapd` attempts to free a page. The third value sets the number of pages `kswapd` attempts to write in a single attempt. Proper tuning of this final value can

improve performance on a system using a lot of swap space by telling the kernel to write pages in large chunks, minimizing the number of disk seeks.

- `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.
- `hugetlb_pool` — Specifies in megabytes the size of hugepages—large, physically continuous memory pages. These pages can be used to create large TLB virtual memory mappings, which are useful for RAM-intensive database applications. TLB is a special in-CPU cache designed for such virtual memory mappings.

Although this feature can be adjusted at runtime, it is sensitive to fragmentation issues when growing the pool while the `MemFree` field of `/proc/meminfo` is low. For this reason, it may be necessary to place new settings in `/etc/sysctl.conf` and reboot. Refer to Section 5.4 *Using the `sysctl` Command* for information about `sysctl`.

Refer to `/usr/src/linux-2.4/Documentation/vm/hugetlbpage.txt` for more information about configuring hugepages.



### Important

Despite being mentioned in `hugetlbpage.txt`, the file `/proc/sys/vm/nr_hugepages` does *not* exist within Red Hat Enterprise Linux. Instead `hugetlb_pool` should be used to configure the number of hugepages available for the system. Also, it is important to remember that `nr_hugepages` uses hugepage units, while `hugetlb_pool` configures hugepages in megabytes.

- `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 overcommit 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 overloading the memory available on a system. This is the default setting.
  - 1 — The kernel performs no memory overcommit 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.



### Note

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.
- `pagecache` — Controls the percentage of total system memory used for page cache. The following is a typical output for this file:

```
1          15        100
```

The first value sets the minimum memory to be used as buffer and page cache memory. The middle value sets the percentage of system memory dedicated to buffer and page cache memory where the memory management subsystem begins to clear buffer cache more than other kinds of memory to compensate for a general lack of free memory. The final value specifies the maximum memory to be used as buffer memory, but is not yet implemented.

- `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.
- `pagetable_cache` — Controls the number of page tables that are cached on a per-processor basis. The first and second values relate to the minimum and maximum number of page tables to set aside, respectively.

The `/usr/src/linux-2.4/Documentation/sysctl/vm.txt` file contains additional information on these files.

### 5.3.10. `/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`).

### 5.3.11. `/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 modem 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.

Registered line disciplines are stored in the `ldiscs` file, and more detailed information is available within the `ldisc/` directory.

## 5.4. Using the `sysctl` Command

The `/sbin/sysctl` command is used to view, set, and automate kernel settings in the `/proc/sys/` directory.

To get 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, `/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 instance instead of using the following command:

```
echo 1 > /proc/sys/kernel/sysrq
```

The equivalent `sysctl` command is as follows:

```
sysctl -w kernel.sysrq="1"
kernel.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, the `init` program runs the `/etc/rc.d/rc.sysinit` script. This script contains a command to execute `sysctl` using `/etc/sysctl.conf` to determine the values passed to the kernel. Any values added to `/etc/sysctl.conf` therefore take effect each time the system boots.

## 5.5. Additional Resources

Below are additional sources of information about `proc` file system.

### 5.5.1. Installed Documentation

Some of the best documentation about the `proc` file system is installed on the system by default.

- `/usr/src/linux-2.4/Documentation/filesystems/proc.txt` — Contains assorted, but limited, information about all aspects of the `/proc/` directory.
- `/usr/src/linux-2.4/Documentation/sysrq.txt` — An overview of System Request Key options.
- `/usr/src/linux-2.4/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`).
- `/usr/src/linux-2.4/Documentation/networking/ip-sysctl.txt` — A detailed overview of IP networking options.
- `/usr/src/linux-2.4/` — Some of the most authoritative information on the `/proc/` directory can be found by reading the kernel source code. Make sure the `kernel-source` RPM is installed on the system and look in the `/usr/src/linux-2.4/` directory for the source code.

### 5.5.2. Useful Websites

- <http://www.linuxhq.com/> — This website maintains a complete database of source, patches, and documentation for various versions of the Linux kernel.



## Users and Groups

The control of *users* and *groups* is a core element of Red Hat Enterprise Linux system administration.

*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 the same group can read, write, or execute files owned by the group.

Each user and group has a unique numerical identification number called a *userid* (*UID*) and a *groupid* (*GID*) respectively.

The user who creates a file is assigned as the owner and group owner. The file is also assigned separate read, write, and execute permissions for the owner, the group, and everyone else. The owner of a file can be changed only by the root user. The group to which a file belongs can be changed by root or by the owner of the file if the owner is part of the group being added to the file. Access permissions can be changed by both the root user and the owner of the file.

Red Hat Enterprise Linux supports *access control lists* (*ACLs*) for files and directories which allow permissions for specific users outside of the owner to be set. For more information about using *ACLs*, refer to the chapter titled *Access Control Lists* in the *Red Hat Enterprise Linux System Administration Guide*.

Proper management of users and groups, and effective management of file permissions are among the most important tasks a system administrator undertakes. For a detailed look at strategies for managing users and groups, refer to the chapter titled *Managing User Accounts and Resource Access* in the *Red Hat Enterprise Linux Introduction to System Administration*.

### 6.1. User and Group Management Tools

Managing users and groups can be a tedious task, but Red Hat Enterprise Linux provides tools and conventions to make their management easier.

The easiest way to manage users and groups is through the graphical application, **User Manager** (`redhat-config-users`). For more information on **User Manager**, refer to the chapter titled *User and Group Configuration* in the *Red Hat Enterprise Linux System Administration Guide*.

The following command line tools can also be used to manage users and groups:

- `useradd`, `usermod`, and `userdel` — Industry-standard methods of adding, deleting and modifying user accounts.
- `groupadd`, `groupmod`, and `groupdel` — Industry-standard methods of adding, deleting, and modifying user groups.
- `gpasswd` — Industry-standard method of administering the `/etc/group` file.
- `pwck`, `grpck` — Tools used for the verification of the password, group, and associated shadow files.
- `pwconv`, `pwunconv` — Tools used for the conversion of passwords to shadow passwords and back to standard passwords.

For an overview of users and group management, refer to the *Red Hat Enterprise Linux Introduction to System Administration*. For a detailed look at command line tools for managing users and groups, see the chapter titled *User and Group Configuration* in the *Red Hat Enterprise Linux System Administration Guide*.

## 6.2. Standard Users

Table 6-1 lists the standard users configured in the `/etc/passwd` file by an "Everything" installation. The groupid (GID) in this table is the *primary group* for the user. See Section 6.3 *Standard Groups* for a listing of standard groups.

User	UID	GID	Home Directory	Shell
root	0	0	/root	/bin/bash
bin	1	1	/bin	/sbin/nologin
daemon	2	2	/sbin	/sbin/nologin
adm	3	4	/var/adm	/sbin/nologin
lp	4	7	/var/spool/lpd	/sbin/nologin
sync	5	0	/sbin	/bin/sync
shutdown	6	0	/sbin	/sbin/shutdown
halt	7	0	/sbin	/sbin/halt
mail	8	12	/var/spool/mail	/sbin/nologin
news	9	13	/var/spool/news	
uucp	10	14	/var/spool/uucp	/sbin/nologin
operator	11	0	/root	/sbin/nologin
games	12	100	/usr/games	/sbin/nologin
gopher	13	30	/usr/lib/gopher-data	/sbin/nologin
ftp	14	50	/var/ftp	/sbin/nologin
nobody	99	99	/	/sbin/nologin
rpm	37	37	/var/lib/rpm	/bin/bash
vcsa	69	69	/dev	/sbin/nologin
ntp	38	38	/etc/ntp	/sbin/nologin
canna	39	39	/var/lib/canna	/sbin/nologin
nscd	28	28	/	/bin/false
rpc	32	32	/	/sbin/nologin
postfix	89	89	/var/spool/postfix	/bin/true
named	25	25	/var/named	/bin/false
amanda	33	6	var/lib/amanda/	/bin/bash
postgres	26	26	/var/lib/pgsql	/bin/bash
sshd	74	74	/var/empty/sshd	/sbin/nologin
rpcuser	29	29	/var/lib/nfs	/sbin/nologin
nsfnobody	65534	65534	/var/lib/nfs	/sbin/nologin

User	UID	GID	Home Directory	Shell
pvm	24	24	/usr/share/pvm3	/bin/bash
apache	48	48	/var/www	/bin/false
xfst	43	43	/etc/X11/fs	/sbin/nologin
desktop	80	80	/var/lib/menu/kde	/sbin/nologin
gdm	42	42	/var/gdm	/sbin/nologin
mysql	27	27	/var/lib/mysql	/bin/bash
webalizer	67	67	/var/www/html/usage	/sbin/nologin
mailnull	47	47	/var/spool/mqueue	/sbin/nologin
smmsp	51	51	/var/spool/mqueue	/sbin/nologin
squid	23	23	/var/spool/squid	/dev/null
ldap	55	55	/var/lib/ldap	/bin/false
netdump	34	34	/var/crash	/bin/bash
pcap	77	77	/var/arpwatch	/sbin/nologin
radvd	75	75	/	/bin/false
quagga	92	92	/var/run/quagga	/bin/false
winn	49	49	/var/lib/winn	/bin/bash

Table 6-1. Standard Users

### 6.3. Standard Groups

Table 6-2 lists the standard groups configured by an "Everything" installation. Groups are stored in the `/etc/group` file.

Group	GID	Members
root	0	root
bin	1	root, bin, daemon
daemon	2	root, bin, daemon
sys	3	root, bin, adm
adm	4	root, adm, daemon
tty	5	
disk	6	root
lp	7	daemon, lp
mem	8	
kmem	9	
wheel	10	root
mail	12	mail, postfix

Group	GID	Members
news	13	news
uucp	14	uucp
man	15	
games	20	
gopher	30	
dip	40	
ftp	50	
lock	54	
nobody	99	
users	100	
rpm	37	
utmp	22	
floppy	19	
vcsa	69	
ntp	38	
canna	39	
nscd	28	
rpc	32	
postdrop	90	
postfix	89	
named	25	
postgres	26	
sshd	74	
rpcuser	29	
nfsnobody	65534	
pvm	24	
apache	48	
xf	43	
desktop	80	
gdm	42	
mysql	27	
webalizer	67	
mailnull	47	
smmsp	51	
squid	23	

Group	GID	Members
ldap	55	
netdump	34	
pcap	77	
quaggavty	101	
quagga	92	
radvd	75	
slocate	21	
wnn	49	

Table 6-2. Standard Groups

## 6.4. User Private Groups

Red Hat Enterprise Linux uses a *user private group (UPG)* scheme, which makes UNIX groups easier to manage.

A UPG is created whenever a new user is added to the system. A UPG has the same name as the user for which it was created and that user is the only member of the UPG.

UPGs makes it safe to set default permissions for a newly created file or directory which allow both the user and *that user's group* 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.

### 6.4.1. Group Directories

Many IT organizations like to create a group for each major project and then assign people to the group if they need to access that project's files. Using this traditional scheme, managing files has been difficult because 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 is difficult to associate the right files with the right group. Using the UPG scheme, however, 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.

Lets say, for example, that a group of people work on files in the `/usr/lib/emacs/site-lisp/` directory. Some people are trusted to modify the directory, but certainly not everyone is trusted. First create an `emacs` group, as in the following command:

```
/usr/sbin/groupadd emacs
```

To associate the contents of the directory with the `emacs` group, type:

```
chown -R root:emacs /usr/lib/emacs/site-lisp
```

Now, it is possible to add the proper users to the group with the `gpasswd` command:

```
/usr/bin/gpasswd -a <username> emacs
```

To allow the users to actually create files in the directory, use the following command:

```
chmod 775 /usr/lib/emacs/site-lisp
```

When a user creates a new file, it is assigned the group of the user's default private group. Next, set the `setgid` bit, which assigns everything created in the directory the same group permission as the directory itself (`emacs`). Use the following command:

```
chmod 2775 /usr/lib/emacs/site-lisp
```

At this point, because each user's default `umask` is `002`, all members of the `emacs` group can create and edit files in the `/usr/lib/emacs/site-lisp/` directory without the administrator having to change file permissions every time users write new files.

## 6.5. Shadow Passwords

In multiuser environments it is very important to use *shadow passwords* (provided by the `shadow-utils` package). Doing so enhances the security of system authentication files. For this reason, the installation program enables shadow passwords by default.

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

- Improves 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.
- Stores information about password aging.
- Allows the use 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.

Below is a list of commands which do not work without first enabling shadow passwords:

- `chage`
- `gpasswd`
- `/usr/sbin/usermod -e` or `-f` options
- `/usr/sbin/useradd -e` or `-f` options

## 6.6. Additional Resources

For more information about users and groups, and tools to manage them, refer to the following resources.

### 6.6.1. Installed Documentation

- Related man pages — There are a number of man pages for the various applications and configuration files involved with managing users and groups. The following is a list of some of the more important man pages.

### User and Group Administrative Applications

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

### Configuration Files

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

## 6.6.2. Related Books

- *Red Hat Enterprise Linux Introduction to System Administration*; Red Hat, Inc. — This companion manual provides an overview of concepts and techniques of system administration. The chapter titled *Managing User Accounts and Resource Access* has great information pertaining to user and group account management.
- *Red Hat Enterprise Linux System Administration Guide*; Red Hat, Inc. — This companion manual contains more information on managing users and groups as well as advanced permission configuration using ACLs. Refer to the chapters titled *User and Group Configuration* and *Access Control Lists* for details.
- *Red Hat Enterprise Linux Security Guide*; Red Hat, Inc. — This companion manual provides security-related aspects of user accounts, namely choosing strong passwords.





## The X Window System

While the heart of Red Hat Enterprise Linux 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*.

Various windowing environments have existed in the UNIX™ world for decades, predating many of the current mainstream operating systems. Through the years X has become the dominant graphical environment for UNIX-like operating systems.

The graphical environment for Red Hat Enterprise Linux is supplied by XFree86™, an open source implementation of X. XFree86 is a large scale, rapidly 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 can run on a variety of different operating systems and platforms.

The X Window System uses a client-server architecture. The *X server* 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.

### 7.1. XFree86

Red Hat Enterprise Linux 3 uses XFree86 version 4.x as the base X Window System, which includes many cutting edge XFree86 technology enhancements such as 3D hardware acceleration support, the XRender extension for anti-aliased fonts, a modular driver-based design, and support for modern video hardware and input devices.



#### Important

Red Hat Enterprise Linux no longer provides XFree86 version 3 server packages. Before upgrading to the latest version of Red Hat Enterprise Linux, be sure the video card is compatible with XFree86 version 4 by checking the Red Hat Hardware Compatibility List located online at <http://hardware.redhat.com/>.

The files related to XFree86 reside primarily in two locations:

`/usr/X11R6/`

Contains X server and some client applications, as well as X header files, libraries, modules, and documentation.

`/etc/X11/`

Contains configuration files for X client and server applications. This includes configuration files for the X server itself, the older `xfs` font server, the X display managers, and many other base components.

It is important to note that the configuration file for the newer Fontconfig-based font architecture is `/etc/fonts/fonts.conf` (which obsoletes the `/etc/X11/XftConfig` file). For more on configuring and adding fonts, refer to Section 7.4 *Fonts*.

Because the XFree86 server performs advanced tasks on a wide array of hardware, it requires detailed configuration. The installation program installs and configures XFree86 automatically, unless the XFree86 packages are not selected for installation. However, if the monitor or video card

changes, XFree86 must be reconfigured. The best way to do this is to use the **X Configuration Tool** (`redhat-config-xfree86`).

To start the **X Configuration Tool** while in an active X session, go to the **Main Menu Button** (on the Panel) => **System Settings** => **Display**. After using the **X Configuration Tool** during an X session, changes takes effect after logging out and logging back in. For more about using the **X Configuration Tool**, refer to the chapter titled *X Window System Configuration* in the *Red Hat Enterprise Linux System Administration Guide*.

In some situations, reconfiguring the XFree86 server may require manually editing its configuration file, `/etc/X11/XF86Config`. For information about the structure of this file, refer to Section 7.3 *XFree86 Server Configuration Files*.

## 7.2. Desktop Environments and Window Managers

Once an XFree86 server is running, X client applications can connect to it and create a GUI for the user. A range of GUIs are possible with Red Hat Enterprise Linux, from the rudimentary *Tab Window Manager* to the highly developed, interactive *GNOME* desktop environment most Red Hat Enterprise Linux users are familiar with.

To create the latter, more advanced GUI, two main classes of X client applications must connect to the XFree86 server: a *desktop environment* and a *window manager*.

### 7.2.1. Desktop Environments

A desktop environment brings together assorted X clients which, when used together, create a common graphical user environment and 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.

Red Hat Enterprise Linux provides two desktop environments:

- *GNOME* — The default desktop environment for Red Hat Enterprise Linux based on the GTK+ 2 graphical toolkit.
- *KDE* — An alternative desktop environment based on the Qt 3 graphical toolkit.

Both GNOME and KDE have advanced productivity applications, such as word processors, spreadsheets, and Web browsers, and 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 visa versa.

### 7.2.2. Window Managers

*Window managers* are X client programs which are either part of a desktop environment or, in some cases, standalone. 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.

Five window managers are included with Red Hat Enterprise Linux:

- *kwin* — The *KWin* window manager is the default window manager for KDE. It is an efficient window manager which supports custom themes.
- *metacity* — The *Metacity* window manager is the default window manager for GNOME. It is a simple and efficient window manager which supports custom themes.

- `mwm` — The *Motif* window manager is a basic, standalone window manager. Since it is designed to be a standalone window manager, it should not be used in conjunction with GNOME or KDE.
- `twm` — The minimalist *Tab Window Manager*, which provides the most basic tool set of any of the window managers and can be used either standalone or with a desktop environment. It is installed as part of XFree86.

These window managers can be run without desktop environments to gain a better sense of their differences. To do this, type the `xinit -e <path-to-window-manager>` command, where `<path-to-window-manager>` is the location of the window manager binary file. The binary file can be found by typing `which <window-manager-name>`, where `<window-manager-name>` is the name of the window manager you are querying.

## 7.3. XFree86 Server Configuration Files

The XFree86 server is a single binary executable (`/usr/X11R6/bin/XFree86`) that dynamically loads any necessary X server modules at runtime from the `/usr/X11R6/lib/modules/` directory. Some of these modules are automatically loaded by the server, while others are optional and must be specified in the XFree86 server configuration file.

The XFree86 server and associated configuration files are stored in the `/etc/X11/` directory. The configuration file for the XFree86 server is `/etc/X11/XF86Config`. When Red Hat Enterprise Linux is installed, the configuration files for XFree86 are created using information gathered about the system hardware during the installation process.

### 7.3.1. XF86Config

While there is rarely a need to manually edit `/etc/X11/XF86Config`, it is useful to understand the various sections and optional parameters available, especially when troubleshooting.

#### 7.3.1.1. The Structure

The `/etc/X11/XF86Config` file 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. Within each of the sections are lines containing option names and at least one option value, sometimes surrounded with double quotes (").

Lines beginning with a hash mark (#) are not read by the XFree86 server and are used for human-readable comments.

Some options within the `/etc/X11/XF86Config` file accept a boolean switch which turns the feature on or off. Acceptable boolean values are:

- `1, on, true, or yes` — Turns the option on.
- `0, off, false, or no` — Turns the option off.

The following are some of the more important sections in the order they appear in a typical `/etc/X11/XF86Config` file. More detailed information about the XFree86 server configuration file can be found in the `XF86Config` man page.

### 7.3.1.2. ServerFlags

The optional `ServerFlags` section contains miscellaneous global XFree86 server settings. Any settings in this section may be overridden by options placed in the `ServerLayout` section (refer to Section 7.3.1.3 *ServerLayout* for details).

Each entry within the `ServerFlags` section is on its own line and begins with the term `Option` followed by an option enclosed in double quotation marks ("").

The following is a sample `ServerFlags` section:

```
Section "ServerFlags"
    Option "DontZap" "true"
EndSection
```

The following is a list of 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 XFree86 server.
- `"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.

### 7.3.1.3. ServerLayout

The `ServerLayout` section binds together the input and output devices controlled by the XFree86 server. At a minimum, this section must specify one output device and at least two input devices (a keyboard and a mouse).

The following example illustrates a typical `ServerLayout` section:

```
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 XFree86 server. More than one `Screen` options may be present.

The following is an example of a typical `Screen` entry:

```
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".

If the video card has more than one head, another `Screen` entry would be necessary with a different number and a different `Screen` section identifier.

The numbers to the right of "Screen0" give the X and Y absolute 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 XFree86 server.

There must be at least two `InputDevice` entries: one for the default mouse and one for the default keyboard. The options `CorePointer` and `CoreKeyboard` indicate these are the primary mouse and keyboard.

- 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 `XF86Config` man page.

It is possible to create more than one `ServerLayout` section. However, the server only reads the first one to appear unless an alternate `ServerLayout` section is specified as a command line argument.

#### 7.3.1.4. Files

The `Files` section sets paths for services vital to the XFree86 server, such as the font path.

The following example illustrates a typical `Files` section:

```
Section "Files"
    RgbPath      "/usr/X11R6/lib/X11/rgb"
    FontPath     "unix/:7100"
EndSection
```

The following entries are commonly used in the `Files` section:

- `RgbPath` — Specifies the location of the RGB color database. This database defines all valid color names in XFree86 and ties them to specific RGB values.
- `FontPath` — Specifies where the XFree86 server must connect to obtain fonts from the `xf86` font server.

By default, the `FontPath` is `unix/:7100`. This tells the XFree86 server to obtain font information using UNIX-domain sockets for inter-process communication (IPC) on port 7100.

Refer to Section 7.4 *Fonts* for more information concerning XFree86 and fonts.

- `ModulePath` — An optional parameter which specifies alternate directories which store XFree86 server modules.

#### 7.3.1.5. Module

The `Module` section specifies which modules from the `/usr/X11R6/lib/modules/` directory the XFree86 server is to load. Modules add additional functionality to the XFree86 server.

The following example illustrates a typical `Module` section:

```
Section "Module"
    Load "dbe"
    Load "extmod"
    Load "fbdevhw"
    Load "glx"
    Load "record"
    Load "freetype"
    Load "type1"
    Load "dri"
EndSection
```

### 7.3.1.6. InputDevice

Each `InputDevice` section configures one input device for the XFree86 server. Systems typically have at least two `InputDevice` sections, keyboard and mouse.

The following example illustrates a typical `InputDevice` section for a mouse:

```
Section "InputDevice"
    Identifier "Mouse0"
    Driver "mouse"
    Option "Protocol" "IMPS/2"
    Option "Device" "/dev/input/mice"
    Option "Emulate3Buttons" "no"
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 XFree86 must load for the device.
- `Option` — Specifies necessary options pertaining to the device.

For a mouse, these options typically include:

- `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 `XF86Config` man page for a list of valid options for this section.

By default the `InputDevice` section has comments to allow users to configure additional options.

### 7.3.1.7. Monitor section

Each `Monitor` section configures one type of monitor used by the system. While one `Monitor` section is the minimum, additional instances may occur for each monitor type in use with the machine.

The best way to configure a monitor is to configure X during the installation process or by using the **X Configuration Tool**. For more about using the **X Configuration Tool**, refer to the chapter titled *X Window System Configuration* in the *Red Hat Enterprise Linux System Administration Guide*.

This example illustrates 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
```

**Warning**

Be careful if manually editing values in the `Monitor` section of `/etc/X11/XF86Config`. Inappropriate values can damage or destroy a monitor. Consult the monitor's documentation for a listing of safe operating parameters.

The following are commonly entries 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 XFree86 server determine the validity of built in or specified `Modeline` entries for the monitor.
- `VertRefresh` — Specifies the range of vertical refresh range frequencies supported by the monitor, in kHz. These values help the XFree86 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 `XF86Config` 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 `XF86Config` man page.

### 7.3.1.8. Device

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 best way to configure a video card is to configure X during the installation process or by using the **X Configuration Tool**. For more about using the **X Configuration Tool**, refer to the chapter titled *X Window System Configuration* in the *Red Hat Enterprise Linux System Administration Guide*.

The following example illustrates 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 XFree86 server must load to utilize the video card. A list of drivers can be found in `/usr/X11R6/lib/X11/Cards`, 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 XFree86 server cannot probe to detect the amount of video RAM.
- `BusID` — An optional entry which specifies the bus location of the video card. This option is only mandatory for systems with multiple cards.
- `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 `XFree86Config` man page.

One of the more common options is `"dpms"`, which activates Service Star energy compliance for the monitor.

### 7.3.1.9. Screen

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 illustrates a typical `Screen` section:

```
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 a required entry.
- `DefaultDepth` — Specifies the default color depth in bits. In the previous example, 16, which provides thousands of colors, is the default. Multiple `DefaultDepth` entries are permitted, but at least one must be present.



- SubSection "Display" — Specifies the screen modes available at a particular color depth. A Screen section may have multiple Display subsections, but there must be at least one for the color depth specified in the DefaultDepth entry.
- 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 XF86Config man page.

### 7.3.1.10. DRI

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 ignored unless DRI is enabled in the Module section.

The following example illustrates a typical DRI section:

```
Section "DRI"
    Group      0
    Mode       0666
EndSection
```

Since different video cards use DRI in different ways, do not alter the values for this section without first referring to the `/usr/X11R6/lib/X11/doc/README.DRI` file.

## 7.4. Fonts

Red Hat Enterprise Linux uses two methods to manage and display fonts under XFree86. The newer Fontconfig font subsystem 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 toolkit.

For compatibility, Red Hat Enterprise Linux includes the original font subsystem, called the core X font subsystem. This system, which is over 15 years old, is based around the *X Font Server (xfs)*.

This section discusses how to configure fonts for X using both systems.

### 7.4.1. Fontconfig

The Fontconfig font subsystem allows applications to directly access fonts on the system and use Xft or other rendering mechanisms to render Fontconfig fonts with advanced anti-aliasing. Graphical applications can use the Xft library with Fontconfig to draw text to the screen.

Over time, the Fontconfig/Xft font subsystem replaces the core X font subsystem.



#### Important

The Fontconfig font subsystem does not yet work for **OpenOffice.org**, which uses its own font rendering technology.

It is important to note that Fontconfig uses the `/etc/fonts/fonts.conf` configuration file, which replaces `/etc/X11/XftConfig`. The Fontconfig configuration file should not be edited by hand.

**Tip**

Due to the transition to the new font system, GTK+ 1.2 applications are not affected by any changes made via the **Font Preferences** dialog (accessed by selecting **Main Menu Button** [on the Panel] => **Preferences** => **Font**). For these applications, a font can be configured by adding the following lines to the file `~/.gtkrc.mine`:

```
style "user-font" {
fontset = "<font-specification>"
}
widget_class "*" style "user-font"
```

Replace `<font-specification>` with a font specification in the style used by traditional X applications, such as `-adobe-helvetica-medium-r-normal--*-*-*-*-*`. A full list of core fonts can be obtained by running `xlsfonts` or created interactively using the `xfonstsel` command.

### 7.4.1.1. Adding Fonts to Fontconfig

Adding new fonts to the Fontconfig subsystem is a straightforward process.

1. To add fonts systemwide, copy the new fonts into the `/usr/share/fonts/local/` directory. To add fonts for an individual user, copy the new fonts into the `.fonts/` directory in the user's home directory.
2. Use the `fc-cache` command to update the font information cache, as in the following example:  
`4fc-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/`).

**Tip**

Individual users may also install fonts graphically, by typing `fonts:///` into the **Nautilus** address bar, and dragging the new font files there.

**Important**

If the font filename ends with a `.gz` extension, it is compressed and cannot be used until uncompressed. To do this, use the `gunzip` command or double-click the file and drag the font to a directory in **Nautilus**.

## 7.4.2. Core X Font System

For compatibility, Red Hat Enterprise Linux provides the core X font subsystem, which uses the X Font Server (`xfs`) to provide fonts to X client applications.

The XFree86 server looks for a font server specified in the `FontPath` directive within the `Files` section of the `/etc/X11/XF86Config` configuration file. Refer to Section 7.3.1.4 *Files* for more information about the `FontPath` entry.

The XFree86 server connects to the `xfs` server on a specified port to acquire font information. For this reason, the `xfs` service must be running for X to start. For more about configuring services for a particular runlevel, refer to the chapter titled *Controlling Access to Services* in the *Red Hat Enterprise Linux System Administration Guide*.

### 7.4.2.1. `xfs` Configuration

The `/etc/rc.d/init.d/xfs` script starts the `xfs` server. Several options can be configured within its configuration file, `/etc/X11/fs/config`.

The following is a list of the more common options:

- `alternate-servers` — Specifies a list of alternate font servers to be used if this font server is not available. A comma must separate each font server in a list.
- `catalogue` — Specifies an ordered list of font paths to use. A comma must separate each font path in a list.

Use the string `:unscaled` immediately after the font path to make the unscaled fonts in that path load first. Then specify the entire path again, so that other scaled fonts are also loaded.

- `client-limit` — Specifies the maximum number of clients the font server services. The default is 10.
- `clone-self` — Allows the font server to clone a new version of itself when the `client-limit` is hit. By default, this option is on.
- `default-point-size` — Specifies the default point size for any font that does not specify this value. The value for this option is set in decipoints. The default of 120 corresponds to a 12 point font.
- `default-resolutions` — Specifies a list of resolutions supported by the XFree86 server. Each resolution in the list must be separated by a comma.
- `deferglyphs` — Specifies whether to defer loading *glyphs* (the graphic used to visually represent a font). To disable this feature use `none`, to enable this feature for all fonts use `all`, or to turn this feature on only for 16-bit fonts use `16`.
- `error-file` — Specifies the path and file name of a location where `xfs` errors are logged.
- `no-listen` — Prevents `xfs` from listening to particular protocols. By default, this option is set to prevent `xfs` from listening on TCP ports for security reasons.



#### Tip

If using `xfs` to serve fonts over the network, remove this line.

- `port` — Specifies the TCP port that `xfs` listens on if `no-listen` does not exist or is commented out.
- `use-syslog` — Specifies whether to use the system error log.

### 7.4.2.2. Adding Fonts to `xfs`

To add fonts to the core X font subsystem (`xfs`), follow these steps:

1. If it does not already exist, create a directory called `/usr/share/fonts/local/` using the following command as root:

```
mkdir /usr/share/fonts/local/
```

If creating the `/usr/share/fonts/local/` directory is necessary, it must be added to the `xfs` path using the following command as root:

```
chkfontpath --add /usr/share/fonts/local/
```

2. Copy the new font file into the `/usr/share/fonts/local/` directory
3. Update the font information by issuing the following command as root:
 

```
ttmfdir -d /usr/share/fonts/local/ -o /usr/share/fonts/local/fonts.scale
```
4. Reload the `xfs` font server configuration file by issuing the following command as root:
 

```
service xfs reload
```

## 7.5. Runlevels and XFree86

In most cases, the default installation of Red Hat Enterprise Linux configures a machine to boot into a graphical login environment, known as runlevel 5. It is possible, however, to boot into the text-only multi-user mode called runlevel 3 and begin an X session from there.

For more information about runlevels, refer to Section 1.4 *SysV Init Runlevels*.

This section reviews how XFree86 starts up in both runlevel 3 and runlevel 5.

### 7.5.1. 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 XFree86 server and connects X clients 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 7.5.2 *Runlevel 5* for more information about display managers.

When the `startx` command is executed, it searches for a `.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.

The default `xinitrc` script then looks 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.

After setting these options, the `xinitrc` script executes all scripts located in the `/etc/X11/xinit/xinitrc.d/` directory. One important script in this directory is `xinput`, which configures settings such as the default language.

Next, the `xinitrc` script tries 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/init/Xclients` script attempts to start another desktop environment, trying GNOME first and then KDE followed by `twm`.

The user is returned to a text mode user session after logging out of X from runlevel 3.

### 7.5.2. 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 environments 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` — The default display manager for Red Hat Enterprise Linux, `gdm` 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.
- `xdm` — A very basic display manager which only lets the user log in to the system.

When booting into runlevel 5, the `prefdm` script determines the preferred display manager by referencing the `/etc/sysconfig/desktop` file. A list of options for this file is available within the `/usr/share/doc/initcripts-<version-number>/sysconfig.txt` file (where `<version-number>` is the version number of the `initcripts` package).

Each of the display managers references 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.

The user can specify which desktop environment they want to utilize when they authenticate using the `gdm` or `kdm` display managers by selecting it from the **Sessions** menu item (accessed by selecting **Main Menu Button** [on the Panel] => **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/xinit/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 continued running after the user logged in, takes control by spawning a new display manager. This restarts the XFree86 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 about 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) and the `xdm` man page.

## 7.6. Additional Resources

There is a large amount of detailed information available about the XFree86 server, the clients that connect to it, and the assorted desktop environments and window managers.

### 7.6.1. Installed Documentation

- `/usr/X11R6/lib/X11/doc/README` — Briefly describes the XFree86 architecture and how to get additional information about the XFree86 project as a new user.
- `/usr/X11R6/lib/X11/doc/RELNOTES` — For advanced users that want to read about the latest features available in XFree86.
- `man XF86Config` — Contains information about the XFree86 configuration files, including the meaning and syntax for the different sections within the files.
- `man XFree86` — The primary man page for all XFree86 information, details the difference between local and network X server connections, explores common environmental variables, lists command line options, and provides helpful administrative key combinations.
- `man Xserver` — Describes the X display server.

### 7.6.2. Useful Websites

- <http://www.xfree86.org/> — Home page of the XFree86 project, which produces the XFree86 open source version of the X Window System. XFree86 is bundled with Red Hat Enterprise Linux to control the necessary hardware and provide a GUI environment.
- <http://sourceforge.net/projects/dri/> — Home page of the DRI (Direct Rendering Infrastructure) project. The DRI is the core hardware 3D acceleration component of XFree86.
- <http://www.redhat.com/mirrors/LDP/HOWTO/XFree86-HOWTO/> — A HOWTO document detailing the manual installation and custom configuration of XFree86.
- <http://www.gnome.org/> — Home of the GNOME project.
- <http://www.kde.org/> — Home of the KDE desktop environment.
- <http://nexp.cs.pdx.edu/fontconfig/> — Home of the Fontconfig font subsystem for XFree86.

### 7.6.3. Related Books

- *The Concise Guide to XFree86 for Linux* by Aron Hsiao; Que — Provides an expert's view of the operation of XFree86 on Linux systems.
- *The New XFree86* by Bill Ball; Prima Publishing — Discusses XFree86 and its relationship with the popular desktop environments, such as GNOME and KDE.
- *Beginning GTK+ and GNOME* by Peter Wright; Wrox Press, Inc. — Introduces programmers to the GNOME architecture, showing them how to get started with GTK+.
- *GTK+/GNOME Application Development* by Havoc Pennington; New Riders Publishing — An advanced look into the heart of GTK+ programming, focusing on sample code and a thorough look at the available APIs.
- *KDE 2.0 Development* by David Sweet and Matthias Ettrich; Sams Publishing — Instructs beginning and advanced developers in how to take advantage of the many environment guidelines required to built QT applications for KDE.

## II. Network Services Reference

It is possible to deploy a wide variety of network services under Red Hat Enterprise Linux. This part describes how network interfaces are configured as well as provides details about critical network services such as FTP, NFS, the Apache HTTP Server, Sendmail, Postfix, Fetchmail, Procmal, BIND, and LDAP.

### Table of Contents

8. Network Interfaces.....	103
9. Network File System (NFS).....	113
10. Apache HTTP Server.....	125
11. FTP.....	157
12. Email .....	171
13. Berkeley Internet Name Domain (BIND) .....	193
14. Lightweight Directory Access Protocol (LDAP) .....	213





## Network Interfaces

Under Red Hat Enterprise Linux, all network communications occur between configured software *interfaces* and *physical networking devices* connected to the system.

The configuration files for network interfaces, and the scripts to activate and deactivate them, are located in the `/etc/sysconfig/network-scripts/` directory. 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:

- *Interface configuration files*
- *Interface control scripts*
- *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 Red Hat Enterprise Linux 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` man page.
- `/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` man page.
- `/etc/sysconfig/network` — Specifies routing and host information for all network interfaces. For more information about this file and the directives it accepts, refer to Section 4.1.22 `/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.



#### Caution

The `/etc/sysconfig/networking/` directory is used by the **Network Administration Tool** (`redhat-config-network`) and its contents should not be edited manually. For more information about configuring network interfaces using the **Network Administration Tool**, refer to the chapter called *Network Configuration* in the *Red Hat Enterprise Linux System Administration Guide*.

## 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 `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-eth<X>` 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
NETWORK=10.0.1.0
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 quite a bit different because IP information is provided by the DHCP server:

```
DEVICE=eth0
BOOTPROTO=dhcp
ONBOOT=yes
```

The **Network Administration Tool** (`redhat-config-network`) is an easy way to make changes to the various network interface configuration files (refer to the chapter titled *Network Configuration* in the *Red Hat Enterprise Linux System Administration Guide* for detailed instructions on using this tool).

However, it is also possible to edit the configuration files for a given network interface manually.

Below is a listing of the configurable parameters in an Ethernet interface configuration 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.
- `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` — Only use this option if the DHCP server requires the client to specify a host-name before receiving an IP address. (The DHCP server daemon in Red Hat Enterprise Linux does not support this feature.)

- `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`.
- `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 is useful for machines with multiple NICs 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 IP address.
- `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 `HWADDR`.
- `MASTER=<bond-interface>`, where `<bond-interface>` is the channel bonding interface to which the interface 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 about channel bonding interfaces.

- `NETMASK=<mask>`, where `<mask>` is the netmask value.
- `NETWORK=<address>`, where `<address>` is the network address. This directive is deprecated.
- `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=<bond-interface>`, where `<bond-interface>` 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 bond 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. IPsec Interfaces

With Red Hat Enterprise Linux it is possible to connect to other hosts or networks using a secure IP connection, known as IPsec. For instructions on setting up IPsec using the **Network Administration Tool** (`redhat-config-network`) refer to the chapter titled *Network Configuration* in the *Red Hat Enterprise Linux System Administration Guide*. For instructions on setting up IPsec manually, refer to the chapter titled *Virtual Private Networks* in the *Red Hat Enterprise Linux Security Guide*.

The following is the `ifcfg` file for a network-to-network IPsec connection for LAN A. The unique name to identify the connection in this example is `ipsec1`, so the resulting file is named `/etc/sysconfig/network-scripts/ifcfg-ipsec1`.

```
TYPE=IPsec
ONBOOT=yes
IKE_METHOD=PSK
SRCNET=192.168.1.0/24
DSTNET=192.168.2.0/24
DST=X.X.X.X
```

In the example above, `X.X.X.X` is the publicly routable IP address of the destination IPsec router.

Below is a listing of the configurable parameters for an IPsec interface:

- `DST=<address>`, where `<address>` is the IP address of the IPsec destination host or router. This is used for both host-to-host and network-to-network IPsec configurations.
- `DSTNET=<network>`, where `<network>` is the network address of the IPsec destination network. This is only used for network-to-network IPsec configurations.
- `SRC=<address>`, where `<address>` is the IP address of the IPsec source host or router. This setting is optional and is only used for host-to-host IPsec configurations.
- `SRCNET=<network>`, where `<network>` is the network address of the IPsec source network. This is only used for network-to-network IPsec configurations.
- `TYPE=<interface-type>`, where `<interface-type>` is `IPSEC`.

Refer to `/usr/share/doc/initscripts-<version-number>/sysconfig.txt` (replace `<version-number>` with the version of the `initscripts` package installed) for configuration parameters if using manual key encryption with IPsec.

If `racoon` is used to automatically manage key encryption, the following options are required:

- `IKE_METHOD=<encryption-method>`, where `<encryption-method>` is either `PSK`, `X509`, or `GSSAPI`. If `PSK` is specified, the `IKE_PSK` parameter must also be set. If `X509` is specified, the `IKE_CERTFILE` parameter must also be set.
- `IKE_PSK=<shared-key>`, where `<shared-key>` is the shared, secret value for the PSK (pre-shared keys) method.
- `IKE_CERTFILE=<cert-file>`, where `<cert-file>` is a valid X.509 certificate file for the host.
- `IKE_PEER_CERTFILE=<cert-file>`, where `<cert-file>` is a valid X.509 certificate file for the *remote* host.
- `IKE_DNSSEC=<answer>`, where `<answer>` is `yes`. The `racoon` daemon retrieves the remote host's X.509 certificate via DNS. If a `IKE_PEER_CERTFILE` is specified, do *not* include this parameter.

For more information about the encryption algorithms available for IPsec, refer to the `setkey` man page. For more information about `racoon`, refer to the `racoon` and `racoon.conf` man pages.

### 8.2.3. Channel Bonding Interfaces

Red Hat Enterprise Linux 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-bond<N>`, replacing `<N>` with the number for the interface, such as `0`.

The contents of the file can be identical to whatever type of interface that is getting bonded, such as an Ethernet interface. The only difference is that the `DEVICE=` directive must be `bond<N>`, replacing `<N>` with the number for the interface.

The following is a sample channel bonding configuration file:

```
DEVICE=bond0
BOOTPROTO=none
ONBOOT=yes
NETWORK=10.0.1.0
NETMASK=255.255.255.0
IPADDR=10.0.1.27
USERCTL=no
```

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 channel bonding two Ethernet interfaces, both `eth0` and `eth1` may look like the following example:

```
DEVICE=eth<N>
BOOTPROTO=none
ONBOOT=yes
MASTER=bond0
SLAVE=yes
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 insure that the module is loaded when the channel bonding interface is brought up, add the following line to `/etc/modules.conf`:

```
alias bond<N> bonding
```

Replace `<N>` with the number of the interface, such as `0`. For each configured channel bonding interface, there must be a corresponding entry in `/etc/modules.conf`.

Once `/etc/modules.conf` is configured and the channel bonding interface and network interfaces are configured, the `ifup` command be used to bring up the channel bonding interface.



#### Important

Important aspects of the channel bonding interface are controlled through the kernel module. For more information about controlling the `bonding` modules, refer to Section A.3.2 *The Channel Bonding Module*.

### 8.2.4. Alias and Clone Files

Two lesser-used types of interface configuration files are *alias* and *clone* files.

Alias interface configuration files follow the naming convention `ifcfg-<if-name>:<alias-value>`. They are used primarily to bind multiple addresses to a single interface.

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 request via the fixed, 10.0.0.2 IP address.



#### Caution

Alias interfaces do not support DHCP.

A clone interface configuration file should follow this 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.

The easiest way to create alias and clone interface configuration files is to use the graphical **Network Administration Tool**. For more on using this tool, refer to the chapter called *Network Configuration* in the *Red Hat Enterprise Linux System Administration Guide*.

### 8.2.5. Dialup Interfaces

If 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-ppp<X>` (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, not already discussed, 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 remote system's IP address. This is usually left unspecified.

- `WVDIALSECT=<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.

### 8.2.6. Other Interfaces

Other common interface configuration files that use these options 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.



#### Warning

Never edit the loopback interface script, `/etc/sysconfig/network-scripts/ifcfg-lo`, 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.
- `ifcfg-plip0` — A *Parallel Line Interface Protocol (PLIP)* connection works much the same way as an Ethernet device, except that it utilizes a parallel port.
- `ifcfg-tr0` — *Token Ring* topologies are not as common on *Local Area Networks (LANs)* as they once were, having been eclipsed by Ethernet.

## 8.3. Interface Control Scripts

The interface control scripts activate and deactivate system interfaces. There are two primary interface control scripts, `/sbin/ifdown` and `/sbin/ifup`, that call on control scripts located in the `/etc/sysconfig/network-scripts/` directory.

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
```



#### Caution

The `ifup` and `ifdown` interface scripts are the only scripts that the user should use to bring up and take down network interfaces.

The following scripts are described for reference purposes only.

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 8.4 *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-cipcb` and `ifdown-cipcb` — Used to bring *Crypto IP Encapsulation (CIPE)* interfaces up and down.
- `ifup-ipv6` and `ifdown-ipv6` — Used to bring IPv6 interfaces up and down.
- `ifup-ipx` — Used to bring up an IPX interface.
- `ifup-plip` — Used to bring up a PLIP interface.
- `ifup-plusb` — Used to bring 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` — Used to bring 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-sl` and `ifdown-sl` — Used to bring a SLIP interface up or down.



### Warning

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 `/sbin/service` command on the network service (`/etc/rc.d/init.d/network`), as illustrated the following command:

```
/sbin/service network <action>
```

In this example `<action>` can be either `start`, `stop`, or `restart`.

To view a list of configured devices and currently active network interfaces, use the following command:

```
/sbin/service network status
```

## 8.4. Network Function Files

Red Hat Enterprise Linux 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 an interface's status, setting hostnames, finding a gateway device, verifying whether or not if a particular device is down, and adding a default route.

As the functions required for IPv6 interfaces are different than 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 can be found in this file.

## 8.5. Additional Resources

The following are resources which explain more about network interfaces.

### 8.5.1. Installed Documentation

- `/usr/share/doc/initcripts-<version>/sysconfig.txt` — A guide to available options for network configuration files, including IPv6 options not covered in this chapter.
- `/usr/share/doc/iproute-<version>/ip-cref.ps` — This file contains a wealth of information about the `ip` command, which can be used to manipulate routing tables, among other things. Use the `ggv` or `kghostview` application to view this file.

## Network File System (NFS)

A *Network File System (NFS)* allows remote hosts to mount file systems over a network and interact with those file systems as though they are mounted locally. This enables system administrators to consolidate resources onto centralized servers on the network.

This chapter focuses on fundamental NFS concepts and supplemental information. For specific instructions regarding the configuration and operation of NFS server and client software, refer to the chapter titled *Network File System (NFS)* in the *Red Hat Enterprise Linux System Administration Guide*.

### 9.1. How It Works

Currently, there are two versions of NFS. NFS version 2 (NFSv2) is older and is widely supported. NFS version 3 (NFSv3) has more features, including variable size file handling and better error reporting, but is not fully compatible with NFSv2 clients. Red Hat Enterprise Linux serves both NFSv2 and NFSv3 clients, and when mounting a file system via NFS, Red Hat Enterprise Linux uses NFSv3 by default, if server the supports it.

NFSv2 uses the *User Datagram Protocol (UDP)* to provide a stateless network connection between the client and server. NFSv3 can use either UDP or *Transmission Control Protocol (TCP)* running over an IP network.

The stateless UDP connection under normal conditions minimizes network traffic, as the NFS server sends the client a cookie after the client is authorized to access the shared volume. This cookie is a random value stored on the server's side and is passed along with RPC requests from the client. The NFS server can be restarted without affecting the clients and the cookie remains intact. However, because UDP is stateless, if the server goes down unexpectedly, UDP clients continue to saturate the network with requests for the server. For this reason, TCP is the preferred protocol when connecting to an NFSv3 server.



#### Note

For compatibility purposes, UDP is the default transport protocol for NFS under Red Hat Enterprise Linux. Refer to the chapter titled *Network File System (NFS)* in the *Red Hat Enterprise Linux System Administration Guide* for more information about connecting to NFS servers using TCP.

The only time NFS performs authentication is when a client system attempts to mount the shared NFS resource. To limit access to the NFS service, TCP wrappers are used. TCP wrappers read the `/etc/hosts.allow` and `/etc/hosts.deny` files to determine if a particular client or network is permitted or denied access to the NFS service. For more information on configuring access controls with TCP wrappers, refer to Chapter 16 *TCP Wrappers and xinetd*.

After the client is granted access by TCP wrappers, the NFS server refers to its configuration file, `/etc/exports`, to determine whether the client is allowed to access any of the exported file systems. Once access is granted, all file and directory operations are available to the user.

**Warning**

NFS mount privileges are granted to the client host, not the user. Therefore, exported file systems can be accessed by any user on a client host with access permissions. When configuring the NFS shares, be very careful which hosts get read/write permissions (`rw`).

### 9.1.1. Required Services

Red Hat Enterprise Linux uses a combination of kernel-level support and daemon processes to provide NFS file sharing. NFS relies on *Remote Procedure Calls (RPC)* to route requests between clients and servers. RPC services under Linux are controlled by the `portmap` service. To share or mount NFS file systems, the following services work together:

- `nfs` — Starts the appropriate RPC processes to service requests for shared NFS file systems.
- `nfslock` — An optional service that starts the appropriate RPC processes to allow NFS clients to lock files on the server.
- `portmap` — The RPC service for Linux; it responds to requests for RPC services and sets up connections to the requested RPC service.

The following RPC processes work together behind the scenes to facilitate NFS services:

- `rpc.mountd` — This process receives mount requests from NFS clients and verifies the requested file system is currently exported. This process is started automatically by the `nfs` service and does not require user configuration.
- `rpc.nfsd` — This process is the NFS server. It works with the Linux kernel to meet the dynamic demands of NFS clients, such as providing server threads each time an NFS client connects. This process corresponds to the `nfs` service.
- `rpc.lockd` — An optional process that allows NFS clients to lock files on the server. This process corresponds to the `nfslock` service.
- `rpc.statd` — This process implements the *Network Status Monitor (NSM)* RPC protocol which notifies NFS clients when an NFS server is restarted without being gracefully brought down. This process is started automatically by the `nfslock` service and does not require user configuration.
- `rpc.rquotad` — This process provides user quota information for remote users. This process is started automatically by the `nfs` service and does not require user configuration.

### 9.1.2. NFS and portmap

The `portmap` service under Linux maps RPC requests to the correct services. RPC processes notify `portmap` when they start, revealing the port number they are monitoring and the RPC program numbers they expect to serve. The client system then contacts `portmap` on the server with a particular RPC program number. The `portmap` service redirects the client to the proper port number so it can communicate with the requested service.

Because RPC-based services rely on `portmap` to make all connections with incoming client requests, `portmap` must be available before any of these services start.

The `portmap` service uses TCP wrappers for access control, and access control rules for `portmap` affect *all* RPC-based services. Alternatively, it is possible to specify access control rules for each of the NFS RPC daemons. The man pages for `rpc.mountd` and `rpc.statd` contain information regarding the precise syntax for these rules.

### 9.1.2.1. Troubleshooting NFS and portmap

Because `portmap` provides coordination between RPC services and the port numbers used to communicate with them, it is useful to view the status of current RPC services using `portmap` when troubleshooting. The `rpcinfo` command shows each RPC-based service with port numbers, an RPC program number, a version and an IP protocol type (TCP or UDP).

To make sure the proper NFS RPC-based services are enabled for `portmap`, issue the following command as root:

```
rpcinfo -p
```

The following is sample output from this command:

```

program vers proto  port
100000    2    tcp    111  portmapper
100000    2    udp    111  portmapper
100021    1    udp    32774 nlockmgr
100021    3    udp    32774 nlockmgr
100021    4    udp    32774 nlockmgr
100021    1    tcp    34437 nlockmgr
100021    3    tcp    34437 nlockmgr
100021    4    tcp    34437 nlockmgr
100011    1    udp    819  rquotad
100011    2    udp    819  rquotad
100011    1    tcp    822  rquotad
100011    2    tcp    822  rquotad
100003    2    udp    2049 nfs
100003    3    udp    2049 nfs
100003    2    tcp    2049 nfs
100003    3    tcp    2049 nfs
100005    1    udp    836  mountd
100005    1    tcp    839  mountd
100005    2    udp    836  mountd
100005    2    tcp    839  mountd
100005    3    udp    836  mountd
100005    3    tcp    839  mountd

```

The output from this command reveals that the correct NFS services are running. If one of the NFS services does not start up correctly, `portmap` is unable to map RPC requests from clients for that service to the correct port. In many cases, if NFS is not present in `rpcinfo` output, restarting NFS causes the service to correctly register with `portmap` and begin working. For instructions on starting NFS, refer to Section 9.2 *Starting and Stopping NFS*.

Other useful options are available for the `rpcinfo` command. Refer to the `rpcinfo` man page for more information.

## 9.2. Starting and Stopping NFS

To run an NFS server, the `portmap` service must be running. To verify that `portmap` is active, type the following command as root:

```
/sbin/service portmap status
```

If the `portmap` service is running, then the `nfs` service can be started. To start an NFS server, as root type:

```
/sbin/service nfs start
```

To stop the server, as root type:

```
/sbin/service nfs stop
```

The `restart` option is a shorthand way of stopping and then starting NFS. This is the most efficient way to make configuration changes take effect after editing the configuration file for NFS.

To restart the server, as root type:

```
/sbin/service nfs restart
```

The `condrestart` (*conditional restart*) option only starts `nfs` 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:

```
/sbin/service nfs condrestart
```

To reload the NFS server configuration file without restarting the service, as root type:

```
/sbin/service nfs reload
```

By default, the `nfs` service does *not* start automatically at boot time. To configure the NFS to start up at boot time, use an `initscript` utility, such as `/sbin/chkconfig`, `/sbin/ntsysv`, or the **Services Configuration Tool** program. Refer to the chapter titled *Controlling Access to Services* in *Red Hat Enterprise Linux System Administration Guide* for more information regarding these tools.

## 9.3. NFS Server Configuration

There are three ways to configure an NFS server under Red Hat Enterprise Linux: using the **NFS Server Configuration Tool** (`redhat-config-nfs`), manually editing its configuration file (`/etc/exports`), or using the `/usr/sbin/exportfs` command.

For instructions on using **NFS Server Configuration Tool**, refer to the chapter titled *Network File System (NFS)* in the *Red Hat Enterprise Linux System Administration Guide*. The remainder of this section discusses manually editing `/etc/exports` and using the `/usr/sbin/exportfs` command to export NFS file systems.

### 9.3.1. NFS Server Configuration File

The `/etc/exports` file controls which file systems are exported to remote hosts and specifies options. Blank lines are ignored, comments can be made by starting a line with the hash mark (`#`), and long lines can be wrapped with a backslash (`\`). Each exported file system should be on its own individual line, and any lists of authorized hosts placed after an exported file system must be separated by space characters. Options for each of the hosts must be placed in parentheses directly after the host identifier, without any spaces separating the host and the first parenthesis.

A line for an exported file system has the following structure:

```
<export> <host1> (<options>) <hostN> (<options>)...
```

In this structure, replace `<export>` with the directory being exported, replace `<host1>` with the host or network to which the export is being shared, and replace `(<options>)` with the options for that host or network. Additional hosts can be specified in a space separated list.

The following methods can be used to specify host names:

- *single host* — Where one particular host is specified with a fully qualified domain name, hostname, or IP address.
- *wildcards* — Where a \* or ? character is used to take into account a grouping of fully qualified domain names that match a particular string of letters. Wildcards are not to be used with IP addresses; however, it is possible for them to work accidentally if reverse DNS lookups fail.

Be careful when using wildcards with fully qualified domain names, as they tend to be more exact than expected. For example, the use of \*.example.com as wildcard allows sales.example.com to access an exported file system, but not bob.sales.example.com. To match both possibilities both \*.example.com and \*.\*.example.com must be specified.

- *IP networks* — Allows the matching of hosts based on their IP addresses within a larger network. For example, 192.168.0.0/28 allows the first 16 IP addresses, from 192.168.0.0 to 192.168.0.15, to access the exported file system, but not 192.168.0.16 and higher.
- *netgroups* — Permits an NIS netgroup name, written as @<group-name>, to be used. This effectively puts the NIS server in charge of access control for this exported file system, where users can be added and removed from an NIS group without affecting /etc/exports.

In its simplest form, /etc/exports need only specify the exported directory and the hosts permitted to access it, as in the following example:

```
/exported/directory bob.example.com
```

In the example, bob.example.com can mount /exported/directory/. Because no options are specified in this example, the following default NFS options take effect:

- *ro* — Mounts of the exported file system are read-only. Remote hosts are not able to make changes to the data shared on the file system. To allow hosts to make changes to the file system, the read/write (rw) option must be specified.
- *async* — Allows the server to write data at non-regular intervals. This setting works best if the exported file system is read-only. If the exported file system is read/write and hosts are making changes to the file system when the server crashes, data can be lost. By specifying the sync option, all file writes are committed to the disk before the write request by the client is completed. The sync option, however, can lower performance.
- *wdelay* — Causes the NFS server to delay writing to the disk if it suspects another write request is imminent. This can improve performance by reducing the number of times the disk must be accessed by separate write commands, reducing write overhead. The no\_wdelay option turns off this feature, but is only available when using the sync option.
- *root\_squash* — Prevents root users connected remotely from having root privileges and assigns them the user ID for the user nfsnobody. This effectively "squashes" the power of the remote root user to the lowest local user, preventing unauthorized alteration of files on the remote server. Alternatively, the no\_root\_squash option turns off root squashing. To squash every remote user, including root, use the all\_squash option. To specify the user and group IDs to use with remote users from a particular host, use the anonuid and anongid options, respectively. In this case, a special user account can be created for remote NFS users to share and specify (anonuid=<uid-value>, anongid=<gid-value>), where <uid-value> is the user ID number and <gid-value> is the group ID number.



### Important

By default, *access control lists (ACLs)* are supported by NFS under Red Hat Enterprise Linux. To disable this feature, specify the no\_acl option when exporting the file system. For more about this feature, refer to the chapter titled *Network File System (NFS)* in the *Red Hat Enterprise Linux System Administration Guide*.

Each default for every exported file system must be explicitly overridden. For example, if the `rw` option is not specified, then the exported file system is shared as read-only. The following is a sample line from `/etc/exports` which overrides two default options:

```
/another/exported/directory 192.168.0.3(rw, sync)
```

In this example `192.168.0.3` can mount `/another/exported/directory/` read/write and all transfers to disk are committed to the disk before the write request by the client is completed.

Additionally, other options are available where no default value is specified. These include the ability to disable sub-tree checking, allow access from insecure ports, and allow insecure file locks (necessary for certain early NFS client implementations). Refer to the `exports` man page for details on these lesser used options.



### Warning

The format of the `/etc/exports` file is very precise, particularly in regards to use of the space character. Remember to always separate exported file systems from hosts and hosts from one another with a space character. However, there should be no other space characters in the file except on comment lines.

For example, the following two lines do not mean the same thing:

```
/home bob.example.com(rw)
/home bob.example.com (rw)
```

The first line allows only users from `bob.example.com` read/write access to the `/home` directory. The second line allows users from `bob.example.com` to mount the directory read-only (the default), but the rest of the world can mount it read/write.

For detailed instructions on configuring an NFS server by editing `/etc/exports`, refer to the chapter titled *Network File System (NFS)* in the *Red Hat Enterprise Linux System Administration Guide*.

## 9.3.2. The `exportfs` Command

Every file system being exported to remote users via NFS, as well as the access level for those file systems, are listed in the `/etc/exports` file. When the `nfs` service starts, the `/usr/sbin/exportfs` command launches and reads this file, and passes to `rpc.mountd` and `rpc.nfsd` the file systems available to remote users.

When issued manually, the `/usr/sbin/exportfs` command allows the root user to selectively export or unexport directories without restarting the NFS service. When passed the proper options, the `/usr/sbin/exportfs` command writes the exported file systems to `/var/lib/nfs/xtab`. Since `rpc.mountd` refers to the `xtab` file when deciding access privileges to a file system, changes to the list of exported file systems take effect immediately.

The following is a list of commonly used options available for `/usr/sbin/exportfs`:

- `-r` — Causes all directories listed in `/etc/exports` to be exported by constructing a new export list in `/etc/lib/nfs/xtab`. This option effectively refreshes the export list with any changes that have been made to `/etc/exports`.
- `-a` — Causes all directories to be exported or unexported, depending on what other options are passed to `/usr/sbin/exportfs`. If no other options are specified, `/usr/sbin/exportfs` exports all file systems specified in `/etc/exports`.



- `-o file-systems` — Specifies directories to be exported that are not listed in `/etc/exports`. Replace `file-systems` with additional file systems to be exported. These file systems must be formatted the same way they are specified in `/etc/exports`. Refer to Section 9.3.1 *NFS Server Configuration File* for more information on `/etc/exports` syntax. This option is often used to test an exported file system before adding it permanently to the list of file systems to be exported.
- `-i` — Ignores `/etc/exports`; only options given from the command line are used to define exported file systems.
- `-u` — Unexports all shared directories. The command `/usr/sbin/exportfs -ua` suspends NFS file sharing while keeping all NFS daemons up. To reenables NFS sharing, type `exportfs -r`.
- `-v` — Verbose operation, where the file systems being exported or unexported are displayed in greater detail when the `exportfs` command is executed.

If no options are passed to the `/usr/sbin/exportfs` command, it displays a list of currently exported file systems.

For more information about the `/usr/sbin/exportfs` command, refer to the `exportfs` man page.

## 9.4. NFS Client Configuration Files

NFS shares are mounted on the client side using the `mount` command. The format of the command is as follows:

```
mount -o <options> <host>:</remote/export> </local/directory>
```

Replace `<options>` with a comma separated list of options for the NFS file system (refer to Section 9.4.3 *Common NFS Mount Options* for details). Replace `<host>` with the remote host, `</remote/export>` with the remote directory being mounted, and replace `</local/directory>` with the local directory where the remote file system is to be mounted.

Refer to the `mount` man page for more details.

If accessing an NFS share by manually issuing the `mount` command, the file system must be remounted manually after the system is rebooted. Red Hat Enterprise Linux offers two methods for mounting remote file systems automatically at boot time: the `/etc/fstab` file or the `autofs` service.

### 9.4.1. /etc/fstab

The `/etc/fstab` file is referenced by the `netfs` service at boot time, so lines referencing NFS shares have the same effect as manually typing the `mount` command during the boot process.

A sample `/etc/fstab` line to mount an NFS export looks like the following example:

```
<server>:</remote/export> </local/directory> nfs <options> 0 0
```

Replace `<server>` with the hostname, IP address, or fully qualified domain name of the server exporting the file system.

Replace `</remote/export>` with the path to the exported directory.

Replace `</local/directory;>` with the local file system on which the exported directory is mounted. This mount point must exist before `/etc/fstab` is read or the mount fails.

The `nfs` option specifies the type of file system being mounted.

Replace `<options>` with a comma separated list of options for the NFS file system (refer to Section 9.4.3 *Common NFS Mount Options* for details). Refer to the `fstab` man page for additional information.

### 9.4.2. autofs

One drawback to using `/etc/fstab` is that, regardless of how infrequently a user accesses the NFS mounted file system, the system must dedicate resources to keep the mounted file system in place. This is not a problem with one or two mounts, but when the system is maintaining mounts to a dozen systems at one time, overall system performance can suffer. An alternative to `/etc/fstab` is to use the kernel-based `automount` utility, which can mount and unmount NFS file systems automatically, saving resources.

The `autofs` service is used to control the `automount` command through the `/etc/auto.master` primary configuration file. While `automount` can be specified on the command line, it is more convenient to specify the mount points, hostname, exported directory, and options in a set of files rather than typing them manually.

The `autofs` configuration files are arranged in a parent-child relationship. The main configuration file (`/etc/auto.master`) lists mount points on the system that are linked to a particular *map type*, which takes the form of other configuration files, programs, NIS maps, and other less common mount methods. The `auto.master` file contains lines referring to each of these mount points, organized in the following manner:

```
<mount-point> <map-type>
```

The `<mount-point>` element specifies the location of the mount on the local file system. The `<map-type>` specifies how the mount point is mounted. The most common method for auto mounting NFS exports is to use a file as the map type for the particular mount point. The map file is usually named `auto.<mount-point>`, where `<mount-point>` is the mount point designated in `auto.master`. A line within map files to mount an NFS export looks like the following example:

```
</local/directory> -<options> <server>:</remote/export>
```

Replace `</local/directory;>` with the local file system on which the exported directory is mounted. This mount point must exist before the map file is read, else the mount fails.

Replace `<options>` with a comma separated list of options for the NFS file system (refer to Section 9.4.3 *Common NFS Mount Options* for details). Be sure to include the hyphen character (`-`) immediately before the options list.

Replace `<server>` with the hostname, IP address, or fully qualified domain name of the server exporting the file system.

Replace `</remote/export>` with the path to the exported directory.

Replace `<options>` with a comma separated list of options for the NFS file system (refer to Section 9.4.3 *Common NFS Mount Options* for details).

While `autofs` configuration files can be used for a variety of mounts to many types of devices and file systems, they are particularly useful in creating NFS mounts. For example, some organizations store a user's `/home/` directory on a central server via an NFS share, then configure the `auto.master` file on each of the workstations to point to an `auto.home` file containing the specifics for how to mount the `/home/` directory via NFS. This allows the user to access personal data and configuration files in their `/home/` directory by logging in anywhere on the network. The `auto.master` file in this situation would look similar to this:

```
/home /etc/auto.home
```

This sets up the `/home/` mount point on the local system to be configured by the `/etc/auto.home` file, which looks similar to the example below:

```
* -fstype=nfs,soft,intr,rsize=8192,wszise=8192,nosuid,tcp server.example.com:/home
```

This line states that any directory a user tries to access under the local `/home/` directory (due to the asterisk character) should result in an NFS mount on the `server.example.com` system on the mount point `/home/`. The mount options specify that each `/home/` directory NFS mounts should use a particular collection of settings. For more information on mount options, including the ones used in this example, refer to Section 9.4.3 *Common NFS Mount Options*.

For more information about `autofs` configuration files, refer to the `auto.master` man page.

### 9.4.3. Common NFS Mount Options

Beyond mounting a file system via NFS on a remote host, a number of different options can be specified at the time of the mount that can make it easier to use. These options can be used with manual `mount` commands, `/etc/fstab` settings, and `autofs`.

The following are options commonly used for NFS mounts:

- `hard` or `soft` — Specifies whether the program using a file via an NFS connection should stop and wait (`hard`) for the server to come back online if the host serving the exported file system is unavailable, or if it should report an error (`soft`).

If `hard` is specified, the user cannot terminate the process waiting for the NFS communication to resume unless the `intr` option is also specified.

If `soft`, is specified, the user can set an additional `timeo=<value>` option, where `<value>` specifies the number of seconds to pass before the error is reported.

- `intr` — Allows NFS requests to be interrupted if the server goes down or cannot be reached.
- `nfsvers=2` or `nfsvers=3` — Specifies which version of the NFS protocol to use.
- `noexec` — Disables file locking. This setting is occasionally required when connecting to older NFS servers.
- `noexec` — Prevents execution of binaries on mounted file systems. This is useful if the system is mounting a non-Linux file system via NFS containing incompatible binaries.
- `nosuid` — Disables set-user-identifier or set-group-identifier bits. This prevents remote users from gaining higher privileges by running a `setuid` program.
- `rsize=8192` and `wsize=8192` — These settings speed up NFS communication for reads (`rsize`) and writes (`wsize`) by setting a larger data block size, in bytes, to be transferred at one time. Be careful when changing these values; some older Linux kernels and network cards do not work well with larger block sizes.
- `tcp` — Specifies for the NFS mount to use the TCP protocol instead of UDP.

Many more options are listed on the `mount` man page, including options for mounting non-NFS file systems.

## 9.5. Securing NFS

NFS is well suited for sharing entire file systems with a large number of known hosts in a transparent manner. However, with ease of use comes a variety of potential security problems.

The following points should be considered when exporting NFS file systems on a server or mounting them on a client. Doing so minimizes NFS security risks and better protects data on the server.

For a concise listing of steps administrators can take to secure NFS servers, refer the the chapter titled *Server Security* in the *Red Hat Enterprise Linux Security Guide*.

### 9.5.1. Host Access

NFS controls who can mount an exported file system based on the host making the mount request, not the user that actually uses the file system. Hosts must be given explicit rights to mount the exported file system. Access control is not possible for users, other than through file and directory permissions. In other words, once a file system is exported via NFS, any user on any remote host connected to the NFS server can access the shared data. To limit the potential risks, administrators often allow read-only access or squash user permissions to a common user and group ID. Unfortunately, these solutions prevent the NFS share from being used in the way it was originally intended.

Additionally, if an attacker gains control of the DNS server used by the system exporting the NFS file system, the system associated with a particular hostname or fully qualified domain name can be pointed to an unauthorized machine. At this point, the unauthorized machine *is* the system permitted to mount the NFS share, since no username or password information is exchanged to provide additional security for the NFS mount.

Wildcards should be used sparingly when exporting directories via NFS as it is possible for the scope of the wildcard to encompass more systems than intended.

It is also possible to restrict access to the `portmap` service via TCP wrappers. Access to ports used by `portmap`, `rpc.mountd`, and `rpc.nfsd` can also be limited by creating firewall rules with `iptables`.

For more information on securing NFS and `portmap`, refer to the chapter titled *Server Security* in the *Red Hat Enterprise Linux Security Guide*. Additional information about firewalls can be found in Chapter 17 *iptables*.

### 9.5.2. File Permissions

Once the NFS file system is mounted read/write by a remote host, the only protection each shared file has is its permissions. If two users that share the same user ID value mount the same NFS file system, they can modify each others files. Additionally, anyone logged in as root on the client system can use the `su -` command to become a user who could access particular files via the NFS share. For more on NFS and user ID conflicts, refer to the chapter titled *Managing User Accounts and Resource Access* in the *Red Hat Enterprise Linux Introduction to System Administration*.

By default, access control lists (ACLs) are supported by NFS under Red Hat Enterprise Linux. It is not recommended that this feature be disabled. For more about this feature, refer to the chapter titled *Network File System (NFS)* in the *Red Hat Enterprise Linux System Administration Guide*.

The default behavior when exporting a file system via NFS is to use *root squashing*. This sets the user ID of anyone accessing the NFS share as the root user on their local machine to a value of the server's `nfsnobody` account. Never turn off root squashing.

If exporting an NFS share read-only, consider using the `all_squash` option, which makes every user accessing the exported file system take the user ID of the `nfsnobody` user.

## 9.6. Additional Resources

Administering an NFS server can be a challenge. Many options, including quite a few not mentioned in this chapter, are available for exporting or mounting NFS shares. Consult the following sources for more information.

### 9.6.1. Installed Documentation

- `/usr/share/doc/nfs-utils-<version-number>/` — Replace `<version-number>` with the version number of the NFS package installed. This directory contains a wealth of

information about the NFS implementation for Linux, including a look at various NFS configurations and their impact on file transfer performance.

- `man mount` — Contains a comprehensive look at mount options for both NFS server and client configurations.
- `man fstab` — Gives details for the format of the `/etc/fstab` file used to mount file systems at system boot.
- `man nfs` — Provides detail on NFS-specific file system export and mount options.
- `man exports` — Shows common options used in the `/etc/exports` file when exporting NFS file systems.

### 9.6.2. Useful Websites

- <http://sourceforge.net/projects/nfs/> — The home of the Linux NFS project and a great place for project status updates.

### 9.6.3. Related Books

- *Managing NFS and NIS* by Hal Stern, Mike Eisler, and Ricardo Labiaga; O'Reilly & Associates — Makes an excellent reference guide for the many different NFS export and mount options available.
- *NFS Illustrated* by Brent Callaghan; Addison-Wesley Publishing Company — Provides comparisons of NFS to other network file systems and shows, in detail, how NFS communication occurs.
- *Red Hat Enterprise Linux System Administration Guide*; Red Hat, Inc. — The *Network File System (NFS)* chapter explains concisely how to set up an NFS clients and servers.
- *Red Hat Enterprise Linux Security Guide*; Red Hat, Inc. — The *Server Security* chapter explains ways to secure NFS and other services.



## Apache HTTP Server

The Apache HTTP Server is a robust, commercial-grade open source Web server developed by the Apache Software Foundation (<http://www.apache.org/>). Red Hat Enterprise Linux includes the Apache HTTP Server 2.0 as well as a number of server modules designed to enhance its functionality.

The default configuration file installed with the Apache HTTP Server works without alteration for most situations. This chapter outlines many of the directives found within its configuration file (`/etc/httpd/conf/httpd.conf`) to aid those who require a custom configuration or need to convert a configuration file from the older Apache HTTP Server 1.3 format.



### Warning

If using the graphical **HTTP Configuration Tool** (`redhat-config-httpd`), *do not* hand edit the Apache HTTP Server's configuration file as the **HTTP Configuration Tool** regenerates this file whenever it is used.

For more information about the **HTTP Configuration Tool**, please refer to the chapter titled *Apache HTTP Server Configuration* in the *Red Hat Enterprise Linux System Administration Guide*.

## 10.1. Apache HTTP Server 2.0

There are important differences between the Apache HTTP Server 2.0 and version 1.3 (version 1.3 shipped with Red Hat Linux 7.3 and earlier). This section reviews some of the features of Apache HTTP Server 2.0 and outlines important changes. For instructions on migrating a version 1.3 configuration file to the 2.0 format, refer to Section 10.2 *Migrating Apache HTTP Server 1.3 Configuration Files*.

### 10.1.1. Features of Apache HTTP Server 2.0

The arrival of Apache HTTP Server 2.0 brings with it a number of new features, including:

- *New Apache API* — Modules utilize a new, more powerful set of Application Programming Interfaces (APIs).



### Important

Modules built for Apache HTTP Server 1.3 do not work without being ported to the new API. If unsure whether or not a particular module has been ported, consult the developer *before* upgrading.

- *Filtering* — Modules can act as content filters. Refer to Section 10.2.4 *Modules and Apache HTTP Server 2.0* for more on how filtering works.
- *IPv6 Support* — The next generation IP addressing format is supported.
- *Simplified Directives* — A number of confusing directives have been removed while others have been simplified. Refer to Section 10.5 *Configuration Directives in httpd.conf* for more information about specific directives.

- *Multilingual Error Responses* — When using *Server Side Include (SSI)* documents, customizable error response pages can be delivered in multiple languages.
- *Multiprotocol Support* — Multiple protocols are supported.

A more complete list of changes can be found online at <http://httpd.apache.org/docs-2.0/>.

### 10.1.2. Packaging Changes in Apache HTTP Server 2.0

Starting with Red Hat Linux 8.0, the Apache HTTP Server packages were renamed. Also, some related packages were renamed, deprecated, or incorporated into other packages.

Below is a list of the packaging changes:

- The `apache`, `apache-devel` and `apache-manual` packages were renamed to `httpd`, `httpd-devel` and `httpd-manual` respectively.
- The `mod_dav` package was incorporated into the `httpd` package.
- The `mod_put` and `mod_roaming` packages were removed, since their functionality is a subset of that provided by `mod_dav` (which is now incorporated into the `httpd` package).
- The `mod_auth_any` and `mod_bandwidth` packages were removed.
- The version number for the `mod_ssl` package is now synchronized with the `httpd` package. This means that the `mod_ssl` package for Apache HTTP Server 2.0 has a *lower* version number than `mod_ssl` package for Apache HTTP Server 1.3.

### 10.1.3. File System Changes in Apache HTTP Server 2.0

The following changes to the file system layout occur when upgrading to Apache HTTP Server 2.0:

- *A new configuration directory, `/etc/httpd/conf.d/`, has been added.* — This new directory is used to store configuration files for individually packaged modules, such as `mod_ssl`, `mod_perl`, and `php`. The server is instructed to load configuration files from this location by the directive `Include conf.d/*.conf` within the Apache HTTP Server configuration file, `/etc/httpd/conf/httpd.conf`.



#### Important

It is vital that the line specifying the new configuration directory be inserted when migrating an existing configuration.

- *The `ab` and `logresolve` programs have been moved.* — These utility programs have been moved from the `/usr/sbin/` directory and into the `/usr/bin/` directory. This causes scripts with absolute paths for these binaries to fail.
- *The `dbmmanage` command has been replaced.* — The `dbmmanage` command has been replaced with `htdbm`. Refer to Section 10.2.4.4 *The `mod_auth_dbm` and `mod_auth_db` Modules* for more information.
- *The `logrotate` configuration file has been renamed.* — The `logrotate` configuration file has been renamed from `/etc/logrotate.d/apache` to `/etc/logrotate.d/httpd`.

The next section outlines how to migrate an Apache HTTP Server 1.3 configuration to the new 2.0 format.



## 10.2. Migrating Apache HTTP Server 1.3 Configuration Files

This section is for those migrating an Apache HTTP Server 1.3 configuration file to be utilized by Apache HTTP Server 2.0.

If upgrading the to Red Hat Enterprise Linux 3 from Red Hat Enterprise Linux 2.1, then the new stock configuration file for the Apache HTTP Server 2.0 package is installed as `/etc/httpd/conf/httpd.conf.rpmnew` and the original version 1.3 `httpd.conf` is not touched. It is, of course, entirely up to you whether to use the new configuration file and migrate the old settings to it or use the existing file as a base and modify it to suit; however, some parts of the file have changed more than others and a mixed approach is generally the best. The stock configuration files for both version 1.3 and 2.0 are divided into three sections.

If the `/etc/httpd/conf/httpd.conf` file is a modified version of the newly installed default and a saved a copy of the original configuration file is available, it may be easiest to invoke the `diff` command, as in the following example:

```
diff -u httpd.conf.orig httpd.conf | less
```

This command highlights any modifications made. If a copy of the original file is not available, extract it from an RPM package using the `rpm2cpio` and `cpio` commands, as in the following example:

```
rpm2cpio apache-<version-number>.i386.rpm | cpio -i --make
```

In the above command, replace `<version-number>` with the version number for the `apache` package.

Finally, it is useful to know that the Apache HTTP Server has a testing mode to check for configuration errors. To use access it, type the following command:

```
apachectl configtest
```

### 10.2.1. Global Environment Configuration

The global environment section of the configuration file contains directives which affect the overall operation of the Apache HTTP Server, such as the number of concurrent requests it can handle and the locations of the various files. This section requires a large number of changes, as compared to the others, and it is therefore recommended to base this section on the Apache HTTP Server 2.0 configuration file and migrate the old settings into it.

#### 10.2.1.1. Interface and Port Binding

The `BindAddress` and `Port` directives no longer exist; their functionality is now provided by a more flexible `Listen` directive.

If `Port 80` was set in the 1.3 version configuration file, change it to `Listen 80` in the 2.0 configuration file. If `Port` was set to some value *other than 80*, then append the port number to the contents of the `ServerName` directive.

For example, the following is a sample Apache HTTP Server 1.3 directive:

```
Port 123
ServerName www.example.com
```

To migrate this setting to Apache HTTP Server 2.0, use the following structure:

```
Listen 123
ServerName www.example.com:123
```

For more on this topic, refer to the following documentation on the Apache Software Foundation's website:

- [http://httpd.apache.org/docs-2.0/mod/mpm\\_common.html#listen](http://httpd.apache.org/docs-2.0/mod/mpm_common.html#listen)
- <http://httpd.apache.org/docs-2.0/mod/core.html#servername>

### 10.2.1.2. Server-Pool Size Regulation

When the Apache HTTP Server accepts requests, it dispatches child-processes or threads to handle them. This group of child processes or threads is known as a *server-pool*. Under Apache HTTP Server 2.0, the responsibility for creating and maintaining these server-pools has been abstracted to a group of modules called *Multi-Processing Modules (MPMs)*. Unlike other modules, only one module from the MPM group can be loaded by the Apache HTTP Server. There are three MPM modules that ship with 2.0: `prefork`, `worker`, and `perchild`. Currently only the `prefork` and `worker` MPMs are available, although the `perchild` MPM may be made available at a later date.

The original Apache HTTP Server 1.3 behavior has been moved into the `prefork` MPM. The `prefork` MPM accepts the same directives as Apache HTTP Server 1.3, so the following directives may be migrated directly:

- `StartServers`
- `MinSpareServers`
- `MaxSpareServers`
- `MaxClients`
- `MaxRequestsPerChild`

The `worker` MPM implements a multi-process, multi-threaded server providing greater scalability. When using this MPM, requests are handled by threads, conserving system resources and allowing large numbers of requests to be served efficiently. Although some of the directives accepted by the `worker` MPM are the same as those accepted by the `prefork` MPM, the values for those directives should not be transferred directly from an Apache HTTP Server 1.3 installation. It is best to instead use the default values as a guide, then experiment to determine what values work best.



#### Important

To use the `worker` MPM, create the file `/etc/sysconfig/httpd`. In the file add the following directive:

```
HTTPD=/usr/sbin/httpd.worker
```

For more on the topic of MPMs, refer to the following documentation on the Apache Software Foundation's website:

- <http://httpd.apache.org/docs-2.0/mpm.html>

### 10.2.1.3. Dynamic Shared Object (DSO) Support

There are many changes required here, and it is highly recommended that anyone trying to modify an Apache HTTP Server 1.3 configuration to suit version 2.0 (as opposed to migrating the changes into the version 2.0 configuration) copy this section from the stock Apache HTTP Server 2.0 configuration file.

Those who do not want to copy the section from the stock Apache HTTP Server 2.0 configuration should note the following:

- The `AddModule` and `ClearModuleList` directives no longer exist. These directives were used to ensure that modules could be enabled in the correct order. The Apache HTTP Server 2.0 API allows modules to specify their ordering, eliminating the need for these two directives.
- The order of the `LoadModule` lines is no longer relevant in most cases.
- Many modules have been added, removed, renamed, split up, or incorporated into others.
- `LoadModule` lines for modules packaged in their own RPMs (`mod_ssl`, `php`, `mod_perl`, and the like) are no longer necessary as they can be found in their relevant files within the `/etc/httpd/conf.d/` directory.
- The various `HAVE_XXX` definitions are no longer defined.



### Important

If modifying the original file, please note that it is of paramount importance that the `httpd.conf` contains the following directive:

```
Include conf.d/*.conf
```

Omission of this directive results in the failure of all modules packaged in their own RPMs (such as `mod_perl`, `php`, and `mod_ssl`).

#### 10.2.1.4. Other Global Environment Changes

The following directives have been removed from Apache HTTP Server 2.0's configuration:

- `ServerType` — The Apache HTTP Server can only be run as `ServerType standalone` making this directive irrelevant.
- `AccessConfig` and `ResourceConfig` — These directives have been removed as they mirror the functionality of the `Include` directive. If the `AccessConfig` and `ResourceConfig` directives are set, replace them with `Include` directives.

To ensure that the files are read in the order implied by the older directives, the `Include` directives should be placed at the end of the `httpd.conf`, with the one corresponding to `ResourceConfig` preceding the one corresponding to `AccessConfig`. If using the default values, include them explicitly as `conf/srm.conf` and `conf/access.conf` files.

### 10.2.2. Main Server Configuration

The main server configuration section of the configuration file sets up the main server, which responds to any requests that are not handled by a virtual host defined within a `<VirtualHost>` container. Values here also provide defaults for any `<VirtualHost>` containers defined.

The directives used in this section have changed little between Apache HTTP Server 1.3 and version 2.0. If the main server configuration is heavily customized, it may be easier to modify the existing configuration file to suit Apache HTTP Server 2.0. Users with only lightly customized main server sections should migrate their changes into the default 2.0 configuration.

### 10.2.2.1. UserDir Mapping

The `UserDir` directive is used to enable URLs such as `http://example.com/~bob/` to map to a subdirectory within the home directory of the user `bob`, such as `/home/bob/public_html/`. A side-effect of this feature allows a potential attacker to determine whether a given username is present on the system. For this reason, the default configuration for Apache HTTP Server 2.0 disables this directive.

To enable `UserDir` mapping, change the directive in `httpd.conf` from:

```
UserDir disable
```

to the following:

```
UserDir public_html
```

For more on this topic, refer to the following documentation on the Apache Software Foundation's website:

- [http://httpd.apache.org/docs-2.0/mod/mod\\_userdir.html#userdir](http://httpd.apache.org/docs-2.0/mod/mod_userdir.html#userdir)

### 10.2.2.2. Logging

The following logging directives have been removed:

- `AgentLog`
- `RefererLog`
- `RefererIgnore`

However, agent and referrer logs are still available using the `CustomLog` and `LogFormat` directives.

For more on this topic, refer to the following documentation on the Apache Software Foundation's website:

- [http://httpd.apache.org/docs-2.0/mod/mod\\_log\\_config.html#customlog](http://httpd.apache.org/docs-2.0/mod/mod_log_config.html#customlog)
- [http://httpd.apache.org/docs-2.0/mod/mod\\_log\\_config.html#logformat](http://httpd.apache.org/docs-2.0/mod/mod_log_config.html#logformat)

### 10.2.2.3. Directory Indexing

The deprecated `FancyIndexing` directive has now been removed. The same functionality is available through the `FancyIndexing` *option* within the `IndexOptions` directive.

The new `VersionSort` option to the `IndexOptions` directive causes files containing version numbers to be sorted in a more natural way. For example, `httpd-2.0.6.tar` appears before `httpd-2.0.36.tar` in a directory index page.

The defaults for the `ReadmeName` and `HeaderName` directives have changed from `README` and `HEADER` to `README.html` and `HEADER.html`.

For more on this topic, refer to the following documentation on the Apache Software Foundation's website:

- [http://httpd.apache.org/docs-2.0/mod/mod\\_autoindex.html#indexoptions](http://httpd.apache.org/docs-2.0/mod/mod_autoindex.html#indexoptions)
- [http://httpd.apache.org/docs-2.0/mod/mod\\_autoindex.html#readmeName](http://httpd.apache.org/docs-2.0/mod/mod_autoindex.html#readmeName)
- [http://httpd.apache.org/docs-2.0/mod/mod\\_autoindex.html#headerName](http://httpd.apache.org/docs-2.0/mod/mod_autoindex.html#headerName)

#### 10.2.2.4. Content Negotiation

The `CacheNegotiatedDocs` directive now takes the argument `on` or `off`. Existing instances of `CacheNegotiatedDocs` should be replaced with `CacheNegotiatedDocs on`.

For more on this topic, refer to the following documentation on the Apache Software Foundation's website:

- [http://httpd.apache.org/docs-2.0/mod/mod\\_negotiation.html#cachenegotiateddocs](http://httpd.apache.org/docs-2.0/mod/mod_negotiation.html#cachenegotiateddocs)

#### 10.2.2.5. Error Documents

To use a hard-coded message with the `ErrorDocument` directive, the message should be enclosed in a pair of double quotation marks ["], rather than just preceded by a double quotation mark as required in Apache HTTP Server 1.3.

For example, the following is a sample Apache HTTP Server 1.3 directive:

```
ErrorDocument 404 "The document was not found"
```

To migrate an `ErrorDocument` setting to Apache HTTP Server 2.0, use the following structure:

```
ErrorDocument 404 "The document was not found"
```

Note the trailing double quote in the previous `ErrorDocument` directive example.

For more on this topic, refer to the following documentation on the Apache Software Foundation's website:

- <http://httpd.apache.org/docs-2.0/mod/core.html#errordocument>

### 10.2.3. Virtual Hosts Configuration

The contents of all `<VirtualHost>` containers should be migrated in the same way as the main server section as described in Section 10.2.2 *Main Server Configuration*.



#### Important

Note that SSL/TLS virtual host configuration has been moved out of the main server configuration file and into `/etc/httpd/conf.d/ssl.conf`.

For more on this topic, refer to the chapter titled *Apache HTTP Secure Server Configuration* in the *Red Hat Enterprise Linux System Administration Guide* and the documentation online at the following URL:

- <http://httpd.apache.org/docs-2.0/vhosts/>

## 10.2.4. Modules and Apache HTTP Server 2.0

In Apache HTTP Server 2.0, the module system has been changed to allow modules to be chained together or combined in new and interesting ways. *Common Gateway Interface (CGI)* scripts, for example, can generate server-parsed HTML documents which can then be processed by `mod_include`. This opens up a tremendous number of possibilities with regards to how modules can be combined to achieve a specific goal.

The way this works is that each request is served by exactly one *handler* module followed by zero or more *filter* modules.

Under Apache HTTP Server 1.3, for example, a Perl script would be handled in its entirety by the Perl module (`mod_perl`). Under Apache HTTP Server 2.0, the request is initially *handled* by the core module — which serves static files — and is then *filtered* by `mod_perl`.

Exactly how to use this, and all other new features of Apache HTTP Server 2.0, is beyond the scope of this document; however, the change has ramifications if the `PATH_INFO` directive is used for a document which is handled by a module that is now implemented as a filter, as each contains trailing path information after the true file name. The core module, which initially handles the request, does not by default understand `PATH_INFO` and returns 404 Not Found errors for requests that contain such information. As an alternative, use the `AcceptPathInfo` directive to coerce the core module into accepting requests with `PATH_INFO`.

The following is an example of this directive:

```
AcceptPathInfo on
```

For more on this topic, refer to the following documentation on the Apache Software Foundation's website:

- <http://httpd.apache.org/docs-2.0/mod/core.html#acceptpathinfo>
- <http://httpd.apache.org/docs-2.0/handler.html>
- <http://httpd.apache.org/docs-2.0/filter.html>

### 10.2.4.1. The `mod_ssl` Module

The configuration for `mod_ssl` has been moved from the `httpd.conf` file into the `/etc/httpd/conf.d/ssl.conf` file. For this file to be loaded, and hence for `mod_ssl` to work, the statement `Include conf.d/*.conf` must be in the `httpd.conf` file as described in Section 10.2.1.3 *Dynamic Shared Object (DSO) Support*.

`ServerName` directives in SSL virtual hosts must explicitly specify the port number.

For example, the following is a sample Apache HTTP Server 1.3 directive:

```
<VirtualHost _default_:443>
  # General setup for the virtual host
  ServerName ssl.example.name
  ...
</VirtualHost>
```

To migrate this setting to Apache HTTP Server 2.0, use the following structure:

```
<VirtualHost _default_:443>
  # General setup for the virtual host
  ServerName ssl.host.name:443
  ...
</VirtualHost>
```

It is also important to note that both the `SSLLog` and `SSLLogLevel` directives have been removed. The `mod_ssl` module now obeys the `ErrorLog` and `LogLevel` directives. Refer to Section 10.5.34 *ErrorLog* and Section 10.5.35 *LogLevel* for more information about these directives.

For more on this topic, refer to the following documentation on the Apache Software Foundation's website:

- [http://httpd.apache.org/docs-2.0/mod/mod\\_ssl.html](http://httpd.apache.org/docs-2.0/mod/mod_ssl.html)
- <http://httpd.apache.org/docs-2.0/vhosts/>

#### 10.2.4.2. The `mod_proxy` Module

Proxy access control statements are now placed inside a `<Proxy>` block rather than a `<Directory proxy>`.

The caching functionality of the old `mod_proxy` has been split out into the following three modules:

- `mod_cache`
- `mod_disk_cache`
- `mod_mem_cache`

These generally use directives similar to the older versions of the `mod_proxy` module, but it is advisable to verify each directive before migrating any cache settings.

For more on this topic, refer to the following documentation on the Apache Software Foundation's website:

- [http://httpd.apache.org/docs-2.0/mod/mod\\_proxy.html](http://httpd.apache.org/docs-2.0/mod/mod_proxy.html)

#### 10.2.4.3. The `mod_include` Module

The `mod_include` module is now implemented as a filter and is therefore enabled differently. Refer to Section 10.2.4 *Modules and Apache HTTP Server 2.0* for more about filters.

For example, the following is a sample Apache HTTP Server 1.3 directive:

```
AddType text/html .shtml
AddHandler server-parsed .shtml
```

To migrate this setting to Apache HTTP Server 2.0, use the following structure:

```
AddType text/html .shtml
AddOutputFilter INCLUDES .shtml
```

Note that just as before, the `Options +Includes` directive is still required for the `<Directory>` container or in a `.htaccess` file.

For more on this topic, refer to the following documentation on the Apache Software Foundation's website:

- [http://httpd.apache.org/docs-2.0/mod/mod\\_include.html](http://httpd.apache.org/docs-2.0/mod/mod_include.html)

#### 10.2.4.4. The `mod_auth_dbm` and `mod_auth_db` Modules

Apache HTTP Server 1.3 supported two authentication modules, `mod_auth_db` and `mod_auth_dbm`, which used Berkeley Databases and DBM databases respectively. These modules have been combined into a single module named `mod_auth_dbm` in Apache HTTP Server 2.0, which can access several different database formats. To migrate from `mod_auth_db`, configuration files should be adjusted by replacing `AuthDBUserFile` and `AuthDBGroupFile` with the `mod_auth_dbm` equivalents: `AuthDBMUserFile` and `AuthDBMGroupFile`. Also, the directive `AuthDBMType DB` must be added to indicate the type of database file in use.

The following example shows a sample `mod_auth_db` configuration for Apache HTTP Server 1.3:

```
<Location /private/>
  AuthType Basic
  AuthName "My Private Files"
  AuthDBUserFile /var/www/authdb
  require valid-user
</Location>
```

To migrate this setting to version 2.0 of Apache HTTP Server, use the following structure:

```
<Location /private/>
  AuthType Basic
  AuthName "My Private Files"
  AuthDBMUserFile /var/www/authdb
  AuthDBMType DB
  require valid-user
</Location>
```

Note that the `AuthDBMUserFile` directive can also be used in `.htaccess` files.

The `dbmmanage` Perl script, used to manipulate user name and password databases, has been replaced by `htdbm` in Apache HTTP Server 2.0. The `htdbm` program offers equivalent functionality and like `mod_auth_dbm` can operate a variety of database formats; the `-T` option can be used on the command line to specify the format to use.

Table 10-1 shows how to migrate from a DBM-format database to `htdbm` format using `dbmmanage`.

Action	dbmmanage command (1.3)	Equivalent htdbm command (2.0)
Add user to database (using given password)	<code>dbmmanage authdb add username password</code>	<code>htdbm -b -TDB authdb username password</code>
Add user to database (prompts for password)	<code>dbmmanage authdb adduser username</code>	<code>htdbm -TDB authdb username</code>
Remove user from database	<code>dbmmanage authdb delete username</code>	<code>htdbm -x -TDB authdb username</code>
List users in database	<code>dbmmanage authdb view</code>	<code>htdbm -l -TDB authdb</code>
Verify a password	<code>dbmmanage authdb check username</code>	<code>htdbm -v -TDB authdb username</code>

**Table 10-1. Migrating from `dbmmanage` to `htdbm`**

The `-m` and `-s` options work with both `dbmmanage` and `htdbm`, enabling the use of the MD5 or SHA1 algorithms for hashing passwords, respectively.

When creating a new database with `htdbm`, the `-c` option must be used.



For more on this topic, refer to the following documentation on the Apache Software Foundation's website:

- [http://httpd.apache.org/docs-2.0/mod/mod\\_auth\\_dbm.html](http://httpd.apache.org/docs-2.0/mod/mod_auth_dbm.html)

#### 10.2.4.5. The `mod_perl` Module

The configuration for `mod_perl` has been moved from `httpd.conf` into the file `/etc/httpd/conf.d/perl.conf`. For this file to be loaded, and hence for `mod_perl` to work, the statement `Include conf.d/*.conf` must be included in `httpd.conf` as described in Section 10.2.1.3 *Dynamic Shared Object (DSO) Support*.

Occurrences of `Apache::` in `httpd.conf` must be replaced with `ModPerl::`. Additionally, the manner in which handlers are registered has been changed.

This is a sample Apache HTTP Server 1.3 `mod_perl` configuration:

```
<Directory /var/www/perl>
    SetHandler perl-script
    PerlHandler Apache::Registry
    Options +ExecCGI
</Directory>
```

This is the equivalent `mod_perl` for Apache HTTP Server 2.0:

```
<Directory /var/www/perl>
    SetHandler perl-script
    PerlModule ModPerl::Registry
    PerlHandler ModPerl::Registry::handler
    Options +ExecCGI
</Directory>
```

Most modules for `mod_perl` 1.x should work without modification with `mod_perl` 2.x. XS modules require recompilation and may require minor Makefile modifications.

#### 10.2.4.6. The `mod_python` Module

Configuration for `mod_python` has moved from `httpd.conf` to the `/etc/httpd/conf.d/python.conf` file. For this file to be loaded, and hence for `mod_python` to work, the statement `Include conf.d/*.conf` must be in `httpd.conf` as described in Section 10.2.1.3 *Dynamic Shared Object (DSO) Support*.

#### 10.2.4.7. PHP

The configuration for PHP has been moved from `httpd.conf` into the file `/etc/httpd/conf.d/php.conf`. For this file to be loaded, the statement `Include conf.d/*.conf` must be in `httpd.conf` as described in Section 10.2.1.3 *Dynamic Shared Object (DSO) Support*.

The PHP is now implemented as a filter and must therefore be enabled in a different manor. Refer to Section 10.2.4 *Modules and Apache HTTP Server 2.0* for more about filters.

Under Apache HTTP Server 1.3, PHP was implemented using the following directives:

```
AddType application/x-httpd-php .php
AddType application/x-httpd-php-source .phps
```

Under Apache HTTP Server 2.0, use the following directives instead:

```
<Files *.php>
    SetOutputFilter PHP
    SetInputFilter PHP
</Files>
```

In PHP version 4.2.0 and later the default set of predefined variables which are available in the global scope has changed. Individual input and server variables are, by default, no longer placed directly into the global scope. This change may cause scripts to break. Revert to the old behavior by setting `register_globals` to `On` in the file `/etc/php.ini`.

For more on this topic, refer to the following URL for details concerning the global scope changes:

- [http://www.php.net/release\\_4\\_1\\_0.php](http://www.php.net/release_4_1_0.php)

### 10.3. After Installation

After installing the `httpd` package, review the Apache HTTP Server's documentation available online at <http://httpd.apache.org/docs-2.0/>.

The Apache HTTP Server's documentation contains a full list and complete descriptions of all configuration options. For the convenience, this chapter provides short descriptions of the configuration directives used by Apache HTTP Server 2.0.

The Apache HTTP Server 2.0 includes the ability to set up secure Web servers using the strong SSL encryption provided by the `mod_ssl` and `openssl` packages. When looking through the configuration files, be aware that it includes both a non-secure and a secure Web server. The secure Web server runs as a virtual host, which is configured in the `/etc/httpd/conf.d/ssl.conf` file. For more information about virtual hosts, refer to Section 10.8 *Virtual Hosts*. For information on configuring a secure server virtual host, Section 10.8.1 *Setting Up Virtual Hosts*. For information on setting up an Apache HTTP Secure Server refer to the chapter titled *Apache HTTP Secure Server Configuration* in the *Red Hat Enterprise Linux System Administration Guide*.



#### Note

Red Hat, Inc. does not ship FrontPage extensions as the Microsoft™ license prohibits the inclusion of these extensions in a third party product. More information about FrontPage extensions and the Apache HTTP Server can be found online at <http://www.rtr.com/fpsupport/>.

### 10.4. Starting and Stopping `httpd`

The `httpd` RPM installs the `/etc/init.d/httpd` script, which can be accessed using the `/sbin/service` command.

To start the server, as root type:

```
/sbin/service httpd start
```

To stop the server, as root type:

```
/sbin/service httpd stop
```

The `restart` option is a shorthand way of stopping and then starting the Apache HTTP Server.

To restart the server, as root type:

```
/sbin/service httpd restart
```

**Note**

If running the Apache HTTP Server as a secure server, it may be necessary to type the server password whenever using the `start` or `restart` options.

After editing the `httpd.conf` file, however, it is not necessary to explicitly stop and start the server. Instead, use the `reload` option.

To reload the server configuration file, as root type:

```
/sbin/service httpd reload
```

**Note**

If running the Apache HTTP Server as a secure server, the server password is *not* required when using the `reload` option.

By default, the `httpd` service does *not* start automatically at boot time. To configure the `httpd` service to start up at boot time, use an initscript utility, such as `/sbin/chkconfig`, `/sbin/ntsysv`, or the **Services Configuration Tool** program. Refer to the chapter titled *Controlling Access to Services* in *Red Hat Enterprise Linux System Administration Guide* for more information regarding these tools.

**Note**

If running the Apache HTTP Server as a secure server, the secure server's password is required after the machine boots when using an encrypted private SSL key.

For information about setting up an Apache HTTP Secure Server refer to the chapter titled *Apache HTTP Secure Server Configuration* in the *Red Hat Enterprise Linux System Administration Guide*.

## 10.5. Configuration Directives in `httpd.conf`

The Apache HTTP Server configuration file is `/etc/httpd/conf/httpd.conf`. The `httpd.conf` file is well-commented and mostly self-explanatory. The default configuration works for most situations; however, it is a good idea to become familiar some of the more important configuration options.

**Warning**

With the release of Apache HTTP Server 2.0, many configuration options have changed. If migrating a version 1.3 configuration file to the 2.0 format, refer to Section 10.2 *Migrating Apache HTTP Server 1.3 Configuration Files*.

### 10.5.1. General Configuration Tips

If configuring the Apache HTTP Server, edit `/etc/httpd/conf/httpd.conf` and then either reload, restart, or stop and start the `httpd` process as outlined in Section 10.4 *Starting and Stopping httpd*.

Before editing `httpd.conf`, make a copy the original file. Creating a backup makes it easier to recover from mistakes made while editing the configuration file.

If a mistake is made and the Web server does not work correctly, first review recently edited passages in `httpd.conf` to verify there are no typos.

Next look in the Web server's error log, `/var/log/httpd/error_log`. The error log may not be easy to interpret, depending on your level of expertise. However, the last entries in the error log should provide useful information.

The following subsections contain a list of short descriptions for many of the directives included in `httpd.conf`. These descriptions are not exhaustive. For more information, refer to the Apache documentation online at <http://httpd.apache.org/docs-2.0/>.

For more information about `mod_ssl` directives, refer to the documentation online at [http://httpd.apache.org/docs-2.0/mod/mod\\_ssl.html](http://httpd.apache.org/docs-2.0/mod/mod_ssl.html).

### 10.5.2. ServerRoot

The `ServerRoot` directive specifies the top-level directory containing website content. By default, `ServerRoot` is set to `"/etc/httpd"` for both secure and non-secure servers.

### 10.5.3. PidFile

`PidFile` names the file where the server records its process ID (PID). By default the PID is listed in `/var/run/httpd.pid`.

### 10.5.4. Timeout

`Timeout` defines, in seconds, the amount of time that the server waits for receipts and transmissions during communications. `Timeout` is set to 300 seconds by default, which is appropriate for most situations.

### 10.5.5. KeepAlive

`KeepAlive` sets whether the server allows more than one request per connection and can be used to prevent any one client from consuming too much of the server's resources.

By default `Keepalive` is set to `off`. If `Keepalive` is set to `on` and the server becomes very busy, the server can quickly spawn the maximum number of child processes. In this situation, the server slows down significantly. If `Keepalive` is enabled, it is a good idea to set the `KeepAliveTimeout` low (refer to Section 10.5.7 *KeepAliveTimeout* for more information about the `KeepAliveTimeout`

directive) and monitor the `/var/log/httpd/error_log` log file on the server. This log reports when the server is running out of child processes.

### 10.5.6. MaxKeepAliveRequests

This directive sets the maximum number of requests allowed per persistent connection. The Apache Project recommends a high setting, which improves the server's performance. `MaxKeepAliveRequests` is set to 100 by default, which should be appropriate for most situations.

### 10.5.7. KeepAliveTimeout

`KeepAliveTimeout` sets the number of seconds the server waits after a request has been served before it closes the connection. Once the server receives a request, the `Timeout` directive applies instead. `KeepAliveTimeout` is set to 15 seconds by default.

### 10.5.8. IfModule

`<IfModule>` and `</IfModule>` tags create a conditional container which are only activated if the specified module is loaded. Directives within the `IfModule` container are processed under one of two conditions. The directives are processed if the module contained within the starting `<IfModule>` tag is loaded. Or, if an exclamation point `!` appears before the module name, the directives are processed only if the module specified in the `<IfModule>` tag is *not* loaded.

For more information about Apache HTTP Server modules, refer to Section 10.7 *Adding Modules*.

### 10.5.9. MPM Specific Server-Pool Directives

As explained in Section 10.2.1.2 *Server-Pool Size Regulation*, under Apache HTTP Server 2.0 the responsibility for managing characteristics of the server-pool falls to a module group called MPMs. The characteristics of the server-pool differ depending upon which MPM is used. For this reason, an `IfModule` container is necessary to define the server-pool for the MPM in use.

By default, Apache HTTP Server 2.0 defines the server-pool for both the `prefork` and `worker` MPMs.

The following is a list of directives found within the MPM-specific server-pool containers.

#### 10.5.9.1. StartServers

`StartServers` sets how many server processes are created upon startup. Since the Web server dynamically kills and creates server processes based on traffic load, it is not necessary to change this parameter. The Web server is set to start 8 server processes at startup for the `prefork` MPM and 2 for the `worker` MPM.

#### 10.5.9.2. MaxRequestsPerChild

`MaxRequestsPerChild` sets the total number of requests each child server process serves before the child dies. The main reason for setting `MaxRequestsPerChild` is to avoid long-lived process induced memory leaks. The default `MaxRequestsPerChild` for the `prefork` MPM is 1000 and for the `worker` MPM is 0.

### 10.5.9.3. MaxClients

`MaxClients` sets a limit on the total number of server processes, or simultaneously connected clients, that can run at one time. The main purpose of this directive is to keep a runaway Apache HTTP Server from crashing the operating system. For busy servers this value should be set to a high value. The server's default is set to 150 regardless of the MPM in use. However, it is not recommended that the value for `MaxClients` exceeds 256 when using the `prefork` MPM.

### 10.5.9.4. MinSpareServers and MaxSpareServers

These values are only used with the `prefork` MPM. They adjust how the Apache HTTP Server dynamically adapts to the perceived load by maintaining an appropriate number of spare server processes based on the number of incoming requests. The server checks the number of servers waiting for a request and kills some if there are more than `MaxSpareServers` or creates some if the number of servers is less than `MinSpareServers`.

The default `MinSpareServers` value is 5; the default `MaxSpareServers` value is 20. These default settings should be appropriate for most situations. Be careful not to increase the `MinSpareServers` to a large number as doing so creates a heavy processing load on the server even when traffic is light.

### 10.5.9.5. MinSpareThreads and MaxSpareThreads

These values are only used with the `worker` MPM. They adjust how the Apache HTTP Server dynamically adapts to the perceived load by maintaining an appropriate number of spare server threads based on the number of incoming requests. The server checks the number of server threads waiting for a request and kills some if there are more than `MaxSpareThreads` or creates some if the number of servers is less than `MinSpareThreads`.

The default `MinSpareThreads` value is 25; the default `MaxSpareThreads` value is 75. These default settings should be appropriate for most situations. The value for `MaxSpareThreads` is must be greater than or equal to the sum of `MinSpareThreads` and `ThreadsPerChild` or Apache HTTP Server automatically corrects it.

### 10.5.9.6. ThreadsPerChild

This value is only used with the `worker` MPM. It sets the number of threads within each child process. The default value for this directive is 25.

## 10.5.10. Listen

The `Listen` command identifies the ports on which the Web server accepts incoming requests. By default, the Apache HTTP Server is set to listen to port 80 for non-secure Web communications and (in the `/etc/httpd/conf.d/ssl.conf` file which defines any secure servers) to port 443 for secure Web communications.

If the Apache HTTP Server is configured to listen to a port under 1024, only the root user can start it. For port 1024 and above, `httpd` can be started as a regular user.

The `Listen` directive can also be used to specify particular IP addresses over which the server accepts connections.

### 10.5.11. Include

`Include` allows other configuration files to be included at runtime.

The path to these configuration files can be absolute or relative to the `ServerRoot`.



#### Important

For the server to use individually packaged modules, such as `mod_ssl`, `mod_perl`, and `php`, the following directive must be included in Section 1: Global Environment of `httpd.conf`:

```
Include conf.d/*.conf
```

### 10.5.12. LoadModule

`LoadModule` is used to load in Dynamic Shared Object (DSO) modules. More information on the Apache HTTP Server's DSO support, including instructions for using the `LoadModule` directive, can be found in Section 10.7 *Adding Modules*. Note, the load order of the modules is *no longer important* with Apache HTTP Server 2.0. Refer to Section 10.2.1.3 *Dynamic Shared Object (DSO) Support* for more information about Apache HTTP Server 2.0 DSO support.

### 10.5.13. ExtendedStatus

The `ExtendedStatus` directive controls whether Apache generates basic (`off`) or detailed server status information (`on`), when the `server-status` handler is called. The `Server-status` handler is called using `Location` tags. More information on calling `server-status` is included in Section 10.5.59 *Location*.

### 10.5.14. IfDefine

The `IfDefine` tags surround configuration directives that are applied if the "test" stated in the `IfDefine` tag is true. The directives are ignored if the test is false.

The test in the `IfDefine` tags is a parameter name (for example, `HAVE_PERL`). If the parameter is defined, meaning that it is provided as an argument to the server's start-up command, then the test is true. In this case, when the Web server is started, the test is true and the directives contained in the `IfDefine` tags are applied.

### 10.5.15. User

The `User` directive sets the user name of the server process and determines what files the server is allowed to access. Any files inaccessible to this user are also inaccessible to clients connecting to the Apache HTTP Server.

By default `User` is set to `apache`.

**Note**

For security reasons, the Apache HTTP Server refuses to run as the root user.

**10.5.16. Group**

Specifies the group name of the Apache HTTP Server processes.

By default `Group` is set to `apache`.

**10.5.17. ServerAdmin**

Sets the `ServerAdmin` directive to the email address of the Web server administrator. This email address shows up in error messages on server-generated Web pages, so users can report a problem by sending email to the server administrator.

By default, `ServerAdmin` is set to `root@localhost`.

A common way to set up `ServerAdmin` is to set it to `webmaster@example.com`. Then alias `webmaster` to the person responsible for the Web server in `/etc/aliases` and run `/usr/bin/newaliases`.

**10.5.18. ServerName**

`ServerName` specifies a hostname and port number (matching the `Listen` directive) for the server. The `ServerName` does not need to match the machine's actual hostname. For example, the Web server may be `www.example.com`, but the server's hostname is actually `foo.example.com`. The value specified in `ServerName` must be a valid Domain Name Service (DNS) name that can be resolved by the system — do not make something up.

The following is a sample `ServerName` directive:

```
ServerName www.example.com:80
```

When specifying a `ServerName`, be sure the IP address and server name pair are included in the `/etc/hosts` file.

**10.5.19. UseCanonicalName**

When set to `on`, this directive configures the Apache HTTP Server to reference itself using the value specified in the `ServerName` and `Port` directives. When `UseCanonicalName` is set to `off`, the server instead uses the value used by the requesting client when referring to itself.

`UseCanonicalName` is set to `off` by default.

**10.5.20. DocumentRoot**

The `DocumentRoot` is the directory which contains most of the HTML files which are served in response to requests. The default `DocumentRoot` for both the non-secure and secure Web servers is the `/var/www/html` directory. For example, the server might receive a request for the following document:

```
http://example.com/foo.html
```



The server looks for the following file in the default directory:

```
/var/www/html/foo.html
```

To change the `DocumentRoot` so that it is not shared by the secure and the non-secure Web servers, refer to Section 10.8 *Virtual Hosts*.

### 10.5.21. Directory

`<Directory /path/to/directory>` and `</Directory>` tags create a container used to enclose a group of configuration directives which apply only to a specific directory and its subdirectories. Any directive which is applicable to a directory may be used within `Directory` tags.

By default, very restrictive parameters are applied to the root directory (`/`), using the `Options` (refer to Section 10.5.22 *Options*) and `AllowOverride` (refer to Section 10.5.23 *AllowOverride*) directives. Under this configuration, any directory on the system which needs more permissive settings has to be explicitly given those settings.

In the default configuration, another `Directory` container is configured for the `DocumentRoot` which assigns less rigid parameters to the directory tree so that the Apache HTTP Server can access the files residing there.

The `Directory` container can be also be used to configure additional `cgi-bin` directories for server-side applications outside of the directory specified in the `ScriptAlias` directive (refer to Section 10.5.40 *ScriptAlias* for more information about the `ScriptAlias` directive).

To accomplish this, the `Directory` container must set the `ExecCGI` option for that directory.

For example, if CGI scripts are located in `/home/my_cgi_directory`, add the following `Directory` container to the `httpd.conf` file:

```
<Directory /home/my_cgi_directory>
    Options +ExecCGI
</Directory>
```

Next, the `AddHandler` directive must be uncommented to identify files with the `.cgi` extension as CGI scripts. Refer to Section 10.5.55 *AddHandler* for instructions on setting `AddHandler`.

For this to work, permissions for CGI scripts, and the entire path to the scripts, must be set to `0755`.

### 10.5.22. Options

The `Options` directive controls which server features are available in a particular directory. For example, under the restrictive parameters specified for the root directory, `Options` is set to only `FollowSymLinks`. No features are enabled, except that the server is allowed to follow symbolic links in the root directory.

By default, in the `DocumentRoot` directory, `Options` is set to include `Indexes` and `FollowSymLinks`. `Indexes` permits the server to generate a directory listing for a directory if no `DirectoryIndex` (for example, `index.html`) is specified. `FollowSymLinks` allows the server to follow symbolic links in that directory.



#### Note

`Options` statements from the main server configuration section needs to be replicated to each `VirtualHost` containers individually. Refer to Section 10.5.65 *VirtualHost* for more information about `VirtualHost` containers.

### 10.5.23. AllowOverride

The `AllowOverride` directive sets whether any `Options` can be overridden by the declarations in an `.htaccess` file. By default, both the root directory and the `DocumentRoot` are set to allow no `.htaccess` overrides.

### 10.5.24. Order

The `Order` directive controls the order in which `allow` and `deny` directives are evaluated. The server is configured to evaluate the `Allow` directives before the `Deny` directives for the `DocumentRoot` directory.

### 10.5.25. Allow

`Allow` specifies which client can access a given directory. The client can be `all`, a domain name, an IP address, a partial IP address, a network/netmask pair, and so on. The `DocumentRoot` directory is configured to `Allow` requests from `all`, meaning everyone has access.

### 10.5.26. Deny

`Deny` works similar to `Allow`, except it specifies who is denied access. The `DocumentRoot` is not configured to `Deny` requests from anyone by default.

### 10.5.27. UserDir

`UserDir` is the subdirectory within each user's home directory where they should place personal HTML files which are served by the Web server. This directive is set to `disable` by default.

The name for the subdirectory is set to `public_html` in the default configuration. For example, the server might receive the following request:

```
http://example.com/~username/foo.html
```

The server would look for the file:

```
/home/username/public_html/foo.html
```

In the above example, `/home/username/` is the user's home directory (note that the default path to users' home directories may vary).

Make sure that the permissions on the users' home directories are set correctly. Users' home directories must be set to 0711. The read (r) and execute (x) bits must be set on the users' `public_html` directories (0755 also works). Files that are served in a users' `public_html` directories must be set to at least 0644.

### 10.5.28. DirectoryIndex

The `DirectoryIndex` is the default page served by the server when a user requests an index of a directory by specifying a forward slash (/) at the end of the directory name.

When a user requests the page `http://example/this_directory/`, they get either the `DirectoryIndex` page if it exists or a server-generated directory list. The default for `DirectoryIndex` is `index.html` and the `index.html.var` type map. The server tries to find either of these files and returns the first one it finds. If it does not find one of these files and `Options Indexes` is set for that directory, the server generates and returns a listing, in HTML format, of the subdirectories and files within the directory, unless the directory listing feature is turned off.

### 10.5.29. AccessFileName

`AccessFileName` names the file which the server should use for access control information in each directory. The default is `.htaccess`.

Immediately after the `AccessFileName` directive, a set of `Files` tags apply access control to any file beginning with a `.ht`. These directives deny Web access to any `.htaccess` files (or other files which begin with `.ht`) for security reasons.

### 10.5.30. CacheNegotiatedDocs

By default, the Web server asks proxy servers not to cache any documents which were negotiated on the basis of content (that is, they may change over time or because of the input from the requester). If `CacheNegotiatedDocs` is set to `on`, this function is disabled and proxy servers are allowed to such cache documents.

### 10.5.31. TypesConfig

`TypesConfig` names the file which sets the default list of MIME type mappings (file name extensions to content types). The default `TypesConfig` file is `/etc/mime.types`. Instead of editing `/etc/mime.types`, the recommended way to add MIME type mappings is to use the `AddType` directive.

For more information about `AddType`, refer to Section 10.5.54 `AddType`.

### 10.5.32. DefaultType

`DefaultType` sets a default content type for the Web server to use for documents whose MIME types cannot be determined. The default is `text/plain`.

### 10.5.33. HostnameLookups

`HostnameLookups` can be set to `on`, `off` or `double`. If `HostnameLookups` is set to `on`, the server automatically resolves the IP address for each connection. Resolving the IP address means that the server makes one or more connections to a DNS server, adding processing overhead. If `HostnameLookups` is set to `double`, the server performs a double-reverse DNS look up adding even more processing overhead.

To conserve resources on the server, `HostnameLookups` is set to `off` by default.

If hostnames are required in server log files, consider running one of the many log analyzer tools that perform the DNS lookups more efficiently and in bulk when rotating the Web server log files.

### 10.5.34. ErrorLog

`ErrorLog` specifies the file where server errors are logged. By default, this directive is set to `/var/log/httpd/error_log`.

### 10.5.35. LogLevel

`LogLevel` sets how verbose the error messages in the error logs are. `LogLevel` can be set (from least verbose to most verbose) to `emerg`, `alert`, `crit`, `error`, `warn`, `notice`, `info` or `debug`. The default `LogLevel` is `warn`.

### 10.5.36. LogFormat

The `LogFormat` directive configures the format of the various Web server log files. The actual `LogFormat` used depends on the settings given in the `CustomLog` directive (refer to Section 10.5.37 *CustomLog*).

The following are the format options if the `CustomLog` directive is set to `combined`:

`%h` (remote host's IP address or hostname)

Lists the remote IP address of the requesting client. If `HostnameLookups` is set to `on`, the client hostname is recorded unless it is not available from DNS.

`%l` (rfc931)

Not used. A hyphen [-] appears in the log file for this field.

`%u` (authenticated user)

If authentication was required, lists the user name of the user is recorded. Usually, this is not used, so a hyphen [-] appears in the log file for this field.

`%t` (date)

Lists the date and time of the request.

`%r` (request string)

Lists the request string exactly as it came from the browser or client.

`%s` (status)

Lists the HTTP status code which was returned to the client host.

`%b` (bytes)

Lists the size of the document.

`%\{%Referer%i\}` (referrer)

Lists the URL of the webpage which referred the client host to Web server.

`%\{%User-Agent%i\}` (user-agent)

Lists the type of Web browser making the request.

### 10.5.37. CustomLog

`CustomLog` identifies the log file and the log file format. By default, the log is recorded to the `/var/log/httpd/access_log` file.

The default `CustomLog` format is combined. The following illustrates the combined log file format:

```
remotehost rfc931 user date "request" status bytes referrer user-agent
```

### 10.5.38. ServerSignature

The `ServerSignature` directive adds a line containing the Apache HTTP Server server version and the `ServerName` to any server-generated documents, such as error messages sent back to clients. `ServerSignature` is set to on by default.

It can also be set to `off` or to `EEmail`. `EEmail`, adds a `mailto:ServerAdmin` HTML tag to the signature line of auto-generated responses.

### 10.5.39. Alias

The `Alias` setting allows directories outside the `DocumentRoot` directory to be accessible. Any URL ending in the alias automatically resolves to the alias' path. By default, one alias for an `icons/` directory is already set up. An `icons/` directory can be accessed by the Web server, but the directory is not in the `DocumentRoot`.

### 10.5.40. ScriptAlias

The `ScriptAlias` directive defines where CGI scripts are located. Generally, it is not good practice to leave CGI scripts within the `DocumentRoot`, where they can potentially be viewed as text documents. For this reason, a special directory outside of the `DocumentRoot` directory containing server-side executables and scripts is designated by the `ScriptAlias` directive. This directory is known as a `cgi-bin` and set to `/var/www/cgi-bin/` by default.

It is possible to establish directories for storing executables outside of the `cgi-bin` directory. For instructions on doing so, refer to Section 10.5.55 `AddHandler` and Section 10.5.21 `Directory`.

### 10.5.41. Redirect

When a webpage is moved, `Redirect` can be used to map the file location to a new URL. The format is as follows:

```
Redirect /<old-path>/<file-name> http://<current-domain>/<current-path>/<file-name>
```

In this example, replace `<old-path>` with the old path information for `<file-name>` and `<current-domain>` and `<current-path>` with the current domain and path information for `<file-name>`.

In this example, any requests for `<file-name>` at the old location is automatically redirected to the new location.

For more advanced redirection techniques, use the `mod_rewrite` module included with the Apache HTTP Server. For more information about configuring the `mod_rewrite` module, refer to the Apache Software Foundation documentation online at [http://httpd.apache.org/docs-2.0/mod/mod\\_rewrite.html](http://httpd.apache.org/docs-2.0/mod/mod_rewrite.html).

### 10.5.42. IndexOptions

`IndexOptions` controls the appearance of server generated directing listings, by adding icons, file descriptions, and so on. If `Options Indexes` is set (refer to Section 10.5.22 *Options*), the Web server generates a directory listing when the Web server receives an HTTP request for a directory without an index.

First, the Web server looks in the requested directory for a file matching the names listed in the `DirectoryIndex` directive (usually, `index.html`). If an `index.html` file is not found, Apache HTTP Server creates an HTML directory listing of the requested directory. The appearance of this directory listing is controlled, in part, by the `IndexOptions` directive.

The default configuration turns on `FancyIndexing`. This means that a user can re-sort a directory listing by clicking on column headers. Another click on the same header switches from ascending to descending order. `FancyIndexing` also shows different icons for different files, based upon file extensions.

The `AddDescription` option, when used in conjunction with `FancyIndexing`, presents a short description for the file in server generated directory listings.

`IndexOptions` has a number of other parameters which can be set to control the appearance of server generated directories. Parameters include `IconHeight` and `IconWidth`, to make the server include HTML `HEIGHT` and `WIDTH` tags for the icons in server generated webpages; `IconsAreLinks`, for making the icons act as part of the HTML link anchor along with the filename and others.

### 10.5.43. AddIconByEncoding

This directive names icons which are displayed by files with MIME encoding in server generated directory listings. For example, by default, the Web server shows the `compressed.gif` icon next to MIME encoded `x-compress` and `x-gzip` files in server generated directory listings.

### 10.5.44. AddIconByType

This directive names icons which are displayed next to files with MIME types in server generated directory listings. For example, the server shows the icon `text.gif` next to files with a mime-type of `text`, in server generated directory listings.

### 10.5.45. AddIcon

`AddIcon` specifies which icon to show in server generated directory listings for files with certain extensions. For example, the Web server is set to show the icon `binary.gif` for files with `.bin` or `.exe` extensions.

### 10.5.46. DefaultIcon

`DefaultIcon` specifies the icon displayed in server generated directory listings for files which have no other icon specified. The `unknown.gif` image file is the default.

### 10.5.47. AddDescription

When using `FancyIndexing` as an `IndexOptions` parameter, the `AddDescription` directive can be used to display user-specified descriptions for certain files or file types in a server generated directory listing. The `AddDescription` directive supports listing specific files, wildcard expressions, or file extensions.

### 10.5.48. ReadmeName

`ReadmeName` names the file which, if it exists in the directory, is appended to the end of server generated directory listings. The Web server first tries to include the file as an HTML document and then try to include it as plain text. By default, `ReadmeName` is set to `README.html`.

### 10.5.49. HeaderName

`HeaderName` names the file which, if it exists in the directory, is prepended to the start of server generated directory listings. Like `ReadmeName`, the server tries to include it as an HTML document if possible or in plain text if not.

### 10.5.50. IndexIgnore

`IndexIgnore` lists file extensions, partial file names, wildcard expressions or full filenames. The Web server does not include any files which match any of those parameters in server generated directory listings.

### 10.5.51. AddEncoding

`AddEncoding` names filename extensions which should specify a particular encoding type. `AddEncoding` can also be used to instruct some browsers to uncompress certain files as they are downloaded.

### 10.5.52. AddLanguage

`AddLanguage` associates file name extensions with specific languages. This directive is useful for Apache HTTP Servers which serve content in multiple languages based on the client Web browser's language settings.

### 10.5.53. LanguagePriority

`LanguagePriority` sets precedence for different languages in case the client Web browser has no language preference set.

### 10.5.54. AddType

Use the `AddType` directive to define or override a default MIME type and file extension pairs. The following example directive tells the Apache HTTP Server to recognize the `.tgz` file extension:

```
AddType application/x-tar .tgz
```

### 10.5.55. AddHandler

`AddHandler` maps file extensions to specific handlers. For example, the `cgi-script` handler can be matched with the extension `.cgi` to automatically treat a file ending with `.cgi` as a CGI script. The following is a sample `AddHandler` directive for the `.cgi` extension.

```
AddHandler cgi-script .cgi
```

This directive enables CGIs outside of the `cgi-bin` to function in any directory on the server which has the `ExecCGI` option within the directories container. Refer to Section 10.5.21 *Directory* for more information about setting the `ExecCGI` option for a directory.

In addition to CGI scripts, the `AddHandler` directive is used to process server-parsed HTML and image-map files.

### 10.5.56. Action

`Action` specifies a MIME content type and CGI script pair, so that whenever a file of that media type is requested, a particular CGI script is executed.

### 10.5.57. ErrorDocument

The `ErrorDocument` directive associates an HTTP response code with a message or a URL to be sent back to the client. By default, the Web server outputs a simple and usually cryptic error message when an error occurs. The `ErrorDocument` directive forces the Web server to instead output a customized message or page.



#### Important

To be valid, the message *must* be enclosed in a pair of double quotes ["].

### 10.5.58. BrowserMatch

The `BrowserMatch` directive allows the server to define environment variables and take appropriate actions based on the User-Agent HTTP header field — which identifies the client's Web browser type. By default, the Web server uses `BrowserMatch` to deny connections to specific browsers with known problems and also to disable keepalives and HTTP header flushes for browsers that are known to have problems with those actions.

### 10.5.59. Location

The `<Location>` and `</Location>` tags create a container in which access control based on URL can be specified.

For instance, to allow people connecting from within the server's domain to see status reports, use the following directives:

```
<Location /server-status>
    SetHandler server-status
    Order deny,allow
    Deny from all
    Allow from <.example.com>
</Location>
```

Replace `<.example.com>` with the second-level domain name for the Web server.

To provide server configuration reports (including installed modules and configuration directives) to requests from inside the domain, use the following directives:

```
<Location /server-info>
```



```

    SetHandler server-info
    Order deny,allow
    Deny from all
    Allow from <.example.com>
</Location>

```

Again, replace `<.example.com>` with the second-level domain name for the Web server.

### 10.5.60. ProxyRequests

To configure the Apache HTTP Server to function as a proxy server, remove the hash marks from the beginning of the `<IfModule mod_proxy.c>` line to load the `mod_proxy` module and set the `ProxyRequests` directive to `On`.

### 10.5.61. Proxy

`<Proxy *>` and `</Proxy>` tags create a container which encloses a group of configuration directives meant to apply only to the proxy server. Many directives which are allowed within a `<Directory>` container may also be used within `<Proxy>` container.

### 10.5.62. ProxyVia

The `ProxyVia` command controls whether or not an HTTP `Via:` header line is sent along with requests or replies which go through the Apache proxy server. The `Via:` header shows the hostname if `ProxyVia` is set to `On`, shows the hostname and the Apache HTTP Server version for `Full`, passes along any `Via:` lines unchanged for `Off`, and `Via:` lines are removed for `Block`.

### 10.5.63. Cache Directives

A number of commented cache directives are supplied by the default Apache HTTP Server configuration file. In most cases, uncommenting these lines by removing the hash mark `#` from the beginning of the line is sufficient. The following, however, is a list of some of the more important cache-related directives.

- `CacheEnable` — Specifies whether the cache is a disk, memory, or file descriptor cache. By default `CacheEnable` configures a disk cache for URLs at or below `/`.
- `CacheRoot` — Specifies the name of the directory containing cached files. The default `CacheRoot` is the `/var/httpd/proxy/` directory.
- `CacheSize` — Specifies how much space the cache can use in kilobytes. The default `CacheSize` is 5 KB.

The following is a list of some of the other common cache-related directives.

- `CacheMaxExpire` — Specifies how long HTML documents are retained (without a reload from the originating Web server) in the cache. The default is 24 hours (86400 seconds).
- `CacheLastModifiedFactor` — Specifies the creation of an expiry (expiration) date for a document which did not come from its originating server with its own expiry set. The default `CacheLastModifiedFactor` is set to 0.1, meaning that the expiry date for such documents equals one-tenth of the amount of time since the document was last modified.
- `CacheDefaultExpire` — Specifies the expiry time in hours for a document that was received using a protocol that does not support expiry times. The default is set to 1 hour (3600 seconds).

- `NoProxy` — Specifies a space-separated list of subnets, IP addresses, domains, or hosts whose content is not cached. This setting is most useful for Intranet sites.

### 10.5.64. NameVirtualHost

The `NameVirtualHost` directive associates an IP address and port number, if necessary, for any name-based virtual hosts. Name-based virtual hosting allows one Apache HTTP Server to serve different domains without using multiple IP addresses.



#### Note

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.

To enable name-based virtual hosting, uncomment the `NameVirtualHost` configuration directive and add the correct IP address. Then add more `VirtualHost` containers for each virtual host.

### 10.5.65. VirtualHost

`<VirtualHost>` and `</VirtualHost>` tags create a container outlining the characteristics of a virtual host. The `VirtualHost` container accepts most configuration directives.

A commented `VirtualHost` container is provided in `httpd.conf`, which illustrates the minimum set of configuration directives necessary for each virtual host. Refer to Section 10.8 *Virtual Hosts* for more information about virtual hosts.



#### Note

The default SSL virtual host container has been moved into the file `/etc/httpd/conf.d/ssl.conf`.

### 10.5.66. Configuration Directives for SSL

The directives in `/etc/httpd/conf.d/ssl.conf` file can be configured to enable secure Web communications using SSL and TLS.

#### 10.5.66.1. SetEnvIf

`SetEnvIf` sets environment variables based on the headers of incoming connections. It is *not* solely an SSL directive, though it is present in the supplied `/etc/httpd/conf.d/ssl.conf` file. Its purpose in this context is to disable HTTP keepalive and to allow SSL to close the connection without a close notify alert from the client browser. This setting is necessary for certain browsers that do not reliably shut down the SSL connection.

For more information on other directives within the SSL configuration file, direct a Web browser to either of the following addresses:

- [http://localhost/manual/mod/mod\\_ssl.html](http://localhost/manual/mod/mod_ssl.html)
- [http://httpd.apache.org/docs-2.0/mod/mod\\_ssl.html](http://httpd.apache.org/docs-2.0/mod/mod_ssl.html)

For information about setting up an Apache HTTP Secure Server, Refer to the chapter titled *Apache HTTP Secure Server Configuration* in the *Red Hat Enterprise Linux System Administration Guide*.

**Note**

In most cases, the SSL directives are configured appropriately as installed. Be cautious when altering Apache HTTP Secure Server directives as misconfiguration can lead to security vulnerabilities.

## 10.6. Default Modules

The Apache HTTP Server is distributed with a number of modules. By default the following modules are installed and enabled with the `httpd` package under Red Hat Enterprise Linux 3:

```
mod_access.so
mod_auth.so
mod_auth_anon.so
mod_auth_dbm.so
mod_auth_digest.so
mod_include.so
mod_log_config.so
mod_env.so
mod_mime_magic.so
mod_cern_meta.so
mod_expires.so
mod_headers.so
mod_usertrack.so
mod_unique_id.so
mod_setenvif.so
mod_mime.so
mod_dav.so
mod_status.so
mod_autoindex.so
mod_asis.so
mod_info.so
mod_dav_fs.so
mod_vhost_alias.so
mod_negotiation.so
mod_dir.so
mod_imap.so
mod_actions.so
mod_speling.so
mod_userdir.so
mod_alias.so
mod_rewrite.so
mod_proxy.so
mod_proxy_ftp.so
mod_proxy_http.so
mod_proxy_connect.so
mod_cache.so
mod_disk_cache.so
mod_file_cache.so
mod_mem_cache.so
mod_cgi.so
```

Additionally, the following modules are available by installing additional packages:

```
mod_auth_mysql
mod_auth_pgsql
mod_perl
mod_python
mod_ssl
php
```

## 10.7. Adding Modules

The Apache HTTP Server supports *Dynamically Shared Objects (DSOs)* or modules, which can easily be loaded at runtime as necessary.

The Apache Project provides complete DSO Documentation at online <http://httpd.apache.org/docs-2.0/dso.html>. Or, if the `http-manual` package is installed, documentation about DSOs can be found online at <http://localhost/manual/mod/>.

For the Apache HTTP Server to use a DSO, it must be specified in a `LoadModule` directive within `/etc/httpd/conf/httpd.conf`; if the module is provided by a separate package, the line must appear within the modules configuration file in the `/etc/httpd/conf.d/` directory. Refer to Section 10.5.12 *LoadModule* for more about the `LoadModule` directive.

If adding or deleting modules from `http.conf`, Apache HTTP Server must be reloaded or restarted, as covered in Section 10.4 *Starting and Stopping httpd*.

If creating a new module, first install the `httpd-devel` package as it contains the include files, the header files, as well as the *APache eXtension* (`/usr/sbin/apxs`) application, which uses the include files and the header files to compile DSOs.

After writing a module, use `/usr/sbin/apxs` to compile the module sources outside the Apache source tree. For more information about using the `/usr/sbin/apxs` command, refer to the the Apache documentation online at <http://httpd.apache.org/docs-2.0/dso.html> and the `apxs` man page.

Once compiled, put the module in the `/usr/lib/httpd/modules/` directory. Then add a `LoadModule` line to the `httpd.conf`, using the following structure:

```
LoadModule <module-name>
<path/to/module.so>
```

In the above example, change `<module-name>` to the name of the module and `<path/to/module.so>` to the path to the DSO.

## 10.8. Virtual Hosts

The Apache HTTP Server's built in virtual hosting allows the server to serve different information based on which IP address, hostname, or port is being requested. A complete guide to using virtual hosts is available online at <http://httpd.apache.org/docs-2.0/vhosts/>.

### 10.8.1. Setting Up Virtual Hosts

To create a name-based virtual host, it is best to use the virtual host container provided in `httpd.conf` as an example.

The virtual host example read as follows:

```
#NameVirtualHost *
#
```

```
#<VirtualHost *>
#   ServerAdmin webmaster@dummy-host.example.com
#   DocumentRoot /www/docs/dummy-host.example.com
#   ServerName dummy-host.example.com
#   ErrorLog logs/dummy-host.example.com-error_log
#   CustomLog logs/dummy-host.example.com-access_log common
#</VirtualHost>
```

To activate name-based virtual hosting, uncomment the `NameVirtualHost` line by removing the hash mark (`#`) and replace the asterisk (`*`) with the IP address assigned to the machine.

Next, configure a virtual host, by uncommenting and customizing the `<VirtualHost>` container.

On the `<VirtualHost>` line, change the asterisk (`*`) to the server's IP address. Change the `ServerName` to a *valid* DNS name assigned to the machine, and configure the other directives as necessary.

The `<VirtualHost>` container is highly customizable and accepts almost every directive available within the main server configuration.



### Tip

If configuring a virtual host to listen on a non-default port, that port must be added to the `Listen` directive in the global settings section of `/etc/httpd/conf/httpd.conf` file.

To activate a newly created virtual host the Apache HTTP Server must be reloaded or restarted. Refer to Section 10.4 *Starting and Stopping httpd* for instructions on doing this.

Comprehensive information about creating and configuring both name-based and IP address-based virtual hosts is provided online at <http://httpd.apache.org/docs-2.0/vhosts/>.

## 10.8.2. The Secure Web Server Virtual Host

By default, the Apache HTTP Server is configured as both a non-secure and a secure server. Both the non-secure and secure servers use the same IP address and host name, but listen on different ports: 80 and 443 respectively. This enables both non-secure and secure communications to take place simultaneously.

One aspect of SSL enhanced HTTP transmissions is that they are more resource intensive than the standard HTTP protocol, so a secure server cannot serve as many pages per second. For this reason it is often a good idea to minimize the information available from the secure server, especially on a high traffic Web site.



### Important

Do not use name-based virtual hosts in conjunction with a secure Web server as the SSL handshake occurs before the HTTP request identifies the appropriate name-based virtual host. Name-based virtual hosts only work with the non-secure Web server.

The configuration directives for the secure server are contained within virtual host tags in the `/etc/httpd/conf.d/ssl.conf` file.

By default, both the secure and the non-secure Web servers share the same `DocumentRoot`. It is recommended that the `DocumentRoot` be different for the secure Web server.

To stop the non-secure Web server from accepting connection, comment the line in `httpd.conf` which reads `Listen 80` by placing a hash mark at the beginning of the line. When finished, it the line looks like the following example:

```
#Listen 80
```

For more information on configuring an SSL enhanced Web server, refer to the chapter titled *Apache HTTP Secure Server Configuration* in the *Red Hat Enterprise Linux System Administration Guide*. For advanced configuration tips, refer to the Apache Software Foundation documentation available online at the following URLs:

- <http://httpd.apache.org/docs-2.0/ssl/>
- <http://httpd.apache.org/docs-2.0/vhosts/>

## 10.9. Additional Resources

To learn more about the Apache HTTP Server, refer to the following resources.

### 10.9.1. 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/> — The official website for `mod_ssl`.
- <http://www.apacheweek.com/> — A comprehensive online weekly newsletter about all things Apache.

### 10.9.2. Related Books

- *Apache Desktop Reference* by Ralf S. Engelschall; Addison Wesley — Written by ASF member and `mod_ssl` author Ralf Engelschall, the *Apache Desktop Reference* provides a concise but comprehensive reference guide to using the Apache HTTP Server at compilation, configuration, and run time. This book is available online at <http://www.apacheref.com/>.
- *Professional Apache* by Peter Wainwright; Wrox Press Ltd — *Professional Apache* is from Wrox Press Ltd's "Programmer to Programmer" series and is aimed at both experienced and novice Web server administrators.
- *Administering Apache* by Mark Allan Arnold; Osborne Media Group — This book is targeted at Internet Service Providers who aim to provide more secure services.
- *Apache Server Unleashed* by Richard Bowen, et al; SAMS BOOKS — An encyclopedic source for the Apache HTTP Server.
- *Apache Pocket Reference* by Andrew Ford, Gigi Estabrook; O'Reilly — This is the latest addition to the O'Reilly Pocket Reference series.
- *Red Hat Enterprise Linux System Administration Guide*; Red Hat, Inc. — Contains a chapter about configuring the Apache HTTP Server using the **HTTP Configuration Tool** and a chapter about configuring the Apache HTTP Server Secure Server.

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 chapter outlines the basics of the FTP protocol, as well as configuration options for the primary FTP server shipped with Red Hat Enterprise Linux, `vsftpd`.

## 11.1. The File Transport Protocol

FTP uses a client server architecture to transfer files using the TCP network protocol. Because FTP is an older protocol, it uses unencrypted username and password authentication. For this reason, it is considered an insecure protocol and should not be used unless absolutely necessary. A good substitute for FTP is `sftp` from the OpenSSH suite of tools. For information about configuring OpenSSH, refer to the chapter titled *OpenSSH* in *Red Hat Enterprise Linux System Administration Guide*. For more information about the SSH protocol, refer to Chapter 19 *SSH 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.

### 11.1.1. 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 are descriptions of these two 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. Limiting the range of unprivileged ports offered for passive connections in the FTP server's configuration file is one way to limit the

number of open ports on a server and simplify the task of creating firewall rules for the server. Refer to Section 11.5.8 *Network Options* for more about limiting passive ports.

## 11.2. FTP Servers

Red Hat Enterprise Linux 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 as 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/tux/>.
- `vsftpd` — a fast, secure FTP daemon which is the preferred FTP server for Red Hat Enterprise Linux. The remainder of this chapter focuses on `vsftpd`.

### 11.2.1. `vsftpd`

The `vsftpd` or Very Secure FTP Daemon is designed from the ground up to be fast, stable, and, most importantly, secure. Its ability to handle large numbers of connections efficiently and securely is why `vsftpd` is the only stand alone FTP distributed with Red Hat Enterprise Linux.

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 `libcapp` 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.

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 distrusted 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.



### 11.3. 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 is a list of the files and directories most often considered when configuring `vsftpd`:

- `/etc/rc.d/init.d/vsftpd` — The *initialization script* (*initscript*) used by the `/sbin/service` command to start, stop, or reload `vsftpd`. Refer to Section 11.4 *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 defines the requirements a user must meet to login to the FTP server. For more information about PAM, refer to Chapter 15 *Pluggable Authentication Modules (PAM)*.
- `/etc/vsftpd/vsftpd.conf` — The configuration file for `vsftpd`. Refer to Section 11.5 *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 access to the users listed or allow the listed users access, 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/` directory — 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.

### 11.4. Starting and Stopping vsftpd

The `vsftpd` RPM installs the `/etc/rc.d/init.d/vsftpd` script, which can be accessed using the `/sbin/service` command.

To start the server, as root type:

```
/sbin/service vsftpd start
```

To stop the server, as root type:

```
/sbin/service vsftpd stop
```

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:

```
/sbin/service vsftpd restart
```

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:

```
/sbin/service vsftpd condrestart
```

By default, the `vsftpd` service does *not* start automatically at boot time. To configure the `vsftpd` service to start up at boot time, use an *initscript* utility, such as `/sbin/chkconfig`, `/sbin/ntsysv`, or the **Services Configuration Tool** program. Refer to the chapter titled *Controlling Access to Services* in *Red Hat Enterprise Linux System Administration Guide* for more information regarding these tools.

### 11.4.1. 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. Refer to the chapter titled *Network Configuration* in *Red Hat Enterprise Linux System Administration Guide* for more information about configuring network devices and device aliases. Additional information can be found about network configuration scripts in Chapter 8 *Network Interfaces*.

Next, the DNS server for the FTP domains must be configured to reference the correct machine. If the DNS server is running on Red Hat Enterprise Linux, refer to the chapter titled *BIND Configuration* in *Red Hat Enterprise Linux System Administration Guide* for instructions about using the **Domain Name Service Configuration Tool** (`redhat-config-bind`). For information about BIND and its configuration files, refer to Chapter 13 *Berkeley Internet Name Domain (BIND)*.

For `vsftpd` to answer requests on different IP addresses, multiple copies of the daemon must be running. The first copy must be run using the `vsftpd` initscripts, as outlined in Section 11.4 *Starting and Stopping vsftpd*. This copy uses the standard configuration file, `/etc/vsftpd/vsftpd.conf`.

Each additional FTP site must have a configuration file with a unique name in the `/etc/vsftpd/` directory, such as `/etc/vsftpd/vsftpd-site-2.conf`. Each configuration file must be readable and writable only by root. Within each configuration file for each FTP server listening on an IPv4 network, the following directive must be unique:

```
listen_address=N.N.N.N
```

Replace `N.N.N.N` with the *unique* IP address for the FTP site being served. If the site is using IPv6, use the `listen_address6` directive instead.

Once each additional server has a configuration file, the `vsftpd` daemon must be launched from a root shell prompt using the following command:

```
vsftpd /etc/vsftpd/<configuration-file> &
```

In the above command, replace `<configuration-file>` with the unique name for the server's configuration file, such as `/etc/vsftpd/vsftpd-site-2.conf`.

Other directives to consider altering on a per-server basis are:

- `anon_root`
- `local_root`
- `vsftpd_log_file`
- `xferlog_file`

For a detailed list of directives available within `vsftpd`'s configuration file, refer to Section 11.5 *vsftpd Configuration Options*.

To configure any additional servers to start automatically at boot time, add the above command to the end of the `/etc/rc.local` file.

## 11.5. `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.



### Important

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 mark (`#`) and are ignored by the daemon.

For a complete list of all directives available, refer to the man page for `vsftpd.conf`.



### Important

For an overview of ways to secure `vsftpd`, refer to the chapter titled *Server Security* in the *Red Hat Enterprise Linux Security Guide*.

The following is a list of some of the more important directives within `/etc/vsftpd/vsftpd.conf`. All directives not explicitly found within `vsftpd`'s configuration file are set to their default value.

## 11.5.1. Daemon Options

The following is a list of directives which control the overall behavior of the `vsftpd` daemon.

- `listen` — When enabled, `vsftpd` runs in standalone mode. Red Hat Enterprise Linux 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 standalone mode, but listen 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). Refer to Chapter 15 *Pluggable Authentication Modules (PAM)* for more information about PAM. If session logging is not necessary, disabling this option allows `vsftpd` to run with less processes and lower privileges.  
The default value is `YES`.

## 11.5.2. Log In Options and Access Controls

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 11.5.3 *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 using 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 `NO`.

Refer to Section 11.5.4 *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`, however under Red Hat Enterprise Linux the value is set to `vsftpd`.

- `tcp_wrappers` — When enabled, TCP wrappers are used to grant access to the server. Also, if the FTP server is configured on multiple IP addresses, the `VSETPD_LOAD_CONF` option can be used to load different configuration files based on the IP address being requested by the client. For more information about TCP Wrappers, refer to Chapter 16 *TCP Wrappers and xinetd*.

The default value is `NO`, however under Red Hat Enterprise Linux the value is set to `YES`.

- `userlist_deny` — 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 Red Hat Enterprise Linux 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`.

- `cmds_allowed` — Specifies a comma separated list of FTP commands that the server allows. Any other commands are rejected.

There is no default value for this directive.

### 11.5.3. Anonymous User Options

The following is a list of directives which control anonymous user access to the server. To use these options, the `anonymous_enable` directive must be set to `YES`.

- `anon_mkdir_write_enable` — 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`.
- `ftp_username` — 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 `ftp`.
- `no_anon_password` — When enabled, the anonymous user is not asked for a password.  
The default value is `NO`.

### 11.5.4. Local User Options

The following is a list of 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`.

**Warning**

Using this configuration 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.

- `passwd_chroot_enable` — When enabled in conjunction with the `chroot_local_user` directive, `vsftpd` change-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.

### 11.5.5. Directory Options

The following is a list of 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 is found within the directory being entered. The name of this file is specified in the `message_file` directive and is `.message` by default.

The default value is `NO`, however under Red Hat Enterprise Linux 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, test 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`.

### 11.5.6. File Transfer Options

The following is a list of 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 `NO`.

### 11.5.7. Logging Options

The following is a list of directives which affect `vsftpd`'s logging behavior.

- `dual_log_enable` — When enabled in conjunction with `xferlog_enable`, `vsftpd` writes two files simultaneously: a `wu-ftp-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/xferlog` 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`, however under Red Hat Enterprise Linux the value is set to `YES`.

- `xferlog_file` — Specifies the `wu-ftp-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-ftp-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`, however under Red Hat Enterprise Linux the value is set to `YES`.



### Important

To maintain compatibility with log files written by the older `wu-ftp` FTP server, the `xferlog_std_format` directive is set to `YES` under Red Hat Enterprise Linux. However, this setting means that connections to the server are not logged.

To both log connections in `vsftpd` format and maintain a `wu-ftp-compatible` file transfer log, set `dual_log_enable` to `YES`.

If maintaining a `wu-ftp-compatible` file transfer log is not important, either set `xferlog_std_format` to `NO`, comment the line with a hash mark (`#`), or delete the line entirely.

## 11.5.8. Network Options

The following is a list of 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`, however under Red Hat Enterprise Linux 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`.

- `idle_session_timeout` — Specifies the maximum amount of time between commands from a remote client. Once triggered, the connection to the remote client is closed.



The default value is 300.

- `listen_address` — Specifies the IP address on which `vsftpd` listens for network connections.

There is no default value for this directive.



#### Tip

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 11.4.1 *Starting Multiple Copies of vsftpd* for more information about multihomed FTP servers.

- `listen_address6` — Specifies the IPv6 address on which `vsftpd` listens for network connections when `listen_ipv6` is set to `YES`.

There is no default value for this directive.



#### Tip

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 11.4.1 *Starting Multiple Copies of vsftpd* for more information about multihomed FTP servers.

- `listen_port` — Specifies the port on which `vsftpd` listens for network connections.

The default value is 21.

- `local_max_rate` — Specifies the maximum rate data is transferred for local users logged into the server in bytes per second.

The default value is 0, which does not limit the transfer rate.

- `max_clients` — Specifies the maximum number of simultaneous clients allowed to connect to the server when it is running in standalone mode, in bytes per second.

The default value is 0, which does not limit connections.

- `max_per_ip` — Specifies the maximum of clients allowed to connected from the same source IP address.

The default value is 0, which does not limit connections.

- `pasv_address` — Specifies the IP address for the public facing IP address of the server for servers behind Network Address Translation (NAT) firewalls. This enables `vsftpd` to hand out the correct return address for passive mode connections.

There is no default value for this directive.

- `pasv_enable` — When enabled, passive mode connects are allowed.

The default value is `YES`.

- `pasv_max_port` — Specifies the highest possible port sent to the FTP clients for passive mode connections. This setting is used to limit the port range so that firewall rules are easier to create.

The default value is 0, which does not limit the highest passive port range. The value must not exceed 65535.

- `pasv_min_port` — Specifies the lowest possible port sent to the FTP clients for passive mode connections. This setting is used to limit the port range so that firewall rules are easier to create.

The default value is 0, which does not limit the lowest passive port range. The value must not be lower 1024.

- `pasv_promiscuous` — When enabled, data connections are not checked to make sure they are originating from the same IP address. This setting is only useful for certain types of tunneling.



### Caution

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 `NO`.

## 11.6. Additional Resources

For more information about `vsftpd`, refer to the following resources.

### 11.6.1. Installed Documentation

- The `/usr/share/doc/vsftpd-<version-number>/` directory — Replace `<version-number>` with the installed version of the `vsftpd` package. This directory contains a `README` with basic information about the software. The `TUNING` file contains basic performance tuning tips and the `SECURITY/` directory contains information about the security model employed by `vsftpd`.
- `vsftpd` related man pages — There are a number of man pages for the daemon and configuration files. The following is a list of some of the more important man pages.

#### Server Applications

- `man vsftpd` — Describes available command line options for `vsftpd`.

#### Configuration Files

- `man vsftpd.conf` — Contains a detailed list of options available within the configuration file for `vsftpd`.
- `man 5 hosts_access` — Describes the format and options available within the TCP wrappers configuration files: `hosts.allow` and `hosts.deny`.

### 11.6.2. Useful Websites

- <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> — This website provides a concise explanation of the differences between active and passive mode FTP.
- <http://war.jgaa.com/ftp/?cmd=rfc> — A comprehensive list of *Request for Comments (RFCs)* related to the FTP protocol.

### 11.6.3. Related Books

- *Red Hat Enterprise Linux Security Guide*; Red Hat, Inc. — The *Server Security* chapter explains ways to secure `vsftpd` and other services.



The birth of electronic mail (*email*) occurred in the early 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 had to 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. Red Hat Enterprise Linux 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.

## 12.1. 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.

### 12.1.1. 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)*.

#### 12.1.1.1. 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 Red Hat Enterprise Linux, 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. Modern SMTP servers attempt to minimize this behavior by allowing only known hosts access to the SMTP server. Those servers that do not impose such restrictions are called *open relay* servers.

By default, Sendmail (`/usr/sbin/sendmail`) is the default SMTP program under Red Hat Enterprise Linux. However, a simpler mail server application called Postfix (`/usr/sbin/postfix`) is also available.

### 12.1.2. 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)*.

Unlike SMTP, both of these protocols require connecting clients to authenticate using a username and password. By default, passwords for both protocols are passed over the network unencrypted.

#### 12.1.2.1. POP

The default POP server under Red Hat Enterprise Linux is `/usr/sbin/ipop3d` and is provided by the `imap` package. 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 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. Refer to Chapter 18 *Kerberos* for more information about Kerberos.
- *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 `ipop3s` service or by using the `/usr/sbin/stunnel` program. Refer to Section 12.5.1 *Securing Communication* for more information.

#### 12.1.2.2. IMAP

The default IMAP server under Red Hat Enterprise Linux is `/usr/sbin/imapd` and is provided by the `imap` package. 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 those 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 `imap`s service, or by using the `/usr/sbin/stunnel` program. Refer to Section 12.5.1 *Securing Communication* for more information.

Other free, as well as commercial, IMAP clients and servers are available, many of which extend the IMAP protocol and provide additional functionality. A comprehensive list can be found online at <http://www.imap.org/products/longlist.htm>.

## 12.2. 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.

### 12.2.1. Mail Transfer Agent

A *Mail Transfer Agent (MTA)* transfers 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 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 Red Hat Enterprise Linux installs two MTAs, Sendmail and Postfix, email client programs are often not required to act as an MTA. Red Hat Enterprise Linux also includes a special purpose MTA called Fetchmail.

For more information on Sendmail, Postfix, and Fetchmail, refer to Section 12.3 *Mail Transport Agents*.

### 12.2.2. 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.

### 12.2.3. Mail User Agent

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 **Mozilla Mail**, or have a very simple, text-based interface, such as `mutt`.

## 12.3. Mail Transport Agents

Red Hat Enterprise Linux includes two primary MTAs, Sendmail and Postfix. Sendmail is configured as the default MTA, although it is easy to switch the default MTA to Postfix.



### Tip

For information about how to switch the default MTA from Sendmail to Postfix, refer to the chapter called *Mail Transport Agent (MTA) Configuration* in the *Red Hat Enterprise Linux System Administration Guide*.

### 12.3.1. 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.

#### 12.3.1.1. 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. They 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 12.6 *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)*.

#### 12.3.1.2. The Default Sendmail Installation

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. Instead, to make configuration changes to Sendmail, edit the `/etc/mail/sendmail.mc` file, back up the original `/etc/mail/sendmail.cf`, and then use the included `m4` macro processor to create a new `/etc/mail/sendmail.cf`. More information on configuring Sendmail can be found in Section 12.3.1.3 *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 command:

```
makemap hash /etc/mail/<name> < /etc/mail/<name>
```

Where `<name>` is replaced with the name of the configuration file to convert.

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 using the following command as root:

```
makemap hash /etc/mail/virtusertable < /etc/mail/virtusertable
```

This creates a new `virtusertable.db` file containing the new configuration.

### 12.3.1.3. Common Sendmail Configuration Changes

When altering the Sendmail configuration file, it is best generate an entirely new `/etc/mail/sendmail.cf` file instead of editing an existing one.



#### Caution

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 the root user. When finished, use the `m4` macro processor to generate a new `sendmail.cf` by executing the following command:

```
m4 /etc/mail/sendmail.mc > /etc/mail/sendmail.cf
```

By default, the `m4` macro processor is installed with Sendmail but is part of the `m4` package.

After creating a new `/etc/mail/sendmail.cf` file, restart Sendmail for the changes to take effect. The easiest way to do this is to type the following command:

```
/sbin/service sendmail restart
```



### Important

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 all together by placing `dnl` at the beginning of the line. When finished, regenerate `/etc/mail/sendmail.cf` by executing the following command:

```
m4 /etc/mail/sendmail.mc > /etc/mail/sendmail.cf
```

The default configuration which ships with Red Hat Enterprise Linux works for most SMTP-only sites. However, it does not work for UUCP (UNIX to UNIX Copy) sites. If using UUCP mail transfers, the `/etc/mail/sendmail.mc` file must be reconfigured and a new `/etc/mail/sendmail.cf` 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 `/etc/mail/sendmail.cf` files.

#### 12.3.1.4. 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`:

```
FEATURE(always_add_domain)dnl
FEATURE('masquerade_entire_domain')
FEATURE('masquerade_envelope')
FEATURE('allmasquerade')
MASQUERADE_AS('bigcorp.com.')
MASQUERADE_DOMAIN('bigcorp.com.')
MASQUERADE_AS(bigcorp.com)
```

After generating a new `sendmail.cf` using `m4`, this configuration makes all mail from inside the network appear as if it were sent from `bigcorp.com`.

#### 12.3.1.5. 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.

For example, forwarding of SMTP messages, also called relaying, has been disabled by default since Sendmail version 8.9. Before this change occurred, Sendmail directs the mail host (`x.org`) 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.

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:

```
badspammer.com      ERROR:550 "Go away and do not spam us anymore"
tux.badspammer.com  OK
10.0                RELAY
```

This example states that any email sent from `badspammer.com` is blocked with a 550 RFC-821 compliant error code, with a message sent back to the spammer. Email sent from the `tux.badspammer.com` sub-domain, is accepted. The last line shows that any email sent from the `10.0.*.*` network can be relayed through the mail server.

Because `/etc/mail/access.db` is a database, use `makemap` to activate any changes. Do this using the following command as root:

```
makemap hash /etc/mail/access < /etc/mail/access
```

This example only represents only 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 12.4.2.6 *Spam Filters* for more about using SpamAssassin.

### 12.3.1.6. Using Sendmail with LDAP

Using the *Lightweight Directory Access Protocol (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 `aliases` and `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:

```
LDAPROUTE_DOMAIN('yourdomain.com')dnl
FEATURE('ldap_routing')dnl
```

**Note**

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 `m4` and restarting Sendmail. Refer to Section 12.3.1.3 *Common Sendmail Configuration Changes* for instructions on doing this.

For more information on LDAP, refer to Chapter 14 *Lightweight Directory Access Protocol (LDAP)*.

## 12.3.2. 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.

To configure 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.

**Important**

Before using Postfix, the default MTA must be switched from Sendmail to Postfix. Refer to the chapter called *Mail Transport Agent (MTA) Configuration* in the *Red Hat Enterprise Linux System Administration Guide* for details on how to do this.

### 12.3.2.1. 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.
- `aliases` — A configurable list required by the mail protocol.
- `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.



### Important

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 12.3.2.2 *Basic Postfix Configuration*.

When changing some options within files in the `/etc/postfix/` directory, it may be necessary to restart the `postfix` service for the changes to take effect. The easiest way to do this is to type the following command:

```
/sbin/service postfix restart
```

### 12.3.2.2. 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 mark (`#`), 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.
- 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 `/etc/postfix/main.cf`. Additional resources including information about LDAP and SpamAssassin integration are available online at <http://www.postfix.org/>.

### 12.3.3. 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.

Fetchmail is configured for each user through the use of a `.fetchmailrc` file in the user's 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.

### 12.3.3.1. 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 the configuration options in the `.fetchmailrc` file and those options are 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 `.fetchmailrc` because it only checks skipped servers when specifically invoked, and does not affect any currently working configurations.

A sample `.fetchmailrc` file looks similar to the following example:

```
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 'user5' there with password 'secret2' is user1 here
    user 'user7' 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.

**Note**

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 here.

**12.3.3.2. 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`.

**12.3.3.3. 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.

**12.3.3.4. 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.*

### 12.3.3.5. 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.

### 12.3.3.6. 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.

### 12.3.3.7. 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 default behavior of deleting messages after downloading them.
- `-l <max-number-bytes>` — Fetchmail does not download any messages over a particular size and to leave them on the remote email server.



- `--quit` — Quits the Fetchmail daemon process.

More commands and `.fetchmailrc` options can be found in the `fetchmail` man page.

## 12.4. Mail Delivery Agents

Red Hat Enterprise Linux includes two primary MDAs, Procmail and `mail`. Both of the applications are considered Local Delivery Agents 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.

Procmail delivers and filters email as it is placed in the mail spool file of the local host. 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` (also called an *rc* file) file in the user's home directory invokes Procmail whenever an MTA receives a new message.

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 `/etc/procmailrc` 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.

By default, no system-wide `rc` files exist in the `/etc/` directory and no `.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.

### 12.4.1. Procmail Configuration

The Procmail configuration files 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 `.procmailrc` 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 `$ORGMAIL`.
- `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 lists, 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
```

If the user wants to turn off Procmail filtering of their email lists but leave spam control in place, they would comment out the first `INCLUDERC` line with a hash mark character (`#`).

- `LOCKSLEEP` — Sets the amount of time, in seconds, between attempts by Procmail to use a particular lockfile. The default is eight seconds.
- `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/$LOGNAME` is used.

- `SUSPEND` — Sets the amount of time, in seconds, that Procmail pauses if a necessary resource, such as swap space, is not available.
- `SWITCHRC` — Allows a user to specify an external file containing additional Procmail recipes, much like the `INCLUDERC` option, except that recipe checking is actually stopped on the referring configuration file and only the recipes on the `SWITCHRC`-specified file are used.
- `VERBOSE` — Causes Procmail to log more information. This option is useful for debugging.

Other important environmental variables are pulled from the shell, such as `LOGNAME`, which is the login name; `HOME`, which is the location of the home directory; and `SHELL`, which is the default shell.

A comprehensive explanation of all environments variables, as well as their default values, is available in the `procmailrc` man page.

### 12.4.2. 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 difficult to understand when read. Additionally, the consistency of the way Procmail recipes are written, regardless of regular expressions, makes it easy to learn by example. To see example Procmail recipes, refer to Section 12.4.2.5 *Recipe Examples*.

Procmail recipes take the following form:

```
:0<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 `*` character can further control the condition.

The `<action-to-perform>` 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 12.4.2.4 *Special Conditions and Actions* for more information about special action characters.

### 12.4.2.1. 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 *nesting block*. A nesting block is a set of actions, contained in braces `{ }`, that are performed on messages which match the recipe's conditions. Nesting blocks can be nested inside one another, providing greater control for identifying and performing actions on messages.

When messages match a delivering recipe, Procmail performs the specified action and stops comparing the message against any other recipes. Messages that match non-delivering recipes continue to be compared against other recipes.

### 12.4.2.2. 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 the 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 occurs by default.
- `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.

#### 12.4.2.3. 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.

#### 12.4.2.4. 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 `*` 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 the 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.
- `|` — 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.

#### 12.4.2.5. 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>). 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 the 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, therefore, 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.



### Caution

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 12.6 *Additional Resources* for more detailed and powerful recipes.

### 12.4.2.6. 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.

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 client application (`spamc`). Configuring SpamAssassin this way, however, requires root access to the host.

To start the `spamd` daemon, type the following command as root:

```
/sbin/service spamassassin start
```

To start the SpamAssassin daemon when the system is booted, use an initscript utility, such as the **Services Configuration Tool** (`redhat-config-services`), to turn on the `spamassassin` service. Refer to Section 1.4.2 *Runlevel Utilities* for more information about initscript utilities.

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
```

## 12.5. Mail User Agents

There are scores of mail programs available under Red Hat Enterprise Linux. There are full-featured, graphical email client programs, such as **Mozilla Mail** or **Ximian Evolution**, as well as text-based email programs such as `mutt`.

For instructions on using these applications, refer to the chapter titled *Email Applications* in the *Red Hat Enterprise Linux Step By Step Guide*.

The remainder of this section focuses on securing communication between the client and server.

### 12.5.1. Securing Communication

Popular MUAs included with Red Hat Enterprise Linux, such as **Mozilla Mail**, **Ximian 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.

#### 12.5.1.1. 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 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.

#### 12.5.1.2. 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 two ways: by applying to a *Certificate Authority* (CA) for an SSL certificate or by creating a self-signed certificate.



#### Caution

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, change to the `/usr/share/ssl/certs/` directory and type the following command as root:

```
make imapd.pem
```

Answer all of the questions to complete the process.

To create a self-signed SSL certificate for POP, change to the `/usr/share/ssl/certs/` directory, and type the following command as root:

```
make ipop3d.pem
```

Again, answer all of the questions to complete the process.

Once finished, use the `/sbin/service` command to start the appropriate daemon (`imaps` or `pop3s`). Then, set the `imaps` or the `pop3s` service to start at the proper runlevels using an initscript utility, such as the **Services Configuration Tool** (`redhat-config-services`). Refer to Section 1.4.2 *Runlevel Utilities* for more information about initscript utilities.

Alternatively, the `stunnel` command can be used as an SSL encryption wrapper around the standard, non-secure daemons, `imapd` or `pop3d`.

The `stunnel` program uses external OpenSSL libraries included with Red Hat Enterprise Linux to provide strong cryptography and protect the connections. It is best to apply to a certificate authority to obtain an SSL certificate, but it is also possible to create a self-signed certificate.

To create a self-signed SSL certificate, change to the `/usr/share/ssl/certs/` directory, and type the following command:

```
make stunnel.pem
```

Again, answer all of the questions to complete the process.

Once the certificate is generated, it is possible to use the `stunnel` command to start the `imapd` mail daemon using the following command:

```
/usr/sbin/stunnel -d 993 -l /usr/sbin/imapd imapd
```

Once this command is issued, it is possible to open an IMAP email client and connect to the email server using SSL encryption.

To start the `pop3d` using the `stunnel` command, type the following command:

```
/usr/sbin/stunnel -d 995 -l /usr/sbin/pop3d pop3d
```

For more information about how to use `stunnel`, read the `stunnel` man page or refer to the documents in the `/usr/share/doc/stunnel-<version-number>/` directory, where `<version-number>` is the version number for `stunnel`.

## 12.6. Additional Resources

The following is a list of additional documentation about email applications.

### 12.6.1. Installed Documentation

- Information on configuring Sendmail is included with the `sendmail` and `sendmail-cf` packages.
  - `/usr/share/sendmail-cf/README.cf` — Contains information on m4, 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>` — Replace `<version-number>` with the version number of Postfix. This directory contains a large amount of information about ways to configure Postfix.
- `/usr/share/doc/fetchmail-<version-number>` — Contains a full list of Fetchmail features in the `FEATURES` file and an introductory FAQ document.
- `/usr/share/doc/procmail-<version-number>` — Contains a `README` file that provides an overview of Procmail, a `FEATURES` file that explores every program feature, and an `FAQ` file with answers to many common configuration questions.

When learning how Procmail works and creating new recipes, the following Procmail man pages are invaluable:

- `procmail` — Provides an overview of how Procmail works and the steps involved with filtering email.



- `procmailrc` — Explains the `rc` file format used to construct recipes.
- `procmailex` — Gives a number of useful, real-world examples of Procmail recipes.
- `procmailscore` — Explains the weighted scoring technique used by Procmail to match a particular recipe to a message.
- `/usr/share/doc/spamassassin-<version-number>/` — This directory contains a large amount of information pertaining to SpamAssassin. Replace `<version-number>` with the version number of the `spamassassin` package.

## 12.6.2. Useful Websites

- <http://www.redhat.com/mirrors/LDP/HOWTO/Mail-Administrator-HOWTO.html> — Provides an overview of how email works, and examines possible email solutions and configurations on the client and server sides.
- <http://www.redhat.com/mirrors/LDP/HOWTO/Mail-User-HOWTO/> — Looks at email from the user's perspective, investigates various popular email client applications and gives an introduction to topics such as aliases, forwarding, auto-replying, mailing lists, mail filters, and spam.
- <http://www.redhat.com/mirrors/LDP/HOWTO/mini/Secure-POP+SSH.html> — Demonstrates a way to retrieve POP email using SSH with port forwarding, so that the email passwords and messages are transferred securely.
- <http://www.sendmail.net/> — Contains news, interviews, and articles concerning Sendmail, including an expanded view of the many options available.
- <http://www.sendmail.org/> — Offers a thorough technical breakdown of Sendmail features and configuration examples.
- <http://www.postfix.org/> — The Postfix project home page contains a wealth of information about Postfix. The mailing list is a particularly good place to look for information.
- <http://catb.org/~esr/fetchmail/> — The home page for Fetchmail, featuring an online manual, and a thorough FAQ.
- <http://www.procmail.org/> — The home page for Procmail with links to assorted mailing lists dedicated to Procmail as well as various FAQ documents.
- <http://www.ling.helsinki.fi/users/rerikssoprocm/mini-faq.html> — An excellent Procmail FAQ, offers troubleshooting tips, details about file locking, and the use of wildcard characters.
- <http://www.uwasa.fi/~ts/info/proctips.html> — Contains dozens of tips that make using Procmail much easier. Includes instructions on how to test `.procmailrc` files and use Procmail scoring to decide if a particular action should be taken.
- <http://www.spamassassin.org/> — The official site of the SpamAssassin project.

## 12.6.3. Related Books

- *Sendmail* by Bryan Costales with Eric Allman et al; O'Reilly & Associates — A good Sendmail reference written with the assistance of the original creator of Delivermail and Sendmail.
- *Removing the Spam: Email Processing and Filtering* by Geoff Mulligan; Addison-Wesley Publishing Company — A volume that looks at various methods used by email administrators using established tools, such as Sendmail and Procmail, to manage spam problems.

- *Internet Email Protocols: A Developer's Guide* by Kevin Johnson; Addison-Wesley Publishing Company — Provides a very thorough review of major email protocols and the security they provide.
- *Managing IMAP* by Dianna Mullet and Kevin Mullet; O'Reilly & Associates — Details the steps required to configure an IMAP server.
- *Red Hat Enterprise Linux Security Guide*; Red Hat, Inc. — The *Server Security* chapter explains ways to secure Sendmail and other services.

## Berkeley Internet Name Domain (BIND)

On most modern networks, including the Internet, users locate other computers by name. This frees users from the daunting task of remembering the numerical network address of network resources. The most effective way to configure a network to allow such name-based connections is to set up a *Domain Name Service (DNS)* or a *nameserver*, which resolves hostnames on the network to numerical addresses and vice versa.

This chapter reviews the nameserver included in Red Hat Enterprise Linux, *Berkeley Internet Name Domain (BIND)* DNS server, with an emphasis on the structure of its configuration files and how it may be administered both locally and remotely.

For instructions on configuring BIND using the graphical **Domain Name Service Configuration Tool** (`redhat-config-bind`), refer to the chapter called *BIND Configuration* in the *Red Hat Enterprise Linux System Administration Guide*.



### Warning

If using the **Domain Name Service Configuration Tool**, do not manually edit any BIND configuration files as all changes will be overwritten the next time the **Domain Name Service Configuration Tool** is used.

## 13.1. Introduction to DNS

When hosts on a network connect to one another via a hostname, also called a *fully qualified domain name (FQDN)*, DNS is used to associate the names of machines to the IP address for the host.

Use of DNS and FQDNs also has advantages for system administrators, allowing the flexibility to change the IP address for a host without effecting name-based queries to the machine. Conversely, administrators can shuffle which machines handle a name-based query.

DNS is normally implemented using centralized servers that are authoritative for some domains and refer to other DNS servers for other domains.

When a client host requests information from a nameserver, it usually connects to port 53. The nameserver then attempts to resolve the FQDN based on its resolver library, which may contain authoritative information about the host requested or cached data from an earlier query. If the nameserver does not already have the answer in its resolver library, it queries other nameservers, called *root nameservers*, to determine which nameservers are authoritative for the FQDN in question. Then, with that information, it queries the authoritative nameservers to determine the IP address of the requested host. If performing a reverse lookup, the same procedure is used, except the query is made with an unknown IP address rather than a name.

### 13.1.1. Nameserver Zones

On the Internet, the FQDN of a host can be broken down into different sections. These sections are organized into a hierarchy (much like a tree), with a main trunk, primary branches, secondary branches, and so forth. Consider the following FQDN:

```
bob.sales.example.com
```

When looking at how an FQDN is resolved to find the IP address that relates to a particular system, read the name from right to left, with each level of the hierarchy divided by periods (.). In this example, `com` defines the *top level domain* for this FQDN. The name `example` is a sub-domain under `com`, while `sales` is a sub-domain under `example`. The name furthest to the left, `bob`, identifies a specific machine hostname.

Except for the hostname, each section is called a *zone*, which defines a specific *namespace*. A namespace controls the naming of the sub-domains to its left. While this example only contains two sub-domains, a FQDN must contain at least one sub-domain but may include many more, depending upon how the namespace is organized.

Zones are defined on authoritative nameservers through the use of *zone files*, which describe the namespace of that zone, the mail servers to be used for a particular domain or sub-domain, and more. Zone files are stored on *primary nameservers* (also called *master nameservers*), which are truly authoritative and where changes are made to the files, and *secondary nameservers* (also called *slave nameservers*), which receive their zone files from the primary nameservers. Any nameserver can be a primary and secondary nameserver for different zones at the same time, and they may also be considered authoritative for multiple zones. It all depends on how the nameserver is configured.

### 13.1.2. Nameserver Types

There are four primary nameserver configuration types:

- *master* — Stores original and authoritative zone records for a namespace, and answers queries about the namespace from other nameservers.
- *slave* — Answers queries from other nameservers concerning namespaces for which it is considered an authority. However, slave nameservers get their namespace information from master nameservers.
- *caching-only* — Offers name to IP resolution services but is not authoritative for any zones. Answers for all resolutions are cached in memory for a fixed period of time, which is specified by the retrieved zone record.
- *forwarding* — Forwards requests to a specific list of nameservers for name resolution. If none of the specified nameservers can perform the resolution, the resolution fails.

A nameserver may be one or more of these types. For example, a nameserver can be a master for some zones, a slave for others, and only offer forwarding resolutions for others.

### 13.1.3. BIND as a Nameserver

BIND performs name resolution services through the `/usr/sbin/named` daemon. BIND also includes an administration utility called `/usr/sbin/rndc`. More information about `rndc` can be found in Section 13.4 *Using rndc*.

BIND stores its configuration files in the following locations:

- `/etc/named.conf` — The configuration file for the `named` daemon.
- `/var/named/` directory — The `named` working directory which stores zone, statistic, and cache files.

The next few sections review the BIND configuration files in more detail.

## 13.2. /etc/named.conf

The `named.conf` file is a collection of statements using nested options surrounded by opening and closing ellipse characters, { }. Administrators must be careful when editing `named.conf` to avoid syntactical errors as many seemingly minor errors will prevent the `named` service from starting.



### Warning

Do *not* manually edit the `/etc/named.conf` file or any files in the `/var/named/` directory if you are using the **Domain Name Service Configuration Tool**. Any manual changes to those files will be overwritten the next time the **Domain Name Service Configuration Tool** is used.

A typical `named.conf` file is organized similar to the following example:

```
<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>;
};
```

### 13.2.1. Common Statement Types

The following types of statements are commonly used in `/etc/named.conf`:

#### 13.2.1.1. `acl` Statement

The `acl` statement (or access control statement) defines groups of hosts which can then be permitted or denied access to the nameserver.

An `acl` statement takes the following form:

```
acl <acl-name> {
    <match-element>;
    [<match-element>; ...]
};
```

In this statement, replace `<acl-name>` with the name of the access control list and replace `<match-element>` with a semi-colon separated list of IP addresses. Most of the time, an individual IP address or IP network notation (such as `10.0.1.0/24`) is used to identify the IP addresses within the `acl` statement.

The following access control lists are already defined as keywords to simplify configuration:

- `any` — Matches every IP address.
- `localhost` — Matches any IP address in use by the local system.

- `localnets` — Matches any IP address on any network to which the local system is connected.
- `none` — Matches no IP addresses.

When used in conjunction with other statements (such as the `options` statement), `acl` statements can be very useful in preventing the misuse of a BIND nameserver.

The following example defines two access control lists and uses an `options` statement to define how they are treated by the nameserver:

```
acl black-hats {
    10.0.2.0/24;
    192.168.0.0/24;
};

acl red-hats {
    10.0.1.0/24;
};

options {
    blackhole { black-hats; };
    allow-query { red-hats; };
    allow-recursion { red-hats; };
}
```

This example contains two access control lists, `black-hats` and `red-hats`. Hosts in the `black-hats` list are denied access to the nameserver, while hosts in the `red-hats` list are given normal access.

### 13.2.1.2. `include` Statement

The `include` statement allows files to be included in a `named.conf` file. This way sensitive configuration data (such as `keys`) can be placed in a separate file with restrictive permissions.

An `include` statement takes the following form:

```
include "<file-name>"
```

In this statement, `<file-name>` is replaced with an absolute path to a file.

### 13.2.1.3. `options` Statement

The `options` statement defines global server configuration options and sets 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.

The `options` statement takes the following form:

```
options {
    <option>;
    [<option>; ...]
};
```

In this statement, the `<option>` directives are replaced with a valid option.

The following are commonly used options:

- `allow-query` — Specifies which hosts are allowed to query this nameserver. By default, all hosts are allowed to query. An access control list, or collection of IP addresses or networks may be used here to only allow particular hosts to query the nameserver.
- `allow-recursion` — Similar to `allow-query`, this option applies to recursive queries. By default, all hosts are allowed to perform recursive queries on the nameserver.
- `blackhole` — Specifies which hosts are not allowed to query the server.
- `directory` — Specifies the named working directory if different from the default value, `/var/named/`.
- `forward` — Specifies the forwarding behavior of a `forwarders` directive.

The following options are accepted:

- `first` — Specifies that the nameservers listed in the `forwarders` directive be queried before `named` attempts to resolve the name itself.
- `only` — Specifies that `named` not attempt name resolution itself in the event queries to nameservers specified in the `forwarders` directive fail.
- `forwarders` — Specifies a list of valid IP addresses for nameservers where requests should be forwarded for resolution.
- `listen-on` — Specifies the network interface on which `named` listens for queries. By default, all interfaces are used.

Using this directive on a DNS server which also acts a gateway, BIND can be configured to only answer queries that originate from one of the networks.

A `listen-on` directive looks like the following example:

```
options {
    listen-on { 10.0.1.1; };
};
```

In this example, only requests that arrive from the network interface serving the private network (10.0.1.1) will be accepted.

- `notify` — Controls whether `named` notifies the slave servers when a zone is updated. It accepts the following options:
  - `yes` — Notifies slave servers.
  - `no` — Does not notify slave servers.
  - `explicit` — Only notifies slave servers specified in an `also-notify` list within a zone statement.
- `pid-file` — Specifies the location of the process ID file created by `named`.
- `statistics-file` — Specifies an alternate location for statistics files. By default, `named` statistics are saved to the `/var/named/named.stats` file.

Dozens of other options are also available, many of which rely upon one another to work properly. Refer to the *BIND 9 Administrator Reference Manual* referenced in Section 13.7.1 *Installed Documentation* and the `bind.conf` man page for more details.

### 13.2.1.4. zone Statement

A `zone` statement defines the characteristics of a zone such as the location of its configuration file and zone-specific options. This statement can be used to override the global `options` statements.

A `zone` statement takes the following form:

```
zone <zone-name> <zone-class> {
    <zone-options>;
    [<zone-options>; ...]
};
```

In this statement, `<zone-name>` is the name of the zone, `<zone-class>` is the optional class of the zone, and `<zone-options>` is a list of options characterizing the zone.

The `<zone-name>` attribute for the zone statement 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 it is placed at the end of hostnames within the `example.com` zone file.

For more information about zone files, see Section 13.3 *Zone Files*.

The most common `zone` statement options include the following:

- `allow-query` — Specifies the clients that are allowed to request information about this zone. The default is to allow all query requests.
- `allow-transfer` — Specifies the slave servers that are allowed to request a transfer of the zone's information. The default is to allow all transfer requests.
- `allow-update` — Specifies the hosts that are allowed to dynamically update information in their zone. The default is to deny all dynamic update requests.

Be careful when allowing hosts to update information about their zone. Do not enable this option unless the host specified is completely trusted. In general, it better to have an administrator manually update the records for a zone and reload the `named` service.

- `file` — Specifies the name of the file in the `named` working directory that contains the zone's configuration data.
- `masters` — Specifies the IP addresses from which to request authoritative zone information and is used only if the zone is defined as `type slave`.
- `notify` — Specifies whether or not `named` notifies the slave servers when a zone is updated. This directive accepts the following options:
  - `yes` — Notifies slave servers.
  - `no` — Does not notify slave servers.
  - `explicit` — Only notifies slave servers specified in an `also-notify` list within a zone statement.
- `type` — Defines the type of zone.

Below is a list of valid options:

- `forward` — Forwards all requests for information about this zone to other nameservers.
- `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 `hint zone`.



- `master` — Designates the nameserver as authoritative for this zone. A zone should be set as the `master` if the zone's configuration files reside on the system.
- `slave` — Designates the nameserver as a slave server for this zone. Also specifies the IP address of the master nameserver for the zone.
- `zone-statistics` — Configures `named` to keep statistics concerning this zone, writing them to either the default location (`/var/named/named.stats`) or the file listed in the `statistics-file` option in the `server` statement. See Section 13.2.2 *Other Statement Types* for more information about the `server` statement.

### 13.2.1.5. Sample zone Statements

Most changes to the `/etc/named.conf` file of a master or slave nameserver involves adding, modifying, or deleting `zone` statements. While these `zone` statements can contain many options, most nameservers require only a small subset to function efficiently. The following `zone` statements are very basic examples illustrating a master-slave nameserver relationship.

The following is an example of a `zone` statement for the primary nameserver hosting `example.com` (`192.168.0.1`):

```
zone "example.com" IN {
    type master;
    file "example.com.zone";
    allow-update { none; };
};
```

In the statement, 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 tells `named` not to allow any other hosts to update.

A slave server's `zone` statement for `example.com` is slightly different from the previous example. For a slave server, the type is set to `slave` and in place of the `allow-update` line is a directive telling `named` the IP address of the master server.

The following is an example slave server `zone` statement for `example.com` zone:

```
zone "example.com" {
    type slave;
    file "example.com.zone";
    masters { 192.168.0.1; };
};
```

This `zone` statement configures `named` on the slave server to query the master server at the `192.168.0.1` IP address for information about the `example.com` zone. The information the slave server receives from the master server is saved to the `/var/named/example.com.zone` file.

## 13.2.2. Other Statement Types

The following is a list of lesser used statement types available within `named.conf`

- `controls` — Configures various security requirements necessary to use the `rndc` command to administer the `named` service.

Refer to Section 13.4.1 *Configuring /etc/named.conf* to learn more about how the `controls` statement is structured and about the options which are available.

- `key "<key-name>"` — Defines 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 used, such as `dsa` or `hmac-md5`.
  - `secret "<key-value>"` — The encrypted key.

Refer to Section 13.4.2 *Configuring /etc/rndc.conf* for instruction on how to write a `key` statement.

- `logging` — Allows for the use of multiple types of logs, called *channels*. By using the `channel` option within the `logging` statement, a customized type of log, with its own file name (`file`), size limit (`size`), versioning (`version`), and level of importance (`severity`), can be constructed. Once a customized channel has been defined, a `category` option is used to categorize the channel and begin logging when `named` is restarted.

By default, `named` logs standard messages to the `syslog` daemon, which places them in `/var/log/messages`. This occurs because several standard channels are built into BIND with various severity levels, such as one that handles informational logging messages (`default_syslog`) and another that specifically handles debugging messages (`default_debug`). 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, see the *BIND 9 Administrator Reference Manual* referenced in Section 13.7.1 *Installed Documentation*.

- `server` — Specifies options that affect how `named` should respond to remote nameservers, especially in regards to notifications and zone transfers.

The `transfer-format` option controls whether one resource record is sent with each message (`one-answer`) or multiple resource records are sent with each message (`many-answers`). While `many-answers` is more efficient, only newer BIND nameservers understand it.

- `trusted-keys` — Contains assorted public keys used for secure DNS (DNSSEC). See Section 13.5.3 *Security* for more information concerning BIND security.
- `view "<view-name>"` — Creates 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 may be used, but their names must be unique. The `match-clients` option specifies the IP addresses that apply to a particular view. Any `options` statements may also be used within a view, overriding the global options already configured for `named`. Most `view` statements contain multiple `zone` statements that apply to the `match-clients` list. The order in which `view` statements are listed is important, as the first `view` statement that matches a particular client's IP address is used.

See Section 13.5.2 *Multiple Views* for more information about the `view` statement.

### 13.2.3. Comment Tags

The following is a list of valid comment tags used within `named.conf`:

- `//` — When placed at the beginning of a line, that line is ignored by `named`.
- `#` — When placed at the beginning of a line, that line is ignored by `named`.
- `/*` and `*/` — When text is enclosed in these tags, the block of text is ignored by `named`.

### 13.3. Zone Files

*Zone files* contain information about a namespace and are stored in the `named` working directory, `/var/named/`, by default. Each zone file is named according to the `file` option data 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`.

Each zone file may contain *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. Directives are optional, but resource records are required to provide name service to a zone.

All directives and resource records should go on their own individual lines.

Comments can be placed after semicolon characters (;) in zone files.

#### 13.3.1. Zone File Directives

Directives begin with the dollar sign character (\$) followed by the name of the directive. They usually appear at the top of the zone file.

The following are commonly used directives:

- `$INCLUDE` — Configures `named` to include another zone file in this zone file at the place where the directive appears. This allows additional zone settings to be stored apart from the main zone file.
- `$ORIGIN` — Appends the domain name to unqualified records, such as those with the hostname and nothing more.

For example, a zone file may contain the following line:

```
$ORIGIN example.com
```

Any names used in resource records that do not end in a trailing period (.) will have `example.com` appended to them.



#### Note

The use of the `$ORIGIN` directive is unnecessary if the zone is specified in `/etc/named.conf` because the zone name is used as the value for the `$ORIGIN` directive by default.

- `$TTL` — Sets the default *Time to Live (TTL)* value for the zone. This is the length of time, in seconds, a zone resource record is 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.

#### 13.3.2. Zone File Resource Records

The primary component of a zone file is its resource records.

There are many types of zone file resource records. The following are used most frequently:

- `A` — Address record, which specifies an IP address to assign to a name, as in this example:  
`<host> IN A <IP-address>`

If the `<host>` value is omitted, then an `A` record points to a default IP address for the top of the namespace. This system is the target for all non-FQDN requests.



The @ symbol places the \$ORIGIN directive (or the zone's name, if the \$ORIGIN directive is not set) as the namespace being defined by this SOA resource record. The hostname of the primary nameserver that is authoritative for this domain is the <primary-name-server> directive, and the email of the person to contact about this namespace is the <hostmaster-email> directive.

The <serial-number> directive is a numerical value incremented every time the zone file is altered to indicate it is time for named to reload the zone. The <time-to-refresh> directive is the numerical value slave servers use to determine how long to wait before asking the master nameserver if any changes have been made to the zone. The <serial-number> directive is a numerical value used by the slave servers to determine if it is using outdated zone data and should therefore refresh it.

The <time-to-retry> directive is a numerical value used by slave servers to determine the length of time to wait before issuing a refresh request in the event the master nameserver is not answering. If the master has not replied to a refresh request before the amount of time specified in the <time-to-expire> directive elapses, the slave servers stop responding as an authority for requests concerning that namespace.

The <minimum-TTL> directive is the quantity of time other nameservers cache the zone's information.

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). The table in Table 13-1 shows an amount of time in seconds and the equivalent time in another format.

Seconds	Other Time Units
60	1M
1800	30M
3600	1H
10800	3H
21600	6H
43200	12H
86400	1D
259200	3D
604800	1W
31536000	365D

**Table 13-1. Seconds compared to other time units**

The following example illustrates the form an SOA resource record might take when it is populated with real values.

```
@      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
```

### 13.3.3. Example Zone File

Seen individually, directives and resource records can be difficult to grasp. However, when placed together in a single file, they become easier to understand.

The following example shows a very basic zone file.

```
$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.

      IN      MX     10    mail.example.com.
      IN      MX     20    mail2.example.com.

      IN      A      10.0.1.5

server1  IN      A      10.0.1.5
server2  IN      A      10.0.1.7
dns1     IN      A      10.0.1.2
dns2     IN      A      10.0.1.3

ftp      IN      CNAME   server1
mail     IN      CNAME   server1
mail2    IN      CNAME   server2
www      IN      CNAME   server2
```

In this example, standard directives and SOA values are used. The authoritative nameservers are set as `dns1.example.com` and `dns2.example.com`, which have A records that tie them to `10.0.1.2` and `10.0.1.3`, respectively.

The email servers configured with the MX records point to `server1` and `server2` via CNAME records. Since the `server1` and `server2` names do not end in a trailing period (`.`), the `$ORIGIN` domain is placed after them, expanding them to `server1.example.com` and `server2.example.com`. Through the related A resource records, their IP addresses can be determined.

FTP and Web services, available at the standard `ftp.example.com` and `www.example.com` names, are pointed at the appropriate servers using CNAME records.

### 13.3.4. Reverse Name Resolution Zone Files

A reverse name resolution zone file is used to translate an IP address in a particular namespace into an FQDN. It looks very similar to a standard zone file, except that PTR resource records are used to link the IP addresses to a fully qualified domain name.

A PTR record looks similar to this:

```
<last-IP-digit>      IN      PTR    <FQDN-of-system>
```

The `<last-IP-digit>` is the last number in an IP address points to a particular system's FQDN.

In the follow example, IP addresses `10.0.1.20` through `10.0.1.25` are pointed to corresponding FQDNs.

```

$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.
      IN      NS      dns2.example.com.

20    IN      PTR     alice.example.com.
21    IN      PTR     betty.example.com.
22    IN      PTR     charlie.example.com.
23    IN      PTR     doug.example.com.
24    IN      PTR     ernest.example.com.
25    IN      PTR     fanny.example.com.

```

This zone file would be called into service with a zone statement in the `named.conf` file which looks similar to the following:

```

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.

## 13.4. Using `rndc`

BIND includes a utility called `rndc` which allows command line administration of the `named` daemon from the localhost or from a remote host.

In order to prevent unauthorized access to the `named` daemon, BIND uses a shared secret key authentication method to grant privileges to hosts. This means an identical key must be present in both `/etc/named.conf` and the `rndc` configuration file, `/etc/rndc.conf`

### 13.4.1. Configuring `/etc/named.conf`

In order for `rndc` to connect to a `named` service, there must a `controls` statement in the BIND server's `/etc/named.conf` file.

The `controls` statement, shown in the following example, allows `rndc` to connect from the localhost.

```

controls {
    inet 127.0.0.1 allow { localhost; } keys { <key-name>; };
};

```

This statement tells `named` to listen on the default TCP port 953 of the loopback address and allow `rndc` commands coming from the localhost, if the proper key is given. The `<key-name>` specifies a name in the `key` statement within the `/etc/named.conf` file. The next example illustrates a sample `key` statement.

```
key "<key-name>" {
    algorithm hmac-md5;
    secret "<key-value>";
};
```

In this case, the `<key-value>` uses the HMAC-MD5 algorithm. Use the following command to generate keys using the HMAC-MD5 algorithm:

```
dnssec-keygen -a hmac-md5 -b <bit-length> -n HOST <key-file-name>
```

A key with at least a 256-bit length is a good idea. The actual key that should be placed in the `<key-value>` area can be found in the `<key-file-name>` file generated by this command.



### Warning

Because `/etc/named.conf` is world-readable, it is a good idea to place the `key` statement in a separate file readable only by root and then use an `include` statement to reference it, as in the following example:

```
include "/etc/rndc.key";
```

## 13.4.2. Configuring `/etc/rndc.conf`

The `key` is the most important statement in `/etc/rndc.conf`.

```
key "<key-name>" {
    algorithm hmac-md5;
    secret "<key-value>";
};
```

The `<key-name>` and `<key-value>` should be exactly the same as their settings in `/etc/named.conf`.

To match the keys specified in the target server's `/etc/named.conf`, add the following lines to `/etc/rndc.conf`.

```
options {
    default-server localhost;
    default-key "<key-name>";
};
```

This directive sets a global default key. However the `rndc` configuration file can also specify different keys for different servers, as in the following example:

```
server localhost {
    key "<key-name>";
};
```



**Caution**

Make sure that only the root user can read or write to the `/etc/rndc.conf` file.

For more information about the `/etc/rndc.conf` file, see the `rndc.conf` man page.

### 13.4.3. Command Line Options

An `rndc` command takes the following form:

```
rndc <options> <command> <command-options>
```

When executing `rndc` on a properly configured localhost, the following commands are available:

- `halt` — Stops the `named` service immediately.
- `querylog` — Logs all queries made to this nameserver.
- `refresh` — Refreshes the nameserver's database.
- `reload` — Reloads the zone files but keeps all other previously cached responses. This command also allows changes to zone files without losing all stored name resolutions.

If changes only affected a specific zone, `reload` only that specific zone by adding the name of the zone after the `reload` command.

- `stats` — Dumps the current `named` statistics to the `/var/named/named.stats` file.
- `stop` — Stops the server gracefully, saving any dynamic update and *Incremental Zone Transfers (IXFR)* data before exiting.

Occasionally, it may be necessary to override the default settings in the `/etc/rndc.conf` file. The following options are available:

- `-c <configuration-file>` — Specifies the alternate location of a configuration file.
- `-p <port-number>` — Specifies a port number to use for the `rndc` connection other than port 953, the default.
- `-s <server>` — Specifies a server other than the `default-server` listed in `/etc/rndc.conf`.
- `-y <key-name>` — Specifies a key other than the `default-key` option in the `/etc/rndc.conf` file.

Additional information about these options can be found in the `rndc` man page.

## 13.5. Advanced Features of BIND

Most BIND implementations only use `named` to provide name resolution services or to act as an authority for a particular domain or sub-domain. However, BIND version 9 has a number of advanced features that allow for a more secure and efficient DNS service.

**Caution**

Some of these advanced features, such as DNSSEC, TSIG, and IXFR, should only be used in network environments with nameservers that support the features. If the network environment includes non-BIND or older BIND nameservers, verify that each advanced feature is supported before attempting to use it.

All of the features mentioned are discussed in greater detail in the *BIND 9 Administrator Reference Manual* referenced in Section 13.7.1 *Installed Documentation*.

### 13.5.1. DNS Protocol Enhancements

BIND supports Incremental Zone Transfers (IXFR), where a slave nameserver only downloads the updated portions of a zone modified on a master nameserver. The standard transfer process requires that the entire zone be transferred to each slave nameserver for even the smallest change. For very popular domains with very lengthy zone files and many slave nameservers, IXFR makes the notification and update process much less resource intensive.

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, AXFR is used. More information on dynamic updating is available in the *BIND 9 Administrator Reference Manual*. See Section 13.7.1 *Installed Documentation* for more information.

### 13.5.2. Multiple Views

Through the use of the `view` statement in `named.conf`, BIND can present different information depending which 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.

The `view` statement uses the `match-clients` option to match IP addresses or entire networks and give them special options and zone data.

### 13.5.3. Security

BIND supports a number of different methods to protect the updating and transfer of zones, on both master and slave nameservers:

- **DNSSEC** — Short for *DNS SECURITY*, this feature allows for zones to be cryptographically signed with a *zone key*.

In this way, the information about a specific zone can be verified as coming from a nameserver that has signed it with a particular private key, as long as the recipient has that nameserver's public key.

BIND version 9 also supports the SIG(0) public/private key method of message authentication.

- **TSIG** — Short for *Transaction SIGNatures*, this feature allows a transfer from master to slave only after verifying that a shared secret key exists on both nameservers.

This feature strengthens the standard IP address-based method of transfer authorization. An attacker 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.

BIND version 9 also supports *TKEY*, which is another shared secret key method of authorizing zone transfers.

### 13.5.4. IP version 6

BIND version 9 supports name service in IP version 6 (IPv6) environments through the use of `A6` zone records.

If the network environment includes both IPv4 and IPv6 hosts, use the `lwresd` lightweight resolver daemon on all network clients. This daemon is a very efficient, caching-only nameserver which understands the new `A6` and `DNAME` records used under IPv6. See the `lwresd` man page for more information.

## 13.6. Common Mistakes to Avoid

It is very common for beginners to make mistakes when editing BIND configuration files. Be sure to avoid the following issues:

- *Take care to increment the serial number when editing a zone file.*

If the serial number is not incremented, the master nameserver will have the correct, new information, but the slave nameservers will never be notified of the change or attempt to refresh their data of that zone.

- *Be careful to use ellipses and semi-colons correctly in the `/etc/named.conf` file.*

An omitted semi-colon or unclosed ellipse section can cause `named` to refuse to start.

- *Remember to place periods (.) in zone files after all `FQDNs` and omit them on hostnames.*

A period at the end of a domain name denotes a fully qualified domain name. If the period is omitted, then `named` appends the name of the zone or the `$ORIGIN` value to complete it.

- *If a firewall is blocking connections from the `named` program to other nameservers, edit its configuration file.*

By default, BIND version 9 uses random ports above 1024 to query other nameservers. Some firewalls, however, expect all nameservers to communicate using only port 53. Force `named` to use port 53 by adding the following line to the `options` statement of `/etc/named.conf`:

```
query-source address * port 53;
```

## 13.7. Additional Resources

The following sources of information will provide additional resources regarding BIND.

### 13.7.1. Installed Documentation

- BIND features a full-range of installed documentation covering many different topics, each placed in its own subject directory:
  - `/usr/share/doc/bind-<version-number>/` Directory — A list of the most recent features. Replace `<version-number>` with the version of `bind` installed on the system.
  - `/usr/share/doc/bind-<version-number>/arm/` Directory — Contains HTML and SGML of the *BIND 9 Administrator Reference Manual*, which details BIND resource requirements, how to configure different types of nameservers, perform load balancing, and other advanced topics. For most new users of BIND, this is the best place to start. Replace `<version-number>` with the version of `bind` installed on the system.

- `/usr/share/doc/bind-<version-number>/draft/` directory — Contains assorted technical documents that reviews issues related to DNS service and some methods proposed to address them. Replace `<version-number>` with the version of `bind` installed on the system.
- `/usr/share/doc/bind-<version-number>/misc/` directory — Contains documents 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`. Replace `<version-number>` with the version of `bind` installed on the system.
- `/usr/share/doc/bind-<version-number>/rfc/` directory — Every RFC document related to BIND is in this directory. Replace `<version-number>` with the version of `bind` installed on the system.
- BIND related man pages — There are a number of man pages for the various applications and configuration files involved with BIND. The following is a list of some of the more important man pages.

#### Administrative Applications

- `man rndc` — Explains the different options available when using the `rndc` command to control a BIND nameserver.

#### Server Applications

- `man named` — Explores assorted arguments that can be used to control the BIND name-server daemon.
- `man lwresd` — Describes the purpose of and options available for the lightweight resolver daemon.

#### Configuration Files

- `man named.conf` — A comprehensive list of options available within the `named` configuration file.
- `man rndc.conf` — A comprehensive list of options available within the `rndc` configuration file.

### 13.7.2. Useful Websites

- <http://www.isc.org/products/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*.

- <http://www.redhat.com/mirrors/LDP/HOWTO/DNS-HOWTO.html> — Covers the use of BIND as a resolving, caching nameserver or the configuration of various zone files necessary to serve as the primary nameserver for a domain.

### 13.7.3. Related Books

- *Red Hat Enterprise Linux System Administration Guide* — The *BIND Configuration* chapter explains how to set up a DNS server using the **Domain Name Service Configuration Tool**.
- *DNS and BIND* by Paul Albitz and Cricket Liu; O'Reilly & Associates — A popular reference that explains both common and esoteric BIND configuration options, as well as providing 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.



# Lightweight Directory Access Protocol (LDAP)

*Lightweight Directory Access Protocol (LDAP)* 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 hierarchal manner using directories. These directories can store a variety of information and can even be used in a manner similar to Network Information Service (NIS), enabling anyone to access their account from any machine on the LDAP enabled network.

In many cases LDAP is used as a virtual phone directory, allowing users to easily access contact information for other users. But LDAP is more flexible than a traditional phone directory, as it is capable of referring a querent to other LDAP servers throughout the world, providing an ad-hoc global repository of information. Currently, however, LDAP is more commonly used within individual organizations, like universities, government departments, and private companies.

LDAP is a client/server system. The server can use a variety of databases to store a directory, each optimized for quick and copious read operations. When an LDAP client application connects to an LDAP server, it can either query a directory or attempt to modify it. In the event of a query, the server either answers the query locally, or it can refer the querent to an LDAP server which does have the answer. If the client application is attempting to modify information within an LDAP directory, the server verifies that the user has permission to make the change and then adds or updates the information.

This chapter refers to the configuration and use of OpenLDAP 2.0, an open source implementation of the LDAPv2 and LDAPv3 protocols.

## 14.1. Why Use LDAP?

The main benefit of using LDAP is that information for an entire organization can be consolidated into a central repository. For example, rather than managing user lists for each group within an organization, LDAP can be used as a central directory accessible from anywhere on the network. And because LDAP supports Secure Sockets Layer (SSL) and Transport Layer Security (TLS), sensitive data can be protected from prying eyes.

LDAP also supports a number of back-end databases in which to store directories. This allows administrators the flexibility to deploy the database best suited for the type of information the server is to disseminate. Because LDAP also has a well-defined client Application Programming Interface (API), the number of LDAP-enabled applications are numerous and increasing in quantity and quality.

### 14.1.1. OpenLDAP 2.0 Feature Enhancements

OpenLDAP 2.0 includes a number of important features.

- *LDAPv3 Support* — OpenLDAP 2.0 supports Authentication and Security Layer (SASL), Transport Layer Security (TLS), and Secure Sockets Layer (SSL), among other improvements. Many of the changes in the protocol since LDAPv2 are designed to make LDAP more secure.
- *IPv6 Support* — OpenLDAP supports the next generation Internet Protocol version 6.
- *LDAP Over IPC* — OpenLDAP can communicate within a system using interprocess communication (IPC). This enhances security by eliminating the need to communicate over a network.
- *Updated C API* — Improves the way programmers can connect to and use LDAP directory servers.

- *LDIFv1 Support* — Provides full compliance with the LDAP Data Interchange Format (LDIF) version 1.
- *Enhanced Stand-Alone LDAP Server* — Includes an updated access control system, thread pooling, better tools, and much more.

## 14.2. LDAP Terminology

Any discussion of LDAP requires a basic understanding of a set of LDAP-specific terms:

- *entry* — A single unit within an LDAP directory. Each entry is identified by its unique *Distinguished Name (DN)*.
- *attributes* — Information directly associated with an entry. For example, an organization could be represented as an LDAP entry. Attributes associated with the organization might be its fax number, its address, and so on. People can also be represented as entries in the LDAP directory. Common attributes for people include the person's telephone number and email address.

Some attributes are required, while other attributes are optional. An *objectclass* definition sets which attributes are required and which are not for each entry. Objectclass definitions are found in various schema files, located in the `/etc/openldap/schema/` directory. For more information on LDAP schema, refer to Section 14.5 *The /etc/openldap/schema/ Directory*.

- *LDIF* — The *LDAP Data Interchange Format (LDIF)* is an ASCII text representation of LDAP entries. Files used for importing data to LDAP servers must be in LDIF format. An LDIF entry looks similar to the following example:

```
[<id>]
dn: <distinguished name>
<attrtype>: <attrvalue>
<attrtype>: <attrvalue>
<attrtype>: <attrvalue>
```

Each entry can contain as many `<attrtype>: <attrvalue>` pairs as needed. A blank line indicates the end of an entry.



### Caution

All `<attrtype>` and `<attrvalue>` pairs *must* be defined in a corresponding schema file to use this information.

Any value enclosed within a "<" and a ">" is a variable and can be set whenever a new LDAP entry is created. This rule does not apply, however, to `<id>`. The `<id>` is a number determined by the application used to edit the entry.

## 14.3. OpenLDAP Daemons and Utilities

The suite of OpenLDAP libraries and tools are found within the following packages:

- `openldap` — Contains the libraries necessary to run the OpenLDAP server and client applications.
- `openldap-clients` — Contains command line tools for viewing and modifying directories on an LDAP server.
- `openldap-servers` — Contains the servers and other utilities necessary to configure and run an LDAP server.



There are two servers contained in the `openldap-servers` package: the *Standalone LDAP Daemon* (`/usr/sbin/slapd`) and the *Standalone LDAP Update Replication Daemon* (`/usr/sbin/slurpd`).

The `slapd` daemon is the standalone LDAP server while the `slurpd` daemon is used to synchronize changes from one LDAP server to other LDAP servers on the network. The `slurpd` daemon is only used when dealing with multiple LDAP servers.

To perform administrative tasks, the `openldap-servers` package installs the following utilities into the `/usr/sbin/` directory:

- `slapadd` — Adds entries from an LDIF file to an LDAP directory. For example, the command `/usr/sbin/slapadd -l ldif-input` reads in the LDIF file, `ldif-input`, containing the new entries.
- `slapcat` — Pulls entries out of an LDAP directory in the default format, Berkeley DB, and saves them in an LDIF file. For example, the command `/usr/sbin/slapcat -l ldif-output` outputs an LDIF file called `ldif-output` containing the entries from the LDAP directory. This command works for directories created under Red Hat Enterprise Linux 3 and Red Hat Linux 9.
- `slapcat-gdbm` — Pulls entries out of an LDAP directory in the `gdbm` format (the default in earlier versions of OpenLDAP) and saves them in an LDIF file. This command is provided solely as a means for migrating a directory from OpenLDAP implemented under Red Hat Enterprise Linux 2.1 and Red Hat Linux versions 7.x through 8. Refer to Section 14.8 *Migrating Directories from Earlier Releases* for information on how to use this command.
- `slapindex` — Re-indexes the `slapd` directory based on the current content. This tool should be run whenever indexing options within `/etc/openldap/slapd.conf` are changed.
- `slappasswd` — Generates an encrypted user password value for use with `ldapmodify` or the `rootpw` value in the `slapd` configuration file, `/etc/openldap/slapd.conf`. Execute the `/usr/sbin/slappasswd` command to create the password.



### Warning

Be sure to stop `slapd` by issuing `/sbin/service ldap stop` before using `slapadd`, `slapcat` or `slapindex`. Otherwise, the integrity of the LDAP directory is at risk.

For more information about how to use these utilities, refer to their respective man pages.

The `openldap-clients` package installs tools into `/usr/bin/` which are used to add, modify, and delete entries in an LDAP directory. These tools include the following:

- `ldapmodify` — Modifies entries in an LDAP directory, accepting input via a file or standard input.
- `ldapadd` — Adds entries to an LDAP directory by accepting input via a file or standard input; `ldapadd` is actually a hard link to `ldapmodify -a`.
- `ldapdelete` — Deletes entries from an LDAP directory by accepting input via user input at a shell prompt or via a file.
- `ldapmodify` — Modifies entries in an LDAP directory, accepting input via a file or standard input.
- `ldappasswd` — Sets the password for an LDAP user.
- `ldapsearch` — Searches for entries in an LDAP directory using a shell prompt.

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.

### 14.3.1. NSS, PAM, and LDAP

In addition to the OpenLDAP packages, Red Hat Enterprise Linux includes a package called `nss_ldap`, which enhances LDAP's ability to integrate into both Linux and other UNIX environments.

The `nss_ldap` package provides the following modules:

- `/lib/libnss_ldap-<glibc-version>.so`
- `/lib/security/pam_ldap.so`

The `libnss_ldap-<glibc-version>.so` module allows applications to look up users, groups, hosts, and other information using an LDAP directory via `glibc`'s *Nameservice Switch* (NSS) interface (replace `<glibc-version>` with the version of `libnss_ldap` in use). NSS allows applications to authenticate using LDAP in conjunction with the *Network Information Service* (NIS) name service and flat authentication files.

The `pam_ldap` module allows PAM-aware applications to authenticate users using information stored in an LDAP directory. PAM-aware applications include console login, POP and IMAP mail servers, and Samba. By deploying an LDAP server on a network, all of these applications can authenticate using the same user ID and password combination, greatly simplifying administration.

### 14.3.2. PHP4, the Apache HTTP Server, and LDAP

Red Hat Enterprise Linux includes a package containing an LDAP module for the PHP server-side scripting language.

The `php-ldap` package adds LDAP support to the PHP4 HTML-embedded scripting language via the `/usr/lib/php4/ldap.so` module. This module allows PHP4 scripts to access information stored in an LDAP directory.



#### Important

Red Hat Enterprise Linux no longer ships with the `auth_ldap` package. This package provided LDAP support for versions 1.3 and earlier of the Apache HTTP Server. Refer to the Apache Software Foundation website at <http://www.apache.org/> for details on the status of this module.

### 14.3.3. LDAP Client Applications

There are graphical LDAP clients available which support creating and modifying directories, but they are not included with Red Hat Enterprise Linux. One such application is **LDAP Browser/Editor** — A Java-based tool available online at <http://www.iit.edu/~gawojar/ldap/>.

Most other LDAP clients access directories as read-only, using them to reference, but not alter, organization-wide information. Some examples of such applications are **Sendmail**, **Mozilla**, **Gnome Meeting**, and **Evolution**.

## 14.4. OpenLDAP Configuration Files

OpenLDAP configuration files are installed into the `/etc/openldap/` directory. The following is a brief list highlighting the most important directories and files:

- `/etc/openldap/ldap.conf` — This is the configuration file for all *client* applications which use the OpenLDAP libraries such as `ldapsearch`, `ldapadd`, `Sendmail`, **Evolution**, and **Gnome Meeting**.
- `/etc/openldap/slapd.conf` — This is the configuration file for the `slapd` daemon. Refer to Section 14.6.1 *Editing /etc/openldap/slapd.conf* for more information file.
- `/etc/openldap/schema/` directory — This subdirectory contains the schema used by the `slapd` daemon. Refer to Section 14.5 *The /etc/openldap/schema/ Directory* for more information.



#### Note

If the `nss_ldap` package is installed, it creates a file named `/etc/ldap.conf`. This file is used by the PAM and NSS modules supplied by the `nss_ldap` package. Refer to Section 14.7 *Configuring a System to Authenticate Using OpenLDAP* for more information.

## 14.5. The `/etc/openldap/schema/` Directory

The `/etc/openldap/schema/` directory holds LDAP definitions, previously located in the `slapd.at.conf` and `slapd.oc.conf` files. All *attribute syntax definitions* and *objectclass definitions* are now located in the different schema files. The various schema files are referenced in `/etc/openldap/slapd.conf` using `include` lines, as shown in this example:

```
include /etc/openldap/schema/core.schema
include /etc/openldap/schema/cosine.schema
include /etc/openldap/schema/inetorgperson.schema
include /etc/openldap/schema/nis.schema
include /etc/openldap/schema/rfc822-MailMember.schema
include /etc/openldap/schema/autofs.schema
include /etc/openldap/schema/kerberosobject.schema
```



#### Caution

Do not modify schema items defined in the schema files installed by OpenLDAP.

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. To do this, create a `local.schema` file in the `/etc/openldap/schema/` directory. Reference this new schema within `slapd.conf` by adding the following line below the default `include` schema lines:

```
include /etc/openldap/schema/local.schema
```

Next, define new attribute types and object classes within the `local.schema` file. Many organizations use existing attribute types from the schema files installed by default and add new object classes to the `local.schema` file.

Extending the schema to match certain specialized requirements is quite involved and beyond the scope of this chapter. Visit <http://www.openldap.org/doc/admin/schema.html> for information.

## 14.6. OpenLDAP Setup Overview

This section provides a quick overview for installing and configuring an OpenLDAP directory. For more details, refer to the following URLs:

- <http://www.openldap.org/doc/admin/quickstart.html> — The *Quick-Start Guide* on the OpenLDAP website.
- <http://www.redhat.com/mirrors/LDP/HOWTO/LDAP-HOWTO.html> — The *LDAP Linux HOWTO* from the Linux Documentation Project, mirrored on Red Hat's website.

The basic steps for creating an LDAP server are as follows:

1. Install the `openldap`, `openldap-servers`, and `openldap-clients` RPMs.
2. Edit the `/etc/openldap/slapd.conf` file to specify the LDAP domain and server. Refer to Section 14.6.1 *Editing /etc/openldap/slapd.conf* for more information.

3. Start `slapd` with the command:

```
/sbin/service/ldap start
```

After configuring LDAP, use `chkconfig`, `ntsysv`, or the **Services Configuration Tool** to configure LDAP to start at boot time. For more information about configuring services, refer to the chapter titled *Controlling Access to Services* in the *Red Hat Enterprise Linux System Administration Guide*.

4. Add entries to an LDAP directory with `ldapadd`.
5. Use `ldapsearch` to determine if `slapd` is accessing the information correctly.
6. At this point, the LDAP directory should be functioning properly and can be configured with LDAP-enabled applications.

### 14.6.1. Editing /etc/openldap/slapd.conf

To use the `slapd` LDAP server, modify its configuration file, `/etc/openldap/slapd.conf`, to specify the correct domain and server.

The `suffix` line names the domain for which the LDAP server provides information and should be changed from:

```
suffix          "dc=your-domain,dc=com"
```

so that it reflects a fully qualified domain name. For example:

```
suffix          "dc=example,dc=com"
```

The `rootdn` entry is the *Distinguished Name (DN)* for a user who is unrestricted by access controls or administrative limit parameters set for operations on the LDAP directory. The `rootdn` user can be thought of as the root user for the LDAP directory. In the configuration file, change the `rootdn` line from its default value as in the following example:

```
rootdn          "cn=root,dc=example,dc=com"
```

When populating an LDAP directory over a network, change the `rootpw` line — replacing the default value with an encrypted password string. To create an encrypted password string, type the following command:

```
slappasswd
```

When prompted, type and then re-type a password. The program prints the resulting encrypted password to the shell prompt.

Next, copy the newly created encrypted password into the `/etc/openldap/slapd.conf` on one of the `rootpw` lines and remove the hash mark (`#`).

When finished, the line should look similar to the following example:

```
rootpw {SSHA}vv2y+i6V6esazrIv70xSSnNAJE18bb2u
```



### Warning

LDAP passwords, including the `rootpw` directive specified in `/etc/openldap/slapd.conf`, are sent over the network *unencrypted*, unless TLS encryption is enabled.

To enable TLS encryption, review the comments in `/etc/openldap/slapd.conf` and refer the man page for `slapd.conf`.

For added security, the `rootpw` directive should be commented out after populating the LDAP directory by preceding it with a hash mark (`#`).

When using the `/usr/sbin/slapadd` command line tool locally to populate the LDAP directory, use of the `rootpw` directive is not necessary.



### Important

Only the root user can use `/usr/sbin/slapadd`. However, the directory server runs as the `ldap` user. Therefore the directory server is unable to modify any files created by `slapadd`. To correct this issue, after using `slapadd`, type the following command:

```
chown -R ldap /var/lib/ldap
```

## 14.7. Configuring a System to Authenticate Using OpenLDAP

This section provides a brief overview of how to configure OpenLDAP user authentication. Unless you are an OpenLDAP expert, more documentation than is provided here is necessary. Refer to the references provided in Section 14.9 *Additional Resources* for more information.

### *Install the Necessary LDAP Package*

First, make sure that the appropriate packages are installed on both the LDAP server and the LDAP client machines. The LDAP server needs the `openldap-servers` package.

The `openldap`, `openldap-clients`, and `nss_ldap` packages need to be installed on all LDAP client machines.

### *Edit the Configuration Files*

- On the server, edit the `/etc/openldap/slapd.conf` file on the LDAP server to make sure it matches the specifics of the organization. Refer to Section 14.6.1 *Editing /etc/openldap/slapd.conf* for instructions about editing `slapd.conf`.

- On the client machines, both `/etc/ldap.conf` and `/etc/openldap/ldap.conf` need to contain the proper server and search base information for the organization.

To do this, run the graphical **Authentication Configuration Tool** (`authconfig-gtk`) and select **Enable LDAP Support** under the **User Information** tab.

It is also possible to edit these files by hand.

- On the client machines, the `/etc/nsswitch.conf` must be edited to use LDAP.

To do this, run the **Authentication Configuration Tool** (`authconfig-gtk`) and select **Enable LDAP Support** under the **User Information** tab.

If editing `/etc/nsswitch.conf` by hand, add `ldap` to the appropriate lines.

For example:

```
passwd: files ldap
shadow: files ldap
group: files ldap
```

### 14.7.1. PAM and LDAP

To have standard PAM-enabled applications use LDAP for authentication, run the **Authentication Configuration Tool** (`authconfig-gtk`) and select **Enable LDAP Support** under the the **Authentication** tab. For more about configuring PAM, refer to Chapter 15 *Pluggable Authentication Modules (PAM)* and the PAM man pages.

### 14.7.2. Migrating Old Authentication Information to LDAP Format

The `/usr/share/openldap/migration/` directory contains a set of shell and Perl scripts for migrating authentication information into LDAP format.



#### Note

Perl must be installed on the system to use these scripts.

First, modify the `migrate_common.ph` file so that it reflects the correct domain. The default DNS domain should be changed from its default value to something like:

```
$DEFAULT_MAIL_DOMAIN = "example";
```

The default base should also be changed, to something like:

```
$DEFAULT_BASE =
"dc=example,dc=com";
```

The job of migrating a user database into a format that is LDAP readable falls to a group of migration scripts installed in the same directory. Using Table 14-1, decide which script to run to migrate the user database.

Run the appropriate script based on the existing name service.

The `README` and the `migration-tools.txt` files in the `/usr/share/openldap/migration/` directory provide more details on how to migrate the information.

Existing name service	Is LDAP running?	Script to Use
/etc flat files	yes	migrate_all_online.sh
/etc flat files	no	migrate_all_offline.sh
NetInfo	yes	migrate_all_netinfo_online.sh
NetInfo	no	migrate_all_netinfo_offline.sh
NIS (YP)	yes	migrate_all_nis_online.sh
NIS (YP)	no	migrate_all_nis_offline.sh

Table 14-1. LDAP Migration Scripts

## 14.8. Migrating Directories from Earlier Releases

Beginning with the release of Red Hat Linux 9, OpenLDAP uses Sleepy Cat Software's *Berkeley DB* system as its on-disk storage format for directories. Earlier versions of OpenLDAP used *GNU Database Manager (gdbm)*. For this reason, before upgrading an LDAP implementation to Red Hat Enterprise Linux 3 from Red Hat Enterprise Linux 2.1 or Red Hat Linux 7.x through 8, perform the following steps:

1. Before upgrading the operating system, run the command `/usr/sbin/slapcat -l ldif-output`. This outputs an LDIF file called *ldif-output* containing the entries from the LDAP directory.
2. Upgrade the operating system, being careful not to reformat the partition containing the LDIF file.
3. Re-import the LDAP directory to the upgraded Berkeley DB format by executing the command `/usr/sbin/slapadd -l ldif-output`.



### Important

If an LDAP directory is not exported before upgrading to Red Hat Enterprise Linux 3 from Red Hat Enterprise Linux 2.1 or Red Hat Linux 7.x through 8, use the command `/usr/sbin/slapcat-gdbm -l ldif-output` to extract the older directory (replacing *ldif-output* with the file name for the LDIF output). This command creates an LDIF file suitable for importing with the `slapadd` command.

### 14.8.1. Migrating 1.x Directories

Beginning with Red Hat Linux 7.1, the on-disk storage format used by the `slapd` LDAP server changed to `gdbm`. If upgrading an LDAP directory from a system that ran Red Hat Linux 7 or earlier, it is necessary to extract the existing LDAP directories to an LDIF file using the following command:

```
ldbmcats -n > <ldif_file>
```

In the above command, change `<ldif_file>` to the name of the output file. Next type the following command to import this file:

```
slapadd -l <ldif_file>
```



### Important

Only the root user may use `/usr/sbin/slapadd`. However, the directory server runs as the `ldap` user. Therefore the directory server is unable to modify any files created by `slapadd`. To correct this issue, after using `slapadd`, type the following command:

```
chown -R ldap /var/lib/ldap
```

## 14.9. Additional Resources

More information concerning LDAP is available. Review the following sources, especially the OpenLDAP website and the LDAP HOWTO, before configuring LDAP on the system.

### 14.9.1. Installed Documentation

- `/usr/share/docs/openldap-<versionnumber>/` directory — Contains a general README document and miscellaneous information.
- LDAP related man pages — There are a number of man pages for the various applications and configuration files involved with LDAP. The following is a list of some of the more important man pages.

#### 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 a an LDAP user.

#### Server Applications

- `man slapd` — Describes available command line options for the LDAP server.
- `man slurpd` — Describes available command line options for the LDAP replication server.

#### Administrative Applications

- `man slapadd` — Describes available command line options for this tool used to add entries to a `slapd` database.
- `man slapcat` — Describes available command line options for this tool used to generate an LDIF file from a `slapd` database.
- `man slapindex` — Describes available command line options for this tool used to regenerate an index based upon the contents of a `slapd` database.



- `man slapasswd` — Describes available command line options for this tool used to generate a 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.conf` — Describes the format and options available within the configuration file referenced by both the LDAP server applications (`slapd` and `slurpd`) and LDAP administrative tools (`slapadd`, `slapcat`, and `slapindex`).

## 14.9.2. Useful Websites

- <http://www.openldap.org/> — Home of the OpenLDAP Project. This website contains a wealth of information about configuring OpenLDAP.
- <http://www.redhat.com/mirrors/LDP/HOWTO/LDAP-HOWTO.html> — An older, but still relevant LDAP HOWTO.
- <http://www.padl.com/> — Developers of `nss_ldap` and `pam_ldap`, among other useful LDAP tools.
- <http://www.kingsmountain.com/ldapRoadmap.shtml> — Jeff Hodges' LDAP Road Map contains links to several useful FAQs and emerging news concerning the LDAP protocol.
- <http://www.newarchitectmag.com/archives/2000/05/wilcox/> — A useful look at managing groups in LDAP.
- <http://www.ldapman.org/articles/> — Articles that offer a good introduction to LDAP, including methods to design a directory tree and customizing directory structures.

## 14.9.3. Related Books

- *Implementing LDAP* by Mark Wilcox; Wrox Press, Inc.
- *Understanding and Deploying LDAP Directory Services* by Tim Howes et al.; Macmillan Technical Publishing



## III. Security Reference

Using secure protocols is a critical part of maintaining system integrity. This part describes critical tools used for the purpose of user authentication, network access control, and secure network communication. For more information about securing a Red Hat Enterprise Linux system, refer to the *Red Hat Enterprise Linux Security Guide*.

### Table of Contents

15. Pluggable Authentication Modules (PAM) .....	227
16. TCP Wrappers and <code>xinetd</code> .....	237
17. <code>iptables</code> .....	251
18. Kerberos.....	263
19. SSH Protocol.....	273



## Pluggable Authentication Modules (PAM)

Programs which grant users access to a system verify each user's identity through a process called *authentication*. Historically, each such program had its own way of performing the task of authentication. Under Red Hat Enterprise Linux, many such programs are configured to use a centralized authentication mechanism called *Pluggable Authentication Modules* or *PAM*.

PAM uses a pluggable, modular architecture, which affords the system administrator a great deal of flexibility in setting authentication policies for the system.

In most situations, the default PAM configuration file for a PAM-aware application is sufficient. However, sometimes it may become necessary to edit a PAM configuration file. Because misconfiguration of PAM can compromise system security, it is important to understand the structure of these files before making any modifications (refer to Section 15.3 *PAM Configuration File Format* for more information).

### 15.1. Advantages of PAM

PAM offers the following advantages:

- It provides a common authentication scheme that can be used with a wide variety of applications.
- It allows a large amount of flexibility and control over authentication for both system administrators and application developers.
- It allows application developers to develop programs without creating their own authentication scheme.

### 15.2. PAM Configuration Files

The directory `/etc/pam.d/` contains the PAM configuration files for each PAM-aware application. In earlier versions of PAM, the file `/etc/pam.conf` was used, but this file is now deprecated and is only used if the `/etc/pam.d/` directory does not exist.

#### 15.2.1. PAM Service Files

Each PAM-aware application or *service* has a file within the `/etc/pam.d/` directory. Each file within this directory bears the name of the service for which it controls access.

It is up to the PAM-aware program to define its service name and install its own PAM configuration file in the `/etc/pam.d/` directory. For example, the `login` program defines its service name as `login` and installs the `/etc/pam.d/login` PAM configuration file.

### 15.3. PAM Configuration File Format

Each PAM configuration file contains a group of directives formatted as follows:

```
<module interface> <control flag> <module name> <module arguments>
```

Each of these elements are explained in the subsequent sections.

### 15.3.1. Module Interface

There are four types of PAM module interfaces which correlate to different aspects of the authorization process:

- `auth` — This module interface authenticates the use. For example, it asks for and verifies the validity of a password. Modules with this interface can also set credentials, such as group memberships or Kerberos tickets.
- `account` — This module interface verifies that access is allowed. For example, it may check if a user account is expired or is allowed to log in at a particular time of day.
- `password` — This module interface sets and verifies passwords.
- `session` — This module interface configures and manages user sessions. Modules with this interface can also perform additional tasks that are needed to allow access, like mounting a user's home directory and making the user's mailbox available.



#### Note

An individual module can provide any or all module interfaces. For instance, `pam_unix.so` provides all four module interfaces.

In a PAM configuration file, the module interface is the first field defined. For example a typical line in a configuration may look like this:

```
auth      required pam_unix.so
```

This instructs PAM to use the `pam_unix.so` module's `auth` interface.

#### 15.3.1.1. Stacking Module Interfaces

Module interface directives can be *stacked*, or placed upon one another, so that multiple modules are used together for one purpose. For this reason, the order in which the modules are listed is very important to the authentication process.

Stacking makes it very easy for an administrator to require specific conditions to exist before allowing the user to authenticate. For example, `rlogin` normally uses five stacked `auth` modules, as seen in its PAM configuration file:

```
auth      required pam_nologin.so
auth      required pam_securetty.so
auth      required pam_env.so
auth      sufficient pam_rhosts_auth.so
auth      required pam_stack.so service=system-auth
```

Before someone is allowed to use `rlogin`, PAM verifies that the `/etc/nologin` file does not exist, that they are not trying to log in remotely as a root user over a network connection, and that any environmental variables can be loaded. Then, if a successful `rhosts` authentication is performed, the connection is allowed. If the `rhosts` authentication fails, then standard password authentication is performed.

### 15.3.2. Control Flag

All PAM modules generate a success or failure result when called. Control flags tell PAM what do with the result. Since modules can be stacked in a particular order, control flags decide how important the success or failure of a particular module is to the overall goal of authenticating the user to the service.

There are four predefined control flags:

- `required` — The module result must be successful for authentication to continue. If a `required` module result fails, the user is not notified until results on all modules referencing that interface are completed.
- `requisite` — The module result must be successful for authentication to continue. However, if a `requisite` module result fails, the user is notified immediately with a message reflecting the first failed `required` *or* `requisite` module.
- `sufficient` — The module result is ignored if it fails. However, if a `sufficient` flagged module result is successful *and* no `required` flagged modules above it have failed, then no other results are required and the user is authenticated to the service.
- `optional` — The module result is ignored. A module flagged as `optional` only becomes necessary for successful authentication when there are no other modules referencing the interface.



#### Important

The order in which `required` modules are called is not critical. The `sufficient` and `requisite` control flags cause order to become important.

A newer control flag syntax which allows for more precise control is now available for PAM. Please see the PAM docs located in the `/usr/share/doc/pam-<version-number>/` directory for information on this new syntax (where `<version-number>` is the version number for PAM).

### 15.3.3. Module Name

The module name provides PAM the name of the pluggable module containing the specified module interface. Under older versions of Red Hat Enterprise Linux, the full path to the module was provided within the PAM configuration file, such as `/lib/security/pam_stack.so`. However, since the advent of multilib systems, which store 64-bit PAM modules within the `/lib64/security/` directory, the directory name is omitted because the applications is linked the appropriate version of `libpam`, which can locate the correct version of the module.

### 15.3.4. Module Arguments

PAM uses arguments to pass information to a pluggable module during authentication for some modules.

For example, the `pam_userdb.so` module uses secrets stored in a Berkeley DB file to authenticate the user. Berkeley DB is an open source database system embedded in many applications. The module takes a `db` argument so that Berkeley DB knows which database to use for the requested service.

A typical `pam_userdb.so` line within a PAM configuration file looks like this:

```
auth        required pam_userdb.so db=<path-to-file>
```

In the previous example, replace `<path-to-file>` with the full path to the Berkeley DB database file.

Invalid arguments are ignored and do not otherwise affect the success or failure of the PAM module. However, most modules will report an error to the `/var/log/messages` file.

## 15.4. Sample PAM Configuration Files

Below is a sample PAM application configuration file:

```

#%PAM-1.0
auth      required  pam_securetty.so
auth      required  pam_unix.so shadow nullok
auth      required  pam_nologin.so
account   required  pam_unix.so
password  required  pam_cracklib.so retry=3
password  required  pam_unix.so shadow nullok use_authtok
session   required  pam_unix.so

```

The first line is a comment as denoted by the hash mark (#) at the beginning of the line.

Lines two through four stack three modules for login authentication.

```
auth      required  pam_securetty.so
```

This module makes sure that *if* the user is trying to log in as root, the tty on which the user is logging in is listed in the `/etc/securetty` file, *if* that file exists.

```
auth      required  pam_unix.so shadow nullok
```

This module prompts the user for a password and then checks the password using the information stored in `/etc/passwd` and, if it exists, `/etc/shadow`. The `pam_unix.so` module automatically detects and uses shadow passwords to authenticate users. Please refer to Section 6.5 *Shadow Passwords* for more information.

The argument `nullok` instructs the `pam_unix.so` module to allow a blank password.

```
auth      required  pam_nologin.so
```

This is the final authentication step. It verifies whether or not the file `/etc/nologin` exists. If `nologin` does exist and the user is not root, authentication fails.



### Note

In this example, all three `auth` modules are checked, even if the first `auth` module fails. This prevents the user from knowing at what stage their authentication failed. Such knowledge in the hands of an attacker could allow them to more easily deduce how to crack the system.

```
account   required  pam_unix.so
```

This module performs any necessary account verification. For example, if shadow passwords have been enabled, the account component of the `pam_unix.so` module checks to see if the account has expired or if the user has not changed the password within the grace period allowed.

```
password  required  pam_cracklib.so retry=3
```



If a password has expired, the password component of the `pam_cracklib.so` module prompts for a new password. It then tests the newly created password to see whether it can easily be determined by a dictionary-based password cracking program. If it fails this test the first time, it gives the user two more chances to create a strong password, as specified in the `retry=3` argument.

```
password required pam_unix.so shadow nullok use_authtok
```

This line specifies that if the program changes the user's password, it should use the `password` component of the `pam_unix.so` module to do so. This only happens if the `auth` portion of the `pam_unix.so` module has determined that the password needs to be changed.

The argument `shadow` tells the module to create shadow passwords when updating a user's password.

The argument `nullok` instructs the module to allow the user to change their password *from* a blank password, otherwise a null password is treated as an account lock.

The final argument on this line, `use_authtok`, provides a good example of the importance of order when stacking PAM modules. This argument tells the module not to prompt the user for a new password. Instead, it accepts any password that was recorded by a previous password module. In this way all, new passwords must pass the `pam_cracklib.so` test for secure passwords before being accepted.

```
session required pam_unix.so
```

The final line specifies that the session component of the `pam_unix.so` module manages the session. This module logs the username and the service type to `/var/log/messages` at the beginning and end of each session. It can be supplemented by stacking it with other session modules for more functionality.

The next sample configuration file illustrates `auth` module stacking for the `rlogin` program.

```
##PAM-1.0
auth      required      pam_nologin.so
auth      required      pam_securetty.so
auth      required      pam_env.so
auth      sufficient    pam_rhosts_auth.so
auth      required      pam_stack.so service=system-auth
```

First, `pam_nologin.so` checks to see if `/etc/nologin` exists. If it does, no one can log in except for root.

```
auth      required      pam_securetty.so
```

The `pam_securetty.so` module prevents the root user from logging in on insecure terminals. This effectively disallows all root `rlogin` attempts due to the application's limited security safeguards.



#### Tip

To log in remotely as the root user, use OpenSSH instead. For more information on the SSH protocol, see Chapter 19 *SSH Protocol*.

```
auth      required      pam_env.so
```

This line loads the `pam_env.so` module, which sets the environmental variables specified in `/etc/security/pam_env.conf`.

```
auth      sufficient    pam_rhosts_auth.so
```

The `pam_rhosts_auth.so` module authenticates the user using `.rhosts` in the user's home directory. If this succeeds, PAM immediately considers the authentication to have succeeded. If `pam_rhosts_auth.so` fails to authenticate the user, the authentication attempt is ignored.

```
auth      required      pam_stack.so service=system-auth
```

If the `pam_rhosts_auth.so` module fails to successfully authenticate the user, the `pam_stack.so` module performs normal password authentication.

The argument `service=system-auth` indicates that the user must now pass through the PAM configuration for system authentication as found in `/etc/pam.d/system-auth`.



### Tip

To prevent PAM from prompting for a password when the `securetty` result fails, change the `pam_securetty.so` module from `required` to `requisite`.

## 15.5. Creating PAM Modules

New PAM modules can be added at any time for PAM-aware applications to use. For example, if a developer invents a one-time-password creation method and writes a PAM module to support it, PAM-aware programs can immediately use the new module and password method without being recompiled or otherwise modified. This allows developers and system administrators to mix-and-match, as well as test, authentication methods for different programs without recompiling them.

Documentation on writing modules is included with the system in the `/usr/share/doc/pam-<version-number>/` directory (where `<version-number>` is the version number for PAM).

## 15.6. PAM and Administrative Credential Caching

A variety of graphical administrative tools under Red Hat Enterprise Linux give users elevated privileges for up to five minutes via the `pam_timestamp.so` module. It is important to understand how this mechanism works because a user who walks away from a terminal while `pam_timestamp.so` is in effect leaves the machine open to manipulation by anyone with physical access to the console.

Under the PAM timestamp scheme, the graphical administrative application prompts the user for the root password when it is launched. Once authenticated, the `pam_timestamp.so` module creates a timestamp file within the `/var/run/sudo/` directory by default. If the timestamp file already exists, other graphical administrative programs will not prompt for a password. Instead, the `pam_timestamp.so` module will freshen the timestamp file — reserving an extra five minutes of unchallenged administrative access for the user.

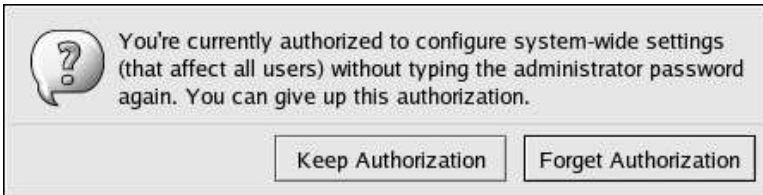
The existence of the timestamp file is denoted by an authentication icon in the notification area of the panel. Below is an illustration of the authentication icon:



**Figure 15-1. The Authentication Icon**

### 15.6.1. Removing the Timestamp File

It is recommended that before walking away from a console where a PAM timestamp is active, the timestamp file be destroyed. To do this from within a graphical environment, click on the authentication icon on the panel. When a dialog box appears, click on the **Forget Authorization** button.



**Figure 15-2. Authentication Icon Dialog**

If logged into a system remotely using `ssh`, use the `/sbin/pam_timestamp_check -k root` command to destroy the timestamp file.



#### Note

You must be logged in as the user who originally invoked the `pam_timestamp.so` module in order to use the `/sbin/pam_timestamp_check` command. Do not log in as root to issue this command.

For information about destroying the timestamp file using `pam_timestamp_check`, refer to the `pam_timestamp_check` man page.

### 15.6.2. Common `pam_timestamp` Directives

The `pam_timestamp.so` module accepts several directives. Below are the two most commonly used options:

- `timestamp_timeout` — Specifies the number of seconds the during which the timestamp file is valid (in seconds). The default value is 300 seconds (five minutes).
- `timestampdir` — Specifies the directory in which the timestamp file is stored. The default value is `/var/run/sudo`.

For more information about controlling the `pam_timestamp.so` module, refer to Section 15.8.1 *Installed Documentation*.

## 15.7. PAM and Device Ownership

Red Hat Enterprise Linux allows the first user to log in on the physical console of the machine the ability to manipulate some devices and perform some tasks normally reserved for the root user. This is controlled by a PAM module called `pam_console.so`.

### 15.7.1. Device Ownership

When a user logs into a Red Hat Enterprise Linux system, the `pam_console.so` module is called by `login` or the graphical login programs, `gdm` and `kdm`. If this user is the first user to log in at the physical console — called the *console user* — the module grants the user ownership of a variety of devices normally owned by root. The console user owns these devices until the last local session for that user ends. Once the user has logged out, ownership of the devices reverts back to the root user.

The devices affected include, but are not limited to, sound cards, diskette drives, and CD-ROM drives. This allows a local user to manipulate these devices without attaining root access, thus simplifying common tasks for the console user.

By modifying the file `/etc/security/console.perms`, the administrator can edit the list of devices controlled by `pam_console.so`.



#### Warning

If the `gdm`, `kdm`, or `xdm` display manager configuration file has been altered to allow remote users to log in *and* the host is configured to run at runlevel 5, it is advisable to change the `<console>` and `<xconsole>` directives within the `/etc/security/console.perms` to the following values:

```
<console>=tty[0-9][0-9]* vc/[0-9][0-9]* :0\.[0-9] :0
<xconsole>=:0\.[0-9] :0
```

Doing this will prevent remote users from gaining access to devices and restricted applications on the machine.

If the `gdm`, `kdm`, or `xdm` display manager configuration file has been altered to allow remote users to log in *and* the host is configured to run at any multiple user runlevel other than 5, it is advisable to remove the `<xconsole>` directive entirely and change the `<console>` directive to the following value:

```
<console>=tty[0-9][0-9]* vc/[0-9][0-9]*
```

### 15.7.2. Application Access

The console user is also allowed access to certain programs with a file bearing the command name in the `/etc/security/console.apps/` directory.

One notable group of applications the console user has access to are three programs which shut off or reboot the system. These are:

- `/sbin/halt`
- `/sbin/reboot`
- `/sbin/poweroff`

Because these are PAM-aware applications, they call the `pam_console.so` module as a requirement for use.

For more information, refer to the Section 15.8.1 *Installed Documentation*.

## 15.8. Additional Resources

The following resources further explain methods to use and configure PAM. In addition to these resources, read the PAM configuration files on the system to better understand how they are structured.

### 15.8.1. Installed Documentation

- PAM related man pages — There are a number of man pages for the various applications and configuration files involved with PAM. The following is a list of some of the more important man pages.

#### Configuration Files

- `man pam` — Good introductory information on PAM, including the structure and purpose of the PAM configuration files. Note that although this man page talks about the `/etc/pam.conf` file, the actual configuration files for PAM under Red Hat Enterprise Linux are in the `/etc/pam.d/` directory.
  - `man pam_console` — Describes the purpose of the `pam_console.so` module. It also describes the appropriate syntax for an entry within a PAM configuration file.
  - `man console.apps` — Describes the format and options available within `/etc/security/console.apps` the configuration file which defines which applications are accessible by the console user assigned by PAM.
  - `man console.perms` — Describes the format and options available within `/etc/security/console.perms`, the configuration file for the console user permissions assigned by PAM.
  - `man pam_timestamp` — Describes the `pam_timestamp.so` module.
- 
- `/usr/share/doc/pam-<version-number>` — Contains a *System Administrators' Guide*, a *Module Writers' Manual*, and the *Application Developers' Manual*, as well as a copy of the PAM standard, DCE-RFC 86.0 (replace `<version-number>` with the version number of PAM).
  - `/usr/share/doc/pam-<version-number>/txts/README.pam_timestamp` — Contains information about the `pam_timestamp.so` PAM module (replace `<version-number>` with the version number of PAM).

### 15.8.2. Useful Websites

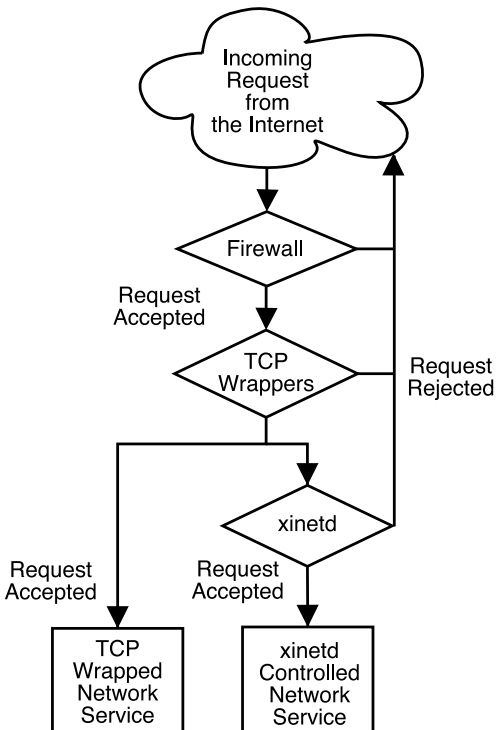
- <http://www.kernel.org/pub/linux/libs/pam/> — The primary distribution website for the Linux-PAM project, containing information on various PAM modules, a FAQ, and additional PAM documentation.



## TCP Wrappers and `xinetd`

Controlling access to network services is one of the most important security tasks facing a server administrator. Fortunately, under Red Hat Enterprise Linux there are a number of tools which do just that. For instance, an `iptables`-based firewall filters out unwelcome network packets within the kernel's network stack. For network services that utilize it, *TCP wrappers* add an additional layer of protection by defining which hosts are allowed or not allowed to connect to "wrapped" network services. One such wrapped network service is the `xinetd` *super server*. This service is called a super server because it controls connections to a subset of network services and further refines access control.

Figure 16-1 is a basic illustration of how these tools work together to protect network services.



**Figure 16-1.** Access Control to Network Services

This chapter focuses on the role of TCP wrappers and `xinetd` in controlling access to network services and reviews how these tools can be used to enhance both logging and utilization management. For a discussion of firewalling with `iptables`, refer to Chapter 17 *iptables*.

## 16.1. TCP Wrappers

The TCP wrappers package (`tcp_wrappers`) is installed by default and provides host-based access control to network services. The most important component within the package is the `/usr/lib/libwrap.a` library. In general terms, a TCP wrapped service is one that has been compiled against the `libwrap.a` library.

When a connection attempt is made to a TCP wrapped service, the service first references the *hosts access* files (`/etc/hosts.allow` and `/etc/hosts.deny`) to determine whether or not the client host is allowed to connect. In most cases, it then uses the syslog daemon (`syslogd`) to write the name of the requesting host and the requested service to `/var/log/secure` or `/var/log/messages`.

If a client host is allowed to connect, TCP wrappers release control of the connection to the requested service and do not interfere further with communication between the client host and the server.

In addition to access control and logging, TCP wrappers can activate commands to interact with the client before denying or releasing control of the connection to the requested network service.

Because TCP wrappers are a valuable addition to any server administrator's arsenal of security tools, most network services within Red Hat Enterprise Linux are linked against the `libwrap.a` library. Some such applications include `/usr/sbin/sshd`, `/usr/sbin/sendmail`, and `/usr/sbin/xinetd`.



### Note

To determine if a network service binary is linked against `libwrap.a`, type the following command as the root user:

```
strings -f <binary-name> | grep hosts_access
```

Replace `<binary-name>` with the name of the network service binary.

If a prompt is returned, then the network service is *not* linked against `libwrap.a`.

### 16.1.1. Advantages of TCP Wrappers

TCP wrappers provide the following advantages over other network service control techniques:

- *Transparency to both the client host and the wrapped network service.* — Both the connecting client and the wrapped network service are unaware that TCP wrappers are in use. Legitimate users are logged and connected to the requested service while connections from banned clients fail.
- *Centralized management of multiple protocols.* — TCP wrappers operate separately from the network services they protect, allowing many server applications to share a common set of configuration files for simpler management.

## 16.2. TCP Wrappers Configuration Files

To determine if a client machine is allowed to connect to a service, TCP wrappers reference the following two files, which are commonly referred to as hosts access files:

- `/etc/hosts.allow`
- `/etc/hosts.deny`

When a client request is received by a TCP wrapped service, it takes the following basic steps:



1. *References* `/etc/hosts.allow`. — The TCP wrapped service sequentially parses the `/etc/hosts.allow` file and applies the first rule specified for that service. If it finds a matching rule, it allows the connection. If not, it moves on to step 2.
2. *References* `/etc/hosts.deny`. — The TCP wrapped service sequentially parses the `/etc/hosts.deny` file. If it finds a matching rule is denies the connection. If not, access to the service is granted.

The following are important points to consider when using TCP wrappers to protect network services:

- Because access rules in `hosts.allow` are applied first, they take precedence over rules specified in `hosts.deny`. Therefore, if access to a service is allowed in `hosts.allow`, a rule denying access to that same service in `hosts.deny` is ignored.
- The rules in each file are read from the top down and the first matching rule for a given service is the only one applied. Therefore the order of the rules is extremely important.
- If no rules for the service are found in either file, or if neither file exists, access to the service is granted.
- TCP wrapped services do not cache the rules from the hosts access files, so any changes to `hosts.allow` or `hosts.deny` take effect immediately without restarting network services.



### Warning

If the last line of a hosts access file is not a newline character (created by pressing the [Enter] key), the last rule in the file fails and an error is logged to either `/var/log/messages` or `/var/log/secure`. This is also the case for a rules that span multiple lines without using the backslash. The following example illustrates the relevant portion of a log message for a rule failure due to either of these circumstances:

```
warning: /etc/hosts.allow, line 20: missing newline or line too long
```

## 16.2.1. Formatting Access Rules

The format for both `/etc/hosts.allow` and `/etc/hosts.deny` are identical. Any blank lines or lines that start with a hash mark (#) are ignored, and each rule must be on its own line.

Each rule uses the following basic format to control access to network services:

```
<daemon list>: <client list> [: <option>: <option>: ...]
```

- `<daemon list>` — A comma separated list of process names (*not* service names) or the ALL wildcard (see Section 16.2.1.1 *Wildcards*). The daemon list also accepts *operators* listed in Section 16.2.1.4 *Operators* to allow greater flexibility.
- `<client list>` — A comma separated list of hostnames, host IP addresses, special *patterns* (see Section 16.2.1.2 *Patterns*), or special wildcards (refer to Section 16.2.1.1 *Wildcards*) which identify the hosts effected by the rule. The client list also accepts *operators* listed in Section 16.2.1.4 *Operators* to allow greater flexibility.
- `<option>` — An optional action or colon separated list of actions performed when the rule is triggered. Option fields support *expansions* (refer to Section 16.2.2.4 *Expansions*), launch shell commands, allow or deny access, and alter logging behavior (refer to Section 16.2.2 *Option Fields*).

The following is a basic sample hosts access rule:

```
vsftpd : .example.com
```

This rule instructs TCP wrappers to watch for connections to the FTP daemon (`vsftpd`) from any host in the `example.com` domain. If this rule appears in `hosts.allow`, the connection is accepted. If this rule appears in `hosts.deny`, the connection is rejected.

The next sample hosts access rule is more complex and uses two option fields:

```
sshd : .example.com \
: spawn /bin/echo `/bin/date` access denied>>/var/log/sshd.log \
: deny
```

Note that in this example that each option field is preceded by the backslash (`\`). Use of the backslash prevents failure of the rule due to length.

This sample rule states that if a connection to the SSH daemon (`sshd`) is attempted from a host in the `example.com` domain, execute the `echo` command (which will log the attempt to a special file), and deny the connection. Because the optional `deny` directive is used, this line will deny access even if it appears in the `hosts.allow` file. For a more detailed look at available options, refer to Section 16.2.2 *Option Fields*.

### 16.2.1.1. Wildcards

Wildcards allow TCP wrappers to more easily match groups of daemons or hosts. They are used most frequently in the client list field of access rules.

The following wildcards may be used:

- `ALL` — Matches everything. It can be used for both the daemon list and the client list.
- `LOCAL` — Matches any host that does not contain a period (`.`), such as `localhost`.
- `KNOWN` — Matches any host where the hostname and host address are known or where the user is known.
- `UNKNOWN` — Matches any host where the hostname or host address are unknown or where the user is unknown.
- `PARANOID` — Matches any host where the hostname does not match the host address.



#### Caution

The `KNOWN`, `UNKNOWN`, and `PARANOID` wildcards should be used with care as a disruption in name resolution may prevent legitimate users from gaining access to a service.

### 16.2.1.2. Patterns

Patterns can be used in the client list field of access rules to more precisely specify groups of client hosts.

The following is a list of the most common accepted patterns for a client list entry:

- *Hostname beginning with a period (`.`)* — Placing a period at the beginning of a hostname, matches all hosts sharing the listed components of the name. The following example applies to any host within the `example.com` domain:

```
ALL : .example.com
```

- *IP address ending with a period (.)* — Placing a period at the end of an IP address matches all hosts sharing the initial numeric groups of an IP address. The following example applies to any host within the `192.168.x.x` network:

```
ALL : 192.168.
```

- *IP address/netmask pair* — Netmask expressions can also be used as a pattern to control access to a particular group of IP addresses. The following example applies to any host with an address of `192.168.0.0` through `192.168.1.255`:

```
ALL : 192.168.0.0/255.255.254.0
```



### Important

When working in the IPv4 address space, the address/prefix length (*prefixlen*) pair declarations are not supported. Only IPv6 rules can use this format.

- *[IPv6 address]/prefixlen pair* — `[net]/prefixlen` pairs can also be used as a pattern to control access to a particular group of IPv6 addresses. The following example would apply to any host with an address of `3ffe:505:2:1::` through `3ffe:505:2:1:ffff:ffff:ffff:ffff`:

```
ALL : [3ffe:505:2:1::]/64
```

- *The asterisk (\*)* — Asterisks can be used to match entire groups of hostnames or IP addresses, as long as they are not mixed in a client list containing other types of patterns. The following example would apply to any host within the `example.com` domain:

```
ALL : *.example.com
```

- *The slash (/)* — If a client list begins with a slash, it is treated as a file name. This is useful if rules specifying large numbers of hosts are necessary. The following example refers TCP wrappers to the `/etc/telnet.hosts` file for all Telnet connections:

```
in.telnetd : /etc/telnet.hosts
```

Other, lesser used patterns are also accepted by TCP wrappers. Refer to the `hosts_access` man 5 page for more information.



### Warning

Be very careful when using hostnames and domain names. Attackers can use a variety of tricks to circumvent accurate name resolution. In addition, disruption in DNS service prevents even authorized users from using network services.

It is, therefore, best to use IP addresses whenever possible.

### 16.2.1.3. Portmap and TCP Wrappers

When creating access control rules for `portmap`, do not use hostnames as `portmap`'s implementation of TCP wrappers does not support host look ups. For this reason, only use IP addresses or the keyword `ALL` when specifying hosts in `hosts.allow` or `hosts.deny`.

In addition, changes to `portmap` access control rules may not take affect immediately without restarting the `portmap` service.

Widely used services, such as NIS and NFS, depend on `portmap` to operate, so be aware of these limitations.

#### 16.2.1.4. Operators

At present, access control rules accept one operator, `EXCEPT`. It can be used in both the daemon list and the client list of a rule.

The `EXCEPT` operator allows specific exceptions to broader matches within the same rule.

In the following example from a `hosts.allow` file, all `example.com` hosts are allowed to connect to all services except `cracker.example.com`:

```
ALL: .example.com EXCEPT cracker.example.com
```

In the another example from a `hosts.allow` file, clients from the `192.168.0.x` network can use all services except for FTP:

```
ALL EXCEPT vsftpd: 192.168.0.
```



#### Note

Organizationally, it is often easier to avoid using `EXCEPT` operators. This allows other administrators to quickly scan the appropriate files to see what hosts should be allowed or denied access to services, without having to sort through `EXCEPT` operators.

### 16.2.2. Option Fields

In addition to basic rules allowing and denying access, the Red Hat Enterprise Linux implementation of TCP wrappers supports extensions to the access control language through option fields. By using option fields within hosts access rules, administrators can accomplish a variety of tasks such as altering log behavior, consolidating access control, and launching shell commands.

#### 16.2.2.1. Logging

Option fields let administrators easily change the log facility and priority level for a rule by using the `severity` directive.

In the following example, connections to the SSH daemon from any host in the `example.com` domain are logged to the default `authpriv syslog` facility (because no facility value is specified) with a priority of `emerg`:

```
sshd : .example.com : severity emerg
```

It is also possible to specify a facility using the `severity` option. The following example logs any SSH connection attempts by hosts from the `example.com` domain to the `local0` facility with a priority of `alert`:

```
sshd : .example.com : severity local0.alert
```

**Note**

In practice, this example does not work until the `syslog` daemon (`syslogd`) is configured to log to the `local0` facility. Refer to the `syslog.conf` man page for information about configuring custom log facilities.

**16.2.2.2. Access Control**

Option fields also allow administrators to explicitly allow or deny hosts in a single rule by adding the `allow` or `deny` directive as the final option.

For instance, the following two rules allow SSH connections from `client-1.example.com`, but deny connections from `client-2.example.com`:

```
sshd : client-1.example.com : allow
sshd : client-2.example.com : deny
```

By allowing access control on a per-rule basis, the option field allows administrators to consolidate all access rules into a single file: either `hosts.allow` or `hosts.deny`. Some consider this an easier way of organizing access rules.

**16.2.2.3. Shell Commands**

Option fields allow access rules to launch shell commands through the following two directives:

- `spawn` — Launches a shell command as a child process. This option directive can perform tasks like using `/usr/sbin/safe_finger` to get more information about the requesting client or create special log files using the `echo` command.

In the following example, clients attempting to access Telnet services from the `example.com` domain are quietly logged to a special file:

```
in.telnetd : .example.com \
    : spawn /bin/echo `bin/date` from %h>>/var/log/telnet.log \
    : allow
```

- `twist` — Replaces the requested service with the specified command. This directive is often used to set up traps for intruders (also called "honey pots"). It can also be used to send messages to connecting clients. The `twist` command must occur at the end of the rule line.

In the following example, clients attempting to access FTP services from the `example.com` domain are sent a message via the `echo` command:

```
vsftpd : .example.com \
    : twist /bin/echo "421 Bad hacker, go away!"
```

For more information about shell command options, refer to the `hosts_options` man page.

**16.2.2.4. Expansions**

Expansions, when used in conjunction with the `spawn` and `twist` directives provide information about the client, server, and processes involved.

Below is a list of supported expansions:

- `%a` — Supplies the client's IP address.
- `%A` — Supplies the server's IP address.

- `%c` — Supplies a variety of client information, such as the username and hostname, or the username and IP address.
- `%d` — Supplies the daemon process name.
- `%h` — Supplies the client's hostname (or IP address, if the hostname is unavailable).
- `%H` — Supplies the server's hostname (or IP address, if the hostname is unavailable).
- `%n` — Supplies the client's hostname. If unavailable, `unknown` is printed. If the client's hostname and host address do not match, `paranoid` is printed.
- `%N` — Supplies the server's hostname. If unavailable, `unknown` is printed. If the server's hostname and host address do not match, `paranoid` is printed.
- `%p` — Supplies the daemon process ID.
- `%s` — Supplies various types of server information, such as the daemon process and the host or IP address of the server.
- `%u` — Supplies the client's username. If unavailable, `unknown` is printed.

The following sample rule uses an expansion in conjunction with the `spawn` command to identify the client host in a customized log file.

When connections to the SSH daemon (`sshd`) is attempted from a host in the `example.com` domain, execute the `echo` command to log the attempt, including the client hostname (by using the `%h` expansion), to a special file:

```
sshd : .example.com \
: spawn /bin/echo `/bin/date` access denied to %h>>/var/log/sshd.log \
: deny
```

Similarly, expansions can be used to personalize messages back to the client. In the following example, clients attempting to access FTP services from the `example.com` domain are informed that they have been banned from the server:

```
vsftpd : .example.com \
: twist /bin/echo "421 %h has been banned from this server!"
```

For a full explanation of available expansions, as well as additional access control options, refer to section 5 of the man pages for `hosts_access` (man 5 `hosts_access`) and the man page for `hosts_options`.

For additional information about TCP wrappers, refer to Section 16.5 *Additional Resources*. For more information about how to secure TCP wrappers, refer to the chapter titled *Server Security* in the *Red Hat Enterprise Linux Security Guide*.

### 16.3. `xinetd`

The `xinetd` daemon is a TCP wrapped *super service* which controls access to a subset of popular network services including FTP, IMAP, and Telnet. It also provides service-specific configuration options for access control, enhanced logging, binding, redirection, and resource utilization control.

When a client host attempts to connect to a network service controlled by `xinetd`, the super service receives the request and checks for any TCP wrappers access control rules. If access is allowed, `xinetd` verifies that the connection is allowed under its own access rules for that service and that the service is not consuming more than its allotted amount of resources or in breach of any defined rules. It then starts an instance of the requested service and passes control of the connection to it. Once the

connection is established, `xinetd` does not interfere further with communication between the client host and the server.

## 16.4. `xinetd` Configuration Files

The configuration files for `xinetd` are as follows:

- `/etc/xinetd.conf` — The global `xinetd` configuration file.
- `/etc/xinetd.d/` directory — The directory containing all service-specific files.

### 16.4.1. The `/etc/xinetd.conf` File

The `/etc/xinetd.conf` file contains general configuration settings which effect every service under `xinetd`'s control. It is read once when the `xinetd` service is started, so for configuration changes to take effect, the administrator must restart the `xinetd` service. Below is a sample `/etc/xinetd.conf` file:

```
defaults
{
    instances             = 60
    log_type              = SYSLOG authpriv
    log_on_success        = HOST PID
    log_on_failure        = HOST
    cps                   = 25 30
}
includedir /etc/xinetd.d
```

These lines control the following aspects of `xinetd`:

- `instances` — Sets the maximum number of requests `xinetd` can handle at once.
- `log_type` — Configures `xinetd` to use the `authpriv` log facility, which writes log entries to the `/var/log/secure` file. Adding a directive such as `FILE /var/log/xinetdlog` would create a custom log file called `xinetdlog` in the `/var/log/` directory.
- `log_on_success` — Configures `xinetd` to log if the connection is successful. By default, the remote host's IP address and the process ID of server processing the request are recorded.
- `log_on_failure` — Configures `xinetd` to log if there is a connection failure or if the connection is not allowed.
- `cps` — Configures `xinetd` to allow no more than 25 connections per second to any given service. If this limit is reached, the service is retired for 30 seconds.
- `includedir /etc/xinetd.d/` — Includes options declared in the service-specific configuration files located in the `/etc/xinetd.d/` directory. Refer to Section 16.4.2 *The `/etc/xinetd.d/` Directory* for more information about this directory.



#### Note

Often, both the `log_on_success` and `log_on_failure` settings in `/etc/xinetd.conf` are further modified in the service-specific log files. For this reason, more information may appear in a given service's log than the `/etc/xinetd.conf` file may indicate. Refer to Section 16.4.3.1 *Logging Options* for more about logging options.

### 16.4.2. The `/etc/xinetd.d/` Directory

The files in the `/etc/xinetd.d/` directory contains the configuration files for each service managed by `xinetd` and the names of the files correlate to the service. As with `xinetd.conf`, this file is read only when the `xinetd` service is started. For any changes to take effect, the administrator must restart the `xinetd` service.

The format of files in the `/etc/xinetd.d/` directory use the same conventions as `/etc/xinetd.conf`. The primary reason the configuration for each service is stored in a separate file is to make customization easier and less likely to effect other services.

To gain an understanding of how these files are structured, consider the `/etc/xinetd.d/telnet` file:

```
service telnet
{
    flags          = REUSE
    socket_type    = stream
    wait          = no
    user          = root
    server        = /usr/sbin/in.telnetd
    log_on_failure += USERID
    disable       = yes
}
```

These lines control various aspects of the `telnet` service:

- `service` — Defines the service name, usually one listed in the `/etc/services` file.
- `flags` — Sets any of a number of attributes for the connection. `REUSE` instructs `xinetd` to reuse the socket for a Telnet connection.
- `socket_type` — Sets the network socket type to `stream`.
- `wait` — Defines whether the service is single-threaded (`yes`) or multi-threaded (`no`).
- `user` — Defines what user ID the process process will run under.
- `server` — Defines the binary executable to be launched.
- `log_on_failure` — Defines logging parameters for `log_on_failure` in addition to those already defined in `xinetd.conf`.
- `disable` — Defines whether or not the service is active.

### 16.4.3. Altering `xinetd` Configuration Files

There are a large assortment of directives available for `xinetd` protected services. This section highlights some of the more commonly used options.

#### 16.4.3.1. Logging Options

The following logging options are available for both `/etc/xinetd.conf` and the service-specific configuration files within the `/etc/xinetd.d/` directory.

Below is a list of some of the more commonly used logging options:

- `ATTEMPT` — Logs the fact that a failed attempt was made (`log_on_failure`).
- `DURATION` — Logs the length of time the service is used by a remote system (`log_on_success`).
- `EXIT` — Logs the exit status or termination signal of the service (`log_on_success`).



- `HOST` — Logs the remote host's IP address (`log_on_failure` and `log_on_success`).
- `PID` — Logs the process ID of the server receiving the request (`log_on_success`).
- `USERID` — Logs the remote user using the method defined in RFC 1413 for all multi-threaded stream services (`log_on_failure` and `log_on_success`).

For a complete list of logging options, consult the `xinetd.conf` man page.

### 16.4.3.2. Access Control Options

Users of `xinetd` services can choose to use the TCP wrappers hosts access rules, provide access control via the `xinetd` configuration files, or a mixture of both. Information concerning the use of TCP wrappers hosts access control files can be found in Section 16.2 *TCP Wrappers Configuration Files*.

This section discusses using `xinetd` to control access to services.



#### Note

Unlike TCP wrappers, changes to access control only take effect if the `xinetd` administrator restarts the `xinetd` service.

Also, unlike TCP wrappers, access control through `xinetd` only affects services controlled by `xinetd`.

The `xinetd` hosts access control differs from the method used by TCP wrappers. While TCP wrappers places all of the access configuration within two files, `/etc/hosts.allow` and `/etc/hosts.deny`, `xinetd`'s access control is found in each service's configuration file within the `/etc/xinetd.d/` directory.

The following hosts access options are supported by `xinetd`:

- `only_from` — Allows only the specified hosts to use the service.
- `no_access` — Blocks listed hosts from using the service.
- `access_times` — Specifies the time range when a particular service may be used. The time range must be stated in 24-hour format notation, `HH:MM-HH:MM`.

The `only_from` and `no_access` options can use a list of IP addresses or host names, or can specify an entire network. Like TCP wrappers, combining `xinetd` access control with the enhanced logging configuration can increase security by blocking requests from banned hosts while verbosely recording each connection attempt.

For example, the following `/etc/xinetd.d/telnet` file can be used to block Telnet access from a particular network group and restrict the overall time range that even allowed users can log in:

```
service telnet
{
    disable           = no
    flags             = REUSE
    socket_type      = stream
    wait             = no
    user             = root
    server           = /usr/sbin/in.telnetd
    log_on_failure   += USERID
    no_access        = 10.0.1.0/24
    log_on_success   += PID HOST EXIT
    access_times     = 09:45-16:15
}
```

```
}
```

In this example, when client system from the 10.0.1.0/24 network, such as 10.0.1.2, tries to access the Telnet service, it receives a message stating the following message:

```
Connection closed by foreign host.
```

In addition, their login attempts are logged in `/var/log/secure` as follows:

```
May 15 17:38:49 boo xinetd[16252]: START: telnet pid=16256 from=10.0.1.2
May 15 17:38:49 boo xinetd[16256]: FAIL: telnet address from=10.0.1.2
May 15 17:38:49 boo xinetd[16252]: EXIT: telnet status=0 pid=16256
```

When using TCP wrappers in conjunction with `xinetd` access controls, it is important to understand the relationship between the two access control mechanisms.

The following is the order of operations followed by `xinetd` when a client requests a connection:

1. The `xinetd` daemon accesses the TCP wrappers hosts access rules through a `libwrap.a` library call. If a deny rule matches the client host, the connection is dropped. If an allow rule matches the client host, the connection is passed on to `xinetd`.
2. The `xinetd` daemon checks its own access control rules both for the `xinetd` service and the requested service. If a deny rule matches the client host the connection is dropped. Otherwise, `xinetd` starts an instance of the requested service and passes control of the connection to it.



### Important

Care should be taken when using TCP wrappers access controls in conjunction with `xinetd` access controls. Misconfiguration can cause undesired effects.

### 16.4.3.3. Binding and Redirection Options

The service configuration files for `xinetd` support binding the service to an IP address and redirecting incoming requests for that service to another IP address, hostname, or port.

Binding is controlled with the `bind` option in the service-specific configuration files and links the service to one IP address on the system. Once configured, the `bind` option only allows requests for the proper IP address to access the service. This way different services can be bound to different network interfaces based on need.

This is particularly useful for systems with multiple network adapters or with multiple IP addresses configured. On such a system, insecure services, like Telnet, can be configured to listen only on the interface connected to a private network and not to the interface connected with the Internet.

The `redirect` option accepts an IP address or hostname followed by a port number. It configures the service to redirect any requests for this service to the specified host and port number. This feature can be used to point to another port number on the same system, redirect the request to different IP address on the same machine, shift the request to a totally different system and port number, or any combination of these options. In this way, a user connecting to certain service on a system may be rerouted to another system with no disruption.

The `xinetd` daemon is able to accomplish this redirection by spawning a process that stays alive for the duration of the connection between the requesting client machine and the host actually providing the service, transferring data between the two systems.

But the advantages of the `bind` and `redirect` options are most clearly evident when they are used together. By binding a service to a particular IP address on a system and then redirecting requests for this service to a second machine that only the first machine can see, an internal system can be used to provide services for a totally different network. Alternatively, these options can be used to limit the exposure of a particular service on a multi-homed machine to a known IP address, as well as redirect any requests for that service to another machine specially configured for that purpose.

For example, consider a system that is used as a firewall with this setting for its Telnet service:

```
service telnet
{
    socket_type = stream
    wait = no
    server = /usr/sbin/in.telnetd
    log_on_success += DURATION USERID
    log_on_failure += USERID
    bind = 123.123.123.123
    redirect = 10.0.1.13 23
}
```

The `bind` and `redirect` options in this file ensures that the Telnet service on the machine is bound to the external IP address (123.123.123.123), the one facing the Internet. In addition, any requests for Telnet service sent to 123.123.123.123 are redirected via a second network adapter to an internal IP address (10.0.1.13) that only the firewall and internal systems can access. The firewall then send the communication between the two systems, and the connecting system thinks it is connected to 123.123.123.123 when it is actually connected to a different machine.

This feature is particularly useful for users with broadband connections and only one fixed IP address. When using Network Address Translation (NAT), the systems behind the gateway machine, which are using internal-only IP addresses, are not available from outside the gateway system. However, when certain services controlled by `xinetd` are configured with the `bind` and `redirect` options, the gateway machine can act as a proxy between outside systems and a particular internal machine configured to provide the service. In addition, the various `xinetd` access control and logging options are also available for additional protection.

#### 16.4.3.4. Resource Management Options

The `xinetd` daemon can add a basic level of protection from a Denial of Service (DoS) attacks. Below is a list of directives which can aid in limiting the effectiveness of such attacks:

- `per_source` — Defines the maximum number of instances for a service per source IP address. It accepts only integers as an argument and can be used in both `xinetd.conf` and in the service-specific configuration files in the `xinetd.d/` directory.
- `cps` — Defines the maximum of connections per second. This directive takes two integer arguments separated by white space. The first is the maximum number of connections allowed to the service per second. The second is the number of seconds `xinetd` must wait before re-enabling the service. It accepts only integers as an argument and can be used in both `xinetd.conf` and in the service-specific configuration files in the `xinetd.d/` directory.
- `max_load` — Defines the CPU usage threshold for a service. It accepts a floating point number argument.

There more resource management options available for `xinetd`. Refer to the chapter titled *Server Security* in the *Red Hat Enterprise Linux Security Guide* for more information. Also consult the `xinetd.conf` man page.

## 16.5. Additional Resources

Additional information concerning TCP wrappers and `xinetd` is available from system documentation and on the Internet.

### 16.5.1. Installed Documentation

The bundled documentation on your system is a good place to start looking for additional TCP Wrappers, `xinetd`, and access control configuration options.

- `/usr/share/doc/tcp_wrappers-<version>/` — Contains a `README` file that discusses how TCP wrappers work and the various hostname and host address spoofing risks that exist.
- `/usr/share/doc/xinetd-<version>/` — Includes a `README` file that discusses aspects of access control and a `sample.conf` file with various ideas for modifying service-specific configuration files in the `/etc/xinetd.d/` directory.
- TCP wrappers and `xinetd` related man pages — There are a number of man pages for the various applications and configuration files involved with TCP wrappers and `xinetd`. The following is a list of some of the more important man pages.

#### Server Applications

- `man xinetd` — The man page for the `xinetd` super service daemon.

#### Configuration Files

- `man 5 hosts_access` — The man page for the TCP wrappers hosts access control files.
- `man hosts_options` — The man page for the TCP wrappers options fields.
- `man xinetd.conf` — The man page listing `xinetd` configuration options.

### 16.5.2. Useful Websites

- <http://www.xinetd.org/> — The home of `xinetd`, containing sample configuration files, a full listing of features, and an informative FAQ.
- <http://www.macsecurity.org/resources/xinetd/tutorial.shtml> — A thorough tutorial that discusses many different ways to tweak default `xinetd` configuration files to meet specific security goals.

### 16.5.3. Related Books

- *Red Hat Enterprise Linux Security Guide*; Red Hat, Inc. — Provides an overview of workstation, server, and network security with specific suggestions regarding TCP wrappers and `xinetd`.
- *Hacking Linux Exposed* by Brian Hatch, James Lee, and George Kurtz; Osbourne/McGraw-Hill — An excellent security resource with featuring information about TCP wrappers and `xinetd`.

Installed with Red Hat Enterprise Linux are advanced tools for network *packet filtering* — the process of controlling network packets as they enter, move through, and exit the network stack within the kernel. Pre-2.4 kernels relied on `ipchains` for packet filtering and used lists of rules applied to packets at each step of the filtering process. The introduction of the 2.4 kernel brought with it `iptables` (also called *netfilter*), which is similar to `ipchains` but greatly expands the scope and control available for filtering network packets.

This chapter focuses on packet filtering basics, defines the differences between `ipchains` and `iptables`, explains various options available with `iptables` commands, and explains how filtering rules can be preserved between system reboots.

For instructions on constructing `iptables` rules or setting up a firewall based on these rules, refer to Section 17.7 *Additional Resources*.

 **Warning**

The default firewall mechanism under the 2.4 kernel is `iptables`, but `iptables` cannot be used if `ipchains` are already running. If `ipchains` are present at boot time, the kernel issues an error and fail to start `iptables`.

The functionality of `ipchains` is not affected by these errors.

## 17.1. Packet Filtering

The Linux kernel has the built-in ability to filter packets, allowing some of them to be received by or pass through the system while stopping others. The 2.4 kernel's netfilter has three built-in *tables* or *rules lists*. They are as follows:

- `filter` — The default table for handling network packets.
- `nat` — Used to alter packets that create a new connection and used for *Network Address Translation (NAT)*.
- `mangle` — Used for specific types of packet alteration.

 **Tip**

In addition to these built in tables, specialized tables can be created and stored in the `/lib/modules/<kernel-version>/kernel/net/ipv4/netfilter/` directory (where `<kernel-version>` corresponds to the version kernel number).

Each table has a group of built-in *chains* which correspond to the actions performed on the packet by the netfilter.

The built-in chains for the `filter` table are as follows:

- `INPUT` — Applies to network packets that are targeted for the host.
- `OUTPUT` — Applies to locally-generated network packets.

- *FORWARD* — Applies to network packets routed through the host.

The built-in chains for the `nat` table are as follows:

- *PREROUTING* — Alters network packets when they arrive.
- *OUTPUT* — Alters locally-generated network packets before they are sent out.
- *POSTROUTING* — Alters network packets before they are sent out.

The built-in chains for the `mangle` table are as follows:

- *INPUT* — Alters network packets targeted for the host.
- *OUTPUT* — Alters locally-generated network packets before they are sent out.
- *FORWARD* — Alters network packets routed through the host.
- *PREROUTING* — Alters incoming network packets before they are routed.
- *POSTROUTING* — Alters network packets before they are sent out.

Every network packet received by or sent out of a Linux system is subject to at least one table. However, a packet may be subjected to multiple rules within each table before emerging at the end of the chain. The structure and purpose of these rules may vary, but they usually seek to identify a packet coming from or going to a particular IP address or set of addresses when using a particular protocol and network service.

Regardless of their destination, when packets match a particular rule in one of the tables, a *target* or action is applied to them. If the rule specifies an `ACCEPT` target for a matching packet, the packet skips the rest of the rule checks and is allowed to continue to its destination. If a rule specifies a `DROP` target, that packet is refused access to the system and nothing is sent back to the host that sent the packet. If a rule specifies a `QUEUE` target, the packet is passed to user-space. If a rule specifies the optional `REJECT` target, the packet is dropped, but an error packet is sent to the packet's originator.

Every chain has a default policy to `ACCEPT`, `DROP`, `REJECT`, or `QUEUE`. If none of the rules in the chain apply to the packet, then the packet is dealt with in accordance with the default policy.

The `iptables` command configures these tables, as well as sets up new tables if necessary.

## 17.2. Differences between iptables and ipchains

At first glance, `ipchains` and `iptables` appear to be quite similar. Both methods of packet filtering use chains of rules operating within the Linux kernel to decide what to do with packets that match the specified rule or set of rules. However, `iptables` offers a more extensible way of filtering packets, giving the administrator a greater amount of control without building a great deal of complexity into the system.

Specifically, users comfortable with `ipchains` should be aware of the following significant differences between `ipchains` and `iptables` before attempting to use `iptables`:

- *Under iptables, each filtered packet is processed using rules from only one chain rather than multiple chains.* For instance, a `FORWARD` packet coming into a system using `ipchains` would have to go through the `INPUT`, `FORWARD`, and `OUTPUT` chains to move along to its destination. However, `iptables` only sends packets to the `INPUT` chain if they are destined for the local system and only sends them to the `OUTPUT` chain if the local system generated the packets. For this reason, it is important to place the rule designed to catch a particular packet within the rule that actually handles the packet.
- *The DENY target has been changed to DROP.* In `ipchains`, packets that matched a rule in a chain could be directed to the `DENY` target. This target must be changed to `DROP` under `iptables`.

- *Order matters when placing options in a rule.* Previously, with `ipchains`, the order of the rule options did not matter. The `iptables` command uses stricter syntax. For example, in `iptables` commands the protocol (ICMP, TCP, or UDP) must be specified before the source or destination ports.
- *When specifying network interfaces to be used with a rule, you must only use incoming interfaces (-i option) with INPUT or FORWARD chains and outgoing interfaces (-o option) with FORWARD or OUTPUT chains.* This is necessary because OUTPUT chains are no longer used by incoming interfaces, and INPUT chains are not seen by packets moving through outgoing interfaces.

This is not a comprehensive list of the changes, given that `iptables` is a fundamentally rewritten network filter. For more specific information, refer to the *Linux 2.4 Packet Filtering HOWTO* found in Section 17.7 *Additional Resources*.

### 17.3. Options Used within iptables Commands

Rules for filtering packets are put in place using the `iptables` command. When using the `iptables` command, the following aspects of the packet are most often used as criteria:

- *Packet Type* — Specifies the type of packets the command filters.
- *Packet Source/Destination* — Specifies which packets the command filters based on the source or destination of the packet.
- *Target* — Specifies what action is taken on packets matching the above criteria.

For more information on specific options which address these aspects of a packet, refer to Section 17.3.4 *iptables Match Options* and Section 17.3.5 *Target Options*.

The options used with given `iptables` rule must be grouped logically, based on the purpose and conditions of the overall rule, for the rule to be valid. The remainder of this section explains commonly-used options for the `iptables` command.

#### 17.3.1. Structure of iptables Options

Many `iptables` commands have the following structure:

```
iptables [-t <table-name>] <command> <chain-name> <parameter-1> \  
        <option-1> <parameter-n> <option-n>
```

The `<table-name>` option allows the user to select a table other than the default `filter` table to use with the command. The `<command>` option dictates a specific action to perform, such as appending or deleting the rule specified by the `<chain-name>` option. Following the `<chain-name>` are pairs of parameters and options that define what happens when a packet matches the rule.

When looking at the structure of an `iptables` command, it is important to remember that, unlike most other commands, the length and complexity of an `iptables` command can change based on its purpose. A command to remove a rule from a chain can be very short, while a command designed to filter packets from a particular subnet using a variety of specific parameters and options can be rather lengthy. When creating `iptables` commands it is helpful to recognize that some parameters and options may create the need for other parameters and options to further specify the previous option's request. To construct a valid rule, this must continue until every parameter and option that requires another set of options is satisfied.

Type `iptables -h` to view a comprehensive list of `iptables` command structures.

### 17.3.2. Command Options

Command options instruct `iptables` to perform a specific action. Only one command option is allowed per `iptables` command. With the exception of the help command, all commands are written in upper-case characters.

The `iptables` commands are as follows:

- `-A` — Appends the `iptables` rule to the end of the specified chain. This is the command used to add a rule when rule order in the chain does not matter.
- `-C` — Checks a particular rule before adding it to the user-specified chain. This command can help you construct complicated `iptables` rules by prompting you for additional parameters and options.
- `-D` — Deletes a rule in a particular chain by number (such as 5 for the fifth rule in a chain). You can also type the entire rule, and `iptables` deletes the rule in the chain that matches it.
- `-E` — Renames a user-defined chain. This does not affect the structure of the table.
- `-F` — Flushes the selected chain, which effectively deletes every rule in the the chain. If no chain is specified, this command flushes every rule from every chain.
- `-h` — Provides a list of command structures, as well as a quick summary of command parameters and options.
- `-I` — Inserts a rule in a chain at a point specified by a user-defined integer value. If no number is specified, `iptables` places the command at the top of the chain.



#### Caution

Be aware when using the `-A` or `-I` option that the order of the rules within a chain are important for determining which rules apply to which packets.

- `-L` — Lists all of the rules in the chain specified after the command. To list all rules in all chains in the default `filter` table, do not specify a chain or table. Otherwise, the following syntax should be used to list the rules in a specific chain in a particular table:  

```
iptables -L <chain-name> -t <table-name>
```

Additional options for the `-L` command option which provide rule numbers and allow more verbose rule descriptions are described in Section 17.3.6 *Listing Options*.

- `-N` — Creates a new chain with a user-specified name.
- `-P` — Sets the default policy for the specified chain, so that when packets traverse an entire chain without matching a rule, they are sent on to the specified target, such as `ACCEPT` or `DROP`.
- `-R` — Replaces a rule in the specified chain. The rule's number must be specified after the chain's name. The first rule in a chain corresponds to rule number one.
- `-X` — Deletes a user-specified chain. Deleting a built-in chain for any table is not allowed.
- `-Z` — Zeros the byte and packet counters in all chains for a table.

### 17.3.3. iptables Parameter Options

Once certain `iptables` commands are specified, including those used to add, append, delete, insert, or replace rules within a particular chain, parameters are required to construct a packet filtering rule.

- `-c` — Resets the counters for a particular rule. This parameter accepts the `PKTS` and `BYTES` options to specify what counter to reset.



- `-d` — Sets the destination hostname, IP address, or network of a packet that matches the rule. When matching a network, the following IP address/netmask formats are supported:
  - `N.N.N.N/M.M.M.M` — Where `N.N.N.N` is the IP address range and `M.M.M.M` is the netmask.
  - `N.N.N.N/M` — Where `N.N.N.N` is the IP address range and `M` is the bitmask.
- `-f` — Applies this rule only to fragmented packets.  
By using the `!` option after this parameter, only unfragmented packets are matched.
- `-i` — Sets the incoming network interface, such as `eth0` or `ppp0`. With `iptables`, this optional parameter may only be used with the `INPUT` and `FORWARD` chains when used with the `filter` table and the `PREROUTING` chain with the `nat` and `mangle` tables.

This parameter also supports the following special options:

- `!` — Reverses the directive, meaning any specified interfaces are excluded from this rule.
- `+` — A wildcard character used to match all interfaces that match the specified string. For example, the parameter `-i eth+` would apply this rule to any Ethernet interfaces but exclude any other interfaces, such as `ppp0`.

If the `-i` parameter is used but no interface is specified, then every interface is affected by the rule.

- `-j` — Jumps to the specified target when a packet matches a particular rule. Valid targets to be used after the `-j` option include the standard options (`ACCEPT`, `DROP`, `QUEUE`, and `RETURN`) as well as extended options that are available through modules loaded by default with the Red Hat Enterprise Linux `iptables` RPM package, such as `LOG`, `MARK`, and `REJECT`, among others. Refer to the `iptables` man page for more information about these and other targets.

It is also possible to direct a packet matching this rule to a user-defined chain outside of the current chain so that other rules can be applied to the packet.

If no target is specified, the packet moves past the rule with no action taken. However, the counter for this rule increases by one.

- `-o` — Sets the outgoing network interface for a rule and may only be used with `OUTPUT` and `FORWARD` chains in the `filter` table, and the `POSTROUTING` chain in the `nat` and `mangle` tables. This parameter's options are the same as those of the incoming network interface parameter (`-i`).
- `-p` — Sets the IP protocol for the rule, which can be either `icmp`, `tcp`, `udp`, or `all`, to match every supported protocol. In addition, any protocols listed in `/etc/protocols` may also be used. If this option is omitted when creating a rule, the `all` option is the default.
- `-s` — Sets the source for a particular packet using the same syntax as the destination (`-d`) parameter.

### 17.3.4. iptables Match Options

Different network protocols provide specialized matching options which can be configured to match a particular packet using that protocol. However, the protocol must first be specified in the `iptables` command. For example `-p tcp <protocol-name>` (where `<protocol-name>` is the target protocol), makes options for the specified protocol available.

#### 17.3.4.1. TCP Protocol

These match options are available for the TCP protocol (`-p tcp`):

- `--dport` — Sets the destination port for the packet. Use either a network service name (such as `www` or `smtp`), port number, or range of port numbers to configure this option. To browse the names

and aliases of network services and the port numbers they use, view the `/etc/services` file. The `--destination-port` match option is synonymous with `--dport`.

To specify a specific range of port numbers, separate the two numbers with a colon (:), such as `-p tcp --dport 3000:3200`. The largest acceptable valid range is `0:65535`.

Use an exclamation point character (!) after the `--dport` option to match all packets which *do not* use that network service or port.

- `--sport` — Sets the source port of the packet using the same options as `--dport`. The `--source-port` match option is synonymous with `--sport`.
- `--syn` — Applies to all TCP packets designed to initiate communication, commonly called *SYN packets*. Any packets that carry a data payload are not touched. Placing an exclamation point character (!) as a flag after the `--syn` option causes all non-SYN packets to be matched.
- `--tcp-flags` — Allows TCP packets with specific bits, or flags, set to be matched with a rule. The `--tcp-flags` match option accepts two parameters. The first parameter is the mask, which sets the flags to be examined in the packet. The second parameter refers to the flag that must be set to match.

The possible flags are:

- ACK
- FIN
- PSH
- RST
- SYN
- URG
- ALL
- NONE

For example, an `iptables` rule which contains `-p tcp --tcp-flags ACK,FIN,SYN SYN` only matches TCP packets that have the SYN flag set and the ACK and FIN flags unset.

Using the exclamation point character (!) after `--tcp-flags` reverses the effect of the match option.

- `--tcp-option` — Attempts to match with TCP-specific options that can be set within a particular packet. This match option can also be reversed with the exclamation point character (!).

### 17.3.4.2. UDP Protocol

These match options are available for the UDP protocol (`-p udp`):

- `--dport` — Specifies the destination port of the UDP packet, using the service name, port number, or range of port numbers. The `--destination-port` match option is synonymous with `--dport`. Refer to the `--dport` match option in Section 17.3.4.1 *TCP Protocol* for ways to use this option.
- `--sport` — Specifies the source port of the UDP packet, using the service name, port number, or range of port numbers. The `--source-port` match option is synonymous with `--sport`. Refer to the `--sport` match option in Section 17.3.4.1 *TCP Protocol* for ways to use this option.

### 17.3.4.3. ICMP Protocol

The following match options are available for the Internet Control Message Protocol (ICMP) (`-p icmp`):

- `--icmp-type` — Sets the name or number of the ICMP type to match with the rule. A list of valid ICMP names can be retrieved by typing the `iptables -p icmp -h` command.

### 17.3.4.4. Additional Match Option Modules

Additional match options are also available through modules loaded by the `iptables` command. To use a match option module, load the module by name using the `-m` option, such as `-m <module-name>` (replacing `<module-name>` with the name of the module).

A large number of modules are available by default. It is even possible to create modules that provide additional functionality.

The following is a partial list of the most commonly used modules:

- `limit` module — Places limits on how many packets are matched to a particular rule. This is especially beneficial when used in conjunction with the `LOG` target as it can prevent a flood of matching packets from filling up the system log with repetitive messages or using up system resources. Refer to Section 17.3.5 *Target Options* for more information about the `LOG` target.

The `limit` module enables the following options:

- `--limit` — Sets the number of matches for a particular range of time, specified with a number and time modifier arranged in a `<number>/<time>` format. For example, using `--limit 5/hour` only lets a rule match 5 times in a single hour.

If a number and time modifier are not used, the default value of `3/hour` is assumed.

- `--limit-burst` — Sets a limit on the number of packets able to match a rule at one time. This option should be used in conjunction with the `--limit` option, and it accepts a number to set the burst threshold.

If no number is specified, only five packets are initially able to match the rule.

- `state` module — Enables state matching.

The `state` module enables the following options:

- `--state` — match a packet with the following connection states:
  - `ESTABLISHED` — The matching packet is associated with other packets in an established connection.
  - `INVALID` — The matching packet cannot be tied to a known connection.
  - `NEW` — The matching packet is either creating a new connection or is part of a two-way connection not previously seen.
  - `RELATED` — The matching packet is starting a new connection related in some way to an existing connection.

These connection states can be used in combination with one another by separating them with commas, such as `-m state --state INVALID,NEW`.

- `mac` module — Enables hardware MAC address matching.

The `mac` module enables the following option:

- `--mac-source` — Matches a MAC address of the network interface card that sent the packet. To exclude a MAC address from a rule, place an exclamation point (!) after the `--mac-source` match option.

To view other match options available through modules, refer to the `iptables` man page.

### 17.3.5. Target Options

Once a packet has matched a particular rule, the rule can direct the packet to a number of different targets that decide its fate and, possibly, take additional actions. Each chain has a default target, which is used if none of the rules on that chain match a packet or if none of the rules which match the packet specify a target.

The following are the standard targets:

- `<user-defined-chain>` — Replace `<user-defined-chain>` with the name of a user-defined chain within the table. This target passes the packet to the target chain.
- `ACCEPT` — Allows the packet to successfully move on to its destination or another chain.
- `DROP` — Drops the packet without responding to the requester. The system that sent the packet is not notified of the failure.
- `QUEUE` — The packet is queued for handling by a user-space application.
- `RETURN` — Stops checking the packet against rules in the current chain. If the packet with a `RETURN` target matches a rule in a chain called from another chain, the packet is returned to the first chain to resume rule checking where it left off. If the `RETURN` rule is used on a built-in chain and the packet cannot move up to its previous chain, the default target for the current chain decides what action to take.

In addition to these standard targets, various other targets may be used with extensions called *target modules*. For more information about match option modules, refer to Section 17.3.4.4 *Additional Match Option Modules*.

There are many extended target modules, most of which only apply to specific tables or situations. A couple of the most popular target modules included by default in Red Hat Enterprise Linux are:

- `LOG` — Logs all packets that match this rule. Since the packets are logged by the kernel, the `/etc/syslog.conf` file determines where these log entries are written. By default, they are placed in the `/var/log/messages` file.

Additional options can be used after the `LOG` target to specify the way in which logging occurs:

- `--log-level` — Sets the priority level of a logging event. A list of priority levels can be found within the `syslog.conf` man page.
- `--log-ip-options` — Any options set in the header of a IP packet is logged.
- `--log-prefix` — Places a string of up to 29 characters before the log line when it is written. This is useful for writing syslog filters for use in conjunction with packet logging.
- `--log-tcp-options` — Any options set in the header of a TCP packet are logged.
- `--log-tcp-sequence` — Writes the TCP sequence number for the packet in the log.
- `REJECT` — Sends an error packet back to the remote system and drops the packet.

The `REJECT` target accepts `--reject-with <type>` (where `<type>` is the rejection type) allowing more detailed information to be sent back with the error packet. The message `port-unreachable` is the default `<type>` error given if no other option is used. For a full list of `<type>` options, refer to the `iptables` man page.

Other target extensions, including several that are useful for IP masquerading using the `nat` table or with packet alteration using the `mangle` table, can be found in the `iptables` man page.

### 17.3.6. Listing Options

The default list command, `iptables -L`, provides a very basic overview of the default filter table's current chains. Additional options provide more information:

- `-v` — Displays verbose output, such as the number of packets and bytes each chain has seen, the number of packets and bytes each rule has matched, and which interfaces apply to a particular rule.
- `-x` — Expands numbers into their exact values. On a busy system, the number of packets and bytes seen by a particular chain or rule may be abbreviated using `K` (thousands), `M` (millions), and `G` (billions) at the end of the number. This option forces the full number to be displayed.
- `-n` — Displays IP addresses and port numbers in numeric format, rather than the default hostname and network service format.
- `--line-numbers` — Lists rules in each chain next to their numeric order in the chain. This option is useful when attempting to delete the specific rule in a chain or to locate where to insert a rule within a chain.
- `-t` — Specifies a table name.

## 17.4. Saving iptables Rules

Rules created with the `iptables` command are stored in memory. If the system is restarted before saving the `iptables` rule set, all rules will be lost. For netfilter rules to persist through system reboot, they need to be saved. To do this, log in as root and type:

```
/sbin/service iptables save
```

This executes the `iptables` init script, which runs the `/sbin/iptables-save` program and writes the current `iptables` configuration to `/etc/sysconfig/iptables`. The existing `/etc/sysconfig/iptables` file is saved as `/etc/sysconfig/iptables.save`.

The next time the system boots, the `iptables` init script reapplies the rules saved in `/etc/sysconfig/iptables` by using the `/sbin/iptables-restore` command.

While it is always a good idea to test a new `iptables` rule before committing it to the `/etc/sysconfig/iptables` file, it is possible to copy `iptables` rules into this file from another system's version of this file. This provides a quick way to distribute sets of `iptables` rules to multiple machines.



#### Important

If distributing the `/etc/sysconfig/iptables` file to other machines, type `/sbin/service iptables restart` for the new rules take effect.

## 17.5. iptables Control Scripts

There are two basic methods for controlling iptables under Red Hat Enterprise Linux:

- **Security Level Configuration Tool** (`redhat-config-securitylevel`) — A graphical interface for creating, activating, and saving basic firewall rules. For more information about how to use this tool, refer to the chapter titled *Basic Firewall Configuration* in the *Red Hat Enterprise Linux System Administration Guide*.
- `/sbin/service iptables <option>` — A command issued by the root user capable of activating, deactivating, and performing other functions of iptables via its initscript. Replace `<option>` in the command with one of the following directives:
  - `start` — If a firewall is configured (meaning `/etc/sysconfig/iptables` exists), all running iptables are stopped completely and then started using the `/sbin/iptables-restore` command. The `start` directive will only work if the `ipchains` kernel module is not loaded.
  - `stop` — If a firewall is running, the firewall rules in memory are flushed, and all iptables modules and helpers are unloaded.

If the `IPTABLES_SAVE_ON_STOP` directive within the `/etc/sysconfig/iptables-config` configuration file is changed from its default value to `yes`, current rules are saved to `/etc/sysconfig/iptables` and any existing rules are moved to the file `/etc/sysconfig/iptables.save`.

Refer to Section 17.5.1 *iptables Control Scripts Configuration File* for more information about the `iptables-config` file.

- `restart` — If a firewall is running, the firewall rules in memory are flushed, and the firewall is started again if it is configured in `/etc/sysconfig/iptables`. The `restart` directive will only work if the `ipchains` kernel module is not loaded.

If the `IPTABLES_SAVE_ON_RESTART` directive within the `/etc/sysconfig/iptables-config` configuration file is changed from its default value to `yes`, current rules are saved to `/etc/sysconfig/iptables` and any existing rules are moved to the file `/etc/sysconfig/iptables.save`.

Refer to Section 17.5.1 *iptables Control Scripts Configuration File* for more information about the `iptables-config` file.

- `status` — Prints to the shell prompt the status of the firewall and a list of all active rules. If no firewall rules are loaded or configured, it indicates this fact.

A listing of active rules containing domain and hostnames within rules lists unless the default value for `IPTABLES_STATUS_NUMERIC` is changed to `yes` within the `/etc/sysconfig/iptables-config` configuration file. Refer to Section 17.5.1 *iptables Control Scripts Configuration File* for more information about the `iptables-config` file.

- `panic` — Flushes all firewall rules. The policy of all configured tables is set to `DROP`.
- `save` — Saves firewall rules to `/etc/sysconfig/iptables` using `iptables-save`. Refer to Section 17.4 *Saving iptables Rules* for more information about saving firewall rules.



### Tip

To use the same initscript commands to control netfilter for IPv6, substitute `ip6tables` for `iptables` in the `/sbin/service` commands listed in this section. For more information about IPv6 and netfilter, refer to Section 17.6 *ip6tables and IPv6*.

### 17.5.1. iptables Control Scripts Configuration File

The behavior of the `iptables` initscripts is controlled by the `/etc/sysconfig/iptables-config` configuration file. The following is a list of directives contained within this file:

- `IPTABLES_MODULES` — Specifies a space-separated list of additional `iptables` modules to load when a firewall is activated. These can include connection tracking and NAT helpers.
- `IPTABLES_SAVE_ON_STOP` — Saves current firewall rules to `/etc/sysconfig/iptables` when the firewall is stopped. This directive accepts the following values:
  - `yes` — Saves existing rules to `/etc/sysconfig/iptables` when the firewall is stopped, moving the previous version to `/etc/sysconfig/iptables.save`.
  - `no` — The default value. Does not save existing rules when the firewall is stopped.
- `IPTABLES_SAVE_ON_RESTART` — Saves current firewall rules when the firewall is restarted. This directive accepts the following values:
  - `yes` — Saves existing rules to `/etc/sysconfig/iptables` when the firewall is restarted, moving the previous version to `/etc/sysconfig/iptables.save`.
  - `no` — The default value. Does not save existing rules when the firewall is restarted.
- `IPTABLES_SAVE_COUNTER` — Saves and restores all packet and byte counters in all chains and rules. This directive accepts the following values:
  - `yes` — Saves the counter values.
  - `no` — The default value. Does not save the counter values.
- `IPTABLES_STATUS_NUMERIC` — Outputs IP addresses in a status output instead of domain or hostnames. This directive accepts the following values:
  - `yes` — Returns only IP addresses within a status output.
  - `no` — The default value. Returns domain or hostnames within a status output.

### 17.6. ip6tables and IPv6

If the `iptables-ipv6` package is installed, netfilter under Red Hat Enterprise Linux can filter the next-generation IPv6 Internet protocol. The command used to manipulate the IPv6 netfilter is `ip6tables`. Most directives for this command are identical to those used for `iptables`, except the `nat` table is not yet supported. This means that it is not yet possible to perform IPv6 network address translation tasks, such as masquerading and port forwarding.

Saved rules for `ip6tables` are stored in the `/etc/sysconfig/ip6tables` file. Old rules saved by the `ip6tables` initscripts are saved in the `/etc/sysconfig/ip6tables.save` file.

The configuration file for `ip6tables` initscript is `/etc/sysconfig/ip6tables-config` and the names for each directive vary slightly. For instance, the `iptables-config` directive `IPTABLES_MODULES` is `IP6TABLES_MODULES` in `ip6tables-config`.

## 17.7. Additional Resources

Refer to the following sources for additional information on packet filtering with `iptables`.

### 17.7.1. Installed Documentation

- `man iptables` — Contains a description of `iptables` as well as a comprehensive list of targets, options, and match extensions.

### 17.7.2. Useful Websites

- <http://www.netfilter.org/> — The home of the netfilter/iptables project. Contains assorted information about `iptables`, including a FAQ addressing specific problems and various helpful guides by Rusty Russell, the Linux IP firewall maintainer. The HOWTO documents on the site cover subjects such as basic networking concepts, 2.4 kernel packet filtering, and NAT configurations.
- [http://www.linuxnewbie.org/nhf/Security/IPtables\\_Basics.html](http://www.linuxnewbie.org/nhf/Security/IPtables_Basics.html) — A basic and general look at the way packets move through the Linux kernel, plus an introduction to constructing basic `iptables` commands.
- <http://www.redhat.com/support/resources/networking/firewall.html> — This webpage links to a variety of update-to-date packet filter resources.
- *Red Hat Enterprise Linux Security Guide*; Red Hat, Inc. — Contains a chapter about the role of firewalls within an overall security strategy as well as strategies for constructing firewall rules.
- *Red Hat Enterprise Linux System Administration Guide*; Red Hat, Inc. — Contains a chapter about configuring firewalls using **Security Level Configuration Tool**.



## Kerberos

System security and integrity within a network can be unwieldy. It can occupy the time of several administrators just to keep track of what services are being run on a network and the manner in which these services are used. Moreover, authenticating users to network services can prove dangerous when the method used by the protocol is inherently insecure, as evidenced by the transfer of unencrypted passwords over a network under the FTP and Telnet protocols. Kerberos is a way to eliminate the need for protocols that allow unsafe methods of authentication, thereby enhancing overall network security.

### 18.1. What is Kerberos?

Kerberos is a network authentication protocol created by MIT which uses symmetric-key cryptography<sup>1</sup> to authenticate users to network services — eliminating the need to send passwords over the network. When users authenticate to network services using Kerberos, unauthorized users attempting to gather passwords by monitoring network traffic are effectively thwarted.

#### 18.1.1. Advantages of Kerberos

Most conventional network services use password-based authentication schemes. Such schemes require a user to authenticate to a given network server by supplying their user name and password. Unfortunately, the transmission of authentication information for many services is unencrypted. For such a scheme to be secure, the network has to be inaccessible to outsiders, and all computers and users on the network must be trusted and trustworthy.

Even if this is the case, once a network is connected to the Internet, it can no longer be assumed that the network is secure. Any attacker who gains access to the network can use a simple packet analyzer, also known as a packet sniffer, to intercept usernames and passwords sent in this manner, compromising user accounts and the integrity of the entire security infrastructure.

The primary design goal of Kerberos is to eliminate the transmission of unencrypted passwords across the network. If used properly, Kerberos effectively eliminates the threat packet sniffers would otherwise pose on a network.

#### 18.1.2. Disadvantages of Kerberos

Although Kerberos removes a common and severe security threat, it may be difficult to implement for a variety of reasons:

- Migrating user passwords from a standard UNIX password database, such as `/etc/passwd` or `/etc/shadow`, to a Kerberos password database can be tedious, as there is no automated mechanism to perform this task. For more information, refer to question number 2.23 in the online Kerberos FAQ:

<http://www.nrl.navy.mil/CCS/people/kenh/kerberos-faq.html>

- Kerberos has only partial compatibility with the Pluggable Authentication Modules (PAM) system used by most Red Hat Enterprise Linux servers. For more information about this issue, refer to Section 18.4 *Kerberos and PAM*.

---

1. A system where both the client and the server share a common key that is used to encrypt and decrypt network communication

- Kerberos assumes that each user is trusted and is using an untrusted host on an untrusted network. Its primary goal is to prevent unencrypted passwords from being sent across that network. However, if anyone other than the proper user has access to the one host that issues tickets used for authentication — called the *key distribution center (KDC)* — the entire Kerberos authentication system is at risk.
- For an application to use Kerberos, its source must be modified to make the appropriate calls into the Kerberos libraries. Applications modified in this way are considered to be *kerberized*. For some applications, this can be quite problematic due to the size of the application or its design. For other incompatible applications, changes must be made to the way in which the server and client side communicate. Again, this may require extensive programming. Closed-source applications that do not have Kerberos support by default are often the most problematic.
- Kerberos is an all or nothing solution. Once Kerberos is used on the network, any unencrypted passwords transferred to a non-kerberized service is at risk. Thus, the network gains no benefit from the use of Kerberos. To secure a network with Kerberos, one must either use kerberized versions of *all* client/server applications which send unencrypted passwords or not use *any* such client/server applications at all.

## 18.2. Kerberos Terminology

Kerberos has its own terminology to define various aspects of the service. Before learning how kerberos works, it is important to learn the following terms.

### Authentication Server (AS)

A server that issues tickets for a desired service which are in turn given to users for access to the service. The AS responds to requests from clients who do not have or do not send credentials with a request. It is usually used to gain access to the Ticket-granting Server (TGS) service by issuing a Ticket-granting Ticket (TGT). The AS usually runs on the same host as the Key Distribution Center (KDC).

### ciphertext

Encrypted data.

### client

An entity on the network (a user, a host, or an application) that can receive a ticket from Kerberos.

### credentials

A temporary set of electronic credentials that verify the identity of a client for a particular service. Also called a ticket.

### credential cache or ticket file

A file which contains the keys for encrypting communications between a user and various network services. Kerberos 5 supports a framework for using other cache types, such as shared memory, but files are more thoroughly supported.

### crypt hash

A one way hash used to authenticate users. While more secure than unencrypted data, it is fairly easy to decrypt for an experienced cracker.

## GSS-API

The Generic Security Service Application Program Interface (defined in RFC-2743 published by The Internet Engineering Task Force) is a set of functions which provide security services. This API is used by clients and services to authenticate to each other without either program having specific knowledge of the underlying mechanism. If a network service (such as IMAP) uses GSS-API, it can authenticate using Kerberos.

## hash

A number generated from text and used to ensure that transmitted data has not been tampered with.

## key

Data used when encrypting or decrypting other data. Encrypted data cannot be decrypted without the proper key or extremely good guessing.

## Key Distribution Center (KDC)

A service that issues Kerberos tickets, usually run on the same host as the Ticket-granting Server (TGS).

## key table or keytab

A file that includes an unencrypted list of principals and their keys. Servers retrieve the keys they need from keytab files instead of using `kinit`. The default keytab file is `/etc/krb5.keytab`. The KDC administration server, `/usr/kerberos/sbin/kadmind`, is the only service that uses any other file (it uses `/var/kerberos/krb5kdc/kadm5.keytab`).

`kinit`

The `kinit` command allows a principal who has already logged in to obtain and cache the initial Ticket-granting Ticket (TGT). For more information about using the `kinit` command, refer to its man page.

## principal

The principal name or principal is the unique name of a user or service allowed to authenticate using Kerberos. A principal name follows the form `root[/instance]@REALM`. For a typical user, the root is the same as their login ID. The `instance` is optional. If the principal has an instance, it is separated from the root with a forward slash ("/"). An empty string ("") is considered a valid instance (which differs from the default `NULL` instance), but using it can be confusing. All principals in a realm have their own key, which for users is derived from a password or is randomly set for services.

## realm

A network that uses Kerberos, composed of one or more servers called KDCs and a potentially large number of clients.

## service

A program accessed over the network.

## ticket

A temporary set of electronic credentials that verify the identity of a client for a particular service. Also called credentials.

### Ticket-granting Server (TGS)

A server that issues tickets for a desired service which are in turn given to users for access to the service. The TGS usually runs on the same host as the KDC.

### Ticket-granting Ticket (TGT)

A special ticket that allows the client to obtain additional tickets without applying for them from the KDC.

### unencrypted password

A plain text, human-readable password.

## 18.3. How Kerberos Works

Kerberos differs from username/password authentication methods because instead of authenticating each user to each network service, it uses symmetric encryption and a trusted third party — known as the Key Distribution Center (KDC) — to authenticate users to a suite of network services. Once a user authenticates to the KDC, it sends a ticket specific to that session back to the user's machine and any kerberized services look for the ticket on the user's machine rather than asking the user to authenticate using a password.

When a user on a kerberized network logs in to their workstation, their principal is sent to the KDC in a request for a Ticket-granting Ticket (TGT) from the Authentication Server (AS). This request can be sent by the login program so that it is transparent to the user or can be sent by the `kinit` program after the user logs in.

The KDC checks for the principal in its database. If the principal is found, the KDC creates a TGT, which is encrypted using the user's key and returned to that user.

The login or `kinit` program on the client machine then decrypts the TGT using the user's key (which it computes from the user's password). The user's key is used only on the client machine and is *not* sent over the network.

The TGT is set to expire after a certain period of time (usually ten hours) and stored in the client machine's credentials cache. An expiration time is set so that a compromised TGT is of use to an attacker for only a short period of time. Once the TGT is issued, the user does not have to re-enter their password until the TGT expires or they logout and login again.

Whenever the user needs access to a network service, the client software uses the TGT to request a new ticket for that specific service from the Ticket-granting Server (TGS). The service ticket is then used to authenticate the user to that service transparently.



### Warning

The Kerberos system can be compromised any time any user on the network authenticates against a non-kerberized service by sending a password in plain text. Use of non-kerberized services is discouraged. Such services include Telnet and FTP. Use of other encrypted protocols, such as SSH or SSL secured services, however, is acceptable, though not ideal.

This is only a broad overview of how Kerberos authentication works. Those seeking a more in-depth look at Kerberos authentication should refer to Section 18.7 *Additional Resources*.

**Note**

Kerberos depends on certain network services to work correctly. First, Kerberos requires approximate clock synchronization between the machines on the network. Therefore, a clock synchronization program should be set up for the network, such as `ntpd`. For more about configuring `ntpd`, refer to `/usr/share/doc/ntp-<version-number>/index.htm` for details about how to set up Network Time Protocol servers (replace `<version-number>` with the version number of the `ntp` package installed on the system).

Also, since certain aspects of Kerberos rely on the Domain Name Service (DNS), be sure that the DNS entries and hosts on the network are all properly configured. Refer to the *Kerberos V5 System Administrator's Guide*, provided in PostScript and HTML formats in `/usr/share/doc/krb5-server-<version-number>` for more information (replace `<version-number>` with the version number of the `krb5-server` package installed on the system).

## 18.4. Kerberos and PAM

Currently, kerberized services do not make use of Pluggable Authentication Modules (PAM) — kerberized servers bypass PAM completely. However, applications that use PAM can make use of Kerberos for authentication if the `pam_krb5` module (provided in the `pam_krb5` package) is installed. The `pam_krb5` package contains sample configuration files that allow services like `login` and `gdm` to authenticate users and obtain initial credentials using their passwords. If access to network servers is always performed using kerberized services or services that use GSS-API, such as IMAP, the network can be considered reasonably safe.

**Tip**

Administrators should be careful to not allow users to authenticate to most network services using Kerberos passwords. Many protocols used by these services do not encrypt the password before sending it over the network, destroying the benefits of the Kerberos system. For example, users should not be allowed to authenticate using their Kerberos passwords over Telnet.

## 18.5. Configuring a Kerberos 5 Server

When setting up Kerberos, install the server first. If it is necessary to set up slave servers, the details of setting up relationships between master and slave servers are covered in the *Kerberos 5 Installation Guide* located in the `/usr/share/doc/krb5-server-<version-number>` directory (replace `<version-number>` with the version number of the `krb5-server` package installed on the system).

To configure a basic Kerberos server, follow these steps:

1. Be sure that clock synchronization and DNS are functioning on all client and server machines before configuring Kerberos 5. Pay particular attention to time synchronization between the Kerberos server and its clients. If the server and client clocks are different by more than five minutes (this default amount is configurable in Kerberos 5), Kerberos clients can not authenticate to the server. This clock synchronization is necessary to prevent an attacker from using an old Kerberos ticket to masquerade as a valid user.

It is advisable to set up a Network Time Protocol (NTP) compatible client/server network even if Kerberos is not being used. Red Hat Enterprise Linux includes the `ntp` package for this pur-

pose. Refer to `/usr/share/doc/ntp-<version-number>/index.htm` for details about how to set up Network Time Protocol servers and `http://www.eecis.udel.edu/~ntp` for additional information about NTP.

2. Install the `krb5-libs`, `krb5-server`, and `krb5-workstation` packages on the dedicated machine which runs the KDC. This machine needs to be very secure — if possible, it should not run any services other than the KDC.

If a graphical user interface is required to administrate Kerberos, install the `gnome-kerberos` package. It contains `krb5`, a GUI tool for managing tickets.

3. Edit the `/etc/krb5.conf` and `/var/kerberos/krb5kdc/kdc.conf` configuration files to reflect the realm name and domain-to-realm mappings. A simple realm can be constructed by replacing instances of `EXAMPLE.COM` and `example.com` with the correct domain name — being certain to keep uppercase and lowercase names in the correct format — and by changing the KDC from `kerberos.example.com` to the name of the Kerberos server. By convention, all realm names are uppercase and all DNS hostnames and domain names are lowercase. For full details about the formats of these files, refer to their respective man pages.
4. Create the database using the `kdb5_util` utility from a shell prompt:

```
/usr/kerberos/sbin/kdb5_util create -s
```

The `create` command creates the database that used to store keys for the Kerberos realm. The `-s` switch forces creation of a *stash* file in which the master server key is stored. If no *stash* file is present from which to read the key, the Kerberos server (`krb5kdc`) prompts the user for the master server password (which can be used to regenerate the key) every time it starts.

5. Edit the `/var/kerberos/krb5kdc/kadm5.acl` file. This file is used by `kadmind` to determine which principals have administrative access to the Kerberos database and their level of access. Most organizations can get by with a single line:

```
*/admin@EXAMPLE.COM *
```

Most users are represented in the database by a single principal (with a `NULL`, or empty, instance, such as `joe@EXAMPLE.COM`). With this configuration, users with a second principal with an instance of `admin` (for example, `joe/admin@EXAMPLE.COM`) are able to wield full power over the realm's Kerberos database.

Once `kadmind` is started on the server, any user can to access its services by running `kadmin` on any of the clients or servers in the realm. However, only users listed in the `kadm5.acl` file can modify the database in any way, except for changing their own passwords.



#### Note

The `kadmin` utility communicates with the `kadmind` server over the network, and uses Kerberos to handle authentication. For this reason, the first principal must already exist before connecting to the server over the network to administer it. Create the first principal with the `kadmin.local` command, which is specifically designed to be used on the same host as the KDC and does not use Kerberos for authentication.

Type the following `kadmin.local` command at the KDC terminal to create the first principal:

```
/usr/kerberos/sbin/kadmin.local -q "addprinc username/admin"
```

6. Start Kerberos using the following commands:

```
/sbin/service krb5kdc start
/sbin/service kadmind start
/sbin/service krb524 start
```

7. Add principals for the users using the `addprinc` command with `kadmin`. `kadmin` and `kadmin.local` are command line interfaces to the KDC. As such, many commands are available after launching the `kadmin` program. Refer to the `kadmin` man page for more information.

- Verify that the KDC is issuing tickets. First, run `kinit` to obtain a ticket and store it in a credential cache file. Next, use `klist` to view the list of credentials in the cache and use `kdestroy` to destroy the cache and the credentials it contains.



#### Note

By default, `kinit` attempts to authenticate using the login user name of the account used when logging into the system (not the Kerberos server). If that user name does not correspond to a principal in the Kerberos database, `kinit` issues an error message. If that happens, supply `kinit` with the name of the correct principal as an argument on the command line (`kinit <principal>`).

Once these steps are completed, the Kerberos server should be up and running.

## 18.6. Configuring a Kerberos 5 Client

Setting up a Kerberos 5 client is less involved than setting up a server. At a minimum, install the client packages and provide each client with a valid `krb5.conf` configuration file. Kerberized versions of `rsh` and `rlogin` also requires some configuration changes.

- Be sure that time synchronization is in place between the Kerberos client and the KDC. Refer to Section 18.5 *Configuring a Kerberos 5 Server* for more information. In addition, verify that DNS is working properly on the Kerberos client before configuring the Kerberos client programs.
- Install the `krb5-libs` and `krb5-workstation` packages on all of the client machines. Supply a valid `/etc/krb5.conf` file for each client (usually this can be the same `krb5.conf` file used by the KDC).
- Before a workstation in the realm can allow users to connect using kerberized `rsh` and `rlogin`, that workstation needs to have the `xinetd` package installed and have its own host principal in the Kerberos database. The `kshd` and `klogind` server programs also need access to the keys for their service's principal.

Using `kadmin`, add a host principal for the workstation on the KDC. The instance in this case is the hostname of the workstation. Use the `-randkey` option for the `kadmin's` `addprinc` command to create the principal and assign it a random key:

```
addprinc -randkey host/blah.example.com
```

Now that the principal has been created, keys can be extracted for the workstation by running `kadmin` on the workstation itself, and using the `ktadd` command within `kadmin`:

```
ktadd -k /etc/krb5.keytab host/blah.example.com
```

- To use other kerberized network services they need to be started. Below is a list of some of the more common kerberized services and instructions about enabling them:
  - `rsh` and `rlogin` — To use the kerberized versions of `rsh` and `rlogin`, enable `klogin`, `eklogin`, and `kshell`.
  - Telnet — To use kerberized Telnet, `krb5-telnet` must be enabled.
  - FTP — To provide FTP access, create and extract a key for the principal with a root of `ftp`. Be certain to set the instance to the fully qualified hostname of the FTP server, then enable `gssftp`.
  - IMAP — The IMAP server included in the `imap` package uses GSS-API authentication using Kerberos 5 if it finds the proper key in `/etc/krb5.keytab`. The root for the principal should be `imap`.

- **CVS** — A kerberized CVS server, `gserver`, uses a principal with a root of `cvs` and is otherwise identical to the CVS `pserver`.

For details about how to enable services, refer to the chapter titled *Controlling Access to Services* in the *Red Hat Enterprise Linux System Administration Guide*.

## 18.7. Additional Resources

For more information about Kerberos, refer to the following resources.

### 18.7.1. Installed Documentation

- The `/usr/share/doc/krb5-server-<version-number>/` directory — The *Kerberos V5 Installation Guide* and the *Kerberos V5 System Administrator's Guide* in PostScript and HTML formats. The `krb5-server` package must be installed.
- The `/usr/share/doc/krb5-workstation-<version-number>/` directory — The *Kerberos V5 UNIX User's Guide* in PostScript and HTML formats. The `krb5-workstation` package must be installed.
- **Kerberos man pages** — There are a number of man pages for the various applications and configuration files involved with a Kerberos implementation. The following is a list of some of the more important man pages.

#### Client Applications

- `man krb5` — An introduction to the Kerberos system which describes how credentials work and provides recommendations for obtaining and destroying Kerberos tickets. The bottom of the man page references a number of related man pages.
- `man kinit` — Describes how to use this command to obtain and cache a ticket-granting ticket.
- `man kdestroy` — Describes how to use this command to destroy Kerberos credentials.
- `man klist` — Describes how to use this command to list cached Kerberos credentials.

#### Administrative Applications

- `man kadmind` — Describes how to use this command to administer the Kerberos V5 database.
- `man kdb5_util` — Describes how to use this command to create and perform low-level administrative functions on the Kerberos V5 database.

#### Server Applications

- `man krb5kdc` — Describes available command line options for the Kerberos V5 Key Distribution Center.
- `man kadmind` — Describes available command line options for the Kerberos V5 administration server.



### Configuration Files

- `man krb5.conf` — Describes the format and options available within the configuration file for the Kerberos V5 library.
- `man kdc.conf` — Describes the format and options available within the configuration file for the Kerberos V5 Authentication Server (AS) and Key Distribution Center (KDC).

### 18.7.2. Useful Websites

- <http://web.mit.edu/kerberos/www/> — *Kerberos: The Network Authentication Protocol* webpage from MIT.
- <http://www.nrl.navy.mil/CCS/people/kenh/kerberos-faq.html> — The Kerberos Frequently Asked Questions (FAQ).
- <ftp://athena-dist.mit.edu/pub/kerberos/doc/usenix.PS> — The PostScript version of *Kerberos: An Authentication Service for Open Network Systems* by Jennifer G. Steiner, Clifford Neuman, and Jeffrey I. Schiller. This document is the original paper describing Kerberos.
- <http://web.mit.edu/kerberos/www/dialogue.html> — *Designing an Authentication System: a Dialogue in Four Scenes* originally by Bill Bryant in 1988, modified by Theodore Ts'o in 1997. This document is a conversation between two developers who are thinking through the creation of a Kerberos-style authentication system. The conversational style of the discussion make this a good starting place for people who are completely unfamiliar with Kerberos.
- <http://www.ornl.gov/~jar/HowToKerb.html> — *How to Kerberize your site* is a good reference for kerberizing a network.
- <http://www.networkcomputing.com/netdesign/kerb1.html> — *Kerberos Network Design Manual* is a thorough overview of the Kerberos system.



SSH™ (or Secure *SHell*) is a protocol which facilitates secure communications between two systems using a client/server architecture and allowing users to log into server host systems remotely. But unlike other remote communication protocols such as FTP or Telnet, SSH encrypts the login session, making it impossible for intruders to collect unencrypted passwords.

SSH 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.

## 19.1. Features of SSH

The SSH protocol provides the following safeguards:

- After an initial connection, the client can verify that it is connecting to the same server it had connected to previously.
- The client transmits its authentication information to the server using strong, 128-bit encryption.
- All data sent and received during a session is transferred using 128-bit encryption, making intercepted transmissions extremely difficult to decrypt and read.
- The client can forward X11<sup>1</sup> applications from the server. This technique, called *X11 forwarding*, provides a secure means to use graphical applications over a network.

Because the SSH protocol encrypts everything it sends and receives, it can be used to secure otherwise insecure protocols. Using a technique called *port forwarding*, an SSH server can become a conduit to secure otherwise insecure protocols, like POP, and increasing overall system and data security.

Red Hat Enterprise Linux includes the general OpenSSH package (`openssh`) as well as the OpenSSH server (`openssh-server`) and client (`openssh-clients`) packages. Refer to the chapter titled *OpenSSH* in the *Red Hat Enterprise Linux System Administration Guide* for instructions on installing and deploying OpenSSH. Also note that the OpenSSH packages require the OpenSSL package (`openssl`) which installs several important cryptographic libraries, enabling OpenSSH to provide encrypted communications.

### 19.1.1. Why Use SSH?

Nefarious computer users 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* — In this scenario, the attacker can be somewhere on the network between the communicating entities, copying any information passed between them. The attacker may intercept and keep the information, or alter the information and send it on to the intended recipient.

This attack can be mounted through the use of a packet sniffer — a common network utility.

---

1. X11 refers to the X11R6 windowing display system, traditionally referred to as the X Window System or X. Red Hat Enterprise Linux includes XFree86, an open source X Window System.

- *Impersonation of a particular host* — Using this strategy, an attacker’s system is configured to pose as the intended recipient of a transmission. If this strategy works, the user’s system will remain unaware that it is communicating with the wrong host.

This attack can be mounted through techniques known as DNS poisoning<sup>2</sup> or IP spoofing<sup>3</sup>.

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 will not work, since each packet is encrypted using a key known only by the local and remote systems.

## 19.2. SSH Protocol Versions

The SSH protocol allows any client and server programs built to the protocol’s specifications to communicate securely and to be used interchangeably.

Two varieties of SSH (version 1 and version 2) currently exist. SSH version 1 makes use of several patented encryption algorithms (however, some of these patents have expired) and is vulnerable to a well known security exploit that allows an attacker to insert data into the communication stream. The OpenSSH suite under Red Hat Enterprise Linux uses SSH version 2 by default because this version of the protocol has an enhanced key exchange algorithm not vulnerable to the same exploit. However, the OpenSSH suite does also support version 1 connections.



### Important

It is recommended that only SSH version 2-compatible servers and clients are used whenever possible.

## 19.3. Event Sequence of an SSH Connection

The following series of events help protect the integrity of SSH communication between two hosts.

- A cryptographic handshake is made so that the client can verify that it is communicating with the correct server.
- The transport layer of the connection between the client and remote host is encrypted using a symmetric cipher.
- The client authenticates itself to the server.
- The remote client interacts with the remote host over the encrypted connection.

---

2. DNS poisoning occurs when an intruder cracks a DNS server, pointing client systems to a maliciously duplicated host.

3. IP spoofing occurs when an intruder sends network packets which falsely appear to be from a trusted host on the network.

### 19.3.1. 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 will be unknown to the client and it will not connect. OpenSSH gets around this problem by accepting the server's host key after the user is notified and verifies the acceptance of 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.



#### Caution

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.

### 19.3.2. 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. Thanks to the secure nature of the SSH transport layer, even seemingly insecure authentication methods, such as a host and password-based authentication, are safe to use.

### 19.3.3. Channels

After a successful authentication over the SSH transport layer, multiple *channels* are opened via a technique called multiplexing<sup>4</sup>. 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 will 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.

## 19.4. OpenSSH Configuration Files

OpenSSH has two different sets of configuration files: one for client programs (*ssh*, *scp*, and *sftp*) and one for the server daemon (*sshd*).

System-wide SSH configuration information is stored in the `/etc/ssh/` directory:

- `moduli` — 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.
- `ssh_config` — The system-wide default SSH client configuration file. It is overridden if one is also present in the user's home directory (`~/.ssh/config`).
- `sshd_config` — The configuration file for the `sshd` daemon.
- `ssh_host_dsa_key` — The DSA private key used by the `sshd` daemon.
- `ssh_host_dsa_key.pub` — The DSA public key used by the `sshd` daemon.
- `ssh_host_key` — The RSA private key used by the `sshd` daemon for version 1 of the SSH protocol.
- `ssh_host_key.pub` — The RSA public key used by the `sshd` daemon for version 1 of the SSH protocol.
- `ssh_host_rsa_key` — The RSA private key used by the `sshd` daemon for version 2 of the SSH protocol.
- `ssh_host_rsa_key.pub` — The RSA public key used by the `sshd` daemon for version 2 of the SSH protocol.

User-specific SSH configuration information is stored in the user's home directory within the `~/.ssh/` directory:

---

4. A multiplexed connection consists of several signals being sent over a shared, common medium. With SSH, different channels are sent over a common secure connection.

- `authorized_keys` — This file 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.
- `id_dsa` — Contains the DSA private key of the user.
- `id_dsa.pub` — The DSA public key of the user.
- `id_rsa` — The RSA private key used by `ssh` for version 2 of the SSH protocol.
- `id_rsa.pub` — The RSA public key used by `ssh` for version 2 of the SSH protocol
- `identity` — The RSA private key used by `ssh` for version 1 of the SSH protocol.
- `identity.pub` — The RSA public key used by `ssh` for version 1 of the SSH protocol.
- `known_hosts` — This file 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.



### Important

If a SSH server's host key has changed, the client will notify the user that the connection cannot proceed until the server's host key is deleted from the `known_hosts` file using a text editor. Before doing this, however, contact the system administrator of the SSH server to verify the server is not compromised.

Refer to the man pages for `ssh_config` and `sshd_config` for information concerning the various directives available in the SSH configuration files.

## 19.5. 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.

### 19.5.1. X11 Forwarding

Opening an X11 session over an established SSH connection is as easy as running an X program on a local machine. 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 with `up2date`. To do this, connect to the server using `ssh` and type:

```
up2date &
```

After supplying the root password for the server, the **Red Hat Update Agent** will appear and allow the the remote user to safely update the remote system.

### 19.5.2. 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 the following command:

```
ssh -L local-port:remote-hostname:remote-port username@hostname
```

**Note**

Setting up port forwarding to listen on ports below 1024 requires root level access.

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 mail. 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, SSH 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 mail. Note that by 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 (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.

**Note**

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.

## 19.6. Requiring SSH for Remote Connections

For SSH to be truly effective, using insecure connection protocols, such as Telnet and FTP 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`
- `vsftpd`

To disable insecure connection methods to the system, use the command line program `chkconfig`, the ncurses-based program `ntsysv`, or the **Services Configuration Tool** (`redhat-config-services`) graphical application. All of these tools require root level access.

For more information on runlevels and configuring services with `chkconfig`, `ntsysv`, and the **Services Configuration Tool**, refer to the chapter titled *Controlling Access to Services* in the *Red Hat Enterprise Linux System Administration Guide*.

## 19.7. Additional Resources

For more information about SSH, refer to the following resources.

### 19.7.1. Installed Documentation

- The `/usr/share/doc/openssh-<version-number>/` directory — Replace `<version-number>` with the installed version of the OpenSSH package. This directory contains a `README` with basic information about the OpenSSH project and a file called `RFC.nroff` with general information about the SSH protocol.
- SSH related man pages — There are a number of man pages for the various applications and configuration files involved with SSH. The following is a list of some of the more important man pages.

#### Client Applications

- `man ssh` — Describes how to use this command to connect to an SSH server.
- `man scp` — Describes how to use this command to copy files to and from an SSH server.
- `man sftp` — Describes how to use this command to interactively copy files to and from and SSH server.

#### Server Applications

- `man sshd` — Describes available command line options for the SSH server.

#### Configuration Files

- `man ssh_config` — Describes the format and options available within the configuration file for SSH clients.
- `man sshd_config` — Describes the format and options available within the configuration file for the SSH server.

### 19.7.2. Useful Websites

- <http://www.openssh.com> — The OpenSSH FAQ page, bug reports, mailing lists, project goals, and a more technical explanation of the security features.
- <http://www.openssl.org> — The OpenSSL FAQ page, mailing lists, and a description of the project goal.
- <http://www.freessh.org> — SSH client software for other platforms.

### 19.7.3. Related Books

- *Red Hat Enterprise Linux System Administration Guide*; Red Hat, Inc. — The *OpenSSH* chapter explains how to set up an SSH server and use the SSH client software provided in the OpenSSH suite of tools. It also explains how to generate an RSA (or DSA) key pair, which allow for password-free logins.

## IV. Appendixes

### Table of Contents

A. General Parameters and Modules .....	283
---	-----



## General Parameters and Modules

This appendix is provided to illustrate *some* of the possible parameters available for common hardware device *drivers*<sup>1</sup>, which under Red Hat Enterprise Linux are called kernel *modules*. In most cases, the default parameters will work. However, there may be times when extra module parameters are necessary for a device to function properly or to override the module's default parameters for the device.

During installation, Red Hat Enterprise Linux uses a limited subset of device drivers to create a stable installation environment. Although the installation program supports installation on many different types of hardware, some drivers (including those for SCSI adapters and network adapters are not included in the installation kernel. Rather, they must be loaded as modules by the user at boot time. For information about extra kernel modules during the installation process, refer to the section concerning alternative boot methods in the chapter titled *Steps to Get You Started* in the *Red Hat Enterprise Linux Installation Guide*.

Once installation is completed, support exists for a large number of devices through kernel modules.



### Important

Red Hat provides a large number of unsupported device drivers in a group of packages called `kernel-unsupported-<kernel-version>`, `kernel-smp-unsupported-<kernel-version>`, and `kernel-hugemem-unsupported-<kernel-version>`. Replace `<kernel-version>` with the version of the kernel installed on the system. These packages are not installed by the Red Hat Enterprise Linux installation program, and the modules provided are not supported by Red Hat, Inc..

## A.1. Specifying Module Parameters

In some situations, it may be necessary to supply parameters to a module as it is loaded for it to function properly.

For instance, to enable full duplex at 100Mbps connection speed for an Intel Ether Express/100 card, load the `e100` driver with the `e100_speed_duplex=4` option.



### Caution

When a parameter has commas, be sure *not* to put a space after a comma.

## A.2. SCSI parameters

Hardware	Module	Parameters
3ware Storage Controller	<code>3w-xxxx.o</code>	

---

1. A driver is software which enables Linux to use a particular hardware device. Without a driver, the kernel can not communicate with attached devices.

Hardware	Module	Parameters
NCR53c810/820/720, NCR53c700/710/700-66	53c7,8xx.o	
Adaptec AACRAID	aacraid.o	
Adaptec 28xx, R9xx, 39xx AHA-284x, AHA-29xx, AHA-394x, AHA-398x, AHA-274x, AHA-274xT, AHA-2842, AHA-2910B, AHA-2920C, AHA-2930/U/U2, AHA-2940/W/U/UW/AU/ U2W/U2/U2B/, U2BOEM, AHA-2944D/WD/UD/UWD, AHA-2950U2/W/B, AHA-3940/U/W/UW/ AUW/U2W/U2B, AHA-3950U2D, AHA-3985/U/W/UW, AIC-777x, AIC-785x, AIC-786x, AIC-787x, AIC-788x , AIC-789x, AIC-3860	aic7xxx.o	
ICP RAID Controller	gdth.o	
IBM ServeRAID	ips.o	
AMI MegaRAID 418, 428, 438, 466, 762	megaraid.o	
Qlogic 1280	qlal280.o	

Table A-1. SCSI Parameters

### A.3. Ethernet Parameters



#### Important

Most modern Ethernet-based network interface cards (NICs), do not require module parameters to alter settings. Instead, they can be configured using `ethtool` or `mii-tool`. Only after these tools fail to work should module parameters be adjusted.

For information about using these tools, consult the man pages for `ethtool` and `mii-tool`.

Hardware	Module	Parameters
3Com EtherLink PCI III/XL Vortex (3c590, 3c592, 3c595, 3c597) Boomerang (3c900, 3c905, 3c595)	3c59x.o	<code>full_duplex=</code> 0 is off 1 is on

Hardware	Module	Parameters
>RTL8139, SMC EZ Card Fast Ethernet, RealTek cards using RTL8129, or RTL8139 Fast Ethernet chipsets	8139too.o	
Intel Ether Express/100 driver	e100.o	e100_speed_duplex= <i>X</i> <i>If X =</i> 0 = autodetect speed and duplex 1 = 10Mbps, half duplex 2 = 10Mbps, full duplex 3 = 100Mbps, half duplex 4 = 100Mbps, full duplex
Intel EtherExpress/1000 Gigabit	e1000.o	
Intel i82557/i82558 PCI EtherExpressPro driver	eeepro100.o	
NatSemi DP83815 Fast Ethernet	natsemi.o	
AMD PCnet32 and AMD PCnetPCI	pcnet32.o	
SIS 900/701G PCI Fast Ethernet	sis900.o	
ThunderLAN	tlan.o	
Digital 21x4x Tulip PCI Ethernet cards SMC EtherPower 10 PCI(8432T/8432BT) SMC EtherPower 10/100 PCI(9332DST) DEC EtherWorks 100/10 PCI(DE500-XA) DEC EtherWorks 10 PCI(DE450) DEC QSILVER's, Znyx 312 etherarray Allied Telesis LA100PCI-T Danpex EN-9400, Cogent EM110	tulip.o	io= <i>io_port</i>
VIA Rhine PCI Fast Ethernet cards with either the VIA VT86c100A Rhine-II PCI or 3043 Rhine-I D-Link DFE-930-TX PCI 10/100	via-rhine.o	

Table A-2. Ethernet Module Parameters

### A.3.1. 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 `/etc/modules.conf`. Refer to the chapter titled *Kernel Modules* in the *Red Hat Enterprise Linux System Administration Guide* for more information.

For additional information about using more than one Ethernet card, refer to the *Linux Ethernet-HOWTO* online at <http://www.redhat.com/mirrors/LDP/HOWTO/Ethernet-HOWTO.html>.

### A.3.2. The Channel Bonding Module

Red Hat Enterprise Linux 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. Add the following line to `/etc/modules.conf`:  

```
alias bond<N> bonding
```

 Replace `<N>` with the interface number, such as 0. For each configured channel bonding interface, there must be a corresponding entry in `/etc/modules.conf`.
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 A.3.2.1 *bonding Module Directives* for a listing of available options.
4. After testing, place preferred module options in `/etc/modules.conf`.

#### A.3.2.1. bonding Module Directives

Before finalizing the settings for the `bonding` module, it is a good idea to test which settings work best. To do this, open a shell prompt as root and type:

```
tail -f /var/log/messages
```

Open another shell prompt and use the `/sbin/insmod` command to load the `bonding` module with different parameters while observing the kernel messages for errors.

The `/sbin/insmod` command is issued in the following format:

```
/sbin/insmod bond<N> <parameter=value>
```

Replace `<N>` with the number for the bonding interface. Replace `<parameter=value>` with a space separated list of desired parameters for the interface.

Once satisfied that there are no errors and after verifying the performance of the bonding interface, add the appropriate `bonding` module parameters to `/etc/modules.conf`.

The following is a list of available parameters for the `bonding` module:

- `mode=` — Specifies one of four policies allowed for the `bonding` module. Acceptable values for this parameter are:
  - 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.
  - 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.



- 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.
- 3 — Sets a round-robin policy for fault tolerance and load balancing. Transmissions are sent out sequentially on each bonded slave interface beginning with the first one available.

- `miimon=` — Specifies (in milliseconds) how often MII link monitoring occurs. This is useful if high availability is required because MII 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:

```
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.

- `downdelay=` — 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.
- `updelay=` — 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.
- `arp_interval=` — Specifies (in milliseconds) how often ARP monitoring occurs.

If using this setting while in `mode 0` or `2` (the two load-balancing modes) the network switch must be configured to distribute packets evenly across the NICs. For more information on how to accomplish this, refer to `/usr/src/linux-2.4/Documentation/networking/bonding.txt2`.

The value is set to 0 by default, which disables it.

- `arp_ip_target=` — 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.
- `primary=` — 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 `/usr/src/linux-2.4/Documentation/networking/bonding.txt2` for more information.

- `multicast=` — Specifies an integer value for the type of multicast support desired.

Acceptable values for this parameter are:

- 0 — Disables multicast support.
- 1 — Enables multicast support, but only on the active slave.
- 2 — Enables multicast support on all slaves (the default).

---

2. This document is installed with the `kernel-source` package.

2. This document is installed with the `kernel-source` package.

**Important**

It is essential that either the `arp_interval` and `arp_ip_target` or `miimon` parameters are specified. Failure to do so can cause degradation of network performance in the event a link fails.

Refer to `/usr/src/linux-2.4/Documentation/networking/bonding.txt`<sup>2</sup> for detailed instructions regarding bonding interfaces.

---

2. This document is installed with the `kernel-source` package.

# Index

## Symbols

- .fetchmailrc, 180
  - global options, 181
  - server options, 181
  - user options, 181
- .procmailrc, 183
- /etc/named.conf
  - (See BIND)
- /etc/pam.conf, 227
  - (See Also PAM)
- /etc/pam.d, 227
  - (See Also PAM)
- /etc/sysconfig directory
  - (See sysconfig directory)
- /lib/security/, 227
  - (See Also PAM)
- /lib64/security/, 227
  - (See Also PAM)
- /proc/ directory
  - (See proc file system)

## A

- about, 3
- access control, 237
- AccessFileName
  - Apache configuration directive, 145
- Action
  - Apache configuration directive, 150
- AddDescription
  - Apache configuration directive, 148
- AddEncoding
  - Apache configuration directive, 149
- AddHandler
  - Apache configuration directive, 149
- AddIcon
  - Apache configuration directive, 148
- AddIconByEncoding
  - Apache configuration directive, 148
- AddIconByType
  - Apache configuration directive, 148
- AddLanguage
  - Apache configuration directive, 149
- AddType
  - Apache configuration directive, 149
- Alias
  - Apache configuration directive, 147
- Allow
  - Apache configuration directive, 144
- AllowOverride
  - Apache configuration directive, 144
- Apache

- (See Apache HTTP Server)
- Apache HTTP Server

- 1.3
  - migration to 2.0, 127
- 2.0
  - features of, 125
  - file system changes, 126
  - migration from 1.3, 127
  - MPM specific directives, 139
  - packaging changes, 126
- additional resources, 156
  - related books, 156
  - useful websites, 156
- configuration, 137
- introducing, 125
- log files
  - /var/log/httpd/error\_log, 137
  - combined log file format, 146, 147
  - format of, 146
  - troubleshooting with, 137, 138
  - using log analyzer tools with, 145
- migration to 2.0, 127
  - bind addresses and ports, 127
  - content negotiation, 131
  - directory indexing, 130
  - DSO Support, 128
  - error documents, 131
  - logging, 130
  - module system changes, 132
  - mod\_auth\_db, 134
  - mod\_auth\_dbm, 134
  - mod\_include, 133
  - mod\_perl, 135
  - mod\_proxy, 133
  - mod\_ssl, 132
  - PHP, 135
  - removed directives, 129
  - server-pool size, 128
  - UserDir directive, 130
  - virtual hosts configuration, 131
- Multi-Processing Modules
  - activating worker MPM, 128
  - prefork, 128
  - worker, 128
- reloading, 136
- restarting, 136
- running without security, 154
- server status reports, 150
- starting, 136
- stopping, 136
- troubleshooting, 137
- Apache HTTP Server modules, 153
- APXS Apache utility, 154
- Authentication Configuration Tool
  - and LDAP, 219, 220
- autofs, 120

(See Also NFS)

## B

Basic Input/Output System

(See BIOS)

Berkeley Internet Name Domain

(See BIND)

**BIND**

- additional resources, 209
  - installed documentation, 209
  - related books, 211
  - useful websites, 210
- common mistakes, 209
- configuration files
  - /etc/named.conf, 194, 195
  - /var/named/directory, 194
  - zone files, 201
- configuration of
  - reverse name resolution, 204
  - zone file directives, 201
  - zone file examples, 204
  - zone file resource records, 201
  - zone statements sample, 199
- features, 207
  - DNS enhancements, 208
  - IPv6, 209
  - multiple views, 208
  - security, 208
- introducing, 193, 193
- named daemon, 194
- nameserver
  - definition of, 193
- nameserver types
  - caching-only, 194
  - forwarding, 194
  - master, 194
  - slave, 194
- rndc program, 205
  - /etc/rndc.conf, 206
  - command line options, 207
  - configuring keys, 206
  - configuring named to use, 205
- root nameserver
  - definition of, 193
- zones
  - definition of, 193

**BIOS**

- definition of, 1
- (See Also boot process)

block devices, 48

(See Also /proc/devices)

definition of, 48

boot directory, 26

boot loaders, 19, 11

(See Also LILO)

(See Also GRUB)

definition of, 11

types of

- ELILO, 11
- GRUB, 11
- LILO, 11
- OS/400, 11
- YABOOT, 11
- z/IPL, 11

boot process, 1, 1

(See Also boot loaders)

chain loading, 11

direct loading, 11

for x86, 1

stages of, 1, 1

/sbin/init command, 4

BIOS, 1

boot loader, 2

EFI shell, 1

kernel, 3

BrowserMatch

Apache configuration directive, 150

## C

cache directives for Apache, 151

CacheNegotiatedDocs

Apache configuration directive, 145

caching-only nameserver

(See BIND)

CGI scripts

allowing execution outside cgi-bin, 143

outside the ScriptAlias, 149

channel bonding

interface

configuration of, 107

module configuration, 286

module directives, 286

character devices, 48

(See Also /proc/devices)

definition of, 48

chkconfig, 8

(See Also services)

configuration

Apache HTTP Server, 137

virtual hosts, 154

configuration directives, Apache, 138

AccessFileName, 145

Action, 150

AddDescription, 148

AddEncoding, 149

AddHandler, 149

AddIcon, 148

AddIconByEncoding, 148

- AddIconByType, 148
- AddLanguage, 149
- AddType, 149
- Alias, 147
- Allow, 144
- AllowOverride, 144
- BrowserMatch, 150
- CacheNegotiatedDocs, 145
- CustomLog, 147
- DefaultIcon, 148
- DefaultType, 145
- Deny, 144
- Directory, 143
- DirectoryIndex, 145
- DocumentRoot, 142
- ErrorDocument, 150
- ErrorLog, 146
- ExtendedStatus, 141
- for cache functionality, 151
- Group, 142
- HeaderName, 149
- HostnameLookups, 145
- IfDefine, 141
- IfModule, 139
- Include, 141
- IndexIgnore, 149
- IndexOptions, 148
- KeepAlive, 138
  - (See Also KeepAliveTimeout)
  - troubleshooting, 138
- KeepAliveTimeout, 139
- LanguagePriority, 149
- Listen, 140
- LoadModule, 141
- Location, 150
- LogFormat
  - format options, 146
- LogLevel, 146
- MaxClients, 140
- MaxKeepAliveRequests, 139
- MaxRequestsPerChild, 139
- MaxSpareServers, 140
- MaxSpareThreads, 140
- MinSpareServers, 140
- MinSpareThreads, 140
- NameVirtualHost, 152
- Options, 143
- Order, 144
- PidFile, 138
- Proxy, 151
- ProxyRequests, 151
- ProxyVia, 151
- ReadmeName, 149
- Redirect, 147
- ScriptAlias, 147
- ServerAdmin, 142

- ServerName, 142
- ServerRoot, 138
- ServerSignature, 147
- SetEnvIf, 152
- SSL configuration, 152
- StartServers, 139
- ThreadsPerChild, 140
- Timeout, 138
- TypesConfig, 145
- UseCanonicalName, 142
- User, 141
- UserDir, 144
- VirtualHost, 152
- conventions
  - document, v
- copying and pasting text
  - when using X, viii
- CustomLog
  - Apache configuration directive, 147

## D

- DefaultIcon
  - Apache configuration directive, 148
- DefaultType
  - Apache configuration directive, 145
- Denial of Service
  - prevention using xinetd, 249
  - (See Also xinetd)
- Denial of Service attack, 73
  - (See Also /proc/sys/net/ directory)
  - definition of, 73
- Deny
  - Apache configuration directive, 144
- desktop environments
  - (See XFree86)
- dev directory, 26
- devices, local
  - ownership of, 233
  - (See Also PAM)
- directories
  - /boot/, 26
  - /dev/, 26
  - /etc/, 26
  - /lib/, 26
  - /mnt/, 26
  - /opt/, 26
  - /proc/, 27
  - /sbin/, 27
  - /usr/, 27
  - /usr/local/, 28
  - /var/, 28
- Directory
  - Apache configuration directive, 143
- DirectoryIndex

- Apache configuration directive, 145
- display managers
  - (See XFree86)
- DNS, 193
  - (See Also BIND)
  - introducing, 193
- documentation
  - experienced user, iv
  - finding appropriate, ii
  - first-time users, iii
    - books, iv
    - newsgroups, iv
    - websites, iii
  - guru, v
- DocumentRoot
  - Apache configuration directive, 142
  - changing, 154
  - changing shared, 155
- DoS
  - (See Denial of Service)
- DoS attack
  - (See Denial of Service attack)
- drag and drop, viii
- drivers
  - (See kernel modules)
- DSOs
  - loading, 154

## E

- EFI shell
  - definition of, 1
  - (See Also boot process)
- ELILO, 3, 11
  - (See Also boot loaders)
- email
  - additional resources, 190
  - installed documentation, 190
  - related books, 191
  - useful websites, 191
- Fetchmail, 179
  - history of, 171
  - Postfix, 178
  - Procmail, 183
  - program classifications, 173
  - protocols, 171
    - IMAP, 172
    - POP, 172
    - SMTP, 171
  - security, 189
    - clients, 189
    - servers, 189
  - Sendmail, 174
  - spam
    - filtering out, 188

- types
  - Mail Delivery Agent, 173
  - Mail Transfer Agent, 173
  - Mail User Agent, 174
- epoch, 59
  - (See Also /proc/stat)
  - definition of, 59
- ErrorDocument
  - Apache configuration directive, 150
- ErrorLog
  - Apache configuration directive, 146
- etc directory, 26
- Ethernet
  - (See network)
- Ethernet modules
  - (See kernel modules)
- execution domains, 49
  - (See Also /proc/execcdomains)
  - definition of, 49
- ExtendedStatus
  - Apache configuration directive, 141
- Extensible Firmware Interface shell
  - (See EFI shell)

## F

- feedback
  - contact information, viii
- Fetchmail, 179
  - additional resources, 190
  - command options, 182
    - informational, 182
    - special, 182
  - configuration options, 180
    - global options, 181
    - server options, 181
    - user options, 181
- FHS, 25, 25
  - (See Also file system)
  - (See Also file system)
- file system
  - FHS standard, 25
  - hierarchy, 25
  - organization, 25
  - structure, 25
  - virtual
    - (See proc file system)
- files, proc file system
  - changing, 46, 76
  - viewing, 45, 76
- forwarding nameserver
  - (See BIND)
- frame buffer device, 49
  - (See Also /proc/fb)
- FrontPage, 136

fstab, 119  
 (See Also NFS)  
 FTP, 157  
 (See Also vsftpd)  
 active mode, 157  
 command port, 157  
 data port, 157  
 definition of, 157  
 introducing, 157  
 passive mode, 157  
 server software  
 Red Hat Content Accelerator, 158  
 vsftpd, 158

## G

GNOME, 88  
 (See Also XFree86)  
 Group  
 Apache configuration directive, 142  
 groups  
 additional resources, 84  
 installed documentation, 84  
 related books, 85  
 GID, 79  
 introducing, 79  
 shared directories, 83  
 standard, 81  
 tools for management of  
 groupadd, 79, 83  
 redhat-config-users, 83  
 User Manager, 79  
 user private, 83  
 GRUB, 11, 2  
 (See Also boot loaders)  
 (See Also boot loaders)  
 additional resources, 22  
 installed documentation, 22  
 related books, 23  
 useful websites, 22  
 boot process, 11  
 changing runlevels with, 15, 22  
 commands, 16  
 configuration file  
 /boot/grub/grub.conf, 17  
 structure, 17  
 definition of, 11  
 features, 12  
 installing, 13  
 interfaces, 15  
 command line, 15  
 menu, 15  
 menu entry editor, 15  
 order of, 16  
 menu configuration file, 17

directives, 18  
 role in boot process, 2  
 terminology, 13  
 devices, 13  
 files, 14  
 root file system, 15  
 grub.conf, 17  
 (See Also GRUB)

## H

halt, 8  
 (See Also shutdown)  
 HeaderName  
 Apache configuration directive, 149  
 hierarchy, file system, 25  
 HostnameLookups  
 Apache configuration directive, 145  
 hosts access files  
 (See TCP wrappers)  
 hosts.allow  
 (See TCP wrappers)  
 hosts.deny  
 (See TCP wrappers)  
 httpd.conf  
 (See configuration directives, Apache)  
 hugepages  
 configuration of, 74

## I

IfDefine  
 Apache configuration directive, 141  
 ifdown, 110  
 IfModule  
 Apache configuration directive, 139  
 ifup, 110  
 Include  
 Apache configuration directive, 141  
 IndexIgnore  
 Apache configuration directive, 149  
 IndexOptions  
 Apache configuration directive, 148  
 init command, 4  
 (See Also boot process)  
 configuration files  
 /etc/inittab, 7  
 role in boot process, 4  
 (See Also boot process)  
 runlevels  
 directories for, 7  
 runlevels accessed by, 7  
 SysV init  
 definition of, 7  
 initrd directory, 30

introduction, i

ip6tables

control scripts

panic, 260

restart, 260

save, 260

start, 260

status, 260

stop, 260

introducing, 261

ipchains

(See iptables)

IPsec

(See network)

iptables

/sbin/iptables-restore, 259

/sbin/iptables-save, 259

additional resources, 262

installed documentation, 262

useful websites, 262

chains

target, 251

compared with ipchains, 252

configuration files

/etc/sysconfig/iptables, 259

/etc/sysconfig/iptables-config, 261

/etc/sysconfig/iptables.save, 259

control scripts

panic, 260

restart, 260

save, 259, 260

start, 260

status, 260

stop, 260

match options, 255

modules, 257

options, 253

commands, 254

listing, 259

parameters, 254

structure of, 253

target, 258

overview of, 251

packet filtering basics, 251

protocols

ICMP, 257

TCP, 255

UDP, 256

rules list, 251

saving rules, 259

tables, 251

## K

KDE, 88

(See Also XFree86)

KeepAlive

Apache configuration directive, 138

KeepAliveTimeout

Apache configuration directive, 139

Kerberos

additional resources, 270

installed documentation, 270

useful websites, 271

advantages of, 263

and PAM, 267

Authentication Server (AS), 266

clients set up, 269

definition of, 263

disadvantages of, 263

how it works, 266

Key Distribution Center (KDC), 266

server set up, 267

terminology, 264

Ticket-granting Server (TGS), 266

Ticket-granting Ticket (TGT), 266

kernel

role in boot process, 3

kernel modules

Ethernet modules

parameters, 284

supporting multiple cards, 285

introducing, 283

module parameters

specifying, 283

SCSI modules

parameters, 283

types of, 283

kwin, 88

(See Also XFree86)

## L

LanguagePriority

Apache configuration directive, 149

LDAP

additional resources, 222

installed documentation, 222

related books, 223

useful websites, 223

advantages of, 213

applications

ldapadd, 214

ldapdelete, 214

ldapmodify, 214

ldappasswd, 214

ldapsearch, 214

OpenLDAP suite, 214



- slapadd, 214
- slapcat, 214
- slapcat-gdbm, 214
- slapd, 214
- slapindex, 214
- slappasswd, 214
- slurpd, 214
- utilities, 214
- authentication using, 219
  - Authentication Configuration Tool, 219
  - editing /etc/ldap.conf, 219
  - editing /etc/nsswitch.conf, 219
  - editing /etc/openldap/ldap.conf, 219
  - editing slapd.conf, 219
  - packages, 219
  - PAM, 220
  - setting up clients, 219
- client applications, 216
- configuration files
  - /etc/ldap.conf, 216
  - /etc/openldap/ldap.conf, 216
  - /etc/openldap/schema/ directory, 216, 217
  - /etc/openldap/slapd.conf, 216, 218
- daemons, 214
- definition of, 213
- LDAPv2, 213
- LDAPv3, 213
- LDIF
  - format of, 214
- OpenLDAP features, 213
- setting up, 218
  - migrating 1.x directories, 221
  - migrating older directories, 221
- terminology, 214
- upgrading directories, 221
- using with Apache HTTP Server, 216
- using with NSS, 216
- using with PAM, 216
- using with PHP4, 216
- ldapadd command, 214
  - (See Also LDAP)
- ldapdelete command, 214
  - (See Also LDAP)
- ldapmodify command, 214
  - (See Also LDAP)
- ldappasswd command, 214
  - (See Also LDAP)
- ldapsearch command, 214
  - (See Also LDAP)
- lib directory, 26
- Lightweight Directory Access Protocol
  - (See LDAP)
- LILO, 11, 2
  - (See Also boot loaders)
  - (See Also boot loaders)
  - additional resources, 22

- installed documentation, 22
- related books, 23
- useful websites, 22
- boot process, 19
- changing runlevels with, 22
- configuration file
  - /etc/lilo.conf, 20
- definition of, 19
- role in boot process, 2
- lilo.conf, 20
  - (See Also LILO)
- Listen
  - Apache configuration directive, 140
- LoadModule
  - Apache configuration directive, 141
- Location
  - Apache configuration directive, 150
- LogFormat
  - Apache configuration directive, 146
- LogLevel
  - Apache configuration directive, 146
- lspci, 57

## M

- Mail Delivery Agent
  - (See email)
- Mail Transfer Agent
  - (See email)
- Mail User Agent
  - (See email)
- Master Boot Record
  - (See MBR)
  - (See MBR)
- master nameserver
  - (See BIND)
- MaxClients
  - Apache configuration directive, 140
- MaxKeepAliveRequests
  - Apache configuration directive, 139
- MaxRequestsPerChild
  - Apache configuration directive, 139
- MaxSpareServers
  - Apache configuration directive, 140
- MaxSpareThreads
  - Apache configuration directive, 140
- MBR
  - definition of, 1, 1
  - (See Also boot loaders)
  - (See Also boot process)
- MDA
  - (See Mail Delivery Agent)
- metacity, 88
  - (See Also XFree86)
- MinSpareServers

- Apache configuration directive, 140
- MinSpareThreads
  - Apache configuration directive, 140
- mnt directory, 26
- module parameters
  - (See kernel modules)
- modules
  - (See kernel modules)
  - (See kernel modules)
- Apache
  - loading, 154
  - the own, 154
- default, 153
- mouse
  - how to use, viii
- MTA
  - (See Mail Transfer Agent)
- MUA
  - (See Mail User Agent)
- mwm, 88
  - (See Also XFree86)

## N

- named daemon
  - (See BIND)
- named.conf
  - (See BIND)
- nameserver
  - (See BIND)
- NameVirtualHost
  - Apache configuration directive, 152
- netfilter
  - (See iptables)
- network
  - additional resources, 112
  - commands
    - /sbin/ifdown, 110
    - /sbin/ifup, 110
    - /sbin/service network, 110
  - configuration, 104
  - functions, 111
  - interfaces, 104
    - alias, 108
    - channel bonding, 107
    - clone, 108
    - dialup, 108
    - Ethernet, 104
    - IPsec, 106
  - scripts, 103
- Network File System
  - (See NFS)
- NFS
  - additional resources, 122
  - installed documentation, 122

- related books, 123
- useful websites, 123
- client
  - /etc/fstab, 119
  - autofs, 120
  - configuration, 119
  - mount options, 121
- condrestart, 115
- how it works, 113
- introducing, 113
- portmap, 114
- reloading, 115
- required services, 114
- restarting, 115
- security, 121
  - file permissions, 122
  - host access, 122
- server configuration, 116
  - /etc/exports, 116
  - exportfs command, 118
- starting, 115
- status, 115
- stopping, 115
- TCP, 113
- UDP, 113
- NIC modules
  - (See kernel modules)
- non-secure Web server
  - disabling, 155
- ntsysv, 8
  - (See Also services)

## O

- objects, dynamically shared
  - (See DSOS)
- OpenLDAP
  - (See LDAP)
- OpenSSH, 273
  - (See Also SSH)
  - configuration files for, 276
- opt directory, 26
- Options
  - Apache configuration directive, 143
- Order
  - Apache configuration directive, 144
- OS/400, 11
  - (See Also boot loaders)

## P

- packet filtering
  - (See iptables)
- PAM
  - additional resources, 235
    - installed documentation, 235
    - useful websites, 235
  - advantages of, 227
  - configuration files, 227
  - control flags, 229
  - definition of, 227
  - Kerberos and, 267
  - modules, 228
    - arguments, 229
    - components, 228
    - creating, 232
    - interfaces, 228
    - location of, 229
    - stacking, 228, 230
  - pam\_console
    - definition of, 233
  - pam\_timestamp
    - authentication icon and, 232
    - definition of, 232
    - destroying timestamps, 233
    - directives, 233
  - pam\_timestamp\_check
    - destroying timestamp using, 233
  - sample configuration files, 230
  - service files, 227
  - shadow passwords, 230
- pam\_console
  - (See PAM)
- pam\_timestamp
  - (See PAM)
- pam\_timestamp\_check
  - (See PAM)
- password, 230
  - (See Also PAM)
  - shadow passwords, 230
- passwords
  - shadow, 84
- PidFile
  - Apache configuration directive, 138
- Pluggable Authentication Modules
  - (See PAM)
- portmap, 114
  - (See Also NFS)
  - NFS, 115
  - rpcinfo, 115
  - status, 115
- Postfix, 178
  - default installation, 178
- prefdm
  - (See XFree86)
- proc directory, 27
- proc file system
  - /proc/apm, 47
  - /proc/bus/ directory, 62
  - /proc/cmdline, 47
  - /proc/cpuinfo, 47
  - /proc/devices
    - block devices, 48
    - character devices, 48
  - /proc/dma, 49
  - /proc/driver/ directory, 63
  - /proc/execdomains, 49
  - /proc/fb, 49
  - /proc/filesystems, 50
  - /proc/fs/ directory, 63
  - /proc/ide directory
    - device directories, 64
  - /proc/ide/ directory, 64
  - /proc/interrupts, 50
  - /proc/iomem, 51
  - /proc/ioports, 51
  - /proc/irq/ directory, 65
  - /proc/isapnp, 52
  - /proc/kcore, 53
  - /proc/kmsg, 53
  - /proc/ksyms, 53
  - /proc/loadavg, 53
  - /proc/locks, 54
  - /proc/mdstat, 54
  - /proc/meminfo, 54
  - /proc/misc, 56
  - /proc/modules, 56
  - /proc/mounts, 57
  - /proc/mtrr, 57
  - /proc/net/ directory, 65
  - /proc/partitions, 57
  - /proc/pci
    - viewing using lspci, 57
  - /proc/scsi/ directory, 66
  - /proc/self/ directory, 62
  - /proc/slabinfo, 58
  - /proc/stat, 59
  - /proc/swaps, 60
  - /proc/sys/ directory, 68, 76
    - (See Also sysctl)
    - /proc/sys/dev/ directory, 69
    - /proc/sys/fs/ directory, 69
    - /proc/sys/kernel/ directory, 70
    - /proc/sys/kernel/sysrq
      - (See system request key)
    - /proc/sys/net/ directory, 73
    - /proc/sys/vm/ directory, 74
  - /proc/sysrq-trigger, 59
  - /proc/sysvipc/ directory, 76
  - /proc/tty/ directory, 76
  - /proc/uptime, 60

- `/proc/version`, 60
- additional resources, 77
  - installed documentation, 77
  - useful websites, 78
- changing files within, 46, 68, 76
- files within, top-level, 46
- introduced, 45
- process directories, 60
- subdirectories within, 60
- viewing files within, 45

#### Procmail, 183

- additional resources, 190
- configuration, 183
- recipes, 184
  - delivering, 185
  - examples, 186
  - flags, 185
  - local lockfiles, 186
  - non-delivering, 185
  - SpamAssassin, 188
  - special actions, 186
  - special conditions, 186

#### programs

- running at boot time, 6

#### Proxy

- Apache configuration directive, 151
- proxy server, 151, 151

#### ProxyRequests

- Apache configuration directive, 151

#### ProxyVia

- Apache configuration directive, 151

- `public_html` directories, 144

## R

#### `rc.local`

- modifying, 6

#### `rc.serial`, 6

- (See Also `setserial` command)

#### ReadmeName

- Apache configuration directive, 149

#### Red Hat Enterprise Linux-specific file locations

- `/etc/sysconfig/`, 30

- (See Also `sysconfig` directory)

- `/var/lib/rpm/`, 30

- `/var/spool/up2date/`, 30

#### Redirect

- Apache configuration directive, 147

#### root nameserver

- (See `BIND`)

#### `rpcinfo`, 115

#### runlevels

- (See `init` command)

- changing at boot time, 22

- changing with `GRUB`, 15

- configuration of, 8

- (See Also `services`)

## S

- `sbin` directory, 27

#### ScriptAlias

- Apache configuration directive, 147

#### SCSI modules

- (See kernel modules)

#### security

- running Apache without, 154

#### Sendmail, 174

- additional resources, 190

- aliases, 176

- common configuration changes, 175

- default installation, 174

- LDAP and, 177

- limitations, 174

- masquerading, 176

- purpose, 174

- spam, 176

- with `UUCP`, 175

#### serial ports

- (See `setserial` command)

- server side includes, 143, 149

#### ServerAdmin

- Apache configuration directive, 142

#### ServerName

- Apache configuration directive, 142

#### ServerRoot

- Apache configuration directive, 138

#### ServerSignature

- Apache configuration directive, 147

#### services

- configuring with `chkconfig`, 8

- configuring with `ntsysv`, 8

- configuring with `Services Configuration Tool`, 8

- `Services Configuration Tool`, 8

- (See Also `services`)

#### SetEnvIf

- Apache configuration directive, 152

#### setserial command

- configuring, 6

#### shadow

- (See `password`)

- shadow passwords

- overview of, 84

- shutdown, 8

- (See Also `halt`)

#### slab pools

- (See `/proc/slabinfo`)

- `slapadd` command, 214

- (See Also `LDAP`)

- `slapcat` command, 214

- (See Also LDAP)
- slapcat-gdbm command, 214
  - (See Also LDAP)
- slapd command, 214
  - (See Also LDAP)
- slapindex command, 214
  - (See Also LDAP)
- slappasswd command, 214
  - (See Also LDAP)
- slave nameserver
  - (See BIND)
- slurpd command, 214
  - (See Also LDAP)
- SpamAssassin
  - using with Procmail, 188
- SSH protocol, 273
  - additional resources, 279
    - installed documentation, 279
    - related books, 280
    - useful websites, 280
  - authentication, 275
  - configuration files, 276
  - connection sequence, 274
  - features of, 273
  - insecure protocols and, 278
  - layers of
    - channels, 276
    - transport layer, 275
  - port forwarding, 277
  - requiring for remote login, 278
  - security risks, 273
  - version 1, 274
  - version 2, 274
  - X11 forwarding, 277
- SSL configuration, 152
- StartServers
  - Apache configuration directive, 139
- startx
  - (See XFree86)
- stunnel, 189
- sysconfig directory, 30
  - /etc/sysconfig/amd, 32
  - /etc/sysconfig/apm-scripts/ directory, 42
  - /etc/sysconfig/apmd, 32
  - /etc/sysconfig/authconfig, 32
  - /etc/sysconfig/cbq/ directory, 42
  - /etc/sysconfig/clock, 33
  - /etc/sysconfig/desktop, 33
  - /etc/sysconfig/devlabel, 34
  - /etc/sysconfig/dhcpd, 34
  - /etc/sysconfig/firstboot, 34
  - /etc/sysconfig/gpm, 34
  - /etc/sysconfig/harddisks, 34
  - /etc/sysconfig/hwconf, 35
  - /etc/sysconfig/init, 35
  - /etc/sysconfig/iptables-config, 36
  - /etc/sysconfig/iptables, 36, 259
  - /etc/sysconfig/irda, 37
  - /etc/sysconfig/keyboard, 37
  - /etc/sysconfig/kudzu, 37
  - /etc/sysconfig/mouse, 38
  - /etc/sysconfig/named, 38
  - /etc/sysconfig/netdump, 39
  - /etc/sysconfig/network, 39
  - /etc/sysconfig/network-scripts/ directory, 103
  - /etc/sysconfig/ntp, 39
  - /etc/sysconfig/pcmcia, 39
  - /etc/sysconfig/radvd, 40
  - /etc/sysconfig/rawdevices, 40
  - /etc/sysconfig/redhat-config-securitylevel, 40
  - /etc/sysconfig/redhat-config-users, 40
  - /etc/sysconfig/redhat-logviewer, 41
  - /etc/sysconfig/rhn/ directory, 43
  - /etc/sysconfig/samba, 41
  - /etc/sysconfig/sendmail, 41
  - /etc/sysconfig/spamassassin, 41
  - /etc/sysconfig/squid, 41
  - /etc/sysconfig/tux, 42
  - /etc/sysconfig/vncservers, 42
  - /etc/sysconfig/xinetd, 42
  - additional information about, 31
  - additional resources, 43
    - installed documentation, 43
  - directories in, 42
  - files found in, 31
- sysconfig/ directory
  - /etc/sysconfig/network-scripts/ directory, 42
    - (See Also network)
  - /etc/sysconfig/networking/ directory, 42
- sysctl
  - configuring with /etc/sysctl.conf, 76
  - controlling /proc/sys/, 76
- SysRq
  - (See system request key)
- System Request Key
  - definition of, 68
  - enabling, 68
  - setting timing for, 70
- SysV init
  - (See init command)

**T**

- TCP wrappers, 244
  - (See Also `xinetd`)
  - additional resources, 250
  - installed documentation, 250
  - related books, 250
  - useful websites, 250
- advantages of, 238
- configuration files
  - `/etc/hosts.allow`, 238, 238
  - `/etc/hosts.deny`, 238, 238
  - access control option, 243
  - expansions, 243
  - formatting rules within, 239
  - hosts access files, 238
  - log option, 242
  - operators, 242
  - option fields, 242
  - patterns, 240
  - shell command option, 243
  - spawn option, 243
  - twist option, 243
  - wildcards, 240
- definition of, 238
- introducing, 237
- `ThreadsPerChild`
  - Apache configuration directive, 140
- `Timeout`
  - Apache configuration directive, 138
- TLB cache
  - (See `hugepages`)
- troubleshooting
  - error log, 146
- `twm`, 88
  - (See Also `XFree86`)
- `TypesConfig`
  - Apache configuration directive, 145

**U**

- `UseCanonicalName`
  - Apache configuration directive, 142
- User
  - Apache configuration directive, 141
- user private groups
  - (See `groups`)
  - and shared directories, 83
- `UserDir`
  - Apache configuration directive, 144
- users
  - `/etc/passwd`, 80
  - additional resources, 84
    - installed documentation, 84
    - related books, 85
  - introducing, 79

- personal HTML directories, 144
- standard, 80
- tools for management of
  - User Manager, 79
  - `useradd`, 79
- UID, 79
- `usr` directory, 27
- `usr/local/` directory, 28

**V**

- `var` directory, 28
- `var/lib/rpm/` directory, 30
- `var/spool/updates/` directory, 30
- virtual file system
  - (See `proc` file system)
- virtual files
  - (See `proc` file system)
- virtual hosts
  - configuring, 154
  - `Listen` command, 155
  - name-based, 154
  - Options, 143
  - server side includes, 149
- `VirtualHost`
  - Apache configuration directive, 152
- `vsftpd`, 158
  - (See Also `FTP`)
  - additional resources, 168
    - installed documentation, 168
    - related books, 169
    - useful websites, 168
  - `condrestart`, 159
  - configuration file
    - `/etc/vsftpd/vsftpd.conf`, 160
    - access controls, 161
    - anonymous user options, 163
    - daemon options, 161
    - directory options, 164
    - file transfer options, 165
    - format of, 160
    - local user options, 163
    - logging options, 165
    - login options, 161
    - network options, 166
  - multihomed configuration, 160
  - restarting, 159
  - RPM
    - files installed by, 159
  - security features, 158
  - starting, 159
  - starting multiple copies of, 160
  - status, 159
  - stopping, 159

**W**

- webmaster
  - email address for, 142
- window managers
  - (See XFree86)

**X**

- X
  - (See XFree86)
- X Window System
  - (See XFree86)
- X.500
  - (See LDAP)
- X.500 Lite
  - (See LDAP)
- XFree86
  - /etc/X11/XF86Config
    - boolean values for, 89
    - Device, 93
    - DRI, 95
    - Files section, 91
    - InputDevice section, 92
    - introducing, 89
    - Module section, 91
    - Monitor, 92
    - Screen, 94
    - Section tag, 89
    - ServerFlags section, 90
    - ServerLayout section, 90
    - structure of, 89
  - additional resources, 99
    - installed documentation, 100
    - related books, 100
    - useful websites, 100
  - configuration files
    - /etc/X11/ directory, 89
    - /etc/X11/XF86Config, 89
    - options within, 89
    - server options, 89
  - desktop environments
    - GNOME, 88
    - KDE, 88
  - display managers
    - configuration of preferred, 99
    - definition of, 99
    - gdm, 99
    - kdm, 99
    - prefdm script, 99
    - xdm, 99
  - fonts
    - core X font subsystem, 97
    - Fontconfig, 95
    - Fontconfig, adding fonts to, 96
    - FreeType, 95

- introducing, 95
- X Font Server, 97
- X Render Extension, 95
- xfs, 97
  - xfs configuration, 97
  - xfs, adding fonts to, 98
  - Xft, 95
- introducing, 87
- runlevels
  - 3, 98
  - 5, 99
- runlevels and, 98
- utilities
  - X Configuration Tool, 87
- window managers
  - kwin, 88
  - metacity, 88
  - mwm, 88
  - twm, 88
- X clients, 87, 88
  - desktop environments, 88
  - startx command, 98
  - window managers, 88
  - xinit command, 98
- X server, 87
  - features of, 87
  - XFree86, 87
- xinetd, 244
  - (See Also TCP wrappers)
  - additional resources
    - installed documentation, 250
    - related books, 250
    - useful websites, 250
  - configuration files, 245
    - /etc/xinetd.conf, 245
    - /etc/xinetd.d/ directory, 246
  - access control options, 247
  - binding options, 248
  - logging options, 245, 246, 246
  - redirection options, 248
  - resource management options, 249
  - DoS attacks and, 249
  - introducing, 237, 244
  - relationship with TCP wrappers, 247
- xinit
  - (See XFree86)

**Y**

- YABOOT, 11
  - (See Also boot loaders)

**Z**

z/IPL, 11

(See Also boot loaders)



The manuals are written in DocBook SGML v4.1 format. The HTML and PDF formats are produced using custom DSSSL stylesheets and custom jade wrapper scripts. The DocBook SGML files are written in **Emacs** with the help of PSGML mode.

Garrett LeSage created the admonition graphics (note, tip, important, caution, and warning). They may be freely redistributed with the Red Hat documentation.

The Red Hat Product Documentation Team consists of the following people:

Sandra A. Moore — Primary Writer/Maintainer of the *Red Hat Enterprise Linux Installation Guide for the x86, Itanium™, and AMD64 Architectures*; Primary Writer/Maintainer of the *Red Hat Enterprise Linux Installation Guide for the IBM® eServer™ iSeries™ and IBM® eServer™ pSeries™ Architectures*; Contributing Writer to the *Red Hat Enterprise Linux Step By Step Guide*

Tammy Fox — Primary Writer/Maintainer of the *Red Hat Enterprise Linux System Administration Guide*; Contributing Writer to the *Red Hat Enterprise Linux Installation Guide for the x86, Itanium™, and AMD64 Architectures*; Contributing Writer to the *Red Hat Enterprise Linux Security Guide*; Contributing Writer to the *Red Hat Enterprise Linux Step By Step Guide*; Writer/Maintainer of custom DocBook stylesheets and scripts

Edward C. Bailey — Primary Writer/Maintainer of the *Red Hat Enterprise Linux Introduction to System Administration*; Primary Writer/Maintainer of the *Release Notes*; Contributing Writer to the *Red Hat Enterprise Linux Installation Guide for the x86, Itanium™, and AMD64 Architectures*

Johnray Fuller — Primary Writer/Maintainer of the *Red Hat Enterprise Linux Reference Guide*; Co-writer/Co-maintainer of the *Red Hat Enterprise Linux Security Guide*; Contributing Writer to the *Red Hat Enterprise Linux Introduction to System Administration*

John Ha — Primary Writer/Maintainer of the *Red Hat Cluster Suite Configuring and Managing a Cluster*; Primary Writer/Maintainer of the *Red Hat Glossary*; Primary Writer/Maintainer of the *Red Hat Enterprise Linux Installation Guide for the IBM® S/390® and IBM® eServer™ zSeries® Architectures*; Co-writer/Co-maintainer of the *Red Hat Enterprise Linux Security Guide*; Contributing Writer to the *Red Hat Enterprise Linux Introduction to System Administration*; Contributing Writer to the *Red Hat Enterprise Linux Step By Step Guide*

The Red Hat Localization Team consists of the following people:

Jean-Paul Aubry — French translations

David Barzilay — Brazilian Portuguese translations

Bernd Groh — German translations

James Hashida — Japanese translations

Michelle Ji-yeen Kim — Korean translations

Yelitza Louze — Spanish translations

Noriko Mizumoto — Japanese translations

Nadine Richter — German translations

Audrey Simons — French translations

Francesco Valente — Italian translations

Sarah Saiying Wang — Simplified Chinese translations

Ben Hung-Pin Wu — Traditional Chinese translations

