Red Hat Enterprise Linux 7

Security Guide

A Guide to Securing Red Hat Enterprise Linux 7

Last Updated: 2018-10-22

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Abstract

This book assists users and administrators in learning the processes and practices of securing workstations and servers against local and remote intrusion, exploitation, and malicious activity. Focused on Red Hat Enterprise Linux but detailing concepts and techniques valid for all Linux systems, this guide details the planning and the tools involved in creating a secured computing environment for the data center, workplace, and home. With proper administrative knowledge, vigilance, and tools, systems running Linux can be both fully functional and secured from most common intrusion and exploit methods.

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CHAPTER 1. OVERVIEW OF SECURITY TOPICS

Due to the increased reliance on powerful, networked computers to help run businesses and keep track of our personal information, entire industries have been formed around the practice of network and computer security. Enterprises have solicited the knowledge and skills of security experts to properly audit systems and tailor solutions to fit the operating requirements of their organization. Because most organizations are increasingly dynamic in nature, their workers are accessing critical company IT resources locally and remotely, hence the need for secure computing environments has become more pronounced.

Unfortunately, many organizations (as well as individual users) regard security as more of an afterthought, a process that is overlooked in favor of increased power, productivity, convenience, ease of use, and budgetary concerns. Proper security implementation is often enacted postmortem — *after* an unauthorized intrusion has already occurred. Taking the correct measures prior to connecting a site to an untrusted network, such as the Internet, is an effective means of thwarting many attempts at intrusion.

NOTE

This document makes several references to files in the **/lib** directory. When using 64-bit systems, some of the files mentioned may instead be located in **/lib64**.

1.1. WHAT IS COMPUTER SECURITY?

Computer security is a general term that covers a wide area of computing and information processing. Industries that depend on computer systems and networks to conduct daily business transactions and access critical information regard their data as an important part of their overall assets. Several terms and metrics have entered our daily business vocabulary, such as total cost of ownership (TCO), return on investment (ROI), and quality of service (QoS). Using these metrics, industries can calculate aspects such as data integrity and high-availability (HA) as part of their planning and process management costs. In some industries, such as electronic commerce, the availability and trustworthiness of data can mean the difference between success and failure.

1.1.1. Standardizing Security

Enterprises in every industry rely on regulations and rules that are set by standards-making bodies such as the American Medical Association (AMA) or the Institute of Electrical and Electronics Engineers (IEEE). The same ideals hold true for information security. Many security consultants and vendors agree upon the standard security model known as CIA, or *Confidentiality, Integrity, and Availability.* This three-tiered model is a generally accepted component to assessing risks of sensitive information and establishing security policy. The following describes the CIA model in further detail:

- Confidentiality — Sensitive information must be available only to a set of pre-defined individuals. Unauthorized transmission and usage of information should be restricted. For example, confidentiality of information ensures that a customer's personal or financial information is not obtained by an unauthorized individual for malicious purposes such as identity theft or credit fraud.

- Integrity — Information should not be altered in ways that render it incomplete or incorrect. Unauthorized users should be restricted from the ability to modify or destroy sensitive information.

- Availability — Information should be accessible to authorized users any time that it is needed. Availability is a warranty that information can be obtained with an agreed-upon frequency and timeliness. This is often measured in terms of percentages and agreed to formally in Service

Level Agreements (SLAs) used by network service providers and their enterprise clients.

1.1.2. Cryptographic Software and Certifications

The following Red Hat Knowledgebase article provides an overview of the Red Hat Enterprise Linux core crypto components, documenting which are they, how are they selected, how are they integrated into the operating system, how do they support hardware security modules and smart cards, and how do crypto certifications apply to them.

- RHEL7 Core Crypto Components

1.2. SECURITY CONTROLS

Computer security is often divided into three distinct master categories, commonly referred to as *controls*:

- Physical
- Technical
- Administrative

These three broad categories define the main objectives of proper security implementation. Within these controls are sub-categories that further detail the controls and how to implement them.

1.2.1. Physical Controls

Physical control is the implementation of security measures in a defined structure used to deter or prevent unauthorized access to sensitive material. Examples of physical controls are:

- Closed-circuit surveillance cameras
- Motion or thermal alarm systems
- Security guards
- Picture IDs
- Locked and dead-bolted steel doors
- Biometrics (includes fingerprint, voice, face, iris, handwriting, and other automated methods used to recognize individuals)

1.2.2. Technical Controls

Technical controls use technology as a basis for controlling the access and usage of sensitive data throughout a physical structure and over a network. Technical controls are far-reaching in scope and encompass such technologies as:

- Encryption
- Smart cards
- Network authentication
- Access control lists (ACLs)

- File integrity auditing software

1.2.3. Administrative Controls

Administrative controls define the human factors of security. They involve all levels of personnel within an organization and determine which users have access to what resources and information by such means as:

- Training and awareness
- Disaster preparedness and recovery plans
- Personnel recruitment and separation strategies
- Personnel registration and accounting

1.3. VULNERABILITY ASSESSMENT

Given time, resources, and motivation, an attacker can break into nearly any system. All of the security procedures and technologies currently available cannot guarantee that any systems are completely safe from intrusion. Routers help secure gateways to the Internet. Firewalls help secure the edge of the network. Virtual Private Networks safely pass data in an encrypted stream. Intrusion detection systems warn you of malicious activity. However, the success of each of these technologies is dependent upon a number of variables, including:

- The expertise of the staff responsible for configuring, monitoring, and maintaining the technologies.
- The ability to patch and update services and kernels quickly and efficiently.
- The ability of those responsible to keep constant vigilance over the network.

Given the dynamic state of data systems and technologies, securing corporate resources can be quite complex. Due to this complexity, it is often difficult to find expert resources for all of your systems. While it is possible to have personnel knowledgeable in many areas of information security at a high level, it is difficult to retain staff who are experts in more than a few subject areas. This is mainly because each subject area of information security requires constant attention and focus. Information security does not stand still.

A vulnerability assessment is an internal audit of your network and system security; the results of which indicate the confidentiality, integrity, and availability of your network (as explained in Section 1.1.1, “Standardizing Security”). Typically, vulnerability assessment starts with a reconnaissance phase, during which important data regarding the target systems and resources is gathered. This phase leads to the system readiness phase, whereby the target is essentially checked for all known vulnerabilities. The readiness phase culminates in the reporting phase, where the findings are classified into categories of high, medium, and low risk; and methods for improving the security (or mitigating the risk of vulnerability) of the target are discussed

If you were to perform a vulnerability assessment of your home, you would likely check each door to your home to see if they are closed and locked. You would also check every window, making sure that they closed completely and latch correctly. This same concept applies to systems, networks, and electronic data. Malicious users are the thieves and vandals of your data. Focus on their tools, mentality, and motivations, and you can then react swiftly to their actions.

1.3.1. Defining Assessment and Testing

Vulnerability assessments may be broken down into one of two types: *outside looking in* and *inside looking around*.

When performing an outside-looking-in vulnerability assessment, you are attempting to compromise your systems from the outside. Being external to your company provides you with the cracker's viewpoint. You see what a cracker sees — publicly-routable IP addresses, systems on your *DMZ*, external interfaces of your firewall, and more. DMZ stands for "demilitarized zone", which corresponds to a computer or small subnetwork that sits between a trusted internal network, such as a corporate private LAN, and an untrusted external network, such as the public Internet. Typically, the DMZ contains devices accessible to Internet traffic, such as Web (HTTP) servers, FTP servers, SMTP (e-mail) servers and DNS servers.

When you perform an inside-looking-around vulnerability assessment, you are at an advantage since you are internal and your status is elevated to trusted. This is the viewpoint you and your co-workers have once logged on to your systems. You see print servers, file servers, databases, and other resources.

There are striking distinctions between the two types of vulnerability assessments. Being internal to your company gives you more privileges than an outsider. In most organizations, security is configured to keep intruders out. Very little is done to secure the internals of the organization (such as departmental firewalls, user-level access controls, and authentication procedures for internal resources). Typically, there are many more resources when looking around inside as most systems are internal to a company. Once you are outside the company, your status is untrusted. The systems and resources available to you externally are usually very limited.

Consider the difference between vulnerability assessments and *penetration tests*. Think of a vulnerability assessment as the first step to a penetration test. The information gleaned from the assessment is used for testing. Whereas the assessment is undertaken to check for holes and potential vulnerabilities, the penetration testing actually attempts to exploit the findings.

Assessing network infrastructure is a dynamic process. Security, both information and physical, is dynamic. Performing an assessment shows an overview, which can turn up false positives and false negatives. A false positive is a result, where the tool finds vulnerabilities which in reality do not exist. A false negative is when it omits actual vulnerabilities.

Security administrators are only as good as the tools they use and the knowledge they retain. Take any of the assessment tools currently available, run them against your system, and it is almost a guarantee that there are some false positives. Whether by program fault or user error, the result is the same. The tool may find false positives, or, even worse, false negatives.

Now that the difference between a vulnerability assessment and a penetration test is defined, take the findings of the assessment and review them carefully before conducting a penetration test as part of your new best practices approach.

WARNING

Do not attempt to exploit vulnerabilities on production systems. Doing so can have adverse effects on productivity and efficiency of your systems and network.

The following list examines some of the benefits to performing vulnerability assessments.

- Creates proactive focus on information security.
- Finds potential exploits before crackers find them.
- Results in systems being kept up to date and patched.
- Promotes growth and aids in developing staff expertise.
- Abates financial loss and negative publicity.

1.3.2. Establishing a Methodology for Vulnerability Assessment

To aid in the selection of tools for a vulnerability assessment, it is helpful to establish a vulnerability assessment methodology. Unfortunately, there is no predefined or industry approved methodology at this time; however, common sense and best practices can act as a sufficient guide.

What is the target? Are we looking at one server, or are we looking at our entire network and everything within the network? Are we external or internal to the company? The answers to these questions are important as they help determine not only which tools to select but also the manner in which they are used.

To learn more about establishing methodologies, see the following website:

- https://www.owasp.org/ — *The Open Web Application Security Project*

1.3.3. Vulnerability Assessment Tools

An assessment can start by using some form of an information-gathering tool. When assessing the entire network, map the layout first to find the hosts that are running. Once located, examine each host individually. Focusing on these hosts requires another set of tools. Knowing which tools to use may be the most crucial step in finding vulnerabilities.

Just as in any aspect of everyday life, there are many different tools that perform the same job. This concept applies to performing vulnerability assessments as well. There are tools specific to operating systems, applications, and even networks (based on the protocols used). Some tools are free; others are not. Some tools are intuitive and easy to use, while others are cryptic and poorly documented but have features that other tools do not.

Finding the right tools may be a daunting task and, in the end, experience counts. If possible, set up a test lab and try out as many tools as you can, noting the strengths and weaknesses of each. Review the **README** file or man page for the tools. Additionally, look to the Internet for more information, such as articles, step-by-step guides, or even mailing lists specific to the tools.

The tools discussed below are just a small sampling of the available tools.

1.3.3.1. Scanning Hosts with Nmap

Nmap is a popular tool that can be used to determine the layout of a network. **Nmap** has been available for many years and is probably the most often used tool when gathering information. An excellent manual page is included that provides detailed descriptions of its options and usage. Administrators can use **Nmap** on a network to find host systems and open ports on those systems.

Nmap is a competent first step in vulnerability assessment. You can map out all the hosts within your network and even pass an option that allows **Nmap** to attempt to identify the operating system running on a particular host. **Nmap** is a good foundation for establishing a policy of using secure services and restricting unused services.

To install **Nmap**, run the **yum install nmap** command as the **root** user.

1.3.3.1.1. Using Nmap

Nmap can be run from a shell prompt by typing the **nmap** command followed by the host name or **IP** address of the machine to scan:

```
nmap <hostname>
```

For example, to scan a machine with host name **foo.example.com**, type the following at a shell prompt:

```
~]$ nmap foo.example.com
```

The results of a basic scan (which could take up to a few minutes, depending on where the host is located and other network conditions) look similar to the following:

```
Interesting ports on foo.example.com:
Not shown: 1710 filtered ports
PORT    STATE  SERVICE
22/tcp  open   ssh
53/tcp  open   domain
80/tcp  open   http
113/tcp closed auth
```

Nmap tests the most common network communication ports for listening or waiting services. This knowledge can be helpful to an administrator who wants to close unnecessary or unused services.

For more information about using **Nmap**, see the official homepage at the following URL:

http://www.insecure.org/

1.3.3.2. Nessus

Nessus is a full-service security scanner. The plug-in architecture of **Nessus** allows users to customize it for their systems and networks. As with any scanner, **Nessus** is only as good as the signature database it relies upon. Fortunately, **Nessus** is frequently updated and features full reporting, host scanning, and real-time vulnerability searches. Remember that there could be false positives and false negatives, even in a tool as powerful and as frequently updated as **Nessus**.

NOTE

The **Nessus** client and server software requires a subscription to use. It has been included in this document as a reference to users who may be interested in using this popular application.

For more information about **Nessus**, see the official website at the following URL:

http://www.nessus.org/

1.3.3.3. OpenVAS

OpenVAS (*Open Vulnerability Assessment System*) is a set of tools and services that can be used to

scan for vulnerabilities and for a comprehensive vulnerability management. The **OpenVAS** framework offers a number of web-based, desktop, and command line tools for controlling the various components of the solution. The core functionality of **OpenVAS** is provided by a security scanner, which makes use of over 33 thousand daily-updated Network Vulnerability Tests (NVT). Unlike **Nessus** (see Section 1.3.3.2, “**Nessus**”), **OpenVAS** does not require any subscription.

For more information about OpenVAS, see the official website at the following URL:

http://www.openvas.org/

1.3.3.4. Nikto

Nikto is an excellent *common gateway interface* (CGI) script scanner. **Nikto** not only checks for CGI vulnerabilities but does so in an evasive manner, so as to elude intrusion-detection systems. It comes with thorough documentation which should be carefully reviewed prior to running the program. If you have web servers serving CGI scripts, **Nikto** can be an excellent resource for checking the security of these servers.

More information about **Nikto** can be found at the following URL:

http://cirt.net/nikto2

1.4. SECURITY THREATS

1.4.1. Threats to Network Security

Bad practices when configuring the following aspects of a network can increase the risk of an attack.

Insecure Architectures
A misconfigured network is a primary entry point for unauthorized users. Leaving a trust-based, open local network vulnerable to the highly-insecure Internet is much like leaving a door ajar in a crime-ridden neighborhood — nothing may happen for an arbitrary amount of time, but someone exploits the opportunity *eventually*.

Broadcast Networks
System administrators often fail to realize the importance of networking hardware in their security schemes. Simple hardware, such as hubs and routers, relies on the broadcast or non-switched principle; that is, whenever a node transmits data across the network to a recipient node, the hub or router sends a broadcast of the data packets until the recipient node receives and processes the data. This method is the most vulnerable to address resolution protocol (*ARP*) or media access control (*MAC*) address spoofing by both outside intruders and unauthorized users on local hosts.

Centralized Servers
Another potential networking pitfall is the use of centralized computing. A common cost-cutting measure for many businesses is to consolidate all services to a single powerful machine. This can be convenient as it is easier to manage and costs considerably less than multiple-server configurations. However, a centralized server introduces a single point of failure on the network. If the central server is compromised, it may render the network completely useless or worse, prone to data manipulation or theft. In these situations, a central server becomes an open door that allows access to the entire network.

1.4.2. Threats to Server Security

Server security is as important as network security because servers often hold a great deal of an organization's vital information. If a server is compromised, all of its contents may become available for the cracker to steal or manipulate at will. The following sections detail some of the main issues.

Unused Services and Open Ports

A full installation of Red Hat Enterprise Linux 7 contains more than 1000 application and library packages. However, most server administrators do not opt to install every single package in the distribution, preferring instead to install a base installation of packages, including several server applications. See Section 2.3, “Installing the Minimum Amount of Packages Required” for an explanation of the reasons to limit the number of installed packages and for additional resources.

A common occurrence among system administrators is to install the operating system without paying attention to what programs are actually being installed. This can be problematic because unneeded services may be installed, configured with the default settings, and possibly turned on. This can cause unwanted services, such as Telnet, DHCP, or DNS, to run on a server or workstation without the administrator realizing it, which in turn can cause unwanted traffic to the server or even a potential pathway into the system for crackers. See Section 4.3, “Securing Services” for information on closing ports and disabling unused services.

Unpatched Services

Most server applications that are included in a default installation are solid, thoroughly tested pieces of software. Having been in use in production environments for many years, their code has been thoroughly refined and many of the bugs have been found and fixed.

However, there is no such thing as perfect software and there is always room for further refinement. Moreover, newer software is often not as rigorously tested as one might expect, because of its recent arrival to production environments or because it may not be as popular as other server software.

Developers and system administrators often find exploitable bugs in server applications and publish the information on bug tracking and security-related websites such as the Bugtraq mailing list (http://www.securityfocus.com) or the Computer Emergency Response Team (CERT) website (http://www.cert.org). Although these mechanisms are an effective way of alerting the community to security vulnerabilities, it is up to system administrators to patch their systems promptly. This is particularly true because crackers have access to these same vulnerability tracking services and will use the information to crack unpatched systems whenever they can. Good system administration requires vigilance, constant bug tracking, and proper system maintenance to ensure a more secure computing environment.

See Chapter 3, *Keeping Your System Up-to-Date* for more information about keeping a system up-to-date.

Inattentive Administration

Administrators who fail to patch their systems are one of the greatest threats to server security. According to the *SysAdmin, Audit, Network, Security Institute* (*SANS*), the primary cause of computer security vulnerability is "assigning untrained people to maintain security and providing neither the training nor the time to make it possible to learn and do the job."[1] This applies as much to inexperienced administrators as it does to overconfident or amotivated administrators.

Some administrators fail to patch their servers and workstations, while others fail to watch log messages from the system kernel or network traffic. Another common error is when default passwords or keys to services are left unchanged. For example, some databases have default administration passwords because the database developers assume that the system administrator changes these passwords immediately after installation. If a database administrator fails to change this password, even an inexperienced cracker can use a widely-known default password to gain administrative privileges to the database. These are only a few examples of how inattentive administration can lead to compromised servers.

Inherently Insecure Services

Even the most vigilant organization can fall victim to vulnerabilities if the network services they choose are inherently insecure. For instance, there are many services developed under the assumption that they are used over trusted networks; however, this assumption fails as soon as the service becomes available over the Internet — which is itself inherently untrusted.

One category of insecure network services are those that require unencrypted usernames and passwords for authentication. Telnet and FTP are two such services. If packet sniffing software is monitoring traffic between the remote user and such a service usernames and passwords can be easily intercepted.

Inherently, such services can also more easily fall prey to what the security industry terms the *man-in-the-middle* attack. In this type of attack, a cracker redirects network traffic by tricking a cracked name server on the network to point to his machine instead of the intended server. Once someone opens a remote session to the server, the attacker's machine acts as an invisible conduit, sitting quietly between the remote service and the unsuspecting user capturing information. In this way a cracker can gather administrative passwords and raw data without the server or the user realizing it.

Another category of insecure services include network file systems and information services such as NFS or NIS, which are developed explicitly for LAN usage but are, unfortunately, extended to include WANs (for remote users). NFS does not, by default, have any authentication or security mechanisms configured to prevent a cracker from mounting the NFS share and accessing anything contained therein. NIS, as well, has vital information that must be known by every computer on a network, including passwords and file permissions, within a plain text ASCII or DBM (ASCII-derived) database. A cracker who gains access to this database can then access every user account on a network, including the administrator's account.

By default, Red Hat Enterprise Linux 7 is released with all such services turned off. However, since administrators often find themselves forced to use these services, careful configuration is critical. See Section 4.3, “Securing Services” for more information about setting up services in a safe manner.

1.4.3. Threats to Workstation and Home PC Security

Workstations and home PCs may not be as prone to attack as networks or servers, but since they often contain sensitive data, such as credit card information, they are targeted by system crackers. Workstations can also be co-opted without the user's knowledge and used by attackers as "slave" machines in coordinated attacks. For these reasons, knowing the vulnerabilities of a workstation can save users the headache of reinstalling the operating system, or worse, recovering from data theft.

Bad Passwords

Bad passwords are one of the easiest ways for an attacker to gain access to a system. For more on how to avoid common pitfalls when creating a password, see Section 4.1.1, “Password Security”.

Vulnerable Client Applications

Although an administrator may have a fully secure and patched server, that does not mean remote users are secure when accessing it. For instance, if the server offers Telnet or FTP services over a public network, an attacker can capture the plain text usernames and passwords as they pass over the network, and then use the account information to access the remote user's workstation.

Even when using secure protocols, such as SSH, a remote user may be vulnerable to certain attacks if they do not keep their client applications updated. For instance, v.1 SSH clients are vulnerable to an X-forwarding attack from malicious SSH servers. Once connected to the server, the attacker can quietly capture any keystrokes and mouse clicks made by the client over the network. This problem was fixed in the v.2 SSH protocol, but it is up to the user to keep track of what applications have such vulnerabilities and update them as necessary.

Section 4.1, “Desktop Security” discusses in more detail what steps administrators and home users should take to limit the vulnerability of computer workstations.

1.5. COMMON EXPLOITS AND ATTACKS

Table 1.1, “Common Exploits” details some of the most common exploits and entry points used by intruders to access organizational network resources. Key to these common exploits are the explanations of how they are performed and how administrators can properly safeguard their network against such attacks.

Table 1.1. Common Exploits

Exploit	Description	Notes
Null or Default Passwords	Leaving administrative passwords blank or using a default password set by the product vendor. This is most common in hardware such as routers and firewalls, but some services that run on Linux can contain default administrator passwords as well (though Red Hat Enterprise Linux 7 does not ship with them).	Commonly associated with networking hardware such as routers, firewalls, VPNs, and network attached storage (NAS) appliances. Common in many legacy operating systems, especially those that bundle services (such as UNIX and Windows.) Administrators sometimes create privileged user accounts in a rush and leave the password null, creating a perfect entry point for malicious users who discover the account.
Default Shared Keys	Secure services sometimes package default security keys for development or evaluation testing purposes. If these keys are left unchanged and are placed in a production environment on the Internet, *all* users with the same default keys have access to that shared-key resource, and any sensitive information that it contains.	Most common in wireless access points and preconfigured secure server appliances.
IP Spoofing	A remote machine acts as a node on your local network, finds vulnerabilities with your servers, and installs a backdoor program or Trojan horse to gain control over your network resources.	Spoofing is quite difficult as it involves the attacker predicting TCP/IP sequence numbers to coordinate a connection to target systems, but several tools are available to assist crackers in performing such a vulnerability. Depends on target system running services (such as **rsh**, **telnet**, FTP and others) that use *source-based* authentication techniques, which are not recommended when compared to PKI or other forms of encrypted authentication used in **ssh** or SSL/TLS.

Exploit	Description	Notes
Eavesdropping	Collecting data that passes between two active nodes on a network by eavesdropping on the connection between the two nodes.	This type of attack works mostly with plain text transmission protocols such as Telnet, FTP, and HTTP transfers. Remote attacker must have access to a compromised system on a LAN in order to perform such an attack; usually the cracker has used an active attack (such as IP spoofing or man-in-the-middle) to compromise a system on the LAN. Preventative measures include services with cryptographic key exchange, one-time passwords, or encrypted authentication to prevent password snooping; strong encryption during transmission is also advised.
Service Vulnerabilities	An attacker finds a flaw or loophole in a service run over the Internet; through this vulnerability, the attacker compromises the entire system and any data that it may hold, and could possibly compromise other systems on the network.	HTTP-based services such as CGI are vulnerable to remote command execution and even interactive shell access. Even if the HTTP service runs as a non-privileged user such as "nobody", information such as configuration files and network maps can be read, or the attacker can start a denial of service attack which drains system resources or renders it unavailable to other users. Services sometimes can have vulnerabilities that go unnoticed during development and testing; these vulnerabilities (such as *buffer overflows*, where attackers crash a service using arbitrary values that fill the memory buffer of an application, giving the attacker an interactive command prompt from which they may execute arbitrary commands) can give complete administrative control to an attacker. Administrators should make sure that services do not run as the root user, and should stay vigilant of patches and errata updates for applications from vendors or security organizations such as CERT and CVE.

Exploit	Description	Notes
Application Vulnerabilities	Attackers find faults in desktop and workstation applications (such as email clients) and execute arbitrary code, implant Trojan horses for future compromise, or crash systems. Further exploitation can occur if the compromised workstation has administrative privileges on the rest of the network.	Workstations and desktops are more prone to exploitation as workers do not have the expertise or experience to prevent or detect a compromise; it is imperative to inform individuals of the risks they are taking when they install unauthorized software or open unsolicited email attachments. Safeguards can be implemented such that email client software does not automatically open or execute attachments. Additionally, the automatic update of workstation software using Red Hat Network; or other system management services can alleviate the burdens of multi-seat security deployments.
Denial of Service (DoS) Attacks	Attacker or group of attackers coordinate against an organization's network or server resources by sending unauthorized packets to the target host (either server, router, or workstation). This forces the resource to become unavailable to legitimate users.	The most reported DoS case in the US occurred in 2000. Several highly-trafficked commercial and government sites were rendered unavailable by a coordinated ping flood attack using several compromised systems with high bandwidth connections acting as *zombies*, or redirected broadcast nodes. Source packets are usually forged (as well as rebroadcast), making investigation as to the true source of the attack difficult. Advances in ingress filtering (IETF rfc2267) using **`iptables`** and Network Intrusion Detection Systems such as **`snort`** assist administrators in tracking down and preventing distributed DoS attacks.

[1] http://www.sans.org/security-resources/mistakes.php

CHAPTER 2. SECURITY TIPS FOR INSTALLATION

Security begins with the first time you put that CD or DVD into your disk drive to install Red Hat Enterprise Linux 7. Configuring your system securely from the beginning makes it easier to implement additional security settings later.

2.1. SECURING BIOS

Password protection for the BIOS (or BIOS equivalent) and the boot loader can prevent unauthorized users who have physical access to systems from booting using removable media or obtaining root privileges through single user mode. The security measures you should take to protect against such attacks depends both on the sensitivity of the information on the workstation and the location of the machine.

For example, if a machine is used in a trade show and contains no sensitive information, then it may not be critical to prevent such attacks. However, if an employee's laptop with private, unencrypted SSH keys for the corporate network is left unattended at that same trade show, it could lead to a major security breach with ramifications for the entire company.

If the workstation is located in a place where only authorized or trusted people have access, however, then securing the BIOS or the boot loader may not be necessary.

2.1.1. BIOS Passwords

The two primary reasons for password protecting the BIOS of a computer are[2]:

1. *Preventing Changes to BIOS Settings* — If an intruder has access to the BIOS, they can set it to boot from a CD-ROM or a flash drive. This makes it possible for them to enter rescue mode or single user mode, which in turn allows them to start arbitrary processes on the system or copy sensitive data.

2. *Preventing System Booting* — Some BIOSes allow password protection of the boot process. When activated, an attacker is forced to enter a password before the BIOS launches the boot loader.

Because the methods for setting a BIOS password vary between computer manufacturers, consult the computer's manual for specific instructions.

If you forget the BIOS password, it can either be reset with jumpers on the motherboard or by disconnecting the CMOS battery. For this reason, it is good practice to lock the computer case if possible. However, consult the manual for the computer or motherboard before attempting to disconnect the CMOS battery.

2.1.1.1. Securing Non-BIOS-based Systems

Other systems and architectures use different programs to perform low-level tasks roughly equivalent to those of the BIOS on x86 systems. For example, the *Unified Extensible Firmware Interface* (*UEFI*) shell.

For instructions on password protecting BIOS-like programs, see the manufacturer's instructions.

2.2. PARTITIONING THE DISK

Red Hat recommends creating separate partitions for the **/boot**, **/**, **/home/tmp**, and **/var/tmp/** directories. The reasons for each are different, and we will address each partition.

/boot

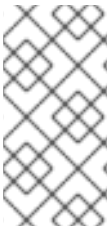
This partition is the first partition that is read by the system during boot up. The boot loader and kernel images that are used to boot your system into Red Hat Enterprise Linux 7 are stored in this partition. This partition should not be encrypted. If this partition is included in / and that partition is encrypted or otherwise becomes unavailable then your system will not be able to boot.

/home

When user data (**/home**) is stored in / instead of in a separate partition, the partition can fill up causing the operating system to become unstable. Also, when upgrading your system to the next version of Red Hat Enterprise Linux 7 it is a lot easier when you can keep your data in the **/home** partition as it will not be overwritten during installation. If the root partition (/) becomes corrupt your data could be lost forever. By using a separate partition there is slightly more protection against data loss. You can also target this partition for frequent backups.

/tmp and /var/tmp/

Both the **/tmp** and **/var/tmp/** directories are used to store data that does not need to be stored for a long period of time. However, if a lot of data floods one of these directories it can consume all of your storage space. If this happens and these directories are stored within / then your system could become unstable and crash. For this reason, moving these directories into their own partitions is a good idea.



NOTE

During the installation process, an option to encrypt partitions is presented to you. The user must supply a passphrase. This passphrase will be used as a key to unlock the bulk encryption key, which is used to secure the partition's data. For more information on LUKS, see Section 4.9.1, “Using LUKS Disk Encryption”.

2.3. INSTALLING THE MINIMUM AMOUNT OF PACKAGES REQUIRED

It is best practice to install only the packages you will use because each piece of software on your computer could possibly contain a vulnerability. If you are installing from the DVD media, take the opportunity to select exactly what packages you want to install during the installation. If you find you need another package, you can always add it to the system later.

For more information about installing the **Minimal install** environment, see the Software Selection chapter of the Red Hat Enterprise Linux 7 Installation Guide. A minimal installation can also be performed by a Kickstart file using the **--nobase** option. For more information about Kickstart installations, see the Package Selection section from the Red Hat Enterprise Linux 7 Installation Guide.

2.4. RESTRICTING NETWORK CONNECTIVITY DURING THE INSTALLATION PROCESS

When installing Red Hat Enterprise Linux, the installation medium represents a snapshot of the system at a particular time. Because of this, it may not be up-to-date with the latest security fixes and may be vulnerable to certain issues that were fixed only after the system provided by the installation medium was released.

When installing a potentially vulnerable operating system, always limit exposure only to the closest necessary network zone. The safest choice is the “no network” zone, which means to leave your machine disconnected during the installation process. In some cases, a LAN or intranet connection is

sufficient while the Internet connection is the riskiest. To follow the best security practices, choose the closest zone with your repository while installing Red Hat Enterprise Linux from a network.

For more information about configuring network connectivity, see the Network & Hostname chapter of the Red Hat Enterprise Linux 7 Installation Guide.

2.5. POST-INSTALLATION PROCEDURES

The following steps are the security-related procedures that should be performed immediately after installation of Red Hat Enterprise Linux.

1. Update your system. enter the following command as root:

```
~]# yum update
```

2. Even though the firewall service, **firewalld**, is automatically enabled with the installation of Red Hat Enterprise Linux, there are scenarios where it might be explicitly disabled, for example in the kickstart configuration. In such a case, it is recommended to consider re-enabling the firewall.

   To start **firewalld** enter the following commands as root:

```
~]# systemctl start firewalld
~]# systemctl enable firewalld
```

3. To enhance security, disable services you do not need. For example, if there are no printers installed on your computer, disable the **cups** service using the following command:

```
~]# systemctl disable cups
```

   To review active services, enter the following command:

```
~]$ systemctl list-units | grep service
```

2.6. ADDITIONAL RESOURCES

For more information about installation in general, see the Red Hat Enterprise Linux 7 Installation Guide.

---

[2] Since system BIOSes differ between manufacturers, some may not support password protection of either type, while others may support one type but not the other.

CHAPTER 3. KEEPING YOUR SYSTEM UP-TO-DATE

This chapter describes the process of keeping your system up-to-date, which involves planning and configuring the way security updates are installed, applying changes introduced by newly updated packages, and using the Red Hat Customer Portal for keeping track of security advisories.

3.1. MAINTAINING INSTALLED SOFTWARE

As security vulnerabilities are discovered, the affected software must be updated in order to limit any potential security risks. If the software is a part of a package within a Red Hat Enterprise Linux distribution that is currently supported, Red Hat is committed to releasing updated packages that fix the vulnerabilities as soon as possible.

Often, announcements about a given security exploit are accompanied with a patch (or source code) that fixes the problem. This patch is then applied to the Red Hat Enterprise Linux package and tested and released as an erratum update. However, if an announcement does not include a patch, Red Hat developers first work with the maintainer of the software to fix the problem. Once the problem is fixed, the package is tested and released as an erratum update.

If an erratum update is released for software used on your system, it is highly recommended that you update the affected packages as soon as possible to minimize the amount of time the system is potentially vulnerable.

3.1.1. Planning and Configuring Security Updates

All software contains bugs. Often, these bugs can result in a vulnerability that can expose your system to malicious users. Packages that have not been updated are a common cause of computer intrusions. Implement a plan for installing security patches in a timely manner to quickly eliminate discovered vulnerabilities, so they cannot be exploited.

Test security updates when they become available and schedule them for installation. Additional controls need to be used to protect the system during the time between the release of the update and its installation on the system. These controls depend on the exact vulnerability, but may include additional firewall rules, the use of external firewalls, or changes in software settings.

Bugs in supported packages are fixed using the errata mechanism. An erratum consists of one or more RPM packages accompanied by a brief explanation of the problem that the particular erratum deals with. All errata are distributed to customers with active subscriptions through the **Red Hat Subscription Management** service. Errata that address security issues are called *Red Hat Security Advisories*.

For more information on working with security errata, see Section 3.2.1, “Viewing Security Advisories on the Customer Portal”. For detailed information about the **Red Hat Subscription Management** service, including instructions on how to migrate from **RHN Classic**, see the documentation related to this service: Red Hat Subscription Management.

3.1.1.1. Using the Security Features of Yum

The **Yum** package manager includes several security-related features that can be used to search, list, display, and install security errata. These features also make it possible to use **Yum** to install nothing but security updates.

To check for security-related updates available for your system, enter the following command as **root**:

```
~]# yum check-update --security
Loaded plugins: langpacks, product-id, subscription-manager
```

```
rhel-7-workstation-rpms/x86_64                  | 3.4 kB  00:00:00
No packages needed for security; 0 packages available
```

Note that the above command runs in a non-interactive mode, so it can be used in scripts for automated checking whether there are any updates available. The command returns an exit value of 100 when there are any security updates available and 0 when there are not. On encountering an error, it returns 1.

Analogously, use the following command to only install security-related updates:

```
~]# yum update --security
```

Use the **updateinfo** subcommand to display or act upon information provided by repositories about available updates. The **updateinfo** subcommand itself accepts a number of commands, some of which pertain to security-related uses. See Table 3.1, “Security-related commands usable with yum updateinfo” for an overview of these commands.

Table 3.1. Security-related commands usable with yum updateinfo

Command	Description
advisory [advisories]	Displays information about one or more advisories. Replace *advisories* with an advisory number or numbers.
cves	Displays the subset of information that pertains to CVE (*Common Vulnerabilities and Exposures*).
security or **sec**	Displays all security-related information.
severity [severity_level] or **sev [severity_level]**	Displays information about security-relevant packages of the supplied *severity_level*.

3.1.2. Updating and Installing Packages

When updating software on a system, it is important to download the update from a trusted source. An attacker can easily rebuild a package with the same version number as the one that is supposed to fix the problem but with a different security exploit and release it on the Internet. If this happens, using security measures, such as verifying files against the original RPM, does not detect the exploit. Thus, it is very important to only download RPMs from trusted sources, such as from Red Hat, and to check the package signatures to verify their integrity.

See the Yum chapter of the Red Hat Enterprise Linux 7 System Administrator's Guide for detailed information on how to use the **Yum** package manager.

3.1.2.1. Verifying Signed Packages

All Red Hat Enterprise Linux packages are signed with the Red Hat **GPG** key. **GPG** stands for **GNU Privacy Guard**, or **GnuPG**, a free software package used for ensuring the authenticity of distributed files. If the verification of a package signature fails, the package may be altered and therefore cannot be trusted.

The **Yum** package manager allows for an automatic verification of all packages it installs or upgrades. This feature is enabled by default. To configure this option on your system, make sure the **gpgcheck** configuration directive is set to **1** in the **/etc/yum.conf** configuration file.

Use the following command to manually verify package files on your filesystem:

```
rpmkeys --checksig package_file.rpm
```

See the Product Signing (GPG) Keys article on the Red Hat Customer Portal for additional information about Red Hat package-signing practices.

3.1.2.2. Installing Signed Packages

To install verified packages (see Section 3.1.2.1, “Verifying Signed Packages” for information on how to verify packages) from your filesystem, use the **yum install** command as the **root** user as follows:

```
yum install package_file.rpm
```

Use a shell glob to install several packages at once. For example, the following commands installs all **.rpm** packages in the current directory:

```
yum install *.rpm
```

IMPORTANT

Before installing any security errata, be sure to read any special instructions contained in the erratum report and execute them accordingly. See Section 3.1.3, “Applying Changes Introduced by Installed Updates” for general instructions about applying changes made by errata updates.

3.1.3. Applying Changes Introduced by Installed Updates

After downloading and installing security errata and updates, it is important to halt the usage of the old software and begin using the new software. How this is done depends on the type of software that has been updated. The following list itemizes the general categories of software and provides instructions for using updated versions after a package upgrade.

NOTE

In general, rebooting the system is the surest way to ensure that the latest version of a software package is used; however, this option is not always required, nor is it always available to the system administrator.

Applications

User-space applications are any programs that can be initiated by the user. Typically, such applications are used only when the user, a script, or an automated task utility launch them.

Once such a user-space application is updated, halt any instances of the application on the system, and launch the program again to use the updated version.

Kernel

The kernel is the core software component for the Red Hat Enterprise Linux 7 operating system. It manages access to memory, the processor, and peripherals, and it schedules all tasks.

Because of its central role, the kernel cannot be restarted without also rebooting the computer. Therefore, an updated version of the kernel cannot be used until the system is rebooted.

KVM

When the qemu-kvm and libvirt packages are updated, it is necessary to stop all guest virtual machines, reload relevant virtualization modules (or reboot the host system), and restart the virtual machines.

Use the **lsmod** command to determine which modules from the following are loaded: **kvm**, **kvm-intel**, or **kvm-amd**. Then use the **modprobe -r** command to remove and subsequently the **modprobe -a** command to reload the affected modules. Fox example:

```
~]# lsmod | grep kvm
kvm_intel             143031  0
kvm                   460181  1 kvm_intel
~]# modprobe -r kvm-intel
~]# modprobe -r kvm
~]# modprobe -a kvm kvm-intel
```

Shared Libraries

Shared libraries are units of code, such as **glibc**, that are used by a number of applications and services. Applications utilizing a shared library typically load the shared code when the application is initialized, so any applications using an updated library must be halted and relaunched.

To determine which running applications link against a particular library, use the **lsof** command:

```
lsof library
```

For example, to determine which running applications link against the **libwrap.so.0** library, type:

```
~]# lsof /lib64/libwrap.so.0
COMMAND     PID USER  FD   TYPE DEVICE SIZE/OFF     NODE NAME
pulseaudi 12363 test mem    REG  253,0    42520 34121785
/usr/lib64/libwrap.so.0.7.6
gnome-set 12365 test mem    REG  253,0    42520 34121785
/usr/lib64/libwrap.so.0.7.6
gnome-she 12454 test mem    REG  253,0    42520 34121785
/usr/lib64/libwrap.so.0.7.6
```

This command returns a list of all the running programs that use **TCP** wrappers for host-access control. Therefore, any program listed must be halted and relaunched when the tcp_wrappers package is updated.

systemd Services

systemd services are persistent server programs usually launched during the boot process. Examples of systemd services include **sshd** or **vsftpd**.

Because these programs usually persist in memory as long as a machine is running, each updated systemd service must be halted and relaunched after its package is upgraded. This can be done as the **root** user using the **systemctl** command:

```
systemctl restart service_name
```

Replace *service_name* with the name of the service you want to restart, such as **sshd**.

Other Software

Follow the instructions outlined by the resources linked below to correctly update the following applications.

- **Red Hat Directory Server** — See the *Release Notes* for the version of the Red Hat Directory Server in question at https://access.redhat.com/site/documentation/en-US/Red_Hat_Directory_Server/.
- **Red Hat Enterprise Virtualization Manager** — See the *Installation Guide* for the version of the Red Hat Enterprise Virtualization in question at https://access.redhat.com/site/documentation/en-US/Red_Hat_Enterprise_Virtualization/.

3.2. USING THE RED HAT CUSTOMER PORTAL

The Red Hat Customer Portal at https://access.redhat.com/ is the main customer-oriented resource for official information related to Red Hat products. You can use it to find documentation, manage your subscriptions, download products and updates, open support cases, and learn about security updates.

3.2.1. Viewing Security Advisories on the Customer Portal

To view security advisories (errata) relevant to the systems for which you have active subscriptions, log into the Customer Portal at https://access.redhat.com/ and click on the **`Download Products & Updates`** button on the main page. When you enter the **`Software & Download Center`** page, continue by clicking on the **`Errata`** button to see a list of advisories pertinent to your registered systems.

To browse a list of all security updates for all active Red Hat products, go to **Security** → **Security Updates** → **Active Products** using the navigation menu at the top of the page.

Click on the erratum code in the left part of the table to display more detailed information about the individual advisories. The next page contains not only a description of the given erratum, including its causes, consequences, and required fixes, but also a list of all packages that the particular erratum updates along with instructions on how to apply the updates. The page also includes links to relevant references, such as related CVE.

3.2.2. Navigating CVE Customer Portal Pages

The CVE (*Common Vulnerabilities and Exposures*) project, maintained by The MITRE Corporation, is a list of standardized names for vulnerabilities and security exposures. To browse a list of CVE that pertain to Red Hat products on the Customer Portal, log into your account at https://access.redhat.com/ and navigate to **Security** → **Resources** → **CVE Database** using the navigation menu at the top of the page.

Click on the CVE code in the left part of the table to display more detailed information about the individual vulnerabilities. The next page contains not only a description of the given CVE but also a list of affected Red Hat products along with links to relevant Red Hat errata.

3.2.3. Understanding Issue Severity Classification

All security issues discovered in Red Hat products are assigned an impact rating by *Red Hat Product Security* according to the severity of the problem. The four-point scale consists of the following levels: Low, Moderate, Important, and Critical. In addition to that, every security issue is rated using the *Common Vulnerability Scoring System* (CVSS) base scores.

Together, these ratings help you understand the impact of security issues, allowing you to schedule and prioritize upgrade strategies for your systems. Note that the ratings reflect the potential risk of a given vulnerability, which is based on a technical analysis of the bug, not the current threat level. This means that the security impact rating does not change if an exploit is released for a particular flaw.

To see a detailed description of the individual levels of severity ratings on the Customer Portal, visit the Severity Ratings page.

3.3. ADDITIONAL RESOURCES

For more information about security updates, ways of applying them, the Red Hat Customer Portal, and related topics, see the resources listed below.

Installed Documentation

- yum(8) — The manual page for the **Yum** package manager provides information about the way **Yum** can be used to install, update, and remove packages on your systems.
- rpmkeys(8) — The manual page for the **rpmkeys** utility describes the way this program can be used to verify the authenticity of downloaded packages.

Online Documentation

- Red Hat Enterprise Linux 7 System Administrator's Guide — The *System Administrator's Guide* for Red Hat Enterprise Linux 7 documents the use of the **Yum** and **rpm** commands that are used to install, update, and remove packages on Red Hat Enterprise Linux 7 systems.
- Red Hat Enterprise Linux 7 SELinux User's and Administrator's Guide — The *SELinux User's and Administrator's Guide* for Red Hat Enterprise Linux 7 documents the configuration of the **SELinux** *mandatory access control* mechanism.

Red Hat Customer Portal

- Red Hat Customer Portal, Security — The Security section of the Customer Portal contains links to the most important resources, including the Red Hat CVE database, and contacts for Red Hat Product Security.
- Red Hat Security Blog — Articles about latest security-related issues from Red Hat security professionals.

See Also

- Chapter 2, *Security Tips for Installation* describes how to configure your system securely from the beginning to make it easier to implement additional security settings later.
- Section 4.9.2, “Creating GPG Keys” describes how to create a set of personal **GPG** keys to authenticate your communications.

CHAPTER 4. HARDENING YOUR SYSTEM WITH TOOLS AND SERVICES

4.1. DESKTOP SECURITY

Red Hat Enterprise Linux 7 offers several ways for hardening the desktop against attacks and preventing unauthorized accesses. This section describes recommended practices for user passwords, session and account locking, and safe handling of removable media.

4.1.1. Password Security

Passwords are the primary method that Red Hat Enterprise Linux 7 uses to verify a user's identity. This is why password security is so important for protection of the user, the workstation, and the network.

For security purposes, the installation program configures the system to use *Secure Hash Algorithm 512* (*SHA512*) and shadow passwords. It is highly recommended that you do not alter these settings.

If shadow passwords are deselected during installation, all passwords are stored as a one-way hash in the world-readable **`/etc/passwd`** file, which makes the system vulnerable to offline password cracking attacks. If an intruder can gain access to the machine as a regular user, he can copy the **`/etc/passwd`** file to his own machine and run any number of password cracking programs against it. If there is an insecure password in the file, it is only a matter of time before the password cracker discovers it.

Shadow passwords eliminate this type of attack by storing the password hashes in the file **`/etc/shadow`**, which is readable only by the root user.

This forces a potential attacker to attempt password cracking remotely by logging into a network service on the machine, such as SSH or FTP. This sort of brute-force attack is much slower and leaves an obvious trail as hundreds of failed login attempts are written to system files. Of course, if the cracker starts an attack in the middle of the night on a system with weak passwords, the cracker may have gained access before dawn and edited the log files to cover his tracks.

In addition to format and storage considerations is the issue of content. The single most important thing a user can do to protect his account against a password cracking attack is create a strong password.

NOTE

Red Hat recommends using a central authentication solution, such as Red Hat Identity Management (IdM). Using a central solution is preferred over using local passwords. For details, see:

- Introduction to Red Hat Identity Management
- Defining Password Policies

4.1.1.1. Creating Strong Passwords

When creating a secure password, the user must remember that long passwords are stronger than short and complex ones. It is not a good idea to create a password of just eight characters, even if it contains digits, special characters and uppercase letters. Password cracking tools, such as John The Ripper, are optimized for breaking such passwords, which are also hard to remember by a person.

In information theory, entropy is the level of uncertainty associated with a random variable and is presented in bits. The higher the entropy value, the more secure the password is. According to NIST SP

800-63-1, passwords that are not present in a dictionary comprised of 50000 commonly selected passwords should have at least 10 bits of entropy. As such, a password that consists of four random words contains around 40 bits of entropy. A long password consisting of multiple words for added security is also called a *passphrase*, for example:

```
randomword1 randomword2 randomword3 randomword4
```

If the system enforces the use of uppercase letters, digits, or special characters, the passphrase that follows the above recommendation can be modified in a simple way, for example by changing the first character to uppercase and appending "**1!**". Note that such a modification *does not* increase the security of the passphrase significantly.

Another way to create a password yourself is using a password generator. The **pwmake** is a command-line tool for generating random passwords that consist of all four groups of characters – uppercase, lowercase, digits and special characters. The utility allows you to specify the number of entropy bits that are used to generate the password. The entropy is pulled from **/dev/urandom**. The minimum number of bits you can specify is 56, which is enough for passwords on systems and services where brute force attacks are rare. 64 bits is adequate for applications where the attacker does not have direct access to the password hash file. For situations when the attacker might obtain the direct access to the password hash or the password is used as an encryption key, 80 to 128 bits should be used. If you specify an invalid number of entropy bits, **pwmake** will use the default of bits. To create a password of 128 bits, enter the following command:

```
pwmake 128
```

While there are different approaches to creating a secure password, always avoid the following bad practices:

- Using a single dictionary word, a word in a foreign language, an inverted word, or only numbers.
- Using less than 10 characters for a password or passphrase.
- Using a sequence of keys from the keyboard layout.
- Writing down your passwords.
- Using personal information in a password, such as birth dates, anniversaries, family member names, or pet names.
- Using the same passphrase or password on multiple machines.

While creating secure passwords is imperative, managing them properly is also important, especially for system administrators within larger organizations. The following section details good practices for creating and managing user passwords within an organization.

4.1.1.2. Forcing Strong Passwords

If an organization has a large number of users, the system administrators have two basic options available to force the use of strong passwords. They can create passwords for the user, or they can let users create their own passwords while verifying the passwords are of adequate strength.

Creating the passwords for the users ensures that the passwords are good, but it becomes a daunting task as the organization grows. It also increases the risk of users writing their passwords down, thus exposing them.

For these reasons, most system administrators prefer to have the users create their own passwords, but actively verify that these passwords are strong enough. In some cases, administrators may force users to change their passwords periodically through password aging.

When users are asked to create or change passwords, they can use the **passwd** command-line utility, which is *PAM*-aware (*Pluggable Authentication Modules*) and checks to see if the password is too short or otherwise easy to crack. This checking is performed by the **pam_pwquality.so** PAM module.

NOTE

In Red Hat Enterprise Linux 7, the **pam_pwquality** PAM module replaced **pam_cracklib**, which was used in Red Hat Enterprise Linux 6 as a default module for password quality checking. It uses the same back end as **pam_cracklib**.

The **pam_pwquality** module is used to check a password's strength against a set of rules. Its procedure consists of two steps: first it checks if the provided password is found in a dictionary. If not, it continues with a number of additional checks. **pam_pwquality** is stacked alongside other PAM modules in the **password** component of the **/etc/pam.d/passwd** file, and the custom set of rules is specified in the **/etc/security/pwquality.conf** configuration file. For a complete list of these checks, see the **pwquality.conf (8)** manual page.

Example 4.1. Configuring password strength-checking in pwquality.conf

To enable using **pam_quality**, add the following line to the **password** stack in the **/etc/pam.d/passwd** file:

```
password    required    pam_pwquality.so retry=3
```

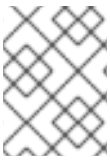
Options for the checks are specified one per line. For example, to require a password with a minimum length of 8 characters, including all four classes of characters, add the following lines to the **/etc/security/pwquality.conf** file:

```
minlen = 8
minclass = 4
```

To set a password strength-check for character sequences and same consecutive characters, add the following lines to **/etc/security/pwquality.conf**:

```
maxsequence = 3
maxrepeat = 3
```

In this example, the password entered cannot contain more than 3 characters in a monotonic sequence, such as **abcd**, and more than 3 identical consecutive characters, such as **1111**.



NOTE

As the root user is the one who enforces the rules for password creation, they can set any password for themselves or for a regular user, despite the warning messages.

4.1.1.3. Configuring Password Aging

Password aging is another technique used by system administrators to defend against bad passwords within an organization. Password aging means that after a specified period (usually 90 days), the user is prompted to create a new password. The theory behind this is that if a user is forced to change his password periodically, a cracked password is only useful to an intruder for a limited amount of time. The downside to password aging, however, is that users are more likely to write their passwords down.

To specify password aging under Red Hat Enterprise Linux 7, make use of the **chage** command.

IMPORTANT

In Red Hat Enterprise Linux 7, shadow passwords are enabled by default. For more information, see the Red Hat Enterprise Linux 7 System Administrator's Guide.

The `-M` option of the **chage** command specifies the maximum number of days the password is valid. For example, to set a user's password to expire in 90 days, use the following command:

```
chage -M 90 username
```

In the above command, replace *username* with the name of the user. To disable password expiration, use the value of `-1` after the `-M` option.

For more information on the options available with the **chage** command, see the table below.

Table 4.1. chage command line options

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

You can also use the **chage** command in interactive mode to modify multiple password aging and account details. Use the following command to enter interactive mode:

```
chage <username>
```

The following is a sample interactive session using this command:

```
~]# chage juan
Changing the aging information for juan
Enter the new value, or press ENTER for the default
Minimum Password Age [0]: 10
Maximum Password Age [99999]: 90
Last Password Change (YYYY-MM-DD) [2006-08-18]:
Password Expiration Warning [7]:
Password Inactive [-1]:
Account Expiration Date (YYYY-MM-DD) [1969-12-31]:
```

You can configure a password to expire the first time a user logs in. This forces users to change passwords immediately.

1. Set up an initial password. To assign a default password, enter the following command at a shell prompt as **root**:

   ```
   passwd username
   ```

   WARNING

   The **passwd** utility has the option to set a null password. Using a null password, while convenient, is a highly insecure practice, as any third party can log in and access the system using the insecure user name. Avoid using null passwords wherever possible. If it is not possible, always make sure that the user is ready to log in before unlocking an account with a null password.

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

   ```
   chage -d 0 username
   ```

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

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

4.1.2. Account Locking

In Red Hat Enterprise Linux 7, the **pam_faillock** PAM module allows system administrators to lock out user accounts after a specified number of failed attempts. Limiting user login attempts serves mainly

as a security measure that aims to prevent possible brute force attacks targeted to obtain a user's account password.

With the **pam_faillock** module, failed login attempts are stored in a separate file for each user in the **/var/run/faillock** directory.

NOTE

The order of lines in the failed attempt log files is important. Any change in this order can lock all user accounts, including the **root** user account when the **even_deny_root** option is used.

Follow these steps to configure account locking:

1. To lock out any non-root user after three unsuccessful attempts and unlock that user after 10 minutes, add two lines to the **auth** section of the **/etc/pam.d/system-auth** and **/etc/pam.d/password-auth** files. After your edits, the entire **auth** section in both files should look like this:

```
1 auth        required      pam_env.so
2 auth        required      pam_faillock.so preauth silent audit
deny=3 unlock_time=600
3 auth        sufficient    pam_unix.so nullok try_first_pass
4 auth        [default=die] pam_faillock.so authfail audit deny=3
unlock_time=600
5 auth        requisite     pam_succeed_if.so uid >= 1000
quiet_success
6 auth        required      pam_deny.so
```

   Lines number 2 and 4 have been added.

2. Add the following line to the **account** section of both files specified in the previous step:

```
account     required      pam_faillock.so
```

3. To apply account locking for the root user as well, add the **even_deny_root** option to the **pam_faillock** entries in the **/etc/pam.d/system-auth** and **/etc/pam.d/password-auth** files:

```
auth        required      pam_faillock.so preauth silent audit
deny=3 even_deny_root unlock_time=600
auth        sufficient    pam_unix.so nullok try_first_pass
auth        [default=die] pam_faillock.so authfail audit deny=3
even_deny_root unlock_time=600

account     required      pam_faillock.so
```

When user **john** attempts to log in for the fourth time after failing to log in three times previously, his account is locked upon the fourth attempt:

```
[yruseva@localhost ~]$ su - john
Account locked due to 3 failed logins
su: incorrect password
```

To prevent the system from locking users out even after multiple failed logins, add the following line just above the line where **pam_faillock** is called for the first time in both **/etc/pam.d/system-auth** and **/etc/pam.d/password-auth**. Also replace **user1**, **user2**, and **user3** with the actual user names.

```
auth [success=1 default=ignore] pam_succeed_if.so user in
user1:user2:user3
```

To view the number of failed attempts per user, run, as **root**, the following command:

```
[root@localhost ~]# faillock
john:
When                Type  Source
Valid
2013-03-05 11:44:14 TTY   pts/0
V
```

To unlock a user's account, run, as **root**, the following command:

```
faillock --user <username> --reset
```

Keeping Custom Settings with authconfig

When modifying authentication configuration using the **authconfig** utility, the **system-auth** and **password-auth** files are overwritten with the settings from the **authconfig** utility. This can be avoided by creating symbolic links in place of the configuration files, which **authconfig** recognizes and does not overwrite. In order to use custom settings in the configuration files and **authconfig** simultaneously, configure account locking using the following steps:

1. Check whether the **system-auth** and **password-auth** files are already symbolic links pointing to **system-auth-ac** and **password-auth-ac** (this is the system default):

   ```
   ~]# ls -l /etc/pam.d/{password,system}-auth
   ```

   If the output is similar to the following, the symbolic links are in place, and you can skip to step number 3:

   ```
   lrwxrwxrwx. 1 root root 16 24. Feb 09.29 /etc/pam.d/password-auth ->
   password-auth-ac
   lrwxrwxrwx. 1 root root 28 24. Feb 09.29 /etc/pam.d/system-auth ->
   system-auth-ac
   ```

   If the **system-auth** and **password-auth** files are not symbolic links, continue with the next step.

2. Rename the configuration files:

   ```
   ~]# mv /etc/pam.d/system-auth /etc/pam.d/system-auth-ac
   ~]# mv /etc/pam.d/password-auth /etc/pam.d/password-auth-ac
   ```

3. Create configuration files with your custom settings:

   ```
   ~]# vi /etc/pam.d/system-auth-local
   ```

The **/etc/pam.d/system-auth-local** file should contain the following lines:

```
auth        required      pam_faillock.so preauth silent audit
deny=3 unlock_time=600
auth        include       system-auth-ac
auth        [default=die] pam_faillock.so authfail silent audit
deny=3 unlock_time=600

account     required      pam_faillock.so
account     include       system-auth-ac

password    include       system-auth-ac

session     include       system-auth-ac
```

```
~]# vi /etc/pam.d/password-auth-local
```

The **/etc/pam.d/password-auth-local** file should contain the following lines:

```
auth        required      pam_faillock.so preauth silent audit
deny=3 unlock_time=600
auth        include       password-auth-ac
auth        [default=die] pam_faillock.so authfail silent audit
deny=3 unlock_time=600

account     required      pam_faillock.so
account     include       password-auth-ac

password    include       password-auth-ac

session     include       password-auth-ac
```

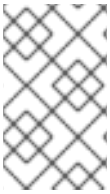
4. Create the following symbolic links:

```
~]# ln -sf /etc/pam.d/system-auth-local /etc/pam.d/system-auth
~]# ln -sf /etc/pam.d/password-auth-local /etc/pam.d/password-auth
```

For more information on various **pam_faillock** configuration options, see the pam_faillock(8) manual page.

4.1.3. Session Locking

Users may need to leave their workstation unattended for a number of reasons during everyday operation. This could present an opportunity for an attacker to physically access the machine, especially in environments with insufficient physical security measures (see Section 1.2.1, “Physical Controls”). Laptops are especially exposed since their mobility interferes with physical security. You can alleviate these risks by using session locking features which prevent access to the system until a correct password is entered.



NOTE

The main advantage of locking the screen instead of logging out is that a lock allows the user's processes (such as file transfers) to continue running. Logging out would stop these processes.

4.1.3.1. Locking Virtual Consoles Using vlock

Users may also need to lock a virtual console. This can be done using a utility called **vlock**. To install this utility, execute the following command as root:

```
~]# yum install vlock
```

After installation, any console session can be locked using the **vlock** command without any additional parameters. This locks the currently active virtual console session while still allowing access to the others. To prevent access to all virtual consoles on the workstation, execute the following:

```
vlock -a
```

In this case, **vlock** locks the currently active console and the **-a** option prevents switching to other virtual consoles.

See the **vlock(1)** man page for additional information.

4.1.4. Enforcing Read-Only Mounting of Removable Media

To enforce read-only mounting of removable media (such as USB flash disks), the administrator can use a **udev** rule to detect removable media and configure them to be mounted read-only using the **blockdev** utility. This is sufficient for enforcing read-only mounting of physical media.

Using blockdev to Force Read-Only Mounting of Removable Media

To force all removable media to be mounted read-only, create a new **udev** configuration file named, for example, **80-readonly-removables.rules** in the **/etc/udev/rules.d/** directory with the following content:

```
SUBSYSTEM=="block",ATTRS{removable}=="1",RUN{program}="/sbin/blockdev --
setro %N"
```

The above **udev** rule ensures that any newly connected removable block (storage) device is automatically configured as read-only using the **blockdev** utility.

Applying New udev Settings

For these settings to take effect, the new **udev** rules need to be applied. The **udev** service automatically detects changes to its configuration files, but new settings are not applied to already existing devices. Only newly connected devices are affected by the new settings. Therefore, you need to unmount and unplug all connected removable media to ensure that the new settings are applied to them when they are next plugged in.

To force **udev** to re-apply all rules to already existing devices, enter the following command as **root**:

```
~# udevadm trigger
```

Note that forcing **udev** to re-apply all rules using the above command does not affect any storage devices that are already mounted.

To force **udev** to reload all rules (in case the new rules are not automatically detected for some reason), use the following command:

```
~# udevadm control --reload
```

4.2. CONTROLLING ROOT ACCESS

When administering a home machine, the user must perform some tasks as the **root** user or by acquiring effective **root** privileges using a *setuid* program, such as **sudo** or **su**. A setuid program is one that operates with the user ID (*UID*) of the program's owner rather than the user operating the program. Such programs are denoted by an **s** in the owner section of a long format listing, as in the following example:

```
~]$ ls -l /bin/su
-rwsr-xr-x. 1 root root 34904 Mar 10  2011 /bin/su
```

NOTE

The **s** may be upper case or lower case. If it appears as upper case, it means that the underlying permission bit has not been set.

For the system administrator of an organization, however, choices must be made as to how much administrative access users within the organization should have to their machines. Through a PAM module called **pam_console.so**, some activities normally reserved only for the root user, such as rebooting and mounting removable media, are allowed for the first user that logs in at the physical console. However, other important system administration tasks, such as altering network settings, configuring a new mouse, or mounting network devices, are not possible without administrative privileges. As a result, system administrators must decide how much access the users on their network should receive.

4.2.1. Disallowing Root Access

If an administrator is uncomfortable allowing users to log in as **root** for these or other reasons, the root password should be kept secret, and access to runlevel one or single user mode should be disallowed through boot loader password protection (see Section 4.2.5, “Securing the Boot Loader” for more information on this topic.)

The following are four different ways that an administrator can further ensure that **root** logins are disallowed:

Changing the root shell

To prevent users from logging in directly as **root**, the system administrator can set the **root** account's shell to **/sbin/nologin** in the **/etc/passwd** file.

Table 4.2. Disabling the Root Shell

Effects	Does Not Affect
Prevents access to a **root** shell and logs any such attempts. The following programs are prevented from accessing the **root** account: • **login** • **gdm** • **kdm** • **xdm** • **su** • **ssh** • **scp** • **sftp**	Programs that do not require a shell, such as FTP clients, mail clients, and many setuid programs. The following programs are *not* prevented from accessing the **root** account: • **sudo** • FTP clients • Email clients

Disabling root access using any console device (tty)

To further limit access to the **root** account, administrators can disable **root** logins at the console by editing the **/etc/securetty** file. This file lists all devices the **root** user is allowed to log into. If the file does not exist at all, the **root** user can log in through any communication device on the system, whether through the console or a raw network interface. This is dangerous, because a user can log in to their machine as **root** using Telnet, which transmits the password in plain text over the network.

By default, Red Hat Enterprise Linux 7's **/etc/securetty** file only allows the **root** user to log in at the console physically attached to the machine. To prevent the **root** user from logging in, remove the contents of this file by typing the following command at a shell prompt as **root**:

```
echo > /etc/securetty
```

To enable **securetty** support in the KDM, GDM, and XDM login managers, add the following line:

```
auth [user_unknown=ignore success=ok ignore=ignore default=bad]
pam_securetty.so
```

to the files listed below:

- **/etc/pam.d/gdm**
- **/etc/pam.d/gdm-autologin**
- **/etc/pam.d/gdm-fingerprint**
- **/etc/pam.d/gdm-password**
- **/etc/pam.d/gdm-smartcard**

- **/etc/pam.d/kdm**
- **/etc/pam.d/kdm-np**
- **/etc/pam.d/xdm**

WARNING

A blank **/etc/securetty** file does *not* prevent the **root** user from logging in remotely using the OpenSSH suite of tools because the console is not opened until after authentication.

Table 4.3. Disabling Root Logins

Effects	Does Not Affect
Prevents access to the **root** account using the console or the network. The following programs are prevented from accessing the **root** account: • **login** • **gdm** • **kdm** • **xdm** • Other network services that open a tty	Programs that do not log in as **root**, but perform administrative tasks through setuid or other mechanisms. The following programs are *not* prevented from accessing the **root** account: • **su** • **sudo** • **ssh** • **scp** • **sftp**

Disabling root SSH logins

To prevent **root** logins through the SSH protocol, edit the SSH daemon's configuration file, **/etc/ssh/sshd_config**, and change the line that reads:

```
#PermitRootLogin yes
```

to read as follows:

```
PermitRootLogin no
```

Table 4.4. Disabling Root SSH Logins

Effects	Does Not Affect
Prevents **root** access using the OpenSSH suite of tools. The following programs are prevented from accessing the **root** account: • **ssh** • **scp** • **sftp**	Programs that are not part of the OpenSSH suite of tools.

Using PAM to limit root access to services

PAM, through the **/lib/security/pam_listfile.so** module, allows great flexibility in denying specific accounts. The administrator can use this module to reference a list of users who are not allowed to log in. To limit **root** access to a system service, edit the file for the target service in the **/etc/pam.d/** directory and make sure the **pam_listfile.so** module is required for authentication.

The following is an example of how the module is used for the **vsftpd** FTP server in the **/etc/pam.d/vsftpd** PAM configuration file (the **** character at the end of the first line is *not* necessary if the directive is on a single line):

```
auth   required   /lib/security/pam_listfile.so   item=user \
sense=deny file=/etc/vsftpd.ftpusers onerr=succeed
```

This instructs PAM to consult the **/etc/vsftpd.ftpusers** file and deny access to the service for any listed user. The administrator can change the name of this file, and can keep separate lists for each service or use one central list to deny access to multiple services.

If the administrator wants to deny access to multiple services, a similar line can be added to the PAM configuration files, such as **/etc/pam.d/pop** and **/etc/pam.d/imap** for mail clients, or **/etc/pam.d/ssh** for SSH clients.

For more information about PAM, see *The Linux-PAM System Administrator's Guide*, located in the **/usr/share/doc/pam-<version>/html/** directory.

Table 4.5. Disabling Root Using PAM

Effects	Does Not Affect
Prevents **root** access to network services that are PAM aware. The following services are prevented from accessing the **root** account: • **login** • **gdm** • **kdm** • **xdm** • **ssh** • **scp** • **sftp** • FTP clients • Email clients • Any PAM aware services	Programs and services that are not PAM aware.

4.2.2. Allowing Root Access

If the users within an organization are trusted and computer-literate, then allowing them **root** access may not be an issue. Allowing **root** access by users means that minor activities, like adding devices or configuring network interfaces, can be handled by the individual users, leaving system administrators free to deal with network security and other important issues.

On the other hand, giving **root** access to individual users can lead to the following issues:

- *Machine Misconfiguration* — Users with **root** access can misconfigure their machines and require assistance to resolve issues. Even worse, they might open up security holes without knowing it.
- *Running Insecure Services* — Users with **root** access might run insecure servers on their machine, such as FTP or Telnet, potentially putting usernames and passwords at risk. These services transmit this information over the network in plain text.
- *Running Email Attachments As Root* — Although rare, email viruses that affect Linux do exist. A malicious program poses the greatest threat when run by the **root** user.
- *Keeping the audit trail intact* — Because the **root** account is often shared by multiple users, so that multiple system administrators can maintain the system, it is impossible to figure out which of those users was **root** at a given time. When using separate logins, the account a user logs in with, as well as a unique number for session tracking purposes, is put into the task structure, which is inherited by every process that the user starts. When using concurrent logins, the unique number can be used to trace actions to specific logins. When an action generates an audit event, it is recorded with the login account and the session associated with that unique number. Use the **aulast** command to view these logins and sessions. The **--proof** option of

the **aulast** command can be used suggest a specific **ausearch** query to isolate auditable events generated by a particular session. For more information about the Audit system, see Chapter 6, *System Auditing*.

4.2.3. Limiting Root Access

Rather than completely denying access to the **root** user, the administrator may want to allow access only through setuid programs, such as **su** or **sudo**. For more information on **su** and **sudo**, see the Gaining Privileges chapter in Red Hat Enterprise Linux 7 System Administrator's Guide, and the **su(1)** and **sudo(8)** man pages.

4.2.4. Enabling Automatic Logouts

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

1. As **root**, add the following line at the beginning of the **/etc/profile** file to make sure the processing of this file cannot be interrupted:

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

2. As **root**, insert the following lines to the **/etc/profile** file to automatically log out after 120 seconds:

```
export TMOUT=120
readonly TMOUT
```

The **TMOUT** variable terminates the shell if there is no activity for the specified number of seconds (set to **120** in the above example). You can change the limit according to the needs of the particular installation.

4.2.5. Securing the Boot Loader

The primary reasons for password protecting a Linux boot loader are as follows:

1. *Preventing Access to Single User Mode* — If attackers can boot the system into single user mode, they are logged in automatically as **root** without being prompted for the **root** password.

WARNING

Protecting access to single user mode with a password by editing the ***SINGLE*** parameter in the **/etc/sysconfig/init** file is not recommended. An attacker can bypass the password by specifying a custom initial command (using the ***init=*** parameter) on the kernel command line in GRUB 2. It is recommended to password-protect the GRUB 2 boot loader, as described in the Protecting GRUB 2 with a Password chapter in Red Hat Enterprise Linux 7 System Administrator's Guide.

2. *Preventing Access to the GRUB 2 Console* — If the machine uses GRUB 2 as its boot loader, an attacker can use the GRUB 2 editor interface to change its configuration or to gather information using the **cat** command.

3. *Preventing Access to Insecure Operating Systems* — If it is a dual-boot system, an attacker can select an operating system at boot time, for example DOS, which ignores access controls and file permissions.

Red Hat Enterprise Linux 7 includes the GRUB 2 boot loader on the Intel 64 and AMD64 platform. For a detailed look at GRUB 2, see the Working With the GRUB 2 Boot Loader chapter in Red Hat Enterprise Linux 7 System Administrator's Guide.

4.2.5.1. Disabling Interactive Startup

Pressing the **I** key at the beginning of the boot sequence allows you to start up your system interactively. During an interactive startup, the system prompts you to start up each service one by one. However, this may allow an attacker who gains physical access to your system to disable the security-related services and gain access to the system.

To prevent users from starting up the system interactively, as **root**, disable the ***PROMPT*** parameter in the **/etc/sysconfig/init** file:

```
PROMPT=no
```

4.2.6. Protecting Hard and Symbolic Links

To prevent malicious users from exploiting potential vulnerabilities caused by unprotected hard and symbolic links, Red Hat Enterprise Linux 7 includes a feature that only allows links to be created or followed provided certain conditions are met.

In case of hard links, one of the following needs to be true:

- The user owns the file to which they link.
- The user already has read and write access to the file to which they link.

In case of symbolic links, processes are only permitted to follow links when outside of world-writeable directories with sticky bits, or one of the following needs to be true:

- The process following the symbolic link is the owner of the symbolic link.
- The owner of the directory is the same as the owner of the symbolic link.

This protection is turned on by default. It is controlled by the following options in the **/usr/lib/sysctl.d/50-default.conf** file:

```
fs.protected_hardlinks = 1
fs.protected_symlinks = 1
```

To override the default settings and disable the protection, create a new configuration file called, for example, **51-no-protect-links.conf** in the **/etc/sysctl.d/** directory with the following content:

```
fs.protected_hardlinks = 0
fs.protected_symlinks = 0
```

NOTE

Note that in order to override the default system settings, the new configuration file needs to have the **.conf** extension, and it needs to be read *after* the default system file (the files are read in lexicographic order, therefore settings contained in a file with a higher number at the beginning of the file name take precedence).

See the sysctl.d(5) manual page for more detailed information about the configuration of kernel parameters at boot using the **sysctl** mechanism.

4.3. SECURING SERVICES

While user access to administrative controls is an important issue for system administrators within an organization, monitoring which network services are active is of paramount importance to anyone who administers and operates a Linux system.

Many services under Red Hat Enterprise Linux 7 are network servers. If a network service is running on a machine, then a server application (called a *daemon*), is listening for connections on one or more network ports. Each of these servers should be treated as a potential avenue of attack.

4.3.1. Risks To Services

Network services can pose many risks for Linux systems. Below is a list of some of the primary issues:

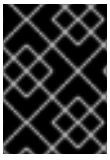
- *Denial of Service Attacks (DoS)* — By flooding a service with requests, a denial of service attack can render a system unusable as it tries to log and answer each request.
- *Distributed Denial of Service Attack (DDoS)* — A type of DoS attack which uses multiple compromised machines (often numbering in the thousands or more) to direct a coordinated attack on a service, flooding it with requests and making it unusable.
- *Script Vulnerability Attacks* — If a server is using scripts to execute server-side actions, as Web servers commonly do, an attacker can target improperly written scripts. These script vulnerability attacks can lead to a buffer overflow condition or allow the attacker to alter files on the system.
- *Buffer Overflow Attacks* — Services that want to listen on ports 1 through 1023 must start either with administrative privileges or the **CAP_NET_BIND_SERVICE** capability needs to be set for

them. Once a process is bound to a port and is listening on it, the privileges or the capability are often dropped. If the privileges or the capability are not dropped, and the application has an exploitable buffer overflow, an attacker could gain access to the system as the user running the daemon. Because exploitable buffer overflows exist, crackers use automated tools to identify systems with vulnerabilities, and once they have gained access, they use automated rootkits to maintain their access to the system.

NOTE

The threat of buffer overflow vulnerabilities is mitigated in Red Hat Enterprise Linux 7 by *ExecShield*, an executable memory segmentation and protection technology supported by x86-compatible uni- and multi-processor kernels. ExecShield reduces the risk of buffer overflow by separating virtual memory into executable and non-executable segments. Any program code that tries to execute outside of the executable segment (such as malicious code injected from a buffer overflow exploit) triggers a segmentation fault and terminates.

Execshield also includes support for *No eXecute* (NX) technology on AMD64 platforms and Intel® 64 systems. These technologies work in conjunction with ExecShield to prevent malicious code from running in the executable portion of virtual memory with a granularity of 4KB of executable code, lowering the risk of attack from buffer overflow exploits.



IMPORTANT

To limit exposure to attacks over the network, all services that are unused should be turned off.

4.3.2. Identifying and Configuring Services

To enhance security, most network services installed with Red Hat Enterprise Linux 7 are turned off by default. There are, however, some notable exceptions:

- **cups** — The default print server for Red Hat Enterprise Linux 7.
- **cups-lpd** — An alternative print server.
- **xinetd** — A super server that controls connections to a range of subordinate servers, such as **gssftp** and **telnet**.
- **sshd** — The OpenSSH server, which is a secure replacement for Telnet.

When determining whether to leave these services running, it is best to use common sense and avoid taking any risks. For example, if a printer is not available, do not leave **cups** running. The same is true for **portreserve**. If you do not mount NFSv3 volumes or use NIS (the **ypbind** service), then **rpcbind** should be disabled. Checking which network services are available to start at boot time is not sufficient. It is recommended to also check which ports are open and listening. Refer to Section 4.4.2, “Verifying Which Ports Are Listening” for more information.

4.3.3. Insecure Services

Potentially, any network service is insecure. This is why turning off unused services is so important. Exploits for services are routinely revealed and patched, making it very important to regularly update packages associated with any network service. See Chapter 3, *Keeping Your System Up-to-Date* for more information.

Some network protocols are inherently more insecure than others. These include any services that:

- *Transmit Usernames and Passwords Over a Network Unencrypted* — Many older protocols, such as Telnet and FTP, do not encrypt the authentication session and should be avoided whenever possible.

- *Transmit Sensitive Data Over a Network Unencrypted* — Many protocols transmit data over the network unencrypted. These protocols include Telnet, FTP, HTTP, and SMTP. Many network file systems, such as NFS and SMB, also transmit information over the network unencrypted. It is the user's responsibility when using these protocols to limit what type of data is transmitted.

Examples of inherently insecure services include **rlogin**, **rsh**, **telnet**, and **vsftpd**.

All remote login and shell programs (**rlogin**, **rsh**, and **telnet**) should be avoided in favor of **SSH**. See Section 4.3.11, “Securing SSH” for more information about **sshd**.

FTP is not as inherently dangerous to the security of the system as remote shells, but **FTP** servers must be carefully configured and monitored to avoid problems. See Section 4.3.9, “Securing FTP” for more information about securing **FTP** servers.

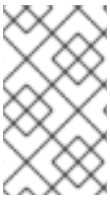
Services that should be carefully implemented and behind a firewall include:

- **auth**
- **nfs-server**
- **smb** and **nbm** (Samba)
- **yppasswdd**
- **ypserv**
- **ypxfrd**

More information on securing network services is available in Section 4.4, “Securing Network Access”.

4.3.4. Securing rpcbind

The **rpcbind** service is a dynamic port assignment daemon for RPC services such as NIS and NFS. It has weak authentication mechanisms and has the ability to assign a wide range of ports for the services it controls. For these reasons, it is difficult to secure.



NOTE

Securing **rpcbind** only affects NFSv2 and NFSv3 implementations, since NFSv4 no longer requires it. If you plan to implement an NFSv2 or NFSv3 server, then **rpcbind** is required, and the following section applies.

If running RPC services, follow these basic rules.

4.3.4.1. Protect rpcbind With TCP Wrappers

It is important to use TCP Wrappers to limit which networks or hosts have access to the **rpcbind** service since it has no built-in form of authentication.

Further, use *only* IP addresses when limiting access to the service. Avoid using host names, as they can be forged by DNS poisoning and other methods.

4.3.4.2. Protect rpcbind With firewalld

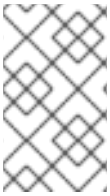
To further restrict access to the **rpcbind** service, it is a good idea to add **firewalld** rules to the server and restrict access to specific networks.

Below are two example **firewalld** rich language commands. The first allows TCP connections to the port 111 (used by the **rpcbind** service) from the 192.168.0.0/24 network. The second allows TCP connections to the same port from the localhost. All other packets are dropped.

```
~]# firewall-cmd --add-rich-rule='rule family="ipv4" port port="111"
protocol="tcp" source address="192.168.0.0/24" invert="True" drop'
~]# firewall-cmd --add-rich-rule='rule family="ipv4" port port="111"
protocol="tcp" source address="127.0.0.1" accept'
```

To similarly limit UDP traffic, use the following command:

```
~]# firewall-cmd --add-rich-rule='rule family="ipv4" port port="111"
protocol="udp" source address="192.168.0.0/24" invert="True" drop'
```



NOTE

Add **--permanent** to the **firewalld** rich language commands to make the settings permanent. See Chapter 5, *Using Firewalls* for more information about implementing firewalls.

4.3.5. Securing rpc.mountd

The **rpc.mountd** daemon implements the server side of the NFS MOUNT protocol, a protocol used by NFS version 2 (*RFC 1904*) and NFS version 3 (*RFC 1813*).

If running RPC services, follow these basic rules.

4.3.5.1. Protect rpc.mountd With TCP Wrappers

It is important to use TCP Wrappers to limit which networks or hosts have access to the **rpc.mountd** service since it has no built-in form of authentication.

Further, use *only* **IP** addresses when limiting access to the service. Avoid using host names, as they can be forged by **DNS** poisoning and other methods.

4.3.5.2. Protect rpc.mountd With firewalld

To further restrict access to the **rpc.mountd** service, add **firewalld** rich language rules to the server and restrict access to specific networks.

Below are two example **firewalld** rich language commands. The first allows **mountd** connections from the **192.168.0.0/24** network. The second allows **mountd** connections from the local host. All other packets are dropped.

```
~]# firewall-cmd --add-rich-rule 'rule family="ipv4" source NOT
```

```
address="192.168.0.0/24" service name="mountd" drop'
~]# firewall-cmd --add-rich-rule 'rule family="ipv4" source
address="127.0.0.1" service name="mountd" accept'
```

NOTE

Add **--permanent** to the **firewalld** rich language commands to make the settings permanent. See Chapter 5, *Using Firewalls* for more information about implementing firewalls.

4.3.6. Securing NIS

The *Network Information Service* (NIS) is an RPC service, called **ypserv**, which is used in conjunction with **rpcbind** and other related services to distribute maps of user names, passwords, and other sensitive information to any computer claiming to be within its domain.

A NIS server is comprised of several applications. They include the following:

- **/usr/sbin/rpc.yppasswdd** — Also called the **yppasswdd** service, this daemon allows users to change their NIS passwords.
- **/usr/sbin/rpc.ypxfrd** — Also called the **ypxfrd** service, this daemon is responsible for NIS map transfers over the network.
- **/usr/sbin/ypserv** — This is the NIS server daemon.

NIS is somewhat insecure by today's standards. It has no host authentication mechanisms and transmits all of its information over the network unencrypted, including password hashes. As a result, extreme care must be taken when setting up a network that uses NIS. This is further complicated by the fact that the default configuration of NIS is inherently insecure.

It is recommended that anyone planning to implement a NIS server first secure the **rpcbind** service as outlined in Section 4.3.4, “Securing rpcbind”, then address the following issues, such as network planning.

4.3.6.1. Carefully Plan the Network

Because NIS transmits sensitive information unencrypted over the network, it is important the service be run behind a firewall and on a segmented and secure network. Whenever NIS information is transmitted over an insecure network, it risks being intercepted. Careful network design can help prevent severe security breaches.

4.3.6.2. Use a Password-like NIS Domain Name and Hostname

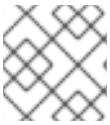
Any machine within a NIS domain can use commands to extract information from the server without authentication, as long as the user knows the NIS server's DNS host name and NIS domain name.

For instance, if someone either connects a laptop computer into the network or breaks into the network from outside (and manages to spoof an internal IP address), the following command reveals the **/etc/passwd** map:

```
ypcat -d <NIS_domain> -h <DNS_hostname> passwd
```

If this attacker is a root user, they can obtain the **/etc/shadow** file by typing the following command:

```
ypcat -d <NIS_domain> -h <DNS_hostname> shadow
```



NOTE

If Kerberos is used, the **/etc/shadow** file is not stored within a NIS map.

To make access to NIS maps harder for an attacker, create a random string for the DNS host name, such as **o7hfawtgmhwg.domain.com**. Similarly, create a *different* randomized NIS domain name. This makes it much more difficult for an attacker to access the NIS server.

4.3.6.3. Edit the /var/yp/securenets File

If the **/var/yp/securenets** file is blank or does not exist (as is the case after a default installation), NIS listens to all networks. One of the first things to do is to put netmask/network pairs in the file so that **ypserv** only responds to requests from the appropriate network.

Below is a sample entry from a **/var/yp/securenets** file:

```
255.255.255.0     192.168.0.0
```

WARNING

Never start a NIS server for the first time without creating the **/var/yp/securenets** file.

This technique does not provide protection from an IP spoofing attack, but it does at least place limits on what networks the NIS server services.

4.3.6.4. Assign Static Ports and Use Rich Language Rules

All of the servers related to NIS can be assigned specific ports except for **rpc.yppasswdd** — the daemon that allows users to change their login passwords. Assigning ports to the other two NIS server daemons, **rpc.ypxfrd** and **ypserv**, allows for the creation of firewall rules to further protect the NIS server daemons from intruders.

To do this, add the following lines to **/etc/sysconfig/network**:

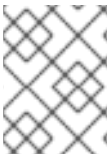
```
YPSERV_ARGS="-p 834"
YPXFRD_ARGS="-p 835"
```

The following rich language **firewalld** rules can then be used to enforce which network the server listens to for these ports:

```
~]# firewall-cmd --add-rich-rule='rule family="ipv4" source
address="192.168.0.0/24" invert="True" port port="834-835" protocol="tcp"
drop'
```

```
~]# firewall-cmd --add-rich-rule='rule family="ipv4" source
address="192.168.0.0/24" invert="True" port port="834-835" protocol="udp"
drop'
```

This means that the server only allows connections to ports 834 and 835 if the requests come from the **192.168.0.0/24** network. The first rule is for **TCP** and the second for **UDP**.



NOTE

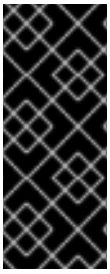
See Chapter 5, *Using Firewalls* for more information about implementing firewalls with iptables commands.

4.3.6.5. Use Kerberos Authentication

One of the issues to consider when NIS is used for authentication is that whenever a user logs into a machine, a password hash from the **/etc/shadow** map is sent over the network. If an intruder gains access to a NIS domain and sniffs network traffic, they can collect user names and password hashes. With enough time, a password cracking program can guess weak passwords, and an attacker can gain access to a valid account on the network.

Since Kerberos uses secret-key cryptography, no password hashes are ever sent over the network, making the system far more secure. See the Logging into IdM Using Kerberos section in the Linux Domain Identity, Authentication, and Policy Guide for more information about Kerberos.

4.3.7. Securing NFS



IMPORTANT

NFS traffic can be sent using TCP in all versions, it should be used with NFSv3, rather than UDP, and is required when using NFSv4. All versions of NFS support Kerberos user and group authentication, as part of the **RPCSEC_GSS** kernel module. Information on **rpcbind** is still included, since Red Hat Enterprise Linux 7 supports NFSv3 which utilizes **rpcbind**.

4.3.7.1. Carefully Plan the Network

NFSv2 and NFSv3 traditionally passed data insecurely. All versions of NFS now have the ability to authenticate (and optionally encrypt) ordinary file system operations using Kerberos. Under NFSv4 all operations can use Kerberos; under NFSv2 or NFSv3, file locking and mounting still do not use it. When using NFSv4.0, delegations may be turned off if the clients are behind NAT or a firewall. For information on the use of NFSv4.1 to allow delegations to operate through NAT and firewalls, see the pNFS section of the Red Hat Enterprise Linux 7 Storage Administration Guide.

4.3.7.2. Securing NFS Mount Options

The use of the **mount** command in the **/etc/fstab** file is explained in the Using the mount Command chapter of the Red Hat Enterprise Linux 7 Storage Administration Guide. From a security administration point of view it is worthwhile to note that the NFS mount options can also be specified in **/etc/nfsmount.conf**, which can be used to set custom default options.

4.3.7.2.1. Review the NFS Server

WARNING

Only export entire file systems. Exporting a subdirectory of a file system can be a security issue. It is possible in some cases for a client to "break out" of the exported part of the file system and get to unexported parts (see the section on subtree checking in the **exports(5)** man page.

Use the **ro** option to export the file system as read-only whenever possible to reduce the number of users able to write to the mounted file system. Only use the **rw** option when specifically required. See the man **exports(5)** page for more information. Allowing write access increases the risk from symlink attacks for example. This includes temporary directories such as **/tmp** and **/usr/tmp**.

Where directories must be mounted with the **rw** option avoid making them world-writable whenever possible to reduce risk. Exporting home directories is also viewed as a risk as some applications store passwords in clear text or weakly encrypted. This risk is being reduced as application code is reviewed and improved. Some users do not set passwords on their SSH keys so this too means home directories present a risk. Enforcing the use of passwords or using Kerberos would mitigate that risk.

Restrict exports only to clients that need access. Use the **showmount -e** command on an NFS server to review what the server is exporting. Do not export anything that is not specifically required.

Do not use the **no_root_squash** option and review existing installations to make sure it is not used. See Section 4.3.7.4, “Do Not Use the no_root_squash Option” for more information.

The **secure** option is the server-side export option used to restrict exports to “reserved” ports. By default, the server allows client communication only from “reserved” ports (ports numbered less than 1024), because traditionally clients have only allowed “trusted” code (such as in-kernel NFS clients) to use those ports. However, on many networks it is not difficult for anyone to become root on some client, so it is rarely safe for the server to assume that communication from a reserved port is privileged. Therefore the restriction to reserved ports is of limited value; it is better to rely on Kerberos, firewalls, and restriction of exports to particular clients.

Most clients still do use reserved ports when possible. However, reserved ports are a limited resource, so clients (especially those with a large number of NFS mounts) may choose to use higher-numbered ports as well. Linux clients may do this using the “noresvport” mount option. If you want to allow this on an export, you may do so with the “insecure” export option.

It is good practice not to allow users to login to a server. While reviewing the above settings on an NFS server conduct a review of who and what can access the server.

4.3.7.2.2. Review the NFS Client

Use the **nosuid** option to disallow the use of a **setuid** program. The **nosuid** option disables the **set-user-identifier** or **set-group-identifier** bits. This prevents remote users from gaining higher privileges by running a setuid program. Use this option on the client and the server side.

The **noexec** option disables all executable files on the client. Use this to prevent users from inadvertently executing files placed in the file system being shared. The **nosuid** and **noexec** options are standard options for most, if not all, file systems.

Use the **nodev** option to prevent “device-files” from being processed as a hardware device by the client.

The **resvport** option is a client-side mount option and **secure** is the corresponding server-side export option (see explanation above). It restricts communication to a "reserved port". The reserved or "well known" ports are reserved for privileged users and processes such as the root user. Setting this option causes the client to use a reserved source port to communicate with the server.

All versions of NFS now support mounting with Kerberos authentication. The mount option to enable this is: **sec=krb5**.

NFSv4 supports mounting with Kerberos using **krb5i** for integrity and **krb5p** for privacy protection. These are used when mounting with **sec=krb5**, but need to be configured on the NFS server. See the man page on exports (**man 5 exports**) for more information.

The NFS man page (**man 5 nfs**) has a “SECURITY CONSIDERATIONS” section which explains the security enhancements in NFSv4 and contains all the NFS specific mount options.

4.3.7.3. Beware of Syntax Errors

The NFS server determines which file systems to export and which hosts to export these directories to by consulting the **/etc/exports** file. Be careful not to add extraneous spaces when editing this file.

For instance, the following line in the **/etc/exports** file shares the directory **/tmp/nfs/** to the host **bob.example.com** with read/write permissions.

```
/tmp/nfs/     bob.example.com(rw)
```

The following line in the **/etc/exports** file, on the other hand, shares the same directory to the host **bob.example.com** with read-only permissions and shares it to the *world* with read/write permissions due to a single space character after the host name.

```
/tmp/nfs/     bob.example.com (rw)
```

It is good practice to check any configured NFS shares by using the **showmount** command to verify what is being shared:

```
showmount -e <hostname>
```

4.3.7.4. Do Not Use the no_root_squash Option

By default, NFS shares change the root user to the **nfsnobody** user, an unprivileged user account. This changes the owner of all root-created files to **nfsnobody**, which prevents uploading of programs with the setuid bit set.

If **no_root_squash** is used, remote root users are able to change any file on the shared file system and leave applications infected by Trojans for other users to inadvertently execute.

4.3.7.5. NFS Firewall Configuration

NFSv4 is the default version of NFS for Red Hat Enterprise Linux 7 and it only requires port 2049 to be open for TCP. If using NFSv3 then four additional ports are required as explained below.

Configuring Ports for NFSv3

The ports used for NFS are assigned dynamically by the **rpcbind** service, which might cause problems when creating firewall rules. To simplify this process, use the **/etc/sysconfig/nfs** file to specify which ports are to be used:

- **MOUNTD_PORT** — TCP and UDP port for mountd (rpc.mountd)
- **STATD_PORT** — TCP and UDP port for status (rpc.statd)

In Red Hat Enterprise Linux 7, set the TCP and UDP port for the NFS lock manager (nlockmgr) in the **/etc/modprobe.d/lockd.conf** file:

- **nlm_tcpport** — TCP port for nlockmgr (rpc.lockd)
- **nlm_udpport** — UDP port nlockmgr (rpc.lockd)

Port numbers specified must not be used by any other service. Configure your firewall to allow the port numbers specified, as well as TCP and UDP port 2049 (NFS). See **/etc/modprobe.d/lockd.conf** for descriptions of additional customizable NFS lock manager parameters.

Run the **rpcinfo -p** command on the NFS server to see which ports and RPC programs are being used.

4.3.7.6. Securing NFS with Red Hat Identity Management

Kerberos-aware NFS setup can be greatly simplified in an environment that is using Red Hat Identity Management, which is included in Red Hat Enterprise Linux.

See the Red Hat Enterprise Linux 7 Linux Domain Identity, Authentication, and Policy Guide, in particular Setting up a Kerberos-aware NFS Server to learn how to secure NFS with Kerberos when using Red Hat Identity Management.

4.3.8. Securing HTTP Servers

4.3.8.1. Securing the Apache HTTP Server

The Apache HTTP Server is one of the most stable and secure services in Red Hat Enterprise Linux 7. A large number of options and techniques are available to secure the Apache HTTP Server — too numerous to delve into deeply here. The following section briefly explains good practices when running the Apache HTTP Server.

Always verify that any scripts running on the system work as intended *before* putting them into production. Also, ensure that only the root user has write permissions to any directory containing scripts or CGIs. To do this, enter the following commands as the root user:

```
chown root <directory_name>
```

```
chmod 755 <directory_name>
```

System administrators should be careful when using the following configuration options (configured in **/etc/httpd/conf/httpd.conf**):

FollowSymLinks

This directive is enabled by default, so be sure to use caution when creating symbolic links to the document root of the Web server. For instance, it is a bad idea to provide a symbolic link to **/**.

`Indexes`

This directive is enabled by default, but may not be desirable. To prevent visitors from browsing files on the server, remove this directive.

`UserDir`

The **`UserDir`** directive is disabled by default because it can confirm the presence of a user account on the system. To enable user directory browsing on the server, use the following directives:

```
UserDir enabled
         UserDir disabled root
```

These directives activate user directory browsing for all user directories other than **`/root/`**. To add users to the list of disabled accounts, add a space-delimited list of users on the **`UserDir disabled`** line.

`ServerTokens`

The **`ServerTokens`** directive controls the server response header field which is sent back to clients. It includes various information which can be customized using the following parameters:

- **`ServerTokens Full`** (default option) — provides all available information (OS type and used modules), for example:

  ```
  Apache/2.0.41 (Unix) PHP/4.2.2 MyMod/1.2
  ```

- **`ServerTokens Prod`** or **`ServerTokens ProductOnly`** — provides the following information:

  ```
  Apache
  ```

- **`ServerTokens Major`** — provides the following information:

  ```
  Apache/2
  ```

- **`ServerTokens Minor`** — provides the following information:

  ```
  Apache/2.0
  ```

- **`ServerTokens Min`** or **`ServerTokens Minimal`** — provides the following information:

  ```
  Apache/2.0.41
  ```

- **`ServerTokens OS`** — provides the following information:

  ```
  Apache/2.0.41 (Unix)
  ```

It is recommended to use the **`ServerTokens Prod`** option so that a possible attacker does not gain any valuable information about your system.

IMPORTANT

Do not remove the **IncludesNoExec** directive. By default, the *Server-Side Includes* (SSI) module cannot execute commands. It is recommended that you do not change this setting unless absolutely necessary, as it could, potentially, enable an attacker to execute commands on the system.

Removing httpd Modules
In certain scenarios, it is beneficial to remove certain **httpd** modules to limit the functionality of the HTTP Server. To do so, edit configuration files in the **/etc/httpd/conf.modules.d** directory. For example, to remove the proxy module:

```
echo '# All proxy modules disabled' > /etc/httpd/conf.modules.d/00-
proxy.conf
```

Note that the **/etc/httpd/conf.d/** directory contains configuration files which are used to load modules as well.

httpd and SELinux
For information, see the The Apache HTTP Server and SELinux chapter from the Red Hat Enterprise Linux 7 SELinux User's and Administrator's Guide.

4.3.8.2. Securing NGINX

NGINX is a high-performance HTTP and proxy server. This section briefly documents additional steps that harden your NGINX configuration. Perform all of the following configuration changes in the **server** section of your NGINX configuration files.

Disabling Version Strings
To prevent attackers from learning the version of NGINX running on your server, use the following configuration option:

```
server_tokens        off;
```

This has the effect of removing the version number and simply reporting the string **nginx** in all requests served by NGINX:

```
$ curl -sI http://localhost | grep Server
Server: nginx
```

Including Additional Security-related Headers
Each request served by NGINX can include additional HTTP headers that mitigate certain known web application vulnerabilities:

- **add_header X-Frame-Options SAMEORIGIN;** — this option denies any page outside of your domain to frame any content served by NGINX, effectively mitigating clickjacking attacks.
- **add_header X-Content-Type-Options nosniff;** — this option prevents MIME-type sniffing in certain older browsers.
- **add_header X-XSS-Protection "1; mode=block";** — this option enables the Cross-Site Scripting (XSS) filtering, which prevents a browser from rendering potentially malicious content included in a response by NGINX.

Disabling Potentially Harmful HTTP Methods
If enabled, some of the HTTP methods may allow an attacker to perform actions on the web server that were designed for developers to test web applications. For example, the TRACE method is known to allow Cross-Site Tracing (XST).

Your NGINX server can disallow these harmful HTTP methods as well as any arbitrary methods by whitelisting only those that should be allowed. For example:

```
# Allow GET, PUT, POST; return "405 Method Not Allowed" for all others.
if ( $request_method !~ ^(GET|PUT|POST)$ ) {
    return 405;
}
```

Configuring SSL
To protect the data served by your NGINX web server, consider serving it over HTTPS only. To generate a secure configuration profile for enabling SSL in your NGINX server, see the Mozilla SSL Configuration Generator. The generated configuration assures that known vulnerable protocols (for example, SSLv2 or SSLv3), ciphers, and hashing algorithms (for example, 3DES or MD5) are disabled.

You can also use the SSL Server Test to verify that your configuration meets modern security requirements.

4.3.9. Securing FTP

The *File Transfer Protocol* (FTP) is an older TCP protocol designed to transfer files over a network. Because all transactions with the server, including user authentication, are unencrypted, it is considered an insecure protocol and should be carefully configured.

Red Hat Enterprise Linux 7 provides two FTP servers:

- **Red Hat Content Accelerator** (`tux`) — A kernel-space Web server with FTP capabilities.
- `vsftpd` — A standalone, security oriented implementation of the FTP service.

The following security guidelines are for setting up the `vsftpd` FTP service.

4.3.9.1. FTP Greeting Banner

Before submitting a user name and password, all users are presented with a greeting banner. By default, this banner includes version information useful to crackers trying to identify weaknesses in a system.

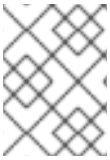
To change the greeting banner for `vsftpd`, add the following directive to the `/etc/vsftpd/vsftpd.conf` file:

```
ftpd_banner=<insert_greeting_here>
```

Replace *<insert_greeting_here>* in the above directive with the text of the greeting message.

For mutli-line banners, it is best to use a banner file. To simplify management of multiple banners, place all banners in a new directory called `/etc/banners/`. The banner file for FTP connections in this example is `/etc/banners/ftp.msg`. Below is an example of what such a file may look like:

```
########## Hello, all activity on ftp.example.com is logged. ##########
```



NOTE

It is not necessary to begin each line of the file with **220** as specified in Section 4.4.1, "Securing Services With TCP Wrappers and xinetd".

To reference this greeting banner file for **vsftpd**, add the following directive to the **/etc/vsftpd/vsftpd.conf** file:

```
banner_file=/etc/banners/ftp.msg
```

It also is possible to send additional banners to incoming connections using TCP Wrappers as described in Section 4.4.1.1, "TCP Wrappers and Connection Banners".

4.3.9.2. Anonymous Access

The presence of the **/var/ftp/** directory activates the anonymous account.

The easiest way to create this directory is to install the **vsftpd** package. This package establishes a directory tree for anonymous users and configures the permissions on directories to read-only for anonymous users.

By default the anonymous user cannot write to any directories.

WARNING

If enabling anonymous access to an FTP server, be aware of where sensitive data is stored.

4.3.9.2.1. Anonymous Upload

To allow anonymous users to upload files, it is recommended that a write-only directory be created within **/var/ftp/pub/**. To do this, enter the following command as root:

```
~]# mkdir /var/ftp/pub/upload
```

Next, change the permissions so that anonymous users cannot view the contents of the directory:

```
~]# chmod 730 /var/ftp/pub/upload
```

A long format listing of the directory should look like this:

```
~]# ls -ld /var/ftp/pub/upload
drwx-wx---. 2 root ftp 4096 Nov 14 22:57 /var/ftp/pub/upload
```

Administrators who allow anonymous users to read and write in directories often find that their servers become a repository of stolen software.

Additionally, under **vsftpd**, add the following line to the **/etc/vsftpd/vsftpd.conf** file:

```
anon_upload_enable=YES
```

4.3.9.3. User Accounts

Because FTP transmits unencrypted user names and passwords over insecure networks for authentication, it is a good idea to deny system users access to the server from their user accounts.

To disable all user accounts in **vsftpd**, add the following directive to **/etc/vsftpd/vsftpd.conf**:

```
local_enable=NO
```

4.3.9.3.1. Restricting User Accounts

To disable FTP access for specific accounts or specific groups of accounts, such as the root user and those with **sudo** privileges, the easiest way is to use a PAM list file as described in Section 4.2.1, “Disallowing Root Access”. The PAM configuration file for **vsftpd** is **/etc/pam.d/vsftpd**.

It is also possible to disable user accounts within each service directly.

To disable specific user accounts in **vsftpd**, add the user name to **/etc/vsftpd/ftpusers**

4.3.9.4. Use TCP Wrappers To Control Access

Use TCP Wrappers to control access to either FTP daemon as outlined in Section 4.4.1, “Securing Services With TCP Wrappers and xinetd”.

4.3.10. Securing Postfix

Postfix is a Mail Transfer Agent (MTA) that uses the Simple Mail Transfer Protocol (SMTP) to deliver electronic messages between other MTAs and to email clients or delivery agents. Although many MTAs are capable of encrypting traffic between one another, most do not, so sending email over any public networks is considered an inherently insecure form of communication. Postfix replaces Sendmail as the default MTA in Red Hat Enterprise Linux 7.

It is recommended that anyone planning to implement a Postfix server address the following issues.

4.3.10.1. Limiting a Denial of Service Attack

Because of the nature of email, a determined attacker can flood the server with mail fairly easily and cause a denial of service. The effectiveness of such attacks can be limited by setting limits of the directives in the **/etc/postfix/main.cf** file. You can change the value of the directives which are already there or you can add the directives you need with the value you want in the following format:

```
<directive> = <value>
```

. The following is a list of directives that can be used for limiting a denial of service attack:

- **smtpd_client_connection_rate_limit** — The maximum number of connection attempts any client is allowed to make to this service per time unit (described below). The default value is 0, which means a client can make as many connections per time unit as Postfix can accept. By default, clients in trusted networks are excluded.

- **anvil_rate_time_unit** — This time unit is used for rate limit calculations. The default value is 60 seconds.
- **smtpd_client_event_limit_exceptions** — Clients that are excluded from the connection and rate limit commands. By default, clients in trusted networks are excluded.
- **smtpd_client_message_rate_limit** — The maximum number of message deliveries a client is allowed to request per time unit (regardless of whether or not Postfix actually accepts those messages).
- **default_process_limit** — The default maximum number of Postfix child processes that provide a given service. This limit can be overruled for specific services in the **master.cf** file. By default the value is 100.
- **queue_minfree** — The minimum amount of free space in bytes in the queue file system that is needed to receive mail. This is currently used by the Postfix SMTP server to decide if it will accept any mail at all. By default, the Postfix SMTP server rejects **MAIL FROM** commands when the amount of free space is less than 1.5 times the message_size_limit. To specify a higher minimum free space limit, specify a queue_minfree value that is at least 1.5 times the message_size_limit. By default the queue_minfree value is 0.
- **header_size_limit** — The maximum amount of memory in bytes for storing a message header. If a header is larger, the excess is discarded. By default the value is 102400.
- **message_size_limit** — The maximum size in bytes of a message, including envelope information. By default the value is 10240000.

4.3.10.2. NFS and Postfix

Never put the mail spool directory, **/var/spool/postfix/**, on an NFS shared volume. Because NFSv2 and NFSv3 do not maintain control over user and group IDs, two or more users can have the same UID, and receive and read each other's mail.

NOTE

With NFSv4 using Kerberos, this is not the case, since the **SECRPC_GSS** kernel module does not utilize UID-based authentication. However, it is still considered good practice *not* to put the mail spool directory on NFS shared volumes.

4.3.10.3. Mail-only Users

To help prevent local user exploits on the Postfix server, it is best for mail users to only access the Postfix server using an email program. Shell accounts on the mail server should not be allowed and all user shells in the **/etc/passwd** file should be set to **/sbin/nologin** (with the possible exception of the root user).

4.3.10.4. Disable Postfix Network Listening

By default, Postfix is set up to only listen to the local loopback address. You can verify this by viewing the file **/etc/postfix/main.cf**.

View the file **/etc/postfix/main.cf** to ensure that only the following ***inet_interfaces*** line appears:

```
inet_interfaces = localhost
```

This ensures that Postfix only accepts mail messages (such as cron job reports) from the local system and not from the network. This is the default setting and protects Postfix from a network attack.

For removal of the localhost restriction and allowing Postfix to listen on all interfaces the ***inet_interfaces = all*** setting can be used.

4.3.10.5. Configuring Postfix to Use SASL

The Red Hat Enterprise Linux 7 version of **Postfix** can use the **Dovecot** or **Cyrus SASL** implementations for *SMTP Authentication* (or *SMTP AUTH*). SMTP Authentication is an extension of the **Simple Mail Transfer Protocol**. When enabled, **SMTP** clients are required to authenticate to the **SMTP** server using an authentication method supported and accepted by both the server and the client. This section describes how to configure **Postfix** to make use of the **Dovecot SASL** implementation.

To install the **Dovecot POP**/**IMAP** server, and thus make the **Dovecot SASL** implementation available on your system, issue the following command as the **root** user:

```
~]# yum install dovecot
```

The **Postfix SMTP** server can communicate with the **Dovecot SASL** implementation using either a *UNIX-domain socket* or a *TCP socket*. The latter method is only needed in case the **Postfix** and **Dovecot** applications are running on separate machines. This guide gives preference to the UNIX-domain socket method, which affords better privacy.

In order to instruct **Postfix** to use the **Dovecot SASL** implementation, a number of configuration changes need to be performed for both applications. Follow the procedures below to effect these changes.

Setting Up Dovecot

1. Modify the main **Dovecot** configuration file, **/etc/dovecot/conf.d/10-master.conf**, to include the following lines (the default configuration file already includes most of the relevant section, and the lines just need to be uncommented):

   ```
   service auth {
     unix_listener /var/spool/postfix/private/auth {
       mode = 0660
       user = postfix
       group = postfix
     }
   }
   ```

   The above example assumes the use of UNIX-domain sockets for communication between **Postfix** and **Dovecot**. It also assumes default settings of the **Postfix SMTP** server, which include the mail queue located in the **/var/spool/postfix/** directory, and the application running under the **postfix** user and group. In this way, read and write permissions are limited to the **postfix** user and group.

   Alternatively, you can use the following configuration to set up **Dovecot** to listen for **Postfix** authentication requests through **TCP**:

   ```
   service auth {
     inet_listener {
   ```

```
    port = 12345
  }
}
```

In the above example, replace **12345** with the number of the port you want to use.

2. Edit the **/etc/dovecot/conf.d/10-auth.conf** configuration file to instruct **Dovecot** to provide the **Postfix SMTP** server with the **plain** and **login** authentication mechanisms:

```
auth_mechanisms = plain login
```

Setting Up Postfix

In the case of **Postfix**, only the main configuration file, **/etc/postfix/main.cf**, needs to be modified. Add or edit the following configuration directives:

1. Enable SMTP Authentication in the **Postfix SMTP** server:

```
smtpd_sasl_auth_enable = yes
```

2. Instruct **Postfix** to use the **Dovecot SASL** implementation for SMTP Authentication:

```
smtpd_sasl_type = dovecot
```

3. Provide the authentication path relative to the **Postfix** queue directory (note that the use of a relative path ensures that the configuration works regardless of whether the **Postfix** server runs in a **chroot** or not):

```
smtpd_sasl_path = private/auth
```

This step assumes that you want to use UNIX-domain sockets for communication between **Postfix** and **Dovecot**. To configure **Postfix** to look for **Dovecot** on a different machine in case you use **TCP** sockets for communication, use configuration values similar to the following:

```
smtpd_sasl_path = inet:127.0.0.1:12345
```

In the above example, **127.0.0.1** needs to be substituted by the **IP** address of the **Dovecot** machine and **12345** by the port specified in **Dovecot**'s **/etc/dovecot/conf.d/10-master.conf** configuration file.

4. Specify **SASL** mechanisms that the **Postfix SMTP** server makes available to clients. Note that different mechanisms can be specified for encrypted and unencrypted sessions.

```
smtpd_sasl_security_options = noanonymous, noplaintext
smtpd_sasl_tls_security_options = noanonymous
```

The above example specifies that during unencrypted sessions, no anonymous authentication is allowed and no mechanisms that transmit unencrypted user names or passwords are allowed. For encrypted sessions (using **TLS**), only non-anonymous authentication mechanisms are allowed.

See http://www.postfix.org/SASL_README.html#smtpd_sasl_security_options for a list of all supported policies for limiting allowed **SASL** mechanisms.

Additional Resources
The following online resources provide additional information useful for configuring **Postfix** SMTP Authentication through **SASL**.

- http://wiki2.dovecot.org/HowTo/PostfixAndDovecotSASL — Contains information on how to set up **Postfix** to use the **Dovecot SASL** implementation for SMTP Authentication.
- http://www.postfix.org/SASL_README.html#server_sasl — Contains information on how to set up **Postfix** to use either the **Dovecot** or **Cyrus SASL** implementations for SMTP Authentication.

4.3.11. Securing SSH

Secure Shell (SSH) is a powerful network protocol used to communicate with another system over a secure channel. The transmissions over **SSH** are encrypted and protected from interception. See the OpenSSH chapter of the Red Hat Enterprise Linux 7 System Administrator's Guide for general information about the **SSH** protocol and about using the **SSH** service in Red Hat Enterprise Linux 7.

IMPORTANT

This section draws attention to the most common ways of securing an **SSH** setup. By no means should this list of suggested measures be considered exhaustive or definitive. See **sshd_config(5)** for a description of all configuration directives available for modifying the behavior of the **sshd** daemon and to **ssh(1)** for an explanation of basic **SSH** concepts.

4.3.11.1. Cryptographic Login

SSH supports the use of cryptographic keys for logging in to computers. This is much more secure than using only a password. If you combine this method with other authentication methods, it can be considered a multi-factor authentication. See Section 4.3.11.2, “Multiple Authentication Methods” for more information about using multiple authentication methods.

In order to enable the use of cryptographic keys for authentication, the **PubkeyAuthentication** configuration directive in the **/etc/ssh/sshd_config** file needs to be set to **yes**. Note that this is the default setting. Set the **PasswordAuthentication** directive to **no** to disable the possibility of using passwords for logging in.

SSH keys can be generated using the **ssh-keygen** command. If invoked without additional arguments, it creates a 2048-bit RSA key set. The keys are stored, by default, in the **~/.ssh/** directory. You can utilize the **-b** switch to modify the bit-strength of the key. Using 2048-bit keys is normally sufficient. The Configuring OpenSSH chapter in the Red Hat Enterprise Linux 7 System Administrator's Guide includes detailed information about generating key pairs.

You should see the two keys in your **~/.ssh/** directory. If you accepted the defaults when running the **ssh-keygen** command, then the generated files are named **id_rsa** and **id_rsa.pub** and contain the private and public key respectively. You should always protect the private key from exposure by making it unreadable by anyone else but the file's owner. The public key, however, needs to be transferred to the system you are going to log in to. You can use the **ssh-copy-id** command to transfer the key to the server:

```
~]$ ssh-copy-id -i [user@]server
```

This command will also automatically append the public key to the **~/.ssh/authorized_keys** file on the *server*. The **sshd** daemon will check this file when you attempt to log in to the server.

Similarly to passwords and any other authentication mechanism, you should change your **SSH** keys regularly. When you do, make sure you remove any unused keys from the **authorized_keys** file.

4.3.11.2. Multiple Authentication Methods

Using multiple authentication methods, or multi-factor authentication, increases the level of protection against unauthorized access, and as such should be considered when hardening a system to prevent it from being compromised. Users attempting to log in to a system that uses multi-factor authentication must successfully complete all specified authentication methods in order to be granted access.

Use the **AuthenticationMethods** configuration directive in the **/etc/ssh/sshd_config** file to specify which authentication methods are to be utilized. Note that it is possible to define more than one list of required authentication methods using this directive. If that is the case, the user must complete every method in at least one of the lists. The lists need to be separated by blank spaces, and the individual authentication-method names within the lists must be comma-separated. For example:

```
AuthenticationMethods publickey,gssapi-with-mic publickey,keyboard-
interactive
```

An **sshd** daemon configured using the above **AuthenticationMethods** directive only grants access if the user attempting to log in successfully completes either **publickey** authentication followed by **gssapi-with-mic** or by **keyboard-interactive** authentication. Note that each of the requested authentication methods needs to be explicitly enabled using a corresponding configuration directive (such as **PubkeyAuthentication**) in the **/etc/ssh/sshd_config** file. See the *AUTHENTICATION* section of **ssh(1)** for a general list of available authentication methods.

4.3.11.3. Other Ways of Securing SSH

Protocol Version
Even though the implementation of the **SSH** protocol supplied with Red Hat Enterprise Linux 7 still supports both the SSH-1 and SSH-2 versions of the protocol for SSH clients, only the latter should be used whenever possible. The SSH-2 version contains a number of improvements over the older SSH-1, and the majority of advanced configuration options is only available when using SSH-2.

Red Hat recommends using SSH-2 to maximize the extent to which the **SSH** protocol protects the authentication and communication for which it is used. The version or versions of the protocol supported by the **sshd** daemon can be specified using the **Protocol** configuration directive in the **/etc/ssh/sshd_config** file. The default setting is **2**. Note that the SSH-2 version is the only version supported by the Red Hat Enterprise Linux 7 SSH server.

Key Types
While the **ssh-keygen** command generates a pair of SSH-2 RSA keys by default, using the **-t** option, it can be instructed to generate DSA or ECDSA keys as well. The ECDSA (Elliptic Curve Digital Signature Algorithm) offers better performance at the same equivalent symmetric key length. It also generates shorter keys.

Non-Default Port
By default, the **sshd** daemon listens on TCP port **22**. Changing the port reduces the exposure of the system to attacks based on automated network scanning, thus increasing security through obscurity. The port can be specified using the **Port** directive in the **/etc/ssh/sshd_config** configuration file. Note also that the default SELinux policy must be changed to allow for the use of a non-default port. You can do this by modifying the **ssh_port_t** SELinux type by typing the following command as **root**:

```
~]# semanage -a -t ssh_port_t -p tcp port_number
```

In the above command, replace *port_number* with the new port number specified using the **Port** directive.

No Root Login
Provided that your particular use case does not require the possibility of logging in as the **root** user, you should consider setting the **PermitRootLogin** configuration directive to **no** in the **/etc/ssh/sshd_config** file. By disabling the possibility of logging in as the **root** user, the administrator can audit which user runs what privileged command after they log in as regular users and then gain **root** rights.

Using the X Security extension
The X server in Red Hat Enterprise Linux 7 clients does not provide the X Security extension. Therefore clients cannot request another security layer when connecting to untrusted SSH servers with X11 forwarding. The most applications were not able to run with this extension enabled anyway. By default, the **ForwardX11Trusted** option in the **/etc/ssh/ssh_config** file is set to **yes**, and there is no difference between the **ssh -X *remote_machine*** (untrusted host) and **ssh -Y *remote_machine*** (trusted host) command.

WARNING

Red Hat recommends not using X11 forwarding while connecting to untrusted hosts.

4.3.12. Securing PostgreSQL

PostgreSQL is an Object-Relational database management system (DBMS). In Red Hat Enterprise Linux 7, the **postgresql-server** package provides **PostgreSQL**. If it is not installed, enter the following command as the root user to install it:

```
~]# yum install postgresql-server
```

Before you can start using **PostgreSQL**, you must initialize a database storage area on disk. This is called a database cluster. To initialize a database cluster, use the command initdb, which is installed with **PostgreSQL**. The desired file system location of your database cluster is indicated by the **-D** option. For example:

```
~]$ initdb -D /home/postgresql/db1
```

The **initdb** command will attempt to create the directory you specify if it does not already exist. We use the name */home/postgresql/db1* in this example. The */home/postgresql/db1* directory contains all the data stored in the database and also the client authentication configuration file:

```
~]$ cat pg_hba.conf
# PostgreSQL Client Authentication Configuration File
# This file controls: which hosts are allowed to connect, how clients
# are authenticated, which PostgreSQL user names they can use, which
# databases they can access.  Records take one of these forms:
#
# local      DATABASE  USER  METHOD  [OPTIONS]
```

```
# host       DATABASE  USER  ADDRESS  METHOD  [OPTIONS]
# hostssl    DATABASE  USER  ADDRESS  METHOD  [OPTIONS]
# hostnossl  DATABASE  USER  ADDRESS  METHOD  [OPTIONS]
```

The following line in the **pg_hba.conf** file allows any authenticated local users to access any databases with their user names:

```
local   all             all                                     trust
```

This can be problematic when you use layered applications that create database users and no local users. If you do not want to explicitly control all user names on the system, remove this line from the **pg_hba.conf** file.

4.3.13. Securing Docker

Docker is an open source project that automates the deployment of applications inside Linux Containers, and provides the capability to package an application with its runtime dependencies into a container. To make your **Docker** workflow more secure, follow procedures in the Red Hat Enterprise Linux Atomic Host 7 Container Security Guide.

4.4. SECURING NETWORK ACCESS

4.4.1. Securing Services With TCP Wrappers and xinetd

TCP Wrappers are capable of much more than denying access to services. This section illustrates how they can be used to send connection banners, warn of attacks from particular hosts, and enhance logging functionality. See the hosts_options(5) man page for information about the TCP Wrapper functionality and control language. See the xinetd.conf(5) man page for the available flags, which act as options you can apply to a service.

4.4.1.1. TCP Wrappers and Connection Banners

Displaying a suitable banner when users connect to a service is a good way to let potential attackers know that the system administrator is being vigilant. You can also control what information about the system is presented to users. To implement a TCP Wrappers banner for a service, use the **banner** option.

This example implements a banner for **vsftpd**. To begin, create a banner file. It can be anywhere on the system, but it must have same name as the daemon. For this example, the file is called **/etc/banners/vsftpd** and contains the following lines:

```
220-Hello, %c
220-All activity on ftp.example.com is logged.
220-Inappropriate use will result in your access privileges being removed.
```

The **%c** token supplies a variety of client information, such as the user name and host name, or the user name and IP address to make the connection even more intimidating.

For this banner to be displayed to incoming connections, add the following line to the **/etc/hosts.allow** file:

```
vsftpd : ALL : banners /etc/banners/
```

4.4.1.2. TCP Wrappers and Attack Warnings

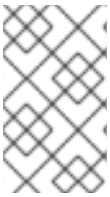
If a particular host or network has been detected attacking the server, TCP Wrappers can be used to warn the administrator of subsequent attacks from that host or network using the **spawn** directive.

In this example, assume that a cracker from the 206.182.68.0/24 network has been detected attempting to attack the server. Place the following line in the **/etc/hosts.deny** file to deny any connection attempts from that network, and to log the attempts to a special file:

```
ALL : 206.182.68.0 : spawn /bin/echo `date` %c %d >>
/var/log/intruder_alert
```

The **%d** token supplies the name of the service that the attacker was trying to access.

To allow the connection and log it, place the **spawn** directive in the **/etc/hosts.allow** file.



NOTE

Because the **spawn** directive executes any shell command, it is a good idea to create a special script to notify the administrator or execute a chain of commands in the event that a particular client attempts to connect to the server.

4.4.1.3. TCP Wrappers and Enhanced Logging

If certain types of connections are of more concern than others, the log level can be elevated for that service using the **severity** option.

For this example, assume that anyone attempting to connect to port 23 (the Telnet port) on an FTP server is a cracker. To denote this, place an **emerg** flag in the log files instead of the default flag, **info**, and deny the connection.

To do this, place the following line in **/etc/hosts.deny**:

```
in.telnetd : ALL : severity emerg
```

This uses the default **authpriv** logging facility, but elevates the priority from the default value of **info** to **emerg**, which posts log messages directly to the console.

4.4.2. Verifying Which Ports Are Listening

It is important to close unused ports to avoid possible attacks. For unexpected ports in listening state, you should investigate for possible signs of intrusion.

Using netstat for Open Ports Scan

Enter the following command as **root** to determine which ports are listening for connections from the network:

```
~]# netstat -pan -A inet,inet6 | grep -v ESTABLISHED
Active Internet connections (servers and established)
Proto Recv-Q Send-Q Local Address       Foreign Address    State
PID/Program name
Active Internet connections (servers and established)
Proto Recv-Q Send-Q Local Address           Foreign Address         State
PID/Program name
```

```
tcp        0      0 0.0.0.0:111             0.0.0.0:*
LISTEN      1/systemd
tcp        0      0 192.168.124.1:53        0.0.0.0:*
LISTEN      1829/dnsmasq
tcp        0      0 0.0.0.0:22              0.0.0.0:*
LISTEN      1176/sshd
tcp        0      0 127.0.0.1:631           0.0.0.0:*
LISTEN      1177/cupsd
tcp6       0      0 :::111                  :::*
LISTEN      1/systemd
tcp6       0      0 ::1:25                  :::*
LISTEN      1664/master
sctp             0.0.0.0:2500
LISTEN   20985/sctp_darn
udp        0      0 192.168.124.1:53        0.0.0.0:*
1829/dnsmasq
udp        0      0 0.0.0.0:67              0.0.0.0:*
977/dhclient
...
```

Use the **-l** option of the **netstat** command to display only listening server sockets:

```
~]# netstat -tlnw
Active Internet connections (only servers)
Proto Recv-Q Send-Q Local Address           Foreign Address         State
tcp        0      0 0.0.0.0:111             0.0.0.0:*
LISTEN
tcp        0      0 192.168.124.1:53        0.0.0.0:*
LISTEN
tcp        0      0 0.0.0.0:22              0.0.0.0:*
LISTEN
tcp        0      0 127.0.0.1:631           0.0.0.0:*
LISTEN
tcp        0      0 127.0.0.1:25            0.0.0.0:*
LISTEN
tcp6       0      0 :::111                  :::*
LISTEN
tcp6       0      0 :::22                   :::*
LISTEN
tcp6       0      0 ::1:631                 :::*
LISTEN
tcp6       0      0 ::1:25                  :::*
LISTEN
raw6       0      0 :::58                   :::*                    7
```

Using ss for Open Ports Scan

Alternatively, use the **ss** utility to list open ports in the listening state. It can display more TCP and state information than **netstat**.

```
~]# ss -tlw
etid State      Recv-Q Send-Q     Local Address:Port
Peer Address:Port
udp   UNCONN     0      0                    :::ipv6-icmp
:::*
tcp   LISTEN     0      128                   *:sunrpc
```

```
*:*
tcp   LISTEN     0      5          192.168.124.1:domain
*:*
tcp   LISTEN     0      128                 *:ssh
*:*
tcp   LISTEN     0      128            127.0.0.1:ipp
*:*
tcp   LISTEN     0      100            127.0.0.1:smtp
*:*
tcp   LISTEN     0      128                :::sunrpc
:::*
tcp   LISTEN     0      128                :::ssh
:::*
tcp   LISTEN     0      128               ::1:ipp
:::*
tcp   LISTEN     0      100               ::1:smtp
:::*
```

```
~]# ss -plno -A tcp,udp,sctp
Netid State      Recv-Q Send-Q       Local Address:Port
Peer Address:Port
udp   UNCONN     0      0            192.168.124.1:53
*:*                   users:(("dnsmasq",pid=1829,fd=5))
udp   UNCONN     0      0                *%virbr0:67
*:*                   users:(("dnsmasq",pid=1829,fd=3))
udp   UNCONN     0      0                        *:68
*:*                   users:(("dhclient",pid=977,fd=6))
...
tcp   LISTEN     0      5            192.168.124.1:53
*:*                   users:(("dnsmasq",pid=1829,fd=6))
tcp   LISTEN     0      128                      *:22
*:*                   users:(("sshd",pid=1176,fd=3))
tcp   LISTEN     0      128              127.0.0.1:631
*:*                   users:(("cupsd",pid=1177,fd=12))
tcp   LISTEN     0      100              127.0.0.1:25
*:*                   users:(("master",pid=1664,fd=13))
...
sctp  LISTEN     0      5                        *:2500
*:*                   users:(("sctp_darn",pid=20985,fd=3))
```

The **UNCONN** state shows the ports in UDP listening mode.

Make a scan for every IP address shown in the **ss** output (except for localhost 127.0.0.0 or ::1 range) from an external system. Use the **-6** option for scanning an IPv6 address.

Proceed then to make external checks using the **nmap** tool from another remote machine connected through the network to the first system. This can be used to verify rules in **firewalld**. The following is an example to determine which ports are listening for TCP connections:

```
~]# nmap -sT -O 192.168.122.65
    Starting Nmap 6.40 ( http://nmap.org ) at 2017-03-27 09:30 CEST
    Nmap scan report for 192.168.122.65
    Host is up (0.00032s latency).
    Not shown: 998 closed ports
    PORT    STATE SERVICE
```

```
    22/tcp  open  ssh
    111/tcp open  rpcbind
    Device type: general purpose
    Running: Linux 3.X
    OS CPE: cpe:/o:linux:linux_kernel:3
    OS details: Linux 3.7 - 3.9
    Network Distance: 0 hops

    OS detection performed. Please report any incorrect results at
http://nmap.org/submit/ .
    Nmap done: 1 IP address (1 host up) scanned in 1.79 seconds
```

The TCP connect scan **(-sT)** is the default TCP scan type when the TCP SYN scan **(-sS)** is not an option. The **-O** option detects the operating system of the host.

Using netstat and ss to Scan for Open SCTP Ports

The **netstat** utility prints information about the Linux networking subsystem. To display protocol statistics for open Stream Control Transmission Protocol (SCTP) ports, enter the following command as **root**:

```
~]# netstat -plnS
Active Internet connections (only servers)
Proto Recv-Q Send-Q Local Address   Foreign Address  State    PID/Program
name
sctp                127.0.0.1:250                   LISTEN
4125/sctp_darn
sctp       0      0 127.0.0.1:260   127.0.0.1:250    CLOSE
4250/sctp_darn
sctp       0      0 127.0.0.1:250   127.0.0.1:260    LISTEN
4125/sctp_darn
```

```
~]# netstat -nl -A inet,inet6 | grep 2500
sctp                0.0.0.0:2500
LISTEN
```

The **ss** utility is also able to show SCTP open ports:

```
~]# ss -an | grep 2500
sctp   LISTEN     0      5         *:2500                  *:*
```

See the ss(8), netstat(8), nmap(1), and services(5) manual pages for more information.

4.4.3. Disabling Source Routing

Source routing is an Internet Protocol mechanism that allows an IP packet to carry information, a list of addresses, that tells a router the path the packet must take. There is also an option to record the hops as the route is traversed. The list of hops taken, the "route record", provides the destination with a return path to the source. This allows the source (the sending host) to specify the route, loosely or strictly, ignoring the routing tables of some or all of the routers. It can allow a user to redirect network traffic for malicious purposes. Therefore, source-based routing should be disabled.

The **accept_source_route** option causes network interfaces to accept packets with the *Strict Source Routing* (SSR) or *Loose Source Routing* (LSR) option set. The acceptance of source routed packets is controlled by sysctl settings. Issue the following command as root to drop packets with the SSR or LSR option set:

```
~]# /sbin/sysctl -w net.ipv4.conf.all.accept_source_route=0
```

Disabling the forwarding of packets should also be done in conjunction with the above when possible (disabling forwarding may interfere with virtualization). Issue the commands listed below as root:

These commands disable forwarding of IPv4 and IPv6 packets on all interfaces:

```
~]# /sbin/sysctl -w net.ipv4.conf.all.forwarding=0
```

```
~]# /sbin/sysctl -w net.ipv6.conf.all.forwarding=0
```

These commands disable forwarding of all multicast packets on all interfaces:

```
~]# /sbin/sysctl -w net.ipv4.conf.all.mc_forwarding=0
```

```
~]# /sbin/sysctl -w net.ipv6.conf.all.mc_forwarding=0
```

Accepting ICMP redirects has few legitimate uses. Disable the acceptance and sending of ICMP redirected packets unless specifically required.

These commands disable acceptance of all ICMP redirected packets on all interfaces:

```
~]# /sbin/sysctl -w net.ipv4.conf.all.accept_redirects=0
```

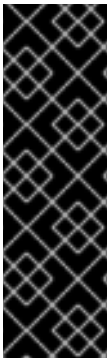
```
~]# /sbin/sysctl -w net.ipv6.conf.all.accept_redirects=0
```

This command disables acceptance of secure ICMP redirected packets on all interfaces:

```
~]# /sbin/sysctl -w net.ipv4.conf.all.secure_redirects=0
```

This command disables acceptance of all IPv4 ICMP redirected packets on all interfaces:

```
~]# /sbin/sysctl -w net.ipv4.conf.all.send_redirects=0
```



IMPORTANT

Sending of ICMP redirects remains active if at least one of the net.ipv4.conf.all.send_redirects or net.ipv4.conf.*interface*.send_redirects options is set to enabled. Ensure that you set the net.ipv4.conf.*interface*.send_redirects option to the **0** value for every *interface*. To automatically disable sending of ICMP requests whenever you add a new interface, enter the following command:

```
~]# /sbin/sysctl -w net.ipv4.conf.default.send_redirects=0
```

There is only a directive to disable sending of IPv4 redirected packets. See RFC4294 for an explanation of “IPv6 Node Requirements” which resulted in this difference between IPv4 and IPv6.

NOTE

To make these settings persistent across reboots, modify the **/etc/sysctl.conf** file. For example, to disable acceptance of all IPv4 ICMP redirected packets on all interfaces, open the **/etc/sysctl.conf** file with an editor running as the **root** user and add a line as follows:

```
net.ipv4.conf.all.send_redirects=0
```

See the sysctl man page, **sysctl(8)**, for more information. See RFC791 for an explanation of the Internet options related to source based routing and its variants.

WARNING

Ethernet networks provide additional ways to redirect traffic, such as ARP or MAC address spoofing, unauthorized DHCP servers, and IPv6 router or neighbor advertisements. In addition, unicast traffic is occasionally broadcast, causing information leaks. These weaknesses can only be addressed by specific countermeasures implemented by the network operator. Host-based countermeasures are not fully effective.

4.4.3.1. Reverse Path Forwarding

Reverse Path Forwarding is used to prevent packets that arrived through one interface from leaving through a different interface. When outgoing routes and incoming routes are different, it is sometimes referred to as *asymmetric routing*. Routers often route packets this way, but most hosts should not need to do this. Exceptions are such applications that involve sending traffic out over one link and receiving traffic over another link from a different service provider. For example, using leased lines in combination with xDSL or satellite links with 3G modems. If such a scenario is applicable to you, then turning off reverse path forwarding on the incoming interface is necessary. In short, unless you know that it is required, it is best enabled as it prevents users spoofing **IP** addresses from local subnets and reduces the opportunity for DDoS attacks.

NOTE

Red Hat Enterprise Linux 7 defaults to using *Strict Reverse Path Forwarding* following the Strict Reverse Path recommendation from RFC 3704, Ingress Filtering for Multihomed Networks..

WARNING

If forwarding is enabled, then Reverse Path Forwarding should only be disabled if there are other means for source-address validation (such as **iptables** rules for example).

rp_filter

Reverse Path Forwarding is enabled by means of the **rp_filter** directive. The **sysctl** utility can be used to make changes to the running system, and permanent changes can be made by adding lines to the **/etc/sysctl.conf** file. The **rp_filter** option is used to direct the kernel to select from one of three modes.

To make a temporary global change, enter the following commands as **root**:

```
sysctl -w  net.ipv4.conf.default.rp_filter=integer
sysctl -w net.ipv4.conf.all.rp_filter=integer
```

where *integer* is one of the following:

- **0** — No source validation.
- **1** — Strict mode as defined in RFC 3704.
- **2** — Loose mode as defined in RFC 3704.

The setting can be overridden per network interface using the **net.ipv4.conf.*interface*.rp_filter** command as follows:

```
sysctl -w net.ipv4.conf.interface.rp_filter=integer
```

NOTE

To make these settings persistent across reboots, modify the **/etc/sysctl.conf** file. For example, to change the mode for all interfaces, open the **/etc/sysctl.conf** file with an editor running as the **root** user and add a line as follows:

```
net.ipv4.conf.all.rp_filter=2
```

IPv6_rpfilter

In case of the **IPv6** protocol the **firewalld** daemon applies to Reverse Path Forwarding by default. The setting can be checked in the **/etc/firewalld/firewalld.conf** file. You can change the **firewalld** behavior by setting the **IPv6_rpfilter** option.

If you need a custom configuration of Reverse Path Forwarding, you can perform it *without* the **firewalld** daemon by using the **ip6tables** command as follows:

```
ip6tables -t raw -I PREROUTING -m rpfilter --invert -j DROP
```

This rule should be inserted near the beginning of the raw/PREROUTING chain, so that it applies to all traffic, in particular before the stateful matching rules. For more information about the **iptables** and **ip6tables** services, see Section 5.13, “Setting and Controlling IP sets using **iptables**”.

Enabling Packet Forwarding

To enable packets arriving from outside of a system to be forwarded to another external host, IP forwarding must be enabled in the kernel. Log in as **root** and change the line which reads **net.ipv4.ip_forward = 0** in the **/etc/sysctl.conf** file to the following:

```
net.ipv4.ip_forward = 1
```

To load the changes from the **/etc/sysctl.conf** file, enter the following command:

```
/sbin/sysctl -p
```

To check if IP forwarding is turned on, issue the following command as **root**:

```
/sbin/sysctl net.ipv4.ip_forward
```

If the above command returns a **1**, then IP forwarding is enabled. If it returns a**0**, then you can turn it on manually using the following command:

```
/sbin/sysctl -w net.ipv4.ip_forward=1
```

4.4.3.2. Additional Resources

The following are resources which explain more about Reverse Path Forwarding.

- **Installed Documentation**

  /usr/share/doc/kernel-doc-*version*/Documentation/networking/ip-sysctl.txt - This file contains a complete list of files and options available in the directory. Before accessing the kernel documentation for the first time, enter the following command as **root**:

  ```
  ~]# yum install kernel-doc
  ```

- **Online Documentation**

  See RFC 3704 for an explanation of Ingress Filtering for Multihomed Networks.

4.5. SECURING DNS TRAFFIC WITH DNSSEC

4.5.1. Introduction to DNSSEC

DNSSEC is a set of *Domain Name System Security Extensions* (DNSSEC) that enables a **DNS** client to authenticate and check the integrity of responses from a **DNS** nameserver in order to verify their origin and to determine if they have been tampered with in transit.

4.5.2. Understanding DNSSEC

For connecting over the Internet, a growing number of websites now offer the ability to connect securely using **HTTPS**. However, before connecting to an **HTTPS** webserver, a **DNS** lookup must be performed, unless you enter the IP address directly. These **DNS** lookups are done insecurely and are subject to *man-in-the-middle* attacks due to lack of authentication. In other words, a **DNS** client cannot have confidence that the replies that appear to come from a given **DNS** nameserver are authentic and have not been tampered with. More importantly, a recursive nameserver cannot be sure that the records it obtains from other nameservers are genuine. The **DNS** protocol did not provide a mechanism for the client to ensure it

was not subject to a man-in-the-middle attack. DNSSEC was introduced to address the lack of authentication and integrity checks when resolving domain names using **DNS**. It does not address the problem of confidentiality.

Publishing DNSSEC information involves digitally signing **DNS** resource records as well as distributing public keys in such a way as to enable **DNS** resolvers to build a hierarchical chain of trust. Digital signatures for all **DNS** resource records are generated and added to the zone as digital signature resource records (RRSIG). The public key of a zone is added as a DNSKEY resource record. To build the hierarchical chain, hashes of the DNSKEY are published in the parent zone as *Delegation of Signing* (DS) resource records. To facilitate proof of non-existence, the *NextSECure* (NSEC) and NSEC3 resource records are used. In a DNSSEC signed zone, each *resource record set* (RRset) has a corresponding RRSIG resource record. Note that records used for delegation to a child zone (NS and glue records) are not signed; these records appear in the child zone and are signed there.

Processing DNSSEC information is done by resolvers that are configured with the root zone public key. Using this key, resolvers can verify the signatures used in the root zone. For example, the root zone has signed the DS record for `.com`. The root zone also serves NS and glue records for the `.com` name servers. The resolver follows this delegation and queries for the DNSKEY record of `.com` using these delegated name servers. The hash of the DNSKEY record obtained should match the DS record in the root zone. If so, the resolver will trust the obtained DNSKEY for `.com`. In the `.com` zone, the RRSIG records are created by the `.com` DNSKEY. This process is repeated similarly for delegations within `.com`, such as `redhat.com`. Using this method, a validating **DNS** resolver only needs to be configured with one root key while it collects many DNSKEYs from around the world during its normal operation. If a cryptographic check fails, the resolver will return SERVFAIL to the application.

DNSSEC has been designed in such a way that it will be completely invisible to applications not supporting DNSSEC. If a non-DNSSEC application queries a DNSSEC capable resolver, it will receive the answer without any of these new resource record types such as RRSIG. However, the DNSSEC capable resolver will still perform all cryptographic checks, and will still return a SERVFAIL error to the application if it detects malicious **DNS** answers. DNSSEC protects the integrity of the data between **DNS** servers (authoritative and recursive), it does not provide security between the application and the resolver. Therefore, it is important that the applications are given a secure transport to their resolver. The easiest way to accomplish that is to run a DNSSEC capable resolver on `localhost` and use `127.0.0.1` in `/etc/resolv.conf`. Alternatively a VPN connection to a remote **DNS** server could be used.

Understanding the Hotspot Problem

Wi-Fi Hotspots or VPNs rely on “DNS lies”: Captive portals tend to hijack **DNS** in order to redirect users to a page where they are required to authenticate (or pay) for the Wi-Fi service. Users connecting to a VPN often need to use an “internal only” **DNS** server in order to locate resources that do not exist outside the corporate network. This requires additional handling by software. For example, **dnssec-trigger** can be used to detect if a Hotspot is hijacking the **DNS** queries and **unbound** can act as a proxy nameserver to handle the DNSSEC queries.

Choosing a DNSSEC Capable Recursive Resolver

To deploy a DNSSEC capable recursive resolver, either **BIND** or **unbound** can be used. Both enable DNSSEC by default and are configured with the DNSSEC root key. To enable DNSSEC on a server, either will work however the use of **unbound** is preferred on mobile devices, such as notebooks, as it allows the local user to dynamically reconfigure the DNSSEC overrides required for Hotspots when using **dnssec-trigger**, and for VPNs when using **Libreswan**. The **unbound** daemon further supports the deployment of DNSSEC exceptions listed in the `etc/unbound/*.d/` directories which can be useful to both servers and mobile devices.

4.5.3. Understanding Dnssec-trigger

Once **unbound** is installed and configured in **/etc/resolv.conf**, all **DNS** queries from applications are processed by **unbound**. **dnssec-trigger** only reconfigures the **unbound** resolver when triggered to do so. This mostly applies to roaming client machines, such as laptops, that connect to different Wi-Fi networks. The process is as follows:

- **NetworkManager** "triggers" **dnssec-trigger** when a new **DNS** server is obtained through **DHCP**.
- **Dnssec-trigger** then performs a number of tests against the server and decides whether or not it properly supports DNSSEC.
- If it does, then **dnssec-trigger** reconfigures **unbound** to use that **DNS** server as a forwarder for all queries.
- If the tests fail, **dnssec-trigger** will ignore the new **DNS** server and try a few available fall-back methods.
- If it determines that an unrestricted port 53 (**UDP** and **TCP**) is available, it will tell **unbound** to become a full recursive **DNS** server without using any forwarder.
- If this is not possible, for example because port 53 is blocked by a firewall for everything except reaching the network's **DNS** server itself, it will try to use **DNS** to port 80, or **TLS** encapsulated **DNS** to port 443. Servers running **DNS** on port 80 and 443 can be configured in **/etc/dnssec-trigger/dnssec-trigger.conf**. Commented out examples should be available in the default configuration file.
- If these fall-back methods also fail, **dnssec-trigger** offers to either operate insecurely, which would bypass DNSSEC completely, or run in "cache only" mode where it will not attempt new **DNS** queries but will answer for everything it already has in the cache.

Wi-Fi Hotspots increasingly redirect users to a sign-on page before granting access to the Internet. During the probing sequence outlined above, if a redirection is detected, the user is prompted to ask if a login is required to gain Internet access. The **dnssec-trigger** daemon continues to probe for DNSSEC resolvers every ten seconds. See Section 4.5.8, "Using Dnssec-trigger" for information on using the **dnssec-trigger** graphical utility.

4.5.4. VPN Supplied Domains and Name Servers

Some types of VPN connections can convey a domain and a list of nameservers to use for that domain as part of the VPN tunnel setup. On **Red Hat Enterprise Linux**, this is supported by **NetworkManager**. This means that the combination of **unbound**, **dnssec-trigger**, and **NetworkManager** can properly support domains and name servers provided by VPN software. Once the VPN tunnel comes up, the local **unbound** cache is flushed for all entries of the domain name received, so that queries for names within the domain name are fetched fresh from the internal name servers reached using the VPN. When the VPN tunnel is terminated, the **unbound** cache is flushed again to ensure any queries for the domain will return the public IP addresses, and not the previously obtained private IP addresses. See Section 4.5.11, "Configuring DNSSEC Validation for Connection Supplied Domains".

4.5.5. Recommended Naming Practices

Red Hat recommends that both static and transient names match the *fully-qualified domain name* (FQDN) used for the machine in **DNS**, such as **host.example.com**.

The Internet Corporation for Assigned Names and Numbers (ICANN) sometimes adds previously unregistered Top-Level Domains (such as **.yourcompany**) to the public register. Therefore, Red Hat strongly recommends that you do not use a domain name that is not delegated to you, even on a private

network, as this can result in a domain name that resolves differently depending on network configuration. As a result, network resources can become unavailable. Using domain names that are not delegated to you also makes DNSSEC more difficult to deploy and maintain, as domain name collisions require manual configuration to enable DNSSEC validation. See the ICANN FAQ on domain name collision for more information on this issue.

4.5.6. Understanding Trust Anchors

In a hierarchical cryptographic system, a *trust anchor* is an authoritative entity which is assumed to be trustworthy. For example, in X.509 architecture, a root certificate is a trust anchor from which a chain of trust is derived. The trust anchor must be put in the possession of the trusting party beforehand to make path validation possible.

In the context of DNSSEC, a trust anchor consists of a **DNS** name and public key (or hash of the public key) associated with that name. It is expressed as a base 64 encoded key. It is similar to a certificate in that it is a means of exchanging information, including a public key, which can be used to verify and authenticate **DNS** records. RFC 4033 defines a trust anchor as a configured DNSKEY RR or DS RR hash of a DNSKEY RR. A validating security-aware resolver uses this public key or hash as a starting point for building the authentication chain to a signed DNS response. In general, a validating resolver will have to obtain the initial values of its trust anchors through some secure or trusted means outside the DNS protocol. Presence of a trust anchor also implies that the resolver should expect the zone to which the trust anchor points to be signed.

4.5.7. Installing DNSSEC

4.5.7.1. Installing unbound

In order to validate **DNS** using DNSSEC locally on a machine, it is necessary to install the **DNS** resolver **unbound** (or **bind**). It is only necessary to install **dnssec-trigger** on mobile devices. For servers, **unbound** should be sufficient although a forwarding configuration for the local domain might be required depending on where the server is located (LAN or Internet). **dnssec-trigger** will currently only help with the global public DNS zone. **NetworkManager**, **dhclient**, and VPN applications can often gather the domain list (and nameserver list as well) automatically, but not **dnssec-trigger** nor **unbound**.

To install **unbound** enter the following command as the **root** user:

```
~]# yum install unbound
```

4.5.7.2. Checking if unbound is Running

To determine whether the **unbound** daemon is running, enter the following command:

```
~]$ systemctl status unbound
 unbound.service - Unbound recursive Domain Name Server
   Loaded: loaded (/usr/lib/systemd/system/unbound.service; disabled)
   Active: active (running) since Wed 2013-03-13 01:19:30 CET; 6h ago
```

The **systemctl status** command will report **unbound** as **Active: inactive (dead)** if the **unbound** service is not running.

4.5.7.3. Starting unbound

To start the **unbound** daemon for the current session, enter the following command as the **root** user:

```
~]# systemctl start unbound
```

Run the **systemctl enable** command to ensure that **unbound** starts up every time the system boots:

```
~]# systemctl enable unbound
```

The **unbound** daemon allows configuration of local data or overrides using the following directories:

- The **/etc/unbound/conf.d** directory is used to add configurations for a specific domain name. This is used to redirect queries for a domain name to a specific **DNS** server. This is often used for sub-domains that only exist within a corporate WAN.
- The **/etc/unbound/keys.d** directory is used to add trust anchors for a specific domain name. This is required when an internal-only name is DNSSEC signed, but there is no publicly existing DS record to build a path of trust. Another use case is when an internal version of a domain is signed using a different DNSKEY than the publicly available name outside the corporate WAN.
- The **/etc/unbound/local.d** directory is used to add specific **DNS** data as a local override. This can be used to build blacklists or create manual overrides. This data will be returned to clients by **unbound**, but it will not be marked as DNSSEC signed.

NetworkManager, as well as some VPN software, may change the configuration dynamically. These configuration directories contain commented out example entries. For further information see the **unbound.conf(5)** man page.

4.5.7.4. Installing Dnssec-trigger

The **dnssec-trigger** application runs as a daemon, **dnssec-triggerd**. To install **dnssec-trigger** enter the following command as the **root** user:

```
~]# yum install dnssec-trigger
```

4.5.7.5. Checking if the Dnssec-trigger Daemon is Running

To determine whether **dnssec-triggerd** is running, enter the following command:

```
~]$ systemctl status dnssec-triggerd
systemctl status dnssec-triggerd.service
dnssec-triggerd.service - Reconfigure local DNS(SEC) resolver on network
change
   Loaded: loaded (/usr/lib/systemd/system/dnssec-triggerd.service;
enabled)
   Active: active (running) since Wed 2013-03-13 06:10:44 CET; 1h 41min
ago
```

The **systemctl status** command will report **dnssec-triggerd** as **Active: inactive (dead)** if the **dnssec-triggerd** daemon is not running. To start it for the current session enter the following command as the **root** user:

```
~]# systemctl start dnssec-triggerd
```

Run the **systemctl enable** command to ensure that **dnssec-triggerd** starts up every time the system boots:

```
~]# systemctl enable dnssec-triggerd
```

4.5.8. Using Dnssec-trigger

The **dnssec-trigger** application has a GNOME panel utility for displaying DNSSEC probe results and for performing DNSSEC probe requests on demand. To start the utility, press the **Super** key to enter the Activities Overview, type **DNSSEC** and then press **Enter**. An icon resembling a ships anchor is added to the message tray at the bottom of the screen. Press the round blue notification icon in the bottom right of the screen to reveal it. Right click the anchor icon to display a pop-up menu.

In normal operations **unbound** is used locally as the name server, and **resolv.conf** points to **127.0.0.1**. When you click **OK** on the **Hotspot Sign-On** panel this is changed. The **DNS** servers are queried from **NetworkManager** and put in **resolv.conf**. Now you can authenticate on the Hotspot's sign-on page. The anchor icon shows a big red exclamation mark to warn you that **DNS** queries are being made insecurely. When authenticated, **dnssec-trigger** should automatically detect this and switch back to secure mode, although in some cases it cannot and the user has to do this manually by selecting **Reprobe**.

Dnssec-trigger does not normally require any user interaction. Once started, it works in the background and if a problem is encountered it notifies the user by means of a pop-up text box. It also informs **unbound** about changes to the **resolv.conf** file.

4.5.9. Using dig With DNSSEC

To see whether DNSSEC is working, one can use various command line tools. The best tool to use is the **dig** command from the bind-utils package. Other tools that are useful are **drill** from the ldns package and **unbound-host** from the unbound package. The old **DNS** utilities **nslookup** and **host** are obsolete and should not be used.

To send a query requesting DNSSEC data using **dig**, the option **+dnssec** is added to the command, for example:

```
~]$ dig +dnssec whitehouse.gov
; <<>> DiG 9.9.3-rl.13207.22-P2-RedHat-9.9.3-4.P2.el7 <<>> +dnssec
whitehouse.gov
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 21388
;; flags: qr rd ra ad; QUERY: 1, ANSWER: 2, AUTHORITY: 0, ADDITIONAL: 1

;; OPT PSEUDOSECTION:
; EDNS: version: 0, flags: do; udp: 4096
;; QUESTION SECTION:
;whitehouse.gov.   IN A

;; ANSWER SECTION:
whitehouse.gov.  20 IN A 72.246.36.110
whitehouse.gov.  20 IN RRSIG A 7 2 20 20130825124016 20130822114016 8399
whitehouse.gov. BB8VHWEkIaKpaLprt3hq1GkjDROvkmjYTBxiGhuki/BJn3PoIGyrftxR
HH0377I0Lsybj/uZv5hL4UwWd/lw6Gn8GPikqhztAkgMxddMQ2IARP6p
wbMOKbSUuV6NGUT1WWwpbi+LelFMqQcAq3Se66iyH0Jem7HtgPEUE1Zc 3oI=

;; Query time: 227 msec
```

```
;; SERVER: 127.0.0.1#53(127.0.0.1)
;; WHEN: Thu Aug 22 22:01:52 EDT 2013
;; MSG SIZE  rcvd: 233
```

In addition to the A record, an RRSIG record is returned which contains the DNSSEC signature, as well as the inception time and expiration time of the signature. The **unbound** server indicated that the data was DNSSEC authenticated by returning the **ad** bit in the **flags:** section at the top.

If DNSSEC validation fails, the **dig** command would return a SERVFAIL error:

```
~]$ dig badsign-a.test.dnssec-tools.org
; <<>> DiG 9.9.3-rl.156.01-P1-RedHat-9.9.3-3.P1.el7 <<>> badsign-
a.test.dnssec-tools.org
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: SERVFAIL, id: 1010
;; flags: qr rd ra; QUERY: 1, ANSWER: 0, AUTHORITY: 0, ADDITIONAL: 1

;; OPT PSEUDOSECTION:
; EDNS: version: 0, flags:; udp: 4096
;; QUESTION SECTION:
;badsign-a.test.dnssec-tools.org. IN A

;; Query time: 1284 msec
;; SERVER: 127.0.0.1#53(127.0.0.1)
;; WHEN: Thu Aug 22 22:04:52 EDT 2013
;; MSG SIZE  rcvd: 60]
```

To request more information about the failure, DNSSEC checking can be disabled by specifying the **+cd** option to the **dig** command:

```
~]$ dig +cd +dnssec badsign-a.test.dnssec-tools.org
; <<>> DiG 9.9.3-rl.156.01-P1-RedHat-9.9.3-3.P1.el7 <<>> +cd +dnssec
badsign-a.test.dnssec-tools.org
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 26065
;; flags: qr rd ra cd; QUERY: 1, ANSWER: 2, AUTHORITY: 0, ADDITIONAL: 1

;; OPT PSEUDOSECTION:
; EDNS: version: 0, flags: do; udp: 4096
;; QUESTION SECTION:
;badsign-a.test.dnssec-tools.org. IN A

;; ANSWER SECTION:
badsign-a.test.dnssec-tools.org. 49 IN A 75.119.216.33
badsign-a.test.dnssec-tools.org. 49 IN RRSIG A 5 4 86400 20130919183720
20130820173720 19442 test.dnssec-tools.org.
E572dLKMvYB4cgTRyAHIKKEvdOP7tockQb7hXFNZKVbfXbZJOIDREJrr
zCgAfJ2hykfY0yJHAlnuQvM0s6xOnNBSvc2xLIybJdfTaN6kSR0YFdYZ
n2NpPctn2kUBn5UR1BJRin3Gqy20LZlZx2KD7cZBtieMsU/IunyhCSc0 kYw=

;; Query time: 1 msec
```

```
;; SERVER: 127.0.0.1#53(127.0.0.1)
;; WHEN: Thu Aug 22 22:06:31 EDT 2013
;; MSG SIZE  rcvd: 257
```

Often, DNSSEC mistakes manifest themselves by bad inception or expiration time, although in this example, the people at www.dnssec-tools.org have mangled this RRSIG signature on purpose, which we would not be able to detect by looking at this output manually. The error will show in the output of **`systemctl status unbound`** and the **unbound** daemon logs these errors to **syslog** as follows:

```
Aug 22 22:04:52 laptop unbound: [3065:0] info: validation failure badsign-
a.test.dnssec-tools.org. A IN
```

An example using **`unbound-host`**:

```
~]$ unbound-host -C /etc/unbound/unbound.conf -v whitehouse.gov
whitehouse.gov has address 184.25.196.110 (secure)
whitehouse.gov has IPv6 address 2600:1417:11:2:8800::fc4 (secure)
whitehouse.gov has IPv6 address 2600:1417:11:2:8000::fc4 (secure)
whitehouse.gov mail is handled by 105 mail1.eop.gov. (secure)
whitehouse.gov mail is handled by 110 mail5.eop.gov. (secure)
whitehouse.gov mail is handled by 105 mail4.eop.gov. (secure)
whitehouse.gov mail is handled by 110 mail6.eop.gov. (secure)
whitehouse.gov mail is handled by 105 mail2.eop.gov. (secure)
whitehouse.gov mail is handled by 105 mail3.eop.gov. (secure)
```

4.5.10. Setting up Hotspot Detection Infrastructure for Dnssec-trigger

When connecting to a network, **dnssec-trigger** attempts to detect a Hotspot. A Hotspot is generally a device that forces user interaction with a web page before they can use the network resources. The detection is done by attempting to download a specific fixed web page with known content. If there is a Hotspot, then the content received will not be as expected.

To set up a fixed web page with known content that can be used by **dnssec-trigger** to detect a Hotspot, proceed as follows:

1. Set up a web server on some machine that is publicly reachable on the Internet. See the Web Servers chapter in the Red Hat Enterprise Linux 7 System Administrator's Guide. .

2. Once you have the server running, publish a static page with known content on it. The page does not need to be a valid HTML page. For example, you could use a plain-text file named **`hotspot.txt`** that contains only the string **`OK`**. Assuming your server is located at **`example.com`** and you published your **`hotspot.txt`** file in the web server ***`document_root`*`/static/`** sub-directory, then the address to your static web page would be **`example.com/static/hotspot.txt`**. See the **`DocumentRoot`** directive in the Web Servers chapter in the Red Hat Enterprise Linux 7 System Administrator's Guide.

3. Add the following line to the **`/etc/dnssec-trigger/dnssec-trigger.conf`** file:

   ```
   url: "http://example.com/static/hotspot.txt OK"
   ```

   This command adds a URL that is probed using **`HTTP`** (port 80). The first part is the URL that will be resolved and the page that will be downloaded. The second part of the command is the text string that the downloaded webpage is expected to contain.

For more information on the configuration options see the man page **dnssec-trigger.conf(8)**.

4.5.11. Configuring DNSSEC Validation for Connection Supplied Domains

By default, forward zones with proper nameservers are automatically added into **unbound** by **dnssec-trigger** for every domain provided by any connection, except Wi-Fi connections through **NetworkManager**. By default, all forward zones added into **unbound** are DNSSEC validated.

The default behavior for validating forward zones can be altered, so that all forward zones will **not** be DNSSEC validated by default. To do this, change the **validate_connection_provided_zones** variable in the **dnssec-trigger** configuration file **/etc/dnssec.conf**. As **root** user, open and edit the line as follows:

```
validate_connection_provided_zones=no
```

The change is not done for any existing forward zones, but only for future forward zones. Therefore if you want to disable DNSSEC for the current provided domain, you need to reconnect.

4.5.11.1. Configuring DNSSEC Validation for Wi-Fi Supplied Domains

Adding forward zones for Wi-Fi provided zones can be enabled. To do this, change the **add_wifi_provided_zones** variable in the **dnssec-trigger** configuration file, **/etc/dnssec.conf**. As **root** user, open and edit the line as follows:

```
add_wifi_provided_zones=yes
```

The change is not done for any existing forward zones, but only for future forward zones. Therefore, if you want to enable DNSSEC for the current Wi-Fi provided domain, you need to reconnect (restart) the Wi-Fi connection.

WARNING

Turning **on** the addition of Wi-Fi provided domains as forward zones into **unbound** may have security implications such as:

1. A Wi-Fi access point can intentionally provide you a domain through **DHCP** for which it does not have authority and route all your **DNS** queries to its **DNS** servers.
2. If you have the DNSSEC validation of forward zones turned **off**, the Wi-Fi provided **DNS** servers can spoof the **IP** address for domain names from the provided domain without you knowing it.

4.5.12. Additional Resources

The following are resources which explain more about DNSSEC.

4.5.12.1. Installed Documentation

- **dnssec-trigger(8)** man page — Describes command options for **dnssec-triggerd**, **dnssec-trigger-control** and **dnssec-trigger-panel**.
- **dnssec-trigger.conf(8)** man page — Describes the configuration options for **dnssec-triggerd**.
- **unbound(8)** man page — Describes the command options for **unbound**, the **DNS** validating resolver.
- **unbound.conf(5)** man page — Contains information on how to configure **unbound**.
- **resolv.conf(5)** man page — Contains information that is read by the resolver routines.

4.5.12.2. Online Documentation

http://tools.ietf.org/html/rfc4033

RFC 4033 DNS Security Introduction and Requirements.

http://www.dnssec.net/

A website with links to many DNSSEC resources.

http://www.dnssec-deployment.org/

The DNSSEC Deployment Initiative, sponsored by the Department for Homeland Security, contains a lot of DNSSEC information and has a mailing list to discuss DNSSEC deployment issues.

http://www.internetsociety.org/deploy360/dnssec/community/

The Internet Society's “Deploy 360” initiative to stimulate and coordinate DNSSEC deployment is a good resource for finding communities and DNSSEC activities worldwide.

http://www.unbound.net/

This document contains general information about the **unbound DNS** service.

http://www.nlnetlabs.nl/projects/dnssec-trigger/

This document contains general information about **dnssec-trigger**.

4.6. SECURING VIRTUAL PRIVATE NETWORKS (VPNS) USING LIBRESWAN

In Red Hat Enterprise Linux 7, a *Virtual Private Network* (VPN) can be configured using the **IPsec** protocol which is supported by the **Libreswan** application. **Libreswan** is a continuation of the **Openswan** application and many examples from the **Openswan** documentation are interchangeable with **Libreswan**. The **NetworkManager IPsec** plug-in is called NetworkManager-libreswan. Users of GNOME Shell should install the NetworkManager-libreswan-gnome package, which has NetworkManager-libreswan as a dependency. Note that the NetworkManager-libreswan-gnome package is only available from the Optional channel. See Enabling Supplementary and Optional Repositories.

The **IPsec** protocol for VPN is itself configured using the *Internet Key Exchange* (IKE) protocol. The terms IPsec and IKE are used interchangeably. An IPsec VPN is also called an IKE VPN, IKEv2 VPN, XAUTH VPN, Cisco VPN or IKE/IPsec VPN. A variant of an IPsec VPN that also uses the *Level 2*

Tunneling Protocol (L2TP) is usually called an L2TP/IPsec VPN, which requires the Optional channel **xl2tpd** application.

Libreswan is an open-source, user-space **IKE** implementation available in Red Hat Enterprise Linux 7. **IKE** version 1 and 2 are implemented as a user-level daemon. The IKE protocol itself is also encrypted. The **IPsec** protocol is implemented by the Linux kernel and **Libreswan** configures the kernel to add and remove VPN tunnel configurations.

The **IKE** protocol uses UDP port 500 and 4500. The **IPsec** protocol consists of two different protocols, *Encapsulated Security Payload* (ESP) which has protocol number 50, and *Authenticated Header* (AH) which as protocol number 51. The **AH** protocol is not recommended for use. Users of **AH** are recommended to migrate to **ESP** with null encryption.

The **IPsec** protocol has two different modes of operation, **Tunnel Mode** (the default) and **Transport Mode**. It is possible to configure the kernel with IPsec without IKE. This is called **Manual Keying**. It is possible to configure manual keying using the **ip xfrm** commands, however, this is strongly discouraged for security reasons. **Libreswan** interfaces with the Linux kernel using netlink. Packet encryption and decryption happen in the Linux kernel.

Libreswan uses the *Network Security Services* (NSS) cryptographic library. Both libreswan and NSS are certified for use with the *Federal Information Processing Standard* (FIPS) Publication 140-2.

IMPORTANT

IKE/**IPsec** VPNs, implemented by **Libreswan** and the Linux kernel, is the only VPN technology recommended for use in Red Hat Enterprise Linux 7. Do not use any other VPN technology without understanding the risks of doing so.

4.6.1. Installing Libreswan

To install **Libreswan**, enter the following command as **root**:

```
~]# yum install libreswan
```

To check that **Libreswan** is installed:

```
~]$ yum info libreswan
```

After a new installation of **Libreswan**, the NSS database should be initialized as part of the installation process. Before you start a new database, remove the old database as follows:

```
~]# systemctl stop ipsec
~]# rm /etc/ipsec.d/*db
```

Then, to initialize a new NSS database, enter the following command as **root**:

```
~]# ipsec initnss
Initializing NSS database
```

Only when operating in FIPS mode, it is necessary to protect the NSS database with a password. To initialize the database for FIPS mode, instead of the previous command, use:

```
~]# certutil -N -d sql:/etc/ipsec.d
```

```
Enter a password which will be used to encrypt your keys.
The password should be at least 8 characters long,
and should contain at least one non-alphabetic character.

Enter new password:
Re-enter password:
```

To start the **ipsec** daemon provided by **Libreswan**, issue the following command as **root**:

```
~]# systemctl start ipsec
```

To confirm that the daemon is now running:

```
~]$ systemctl status ipsec
* ipsec.service - Internet Key Exchange (IKE) Protocol Daemon for IPsec
   Loaded: loaded (/usr/lib/systemd/system/ipsec.service; disabled; vendor
preset: disabled)
   Active: active (running) since Sun 2018-03-18 18:44:43 EDT; 3s ago
     Docs: man:ipsec(8)
           man:pluto(8)
           man:ipsec.conf(5)
  Process: 20358 ExecStopPost=/usr/sbin/ipsec --stopnflog (code=exited,
status=0/SUCCESS)
  Process: 20355 ExecStopPost=/sbin/ip xfrm state flush (code=exited,
status=0/SUCCESS)
  Process: 20352 ExecStopPost=/sbin/ip xfrm policy flush (code=exited,
status=0/SUCCESS)
  Process: 20347 ExecStop=/usr/libexec/ipsec/whack --shutdown
(code=exited, status=0/SUCCESS)
  Process: 20634 ExecStartPre=/usr/sbin/ipsec --checknflog (code=exited,
status=0/SUCCESS)
  Process: 20631 ExecStartPre=/usr/sbin/ipsec --checknss (code=exited,
status=0/SUCCESS)
  Process: 20369 ExecStartPre=/usr/libexec/ipsec/_stackmanager start
(code=exited, status=0/SUCCESS)
  Process: 20366 ExecStartPre=/usr/libexec/ipsec/addconn --config
/etc/ipsec.conf --checkconfig (code=exited, status=0/SUCCESS)
 Main PID: 20646 (pluto)
   Status: "Startup completed."
   CGroup: /system.slice/ipsec.service
           └─20646 /usr/libexec/ipsec/pluto --leak-detective --config
/etc/ipsec.conf --nofork
```

To ensure that **Libreswan** will start when the system starts, issue the following command as **root**:

```
~]# systemctl enable ipsec
```

Configure any intermediate as well as host-based firewalls to permit the **ipsec** service. See Chapter 5, *Using Firewalls* for information on firewalls and allowing specific services to pass through. **Libreswan** requires the firewall to allow the following packets:

- **UDP** port 500 and 4500 for the **Internet Key Exchange** (IKE) protocol
- Protocol 50 for **Encapsulated Security Payload** (ESP) **IPsec** packets

- Protocol 51 for **Authenticated Header** (AH) **IPsec** packets (uncommon)

We present three examples of using **Libreswan** to set up an **IPsec** VPN. The first example is for connecting two hosts together so that they may communicate securely. The second example is connecting two sites together to form one network. The third example is supporting remote users, known as *road warriors* in this context.

4.6.2. Creating VPN Configurations Using Libreswan

Libreswan does not use the terms “source” and “destination” or “server” and “client” since IKE/IPsec are peer to peer protocols. Instead, it uses the terms “left” and “right” to refer to end points (the hosts). This also allows the same configuration to be used on both end points in most cases, although a lot of administrators choose to always use “left” for the local host and “right” for the remote host.

There are four commonly used methods for authentication of endpoints:

- *Pre-Shared Keys* (PSK) is the simplest authentication method. PSKs should consist of random characters and have a length of at least 20 characters. In FIPS mode, PSKs need to comply to a minimum strength requirement depending on the integrity algorithm used. It is recommended not to use PSKs shorter than 64 random characters.

- Raw RSA keys are commonly used for static host-to-host or subnet-to-subnet **IPsec** configurations. The hosts are manually configured with each other's public RSA key. This method does not scale well when dozens or more hosts all need to setup **IPsec** tunnels to each other.

- X.509 certificates are commonly used for large-scale deployments where there are many hosts that need to connect to a common **IPsec** gateway. A central *certificate authority* (CA) is used to sign RSA certificates for hosts or users. This central CA is responsible for relaying trust, including the revocations of individual hosts or users.

- NULL Authentication is used to gain mesh encryption without authentication. It protects against passive attacks but does not protect against active attacks. However, since **IKEv2** allows asymmetrical authentication methods, NULL Authentication can also be used for internet scale Opportunistic IPsec, where clients authenticate the server, but servers do not authenticate the client. This model is similar to secure websites using **TLS** (also known as https:// websites).

In addition to these authentication methods, an additional authentication can be added to protect against possible attacks by quantum computers. This additional authentication method is called *Postquantum Preshared Keys* (PPK. Individual clients or groups of clients can use their own PPK by specifying a (PPKID that corresponds to an out-of-band configured PreShared Key. See Section 4.6.9, “Using the Protection against Quantum Computers”.

4.6.3. Creating Host-To-Host VPN Using Libreswan

To configure **Libreswan** to create a host-to-host **IPsec** VPN, between two hosts referred to as “left” and “right”, enter the following commands as **root** on both of the hosts (“left” and “right”) to create new raw RSA key pairs:

```
~]# ipsec newhostkey
Generated RSA key pair with CKAID 14936e48e756eb107fa1438e25a345b46d80433f
was stored in the NSS database
```

This generates an RSA key pair for the host. The process of generating RSA keys can take many minutes, especially on virtual machines with low entropy.

To view the host public key so it can be specified in a configuration as the “left” side, issue the following command as **root** on the host where the new hostkey was added, using the CKAID returned by the “newhostkey” command:

```
~]# ipsec showhostkey --left --ckaid
14936e48e756eb107fa1438e25a345b46d80433f
 # rsakey AQPFKElpV
 leftrsasigkey=0sAQPFKElpV2GdCF0Ux9Kqhcap53Kaa+uCgduoT2I3x6LkRK8N+GiVGkRH4
Xg+WMrzRb94kDDD8m/BO/Md+A30u0NjDk724jWuUU215rnpwvbdAob8pxYc4ReSgjQ/DkqQvse
moeF4kimMU1OBPNU7lBw4hTBFzu+iVUYMELwQSXpremLXHBNIamUbe5R1+ibgxO19l/PAbZwxy
GX/ueBMBvSQ+H0UqdGKbq7UgSEQTFa4/gqdYZDDzx55tpZk2Z3es+EWdURwJOgGiiiIFuBagas
HFpeu9Teb1VzRyytnyNiJCBVhWVqsB4h6eaQ9RpAMmqBdBeNHfXwb6/hg+JIKJgjidXvGtgWBY
NDpG40fEFh9USaFlSdiHO+dmGyZQ74Rg9sWLtiVdlH1YEBUtQb8f8FVry9wSn6AZqPlpGgUdtk
TYUCaaifsYH4hoIA0nku4Fy/Ugej89ZdrSN7Lt+igns4FysMmBOl9Wi9+LWnfl+dm4Nc6UNgLE
8kZc+8vMJGkLi4SYjk2/MFYgqGX/COxSCPBFUZFiNK7Wda0kWea/FqE1heem7rvKAPIiqMymjS
mytZI9hhkCD16pCdgrO3fJXsfAUChYYSPyPQClkavvBL/wNK9zlaOwssTaKTj4Xn90SrZaxTEj
pqUeQ==
```

You will need this key to add to the configuration file on both hosts as explained below. If you forgot the CKAID, you can obtain a list of all host keys on a machine using:

```
~]# ipsec showhostkey --list
< 1 >  RSA keyid: AQPFKElpV ckaid:
14936e48e756eb107fa1438e25a345b46d80433f
```

The secret part of the keypair is stored inside the “NSS database” which resides in **/etc/ipsec.d/*.db**.

To make a configuration file for this host-to-host tunnel, the lines **leftrsasigkey=** and **rightrsasigkey=** from above are added to a custom configuration file placed in the **/etc/ipsec.d/** directory.

Using an editor running as **root**, create a file with a suitable name in the following format:

```
/etc/ipsec.d/my_host-to-host.conf
```

Edit the file as follows:

```
conn mytunnel
    leftid=@west.example.com
    left=192.1.2.23
    leftrsasigkey=0sAQOrlo+hOafUZDlCQmXFrje/oZm [...]
W2n417C/4urYHQkCvuIQ==
    rightid=@east.example.com
    right=192.1.2.45
    rightrsasigkey=0sAQO3fwC6nSSGgt64DWiYZzuHbc4 [...] D/v8t5YTQ==
    authby=rsasig
    # load and initiate automatically
    auto=start
```

Public keys can also be configured by their CKAID instead of by their RSAID. In that case use “leftckaid=” instead of “leftrsasigkey=”

You can use the identical configuration file on both left and right hosts. Libreswan automatically detects if

it is “left” or “right” based on the specified IP addresses or hostnames. If one of the hosts is a mobile host, which implies the **IP** address is not known in advance, then on the mobile client use **%defaultroute** as its **IP** address. This will pick up the dynamic **IP** address automatically. On the static server host that accepts connections from incoming mobile hosts, specify the mobile host using **%any** for its **IP** address.

Ensure the **leftrsasigkey** value is obtained from the “left” host and the **rightrsasigkey** value is obtained from the “right” host. The same applies when using **leftckaid** and **rightckaid**.

Restart **ipsec** to ensure it reads the new configuration and if configured to start on boot, to confirm that the tunnels establish:

```
~]# systemctl restart ipsec
```

When using the **auto=start** option, the **IPsec** tunnel should be established within a few seconds. You can manually load and start the tunnel by entering the following commands as **root**:

```
~]# ipsec auto --add mytunnel
~]# ipsec auto --up mytunnel
```

4.6.3.1. Verifying Host-To-Host VPN Using Libreswan

The **IKE** negotiation takes place on **UDP** ports 500 and 4500. **IPsec** packets show up as **Encapsulated Security Payload** (ESP) packets. The **ESP** protocol has no ports. When the VPN connection needs to pass through a NAT router, the **ESP** packets are encapsulated in **UDP** packets on port 4500.

To verify that packets are being sent through the VPN tunnel, issue a command as **root** in the following format:

```
~]# tcpdump -n -i interface esp or udp port 500 or udp port 4500
00:32:32.632165 IP 192.1.2.45 > 192.1.2.23: ESP(spi=0x63ad7e17,seq=0x1a),
length 132
00:32:32.632592 IP 192.1.2.23 > 192.1.2.45: ESP(spi=0x4841b647,seq=0x1a),
length 132
00:32:32.632592 IP 192.0.2.254 > 192.0.1.254: ICMP echo reply, id 2489,
seq 7, length 64
00:32:33.632221 IP 192.1.2.45 > 192.1.2.23: ESP(spi=0x63ad7e17,seq=0x1b),
length 132
00:32:33.632731 IP 192.1.2.23 > 192.1.2.45: ESP(spi=0x4841b647,seq=0x1b),
length 132
00:32:33.632731 IP 192.0.2.254 > 192.0.1.254: ICMP echo reply, id 2489,
seq 8, length 64
00:32:34.632183 IP 192.1.2.45 > 192.1.2.23: ESP(spi=0x63ad7e17,seq=0x1c),
length 132
00:32:34.632607 IP 192.1.2.23 > 192.1.2.45: ESP(spi=0x4841b647,seq=0x1c),
length 132
00:32:34.632607 IP 192.0.2.254 > 192.0.1.254: ICMP echo reply, id 2489,
seq 9, length 64
00:32:35.632233 IP 192.1.2.45 > 192.1.2.23: ESP(spi=0x63ad7e17,seq=0x1d),
length 132
00:32:35.632685 IP 192.1.2.23 > 192.1.2.45: ESP(spi=0x4841b647,seq=0x1d),
```

```
length 132
00:32:35.632685 IP 192.0.2.254 > 192.0.1.254: ICMP echo reply, id 2489,
seq 10, length 64
```

Where *interface* is the interface known to carry the traffic. To end the capture with **tcpdump**, press **Ctrl**+**C**.

NOTE

The **tcpdump** command interacts a little unexpectedly with **IPsec**. It only sees the outgoing encrypted packet, not the outgoing plaintext packet. It does see the encrypted incoming packet, as well as the decrypted incoming packet. If possible, run **tcpdump** on a router between the two machines and not on one of the endpoints itself. When using the Virtual Tunnel Interface (VTI), tcpdump on the physical interface shows **ESP** packets, while tcpdump on the VTI interface shows the cleartext traffic.

Another easy way to see if a tunnel is up, and additionally see how much traffic has gone through the tunnel, issue the following command as **root**:

```
~]# ipsec whack --trafficstatus
006 #2: "mytunnel", type=ESP, add_time=1234567890, inBytes=336, out
Bytes=336, id='@east'
```

4.6.4. Configuring Site-to-Site VPN Using Libreswan

In order for **Libreswan** to create a site-to-site **IPsec** VPN, joining together two networks, an **IPsec** tunnel is created between two hosts, endpoints, which are configured to permit traffic from one or more subnets to pass through. They can therefore be thought of as gateways to the remote portion of the network. The configuration of the site-to-site VPN only differs from the host-to-host VPN in that one or more networks or subnets must be specified in the configuration file.

To configure **Libreswan** to create a site-to-site **IPsec** VPN, first configure a host-to-host **IPsec** VPN as described in Section 4.6.3, “Creating Host-To-Host VPN Using Libreswan” and then copy or move the file to a file with a suitable name, such as **/etc/ipsec.d/my_site-to-site.conf**. Using an editor running as **root**, edit the custom configuration file **/etc/ipsec.d/my_site-to-site.conf** as follows:

```
conn mysubnet
    also=mytunnel
    leftsubnet=192.0.1.0/24
    rightsubnet=192.0.2.0/24
    auto=start

conn mysubnet6
    also=mytunnel
    connaddrfamily=ipv6
    leftsubnet=2001:db8:0:1::/64
    rightsubnet=2001:db8:0:2::/64
    auto=start

conn mytunnel
    leftid=@west.example.com
    left=192.1.2.23
```

```
    leftrsasigkey=0sAQOrlo+hOafUZDlCQmXFrje/oZm [...]
W2n417C/4urYHQkCvuIQ==
    rightid=@east.example.com
    right=192.1.2.45
    rightrsasigkey=0sAQO3fwC6nSSGgt64DWiYZzuHbc4 [...] D/v8t5YTQ==
    authby=rsasig
```

To bring the tunnels up, restart **Libreswan** or manually load and initiate all the connections using the following commands as **root**:

```
~]# ipsec auto --add mysubnet
```

```
~]# ipsec auto --add mysubnet6
```

```
~]# ipsec auto --up mysubnet
104 "mysubnet" #1: STATE_MAIN_I1: initiate
003 "mysubnet" #1: received Vendor ID payload [Dead Peer Detection]
003 "mytunnel" #1: received Vendor ID payload [FRAGMENTATION]
106 "mysubnet" #1: STATE_MAIN_I2: sent MI2, expecting MR2
108 "mysubnet" #1: STATE_MAIN_I3: sent MI3, expecting MR3
003 "mysubnet" #1: received Vendor ID payload [CAN-IKEv2]
004 "mysubnet" #1: STATE_MAIN_I4: ISAKMP SA established
{auth=OAKLEY_RSA_SIG cipher=aes_128 prf=oakley_sha group=modp2048}
117 "mysubnet" #2: STATE_QUICK_I1: initiate
004 "mysubnet" #2: STATE_QUICK_I2: sent QI2, IPsec SA established tunnel
mode {ESP=>0x9414a615 <0x1a8eb4ef xfrm=AES_128-HMAC_SHA1 NATOA=none
NATD=none DPD=none}
```

```
~]# ipsec auto --up mysubnet6
003 "mytunnel" #1: received Vendor ID payload [FRAGMENTATION]
117 "mysubnet" #2: STATE_QUICK_I1: initiate
004 "mysubnet" #2: STATE_QUICK_I2: sent QI2, IPsec SA established tunnel
mode {ESP=>0x06fe2099 <0x75eaa862 xfrm=AES_128-HMAC_SHA1 NATOA=none
NATD=none DPD=none}
```

4.6.4.1. Verifying Site-to-Site VPN Using Libreswan

Verifying that packets are being sent through the VPN tunnel is the same procedure as explained in Section 4.6.3.1, “Verifying Host-To-Host VPN Using Libreswan”.

4.6.5. Configuring Site-to-Site Single Tunnel VPN Using Libreswan

Often, when a site-to-site tunnel is built, the gateways need to communicate with each other using their internal **IP** addresses instead of their public **IP** addresses. This can be accomplished using a single tunnel. If the left host, with host name **west**, has internal **IP** address **192.0.1.254** and the right host, with host name **east**, has internal **IP** address **192.0.2.254**, the following configuration using a single tunnel can be used:

```
conn mysubnet
    leftid=@west.example.com
    leftrsasigkey=0sAQOrlo+hOafUZDlCQmXFrje/oZm [...]
W2n417C/4urYHQkCvuIQ==
    left=192.1.2.23
```

```
    leftsourceip=192.0.1.254
    leftsubnet=192.0.1.0/24
    rightid=@east.example.com
    rightrsasigkey=0sAQO3fwC6nSSGgt64DWiYZzuHbc4 [...] D/v8t5YTQ==
    right=192.1.2.45
    rightsourceip=192.0.2.254
    rightsubnet=192.0.2.0/24
    auto=start
    authby=rsasig
```

4.6.6. Configuring Subnet Extrusion Using Libreswan

IPsec is often deployed in a hub-and-spoke architecture. Each leaf node has an **IP** range that is part of a larger range. Leaves communicate with each other through the hub. This is called *subnet extrusion*.

Example 4.2. Configuring Simple Subnet Extrusion Setup

In the following example, we configure the head office with **10.0.0.0/8** and two branches that use a smaller **/24** subnet.

At the head office:

```
conn branch1
    left=1.2.3.4
    leftid=@headoffice
    leftsubnet=0.0.0.0/0
    leftrsasigkey=0sA[...]
    #
    right=5.6.7.8
    rightid=@branch1
    rightsubnet=10.0.1.0/24
    rightrsasigkey=0sAXXXX[...]
    #
    auto=start
    authby=rsasig

conn branch2
    left=1.2.3.4
    leftid=@headoffice
    leftsubnet=0.0.0.0/0
    leftrsasigkey=0sA[...]
    #
    right=10.11.12.13
    rightid=@branch2
    rightsubnet=10.0.2.0/24
    rightrsasigkey=0sAYYYY[...]
    #
    auto=start
    authby=rsasig
```

At the “branch1” office, we use the same connection. Additionally, we use a pass-through connection to exclude our local LAN traffic from being sent through the tunnel:

```
conn branch1
    left=1.2.3.4
```

```
    leftid=@headoffice
    leftsubnet=0.0.0.0/0
    leftrsasigkey=0sA[...]
    #
    right=10.11.12.13
    rightid=@branch2
    rightsubnet=10.0.1.0/24
    rightrsasigkey=0sAYYYY[...]
    #
    auto=start
    authby=rsasig

conn passthrough
    left=1.2.3.4
    right=0.0.0.0
    leftsubnet=10.0.1.0/24
    rightsubnet=10.0.1.0/24
    authby=never
    type=passthrough
    auto=route
```

4.6.7. Configuring IKEv2 Remote Access VPN Libreswan

Road warriors are traveling users with mobile clients with a dynamically assigned **IP** address, such as laptops. These are authenticated using certificates. To avoid needing to use the old IKEv1 XAUTH protocol, IKEv2 is used in the following example:

On the server:

```
conn roadwarriors
    ikev2=insist
    # Support (roaming) MOBIKE clients (RFC 4555)
    mobike=yes
    fragmentation=yes
    left=1.2.3.4
    # if access to the LAN is given, enable this, otherwise use 0.0.0.0/0
    # leftsubnet=10.10.0.0/16
    leftsubnet=0.0.0.0/0
    leftcert=gw.example.com
    leftid=%fromcert
    leftxauthserver=yes
    leftmodecfgserver=yes
    right=%any
    # trust our own Certificate Agency
    rightca=%same
    # pick an IP address pool to assign to remote users
    # 100.64.0.0/16 prevents RFC1918 clashes when remote users are behind
NAT
    rightaddresspool=100.64.13.100-100.64.13.254
    # if you want remote clients to use some local DNS zones and servers
    modecfgdns="1.2.3.4, 5.6.7.8"
    modecfgdomains="internal.company.com, corp"
    rightxauthclient=yes
    rightmodecfgclient=yes
```

```
    authby=rsasig
    # optionally, run the client X.509 ID through pam to allow/deny client
    # pam-authorize=yes
    # load connection, don't initiate
    auto=add
    # kill vanished roadwarriors
    dpddelay=1m
    dpdtimeout=5m
    dpdaction=%clear
```

On the mobile client, the road warrior's device, use a slight variation of the previous configuration:

```
conn to-vpn-server
    ikev2=insist
    # pick up our dynamic IP
    left=%defaultroute
    leftsubnet=0.0.0.0/0
    leftcert=myname.example.com
    leftid=%fromcert
    leftmodecfgclient=yes
    # right can also be a DNS hostname
    right=1.2.3.4
    # if access to the remote LAN is required, enable this, otherwise use
0.0.0.0/0
    # rightsubnet=10.10.0.0/16
    rightsubnet=0.0.0.0/0
    # trust our own Certificate Agency
    rightca=%same
    authby=rsasig
    # allow narrowing to the server’s suggested assigned IP and remote
subnet
    narrowing=yes
    # Support (roaming) MOBIKE clients (RFC 4555)
    mobike=yes
    # Initiate connection
    auto=start
```

4.6.8. Configuring IKEv1 Remote Access VPN Libreswan and XAUTH with X.509

Libreswan offers a method to natively assign **IP** address and DNS information to roaming VPN clients as the connection is established by using the XAUTH **IPsec** extension. XAUTH can be deployed using PSK or X.509 certificates. Deploying using X.509 is more secure. Client certificates can be revoked by a certificate revocation list or by *Online Certificate Status Protocol* (OCSP). With X.509 certificates, individual clients cannot impersonate the server. With a PSK, also called Group Password, this is theoretically possible.

XAUTH requires the VPN client to additionally identify itself with a user name and password. For One time Passwords (OTP), such as Google Authenticator or RSA SecureID tokens, the one-time token is appended to the user password.

There are three possible back ends for XAUTH:

xauthby=pam

This uses the configuration in **/etc/pam.d/pluto** to authenticate the user. **Pam** can be configured to use various back ends by itself. It can use the system account user-password scheme, an LDAP directory, a RADIUS server or a custom password authentication module.

xauthby=file

This uses the **/etc/ipsec.d/passwd** configuration file (it should not be confused with the **/etc/ipsec.d/nsspassword** file). The format of this file is similar to the **Apache .htpasswd** file and the **Apache htpasswd** command can be used to create entries in this file. However, after the user name and password, a third column is required with the connection name of the **IPsec** connection used, for example when using a **conn remoteusers** to offer VPN to remove users, a password file entry should look as follows:

```
user1:$apr1$MIwQ3DHb$1I69LzTnZhnCT2DPQmAOK.:remoteusers
```

NOTE

When using the **htpasswd** command, the connection name has to be manually added after the *user:password* part on each line.

xauthby=alwaysok

The server always pretends the XAUTH user and password combination is correct. The client still has to specify a user name and a password, although the server ignores these. This should only be used when users are already identified by X.509 certificates, or when testing the VPN without needing an XAUTH back end.

An example configuration with X.509 certificates:

```
conn xauth-rsa
    ikev2=never
    auto=add
    authby=rsasig
    pfs=no
    rekey=no
    left=ServerIP
    leftcert=vpn.example.com
    #leftid=%fromcert
    leftid=vpn.example.com
    leftsendcert=always
    leftsubnet=0.0.0.0/0
    rightaddresspool=10.234.123.2-10.234.123.254
    right=%any
    rightrsasigkey=%cert
    modecfgdns1=1.2.3.4
    modecfgdns2=8.8.8.8
    modecfgdomain=example.com
    modecfgbanner="Authorized Access is allowed"
    leftxauthserver=yes
    rightxauthclient=yes
    leftmodecfgserver=yes
    rightmodecfgclient=yes
    modecfgpull=yes
    xauthby=pam
```

```
    dpddelay=30
    dpdtimeout=120
    dpdaction=clear
    ike_frag=yes
    # for walled-garden on xauth failure
    # xauthfail=soft
    # leftupdown=/custom/_updown
```

When **xauthfail** is set to soft, instead of hard, authentication failures are ignored, and the VPN is setup as if the user authenticated properly. A custom updown script can be used to check for the environment variable **XAUTH_FAILED**. Such users can then be redirected, for example, using **iptables** DNAT, to a “walled garden” where they can contact the administrator or renew a paid subscription to the service.

VPN clients use the **modecfgdomain** value and the DNS entries to redirect queries for the specified domain to these specified nameservers. This allows roaming users to access internal-only resources using the internal DNS names. Note while IKEv2 supports a comma seperated list of domain names and nameserver IP addresses using **modecfgdomains** and **modecfgdns**, the IKEv1 protocol only supports one domain name, and libreswan only supports up to two nameserver IP addresses.

If **leftsubnet** is not **0.0.0.0/0**, split tunneling configuration requests are sent automatically to the client. For example, when using **leftsubnet=10.0.0.0/8**, the VPN client would only send traffic for **10.0.0.0/8** through the VPN.

4.6.9. Using the Protection against Quantum Computers

Using IKEv1 with PreShared Keys gave protection against quantum attackers. The redesign of IKEv2 does not offer this protection natively. **Libreswan** offers the use of *Postquantum Preshared Keys* (PPK) to protect IKEv2 connections against quantum attacks.

To enable optional PPK support, add **ppk=yes** to the connection definition. To require PPK, add **ppk=insist**. Then, each client can be given a PPK ID with a secret value that is communicated out-of-band (and preferably quantum safe). The PPK's should be very strong in randomness and not be based on dictionary words. The PPK ID and PPK data itself are stored in **ipsec.secrets**, for example:

```
@west @east : PPKS "user1" "thestringismeanttobearandomstr"
```

The **PPKS** refers to static PPKs. There is an experimental function to use one-time-pad based Dynamic PPKs. Upon each connection, a new part of a onetime pad is used as the PPK. When used, that part of the dynamic PPK inside the file is overwritten with zeroes to prevent re-use. If there is no more one time pad material left, the connection fails. See the **ipsec.secrets(5)** man page for more information.

WARNING

The implementation of dynamic PPKs is provided as a Technology Preview and this functionality should be used with caution. See the Red Hat Enterprise Linux 7.5 Release Notes for more information.

4.6.10. Additional Resources

The following sources of information provide additional resources regarding **Libreswan** and the **ipsec** daemon.

4.6.10.1. Installed Documentation

- **ipsec(8)** man page — Describes command options for **ipsec**.
- **ipsec.conf(5)** man page — Contains information on configuring **ipsec**.
- **ipsec.secrets(5)** man page — Describes the format of the **ipsec.secrets** file.
- **ipsec_auto(8)** man page — Describes the use of the **auto** command line client for manipulating **Libreswan IPsec** connections established using automatic exchanges of keys.
- **ipsec_rsasigkey(8)** man page — Describes the tool used to generate RSA signature keys.
- **/usr/share/doc/libreswan-*version*/**

4.6.10.2. Online Documentation

https://libreswan.org

The website of the upstream project.

https://libreswan.org/wiki

The Libreswan Project Wiki.

https://libreswan.org/man/

All Libreswan man pages.

4.7. USING OPENSSL

OpenSSL is a library that provides cryptographic protocols to applications. The **openssl** command line utility enables using the cryptographic functions from the shell. It includes an interactive mode.

The **openssl** command line utility has a number of pseudo-commands to provide information on the commands that the version of **openssl** installed on the system supports. The pseudo-commands **list-standard-commands**, **list-message-digest-commands**, and **list-cipher-commands** output a list of all standard commands, message digest commands, or cipher commands, respectively, that are available in the present **openssl** utility.

The pseudo-commands **list-cipher-algorithms** and **list-message-digest-algorithms** list all cipher and message digest names. The pseudo-command **list-public-key-algorithms** lists all supported public key algorithms. For example, to list the supported public key algorithms, issue the following command:

```
~]$ openssl list-public-key-algorithms
```

The pseudo-command no-*command-name* tests whether a *command-name* of the specified name is available. Intended for use in shell scripts. See man openssl(1) for more information.

4.7.1. Creating and Managing Encryption Keys

With **OpenSSL**, public keys are derived from the corresponding private key. Therefore the first step, once having decided on the algorithm, is to generate the private key. In these examples the private key is referred to as *privkey.pem*. For example, to create an RSA private key using default parameters, issue the following command:

```
~]$ openssl genpkey -algorithm RSA -out privkey.pem
```

The RSA algorithm supports the following options:

- **rsa_keygen_bits:numbits** — The number of bits in the generated key. If not specified **1024** is used.
- **rsa_keygen_pubexp:value** — The RSA public exponent value. This can be a large decimal value, or a hexadecimal value if preceded by **0x**. The default value is **65537**.

For example, to create a 2048 bit RSA private key using **3** as the public exponent, issue the following command:

```
~]$ openssl genpkey -algorithm RSA -out privkey.pem -pkeyopt
rsa_keygen_bits:2048 \ -pkeyopt rsa_keygen_pubexp:3
```

To encrypt the private key as it is output using 128 bit AES and the passphrase “hello”, issue the following command:

```
~]$ openssl genpkey -algorithm RSA -out privkey.pem -aes-128-cbc -pass
pass:hello
```

See man genpkey(1) for more information on generating private keys.

4.7.2. Generating Certificates

To generate a certificate using **OpenSSL**, it is necessary to have a private key available. In these examples the private key is referred to as *privkey.pem*. If you have not yet generated a private key, see Section 4.7.1, “Creating and Managing Encryption Keys”

To have a certificate signed by a *certificate authority* (CA), it is necessary to generate a certificate and then send it to a CA for signing. This is referred to as a certificate signing request. See Section 4.7.2.1, “Creating a Certificate Signing Request” for more information. The alternative is to create a self-signed certificate. See Section 4.7.2.2, “Creating a Self-signed Certificate” for more information.

4.7.2.1. Creating a Certificate Signing Request

To create a certificate for submission to a CA, issue a command in the following format:

```
~]$ openssl req -new -key privkey.pem -out cert.csr
```

This will create an X.509 certificate called **cert.csr** encoded in the default *privacy-enhanced electronic mail* (PEM) format. The name PEM is derived from “Privacy Enhancement for Internet Electronic Mail” described in RFC 1424. To generate a certificate file in the alternative DER format, use the **-outform DER** command option.

After issuing the above command, you will be prompted for information about you and the organization in order to create a *distinguished name* (DN) for the certificate. You will need the following information:

- The two letter country code for your country
- The full name of your state or province
- City or Town
- The name of your organization
- The name of the unit within your organization
- Your name or the host name of the system
- Your email address

The req(1) man page describes the PKCS# 10 certificate request and generating utility. Default settings used in the certificate creating process are contained within the **/etc/pki/tls/openssl.cnf** file. See man **openssl.cnf(5)** for more information.

4.7.2.2. Creating a Self-signed Certificate

To generate a self-signed certificate, valid for **366** days, issue a command in the following format:

```
~]$ openssl req -new -x509 -key privkey.pem -out selfcert.pem -days 366
```

4.7.2.3. Creating a Certificate Using a Makefile

The **/etc/pki/tls/certs/** directory contains a **Makefile** which can be used to create certificates using the **make** command. To view the usage instructions, issue a command as follows:

```
~]$ make -f /etc/pki/tls/certs/Makefile
```

Alternatively, change to the directory and issue the **make** command as follows:

```
~]$ cd /etc/pki/tls/certs/
~]$ make
```

See the make(1) man page for more information.

4.7.3. Verifying Certificates

A certificate signed by a CA is referred to as a trusted certificate. A self-signed certificate is therefore an untrusted certificate. The verify utility uses the same SSL and S/MIME functions to verify a certificate as is used by **OpenSSL** in normal operation. If an error is found it is reported and then an attempt is made to continue testing in order to report any other errors.

To verify multiple individual X.509 certificates in PEM format, issue a command in the following format:

```
~]$ openssl verify cert1.pem cert2.pem
```

To verify a certificate chain the leaf certificate must be in **cert.pem** and the intermediate certificates which you do not trust must be directly concatenated in **untrusted.pem**. The trusted root CA certificate must be either among the default CA listed in **/etc/pki/tls/certs/ca-bundle.crt** or in a **cacert.pem** file. Then, to verify the chain, issue a command in the following format:

```
~]$ openssl verify -untrusted untrusted.pem -CAfile cacert.pem cert.pem
```

See man verify(1) for more information.

IMPORTANT

Verification of signatures using the MD5 hash algorithm is disabled in Red Hat Enterprise Linux 7 due to insufficient strength of this algorithm. Always use strong algorithms such as SHA256.

4.7.4. Encrypting and Decrypting a File

For encrypting (and decrypting) files with **OpenSSL**, either the **pkeyutl** or **enc** built-in commands can be used. With **pkeyutl**, **RSA** keys are used to perform the encrypting and decrypting, whereas with **enc**, symmetric algorithms are used.

Using RSA Keys

To encrypt a file called **plaintext**, issue a command as follows:

```
~]$ openssl pkeyutl -in plaintext -out cyphertext -inkey privkey.pem
```

The default format for keys and certificates is PEM. If required, use the **-keyform DER** option to specify the DER key format.

To specify a cryptographic engine, use the **-engine** option as follows:

```
~]$ openssl pkeyutl -in plaintext -out cyphertext -inkey privkey.pem -
engine id
```

Where *id* is the ID of the cryptographic engine. To check the availability of an engine, issue the following command:

```
~]$ openssl engine -t
```

To sign a data file called *plaintext*, issue a command as follows:

```
~]$ openssl pkeyutl -sign -in plaintext -out sigtext -inkey privkey.pem
```

To verify a signed data file and to extract the data, issue a command as follows:

```
~]$ openssl pkeyutl -verifyrecover -in sig -inkey key.pem
```

To verify the signature, for example using a DSA key, issue a command as follows:

```
~]$ openssl pkeyutl -verify -in file -sigfile sig -inkey key.pem
```

The pkeyutl(1) manual page describes the public key algorithm utility.

Using Symmetric Algorithms

To list available symmetric encryption algorithms, execute the **enc** command with an unsupported option, such as **-l**:

```
~]$ openssl enc -l
```

To specify an algorithm, use its name as an option. For example, to use the **aes-128-cbc** algorithm, use the following syntax:

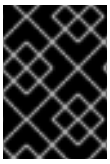
```
openssl enc -aes-128-cbc
```

To encrypt a file called **plaintext** using the **aes-128-cbc** algorithm, enter the following command:

```
~]$ openssl enc -aes-128-cbc -in plaintext -out plaintext.aes-128-cbc
```

To decrypt the file obtained in the previous example, use the **-d** option as in the following example:

```
~]$ openssl enc -aes-128-cbc -d -in plaintext.aes-128-cbc -out plaintext
```



IMPORTANT

The **enc** command does not properly support **AEAD** ciphers, and the **ecb** mode is not considered secure. For best results, do not use other modes than **cbc**, **cfb**, **ofb**, or **ctr**.

4.7.5. Generating Message Digests

The **dgst** command produces the message digest of a supplied file or files in hexadecimal form. The command can also be used for digital signing and verification. The message digest command takes the following form:

```
openssl dgst algorithm -out filename -sign private-key
```

Where *algorithm* is one of **md5|md4|md2|sha1|sha|mdc2|ripemd160|dss1**. At time of writing, the SHA1 algorithm is preferred. If you need to sign or verify using DSA, then the **dss1** option must be used together with a file containing random data specified by the **-rand** option.

To produce a message digest in the default Hex format using the sha1 algorithm, issue the following command:

```
~]$ openssl dgst sha1 -out digest-file
```

To digitally sign the digest, using a private key *privekey.pem*, issue the following command:

```
~]$ openssl dgst sha1 -out digest-file -sign privkey.pem
```

See man dgst(1) for more information.

4.7.6. Generating Password Hashes

The **passwd** command computes the hash of a password. To compute the hash of a password on the command line, issue a command as follows:

```
~]$ openssl passwd password
```

The **-crypt** algorithm is used by default.

To compute the hash of a password from standard input, using the MD5 based BSD algorithm **1**, issue a command as follows:

```
~]$ openssl passwd -1 password
```

The **-apr1** option specifies the Apache variant of the BSD algorithm.

To compute the hash of a password stored in a file, and using a salt **xx**, issue a command as follows:

```
~]$ openssl passwd -salt xx -in password-file
```

The password is sent to standard output and there is no **-out** option to specify an output file. The **-table** will generate a table of password hashes with their corresponding clear text password.

See man sslpasswd(1) for more information and examples.

4.7.7. Generating Random Data

To generate a file containing random data, using a seed file, issue the following command:

```
~]$ openssl rand -out rand-file -rand seed-file
```

Multiple files for seeding the random data process can be specified using the colon, **:**, as a list separator.

See man rand(1) for more information.

4.7.8. Benchmarking Your System

To test the computational speed of a system for a given algorithm, issue a command in the following format:

```
~]$ openssl speed algorithm
```

where *algorithm* is one of the supported algorithms you intended to use. To list the available algorithms, type **openssl speed** and then press tab.

4.7.9. Configuring OpenSSL

OpenSSL has a configuration file **/etc/pki/tls/openssl.cnf**, referred to as the master configuration file, which is read by the OpenSSL library. It is also possible to have individual configuration files for each application. The configuration file contains a number of sections with section names as follows: **[section_name]**. Note the first part of the file, up until the first **[section_name]**, is referred to as the default section. When OpenSSL is searching for names in the configuration file the named sections are searched first. All OpenSSL commands use the master OpenSSL configuration file unless an option is used in the command to specify an alternative configuration file. The configuration file is explained in detail in the **config(5)** man page.

Two RFCs explain the contents of a certificate file. They are:

- *Internet X.509 Public Key Infrastructure Certificate and Certificate Revocation List (CRL) Profile*
- *Updates to the Internet X.509 Public Key Infrastructure Certificate and Certificate Revocation List (CRL) Profile*

4.8. USING STUNNEL

The **stunnel** program is an encryption wrapper between a client and a server. It listens on the port specified in its configuration file, encrypts the communitation with the client, and forwards the data to the original daemon listening on its usual port. This way, you can secure any service that itself does not support any type of encryption, or improve the security of a service that uses a type of encryption that you want to avoid for security reasons, such as SSL versions 2 and 3, affected by the POODLE SSL vulnerability (CVE-2014-3566). See https://access.redhat.com/solutions/1234773 for details. **CUPS** is an example of a component that does not provide a way to disable SSL in its own configuration.

4.8.1. Installing stunnel

Install the stunnel package by entering the following command as **root**:

```
~]# yum install stunnel
```

4.8.2. Configuring stunnel as a TLS Wrapper

To configure **stunnel**, follow these steps:

1. You need a valid certificate for **stunnel** regardless of what service you use it with. If you do not have a suitable certificate, you can apply to a *Certificate Authority* to obtain one, or you can create a self-signed certificate.

   WARNING

   Always use certificates signed by a Certificate Authority for servers running in a production environment. Self-signed certificates are only appropriate for testing purposes or private networks.

   See Section 4.7.2.1, “Creating a Certificate Signing Request” for more information about certificates granted by a Certificate Authority. On the other hand, to create a self-signed certificate for **stunnel**, enter the **/etc/pki/tls/certs/** directory and type the following command as **root**:

   ```
   certs]# make stunnel.pem
   ```

   Answer all of the questions to complete the process.

2. When you have a certificate, create a configuration file for **stunnel**. It is a text file in which every line specifies an option or the beginning of a service definition. You can also keep comments and empty lines in the file to improve its legibility, where comments start with a semicolon.

   The stunnel RPM package contains the **/etc/stunnel/** directory, in which you can store the configuration file. Although **stunnel** does not require any special format of the file name or its extension, use **/etc/stunnel/stunnel.conf**. The following content configures **stunnel** as a TLS wrapper:

```
cert = /etc/pki/tls/certs/stunnel.pem
; Allow only TLS, thus avoiding SSL
sslVersion = TLSv1
chroot = /var/run/stunnel
setuid = nobody
setgid = nobody
pid = /stunnel.pid
socket = l:TCP_NODELAY=1
socket = r:TCP_NODELAY=1

[service_name]
accept = port
connect = port
TIMEOUTclose = 0
```

Alternatively, you can avoid SSL by replacing the line containing **`sslVersion = TLSv1`** with the following lines:

```
options = NO_SSLv2
options = NO_SSLv3
```

The purpose of the options is as follows:

- **`cert`** — the path to your certificate
- **`sslVersion`** — the version of SSL; note that you can use **`TLS`** here even though SSL and TLS are two independent cryptographic protocols
- **`chroot`** — the changed root directory in which the stunnel process runs, for greater security
- **`setuid`**, **`setgid`** — the user and group that the **stunnel** process runs as; **nobody** is a restricted system account
- **`pid`** — the file in which **stunnel** saves its process ID, relative to **`chroot`**
- **`socket`** — local and remote socket options; in this case, disable *Nagle's algorithm* to improve network latency
- **`[service_name]`** — the beginning of the service definition; the options used below this line apply to the given service only, whereas the options above affect **stunnel** globally
- **`accept`** — the port to listen on
- **`connect`** — the port to connect to; this must be the port that the service you are securing uses
- **`TIMEOUTclose`** — how many seconds to wait for the *close_notify* alert from the client; **`0`** instructs **stunnel** not to wait at all
- **`options`** — OpenSSL library options

Example 4.3. Securing CUPS

To configure stunnel as a TLS wrapper for **CUPS**, use the following values:

```
[cups]
accept = 632
connect = 631
```

Instead of **632**, you can use any free port that you prefer. **631** is the port that **CUPS** normally uses.

3. Create the **chroot** directory and give the user specified by the **setuid** option write access to it. To do so, enter the following commands as **root**:

```
~]# mkdir /var/run/stunnel
~]# chown nobody:nobody /var/run/stunnel
```

This allows **stunnel** to create the PID file.

4. If your system is using firewall settings that disallow access to the new port, change them accordingly. See Section 5.6.7, “Opening Ports using GUI” for details.

5. When you have created the configuration file and the **chroot** directory, and when you are sure that the specified port is accessible, you are ready to start using **stunnel**.

4.8.3. Starting, Stopping, and Restarting stunnel

To start **stunnel**, enter the following command as **root**:

```
~]# stunnel /etc/stunnel/stunnel.conf
```

By default, **stunnel** uses **/var/log/secure** to log its output.

To terminate **stunnel**, kill the process by running the following command as **root**:

```
~]# kill `cat /var/run/stunnel/stunnel.pid`
```

If you edit the configuration file while **stunnel** is running, terminate **stunnel** and start it again for your changes to take effect.

4.9. ENCRYPTION

4.9.1. Using LUKS Disk Encryption

Linux Unified Key Setup-on-disk-format (or LUKS) allows you to encrypt partitions on your Linux computer. This is particularly important when it comes to mobile computers and removable media. LUKS allows multiple user keys to decrypt a master key, which is used for the bulk encryption of the partition.

Overview of LUKS

What LUKS does

- LUKS encrypts entire block devices and is therefore well-suited for protecting the contents of mobile devices such as removable storage media or laptop disk drives.

- The underlying contents of the encrypted block device are arbitrary. This makes it useful for encrypting **swap** devices. This can also be useful with certain databases that use specially formatted block devices for data storage.
- LUKS uses the existing device mapper kernel subsystem.
- LUKS provides passphrase strengthening which protects against dictionary attacks.
- LUKS devices contain multiple key slots, allowing users to add backup keys or passphrases.

What LUKS does *not* do:

- LUKS is not well-suited for applications requiring many (more than eight) users to have distinct access keys to the same device.
- LUKS is not well-suited for applications requiring file-level encryption.

4.9.1.1. LUKS Implementation in Red Hat Enterprise Linux

Red Hat Enterprise Linux 7 utilizes LUKS to perform file system encryption. By default, the option to encrypt the file system is unchecked during the installation. If you select the option to encrypt your hard drive, you will be prompted for a passphrase that will be asked every time you boot the computer. This passphrase "unlocks" the bulk encryption key that is used to decrypt your partition. If you choose to modify the default partition table you can choose which partitions you want to encrypt. This is set in the partition table settings.

The default cipher used for LUKS (see **`cryptsetup --help`**) is aes-xts-plain64. The default key size for LUKS is 256 bits. The default key size for LUKS with **Anaconda** (XTS mode) is 512 bits. Ciphers that are available are:

- AES - Advanced Encryption Standard - FIPS PUB 197
- Twofish (A 128-bit Block Cipher)
- Serpent
- cast5 - RFC 2144
- cast6 - RFC 2612

4.9.1.2. Manually Encrypting Directories

WARNING

Following this procedure will remove all data on the partition that you are encrypting. You WILL lose all your information! Make sure you backup your data to an external source before beginning this procedure!

1. Enter runlevel 1 by typing the following at a shell prompt as root:

   -

```
telinit 1
```

2. Unmount your existing **/home**:

```
umount /home
```

3. If the command in the previous step fails, use **fuser** to find processes hogging **/home** and kill them:

```
fuser -mvk /home
```

4. Verify **/home** is no longer mounted:

```
grep home /proc/mounts
```

5. Fill your partition with random data:

```
shred -v --iterations=1 /dev/VG00/LV_home
```

This command proceeds at the sequential write speed of your device and may take some time to complete. It is an important step to ensure no unencrypted data is left on a used device, and to obfuscate the parts of the device that contain encrypted data as opposed to just random data.

6. Initialize your partition:

```
cryptsetup --verbose --verify-passphrase luksFormat
/dev/VG00/LV_home
```

7. Open the newly encrypted device:

```
cryptsetup luksOpen /dev/VG00/LV_home home
```

8. Make sure the device is present:

```
ls -l /dev/mapper | grep home
```

9. Create a file system:

```
mkfs.ext3 /dev/mapper/home
```

10. Mount the file system:

```
mount /dev/mapper/home /home
```

11. Make sure the file system is visible:

```
df -h | grep home
```

12. Add the following to the **/etc/crypttab** file:

```
```

```
home /dev/VG00/LV_home none
```

13. Edit the **/etc/fstab** file, removing the old entry for **/home** and adding the following line:

```
/dev/mapper/home /home ext3 defaults 1 2
```

14. Restore default SELinux security contexts:

```
/sbin/restorecon -v -R /home
```

15. Reboot the machine:

```
shutdown -r now
```

16. The entry in the **/etc/crypttab** makes your computer ask your **luks** passphrase on boot.

17. Log in as root and restore your backup.

You now have an encrypted partition for all of your data to safely rest while the computer is off.

4.9.1.3. Add a New Passphrase to an Existing Device

Use the following command to add a new passphrase to an existing device:

```
cryptsetup luksAddKey device
```

After being prompted for any one of the existing passprases for authentication, you will be prompted to enter the new passphrase.

4.9.1.4. Remove a Passphrase from an Existing Device

Use the following command to remove a passphrase from an existing device:

```
cryptsetup luksRemoveKey device
```

You will be prompted for the passphrase you want to remove and then for any one of the remaining passphrases for authentication.

4.9.1.5. Creating Encrypted Block Devices in Anaconda

You can create encrypted devices during system installation. This allows you to easily configure a system with encrypted partitions.

To enable block device encryption, check the **Encrypt System** check box when selecting automatic partitioning or the **Encrypt** check box when creating an individual partition, software RAID array, or logical volume. After you finish partitioning, you will be prompted for an encryption passphrase. This passphrase will be required to access the encrypted devices. If you have pre-existing LUKS devices and provided correct passphrases for them earlier in the install process the passphrase entry dialog will also contain a check box. Checking this check box indicates that you would like the new passphrase to be added to an available slot in each of the pre-existing encrypted block devices.

NOTE

Checking the **Encrypt System** check box on the **Automatic Partitioning** screen and then choosing **Create custom layout** does not cause any block devices to be encrypted automatically.

NOTE

You can use **kickstart** to set a separate passphrase for each new encrypted block device.

4.9.1.6. Additional Resources

For additional information on LUKS or encrypting hard drives under Red Hat Enterprise Linux 7 visit one of the following links:

- LUKS home page
- LUKS/cryptsetup FAQ
- LUKS - Linux Unified Key Setup Wikipedia article
- HOWTO: Creating an encrypted Physical Volume (PV) using a second hard drive and pvmove

4.9.2. Creating GPG Keys

GPG is used to identify yourself and authenticate your communications, including those with people you do not know. GPG allows anyone reading a GPG-signed email to verify its authenticity. In other words, GPG allows someone to be reasonably certain that communications signed by you actually are from you. GPG is useful because it helps prevent third parties from altering code or intercepting conversations and altering the message.

4.9.2.1. Creating GPG Keys in GNOME

To create a GPG Key in **GNOME**, follow these steps:

1. Install the **Seahorse** utility, which makes GPG key management easier:

```
~]# yum install seahorse
```

2. To create a key, from the **Applications** → **Accessories** menu select **Passwords and Encryption Keys**, which starts the application **Seahorse**.

3. From the **File** menu select **New** and then **PGP Key**. Then click **Continue**.

4. Type your full name, email address, and an optional comment describing who you are (for example: John C. Smith, **jsmith@example.com**, Software Engineer). Click **Create**. A dialog is displayed asking for a passphrase for the key. Choose a strong passphrase but also easy to remember. Click **OK** and the key is created.

WARNING

If you forget your passphrase, you will not be able to decrypt the data.

To find your GPG key ID, look in the **Key ID** column next to the newly created key. In most cases, if you are asked for the key ID, prepend **0x** to the key ID, as in **0x6789ABCD**. You should make a backup of your private key and store it somewhere secure.

4.9.2.2. Creating GPG Keys in KDE

To create a GPG Key in **KDE**, follow these steps:

1. Start the **KGpg** program from the main menu by selecting **Applications** → **Utilities** → **Encryption Tool**. If you have never used **KGpg** before, the program walks you through the process of creating your own GPG keypair.

2. A dialog box appears prompting you to create a new key pair. Enter your name, email address, and an optional comment. You can also choose an expiration time for your key, as well as the key strength (number of bits) and algorithms.

3. Enter your passphrase in the next dialog box. At this point, your key appears in the main **KGpg** window.

WARNING

If you forget your passphrase, you will not be able to decrypt the data.

To find your GPG key ID, look in the **Key ID** column next to the newly created key. In most cases, if you are asked for the key ID, prepend **0x** to the key ID, as in **0x6789ABCD**. You should make a backup of your private key and store it somewhere secure.

4.9.2.3. Creating GPG Keys Using the Command Line

1. Use the following shell command:

   ```
   ~]$ gpg2 --gen-key
   ```

   This command generates a key pair that consists of a public and a private key. Other people use your public key to authenticate and decrypt your communications. Distribute your public key as widely as possible, especially to people who you know will want to receive authentic communications from you, such as a mailing list.

2. A series of prompts directs you through the process. Press the **Enter** key to assign a default value if desired. The first prompt asks you to select what kind of key you prefer:

```
Please select what kind of key you want:
(1) RSA and RSA (default)
(2) DSA and Elgamal
(3) DSA (sign only)
(4) RSA (sign only)
Your selection?
```

In almost all cases, the default is the correct choice. An RSA/RSA key allows you not only to sign communications, but also to encrypt files.

3. Choose the key size:

```
RSA keys may be between 1024 and 4096 bits long.
What keysize do you want? (2048)
```

Again, the default, 2048, is sufficient for almost all users, and represents an extremely strong level of security.

4. Choose when the key will expire. It is a good idea to choose an expiration date instead of using the default, which is **none**. If, for example, the email address on the key becomes invalid, an expiration date will remind others to stop using that public key.

```
Please specify how long the key should be valid.
0 = key does not expire
d = key expires in n days
w = key expires in n weeks
m = key expires in n months
y = key expires in n years
key is valid for? (0)
```

Entering a value of **1y**, for example, makes the key valid for one year. (You may change this expiration date after the key is generated, if you change your mind.)

5. Before the **gpg2** application asks for signature information, the following prompt appears:

```
Is this correct (y/N)?
```

Enter **y** to finish the process.

6. Enter your name and email address for your GPG key. Remember this process is about authenticating you as a real individual. For this reason, include your real name. If you choose a bogus email address, it will be more difficult for others to find your public key. This makes authenticating your communications difficult. If you are using this GPG key for self-introduction on a mailing list, for example, enter the email address you use on that list.

Use the comment field to include aliases or other information. (Some people use different keys for different purposes and identify each key with a comment, such as "Office" or "Open Source Projects.")

7. At the confirmation prompt, enter the letter **0** to continue if all entries are correct, or use the other options to fix any problems. Finally, enter a passphrase for your secret key. The **gpg2** program asks you to enter your passphrase twice to ensure you made no typing errors.

8. Finally, **gpg2** generates random data to make your key as unique as possible. Move your mouse, type random keys, or perform other tasks on the system during this step to speed up the process. Once this step is finished, your keys are complete and ready to use:

```
pub  1024D/1B2AFA1C 2005-03-31 John Q. Doe <jqdoe@example.com>
Key fingerprint = 117C FE83 22EA B843 3E86  6486 4320 545E 1B2A FA1C
sub  1024g/CEA4B22E 2005-03-31 [expires: 2006-03-31]
```

9. The key fingerprint is a shorthand "signature" for your key. It allows you to confirm to others that they have received your actual public key without any tampering. You do not need to write this fingerprint down. To display the fingerprint at any time, use this command, substituting your email address:

```
~]$ gpg2 --fingerprint jqdoe@example.com
```

Your "GPG key ID" consists of 8 hex digits identifying the public key. In the example above, the GPG key ID is **1B2AFA1C**. In most cases, if you are asked for the key ID, prepend **0x** to the key ID, as in **0x6789ABCD**.

WARNING

If you forget your passphrase, the key cannot be used and any data encrypted using that key will be lost.

4.9.2.4. About Public Key Encryption

1. Wikipedia - Public Key Cryptography
2. HowStuffWorks - Encryption

4.9.3. Using openCryptoki for Public-Key Cryptography

openCryptoki is a Linux implementation of *PKCS#11*, which is a *Public-Key Cryptography Standard* that defines an application programming interface (API) to cryptographic devices called tokens. Tokens may be implemented in hardware or software. This chapter provides an overview of the way the **openCryptoki** system is installed, configured, and used in Red Hat Enterprise Linux 7.

4.9.3.1. Installing openCryptoki and Starting the Service

To install the basic **openCryptoki** packages on your system, including a software implementation of a token for testing purposes, enter the following command as **root**:

```
~]# yum install opencryptoki
```

Depending on the type of hardware tokens you intend to use, you may need to install additional packages that provide support for your specific use case. For example, to obtain support for *Trusted Platform Module* (TPM) devices, you need to install the opencryptoki-tpmtok package.

See the Installing Packages section of the Red Hat Enterprise Linux 7 System Administrator's Guide for general information on how to install packages using the **Yum** package manager.

To enable the **openCryptoki** service, you need to run the **pkcsslotd** daemon. Start the daemon for the current session by executing the following command as **root**:

```
~]# systemctl start pkcsslotd
```

To ensure that the service is automatically started at boot time, enter the following command:

```
~]# systemctl enable pkcsslotd
```

See the Managing Services with systemd chapter of the Red Hat Enterprise Linux 7 System Administrator's Guide for more information on how to use systemd targets to manage services.

4.9.3.2. Configuring and Using openCryptoki

When started, the **pkcsslotd** daemon reads the **/etc/opencryptoki/opencryptoki.conf** configuration file, which it uses to collect information about the tokens configured to work with the system and about their slots.

The file defines the individual slots using key-value pairs. Each slot definition can contain a description, a specification of the token library to be used, and an ID of the slot's manufacturer. Optionally, the version of the slot's hardware and firmware may be defined. See the opencryptoki.conf(5) manual page for a description of the file's format and for a more detailed description of the individual keys and the values that can be assigned to them.

To modify the behavior of the **pkcsslotd** daemon at run time, use the **pkcsconf** utility. This tool allows you to show and configure the state of the daemon, as well as to list and modify the currently configured slots and tokens. For example, to display information about tokens, issue the following command (note that all non-root users that need to communicate with the **pkcsslotd** daemon must be a part of the **pkcs11** system group):

```
~]$ pkcsconf -t
```

See the pkcsconf(1) manual page for a list of arguments available with the **pkcsconf** tool.

WARNING

Keep in mind that only fully trusted users should be assigned membership in the **pkcs11** group, as all members of this group have the right to block other users of the **openCryptoki** service from accessing configured PKCS#11 tokens. All members of this group can also execute arbitrary code with the privileges of any other users of **openCryptoki**.

4.9.4. Using Smart Cards to Supply Credentials to OpenSSH

The smart card is a lightweight hardware security module in a USB stick, MicroSD, or SmartCard form factor. It provides a remotely manageable secure key store. In Red Hat Enterprise Linux 7, OpenSSH supports authentication using smart cards.

To use your smart card with OpenSSH, store the public key from the card to the **~/.ssh/authorized_keys** file. Install the **PKCS#11** library provided by the opensc package on the client. **PKCS#11** is a Public-Key Cryptography Standard that defines an application programming interface (API) to cryptographic devices called tokens. Enter the following command as **root**:

```
~]# yum install opensc
```

4.9.4.1. Retrieving a Public Key from a Card

To list the keys on your card, use the **ssh-keygen** command. Specify the shared library (OpenSC in the following example) with the **-D** directive.

```
~]$ ssh-keygen -D /usr/lib64/pkcs11/opensc-pkcs11.so
ssh-rsa AAAAB3NzaC1yc[...]+g4Mb9
```

4.9.4.2. Storing a Public Key on a Server

To enable authentication using a smart card on a remote server, transfer the public key to the remote server. Do it by copying the retrieved string (key) and pasting it to the remote shell, or by storing your key to a file (**smartcard.pub** in the following example) and using the **ssh-copy-id** command:

```
~]$ ssh-copy-id -f -i smartcard.pub user@hostname
user@hostname's password:

Number of key(s) added: 1

Now try logging into the machine, with:   "ssh user@hostname"
and check to make sure that only the key(s) you wanted were added.
```

Storing a public key without a private key file requires to use the **SSH_COPY_ID_LEGACY=1** environment variable or the **-f** option.

4.9.4.3. Authenticating to a Server with a Key on a Smart Card

OpenSSH can read your public key from a smart card and perform operations with your private key without exposing the key itself. This means that the private key does not leave the card. To connect to a remote server using your smart card for authentication, enter the following command and enter the PIN protecting your card:

```
[localhost ~]$ ssh -I /usr/lib64/pkcs11/opensc-pkcs11.so hostname
Enter PIN for 'Test (UserPIN)':
[hostname ~]$
```

Replace the *hostname* with the actual host name to which you want to connect.

To save unnecessary typing next time you connect to the remote server, store the path to the **PKCS#11** library in your **~/.ssh/config** file:

```
Host hostname
    PKCS11Provider /usr/lib64/pkcs11/opensc-pkcs11.so
```

Connect by running the **ssh** command without any additional options:

```
[localhost ~]$ ssh hostname
Enter PIN for 'Test (UserPIN)':
[hostname ~]$
```

4.9.4.4. Using `ssh-agent` to Automate PIN Logging In

Set up environmental variables to start using **ssh-agent**. You can skip this step in most cases because **ssh-agent** is already running in a typical session. Use the following command to check whether you can connect to your authentication agent:

```
~]$ ssh-add -l
Could not open a connection to your authentication agent.
~]$ eval `ssh-agent`
```

To avoid writing your PIN every time you connect using this key, add the card to the agent by running the following command:

```
~]$ ssh-add -s /usr/lib64/pkcs11/opensc-pkcs11.so
Enter PIN for 'Test (UserPIN)':
Card added: /usr/lib64/pkcs11/opensc-pkcs11.so
```

To remove the card from **ssh-agent**, use the following command:

```
~]$ ssh-add -e /usr/lib64/pkcs11/opensc-pkcs11.so
Card removed: /usr/lib64/pkcs11/opensc-pkcs11.so
```

NOTE

FIPS 201-2 requires explicit user action by the Personal Identity Verification (PIV) cardholder as a condition for use of the digital signature key stored on the card. OpenSC correctly enforces this requirement.

However, for some applications it is impractical to require the cardholder to enter the PIN for each signature. To cache the smart card PIN, remove the # character before the **pin_cache_ignore_user_consent = true;** option in the **/etc/opensc-x86_64.conf**.

See the Cardholder Authentication for the PIV Digital Signature Key (NISTIR 7863) report for more information.

4.9.4.5. Additional Resources

Setting up your hardware or software token is described in the Smart Card support in Red Hat Enterprise Linux 7 article.

For more information about the **pkcs11-tool** utility for managing and using smart cards and similar **PKCS#11** security tokens, see the **pkcs11-tool(1)** man page.

4.9.5. Trusted and Encrypted Keys

Trusted and encrypted keys are variable-length symmetric keys generated by the kernel that utilize the kernel keyring service. The fact that the keys never appear in user space in an unencrypted form means that their integrity can be verified, which in turn means that they can be used, for example, by the extended verification module (EVM) to verify and confirm the integrity of a running system. User-level programs can only ever access the keys in the form of encrypted *blobs*.

Trusted keys need a hardware component: the *Trusted Platform Module* (TPM) chip, which is used to both create and encrypt (*seal*) the keys. The TPM seals the keys using a 2048-bit **RSA** key called the *storage root key* (SRK).

In addition to that, trusted keys may also be sealed using a specific set of the TPM's *platform configuration register* (PCR) values. The PCR contains a set of integrity-management values that reflect the BIOS, boot loader, and operating system. This means that PCR-sealed keys can only be decrypted by the TPM on the exact same system on which they were encrypted. However, once a PCR-sealed trusted key is loaded (added to a keyring), and thus its associated PCR values are verified, it can be updated with new (or future) PCR values, so that a new kernel, for example, can be booted. A single key can also be saved as multiple blobs, each with different PCR values.

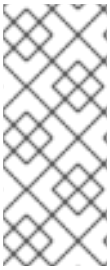
Encrypted keys do not require a TPM, as they use the kernel **AES** encryption, which makes them faster than trusted keys. Encrypted keys are created using kernel-generated random numbers and encrypted by a *master key* when they are exported into user-space blobs. This master key can be either a trusted key or a user key, which is their main disadvantage — if the master key is not a trusted key, the encrypted key is only as secure as the user key used to encrypt it.

4.9.5.1. Working with Keys

Prior to any operations with keys, relevant kernel modules need to be loaded. For trusted keys, it is the **trusted** module, and for encrypted keys, it is the **encrypted-keys** module. Use the following command as the **root** user to load both of these modules at once:

```
~]# modprobe trusted encrypted-keys
```

Trusted and encrypted keys can be created, loaded, exported, and updated using the **keyctl** utility. For detailed information about using **keyctl**, see keyctl(1).



NOTE

In order to use a TPM (such as for creating and sealing trusted keys), it needs to be enabled and active. This can be usually achieved through a setting in the machine's BIOS or using the **tpm_setactive** command from the tpm-tools package of utilities. Also, the **TrouSers** application needs to be installed (the trousers package), and the **tcsd** daemon, which is a part of the **TrouSers** suite, running to communicate with the TPM.

To create a trusted key using a TPM, execute the **keyctl** command with the following syntax:

```
keyctl add trusted name "new keylength [options]" keyring
```

Using the above syntax, an example command can be constructed as follows:

```
~]$ keyctl add trusted kmk "new 32" @u
642500861
```

The above example creates a trusted key called **kmk** with the length of 32 bytes (256 bits) and places it in the user keyring (**@u**). The keys may have a length of 32 to 128 bytes (256 to 1024 bits). Use the **show** subcommand to list the current structure of the kernel keyrings:

```
~]$ keyctl show
Session Keyring
       -3 --alswrv    500   500  keyring: _ses
 97833714 --alswrv    500    -1   \_ keyring: _uid.1000
642500861 --alswrv    500   500       \_ trusted: kmk
```

The **print** subcommand outputs the encrypted key to the standard output. To export the key to a user-space blob, use the **pipe** subcommand as follows:

```
~]$ keyctl pipe 642500861 > kmk.blob
```

To load the trusted key from the user-space blob, use the **add** command again with the blob as an argument:

```
~]$ keyctl add trusted kmk "load `cat kmk.blob`" @u
268728824
```

The TPM-sealed trusted key can then be employed to create secure encrypted keys. The following command syntax is used for generating encrypted keys:

```
~]$ keyctl add encrypted name "new [format] key-type:master-key-name
keylength" keyring
```

Based on the above syntax, a command for generating an encrypted key using the already created trusted key can be constructed as follows:

```
~]$ keyctl add encrypted encr-key "new trusted:kmk 32" @u
159771175
```

To create an encrypted key on systems where a TPM is not available, use a random sequence of numbers to generate a user key, which is then used to seal the actual encrypted keys.

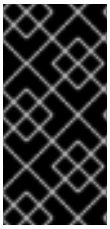
```
~]$ keyctl add user kmk-user "`dd if=/dev/urandom bs=1 count=32
2>/dev/null`" @u
427069434
```

Then generate the encrypted key using the random-number user key:

```
~]$ keyctl add encrypted encr-key "new user:kmk-user 32" @u
1012412758
```

The **list** subcommand can be used to list all keys in the specified kernel keyring:

```
~]$ keyctl list @u
2 keys in keyring:
427069434: --alswrv  1000  1000 user: kmk-user
1012412758: --alswrv  1000  1000 encrypted: encr-key
```



IMPORTANT

Keep in mind that encrypted keys that are not sealed by a master trusted key are only as secure as the user master key (random-number key) used to encrypt them. Therefore, the master user key should be loaded as securely as possible and preferably early during the boot process.

4.9.5.2. Additional Resources

The following offline and online resources can be used to acquire additional information pertaining to the use of trusted and encrypted keys.

Installed Documentation

- keyctl(1) — Describes the use of the **keyctl** utility and its subcommands.

Online Documentation

- Red Hat Enterprise Linux 7 SELinux User's and Administrator's Guide — The *SELinux User's and Administrator's Guide* for Red Hat Enterprise Linux 7 describes the basic principles of **SELinux** and documents in detail how to configure and use **SELinux** with various services, such as the **Apache HTTP Server**.

- https://www.kernel.org/doc/Documentation/security/keys-trusted-encrypted.txt — The official documentation about the trusted and encrypted keys feature of the Linux kernel.

See Also

- Section A.1.1, “Advanced Encryption Standard — AES” provides a concise description of the **Advanced Encryption Standard**.

- Section A.2, “Public-key Encryption” describes the public-key cryptographic approach and the various cryptographic protocols it uses.

4.9.6. Using the Random Number Generator

In order to be able to generate secure cryptographic keys that cannot be easily broken, a source of random numbers is required. Generally, the more random the numbers are, the better the chance of obtaining unique keys. *Entropy* for generating random numbers is usually obtained from computing environmental "noise" or using a hardware *random number generator*.

The **rngd** daemon, which is a part of the rng-tools package, is capable of using both environmental noise and hardware random number generators for extracting entropy. The daemon checks whether the data supplied by the source of randomness is sufficiently random and then stores it in the random-number entropy pool of the kernel. The random numbers it generates are made available through the **/dev/random** and **/dev/urandom** character devices.

The difference between **/dev/random** and **/dev/urandom** is that the former is a blocking device, which means it stops supplying numbers when it determines that the amount of entropy is insufficient for generating a properly random output. Conversely, **/dev/urandom** is a non-blocking source, which reuses the entropy pool of the kernel and is thus able to provide an unlimited supply of pseudo-random numbers, albeit with less entropy. As such, **/dev/urandom** should not be used for creating long-term cryptographic keys.

To install the rng-tools package, issue the following command as the **root** user:

```
~]# yum install rng-tools
```

To start the **rngd** daemon, execute the following command as **root**:

```
~]# systemctl start rngd
```

To query the status of the daemon, use the following command:

```
~]# systemctl status rngd
```

To start the **rngd** daemon with optional parameters, execute it directly. For example, to specify an alternative source of random-number input (other than **/dev/hwrandom**), use the following command:

```
~]# rngd --rng-device=/dev/hwrng
```

The above command starts the **rngd** daemon with **/dev/hwrng** as the device from which random numbers are read. Similarly, you can use the **-o** (or **--random-device**) option to choose the kernel device for random-number output (other than the default **/dev/random**). See the rngd(8) manual page for a list of all available options.

To check which sources of entropy are available in a given system, execute the following command as **root**:

```
~]# rngd -vf
Unable to open file: /dev/tpm0
Available entropy sources:
 DRNG
```

NOTE

After entering the **rngd -v** command, the according process continues running in background. The **-b, --background** option (become a daemon) is applied by default.

If there is not any TPM device present, you will see only the Intel Digital Random Number Generator (DRNG) as a source of entropy. To check if your CPU supports the RDRAND processor instruction, enter the following command:

```
~]$ cat /proc/cpuinfo | grep rdrand
```

NOTE

For more information and software code examples, see Intel Digital Random Number Generator (DRNG) Software Implementation Guide.

The rng-tools package also contains the **rngtest** utility, which can be used to check the randomness of data. To test the level of randomness of the output of **/dev/random**, use the **rngtest** tool as follows:

```
~]$ cat /dev/random | rngtest -c 1000
rngtest 5
Copyright (c) 2004 by Henrique de Moraes Holschuh
```

```
This is free software; see the source for copying conditions. There is NO
warranty; not even for MERCHANTABILITY or FITNESS FOR A PARTICULAR
PURPOSE.

rngtest: starting FIPS tests...
rngtest: bits received from input: 20000032
rngtest: FIPS 140-2 successes: 998
rngtest: FIPS 140-2 failures: 2
rngtest: FIPS 140-2(2001-10-10) Monobit: 0
rngtest: FIPS 140-2(2001-10-10) Poker: 0
rngtest: FIPS 140-2(2001-10-10) Runs: 0
rngtest: FIPS 140-2(2001-10-10) Long run: 2
rngtest: FIPS 140-2(2001-10-10) Continuous run: 0
rngtest: input channel speed: (min=1.171; avg=8.453; max=11.374)Mibits/s
rngtest: FIPS tests speed: (min=15.545; avg=143.126; max=157.632)Mibits/s
rngtest: Program run time: 2390520 microseconds
```

A high number of failures shown in the output of the **rngtest** tool indicates that the randomness of the tested data is insufficient and should not be relied upon. See the rngtest(1) manual page for a list of options available for the **rngtest** utility.

Red Hat Enterprise Linux 7 introduced the **virtio RNG** (Random Number Generator) device that provides **KVM** virtual machines with access to entropy from the host machine. With the recommended setup, hwrng feeds into the entropy pool of the host Linux kernel (through **`/dev/random`**), and **QEMU** will use **`/dev/random`** as the source for entropy requested by guests.

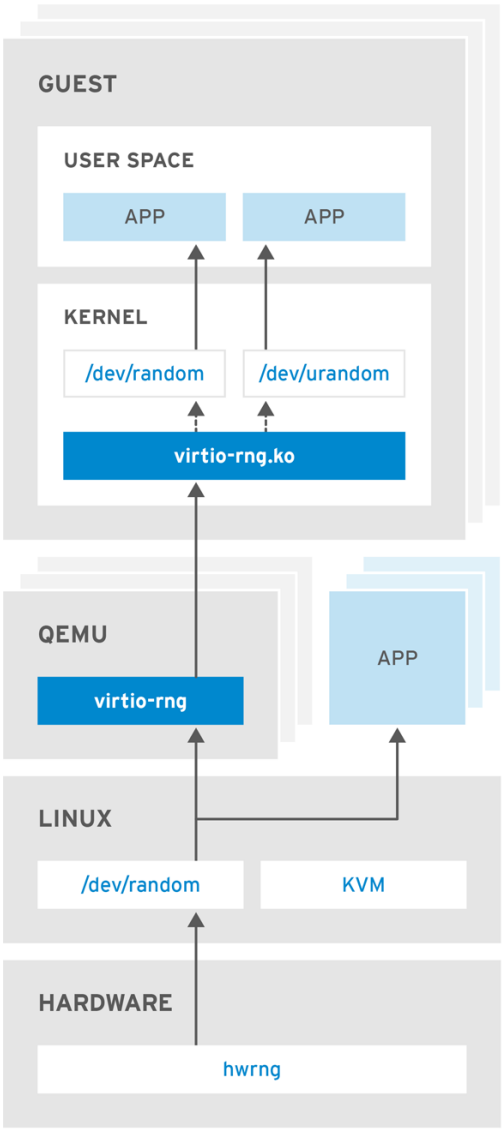


Figure 4.1. The virtio RNG device

Previously, Red Hat Enterprise Linux 7.0 and Red Hat Enterprise Linux 6 guests could make use of the entropy from hosts through the rngd user space daemon. Setting up the daemon was a manual step for each Red Hat Enterprise Linux installation. With Red Hat Enterprise Linux 7.1, the manual step has been eliminated, making the entire process seamless and automatic. The use of rngd is now not required and the guest kernel itself fetches entropy from the host when the available entropy falls below a specific threshold. The guest kernel is then in a position to make random numbers available to applications as soon as they request them.

The Red Hat Enterprise Linux installer, **Anaconda**, now provides the **virtio-rng** module in its installer image, making available host entropy during the Red Hat Enterprise Linux installation.

4.10. CONFIGURING AUTOMATED UNLOCKING OF ENCRYPTED VOLUMES USING POLICY-BASED DECRYPTION

The Policy-Based Decryption (PBD) is a collection of technologies that enable unlocking encrypted root and secondary volumes of hard drives on physical and virtual machines. PBD uses a variety of unlocking methods, such as user passwords, a Trusted Platform Module (TPM) device, a PKCS#11 device connected to a system, for example, a smart card, or a special network server.

PBD allows combining different unlocking methods into a policy, which makes it possible to unlock the same volume in different ways. The current implementation of the PBD in Red Hat Enterprise Linux consists of the Clevis framework and plug-ins called *pins*. Each pin provides a separate unlocking capability. Currently, the following pins are available:

- **`tang`** - allows volumes to be unlocked using a network server
- **`tpm2`** - allows volumes to be unlocked using a TPM2 policy

The Network Bound Disc Encryption (NBDE) is a subcategory of PBD that allows binding encrypted volumes to a special network server. The current implementation of the NBDE includes a Clevis pin for Tang server and the Tang server itself.

4.10.1. Network-Bound Disk Encryption

The Network-Bound Disk Encryption (NBDE) allows the user to encrypt root volumes of hard drives on physical and virtual machines without requiring to manually enter a password when systems are restarted.

In Red Hat Enterprise Linux 7, NBDE is implemented through the following components and technologies:

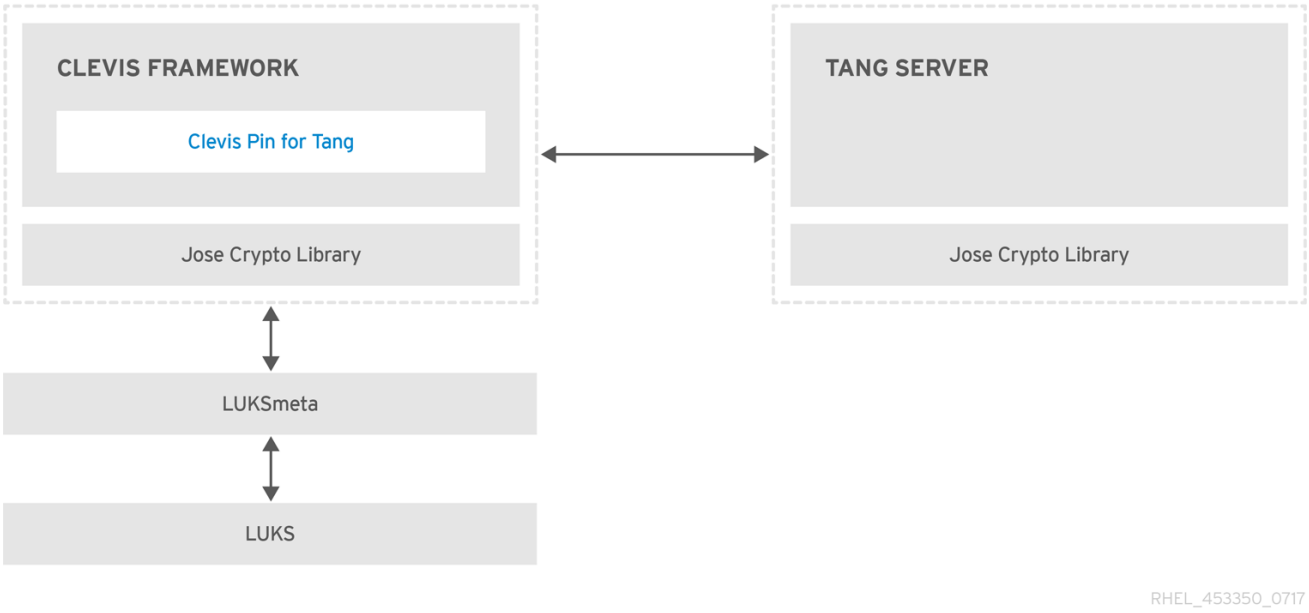


Figure 4.2. The Network-Bound Disk Encryption using Clevis and Tang

Tang is a server for binding data to network presence. It makes a system containing your data available when the system is bound to a certain secure network. Tang is stateless and does not require TLS or authentication. Unlike escrow-based solutions, where the server stores all encryption keys and has knowledge of every key ever used, Tang never interacts with any client keys, so it never gains any identifying information from the client.

Clevis is a pluggable framework for automated decryption. In NBDE, Clevis provides automated unlocking of LUKS volumes. The clevis package provides the client side of the feature.

A *Clevis pin* is a plug-in into the Clevis framework. One of such pins is a plug-in that implements interactions with the NBDE server — Tang.

Clevis and Tang are generic client and server components that provide network-bound encryption. In Red Hat Enterprise Linux 7, they are used in conjunction with LUKS to encrypt and decrypt root and non-root storage volumes to accomplish Network-Bound Disk Encryption.

Both client- and server-side components use the *José* library to perform encryption and decryption operations.

When you begin provisioning NBDE, the Clevis pin for Tang server gets a list of the Tang server's advertised asymmetric keys. Alternatively, since the keys are asymmetric, a list of Tang's public keys can be distributed out of band so that clients can operate without access to the Tang server. This mode is called *offline provisioning*.

The Clevis pin for Tang uses one of the public keys to generate a unique, cryptographically-strong encryption key. Once the data is encrypted using this key, the key is discarded. The Clevis client should store the state produced by this provisioning operation in a convenient location. This process of encrypting data is the *provisioning step*. The provisioning state for NBDE is stored in the LUKS header leveraging the luksmeta package.

When the client is ready to access its data, it loads the metadata produced in the provisioning step and it responds to recover the encryption key. This process is the *recovery step*.

In NBDE, Clevis binds a LUKS volume using a pin so that it can be automatically unlocked. After successful completion of the binding process, the disk can be unlocked using the provided Dracut unlocker.

4.10.2. Installing an Encryption Client - Clevis

To install the Clevis pluggable framework and its pins on a machine (client) with an encrypted volume, enter the following command as **root**:

```
~]# yum install clevis
```

To decrypt data, use the **clevis decrypt** command and provide a cipher text in the JSON Web Encryption (JWE) format, for example:

```
~]$ clevis decrypt < secret.jwe
```

For more information, see the built-in CLI help:

```
~]$ clevis
Usage: clevis COMMAND [OPTIONS]

  clevis decrypt      Decrypts using the policy defined at encryption time
  clevis encrypt http Encrypts using a REST HTTP escrow server policy
  clevis encrypt sss  Encrypts using a Shamir's Secret Sharing policy
  clevis encrypt tang Encrypts using a Tang binding server policy
  clevis encrypt tpm2 Encrypts using a TPM2.0 chip binding policy

~]$ clevis decrypt
Usage: clevis decrypt < JWE > PLAINTEXT

Decrypts using the policy defined at encryption time

~]$ clevis encrypt tang
Usage: clevis encrypt tang CONFIG < PLAINTEXT > JWE
```

```
Encrypts using a Tang binding server policy

This command uses the following configuration properties:

  url: <string>   The base URL of the Tang server (REQUIRED)

  thp: <string>   The thumbprint of a trusted signing key

  adv: <string>   A filename containing a trusted advertisement
  adv: <object>   A trusted advertisement (raw JSON)

Obtaining the thumbprint of a trusted signing key is easy. If you
have access to the Tang server's database directory, simply do:

    $ jose jwk thp -i $DBDIR/$SIG.jwk

Alternatively, if you have certainty that your network connection
is not compromised (not likely), you can download the advertisement
yourself using:

    $ curl -f $URL/adv > adv.jws
```

4.10.3. Deploying a Tang server

To install the tang package and its dependencies, enter the following command as **root**:

```
~]# yum install tang
```

Enable and start the **tangd** service using systemd:

```
~]# systemctl enable tangd.socket --now
Created symlink from /etc/systemd/system/multi-
user.target.wants/tangd.socket to /usr/lib/systemd/system/tangd.socket.
```

Since **tangd** uses the **systemd** socket activation mechanism, the server starts as soon as the first connection comes in. A new set of cryptographic keys is automatically generated at the first start.

To perform cryptographic operations such as manual key generation, use the **jose** utility. Enter the **jose -h** command or see the **jose(1)** man pages for more information.

Example 4.4. Rotating Tang Keys

It is important to periodically rotate your keys. The precise interval at which you should rotate them depends upon your application, key sizes, and institutional policy. For some common recommendations, see the Cryptographic Key Length Recommendation page.

To rotate keys, start with the generation of new keys in the key database directory, typically **/var/db/tang**. For example, you can create new signature and exchange keys with the following commands:

```
~]# DB=/var/db/tang
~]# jose jwk gen -i '{"alg":"ES512"}' -o $DB/new_sig.jwk
~]# jose jwk gen -i '{"alg":"ECMR"}' -o $DB/new_exc.jwk
```

Rename the old keys to have a leading `.` to hide them from advertisement. Note that the file names in the following example differs from real and unique file names in the key database directory.

```
~]# mv $DB/old_sig.jwk $DB/.old_sig.jwk
~]# mv $DB/old_exc.jwk $DB/.old_exc.jwk
```

Tang immediately picks up all changes. No restart is required.

At this point, new client bindings pick up the new keys and old clients can continue to utilize the old keys. When you are sure that all old clients use the new keys, you can remove the old keys.

WARNING

Be aware that removing the old keys while clients are still using them can result in data loss.

Tang uses port 80 for communication. This port is also widely-used for web servers. To change Tang's port number, override the **`tangd.socket`** unit file using the standard **`systemd`** mechanisms. See Red Hat Enterprise Linux 7 System Administrator's Guide: Creating and Modifying systemd Unit Files for more information.

4.10.3.1. Deploying High-Availability Systems

Tang provides two methods for building a high-availability deployment:

1. **Client Redundancy (Recommended)**

   Clients should be configured with the ability to bind to multiple Tang servers. In this setup, each Tang server has its own keys and clients are able to decrypt by contacting a subset of these servers. Clevis already supports this workflow through its **`sss`** plug-in.

   For more information about this setup, see the following man pages:

   - **`tang(8)`**, section High Availability
   - **`clevis(1)`**, section Shamir's Secret Sharing
   - **`clevis-encrypt-sss(1)`**

   Red Hat recommends this method for a high-availability deployment.

2. **Key Sharing**

   For redundancy purposes, more than one instance of Tang can be deployed. To set up a second or any subsequent instance, install the tang packages and copy the key directory to the new host using **`rsync`** over SSH. Note that Red Hat does not recommend this method because sharing keys increases the risk of key compromise and requires additional automation infrastructure.

4.10.4. Deploying an Encryption Client for an NBDE system with Tang

Prerequisities

- The Clevis framework is installed. See Section 4.10.2, “Installing an Encryption Client - Clevis”
- A Tang server is available. See Section 4.10.3, “Deploying a Tang server”

Procedure

To bind a Clevis encryption client to a Tang server, use the **clevis encrypt tang** sub-command:

```
~]$ clevis encrypt tang '{"url":"http://tang.srv"}' < input-plain.txt >
secret.jwe
The advertisement contains the following signing keys:

_OsIk0T-E2l6qjfdDiwVmidoZjA

Do you wish to trust these keys? [ynYN] y
```

Change the *http://tang.srv* URL in the previous example to match the URL of the server where tang is installed. The *secret.jwe* output file contains your encrypted cipher text in the JSON Web Encryption format. This cipher text is read from the *input-plain.txt* input file.

To decrypt data, use the **clevis decrypt** command and provide the cipher text (JWE):

```
~]$ clevis decrypt < secret.jwe > output-plain.txt
```

For more information, see the **clevis-encrypt-tang(1)** man page or use the built-in CLI help:

```
~]$ clevis
Usage: clevis COMMAND [OPTIONS]

  clevis decrypt      Decrypts using the policy defined at encryption time
  clevis encrypt http Encrypts using a REST HTTP escrow server policy
  clevis encrypt sss  Encrypts using a Shamir's Secret Sharing policy
  clevis encrypt tang Encrypts using a Tang binding server policy
  clevis encrypt tang Encrypts using a Tang binding server policy
  clevis luks bind    Binds a LUKSv1 device using the specified policy
  clevis luks unlock  Unlocks a LUKSv1 volume

~]$ clevis decrypt
Usage: clevis decrypt < JWE > PLAINTEXT

Decrypts using the policy defined at encryption time

~]$ clevis encrypt tang
Usage: clevis encrypt tang CONFIG < PLAINTEXT > JWE

Encrypts using a Tang binding server policy

This command uses the following configuration properties:

  url: <string>   The base URL of the Tang server (REQUIRED)

  thp: <string>   The thumbprint of a trusted signing key
```

```
  adv: <string>   A filename containing a trusted advertisement
  adv: <object>   A trusted advertisement (raw JSON)

Obtaining the thumbprint of a trusted signing key is easy. If you
have access to the Tang server's database directory, simply do:

    $ jose jwk thp -i $DBDIR/$SIG.jwk

Alternatively, if you have certainty that your network connection
is not compromised (not likely), you can download the advertisement
yourself using:

    $ curl -f $URL/adv > adv.jws
```

4.10.5. Deploying an Encryption Client with a TPM 2.0 Policy

On systems with the 64-bit Intel or 64-bit AMD architecture, to deploy a client that encrypts using a Trusted Platform Module 2.0 (TPM 2.0) chip, use the **`clevis encrypt tpm2`** sub-command with the only argument in form of the JSON configuration object:

```
~]$ clevis encrypt tpm2 '{}' < input-plain.txt > secret.jwe
```

To choose a different hierarchy, hash, and key algorithms, specify configuration properties, for example:

```
~]$ clevis encrypt tpm2 '{"hash":"sha1","key":"rsa"}' < input-plain.txt >
secret.jwe
```

To decrypt the data, provide the ciphertext in the JSON Web Encryption (JWE) format:

```
~]$ clevis decrypt < secret.jwe > output-plain.txt
```

The pin also supports sealing data to a Platform Configuration Registers (PCR) state. That way, the data can only be unsealed if the PCRs hashes values match the policy used when sealing.

For example, to seal the data to the PCR with index 0 and 1 for the SHA1 bank:

```
~]$ clevis encrypt tpm2 '{"pcr_bank":"sha1","pcr_ids":"0,1"}' < input-
plain.txt > secret.jwe
```

For more information and the list of possible configuration properties, see the **`clevis-encrypt-tpm2(1)`** man page.

4.10.6. Configuring Manual Enrollment of Root Volumes

To automatically unlock an existing LUKS-encrypted root volume, install the clevis-luks subpackage and bind the volume to a Tang server using the **`clevis luks bind`** command:

```
~]# yum install clevis-luks
```

```
~]# clevis luks bind -d /dev/sda tang '{"url":"http://tang.srv"}'
The advertisement contains the following signing keys:
```

```
_OsIk0T-E2l6qjfdDiwVmidoZjA

Do you wish to trust these keys? [ynYN] y
You are about to initialize a LUKS device for metadata storage.
Attempting to initialize it may result in data loss if data was
already written into the LUKS header gap in a different format.
A backup is advised before initialization is performed.

Do you wish to initialize /dev/sda? [yn] y
Enter existing LUKS password:
```

This command performs four steps:

1. Creates a new key with the same entropy as the LUKS master key.
2. Encrypts the new key with Clevis.
3. Stores the Clevis JWE object in the LUKS header with LUKSMeta.
4. Enables the new key for use with LUKS.

This disk can now be unlocked with your existing password as well as with the Clevis policy. For more information, see the **clevis-luks-bind(1)** man page.

NOTE

The binding procedure assumes that there is at least one free LUKS password slot. The **clevis luks bind** command takes one of the slots.

To verify that the Clevis JWE object is successfully placed in a LUKS header, use the **luksmeta show** command:

```
~]# luksmeta show -d /dev/sda
0   active empty
1   active cb6e8904-81ff-40da-a84a-07ab9ab5715e
2 inactive empty
3 inactive empty
4 inactive empty
5 inactive empty
6 inactive empty
7 inactive empty
```

To enable the early boot system to process the disk binding, enter the following commands on an already installed system:

```
~]# yum install clevis-dracut
~]# dracut -f
```

IMPORTANT

To use NBDE for clients with static IP configuration (without DHCP), pass your network configuration to the dracut tool manually, for example:

```
~]# dracut -f --kernel-cmdline "ip=192.0.2.10
netmask=255.255.255.0 gateway=192.0.2.1 nameserver=192.0.2.45"
```

Alternatively, create a .conf file in the **/etc/dracut.conf.d/** directory with the static network information. For example:

```
~]# cat /etc/dracut.conf.d/static_ip.conf
kernel_cmdline="ip= 10.0.0.103 netmask=255.255.252.0
gateway=10.0.0.1 nameserver=10.0.0.1"
```

Regenerate the initial RAM disk image:

```
~]# dracut -f
```

See the **dracut.cmdline(7)** man page for more information.

4.10.7. Configuring Automated Enrollment Using Kickstart

Clevis can integrate with Kickstart to provide a fully automated enrollment process.

1. Instruct Kickstart to partition the disk such that the root partition has enabled LUKS encryption with a temporary password. The password is temporary for the enrollment process.

   ```
   part /boot --fstype="xfs" --ondisk=vda --size=256
   part / --fstype="xfs" --ondisk=vda --grow --encrypted --
   passphrase=temppass
   ```

2. Install the related Clevis packages by listing them in the **%packages** section:

   ```
   %packages
   clevis-dracut
   %end
   ```

3. Call **clevis luks bind** to perform binding in the **%post** section. Afterward, remove the temporary password:

   ```
   %post
   clevis luks bind -f -k- -d /dev/vda2 \
   tang '{"url":"http://tang.srv","thp":"_OsIk0T-E2l6qjfdDiwVmidoZjA"}'
   \ <<< "temppass"
   cryptsetup luksRemoveKey /dev/vda2 - <<< "temppass"
   %end
   ```

   In the above example, note that we specify the thumbprint that we trust on the Tang server as part of our binding configuration, enabling binding to be completely non-interactive.

   You can use an analogous procedure when using a TPM 2.0 policy instead of a Tang server.

For more information on Kickstart installations, see the Red Hat Enterprise Linux 7 Installation Guide. For information on Linux Unified Key Setup-on-disk-format (LUKS), see Section 4.9.1, “Using LUKS Disk Encryption”.

4.10.8. Configuring Automated Unlocking of Removable Storage Devices

To automatically unlock a LUKS-encrypted removable storage device, such as a USB drive, install the clevis-udisks2 package:

```
~]# yum install clevis-udisks2
```

Reboot the system, and then perform the binding step using the **clevis luks bind** command as described in Section 4.10.6, “Configuring Manual Enrollment of Root Volumes”, for example:

```
~]# clevis luks bind -d /dev/sdb1 tang '{"url":"http://tang.srv"}'
```

The LUKS-encrypted removable device can be now unlocked automatically in your GNOME desktop session. The device bound to a Clevis policy can be also unlocked by the **clevis luks unlock** command:

```
~]# clevis luks unlock -d /dev/sdb1
```

You can use an analogous procedure when using a TPM 2.0 policy instead of a Tang server.

4.10.9. Configuring Automated Unlocking of Non-root Volumes at Boot Time

To use NBDE to also unlock LUKS-encrypted non-root volumes, perform the following steps:

1. Install the clevis-systemd package:

   ```
   ~]# yum install clevis-systemd
   ```

2. Enable the Clevis unlocker service:

   ```
   ~]# systemctl enable clevis-luks-askpass.path
   Created symlink from /etc/systemd/system/remote-
   fs.target.wants/clevis-luks-askpass.path to
   /usr/lib/systemd/system/clevis-luks-askpass.path.
   ```

3. Perform the binding step using the **clevis luks bind** command as described in Section 4.10.6, “Configuring Manual Enrollment of Root Volumes”.

4. To set up the encrypted block device during system boot, add the corresponding line with the **_netdev** option to the **/etc/crypttab** configuration file. See the **crypttab(5)** man page for more information.

5. Add the volume to the list of accessible filesystems in the **/etc/fstab** file. Use the **_netdev** option in this configuration file, too. See the **fstab(5)** man page for more information.

4.10.10. Deploying Virtual Machines in a NBDE Network

The **clevis luks bind** command does not change the LUKS master key. This implies that if you create a LUKS-encrypted image for use in a virtual machine or cloud environment, all the instances that run this image will share a master key. This is extremely insecure and should be avoided at all times.

This is not a limitation of Clevis but a design principle of LUKS. If you wish to have encrypted root volumes in a cloud, you need to make sure that you perform the installation process (usually using Kickstart) for each instance of Red Hat Enterprise Linux in a cloud as well. The images cannot be shared without also sharing a LUKS master key.

If you intend to deploy automated unlocking in a virtualized environment, Red Hat strongly recommends that you use systems such as lorax or virt-install together with a Kickstart file (see Section 4.10.7, “Configuring Automated Enrollment Using Kickstart”) or another automated provisioning tool to ensure that each encrypted VM has a unique master key.

4.10.11. Building Automatically-enrollable VM Images for Cloud Environments using NBDE

Deploying automatically-enrollable encrypted images in a cloud environment can provide a unique set of challenges. Like other virtualization environments detailed above, images should be instantiated at most once to avoid sharing the LUKS master key. Therefore, automated deployment systems systems such as lorax or virt-install together with a Kickstart file should be used to ensure master key uniqueness during the image building process.

Cloud environments enable two Tang server deployment options which we consider here. First, the Tang server can be deployed within the cloud environment itself. Second, the Tang server can be deployed outside of the cloud on independent infrastructure with a VPN link between the two infrastructures.

Deploying Tang natively in the cloud does allow for easy deployment. However, given that it shares infrastructure with the data persistence layer of ciphertext of other systems, it may be possible for both the Tang server’s private key and the Clevis metadata to be stored on the same physical disk. Access to this physical disk permits a full compromise of the ciphertext data.

IMPORTANT

For this reason, Red Hat strongly recommends maintaining a physical separation between the location where the data is stored and the system where Tang is running. This separation between the cloud and the Tang server ensures that the Tang server’s private key cannot be accidentally combined with the Clevis metadata. It also provides local control of the Tang server if the cloud infrastructure is at risk.

4.10.12. Additional Resources

For more information, see the following man pages:

- **tang(8)**
- **clevis(1)**
- **jose(1)**
- **clevis-luks-unlockers(1)**
- **tang-nagios(1)**

4.11. CHECKING INTEGRITY WITH AIDE

Advanced Intrusion Detection Environment (**AIDE**) is a utility that creates a database of files on the system, and then uses that database to ensure file integrity and detect system intrusions.

4.11.1. Installing AIDE

To install the aide package, enter the following command as **root**:

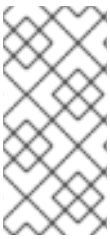
```
~]# yum install aide
```

To generate an initial database, enter the following command as **root**:

```
~]# aide --init

AIDE, version 0.15.1

### AIDE database at /var/lib/aide/aide.db.new.gz initialized.
```



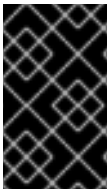
NOTE

In the default configuration, the **aide --init** command checks just a set of directories and files defined in the **/etc/aide.conf** file. To include additional directories or files in the AIDE database, and to change their watched parameters, edit **/etc/aide.conf** accordingly.

To start using the database, remove the **.new** substring from the initial database file name:

```
~]# mv /var/lib/aide/aide.db.new.gz /var/lib/aide/aide.db.gz
```

To change the location of the **AIDE** database, edit the **/etc/aide.conf** file and modify the **DBDIR** value. For additional security, store the database, configuration, and the **/usr/sbin/aide** binary file in a secure location such as a read-only media.



IMPORTANT

To avoid SELinux denials after the AIDE database location change, update your SELinux policy accordingly. See the SELinux User's and Administrator's Guide for more information.

4.11.2. Performing Integrity Checks

To initiate a manual check, enter the following command as **root**:

```
~]# aide --check
AIDE 0.15.1 found differences between database and filesystem!!
Start timestamp: 2017-03-30 14:12:56

Summary:
  Total number of files: 147173
  Added files:   1
```

```
  Removed files:  0
  Changed files:  2
...
```

At a minimum, **AIDE** should be configured to run a weekly scan. At most, **AIDE** should be run daily. For example, to schedule a daily execution of **AIDE** at *4:05 am* using **cron** (see the Automating System Tasks chapter in the System Administrator's Guide), add the following line to **/etc/crontab**:

```
05 4 * * * root /usr/sbin/aide --check
```

4.11.3. Updating an AIDE Database

After the changes of your system such as package updates or configuration files adjustments are verified, update your baseline **AIDE** database:

```
~]# aide --update
```

The **aide --update** command creates the **/var/lib/aide/aide.db.new.gz** database file. To start using it for integrity checks, remove the **.new** substring from the file name.

4.11.4. Additional Resources

For additional information on AIDE, see the following documentation:

- **aide(1)** man page
- **aide.conf(5)** man page
- Guide to the Secure Configuration of Red Hat Enterprise Linux 7 (OpenSCAP Security Guide): Verify Integrity with AIDE
- The AIDE manual

4.12. USING USBGUARD

The **USBGuard** software framework provides system protection against intrusive USB devices by implementing basic whitelisting and blacklisting capabilities based on device attributes. To enforce a user-defined policy, **USBGuard** uses the Linux kernel USB device authorization feature. The **USBGuard** framework provides the following components:

- The daemon component with an inter-process communication (IPC) interface for dynamic interaction and policy enforcement.
- The command-line interface to interact with a running **USBGuard** instance.
- The rule language for writing USB device authorization policies.
- The C++ API for interacting with the daemon component implemented in a shared library.

4.12.1. Installing USBGuard

To install the usbguard package, enter the following command as **root**:

```
~]# yum install usbguard
```

To create the initial rule set, enter the following command as **root**:

```
~]# usbguard generate-policy > /etc/usbguard/rules.conf
```

NOTE

To customize the **USBGuard** rule set, edit the **/etc/usbguard/rules.conf** file. See the **usbguard-rules.conf(5)** man page for more information. Additionally, see Section 4.12.3, “Using the Rule Language to Create Your Own Policy” for examples.

To start the **USBGuard** daemon, enter the following command as **root**:

```
~]# systemctl start usbguard.service
~]# systemctl status usbguard
● usbguard.service - USBGuard daemon
   Loaded: loaded (/usr/lib/systemd/system/usbguard.service; disabled;
vendor preset: disabled)
   Active: active (running) since Tue 2017-06-06 13:29:31 CEST; 9s ago
     Docs: man:usbguard-daemon(8)
 Main PID: 4984 (usbguard-daemon)
   CGroup: /system.slice/usbguard.service
           └─4984 /usr/sbin/usbguard-daemon -k -c /etc/usbguard/usbguard-
daem...
```

To ensure **USBGuard** starts automatically at system start, use the following command as **root**:

```
~]# systemctl enable usbguard.service
Created symlink from
/etc/systemd/system/basic.target.wants/usbguard.service to
/usr/lib/systemd/system/usbguard.service.
```

To list all USB devices recognized by **USBGuard**, enter the following command as **root**:

```
~]# usbguard list-devices
1: allow id 1d6b:0002 serial "0000:00:06.7" name "EHCI Host Controller"
hash "JDOb0BiktYs2ct3mSQKopnOOV2h9MGYADwhT+oUtF2s=" parent-hash
"4PHGcaDKWtPjKDwYpIRG722cB9SlGz9l9Iea93+Gt9c=" via-port "usb1" with-
interface 09:00:00
...
6: block id 1b1c:1ab1 serial "000024937962" name "Voyager" hash
"CrXgiaWIf2bZAU+5WkzOE7y0rdSO82XMzubn7HDb95Q=" parent-hash
"JDOb0BiktYs2ct3mSQKopnOOV2h9MGYADwhT+oUtF2s=" via-port "1-3" with-
interface 08:06:50
```

To authorize a device to interact with the system, use the **allow-device** option:

```
~]# usbguard allow-device 6
```

To deauthorize and remove a device from the system, use the **reject-device** option. To just deauthorize a device, use the **usbguard** command with the **block-device** option:

```
~]# usbguard block-device 6
```

USBGuard uses the *block* and *reject* terms with the following meaning:

- block - do not talk to this device for now
- reject - ignore this device as if did not exist

To see all options of the **usbguard** command, enter it with the **--help** directive:

```
~]$ usbguard --help
```

4.12.2. Creating a White List and a Black List

The **usbguard-daemon.conf** file is loaded by the **usbguard** daemon after it parses its command-line options and is used to configure runtime parameters of the daemon. To override the default configuration file (**/etc/usbguard/usbguard-daemon.conf**), use the **-c** command-line option. See the **usbguard-daemon(8)** man page for further details.

To create a white list or a black list, edit the **usbguard-daemon.conf** file and use the following options:

USBGuard configuration file

RuleFile=*<path>*

The **usbguard** daemon use this file to load the policy rule set from it and to write new rules received through the IPC interface.

IPCAllowedUsers=*<username> [<username> ...]*

A space-delimited list of user names that the daemon will accept IPC connections from.

IPCAllowedGroups=*<groupname> [<groupname> ...]*

A space-delimited list of group names that the daemon will accept IPC connections from.

IPCAccessControlFiles=*<path>*

Path to a directory holding the IPC access control files.

ImplicitPolicyTarget=*<target>*

How to treat devices that do not match any rule in the policy. Accepted values: allow, block, reject.

PresentDevicePolicy=*<policy>*

How to treat devices that are already connected when the daemon starts:

- allow - authorize every present device
- block - deauthorize every present device
- reject - remove every present device
- keep - just sync the internal state and leave it

- apply-policy - evaluate the ruleset for every present device

PresentControllerPolicy=*<policy>*

How to treat USB controllers that are already connected when the daemon starts:

- allow - authorize every present device
- block - deauthorize every present device
- reject - remove every present device
- keep - just sync the internal state and leave it
- apply-policy - evaluate the ruleset for every present device

Example 4.5. USBGuard configuration

The following configuration file orders the **usbguard** daemon to load rules from the **/etc/usbguard/rules.conf** file and it allows only users from the **usbguard** group to use the IPC interface:

```
RuleFile=/etc/usbguard/rules.conf
IPCAccessControlFiles=/etc/usbguard/IPCAccessControl.d/
```

To specify the IPC Access Control List (ACL), use the **usbguard add-user** or **usbguard remove-user** commands. See the **usbguard(1)** for more details. In this example, to allow users from the **usbguard** group to modify USB device authorization state, list USB devices, listen to exception events, and list USB authorization policy, enter the following command as **root**:

```
~]# usbguard add-user -g usbguard --devices=modify,list,listen --
policy=list --exceptions=listen
```

IMPORTANT

The daemon provides the **USBGuard** public IPC interface. In Red Hat Enterprise Linux, the access to this interface is by default limited to the **root** user only. Consider setting either the **IPCAccessControlFiles** option (recommended) or the **IPCAllowedUsers** and **IPCAllowedGroups** options to limit access to the IPC interface. Do not leave the ACL unconfigured as this exposes the IPC interface to all local users and it allows them to manipulate the authorization state of USB devices and modify the **USBGuard** policy.

For more information, see the IPC Access Control section in the **usbguard-daemon.conf(5)** man page.

4.12.3. Using the Rule Language to Create Your Own Policy

The **usbguard** daemon decides whether to authorize a USB device based on a policy defined by a set of rules. When a USB device is inserted into the system, the daemon scans the existing rules sequentially and when a matching rule is found, it either authorizes (allows), deauthorizes (blocks) or

removes (rejects) the device, based on the rule target. If no matching rule is found, the decision is based on an implicit default target. This implicit default is to block the device until a decision is made by the user.

The rule language grammar is the following:

```
rule ::= target device_id device_attributes conditions.

target ::= "allow" | "block" | "reject".

device_id ::= "*:*" | vendor_id ":*" | vendor_id ":" product_id.

device_attributes ::= device_attributes | attribute.
device_attributes ::= .

conditions ::= conditions | condition.
conditions ::= .
```

For more details about the rule language such as targets, device specification, or device attributes, see the **usbguard-rules.conf(5)** man page.

Example 4.6. USBguard example policies

Allow USB mass storage devices and block everything else

This policy blocks any device that is not just a mass storage device. Devices with a hidden keyboard interface in a USB flash disk are blocked. Only devices with a single mass storage interface are allowed to interact with the operating system. The policy consists of a single rule:

```
allow with-interface equals { 08:*:* }
```

The blocking is implicit because there is no block rule. Implicit blocking is useful to desktop users because a desktop applet listening to **USBGuard** events can ask the user for a decision if an implicit target was selected for a device.

Allow a specific Yubikey device to be connected through a specific port

Reject everything else on that port.

```
allow 1050:0011 name "Yubico Yubikey II" serial "0001234567" via-port
"1-2" hash "044b5e168d40ee0245478416caf3d998"
reject via-port "1-2"
```

Reject devices with suspicious combination of interfaces

A USB flash disk which implements a keyboard or a network interface is very suspicious. The following set of rules forms a policy which allows USB flash disks and explicitly rejects devices with an additional and suspicious interface.

```
allow with-interface equals { 08:*:* }
reject with-interface all-of { 08:*:* 03:00:* }
reject with-interface all-of { 08:*:* 03:01:* }
reject with-interface all-of { 08:*:* e0:*:* }
reject with-interface all-of { 08:*:* 02:*:* }
```

NOTE

Blacklisting is the wrong approach and you should not just blacklist a set of devices and allow the rest. The policy above assumes that blocking is the implicit default. Rejecting a set of devices considered as "bad" is a good approach how to limit the exposure of the system to such devices as much as possible.

Allow a keyboard-only USB device

The following rule allows a keyboard-only USB device only if there is not a USB device with a keyboard interface already allowed.

```
allow with-interface one-of { 03:00:01 03:01:01 } if !allowed-
matches(with-interface one-of { 03:00:01 03:01:01 })
```

After an initial policy generation using the **`usbguard generate-policy`** command, edit the **`/etc/usbguard/rules.conf`** to customize the **USBGuard** policy rules.

```
~]$ usbguard generate-policy > rules.conf
~]$ vim rules.conf
```

To install the updated policy and make your changes effective, use the following commands:

```
~]# install -m 0600 -o root -g root rules.conf /etc/usbguard/rules.conf
```

4.12.4. Additional Resources

For additional information on **USBGuard**, see the following documentation:

- **`usbguard(1)`** man page
- **`usbguard-rules.conf(5)`** man page
- **`usbguard-daemon(8)`** man page
- **`usbguard-daemon.conf(5)`** man page
- The USBGuard homepage

4.13. HARDENING TLS CONFIGURATION

`TLS` (**`Transport Layer Security`**) is a cryptographic protocol used to secure network communications. When hardening system security settings by configuring preferred *key-exchange protocols*, *authentication methods*, and *encryption algorithms*, it is necessary to bear in mind that the broader the range of supported clients, the lower the resulting security. Conversely, strict security settings lead to a limited compatibility with clients, which can result in some users being locked out of the system. Be sure to target the strictest available configuration and only relax it when it is required for compatibility reasons.

Note that the default settings provided by libraries included in Red Hat Enterprise Linux 7 are secure enough for most deployments. The **`TLS`** implementations use secure algorithms where possible while not

preventing connections from or to legacy clients or servers. Apply the hardened settings described in this section in environments with strict security requirements where legacy clients or servers that do not support secure algorithms or protocols are not expected or allowed to connect.

4.13.1. Choosing Algorithms to Enable

There are several components that need to be selected and configured. Each of the following directly influences the robustness of the resulting configuration (and, consequently, the level of support in clients) or the computational demands that the solution has on the system.

Protocol Versions

The latest version of **TLS** provides the best security mechanism. Unless you have a compelling reason to include support for older versions of **TLS** (or even **SSL**), allow your systems to negotiate connections using only the latest version of **TLS**.

Do not allow negotiation using **SSL** version 2 or 3. Both of those versions have serious security vulnerabilities. Only allow negotiation using **TLS** version 1.0 or higher. The current version of **TLS**, 1.2, should always be preferred.

NOTE

Please note that currently, the security of all versions of **TLS** depends on the use of **TLS** extensions, specific ciphers (see below), and other workarounds. All **TLS** connection peers need to implement secure renegotiation indication (RFC 5746), must not support compression, and must implement mitigating measures for timing attacks against **CBC**-mode ciphers (the Lucky Thirteen attack). **TLS 1.0** clients need to additionally implement record splitting (a workaround against the BEAST attack). **TLS 1.2** supports *Authenticated Encryption with Associated Data* (AEAD) mode ciphers like **AES-GCM**, **AES-CCM**, or **Camellia-GCM**, which have no known issues. All the mentioned mitigations are implemented in cryptographic libraries included in Red Hat Enterprise Linux.

See Table 4.6, “Protocol Versions” for a quick overview of protocol versions and recommended usage.

Table 4.6. Protocol Versions

Protocol Version	Usage Recommendation
SSL v2	Do not use. Has serious security vulnerabilities.
SSL v3	Do not use. Has serious security vulnerabilities.
TLS 1.0	Use for interoperability purposes where needed. Has known issues that cannot be mitigated in a way that guarantees interoperability, and thus mitigations are not enabled by default. Does not support modern cipher suites.
TLS 1.1	Use for interoperability purposes where needed. Has no known issues but relies on protocol fixes that are included in all the **TLS** implementations in Red Hat Enterprise Linux. Does not support modern cipher suites.
TLS 1.2	Recommended version. Supports the modern **AEAD** cipher suites.

Some components in Red Hat Enterprise Linux are configured to use **TLS 1.0** even though they provide support for **TLS 1.1** or even **1.2**. This is motivated by an attempt to achieve the highest level of interoperability with external services that may not support the latest versions of **TLS**. Depending on your interoperability requirements, enable the highest available version of **TLS**.

IMPORTANT

SSL v3 is not recommended for use. However, if, despite the fact that it is considered insecure and unsuitable for general use, you absolutely must leave **SSL v3** enabled, see Section 4.8, “Using stunnel” for instructions on how to use **stunnel** to securely encrypt communications even when using services that do not support encryption or are only capable of using obsolete and insecure modes of encryption.

Cipher Suites

Modern, more secure *cipher suites* should be preferred to old, insecure ones. Always disable the use of eNULL and aNULL cipher suites, which do not offer any encryption or authentication at all. If at all possible, ciphers suites based on **RC4** or **HMAC-MD5**, which have serious shortcomings, should also be disabled. The same applies to the so-called *export* cipher suites, which have been intentionally made weaker, and thus are easy to break.

While not immediately insecure, cipher suites that offer less than 128 bits of security should not be considered for their short useful life. Algorithms that use 128 bit of security or more can be expected to be unbreakable for at least several years, and are thus strongly recommended. Note that while **3DES** ciphers advertise the use of 168 bits, they actually offer 112 bits of security.

Always give preference to cipher suites that support *(perfect) forward secrecy* (*PFS*), which ensures the confidentiality of encrypted data even in case the server key is compromised. This rules out the fast **RSA** key exchange, but allows for the use of **ECDHE** and **DHE**. Of the two, **ECDHE** is the faster and therefore the preferred choice.

You should also give preference to **AEAD** ciphers, such as **AES-GCM**, before **CBC**-mode ciphers as they are not vulnerable to padding oracle attacks. Additionally, in many cases, **AES-GCM** is faster than **AES** in **CBC** mode, especially when the hardware has cryptographic accelerators for **AES**.

Note also that when using the **ECDHE** key exchange with **ECDSA** certificates, the transaction is even faster than pure **RSA** key exchange. To provide support for legacy clients, you can install two pairs of certificates and keys on a server: one with **ECDSA** keys (for new clients) and one with **RSA** keys (for legacy ones).

Public Key Length

When using **RSA** keys, always prefer key lengths of at least 3072 bits signed by at least SHA-256, which is sufficiently large for true 128 bits of security.

WARNING

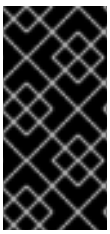
Keep in mind that the security of your system is only as strong as the weakest link in the chain. For example, a strong cipher alone does not guarantee good security. The keys and the certificates are just as important, as well as the hash functions and keys used by the *Certification Authority* (*CA*) to sign your keys.

4.13.2. Using Implementations of TLS

Red Hat Enterprise Linux 7 is distributed with several full-featured implementations of **TLS**. In this section, the configuration of **OpenSSL** and **GnuTLS** is described. See Section 4.13.3, “Configuring Specific Applications” for instructions on how to configure **TLS** support in individual applications.

The available **TLS** implementations offer support for various *cipher suites* that define all the elements that come together when establishing and using **TLS**-secured communications.

Use the tools included with the different implementations to list and specify cipher suites that provide the best possible security for your use case while considering the recommendations outlined in Section 4.13.1, “Choosing Algorithms to Enable”. The resulting cipher suites can then be used to configure the way individual applications negotiate and secure connections.



IMPORTANT

Be sure to check your settings following every update or upgrade of the **TLS** implementation you use or the applications that utilize that implementation. New versions may introduce new cipher suites that you do not want to have enabled and that your current configuration does not disable.

4.13.2.1. Working with Cipher Suites in OpenSSL

OpenSSL is a toolkit and a cryptography library that support the **SSL** and **TLS** protocols. On Red Hat Enterprise Linux 7, a configuration file is provided at **/etc/pki/tls/openssl.cnf**. The format of this configuration file is described in config(1). See also Section 4.7.9, “Configuring OpenSSL”.

To get a list of all cipher suites supported by your installation of **OpenSSL**, use the **openssl** command with the **ciphers** subcommand as follows:

```
~]$ openssl ciphers -v 'ALL:COMPLEMENTOFALL'
```

Pass other parameters (referred to as *cipher strings* and *keywords* in **OpenSSL** documentation) to the **ciphers** subcommand to narrow the output. Special keywords can be used to only list suites that satisfy a certain condition. For example, to only list suites that are defined as belonging to the **HIGH** group, use the following command:

```
~]$ openssl ciphers -v 'HIGH'
```

See the ciphers(1) manual page for a list of available keywords and cipher strings.

To obtain a list of cipher suites that satisfy the recommendations outlined in Section 4.13.1, “Choosing Algorithms to Enable”, use a command similar to the following:

```
~]$ openssl ciphers -v 'kEECDH+aECDSA+AES:kEECDH+AES+aRSA:kEDH+aRSA+AES' |
column -t
ECDHE-ECDSA-AES256-GCM-SHA384  TLSv1.2  Kx=ECDH  Au=ECDSA  Enc=AESGCM(256)
Mac=AEAD
ECDHE-ECDSA-AES256-SHA384      TLSv1.2  Kx=ECDH  Au=ECDSA  Enc=AES(256)
Mac=SHA384
ECDHE-ECDSA-AES256-SHA         SSLv3    Kx=ECDH  Au=ECDSA  Enc=AES(256)
Mac=SHA1
ECDHE-ECDSA-AES128-GCM-SHA256  TLSv1.2  Kx=ECDH  Au=ECDSA  Enc=AESGCM(128)
Mac=AEAD
```

```
ECDHE-ECDSA-AES128-SHA256       TLSv1.2  Kx=ECDH   Au=ECDSA  Enc=AES(128)
Mac=SHA256
ECDHE-ECDSA-AES128-SHA          SSLv3    Kx=ECDH   Au=ECDSA  Enc=AES(128)
Mac=SHA1
ECDHE-RSA-AES256-GCM-SHA384     TLSv1.2  Kx=ECDH   Au=RSA    Enc=AESGCM(256)
Mac=AEAD
ECDHE-RSA-AES256-SHA384         TLSv1.2  Kx=ECDH   Au=RSA    Enc=AES(256)
Mac=SHA384
ECDHE-RSA-AES256-SHA            SSLv3    Kx=ECDH   Au=RSA    Enc=AES(256)
Mac=SHA1
ECDHE-RSA-AES128-GCM-SHA256     TLSv1.2  Kx=ECDH   Au=RSA    Enc=AESGCM(128)
Mac=AEAD
ECDHE-RSA-AES128-SHA256         TLSv1.2  Kx=ECDH   Au=RSA    Enc=AES(128)
Mac=SHA256
ECDHE-RSA-AES128-SHA            SSLv3    Kx=ECDH   Au=RSA    Enc=AES(128)
Mac=SHA1
DHE-RSA-AES256-GCM-SHA384       TLSv1.2  Kx=DH     Au=RSA    Enc=AESGCM(256)
Mac=AEAD
DHE-RSA-AES256-SHA256           TLSv1.2  Kx=DH     Au=RSA    Enc=AES(256)
Mac=SHA256
DHE-RSA-AES256-SHA              SSLv3    Kx=DH     Au=RSA    Enc=AES(256)
Mac=SHA1
DHE-RSA-AES128-GCM-SHA256       TLSv1.2  Kx=DH     Au=RSA    Enc=AESGCM(128)
Mac=AEAD
DHE-RSA-AES128-SHA256           TLSv1.2  Kx=DH     Au=RSA    Enc=AES(128)
Mac=SHA256
DHE-RSA-AES128-SHA              SSLv3    Kx=DH     Au=RSA    Enc=AES(128)
Mac=SHA1
```

The above command omits all insecure ciphers, gives preference to **ephemeral elliptic curve Diffie-Hellman** key exchange and **ECDSA** ciphers, and omits **RSA** key exchange (thus ensuring *perfect forward secrecy*).

Note that this is a rather strict configuration, and it might be necessary to relax the conditions in real-world scenarios to allow for a compatibility with a broader range of clients.

4.13.2.2. Working with Cipher Suites in GnuTLS

GnuTLS is a communications library that implements the **SSL** and **TLS** protocols and related technologies.

NOTE

The **GnuTLS** installation on Red Hat Enterprise Linux 7 offers optimal default configuration values that provide sufficient security for the majority of use cases. Unless you need to satisfy special security requirements, it is recommended to use the supplied defaults.

Use the **gnutls-cli** command with the **-l** (or **--list**) option to list all supported cipher suites:

```
~]$ gnutls-cli -l
```

To narrow the list of cipher suites displayed by the **-l** option, pass one or more parameters (referred to as *priority strings* and *keywords* in **GnuTLS** documentation) to the **--priority** option. See the

GnuTLS documentation at http://www.gnutls.org/manual/gnutls.html#Priority-Strings for a list of all available priority strings. For example, issue the following command to get a list of cipher suites that offer at least 128 bits of security:

```
~]$ gnutls-cli --priority SECURE128 -l
```

To obtain a list of cipher suites that satisfy the recommendations outlined in Section 4.13.1, “Choosing Algorithms to Enable”, use a command similar to the following:

```
~]$ gnutls-cli --priority SECURE256:+SECURE128:-VERS-TLS-ALL:+VERS-
TLS1.2:-RSA:-DHE-DSS:-CAMELLIA-128-CBC:-CAMELLIA-256-CBC -l
Cipher suites for SECURE256:+SECURE128:-VERS-TLS-ALL:+VERS-TLS1.2:-RSA:-
DHE-DSS:-CAMELLIA-128-CBC:-CAMELLIA-256-CBC
TLS_ECDHE_ECDSA_AES_256_GCM_SHA384                      0xc0, 0x2c
TLS1.2
TLS_ECDHE_ECDSA_AES_256_CBC_SHA384                      0xc0, 0x24
TLS1.2
TLS_ECDHE_ECDSA_AES_256_CBC_SHA1                        0xc0, 0x0a
SSL3.0
TLS_ECDHE_ECDSA_AES_128_GCM_SHA256                      0xc0, 0x2b
TLS1.2
TLS_ECDHE_ECDSA_AES_128_CBC_SHA256                      0xc0, 0x23
TLS1.2
TLS_ECDHE_ECDSA_AES_128_CBC_SHA1                        0xc0, 0x09
SSL3.0
TLS_ECDHE_RSA_AES_256_GCM_SHA384                        0xc0, 0x30
TLS1.2
TLS_ECDHE_RSA_AES_256_CBC_SHA1                          0xc0, 0x14
SSL3.0
TLS_ECDHE_RSA_AES_128_GCM_SHA256                        0xc0, 0x2f
TLS1.2
TLS_ECDHE_RSA_AES_128_CBC_SHA256                        0xc0, 0x27
TLS1.2
TLS_ECDHE_RSA_AES_128_CBC_SHA1                          0xc0, 0x13
SSL3.0
TLS_DHE_RSA_AES_256_CBC_SHA256                          0x00, 0x6b
TLS1.2
TLS_DHE_RSA_AES_256_CBC_SHA1                            0x00, 0x39
SSL3.0
TLS_DHE_RSA_AES_128_GCM_SHA256                          0x00, 0x9e
TLS1.2
TLS_DHE_RSA_AES_128_CBC_SHA256                          0x00, 0x67
TLS1.2
TLS_DHE_RSA_AES_128_CBC_SHA1                            0x00, 0x33
SSL3.0

Certificate types: CTYPE-X.509
Protocols: VERS-TLS1.2
Compression: COMP-NULL
Elliptic curves: CURVE-SECP384R1, CURVE-SECP521R1, CURVE-SECP256R1
PK-signatures: SIGN-RSA-SHA384, SIGN-ECDSA-SHA384, SIGN-RSA-SHA512, SIGN-
ECDSA-SHA512, SIGN-RSA-SHA256, SIGN-DSA-SHA256, SIGN-ECDSA-SHA256
```

The above command limits the output to ciphers with at least 128 bits of security while giving preference to the stronger ones. It also forbids **RSA** key exchange and **DSS** authentication.

Note that this is a rather strict configuration, and it might be necessary to relax the conditions in real-world scenarios to allow for a compatibility with a broader range of clients.

4.13.3. Configuring Specific Applications

Different applications provide their own configuration mechanisms for **TLS**. This section describes the **TLS**-related configuration files employed by the most commonly used server applications and offers examples of typical configurations.

Regardless of the configuration you choose to use, always make sure to mandate that your server application enforces *server-side cipher order*, so that the cipher suite to be used is determined by the order you configure.

4.13.3.1. Configuring the Apache HTTP Server

The **Apache HTTP Server** can use both **OpenSSL** and **NSS** libraries for its **TLS** needs. Depending on your choice of the **TLS** library, you need to install either the **mod_ssl** or the **mod_nss** module (provided by eponymous packages). For example, to install the package that provides the **OpenSSL mod_ssl** module, issue the following command as root:

```
~]# yum install mod_ssl
```

The mod_ssl package installs the **/etc/httpd/conf.d/ssl.conf** configuration file, which can be used to modify the **TLS**-related settings of the **Apache HTTP Server**. Similarly, the mod_nss package installs the **/etc/httpd/conf.d/nss.conf** configuration file.

Install the httpd-manual package to obtain complete documentation for the **Apache HTTP Server**, including **TLS** configuration. The directives available in the **/etc/httpd/conf.d/ssl.conf** configuration file are described in detail in **/usr/share/httpd/manual/mod/mod_ssl.html**. Examples of various settings are in **/usr/share/httpd/manual/ssl/ssl_howto.html**.

When modifying the settings in the **/etc/httpd/conf.d/ssl.conf** configuration file, be sure to consider the following three directives at the minimum:

SSLProtocol

Use this directive to specify the version of **TLS** (or **SSL**) you want to allow.

SSLCipherSuite

Use this directive to specify your preferred cipher suite or disable the ones you want to disallow.

SSLHonorCipherOrder

Uncomment and set this directive to **on** to ensure that the connecting clients adhere to the order of ciphers you specified.

For example:

```
SSLProtocol all -SSLv2 -SSLv3
SSLCipherSuite HIGH:!aNULL:!MD5
SSLHonorCipherOrder on
```

Note that the above configuration is the bare minimum, and it can be hardened significantly by following the recommendations outlined in Section 4.13.1, “Choosing Algorithms to Enable”.

To configure and use the **mod_nss** module, modify the **/etc/httpd/conf.d/nss.conf** configuration file. The **mod_nss** module is derived from **mod_ssl**, and as such it shares many features with it, not least the structure of the configuration file, and the directives that are available. Note that the **mod_nss** directives have a prefix of **NSS** instead of **SSL**. See https://git.fedorahosted.org/cgit/mod_nss.git/plain/docs/mod_nss.html for an overview of information about **mod_nss**, including a list of **mod_ssl** configuration directives that are not applicable to **mod_nss**.

4.13.3.2. Configuring the Dovecot Mail Server

To configure your installation of the **Dovecot** mail server to use **TLS**, modify the **/etc/dovecot/conf.d/10-ssl.conf** configuration file. You can find an explanation of some of the basic configuration directives available in that file in **/usr/share/doc/dovecot-2.2.10/wiki/SSL.DovecotConfiguration.txt** (this help file is installed along with the standard installation of **Dovecot**).

When modifying the settings in the **/etc/dovecot/conf.d/10-ssl.conf** configuration file, be sure to consider the following three directives at the minimum:

ssl_protocols

Use this directive to specify the version of **TLS** (or **SSL**) you want to allow.

ssl_cipher_list

Use this directive to specify your preferred cipher suites or disable the ones you want to disallow.

ssl_prefer_server_ciphers

Uncomment and set this directive to **yes** to ensure that the connecting clients adhere to the order of ciphers you specified.

For example:

```
ssl_protocols = !SSLv2 !SSLv3
ssl_cipher_list = HIGH:!aNULL:!MD5
ssl_prefer_server_ciphers = yes
```

Note that the above configuration is the bare minimum, and it can be hardened significantly by following the recommendations outlined in Section 4.13.1, “Choosing Algorithms to Enable”.

4.13.4. Additional Information

For more information about **TLS** configuration and related topics, see the resources listed below.

Installed Documentation

- config(1) — Describes the format of the **/etc/ssl/openssl.conf** configuration file.
- ciphers(1) — Includes a list of available **OpenSSL** keywords and cipher strings.

- **/usr/share/httpd/manual/mod/mod_ssl.html** — Contains detailed descriptions of the directives available in the **/etc/httpd/conf.d/ssl.conf** configuration file used by the **mod_ssl** module for the **Apache HTTP Server**.
- **/usr/share/httpd/manual/ssl/ssl_howto.html** — Contains practical examples of real-world settings in the **/etc/httpd/conf.d/ssl.conf** configuration file used by the **mod_ssl** module for the **Apache HTTP Server**.
- **/usr/share/doc/dovecot-2.2.10/wiki/SSL.DovecotConfiguration.txt** — Explains some of the basic configuration directives available in the **/etc/dovecot/conf.d/10-ssl.conf** configuration file used by the **Dovecot** mail server.

Online Documentation

- Red Hat Enterprise Linux 7 SELinux User's and Administrator's Guide — The *SELinux User's and Administrator's Guide* for Red Hat Enterprise Linux 7 describes the basic principles of **SELinux** and documents in detail how to configure and use **SELinux** with various services, such as the **Apache HTTP Server**.
- http://tools.ietf.org/html/draft-ietf-uta-tls-bcp-00 — Recommendations for secure use of **TLS** and **DTLS**.

See Also

- Section A.2.4, “SSL/TLS” provides a concise description of the **SSL** and **TLS** protocols.
- Section 4.7, “Using OpenSSL” describes, among other things, how to use **OpenSSL** to create and manage keys, generate certificates, and encrypt and decrypt files.

4.14. USING SHARED SYSTEM CERTIFICATES

The Shared System Certificates storage allows NSS, GnuTLS, OpenSSL, and Java to share a default source for retrieving system certificate anchors and black list information. By default, the trust store contains the Mozilla CA list, including positive and negative trust. The system allows updating of the core Mozilla CA list or choosing another certificate list.

4.14.1. Using a System-wide Trust Store

In Red Hat Enterprise Linux 7, the consolidated system-wide trust store is located in the **/etc/pki/ca-trust/** and **/usr/share/pki/ca-trust-source/** directories. The trust settings in **/usr/share/pki/ca-trust-source/** are processed with lower priority than settings in **/etc/pki/ca-trust/**.

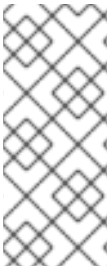
Certificate files are treated depending on the subdirectory they are installed to:

- **/usr/share/pki/ca-trust-source/anchors/** or **/etc/pki/ca-trust/source/anchors/** - for trust anchors. See Section 4.5.6, “Understanding Trust Anchors”.
- **/usr/share/pki/ca-trust-source/blacklist/** or **/etc/pki/ca-trust/source/blacklist/** - for distrusted certificates.
- **/usr/share/pki/ca-trust-source/** or **/etc/pki/ca-trust/source/** - for certificates in the extended BEGIN TRUSTED file format.

4.14.2. Adding New Certificates

To add a certificate in the simple PEM or DER file formats to the list of CAs trusted on the system, copy the certificate file to the **/usr/share/pki/ca-trust-source/anchors/** or **/etc/pki/ca-trust/source/anchors/** directory. To update the system-wide trust store configuration, use the **update-ca-trust** command, for example:

```
# cp ~/certificate-trust-examples/Cert-trust-test-ca.pem
/usr/share/pki/ca-trust-source/anchors/
# update-ca-trust
```



NOTE

While the Firefox browser is able to use an added certificate without executing **update-ca-trust**, it is recommended to run **update-ca-trust** after a CA change. Also note that browsers, such as Firefox, Epiphany, or Chromium, cache files, and you might need to clear the browser's cache or restart your browser to load the current system certificates configuration.

4.14.3. Managing Trusted System Certificates

To list, extract, add, remove, or change trust anchors, use the **trust** command. To see the built-in help for this command, enter it without any arguments or with the **--help** directive:

```
$ trust
usage: trust command <args>...

Common trust commands are:
  list             List trust or certificates
  extract          Extract certificates and trust
  extract-compat   Extract trust compatibility bundles
  anchor           Add, remove, change trust anchors
  dump             Dump trust objects in internal format

See 'trust <command> --help' for more information
```

To list all system trust anchors and certificates, use the **trust list** command:

```
$ trust list
pkcs11:id=%d2%87%b4%e3%df%37%27%93%55%f6%56%ea%81%e5%36%cc%8c%1e%3f%bd;typ
e=cert
    type: certificate
    label: ACCVRAIZ1
    trust: anchor
    category: authority

pkcs11:id=%a6%b3%e1%2b%2b%49%b6%d7%73%a1%aa%94%f5%01%e7%73%65%4c%ac%50;typ
e=cert
    type: certificate
    label: ACEDICOM Root
    trust: anchor
    category: authority
...
[output has been truncated]
```

All sub-commands of the **trust** commands offer a detailed built-in help, for example:

```
$ trust list --help
usage: trust list --filter=<what>

  --filter=<what>     filter of what to export
                        ca-anchors        certificate anchors
                        blacklist         blacklisted certificates
                        trust-policy      anchors and blacklist (default)
                        certificates      all certificates
                        pkcs11:object=xx  a PKCS#11 URI
  --purpose=<usage>   limit to certificates usable for the purpose
                        server-auth       for authenticating servers
                        client-auth       for authenticating clients
                        email             for email protection
                        code-signing      for authenticating signed code
                        1.2.3.4.5...      an arbitrary object id
  -v, --verbose       show verbose debug output
  -q, --quiet         suppress command output
```

To store a trust anchor into the system-wide trust store, use the **trust anchor** sub-command and specify a *path.to* a certificate, for example:

```
# trust anchor path.to/certificate.crt
```

To remove a certificate, use either a *path.to* a certificate or an ID of a certificate:

```
# trust anchor --remove path.to/certificate.crt
# trust anchor --remove "pkcs11:id=%AA%BB%CC%DD%EE;type=cert"
```

4.14.4. Additional Resources

For more information, see the following man pages:

- **update-ca-trust(8)**
- **trust(1)**

4.15. USING MACSEC

Media Access Control Security (**MACsec**, IEEE 802.1AE) encrypts and authenticates all traffic in LANs with the GCM-AES-128 algorithm. **MACsec** can protect not only **IP** but also Address Resolution Protocol (ARP), Neighbor Discovery (ND), or **DHCP**. While **IPsec** operates on the network layer (layer 3) and **SSL** or **TLS** on the application layer (layer 7), **MACsec** operates in the data link layer (layer 2). Combine **MACsec** with security protocols for other networking layers to take advantage of different security features that these standards provide.

See the MACsec: a different solution to encrypt network traffic article for more information about the architecture of a **MACsec** network, use case scenarios, and configuration examples.

For examples how to configure MACsec using **wpa_supplicant** and **NetworkManager**, see the Red Hat Enterprise Linux 7 Networking Guide.

4.16. REMOVING DATA SECURELY USING SCRUB

The **scrub** utility sets patterns on special files or disk devices to make retrieving data more difficult. Using **scrub** is faster than writing random data on a disk. This process provides high availability, reliability, and data protection.

To start using the **scrub** command, install the scrub package:

```
~]# yum install scrub
```

The **scrub** utility operates in one of the following basic modes:

Character or Block Device

The *special file* corresponding to a whole disk is scrubbed and all data on it, is destroyed. This is the most effective method.

```
scrub [OPTIONS] special file
```

File

A regular file is scrubbed and only the data in the file is destroyed.

```
scrub [OPTIONS] file
```

Directory

With the **-X** option, a directory is created and filled with files until the file system is full. Then, the files are scrubbed as in file mode.

```
scrub -X [OPTIONS] directory
```

Example 4.7. Scrubbing a Raw Device

To **scrub** a raw device */dev/sdf1* with default National Nuclear Security Administration (NNSA) patterns, enter the following command:

```
~]# scrub /dev/sdf1
scrub: using NNSA NAP-14.1-C patterns
scrub: please verify that device size below is correct!
scrub: scrubbing /dev/sdf1 1995650048 bytes (~1GB)
scrub: random  |.............................................|
scrub: random  |.............................................|
scrub: 0x00    |.............................................|
scrub: verify  |.............................................|
```

Example 4.8. Scrubbing a File

1. Create a *1MB* file:

```
~]$ base64 /dev/urandom | head -c $[ 1024*1024 ] > file.txt
```

2. Show the file size:

```
~]$ ls -lh
total 1.0M
-rw-rw-r--. 1 username username 1.0M Sep  8 15:23 file.txt
```

3. Show the contents of the file:

```
~]$ head -1 file.txt
JnNpaTEveB/IYsbM9lhuJdw+0jKhwCIBUsxLXLAyB8uItotUlNHKKUeS/7bCRKDogE
P+yJm8VQkL
```

4. Scrub the file:

```
~]$ scrub file.txt
scrub: using NNSA NAP-14.1-C patterns
scrub: scrubbing file.txt 1048576 bytes (~1024KB)
scrub: random  |.............................................|
scrub: random  |.............................................|
scrub: 0x00    |.............................................|
scrub: verify  |.............................................|
```

5. Verify that the file contents have been scrubbed:

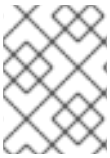
```
~]$ cat file.txt
SCRUBBED!
```

6. Verify that the file size remains the same:

```
~]$ ls -lh
total 1.0M
-rw-rw-r--. 1 username username 1.0M Sep  8 15:24 file.txt
```

For more information on **scrub** modes, options, methods, and caveats, see the scrub(1) man page.

CHAPTER 5. USING FIREWALLS



NOTE

To expand your expertise, you might also be interested in the Red Hat Server Hardening (RH413) training course.

5.1. GETTING STARTED WITH `FIREWALLD`

A *firewall* is a way to protect machines from any unwanted traffic from outside. It enables users to control incoming network traffic on host machines by defining a set of *firewall rules*. These rules are used to sort the incoming traffic and either block it or allow through.

`firewalld` is a firewall service daemon that provides a dynamic customizable host-based firewall with a **`D-Bus`** interface. Being dynamic, it enables creating, changing, and deleting the rules without the necessity to restart the firewall daemon each time the rules are changed.

`firewalld` uses the concepts of *zones* and *services*, that simplify the traffic management. Zones are predefined sets of rules. Network interfaces and sources can be assigned to a zone. The traffic allowed depends on the network your computer is connected to and the security level this network is assigned. Firewall services are predefined rules that cover all necessary settings to allow incoming traffic for a specific service and they apply within a zone.

Services use one or more *ports* or *addresses* for network communication. Firewalls filter communication based on ports. To allow network traffic for a service, its ports must be *open*. **`firewalld`** blocks all traffic on ports that are not explicitly set as open. Some zones, such as *trusted*, allow all traffic by default.

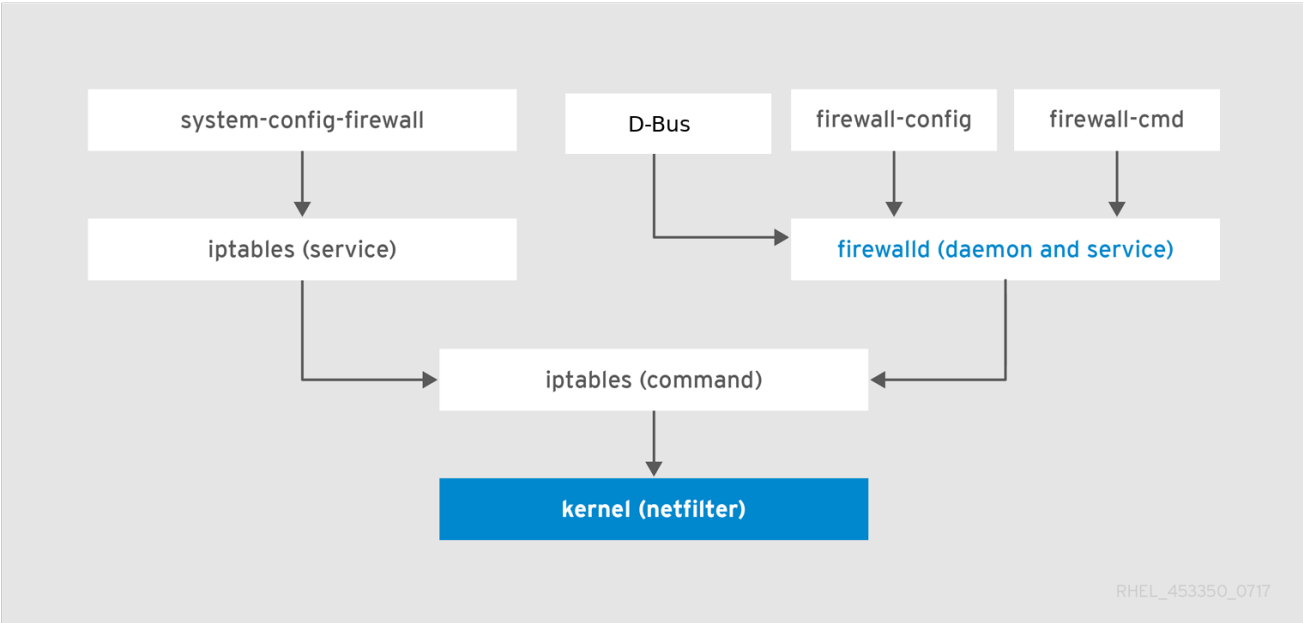


Figure 5.1. The Firewall Stack

5.1.1. Zones

`firewalld` can be used to separate networks into different zones according to the level of trust that the user has decided to place on the interfaces and traffic within that network. A connection can only be part of one zone, but a zone can be used for many network connections.

NetworkManager notifies **firewalld** of the zone of an interface. You can assign zones to interfaces with **NetworkManager**, with the **firewall-config** tool, or the **firewall-cmd** command-line tool. The latter two only edit the appropriate **NetworkManager** configuration files. If you change the zone of the interface using **firewall-cmd** or **firewall-config**, the request is forwarded to **NetworkManager** and is not handled by **firewalld**.

The predefined zones are stored in the **/usr/lib/firewalld/zones/** directory and can be instantly applied to any available network interface. These files are copied to the **/etc/firewalld/zones/** directory only after they are modified. The following table describes the default settings of the predefined zones:

block

Any incoming network connections are rejected with an icmp-host-prohibited message for **IPv4** and icmp6-adm-prohibited for **IPv6**. Only network connections initiated from within the system are possible.

dmz

For computers in your demilitarized zone that are publicly-accessible with limited access to your internal network. Only selected incoming connections are accepted.

drop

Any incoming network packets are dropped without any notification. Only outgoing network connections are possible.

external

For use on external networks with masquerading enabled, especially for routers. You do not trust the other computers on the network to not harm your computer. Only selected incoming connections are accepted.

home

For use at home when you mostly trust the other computers on the network. Only selected incoming connections are accepted.

internal

For use on internal networks when you mostly trust the other computers on the network. Only selected incoming connections are accepted.

public

For use in public areas where you do not trust other computers on the network. Only selected incoming connections are accepted.

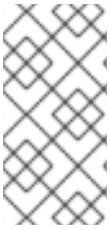
trusted

All network connections are accepted.

work

For use at work where you mostly trust the other computers on the network. Only selected incoming connections are accepted.

One of these zones is set as the *default* zone. When interface connections are added to **NetworkManager**, they are assigned to the default zone. On installation, the default zone in **firewalld** is set to be the **public** zone. The default zone can be changed.



NOTE

The network zone names have been chosen to be self-explanatory and to allow users to quickly make a reasonable decision. To avoid any security problems, review the default zone configuration and disable any unnecessary services according to your needs and risk assessments.

5.1.2. Predefined Services

A service can be a list of local ports, protocols, source ports, and destinations, as well as a list of firewall helper modules automatically loaded if a service is enabled. Using services saves users time because they can achieve several tasks, such as opening ports, defining protocols, enabling packet forwarding and more, in a single step, rather than setting up everything one after another.

Service configuration options and generic file information are described in the **firewalld.service(5)** man page. The services are specified by means of individual XML configuration files, which are named in the following format: ***service-name*.xml**. Protocol names are preferred over service or application names in **firewalld**.

5.1.3. Runtime and Permanent Settings

Any changes committed in *runtime* mode only apply while **firewalld** is running. When **firewalld** is restarted, the settings revert to their *permanent* values.

To make the changes persistent across reboots, apply them again using the **--permanent** option. Alternatively, to make changes persistent while **firewalld** is running, use the **--runtime-to-permanent** **firewall-cmd** option.

If you set the rules while **firewalld** is running using only the **--permanent** option, they do not become effective before **firewalld** is restarted. However, restarting **firewalld** closes all open ports and stops the networking traffic.

5.1.4. Modifying Settings in Runtime and Permanent Configuration using CLI

Using the CLI, you do not modify the firewall settings in both modes at the same time. You only modify either runtime or permanent mode. To modify the firewall settings in the permanent mode, use the **--permanent** option with the **firewall-cmd** command.

```
~]# firewall-cmd --permanent <other options>
```

Without this option, the command modifies runtime mode.

To change settings in both modes, you can use two methods:

1. Change runtime settings and then make them permanent as follows:

```
~]# firewall-cmd <other options>
~]# firewall-cmd --runtime-to-permanent
```

2. Set permanent settings and reload the settings into runtime mode:

```
~]# firewall-cmd --permanent <other options>
~]# firewall-cmd --reload
```

The first method allows you to test the settings before you apply them to the permanent mode.

NOTE

It is possible, especially on remote systems, that an incorrect setting results in a user locking themselves out of a machine. To prevent such situations, use the **`--timeout`** option. After a specified amount of time, any change reverts to its previous state. Using this options excludes the **`--permanent`** option.

For example, to add the **SSH** service for 15 minutes:

```
~]# firewall-cmd --add-service=ssh --timeout 15m
```

5.2. INSTALLING THE FIREWALL-CONFIG GUI CONFIGURATION TOOL

To use the **firewall-config** GUI configuration tool, install the firewall-config package as **`root`**:

```
~]# yum install firewall-config
```

Alternatively, in **GNOME**, use the **`Super`** key and type **`Software`** to launch the **Software Sources** application. Type **`firewall`** to the search box, which appears after selecting the search button in the top-right corner. Select the **Firewall** item from the search results, and click on the **`Install`** button.

To run **firewall-config**, use either the **`firewall-config`** command or press the **`Super`** key to enter the **Activities Overview**, type **`firewall`**, and press **`Enter`**.

5.3. VIEWING THE CURRENT STATUS AND SETTINGS OF `FIREWALLD`

5.3.1. Viewing the Current Status of `firewalld`

The firewall service, **`firewalld`**, is installed on the system by default. Use the **`firewalld`** CLI interface to check that the service is running.

To see the status of the service:

```
~]# firewall-cmd --state
```

For more information about the service status, use the **`systemctl status`** sub-command:

```
~]# systemctl status firewalld
firewalld.service - firewalld - dynamic firewall daemon
   Loaded: loaded (/usr/lib/systemd/system/firewalld.service; enabled;
vendor pr
   Active: active (running) since Mon 2017-12-18 16:05:15 CET; 50min ago
     Docs: man:firewalld(1)
 Main PID: 705 (firewalld)
```

```
     Tasks: 2 (limit: 4915)
    CGroup: /system.slice/firewalld.service
            └─705 /usr/bin/python3 -Es /usr/sbin/firewalld --nofork --nopid
```

Furthermore, it is important to know how **firewalld** is set up and which rules are in force before you try to edit the settings. To display the firewall settings, see Section 5.3.2, “Viewing Current **firewalld** Settings”

5.3.2. Viewing Current `firewalld` Settings

5.3.2.1. Viewing Allowed Services using GUI

To view the list of services using the graphical **firewall-config** tool, press the **Super** key to enter the Activities Overview, type **firewall**, and press **Enter**. The **firewall-config** tool appears. You can now view the list of services under the **Services** tab.

Alternatively, to start the graphical firewall configuration tool using the command-line, enter the following command:

```
~]$ firewall-config
```

The **Firewall Configuration** window opens. Note that this command can be run as a normal user, but you are prompted for an administrator password occasionally.

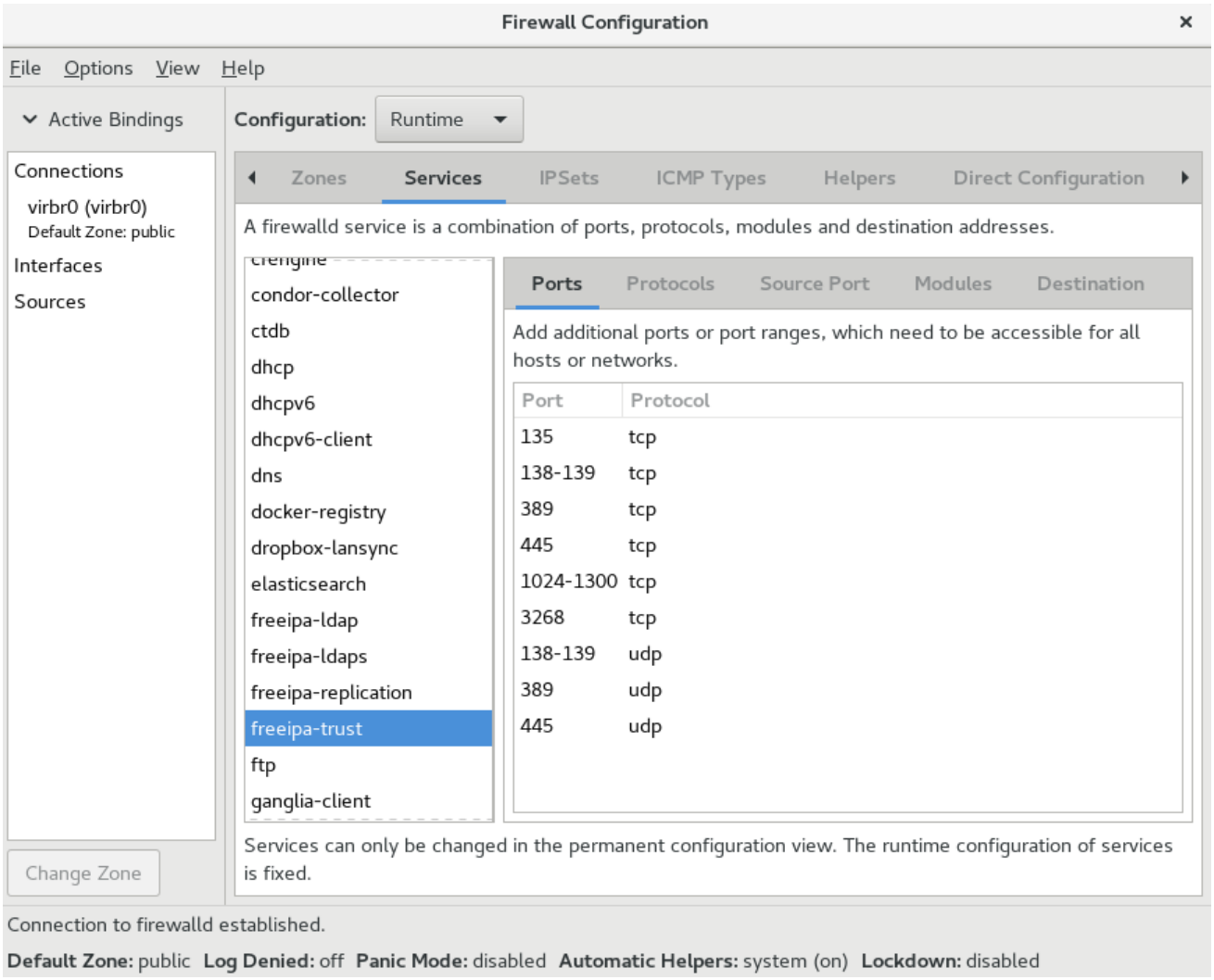


Figure 5.2. The Services tab in firewall-config

5.3.2.2. Viewing `firewalld` Settings using CLI

With the CLI client, it is possible to get different views of the current firewall settings. The **`--list-all`** option shows a complete overview of the **`firewalld`** settings.

`firewalld` uses zones to manage the traffic. If a zone is not specified by the **`--zone`** option, the command is effective in the default zone assigned to the active network interface and connection.

To list all the relevant information for the default zone:

```
~]# firewall-cmd --list-all
public
  target: default
  icmp-block-inversion: no
  interfaces:
  sources:
  services: ssh dhcpv6-client
  ports:
  protocols:
  masquerade: no
  forward-ports:
```

```
  source-ports:
  icmp-blocks:
  rich rules:
```

NOTE

To specify the zone for which to display the settings, add the **--zone=*zone-name*** argument to the **firewall-cmd --list-all** command, for example:

```
~]# firewall-cmd --list-all --zone=home
home
  target: default
  icmp-block-inversion: no
  interfaces:
  sources:
  services: ssh mdns samba-client dhcpv6-client
... [output truncated]
```

To see the settings for particular information, such as services or ports, use a specific option. See the **firewalld** manual pages or get a list of the options using the command help:

```
~]# firewall-cmd --help

Usage: firewall-cmd [OPTIONS...]

General Options
  -h, --help           Prints a short help text and exists
  -V, --version        Print the version string of firewalld
  -q, --quiet          Do not print status messages

Status Options
  --state              Return and print firewalld state
  --reload             Reload firewall and keep state information
... [output truncated]
```

For example, to see which services are allowed in the current zone:

```
~]# firewall-cmd --list-services
ssh dhcpv6-client
```

Listing the settings for a certain subpart using the CLI tool can sometimes be difficult to interpret. For example, you allow the **SSH** service and **firewalld** opens the necessary port (22) for the service. Later, if you list the allowed services, the list shows the **SSH** service, but if you list open ports, it does not show any. Therefore, it is recommended to use the **--list-all** option to make sure you receive a complete information.

5.4. STARTING FIREWALLD

To start **firewalld**, enter the following command as **root**:

```
~]# systemctl unmask firewalld
~]# systemctl start firewalld
```

To ensure **firewalld** starts automatically at system start, enter the following command as **root**:

```
~]# systemctl enable firewalld
```

5.5. STOPPING FIREWALLD

To stop **firewalld**, enter the following command as **root**:

```
~]# systemctl stop firewalld
```

To prevent **firewalld** from starting automatically at system start, enter the following command as **root**:

```
~]# systemctl disable firewalld
```

To make sure firewalld is not started by accessing the **firewalld D-Bus** interface and also if other services require **firewalld**, enter the following command as **root**:

```
~]# systemctl mask firewalld
```

5.6. CONTROLLING TRAFFIC

5.6.1. Predefined Services

Services can be added and removed using the graphical **firewall-config** tool, **firewall-cmd**, and **firewall-offline-cmd**.

Alternatively, you can edit the XML files in the **/etc/firewalld/services/** directory. If a service is not added or changed by the user, then no corresponding XML file is found in **/etc/firewalld/services/**. The files in the **/usr/lib/firewalld/services/** directory can be used as templates if you want to add or change a service.

5.6.2. Disabling All Traffic in Case of Emergency using CLI

In an emergency situation, such as a system attack, it is possible to disable all network traffic and cut off the attacker.

To immediately disable networking traffic, switch panic mode on:

```
~]# firewall-cmd --panic-on
```

Switching off panic mode reverts the firewall to its permanent settings. To switch panic mode off:

```
~]# firewall-cmd --panic-off
```

To see whether panic mode is switched on or off, use:

```
~]# firewall-cmd --query-panic
```

5.6.3. Controlling Traffic with Predefined Services using CLI

The most straightforward method to control traffic is to add a predefined service to **firewalld**. This opens all necessary ports and modifies other settings according to the *service definition file*.

1. Check that the service is not already allowed:

```
~]# firewall-cmd --list-services
ssh dhcpv6-client
```

2. List all predefined services:

```
~]# firewall-cmd --get-services
RH-Satellite-6 amanda-client amanda-k5-client bacula bacula-client
bitcoin bitcoin-rpc bitcoin-testnet bitcoin-testnet-rpc ceph ceph-
mon cfengine condor-collector ctdb dhcp dhcpv6 dhcpv6-client dns
docker-registry ...
[output truncated]
```

3. Add the service to the allowed services:

```
~]# firewall-cmd --add-service=<service-name>
```

4. Make the new settings persistent:

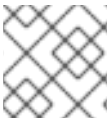
```
~]# firewall-cmd --runtime-to-permanent
```

5.6.4. Controlling Traffic with Predefined Services using GUI

To enable or disable a predefined or custom service, start the **firewall-config** tool and select the network zone whose services are to be configured. Select the **Services** tab and select the check box for each type of service you want to trust. Clear the check box to block a service.

To edit a service, start the **firewall-config** tool and select **Permanent** from the menu labeled **Configuration**. Additional icons and menu buttons appear at the bottom of the **Services** window. Select the service you want to configure.

The **Ports**, **Protocols**, and **Source Port** tabs enable adding, changing, and removing of ports, protocols, and source port for the selected service. The modules tab is for configuring **Netfilter** helper modules. The **Destination** tab enables limiting traffic to a particular destination address and Internet Protocol (**IPv4** or **IPv6**).



NOTE

It is not possible to alter service settings in **Runtime** mode.

5.6.5. Adding New Services

Services can be added and removed using the graphical **firewall-config** tool, **firewall-cmd**, and **firewall-offline-cmd**. Alternatively, you can edit the XML files in **/etc/firewalld/services/**. If a service is not added or changed by the user, then no corresponding XML file are found in

/etc/firewalld/services/. The files **/usr/lib/firewalld/services/** can be used as templates if you want to add or change a service.

To add a new service in a terminal, use **firewall-cmd**, or **firewall-offline-cmd** in case of not active **firewalld**. enter the following command to add a new and empty service:

```
~]$ firewall-cmd --new-service=service-name
```

To add a new service using a local file, use the following command:

```
~]$ firewall-cmd --new-service-from-file=service-name.xml
```

You can change the service name with the additional **--name=*service-name*** option.

As soon as service settings are changed, an updated copy of the service is placed into **/etc/firewalld/services/**.

As **root**, you can enter the following command to copy a service manually:

```
~]# cp /usr/lib/firewalld/services/service-name.xml
/etc/firewalld/services/service-name.xml
```

firewalld loads files from **/usr/lib/firewalld/services** in the first place. If files are placed in **/etc/firewalld/services** and they are valid, then these will override the matching files from **/usr/lib/firewalld/services**. The overriden files in **/usr/lib/firewalld/services** are used as soon as the matching files in **/etc/firewalld/services** have been removed or if **firewalld** has been asked to load the defaults of the services. This applies to the permanent environment only. A reload is needed to get these fallbacks also in the runtime environment.

5.6.6. Controlling Ports using CLI

Ports are logical devices that enable an operating system to receive and distinguish network traffic and forward it accordingly to system services. These are usually represented by a daemon that listens on the port, that is it waits for any traffic coming to this port.

Normally, system services listen on standard ports that are reserved for them. The **httpd** daemon, for example, listens on port 80. However, system administrators by default configure daemons to listen on different ports to enhance security or for other reasons.

Opening a Port

Through open ports, the system is accessible from the outside, which represents a security risk. Generally, keep ports closed and only open them if they are required for certain services.

To get a list of open ports in the current zone:

1. List all allowed ports:

   ```
   ~]# firewall-cmd --list-ports
   ```

2. Add a port to the allowed ports to open it for incoming traffic:

   ```
   ~]# firewall-cmd --add-port=port-number/port-type
   ```

3. Make the new settings persistent:

```
~]# firewall-cmd --runtime-to-permanent
```

The port types are either **tcp**, **udp**, **sctp**, or **dccp**. The type must match the type of network communication.

Closing a Port

When an open port is no longer needed, close that port in **firewalld**. It is highly recommended to close all unnecessary ports as soon as they are not used because leaving a port open represents a security risk.

To close a port, remove it from the list of allowed ports:

1. List all allowed ports:

```
~]# firewall-cmd --list-ports
[WARNING]
====
This command will only give you a list of ports that have been
opened as ports. You will not be able to see any open ports that
have been opened as a service. Therefore, you should consider using
the --list-all option instead of --list-ports.
====
```

2. Remove the port from the allowed ports to close it for the incoming traffic:

```
~]# firewall-cmd --remove-port=port-number/port-type
```

3. Make the new settings persistent:

```
~]# firewall-cmd --runtime-to-permanent
```

5.6.7. Opening Ports using GUI

To permit traffic through the firewall to a certain port, start the **firewall-config** tool and select the network zone whose settings you want to change. Select the **Ports** tab and click the **Add** button on the right-hand side. The **Port and Protocol** window opens.

Enter the port number or range of ports to permit. Select **tcp** or **udp** from the list.

5.6.8. Controlling Traffic with Protocols using GUI

To permit traffic through the firewall using a certain protocol, start the **firewall-config** tool and select the network zone whose settings you want to change. Select the **Protocols** tab and click the **Add** button on the right-hand side. The **Protocol** window opens.

Either select a protocol from the list or select the **Other Protocol** check box and enter the protocol in the field.

5.6.9. Opening Source Ports using GUI

To permit traffic through the firewall from a certain port, start the firewall-config tool and select the network zone whose settings you want to change. Select the **Source Port** tab and click the **Add** button on the right-hand side. The **Source Port** window opens.

Enter the port number or range of ports to permit. Select **tcp** or **udp** from the list.

5.7. WORKING WITH ZONES

Zones represent a concept to manage incoming traffic more transparently. The zones are connected to networking interfaces or assigned a range of source addresses. You manage firewall rules for each zone independently, which enables you to define complex firewall settings and apply them to the traffic.

5.7.1. Listing Zones

To see which zones are available on your system:

```
~]# firewall-cmd --get-zones
```

The **firewall-cmd --get-zones** command displays all zones that are available on the system, but it does not show any details for particular zones.

To see detailed information for all zones:

```
~]# firewall-cmd --list-all-zones
```

To see detailed information for a specific zone:

```
~]# firewall-cmd --zone=zone-name --list-all
```

5.7.2. Modifying `firewalld` Settings for a Certain Zone

The Section 5.6.3, “Controlling Traffic with Predefined Services using CLI” and Section 5.6.6, “Controlling Ports using CLI” explain how to add services or modify ports in the scope of the current working zone. Sometimes, it is required to set up rules in a different zone.

To work in a different zone, use the **--zone=*zone-name*** option. For example, to allow the **SSH** service in the zone *public*:

```
~]# firewall-cmd --add-service=ssh --zone=public
```

5.7.3. Changing the Default Zone

System administrators assign a zone to a networking interface in its configuration files. If an interface is not assigned to a specific zone, it is assigned to the default zone. After each restart of the **firewalld** service, **firewalld** loads the settings for the default zone and makes it active.

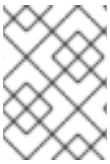
To set up the default zone:

1. Display the current default zone:

   ```
   ~]# firewall-cmd --get-default-zone
   ```

2. Set the new default zone:

```
~]# firewall-cmd --set-default-zone zone-name
```



NOTE

Following this procedure, the setting is a permanent setting, even without the **--permanent** option.

5.7.4. Assigning a Network Interface to a Zone

It is possible to define different sets of rules for different zones and then change the settings quickly by changing the zone for the interface that is being used. With multiple interfaces, a specific zone can be set for each of them to distinguish traffic that is coming through them.

To assign the zone to a specific interface:

1. List the active zones and the interfaces assigned to them:

```
~]# firewall-cmd --get-active-zones
```

2. Assign the interface to a different zone:

```
~]# firewall-cmd --zone=zone-name --change-interface=<interface-
name>
```

NOTE

You do not have to use the **--permanent** option to make the setting persistent across restarts. If you set a new default zone, the setting becomes permanent.

5.7.5. Assigning a Default Zone to a Network Connection

When the connection is managed by **NetworkManager**, it must be aware of a zone that it uses. For every network connection, a zone can be specified, which provides the flexibility of various firewall settings according to the location of the computer with portable devices. Thus, zones and settings can be specified for different locations, such as company or home.

To set a default zone for an Internet connection, use either the **NetworkManager** GUI or edit the **/etc/sysconfig/network-scripts/ifcfg-*connection-name*** file and add a line that assigns a zone to this connection:

```
ZONE=zone-name
```

5.7.6. Creating a New Zone

To use custom zones, create a new zone and use it just like a predefined zone. New zones require the **--permanent** option, otherwise the command does not work.

To create a new zone:

1. Create a new zone:

```
~]# firewall-cmd --new-zone=zone-name
```

2. Check if the new zone is added to your permanent settings:

```
~]# firewall-cmd --get-zones
```

3. Make the new settings persistent:

```
~]# firewall-cmd --runtime-to-permanent
```

5.7.7. Creating a New Zone using a Configuration File

Zones can also be created using a *zone configuration file*. This approach can be helpful when you need to create a new zone, but want to reuse the settings from a different zone and only alter them a little.

A **firewalld** zone configuration file contains the information for a zone. These are the zone description, services, ports, protocols, icmp-blocks, masquerade, forward-ports and rich language rules in an XML file format. The file name has to be ***zone-name*.xml** where the length of *zone-name* is currently limited to 17 chars. The zone configuration files are located in the **/usr/lib/firewalld/zones/** and **/etc/firewalld/zones/** directories.

The following example shows a configuration that allows one service (**SSH**) and one port range, for both the **TCP** and **UDP** protocols.:

```
<?xml version="1.0" encoding="utf-8"?>
<zone>
  <short>My zone</short>
  <description>Here you can describe the characteristic features of the
zone.</description>
  <service name="ssh"/>
  <port port="1025-65535" protocol="tcp"/>
  <port port="1025-65535" protocol="udp"/>
</zone>
```

To change settings for that zone, add or remove sections to add ports, forward ports, services, and so on. For more information, see the **firewalld.zone** manual pages.

5.7.8. Using Zone Targets to Set Default Behavior for Incoming Traffic

For every zone, you can set a default behavior that handles incoming traffic that is not further specified. Such behaviour is defined by setting the target of the zone. There are three options - **default**, **ACCEPT**, **REJECT**, and **DROP**. By setting the target to **ACCEPT**, you accept all incoming packets except those disabled by a specific rule. If you set the target to **REJECT** or **DROP**, you disable all incoming packets except those that you have allowed in specific rules. When packets are rejected, the source machine is informed about the rejection, while there is no information sent when the packets are dropped.

To set a target for a zone:

1. List the information for the specific zone to see the default target:

```
~]$ firewall-cmd --zone=zone-name --list-all
```

2. Set a new target in the zone:

```
~]# firewall-cmd --zone=zone-name --set-target=
<default|ACCEPT|REJECT|DROP>
```

5.8. USING ZONES TO MANAGE INCOMING TRAFFIC DEPENDING ON SOURCE

You can use zones to manage incoming traffic based on its source. That enables you to sort incoming traffic and route it through different zones to allow or disallow services that can be reached by that traffic.

If you add a source to a zone, the zone becomes active and any incoming traffic from that source will be directed through it. You can specify different settings for each zone, which is applied to the traffic from the given sources accordingly. You can use more zones even if you only have one network interface.

5.8.1. Adding a Source

To route incoming traffic into a specific source, add the source to that zone. The source can be an IP address or an IP mask in the Classless Inter-domain Routing (CIDR) notation.

1. To set the source in the current zone:

```
~]# firewall-cmd --add-source=<source>
```

2. To set the source IP address for a specific zone:

```
~]# firewall-cmd --zone=zone-name --add-source=<source>
```

The following procedure allows all incoming traffic from *192.168.2.15* in the **trusted** zone:

1. List all available zones:

```
~]# firewall-cmd --get-zones
```

2. Add the source IP to the trusted zone in the permanent mode:

```
~]# firewall-cmd --zone=trusted --add-source=192.168.2.15
```

3. Make the new settings persistent:

```
~]# firewall-cmd --runtime-to-permanent
```

5.8.2. Removing a Source

Removing a source from the zone cuts off the traffic coming from it.

1. List allowed sources for the required zone:

```
~]# firewall-cmd --zone=zone-name --list-sources
```

2. Remove the source from the zone permanently:

```
~]# firewall-cmd --zone=zone-name --remove-source=<source>
```

3. Make the new settings persistent:

```
~]# firewall-cmd --runtime-to-permanent
```

5.8.3. Adding a Source Port

To enable sorting the traffic based on a port of origin, specify a source port using the **`--add-source-port`** option. You can also combine this with the **`--add-source`** option to limit the traffic to a certain IP address or IP range.

To add a source port:

```
~]# firewall-cmd --zone=zone-name --add-source-port=<port-
name>/<tcp|udp|sctp|dccp>
```

5.8.4. Removing a Source Port

By removing a source port you disable sorting the traffic based on a port of origin.

To remove a source port:

```
~]# firewall-cmd --zone=zone-name --remove-source-port=<port-
name>/<tcp|udp|sctp|dccp>
```

5.8.5. Using Zones and Sources to Allow a Service for Only a Specific Domain

To allow traffic from a specific network to use a service on a machine, use zones and source.

For example, to allow traffic from *192.168.1.0/24* to be able to reach the *HTTP* service while any other traffic is blocked:

1. List all available zones:

```
~]# firewall-cmd --get-zones
block dmz drop external home internal public trusted work
```

2. Add the source to the trusted zone to route the traffic originating from the source through the zone:

```
~]# firewall-cmd --zone=trusted --add-source=192.168.1.0/24
```

3. Add the *http* service in the trusted zone:

```
~]# firewall-cmd --zone=trusted -add-service=http
```

4. Make the new settings persistent:

```
~]# firewall-cmd --runtime-to-permanent
```

5. Check that the trusted zone is active and that the service is allowed in it:

```
~]# firewall-cmd --zone=trusted --list-all
trusted (active)
target: ACCEPT
sources: 192.168.1.0/24
services: http
```

5.8.6. Configuring Traffic Accepted by a Zone Based on Protocol

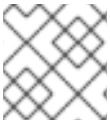
You can allow incoming traffic to be accepted by a zone based on the protocol. All traffic using the specified protocol is accepted by a zone, in which you can apply further rules and filtering.

Adding a Protocol to a Zone

By adding a protocol to a certain zone, you allow all traffic with this protocol to be accepted by this zone.

To add a protocol to a zone:

```
~]# firewall-cmd --zone=zone-name --add-protocol=port-
name/tcp|udp|sctp|dccp|igmp
```



NOTE

To receive multicast traffic, use the **igmp** value with the **--add-protocol** option.

Removing a Protocol from a Zone

By removing a protocol from a certain zone, you stop accepting all traffic based on this protocol by the zone.

To remove a protocol from a zone:

```
~]# firewall-cmd --zone=zone-name --remove-protocol=port-
name/tcp|udp|sctp|dccp|igmp
```

5.9. PORT FORWARDING

Using **firewalld**, you can set up ports redirection so that any incoming traffic that reaches a certain port on your system is delivered to another internal port of your choice or to an external port on another machine.

5.9.1. Adding a Port to Redirect

Before you redirect traffic from one port to another port, or another address, you need to know three things: which port the packets arrive at, what protocol is used, and where you want to redirect them.

To redirect a port to another port:

```
~]# firewall-cmd --add-forward-port=port=port-
number:proto=tcp|udp|sctp|dccp:toport=port-number
```

To redirect a port to another port at a different IP address:

1. Add the port to be forwarded:

```
~]# firewall-cmd --add-forward-port=port=port-
number:proto=tcp|udp:toport=port-number:toaddr=IP/mask
```

2. Enable masquerade:

```
~]# firewall-cmd -add-masquerade
```

Example 5.1. Redirecting TCP Port 80 to Port 88 on the Same Machine

To redirect the port:

1. Redirect the port 80 to port 88 for TCP traffic:

```
~]# firewall-cmd --add-forward-port=port=80:proto=tcp:toport=88
```

2. Make the new settings persistent:

```
~]# firewall-cmd --runtime-to-permanent
```

3. Check that the port is redirected:

```
~]# firewall-cmd --list-all
```

5.9.2. Removing a Redirected Port

To remove a redirected port:

```
~]# firewall-cmd --remove-forward-port=port=port-number:proto=
<tcp|udp>:toport=port-number:toaddr=<IP/mask>
```

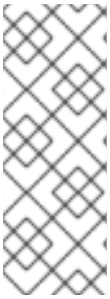
To remove a forwarded port redirected to a different address:

1. Remove the forwarded port:

```
~]# firewall-cmd --remove-forward-port=port=port-number:proto=
<tcp|udp>:toport=port-number:toaddr=<IP/mask>
```

2. Disable masquerade:

```
~]# firewall-cmd --remove-masquerade
```



NOTE

Redirecting ports using this method only works for IPv4-based traffic. For IPv6 redirecting setup, you need to use rich rules. For more information, see Section 5.15, “Configuring Complex Firewall Rules with the "Rich Language" Syntax”.

To redirect to an external system, it is necessary to enable masquerading. For more information, see Section 5.10, “Configuring IP Address Masquerading”.

Example 5.2. Removing TCP Port 80 forwarded to Port 88 on the Same Machine

To remove the port redirection:

1. List redirected ports:

```
~]# firewall-cmd --list-forward-ports
port=80:proto=tcp:toport=88:toaddr=
```

2. Remove the redirected port from the firewall::

```
~]# firewall-cmd --remove-forward-
port=port=80:proto=tcp:toport=88:toaddr=
```

3. Make the new settings persistent:

```
~]# firewall-cmd --runtime-to-permanent
```

5.10. CONFIGURING IP ADDRESS MASQUERADING

To check if IP masquerading is enabled (for example, for the **external** zone), enter the following command as **root**:

```
~]# firewall-cmd --zone=external --query-masquerade
```

The command prints **yes** with exit status **0** if enabled. It prints **no** with exit status **1** otherwise. If **zone** is omitted, the default zone will be used.

To enable IP masquerading, enter the following command as **root**:

```
~]# firewall-cmd --zone=external --add-masquerade
```

To make this setting persistent, repeat the command adding the **--permanent** option.

To disable IP masquerading, enter the following command as **root**:

```
~]# firewall-cmd --zone=external --remove-masquerade
```

To make this setting persistent, repeat the command adding the **--permanent** option.

5.11. MANAGING ICMP REQUESTS

The **Internet Control Message Protocol** (**ICMP**) is a supporting protocol that is used by various network devices to send error messages and operational information indicating a connection problem, for example, that a requested service is not available. **ICMP** differs from transport protocols such as TCP and UDP because it is not used to exchange data between systems.

Unfortunately, it is possible to use the **ICMP** messages, especially **echo-request** and **echo-reply**, to reveal information about your network and misuse such information for various kinds of fraudulent activities. Therefore, **firewalld** enables blocking the **ICMP** requests to protect your network information.

5.11.1. Listing ICMP Requests

The **ICMP** requests are described in individual XML files that are located in the **/usr/lib/firewalld/icmptypes/** directory. You can read these files to see a description of the request. The **firewall-cmd** command controls the **ICMP** requests manipulation.

To list all available **ICMP** types:

```
~]# firewall-cmd --get-icmptypes
```

The **ICMP** request can be used by IPv4, IPv6, or by both protocols. To see for which protocol the **ICMP** request is used:

```
~]# firewall-cmd --info-icmptype=<icmptype>
```

The status of an **ICMP** request shows **yes** if the request is currently blocked or **no** if it is not. To see if an **ICMP** request is currently blocked:

```
~]# firewall-cmd --query-icmp-block=<icmptype>
```

5.11.2. Blocking or Unblocking ICMP Requests

When your server blocks **ICMP** requests, it does not provide the information that it normally would. However, that does not mean that no information is given at all. The clients receive information that the particular **ICMP** request is being blocked (rejected). Blocking the **ICMP** requests should be considered carefully, because it can cause communication problems, especially with IPv6 traffic.

To see if an **ICMP** request is currently blocked:

```
~]# firewall-cmd --query-icmp-block=<icmptype>
```

To block an **ICMP** request:

```
~]# firewall-cmd --add-icmp-block=<icmptype>
```

To remove the block for an **ICMP** request:

```
~]# firewall-cmd --remove-icmp-block=<icmptype>
```

5.11.3. Blocking ICMP Requests without Providing any Information at All

Normally, if you block **ICMP** requests, clients know that you are blocking it. So, a potential attacker who is sniffing for live IP addresses is still able to see that your IP address is online. To hide this information completely, you have to drop all **ICMP** requests.

To block and drop all **ICMP** requests:

1. Set the target of your zone to **DROP**:

```
~]# firewall-cmd --set-target=DROP
```

2. Make the new settings persistent:

```
~]# firewall-cmd --runtime-to-permanent
```

Now, all traffic, including **ICMP** requests, is dropped, except traffic which you have explicitly allowed.

To block and drop certain **ICMP** requests and allow others:

1. Set the target of your zone to **DROP**:

```
~]# firewall-cmd --set-target=DROP
```

2. Add the ICMP block inversion to block all **ICMP** requests at once:

```
~]# firewall-cmd --add-icmp-block-inversion
```

3. Add the ICMP block for those **ICMP** requests that you want to allow:

```
~]# firewall-cmd --add-icmp-block=<icmptype>
```

4. Make the new settings persistent:

```
~]# firewall-cmd --runtime-to-permanent
```

The *block inversion* inverts the setting of the **ICMP** requests blocks, so all requests, that were not previously blocked, are blocked. Those that were blocked are not blocked. Which means that if you need to unblock a request, you must use the blocking command.

To revert this to a fully permissive setting:

1. Set the target of your zone to **default** or **ACCEPT**:

```
~]# firewall-cmd --set-target=default
```

2. Remove all added blocks for **ICMP** requests:

```
~]# firewall-cmd --remove-icmp-block=<icmptype>
```

3. Remove the **ICMP** block inversion:

```
~]# firewall-cmd --remove-icmp-block-inversion
```

4. Make the new settings persistent:

```
~]# firewall-cmd --runtime-to-permanent
```

5.11.4. Configuring the ICMP Filter using GUI

To enable or disable an **ICMP** filter, start the **firewall-config** tool and select the network zone whose messages are to be filtered. Select the **ICMP Filter** tab and select the check box for each type of **ICMP** message you want to filter. Clear the check box to disable a filter. This setting is per direction and the default allows everything.

To edit an **ICMP** type, start the **firewall-config** tool and select **Permanent** mode from the menu labeled **Configuration**. Additional icons appear at the bottom of the **Services** window. Select **Yes** in the following dialog to enable masquerading and to make forwarding to another machine working.

To enable inverting the **ICMP Filter**, click the **Invert Filter** check box on the right. Only marked **ICMP** types are now accepted, all other are rejected. In a zone using the DROP target, they are dropped.

5.12. SETTING AND CONTROLLING IP SETS USING FIREWALLD

To see the list of IP set types supported by **firewalld**, enter the following command as root.

```
~]# firewall-cmd --get-ipset-types
hash:ip hash:ip,mark hash:ip,port hash:ip,port,ip hash:ip,port,net
hash:mac hash:net hash:net,iface hash:net,net hash:net,port
hash:net,port,net
```

5.12.1. Configuring IP Set Options with the Command-Line Client

IP sets can be used in **firewalld** zones as sources and also as sources in rich rules. In Red Hat Enterprise Linux 7, the preferred method is to use the IP sets created with **firewalld** in a direct rule.

To list the IP sets known to **firewalld** in the permanent environment, use the following command as **root**:

```
~]# firewall-cmd --permanent --get-ipsets
```

To add a new IP set, use the following command using the permanent environment as **root**:

```
~]# firewall-cmd --permanent --new-ipset=test --type=hash:net
success
```

The previous command creates a new IP set with the name *test* and the **hash:net** type for **IPv4**. To create an IP set for use with **IPv6**, add the **--option=family=inet6** option. To make the new setting effective in the runtime environment, reload **firewalld**. List the new IP set with the following command as **root**:

```
~]# firewall-cmd --permanent --get-ipsets
test
```

To get more information about the IP set, use the following command as **root**:

```
~]# firewall-cmd --permanent --info-ipset=test
test
type: hash:net
options:
entries:
```

Note that the IP set does not have any entries at the moment. To add an entry to the *test* IP set, use the following command as **root**:

```
~]# firewall-cmd --permanent --ipset=test --add-entry=192.168.0.1
success
```

The previous command adds the IP address *192.168.0.1* to the IP set. To get the list of current entries in the IP set, use the following command as **root**:

```
~]# firewall-cmd --permanent --ipset=test --get-entries
192.168.0.1
```

Generate a file containing a list of IP addresses, for example:

```
~]# cat > iplist.txt <<EOL
192.168.0.2
192.168.0.3
192.168.1.0/24
192.168.2.254
EOL
```

The file with the list of IP addresses for an IP set should contain an entry per line. Lines starting with a hash, a semi-colon, or empty lines are ignored.

To add the addresses from the *iplist.txt* file, use the following command as **root**:

```
~]# firewall-cmd --permanent --ipset=test --add-entries-from-
file=iplist.txt
success
```

To see the extended entries list of the IP set, use the following command as **root**:

```
~]# firewall-cmd --permanent --ipset=test --get-entries
192.168.0.1
192.168.0.2
192.168.0.3
192.168.1.0/24
192.168.2.254
```

To remove the addresses from the IP set and to check the updated entries list, use the following commands as **root**:

```
~]# firewall-cmd --permanent --ipset=test --remove-entries-from-
file=iplist.txt
success
~]# firewall-cmd --permanent --ipset=test --get-entries 192.168.0.1
```

You can add the IP set as a source to a zone to handle all traffic coming in from any of the addresses listed in the IP set with a zone. For example, to add the *test* IP set as a source to the *drop* zone to drop all packets coming from all entries listed in the *test* IP set, use the following command as **root**:

```
~]# firewall-cmd --permanent --zone=drop --add-source=ipset:test
success
```

The **ipset:** prefix in the source shows **firewalld** that the source is an IP set and not an IP address or an address range.

Only the creation and removal of IP sets is limited to the permanent environment, all other IP set options can be used also in the runtime environment without the **--permanent** option.

5.12.2. Configuring a Custom Service for an IP Set

To configure a custom service to create and load the IP set structure before **firewalld** starts:

1. Using an editor running as **root**, create a file as follows:

```
~]# vi /etc/systemd/system/ipset_name.service
[Unit]
Description=ipset_name
Before=firewalld.service

[Service]
Type=oneshot
RemainAfterExit=yes
ExecStart=/usr/local/bin/ipset_name.sh start
ExecStop=/usr/local/bin/ipset_name.sh stop

[Install]
WantedBy=basic.target
```

2. Use the IP set permanently in **firewalld**:

```
~]# vi /etc/firewalld/direct.xml
<?xml version="1.0" encoding="utf-8"?>
<direct>
 <rule ipv="ipv4" table="filter" chain="INPUT" priority="0">-m set -
-match-set <replaceable>ipset_name</replaceable> src -j DROP</rule>
</direct>
```

3. A **firewalld** reload is required to activate the changes:

```
~]# firewall-cmd --reload
```

   This reloads the firewall without losing state information (TCP sessions will not be terminated), but service disruption is possible during the reload.

WARNING

Red Hat does not recommend using IP sets that are not managed through **firewalld**. To use such IP sets, a permanent direct rule is required to reference the set, and a custom service must be added to create these IP sets. This service needs to be started before firewalld starts, otherwise **firewalld** is not able to add the direct rules using these sets. You can add permanent direct rules with the **/etc/firewalld/direct.xml** file.

5.13. SETTING AND CONTROLLING IP SETS USING IPTABLES

The essential differences between **firewalld** and the **iptables** (and **ip6tables**) services are:

- The **iptables service** stores configuration in **/etc/sysconfig/iptables** and **/etc/sysconfig/ip6tables**, while **firewalld** stores it in various XML files in **/usr/lib/firewalld/** and **/etc/firewalld/**. Note that the **/etc/sysconfig/iptables** file does not exist as **firewalld** is installed by default on Red Hat Enterprise Linux.
- With the **iptables service**, every single change means flushing all the old rules and reading all the new rules from **/etc/sysconfig/iptables**, while with **firewalld** there is no recreating of all the rules. Only the differences are applied. Consequently, **firewalld** can change the settings during runtime without existing connections being lost.

Both use **iptables tool** to talk to the kernel packet filter.

To use the **iptables** and **ip6tables** services instead of **firewalld**, first disable **firewalld** by running the following command as **root**:

```
~]# systemctl disable firewalld
~]# systemctl stop firewalld
```

Then install the iptables-services package by entering the following command as **root**:

```
~]# yum install iptables-services
```

The iptables-services package contains the **iptables** service and the **ip6tables** service.

Then, to start the **iptables** and **ip6tables** services, enter the following commands as **root**:

```
~]# systemctl start iptables
~]# systemctl start ip6tables
```

To enable the services to start on every system start, enter the following commands:

```
~]# systemctl enable iptables
~]# systemctl enable ip6tables
```

The **ipset** utility is used to administer *IP sets* in the Linux kernel. An IP set is a framework for storing IP

addresses, port numbers, IP and MAC address pairs, or IP address and port number pairs. The sets are indexed in such a way that very fast matching can be made against a set even when the sets are very large. IP sets enable simpler and more manageable configurations as well as providing performance advantages when using **iptables**. The **iptables** matches and targets referring to sets create references which protect the given sets in the kernel. A set cannot be destroyed while there is a single reference pointing to it.

The use of **ipset** enables **iptables** commands, such as those below, to be replaced by a set:

```
~]# iptables -A INPUT -s 10.0.0.0/8 -j DROP
~]# iptables -A INPUT -s 172.16.0.0/12 -j DROP
~]# iptables -A INPUT -s 192.168.0.0/16 -j DROP
```

The set is created as follows:

```
~]# ipset create my-block-set hash:net
~]# ipset add my-block-set 10.0.0.0/8
~]# ipset add my-block-set 172.16.0.0/12
~]# ipset add my-block-set 192.168.0.0/16
```

The set is then referenced in an **iptables** command as follows:

```
~]# iptables -A INPUT -m set --set my-block-set src -j DROP
```

If the set is used more than once a saving in configuration time is made. If the set contains many entries a saving in processing time is made.

5.14. USING THE DIRECT INTERFACE

It is possible to add and remove chains during runtime by using the **`--direct`** option with the **firewall-cmd** tool. A few examples are presented here. See the **`firewall-cmd(1)`** man page for more information.

It is dangerous to use the direct interface if you are not very familiar with **iptables** as you could inadvertently cause a breach in the firewall.

The direct interface mode is intended for services or applications to add specific firewall rules during runtime. The rules can be made permanent by adding the **`--permanent`** option using the **`firewall-cmd --permanent --direct`** command or by modifying **`/etc/firewalld/direct.xml`**. See man **`firewalld.direct(5)`** for information on the **`/etc/firewalld/direct.xml`** file.

5.14.1. Adding a Rule using the Direct Interface

To add a rule to the “IN_public_allow” chain, enter the following command as **`root`**:

```
~]# firewall-cmd --direct --add-rule ipv4 filter IN_public_allow \
        0 -m tcp -p tcp --dport 666 -j ACCEPT
```

Add the **`--permanent`** option to make the setting persistent.

5.14.2. Removing a Rule using the Direct Interface

To remove a rule from the “IN_public_allow” chain, enter the following command as **`root`**:

```
~]# firewall-cmd --direct --remove-rule ipv4 filter IN_public_allow \
        0 -m tcp -p tcp --dport 666 -j ACCEPT
```

Add the **--permanent** option to make the setting persistent.

5.14.3. Listing Rules using the Direct Interface

To list the rules in the “IN_public_allow” chain, enter the following command as **root**:

```
~]# firewall-cmd --direct --get-rules ipv4 filter IN_public_allow
```

Note that this command (the **--get-rules** option) only lists rules previously added using the **--add-rule** option. It does not list existing **iptables** rules added by other means.

5.15. CONFIGURING COMPLEX FIREWALL RULES WITH THE "RICH LANGUAGE" SYNTAX

With the “rich language” syntax, complex firewall rules can be created in a way that is easier to understand than the direct-interface method. In addition, the settings can be made permanent. The language uses keywords with values and is an abstract representation of **iptables** rules. Zones can be configured using this language; the current configuration method will still be supported.

5.15.1. Formatting of the Rich Language Commands

All the commands in this section need to be run as **root**. The format of the command to add a rule is as follows:

```
firewall-cmd [--zone=zone] --add-rich-rule='rule' [--timeout=timeval]
```

This will add a rich language rule *rule* for zone *zone*. This option can be specified multiple times. If the zone is omitted, the default zone is used. If a timeout is supplied, the rule or rules only stay active for the amount of time specified and will be removed automatically afterwards. The time value can be followed by **s** (seconds), **m** (minutes), or **h** (hours) to specify the unit of time. The default is seconds.

To remove a rule:

```
firewall-cmd [--zone=zone] --remove-rich-rule='rule'
```

This will remove a rich language rule *rule* for zone *zone*. This option can be specified multiple times. If the zone is omitted, the default zone is used.

To check if a rule is present:

```
firewall-cmd [--zone=zone] --query-rich-rule='rule'
```

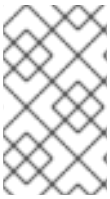
This will return whether a rich language rule *rule* has been added for the zone *zone*. The command prints **yes** with exit status **0** if enabled. It prints **no** with exit status **1** otherwise. If the zone is omitted, the default zone is used.

For information about the rich language representation used in the zone configuration files, see the firewalld.zone(5) man page.

5.15.2. Understanding the Rich Rule Structure

The format or structure of the rich rule commands is as follows:

```
rule [family="rule family"]
    [ source [NOT] [address="address"] [mac="mac-address"] [ipset="ipset"]
]
    [ destination [NOT] address="address" ]
    [ element ]
    [ log [prefix="prefix text"] [level="log level"] [limit
value="rate/duration"] ]
    [ audit ]
    [ action ]
```



NOTE

The structure of the rich rule in the file uses the **NOT** keyword to invert the sense of the source and destination address commands, but the command line uses the **invert**="*true*" option.

A rule is associated with a particular zone. A zone can have several rules. If some rules interact or contradict, the first rule that matches the packet applies.

5.15.3. Understanding the Rich Rule Command Options

family

If the rule family is provided, either **ipv4** or **ipv6**, it limits the rule to **IPv4** or **IPv6**, respectively. If the rule family is not provided, the rule is added for both **IPv4** and **IPv6**. If source or destination addresses are used in a rule, then the rule family needs to be provided. This is also the case for port forwarding.

Source and Destination Addresses

source

By specifying the source address, the origin of a connection attempt can be limited to the source address. A source address or address range is either an IP address or a network IP address with a mask for **IPv4** or **IPv6**. For **IPv4**, the mask can be a network mask or a plain number. For**IPv6**, the mask is a plain number. The use of host names is not supported. It is possible to invert the sense of the source address command by adding the **NOT** keyword; all but the supplied address matches.

A MAC address and also an IP set with type **hash:mac** can be added for **IPv4** and **IPv6** if no **family** is specified for the rule. Other IP sets need to match the**family** setting of the rule.

destination

By specifying the destination address, the target can be limited to the destination address. The destination address uses the same syntax as the source address for IP address or address ranges. The use of source and destination addresses is optional, and the use of a destination addresses is not possible with all elements. This depends on the use of destination addresses, for example, in service entries. You can combine **destination** and **action**.

Elements

The element can be **only one** of the following element types: **service**, **port**, **protocol**, **masquerade**, **icmp-block**, **forward-port**, and **source-port**.

service

The **service** element is one of the **firewalld** provided services. To get a list of the predefined services, enter the following command:

```
~]$ firewall-cmd --get-services
```

If a service provides a destination address, it will conflict with a destination address in the rule and will result in an error. The services using destination addresses internally are mostly services using multicast. The command takes the following form:

```
service name=service_name
```

port

The **port** element can either be a single port number or a port range, for example, **5060-5062**, followed by the protocol, either as **tcp** or **udp**. The command takes the following form:

```
port port=number_or_range protocol=protocol
```

protocol

The **protocol** value can be either a protocol ID number or a protocol name. For allowed **protocol** entries, see **/etc/protocols**. The command takes the following form:

```
protocol value=protocol_name_or_ID
```

icmp-block

Use this command to block one or more **ICMP** types. The **ICMP** type is one of the **ICMP** types **firewalld** supports. To get a listing of supported **ICMP** types, enter the following command:

```
~]$ firewall-cmd --get-icmptypes
```

Specifying an action is not allowed here. **icmp-block** uses the action **reject** internally. The command takes the following form:

```
icmp-block name=icmptype_name
```

masquerade

Turns on IP masquerading in the rule. A source address can be provided to limit masquerading to this area, but not a destination address. Specifying an action is not allowed here.

forward-port

Forward packets from a local port with protocol specified as **tcp** or **udp** to either another port locally, to another machine, or to another port on another machine. The **port** and **to-port** can either be a single port number or a port range. The destination address is a simple IP address. Specifying an action is not allowed here. The **forward-port** command uses the action **accept** internally. The command takes the following form:

```
forward-port port=number_or_range protocol=protocol /
            to-port=number_or_range to-addr=address
```

source-port

Matches the source port of the packet - the port that is used on the origin of a connection attempt. To match a port on current machine, use the **port** element. The **source-port** element can either be a single port number or a port range (for example, 5060-5062) followed by the protocol as **tcp** or **udp**. The command takes the following form:

```
source-port port=number_or_range protocol=protocol
```

Logging

log

Log new connection attempts to the rule with kernel logging, for example, in syslog. You can define a prefix text that will be added to the log message as a prefix. Log level can be one of **emerg**, **alert**, **crit**, **error**, **warning**, **notice**, **info**, or **debug**. The use of log is optional. It is possible to limit logging as follows:

```
log [prefix=prefix text] [level=log level] limit value=rate/duration
```

The rate is a natural positive number [1, ..], with the duration of **s**, **m**, **h**, **d**. **s** means seconds, **m** means minutes, **h** means hours, and **d** days. The maximum limit value is **1/d**, which means at maximum one log entry per day.

audit

Audit provides an alternative way for logging using audit records sent to the service **auditd**. The audit type can be one of **ACCEPT**, **REJECT**, or **DROP**, but it is not specified after the command **audit** as the audit type will be automatically gathered from the rule action. Audit does not have its own parameters, but limit can be added optionally. The use of audit is optional.

Action

accept|reject|drop|mark

An action can be one of **accept**, **reject**, **drop**, or **mark**. The rule can only contain an element or a source. If the rule contains an element, then new connections matching the element will be handled with the action. If the rule contains a source, then everything from the source address will be handled with the action specified.

```
accept | reject [type=reject type] | drop | mark set="mark[/mask]"
```

With **accept**, all new connection attempts will be granted. With **reject**, they will be rejected and their source will get a reject message. The reject type can be set to use another value. With **drop**, all packets will be dropped immediately and no information is sent to the source. With **mark** all packets will be marked with the given *mark* and the optional *mask*.

5.15.4. Using the Rich Rule Log Command

Logging can be done with the **Netfilter** log target and also with the audit target. A new chain is added to

all zones with a name in the format “*zone*_log”, where *zone* is the zone name. This is processed before the **deny** chain to have the proper ordering. The rules or parts of them are placed in separate chains, according to the action of the rule, as follows:

```
zone_log
   zone_deny
   zone_allow
```

All logging rules will be placed in the “*zone*_log” chain, which will be parsed first. All **reject** and **drop** rules will be placed in the “*zone*_deny” chain, which will be parsed after the log chain. All **accept** rules will be placed in the “*zone*_allow” chain, which will be parsed after the **deny** chain. If a rule contains **log** and also **deny** or **allow** actions, the parts of the rule that specify these actions are placed in the matching chains.

5.15.4.1. Using the Rich Rule Log Command Example 1

Enable new **IPv4** and **IPv6** connections for authentication header protocol **AH**:

```
rule protocol value="ah" accept
```

5.15.4.2. Using the Rich Rule Log Command Example 2

Allow new **IPv4** and **IPv6** connections for protocol **FTP** and log 1 per minute using audit:

```
rule service name="ftp" log limit value="1/m" audit accept
```

5.15.4.3. Using the Rich Rule Log Command Example 3

Allow new **IPv4** connections from address **192.168.0.0/24** for protocol **TFTP** and log 1 per minute using syslog:

```
rule family="ipv4" source address="192.168.0.0/24" service name="tftp" log
prefix="tftp" level="info" limit value="1/m" accept
```

5.15.4.4. Using the Rich Rule Log Command Example 4

New **IPv6** connections from **1:2:3:4:6::** for protocol **RADIUS** are all rejected and logged at a rate of 3 per minute. New **IPv6** connections from other sources are accepted:

```
rule family="ipv6" source address="1:2:3:4:6::" service name="radius" log
prefix="dns" level="info" limit value="3/m" reject
rule family="ipv6" service name="radius" accept
```

5.15.4.5. Using the Rich Rule Log Command Example 5

Forward **IPv6** packets received from **1:2:3:4:6::** on port 4011 with protocol **TCP** to **1::2:3:4:7** on port 4012.

```
rule family="ipv6" source address="1:2:3:4:6::" forward-port to-
addr="1::2:3:4:7" to-port="4012" protocol="tcp" port="4011"
```

5.15.4.6. Using the Rich Rule Log Command Example 6

Whitelist a source address to allow all connections from this source.

```
rule family="ipv4" source address="192.168.2.2" accept
```

See the **firewalld.richlanguage(5)** man page for more examples.

5.16. CONFIGURING FIREWALL LOCKDOWN

Local applications or services are able to change the firewall configuration if they are running as **root** (for example, **libvirt**). With this feature, the administrator can lock the firewall configuration so that either no applications or only applications that are added to the lockdown whitelist are able to request firewall changes. The lockdown settings default to disabled. If enabled, the user can be sure that there are no unwanted configuration changes made to the firewall by local applications or services.

5.16.1. Configuring Lockdown with the Command-Line Client

To query whether lockdown is enabled, use the following command as **root**:

```
~]# firewall-cmd --query-lockdown
```

The command prints **yes** with exit status **0** if lockdown is enabled. It prints **no** with exit status **1** otherwise.

To enable lockdown, enter the following command as **root**:

```
~]# firewall-cmd --lockdown-on
```

To disable lockdown, use the following command as **root**:

```
~]# firewall-cmd --lockdown-off
```

5.16.2. Configuring Lockdown Whitelist Options with the Command-Line Client

The lockdown whitelist can contain commands, security contexts, users and user IDs. If a command entry on the whitelist ends with an asterisk “*”, then all command lines starting with that command will match. If the “*” is not there then the absolute command including arguments must match.

The context is the security (SELinux) context of a running application or service. To get the context of a running application use the following command:

```
~]$ ps -e --context
```

That command returns all running applications. Pipe the output through the **grep** tool to get the application of interest. For example:

```
~]$ ps -e --context | grep example_program
```

To list all command lines that are on the whitelist, enter the following command as **root**:

```
~]# firewall-cmd --list-lockdown-whitelist-commands
```

To add a command *command* to the whitelist, enter the following command as **root**:

```
~]# firewall-cmd --add-lockdown-whitelist-command='/usr/bin/python -Es
/usr/bin/command'
```

To remove a command *command* from the whitelist, enter the following command as **root**:

```
~]# firewall-cmd --remove-lockdown-whitelist-command='/usr/bin/python -Es
/usr/bin/command'
```

To query whether the command *command* is on the whitelist, enter the following command as **root**:

```
~]# firewall-cmd --query-lockdown-whitelist-command='/usr/bin/python -Es
/usr/bin/command'
```

The command prints **yes** with exit status **0** if true. It prints **no** with exit status **1** otherwise.

To list all security contexts that are on the whitelist, enter the following command as **root**:

```
~]# firewall-cmd --list-lockdown-whitelist-contexts
```

To add a context *context* to the whitelist, enter the following command as **root**:

```
~]# firewall-cmd --add-lockdown-whitelist-context=context
```

To remove a context *context* from the whitelist, enter the following command as **root**:

```
~]# firewall-cmd --remove-lockdown-whitelist-context=context
```

To query whether the context *context* is on the whitelist, enter the following command as **root**:

```
~]# firewall-cmd --query-lockdown-whitelist-context=context
```

Prints **yes** with exit status **0**, if true, prints **no** with exit status **1** otherwise.

To list all user IDs that are on the whitelist, enter the following command as **root**:

```
~]# firewall-cmd --list-lockdown-whitelist-uids
```

To add a user ID *uid* to the whitelist, enter the following command as **root**:

```
~]# firewall-cmd --add-lockdown-whitelist-uid=uid
```

To remove a user ID *uid* from the whitelist, enter the following command as **root**:

```
~]# firewall-cmd --remove-lockdown-whitelist-uid=uid
```

To query whether the user ID *uid* is on the whitelist, enter the following command:

```
~]$ firewall-cmd --query-lockdown-whitelist-uid=uid
```

Prints **yes** with exit status **0**, if true, prints **no** with exit status **1** otherwise.

To list all user names that are on the whitelist, enter the following command as **root**:

```
~]# firewall-cmd --list-lockdown-whitelist-users
```

To add a user name *user* to the whitelist, enter the following command as **root**:

```
~]# firewall-cmd --add-lockdown-whitelist-user=user
```

To remove a user name *user* from the whitelist, enter the following command as **root**:

```
~]# firewall-cmd --remove-lockdown-whitelist-user=user
```

To query whether the user name *user* is on the whitelist, enter the following command:

```
~]$ firewall-cmd --query-lockdown-whitelist-user=user
```

Prints **yes** with exit status **0**, if true, prints **no** with exit status **1** otherwise.

5.16.3. Configuring Lockdown Whitelist Options with Configuration Files

The default whitelist configuration file contains the **NetworkManager** context and the default context of **libvirt**. The user ID 0 is also on the list.

```
<?xml version="1.0" encoding="utf-8"?>
 <whitelist>
   <selinux context="system_u:system_r:NetworkManager_t:s0"/>
   <selinux context="system_u:system_r:virtd_t:s0-s0:c0.c1023"/>
   <user id="0"/>
 </whitelist>
```

Following is an example whitelist configuration file enabling all commands for the **firewall-cmd** utility, for a user called *user* whose user ID is **815**:

```
<?xml version="1.0" encoding="utf-8"?>
 <whitelist>
   <command name="/usr/bin/python -Es /bin/firewall-cmd*"/>
   <selinux context="system_u:system_r:NetworkManager_t:s0"/>
   <user id="815"/>
   <user name="user"/>
 </whitelist>
```

This example shows both **user id** and **user name**, but only one option is required. Python is the interpreter and is prepended to the command line. You can also use a specific command, for example:

```
/usr/bin/python /bin/firewall-cmd --lockdown-on
```

In that example, only the **--lockdown-on** command is allowed.

NOTE

In Red Hat Enterprise Linux 7, all utilities are placed in the **/usr/bin/** directory and the **/bin/** directory is sym-linked to the **/usr/bin/** directory. In other words, although the path for **firewall-cmd** when run as **root** might resolve to **/bin/firewall-cmd**, **/usr/bin/firewall-cmd** can now be used. All new scripts should use the new location. But be aware that if scripts that run as **root** have been written to use the **/bin/firewall-cmd** path, then that command path must be whitelisted in addition to the **/usr/bin/firewall-cmd** path traditionally used only for non-**root** users.

The "*" at the end of the name attribute of a command means that all commands that start with this string will match. If the "*" is not there then the absolute command including arguments must match.

5.17. CONFIGURING LOGGING FOR DENIED PACKETS

With the **LogDenied** option in the **firewalld**, it is possible to add a simple logging mechanism for denied packets. These are the packets that are rejected or dropped. To change the setting of the logging, edit the **/etc/firewalld/firewalld.conf** file or use the command-line or GUI configuration tool.

If **LogDenied** is enabled, logging rules are added right before the reject and drop rules in the INPUT, FORWARD and OUTPUT chains for the default rules and also the final reject and drop rules in zones. The possible values for this setting are: **all**, **unicast**, **broadcast**, **multicast**, and **off**. The default setting is **off**. With the **unicast**, **broadcast**, and **multicast** setting, the **pkttype** match is used to match the link-layer packet type. With **all**, all packets are logged.

To list the actual **LogDenied** setting with firewall-cmd, use the following command as **root**:

```
~]# firewall-cmd --get-log-denied
off
```

To change the **LogDenied** setting, use the following command as **root**:

```
~]# firewall-cmd --set-log-denied=all
success
```

To change the **LogDenied** setting with the **firewalld** GUI configuration tool, start **firewall-config**, click the **Options** menu and select **Change Log Denied**. The **LogDenied** window appears. Select the new **LogDenied** setting from the menu and click OK.

5.18. ADDITIONAL RESOURCES

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

5.18.1. Installed Documentation

- **firewalld(1)** man page — Describes command options for **firewalld**.
- **firewalld.conf(5)** man page — Contains information to configure **firewalld**.

- **`firewall-cmd(1)`** man page — Describes command options for the **`firewalld`** command-line client.
- **`firewall-config(1)`** man page — Describes settings for the **firewall-config** tool.
- **`firewall-offline-cmd(1)`** man page — Describes command options for the **`firewalld`** offline command-line client.
- **`firewalld.icmptype(5)`** man page — Describes XML configuration files for **`ICMP`** filtering.
- **`firewalld.ipset(5)`** man page — Describes XML configuration files for the **`firewalld IP`** sets.
- **`firewalld.service(5)`** man page — Describes XML configuration files for **firewalld service**.
- **`firewalld.zone(5)`** man page — Describes XML configuration files for **`firewalld`** zone configuration.
- **`firewalld.direct(5)`** man page — Describes the **`firewalld`** direct interface configuration file.
- **`firewalld.lockdown-whitelist(5)`** man page — Describes the **`firewalld`** lockdown whitelist configuration file.
- **`firewalld.richlanguage(5)`** man page — Describes the **`firewalld`** rich language rule syntax.
- **`firewalld.zones(5)`** man page — General description of what zones are and how to configure them.
- **`firewalld.dbus(5)`** man page — Describes the **`D-Bus`** interface of **`firewalld`**.

5.18.2. Online Documentation

- http://www.firewalld.org/ — **`firewalld`** home page.

CHAPTER 6. SYSTEM AUDITING

The Linux Audit system provides a way to track security-relevant information on your system. Based on pre-configured rules, Audit generates log entries to record as much information about the events that are happening on your system as possible. This information is crucial for mission-critical environments to determine the violator of the security policy and the actions they performed. Audit does not provide additional security to your system; rather, it can be used to discover violations of security policies used on your system. These violations can further be prevented by additional security measures such as SELinux.

The following list summarizes some of the information that Audit is capable of recording in its log files:

- Date and time, type, and outcome of an event.
- Sensitivity labels of subjects and objects.
- Association of an event with the identity of the user who triggered the event.
- All modifications to Audit configuration and attempts to access Audit log files.
- All uses of authentication mechanisms, such as SSH, Kerberos, and others.
- Changes to any trusted database, such as **`/etc/passwd`**.
- Attempts to import or export information into or from the system.
- Include or exclude events based on user identity, subject and object labels, and other attributes.

The use of the Audit system is also a requirement for a number of security-related certifications. Audit is designed to meet or exceed the requirements of the following certifications or compliance guides:

- Controlled Access Protection Profile (CAPP)
- Labeled Security Protection Profile (LSPP)
- Rule Set Base Access Control (RSBAC)
- National Industrial Security Program Operating Manual (NISPOM)
- Federal Information Security Management Act (FISMA)
- Payment Card Industry — Data Security Standard (PCI-DSS)
- Security Technical Implementation Guides (STIG)

Audit has also been:

- Evaluated by National Information Assurance Partnership (NIAP) and Best Security Industries (BSI).
- Certified to LSPP/CAPP/RSBAC/EAL4+ on Red Hat Enterprise Linux 5.
- Certified to Operating System Protection Profile / Evaluation Assurance Level 4+ (OSPP/EAL4+) on Red Hat Enterprise Linux 6.

Use Cases

Watching file access

Audit can track whether a file or a directory has been accessed, modified, executed, or the file's attributes have been changed. This is useful, for example, to detect access to important files and have an Audit trail available in case one of these files is corrupted.

Monitoring system calls

Audit can be configured to generate a log entry every time a particular system call is used. This can be used, for example, to track changes to the system time by monitoring the `settimeofday`, `clock_adjtime`, and other time-related system calls.

Recording commands run by a user

Audit can track whether a file has been executed, so rules can be defined to record every execution of a particular command. For example, a rule can be defined for every executable in the `/bin` directory. The resulting log entries can then be searched by user ID to generate an audit trail of executed commands per user.

Recording execution of system pathnames

Aside from watching file access which translates a path to an inode at rule invocation, Audit can now watch the execution of a path even if it does not exist at rule invocation, or if the file is replaced after rule invocation. This allows rules to continue to work after upgrading a program executable or before it is even installed.

Recording security events

The `pam_faillock` authentication module is capable of recording failed login attempts. Audit can be set up to record failed login attempts as well, and provides additional information about the user who attempted to log in.

Searching for events

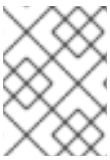
Audit provides the **ausearch** utility, which can be used to filter the log entries and provide a complete audit trail based on a number of conditions.

Running summary reports

The **aureport** utility can be used to generate, among other things, daily reports of recorded events. A system administrator can then analyze these reports and investigate suspicious activity further.

Monitoring network access

The **iptables** and **ebtables** utilities can be configured to trigger Audit events, allowing system administrators to monitor network access.



NOTE

System performance may be affected depending on the amount of information that is collected by Audit.

6.1. AUDIT SYSTEM ARCHITECTURE

The Audit system consists of two main parts: the user-space applications and utilities, and the kernel-side system call processing. The kernel component receives system calls from user-space applications and filters them through one of the three filters: *user*, *task*, or *exit*. Once a system call passes the *exclude*

filter, it is sent through one of the aforementioned filters, which, based on the Audit rule configuration, sends it to the Audit daemon for further processing. Figure 6.1, “Audit System Architecture” illustrates this process.

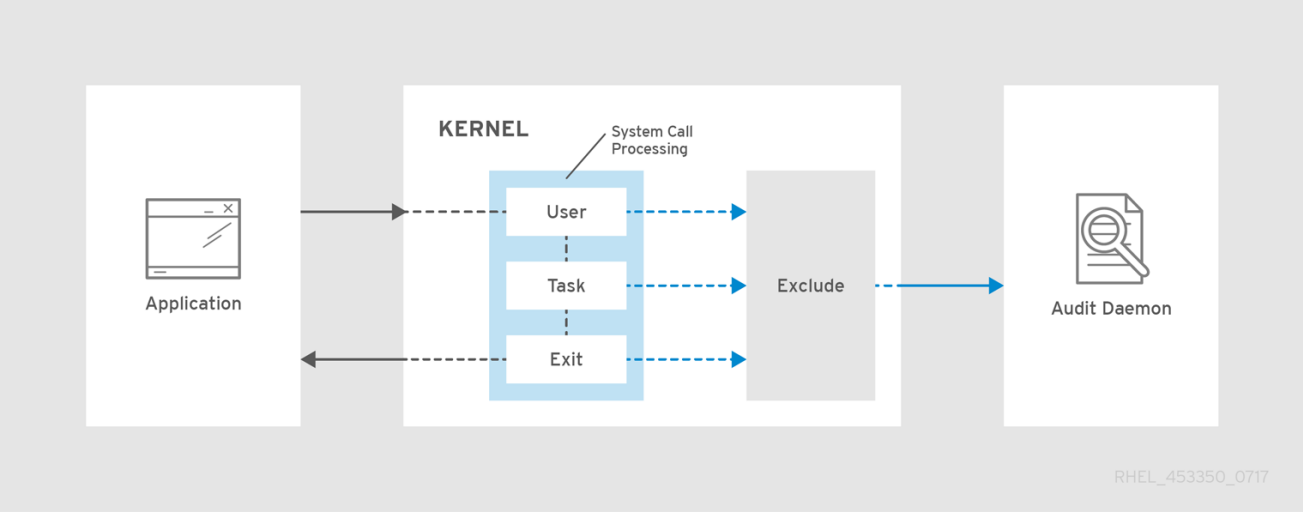


Figure 6.1. Audit System Architecture

The user-space Audit daemon collects the information from the kernel and creates entries in a log file. Other Audit user-space utilities interact with the Audit daemon, the kernel Audit component, or the Audit log files:

- **audisp** — the Audit dispatcher daemon interacts with the Audit daemon and sends events to other applications for further processing. The purpose of this daemon is to provide a plug-in mechanism so that real-time analytical programs can interact with Audit events.
- **auditctl** — the Audit control utility interacts with the kernel Audit component to manage rules and to control a number of settings and parameters of the event generation process.
- The remaining Audit utilities take the contents of the Audit log files as input and generate output based on user's requirements. For example, the **aureport** utility generates a report of all recorded events.

6.2. INSTALLING THE AUDIT PACKAGES

In order to use the Audit system, you must have the audit packages installed on your system. The audit packages (audit and audit-libs) are installed by default on Red Hat Enterprise Linux 7. If you do not have these packages installed, execute the following command as the root user to install Audit and the dependencies:

```
~]# yum install audit
```

6.3. CONFIGURING THE `AUDIT` SERVICE

The Audit daemon can be configured in the **`/etc/audit/auditd.conf`** file. This file consists of configuration parameters that modify the behavior of the Audit daemon. Empty lines and text following a hash sign (#) are ignored. For further details, see the auditd.conf(5) man page.

6.3.1. Configuring `auditd` for a Secure Environment

The default **auditd** configuration should be suitable for most environments. However, if your environment has to meet strict security policies, the following settings are suggested for the Audit daemon configuration in the **/etc/audit/auditd.conf** file:

log_file

The directory that holds the Audit log files (usually **/var/log/audit/**) should reside on a separate mount point. This prevents other processes from consuming space in this directory, and provides accurate detection of the remaining space for the Audit daemon.

max_log_file

Specifies the maximum size of a single Audit log file, must be set to make full use of the available space on the partition that holds the Audit log files.

max_log_file_action

Decides what action is taken once the limit set in ***max_log_file*** is reached, should be set to **keep_logs** to prevent Audit log files from being overwritten.

space_left

Specifies the amount of free space left on the disk for which an action that is set in the ***space_left_action*** parameter is triggered. Must be set to a number that gives the administrator enough time to respond and free up disk space. The ***space_left*** value depends on the rate at which the Audit log files are generated.

space_left_action

It is recommended to set the ***space_left_action*** parameter to **email** or **exec** with an appropriate notification method.

admin_space_left

Specifies the absolute minimum amount of free space for which an action that is set in the ***admin_space_left_action*** parameter is triggered, must be set to a value that leaves enough space to log actions performed by the administrator.

admin_space_left_action

Should be set to **single** to put the system into single-user mode and allow the administrator to free up some disk space.

disk_full_action

Specifies an action that is triggered when no free space is available on the partition that holds the Audit log files, must be set to **halt** or **single**. This ensures that the system is either shut down or operating in single-user mode when Audit can no longer log events.

disk_error_action

Specifies an action that is triggered in case an error is detected on the partition that holds the Audit log files, must be set to **syslog**, **single**, or **halt**, depending on your local security policies regarding the handling of hardware malfunctions.

flush

Should be set to **incremental_async**. It works in combination with the ***freq*** parameter, which determines how many records can be sent to the disk before forcing a hard synchronization with the

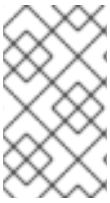
hard drive. The ***freq*** parameter should be set to **100**. These parameters assure that Audit event data is synchronized with the log files on the disk while keeping good performance for bursts of activity.

The remaining configuration options should be set according to your local security policy.

6.4. STARTING THE AUDIT SERVICE

Once **auditd** is configured, start the service to collect Audit information and store it in the log files. Execute the following command as the root user to start **auditd**:

```
~]# service auditd start
```



NOTE

The **service** command is the only way to correctly interact with the **auditd** daemon. You need to use the **service** command so that the **auid** value is properly recorded. You can use the **systemctl** command only for two actions: **enable** and **status**.

To configure **auditd** to start at boot time using the following command as the root user:

```
~]# systemctl enable auditd
```

A number of other actions can be performed on **auditd** using the **service auditd *action*** command, where *action* can be one of the following:

stop

Stops **auditd**.

restart

Restarts **auditd**.

reload or **force-reload**

Reloads the configuration of **auditd** from the **/etc/audit/auditd.conf** file.

rotate

Rotates the log files in the **/var/log/audit/** directory.

resume

Resumes logging of Audit events after it has been previously suspended, for example, when there is not enough free space on the disk partition that holds the Audit log files.

condrestart or **try-restart**

Restarts **auditd** only if it is already running.

status

Displays the running status of **auditd**.

6.5. DEFINING AUDIT RULES

The Audit system operates on a set of rules that define what is to be captured in the log files. The following types of Audit rules can be specified:

Control rules

Allow the Audit system's behavior and some of its configuration to be modified.

File system rules

Also known as file watches, allow the auditing of access to a particular file or a directory.

System call rules

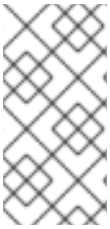
Allow logging of system calls that any specified program makes.

Audit rules can be set:

- on the command line using the **auditctl** utility. Note that these rules are not persistent across reboots. For details, see Section 6.5.1, “Defining Audit Rules with **auditctl**”
- in the **`/etc/audit/audit.rules`** file. For details, see Section 6.5.3, “Defining Persistent Audit Rules and Controls in the **`/etc/audit/audit.rules`** File”

6.5.1. Defining Audit Rules with auditctl

The **`auditctl`** command allows you to control the basic functionality of the Audit system and to define rules that decide which Audit events are logged.



NOTE

All commands which interact with the Audit service and the Audit log files require root privileges. Ensure you execute these commands as the root user. Additionally, CAP_AUDIT_CONTROL is required to set up audit services and CAP_AUDIT_WRITE is required to log user messages.

Defining Control Rules

The following are some of the control rules that allow you to modify the behavior of the Audit system:

`-b`

sets the maximum amount of existing Audit buffers in the kernel, for example:

```
~]# auditctl -b 8192
```

`-f`

sets the action that is performed when a critical error is detected, for example:

```
~]# auditctl -f 2
```

The above configuration triggers a kernel panic in case of a critical error.

`-e`

enables and disables the Audit system or locks its configuration, for example:

```
~]# auditctl -e 2
```

The above command locks the Audit configuration.

-r

sets the rate of generated messages per second, for example:

```
~]# auditctl -r 0
```

The above configuration sets no rate limit on generated messages.

-s

reports the status of the Audit system, for example:

```
~]# auditctl -s
AUDIT_STATUS: enabled=1 flag=2 pid=0 rate_limit=0 backlog_limit=8192
lost=259 backlog=0
```

-l

lists all currently loaded Audit rules, for example:

```
~]# auditctl -l
-w /etc/passwd -p wa -k passwd_changes
-w /etc/selinux -p wa -k selinux_changes
-w /sbin/insmod -p x -k module_insertion
⋮
```

-D

deletes all currently loaded Audit rules, for example:

```
~]# auditctl -D
No rules
```

Defining File System Rules

To define a file system rule, use the following syntax:

```
auditctl -w path_to_file -p permissions -k key_name
```

where:

- *path_to_file* is the file or directory that is audited.
- *permissions* are the permissions that are logged:
  - **r** — read access to a file or a directory.
  - **w** — write access to a file or a directory.

- **x** — execute access to a file or a directory.
- **a** — change in the file's or directory's attribute.

- *key_name* is an optional string that helps you identify which rule or a set of rules generated a particular log entry.

Example 6.1. File System Rules

To define a rule that logs all write access to, and every attribute change of, the **/etc/passwd** file, execute the following command:

```
~]# auditctl -w /etc/passwd -p wa -k passwd_changes
```

Note that the string following the **-k** option is arbitrary.

To define a rule that logs all write access to, and every attribute change of, all the files in the **/etc/selinux/** directory, execute the following command:

```
~]# auditctl -w /etc/selinux/ -p wa -k selinux_changes
```

To define a rule that logs the execution of the **/sbin/insmod** command, which inserts a module into the Linux kernel, execute the following command:

```
~]# auditctl -w /sbin/insmod -p x -k module_insertion
```

Defining System Call Rules

To define a system call rule, use the following syntax:

```
auditctl -a action,filter -S system_call -F field=value -k key_name
```

where:

- *action* and *filter* specify when a certain event is logged. *action* can be either **always** or **never**. *filter* specifies which kernel rule-matching filter is applied to the event. The rule-matching filter can be one of the following: **task**, **exit**, **user**, and **exclude**. For more information about these filters, see the beginning of Section 6.1, “Audit System Architecture”.
- *system_call* specifies the system call by its name. A list of all system calls can be found in the **/usr/include/asm/unistd_64.h** file. Several system calls can be grouped into one rule, each specified after its own **-S** option.
- *field=value* specifies additional options that further modify the rule to match events based on a specified architecture, group ID, process ID, and others. For a full listing of all available field types and their values, see the auditctl(8) man page.
- *key_name* is an optional string that helps you identify which rule or a set of rules generated a particular log entry.

Example 6.2. System Call Rules

To define a rule that creates a log entry every time the **adjtimex** or **settimeofday** system calls are used by a program, and the system uses the 64-bit architecture, execute the following command:

```
~]# auditctl -a always,exit -F arch=b64 -S adjtimex -S settimeofday -k
time_change
```

To define a rule that creates a log entry every time a file is deleted or renamed by a system user whose ID is 1000 or larger, execute the following command:

```
~]# auditctl -a always,exit -S unlink -S unlinkat -S rename -S renameat
-F auid>=1000 -F auid!=4294967295 -k delete
```

Note that the **-F auid!=4294967295** option is used to exclude users whose login UID is not set.

It is also possible to define a file system rule using the system call rule syntax. The following command creates a rule for system calls that is analogous to the **-w /etc/shadow -p wa** file system rule:

```
~]# auditctl -a always,exit -F path=/etc/shadow -F perm=wa
```

6.5.2. Defining Executable File Rules

To define an executable file rule, use the following syntax:

```
auditctl  -a action,filter [ -F arch=cpu -S system_call] -F
exe=path_to_executable_file -k key_name
```

where:

- *action* and *filter* specify when a certain event is logged. *action* can be either **always** or **never**. *filter* specifies which kernel rule-matching filter is applied to the event. The rule-matching filter can be one of the following: **task**, **exit**, **user**, and **exclude**. For more information about these filters, see the beginning of Section 6.1, “Audit System Architecture”.
- *system_call* specifies the system call by its name. A list of all system calls can be found in the **/usr/include/asm/unistd_64.h** file. Several system calls can be grouped into one rule, each specified after its own **-S** option.
- *path_to_executable_file* is the absolute path to the executable file that is audited.
- *key_name* is an optional string that helps you identify which rule or a set of rules generated a particular log entry.

Example 6.3. Executable File Rules

To define a rule that logs all execution of the **/bin/id** program, execute the following command:

```
~]# auditctl -F exe=/bin/id -S execve -k execution_bin_id
```

6.5.3. Defining Persistent Audit Rules and Controls in the `/etc/audit/audit.rules` File

To define Audit rules that are persistent across reboots, you must either directly include them in the **`/etc/audit/audit.rules`** file or use the **augenrules** program that reads rules located in the **`/etc/audit/rules.d/`** directory. The **`/etc/audit/audit.rules`** file uses the same **`auditctl`** command line syntax to specify the rules. Empty lines and text following a hash sign (#) are ignored.

The **`auditctl`** command can also be used to read rules from a specified file using the **`-R`** option, for example:

```
~]# auditctl -R /usr/share/doc/audit/rules/30-stig.rules
```

Defining Control Rules

A file can contain only the following control rules that modify the behavior of the Audit system: **`-b`**, **`-D`**, **`-e`**, **`-f`**, **`-r`**, **`--loginuid-immutable`**, and **`--backlog_wait_time`**. For more information on these options, see the section called “Defining Control Rules”.

Example 6.4. Control Rules in `audit.rules`

```
# Delete all previous rules
-D

# Set buffer size
-b 8192

# Make the configuration immutable -- reboot is required to change audit
rules
-e 2

# Panic when a failure occurs
-f 2

# Generate at most 100 audit messages per second
-r 100

# Make login UID immutable once it is set (may break containers)
--loginuid-immutable 1
```

Defining File System and System Call Rules

File system and system call rules are defined using the **`auditctl`** syntax. The examples in Section 6.5.1, “Defining Audit Rules with **auditctl**” can be represented with the following rules file:

Example 6.5. File System and System Call Rules in `audit.rules`

```
-w /etc/passwd -p wa -k passwd_changes
-w /etc/selinux/ -p wa -k selinux_changes
-w /sbin/insmod -p x -k module_insertion

-a always,exit -F arch=b64 -S adjtimex -S settimeofday -k time_change
-a always,exit -S unlink -S unlinkat -S rename -S renameat -F auid>=1000
-F auid!=4294967295 -k delete
```

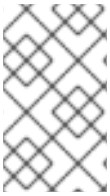
Preconfigured Rules Files

In the **/usr/share/doc/audit/rules/** directory, the audit package provides a set of pre-configured rules files according to various certification standards:

- **30-nispom.rules** — Audit rule configuration that meets the requirements specified in the Information System Security chapter of the National Industrial Security Program Operating Manual.
- **30-pci-dss-v31.rules** — Audit rule configuration that meets the requirements set by Payment Card Industry Data Security Standard (PCI DSS) v3.1.
- **30-stig.rules** — Audit rule configuration that meets the requirements set by Security Technical Implementation Guides (STIG).

To use these configuration files, create a backup of your original **/etc/audit/audit.rules** file and copy the configuration file of your choice over the **/etc/audit/audit.rules** file:

```
~]# cp /etc/audit/audit.rules /etc/audit/audit.rules_backup
~]# cp /usr/share/doc/audit/rules/30-stig.rules /etc/audit/audit.rules
```



NOTE

The Audit rules have a numbering scheme that allows them to be ordered. To learn more about the naming scheme, see the **/usr/share/doc/audit/rules/README-rules** file.

Using augenrules to Define Persistent Rules

The **augenrules** script reads rules located in the **/etc/audit/rules.d/** directory and compiles them into an **audit.rules** file. This script processes all files that ends in **.rules** in a specific order based on their natural sort order. The files in this directory are organized into groups with following meanings:

- 10 - Kernel and auditctl configuration
- 20 - Rules that could match general rules but you want a different match
- 30 - Main rules
- 40 - Optional rules
- 50 - Server-specific rules
- 70 - System local rules
- 90 - Finalize (immutable)

The rules are not meant to be used all at once. They are pieces of a policy that should be thought out and individual files copied to **/etc/audit/rules.d/**. For example, to set a system up in the STIG configuration, copy rules 10-base-config, 30-stig, 31-privileged, and 99-finalize.

Once you have the rules in the **/etc/audit/rules.d/** directory, load them by running the **augenrules** script with the **--load** directive:

```
~]# augenrules --load
```

```
augenrules --load No rules
enabled 1
failure 1
pid 634
rate_limit 0
backlog_limit 8192
lost 0
backlog 0
enabled 1
failure 1
pid 634
rate_limit 0
backlog_limit 8192
lost 0
backlog 1
```

For more information on the Audit rules and the **augenrules** script, see the **audit.rules(8)** and **augenrules(8)** man pages.

6.6. UNDERSTANDING AUDIT LOG FILES

By default, the Audit system stores log entries in the **/var/log/audit/audit.log** file; if log rotation is enabled, rotated **audit.log** files are stored in the same directory.

The following Audit rule logs every attempt to read or modify the **/etc/ssh/sshd_config** file:

```
-w /etc/ssh/sshd_config -p warx -k sshd_config
```

If the **auditd** daemon is running, for example, using the following command creates a new event in the Audit log file:

```
~]$ cat /etc/ssh/sshd_config
```

This event in the **audit.log** file looks as follows:

```
type=SYSCALL msg=audit(1364481363.243:24287): arch=c000003e syscall=2
success=no exit=-13 a0=7fffd19c5592 a1=0 a2=7fffd19c4b50 a3=a items=1
ppid=2686 pid=3538 auid=1000 uid=1000 gid=1000 euid=1000 suid=1000
fsuid=1000 egid=1000 sgid=1000 fsgid=1000 tty=pts0 ses=1 comm="cat"
exe="/bin/cat" subj=unconfined_u:unconfined_r:unconfined_t:s0-s0:c0.c1023
key="sshd_config"
type=CWD msg=audit(1364481363.243:24287):  cwd="/home/shadowman"
type=PATH msg=audit(1364481363.243:24287): item=0
name="/etc/ssh/sshd_config" inode=409248 dev=fd:00 mode=0100600 ouid=0
ogid=0 rdev=00:00 obj=system_u:object_r:etc_t:s0  objtype=NORMAL
cap_fp=none cap_fi=none cap_fe=0 cap_fver=0
type=PROCTITLE msg=audit(1364481363.243:24287) :
proctitle=636174002F6574632F7373682F737368645F636F6E666967
```

The above event consists of four records, which share the same time stamp and serial number. Records always tart with the **type=** keyword. Each record consists of several ***name=value*** pairs separated by a white space or a comma. A detailed analysis of the above event follows:

First Record

type=SYSCALL

The **type** field contains the type of the record. In this example, the **SYSCALL** value specifies that this record was triggered by a system call to the kernel.

For a list of all possible type values and their explanations, see Section B.2, "Audit Record Types".

msg=audit(1364481363.243:24287):

The **msg** field records:

- a time stamp and a unique ID of the record in the form **audit(*time_stamp*:*ID*)**. Multiple records can share the same time stamp and ID if they were generated as part of the same Audit event. The time stamp is using the Unix time format - seconds since 00:00:00 UTC on 1 January 1970.
- various event-specific ***name*=*value*** pairs provided by the kernel or user space applications.

arch=c000003e

The **arch** field contains information about the CPU architecture of the system. The value,**c000003e**, is encoded in hexadecimal notation. When searching Audit records with the **ausearch** command, use the **-i** or **--interpret** option to automatically convert hexadecimal values into their human-readable equivalents. The **c000003e** value is interpreted as **x86_64**.

syscall=2

The **syscall** field records the type of the system call that was sent to the kernel. The value, **2**, can be matched with its human-readable equivalent in the **/usr/include/asm/unistd_64.h** file. In this case, **2** is the **open** system call. Note that the **ausyscall** utility allows you to convert system call numbers to their human-readable equivalents. Use the **ausyscall --dump** command to display a listing of all system calls along with their numbers. For more information, see the ausyscall(8) man page.

success=no

The **success** field records whether the system call recorded in that particular event succeeded or failed. In this case, the call did not succeed.

exit=-13

The **exit** field contains a value that specifies the exit code returned by the system call. This value varies for different system call. You can interpret the value to its human-readable equivalent with the following command:

```
~]# ausearch --interpret --exit -13
```

Note that the previous example assumes that your Audit log contains an event that failed with exit code **-13**.

a0=7fffd19c5592, a1=0, a2=7fffd19c5592, a3=a

The **a0** to **a3** fields record the first four arguments, encoded in hexadecimal notation, of the system call in this event. These arguments depend on the system call that is used; they can be interpreted by the **ausearch** utility.

items=1

The **items** field contains the number of auxiliary records that follow the syscall record.

ppid=2686

The **ppid** field records the Parent Process ID (PPID). In this case, **2686** was the PPID of the parent process such as **bash**.

pid=3538

The **pid** field records the Process ID (PID). In this case, **3538** was the PID of the **cat** process.

auid=1000

The **auid** field records the Audit user ID, that is the loginuid. This ID is assigned to a user upon login and is inherited by every process even when the user's identity changes, for example, by switching user accounts with the **su - john** command.

uid=1000

The **uid** field records the user ID of the user who started the analyzed process. The user ID can be interpreted into user names with the following command: **ausearch -i --uid *UID***.

gid=1000

The **gid** field records the group ID of the user who started the analyzed process.

euid=1000

The **euid** field records the effective user ID of the user who started the analyzed process.

suid=1000

The **suid** field records the set user ID of the user who started the analyzed process.

fsuid=1000

The **fsuid** field records the file system user ID of the user who started the analyzed process.

egid=1000

The **egid** field records the effective group ID of the user who started the analyzed process.

sgid=1000

The **sgid** field records the set group ID of the user who started the analyzed process.

fsgid=1000

The **fsgid** field records the file system group ID of the user who started the analyzed process.

tty=pts0

The **tty** field records the terminal from which the analyzed process was invoked.

ses=1

The **ses** field records the session ID of the session from which the analyzed process was invoked.

comm="cat"

The **comm** field records the command-line name of the command that was used to invoke the analyzed process. In this case, the **cat** command was used to trigger this Audit event.

exe="/bin/cat"

The **exe** field records the path to the executable that was used to invoke the analyzed process.

subj=unconfined_u:unconfined_r:unconfined_t:s0-s0:c0.c1023

The **subj** field records the SELinux context with which the analyzed process was labeled at the time of execution.

key="sshd_config"

The **key** field records the administrator-defined string associated with the rule that generated this event in the Audit log.

Second Record

type=CWD

In the second record, the **type** field value is **CWD** — current working directory. This type is used to record the working directory from which the process that invoked the system call specified in the first record was executed.

The purpose of this record is to record the current process's location in case a relative path winds up being captured in the associated PATH record. This way the absolute path can be reconstructed.

msg=audit(1364481363.243:24287)

The **msg** field holds the same time stamp and ID value as the value in the first record. The time stamp is using the Unix time format - seconds since 00:00:00 UTC on 1 January 1970.

cwd="/home/*user_name*"

The **cwd** field contains the path to the directory in which the system call was invoked.

Third Record

type=PATH

In the third record, the **type** field value is **PATH**. An Audit event contains a **PATH**-type record for every path that is passed to the system call as an argument. In this Audit event, only one path (**/etc/ssh/sshd_config**) was used as an argument.

msg=audit(1364481363.243:24287):

The **msg** field holds the same time stamp and ID value as the value in the first and second record.

item=0

The **item** field indicates which item, of the total number of items referenced in the **SYSCALL** type record, the current record is. This number is zero-based; a value of **0** means it is the first item.

name="/etc/ssh/sshd_config"

The **name** field records the full path of the file or directory that was passed to the system call as an argument. In this case, it was the **/etc/ssh/sshd_config** file.

inode=409248

The **inode** field contains the inode number associated with the file or directory recorded in this event. The following command displays the file or directory that is associated with the **409248** inode number:

```
~]# find / -inum 409248 -print
/etc/ssh/sshd_config
```

dev=fd:00

The **dev** field specifies the minor and major ID of the device that contains the file or directory recorded in this event. In this case, the value represents the **/dev/fd/0** device.

mode=0100600

The **mode** field records the file or directory permissions, encoded in numerical notation as returned by the **stat** command in the **st_mode** field. See the **stat(2)** man page for more information. In this case, **0100600** can be interpreted as **-rw-------**, meaning that only the root user has read and write permissions to the **/etc/ssh/sshd_config** file.

ouid=0

The **ouid** field records the object owner's user ID.

ogid=0

The **ogid** field records the object owner's group ID.

rdev=00:00

The **rdev** field contains a recorded device identifier for special files only. In this case, it is not used as the recorded file is a regular file.

obj=system_u:object_r:etc_t:s0

The **obj** field records the SELinux context with which the recorded file or directory was labeled at the time of execution.

objtype=NORMAL

The **objtype** field records the intent of each path record's operation in the context of a given syscall.

cap_fp=none

The **cap_fp** field records data related to the setting of a permitted file system-based capability of the file or directory object.

cap_fi=none

The **cap_fi** field records data related to the setting of an inherited file system-based capability of the file or directory object.

cap_fe=0

The **cap_fe** field records the setting of the effective bit of the file system-based capability of the file or directory object.

cap_fver=0

The **cap_fver** field records the version of the file system-based capability of the file or directory object.

Fourth Record

type=PROCTITLE

The **type** field contains the type of the record. In this example, the **PROCTITLE** value specifies that this record gives the full command-line that triggered this Audit event, triggered by a system call to the kernel.

proctitle=636174002F6574632F7373682F737368645F636F6E666967

The **proctitle** field records the full command-line of the command that was used to invoke the analyzed process. The field is encoded in hexadecimal notation to not allow the user to influence the Audit log parser. The text decodes to the command that triggered this Audit event. When searching Audit records with the **ausearch** command, use the **-i** or **--interpret** option to automatically convert hexadecimal values into their human-readable equivalents. The **636174002F6574632F7373682F737368645F636F6E666967** value is interpreted as **x86_64**.

The Audit event analyzed above contains only a subset of all possible fields that an event can contain. For a list of all event fields and their explanation, see Section B.1, “Audit Event Fields”. For a list of all event types and their explanation, see Section B.2, “Audit Record Types”.

Example 6.6. Additional audit.log Events

The following Audit event records a successful start of the **auditd** daemon. The **ver** field shows the version of the Audit daemon that was started.

```
type=DAEMON_START msg=audit(1363713609.192:5426): auditd start, ver=2.2
format=raw kernel=2.6.32-358.2.1.el6.x86_64 auid=1000 pid=4979
subj=unconfined_u:system_r:auditd_t:s0 res=success
```

The following Audit event records a failed attempt of user with UID of 1000 to log in as the root user.

```
type=USER_AUTH msg=audit(1364475353.159:24270): user pid=3280 uid=1000
auid=1000 ses=1 subj=unconfined_u:unconfined_r:unconfined_t:s0-
s0:c0.c1023 msg='op=PAM:authentication acct="root" exe="/bin/su"
hostname=? addr=? terminal=pts/0 res=failed'
```

6.7. SEARCHING THE AUDIT LOG FILES

The **ausearch** utility allows you to search Audit log files for specific events. By default, **ausearch** searches the **/var/log/audit/audit.log** file. You can specify a different file using the **ausearch *options* -if *file_name*** command. Supplying multiple options in one **ausearch** command is equivalent to using the *AND* operator between field types and the *OR* operator between multiple instances of the same field type.

Example 6.7. Using `ausearch` to Search Audit Log Files

To search the **`/var/log/audit/audit.log`** file for failed login attempts, use the following command:

```
~]# ausearch --message USER_LOGIN --success no --interpret
```

To search for all account, group, and role changes, use the following command:

```
~]# ausearch -m ADD_USER -m DEL_USER -m ADD_GROUP -m USER_CHAUTHTOK -m
DEL_GROUP -m CHGRP_ID -m ROLE_ASSIGN -m ROLE_REMOVE -i
```

To search for all logged actions performed by a certain user, using the user's login ID (**`auid`**), use the following command:

```
~]# ausearch -ua 1000 -i
```

To search for all failed system calls from yesterday up until now, use the following command:

```
~]# ausearch --start yesterday --end now -m SYSCALL -sv no -i
```

For a full listing of all **`ausearch`** options, see the ausearch(8) man page.

6.8. CREATING AUDIT REPORTS

The **aureport** utility allows you to generate summary and columnar reports on the events recorded in Audit log files. By default, all **`audit.log`** files in the **`/var/log/audit/`** directory are queried to create the report. You can specify a different file to run the report against using the **`aureport`** ***`options`*** **`-if`** ***`file_name`*** command.

Example 6.8. Using `aureport` to Generate Audit Reports

To generate a report for logged events in the past three days excluding the current example day, use the following command:

```
~]# aureport --start 04/08/2013 00:00:00 --end 04/11/2013 00:00:00
```

To generate a report of all executable file events, use the following command:

```
~]# aureport -x
```

To generate a summary of the executable file event report above, use the following command:

```
~]# aureport -x --summary
```

To generate a summary report of failed events for all users, use the following command:

```
~]# aureport -u --failed --summary -i
```

To generate a summary report of all failed login attempts per each system user, use the following command:

```
~]# aureport --login --summary -i
```

To generate a report from an **ausearch** query that searches all file access events for user ID **1000**, use the following command:

```
~]# ausearch --start today --loginuid 1000 --raw | aureport -f --summary
```

To generate a report of all Audit files that are queried and the time range of events they include, use the following command:

```
~]# aureport -t
```

For a full listing of all **aureport** options, see the aureport(8) man page.

6.9. ADDITIONAL RESOURCES

For more information about the Audit system, see the following sources.

Online Sources

- The Linux Audit Documentation Project page: https://github.com/linux-audit/audit-documentation/wiki.

Installed Documentation

Documentation provided by the audit package can be found in the **/usr/share/doc/audit/** directory.

Manual Pages

- audispd.conf(5)
- auditd.conf(5)
- ausearch-expression(5)
- audit.rules(7)
- audispd(8)
- auditctl(8)
- auditd(8)
- aulast(8)
- aulastlog(8)
- aureport(8)
- ausearch(8)

- ausyscall(8)
- autrace(8)
- auvirt(8)

CHAPTER 7. COMPLIANCE AND VULNERABILITY SCANNING WITH OPENSCAP

7.1. SECURITY COMPLIANCE IN RED HAT ENTERPRISE LINUX

A *compliance audit* is a process of figuring out whether a given object follows all the rules written out in a compliance policy. The *compliance policy* is defined by security professionals who specify required settings, often in the form of a checklist, that are to be used in the computing environment.

The compliance policy can vary substantially across organizations and even across different systems within the same organization. Differences among these policies are based on the purpose of these systems and its importance for the organization. The custom software settings and deployment characteristics also raise a need for custom policy checklists.

Red Hat Enterprise Linux provides tools that allow for fully automated compliance audit. These tools are based on the Security Content Automation Protocol (SCAP) standard and are designed for automated tailoring of compliance policies.

Security Compliance Tools Supported on Red Hat Enterprise Linux 7

- **SCAP Workbench** — The **`scap-workbench`** graphical utility is designed to perform configuration and vulnerability scans on a single local or remote system. It can be also used to generate security reports based on these scans and evaluations.
- **OpenSCAP** — The **oscap** command-line utility is designed to perform configuration and vulnerability scans on a local system, to validate security compliance content, and to generate reports and guides based on these scans and evaluations.
- **Script Check Engine (SCE)** — **SCE** is an extension to the **SCAP** protocol that allows administrators to write their security content using a scripting language, such as Bash, Python, or Ruby. The **SCE** extension is provided in the openscap-engine-sce package.
- **SCAP Security Guide (SSG)** — The scap-security-guide package provides the latest collection of security policies for Linux systems. The guidance consists of a catalog of practical hardening advice, linked to government requirements where applicable. The project bridges the gap between generalized policy requirements and specific implementation guidelines.

If you require performing automated compliance audits on multiple systems remotely, you can utilize OpenSCAP solution for Red Hat Satellite. For more information see Section 7.8, “Using OpenSCAP with Red Hat Satellite” and Section 7.10, “Additional Resources”.

7.2. DEFINING COMPLIANCE POLICY

The security or compliance policy is rarely written from scratch. **ISO 27000** standard series, derivative works, and other sources provide security policy templates and practice recommendations that should be helpful to start with. However, organizations building theirs information security program need to amend the policy templates to align with their needs. The policy template should be chosen on the basis of its relevancy to the company environment and then the template has to be adjusted because either the template contains build-in assumptions which cannot be applied to the organization, or the template explicitly requires that certain decisions have to be made.

Red Hat Enterprise Linux auditing capabilities are based on the Security Content Automation Protocol (SCAP) standard. SCAP is a synthesis of interoperable specifications that standardize the format and nomenclature by which software flaw and security configuration information is communicated, both to

machines and humans. SCAP is a multi-purpose framework of specifications that supports automated configuration, vulnerability and patch checking, technical control compliance activities, and security measurement.

In other words, SCAP is a vendor-neutral way of expressing security policy, and as such it is widely used in modern enterprises. SCAP specifications create an ecosystem where the format of security content is well known and standardized while the implementation of the scanner or policy editor is not mandated. Such a status enables organizations to build their security policy (SCAP content) once, no matter how many security vendors do they employ.

The latest version of SCAP includes several underlying standards. These components are organized into groups according to their function within SCAP as follows:

SCAP Components

- *Languages* — This group consists of SCAP languages that define standard vocabularies and conventions for expressing compliance policy.
    - The *eXtensible Configuration Checklist Description Format (XCCDF)* — A language designed to express, organize, and manage security guidance.
    - *Open Vulnerability and Assessment Language (OVAL)* — A language developed to perform logical assertion about the state of the scanned system.
    - *Open Checklist Interactive Language (OCIL)* — A language designed to provide a standard way to query users and interpret user responses to the given questions.
    - *Asset Identification (AI)* — A language developed to provide a data model, methods, and guidance for identifying security assets.
    - *Asset Reporting Format (ARF)* — A language designed to express the transport format of information about collected security assets and the relationship between assets and security reports.
- *Enumerations* — This group includes SCAP standards that define naming format and an official list or dictionary of items from certain security-related areas of interest.
    - *Common Configuration Enumeration (CCE)* — An enumeration of security-relevant configuration elements for applications and operating systems.
    - *Common Platform Enumeration (CPE)* — A structured naming scheme used to identify information technology (IT) systems, platforms, and software packages.
    - *Common Vulnerabilities and Exposures (CVE)* — A reference method to a collection of publicly known software vulnerabilities and exposures.
- *Metrics* — This group comprises of frameworks to identify and evaluate security risks.
    - *Common Configuration Scoring System (CCSS)* — A metric system to evaluate security-relevant configuration elements and assign them scores in order to help users to prioritize appropriate response steps.
    - *Common Vulnerability Scoring System (CVSS)* — A metric system to evaluate software vulnerabilities and assign them scores in order to help users prioritize their security risks.
- *Integrity* — An SCAP specification to maintain integrity of SCAP content and scan results.

- *Trust Model for Security Automation Data (TMSAD)* — A set of recommendations explaining usage of existing specification to represent signatures, hashes, key information, and identity information in context of an XML file within a security automation domain.

Each of the SCAP components has its own XML-based document format and its XML name space. A compliance policy expressed in SCAP can either take a form of a single OVAL definition XML file, data stream file, single zip archive, or a set of separate XML files containing an XCCDF file that represents a policy checklist.

7.2.1. The XCCDF File Format

The XCCDF language is designed to support information interchange, document generation, organizational and situational tailoring, automated compliance testing, and compliance scoring. The language is mostly descriptive and does not contain any commands to perform security scans. However, an XCCDF document can refer to other SCAP components, and as such it can be used to craft a compliance policy that is portable among all the target platforms with the exception of the related assessment documents (OVAL, OCIL).

The common way to represent a compliance policy is a set of XML files where one of the files is an XCCDF checklist. This XCCDF file usually points to the assessment resources, multiple OVAL, OCIL and the Script Check Engine (SCE) files. Furthermore, the file set can contain a CPE dictionary file and an OVAL file defining objects for this dictionary.

Being an XML-based language, the XCCDF defines and uses a vast selection of XML elements and attributes. The following list briefly introduces the main XCCDF elements; for more details about XCCDF, consult the NIST Interagency Report 7275 Revision 4.

Main XML Elements of the XCCDF Document

- **`<xccdf:Benchmark>`** — This is a root element that encloses the whole XCCDF document. It may also contain checklist metadata, such as a title, description, list of authors, date of the latest modification, and status of the checklist acceptance.
- **`<xccdf:Rule>`** — This is a key element that represents a checklist requirement and holds its description. It may contain child elements that define actions verifying or enforcing compliance with the given rule or modify the rule itself.
- **`<xccdf:Value>`** — This key element is used for expressing properties of other XCCDF elements within the benchmark.
- **`<xccdf:Group>`** — This element is used to organize an XCCDF document to structures with the same context or requirement domains by gathering the **`<xccdf:Rule>`**, **`<xccdf:Value>`**, and **`<xccdf:Group>`** elements.
- **`<xccdf:Profile>`** — This element serves for a named tailoring of the XCCDF benchmark. It allows the benchmark to hold several different tailorings. **`<xccdf:Profile>`** utilizes several selector elements, such as **`<xccdf:select>`** or **`<xccdf:refine-rule>`**, to determine which elements are going to be modified and processed while it is in effect.
- **`<xccdf:Tailoring>`** — This element allows defining the benchmark profiles outside the benchmark, which is sometimes desirable for manual tailoring of the compliance policy.
- **`<xccdf:TestResult>`** — This element serves for keeping the scan results for the given benchmark on the target system. Each **`<xccdf:TestResult>`** should refer to the profile that was used to define the compliance policy for the particular scan and it should also contain

important information about the target system that is relevant for the scan.

- **<xccdf:rule-result>** — This is a child element of **<xccdf:TestResult>** that is used to hold the result of applying a specific rule from the benchmark to the target system.
- **<xccdf:fix>** — This is a child element of **<xccdf:Rule>** that serves for remediation of the target system that is not compliant with the given rule. It can contain a command or script that is run on the target system in order to bring the system into compliance the rule.
- **<xccdf:check>** — This is a child element of **<xccdf:Rule>** that refers to an external source which defines how to evaluate the given rule.
- **<xccdf:select>** — This is a selector element that is used for including or excluding the chosen rules or groups of rules from the policy.
- **<xccdf:set-value>** — This is a selector element that is used for overwriting the current value of the specified **<xccdf:Value>** element without modifying any of its other properties.
- **<xccdf:refine-value>** — This is a selector element that is used for specifying constraints of the particular **<xccdf:Value>** element during policy tailoring.
- **<xccdf:refine-rule>** — This selector element allows overwriting properties of the selected rules.

Example 7.1. An Example of an XCCDF Document

```
<?xml version="1.0" encoding="UTF-8"?>
<Benchmark xmlns="http://checklists.nist.gov/xccdf/1.2"
    id="xccdf_com.example.www_benchmark_test">
  <status>incomplete</status>
  <version>0.1</version>
  <Profile id="xccdf_com.example.www_profile_1">
    <title>Profile title is compulsory</title>
    <select idref="xccdf_com.example.www_group_1"
        selected="true"/>
    <select idref="xccdf_com.example.www_rule_1"
        selected="true"/>
    <refine-value idref="xccdf_com.example.www_value_1"
        selector="telnet service"/>
  </Profile>
  <Group id="xccdf_com.example.www_group_1">
    <Value id="xccdf_com.example.www_value_1">
      <value selector="telnet_service">telnet-server</value>
      <value selector="dhcp_servide">dhcpd</value>
      <value selector="ftp_service">tftpd</value>
    </Value>
    <Rule id="xccdf_com.example.www_rule_1">
      <title>The telnet-server Package Shall Not Be Installed </title>
      <rationale>
        Removing the telnet-server package decreases the risk
        of the telnet service's accidental (or intentional) activation
      </rationale>
      <fix platform="cpe:/o:redhat:enterprise_linux:6"
          reboot="false"
          disruption="low"
```

```
          system="urn:xccdf:fix:script:sh">
        yum -y remove
        <sub idref="xccdf_com.example.www_value_1"/>
      </fix>
      <check system="http://oval.mitre.org/XMLSchema/oval-definitions-
5">
        <check-export value-id="xccdf_com.example.www_value_1"
            export-name="oval:com.example.www:var:1"/>
        <check-content-ref href="examplary.oval.xml"
            name="oval:com.example.www:def:1"/>
      </check>
      <check system="http://open-scap.org/page/SCE">
        <check-import import-name="stdout"/>
        <check-content-ref href="telnet_server.sh"/>
      </check>
    </Rule>
  </Group>
</Benchmark>
```

7.2.2. The OVAL File Format

The Open Vulnerability Assessment Language (OVAL) is the essential and oldest component of SCAP. The main goal of the OVAL standard is to enable interoperability among security products. That is achieved by standardization of the following three domains:

1. Representation of the target system configuration.
2. Analysis of the target system for the presence of a particular machine state.
3. Reporting the results of the comparison between the specified machine state and the observed machine state.

Unlike other tools or custom scripts, the OVAL language describes a required state of resources in a declarative manner. The OVAL language code is never executed directly, but by means of an OVAL interpreter tool called *scanner*. The declarative nature of OVAL ensures that the state of the assessed system is not accidentally modified, which is important because security scanners are often run with the highest possible privileges.

OVAL specification is open for public comments and contribution and various IT companies collaborate with the MITRE Corporation, federally funded not-for-profit organization. The OVAL specification is continuously evolving and different editions are distinguished by a version number. The current version 5.11.1 was released in April 2015.

Like all other SCAP components, OVAL is based on XML. The OVAL standard defines several document formats. Each of them includes different kind of information and serves a different purpose.

The OVAL Document Formats

- The *OVAL Definitions* format is the most common OVAL file format that is used directly for system scans. The OVAL Definitions document describes the required state of the target system.
- The *OVAL Variables* format defines variables used to amend the OVAL Definitions document. The OVAL Variables document is typically used in conjunction with the OVAL Definitions document to tailor the security content for the target system at runtime.

- The *OVAL System Characteristics* format holds information about the assessed system. The OVAL System Characteristics document is typically used to compare the actual state of the system against the expected state defined by an OVAL Definitions document.
- The *OVAL Results* is the most comprehensive OVAL format that is used to report results of the system evaluation. The OVAL Results document typically contains copy of the evaluated OVAL definitions, bound OVAL variables, OVAL system characteristics, and results of tests that are computed based on comparison of the system characteristics and the definitions.
- The *OVAL Directives* format is used to tailor verbosity of an OVAL Result document by either including or excluding certain details.
- The *OVAL Common Model* format contains definitions of constructs and enumerations used in several other OVAL schemes. It is used to reuse OVAL definitions in order to avoid duplications across multiple documents.

The OVAL Definitions document consists of a set of configuration requirements where each requirement is defined in the following five basic sections: *definitions*, *tests*, *objects*, *states*, and *variables*. The elements within the definitions section describe which of the tests shall be fulfilled to satisfy the given definition. The test elements link objects and states together. During the system evaluation, a test is considered passed when a resource of the assessed system that is denoted by the given object element corresponds with the given state element. The variables section defines external variables which may be used to adjust elements from the states section. Besides these sections, the OVAL Definitions document typically contains also the *generator* and *signature* sections. The *generator* section holds information about the document origin and various additional information related to its content.

Each element from the OVAL document basic sections is unambiguously identified by an identifier in the following form:

```
oval:namespace:type:ID
```

where *namespace* is a name space defining the identifier, *type* is either *def* for definitions elements, *tst* for tests elements, *obj* for objects element, *ste* for states elements, and *var* for variables elements, and *ID* is an integer value of the identifier.

Example 7.2. An Example of an OVAL Definitions Document

```
<?xml version="1.0" encoding="utf-8"?>
<oval_definitions
    xmlns:lin-def="http://oval.mitre.org/XMLSchema/oval-definitions-
5#linux"
    xmlns:oval="http://oval.mitre.org/XMLSchema/oval-common-5"
    xmlns="http://oval.mitre.org/XMLSchema/oval-definitions-5"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
  <generator>
    <oval:product_name>vim</oval:product_name>
    <oval:schema_version>5.10.1</oval:schema_version>
    <oval:timestamp>2012-11-22T15:00:00+01:00</oval:timestamp>
  </generator>
  <definitions>
    <definition class="inventory"
        id="oval:org.open-scap.cpe.rhel:def:7"
        version="1">
      <metadata>
        <title>Red Hat Enterprise Linux 7</title>
```

```
        <affected family="unix">
          <platform>Red Hat Enterprise Linux 7</platform>
        </affected>
        <reference ref_id="cpe:/o:redhat:enterprise_linux:7"
            source="CPE"/>
        <description>
          The operating system installed on the system is Red Hat
Enterprise Linux 7
        </description>
      </metadata>
      <criteria>
        <criterion comment="Red Hat Enterprise Linux 7 is installed"
            test_ref="oval:org.open-scap.cpe.rhel:tst:7"/>
      </criteria>
    </definition>
  </definitions>
  <tests>
    <lin-def:rpminfo_test check_existence="at_least_one_exists"
        id="oval:org.open-scap.cpe.rhel:tst:7"
        version="1"
        check="at least one"
        comment="redhat-release is version 7">
      <lin-def:object object_ref="oval:org.open-scap.cpe.redhat-
release:obj:1"/>
      <lin-def:state state_ref="oval:org.open-scap.cpe.rhel:ste:7"/>
    </lin-def:rpminfo_test>
  </tests>
  <objects>
    <lin-def:rpmverifyfile_object id="oval:org.open-scap.cpe.redhat-
release:obj:1"
        version="1">
      <!-- This object represents rpm package which owns /etc/redhat-
release file -->
      <lin-def:behaviors nolinkto='true'
          nomd5='true'
          nosize='true'
          nouser='true'
          nogroup='true'
          nomtime='true'
          nomode='true'
          nordev='true'
          noconfigfiles='true'
          noghostfiles='true' />
      <lin-def:name operation="pattern match"/>
      <lin-def:epoch operation="pattern match"/>
      <lin-def:version operation="pattern match"/>
      <lin-def:release operation="pattern match"/>
      <lin-def:arch operation="pattern match"/>
      <lin-def:filepath>/etc/redhat-release</lin-def:filepath>
    </lin-def:rpmverifyfile_object>
  </objects>
  <states>
    <lin-def:rpminfo_state id="oval:org.open-scap.cpe.rhel:ste:7"
        version="1">
      <lin-def:name operation="pattern match">^redhat-release</lin-
def:name>
```

```
      <lin-def:version operation="pattern match">^7[^\d]</lin-
def:version>
    </lin-def:rpminfo_state>
  </states>
</oval_definitions>
```

7.2.3. The Data Stream Format

SCAP data stream is a file format used since SCAP version 1.2 and it represents a bundle of XCCDF, OVAL, and other component files which can be used to define a compliance policy expressed by an XCCDF checklist. It also contains an index and catalog that allow splitting the given data stream into files according to the SCAP components.

The data stream uses XML format that consists of a header formed by a table of contents and a list of the **<ds:component>** elements. Each of these elements encompasses an SCAP component such as XCCDF, OVAL, CPE, and other. The data stream file may contain multiple components of the same type, and thus covering all security policies needed by your organization.

Example 7.3. An Example of a Data Stream Header

```
<ds:data-stream-collection
xmlns:ds="http://scap.nist.gov/schema/scap/source/1.2"
    xmlns:xlink="http://www.w3.org/1999/xlink"
    xmlns:cat="urn:oasis:names:tc:entity:xmlns:xml:catalog"
    id="scap_org.open-scap_collection_from_xccdf_ssg-rhel7-xccdf-
1.2.xml"
    schematron-version="1.0">
  <ds:data-stream id="scap_org.open-scap_datastream_from_xccdf_ssg-
rhel7-xccdf-1.2.xml"
      scap-version="1.2" use-case="OTHER">
  <ds:dictionaries>
    <ds:component-ref id="scap_org.open-scap_cref_output--ssg-rhel7-
cpe-dictionary.xml"
        xlink:href="#scap_org.open-scap_comp_output--ssg-rhel7-cpe-
dictionary.xml">
      <cat:catalog>
        <cat:uri name="ssg-rhel7-cpe-oval.xml"
            uri="#scap_org.open-scap_cref_output--ssg-rhel7-cpe-
oval.xml"/>
      </cat:catalog>
    </ds:component-ref>
  </ds:dictionaries>
  <ds:checklists>
    <ds:component-ref id="scap_org.open-scap_cref_ssg-rhel7-xccdf-
1.2.xml"
        xlink:href="#scap_org.open-scap_comp_ssg-rhel7-xccdf-1.2.xml">
      <cat:catalog>
        <cat:uri name="ssg-rhel7-oval.xml"
            uri="#scap_org.open-scap_cref_ssg-rhel7-oval.xml"/>
      </cat:catalog>
    </ds:component-ref>
  </ds:checklists>
```

```
  <ds:checks>
    <ds:component-ref id="scap_org.open-scap_cref_ssg-rhel7-oval.xml"
        xlink:href="#scap_org.open-scap_comp_ssg-rhel7-oval.xml"/>
    <ds:component-ref id="scap_org.open-scap_cref_output--ssg-rhel7-
cpe-oval.xml"
        xlink:href="#scap_org.open-scap_comp_output--ssg-rhel7-cpe-
oval.xml"/>
    <ds:component-ref id="scap_org.open-scap_cref_output--ssg-rhel7-
oval.xml"
        xlink:href="#scap_org.open-scap_comp_output--ssg-rhel7-
oval.xml"/>
  </ds:checks>
</ds:data-stream>
<ds:component id="scap_org.open-scap_comp_ssg-rhel7-oval.xml"
    timestamp="2014-03-14T16:21:59">
  <oval_definitions xmlns="http://oval.mitre.org/XMLSchema/oval-
definitions-5"
      xmlns:oval="http://oval.mitre.org/XMLSchema/oval-common-5"
      xmlns:ind="http://oval.mitre.org/XMLSchema/oval-definitions-
5#independent"
      xmlns:unix="http://oval.mitre.org/XMLSchema/oval-definitions-
5#unix"
      xmlns:linux="http://oval.mitre.org/XMLSchema/oval-definitions-
5#linux"
      xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
      xsi:schemaLocation="http://oval.mitre.org/XMLSchema/oval-common-5
      oval-common-schema.xsd
          http://oval.mitre.org/XMLSchema/oval-definitions-5
      oval-definitions-schema.xsd
          http://oval.mitre.org/XMLSchema/oval-definitions-
5#independent
      independent-definitions-schema.xsd
          http://oval.mitre.org/XMLSchema/oval-definitions-5#unix
      unix-definitions-schema.xsd
          http://oval.mitre.org/XMLSchema/oval-definitions-5#linux
      linux-definitions-schema.xsd">
```

7.3. USING SCAP WORKBENCH

SCAP Workbench (scap-workbench) is a graphical utility that enables users to perform configuration and vulnerability scans on a single local or a remote system, perform remediation of the system, and generate reports based on scan evaluations. Note that compared with the **oscap** command-line utility, **SCAP Workbench** has only limited functionality. **SCAP Workbench** can also process only security content in the form of XCCDF and data-stream files.

The following sections explain how to install, start, and utilize SCAP Workbench to perform system scans, remediation, scan customization, and display relevant examples for these tasks.

7.3.1. Installing SCAP Workbench

To install **SCAP Workbench** on your system, enter the following command as **root**:

```
~]# yum install scap-workbench
```

This command installs all packages required by SCAP Workbench to function properly, including the scap-workbench package that provides the utility itself. Note that required dependencies, such as the qt and openssh packages, are automatically updated to the newest available version if the packages are already installed on your system.

SCAP Workbench needs a security content to operate. Red Hat recommends to use the SCAP Security Guide (SSG). The scap-security-guide package is installed as a SCAP Workbench dependency and it is located in the **/usr/share/xml/scap/ssg/content/** directory.

To find other possible sources of existing SCAP content that might suit your needs, see Section 7.10, “Additional Resources”.

7.3.2. Running SCAP Workbench

For running **SCAP Workbench** from the **GNOME Classic** desktop environment, press the **Super** key to enter the **Activities Overview**, type **scap-workbench**, and then press **Enter**. The **Super** key appears in a variety of guises, depending on the keyboard and other hardware, but often as either the **Windows** or **Command** key, and typically to the left of the **Spacebar** key.

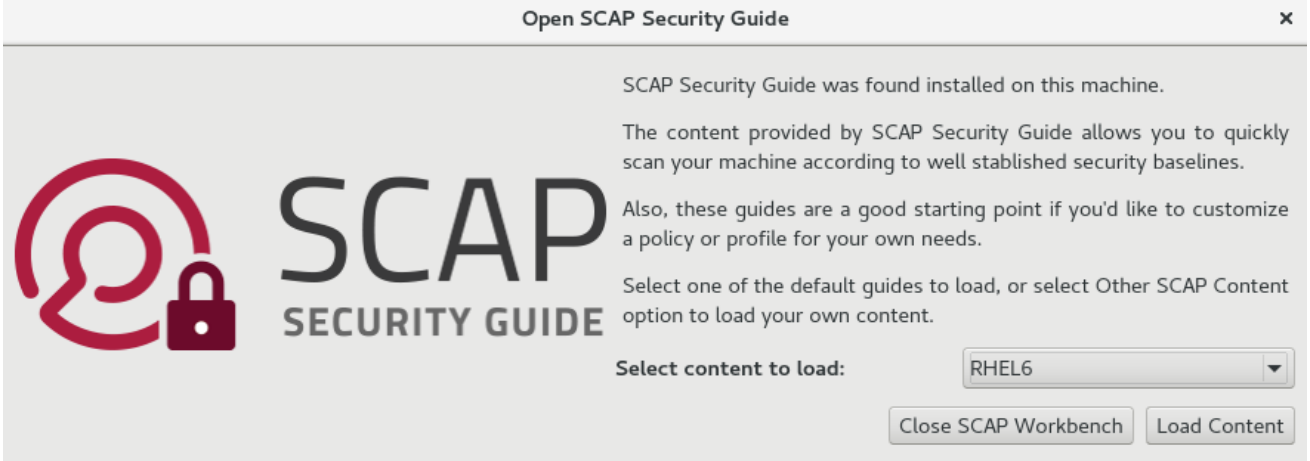


Figure 7.1. Open SCAP Security Guide Window

As soon as you start the utility, the **Open SCAP Security Guide** window appears. After a selection one of the guides, the **SCAP Workbench** window appears. This window consists of several interactive components, which you should become familiar with before you start scanning your system:

File

This menu list offers several options to load or save a SCAP-related content. To show the initial **Open SCAP Security Guide** window, click the menu item with the same name. Alternatively, load another customization file in the XCCDF format by clicking **Open Other Content**. To save your customization as an XCCDF XML file, use the **Save Customization Only** item. The **Save All** allows you to save SCAP files either to the selected directory or as an RPM package.

Customization

This combo box informs you about the customization used for the given security policy. You can select custom rules that are applied for the system evaluation by clicking this combo box. The default value is **(no customization)**, which means that there are no changes to the used security policy. If you make any changes to the selected security profile, you can save those changes as an XML file by clicking the **Save Customization Only** item in the File menu.

Profile

This combo box contains the name of the selected security profile. You can select the security profile from a given XCCDF or data-stream file by clicking this combo box. To create a new profile that inherits properties of the selected security profile, click the **`Customize`** button.

Target

The two radio buttons enable you to select whether the system to be evaluated is a local or remote machine.

Rules

This field displays a list of security rules that are subject of the security policy. Expanding a particular security rule provides detailed information about that rule.

Status bar

This is a graphical bar that indicates status of an operation that is being performed.

Generate remediation role

This pop-up menu enables you to export profile-based remediations to a file. This file contains all available fixes for all rules in the currently selected profile. You can choose the output as a Bash script, an Ansible playbook, or a Puppet manifest. A remediation performed during a system evaluation is based on bash remediations.

This feature enables you to examine individual remediations and possibly edit or cherry-pick them. Therefore, it puts you in full control over the remediation process.

Dry run

Use this check box to get command line arguments to the diagnostics window instead of running the scan.

Fetch remote resources

This check box allows to instruct the scanner to download a remote OVAL content defined in an XML file.

Remediate

This check box enables the remediation feature during the system evaluation. If you check this box, SCAP Workbench attempts to correct system settings that failed to match the state defined by the policy.

Scan

This button enables you to start the evaluation of the specified system.

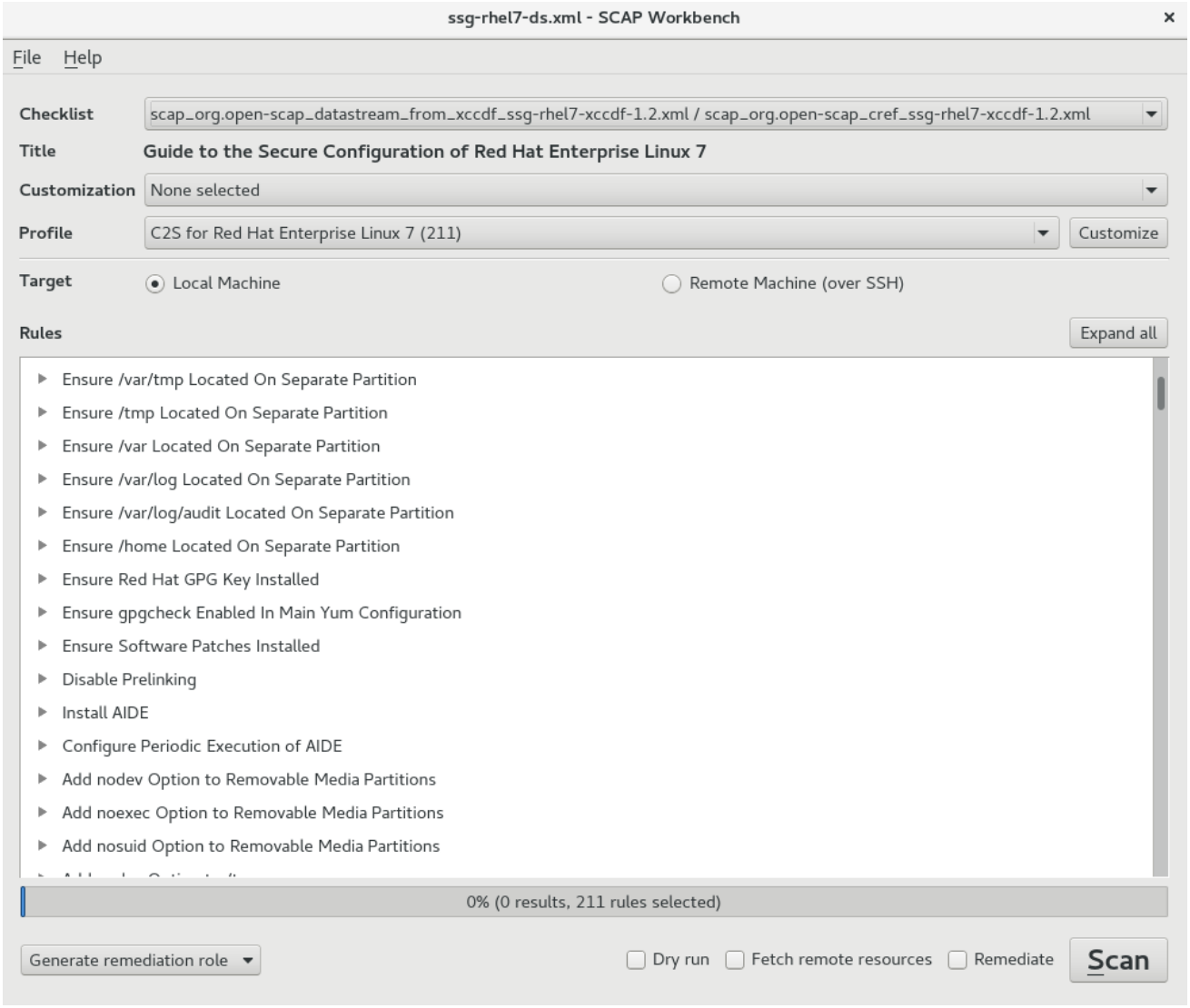


Figure 7.2. SCAP Workbench Window

7.3.3. Scanning the System

The main functionality of **SCAP Workbench** is to perform security scans on a selected system in accordance with the given XCCDF or data stream file. To evaluate your system against the selected security policy, follow these steps:

1. Select a security policy by using either the **`Open SCAP Security Guide`** window, or **`Open Other Content`** in the **`File`** menu and search the respective XCCDF, SCAP RPM or data stream file.

WARNING

Selecting a security policy results in the loss of any previous customization changes that were not saved. To re-apply the lost options, you have to choose the available profile and customization content again. Note that your previous customizations may not be applicable with the new security policy.

2. To use a pre-arranged a file with customized security content specific to your use case, you can load this file by clicking on the **Customization** combo box. You can also create a custom tailoring file by altering an available security profile. For more information, see Section 7.3.4, “Customizing Security Profiles”.

   a. Select the **(no customization)** option if you do not want to use any customization for the current system evaluation. This is the default option if no previous customization was selected.

   b. Select the **(open customization file...)** option to search for the particular tailoring file to be used for the current system evaluation.

   c. If you have previously used some customization file, **SCAP Workbench** remembers this file and adds it to the list. This simplifies the repetitive application of the same scan.

3. Select a suitable security profile by clicking the **Profile** combo box.

   a. To modify the selected profile, click the **Customize** button. For more information about profile customization, see Section 7.3.4, “Customizing Security Profiles”.

4. Select either of two **Target** radio buttons to scan either a local or a remote machine.

   a. If you have selected a remote system, specify it by entering the user name, host name, and the port information as shown in the following example. If you have previously used the remote scan, you can also select a remote system from a list of recently scanned machines.

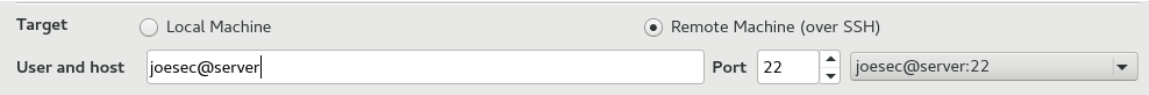


Figure 7.3. Specifying a Remote System

5. You can allow automatic correction of the system configuration by selecting the **Remediate** check box. With this option enabled, **SCAP Workbench** attempts to change the system configuration in accordance with the security rules applied by the policy, should the related checks fail during the system scan.

> **WARNING**
>
> If not used carefully, running the system evaluation with the remediation option enabled could render the system non-functional.

6. Click the **Scan** button to initiate the system scan.

7.3.4. Customizing Security Profiles

After selecting the security profile that suits your security policy, you can further adjust it by clicking the **Customize** button. This opens the new Customization window that enables you to modify the currently selected XCCDF profile without actually changing the respective XCCDF file.

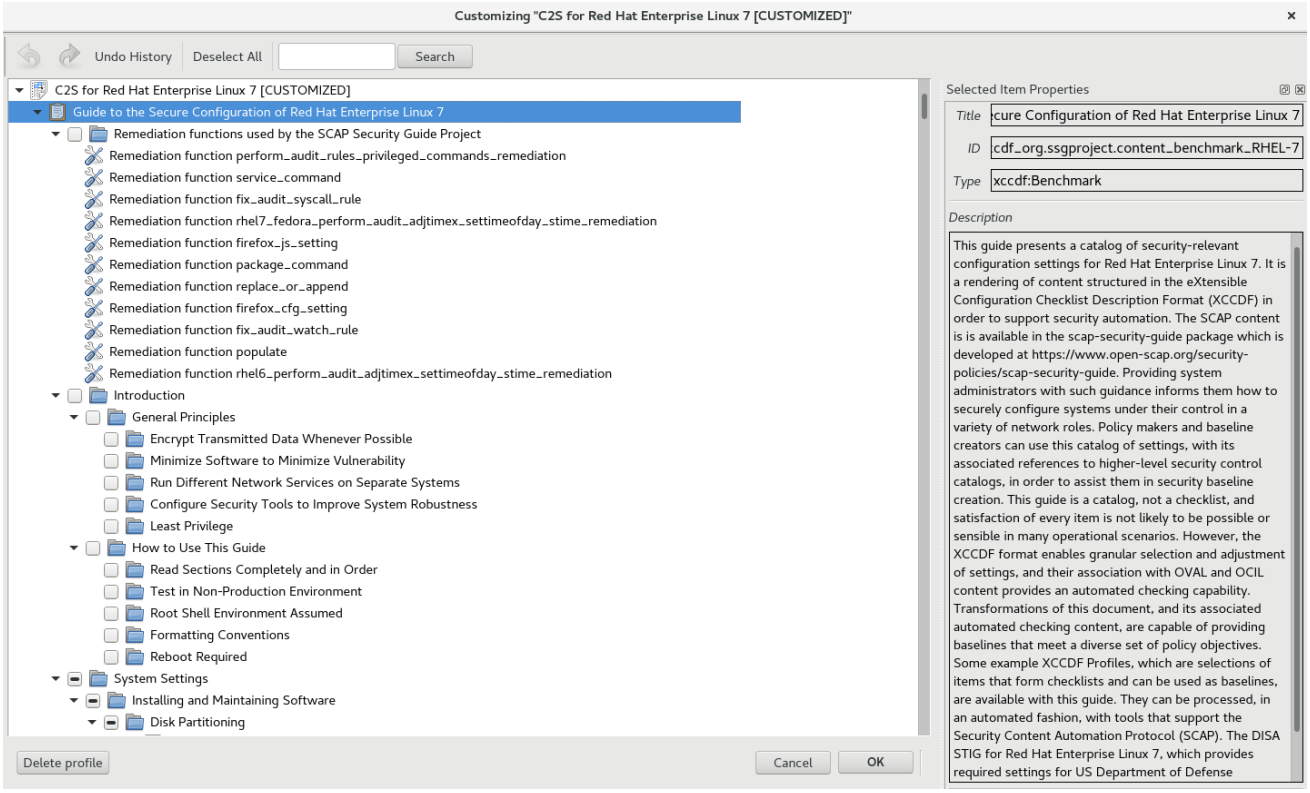


Figure 7.4. Customizing the Selected Security Profile

The **Customization** window contains a complete set of XCCDF elements relevant to the selected security profile with detailed information about each element and its functionality. You can enable or disable these elements by selecting or de-selecting the respective check boxes in the main field of this window. The **Customization** window also supports **undo** and **redo** functionality; you can undo or redo your selections by clicking the respective arrow icon in the top left corner of the window.

You can also change variables that will later be used for evaluation. Find the appropriate item in the **Customization** window, navigate to the right part and use the **Modify value** field.

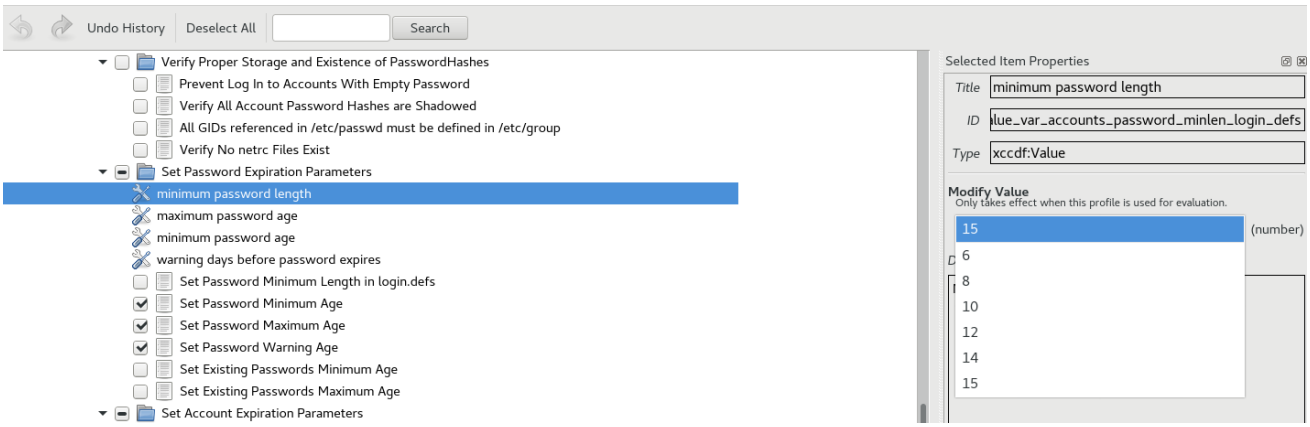


Figure 7.5. Setting a value for the selected item in the Customization window

After you have finished your profile customizations, confirm the changes by clicking the **Confirm Customization** button. Your changes are now in the memory and do not persist if **SCAP Workbench** is closed or certain changes, such as selecting a new SCAP content or choosing another customization option, are made. To store your changes, click the **Save Customization** button in the **SCAP Workbench** window. This action allows you to save your changes to the security profile as an XCCDF customization file in the chosen directory. Note that this customization file can be further selected with other profiles.

7.3.5. Saving SCAP Content

SCAP Workbench also allows you to save SCAP content that is used with your system evaluations. You can either save a customization file separately (see Section 7.3.4, “Customizing Security Profiles”) or you can save all security content at once by clicking the **Save content** combo box and selecting either the **Save into a directory** or **Save as RPM** options.

By selecting the **Save into a directory** option, **SCAP Workbench** saves both the XCCDF or data-stream file and the customization file to the specified location. This can be useful as a backup solution.

By selecting the **Save as RPM** option, you can instruct **SCAP Workbench** to create an RPM package containing the XCCDF or data stream file and customization file. This is useful for distributing the security content to systems that cannot be scanned remotely, or just for delivering the content for further processing.

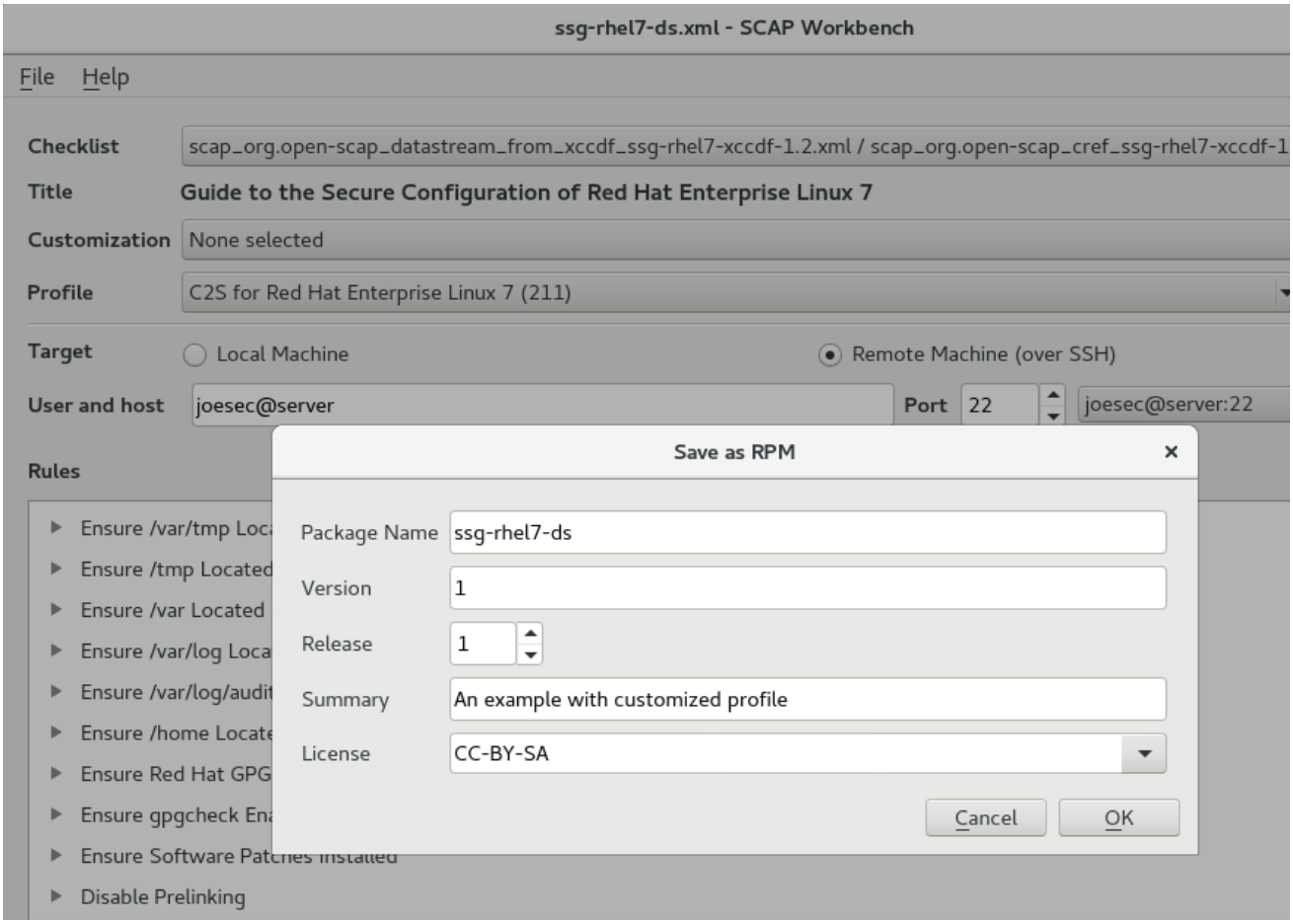


Figure 7.6. Saving the Current SCAP Content as an RPM Package

7.3.6. Viewing Scan Results and Generating Scan Reports and Remediations

After the system scan is finished, three new buttons, **Clear**, **Save Results**, **Generate remediation role**, and **Show Report** will appear instead of the **Scan** button.

WARNING

Clicking the **Clear** button permanently removes the scan results.

To store the scan results in the form of an XCCDF, ARF, or HTML file, click the **Save Results** combo box. Choose the **HTML Report** option to generate the scan report in human-readable form. The XCCDF and ARF (data stream) formats are suitable for further automatic processing. You can repeatedly choose all three options.

If you prefer to view the scan results immediately without saving them, click the **Show Report** button, which opens the scan results in the form of a temporary HTML file in your default web browser.

You can use the **Generate remediation role** pop-up menu to export results-based remediations to a file. This functionality is very similar to the profile-based remediation role export — the difference is that remediations for rules that pass the system evaluation are not exported, so the file may be smaller.

WARNING

Results-based remediation is not supported for tailored profiles. If you need to export those, you can use the **oscap** command-line utility.

7.4. USING OSCAP

The **oscap** command-line utility enables users to scan local systems, validate security compliance content, and generate reports and guides based on these scans and evaluations. This utility serves as a front end to the OpenSCAP library and groups its functionalities to modules (sub-commands) based on the type of SCAP content it processes.

The following sections explain how to install **oscap** and perform the most common operations. Examples are provided to illustrate these tasks. To learn more about specific sub-commands, use the **--help** option with an **oscap** command:

```
oscap [options] module module_operation
[module_operation_options_and_arguments] --help
```

where *module* represents the type of SCAP content that is being processed, and *module_operation* is a sub-command for the specific operation on the SCAP content.

Example 7.4. Getting Help on a Specific oscap Operation

```
~]$ oscap ds sds-split --help
oscap -> ds -> sds-split

Split given SourceDataStream into separate files
```

```
Usage: oscap [options] ds sds-split [options] SDS TARGET_DIRECTORY

SDS - Source data stream that will be split into multiple files.
TARGET_DIRECTORY - Directory of the resulting files.

Options:
   --datastream-id <id>          - ID of the datastream in the
collection to use.
   --xccdf-id <id>               - ID of XCCDF in the datastream that
should be evaluated.
```

To learn about all **oscap** features and the complete list of its options, see the **oscap(8)** manual page.

7.4.1. Installing oscap

To install **oscap** to your system, enter the following command as **root**:

```
~]# yum install openscap-scanner
```

This command enables you to install all packages required by **oscap** to function properly, including the openscap package. To be able to write your own security content, you should also install the openscap-engine-sce package, which provides the Script Check Engine (SCE). The SCE is an extension of the SCAP protocol that allows content authors to write their security content using a scripting language, such as Bash, Python, or Ruby. Note that the openscap-engine-sce package is only available from the Optional channel. See Enabling Supplementary and Optional Repositories.

Optionally, after installing **oscap**, you can check the capabilities of your version of **oscap**, what specifications it supports, where the certain **oscap** files are stored, what kinds of SCAP objects you can use, and other useful information. To display this information, type the following command:

```
~]$ oscap -V
OpenSCAP command line tool (oscap) 1.0.4
Copyright 2009--2014 Red Hat Inc., Durham, North Carolina.

==== Supported specifications ====
XCCDF Version: 1.2
OVAL Version: 5.10.1
CPE Version: 2.3
CVSS Version: 2.0
CVE Version: 2.0
Asset Identification Version: 1.1
Asset Reporting Format Version: 1.1

==== Capabilities added by auto-loaded plugins ====
SCE Version: 1.0 (from libopenscap_sce.so.8)

==== Paths ====
Schema files: /usr/share/openscap/schemas
Schematron files: /usr/share/openscap/xsl
Default CPE files: /usr/share/openscap/cpe
Probes: /usr/libexec/openscap

==== Inbuilt CPE names ====
Red Hat Enterprise Linux - cpe:/o:redhat:enterprise_linux
```

```
Red Hat Enterprise Linux 5 - cpe:/o:redhat:enterprise_linux:5
Red Hat Enterprise Linux 6 - cpe:/o:redhat:enterprise_linux:6
Red Hat Enterprise Linux 7 - cpe:/o:redhat:enterprise_linux:7
Fedora 16 - cpe:/o:fedoraproject:fedora:16
Fedora 17 - cpe:/o:fedoraproject:fedora:17
Fedora 18 - cpe:/o:fedoraproject:fedora:18
Fedora 19 - cpe:/o:fedoraproject:fedora:19
Fedora 20 - cpe:/o:fedoraproject:fedora:20
Fedora 21 - cpe:/o:fedoraproject:fedora:21
Red Hat Enterprise Linux Optional Productivity Applications -
cpe:/a:redhat:rhel_productivity
Red Hat Enterprise Linux Optional Productivity Applications 5 -
cpe:/a:redhat:rhel_productivity:5

==== Supported OVAL objects and associated OpenSCAP probes ====
system_info                  probe_system_info
family                       probe_family
filehash                     probe_filehash
environmentvariable          probe_environmentvariable
textfilecontent54            probe_textfilecontent54
textfilecontent              probe_textfilecontent
variable                     probe_variable
xmlfilecontent               probe_xmlfilecontent
environmentvariable58        probe_environmentvariable58
filehash58                   probe_filehash58
inetlisteningservers         probe_inetlisteningservers
rpminfo                      probe_rpminfo
partition                    probe_partition
iflisteners                  probe_iflisteners
rpmverify                    probe_rpmverify
rpmverifyfile                probe_rpmverifyfile
rpmverifypackage             probe_rpmverifypackage
selinuxboolean               probe_selinuxboolean
selinuxsecuritycontext       probe_selinuxsecuritycontext
file                         probe_file
interface                    probe_interface
password                     probe_password
process                      probe_process
runlevel                     probe_runlevel
shadow                       probe_shadow
uname                        probe_uname
xinetd                       probe_xinetd
sysctl                       probe_sysctl
process58                    probe_process58
fileextendedattribute        probe_fileextendedattribute
routingtable                 probe_routingtable
```

Before you can start using **oscap** effectively, you also need to install or import some security content on your system. For example, you can install the SCAP Security Guide (SSG) package, scap-security-guide, which contains the currently most evolved and elaborate set of security polices for Linux systems. To install the SCAP Security Guide package on your system, enter the following command as root:

```
~]# yum install scap-security-guide
```

After you install scap-security-guide on your system, unless specified otherwise, the SSG security content is available under the **/usr/share/xml/scap/ssg/content/** directory, and you can

proceed with other security compliance operations.

To find other possible sources of existing SCAP content that might suit your needs, see Section 7.10, “Additional Resources”.

After installing the SCAP content on your system, **oscap** can process the content when supplied with the file path to the content. The **oscap** utility supports SCAP version 1.2 and is backward-compatible with SCAP versions 1.1 and 1.0, so it can process earlier versions of SCAP content without any special requirements.

7.4.2. Displaying SCAP Content

SCAP standard defines numerous file formats. The **oscap** utility can process or create files conforming to many of the formats. In order to further process the given file with SCAP content, you need to understand how to use **oscap** with the given file type. If you are unsure how to use a particular file, you can either open and read the file, or you can use the **info** module of **oscap** which parses the file and extracts relevant information in human-readable format.

enter the following command to examine the internal structure of a SCAP document and display useful information such as the document type, specification version, a status of the document, the date the document was published, and the date the document was copied to a file system:

```
oscap info file
```

where *file* is the full path to the security content file being examined. The following example better illustrates the usage of the **oscap info** command:

Example 7.5. Displaying Information About SCAP Content

```
~]$ oscap info /usr/share/xml/scap/ssg/content/ssg-rhel7-ds.xml
Document type: Source Data Stream
Imported: 2014-03-14T12:22:01

Stream: scap_org.open-scap_datastream_from_xccdf_ssg-rhel7-xccdf-1.2.xml
Generated: (null)
Version: 1.2
Checklists:
        Ref-Id: scap_org.open-scap_cref_ssg-rhel7-xccdf-1.2.xml
                Profiles:
                        xccdf_org.ssgproject.content_profile_test
                        xccdf_org.ssgproject.content_profile_rht-ccp
                        xccdf_org.ssgproject.content_profile_common
                        xccdf_org.ssgproject.content_profile_stig-
rhel7-server-upstream
                Referenced check files:
                        ssg-rhel7-oval.xml
                                system:
http://oval.mitre.org/XMLSchema/oval-definitions-5
Checks:
        Ref-Id: scap_org.open-scap_cref_ssg-rhel7-oval.xml
        Ref-Id: scap_org.open-scap_cref_output--ssg-rhel7-cpe-oval.xml
        Ref-Id: scap_org.open-scap_cref_output--ssg-rhel7-oval.xml
Dictionaries:
        Ref-Id: scap_org.open-scap_cref_output--ssg-rhel7-cpe-
dictionary.xml
```

7.4.3. Scanning the System

The most important functionality of **oscap** is to perform configuration and vulnerability scans of a local system. The following is a general syntax of the respective command:

```
oscap [options] module eval [module_operation_options_and_arguments]
```

The **oscap** utility can scan systems against the SCAP content represented by both an **XCCDF** (The eXtensible Configuration Checklist Description Format) benchmark and **OVAL** (Open Vulnerability and Assessment Language) definitions. The security policy can be in the form of a single OVAL or XCCDF file or multiple separate XML files where each file represents a different component (XCCDF, OVAL, CPE, CVE, and others). The result of a scan can be printed to both standard output and an XML file. The result file can then be further processed by **oscap** in order to generate a report in a human-readable format. The following examples illustrate the most common usage of the command.

Example 7.6. Scanning the System Using the SSG OVAL definitions

To scan your system against the SSG OVAL definition file while evaluating all definitions, enter the following command:

```
~]$ oscap oval eval --results scan-oval-results.xml
/usr/share/xml/scap/ssg/content/ssg-rhel7-ds.xml
```

The results of the scan are stored as the **scan-oval-results.xml** file in the current directory.

Example 7.7. Scanning the System Using the SSG OVAL definitions

To evaluate a particular OVAL definition from the security policy represented by the SSG data stream file, enter the following command:

```
~]$ oscap oval eval --id oval:ssg:def:100 --results scan-oval-
results.xml /usr/share/xml/scap/ssg/content/ssg-rhel7-ds.xml
```

The results of the scan are stored as the **scan-oval-results.xml** file in the current directory.

Example 7.8. Scanning the System Using the SSG XCCDF benchmark

To perform the SSG XCCDF benchmark for the **xccdf_org.ssgproject.content_profile_rht-ccp** profile on your system, enter the following command:

```
~]$ oscap xccdf eval --profile xccdf_org.ssgproject.content_profile_rht-
ccp --results scan-xccdf-results.xml
/usr/share/xml/scap/ssg/content/ssg-rhel7-ds.xml
```

The results of the scan are stored as the **scan-xccdf-results.xml** file in the current directory.

NOTE

The **--profile** command-line argument selects the security profile from the given XCCDF or data stream file. The list of available profiles can be obtained by running the **oscap info** command. If the **--profile** command-line argument is omitted the default XCCDF profile is used as required by SCAP standard. Note that the default XCCDF profile may or may not be an appropriate security policy.

7.4.4. Generating Reports and Guides

Another useful features of **oscap** is the ability to generate SCAP content in a human-readable format. The **oscap** utility allows you to transform an XML file into the HTML or plain-text format. This feature is used to generate security guides and checklists, which serve as a source of information, as well as guidance for secure system configuration. The results of system scans can also be transformed to well-readable result reports. The general command syntax is the following:

```
oscap module generate sub-module [specific_module/sub-
module_options_and_arguments] file
```

where *module* is either **xccdf** or **oval**, *sub-module* is a type of the generated document, and *file* represents an XCCDF or OVAL file.

The following are the most common examples of the command usage:

Example 7.9. Generating a Guide with a Checklist

To produce an SSG guide with a checklist for the **xccdf_org.ssgproject.content_profile_rht-ccp** profile, enter the following command:

```
~]$ oscap xccdf generate guide --profile
xccdf_org.ssgproject.content_profile_rht-ccp
/usr/share/xml/scap/ssg/content/ssg-rhel7-ds.xml > ssg-guide-
checklist.html
```

The guide is stored as the **ssg-guide-checklist.html** file in the current directory.

Example 7.10. Transforming an SSG OVAL Scan Result into a Report

To transform a result of an SSG OVAL scan into an HTML file, enter the following command:

```
~]$ oscap oval generate report scan-oval-results.xml > ssg-scan-oval-
report.html
```

The result report is stored as the **ssg-scan-oval-report.html** file in the current directory. This example assumes that you run the command from the same location where the **scan-oval-results.xml** file is stored. Otherwise you need to specify the fully-qualified path of the file that contains the scan results.

Example 7.11. Transforming an SSG XCCDF Scan Result into a Report

To transform a result of an SSG XCCDF scan into an HTML file, enter the following command:

```
~]$ oscap xccdf generate report scan-xccdf-results.xml > scan-xccdf-
report.html
```

The result report is stored as the **ssg-scan-xccdf-report.html** file in the current directory. Alternatively, you can generate this report in the time of the scan using the **--report** command-line argument:

```
~]$ oscap xccdf eval --profile xccdf_org.ssgproject.content_profile_rht-
ccp --results scan-xccdf-results.xml --report scan-xccdf-report.html
/usr/share/xml/scap/ssg/content/ssg-rhel7-ds.xml
```

7.4.5. Validating SCAP Content

Before you start using a security policy on your systems, you should first verify the policy in order to avoid any possible syntax or semantic errors in the policy. The **oscap** utility can be used to validate the security content against standard SCAP XML schemas. The validation results are printed to the standard error stream (stderr). The general syntax of such a validation command is the following:

```
oscap module validate [module_options_and_arguments] file
```

where *file* is the full path to the file being validated. The only exception is the data stream module (ds), which uses the **sds-validate** operation instead of **validate**. Note that all SCAP components within the given data stream are validated automatically and none of the components is specified separately, as can be seen in the following example:

```
~]$ oscap ds sds-validate /usr/share/xml/scap/ssg/content/ssg-rhel7-ds.xml
```

With certain SCAP content, such as OVAL specification, you can also perform a Schematron validation. The Schematron validation is slower than the standard validation but provides deeper analysis, and is thus able to detect more errors. The following SSG example shows typical usage of the command:

```
~]$ oscap oval validate --schematron /usr/share/xml/scap/ssg/content/ssg-
rhel7-ds.xml
```

7.4.6. Using OpenSCAP to Remediate the System

OpenSCAP allows to automatically remediate systems that have been found in a non-compliant state. For system remediation, an XCCDF file with instructions is required. The scap-security-guide package constains certain remediation instructions.

System remediation consists of the following steps:

1. **OpenSCAP** performs a regular XCCDF evaluation.
2. An assessment of the results is performed by evaluating the OVAL definitions. Each rule that has failed is marked as a candidate for remediation.
3. **OpenSCAP** searches for an appropriate fix element, resolves it, prepares the environment, and executes the fix script.

4. Any output of the fix script is captured by **OpenSCAP** and stored within the **`rule-result`** element. The return value of the fix script is stored as well.

5. Whenever **OpenSCAP** executes a fix script, it immediatelly evaluates the OVAL definition again (to verify that the fix script has been applied correctly). During this second run, if the OVAL evaluation returns success, the result of the rule is **`fixed`**, otherwise it is an **`error`**.

6. Detailed results of the remediation are stored in an output XCCDF file. It contains two **`TestResult`** elements. The first **`TestResult`** element represents the scan prior to the remediation. The second **`TestResult`** is derived from the first one and contains remediation results.

There are three modes of operation of **OpenSCAP** with regard to remediation: online, offline, and review.

7.4.6.1. OpenSCAP Online Remediation

Online remediation executes fix elements at the time of scanning. Evaluation and remediation are performed as a part of a single command.

To enable online remediation, use the **`--remediate`** command-line option. For example, to execute online remediation using the scap-security-guide package, run:

```
~]$ oscap xccdf eval --remediate --profile
xccdf_org.ssgproject.content_profile_rht-ccp --results scan-xccdf-
results.xml /usr/share/xml/scap/ssg/content/ssg-rhel7-ds.xml
```

The output of this command consists of two sections. The first section shows the result of the scan prior to the remediation, and the second section shows the result of the scan after applying the remediation. The second part can contain only **`fixed`** and **`error`** results. The **`fixed`** result indicates that the scan performed after the remediation passed. The **`error`** result indicates that even after applying the remediation, the evaluation still does not pass.

7.4.6.2. OpenSCAP Offline Remediation

Offline remediation allows you to postpone fix execution. In the first step, the system is only evaluated, and the results are stored in a **`TestResult`** element in an XCCDF file.

In the second step, **`oscap`** executes the fix scripts and verifies the result. It is safe to store the results into the input file, no data will be lost. During offline remediation, **OpenSCAP** creates a new **`TestResult`** element that is based on the input one and inherits all the data. The newly created **`TestResult`** differs only in the **`rule-result`** elements that have failed. For those, remediation is executed.

To perform offline remediation using the scap-security-guide package, run:

```
~]$ oscap xccdf eval --profile xccdf_org.ssgproject.content_profile_rht-
ccp --results scan-xccdf-results.xml /usr/share/xml/scap/ssg/content/ssg-
rhel7-ds.xml
```

```
~]$ oscap xccdf remediate --results scan-xccdf-results.xml scan-xccdf-
results.xml
```

7.4.6.3. OpenSCAP Remediation Review

The review mode enables users to store remediation instructions to a file for further review. The remediation content is not executed during this operation.

To generate remediation instructions in the form of a shell script, run:

```
~]$ oscap xccdf generate fix --template urn:xccdf:fix:script:sh --profile
xccdf_org.ssgproject.content_profile_rht-ccp --output my-remediation-
script.sh /usr/share/xml/scap/ssg/content/ssg-rhel7-ds.xml
```

7.4.7. Exporting XCCDF Results for the DISA STIG Viewer

The **DISA STIG Viewer** enables users to view results from the perspective of DISA rule IDs. This utility expects the DISA (Defense Information Systems Agency) STIG (Security Technical Implementation Guide) identifiers, for example, *SV-86551r1_rule*, to be used as rule IDs. In most of the publicly-available SCAP content, the convention is to have the DISA STIG IDs attached to XCCDF rules as references or identifiers. Therefore, XCCDF results produced by OpenSCAP and SCAP Security Guide are not readable when opened in DISA STIG Viewer.

OpenSCAP enables you to output your XCCDF results to a format that is compatible with **DISA STIG Viewer**. The transformation takes the attached STIG rule ID reference and replaces the XCCDF rule ID with it.

Example 7.12. Scanning a System for DISA STIG Compliance and Producing Results for STIG Viewer

To scan a local system for DISA STIG compliance and produce XCCDF results that can be opened in **DISA STIG Viewer**:

```
$ oscap xccdf eval --profile xccdf_org.ssgproject.content_profile_stig-
rhel7-disa --stig-viewer stig-results.xml
/usr/share/xml/scap/ssg/content/ssg-rhel7-ds.xml
```

To view the XCCDF Results in DISA STIG Viewer, import the STIG of your choice first, and create a checklist. With the checklist created, use the **Import** → **XCCDF Result File** menu item to fit your results.

NOTE

Note that you can use any of the other **oscap** options with the **--stig-viewer** option to export results with the usual rule IDs.

For more information about STIG Viewing, see the IASE STIG Viewing Guidance web page.

7.5. USING OPENSCAP WITH DOCKER

The **oscap-docker** command-line utility enables users to use the **oscap** program to scan their docker-formatted coptisn ntainer images and containers.

The following section:

- explains the installation of **oscap-docker**

- offers basic examples of usage

To learn more about sub-commands, use the **--help** option with the **oscap-docker** or **oscap** commands.

NOTE

Because a container file system is influenced by mount points, results of scanning an image might differ from results of scanning a container created from it. For example, a mount point that provides only data for processes inside the container in a custom path does not affect results of a scan. However, a mount point in a container done to paths, such as /bin, /etc, or /var, providing new binaries or configuration files can cause differences in results of scanning.

To enable the scanning of images and containers, install the docker package. See the Getting Docker in Red Hat Enterprise Linux 7 chapter of the *Getting Started with Containers* guide for instructions on installing **Docker**.

Enter the following command to install **oscap-docker**:

```
# yum install openscap-utils
```

The following examples use the Red Hat Enterprise Linux 7 image.

```
# docker pull registry.access.redhat.com/rhel7
```

```
# docker images
REPOSITORY                              TAG                 IMAGE ID
registry.access.redhat.com/rhel7        latest              c453594215e4
```

7.5.1. Scanning Docker-formatted Images and Containers for Vulnerabilities

The **oscap-docker** command provides two ways to scan images and containers for vulnerabilities:

- The **image-cve** or **container-cve** sub-commands determine the version of the operating system, download the CVE stream applicable to the given system, and run a vulnerability scan:

  ```
  # oscap-docker image-cve registry.access.redhat.com/rhel7
  ```

- Another, more flexible way, enables you to specify OVAL definitions when checking for vulnerabilities. Use the **image** or **container** sub-command together with **oscap** arguments for an OVAL evaluation. For example, to scan an image using a definitions file downloaded from Red Hat OVAL repository, use the following command:

  ```
  # oscap-docker image registry.access.redhat.com/rhel7 oval eval
  com.redhat.rhsa-all.xml
  ```

7.5.2. Scanning Configuration Compliance of Docker-formatted Images and Containers

To scan for configuration compliance, use the SCAP content provided by the SCAP Security Guide (SSG). Ensure the scap-security-guide package is installed:

```
# yum install scap-security-guide
```

To verify compliance of Red Hat Enterprise Linux 7 image with the Defense Information Systems Agency Security Technical Implementation Guide (DISA STIG) policy, enter the following command:

```
# oscap-docker image registry.access.redhat.com/rhel7 xccdf eval --profile
xccdf_org.ssgproject.content_profile_stig-rhel7-disa
/usr/share/xml/scap/ssg/content/ssg-rhel7-ds.xml
```

The following command scans the running environment of the container with ID *5ef05eef4a01*:

```
# oscap-docker container 5ef05eef4a01 xccdf eval --profile
xccdf_org.ssgproject.content_profile_stig-rhel7-disa
/usr/share/xml/scap/ssg/content/ssg-rhel7-ds.xml
```

To get an XML file with results, use the **`--results`** argument and for generating an HTML report of an evaluation, add the **`--report`** argument. See the **`oscap(8)`** man page for more information.

7.6. USING OPENSCAP WITH THE `ATOMIC SCAN` COMMAND

The **`atomic scan`** command enables users to use **OpenSCAP** scanning capabilities to scan docker-formatted container images and containers on the system. It is possible to scan for known CVE vulnerabilities or for configuration compliance. Additionaly, users can remediate docker-formatted container images to the specified policy.

`atomic scan` and OpenSCAP Scanner Image

To install the **`atomic`** tool for container management, enter the following command:

```
# yum install atomic
```

For more information the **`atomic`** installation, see the Prerequisites in the Atomic CLI Reference.

After the **`atomic`** tool is installed, you also need a scanner, which is used by the **`atomic scan`** command as a back end for scanning images and containers. Red Hat recommends choosing the **OpenSCAP** scanner bundled in the *rhel7/openscap* container image in the registry.access.redhat.com image registry:

```
# atomic install registry.access.redhat.com/rhel7/openscap
```

The *registry.access.redhat.com/rhel7/openscap* container image is used as the default scanner by the **`atomic scan`** command. It currently supports two scan types targeting Red Hat Enterprise Linux systems. To list supported scan types, enter the following command:

```
# atomic scan --scanner openscap --list
```

7.6.1. Scanning Docker-formatted Images and Containers for Vulnerabilities Using `atomic scan`

To scan the containers and container images, use the **atomic scan** command in the following form:

```
# atomic scan [OPTIONS] [ID]
```

where *ID* is the ID of the container image or container. To scan all container images or containers, use the **--images** or **--containers** directive, respectively. To scan both types, use the **--all** directive. The list of available command-line options can be obtained using the **atomic scan --help** command.

NOTE

For a detailed description of the **atomic** command usage and containers, see the Product Documentation for Red Hat Enterprise Linux Atomic Host. The Red Hat Customer Portal also provides a guide to the Atomic command line interface (CLI).

The default scan type of the **atomic scan** command is *CVE scan*. Use it for checking a target for known security vulnerabilities as defined in the CVE OVAL definitions released by Red Hat.

WARNING

The OVAL definitions used by the *CVE scan* type are bundled in the container image during the build process. Red Hat provides weekly updates of the container image. Always use the latest OpenSCAP container image to ensure the definitions are up to date. To find out version of the installed **OpenSCAP** container image:

```
# atomic help registry.access.redhat.com/rhel7/openscap |
grep version
```

Example 7.13. Scanning Red Hat Enterprise Linux 7 Container Images for Known Security Vulnerabilities

The following command scans the Red Hat Enterprise Linux 7 container image for known security vulnerabilities. The **--verbose** directive provides additional details.

```
# atomic scan --verbose registry.access.redhat.com/rhel7:latest
docker run -t --rm -v /etc/localtime:/etc/localtime -v /run/atomic/2017-
11-01-14-55-37-758180:/scanin -v /var/lib/atomic/openscap/2017-11-01-14-
55-37-758180:/scanout:rw,Z -v /etc/oscapd:/etc/oscapd:ro
registry.access.redhat.com/rhel7/openscap oscapd-evaluate scan --no-
standard-compliance --targets chroots-in-dir:///scanin --output /scanout
WARNING:Can't import the 'docker' package. Container scanning
functionality will be disabled.
INFO:Creating tasks directory at '/var/lib/oscapd/tasks' because it
didn't exist.
INFO:Creating results directory at '/var/lib/oscapd/results' because it
didn't exist.
INFO:Creating results work in progress directory at
'/var/lib/oscapd/work_in_progress' because it didn't exist.
INFO:Evaluated EvaluationSpec, exit_code=0.
```

```
INFO:Evaluated EvaluationSpec, exit_code=0.
INFO:[100.00%] Scanned target
'chroot:///scanin/db7a70a0414e589d7c8c162712b329d4fc670fa47ddde721250fb9
fcdbed9cc2'

registry.access.redhat.com/rhel7:latest (db7a70a0414e589)

registry.access.redhat.com/rhel7:latest passed the scan

Files associated with this scan are in /var/lib/atomic/openscap/2017-11-
01-14-55-37-758180.
```

The following command scans the Red Enterprise Linux 7.2 container image with several known security vulnerabilities:

```
#atomic scan registry.access.redhat.com/rhel7:7.2
docker run -t --rm -v /etc/localtime:/etc/localtime -v /run/atomic/2017-
11-01-14-49-36-614281:/scanin -v /var/lib/atomic/openscap/2017-11-01-14-
49-36-614281:/scanout:rw,Z -v /etc/oscapd:/etc/oscapd:ro
registry.access.redhat.com/rhel7/openscap oscapd-evaluate scan --no-
standard-compliance --targets chroots-in-dir:///scanin --output /scanout

registry.access.redhat.com/rhel7:7.2 (98a88a8b722a718)

The following issues were found:

     RHSA-2017:2832: nss security update (Important)
     Severity: Important
       RHSA URL: https://access.redhat.com/errata/RHSA-2017:2832
       RHSA ID: RHSA-2017:2832-01
       Associated CVEs:
           CVE ID: CVE-2017-7805
           CVE URL: https://access.redhat.com/security/cve/CVE-2017-
7805

     RHSA-2017:2016: curl security, bug fix, and enhancement update
(Moderate)
     Severity: Moderate
       RHSA URL: https://access.redhat.com/errata/RHSA-2017:2016
       RHSA ID: RHSA-2017:2016-01
       Associated CVEs:
           CVE ID: CVE-2016-7167
           CVE URL: https://access.redhat.com/security/cve/CVE-2016-
7167

     RHSA-2017:1931: bash security and bug fix update (Moderate)
     Severity: Moderate
       RHSA URL: https://access.redhat.com/errata/RHSA-2017:1931
       RHSA ID: RHSA-2017:1931-01
       Associated CVEs:
           CVE ID: CVE-2016-0634
           CVE URL: https://access.redhat.com/security/cve/CVE-2016-
0634
           CVE ID: CVE-2016-7543
           CVE URL: https://access.redhat.com/security/cve/CVE-2016-
7543
```

```
            CVE ID: CVE-2016-9401
            CVE URL: https://access.redhat.com/security/cve/CVE-2016-
9401

.............

Files associated with this scan are in /var/lib/atomic/openscap/2017-11-
01-14-49-36-614281.
```

7.6.2. Scanning and Remediating Configuration Compliance of Docker-formatted Images and Containers Using `atomic scan`

Scanning for Configuration Compliance of Docker-formatted Images and Containers Using `atomic scan`

The **`atomic scan`** command also supports the *configuration_compliance* scan. Use this type of scanning to evaluate Red Hat Enterprise Linux-based container images and containers with the SCAP content provided by the SCAP Security Guide (SSG) bundled inside the **OpenSCAP** container image. This enables scanning against any profile provided by the SCAP Security Guide.

To list the SCAP content provided by the **OpenSCAP** image for the *configuration_compliance* scan, enter the following command:

```
# atomic help registry.access.redhat.com/rhel7/openscap
```

To verify compliance of the latest Red Hat Enterprise Linux 7 container image with the Defense Information Systems Agency Security Technical Implementation Guide (DISA STIG) policy and generate an HTML report from the scan:

```
#atomic scan --scan_type configuration_compliance --scanner_args xccdf-
id=scap_org.open-scap_cref_ssg-rhel7-xccdf-
1.2.xml,profile=xccdf_org.ssgproject.content_profile_stig-rhel7-
disa,report registry.access.redhat.com/rhel7:latest
```

The output of the previous command contains the information about files associated with the scan at the end:

```
.............

Files associated with this scan are in /var/lib/atomic/openscap/2017-11-
03-13-35-34-296606.

# tree /var/lib/atomic/openscap/2017-11-03-13-35-34-296606
/var/lib/atomic/openscap/2017-11-03-13-35-34-296606
├── db7a70a0414e589d7c8c162712b329d4fc670fa47ddde721250fb9fcdbed9cc2
│   ├── arf.xml
│   ├── fix.sh
│   ├── json
│   └── report.html
└── environment.json

1 directory, 5 files
```

The **`atomic scan`** generates a subdirectory with all the results and reports from a scan in the */var/lib/atomic/openscap/* directory. The *arf.xml* file with results is generated on every scanning for configuration compliance. To generate a human-readable HTML report file, add the **`report`** suboption to the **`--scanner_args`** option.

To generate XCCDF results readable by **DISA STIG Viewer**, add the **`stig-viewer`** suboption to the **`--scanner_args`** option. The results are placed in *stig.xml*. For more information about **DISA STIG Viewer**, see Section 7.4.7, “Exporting XCCDF Results for the **DISA STIG Viewer**”

The **`--scanner_args`** suboptions are separated by the comma character. The specific values for the **`xccdf-id`** and **`profile`** suboptions, which select an XCCDF component and a profile from the specified datastream file, are taken from the bundled SCAP content in the **OpenSCAP** image. The datastream file is selected automatically by the **OpenSCAP** image during scanning based on the target container image or container.

NOTE

When the **`xccdf-id`** suboption of the **`--scanner_args`** option is omitted, the scanner searches for a profile in the first XCCDF component of the selected datastream file. For more details about datastream files, see Section 7.2.3, “The Data Stream Format”.

Remediating Configuration Compliance of Docker-formatted Images and Containers Using `atomic scan`

To remediate docker-formatted container images to the specified policy, add the **`--remediate`** option to the **`atomic scan`** command when scanning for configuration compliance. The following command builds a new remediated container image compliant with the DISA STIG policy from the Red Hat Enterprise Linux 7 container image:

```
# atomic scan --remediate --scan_type configuration_compliance --
scanner_args profile=xccdf_org.ssgproject.content_profile_stig-rhel7-
disa,report registry.access.redhat.com/rhel7:latest

registry.access.redhat.com/rhel7:latest (db7a70a0414e589)

The following issues were found:
............
     Configure Time Service Maxpoll Interval
     Severity: Low
       XCCDF result: fail

     Configure LDAP Client to Use TLS For All Transactions
     Severity: Moderate
       XCCDF result: fail
............
Remediating rule 43/44:
'xccdf_org.ssgproject.content_rule_chronyd_or_ntpd_set_maxpoll'
Remediating rule 44/44:
'xccdf_org.ssgproject.content_rule_ldap_client_start_tls'

Successfully built 9bbc7083760e
Successfully built remediated image 9bbc7083760e from
db7a70a0414e589d7c8c162712b329d4fc670fa47ddde721250fb9fcdbed9cc2.
```

```
Files associated with this scan are in /var/lib/atomic/openscap/2017-11-
06-13-01-42-785000.
```

The configuration compliance scan is run against the original container image to check its compliance with the DISA STIG policy. Based on the scan results, a fix script containing bash remediations for the failed scan results is generated. The fix script is then applied to the original container image - this is called a remediation. The remediation results in a container image with an altered configuration, which is added as a new layer on top of the original container image. The output of the **`atomic scan`** command reports a remediated image ID. To make the image easier to remember, tag it with some name, for example:

```
#docker tag 9bbc7083760e rhel7_disa_stig
```

IMPORTANT

Note that the original container image remains unchanged and only a new layer is created on top of it. The remediation process builds a new container image that contains all the configuration improvements. The content of this layer is defined by the security policy of scanning - in the previous case, the DISA STIG policy. This also means that the remediated container image is no longer signed by Red Hat, which is expected, since it differs from the original container image by containing the remediated layer.

7.7. USING OPENSCAP WITH ANSIBLE

To assist with integrating configuration compliance into your existing Ansible workflow, OpenSCAP generates remediations for use with Ansible. The remediations are generated in a form of Ansible playbooks, either based on profiles or based on scan results.

A playbook based on a SCAP Security Guide (SSG) profile contains fixes for all rules, and the system is remediated according to the profile regardless of the state of the machine. On the other hand, playbooks based on scan results contain only fixes for rules that failed during an evaluation.

In Red Hat Enterprise Linux 7, SSG provides pre-built Ansible playbooks for each profile and Red Hat product. The playbooks are stored in the **`/usr/share/scap-security-guide/ansible/`** directory.

To generate an Ansible playbook based on a profile (for example, the DISA STIG profile for Red Hat Enterprise Linux 7), enter the following command:

```
$ oscap xccdf generate fix --fix-type ansible --profile
xccdf_org.ssgproject.content_profile_stig-rhel7-disa --output stig-rhel7-
role.yml /usr/share/xml/scap/ssg/content/ssg-rhel7-ds.xml
```

To generate an Ansible playbook based on the results of a scan, enter the following command:

```
$ oscap xccdf generate fix --fix-type ansible --result-id xccdf_org.open-
scap_testresult_xccdf_org.ssgproject.content_profile_stig-rhel7-disa --
output stig-playbook-result.yml results.xml
```

where the **`results.xml`** file contains results of the scan obtained when scanning with the **`--results`** option and the **`result-id`** option contains an ID of the **`TestResult`** component in the file with results. To obtain the ID of the **`TestResult`** component, use the **`oscap info`** command on the **`results.xml`** file:

```
$ oscap info results.xml | grep "Result ID"
```

To apply the Ansible playbook, enter the following command:

```
$ ansible-playbook playbook.yml
```

Note that the **ansible-playbook** command is provided by the ansible package. See the **ansible-playbook(1)** man page and the Ansible Tower User Guide for more information.

Filtering Tasks

Tasks contained in playbooks are tagged with the same metadata as rules in an Extensible Configuration Checklist Description Format (XCCDF) file. These tags refer to rule ID, strategy, complexity, disruption, and references, and they can be used to filter the tasks to apply.

For example, to remediate only the rules from the PCI-DSS policy requirement 6.2, enter the following command:

```
$ ansible-playbook --tags=PCI-DSS-Req-6.2 /usr/share/scap-security-
guide/ansible/ssg-rhel7-role-pci-dss.yml
```

To remediate only high-severity rules from the RHEL7 OSPP playbook that are not highly disruptive, enter the following command:

```
$ ansible-playbook --tags=high_severity --skip-tags=high_disruption
/usr/share/scap-security-guide/ansible/ssg-rhel7-role-ospp-rhel7.yml
```

Customizing Playbooks

You can choose between two approaches to customize your playbooks. The first is to generate playbooks from already customized profiles. This approach is better if a customization changes selected rules.

The second approach is just to change the variables in a playbook. This is the Ansible way to customize a playbook.

To generate Ansible playbooks for tailored profiles, use the **--profile** option to specify an ID of a customized profile, and use the **--tailoring-file** option to indicate where a tailoring file is located. These arguments are the same as when performing a scan using a tailored profile, for example:

```
$ oscap xccdf generate fix--fix-type ansible --profile
xccdf_org.ssgproject.content_profile_common_customized --tailoring-file
ssg-rhel7-ds-tailoring.xml --output tailored-playbook.yml
/usr/share/xml/scap/ssg/content/ssg-rhel7-ds.xml
```

To customize variables, use a text editor to edit a playbook. All used variables are listed at the beginning of a playbook, located after the **vars:** string.

7.8. USING OPENSCAP WITH RED HAT SATELLITE

When running multiple Red Hat Enterprise Linux systems, it is important to keep all your systems compliant with your security policy and perform security scans and evaluations remotely from one location. On Red Hat Satellite 6, the OpenSCAP plug-in and content provides the compliance and vulnerability scanning.

This solution supports two methods of performing security compliance scans, viewing and further processing of the scan results. You can either use the **OpenSCAP Satellite Web Interface** or the **Satellite API**. For more information about this solution to security compliance, its requirements and capabilities, see the following Red Hat Satellite 6 documentation:

- Security Compliance Management in the Administering Red Hat Satellite Guide.
- Importing the Red Hat OVAL Repository in the Content Management Guide.

On Red Hat Satellite 5.5, install the spacewalk-oscap package on your Satellite client. See OpenSCAP in RHN Satellite in the RHN Satellite 5.5 User Guide for more information.

7.9. PRACTICAL EXAMPLES

This section demonstrates practical usage of certain security content provided for Red Hat products.

7.9.1. Auditing Security Vulnerabilities of Red Hat Products

Red Hat continuously provides OVAL definitions for their products. These definitions allow for fully automated audit of vulnerabilities in the installed software. To find out more information about this project, see http://www.redhat.com/security/data/metrics/. To download these definitions, enter the following command:

```
~]$ wget http://www.redhat.com/security/data/oval/com.redhat.rhsa-all.xml
```

The users of Red Hat Satellite 5 may find useful the XCCDF part of the patch definitions. To download these definitions, enter the following command:

```
~]$ wget http://www.redhat.com/security/data/metrics/com.redhat.rhsa-
all.xccdf.xml
```

To audit security vulnerabilities for the software installed on the system, enter the following command:

```
~]$ oscap oval eval --results rhsa-results-oval.xml --report oval-
report.html com.redhat.rhsa-all.xml
```

The **oscap** utility maps Red Hat Security Advisories to CVE identifiers that are linked to the National Vulnerability Database and reports which security advisories are not applied.

NOTE

Note that these OVAL definitions are designed to only cover software and updates released by Red Hat. You need to provide additional definitions in order to detect the patch status of third-party software.

7.9.2. Auditing System Settings with SCAP Security Guide

The SCAP Security Guide (SSG) project's package, scap-security-guide, contains the latest set of security polices for Linux systems. To install the SCAP Security Guide package on your system, enter the following command as root:

```
~]# yum install scap-security-guide
```

A part of scap-security-guide is also a guidance for Red Hat Enterprise Linux 7 settings. To inspect the security content available with scap-security-guide, use the **oscap info** module:

```
~]$ oscap info /usr/share/xml/scap/ssg/content/ssg-rhel7-ds.xml
```

The output of this command is an outline of the SSG document and it contains available configuration profiles. To audit your system settings, choose a suitable profile and run the appropriate evaluation command. For example, the following command is used to assess the given system against a draft SCAP profile for Red Hat Certified Cloud Providers:

```
~]$ oscap xccdf eval --profile xccdf_org.ssgproject.content_profile_rht-
ccp --results ssg-rhel7-xccdf-result.xml --report ssg-rhel7-report.html
/usr/share/xml/scap/ssg/content/ssg-rhel7-ds.xml
```

7.10. ADDITIONAL RESOURCES

For more information about various security compliance fields of interest, see the resources below.

Installed Documentation

- oscap(8) — The manual page for the **oscap** command-line utility provides a complete list of available options and their usage explanation.
- scap-workbench(8) — The manual page for the **SCAP Workbench** application provides a basic information about the application as well as some links to potential sources of SCAP content.
- scap-security-guide(8) — The manual page for **scap-security-guide** provides further documentation about the various available SCAP security profiles. Examples how to utilize the provided benchmarks using the **OpenSCAP** utility are provided as well.

Online Documentation

- The OpenSCAP project page — The home page to the OpenSCAP project provides detailed information about the **oscap** utility and other components and projects related to SCAP.
- The SCAP Workbench project page — The home page to the SCAP Workbench project provides detailed information about the **scap-workbench** application.
- The SCAP Security Guide (SSG) project page — The home page to the SSG project that provides the latest security content for Red Hat Enterprise Linux.
- National Institute of Standards and Technology (NIST) SCAP page— This page represents a vast collection of SCAP related materials, including SCAP publications, specifications, and the SCAP Validation Program.
- National Vulnerability Database (NVD) — This page represents the largest repository of SCAP content and other SCAP standards based vulnerability management data.
- Red Hat OVAL content repository — This is a repository containing OVAL definitions for Red Hat Enterprise Linux systems.
- MITRE CVE — This is a database of publicly known security vulnerabilities provided by the MITRE corporation.

- MITRE OVAL — This page represents an OVAL related project provided by the MITRE corporation. Among other OVAL related information, these pages contain the latest version of the OVAL language and a repository of OVAL content with thousands of OVAL definitions.
- Red Hat Satellite documentation — This set of guides describes, among other topics, how to maintain system security on multiple systems by using OpenSCAP.

CHAPTER 8. FEDERAL STANDARDS AND REGULATIONS

In order to maintain security levels, it is possible for your organization to make efforts to comply with federal and industry security specifications, standards and regulations. This chapter describes some of these standards and regulations.

8.1. FEDERAL INFORMATION PROCESSING STANDARD (FIPS)

The Federal Information Processing Standard (FIPS) Publication 140-2 is a computer security standard, developed by the U.S. Government and industry working group to validate the quality of cryptographic modules. See the official FIPS publications here: http://csrc.nist.gov/publications/PubsFIPS.html.

The FIPS 140-2 standard ensures that cryptographic tools implement their algorithms properly. See the full FIPS 140-2 standard at http://dx.doi.org/10.6028/NIST.FIPS.140-2 for further details on these levels and the other specifications of the FIPS standard.

To see the complete list of all FIPS 140-2 certificates, visit http://csrc.nist.gov/groups/STM/cmvp/documents/140-1/140val-all.htm. To learn about compliance requirements, see the Red Hat Government: Standards page.

8.1.1. Enabling FIPS Mode

To make Red Hat Enterprise Linux compliant with the Federal Information Processing Standard (FIPS) Publication 140-2, you need to make several changes to ensure that accredited cryptographic modules are used. You can either enable FIPS mode during system installation or after it.

During the System Installation

To fulfil the *strict FIPS 140-2 compliance*, add the **fips=1** kernel option to the kernel command line during system installation. With this option, all keys' generations are done with FIPS-approved algorithms and continuous monitoring tests in place. After the installation, the system is configured to boot into FIPS mode automatically.

IMPORTANT

Ensure that the system has plenty of entropy during the installation process by moving the mouse around or by pressing many keystrokes. The recommended amount of keystrokes is 256 and more. Less than 256 keystrokes might generate a non-unique key.

After the System Installation

To turn the kernel space and user space of your system into FIPS mode after installation, follow these steps:

1. Install the dracut-fips package:

```
~]# yum install dracut-fips
```

   For CPUs with the AES New Instructions (AES-NI) support, install the dracut-fips-aesni package as well:

```
~]# yum install dracut-fips-aesni
```

2. Regenerate the **initramfs** file:

```
~]# dracut -v -f
```

To enable the in-module integrity verification and to have all required modules present during the kernel boot, the **initramfs** file has to be regenerated.

WARNING

This operation will overwrite the existing **initramfs** file.

3. Modify boot loader configuration.

   To boot into FIPS mode, add the **fips=1** option to the kernel command line of the boot loader. If your **/boot** or **/boot/EFI/** partitions reside on separate partitions, add the **boot=<*partition*>** (where *<partition>* stands for /boot or /boot/EFI) parameter to the kernel command line as well.

   To identify the boot partition, enter the following command:

   ```
   ~]$ df /boot
   Filesystem           1K-blocks      Used Available Use% Mounted on
   /dev/sda1               495844     53780    416464  12% /boot
   ```

   To ensure that the **boot=** configuration option works even if the device naming changes between boots, identify the universally unique identifier (UUID) of the partition by running the following command:

   ```
   ~]$ blkid /dev/sda1
   /dev/sda1: UUID="05c000f1-f899-467b-a4d9-d5ca4424c797" TYPE="ext4"
   ```

   Append the UUID to the kernel command line:

   ```
   boot=UUID=05c000f1-f899-467b-a4d9-d5ca4424c797
   ```

   Depending on your boot loader, make the following changes:

   - GRUB 2

     Add the **fips=1** and **boot=<partition of /boot or /boot/EFI>** options to the **GRUB_CMDLINE_LINUX** key in the **/etc/default/grub** file. To apply the changes to **/etc/default/grub**, rebuild the **grub.cfg** file as follows:

     - On BIOS-based machines, enter the following command as **root**:

       ```
       ~]# grub2-mkconfig -o /etc/grub2.cfg
       ```

     - On UEFI-based machines, enter the following command as **root**:

       ```
       ~]# grub2-mkconfig -o /etc/grub2-efi.cfg
       ```

- zipl (on the IBM z Systems architecture only)

  Add the **fips=1** and **boot=<partition of /boot>** options to the **/etc/zipl.conf** to the kernel command line and apply the changes by running the following command as **root**:

  ```
  ~]# zipl
  ```

4. Make sure prelinking is disabled.

   For proper operation of the in-module integrity verification, prelinking of libraries and binaries has to be disabled. Prelinking is done by the prelink package, which is not installed by default. Unless prelink has been installed, this step is not needed. To disable prelinking, set the **PRELINKING=no** option in the **/etc/sysconfig/prelink** configuration file. To disable existing prelinking on all system files, use the **prelink -u -a** command.

5. Reboot your system.

Enabling FIPS Mode in a Container

A container can be switched to FIPS140-2 mode if the host is also set in FIPS140-2 mode and one of the following requirements is met:

- The dracut-fips package is installed in the container.
- The **/etc/system-fips** file is mounted on the container from the host.

8.2. NATIONAL INDUSTRIAL SECURITY PROGRAM OPERATING MANUAL (NISPOM)

The NISPOM (also called DoD 5220.22-M), as a component of the National Industrial Security Program (NISP), establishes a series of procedures and requirements for all government contractors with regard to classified information. The current NISPOM is dated February 28, 2006, with incorporated major changes from March 28, 2013. The NISPOM document can be downloaded from the following URL: http://www.nispom.org/NISPOM-download.html.

8.3. PAYMENT CARD INDUSTRY DATA SECURITY STANDARD (PCI DSS)

From https://www.pcisecuritystandards.org/about/index.shtml: *The PCI Security Standards Council is an open global forum, launched in 2006, that is responsible for the development, management, education, and awareness of the PCI Security Standards, including the Data Security Standard (DSS).*

You can download the PCI DSS standard from https://www.pcisecuritystandards.org/security_standards/pci_dss.shtml.

8.4. SECURITY TECHNICAL IMPLEMENTATION GUIDE

A Security Technical Implementation Guide (STIG) is a methodology for standardized secure installation and maintenance of computer software and hardware.

See the following URL for more information on STIG: http://iase.disa.mil/stigs/Pages/index.aspx.

APPENDIX A. ENCRYPTION STANDARDS

A.1. SYNCHRONOUS ENCRYPTION

A.1.1. Advanced Encryption Standard — AES

In cryptography, the Advanced Encryption Standard (AES) is an encryption standard adopted by the U.S. Government. The standard comprises three block ciphers, AES-128, AES-192 and AES-256, adopted from a larger collection originally published as Rijndael. Each AES cipher has a 128-bit block size, with key sizes of 128, 192 and 256 bits, respectively. The AES ciphers have been analyzed extensively and are now used worldwide, as was the case with its predecessor, the Data Encryption Standard (DES).[3]

A.1.1.1. AES History

AES was announced by National Institute of Standards and Technology (NIST) as U.S. FIPS PUB 197 (FIPS 197) on November 26, 2001 after a 5-year standardization process. Fifteen competing designs were presented and evaluated before Rijndael was selected as the most suitable. It became effective as a standard May 26, 2002. It is available in many different encryption packages. AES is the first publicly accessible and open cipher approved by the NSA for top secret information (see the Security section in the Wikipedia article on AES).[4]

The Rijndael cipher was developed by two Belgian cryptographers, Joan Daemen and Vincent Rijmen, and submitted by them to the AES selection process. Rijndael is a portmanteau of the names of the two inventors.[5]

A.1.2. Data Encryption Standard — DES

The Data Encryption Standard (DES) is a block cipher (a form of shared secret encryption) that was selected by the National Bureau of Standards as an official Federal Information Processing Standard (FIPS) for the United States in 1976 and which has subsequently enjoyed widespread use internationally. It is based on a symmetric-key algorithm that uses a 56-bit key. The algorithm was initially controversial with classified design elements, a relatively short key length, and suspicions about a National Security Agency (NSA) backdoor. DES consequently came under intense academic scrutiny which motivated the modern understanding of block ciphers and their cryptanalysis.[6]

A.1.2.1. DES History

DES is now considered to be insecure for many applications. This is chiefly due to the 56-bit key size being too small; in January, 1999, distributed.net and the Electronic Frontier Foundation collaborated to publicly break a DES key in 22 hours and 15 minutes. There are also some analytical results which demonstrate theoretical weaknesses in the cipher, although they are unfeasible to mount in practice. The algorithm is believed to be practically secure in the form of Triple DES, although there are theoretical attacks. In recent years, the cipher has been superseded by the Advanced Encryption Standard (AES).[7]

In some documentation, a distinction is made between DES as a standard and DES the algorithm which is referred to as the DEA (the Data Encryption Algorithm).[8]

A.2. PUBLIC-KEY ENCRYPTION

Public-key cryptography is a cryptographic approach, employed by many cryptographic algorithms and

cryptosystems, whose distinguishing characteristic is the use of asymmetric key algorithms instead of or in addition to symmetric key algorithms. Using the techniques of public key-private key cryptography, many methods of protecting communications or authenticating messages formerly unknown have become practical. They do not require a secure initial exchange of one or more secret keys as is required when using symmetric key algorithms. It can also be used to create digital signatures.[9]

Public key cryptography is a fundamental and widely used technology around the world, and is the approach which underlies such Internet standards as Transport Layer Security (TLS) (successor to SSL), PGP and GPG.[10]

The distinguishing technique used in public key cryptography is the use of asymmetric key algorithms, where the key used to encrypt a message is not the same as the key used to decrypt it. Each user has a pair of cryptographic keys — a public key and a private key. The private key is kept secret, whilst the public key may be widely distributed. Messages are encrypted with the recipient's public key and can only be decrypted with the corresponding private key. The keys are related mathematically, but the private key cannot be feasibly (ie, in actual or projected practice) derived from the public key. It was the discovery of such algorithms which revolutionized the practice of cryptography beginning in the middle 1970s.[11]

In contrast, Symmetric-key algorithms, variations of which have been used for some thousands of years, use a single secret key shared by sender and receiver (which must also be kept private, thus accounting for the ambiguity of the common terminology) for both encryption and decryption. To use a symmetric encryption scheme, the sender and receiver must securely share a key in advance.[12]

Because symmetric key algorithms are nearly always much less computationally intensive, it is common to exchange a key using a key-exchange algorithm and transmit data using that key and a symmetric key algorithm. PGP, and the SSL/TLS family of schemes do this, for instance, and are called hybrid cryptosystems in consequence.[13]

A.2.1. Diffie-Hellman

Diffie–Hellman key exchange (D–H) is a cryptographic protocol that allows two parties that have no prior knowledge of each other to jointly establish a shared secret key over an insecure communications channel. This key can then be used to encrypt subsequent communications using a symmetric key cipher.[14]

A.2.1.1. Diffie-Hellman History

The scheme was first published by Whitfield Diffie and Martin Hellman in 1976, although it later emerged that it had been separately invented a few years earlier within GCHQ, the British signals intelligence agency, by Malcolm J. Williamson but was kept classified. In 2002, Hellman suggested the algorithm be called Diffie–Hellman–Merkle key exchange in recognition of Ralph Merkle's contribution to the invention of public-key cryptography (Hellman, 2002).[15]

Although Diffie–Hellman key agreement itself is an anonymous (non-authenticated) key-agreement protocol, it provides the basis for a variety of authenticated protocols, and is used to provide perfect forward secrecy in Transport Layer Security's ephemeral modes (referred to as EDH or DHE depending on the cipher suite).[16]

U.S. Patent 4,200,770, now expired, describes the algorithm and credits Hellman, Diffie, and Merkle as inventors.[17]

A.2.2. RSA

In cryptography, RSA (which stands for Rivest, Shamir and Adleman who first publicly described it) is an algorithm for public-key cryptography. It is the first algorithm known to be suitable for signing as well as encryption, and was one of the first great advances in public key cryptography. RSA is widely used in electronic commerce protocols, and is believed to be secure given sufficiently long keys and the use of up-to-date implementations.

A.2.3. DSA

DSA (Digital Signature Algorithm) is a standard for digital signatures, a United States federal government standard for digital signatures. DSA is for signatures only and is not an encryption algorithm. [18]

A.2.4. SSL/TLS

Transport Layer Security (TLS) and its predecessor, Secure Sockets Layer (SSL), are cryptographic protocols that provide security for communications over networks such as the Internet. TLS and SSL encrypt the segments of network connections at the Transport Layer end-to-end.

Several versions of the protocols are in widespread use in applications like web browsing, electronic mail, Internet faxing, instant messaging and voice-over-IP (VoIP).[19]

A.2.5. Cramer-Shoup Cryptosystem

The Cramer–Shoup system is an asymmetric key encryption algorithm, and was the first efficient scheme proven to be secure against adaptive chosen ciphertext attack using standard cryptographic assumptions. Its security is based on the computational intractability (widely assumed, but not proved) of the decisional Diffie–Hellman assumption. Developed by Ronald Cramer and Victor Shoup in 1998, it is an extension of the ElGamal cryptosystem. In contrast to ElGamal, which is extremely malleable, Cramer–Shoup adds additional elements to ensure non-malleability even against a resourceful attacker. This non-malleability is achieved through the use of a collision-resistant hash function and additional computations, resulting in a ciphertext which is twice as large as in ElGamal.[20]

A.2.6. ElGamal Encryption

In cryptography, the ElGamal encryption system is an asymmetric key encryption algorithm for public-key cryptography which is based on the Diffie-Hellman key agreement. It was described by Taher ElGamal in 1985. ElGamal encryption is used in the free GNU Privacy Guard software, recent versions of PGP, and other cryptosystems.[21]

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[3] "Advanced Encryption Standard." *Wikipedia*. 14 November 2009 http://en.wikipedia.org/wiki/Advanced_Encryption_Standard

[4] "Advanced Encryption Standard." *Wikipedia.* 14 November 2009 http://en.wikipedia.org/wiki/Advanced_Encryption_Standard

[5] "Advanced Encryption Standard." *Wikipedia.* 14 November 2009 http://en.wikipedia.org/wiki/Advanced_Encryption_Standard

[6] "Data Encryption Standard." *Wikipedia.* 14 November 2009 http://en.wikipedia.org/wiki/Data_Encryption_Standard

[7] "Data Encryption Standard." *Wikipedia.* 14 November 2009 http://en.wikipedia.org/wiki/Data_Encryption_Standard

[8] "Data Encryption Standard." *Wikipedia.* 14 November 2009 http://en.wikipedia.org/wiki/Data_Encryption_Standard

[9] "Public-key Encryption." *Wikipedia.* 14 November 2009 http://en.wikipedia.org/wiki/Public-key_cryptography

[10] "Public-key Encryption." *Wikipedia.* 14 November 2009 http://en.wikipedia.org/wiki/Public-key_cryptography

[11] "Public-key Encryption." *Wikipedia.* 14 November 2009 http://en.wikipedia.org/wiki/Public-key_cryptography

[12] "Public-key Encryption." *Wikipedia.* 14 November 2009 http://en.wikipedia.org/wiki/Public-key_cryptography

[13] "Public-key Encryption." *Wikipedia.* 14 November 2009 http://en.wikipedia.org/wiki/Public-key_cryptography

[14] "Diffie-Hellman." *Wikipedia.* 14 November 2009 http://en.wikipedia.org/wiki/Diffie-Hellman

[15] "Diffie-Hellman." *Wikipedia.* 14 November 2009 http://en.wikipedia.org/wiki/Diffie-Hellman

[16] "Diffie-Hellman." *Wikipedia.* 14 November 2009 http://en.wikipedia.org/wiki/Diffie-Hellman

[17] "Diffie-Hellman." *Wikipedia.* 14 November 2009 http://en.wikipedia.org/wiki/Diffie-Hellman

[18] "DSA." *Wikipedia.* 24 February 2010 http://en.wikipedia.org/wiki/Digital_Signature_Algorithm

[19] "TLS/SSL." *Wikipedia.* 24 February 2010 http://en.wikipedia.org/wiki/Transport_Layer_Security

[20] "Cramer-Shoup cryptosystem." *Wikipedia.* 24 February 2010 http://en.wikipedia.org/wiki/Cramer–Shoup_cryptosystem

[21] "ElGamal encryption" *Wikipedia.* 24 February 2010 http://en.wikipedia.org/wiki/ElGamal_encryption

APPENDIX B. AUDIT SYSTEM REFERENCE

B.1. AUDIT EVENT FIELDS

Table B.1, “Event Fields” lists all currently-supported Audit event fields. An event field is the value preceding the equal sign in the Audit log files.

Table B.1. Event Fields

Event Field	Explanation
a0, **a1**, **a2**, **a3**	Records the first four arguments of the system call, encoded in hexadecimal notation.
acct	Records a user's account name.
addr	Records the IPv4 or IPv6 address. This field usually follows a **hostname** field and contains the address the host name resolves to.
arch	Records information about the CPU architecture of the system, encoded in hexadecimal notation.
auid	Records the Audit user ID. This ID is assigned to a user upon login and is inherited by every process even when the user's identity changes (for example, by switching user accounts with **su - john**).
capability	Records the number of bits that were used to set a particular Linux capability. For more information on Linux capabilities, see the capabilities(7) man page.
cap_fe	Records data related to the setting of the effective file system-based capability bit.
cap_fi	Records data related to the setting of an inherited file system-based capability.
cap_fp	Records data related to the setting of a permitted file system-based capability.
cap_fver	Records the version of a file system-based capability.
cap_pe	Records data related to the setting of an effective process-based capability.
cap_pi	Records data related to the setting of an inherited process-based capability.
cap_pp	Records data related to the setting of a permitted process-based capability.
cgroup	Records the path to the **cgroup** that contains the process at the time the Audit event was generated.

Event Field	Explanation
cmd	Records the entire command line that is executed. This is useful in case of shell interpreters where the **exe** field records, for example, **/bin/bash** as the shell interpreter and the **cmd** field records the rest of the command line that is executed, for example **helloworld.sh --help**.
comm	Records the command that is executed. This is useful in case of shell interpreters where the **exe** field records, for example, **/bin/bash** as the shell interpreter and the **comm** field records the name of the script that is executed, for example **helloworld.sh**.
cwd	Records the path to the directory in which a system call was invoked.
data	Records data associated with TTY records.
dev	Records the minor and major ID of the device that contains the file or directory recorded in an event.
devmajor	Records the major device ID.
devminor	Records the minor device ID.
egid	Records the effective group ID of the user who started the analyzed process.
euid	Records the effective user ID of the user who started the analyzed process.
exe	Records the path to the executable that was used to invoke the analyzed process.
exit	Records the exit code returned by a system call. This value varies by system call. You can interpret the value to its human-readable equivalent with the following command: **ausearch --interpret --exit *exit_code***
family	Records the type of address protocol that was used, either IPv4 or IPv6.
filetype	Records the type of the file.
flags	Records the file system name flags.
fsgid	Records the file system group ID of the user who started the analyzed process.
fsuid	Records the file system user ID of the user who started the analyzed process.
gid	Records the group ID.

Event Field	Explanation
hostname	Records the host name.
icmptype	Records the type of a Internet Control Message Protocol (ICMP) package that is received. Audit messages containing this field are usually generated by **iptables**.
id	Records the user ID of an account that was changed.
inode	Records the inode number associated with the file or directory recorded in an Audit event.
inode_gid	Records the group ID of the inode's owner.
inode_uid	Records the user ID of the inode's owner.
items	Records the number of path records that are attached to this record.
key	Records the user defined string associated with a rule that generated a particular event in the Audit log.
list	Records the Audit rule list ID. The following is a list of known IDs: • 0 — **user** • 1 — **task** • 4 — **exit** • 5 — **exclude**
mode	Records the file or directory permissions, encoded in numerical notation.
msg	Records a time stamp and a unique ID of a record, or various event-specific ***<name>=<value>*** pairs provided by the kernel or user space applications.
msgtype	Records the message type that is returned in case of a user-based AVC denial. The message type is determined by D-Bus.
name	Records the full path of the file or directory that was passed to the system call as an argument.
new-disk	Records the name of a new disk resource that is assigned to a virtual machine.
new-mem	Records the amount of a new memory resource that is assigned to a virtual machine.

Event Field	Explanation
new-vcpu	Records the number of a new virtual CPU resource that is assigned to a virtual machine.
new-net	Records the MAC address of a new network interface resource that is assigned to a virtual machine.
new_gid	Records a group ID that is assigned to a user.
oauid	Records the user ID of the user that has logged in to access the system (as opposed to, for example, using **su**) and has started the target process. This field is exclusive to the record of type **OBJ_PID**.
ocomm	Records the command that was used to start the target process.This field is exclusive to the record of type **OBJ_PID**.
opid	Records the process ID of the target process. This field is exclusive to the record of type **OBJ_PID**.
oses	Records the session ID of the target process. This field is exclusive to the record of type **OBJ_PID**.
ouid	Records the real user ID of the target process
obj	Records the SELinux context of an object. An object can be a file, a directory, a socket, or anything that is receiving the action of a subject.
objtype	Records the intent of the PATH record object in the context of a syscall.
obj_gid	Records the group ID of an object.
obj_lev_high	Records the high SELinux level of an object.
obj_lev_low	Records the low SELinux level of an object.
obj_role	Records the SELinux role of an object.
obj_uid	Records the UID of an object
obj_user	Records the user that is associated with an object.
ogid	Records the object owner's group ID.
old-disk	Records the name of an old disk resource when a new disk resource is assigned to a virtual machine.

Event Field	Explanation
old-mem	Records the amount of an old memory resource when a new amount of memory is assigned to a virtual machine.
old-vcpu	Records the number of an old virtual CPU resource when a new virtual CPU is assigned to a virtual machine.
old-net	Records the MAC address of an old network interface resource when a new network interface is assigned to a virtual machine.
old_prom	Records the previous value of the network promiscuity flag.
ouid	Records the real user ID of the user who started the target process.
path	Records the full path of the file or directory that was passed to the system call as an argument in case of AVC-related Audit events
perm	Records the file permission that was used to generate an event (that is, read, write, execute, or attribute change)
pid	The **pid** field semantics depend on the origin of the value in this field. In fields generated from user-space, this field holds a process ID. In fields generated by the kernel, this field holds a thread ID. The thread ID is equal to process ID for single-threaded processes. Note that the value of this thread ID is different from the values of pthread_t IDs used in user-space. For more information, see the gettid(2) man page.
ppid	Records the Parent Process ID (PID).
proctitle	Records the full command-line of the command that was used to invoke the analyzed process. The field is encoded in hexadecimal notation to not allow the user to influence the Audit log parser. The text decodes to the command that triggered this Audit event. When searching Audit records with the **ausearch** command, use the **-i** or **--interpret** option to automatically convert hexadecimal values into their human-readable equivalents.
prom	Records the network promiscuity flag.
proto	Records the networking protocol that was used. This field is specific to Audit events generated by **iptables**.
res	Records the result of the operation that triggered the Audit event.
result	Records the result of the operation that triggered the Audit event.
saddr	Records the socket address.

Event Field	Explanation
sauid	Records the sender Audit login user ID. This ID is provided by D-Bus as the kernel is unable to see which user is sending the original **auid**.
ses	Records the session ID of the session from which the analyzed process was invoked.
sgid	Records the set group ID of the user who started the analyzed process.
sig	Records the number of a signal that causes a program to end abnormally. Usually, this is a sign of a system intrusion.
subj	Records the SELinux context of a subject. A subject can be a process, a user, or anything that is acting upon an object.
subj_clr	Records the SELinux clearance of a subject.
subj_role	Records the SELinux role of a subject.
subj_sen	Records the SELinux sensitivity of a subject.
subj_user	Records the user that is associated with a subject.
success	Records whether a system call was successful or failed.
suid	Records the set user ID of the user who started the analyzed process.
syscall	Records the type of the system call that was sent to the kernel.
terminal	Records the terminal name (without **/dev/**).
tty	Records the name of the controlling terminal. The value **(none)** is used if the process has no controlling terminal.
uid	Records the real user ID of the user who started the analyzed process.
vm	Records the name of a virtual machine from which the Audit event originated.

B.2. AUDIT RECORD TYPES

Table B.2, “Record Types” lists all currently-supported types of Audit records. The event type is specified in the **type=** field at the beginning of every Audit record.

Table B.2. Record Types

Event Type	Explanation
ACCT_LOCK	Triggered when a user-space user account is locked by the administrator.
ACCT_UNLOCK	Triggered when a user-space user account is unlocked by the administrator.
ADD_GROUP	Triggered when a user-space group is added.
ADD_USER	Triggered when a user-space user account is added.
ANOM_ABEND[a]	Triggered when a processes ends abnormally (with a signal that could cause a core dump, if enabled).
ANOM_ACCESS_FS[a]	Triggered when a file or a directory access ends abnormally.
ANOM_ADD_ACCT[a]	Triggered when a user-space account addition ends abnormally.
ANOM_AMTU_FAIL[a]	Triggered when a failure of the Abstract Machine Test Utility (AMTU) is detected.
ANOM_CRYPTO_FAIL[a]	Triggered when a failure in the cryptographic system is detected.
ANOM_DEL_ACCT[a]	Triggered when a user-space account deletion ends abnormally.
ANOM_EXEC[a]	Triggered when an execution of a file ends abnormally.
ANOM_LINK[a]	Triggered when suspicious use of file links is detected.
ANOM_LOGIN_ACCT[a]	Triggered when an account login attempt ends abnormally.
ANOM_LOGIN_FAILURES[a]	Triggered when the limit of failed login attempts is reached.
ANOM_LOGIN_LOCATION[a]	Triggered when a login attempt is made from a forbidden location.
ANOM_LOGIN_SESSIONS[a]	Triggered when a login attempt reaches the maximum amount of concurrent sessions.
ANOM_LOGIN_TIME[a]	Triggered when a login attempt is made at a time when it is prevented by, for example, **pam_time**.
ANOM_MAX_DAC[a]	Triggered when the maximum amount of Discretionary Access Control (DAC) failures is reached.

Event Type	Explanation
ANOM_MAX_MAC[a]	Triggered when the maximum amount of Mandatory Access Control (MAC) failures is reached.
ANOM_MK_EXEC[a]	Triggered when a file is made executable.
ANOM_MOD_ACCT[a]	Triggered when a user-space account modification ends abnormally.
ANOM_PROMISCUOUS[a]	Triggered when a device enables or disables promiscuous mode.
ANOM_RBAC_FAIL[a]	Triggered when a Role-Based Access Control (RBAC) self-test failure is detected.
ANOM_RBAC_INTEGRITY_FAIL[a]	Triggered when a Role-Based Access Control (RBAC) file integrity test failure is detected.
ANOM_ROOT_TRANS[a]	Triggered when a user becomes root.
AVC	Triggered to record an SELinux permission check.
AVC_PATH	Triggered to record the **dentry** and **vfsmount** pair when an SELinux permission check occurs.
BPRM_FCAPS	Triggered when a user executes a program with a file system capability.
CAPSET	Triggered to record the capabilities being set for process-based capabilities, for example, running as root to drop capabilities.
CHGRP_ID	Triggered when a user-space group ID is changed.
CHUSER_ID	Triggered when a user-space user ID is changed.
CONFIG_CHANGE	Triggered when the Audit system configuration is modified.
CRED_ACQ	Triggered when a user acquires user-space credentials.
CRED_DISP	Triggered when a user disposes of user-space credentials.
CRED_REFR	Triggered when a user refreshes their user-space credentials.
CRYPTO_FAILURE_USER	Triggered when a decrypt, encrypt, or randomize cryptographic operation fails.
CRYPTO_IKE_SA	Triggered when an Internet Key Exchange Security Association is established.

Event Type	Explanation
CRYPTO_IPSEC_SA	Triggered when an Internet Protocol Security Association is established.
CRYPTO_KEY_USER	Triggered to record the cryptographic key identifier used for cryptographic purposes.
CRYPTO_LOGIN	Triggered when a cryptographic officer login attempt is detected.
CRYPTO_LOGOUT	Triggered when a cryptographic officer logout attempt is detected.
CRYPTO_PARAM_CHANGE_USER	Triggered when a change in a cryptographic parameter is detected.
CRYPTO_REPLAY_USER	Triggered when a replay attack is detected.
CRYPTO_SESSION	Triggered to record parameters set during a TLS session establishment.
CRYPTO_TEST_USER	Triggered to record cryptographic test results as required by the FIPS-140 standard.
CWD	Triggered to record the current working directory.
DAC_CHECK	Triggered to record DAC check results.
DAEMON_ABORT	Triggered when a daemon is stopped due to an error.
DAEMON_ACCEPT	Triggered when the **auditd** daemon accepts a remote connection.
DAEMON_CLOSE	Triggered when the **auditd** daemon closes a remote connection.
DAEMON_CONFIG	Triggered when a daemon configuration change is detected.
DAEMON_END	Triggered when a daemon is successfully stopped.
DAEMON_ERR	Triggered when an **auditd** daemon internal error is detected.
DAEMON_RESUME	Triggered when the **auditd** daemon resumes logging.
DAEMON_ROTATE	Triggered when the **auditd** daemon rotates the Audit log files.
DAEMON_START	Triggered when the **auditd** daemon is started.
DEL_GROUP	Triggered when a user-space group is deleted
DEL_USER	Triggered when a user-space user is deleted

Event Type	Explanation
DEV_ALLOC	Triggered when a device is allocated.
DEV_DEALLOC	Triggered when a device is deallocated.
EOE	Triggered to record the end of a multi-record event.
EXECVE	Triggered to record arguments of the **execve(2)** system call.
FD_PAIR	Triggered to record the use of the **pipe** and **socketpair** system calls.
FEATURE_CHANGE	Triggered when an Audit feature changed value.
FS_RELABEL	Triggered when a file system relabel operation is detected.
GRP_AUTH	Triggered when a group password is used to authenticate against a user-space group.
GRP_CHAUTHTOK	Triggered when a group account password or PIN is modified.
GRP_MGMT	Triggered to record user-space group account attribute modification.
INTEGRITY_DATA[b]	Triggered to record a data integrity verification event run by the kernel.
INTEGRITY_HASH[b]	Triggered to record a hash type integrity verification event run by the kernel.
INTEGRITY_METADATA[b]	Triggered to record a metadata integrity verification event run by the kernel.
INTEGRITY_PCR[b]	Triggered to record Platform Configuration Register (PCR) invalidation messages.
INTEGRITY_RULE[b]	Triggered to record a policy rule.
INTEGRITY_STATUS[b]	Triggered to record the status of integrity verification.
IPC	Triggered to record information about a Inter-Process Communication object referenced by a system call.
IPC_SET_PERM	Triggered to record information about new values set by an **IPC_SET** control operation on an IPC object.
KERN_MODULE	Triggered to record a kernel module name on load or unload.
KERNEL	Triggered to record the initialization of the Audit system.

Event Type	Explanation
KERNEL_OTHER	Triggered to record information from third-party kernel modules.
LABEL_LEVEL_CHANGE	Triggered when an object's level label is modified.
LABEL_OVERRIDE	Triggered when an administrator overrides an object's level label.
LOGIN	Triggered to record relevant login information when a user log in to access the system.
MAC_CHECK	Triggered when a user space MAC (Mandatory Access Control) decision is made.
MAC_CIPSOV4_ADD	Triggered when a Commercial Internet Protocol Security Option (CIPSO) user adds a new Domain of Interpretation (DOI). Adding DOIs is a part of the packet labeling capabilities of the kernel provided by NetLabel.
MAC_CIPSOV4_DEL	Triggered when a CIPSO user deletes an existing DOI. Adding DOIs is a part of the packet labeling capabilities of the kernel provided by NetLabel.
MAC_CONFIG_CHANGE	Triggered when an SELinux Boolean value is changed.
MAC_IPSEC_EVENT	Triggered to record information about an IPSec event, when one is detected, or when the IPSec configuration changes.
MAC_MAP_ADD	Triggered when a new Linux Security Module (LSM) domain mapping is added. LSM domain mapping is a part of the packet labeling capabilities of the kernel provided by NetLabel.
MAC_MAP_DEL	Triggered when an existing LSM domain mapping is deleted. LSM domain mapping is a part of the packet labeling capabilities of the kernel provided by NetLabel.
MAC_POLICY_LOAD	Triggered when a SELinux policy file is loaded.
MAC_STATUS	Triggered when the SELinux mode (enforcing, permissive, off) is changed.
MAC_UNLBL_ALLOW	Triggered when unlabeled traffic is allowed when using the packet labeling capabilities of the kernel provided by NetLabel.
MAC_UNLBL_STCADD	Triggered when a static label is added when using the packet labeling capabilities of the kernel provided by NetLabel.
MAC_UNLBL_STCDEL	Triggered when a static label is deleted when using the packet labeling capabilities of the kernel provided by NetLabel.
MMAP	Triggered to record a file descriptor and flags of the **mmap(2)** system call.

Event Type	Explanation
MQ_GETSETATTR	Triggered to record the **mq_getattr(3)** and **mq_setattr(3)** message queue attributes.
MQ_NOTIFY	Triggered to record arguments of the **mq_notify(3)** system call.
MQ_OPEN	Triggered to record arguments of the **mq_open(3)** system call.
MQ_SENDRECV	Triggered to record arguments of the **mq_send(3)** and **mq_receive(3)** system calls.
NETFILTER_CFG	Triggered when Netfilter chain modifications are detected.
NETFILTER_PKT	Triggered to record packets traversing Netfilter chains.
OBJ_PID	Triggered to record information about a process to which a signal is sent.
PATH	Triggered to record file name path information.
PROCTITLE	Gives the full command-line that triggered this Audit event, triggered by a system call to the kernel.
RESP_ACCT_LOCK[c]	Triggered when a user account is locked.
RESP_ACCT_LOCK_TIMED[c]	Triggered when a user account is locked for a specified period of time.
RESP_ACCT_REMOTE[c]	Triggered when a user account is locked from a remote session.
RESP_ACCT_UNLOCK_TIMED[c]	Triggered when a user account is unlocked after a configured period of time.
RESP_ALERT[c]	Triggered when an alert email is sent.
RESP_ANOMALY[c]	Triggered when an anomaly was not acted upon.
RESP_EXEC[c]	Triggered when an intrusion detection program responds to a threat originating from the execution of a program.
RESP_HALT[c]	Triggered when the system is shut down.
RESP_KILL_PROC[c]	Triggered when a process is terminated.
RESP_SEBOOL[c]	Triggered when an SELinux Boolean value is set.

Event Type	Explanation
RESP_SINGLE[c]	Triggered when the system is put into single-user mode.
RESP_TERM_ACCESS[c]	Triggered when a session is terminated.
RESP_TERM_LOCK[c]	Triggered when a terminal is locked.
ROLE_ASSIGN	Triggered when an administrator assigns a user to an SELinux role.
ROLE_MODIFY	Triggered when an administrator modifies an SELinux role.
ROLE_REMOVE	Triggered when an administrator removes a user from an SELinux role.
SECCOMP	Triggered when a SECure COMPuting event is detected.
SELINUX_ERR	Triggered when an internal SELinux error is detected.
SERVICE_START	Triggered when a service is started.
SERVICE_STOP	Triggered when a service is stopped.
SOCKADDR	Triggered to record a socket address.
SOCKETCALL	Triggered to record arguments of the **`sys_socketcall`** system call (used to multiplex many socket-related system calls).
SYSCALL	Triggered to record a system call to the kernel.
SYSTEM_BOOT	Triggered when the system is booted up.
SYSTEM_RUNLEVEL	Triggered when the system's run level is changed.
SYSTEM_SHUTDOWN	Triggered when the system is shut down.
TEST	Triggered to record the success value of a test message.
TRUSTED_APP	The record of this type can be used by third party application that require auditing.
TTY	Triggered when TTY input was sent to an administrative process.
USER_ACCT	Triggered when a user-space user authorization attempt is detected.
USER_AUTH	Triggered when a user-space user authentication attempt is detected.

Event Type	Explanation
USER_AVC	Triggered when a user-space AVC message is generated.
USER_CHAUTHTOK	Triggered when a user account password or PIN is modified.
USER_CMD	Triggered when a user-space shell command is executed.
USER_END	Triggered when a user-space session is terminated.
USER_ERR	Triggered when a user account state error is detected.
USER_LABELED_EXPORT	Triggered when an object is exported with an SELinux label.
USER_LOGIN	Triggered when a user logs in.
USER_LOGOUT	Triggered when a user logs out.
USER_MAC_POLICY_LOAD	Triggered when a user-space daemon loads an SELinux policy.
USER_MGMT	Triggered to record user-space user account attribute modification.
USER_ROLE_CHANGE	Triggered when a user's SELinux role is changed.
USER_SELINUX_ERR	Triggered when a user-space SELinux error is detected.
USER_START	Triggered when a user-space session is started.
USER_TTY	Triggered when an explanatory message about TTY input to an administrative process is sent from user-space.
USER_UNLABELED_EXPORT	Triggered when an object is exported without SELinux label.
USYS_CONFIG	Triggered when a user-space system configuration change is detected.
VIRT_CONTROL	Triggered when a virtual machine is started, paused, or stopped.
VIRT_MACHINE_ID	Triggered to record the binding of a label to a virtual machine.
VIRT_RESOURCE	Triggered to record resource assignment of a virtual machine.

Event Type	Explanation

[a] All Audit event types prepended with **ANOM** are intended to be processed by an intrusion detection program.

[b] This event type is related to the Integrity Measurement Architecture (IMA), which functions best with a Trusted Platform Module (TPM) chip.

[c] All Audit event types prepended with **RESP** are intended responses of an intrusion detection system in case it detects malicious activity on the system.

APPENDIX C. REVISION HISTORY

Revision 1-41 **Sat Oct 20 2018** **Mirek Jahoda**
Version for 7.6 GA publication.

Revision 1-32 **Wed Apr 4 2018** **Mirek Jahoda**
Version for 7.5 GA publication.

Revision 1-30 **Thu Jul 27 2017** **Mirek Jahoda**
Version for 7.4 GA publication.

Revision 1-24 **Mon Feb 6 2017** **Mirek Jahoda**
Async release with misc. updates, especially in the firewalld section.

Revision 1-23 **Tue Nov 1 2016** **Mirek Jahoda**
Version for 7.3 GA publication.

Revision 1-19 **Mon Jul 18 2016** **Mirek Jahoda**
The Smart Cards section added.

Revision 1-18 **Mon Jun 27 2016** **Mirek Jahoda**
The OpenSCAP-daemon and Atomic Scan section added.

Revision 1-17 **Fri Jun 3 2016** **Mirek Jahoda**
Async release with misc. updates.

Revision 1-16 **Tue Jan 5 2016** **Robert Krátký**
Post 7.2 GA fixes.

Revision 1-15 **Tue Nov 10 2015** **Robert Krátký**
Version for 7.2 GA release.

Revision 1-14.18 **Mon Nov 09 2015** **Robert Krátký**
Async release with misc. updates.

Revision 1-14.17 **Wed Feb 18 2015** **Robert Krátký**
Version for 7.1 GA release.

Revision 1-14.15 **Fri Dec 06 2014** **Robert Krátký**
Update to sort order on the Red Hat Customer Portal.

Revision 1-14.13 **Thu Nov 27 2014** **Robert Krátký**
Updates reflecting the POODLE vuln.

Revision 1-14.12 **Tue Jun 03 2014** **Tomáš Čapek**
Version for 7.0 GA release.