



Red Hat Enterprise Linux 8

Security hardening

Enhancing security of Red Hat Enterprise Linux 8 systems

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Abstract

Learn the processes and practices for securing Red Hat Enterprise Linux servers and workstations against local and remote intrusion, exploitation, and malicious activity. By using these approaches and tools, you can create a more secure computing environment for the data center, workplace, and home.

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PROVIDING FEEDBACK ON RED HAT DOCUMENTATION

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CHAPTER 1. SECURING RHEL DURING AND RIGHT AFTER INSTALLATION

Security begins even before you start the installation of Red Hat Enterprise Linux. Configuring your system securely from the beginning makes it easier to implement additional security settings later.

1.1. DISK PARTITIONING

The recommended practices for disk partitioning differ for installations on bare-metal machines and for virtualized or cloud environments that support adjusting virtual disk hardware and file systems containing already-installed operating systems.

To ensure separation and protection of data on **bare-metal installations**, create separate partitions for the **/boot**, **/**, **/home**, **/tmp**, and **/var/tmp** directories:

/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 RHEL 8 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 is not 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 RHEL 8 it is a lot easier when you can keep your data in the **/home** partition as it is 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.

For **virtual machines or cloud instances**, the separate **/boot**, **/home**, **/tmp**, and **/var/tmp** partitions are optional because you can increase the virtual disk size and the **/** partition if it begins to fill up. Set up monitoring to regularly check the **/** partition usage so that it does not fill up before you increase the virtual disk size accordingly.



NOTE

During the installation process, you have an option to encrypt partitions. You must supply a passphrase. This passphrase serves as a key to unlock the bulk encryption key, which is used to secure the partition's data.

1.2. RESTRICTING NETWORK CONNECTIVITY DURING THE INSTALLATION PROCESS

When installing RHEL 8, 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 RHEL 8 from a network.

1.3. 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.

1.4. POST-INSTALLATION PROCEDURES

The following steps are the security-related procedures that should be performed immediately after installation of RHEL 8.

- Update your system. Enter the following command as root:

```
# yum update
```

- Even though the firewall service, **firewalld**, is automatically enabled with the installation of Red Hat Enterprise Linux, it might be explicitly disabled, for example, in the Kickstart configuration. In such a case, re-enable the firewall.

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

```
# systemctl start firewalld
# systemctl enable firewalld
```

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

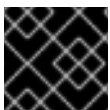
```
# systemctl disable cups
```

To review active services, enter the following command:

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

1.5. DISABLING SMT TO PREVENT CPU SECURITY ISSUES BY USING THE WEB CONSOLE

Disable Simultaneous Multi Threading (SMT) in case of attacks that misuse CPU SMT. Disabling SMT can mitigate security vulnerabilities, such as L1TF or MDS.



IMPORTANT

Disabling SMT might lower the system performance.

Prerequisites

- You have installed the RHEL 8 web console.

- You have enabled the cockpit service.
- Your user account is allowed to log in to the web console.
For instructions, see [Installing and enabling the web console](#).

Procedure

1. Log in to the RHEL 8 web console.
For details, see [Logging in to the web console](#).
2. In the **Overview** tab find the **System information** field and click **View hardware details**.
3. On the **CPU Security** line, click **Mitigations**.
If this link is not present, it means that your system does not support SMT, and therefore is not vulnerable.
4. In the **CPU Security Toggles** table, turn on the **Disable simultaneous multithreading (nosmt)** option.
5. Click the **Save and reboot** button.

After the system restart, the CPU no longer uses SMT.

Additional resources

- [L1TF - L1 Terminal Fault Attack - CVE-2018-3620 & CVE-2018-3646](#)
- [MDS - Microarchitectural Data Sampling - CVE-2018-12130, CVE-2018-12126, CVE-2018-12127, and CVE-2019-11091](#)

CHAPTER 2. SWITCHING RHEL TO FIPS MODE

To enable the cryptographic module self-checks mandated by the Federal Information Processing Standard (FIPS) 140-2, you must operate RHEL 8 in FIPS mode. Starting the installation in FIPS mode is the recommended method if you aim for FIPS compliance.

2.1. FEDERAL INFORMATION PROCESSING STANDARDS 140 AND FIPS MODE

The Federal Information Processing Standards (FIPS) Publication 140 is a series of computer security standards developed by the National Institute of Standards and Technology (NIST) to ensure the quality of cryptographic modules. The FIPS 140 standard ensures that cryptographic tools implement their algorithms correctly. Runtime cryptographic algorithm and integrity self-tests are some of the mechanisms to ensure a system uses cryptography that meets the requirements of the standard.

RHEL in FIPS mode

To ensure that your RHEL system generates and uses all cryptographic keys only with FIPS-approved algorithms, you must switch RHEL to FIPS mode.

You can enable FIPS mode by using one of the following methods:

- Starting the installation in FIPS mode
- Switching the system into FIPS mode after the installation

If you aim for FIPS compliance, start the installation in FIPS mode. This avoids cryptographic key material regeneration and reevaluation of the compliance of the resulting system associated with converting already deployed systems.

To operate a FIPS-compliant system, create all cryptographic key material in FIPS mode. Furthermore, the cryptographic key material must never leave the FIPS environment unless it is securely wrapped and never unwrapped in non-FIPS environments.

The [FIPS - Federal Information Processing Standards](#) section on the [Product compliance](#) Red Hat Customer Portal page provides an overview of the validation status of cryptographic modules for selected RHEL minor releases.

Switching to FIPS mode after the installation

Switching the system to FIPS mode by using the **fips-mode-setup** tool does not guarantee compliance with the FIPS 140 standard. Re-generating all cryptographic keys after setting the system to FIPS mode may not be possible. For example, in the case of an existing IdM realm with users' cryptographic keys you cannot re-generate all the keys. If you cannot start the installation in FIPS mode, always enable FIPS mode as the first step after the installation, before you make any post-installation configuration steps or install any workloads.

The **fips-mode-setup** tool also uses the **FIPS** system-wide cryptographic policy internally. But on top of what the **update-crypto-policies --set FIPS** command does, **fips-mode-setup** ensures the installation of the FIPS dracut module by using the **fips-finish-install** tool, it also adds the **fips=1** boot option to the kernel command line and regenerates the initial RAM disk.

Furthermore, enforcement of restrictions required in FIPS mode depends on the content of the **/proc/sys/crypto/fips_enabled** file. If the file contains **1**, RHEL core cryptographic components switch to mode, in which they use only FIPS-approved implementations of cryptographic algorithms. If **/proc/sys/crypto/fips_enabled** contains **0**, the cryptographic components do not enable their FIPS mode.

FIPS in crypto-policies

The **FIPS** system-wide cryptographic policy helps to configure higher-level restrictions. Therefore, communication protocols supporting cryptographic agility do not announce ciphers that the system refuses when selected. For example, the ChaCha20 algorithm is not FIPS-approved, and the **FIPS** cryptographic policy ensures that TLS servers and clients do not announce the `TLS_ECDHE_ECDSA_WITH_CHACHA20_POLY1305_SHA256` TLS cipher suite, because any attempt to use such a cipher fails.

If you operate RHEL in FIPS mode and use an application providing its own FIPS-mode-related configuration options, ignore these options and the corresponding application guidance. The system running in FIPS mode and the system-wide cryptographic policies enforce only FIPS-compliant cryptography. For example, the Node.js configuration option `--enable-fips` is ignored if the system runs in FIPS mode. If you use the `--enable-fips` option on a system not running in FIPS mode, you do not meet the FIPS-140 compliance requirements.

Additional resources

- [FIPS - Federal Information Processing Standards](#) section on the [Product compliance](#) Red Hat Customer Portal page
- [RHEL system-wide cryptographic policies](#)
- [FIPS publications at NIST Computer Security Resource Center](#) .
- [Federal Information Processing Standards Publication: FIPS 140-3](#)

2.2. INSTALLING THE SYSTEM WITH FIPS MODE ENABLED

To enable the cryptographic module self-checks mandated by the Federal Information Processing Standard (FIPS) 140, enable FIPS mode during the system installation.



IMPORTANT

Only enabling FIPS mode during the RHEL installation ensures that the system generates all keys with FIPS-approved algorithms and continuous monitoring tests in place.



WARNING

After you complete the setup of FIPS mode, you cannot switch off FIPS mode without putting the system into an inconsistent state. If your scenario requires this change, the only correct way is a complete re-installation of the system.

Procedure

1. Add the `fips=1` option to the kernel command line during the system installation.
2. During the software selection stage, do not install any third-party software.
3. After the installation, the system starts in FIPS mode automatically.

Verification

- After the system starts, check that FIPS mode is enabled:

```
$ fips-mode-setup --check
FIPS mode is enabled.
```

Additional resources

- [Editing boot options](#)

2.3. SWITCHING THE SYSTEM TO FIPS MODE

The system-wide cryptographic policies contain a policy level that enables cryptographic algorithms in accordance with the requirements by the Federal Information Processing Standard (FIPS) Publication 140. The **fips-mode-setup** tool that enables or disables FIPS mode internally uses the **FIPS** system-wide cryptographic policy.

Switching the system to FIPS mode by using the **FIPS** system-wide cryptographic policy does not guarantee compliance with the FIPS 140 standard. Re-generating all cryptographic keys after setting the system to FIPS mode may not be possible. For example, in the case of an existing IdM realm with users' cryptographic keys you cannot re-generate all the keys.



IMPORTANT

Only enabling [FIPS mode during the RHEL installation](#) ensures that the system generates all keys with FIPS-approved algorithms and continuous monitoring tests in place.

The **fips-mode-setup** tool uses the **FIPS** policy internally. But on top of what the **update-crypto-policies** command with the **--set FIPS** option does, **fips-mode-setup** ensures the installation of the FIPS dracut module by using the **fips-finish-install** tool, it also adds the **fips=1** boot option to the kernel command line and regenerates the initial RAM disk.



WARNING

After you complete the setup of FIPS mode, you cannot switch off FIPS mode without putting the system into an inconsistent state. If your scenario requires this change, the only correct way is a complete re-installation of the system.

Procedure

1. To switch the system to FIPS mode:

```
# fips-mode-setup --enable
Kernel initramdisks are being regenerated. This might take some time.
Setting system policy to FIPS
Note: System-wide crypto policies are applied on application start-up.
It is recommended to restart the system for the change of policies
```



```

to fully take place.
FIPS mode will be enabled.
Please reboot the system for the setting to take effect.

```

- Restart your system to allow the kernel to switch to FIPS mode:

```
# reboot
```

Verification

- After the restart, you can check the current state of FIPS mode:

```

# fips-mode-setup --check
FIPS mode is enabled.

```

Additional resources

- fips-mode-setup(8)** man page on your system
- [FIPS - Federal Information Processing Standards](#) section on the [Product compliance](#) Red Hat Customer Portal page
- [Security Requirements for Cryptographic Modules](#) on the National Institute of Standards and Technology (NIST) web site.

2.4. ENABLING FIPS MODE IN A CONTAINER

To enable the full set of cryptographic module self-checks mandated by the Federal Information Processing Standard Publication 140-2 (FIPS mode), the host system kernel must be running in FIPS mode. Depending on the version of your host system, enabling FIPS mode on containers either is fully automatic or requires only one command.

The **fips-mode-setup** command does not work correctly in containers, and it cannot be used to enable or check FIPS mode in this scenario.

Prerequisites

- The host system must be in FIPS mode.

Procedure

- On hosts running RHEL 8.1 and 8.2** Set the FIPS cryptographic policy level in the container using the following command, and ignore the advice to use the **fips-mode-setup** command:

```
$ update-crypto-policies --set FIPS
```

- On hosts running RHEL 8.4 and later** On systems with FIPS mode enabled, the **podman** utility automatically enables FIPS mode on supported containers.

Additional resources

- [Switching the system to FIPS mode](#) .

- [Installing the system in FIPS mode](#)
- [FIPS - Federal Information Processing Standards](#) section on the [Product compliance](#) Red Hat Customer Portal page

2.5. LIST OF RHEL APPLICATIONS USING CRYPTOGRAPHY THAT IS NOT COMPLIANT WITH FIPS 140-2

To pass all relevant cryptographic certifications, such as FIPS 140, use libraries from the core cryptographic components set. These libraries, except from **libgcrypt**, also follow the RHEL system-wide cryptographic policies.

See the [RHEL core cryptographic components](#) Red Hat Knowledgebase article for an overview of the core cryptographic components, the information on 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 cryptographic certifications apply to them.

In addition to the following table, in some RHEL 8 Z-stream releases (for example, 8.1.1), the Firefox browser packages have been updated, and they contain a separate copy of the NSS cryptography library. This way, Red Hat wants to avoid the disruption of rebasing such a low-level component in a patch release. As a result, these Firefox packages do not use a FIPS 140-2-validated module.

List of RHEL 8 applications that use cryptography not compliant with FIPS 140-2

FreeRADIUS

The RADIUS protocol uses MD5.

Ghostscript

Custom cryptography implementation (MD5, RC4, SHA-2, AES) to encrypt and decrypt documents.

iPXE

Cryptographic stack for TLS is compiled in, however, it is unused.

Libica

Software fallbacks for various algorithms such as RSA and ECDH through CPACF instructions.

Ovmf (UEFI firmware), Edk2, shim

Full cryptographic stack (an embedded copy of the OpenSSL library).

Perl

HMAC, HMAC-SHA1, HMAC-MD5, SHA-1, SHA-224,...

Pidgin

Implements DES and RC4.

QAT Engine

Mixed hardware and software implementation of cryptographic primitives (RSA, EC, DH, AES,...).

Samba^[1]

Implements AES, DES, and RC4.

SWTPM

Explicitly disables FIPS mode in its OpenSSL usage.

Valgrind

AES, hashes^[2]

zip

Custom cryptography implementation (insecure PKWARE encryption algorithm) to encrypt and decrypt archives using a password.

Additional resources

- [FIPS - Federal Information Processing Standards](#) section on the [Product compliance](#) Red Hat Customer Portal page
- [RHEL core cryptographic components](#) (Red Hat Knowledgebase)

[1] Starting with RHEL 8.3, samba uses FIPS-compliant cryptography.

[2] Re-implements in software hardware-offload operations, such as AES-NI.

CHAPTER 3. USING SYSTEM-WIDE CRYPTOGRAPHIC POLICIES

The system-wide cryptographic policies is a system component that configures the core cryptographic subsystems, covering the TLS, IPsec, SSH, DNSSec, and Kerberos protocols. It provides a small set of policies, which the administrator can select.

3.1. SYSTEM-WIDE CRYPTOGRAPHIC POLICIES

When a system-wide policy is set up, applications in RHEL follow it and refuse to use algorithms and protocols that do not meet the policy, unless you explicitly request the application to do so. That is, the policy applies to the default behavior of applications when running with the system-provided configuration but you can override it if required.

RHEL 8 contains the following predefined policies:

DEFAULT

The default system-wide cryptographic policy level offers secure settings for current threat models. It allows the TLS 1.2 and 1.3 protocols, as well as the IKEv2 and SSH2 protocols. The RSA keys and Diffie-Hellman parameters are accepted if they are at least 2048 bits long.

LEGACY

Ensures maximum compatibility with Red Hat Enterprise Linux 5 and earlier; it is less secure due to an increased attack surface. In addition to the **DEFAULT** level algorithms and protocols, it includes support for the TLS 1.0 and 1.1 protocols. The algorithms DSA, 3DES, and RC4 are allowed, while RSA keys and Diffie-Hellman parameters are accepted if they are at least 1023 bits long.

FUTURE

A stricter forward-looking security level intended for testing a possible future policy. This policy does not allow the use of SHA-1 in signature algorithms. It allows the TLS 1.2 and 1.3 protocols, as well as the IKEv2 and SSH2 protocols. The RSA keys and Diffie-Hellman parameters are accepted if they are at least 3072 bits long. If your system communicates on the public internet, you might face interoperability problems.



IMPORTANT

Because a cryptographic key used by a certificate on the Customer Portal API does not meet the requirements by the **FUTURE** system-wide cryptographic policy, the **redhat-support-tool** utility does not work with this policy level at the moment.

To work around this problem, use the **DEFAULT** cryptographic policy while connecting to the Customer Portal API.

FIPS

Conforms with the FIPS 140 requirements. The **fips-mode-setup** tool, which switches the RHEL system into FIPS mode, uses this policy internally. Switching to the **FIPS** policy does not guarantee compliance with the FIPS 140 standard. You also must re-generate all cryptographic keys after you set the system to FIPS mode. This is not possible in many scenarios.

RHEL also provides the **FIPS:OSPP** system-wide subpolicy, which contains further restrictions for cryptographic algorithms required by the Common Criteria (CC) certification. The system becomes less interoperable after you set this subpolicy. For example, you cannot use RSA and DH keys shorter than 3072 bits, additional SSH algorithms, and several TLS groups. Setting **FIPS:OSPP** also prevents connecting to Red Hat Content Delivery Network (CDN) structure. Furthermore, you

cannot integrate Active Directory (AD) into the IdM deployments that use **FIPS:OSPP**, communication between RHEL hosts using **FIPS:OSPP** and AD domains might not work, or some AD accounts might not be able to authenticate.



NOTE

Your system is not CC-compliant after you set the **FIPS:OSPP** cryptographic subpolicy. The only correct way to make your RHEL system compliant with the CC standard is by following the guidance provided in the **cc-config** package. See [Common Criteria](#) section on the [Product compliance](#) Red Hat Customer Portal page for a list of certified RHEL versions, validation reports, and links to CC guides.

Red Hat continuously adjusts all policy levels so that all libraries provide secure defaults, except when using the **LEGACY** policy. Even though the **LEGACY** profile does not provide secure defaults, it does not include any algorithms that are easily exploitable. As such, the set of enabled algorithms or acceptable key sizes in any provided policy may change during the lifetime of Red Hat Enterprise Linux.

Such changes reflect new security standards and new security research. If you must ensure interoperability with a specific system for the whole lifetime of Red Hat Enterprise Linux, you should opt-out from the system-wide cryptographic policies for components that interact with that system or re-enable specific algorithms using custom cryptographic policies.

The specific algorithms and ciphers described as allowed in the policy levels are available only if an application supports them:

Table 3.1. Cipher suites and protocols enabled in the cryptographic policies

	LEGACY	DEFAULT	FIPS	FUTURE
IKEv1	no	no	no	no
3DES	yes	no	no	no
RC4	yes	no	no	no
DH	min. 1024-bit	min. 2048-bit	min. 2048-bit ^[a]	min. 3072-bit
RSA	min. 1024-bit	min. 2048-bit	min. 2048-bit	min. 3072-bit
DSA	yes	no	no	no
TLS v1.0	yes	no	no	no
TLS v1.1	yes	no	no	no
SHA-1 in digital signatures	yes	yes	no	no
CBC mode ciphers	yes	yes	yes	no ^[b]

	LEGACY	DEFAULT	FIPS	FUTURE
Symmetric ciphers with keys < 256 bits	yes	yes	yes	no
SHA-1 and SHA-224 signatures in certificates	yes	yes	yes	no
<p>[a] You can use only Diffie-Hellman groups defined in RFC 7919 and RFC 3526.</p> <p>[b] CBC ciphers are disabled for TLS. In a non-TLS scenario, AES-128-CBC is disabled but AES-256-CBC is enabled. To disable also AES-256-CBC, apply a custom subpolicy.</p>				

Additional resources

- **crypto-policies(7)** and **update-crypto-policies(8)** man pages on your system
- [Product compliance](#) (Red Hat Customer Portal)

3.2. CHANGING THE SYSTEM-WIDE CRYPTOGRAPHIC POLICY

You can change the system-wide cryptographic policy on your system by using the **update-crypto-policies** tool and restarting your system.

Prerequisites

- You have root privileges on the system.

Procedure

- Optional: Display the current cryptographic policy:

```
$ update-crypto-policies --show
DEFAULT
```

- Set the new cryptographic policy:

```
# update-crypto-policies --set <POLICY>
<POLICY>
```

Replace **<POLICY>** with the policy or subpolicy you want to set, for example **FUTURE**, **LEGACY** or **FIPS:OSPP**.

- Restart the system:

```
# reboot
```

Verification

- Display the current cryptographic policy:

```
$ update-crypto-policies --show
<POLICY>
```

Additional resources

- For more information on system-wide cryptographic policies, see [System-wide cryptographic policies](#)

3.3. SWITCHING THE SYSTEM-WIDE CRYPTOGRAPHIC POLICY TO MODE COMPATIBLE WITH EARLIER RELEASES

The default system-wide cryptographic policy in Red Hat Enterprise Linux 8 does not allow communication using older, insecure protocols. For environments that require to be compatible with Red Hat Enterprise Linux 6 and in some cases also with earlier releases, the less secure **LEGACY** policy level is available.



WARNING

Switching to the **LEGACY** policy level results in a less secure system and applications.

Procedure

1. To switch the system-wide cryptographic policy to the **LEGACY** level, enter the following command as **root**:

```
# update-crypto-policies --set LEGACY
Setting system policy to LEGACY
```

Additional resources

- For the list of available cryptographic policy levels, see the **update-crypto-policies(8)** man page on your system.
- For defining custom cryptographic policies, see the **Custom Policies** section in the **update-crypto-policies(8)** man page and the **Crypto Policy Definition Format** section in the **crypto-policies(7)** man page on your system.

3.4. SETTING UP SYSTEM-WIDE CRYPTOGRAPHIC POLICIES IN THE WEB CONSOLE

You can set one of system-wide cryptographic policies and subpolicies directly in the RHEL web console interface. Besides the four predefined system-wide cryptographic policies, you can also apply the following combinations of policies and subpolicies through the graphical interface now:

DEFAULT:SHA1

The **DEFAULT** policy with the **SHA-1** algorithm enabled.

LEGACY:AD-SUPPORT

The **LEGACY** policy with less secure settings that improve interoperability for Active Directory services.

FIPS:OSPP

The **FIPS** policy with further restrictions required by the Common Criteria for Information Technology Security Evaluation standard.



WARNING

Because the **FIPS:OSPP** system-wide subpolicy contains further restrictions for cryptographic algorithms required by the Common Criteria (CC) certification, the system is less interoperable after you set it. For example, you cannot use RSA and DH keys shorter than 3072 bits, additional SSH algorithms, and several TLS groups. Setting **FIPS:OSPP** also prevents connecting to Red Hat Content Delivery Network (CDN) structure. Furthermore, you cannot integrate Active Directory (AD) into the IdM deployments that use **FIPS:OSPP**, communication between RHEL hosts using **FIPS:OSPP** and AD domains might not work, or some AD accounts might not be able to authenticate.

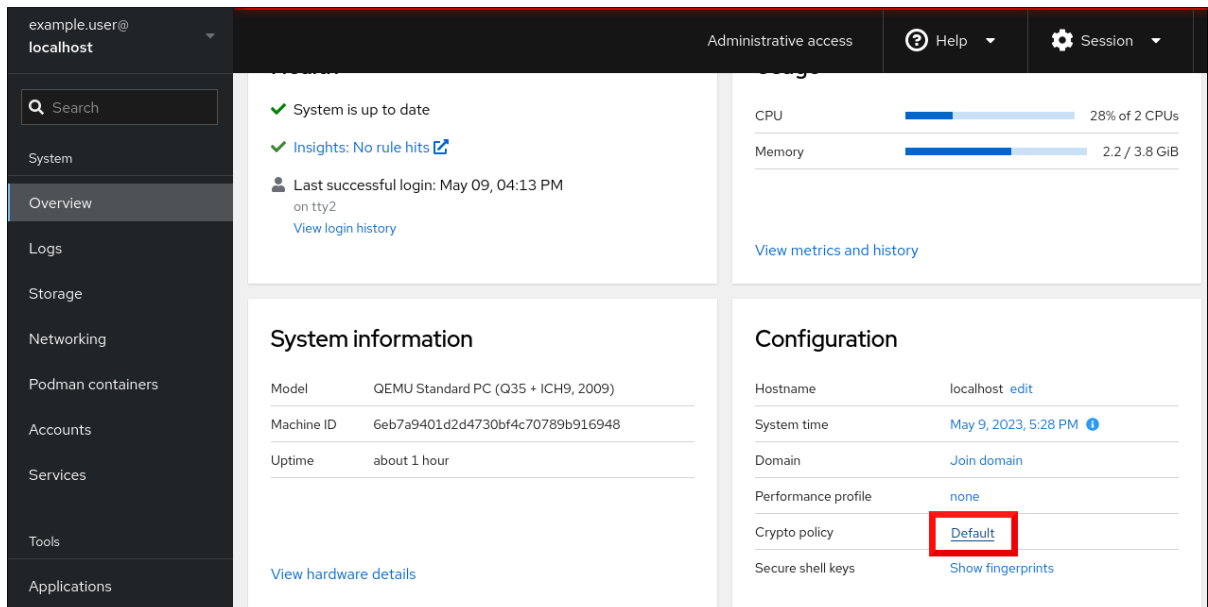
Note that your **system is not CC-compliant** after you set the **FIPS:OSPP** cryptographic subpolicy. The only correct way to make your RHEL system compliant with the CC standard is by following the guidance provided in the **cc-config** package. See the [Common Criteria](#) section on the [Product compliance](#) Red Hat Customer Portal page for a list of certified RHEL versions, validation reports, and links to CC guides hosted at the [National Information Assurance Partnership \(NIAP\)](#) website.

Prerequisites

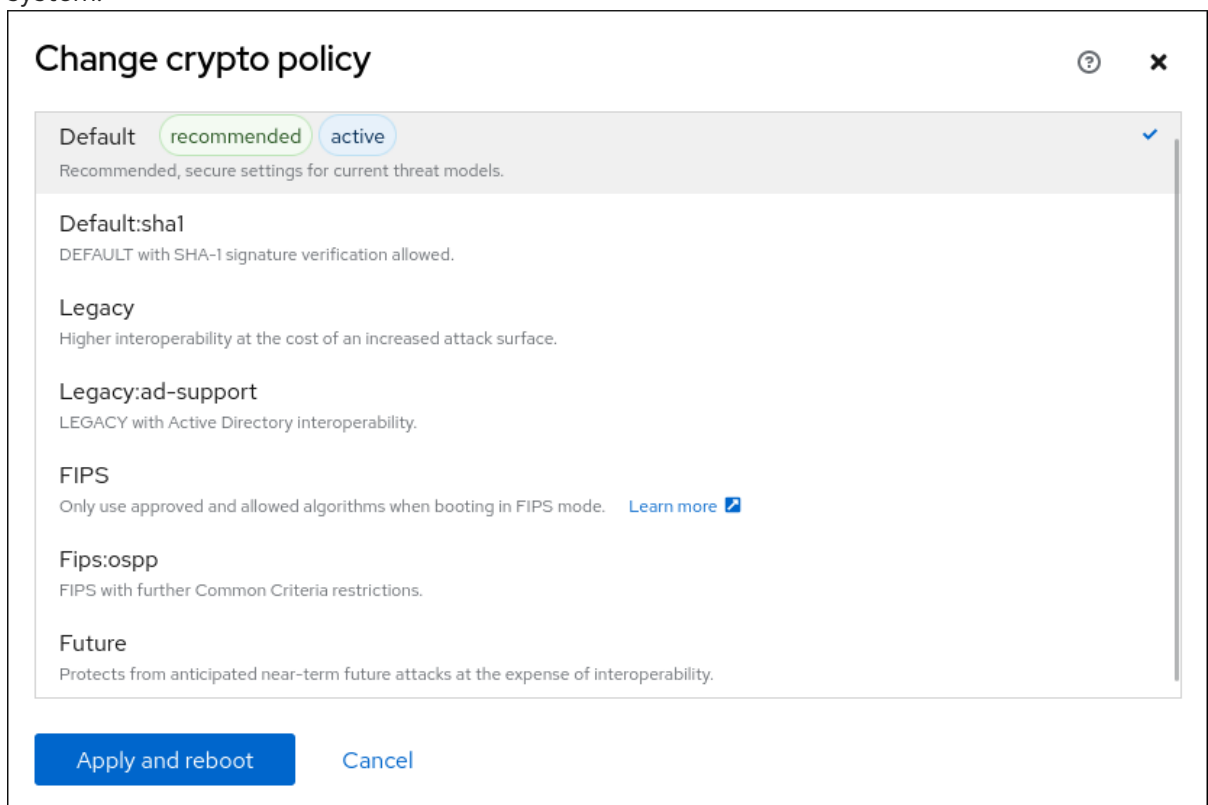
- You have installed the RHEL 8 web console.
- You have enabled the cockpit service.
- Your user account is allowed to log in to the web console.
For instructions, see [Installing and enabling the web console](#).
- You have **root** privileges or permissions to enter administrative commands with **sudo**.

Procedure

1. Log in to the RHEL 8 web console.
For details, see [Logging in to the web console](#).
2. In the **Configuration** card of the **Overview** page, click your current policy value next to **Crypto policy**.



3. In the **Change crypto policy** dialog window, click on the policy you want to start using on your system.



4. Click the **Apply and reboot** button.

Verification

- After the restart, log back in to web console, and check that the **Crypto policy** value corresponds to the one you selected.
Alternatively, you can enter the **update-crypto-policies --show** command to display the current system-wide cryptographic policy in your terminal.

3.5. EXCLUDING AN APPLICATION FROM FOLLOWING SYSTEM-WIDE CRYPTOGRAPHIC POLICIES

You can customize cryptographic settings used by your application preferably by configuring supported cipher suites and protocols directly in the application.

You can also remove a symlink related to your application from the **/etc/crypto-policies/back-ends** directory and replace it with your customized cryptographic settings. This configuration prevents the use of system-wide cryptographic policies for applications that use the excluded back end. Furthermore, this modification is not supported by Red Hat.

3.5.1. Examples of opting out of the system-wide cryptographic policies

wget

To customize cryptographic settings used by the **wget** network downloader, use **--secure-protocol** and **--ciphers** options. For example:

```
$ wget --secure-protocol=TLSv1_1 --ciphers="SECURE128" https://example.com
```

See the HTTPS (SSL/TLS) Options section of the **wget(1)** man page for more information.

curl

To specify ciphers used by the **curl** tool, use the **--ciphers** option and provide a colon-separated list of ciphers as a value. For example:

```
$ curl https://example.com --ciphers '@SECLEVEL=0:DES-CBC3-SHA:RSA-DES-CBC3-SHA'
```

See the **curl(1)** man page for more information.

Firefox

Even though you cannot opt out of system-wide cryptographic policies in the **Firefox** web browser, you can further restrict supported ciphers and TLS versions in Firefox's Configuration Editor. Type **about:config** in the address bar and change the value of the **security.tls.version.min** option as required. Setting **security.tls.version.min** to **1** allows TLS 1.0 as the minimum required, **security.tls.version.min 2** enables TLS 1.1, and so on.

OpenSSH

To opt out of the system-wide cryptographic policies for your OpenSSH server, uncomment the line with the **CRYPTO_POLICY=** variable in the **/etc/sysconfig/sshd** file. After this change, values that you specify in the **Ciphers**, **MACs**, **KexAlgorithms**, and **GSSAPIKexAlgorithms** sections in the **/etc/ssh/sshd_config** file are not overridden.

See the **sshd_config(5)** man page for more information.

To opt out of system-wide cryptographic policies for your OpenSSH client, perform one of the following tasks:

- For a given user, override the global **ssh_config** with a user-specific configuration in the **~/.ssh/config** file.
- For the entire system, specify the cryptographic policy in a drop-in configuration file located in the **/etc/ssh/ssh_config.d/** directory, with a two-digit number prefix smaller than 5, so that it lexicographically precedes the **05-redhat.conf** file, and with a **.conf** suffix, for example, **04-crypto-policy-override.conf**.

See the **ssh_config(5)** man page for more information.

Libreswan

See the [Configuring IPsec connections that opt out of the system-wide crypto policies](#) in the [Securing networks](#) document for detailed information.

Additional resources

- **update-crypto-policies(8)** man page on your system

3.6. CUSTOMIZING SYSTEM-WIDE CRYPTOGRAPHIC POLICIES WITH SUBPOLICIES

Use this procedure to adjust the set of enabled cryptographic algorithms or protocols.

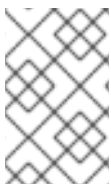
You can either apply custom subpolicies on top of an existing system-wide cryptographic policy or define such a policy from scratch.

The concept of scoped policies allows enabling different sets of algorithms for different back ends. You can limit each configuration directive to specific protocols, libraries, or services.

Furthermore, directives can use asterisks for specifying multiple values using wildcards.

The **/etc/crypto-policies/state/CURRENT.pol** file lists all settings in the currently applied system-wide cryptographic policy after wildcard expansion. To make your cryptographic policy more strict, consider using values listed in the **/usr/share/crypto-policies/policies/FUTURE.pol** file.

You can find example subpolicies in the **/usr/share/crypto-policies/policies/modules/** directory. The subpolicy files in this directory contain also descriptions in lines that are commented out.



NOTE

Customization of system-wide cryptographic policies is available from RHEL 8.2. You can use the concept of scoped policies and the option of using wildcards in RHEL 8.5 and newer.

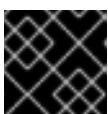
Procedure

1. Checkout to the **/etc/crypto-policies/policies/modules/** directory:

```
# cd /etc/crypto-policies/policies/modules/
```

2. Create subpolicies for your adjustments, for example:

```
# touch MYCRYPTO-1.pmod
# touch SCOPES-AND-WILDCARDS.pmod
```



IMPORTANT

Use upper-case letters in file names of policy modules.

3. Open the policy modules in a text editor of your choice and insert options that modify the system-wide cryptographic policy, for example:

```
# vi MYCRYPTO-1.pmod
```

```
min_rsa_size = 3072  
hash = SHA2-384 SHA2-512 SHA3-384 SHA3-512
```

```
# vi SCOPES-AND-WILDCARDS.pmod
```

```
# Disable the AES-128 cipher, all modes  
cipher = -AES-128-*
```

```
# Disable CHACHA20-POLY1305 for the TLS protocol (OpenSSL, GnuTLS, NSS, and  
OpenJDK)  
cipher@TLS = -CHACHA20-POLY1305
```

```
# Allow using the FFDHE-1024 group with the SSH protocol (libssh and OpenSSH)  
group@SSH = FFDHE-1024+
```

```
# Disable all CBC mode ciphers for the SSH protocol (libssh and OpenSSH)  
cipher@SSH = -*-CBC
```

```
# Allow the AES-256-CBC cipher in applications using libssh  
cipher@libssh = AES-256-CBC+
```

4. Save the changes in the module files.
5. Apply your policy adjustments to the **DEFAULT** system-wide cryptographic policy level:

```
# update-crypto-policies --set DEFAULT:MYCRYPTO-1:SCOPES-AND-WILDCARDS
```

6. To make your cryptographic settings effective for already running services and applications, restart the system:

```
# reboot
```

Verification

- Check that the `/etc/crypto-policies/state/CURRENT.pol` file contains your changes, for example:

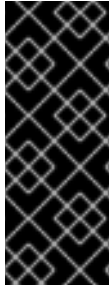
```
$ cat /etc/crypto-policies/state/CURRENT.pol | grep rsa_size  
min_rsa_size = 3072
```

Additional resources

- **Custom Policies** section in the **update-crypto-policies(8)** man page on your system
- **Crypto Policy Definition Format** section in the **crypto-policies(7)** man page on your system
- [How to customize crypto policies in RHEL 8.2](#) Red Hat blog article

3.7. DISABLING SHA-1 BY CUSTOMIZING A SYSTEM-WIDE CRYPTOGRAPHIC POLICY

Because the SHA-1 hash function has an inherently weak design, and advancing cryptanalysis has made it vulnerable to attacks, RHEL 8 does not use SHA-1 by default. Nevertheless, some third-party applications, for example, public signatures, still use SHA-1. To disable the use of SHA-1 in signature algorithms on your system, you can use the **NO-SHA1** policy module.



IMPORTANT

The **NO-SHA1** policy module disables the SHA-1 hash function only in signatures and not elsewhere. In particular, the **NO-SHA1** module still allows the use of SHA-1 with hash-based message authentication codes (HMAC). This is because HMAC security properties do not rely on the collision resistance of the corresponding hash function, and therefore the recent attacks on SHA-1 have a significantly lower impact on the use of SHA-1 for HMAC.

If your scenario requires disabling a specific key exchange (KEX) algorithm combination, for example, **diffie-hellman-group-exchange-sha1**, but you still want to use both the relevant KEX and the algorithm in other combinations, see the Red Hat Knowledgebase solution [Steps to disable the diffie-hellman-group1-sha1 algorithm in SSH](#) for instructions on opting out of system-wide crypto-policies for SSH and configuring SSH directly.



NOTE

The module for disabling SHA-1 is available from RHEL 8.3. Customization of system-wide cryptographic policies is available from RHEL 8.2.

Procedure

1. Apply your policy adjustments to the **DEFAULT** system-wide cryptographic policy level:

```
# update-crypto-policies --set DEFAULT:NO-SHA1
```

2. To make your cryptographic settings effective for already running services and applications, restart the system:

```
# reboot
```

Additional resources

- **Custom Policies** section in the **update-crypto-policies(8)** man page on your system
- **Crypto Policy Definition Format** section in the **crypto-policies(7)** man page on your system
- [How to customize crypto policies in RHEL](#) Red Hat blog article.

3.8. CREATING AND SETTING A CUSTOM SYSTEM-WIDE CRYPTOGRAPHIC POLICY

For specific scenarios, you can customize the system-wide cryptographic policy by creating and using a complete policy file.

**NOTE**

Customization of system-wide cryptographic policies is available from RHEL 8.2.

Procedure

1. Create a policy file for your customizations:

```
# cd /etc/crypto-policies/policies/
# touch MYPOLICY.pol
```

Alternatively, start by copying one of the four predefined policy levels:

```
# cp /usr/share/crypto-policies/policies/DEFAULT.pol /etc/crypto-
policies/policies/MYPOLICY.pol
```

2. Edit the file with your custom cryptographic policy in a text editor of your choice to fit your requirements, for example:

```
# vi /etc/crypto-policies/policies/MYPOLICY.pol
```

3. Switch the system-wide cryptographic policy to your custom level:

```
# update-crypto-policies --set MYPOLICY
```

4. To make your cryptographic settings effective for already running services and applications, restart the system:

```
# reboot
```

Additional resources

- **Custom Policies** section in the **update-crypto-policies(8)** man page and the **Crypto Policy Definition Format** section in the **crypto-policies(7)** man page on your system
- [How to customize crypto policies in RHEL](#) Red Hat blog article

3.9. ENHANCING SECURITY WITH THE **FUTURE CRYPTOGRAPHIC POLICY** USING THE **CRYPTO_POLICIES** RHEL SYSTEM ROLE

You can use the **crypto_policies** RHEL system role to configure the **FUTURE** policy on your managed nodes. This policy helps to achieve for example:

- Future-proofing against emerging threats: anticipates advancements in computational power.
- Enhanced security: stronger encryption standards require longer key lengths and more secure algorithms.
- Compliance with high-security standards: for example in healthcare, telco, and finance the data sensitivity is high, and availability of strong cryptography is critical.

Typically, **FUTURE** is suitable for environments handling highly sensitive data, preparing for future regulations, or adopting long-term security strategies.



WARNING

Legacy systems or software does not have to support the more modern and stricter algorithms and protocols enforced by the **FUTURE** policy. For example, older systems might not support TLS 1.3 or larger key sizes. This could lead to compatibility problems.

Also, using strong algorithms usually increases the computational workload, which could negatively affect your system performance.

Prerequisites

- You have prepared the control node and the managed nodes
- You are logged in to the control node as a user who can run playbooks on the managed nodes.
- The account you use to connect to the managed nodes has **sudo** permissions on them.

Procedure

1. Create a playbook file, for example `~/playbook.yml`, with the following content:

```
---
- name: Configure cryptographic policies
  hosts: managed-node-01.example.com
  tasks:
    - name: Configure the FUTURE cryptographic security policy on the managed node
      ansible.builtin.include_role:
        name: redhat.rhel_system_roles.crypto_policies
      vars:
        - crypto_policies_policy: FUTURE
        - crypto_policies_reboot_ok: true
```

The settings specified in the example playbook include the following:

crypto_policies_policy: FUTURE

Configures the required cryptographic policy (**FUTURE**) on the managed node. It can be either the base policy or a base policy with some sub-policies. The specified base policy and sub-policies have to be available on the managed node. The default value is **null**. It means that the configuration is not changed and the **crypto_policies** RHEL system role will only collect the Ansible facts.

crypto_policies_reboot_ok: true

Causes the system to reboot after the cryptographic policy change to make sure all of the services and applications will read the new configuration files. The default value is **false**.

For details about all variables used in the playbook, see the `/usr/share/ansible/roles/rhel-system-roles.crypto_policies/README.md` file on the control node.

2. Validate the playbook syntax:

```
$ ansible-playbook --syntax-check ~/playbook.yml
```

Note that this command only validates the syntax and does not protect against a wrong but valid configuration.

3. Run the playbook:

```
$ ansible-playbook ~/playbook.yml
```



WARNING

Because the **FIPS:OSPP** system-wide subpolicy contains further restrictions for cryptographic algorithms required by the Common Criteria (CC) certification, the system is less interoperable after you set it. For example, you cannot use RSA and DH keys shorter than 3072 bits, additional SSH algorithms, and several TLS groups. Setting **FIPS:OSPP** also prevents connecting to Red Hat Content Delivery Network (CDN) structure. Furthermore, you cannot integrate Active Directory (AD) into the IdM deployments that use **FIPS:OSPP**, communication between RHEL hosts using **FIPS:OSPP** and AD domains might not work, or some AD accounts might not be able to authenticate.

Note that your **system is not CC-compliant** after you set the **FIPS:OSPP** cryptographic subpolicy. The only correct way to make your RHEL system compliant with the CC standard is by following the guidance provided in the **cc-config** package. See the [Common Criteria](#) section on the [Product compliance](#) Red Hat Customer Portal page for a list of certified RHEL versions, validation reports, and links to CC guides hosted at the [National Information Assurance Partnership \(NIAP\)](#) website.

Verification

1. On the control node, create another playbook named, for example, **verify_playbook.yml**:

```
---
- name: Verification
  hosts: managed-node-01.example.com
  tasks:
    - name: Verify active cryptographic policy
      ansible.builtin.include_role:
        name: redhat.rhel_system_roles.crypto_policies
    - name: Display the currently active cryptographic policy
      ansible.builtin.debug:
        var: crypto_policies_active
```

The settings specified in the example playbook include the following:

crypto_policies_active

An exported Ansible fact that contains the currently active policy name in the format as accepted by the **crypto_policies_policy** variable.

2. Validate the playbook syntax:

```
$ ansible-playbook --syntax-check ~/verify_playbook.yml
```

3. Run the playbook:

```
$ ansible-playbook ~/verify_playbook.yml
TASK [debug] *****
ok: [host] => {
  "crypto_policies_active": "FUTURE"
}
```

The **crypto_policies_active** variable shows the active policy on the managed node.

Additional resources

- [/usr/share/ansible/roles/rhel-system-roles.crypto_policies/README.md](#) file
- [/usr/share/doc/rhel-system-roles/crypto_policies/](#) directory
- [update-crypto-policies\(8\)](#) and [crypto-policies\(7\)](#) manual pages

3.10. ADDITIONAL RESOURCES

- [System-wide crypto policies in RHEL 8](#) and [Strong crypto defaults in RHEL 8 and deprecation of weak crypto algorithms](#) Knowledgebase articles

CHAPTER 4. CONFIGURING APPLICATIONS TO USE CRYPTOGRAPHIC HARDWARE THROUGH PKCS #11

Separating parts of your secret information about dedicated cryptographic devices, such as smart cards and cryptographic tokens for end-user authentication and hardware security modules (HSM) for server applications, provides an additional layer of security. In RHEL, support for cryptographic hardware through the PKCS #11 API is consistent across different applications, and the isolation of secrets on cryptographic hardware is not a complicated task.

4.1. CRYPTOGRAPHIC HARDWARE SUPPORT THROUGH PKCS #11

Public-Key Cryptography Standard (PKCS) #11 defines an application programming interface (API) to cryptographic devices that hold cryptographic information and perform cryptographic functions.

PKCS #11 introduces the *cryptographic token*, an object that presents each hardware or software device to applications in a unified manner. Therefore, applications view devices such as smart cards, which are typically used by persons, and hardware security modules, which are typically used by computers, as PKCS #11 cryptographic tokens.

A PKCS #11 token can store various object types including a certificate; a data object; and a public, private, or secret key. These objects are uniquely identifiable through the PKCS #11 Uniform Resource Identifier (URI) scheme.

A PKCS #11 URI is a standard way to identify a specific object in a PKCS #11 module according to the object attributes. This enables you to configure all libraries and applications with the same configuration string in the form of a URI.

RHEL provides the OpenSC PKCS #11 driver for smart cards by default. However, hardware tokens and HSMs can have their own PKCS #11 modules that do not have their counterpart in the system. You can register such PKCS #11 modules with the **p11-kit** tool, which acts as a wrapper over the registered smart-card drivers in the system.

To make your own PKCS #11 module work on the system, add a new text file to the **/etc/pkcs11/modules/** directory

You can add your own PKCS #11 module into the system by creating a new text file in the **/etc/pkcs11/modules/** directory. For example, the OpenSC configuration file in **p11-kit** looks as follows:

```
$ cat /usr/share/p11-kit/modules/opensc.module  
module: opensc-pkcs11.so
```

Additional resources

- [Consistent PKCS #11 support in Red Hat Enterprise Linux 8](#)
- [The PKCS #11 URI Scheme](#)
- [Controlling access to smart cards](#)

4.2. AUTHENTICATING BY SSH KEYS STORED ON A SMART CARD

You can create and store ECDSA and RSA keys on a smart card and authenticate by the smart card on an OpenSSH client. Smart-card authentication replaces the default password authentication.

Prerequisites

- On the client side, the **opensc** package is installed and the **pcscd** service is running.

Procedure

- List all keys provided by the OpenSC PKCS #11 module including their PKCS #11 URIs and save the output to the **keys.pub** file:

```
$ ssh-keygen -D pkcs11: > keys.pub
```

- Transfer the public key to the remote server. Use the **ssh-copy-id** command with the **keys.pub** file created in the previous step:

```
$ ssh-copy-id -f -i keys.pub <username@ssh-server-example.com>
```

- Connect to *<ssh-server-example.com>* by using the ECDSA key. You can use just a subset of the URI, which uniquely references your key, for example:

```
$ ssh -i "pkcs11:id=%01?module-path=/usr/lib64/pkcs11/opensc-pkcs11.so" <ssh-server-example.com>
Enter PIN for 'SSH key':
[ssh-server-example.com] $
```

Because OpenSSH uses the **p11-kit-proxy** wrapper and the OpenSC PKCS #11 module is registered to the **p11-kit** tool, you can simplify the previous command:

```
$ ssh -i "pkcs11:id=%01" <ssh-server-example.com>
Enter PIN for 'SSH key':
[ssh-server-example.com] $
```

If you skip the **id=** part of a PKCS #11 URI, OpenSSH loads all keys that are available in the proxy module. This can reduce the amount of typing required:

```
$ ssh -i pkcs11: <ssh-server-example.com>
Enter PIN for 'SSH key':
[ssh-server-example.com] $
```

- Optional: You can use the same URI string in the *~/.ssh/config* file to make the configuration permanent:

```
$ cat ~/.ssh/config
IdentityFile "pkcs11:id=%01?module-path=/usr/lib64/pkcs11/opensc-pkcs11.so"
$ ssh <ssh-server-example.com>
Enter PIN for 'SSH key':
[ssh-server-example.com] $
```

The **ssh** client utility now automatically uses this URI and the key from the smart card.

Additional resources

- p11-kit(8)**, **opensc.conf(5)**, **pcscd(8)**, **ssh(1)**, and **ssh-keygen(1)** man pages on your system

4.3. CONFIGURING APPLICATIONS FOR AUTHENTICATION WITH CERTIFICATES ON SMART CARDS

Authentication by using smart cards in applications may increase security and simplify automation. You can integrate the Public Key Cryptography Standard (PKCS) #11 URIs into your application by using the following methods:

- The **Firefox** web browser automatically loads the **p11-kit-proxy** PKCS #11 module. This means that every supported smart card in the system is automatically detected. For using TLS client authentication, no additional setup is required and keys and certificates from a smart card are automatically used when a server requests them.
- If your application uses the **GnuTLS** or **NSS** library, it already supports PKCS #11 URIs. Also, applications that rely on the **OpenSSL** library can access cryptographic hardware modules, including smart cards, through the **pkcs11** engine provided by the **openssl-pkcs11** package.
- Applications that require working with private keys on smart cards and that do not use **NSS**, **GnuTLS**, nor **OpenSSL** can use the **p11-kit** API directly to work with cryptographic hardware modules, including smart cards, rather than using the PKCS #11 API of specific PKCS #11 modules.
- With the **wget** network downloader, you can specify PKCS #11 URIs instead of paths to locally stored private keys and certificates. This might simplify creation of scripts for tasks that require safely stored private keys and certificates. For example:

```
$ wget --private-key 'pkcs11:token=softhsm;id=%01;type=private?pin-value=111111' --
certificate 'pkcs11:token=softhsm;id=%01;type=cert' https://example.com/
```

- You can also specify PKCS #11 URI when using the **curl** tool:

```
$ curl --key 'pkcs11:token=softhsm;id=%01;type=private?pin-value=111111' --cert
'pkcs11:token=softhsm;id=%01;type=cert' https://example.com/
```

Additional resources

- **curl(1)**, **wget(1)**, and **p11-kit(8)** man pages on your system

4.4. USING HSMS PROTECTING PRIVATE KEYS IN APACHE

The **Apache** HTTP server can work with private keys stored on hardware security modules (HSMs), which helps to prevent the keys' disclosure and man-in-the-middle attacks. Note that this usually requires high-performance HSMs for busy servers.

For secure communication in the form of the HTTPS protocol, the **Apache** HTTP server (**httpd**) uses the OpenSSL library. OpenSSL does not support PKCS #11 natively. To use HSMs, you have to install the **openssl-pkcs11** package, which provides access to PKCS #11 modules through the engine interface. You can use a PKCS #11 URI instead of a regular file name to specify a server key and a certificate in the **/etc/httpd/conf.d/ssl.conf** configuration file, for example:

```
SSLCertificateFile "pkcs11:id=%01;token=softhsm;type=cert"
SSLCertificateKeyFile "pkcs11:id=%01;token=softhsm;type=private?pin-value=111111"
```

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 the **/usr/share/httpd/manual/mod/mod_ssl.html** file.

4.5. USING HSMS PROTECTING PRIVATE KEYS IN NGINX

The **Nginx** HTTP server can work with private keys stored on hardware security modules (HSMs), which helps to prevent the keys' disclosure and man-in-the-middle attacks. Note that this usually requires high-performance HSMs for busy servers.

Because **Nginx** also uses the OpenSSL for cryptographic operations, support for PKCS #11 must go through the **openssl-pkcs11** engine. **Nginx** currently supports only loading private keys from an HSM, and a certificate must be provided separately as a regular file. Modify the **ssl_certificate** and **ssl_certificate_key** options in the **server** section of the **/etc/nginx/nginx.conf** configuration file:

```
ssl_certificate    /path/to/cert.pem
ssl_certificate_key "engine:pkcs11:pkcs11:token=softhsm;id=%01;type=private?pin-value=111111";
```

Note that the **engine:pkcs11:** prefix is needed for the PKCS #11 URI in the **Nginx** configuration file. This is because the other **pkcs11** prefix refers to the engine name.

4.6. ADDITIONAL RESOURCES

- **pkcs11.conf(5)** man page on your system

CHAPTER 5. CONTROLLING ACCESS TO SMART CARDS BY USING POLKIT

To cover possible threats that cannot be prevented by mechanisms built into smart cards, such as PINs, PIN pads, and biometrics, and for more fine-grained control, RHEL uses the **polkit** framework for controlling access control to smart cards.

System administrators can configure **polkit** to fit specific scenarios, such as smart-card access for non-privileged or non-local users or services.

5.1. SMART-CARD ACCESS CONTROL THROUGH POLKIT

The Personal Computer/Smart Card (PC/SC) protocol specifies a standard for integrating smart cards and their readers into computing systems. In RHEL, the **pcsc-lite** package provides middleware to access smart cards that use the PC/SC API. A part of this package, the **pcscd** (PC/SC Smart Card) daemon, ensures that the system can access a smart card using the PC/SC protocol.

Because access-control mechanisms built into smart cards, such as PINs, PIN pads, and biometrics, do not cover all possible threats, RHEL uses the **polkit** framework for more robust access control. The **polkit** authorization manager can grant access to privileged operations. In addition to granting access to disks, you can use **polkit** also to specify policies for securing smart cards. For example, you can define which users can perform which operations with a smart card.

After installing the **pcsc-lite** package and starting the **pcscd** daemon, the system enforces policies defined in the **/usr/share/polkit-1/actions/** directory. The default system-wide policy is in the **/usr/share/polkit-1/actions/org.debian.pcsc-lite.policy** file. Polkit policy files use the XML format and the syntax is described in the **polkit(8)** man page on your system.

The **polkitd** service monitors the **/etc/polkit-1/rules.d/** and **/usr/share/polkit-1/rules.d/** directories for any changes in rule files stored in these directories. The files contain authorization rules in JavaScript format. System administrators can add custom rule files in both directories, and **polkitd** reads them in lexical order based on their file name. If two files have the same names, then the file in **/etc/polkit-1/rules.d/** is read first.

If you need to enable smart-card support when the system security services daemon (SSSD) does not run as **root**, you must install the **sssd-polkit-rules** package. The package provides **polkit** integration with SSSD.

Additional resources

- **polkit(8)**, **polkitd(8)**, and **pcscd(8)** man pages on your system

5.2. TROUBLESHOOTING PROBLEMS RELATED TO PC/SC AND POLKIT

Polkit policies that are automatically enforced after you install the **pcsc-lite** package and start the **pcscd** daemon may ask for authentication in the user's session even if the user does not directly interact with a smart card. In GNOME, you can see the following error message:

Authentication is required to access the PC/SC daemon

Note that the system can install the **pcsc-lite** package as a dependency when you install other packages related to smart cards such as **opensc**.

If your scenario does not require any interaction with smart cards and you want to prevent displaying authorization requests for the PC/SC daemon, you can remove the **pcsc-lite** package. Keeping the minimum of necessary packages is a good security practice anyway.

If you use smart cards, start troubleshooting by checking the rules in the system-provided policy file at **/usr/share/polkit-1/actions/org.debian.pcsc-lite.policy**. You can add your custom rule files to the policy in the **/etc/polkit-1/rules.d/** directory, for example, **03-allow-pcsd.rules**. Note that the rule files use the JavaScript syntax, the policy file is in the XML format.

To understand what authorization requests the system displays, check the Journal log, for example:

```
$ journalctl -b | grep pcsc
...
Process 3087 (user: 1001) is NOT authorized for action: access_pcsc
...
```

The previous log entry means that the user is not authorized to perform an action by the policy. You can solve this denial by adding a corresponding rule to **/etc/polkit-1/rules.d/**.

You can search also for log entries related to the **polkitd** unit, for example:

```
$ journalctl -u polkit
...
polkitd[NNN]: Error compiling script /etc/polkit-1/rules.d/00-debug-pcsd.rules
...
polkitd[NNN]: Operator of unix-session:c2 FAILED to authenticate to gain authorization for action
org.debian.pcsc-lite.access_pcsc for unix-process:4800:14441 [/usr/libexec/gsd-smartcard] (owned
by unix-user:group)
...
```

In the previous output, the first entry means that the rule file contains some syntax error. The second entry means that the user failed to gain the access to **pcscd**.

You can also list all applications that use the PC/SC protocol by a short script. Create an executable file, for example, **pcsc-apps.sh**, and insert the following code:

```
#!/bin/bash

cd /proc

for p in [0-9]*
do
  if grep libpcsc-lite.so.1.0.0 $p/maps &> /dev/null
  then
    echo -n "process: "
    cat $p/cmdline
    echo " ($p)"
  fi
done
```

Run the script as **root**:

```
# ./pcsc-apps.sh
process: /usr/libexec/gsd-smartcard (3048)
enable-sync --auto-ssl-client-auth --enable-crashpad (4828)
```

...

Additional resources

- **journalctl**, **polkit(8)**, **polkitd(8)**, and **pcscd(8)** man pages.

5.3. DISPLAYING MORE DETAILED INFORMATION ABOUT POLKIT AUTHORIZATION TO PC/SC

In the default configuration, the **polkit** authorization framework sends only limited information to the Journal log. You can extend **polkit** log entries related to the PC/SC protocol by adding new rules.

Prerequisites

- You have installed the **pcsc-lite** package on your system.
- The **pcscd** daemon is running.

Procedure

1. Create a new file in the **/etc/polkit-1/rules.d/** directory:

```
# touch /etc/polkit-1/rules.d/00-test.rules
```

2. Edit the file in an editor of your choice, for example:

```
# vi /etc/polkit-1/rules.d/00-test.rules
```

3. Insert the following lines:

```
polkit.addRule(function(action, subject) {  
    if (action.id == "org.debian.pcsc-lite.access_pcsc" ||  
        action.id == "org.debian.pcsc-lite.access_card") {  
        polkit.log("action=" + action);  
        polkit.log("subject=" + subject);  
    }  
});
```

Save the file, and exit the editor.

4. Restart the **pcscd** and **polkit** services:

```
# systemctl restart pcscd.service pcscd.socket polkit.service
```

Verification

1. Make an authorization request for **pcscd**. For example, open the Firefox web browser or use the **pkcs11-tool -L** command provided by the **opensc** package.
2. Display the extended log entries, for example:

```
# journalctl -u polkit --since "1 hour ago"
```



```
polkitd[1224]: <no filename>:4: action=[Action id='org.debian.pcsc-lite.access_pcsc']
polkitd[1224]: <no filename>:5: subject=[Subject pid=2020481 user=user'
groups=user,wheel,mock,wireshark seat=null session=null local=true active=true]
```

Additional resources

- **polkit(8)** and **polkitd(8)** man pages.

5.4. ADDITIONAL RESOURCES

- [Controlling access to smart cards](#) Red Hat Blog article.

CHAPTER 6. SCANNING THE SYSTEM FOR CONFIGURATION COMPLIANCE AND VULNERABILITIES

A compliance audit is a process of determining whether a given object follows all the rules specified in a compliance policy. The compliance policy is defined by security professionals who specify the required settings, often in the form of a checklist, that a computing environment should use.

Compliance policies can vary substantially across organizations and even across different systems within the same organization. Differences among these policies are based on the purpose of each system and its importance for the organization. Custom software settings and deployment characteristics also raise a need for custom policy checklists.

6.1. CONFIGURATION COMPLIANCE TOOLS IN RHEL

You can perform a fully automated compliance audit in Red Hat Enterprise Linux by using the following configuration compliance tools. These tools are based on the Security Content Automation Protocol (SCAP) standard and are designed for automated tailoring of compliance policies.

SCAP Workbench

The **scap-workbench** graphical utility is designed to perform configuration and vulnerability scans on a single local or remote system. You can also use it to generate security reports based on these scans and evaluations.

OpenSCAP

The **OpenSCAP** library, with the accompanying **oscap** command-line utility, is designed to perform configuration and vulnerability scans on a local system, to validate configuration compliance content, and to generate reports and guides based on these scans and evaluations.



IMPORTANT

You can experience memory-consumption problems while using **OpenSCAP**, which can cause stopping the program prematurely and prevent generating any result files. See the [OpenSCAP memory-consumption problems](#) Knowledgebase article for details.

SCAP Security Guide (SSG)

The **scap-security-guide** package provides collections 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.

Script Check Engine (SCE)

With SCE, which is an extension to the SCAP protocol, administrators can write their security content by using a scripting language, such as Bash, Python, and Ruby. The SCE extension is provided in the **openscap-engine-sce** package. The SCE itself is not part of the SCAP standard.

To perform automated compliance audits on multiple systems remotely, you can use the OpenSCAP solution for Red Hat Satellite.

Additional resources

- **oscap(8)**, **scap-workbench(8)**, and **scap-security-guide(8)** man pages on your system

- [Red Hat Security Demos: Creating Customized Security Policy Content to Automate Security Compliance](#)
- [Red Hat Security Demos: Defend Yourself with RHEL Security Technologies](#)
- [Managing security compliance in Red Hat Satellite](#)

6.2. VULNERABILITY SCANNING

6.2.1. Red Hat Security Advisories OVAL feed

Red Hat Enterprise Linux security auditing capabilities are based on the Security Content Automation Protocol (SCAP) standard. SCAP is a multi-purpose framework of specifications that supports automated configuration, vulnerability and patch checking, technical control compliance activities, and security measurement.

SCAP specifications create an ecosystem where the format of security content is well-known and standardized although the implementation of the scanner or policy editor is not mandated. This enables organizations to build their security policy (SCAP content) once, no matter how many security vendors they employ.

The Open Vulnerability Assessment Language (OVAL) is the essential and oldest component of SCAP. Unlike other tools and custom scripts, OVAL describes a required state of resources in a declarative manner. OVAL code is never executed directly but using an OVAL interpreter tool called scanner. The declarative nature of OVAL ensures that the state of the assessed system is not accidentally modified.

Like all other SCAP components, OVAL is based on XML. The SCAP standard defines several document formats. Each of them includes a different kind of information and serves a different purpose.

[Red Hat Product Security](#) helps customers evaluate and manage risk by tracking and investigating all security issues affecting Red Hat customers. It provides timely and concise patches and security advisories on the Red Hat Customer Portal. Red Hat creates and supports OVAL patch definitions, providing machine-readable versions of our security advisories.

Because of differences between platforms, versions, and other factors, Red Hat Product Security qualitative severity ratings of vulnerabilities do not directly align with the Common Vulnerability Scoring System (CVSS) baseline ratings provided by third parties. Therefore, we recommend that you use the RHSA OVAL definitions instead of those provided by third parties.

The [RHSA OVAL definitions](#) are available individually and as a complete package, and are updated within an hour of a new security advisory being made available on the Red Hat Customer Portal.

Each OVAL patch definition maps one-to-one to a Red Hat Security Advisory (RHSA). Because an RHSA can contain fixes for multiple vulnerabilities, each vulnerability is listed separately by its Common Vulnerabilities and Exposures (CVE) name and has a link to its entry in our public bug database.

The RHSA OVAL definitions are designed to check for vulnerable versions of RPM packages installed on a system. It is possible to extend these definitions to include further checks, for example, to find out if the packages are being used in a vulnerable configuration. These definitions are designed to cover software and updates shipped by Red Hat. Additional definitions are required to detect the patch status of third-party software.



NOTE

The [Red Hat Insights for Red Hat Enterprise Linux compliance service](#) helps IT security and compliance administrators to assess, monitor, and report on the security policy compliance of Red Hat Enterprise Linux systems. You can also create and manage your SCAP security policies entirely within the compliance service UI.

Additional resources

- [Red Hat and OVAL compatibility](#)
- [Red Hat and CVE compatibility](#)
- [Notifications and Advisories](#) in the [Product Security Overview](#)
- [Security Data Metrics](#)

6.2.2. Scanning the system for vulnerabilities

The **oscap** command-line utility enables you to scan local systems, validate configuration 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.

Prerequisites

- The **openscap-scanner** and **bzip2** packages are installed.

Procedure

1. Download the latest RHSA OVAL definitions for your system:

```
# wget -O - https://www.redhat.com/security/data/oval/v2/RHEL8/rhel-8.oval.xml.bz2 | bzip2 -  
-decompress > rhel-8.oval.xml
```

2. Scan the system for vulnerabilities and save results to the *vulnerability.html* file:

```
# oscap oval eval --report vulnerability.html rhel-8.oval.xml
```

Verification

- Check the results in a browser of your choice, for example:

```
$ firefox vulnerability.html &
```

Additional resources

- **oscap(8)** man page on your system
- [Red Hat OVAL definitions](#)
- [OpenSCAP memory consumption problems](#)

6.2.3. Scanning remote systems for vulnerabilities

You can check remote systems for vulnerabilities with the OpenSCAP scanner by using the **oscap-ssh** tool over the SSH protocol.

Prerequisites

- The **openscap-utils** and **bzip2** packages are installed on the system you use for scanning.
- The **openscap-scanner** package is installed on the remote systems.
- The SSH server is running on the remote systems.

Procedure

1. Download the latest RHSA OVAL definitions for your system:

```
# wget -O - https://www.redhat.com/security/data/oval/v2/RHEL8/rhel-8.oval.xml.bz2 | bzip2 -  
-decompress > rhel-8.oval.xml
```

2. Scan a remote system for vulnerabilities and save the results to a file:

```
# oscap-ssh <username>@<hostname> <port> oval eval --report <scan-report.html> rhel-  
8.oval.xml
```

Replace:

- **<username>@<hostname>** with the user name and host name of the remote system.
- **<port>** with the port number through which you can access the remote system, for example, **22**.
- **<scan-report.html>** with the file name where **oscap** saves the scan results.

Additional resources

- **oscap-ssh(8)**
- [Red Hat OVAL definitions](#)
- [OpenSCAP memory consumption problems](#)

6.3. CONFIGURATION COMPLIANCE SCANNING

6.3.1. Configuration compliance in RHEL

You can use configuration compliance scanning to conform to a baseline defined by a specific organization. For example, if you work with the US government, you might have to align your systems with the Operating System Protection Profile (OSPP), and if you are a payment processor, you might have to align your systems with the Payment Card Industry Data Security Standard (PCI-DSS). You can also perform configuration compliance scanning to harden your system security.

Red Hat recommends you follow the Security Content Automation Protocol (SCAP) content provided in the SCAP Security Guide package because it is in line with Red Hat best practices for affected components.

The SCAP Security Guide package provides content which conforms to the SCAP 1.2 and SCAP 1.3 standards. The **openscap scanner** utility is compatible with both SCAP 1.2 and SCAP 1.3 content provided in the SCAP Security Guide package.

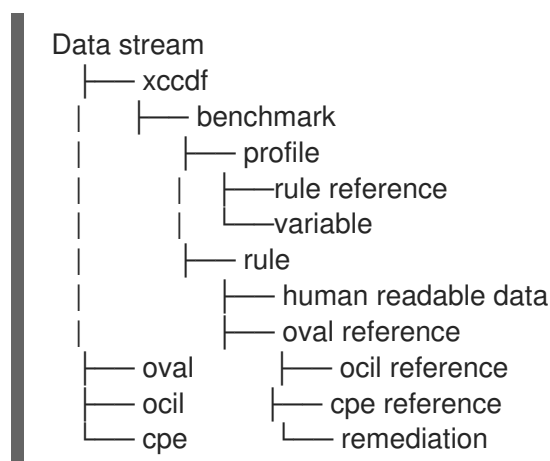


IMPORTANT

Performing a configuration compliance scanning does not guarantee the system is compliant.

The SCAP Security Guide suite provides profiles for several platforms in a form of data stream documents. A data stream is a file that contains definitions, benchmarks, profiles, and individual rules. Each rule specifies the applicability and requirements for compliance. RHEL provides several profiles for compliance with security policies. In addition to the industry standard, Red Hat data streams also contain information for remediation of failed rules.

Structure of compliance scanning resources



A profile is a set of rules based on a security policy, such as OSPP, PCI-DSS, and Health Insurance Portability and Accountability Act (HIPAA). This enables you to audit the system in an automated way for compliance with security standards.

You can modify (tailor) a profile to customize certain rules, for example, password length. For more information about profile tailoring, see [Customizing a security profile with SCAP Workbench](#).

6.3.2. Possible results of an OpenSCAP scan

Depending on the data stream and profile applied to an OpenSCAP scan, as well as various properties of your system, each rule may produce a specific result. These are the possible results with brief explanations of their meanings:

Pass

The scan did not find any conflicts with this rule.

Fail

The scan found a conflict with this rule.

Not checked

OpenSCAP does not perform an automatic evaluation of this rule. Check whether your system conforms to this rule manually.

Not applicable

This rule does not apply to the current configuration.

Not selected

This rule is not part of the profile. OpenSCAP does not evaluate this rule and does not display these rules in the results.

Error

The scan encountered an error. For additional information, you can enter the **oscap** command with the **--verbose DEVEL** option. File a support case on the [Red Hat customer portal](#) or open a ticket in the [RHEL project in Red Hat Jira](#).

Unknown

The scan encountered an unexpected situation. For additional information, you can enter the **oscap** command with the **--verbose DEVEL** option. File a support case on the [Red Hat customer portal](#) or open a ticket in the [RHEL project in Red Hat Jira](#).

6.3.3. Viewing profiles for configuration compliance

Before you decide to use profiles for scanning or remediation, you can list them and check their detailed descriptions using the **oscap info** subcommand.

Prerequisites

- The **openscap-scanner** and **scap-security-guide** packages are installed.

Procedure

1. List all available files with security compliance profiles provided by the SCAP Security Guide project:

```
$ ls /usr/share/xml/scap/ssg/content/
ssg-firefox-cpe-dictionary.xml  ssg-rhel6-ocil.xml
ssg-firefox-cpe-oval.xml       ssg-rhel6-oval.xml
...
ssg-rhel6-ds-1.2.xml           ssg-rhel8-oval.xml
ssg-rhel8-ds.xml               ssg-rhel8-xccdf.xml
...
```

2. Display detailed information about a selected data stream using the **oscap info** subcommand. XML files containing data streams are indicated by the **-ds** string in their names. In the **Profiles** section, you can find a list of available profiles and their IDs:

```
$ oscap info /usr/share/xml/scap/ssg/content/ssg-rhel8-ds.xml
Profiles:
...
Title: Health Insurance Portability and Accountability Act (HIPAA)
Id: xccdf_org.ssgproject.content_profile_hipaa
Title: PCI-DSS v3.2.1 Control Baseline for Red Hat Enterprise Linux 8
Id: xccdf_org.ssgproject.content_profile_pci-dss
Title: OSPP - Protection Profile for General Purpose Operating Systems
Id: xccdf_org.ssgproject.content_profile_ospp
...
```

3. Select a profile from the data stream file and display additional details about the selected profile. To do so, use **oscap info** with the **--profile** option followed by the last section of the ID displayed in the output of the previous command. For example, the ID of the HIPPA profile is **xccdf_org.ssgproject.content_profile_hipaa**, and the value for the **--profile** option is **hipaa**:

```
$ oscap info --profile hipaa /usr/share/xml/scap/ssg/content/ssg-rhel8-ds.xml
...
Profile
Title: Health Insurance Portability and Accountability Act (HIPAA)

Description: The HIPAA Security Rule establishes U.S. national standards to protect
individuals' electronic personal health information that is created, received, used, or
maintained by a covered entity.
...
```

Additional resources

- **scap-security-guide(8)** man page on your system
- [OpenSCAP memory consumption problems](#)

6.3.4. Assessing configuration compliance with a specific baseline

You can determine whether your system or a remote system conforms to a specific baseline, and save the results in a report by using the **oscap** command-line tool.

Prerequisites

- The **openscap-scanner** and **scap-security-guide** packages are installed.
- You know the ID of the profile within the baseline with which the system should comply. To find the ID, see the [Viewing profiles for configuration compliance](#) section.

Procedure

1. Scan the local system for compliance with the selected profile and save the scan results to a file:

```
$ oscap xccdf eval --report <scan-report.html> --profile <profileID>
/usr/share/xml/scap/ssg/content/ssg-rhel8-ds.xml
```

Replace:

- **<scan-report.html>** with the file name where **oscap** saves the scan results.
 - **<profileID>** with the profile ID with which the system should comply, for example, **hipaa**.
2. Optional: Scan a remote system for compliance with the selected profile and save the scan results to a file:

```
$ oscap-ssh <username>@<hostname> <port> xccdf eval --report <scan-report.html> --
profile <profileID> /usr/share/xml/scap/ssg/content/ssg-rhel8-ds.xml
```

Replace:

- **<username>@<hostname>** with the user name and host name of the remote system.
- **<port>** with the port number through which you can access the remote system.
- **<scan-report.html>** with the file name where **oscap** saves the scan results.
- **<profileID>** with the profile ID with which the system should comply, for example, **hipaa**.

Additional resources

- **scap-security-guide(8)** man page on your system
- **SCAP Security Guide** documentation in the **/usr/share/doc/scap-security-guide/** directory
- **/usr/share/doc/scap-security-guide/guides/ssg-rhel8-guide-index.html** – [Guide to the Secure Configuration of Red Hat Enterprise Linux 8] installed with the **scap-security-guide-doc** package
- [OpenSCAP memory consumption problems](#)

6.4. REMEDIATING THE SYSTEM TO ALIGN WITH A SPECIFIC BASELINE

You can remediate the RHEL system to align with a specific baseline. You can remediate the system to align with any profile provided by the SCAP Security Guide. For the details on listing the available profiles, see the [Viewing profiles for configuration compliance](#) section.



WARNING

If not used carefully, running the system evaluation with the **Remediate** option enabled might render the system non-functional. Red Hat does not provide any automated method to revert changes made by security-hardening remediations. Remediations are supported on RHEL systems in the default configuration. If your system has been altered after the installation, running remediation might not make it compliant with the required security profile.

Prerequisites

- The **scap-security-guide** package is installed.

Procedure

1. Remediate the system by using the **oscap** command with the **--remediate** option:

```
# oscap xccdf eval --profile <profileID> --remediate /usr/share/xml/scap/ssg/content/ssg-rhel8-ds.xml
```

Replace **<profileID>** with the profile ID with which the system should comply, for example, **hipaa**.

2. Restart your system.

Verification

1. Evaluate compliance of the system with the profile, and save the scan results to a file:

```
$ oscap xccdf eval --report <scan-report.html> --profile <profileID>
/usr/share/xml/scap/ssg/content/ssg-rhel8-ds.xml
```

Replace:

- **<scan-report.html>** with the file name where **oscap** saves the scan results.
- **<profileID>** with the profile ID with which the system should comply, for example, **hipaa**.

Additional resources

- **scap-security-guide(8)** and **oscap(8)** man pages on your system
- [Complementing the DISA benchmark using the SSG content](#) Knowledgebase article

6.5. REMEDIATING THE SYSTEM TO ALIGN WITH A SPECIFIC BASELINE BY USING AN SSG ANSIBLE PLAYBOOK

You can remediate your system to align with a specific baseline by using an Ansible Playbook file from the SCAP Security Guide project. You can remediate to align with any profile provided by the SCAP Security Guide.



WARNING

If not used carefully, running the system evaluation with the **Remediate** option enabled might render the system non-functional. Red Hat does not provide any automated method to revert changes made by security-hardening remediations. Remediations are supported on RHEL systems in the default configuration. If your system has been altered after the installation, running remediation might not make it compliant with the required security profile.

Prerequisites

- The **scap-security-guide** package is installed.
- The **ansible-core** package is installed. See the [Ansible Installation Guide](#) for more information.
- The **rhc-worker-playbook** package is installed.
- You know the ID of the profile according to which you want to remediate your system. For details, see [Viewing profiles for configuration compliance](#).
- RHEL 8.6 or later is installed. For more information about installing RHEL, see [Interactively installing RHEL from installation media](#).



NOTE

In RHEL 8.5 and earlier versions, Ansible packages were provided through Ansible Engine instead of Ansible Core, and with a different level of support. Do not use Ansible Engine because the packages might not be compatible with Ansible automation content in RHEL 8.6 and later. For more information, see [Scope of support for the Ansible Core package included in the RHEL 9 and RHEL 8.6 and later AppStream repositories](#).

Procedure

1. Remediate your system to align with a selected profile by using Ansible:

```
# ANSIBLE_COLLECTIONS_PATH=/usr/share/rhc-worker-
playbook/ansible/collections/ansible_collections/ ansible-playbook -i "localhost," -c local
/usr/share/scap-security-guide/ansible/rhel8-playbook-<profileID>.yml
```

The **ANSIBLE_COLLECTIONS_PATH** environment variable is necessary for the command to run the playbook.

Replace **<profileID>** with the profile ID of the selected profile.

2. Restart the system.

Verification

- Evaluate the compliance of the system with the selected profile, and save the scan results to a file:

```
# oscap xccdf eval --profile <profileID> --report <scan-report.html>
/usr/share/xml/scap/ssg/content/ssg-rhel8-ds.xml
```

Replace **<scan-report.html>** with the file name where **oscap** saves the scan results.

Additional resources

- **scap-security-guide(8)** and **oscap(8)** man pages on your system
- [Ansible Documentation](#)

6.6. CREATING A REMEDIATION ANSIBLE PLAYBOOK TO ALIGN THE SYSTEM WITH A SPECIFIC BASELINE

You can create an Ansible Playbook that contains only the remediations that are required to align your system with a specific baseline. This playbook is smaller because it does not cover already satisfied requirements. Creating the playbook does not modify your system in any way, you only prepare a file for later application.



NOTE

In RHEL 8.6, Ansible Engine is replaced by the **ansible-core** package, which contains only built-in modules. Note that many Ansible remediations use modules from the community and Portable Operating System Interface (POSIX) collections, which are not included in the built-in modules. In this case, you can use Bash remediations as a substitute for Ansible remediations. The Red Hat Connector in RHEL 8.6 includes the Ansible modules necessary for the remediation playbooks to function with Ansible Core.

Prerequisites

- The **scap-security-guide** package is installed.
- The **ansible-core** package is installed. See the [Ansible Installation Guide](#) for more information.
- The **rhc-worker-playbook** package is installed.
- You know the ID of the profile according to which you want to remediate your system. For details, see [Viewing profiles for configuration compliance](#).

Procedure

1. Scan the system and save the results:

```
# oscap xccdf eval --profile <profileID> --results <profile-results.xml>
/usr/share/xml/scap/ssg/content/ssg-rhel8-ds.xml
```

2. Find the value of the result ID in the file with the results:

```
# oscap info <profile-results.xml>
```

3. Generate an Ansible Playbook based on the file generated in step 1:

```
# oscap xccdf generate fix --fix-type ansible --result-id xccdf_org.open-
scap_testresult_xccdf_org.ssgproject.content_profile_<profileID> --output <profile-
remediations.yml> <profile-results.xml>
```

4. Review that the generated **<profile-remediations.yml>** file contains Ansible remediations for rules that failed in the scan performed in step 1.
5. Remediate your system to align with a selected profile by using Ansible:

```
# ANSIBLE_COLLECTIONS_PATH=/usr/share/rhc-worker-
playbook/ansible/collections/ansible_collections/ ansible-playbook -i "localhost," -c local
<profile-remediations.yml>
```

The **ANSIBLE_COLLECTIONS_PATH** environment variable is necessary for the command to run the playbook.

**WARNING**

If not used carefully, running the system evaluation with the **Remediate** option enabled might render the system non-functional. Red Hat does not provide any automated method to revert changes made by security-hardening remediations. Remediations are supported on RHEL systems in the default configuration. If your system has been altered after the installation, running remediation might not make it compliant with the required security profile.

Verification

- Evaluate the compliance of the system with the selected profile, and save the scan results to a file:

```
# oscap xccdf eval --profile <profileID> --report <scan-report.html>
/usr/share/xml/scap/ssg/content/ssg-rhel8-ds.xml
```

Replace **<scan-report.html>** with the file name where **oscap** saves the scan results.

Additional resources

- **scap-security-guide(8)** and **oscap(8)** man pages on your system
- [Ansible Documentation](#)

6.7. CREATING A REMEDIATION BASH SCRIPT FOR A LATER APPLICATION

Use this procedure to create a Bash script containing remediations that align your system with a security profile such as HIPAA. Using the following steps, you do not do any modifications to your system, you only prepare a file for later application.

Prerequisites

- The **scap-security-guide** package is installed on your RHEL system.

Procedure

1. Use the **oscap** command to scan the system and to save the results to an XML file. In the following example, **oscap** evaluates the system against the **hipaa** profile:

```
# oscap xccdf eval --profile hipaa --results <hipaa-results.xml>
/usr/share/xml/scap/ssg/content/ssg-rhel8-ds.xml
```

2. Find the value of the result ID in the file with the results:

```
# oscap info <hipaa-results.xml>
```

3. Generate a Bash script based on the results file generated in step 1:

```
# oscap xccdf generate fix --fix-type bash --result-id <xccdf_org.open-  
scap_testresult_xccdf_org.ssgproject.content_profile_hipaa> --output <hipaa-  
remediations.sh> <hipaa-results.xml>
```

4. The **<hipaa-remediations.sh>** file contains remediations for rules that failed during the scan performed in step 1. After reviewing this generated file, you can apply it with the **./<hipaa-remediations.sh>** command when you are in the same directory as this file.

Verification

- In a text editor of your choice, review that the **<hipaa-remediations.sh>** file contains rules that failed in the scan performed in step 1.

Additional resources

- **scap-security-guide(8)**, **oscap(8)**, and **bash(1)** man pages on your system

6.8. SCANNING THE SYSTEM WITH A CUSTOMIZED PROFILE USING SCAP WORKBENCH

SCAP Workbench, which is contained in the **scap-workbench** package, 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 **SCAP Workbench** has limited functionality compared with the **oscap** command-line utility. **SCAP Workbench** processes security content in the form of data stream files.

6.8.1. Using SCAP Workbench to scan and remediate the system

To evaluate your system against the selected security policy, use the following procedure.

Prerequisites

- The **scap-workbench** package is installed on your system.

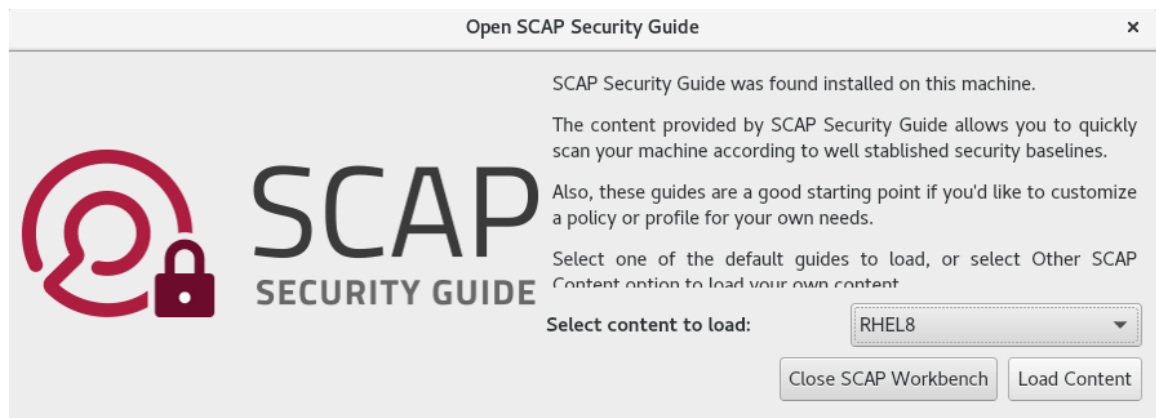
Procedure

1. To run **SCAP Workbench** from the **GNOME Classic** desktop environment, press the **Super** key to enter the **Activities Overview**, type **scap-workbench**, and then press **Enter**. Alternatively, use:

```
$ scap-workbench &
```

2. Select a security policy using either of the following options:

- **Load Content** button on the starting window
- **Open content from SCAP Security Guide**
- **Open Other Content** in the **File** menu, and search the respective XCCDF, SCAP RPM, or data stream file.



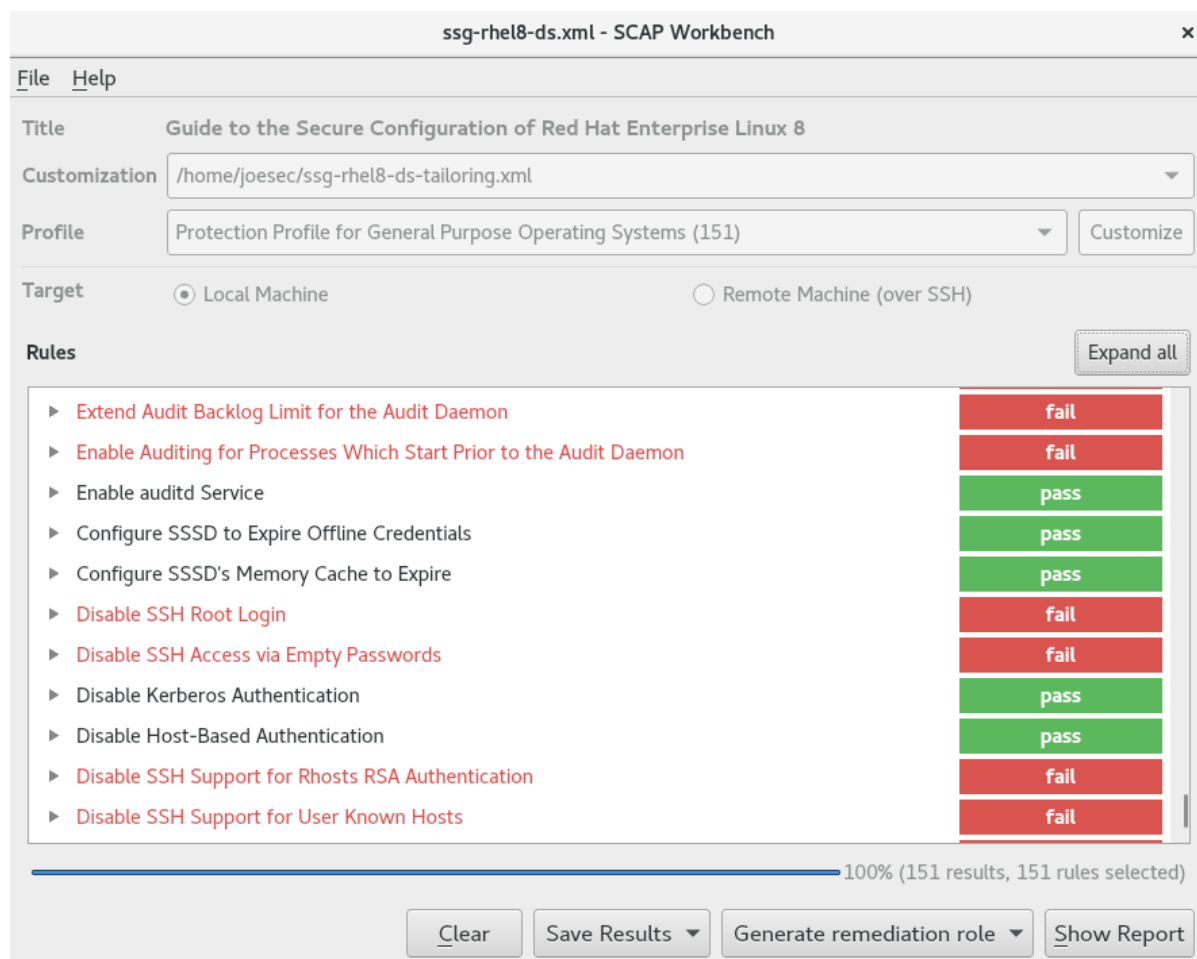
3. You can allow automatic correction of the system configuration by selecting the **Remediate** check box. With this option enabled, **SCAP Workbench** attempts to change the system configuration in accordance with the security rules applied by the policy. This process should fix the related checks that fail during the system scan.



WARNING

If not used carefully, running the system evaluation with the **Remediate** option enabled might render the system non-functional. Red Hat does not provide any automated method to revert changes made by security-hardening remediations. Remediations are supported on RHEL systems in the default configuration. If your system has been altered after the installation, running remediation might not make it compliant with the required security profile.

4. Scan your system with the selected profile by clicking the **Scan** button.



- To store the scan results in 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 format. The XCCDF and ARF (data stream) formats are suitable for further automatic processing. You can repeatedly choose all three options.
- To export results-based remediations to a file, use the **Generate remediation role** pop-up menu.

6.8.2. Customizing a security profile with SCAP Workbench

You can customize a security profile by changing parameters in certain rules (for example, minimum password length), removing rules that you cover in a different way, and selecting additional rules, to implement internal policies. You cannot define new rules by customizing a profile.

The following procedure demonstrates the use of **SCAP Workbench** for customizing (tailoring) a profile. You can also save the tailored profile for use with the **oscap** command-line utility.

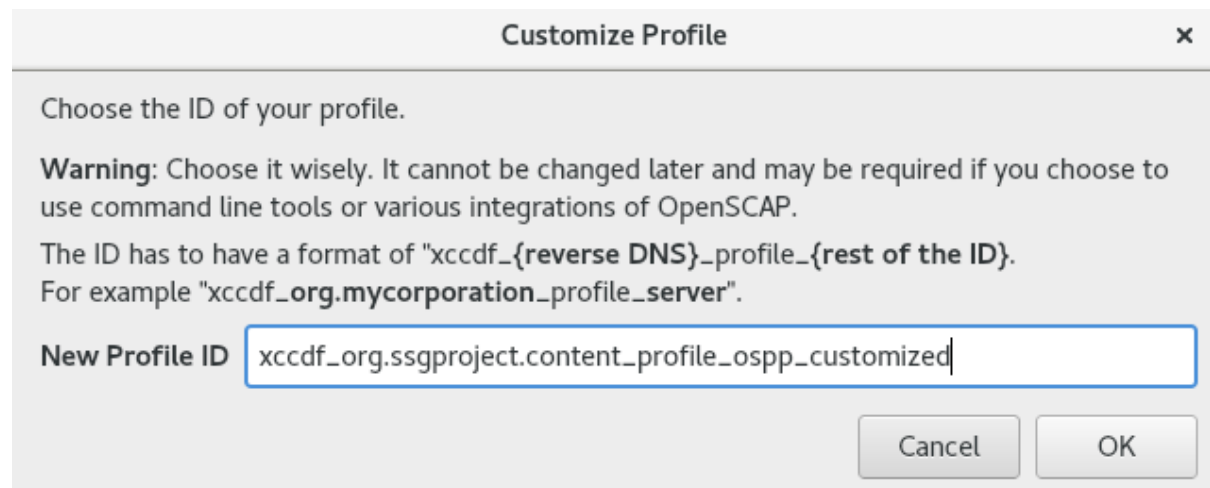
Prerequisites

- The **scap-workbench** package is installed on your system.

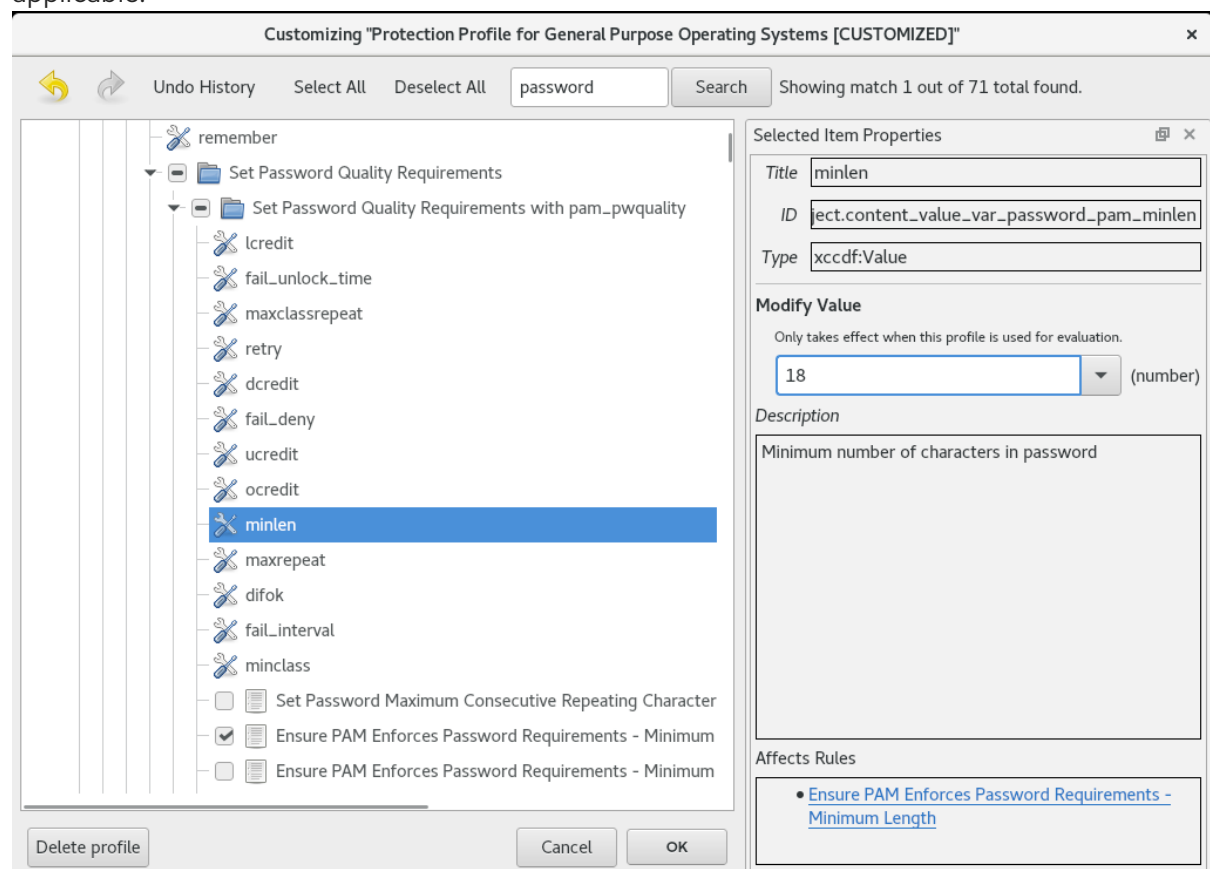
Procedure

- Run **SCAP Workbench**, and select the profile to customize by using either **Open content from SCAP Security Guide** or **Open Other Content** in the **File** menu.
- To adjust the selected security profile according to your needs, click the **Customize** button.

This opens the new Customization window that enables you to modify the currently selected profile without changing the original data stream file. Choose a new profile ID.



3. Find a rule to modify using either the tree structure with rules organized into logical groups or the **Search** field.
4. Include or exclude rules using check boxes in the tree structure, or modify values in rules where applicable.



5. Confirm the changes by clicking the **OK** button.
6. To store your changes permanently, use one of the following options:
 - Save a customization file separately by using **Save Customization Only** in the **File** menu.
 - Save all security content at once by **Save All** in the **File** menu.
If you select the **Into a directory** option, **SCAP Workbench** saves both the data stream file and the customization file to the specified location. You can use this as a backup solution.

By selecting the **As RPM** option, you can instruct **SCAP Workbench** to create an RPM package containing the data stream file and the customization file. This is useful for distributing the security content to systems that cannot be scanned remotely, and for delivering the content for further processing.



NOTE

Because **SCAP Workbench** does not support results-based remediations for tailored profiles, use the exported remediations with the **oscap** command-line utility.

6.8.3. Additional resources

- **scap-workbench(8)** man page on your system
- `/usr/share/doc/scap-workbench/user_manual.html` file provided by the **scap-workbench** package
- [Deploy customized SCAP policies with Satellite 6.x](#) (Red Hat Knowledgebase)

6.9. DEPLOYING SYSTEMS THAT ARE COMPLIANT WITH A SECURITY PROFILE IMMEDIATELY AFTER AN INSTALLATION

You can use the OpenSCAP suite to deploy RHEL systems that are compliant with a security profile, such as OSP, PCI-DSS, and HIPAA profile, immediately after the installation process. Using this deployment method, you can apply specific rules that cannot be applied later using remediation scripts, for example, a rule for password strength and partitioning.

6.9.1. Profiles not compatible with Server with GUI

Certain security profiles provided as part of the **SCAP Security Guide** are not compatible with the extended package set included in the **Server with GUI** base environment. Therefore, do not select **Server with GUI** when installing systems compliant with one of the following profiles:

Table 6.1. Profiles not compatible with Server with GUI

Profile name	Profile ID	Justification	Notes
CIS Red Hat Enterprise Linux 8 Benchmark for Level 2 - Server	xccdf_org.ssgproject.content_profile_cis	Packages xorg-x11-server-Xorg , xorg-x11-server-common , xorg-x11-server-utils , and xorg-x11-server-Xwayland are part of the Server with GUI package set, but the policy requires their removal.	

Profile name	Profile ID	Justification	Notes
CIS Red Hat Enterprise Linux 8 Benchmark for Level 1 – Server	xccdf_org.ssgproject.content_profile_cis_server_l1	Packages xorg-x11-server-Xorg , xorg-x11-server-common , xorg-x11-server-utils , and xorg-x11-server-Xwayland are part of the Server with GUI package set, but the policy requires their removal.	
Unclassified Information in Non-federal Information Systems and Organizations (NIST 800-171)	xccdf_org.ssgproject.content_profile_cui	The nfs-utils package is part of the Server with GUI package set, but the policy requires its removal.	
Protection Profile for General Purpose Operating Systems	xccdf_org.ssgproject.content_profile_ospp	The nfs-utils package is part of the Server with GUI package set, but the policy requires its removal.	
DISA STIG for Red Hat Enterprise Linux 8	xccdf_org.ssgproject.content_profile_stig	Packages xorg-x11-server-Xorg , xorg-x11-server-common , xorg-x11-server-utils , and xorg-x11-server-Xwayland are part of the Server with GUI package set, but the policy requires their removal.	To install a RHEL system as a Server with GUI aligned with DISA STIG in RHEL version 8.4 and later, you can use the DISA STIG with GUI profile.

6.9.2. Deploying baseline-compliant RHEL systems using the graphical installation

Use this procedure to deploy a RHEL system that is aligned with a specific baseline. This example uses Protection Profile for General Purpose Operating System (OSPP).



WARNING

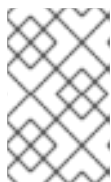
Certain security profiles provided as part of the **SCAP Security Guide** are not compatible with the extended package set included in the **Server with GUI** base environment. For additional details, see [Profiles not compatible with a GUI server](#).

Prerequisites

- You have booted into the **graphical** installation program. Note that the **OSCAP Anaconda Add-on** does not support interactive text-only installation.
- You have accessed the **Installation Summary** window.

Procedure

1. From the **Installation Summary** window, click **Software Selection**. The **Software Selection** window opens.
2. From the **Base Environment** pane, select the **Server** environment. You can select only one base environment.
3. Click **Done** to apply the setting and return to the **Installation Summary** window.
4. Because OSPP has strict partitioning requirements that must be met, create separate partitions for **/boot**, **/home**, **/var**, **/tmp**, **/var/log**, **/var/tmp**, and **/var/log/audit**.
5. Click **Security Policy**. The **Security Policy** window opens.
6. To enable security policies on the system, toggle the **Apply security policy** switch to **ON**.
7. Select **Protection Profile for General Purpose Operating Systems** from the profile pane.
8. Click **Select Profile** to confirm the selection.
9. Confirm the changes in the **Changes that were done or need to be done** pane that is displayed at the bottom of the window. Complete any remaining manual changes.
10. Complete the graphical installation process.



NOTE

The graphical installation program automatically creates a corresponding Kickstart file after a successful installation. You can use the **/root/anaconda-ks.cfg** file to automatically install OSPP-compliant systems.

Verification

- To check the current status of the system after installation is complete, reboot the system and start a new scan:

```
# oscap xccdf eval --profile ospp --report eval_postinstall_report.html  
/usr/share/xml/scap/ssg/content/ssg-rhel8-ds.xml
```

Additional resources

- [Configuring manual partitioning](#)

6.9.3. Deploying baseline-compliant RHEL systems using Kickstart

You can deploy RHEL systems that are aligned with a specific baseline. This example uses Protection Profile for General Purpose Operating System (OSPP).

Prerequisites

- The **scap-security-guide** package is installed on your RHEL 8 system.

Procedure

1. Open the `/usr/share/scap-security-guide/kickstart/ssg-rhel8-ospp-ks.cfg` Kickstart file in an editor of your choice.
2. Update the partitioning scheme to fit your configuration requirements. For OSPP compliance, the separate partitions for **/boot**, **/home**, **/var**, **/tmp**, **/var/log**, **/var/tmp**, and **/var/log/audit** must be preserved, and you can only change the size of the partitions.
3. Start a Kickstart installation as described in [Performing an automated installation using Kickstart](#).



IMPORTANT

Passwords in Kickstart files are not checked for OSPP requirements.

Verification

- To check the current status of the system after installation is complete, reboot the system and start a new scan:

```
# oscap xccdf eval --profile ospp --report eval_postinstall_report.html
/usr/share/xml/scap/ssg/content/ssg-rhel8-ds.xml
```

Additional resources

- [OSCAP Anaconda Add-on](#)
- [Kickstart commands and options reference: %addon org_fedora_oscap](#)

6.10. SCANNING CONTAINER AND CONTAINER IMAGES FOR VULNERABILITIES

Use this procedure to find security vulnerabilities in a container or a container image.



NOTE

The **oscap-podman** command is available from RHEL 8.2. For RHEL 8.1 and 8.0, use the workaround described in the [Using OpenSCAP for scanning containers in RHEL 8](#) Knowledgebase article.

Prerequisites

- The **openscap-utils** and **bzip2** packages are installed.

Procedure

1. Download the latest RHSA OVAL definitions for your system:

```
# wget -O - https://www.redhat.com/security/data/oval/v2/RHEL8/rhel-8.oval.xml.bz2 | bzip2 -
-decompress > rhel-8.oval.xml
```

2. Get the ID of a container or a container image, for example:

```
# podman images
REPOSITORY                                TAG      IMAGE ID      CREATED      SIZE
registry.access.redhat.com/ubi8/ubi      latest   096cae65a207  7 weeks ago  239 MB
```

3. Scan the container or the container image for vulnerabilities and save results to the *vulnerability.html* file:

```
# oscap-podman 096cae65a207 oval eval --report vulnerability.html rhel-8.oval.xml
```

Note that the **oscap-podman** command requires root privileges, and the ID of a container is the first argument.

Verification

- Check the results in a browser of your choice, for example:

```
$ firefox vulnerability.html &
```

Additional resources

- For more information, see the **oscap-podman(8)** and **oscap(8)** man pages.

6.11. ASSESSING SECURITY COMPLIANCE OF A CONTAINER OR A CONTAINER IMAGE WITH A SPECIFIC BASELINE

You can assess the compliance of your container or a container image with a specific security baseline, such as Operating System Protection Profile (OSPP), Payment Card Industry Data Security Standard (PCI-DSS), and Health Insurance Portability and Accountability Act (HIPAA).



NOTE

The **oscap-podman** command is available from RHEL 8.2. For RHEL 8.1 and 8.0, use the workaround described in the [Using OpenSCAP for scanning containers in RHEL 8](#) Knowledgebase article.

Prerequisites

- The **openscap-utils** and **scap-security-guide** packages are installed.
- You have root access to the system.

Procedure

1. Find the ID of a container or a container image:
 - a. To find the ID of a container, enter the **podman ps -a** command.
 - b. To find the ID of a container image, enter the **podman images** command.

- Evaluate the compliance of the container or container image with a profile and save the scan results into a file:

```
# oscap-podman <ID> xccdf eval --report <scan-report.html> --profile <profileID>
/usr/share/xml/scap/ssg/content/ssg-rhel8-ds.xml
```

Replace:

- **<ID>** with the ID of your container or container image
- **<scan-report.html>** with the file name where **oscap** saves the scan results
- **<profileID>** with the profile ID with which the system should comply, for example, **hipaa**, **ospp**, or **pci-dss**

Verification

- Check the results in a browser of your choice, for example:

```
$ firefox <scan-report.html> &
```



NOTE

The rules marked as **notapplicable** apply only to bare-metal and virtualized systems and not to containers or container images.

Additional resources

- **oscap-podman(8)** and **scap-security-guide(8)** man pages.
- **/usr/share/doc/scap-security-guide/** directory.

6.12. SCAP SECURITY GUIDE PROFILES SUPPORTED IN RHEL 8

Use only the SCAP content provided in the particular minor release of RHEL. This is because components that participate in hardening are sometimes updated with new capabilities. SCAP content changes to reflect these updates, but it is not always compatible with earlier versions.

In the following tables, you can find the profiles provided in each minor version of RHEL, together with the version of the policy with which the profile aligns.



NOTE

You can get the information relevant for the version of **scap-security-guide** RPM installed on your system by using the **oscap info** command. For more information, see [Viewing profiles for configuration compliance](#).

Table 6.2. SCAP Security Guide profiles supported in RHEL 8.10

Profile name	Profile ID	Policy version
French National Agency for the Security of Information Systems (ANSSI) BP-028 Enhanced Level	xccdf_org.ssgproject.content_profile_anssi_bp28_enhanced	2.0
French National Agency for the Security of Information Systems (ANSSI) BP-028 High Level	xccdf_org.ssgproject.content_profile_anssi_bp28_high	2.0
French National Agency for the Security of Information Systems (ANSSI) BP-028 Intermediary Level	xccdf_org.ssgproject.content_profile_anssi_bp28_intermediary	2.0
French National Agency for the Security of Information Systems (ANSSI) BP-028 Minimal Level	xccdf_org.ssgproject.content_profile_anssi_bp28_minimal	2.0
CIS Red Hat Enterprise Linux 8 Benchmark for Level 2 - Server	xccdf_org.ssgproject.content_profile_cis	3.0.0
CIS Red Hat Enterprise Linux 8 Benchmark for Level 1 - Server	xccdf_org.ssgproject.content_profile_cis_server_l1	3.0.0
CIS Red Hat Enterprise Linux 8 Benchmark for Level 1 - Workstation	xccdf_org.ssgproject.content_profile_cis_workstation_l1	3.0.0
CIS Red Hat Enterprise Linux 8 Benchmark for Level 2 - Workstation	xccdf_org.ssgproject.content_profile_cis_workstation_l2	3.0.0
Unclassified Information in Non-federal Information Systems and Organizations (NIST 800-171)	xccdf_org.ssgproject.content_profile_cui	r1
Australian Cyber Security Centre (ACSC) Essential Eight	xccdf_org.ssgproject.content_profile_e8	not versioned
Health Insurance Portability and Accountability Act (HIPAA)	xccdf_org.ssgproject.content_profile_hipaa	not versioned
Australian Cyber Security Centre (ACSC) ISM Official	xccdf_org.ssgproject.content_profile_ism_o	not versioned

Profile name	Profile ID	Policy version
Protection Profile for General Purpose Operating Systems	xccdf_org.ssgproject.content_profile_osp	4.2.1
PCI-DSS v3.2.1 Control Baseline for Red Hat Enterprise Linux 8	xccdf_org.ssgproject.content_profile_pci-dss	RHEL 8.10.0 to RHEL 8.10.4:4.0 RHEL 8.10.5 and later:4.0.1 RHEL 8.10.5 and later:4.0.1
The Defense Information Systems Agency Security Technical Implementation Guide (DISA STIG) for Red Hat Enterprise Linux 8	xccdf_org.ssgproject.content_profile_stig	V2R2
The Defense Information Systems Agency Security Technical Implementation Guide (DISA STIG) with GUI for Red Hat Enterprise Linux 8	xccdf_org.ssgproject.content_profile_stig_gui	V2R2

Table 6.3. SCAP Security Guide profiles supported in RHEL 8.9

Profile name	Profile ID	Policy version
French National Agency for the Security of Information Systems (ANSSI) BP-028 Enhanced Level	xccdf_org.ssgproject.content_profile_anssi_bp28_enhanced	2.0
French National Agency for the Security of Information Systems (ANSSI) BP-028 High Level	xccdf_org.ssgproject.content_profile_anssi_bp28_high	2.0
French National Agency for the Security of Information Systems (ANSSI) BP-028 Intermediary Level	xccdf_org.ssgproject.content_profile_anssi_bp28_intermediary	2.0
French National Agency for the Security of Information Systems (ANSSI) BP-028 Minimal Level	xccdf_org.ssgproject.content_profile_anssi_bp28_minimal	2.0
CIS Red Hat Enterprise Linux 8 Benchmark for Level 2 - Server	xccdf_org.ssgproject.content_profile_cis	RHEL 8.9.0 and RHEL 8.9.2:2.0.0 RHEL 8.9.3:3.0.0
CIS Red Hat Enterprise Linux 8 Benchmark for Level 1 - Server	xccdf_org.ssgproject.content_profile_cis_server_l1	RHEL 8.9.0 and RHEL 8.9.2:2.0.0 RHEL 8.9.3:3.0.0

Profile name	Profile ID	Policy version
CIS Red Hat Enterprise Linux 8 Benchmark for Level 1 - Workstation	xccdf_org.ssgproject.content_profile_cis_workstation_l1	RHEL 8.9.0 and RHEL 8.9.2:2.0.0 RHEL 8.9.3:3.0.0
CIS Red Hat Enterprise Linux 8 Benchmark for Level 2 - Workstation	xccdf_org.ssgproject.content_profile_cis_workstation_l2	RHEL 8.9.0 and RHEL 8.9.2:2.0.0 RHEL 8.9.3:3.0.0
Unclassified Information in Non-federal Information Systems and Organizations (NIST 800-171)	xccdf_org.ssgproject.content_profile_cui	r1
Australian Cyber Security Centre (ACSC) Essential Eight	xccdf_org.ssgproject.content_profile_e8	not versioned
Health Insurance Portability and Accountability Act (HIPAA)	xccdf_org.ssgproject.content_profile_hipaa	not versioned
Australian Cyber Security Centre (ACSC) ISM Official	xccdf_org.ssgproject.content_profile_ism_o	not versioned
Protection Profile for General Purpose Operating Systems	xccdf_org.ssgproject.content_profile_ospp	4.2.1
PCI-DSS v3.2.1 Control Baseline for Red Hat Enterprise Linux 8	xccdf_org.ssgproject.content_profile_pci-dss	RHEL 8.9.0 and RHEL 8.9.2:3.2.1 RHEL 8.9.3:4.0
The Defense Information Systems Agency Security Technical Implementation Guide (DISA STIG) for Red Hat Enterprise Linux 8	xccdf_org.ssgproject.content_profile_stig	RHEL 8.9.0 and RHEL 8.9.2:VIR11 RHEL 8.9.3:VIR13
The Defense Information Systems Agency Security Technical Implementation Guide (DISA STIG) with GUI for Red Hat Enterprise Linux 8	xccdf_org.ssgproject.content_profile_stig_gui	RHEL 8.9.0 and RHEL 8.9.2:VIR11 RHEL 8.9.3:VIR13

Table 6.4. SCAP Security Guide profiles supported in RHEL 8.8

Profile name	Profile ID	Policy version
French National Agency for the Security of Information Systems (ANSSI) BP-028 Enhanced Level	xccdf_org.ssgproject.content_profile_anssi_bp28_enhanced	2.0

Profile name	Profile ID	Policy version
French National Agency for the Security of Information Systems (ANSSI) BP-028 High Level	xccdf_org.ssgproject.content_profile_anssi_bp28_high	2.0
French National Agency for the Security of Information Systems (ANSSI) BP-028 Intermediary Level	xccdf_org.ssgproject.content_profile_anssi_bp28_intermediary	2.0
French National Agency for the Security of Information Systems (ANSSI) BP-028 Minimal Level	xccdf_org.ssgproject.content_profile_anssi_bp28_minimal	2.0
CIS Red Hat Enterprise Linux 8 Benchmark for Level 2 - Server	xccdf_org.ssgproject.content_profile_cis	RHEL 8.8.0 and RHEL 8.8.5:2.0.0 RHEL 8.8.6:3.0.0
CIS Red Hat Enterprise Linux 8 Benchmark for Level 1 - Server	xccdf_org.ssgproject.content_profile_cis_server_l1	RHEL 8.8.0 and RHEL 8.8.5:2.0.0 RHEL 8.8.6:3.0.0
CIS Red Hat Enterprise Linux 8 Benchmark for Level 1 - Workstation	xccdf_org.ssgproject.content_profile_cis_workstation_l1	RHEL 8.8.0 and RHEL 8.8.5:2.0.0 RHEL 8.8.6:3.0.0
CIS Red Hat Enterprise Linux 8 Benchmark for Level 2 - Workstation	xccdf_org.ssgproject.content_profile_cis_workstation_l2	RHEL 8.8.0 and RHEL 8.8.5:2.0.0 RHEL 8.8.6:3.0.0
Unclassified Information in Non-federal Information Systems and Organizations (NIST 800-171)	xccdf_org.ssgproject.content_profile_cui	r1
Australian Cyber Security Centre (ACSC) Essential Eight	xccdf_org.ssgproject.content_profile_e8	not versioned
Health Insurance Portability and Accountability Act (HIPAA)	xccdf_org.ssgproject.content_profile_hipaa	not versioned
Australian Cyber Security Centre (ACSC) ISM Official	xccdf_org.ssgproject.content_profile_ism_o	not versioned
Protection Profile for General Purpose Operating Systems	xccdf_org.ssgproject.content_profile_ospp	4.2.1
PCI-DSS v3.2.1 Control Baseline for Red Hat Enterprise Linux 8	xccdf_org.ssgproject.content_profile_pci-dss	RHEL 8.8.0 and RHEL 8.8.5:3.2.1 RHEL 8.8.6 to RHEL 8.8.12:4.0 RHEL 8.8.13 and later:4.0.1

Profile name	Profile ID	Policy version
The Defense Information Systems Agency Security Technical Implementation Guide (DISA STIG) for Red Hat Enterprise Linux 8	xccdf_org.ssgproject.content_profile_stig	V2R2
The Defense Information Systems Agency Security Technical Implementation Guide (DISA STIG) with GUI for Red Hat Enterprise Linux 8	xccdf_org.ssgproject.content_profile_stig_gui	V2R2

Table 6.5. SCAP Security Guide profiles supported in RHEL 8.7

Profile name	Profile ID	Policy version
French National Agency for the Security of Information Systems (ANSSI) BP-028 Enhanced Level	xccdf_org.ssgproject.content_profile_anssi_bp28_enhanced	1.2
French National Agency for the Security of Information Systems (ANSSI) BP-028 High Level	xccdf_org.ssgproject.content_profile_anssi_bp28_high	1.2
French National Agency for the Security of Information Systems (ANSSI) BP-028 Intermediary Level	xccdf_org.ssgproject.content_profile_anssi_bp28_intermediary	1.2
French National Agency for the Security of Information Systems (ANSSI) BP-028 Minimal Level	xccdf_org.ssgproject.content_profile_anssi_bp28_minimal	1.2
CIS Red Hat Enterprise Linux 8 Benchmark for Level 2 - Server	xccdf_org.ssgproject.content_profile_cis	2.0.0
CIS Red Hat Enterprise Linux 8 Benchmark for Level 1 - Server	xccdf_org.ssgproject.content_profile_cis_server_l1	2.0.0
CIS Red Hat Enterprise Linux 8 Benchmark for Level 1 - Workstation	xccdf_org.ssgproject.content_profile_cis_workstation_l1	2.0.0
CIS Red Hat Enterprise Linux 8 Benchmark for Level 2 - Workstation	xccdf_org.ssgproject.content_profile_cis_workstation_l2	2.0.0

Profile name	Profile ID	Policy version
Unclassified Information in Non-federal Information Systems and Organizations (NIST 800-171)	xccdf_org.ssgproject.content_profile_cui	r1
Australian Cyber Security Centre (ACSC) Essential Eight	xccdf_org.ssgproject.content_profile_e8	not versioned
Health Insurance Portability and Accountability Act (HIPAA)	xccdf_org.ssgproject.content_profile_hipaa	not versioned
Australian Cyber Security Centre (ACSC) ISM Official	xccdf_org.ssgproject.content_profile_ism_o	not versioned
Protection Profile for General Purpose Operating Systems	xccdf_org.ssgproject.content_profile_ospp	4.2.1
PCI-DSS v3.2.1 Control Baseline for Red Hat Enterprise Linux 8	xccdf_org.ssgproject.content_profile_pci-dss	3.2.1
The Defense Information Systems Agency Security Technical Implementation Guide (DISA STIG) for Red Hat Enterprise Linux 8	xccdf_org.ssgproject.content_profile_stig	RHEL 8.7.0 and RHEL 8.7.1:V1R7 RHEL 8.7.2 and later:V1R9
The Defense Information Systems Agency Security Technical Implementation Guide (DISA STIG) with GUI for Red Hat Enterprise Linux 8	xccdf_org.ssgproject.content_profile_stig_gui	RHEL 8.7.0 and RHEL 8.7.1:V1R7 RHEL 8.7.2 and later:V1R9

Table 6.6. SCAP Security Guide profiles supported in RHEL 8.6

Profile name	Profile ID	Policy version
French National Agency for the Security of Information Systems (ANSSI) BP-028 Enhanced Level	xccdf_org.ssgproject.content_profile_anssi_bp28_enhanced	RHEL 8.6.0 to 8.6.10:1.2 RHEL 8.6.11 and later:2.0
French National Agency for the Security of Information Systems (ANSSI) BP-028 High Level	xccdf_org.ssgproject.content_profile_anssi_bp28_high	RHEL 8.6.0 to 8.6.10:1.2 RHEL 8.6.11 and later:2.0
French National Agency for the Security of Information Systems (ANSSI) BP-028 Intermediary Level	xccdf_org.ssgproject.content_profile_anssi_bp28_intermediary	RHEL 8.6.0 to 8.6.10:1.2 RHEL 8.6.11 and later:2.0

Profile name	Profile ID	Policy version
French National Agency for the Security of Information Systems (ANSSI) BP-028 Minimal Level	xccdf_org.ssgproject.content_profile_anssi_bp28_minimal	RHEL 8.6.0 to 8.6.10:1.2 RHEL 8.6.11 and later:2.0
CIS Red Hat Enterprise Linux 8 Benchmark for Level 2 - Server	xccdf_org.ssgproject.content_profile_cis	RHEL 8.6.0 to RHEL 8.6.2:1.0.0 RHEL 8.6.3 to RHEL 8.6.15:2.0.0 RHEL 8.6.16 and later:3.0.0
CIS Red Hat Enterprise Linux 8 Benchmark for Level 1 - Server	xccdf_org.ssgproject.content_profile_cis_server_l1	RHEL 8.6.0 to RHEL 8.6.2:1.0.0 RHEL 8.6.3 to RHEL 8.6.15:2.0.0 RHEL 8.6.16 and later:3.0.0
CIS Red Hat Enterprise Linux 8 Benchmark for Level 1 - Workstation	xccdf_org.ssgproject.content_profile_cis_workstation_l1	RHEL 8.6.0 to RHEL 8.6.2:1.0.0 RHEL 8.6.3 to RHEL 8.6.15:2.0.0 RHEL 8.6.16 and later:3.0.0
CIS Red Hat Enterprise Linux 8 Benchmark for Level 2 - Workstation	xccdf_org.ssgproject.content_profile_cis_workstation_l2	RHEL 8.6.0 to RHEL 8.6.2:1.0.0 RHEL 8.6.3 to RHEL 8.6.15:2.0.0 RHEL 8.6.16 and later:3.0.0
Unclassified Information in Non-federal Information Systems and Organizations (NIST 800-171)	xccdf_org.ssgproject.content_profile_cui	r1
Australian Cyber Security Centre (ACSC) Essential Eight	xccdf_org.ssgproject.content_profile_e8	not versioned
Health Insurance Portability and Accountability Act (HIPAA)	xccdf_org.ssgproject.content_profile_hipaa	not versioned
Australian Cyber Security Centre (ACSC) ISM Official	xccdf_org.ssgproject.content_profile_ism_o	not versioned
Protection Profile for General Purpose Operating Systems	xccdf_org.ssgproject.content_profile_ospp	4.2.1
PCI-DSS v3.2.1 Control Baseline for Red Hat Enterprise Linux 8	xccdf_org.ssgproject.content_profile_pci-dss	3.2.1
The Defense Information Systems Agency Security Technical Implementation Guide (DISA STIG) for Red Hat Enterprise Linux 8	xccdf_org.ssgproject.content_profile_stig	RHEL 8.6.0:V1R5 RHEL 8.6.1 and RHEL 8.6.2:V1R6 RHEL 8.6.3 to RHEL 8.6.6:V1R7 RHEL 8.6.7 to RHEL 8.6.10:V1R9 RHEL 8.6.11 to RHEL 8.6.15:V1R11 RHEL 8.6.16 and RHEL 8.6.17:V1R13 RHEL 8.6.18 and later:V1R14

Profile name	Profile ID	Policy version
The Defense Information Systems Agency Security Technical Implementation Guide (DISA STIG) with GUI for Red Hat Enterprise Linux 8	xccdf_org.ssgproject.content_profile_stig_gui	RHEL 8.6.0:V1R5 RHEL 8.6.1 and RHEL 8.6.2:V1R6 RHEL 8.6.3 to RHEL 8.6.6:V1R7 RHEL 8.6.7 to RHEL 8.6.10:V1R9 RHEL 8.6.11 to RHEL 8.6.15:V1R11 RHEL 8.6.16 and RHEL 8.6.17:V1R13 RHEL 8.6.18 and later:V1R14

Table 6.7. SCAP Security Guide profiles supported in RHEL 8.5

Profile name	Profile ID	Policy version
French National Agency for the Security of Information Systems (ANSSI) BP-028 Enhanced Level	xccdf_org.ssgproject.content_profile_anssi_bp28_enhanced	1.2
French National Agency for the Security of Information Systems (ANSSI) BP-028 High Level	xccdf_org.ssgproject.content_profile_anssi_bp28_high	1.2
French National Agency for the Security of Information Systems (ANSSI) BP-028 Intermediary Level	xccdf_org.ssgproject.content_profile_anssi_bp28_intermediary	1.2
French National Agency for the Security of Information Systems (ANSSI) BP-028 Minimal Level	xccdf_org.ssgproject.content_profile_anssi_bp28_minimal	1.2
CIS Red Hat Enterprise Linux 8 Benchmark for Level 2 - Server	xccdf_org.ssgproject.content_profile_cis	1.0.0
CIS Red Hat Enterprise Linux 8 Benchmark for Level 1 - Server	xccdf_org.ssgproject.content_profile_cis_server_l1	1.0.0
CIS Red Hat Enterprise Linux 8 Benchmark for Level 1 - Workstation	xccdf_org.ssgproject.content_profile_cis_workstation_l1	1.0.0
CIS Red Hat Enterprise Linux 8 Benchmark for Level 2 - Workstation	xccdf_org.ssgproject.content_profile_cis_workstation_l2	1.0.0
Unclassified Information in Non-federal Information Systems and Organizations (NIST 800-171)	xccdf_org.ssgproject.content_profile_cui	r1

Profile name	Profile ID	Policy version
Australian Cyber Security Centre (ACSC) Essential Eight	xccdf_org.ssgproject.content_profile_e8	not versioned
Health Insurance Portability and Accountability Act (HIPAA)	xccdf_org.ssgproject.content_profile_hipaa	not versioned
Australian Cyber Security Centre (ACSC) ISM Official	xccdf_org.ssgproject.content_profile_ism_o	not versioned
Protection Profile for General Purpose Operating Systems	xccdf_org.ssgproject.content_profile_ospp	4.2.1
PCI-DSS v3.2.1 Control Baseline for Red Hat Enterprise Linux 8	xccdf_org.ssgproject.content_profile_pci-dss	3.2.1
The Defense Information Systems Agency Security Technical Implementation Guide (DISA STIG) for Red Hat Enterprise Linux 8	xccdf_org.ssgproject.content_profile_stig	RHEL 8.5.0 to RHEL 8.5.3:V1R3 RHEL 8.5.4 and later:V1R5
The Defense Information Systems Agency Security Technical Implementation Guide (DISA STIG) with GUI for Red Hat Enterprise Linux 8	xccdf_org.ssgproject.content_profile_stig_gui	RHEL 8.5.0 to RHEL 8.5.3:V1R3 RHEL 8.5.4 and later:V1R5

Table 6.8. SCAP Security Guide profiles supported in RHEL 8.4

Profile name	Profile ID	Policy version
French National Agency for the Security of Information Systems (ANSSI) BP-028 Enhanced Level	xccdf_org.ssgproject.content_profile_anssi_bp28_enhanced	1.2
French National Agency for the Security of Information Systems (ANSSI) BP-028 High Level	xccdf_org.ssgproject.content_profile_anssi_bp28_high	RHEL 8.4.4 and later:1.2
French National Agency for the Security of Information Systems (ANSSI) BP-028 Intermediary Level	xccdf_org.ssgproject.content_profile_anssi_bp28_intermediary	1.2
French National Agency for the Security of Information Systems (ANSSI) BP-028 Minimal Level	xccdf_org.ssgproject.content_profile_anssi_bp28_minimal	1.2

Profile name	Profile ID	Policy version
CIS Red Hat Enterprise Linux 8 Benchmark for Level 2 - Server	xccdf_org.ssgproject.content_profile_cis	RHEL 8.4.3 and earlier:1.0.0 RHEL 8.4.4 to RHEL 8.4.10:1.0.1 RHEL 8.4.11 and later:2.0.0
CIS Red Hat Enterprise Linux 8 Benchmark for Level 1 - Server	xccdf_org.ssgproject.content_profile_cis_server_l1	RHEL 8.4.4 to RHEL 8.4.10:1.0.1 RHEL 8.4.11 and later:2.0.0
CIS Red Hat Enterprise Linux 8 Benchmark for Level 1 - Workstation	xccdf_org.ssgproject.content_profile_cis_workstation_l1	RHEL 8.4.4 to RHEL 8.4.10:1.0.1 RHEL 8.4.11 and later:2.0.0
CIS Red Hat Enterprise Linux 8 Benchmark for Level 2 - Workstation	xccdf_org.ssgproject.content_profile_cis_workstation_l2	RHEL 8.4.4 to RHEL 8.4.10:1.0.1 RHEL 8.4.11 and later:2.0.0
Unclassified Information in Non-federal Information Systems and Organizations (NIST 800-171)	xccdf_org.ssgproject.content_profile_cui	r1
Australian Cyber Security Centre (ACSC) Essential Eight	xccdf_org.ssgproject.content_profile_e8	not versioned
Australian Cyber Security Centre (ACSC) ISM Official	xccdf_org.ssgproject.content_profile_ism_o	RHEL 8.4.4 and later:not versioned
Health Insurance Portability and Accountability Act (HIPAA)	xccdf_org.ssgproject.content_profile_hipaa	not versioned
Protection Profile for General Purpose Operating Systems	xccdf_org.ssgproject.content_profile_ospp	4.2.1
PCI-DSS v3.2.1 Control Baseline for Red Hat Enterprise Linux 8	xccdf_org.ssgproject.content_profile_pci-dss	3.2.1
The Defense Information Systems Agency Security Technical Implementation Guide (DISA STIG) for Red Hat Enterprise Linux 8	xccdf_org.ssgproject.content_profile_stig	RHEL 8.4.3 and earlier:V1R1 RHEL 8.4.4 to RHEL 8.4.7:V1R3 RHEL 8.4.8:V1R5 RHEL 8.4.9 to RHEL 8.4.10:V1R6 RHEL 8.4.11 to RHEL 8.4.14:V1R7 RHEL 8.4.15 and later:V1R9
The Defense Information Systems Agency Security Technical Implementation Guide (DISA STIG) with GUI for Red Hat Enterprise Linux 8	xccdf_org.ssgproject.content_profile_stig_gui	RHEL 8.4.4 to RHEL 8.4.7:V1R3 RHEL 8.4.8:V1R5 RHEL 8.4.9 to RHEL 8.4.10:V1R6 RHEL 8.4.11 to RHEL 8.4.14:V1R7 RHEL 8.4.15 and later:V1R9

Table 6.9. SCAP Security Guide profiles supported in RHEL 8.3

Profile name	Profile ID	Policy version
CIS Red Hat Enterprise Linux 8 Benchmark	xccdf_org.ssgproject.content_profile_cis	1.0.0
Unclassified Information in Non-federal Information Systems and Organizations (NIST 800-171)	xccdf_org.ssgproject.content_profile_cui	r1
Australian Cyber Security Centre (ACSC) Essential Eight	xccdf_org.ssgproject.content_profile_e8	not versioned
Health Insurance Portability and Accountability Act (HIPAA)	xccdf_org.ssgproject.content_profile_hipaa	not versioned
Protection Profile for General Purpose Operating Systems	xccdf_org.ssgproject.content_profile_ospp	4.2.1
PCI-DSS v3.2.1 Control Baseline for Red Hat Enterprise Linux 8	xccdf_org.ssgproject.content_profile_pci-dss	3.2.1
[DRAFT] The Defense Information Systems Agency Security Technical Implementation Guide (DISA STIG) for Red Hat Enterprise Linux 8	xccdf_org.ssgproject.content_profile_stig	draft

Table 6.10. SCAP Security Guide profiles supported in RHEL 8.2

Profile name	Profile ID	Policy version
Australian Cyber Security Centre (ACSC) Essential Eight	xccdf_org.ssgproject.content_profile_e8	not versioned
Protection Profile for General Purpose Operating Systems	xccdf_org.ssgproject.content_profile_ospp	4.2.1
PCI-DSS v3.2.1 Control Baseline for Red Hat Enterprise Linux 8	xccdf_org.ssgproject.content_profile_pci-dss	3.2.1
[DRAFT] DISA STIG for Red Hat Enterprise Linux 8	xccdf_org.ssgproject.content_profile_stig	draft

Table 6.11. SCAP Security Guide profiles supported in RHEL 8.1

Profile name	Profile ID	Policy version
Protection Profile for General Purpose Operating Systems	xccdf_org.ssgproject.content_profile_osp	4.2.1
PCI-DSS v3.2.1 Control Baseline for Red Hat Enterprise Linux 8	xccdf_org.ssgproject.content_profile_pci-dss	3.2.1

Table 6.12. SCAP Security Guide profiles supported in RHEL 8.0

Profile name	Profile ID	Policy version
OSPP - Protection Profile for General Purpose Operating Systems	xccdf_org.ssgproject.content_profile_osp	draft
PCI-DSS v3.2.1 Control Baseline for Red Hat Enterprise Linux 8	xccdf_org.ssgproject.content_profile_pci-dss	3.2.1

6.13. ADDITIONAL RESOURCES

- [Supported versions of the SCAP Security Guide in RHEL](#)
- [The OpenSCAP project page](#) provides detailed information about the **oscap** utility and other components and projects related to SCAP.
- [The SCAP Workbench project page](#) provides detailed information about the **scap-workbench** application.
- [The SCAP Security Guide \(SSG\) project page](#) provides the latest security content for Red Hat Enterprise Linux.
- [Using OpenSCAP for security compliance and vulnerability scanning](#) - A hands-on lab on running tools based on the Security Content Automation Protocol (SCAP) standard for compliance and vulnerability scanning in RHEL.
- [Red Hat Security Demos: Creating Customized Security Policy Content to Automate Security Compliance](#) - A hands-on lab to get initial experience in automating security compliance using the tools that are included in RHEL to comply with both industry standard security policies and custom security policies. If you want training or access to these lab exercises for your team, contact your Red Hat account team for additional details.
- [Red Hat Security Demos: Defend Yourself with RHEL Security Technologies](#) - A hands-on lab to learn how to implement security at all levels of your RHEL system, using the key security technologies available to you in RHEL, including OpenSCAP. If you want training or access to these lab exercises for your team, contact your Red Hat account team for additional details.
- [National Institute of Standards and Technology \(NIST\) SCAP page](#) has a vast collection of SCAP-related materials, including SCAP publications, specifications, and the SCAP Validation Program.

- [National Vulnerability Database \(NVD\)](#) has the largest repository of SCAP content and other SCAP standards-based vulnerability management data.
- [Red Hat OVAL content repository](#) contains OVAL definitions for vulnerabilities of RHEL systems. This is the recommended source of vulnerability content.
- [MITRE CVE](#) - This is a database of publicly known security vulnerabilities provided by the MITRE corporation. For RHEL, using OVAL CVE content provided by Red Hat is recommended.
- [MITRE OVAL](#) - This is an OVAL-related project provided by the MITRE corporation. Among other OVAL-related information, these pages contain the OVAL language and a repository of OVAL content with thousands of OVAL definitions. Note that for scanning RHEL, using OVAL CVE content provided by Red Hat is recommended.
- [Managing security compliance in Red Hat Satellite](#) - This set of guides describes, among other topics, how to maintain system security on multiple systems by using OpenSCAP.

CHAPTER 7. 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.

7.1. INSTALLING AIDE

To start file-integrity checking with AIDE, you must install the corresponding package and initiate the AIDE database.

Prerequisites

- The **AppStream** repository is enabled.

Procedure

1. Install the **aide** package:

```
# yum install aide
```

2. Generate an initial database:

```
# aide --init
Start timestamp: 2024-07-08 10:39:23 -0400 (AIDE 0.16)
AIDE initialized database at /var/lib/aide/aide.db.new.gz

Number of entries: 55856

-----
The attributes of the (uncompressed) database(s):
-----

/var/lib/aide/aide.db.new.gz
...
SHA512  : mZaWoGzL2m6ZcyyZ/AXTlowliEXWSZqx
        IFYImY4f7id4u+Bq8WeuSE2jasZur/A4
        FPBFaBkoCFHdoE/FW/V94Q==
```

3. Optional: 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.
4. 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
```

5. Optional: 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.

7.2. PERFORMING INTEGRITY CHECKS WITH AIDE

You can use the **crond** service to schedule regular file-integrity checks with AIDE.

Prerequisites

- AIDE is properly installed and its database is initialized. See [Installing AIDE](#)

Procedure

1. To initiate a manual check:

```
# aide --check
Start timestamp: 2024-07-08 10:43:46 -0400 (AIDE 0.16)
AIDE found differences between database and filesystem!!

Summary:
  Total number of entries: 55856
  Added entries: 0
  Removed entries: 0
  Changed entries: 1

-----
Changed entries:
-----

f ...    ..S : /root/.viminfo

-----
Detailed information about changes:
-----

File: /root/.viminfo
SELinux : system_u:object_r:admin_home_t:s | unconfined_u:object_r:admin_home
         0                               | _t:s0
...
```

2. At a minimum, configure the system to run AIDE weekly. Optimally, run AIDE daily. For example, to schedule a daily execution of AIDE at 04:05 a.m. by using the **cron** command, add the following line to the **/etc/crontab** file:

```
05 4 * * * root /usr/sbin/aide --check
```

Additional resources

- **cron(8)** man page on your system

7.3. UPDATING AN AIDE DATABASE

After verifying the changes of your system, such as package updates or configuration files adjustments, update also your baseline AIDE database.

Prerequisites

- AIDE is properly installed and its database is initialized. See [Installing AIDE](#)

Procedure

1. Update your baseline AIDE database:

```
# aide --update
```

The **aide --update** command creates the **/var/lib/aide/aide.db.new.gz** database file.

2. To start using the updated database for integrity checks, remove the **.new** substring from the file name.

7.4. FILE-INTEGRITY TOOLS: AIDE AND IMA

Red Hat Enterprise Linux provides several tools for checking and preserving the integrity of files and directories on your system. The following table helps you decide which tool better fits your scenario.

Table 7.1. Comparison between AIDE and IMA

Question	Advanced Intrusion Detection Environment (AIDE)	Integrity Measurement Architecture (IMA)
What	AIDE is a utility that creates a database of files and directories on the system. This database serves for checking file integrity and detect intrusion detection.	IMA detects if a file is altered by checking file measurement (hash values) compared to previously stored extended attributes.
How	AIDE uses rules to compare the integrity state of the files and directories.	IMA uses file hash values to detect the intrusion.
Why	Detection - AIDE detects if a file is modified by verifying the rules.	Detection and Prevention - IMA detects and prevents an attack by replacing the extended attribute of a file.
Usage	AIDE detects a threat when the file or directory is modified.	IMA detects a threat when someone tries to alter the entire file.
Extension	AIDE checks the integrity of files and directories on the local system.	IMA ensures security on the local and remote systems.

7.5. ADDITIONAL RESOURCES

- **aide(1)** man page on your system
- [Kernel integrity subsystem](#)

CHAPTER 8. ENHANCING SECURITY WITH THE KERNEL INTEGRITY SUBSYSTEM

You can improve the protection of your system by using components of the kernel integrity subsystem. Learn more about the relevant components and their configuration.

8.1. THE KERNEL INTEGRITY SUBSYSTEM

The integrity subsystem is the kernel component that maintains the overall integrity of system data. This subsystem helps in maintaining the system in the same state from the time it was built. Using this subsystem, you can protect executable files, libraries, and configuration files.

The kernel integrity subsystem consists of two major components:

Integrity Measurement Architecture (IMA)

- IMA measures file content whenever it is executed or accessed by cryptographically hashing or signing with cryptographic keys. The keys are stored in the kernel keyring subsystem.
- IMA places the measured values within the kernel's memory space. This prevents users of the system from modifying the measured values.
- IMA allows local and remote parties to verify the measured values.
- IMA provides local validation of the current content of files against the values previously stored in the measurement list within the kernel memory. This extension forbids performing any operation on a specific file in case the current and the previous measures do not match.

Extended Verification Module (EVM)

- EVM protects extended attributes of files (also known as *xattr*) related to system security, such as IMA measurements and SELinux attributes. EVM cryptographically hashes their corresponding values or signs them with cryptographic keys. The keys are stored in the kernel keyring subsystem.

The kernel integrity subsystem can use the Trusted Platform Module (TPM) to further harden system security.

A TPM is a hardware, firmware, or virtual component with integrated cryptographic keys that are built according to the TPM specification by the Trusted Computing Group (TCG) for important cryptographic functions. By providing cryptographic functions from a protected and tamper-proof area of the hardware chip, TPMs are protected from software-based attacks. TPMs provide the following features:

- Random-number generator
- Generator and secure storage for cryptographic keys
- Hashing generator
- Remote attestation

Additional resources

- [Security hardening](#)
- [Basic and advanced configuration of Security-Enhanced Linux \(SELinux\)](#)

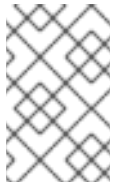
8.2. TRUSTED AND ENCRYPTED KEYS

Trusted keys and *encrypted keys* are an important part of enhancing system security.

Trusted and encrypted keys are variable-length symmetric keys generated by the kernel that use the kernel keyring service. You can verify the integrity of the keys, for example, to allow the extended verification module (EVM) to verify and confirm the integrity of a running system. User-level programs can only access the keys in the form of encrypted *blobs*.

Trusted keys

Trusted keys need the Trusted Platform Module (TPM) chip, which is used to both create and encrypt (seal) the keys. Each TPM has a master wrapping key, called the storage root key, which is stored within the TPM itself.



NOTE

Red Hat Enterprise Linux 8 supports both TPM 1.2 and TPM 2.0. For more information, see the Red Hat Knowledgebase solution [Is Trusted Platform Module \(TPM\) supported by Red Hat?](#).

You can verify the status of TPM 2.0 chip:

```
$ cat /sys/class/tpm/tpm0/tpm_version_major
2
```

You can also enable a TPM 2.0 chip and manage the TPM 2.0 device through settings in the machine firmware.

In addition to that, you can seal the trusted keys with a specific set of the TPM's *platform configuration register* (PCR) values. PCR contains a set of integrity-management values that reflect the firmware, boot loader, and operating system. PCR-sealed keys can only be decrypted by the TPM on the system where they were encrypted. However, when you load a PCR-sealed trusted key to a keyring, its associated PCR values are verified. After verification, you can update the key with new or future PCR values, for example, to support booting a new kernel. Also, you can save a single key as multiple blobs, each with a different PCR value.

Encrypted keys

Encrypted keys do not require a TPM, because they use the kernel Advanced Encryption Standard (AES), 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.

The master key is either a trusted key or a user key. If the master key is not trusted, the security of the encrypted key depends on the user key that was used to encrypt it.

8.3. WORKING WITH TRUSTED KEYS

You can improve system security by using the **keyctl** utility to create, export, load and update trusted keys.

Prerequisites

- For the 64-bit ARM architecture and IBM Z, the **trusted** kernel module is loaded.

```
# modprobe trusted
```

For more information about how to load kernel modules, see [Loading kernel modules at system runtime](#).

- Trusted Platform Module (TPM) is enabled and active. See [The kernel integrity subsystem](#) and [Trusted and encrypted keys](#).



NOTE

Red Hat Enterprise Linux 8 supports both TPM 1.2 and TPM 2.0. If you use TPM 1.2, skip step 1.

Procedure

- Create a 2048-bit RSA key with an SHA-256 primary storage key with a persistent handle of, for example, *81000001*, by using one of the following utilities:

- By using the **tss2** package:

```
# TPM_DEVICE=/dev/tpm0 tsscreateprimary -hi o -st
Handle 80000000
# TPM_DEVICE=/dev/tpm0 tssevictcontrol -hi o -ho 80000000 -hp 81000001
```

- By using the **tpm2-tools** package:

```
# tpm2_createprimary --key-algorithm=rsa2048 --key-context=key.ctx
name-alg:
  value: sha256
  raw: 0xb
...
sym-keybits: 128
rsa: xxxxxx...

# tpm2_evictcontrol -c key.ctx 0x81000001
persistentHandle: 0x81000001
action: persisted
```

- Create a trusted key:

- By using a TPM 2.0 with the syntax of **keyctl add trusted <NAME> "new <KEY_LENGTH> keyhandle=<PERSISTENT-HANDLE> [options]" <KEYRING>**. In this example, the persistent handle is *81000001*.

```
# keyctl add trusted kmk "new 32 keyhandle=0x81000001" @u
642500861
```

The command 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).

- b. By using a TPM 1.2 with the syntax of **keyctl add trusted <NAME> "new <KEY_LENGTH>" <KEYRING>**:

```
# keyctl add trusted kmk "new 32" @u
```

3. 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
```

4. Export the key to a user-space blob by using the serial number of the trusted key:

```
# keyctl pipe 642500861 > kmk.blob
```

The command uses the **pipe** subcommand and the serial number of **kmk**.

5. Load the trusted key from the user-space blob:

```
# keyctl add trusted kmk "load `cat kmk.blob`" @u
268728824
```

6. Create secure encrypted keys that use the TPM-sealed trusted key (**kmk**). Follow this syntax:
**keyctl add encrypted <NAME> "new [FORMAT] <KEY_TYPE>:<PRIMARY_KEY_NAME>
 <KEY_LENGTH>" <KEYRING>**:

```
# keyctl add encrypted encr-key "new trusted:kmk 32" @u
159771175
```

Additional resources

- the **keyctl(1)** manual page

8.4. WORKING WITH ENCRYPTED KEYS

You can improve system security on systems where a Trusted Platform Module (TPM) is not available by managing encrypted keys.

Encrypted keys, unless sealed by a trusted primary key, inherit the security level of the user primary key (random-number key) used for encryption. Therefore, it is highly recommended to load the primary user key securely, ideally early in the boot process.

Prerequisites

- For the 64-bit ARM architecture and IBM Z, the **encrypted-keys** kernel module is loaded:

```
# modprobe encrypted-keys
```

For more information about how to load kernel modules, see [Loading kernel modules at system runtime](#).

Procedure

1. Generate a user key by using a random sequence of numbers:

```
# keyctl add user kmk-user "$(dd if=/dev/urandom bs=1 count=32 2>/dev/null)" @u
427069434
```

The command generates a user key called **kmk-user** which acts as a *primary key* and is used to seal the actual encrypted keys.

2. Generate an encrypted key using the primary key from the previous step:

```
# keyctl add encrypted encr-key "new user:kmk-user 32" @u
1012412758
```

Verification

1. List all keys in the specified user keyring:

```
# keyctl list @u
2 keys in keyring:
427069434: --alswrv 1000 1000 user: kmk-user
1012412758: --alswrv 1000 1000 encrypted: encr-key
```

Additional resources

- The **keyctl(1)** manual page

8.5. ENABLING IMA AND EVM

You can enable and configure Integrity measurement architecture (IMA) and extended verification module (EVM) to improve the security of the operating system.



IMPORTANT

Always enable EVM together with IMA.

Although you can enable EVM alone, EVM appraisal is only triggered by an IMA appraisal rule. Therefore, EVM does not protect file metadata such as SELinux attributes. If file metadata is tampered with offline, EVM can only prevent file metadata changes. It does not prevent file access, such as executing the file.

Prerequisites

- Secure Boot is temporarily disabled.



NOTE

When Secure Boot is enabled, the **ima_appraise=fix** kernel command-line parameter does not work.

- The **securityfs** file system is mounted on the **/sys/kernel/security/** directory and the **/sys/kernel/security/integrity/ima/** directory exists. You can verify where **securityfs** is mounted by using the **mount** command:

```
# mount
...
securityfs on /sys/kernel/security type securityfs (rw,nosuid,nodev,noexec,relatime)
...
```

- The **systemd** service manager is patched to support IMA and EVM on boot time. Verify by using the following command:

```
# grep <options> pattern <files>
```

For example:

```
# dmesg | grep -i -e EVM -e IMA -w
[ 0.598533] ima: No TPM chip found, activating TPM-bypass!
[ 0.599435] ima: Allocated hash algorithm: sha256
[ 0.600266] ima: No architecture policies found
[ 0.600813] evm: Initialising EVM extended attributes:
[ 0.601581] evm: security.selinux
[ 0.601963] evm: security.ima
[ 0.602353] evm: security.capability
[ 0.602713] evm: HMAC attrs: 0x1
[ 1.455657] systemd[1]: systemd 239 (239-74.el8_8) running in system mode. (+PAM
+AUDIT +SELINUX +IMA -APPARMOR +SMACK +SYSVINIT +UTMP +LIBCRYPTSETUP
+GCRYPT +GNUTLS +ACL +XZ +LZ4 +SECCOMP +BLKID +ELFUTILS +KMOD +IDN2 -
IDN +PCRE2 default-hierarchy=legacy)
[ 2.532639] systemd[1]: systemd 239 (239-74.el8_8) running in system mode. (+PAM
+AUDIT +SELINUX +IMA -APPARMOR +SMACK +SYSVINIT +UTMP +LIBCRYPTSETUP
+GCRYPT +GNUTLS +ACL +XZ +LZ4 +SECCOMP +BLKID +ELFUTILS +KMOD +IDN2 -
IDN +PCRE2 default-hierarchy=legacy)
```

Procedure

1. Enable IMA and EVM in the *fix* mode for the current boot entry and allow users to gather and update the IMA measurements by adding the following kernel command-line parameters:

```
# grubby --update-kernel=/boot/vmlinuz-$(uname -r) --
args="ima_policy=appraise_tcb ima_appraise=fix evm=fix"
```

The command enables IMA and EVM in the *fix* mode for the current boot entry to gather and update the IMA measurements.

The **ima_policy=appraise_tcb** kernel command-line parameter ensures that the kernel uses the default Trusted Computing Base (TCB) measurement policy and the appraisal step. The appraisal step forbids access to files whose prior and current measures do not match.

2. Reboot to make the changes come into effect.
3. Optional: Verify the parameters added to the kernel command line:

cat /proc/cmdline

```
BOOT_IMAGE=(hd0,msdos1)/vmlinuz-4.18.0-167.el8.x86_64 root=/dev/mapper/rhel-root
ro crashkernel=auto resume=/dev/mapper/rhel-swap rd.lvm.lv=rhel/root
rd.lvm.lv=rhel/swap rhgb quiet ima_policy=appraise_tcb ima_appraise=fix evm=fix
```

4. Create a kernel master key to protect the EVM key:

```
# keyctl add user kmk "$(dd if=/dev/urandom bs=1 count=32 2> /dev/null)" @u
748544121
```

The **kmk** is kept entirely in the kernel space memory. The 32-byte long value of the **kmk** is generated from random bytes from the **/dev/urandom** file and placed in the user (**@u**) keyring. The key serial number is on the first line of the previous output.

5. Create an encrypted EVM key based on the **kmk**:

```
# keyctl add encrypted evm-key "new user:kmk 64" @u
641780271
```

The command uses the **kmk** to generate and encrypt a 64-byte long user key (named **evm-key**) and places it in the user (**@u**) keyring. The key serial number is on the first line of the previous output.

**IMPORTANT**

It is necessary to name the user key as **evm-key** because that is the name the EVM subsystem is expecting and is working with.

6. Create a directory for exported keys.

```
# mkdir -p /etc/keys/
```

7. Search for the **kmk** and export its unencrypted value into the new directory.

```
# keyctl pipe $(keyctl search @u user kmk) > /etc/keys/kmk
```

8. Search for the **evm-key** and export its encrypted value into the new directory.

```
# keyctl pipe $(keyctl search @u encrypted evm-key) > /etc/keys/evm-key
```

The **evm-key** has been encrypted by the kernel master key earlier.

9. Optional: View the newly created keys:

```
# keyctl show
Session Keyring
974575405 --alswrv 0 0 keyring: ses 299489774 --alswrv 0 65534 | keyring:
uid.0 748544121 --alswrv 0 0 | user: kmk
641780271 --alswrv 0 0 \_ encrypted: evm-key

# ls -l /etc/keys/
```

```
total 8
-rw-r--r--. 1 root root 246 Jun 24 12:44 evm-key
-rw-r--r--. 1 root root 32 Jun 24 12:43 kmk
```

10. Optional: If the keys are removed from the keyring, for example after system reboot, you can import the already exported **kmk** and **evm-key** instead of creating new ones.

- a. Import the **kmk**.

```
# keyctl add user kmk "$(cat /etc/keys/kmk)" @u
451342217
```

- b. Import the **evm-key**.

```
# keyctl add encrypted evm-key "load $(cat /etc/keys/evm-key)" @u
924537557
```

11. Activate EVM.

```
# echo 1 > /sys/kernel/security/evm
```

12. Relabel the whole system.

```
# find / -fstype xfs -type f -uid 0 -exec head -n 1 '{}' >/dev/null \;
```



WARNING

Enabling IMA and EVM without relabeling the system might make the majority of the files on the system inaccessible.

Verification

- Verify that EVM has been initialized:

```
# dmesg | tail -1
[...] evm: key initialized
```

8.6. COLLECTING FILE HASHES WITH INTEGRITY MEASUREMENT ARCHITECTURE

In the *measurement* phase, you can create file hashes and store them as extended attributes (*xattrs*) of those files. With the file hashes, you can generate either an RSA-based digital signature or a Hash-based Message Authentication Code (HMAC-SHA1) and prevent offline tampering attacks on the extended attributes.

Prerequisites

- IMA and EVM are enabled. For more information, see [Enabling integrity measurement architecture and extended verification module](#).
- A valid trusted key or encrypted key is stored in the kernel keyring.
- The **ima-evm-utils**, **attr**, and **keyutils** packages are installed.

Procedure

1. Create a test file:

```
# echo <Test_text> > test_file
```

IMA and EVM ensure that the **test_file** example file has assigned hash values that are stored as its extended attributes.

2. Inspect the file's extended attributes:

```
# getfattr -m . -d test_file
# file: test_file
security.evm=0sAnDly4VPA0HArpPO/EqiutnNyBql
security.ima=0sAQOEDeuUnWzwwKYk+n66h/vby3eD
```

The example output shows extended attributes with the IMA and EVM hash values and SELinux context. EVM adds a **security.evm** extended attribute related to the other attributes. At this point, you can use the **evmctl** utility on **security.evm** to generate either an RSA-based digital signature or a Hash-based Message Authentication Code (HMAC-SHA1).

Additional resources

- [Security hardening](#)

CHAPTER 9. ENCRYPTING BLOCK DEVICES USING LUKS

By using the disk encryption, you can protect the data on a block device by encrypting it. To access the device's decrypted contents, enter a passphrase or key as authentication. This is important for mobile computers and removable media because it helps to protect the device's contents even if it has been physically removed from the system. The LUKS format is a default implementation of block device encryption in Red Hat Enterprise Linux.

9.1. LUKS DISK ENCRYPTION

Linux Unified Key Setup-on-disk-format (LUKS) provides a set of tools that simplifies managing the encrypted devices. With LUKS, you can encrypt block devices and enable multiple user keys to decrypt a master key. For bulk encryption of the partition, use this master key.

Red Hat Enterprise Linux uses LUKS to perform block device encryption. By default, the option to encrypt the block device is unchecked during the installation. If you select the option to encrypt your disk, the system prompts you for a passphrase every time you boot the computer. This passphrase unlocks the bulk encryption key that decrypts your partition. If you want to modify the default partition table, you can select the partitions that you want to encrypt. This is set in the partition table settings.

Ciphers

The default cipher used for LUKS is **aes-xts-plain64**. The default key size for LUKS is 512 bits. The default key size for LUKS with **Anaconda** XTS mode is 512 bits. The following are the available ciphers:

- Advanced Encryption Standard (AES)
- Twofish
- Serpent

Operations performed by LUKS

- LUKS encrypts entire block devices and is therefore well-suited for protecting contents of mobile devices such as removable storage media or laptop disk drives.
- The underlying contents of the encrypted block device are arbitrary, which 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, which means you can add backup keys or passphrases.



IMPORTANT

LUKS is not recommended for the following scenarios:

- Disk-encryption solutions such as LUKS protect the data only when your system is off. After the system is on and LUKS has decrypted the disk, the files on that disk are available to anyone who have access to them.
- Scenarios that require multiple users to have distinct access keys to the same device. The LUKS1 format provides eight key slots and LUKS2 provides up to 32 key slots.
- Applications that require file-level encryption.

Additional resources

- [LUKS Project Home Page](#)
- [LUKS On-Disk Format Specification](#)
- [FIPS 197: Advanced Encryption Standard \(AES\)](#)

9.2. LUKS VERSIONS IN RHEL

In Red Hat Enterprise Linux, the default format for LUKS encryption is LUKS2. The old LUKS1 format remains fully supported and it is provided as a format compatible with earlier Red Hat Enterprise Linux releases. LUKS2 re-encryption is considered more robust and safe to use as compared to LUKS1 re-encryption.

The LUKS2 format enables future updates of various parts without a need to modify binary structures. Internally it uses JSON text format for metadata, provides redundancy of metadata, detects metadata corruption, and automatically repairs from a metadata copy.



IMPORTANT

Do not use LUKS2 in systems that support only LUKS1 because LUKS2 and LUKS1 use different commands to encrypt the disk. Using the wrong command for a LUKS version might cause data loss.

Table 9.1. Encryption commands depending on the LUKS version

LUKS version	Encryption command
LUKS2	cryptsetup reencrypt
LUKS1	cryptsetup-reencrypt

Online re-encryption

The LUKS2 format supports re-encrypting encrypted devices while the devices are in use. For example, you do not have to unmount the file system on the device to perform the following tasks:

- Changing the volume key

- Changing the encryption algorithm
When encrypting a non-encrypted device, you must still unmount the file system. You can remount the file system after a short initialization of the encryption.

The LUKS1 format does not support online re-encryption.

Conversion

In certain situations, you can convert LUKS1 to LUKS2. The conversion is not possible specifically in the following scenarios:

- A LUKS1 device is marked as being used by a Policy-Based Decryption (PBD) Clevis solution. The **cryptsetup** tool does not convert the device when some **luksmeta** metadata are detected.
- A device is active. The device must be in an inactive state before any conversion is possible.

9.3. OPTIONS FOR DATA PROTECTION DURING LUKS2 RE-ENCRYPTION

LUKS2 provides several options that prioritize performance or data protection during the re-encryption process. It provides the following modes for the **resilience** option, and you can select any of these modes by using the **cryptsetup reencrypt --resilience resilience-mode /dev/sdx** command:

checksum

The default mode. It balances data protection and performance.

This mode stores individual checksums of the sectors in the re-encryption area, which the recovery process can detect for the sectors that were re-encrypted by LUKS2. The mode requires that the block device sector write is atomic.

journal

The safest mode but also the slowest. Since this mode journals the re-encryption area in the binary area, the LUKS2 writes the data twice.

none

The **none** mode prioritizes performance and provides no data protection. It protects the data only against safe process termination, such as the **SIGTERM** signal or the user pressing **Ctrl+C** key. Any unexpected system failure or application failure might result in data corruption.

If a LUKS2 re-encryption process terminates unexpectedly by force, LUKS2 can perform the recovery in one of the following ways:

Automatically

By performing any one of the following actions triggers the automatic recovery action during the next LUKS2 device open action:

- Executing the **cryptsetup open** command.
- Attaching the device with the **systemd-cryptsetup** command.

Manually

By using the **cryptsetup repair /dev/sdx** command on the LUKS2 device.

Additional resources

- **cryptsetup-reencrypt(8)** and **cryptsetup-repair(8)** man pages on your system

9.4. ENCRYPTING EXISTING DATA ON A BLOCK DEVICE USING LUKS2

You can encrypt the existing data on a not yet encrypted device by using the LUKS2 format. A new LUKS header is stored in the head of the device.

Prerequisites

- The block device has a file system.
- You have backed up your data.



WARNING

You might lose your data during the encryption process due to a hardware, kernel, or human failure. Ensure that you have a reliable backup before you start encrypting the data.

Procedure

1. Unmount all file systems on the device that you plan to encrypt, for example:

```
# umount /dev/mapper/vg00-lv00
```

2. Make free space for storing a LUKS header. Use one of the following options that suits your scenario:

- In the case of encrypting a logical volume, you can extend the logical volume without resizing the file system. For example:

```
# lvextend -L+32M /dev/mapper/vg00-lv00
```

- Extend the partition by using partition management tools, such as **parted**.
- Shrink the file system on the device. You can use the **resize2fs** utility for the ext2, ext3, or ext4 file systems. Note that you cannot shrink the XFS file system.

3. Initialize the encryption:

```
# cryptsetup reencrypt --encrypt --init-only --reduce-device-size 32M /dev/mapper/vg00-lv00
lv00_encrypted
```

/dev/mapper/lv00_encrypted is now active and ready for online encryption.

4. Mount the device:

```
# mount /dev/mapper/lv00_encrypted /mnt/lv00_encrypted
```

5. Add an entry for a persistent mapping to the **/etc/crypttab** file:

a. Find the **luksUUID**:

```
# cryptsetup luksUUID /dev/mapper/vg00-lv00
a52e2cc9-a5be-47b8-a95d-6bdf4f2d9325
```

b. Open **/etc/crypttab** in a text editor of your choice and add a device in this file:

```
$ vi /etc/crypttab
lv00_encrypted UUID=a52e2cc9-a5be-47b8-a95d-6bdf4f2d9325 none
```

Replace *a52e2cc9-a5be-47b8-a95d-6bdf4f2d9325* with your device's **luksUUID**.

c. Refresh initramfs with **dracut**:

```
$ dracut -f --regenerate-all
```

6. Add an entry for a persistent mounting to the **/etc/fstab** file:

a. Find the file system's UUID of the active LUKS block device:

```
$ blkid -p /dev/mapper/lv00_encrypted
/dev/mapper/lv00-encrypted: UUID="37bc2492-d8fa-4969-9d9b-bb64d3685aa9"
BLOCK_SIZE="4096" TYPE="xfs" USAGE="filesystem"
```

b. Open **/etc/fstab** in a text editor of your choice and add a device in this file, for example:

```
$ vi /etc/fstab
UUID=37bc2492-d8fa-4969-9d9b-bb64d3685aa9 /home auto rw,user,auto 0
```

Replace *37bc2492-d8fa-4969-9d9b-bb64d3685aa9* with your file system's UUID.

7. Resume the online encryption:

```
# cryptsetup reencrypt --resume-only /dev/mapper/vg00-lv00

Enter passphrase for /dev/mapper/vg00-lv00:
Auto-detected active dm device 'lv00_encrypted' for data device /dev/mapper/vg00-lv00.
Finished, time 00:31.130, 10272 MiB written, speed 330.0 MiB/s
```

Verification

1. Verify if the existing data was encrypted:

```
# cryptsetup luksDump /dev/mapper/vg00-lv00

LUKS header information
Version: 2
Epoch: 4
```

```

Metadata area: 16384 [bytes]
Keyslots area: 16744448 [bytes]
UUID: a52e2cc9-a5be-47b8-a95d-6bdf4f2d9325
Label: (no label)
Subsystem: (no subsystem)
Flags: (no flags)

Data segments:
  0: crypt
    offset: 33554432 [bytes]
    length: (whole device)
    cipher: aes-xts-plain64
    [...]

```

2. View the status of the encrypted blank block device:

```

# cryptsetup status lv00_encrypted

/dev/mapper/lv00_encrypted is active and is in use.
type:    LUKS2
cipher:  aes-xts-plain64
keysize: 512 bits
key location: keyring
device:  /dev/mapper/vg00-lv00

```

Additional resources

- **cryptsetup(8)**, **cryptsetup-reencrypt(8)**, **lvextend(8)**, **resize2fs(8)**, and **parted(8)** man pages on your system

9.5. ENCRYPTING EXISTING DATA ON A BLOCK DEVICE USING LUKS2 WITH A DETACHED HEADER

You can encrypt existing data on a block device without creating free space for storing a LUKS header. The header is stored in a detached location, which also serves as an additional layer of security. The procedure uses the LUKS2 encryption format.

Prerequisites

- The block device has a file system.
- You have backed up your data.



WARNING

You might lose your data during the encryption process due to a hardware, kernel, or human failure. Ensure that you have a reliable backup before you start encrypting the data.

Procedure

1. Unmount all file systems on the device, for example:

```
# umount /dev/nvme0n1p1
```

2. Initialize the encryption:

```
# cryptsetup reencrypt --encrypt --init-only --header /home/header /dev/nvme0n1p1
nvme_encrypted
```

WARNING!

=====

Header file does not exist, do you want to create it?

Are you sure? (Type 'yes' in capital letters): YES

Enter passphrase for /home/header:

Verify passphrase:

/dev/mapper/nvme_encrypted is now active and ready for online encryption.

Replace */home/header* with a path to the file with a detached LUKS header. The detached LUKS header has to be accessible to unlock the encrypted device later.

3. Mount the device:

```
# mount /dev/mapper/nvme_encrypted /mnt/nvme_encrypted
```

4. Resume the online encryption:

```
# cryptsetup reencrypt --resume-only --header /home/header /dev/nvme0n1p1
```

Enter passphrase for /dev/nvme0n1p1:

Auto-detected active dm device 'nvme_encrypted' for data device /dev/nvme0n1p1.

Finished, time 00m51s, 10 GiB written, speed 198.2 MiB/s

Verification

1. Verify if the existing data on a block device using LUKS2 with a detached header is encrypted:

```
# cryptsetup luksDump /home/header
```

LUKS header information

Version: 2

Epoch: 88

Metadata area: 16384 [bytes]

Keyslots area: 16744448 [bytes]

UUID: c4f5d274-f4c0-41e3-ac36-22a917ab0386

Label: (no label)

Subsystem: (no subsystem)

Flags: (no flags)

Data segments:

0: crypt

offset: 0 [bytes]

```
length: (whole device)
cipher: aes-xts-plain64
sector: 512 [bytes]
[...]
```

2. View the status of the encrypted blank block device:

```
# cryptsetup status nvme_encrypted

/dev/mapper/nvme_encrypted is active and is in use.
type:    LUKS2
cipher:  aes-xts-plain64
keysize: 512 bits
key location: keyring
device:  /dev/nvme0n1p1
```

Additional resources

- **cryptsetup(8)** and **cryptsetup-reencrypt(8)** man pages on your system

9.6. ENCRYPTING A BLANK BLOCK DEVICE USING LUKS2

You can encrypt a blank block device, which you can use for an encrypted storage by using the LUKS2 format.

Prerequisites

- A blank block device. You can use commands such as **lsblk** to find if there is no real data on that device, for example, a file system.

Procedure

1. Setup a partition as an encrypted LUKS partition:

```
# cryptsetup luksFormat /dev/nvme0n1p1

WARNING!
=====
This will overwrite data on /dev/nvme0n1p1 irrevocably.
Are you sure? (Type 'yes' in capital letters): YES
Enter passphrase for /dev/nvme0n1p1:
Verify passphrase:
```

2. Open an encrypted LUKS partition:

```
# cryptsetup open /dev/nvme0n1p1 nvme0n1p1_encrypted

Enter passphrase for /dev/nvme0n1p1:
```

This unlocks the partition and maps it to a new device by using the device mapper. To not overwrite the encrypted data, this command alerts the kernel that the device is an encrypted device and addressed through LUKS by using the **/dev/mapper/device_mapped_name** path.

3. Create a file system to write encrypted data to the partition, which must be accessed through the device mapped name:

```
# mkfs -t ext4 /dev/mapper/nvme0n1p1_encrypted
```

4. Mount the device:

```
# mount /dev/mapper/nvme0n1p1_encrypted mount-point
```

Verification

1. Verify if the blank block device is encrypted:

```
# cryptsetup luksDump /dev/nvme0n1p1

LUKS header information
Version:      2
Epoch:       3
Metadata area: 16384 [bytes]
Keyslots area: 16744448 [bytes]
UUID:         34ce4870-ffdf-467c-9a9e-345a53ed8a25
Label:        (no label)
Subsystem:    (no subsystem)
Flags:        (no flags)

Data segments:
 0: crypt
offset: 16777216 [bytes]
length: (whole device)
cipher: aes-xts-plain64
sector: 512 [bytes]
[...]
```

2. View the status of the encrypted blank block device:

```
# cryptsetup status nvme0n1p1_encrypted

/dev/mapper/nvme0n1p1_encrypted is active and is in use.
type: LUKS2
cipher: aes-xts-plain64
keysize: 512 bits
key location: keyring
device: /dev/nvme0n1p1
sector size: 512
offset: 32768 sectors
size: 20938752 sectors
mode: read/write
```

Additional resources

- **cryptsetup(8)**, **cryptsetup-open (8)**, and **cryptsetup-luksFormat(8)** man pages on your system


9.7. CONFIGURING THE LUKS PASSPHRASE IN THE WEB CONSOLE

If you want to add encryption to an existing logical volume on your system, you can only do so through formatting the volume.

Prerequisites

- You have installed the RHEL 8 web console.
- You have enabled the cockpit service.
- Your user account is allowed to log in to the web console.
For instructions, see [Installing and enabling the web console](#).
- The **cockpit-storaged** package is installed on your system.
- Available existing logical volume without encryption.

Procedure

1. Log in to the RHEL 8 web console.
For details, see [Logging in to the web console](#).
2. In the panel, click **Storage**.
3. In the **Storage** table, click the menu button  for the storage device you want to encrypt and click **Format**.
4. In the **Encryption field**, select the encryption specification, **LUKS1** or **LUKS2**.
5. Set and confirm your new passphrase.
6. Optional: Modify further encryption options.
7. Finalize formatting settings.
8. Click **Format**.

9.8. CHANGING THE LUKS PASSPHRASE IN THE WEB CONSOLE

Change a LUKS passphrase on an encrypted disk or partition in the web console.

Prerequisites

- You have installed the RHEL 8 web console.
- You have enabled the cockpit service.
- Your user account is allowed to log in to the web console.
For instructions, see [Installing and enabling the web console](#).
- The **cockpit-storaged** package is installed on your system.

Procedure

1. Log in to the RHEL 8 web console.
For details, see [Logging in to the web console](#).

2. In the panel, click **Storage**.
3. In the **Storage** table, select the disk with encrypted data.
4. On the disk page, scroll to the **Keys** section and click the edit button.
5. In the **Change passphrase** dialog window:
 - a. Enter your current passphrase.
 - b. Enter your new passphrase.
 - c. Confirm your new passphrase.
6. Click **Save**.

9.9. CREATING A LUKS2 ENCRYPTED VOLUME BY USING THE `STORAGE` RHEL SYSTEM ROLE

You can use the **storage** role to create and configure a volume encrypted with LUKS by running an Ansible playbook.

Prerequisites

- [You have prepared the control node and the managed nodes](#)
- You are logged in to the control node as a user who can run playbooks on the managed nodes.
- The account you use to connect to the managed nodes has **sudo** permissions on them.

Procedure

1. Store your sensitive variables in an encrypted file:

- a. Create the vault:

```
$ ansible-vault create ~/vault.yml
New Vault password: <vault_password>
Confirm New Vault password: <vault_password>
```

- b. After the **ansible-vault create** command opens an editor, enter the sensitive data in the **<key>: <value>** format:

```
luks_password: <password>
```

- c. Save the changes, and close the editor. Ansible encrypts the data in the vault.

2. Create a playbook file, for example `~/playbook.yml`, with the following content:

```
---
- name: Manage local storage
  hosts: managed-node-01.example.com
  vars_files:
    - ~/vault.yml
  tasks:
```

```
- name: Create and configure a volume encrypted with LUKS
  ansible.builtin.include_role:
    name: redhat.rhel_system_roles.storage
  vars:
    storage_volumes:
      - name: barefs
        type: disk
        disks:
          - sdb
        fs_type: xfs
        fs_label: <label>
        mount_point: /mnt/data
        encryption: true
        encryption_password: "{{ luks_password }}"
```

For details about all variables used in the playbook, see the `/usr/share/ansible/roles/rhel-system-roles.storage/README.md` file on the control node.

3. Validate the playbook syntax:

```
$ ansible-playbook --ask-vault-pass --syntax-check ~/playbook.yml
```

Note that this command only validates the syntax and does not protect against a wrong but valid configuration.

4. Run the playbook:

```
$ ansible-playbook --ask-vault-pass ~/playbook.yml
```

Verification

1. Find the **luksUUID** value of the LUKS encrypted volume:

```
# ansible managed-node-01.example.com -m command -a 'cryptsetup luksUUID /dev/sdb'

4e4e7970-1822-470e-b55a-e91efe5d0f5c
```

2. View the encryption status of the volume:

```
# ansible managed-node-01.example.com -m command -a 'cryptsetup status luks-4e4e7970-1822-470e-b55a-e91efe5d0f5c'

/dev/mapper/luks-4e4e7970-1822-470e-b55a-e91efe5d0f5c is active and is in use.
type: LUKS2
cipher: aes-xts-plain64
keysize: 512 bits
key location: keyring
device: /dev/sdb
...
```

3. Verify the created LUKS encrypted volume:

```
# ansible managed-node-01.example.com -m command -a 'cryptsetup luksDump
```

```
/dev/sdb'
```

```
LUKS header information
```

```
Version:      2
```

```
Epoch:       3
```

```
Metadata area: 16384 [bytes]
```

```
Keyslots area: 16744448 [bytes]
```

```
UUID:         4e4e7970-1822-470e-b55a-e91efe5d0f5c
```

```
Label:        (no label)
```

```
Subsystem:    (no subsystem)
```

```
Flags:        (no flags)
```

```
Data segments:
```

```
  0: crypt
```

```
    offset: 16777216 [bytes]
```

```
    length: (whole device)
```

```
    cipher: aes-xts-plain64
```

```
    sector: 512 [bytes]
```

```
...
```

Additional resources

- **/usr/share/ansible/roles/rhel-system-roles.storage/README.md** file
- **/usr/share/doc/rhel-system-roles/storage/** directory
- [Encrypting block devices by using LUKS](#)
- [Ansible vault](#)

CHAPTER 10. CONFIGURING AUTOMATED UNLOCKING OF ENCRYPTED VOLUMES BY USING POLICY-BASED DECRYPTION

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 RHEL 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 unlocking volumes by using a network server.

tpm2

Allows unlocking volumes by using a TPM2 policy.

sss

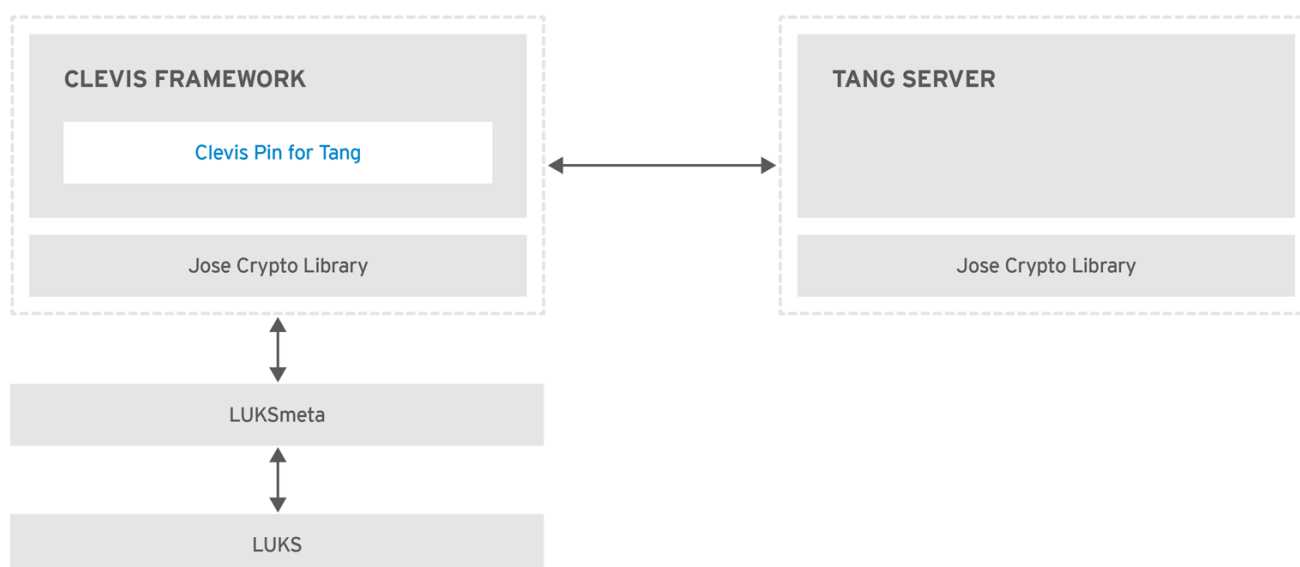
Allows deploying high-availability systems by using the Shamir's Secret Sharing (SSS) cryptographic scheme.

10.1. NETWORK-BOUND DISK ENCRYPTION

The Network Bound Disc Encryption (NBDE) is a subcategory of Policy-Based Decryption (PBD) that allows binding encrypted volumes to a special network server. The current implementation of the NBDE includes a Clevis pin for the Tang server and the Tang server itself.

In RHEL, NBDE is implemented through the following components and technologies:

Figure 10.1. NBDE scheme when using a LUKS1-encrypted volume. The luksmeta package is not used for LUKS2 volumes.



RHEL_453350_0717

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 RHEL, 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 LUKS version 2 (LUKS2) is the default disk-encryption format in RHEL, hence, the provisioning state for NBDE is stored as a token in a LUKS2 header. The leveraging of provisioning state for NBDE by the **luksmeta** package is used only for volumes encrypted with LUKS1.

The Clevis pin for Tang supports both LUKS1 and LUKS2 without specification need. Clevis can encrypt plain-text files but you have to use the **cryptsetup** tool for encrypting block devices. See the [Encrypting block devices using LUKS](#) for more information.

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.



NOTE

If the **kdump** kernel crash dumping mechanism is set to save the content of the system memory to a LUKS-encrypted device, you are prompted for entering a password during the second kernel boot.

Additional resources

- [NBDE \(Network-Bound Disk Encryption\) Technology](#) Knowledgebase article
- **tang(8)**, **clevis(1)**, **jose(1)**, and **clevis-luks-unlockers(7)** man pages on your system
- [How to set up Network-Bound Disk Encryption with multiple LUKS devices \(Clevis + Tang unlocking\)](#) Knowledgebase article

10.2. DEPLOYING A TANG SERVER WITH SELINUX IN ENFORCING MODE

You can use a Tang server to automatically unlock LUKS-encrypted volumes on Clevis-enabled clients. In the minimalistic scenario, you deploy a Tang server on port 80 by installing the **tang** package and entering the **systemctl enable tangd.socket --now** command. The following example procedure demonstrates the deployment of a Tang server running on a custom port as a confined service in SELinux enforcing mode.

Prerequisites

- The **polycoreutils-python-utils** package and its dependencies are installed.
- The **firewalld** service is running.

Procedure

1. To install the **tang** package and its dependencies, enter the following command as **root**:

```
# yum install tang
```

2. Pick an unoccupied port, for example, *7500/tcp*, and allow the **tangd** service to bind to that port:

```
# semanage port -a -t tangd_port_t -p tcp 7500
```

Note that a port can be used only by one service at a time, and thus an attempt to use an already occupied port implies the **ValueError: Port already defined** error message.

3. Open the port in the firewall:

```
# firewall-cmd --add-port=7500/tcp
# firewall-cmd --runtime-to-permanent
```

4. Enable the **tangd** service:

```
# systemctl enable tangd.socket
```

5. Create an override file:

```
# systemctl edit tangd.socket
```

6. In the following editor screen, which opens an empty **override.conf** file located in the **/etc/systemd/system/tangd.socket.d/** directory, change the default port for the Tang server from 80 to the previously picked number by adding the following lines:

```
[Socket]
ListenStream=
ListenStream=7500
```




IMPORTANT

Insert the previous code snippet between the lines starting with **# Anything between here** and **# Lines below this**, otherwise the system discards your changes.

7. Save the changes and exit the editor. In the default **vi** editor, you can do that by pressing **Esc** to switch into command mode, entering **:wq**, and pressing **Enter**.

8. Reload the changed configuration:

```
# systemctl daemon-reload
```

9. Check that your configuration is working:

```
# systemctl show tangd.socket -p Listen
Listen=[::]:7500 (Stream)
```

10. Start the **tangd** service:

```
# systemctl restart tangd.socket
```

Because **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.

Verification

- On your NBDE client, verify that your Tang server works correctly by using the following command. The command must return the identical message you pass for encryption and decryption:

```
# echo test | clevis encrypt tang '{"url": "<tang.server.example.com:7500>"}' -y | clevis decrypt
test
```

Additional resources

- **tang(8)**, **semanage(8)**, **firewall-cmd(1)**, **jose(1)**, **systemd.unit(5)**, and **systemd.socket(5)** man pages on your system

10.3. ROTATING TANG SERVER KEYS AND UPDATING BINDINGS ON CLIENTS

For security reasons, rotate your Tang server keys and update existing bindings on clients periodically. The precise interval at which you should rotate them depends on your application, key sizes, and institutional policy.

Alternatively, you can rotate Tang keys by using the **nbde_server** RHEL system role. See [Using the nbde_server system role for setting up multiple Tang servers](#) for more information.

Prerequisites

- A Tang server is running.

- The **clevis** and **clevis-luks** packages are installed on your clients.
- Note that **clevis luks list**, **clevis luks report**, and **clevis luks regen** have been introduced in RHEL 8.2.

Procedure

1. Rename all keys in the **/var/db/tang** key database directory to have a leading **.** to hide them from advertisement. Note that the file names in the following example differs from unique file names in the key database directory of your Tang server:

```
# cd /var/db/tang
# ls -l
-rw-r--r--. 1 root root 349 Feb  7 14:55 UV6dqXSwe1bRKG3KbJmdiR020hY.jwk
-rw-r--r--. 1 root root 354 Feb  7 14:55 y9hxLTQSiSB5jSEGWnjhY8fDTJU.jwk
# mv UV6dqXSwe1bRKG3KbJmdiR020hY.jwk .UV6dqXSwe1bRKG3KbJmdiR020hY.jwk
# mv y9hxLTQSiSB5jSEGWnjhY8fDTJU.jwk .y9hxLTQSiSB5jSEGWnjhY8fDTJU.jwk
```

2. Check that you renamed and therefore hid all keys from the Tang server advertisement:

```
# ls -l
total 0
```

3. Generate new keys using the **/usr/libexec/tangd-keygen** command in **/var/db/tang** on the Tang server:

```
# /usr/libexec/tangd-keygen /var/db/tang
# ls /var/db/tang
3ZWS6-cDrCG61UPJS2BMmPU4I54.jwk zyLuX6hijUy_PSeUEFDi7hi38.jwk
```

4. Check that your Tang server advertises the signing key from the new key pair, for example:

```
# tang-show-keys 7500
3ZWS6-cDrCG61UPJS2BMmPU4I54
```

5. On your NBDE clients, use the **clevis luks report** command to check if the keys advertised by the Tang server remains the same. You can identify slots with the relevant binding using the **clevis luks list** command, for example:

```
# clevis luks list -d /dev/sda2
1: tang '{"url":"http://tang.srv"}'
# clevis luks report -d /dev/sda2 -s 1
...
Report detected that some keys were rotated.
Do you want to regenerate luks metadata with "clevis luks regen -d /dev/sda2 -s 1"? [ynYN]
```

6. To regenerate LUKS metadata for the new keys either press **y** to the prompt of the previous command, or use the **clevis luks regen** command:

```
# clevis luks regen -d /dev/sda2 -s 1
```

7. When you are sure that all old clients use the new keys, you can remove the old keys from the Tang server, for example:

-

```
# cd /var/db/tang
# rm *.jwk
```



WARNING

Removing the old keys while clients are still using them can result in data loss. If you accidentally remove such keys, use the **clevis luks regen** command on the clients, and provide your LUKS password manually.

Additional resources

- **tang-show-keys(1)**, **clevis-luks-list(1)**, **clevis-luks-report(1)**, and **clevis-luks-regen(1)** man pages on your system

10.4. CONFIGURING AUTOMATED UNLOCKING BY USING A TANG KEY IN THE WEB CONSOLE

You can configure automated unlocking of a LUKS-encrypted storage device using a key provided by a Tang server.

Prerequisites

- You have installed the RHEL 8 web console.
- You have enabled the cockpit service.
- Your user account is allowed to log in to the web console.
For instructions, see [Installing and enabling the web console](#).
- The **cockpit-storaged** and **clevis-luks** packages are installed on your system.
- The **cockpit.socket** service is running at port 9090.
- A Tang server is available. See [Deploying a Tang server with SELinux in enforcing mode](#) for details.
- You have **root** privileges or permissions to enter administrative commands with **sudo**.

Procedure

1. Log in to the RHEL 8 web console.
For details, see [Logging in to the web console](#).
2. Switch to administrative access, provide your credentials, and click **Storage**. In the **Storage** table, click the disk that contains an encrypted volume you plan to add to unlock automatically.
3. In the following page with details of the selected disk, click **+** in the **Keys** section to add a Tang key:

Storage > vda - VirtIO Disk > vda2

Name	-
UUID	44d29c6b-02
Type	Linux filesystem data edit
Size	15.0 GB

Encryption

Encryption type	LUKS2
Cleartext device	/dev/mapper/luks-37128c9a-70a2-483f-8d64-9f00acf80449
Stored passphrase	none edit
Options	discard edit

Keys

Passphrase

Slot 0

[+](#)

[-](#)

- Select **Tang keyserver** as **Key source**, provide the address of your Tang server, and a password that unlocks the LUKS-encrypted device. Click **Add** to confirm:

Add key

Key source ☐ Passphrase ☒ Tang keyserver

Keyserver address

Disk passphrase [Show](#)

Saving a new passphrase requires unlocking the disk. Please provide a current disk passphrase.

[Add](#) [Cancel](#)

The following dialog window provides a command to verify that the key hash matches.

- In a terminal on the Tang server, use the **tang-show-keys** command to display the key hash for comparison. In this example, the Tang server is running on the port 7500:

```
# tang-show-keys 7500
x100_1k6GPiDOaMIL3WbpCjHOy9ul1bSfdhI3M08wO0
```

- Click **Trust key** when the key hashes in the web console and in the output of previously listed commands are the same:

Verify key

Check the key hash with the Tang server.

Copy to clipboard

How to check

In a terminal, run: `ssh tang1. com tang-show-keys`

Check that the SHA-256 or SHA-1 hash from the command matches this dialog.

SHA-256

x100_1k6GPiD0aMLL3WbpCjH0y9u11bSfdhI3M08w00

SHA-1

hmINhleYB000ddFszgICjqJizFI

Trust key
Cancel

- In RHEL 8.8 and later, after you select an encrypted root file system and a Tang server, you can skip adding the **rd.neednet=1** parameter to the kernel command line, installing the **clevis-dracut** package, and regenerating an initial RAM disk (**initrd**). For non-root file systems, the web console now enables the **remote-cryptsetup.target** and **clevis-luks-akspass.path systemd** units, installs the **clevis-systemd** package, and adds the **_netdev** parameter to the **fstab** and **crypttab** configuration files.

Verification

- Check that the newly added Tang key is now listed in the **Keys** section with the **Keyserver** type:

Encryption

Encryption type	LUKS2
Cleartext device	/dev/mapper/luks-37128c9a-70a2-483f-8d64-9f00acf80449
Stored passphrase	none edit
Options	discard edit

Keys

+

Passphrase	Slot 0	edit	-
Keyserver	http://tang1. com/	Slot 1	edit -

- Verify that the bindings are available for the early boot, for example:

```
# lsinitrd | grep clevis-luks
lrwxrwxrwx 1 root root 48 Jan 4 02:56
etc/systemd/system/cryptsetup.target.wants/clevis-luks-askpass.path ->
```

```
/usr/lib/systemd/system/clevis-luks-askpass.path
```

```
...
```

Additional resources

- [Getting started using the RHEL web console](#)

10.5. BASIC NBDE AND TPM2 ENCRYPTION-CLIENT OPERATIONS

The Clevis framework can encrypt plain-text files and decrypt both ciphertexts in the JSON Web Encryption (JWE) format and LUKS-encrypted block devices. Clevis clients can use either Tang network servers or Trusted Platform Module 2.0 (TPM 2.0) chips for cryptographic operations.

The following commands demonstrate the basic functionality provided by Clevis on examples containing plain-text files. You can also use them for troubleshooting your NBDE or Clevis+TPM deployments.

Encryption client bound to a Tang server

- To check that a Clevis encryption client binds to a Tang server, use the **clevis encrypt tang** sub-command:

```
$ clevis encrypt tang '{"url":"http://tang.srv:port"}' < input-plain.txt > secret.jwe
```

The advertisement contains the following signing keys:

```
_Oslk0T-E2l6qjfdDiwVmidoZjA
```

```
Do you wish to trust these keys? [ynYN] y
```

Change the **http://tang.srv:port** 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 JWE format. This cipher text is read from the **input-plain.txt** input file.

Alternatively, if your configuration requires a non-interactive communication with a Tang server without SSH access, you can download an advertisement and save it to a file:

```
$ curl -sfg http://tang.srv:port/adv -o adv.jws
```

Use the advertisement in the **adv.jws** file for any following tasks, such as encryption of files or messages:

```
$ echo 'hello' | clevis encrypt tang '{"url":"http://tang.srv:port","adv":"adv.jws"}
```

- To decrypt data, use the **clevis decrypt** command and provide the cipher text (JWE):

```
$ clevis decrypt < secret.jwe > output-plain.txt
```

Encryption client using TPM 2.0

- To encrypt using a 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":"sha256","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 PCR hashes values match the policy used when sealing.

For example, to seal the data to the PCR with index 0 and 7 for the SHA-256 bank:

```
$ clevis encrypt tpm2 '{"pcr_bank":"sha256","pcr_ids":"0,7"}' < input-plain.txt > secret.jwe
```



WARNING

Hashes in PCRs can be rewritten, and you no longer can unlock your encrypted volume. For this reason, add a strong passphrase that enable you to unlock the encrypted volume manually even when a value in a PCR changes.

If the system cannot automatically unlock your encrypted volume after an upgrade of the **shim-x64** package, see the Red Hat Knowledgebase solution [Clevis TPM2 no longer decrypts LUKS devices after a restart](#).

Additional resources

- **clevis-encrypt-tang(1)**, **clevis-luks-unlockers(7)**, **clevis(1)**, and **clevis-encrypt-tpm2(1)** man pages on your system
- **clevis**, **clevis decrypt**, and **clevis encrypt tang** commands without any arguments show the built-in CLI help, for example:

```
$ clevis encrypt tang
Usage: clevis encrypt tang CONFIG < PLAINTEXT > JWE
...
```

10.6. CONFIGURING NBDE CLIENTS FOR AUTOMATED UNLOCKING OF LUKS-ENCRYPTED VOLUMES

With the Clevis framework, you can configure clients for automated unlocking of LUKS-encrypted volumes when a selected Tang server is available. This creates an NBDE (Network-Bound Disk Encryption) deployment.

Prerequisites

- A Tang server is running and available.

Procedure

1. To automatically unlock an existing LUKS-encrypted volume, install the **clevis-luks** subpackage:

```
# yum install clevis-luks
```

2. Identify the LUKS-encrypted volume for PBD. In the following example, the block device is referred as `/dev/sda2`:

```
# lsblk
NAME                                MAJ:MIN RM  SIZE RO TYPE  MOUNTPOINT
sda                                8:0  0  12G  0 disk
├─sda1                             8:1  0   1G  0 part /boot
├─sda2                             8:2  0  11G  0 part
│   └─luks-40e20552-2ade-4954-9d56-565aa7994fb6 253:0  0   11G  0 crypt
│       ├─rhel-root                 253:0  0   9.8G  0 lvm  /
│       └─rhel-swap                 253:1  0   1.2G  0 lvm  [SWAP]
```

3. Bind the volume to a Tang server using the **clevis luks bind** command:

```
# clevis luks bind -d /dev/sda2 tang '{"url":"http://tang.srv"}'
```

The advertisement contains the following signing keys:

```
_Oslk0T-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.

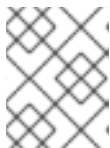
A backup is advised before initialization is performed.

Do you wish to initialize /dev/sda2? [yn] y

Enter existing LUKS password:

This command performs four steps:

- a. Creates a new key with the same entropy as the LUKS master key.
- b. Encrypts the new key with Clevis.
- c. Stores the Clevis JWE object in the LUKS2 header token or uses LUKSMeta if the non-default LUKS1 header is used.
- d. Enables the new key for use with LUKS.



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.

The volume can now be unlocked with your existing password as well as with the Clevis policy.

4. To enable the early boot system to process the disk binding, use the **dracut** tool on an already installed system. In RHEL, Clevis produces a generic **initrd** (initial RAM disk) without host-specific configuration options and does not automatically add parameters such as **rd.neednet=1**

to the kernel command line. If your configuration relies on a Tang pin that requires network during early boot, use the **--hostonly-cmdline** argument and **dracut** adds **rd.neednet=1** when it detects a Tang binding:

- a. Install the **clevis-dracut** package:

```
# yum install clevis-dracut
```

- b. Regenerate the initial RAM disk:

```
# dracut -fv --regenerate-all --hostonly-cmdline
```

- c. Alternatively, create a .conf file in the **/etc/dracut.conf.d/** directory, and add the **hostonly_cmdline=yes** option to the file. Then, you can use **dracut** without **--hostonly-cmdline**, for example:

```
# echo "hostonly_cmdline=yes" > /etc/dracut.conf.d/clevis.conf
# dracut -fv --regenerate-all
```

- d. You can also ensure that networking for a Tang pin is available during early boot by using the **grubby** tool on the system where Clevis is installed:

```
# grubby --update-kernel=ALL --args="rd.neednet=1"
```

Verification

1. Verify that the Clevis JWE object is successfully placed in a LUKS header, use the **clevis luks list** command:

```
# clevis luks list -d /dev/sda2
1: tang '{"url":"http://tang.srv:port"}'
```

2. Check that the bindings are available for the early boot, for example:

```
# lsinitrd | grep clevis-luks
lrwxrwxrwx 1 root root      48 Jan 4 02:56
etc/systemd/system/cryptsetup.target.wants/clevis-luks-askpass.path ->
/usr/lib/systemd/system/clevis-luks-askpass.path
...
```

Additional resources

- **clevis-luks-bind(1)** and **dracut.cmdline(7)** man pages on your system
- [Looking forward to Linux network configuration in the initial ramdisk \(initrd\)](#) (Red Hat Enable Sysadmin)

10.7. CONFIGURING NBDE CLIENTS WITH STATIC IP CONFIGURATION

To use NBDE for clients with static IP configuration (without DHCP), you must pass your network configuration to the **dracut** tool manually.

Prerequisites

- A Tang server is running and available.
- The NBDE client is configured for automated unlocking of encrypted volumes by the Tang server.
For details, see [Configuring NBDE clients for automated unlocking of LUKS-encrypted volumes](#).

Procedure

1. You can provide your static network configuration as a value for the **kernel-cmdline** option in a **dracut** command, for example:

```
# dracut -fv --regenerate-all --kernel-cmdline
"ip=192.0.2.10::192.0.2.1:255.255.255.0::ens3:none nameserver=192.0.2.100"
```

2. Alternatively, create a .conf file in the **/etc/dracut.conf.d/** directory with the static network information and then, regenerate the initial RAM disk image:

```
# cat /etc/dracut.conf.d/static_ip.conf
kernel_cmdline="ip=192.0.2.10::192.0.2.1:255.255.255.0::ens3:none
nameserver=192.0.2.100"
# dracut -fv --regenerate-all
```

10.8. CONFIGURING MANUAL ENROLLMENT OF LUKS-ENCRYPTED VOLUMES BY USING A TPM 2.0 POLICY

You can configure unlocking of LUKS-encrypted volumes by using a Trusted Platform Module 2.0 (TPM 2.0) policy.

Prerequisites

- An accessible TPM 2.0-compatible device.
- A system with the 64-bit Intel or 64-bit AMD architecture.

Procedure

1. To automatically unlock an existing LUKS-encrypted volume, install the **clevis-luks** subpackage:

```
# yum install clevis-luks
```

2. Identify the LUKS-encrypted volume for PBD. In the following example, the block device is referred as **/dev/sda2**:

```
# lsblk
NAME                                MAJ:MIN RM  SIZE RO TYPE  MOUNTPOINT
sda                                8:0  0  12G  0 disk
├─sda1                            8:1  0   1G  0 part  /boot
├─sda2                            8:2  0  11G  0 part
│   └─luks-40e20552-2ade-4954-9d56-565aa7994fb6 253:0  0  11G  0 crypt
│       ├─rhel-root                253:0  0  9.8G  0 lvm  /
│       └─rhel-swap                253:1  0  1.2G  0 lvm  [SWAP]
```

3. Bind the volume to a TPM 2.0 device using the **clevis luks bind** command, for example:

```
# clevis luks bind -d /dev/sda2 tpm2 '{"hash":"sha256","key":"rsa"}'
...
Do you wish to initialize /dev/sda2? [yn] y
Enter existing LUKS password:
```

This command performs four steps:

- a. Creates a new key with the same entropy as the LUKS master key.
- b. Encrypts the new key with Clevis.
- c. Stores the Clevis JWE object in the LUKS2 header token or uses LUKSMeta if the non-default LUKS1 header is used.
- d. Enables the new key for use with LUKS.



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.

Alternatively, if you want to seal data to specific Platform Configuration Registers (PCR) states, add the **pcr_bank** and **pcr_ids** values to the **clevis luks bind** command, for example:

```
# clevis luks bind -d /dev/sda2 tpm2
'{"hash":"sha256","key":"rsa","pcr_bank":"sha256","pcr_ids":"0,1"}'
```



IMPORTANT

Because the data can only be unsealed if PCR hashes values match the policy used when sealing and the hashes can be rewritten, add a strong passphrase that enable you to unlock the encrypted volume manually when a value in a PCR changes.

If the system cannot automatically unlock your encrypted volume after upgrading the **shim-x64** package, see the Red Hat Knowledgebase solution [Clevis TPM2 no longer decrypts LUKS devices after a restart](#).

4. The volume can now be unlocked with your existing password as well as with the Clevis policy.
5. To enable the early boot system to process the disk binding, use the **dracut** tool on an already installed system:

```
# yum install clevis-dracut
# dracut -fv --regenerate-all
```

Verification

1. To verify that the Clevis JWE object is successfully placed in a LUKS header, use the **clevis luks list** command:

—

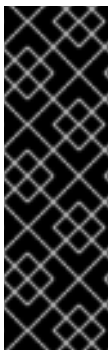
```
# clevis luks list -d /dev/sda2
1: tpm2 '{"hash":"sha256","key":"rsa"}'
```

Additional resources

- **clevis-luks-bind(1)**, **clevis-encrypt-tpm2(1)**, and **dracut.cmdline(7)** man pages on your system

10.9. REMOVING A CLEVIS PIN FROM A LUKS-ENCRYPTED VOLUME MANUALLY

Use the following procedure for manual removing the metadata created by the **clevis luks bind** command and also for wiping a key slot that contains passphrase added by Clevis.



IMPORTANT

The recommended way to remove a Clevis pin from a LUKS-encrypted volume is through the **clevis luks unbind** command. The removal procedure using **clevis luks unbind** consists of only one step and works for both LUKS1 and LUKS2 volumes. The following example command removes the metadata created by the binding step and wipe the key slot **1** on the **/dev/sda2** device:

```
# clevis luks unbind -d /dev/sda2 -s 1
```

Prerequisites

- A LUKS-encrypted volume with a Clevis binding.

Procedure

1. Check which LUKS version the volume, for example **/dev/sda2**, is encrypted by and identify a slot and a token that is bound to Clevis:

```
# cryptsetup luksDump /dev/sda2
LUKS header information
Version:      2
...
Keyslots:
  0: luks2
...
  1: luks2
    Key:      512 bits
    Priority:  normal
    Cipher:   aes-xts-plain64
...
  Tokens:
    0: clevis
      Keyslot: 1
...

```

In the previous example, the Clevis token is identified by **0** and the associated key slot is **1**.

2. In case of LUKS2 encryption, remove the token:

```
# cryptsetup token remove --token-id 0 /dev/sda2
```

3. If your device is encrypted by LUKS1, which is indicated by the **Version: 1** string in the output of the **cryptsetup luksDump** command, perform this additional step with the **luksmeta wipe** command:

```
# luksmeta wipe -d /dev/sda2 -s 1
```

4. Wipe the key slot containing the Clevis passphrase:

```
# cryptsetup luksKillSlot /dev/sda2 1
```

Additional resources

- **clevis-luks-unbind(1)**, **cryptsetup(8)**, and **luksmeta(8)** man pages on your system

10.10. CONFIGURING AUTOMATED ENROLLMENT OF LUKS-ENCRYPTED VOLUMES BY USING KICKSTART

Follow the steps in this procedure to configure an automated installation process that uses Clevis for the enrollment of LUKS-encrypted volumes.

Procedure

1. Instruct Kickstart to partition the disk such that LUKS encryption has enabled for all mount points, other than **/boot**, with a temporary password. The password is temporary for this step of the enrollment process.

```
part /boot --fstype="xfs" --ondisk=vda --size=256
part / --fstype="xfs" --ondisk=vda --grow --encrypted --passphrase=temppass
```

Note that OSPP-compliant systems require a more complex configuration, for example:

```
part /boot --fstype="xfs" --ondisk=vda --size=256
part / --fstype="xfs" --ondisk=vda --size=2048 --encrypted --passphrase=temppass
part /var --fstype="xfs" --ondisk=vda --size=1024 --encrypted --passphrase=temppass
part /tmp --fstype="xfs" --ondisk=vda --size=1024 --encrypted --passphrase=temppass
part /home --fstype="xfs" --ondisk=vda --size=2048 --grow --encrypted --
passphrase=temppass
part /var/log --fstype="xfs" --ondisk=vda --size=1024 --encrypted --passphrase=temppass
part /var/log/audit --fstype="xfs" --ondisk=vda --size=1024 --encrypted --
passphrase=temppass
```

2. Install the related Clevis packages by listing them in the **%packages** section:

```
%packages
clevis-dracut
clevis-luks
clevis-systemd
%end
```

3. Optional: To ensure that you can unlock the encrypted volume manually when required, add a

strong passphrase before you remove the temporary passphrase. For more information, see the Red Hat Knowledgebase solution [How to add a passphrase, key, or keyfile to an existing LUKS device](#).

4. Call **clevis luks bind** to perform binding in the **%post** section. Afterward, remove the temporary password:

```
%post
clevis luks bind -y -k - -d /dev/vda2 \
tang '{"url":"http://tang.srv"}' <<< "temppass"
cryptsetup luksRemoveKey /dev/vda2 <<< "temppass"
dracut -fv --regenerate-all
%end
```

If your configuration relies on a Tang pin that requires network during early boot or you use NBDE clients with static IP configurations, you have to modify the **dracut** command as described in [Configuring manual enrollment of LUKS-encrypted volumes](#).

Note that the **-y** option for the **clevis luks bind** command is available from RHEL 8.3. In RHEL 8.2 and older, replace **-y** by **-f** in the **clevis luks bind** command and download the advertisement from the Tang server:

```
%post
curl -sfg http://tang.srv/adv -o adv.jws
clevis luks bind -f -k - -d /dev/vda2 \
tang '{"url":"http://tang.srv","adv":"adv.jws"}' <<< "temppass"
cryptsetup luksRemoveKey /dev/vda2 <<< "temppass"
dracut -fv --regenerate-all
%end
```



WARNING

The **cryptsetup luksRemoveKey** command prevents any further administration of a LUKS2 device on which you apply it. You can recover a removed master key using the **dmsetup** command only for LUKS1 devices.

You can use an analogous procedure when using a TPM 2.0 policy instead of a Tang server.

Additional resources

- **clevis(1)**, **clevis-luks-bind(1)**, **cryptsetup(8)**, and **dmsetup(8)** man pages on your system
- [Automatically installing RHEL](#)

10.11. CONFIGURING AUTOMATED UNLOCKING OF A LUKS-ENCRYPTED REMOVABLE STORAGE DEVICE

You can set up an automated unlocking process of a LUKS-encrypted USB storage device.

Procedure

1. To automatically unlock a LUKS-encrypted removable storage device, such as a USB drive, install the **clevis-udisks2** package:

```
# yum install clevis-udisks2
```

2. Reboot the system, and then perform the binding step using the **clevis luks bind** command as described in [Configuring manual enrollment of LUKS-encrypted volumes](#), for example:

```
# clevis luks bind -d /dev/sdb1 tang '{"url":"http://tang.srv"}'
```

3. 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.

Additional resources

- **clevis-luks-unlockers(7)** man page on your system

10.12. DEPLOYING HIGH-AVAILABILITY NBDE SYSTEMS

Tang provides two methods for building a high-availability deployment:

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 can decrypt by contacting a subset of these servers. Clevis already supports this workflow through its **sss** plug-in. Red Hat recommends this method for a high-availability deployment.

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.

High-available NBDE using Shamir's Secret Sharing

Shamir's Secret Sharing (SSS) is a cryptographic scheme that divides a secret into several unique parts. To reconstruct the secret, a number of parts is required. The number is called threshold and SSS is also referred to as a thresholding scheme.

Clevis provides an implementation of SSS. It creates a key and divides it into a number of pieces. Each piece is encrypted using another pin including even SSS recursively. Additionally, you define the threshold **t**. If an NBDE deployment decrypts at least **t** pieces, then it recovers the encryption key and the decryption process succeeds. When Clevis detects a smaller number of parts than specified in the threshold, it prints an error message.

Example 1: Redundancy with two Tang servers

The following command decrypts a LUKS-encrypted device when at least one of two Tang servers is available:

```
-
```

```
# clevis luks bind -d /dev/sda1 sss '{"t":1,"pins":{"tang":[{"url":"http://tang1.srv"},
{"url":"http://tang2.srv"}]}}'
```

The previous command used the following configuration scheme:

```
{
  "t":1,
  "pins":{
    "tang":[
      {
        "url":"http://tang1.srv"
      },
      {
        "url":"http://tang2.srv"
      }
    ]
  }
}
```

In this configuration, the SSS threshold **t** is set to **1** and the **clevis luks bind** command successfully reconstructs the secret if at least one from two listed **tang** servers is available.

Example 2: Shared secret on a Tang server and a TPM device

The following command successfully decrypts a LUKS-encrypted device when both the **tang** server and the **tpm2** device are available:

```
# clevis luks bind -d /dev/sda1 sss '{"t":2,"pins":{"tang":[{"url":"http://tang1.srv"}], "tpm2":
{"pcr_ids":"0,7"}]}'
```

The configuration scheme with the SSS threshold 't' set to '2' is now:

```
{
  "t":2,
  "pins":{
    "tang":[
      {
        "url":"http://tang1.srv"
      }
    ],
    "tpm2":{
      "pcr_ids":"0,7"
    }
  }
}
```

Additional resources

- **tang(8)** (section **High Availability**), **clevis(1)** (section **Shamir's Secret Sharing**), and **clevis-encrypt-sss(1)** man pages on your system

10.13. DEPLOYMENT OF 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 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 your scenario requires having encrypted root volumes in a cloud, perform the installation process (usually using Kickstart) for each instance of Red Hat Enterprise Linux in the cloud as well. The images cannot be shared without also sharing a LUKS master key.

To deploy automated unlocking in a virtualized environment, use systems such as **lorax** or **virt-install** together with a Kickstart file (see [Configuring automated enrollment of LUKS-encrypted volumes using Kickstart](#)) or another automated provisioning tool to ensure that each encrypted VM has a unique master key.

Additional resources

- **clevis-luks-bind(1)** man page on your system

10.14. BUILDING AUTOMATICALLY-ENROLLABLE VM IMAGES FOR CLOUD ENVIRONMENTS BY USING NBDE

Deploying automatically-enrollable encrypted images in a cloud environment can provide a unique set of challenges. Like other virtualization environments, it is recommended to reduce the number of instances started from a single image to avoid sharing the LUKS master key.

Therefore, the best practice is to create customized images that are not shared in any public repository and that provide a base for the deployment of a limited amount of instances. The exact number of instances to create should be defined by deployment's security policies and based on the risk tolerance associated with the LUKS master key attack vector.

To build LUKS-enabled automated deployments, 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

Always maintain 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.

10.15. DEPLOYING TANG AS A CONTAINER

The **tang** container image provides Tang-server decryption capabilities for Clevis clients that run either in OpenShift Container Platform (OCP) clusters or in separate virtual machines.

Prerequisites

- The **podman** package and its dependencies are installed on the system.
- You have logged in on the **registry.redhat.io** container catalog using the **podman login registry.redhat.io** command. See [Red Hat Container Registry Authentication](#) for more information.
- The Clevis client is installed on systems containing LUKS-encrypted volumes that you want to automatically unlock by using a Tang server.

Procedure

1. Pull the **tang** container image from the **registry.redhat.io** registry:

```
# podman pull registry.redhat.io/rhel8/tang
```

2. Run the container, specify its port, and specify the path to the Tang keys. The previous example runs the **tang** container, specifies the port **7500**, and indicates a path to the Tang keys of the **/var/db/tang** directory:

```
# podman run -d -p 7500:7500 -v tang-keys:/var/db/tang --name tang
registry.redhat.io/rhel8/tang
```

Note that Tang uses port 80 by default but this may collide with other services such as the Apache HTTP server.

3. Optional: For increased security, rotate the Tang keys periodically. You can use the **tangd-rotate-keys** script, for example:

```
# podman run --rm -v tang-keys:/var/db/tang registry.redhat.io/rhel8/tang tangd-rotate-keys -
v -d /var/db/tang
Rotated key 'rZAMKAseaXBe0rcKXL1hCClq-DY.jwk' -> .rZAMKAseaXBe0rcKXL1hCClq-
DY.jwk'
Rotated key 'x1Alpc6WmnCU-CabD8_4q18vDuw.jwk' -> .x1Alpc6WmnCU-
CabD8_4q18vDuw.jwk'
Created new key GrMMX_WfdqomIU_4RyjpcdlXb0E.jwk
Created new key _dTTfn17sZZqVAp80u3ygFDHtjk.jwk
Keys rotated successfully.
```

Verification

- On a system that contains LUKS-encrypted volumes for automated unlocking by the presence of the Tang server, check that the Clevis client can encrypt and decrypt a plain-text message using Tang:

```
# echo test | clevis encrypt tang '{"url":"http://localhost:7500"}' | clevis decrypt
The advertisement contains the following signing keys:

x1Alpc6WmnCU-CabD8_4q18vDuw

Do you wish to trust these keys? [ynYN] y
test
```

The previous example command shows the **test** string at the end of its output when a Tang server is available on the *localhost* URL and communicates through port 7500.

Additional resources

- **podman(1)**, **clevis(1)**, and **tang(8)** man pages on your system

10.16. CONFIGURING NBDE BY USING RHEL SYSTEM ROLES

You can use the **nbde_client** and **nbde_server** RHEL system roles for automated deployments of Policy-Based Decryption (PBD) solutions using Clevis and Tang. The **rhel-system-roles** package contains these system roles, the related examples, and also the reference documentation.

10.16.1. Using the **nbde_server** RHEL system role for setting up multiple Tang servers

By using the **nbde_server** system role, you can deploy and manage a Tang server as part of an automated disk encryption solution. This role supports the following features:

- Rotating Tang keys
- Deploying and backing up Tang keys

Prerequisites

- [You have prepared the control node and the managed nodes](#)
- You are logged in to the control node as a user who can run playbooks on the managed nodes.
- The account you use to connect to the managed nodes has **sudo** permissions on them.

Procedure

1. Create a playbook file, for example **~/playbook.yml**, with the following content:

```
---
- name: Deploy a Tang server
  hosts: tang.server.example.com
  tasks:
    - name: Install and configure periodic key rotation
      ansible.builtin.include_role:
        name: redhat.rhel_system_roles.nbde_server
  vars:
    nbde_server_rotate_keys: yes
    nbde_server_manage_firewall: true
    nbde_server_manage_selinux: true
```

This example playbook ensures deploying of your Tang server and a key rotation.

The settings specified in the example playbook include the following:

nbde_server_manage_firewall: true

Use the **firewall** system role to manage ports used by the **nbde_server** role.

nbde_server_manage_selinux: true

Use the **selinux** system role to manage ports used by the **nbde_server** role.

For details about all variables used in the playbook, see the `/usr/share/ansible/roles/rhel-system-roles.nbde_server/README.md` file on the control node.

2. Validate the playbook syntax:

```
$ ansible-playbook --syntax-check ~/playbook.yml
```

Note that this command only validates the syntax and does not protect against a wrong but valid configuration.

3. Run the playbook:

```
$ ansible-playbook ~/playbook.yml
```

Verification

- On your NBDE client, verify that your Tang server works correctly by using the following command. The command must return the identical message you pass for encryption and decryption:

```
# ansible managed-node-01.example.com -m command -a 'echo test | clevis encrypt tang  
'{"url":"<tang.server.example.com>"}' -y | clevis decrypt'  
test
```

Additional resources

- `/usr/share/ansible/roles/rhel-system-roles.nbde_server/README.md` file
- `/usr/share/doc/rhel-system-roles/nbde_server/` directory

10.16.2. Setting up Clevis clients with DHCP by using the `nbde_client` RHEL system role

The **`nbde_client`** system role enables you to deploy multiple Clevis clients in an automated way.

This role supports binding a LUKS-encrypted volume to one or more Network-Bound (NBDE) servers – Tang servers. You can either preserve the existing volume encryption with a passphrase or remove it. After removing the passphrase, you can unlock the volume only using NBDE. This is useful when a volume is initially encrypted using a temporary key or password that you should remove after you provision the system.

If you provide both a passphrase and a key file, the role uses what you have provided first. If it does not find any of these valid, it attempts to retrieve a passphrase from an existing binding.

Policy-Based Decryption (PBD) defines a binding as a mapping of a device to a slot. This means that you can have multiple bindings for the same device. The default slot is slot 1.



NOTE

The **`nbde_client`** system role supports only Tang bindings. Therefore, you cannot use it for TPM2 bindings.

Prerequisites

- You have prepared the control node and the managed nodes
- You are logged in to the control node as a user who can run playbooks on the managed nodes.
- The account you use to connect to the managed nodes has **sudo** permissions on them.
- A volume that is already encrypted by using LUKS.

Procedure

1. Create a playbook file, for example `~/playbook.yml`, with the following content:

```
---
- name: Configure clients for unlocking of encrypted volumes by Tang servers
  hosts: managed-node-01.example.com
  tasks:
    - name: Create NBDE client bindings
      ansible.builtin.include_role:
        name: redhat.rhel_system_roles.nbde_client
      vars:
        nbde_client_bindings:
          - device: /dev/rhel/root
            encryption_key_src: /etc/luks/keyfile
            nbde_client_early_boot: true
            state: present
            servers:
              - http://server1.example.com
              - http://server2.example.com
          - device: /dev/rhel/swap
            encryption_key_src: /etc/luks/keyfile
            servers:
              - http://server1.example.com
              - http://server2.example.com
```

This example playbook configures Clevis clients for automated unlocking of two LUKS-encrypted volumes when at least one of two Tang servers is available.

The settings specified in the example playbook include the following:

state: present

The values of **state** indicate the configuration after you run the playbook. Use the **present** value for either creating a new binding or updating an existing one. Contrary to a **clevis luks bind** command, you can use **state: present** also for overwriting an existing binding in its device slot. The **absent** value removes a specified binding.

nbde_client_early_boot: true

The **nbde_client** role ensures that networking for a Tang pin is available during early boot by default. If your scenario requires to disable this feature, add the **nbde_client_early_boot: false** variable to your playbook.

For details about all variables used in the playbook, see the `/usr/share/ansible/roles/rhel-system-roles.nbde_client/README.md` file on the control node.

2. Validate the playbook syntax:

```
$ ansible-playbook --syntax-check ~/playbook.yml
```

Note that this command only validates the syntax and does not protect against a wrong but valid configuration.

3. Run the playbook:

```
$ ansible-playbook ~/playbook.yml
```

Verification

1. On your NBDE client, check that the encrypted volume that should be automatically unlocked by your Tang servers contain the corresponding information in its LUKS pins:

```
# ansible managed-node-01.example.com -m command -a 'clevis luks list -d /dev/rhel/root'
1: tang '{"url": "<http://server1.example.com/>"}'
2: tang '{"url": "<http://server2.example.com/>"}'
```

2. If you do not use the **nbde_client_early_boot: false** variable, verify that the bindings are available for the early boot, for example:

```
# ansible managed-node-01.example.com -m command -a 'lsinitrd | grep clevis-luks'
lrwxrwxrwx 1 root root 48 Jan 4 02:56
etc/systemd/system/cryptsetup.target.wants/clevis-luks-askpass.path ->
/usr/lib/systemd/system/clevis-luks-askpass.path
...
```

Additional resources

- [/usr/share/ansible/roles/rhel-system-roles.nbde_client/README.md](#) file
- [/usr/share/doc/rhel-system-roles/nbde_client/](#) directory

10.16.3. Setting up static-IP Clevis clients by using the nbde_client RHEL system role

The **nbde_client** RHEL system role supports only scenarios with Dynamic Host Configuration Protocol (DHCP). On an NBDE client with static IP configuration, you must pass your network configuration as a kernel boot parameter.

Typically, administrators want to reuse a playbook and not maintain individual playbooks for each host to which Ansible assigns static IP addresses during early boot. In this case, you can use variables in the playbook and provide the settings in an external file. As a result, you need only one playbook and one file with the settings.

Prerequisites

- [You have prepared the control node and the managed nodes](#)
- You are logged in to the control node as a user who can run playbooks on the managed nodes.
- The account you use to connect to the managed nodes has **sudo** permissions on them.
- A volume that is already encrypted by using LUKS.

Procedure

1. Create a file with the network settings of your hosts, for example, **static-ip-settings-clients.yml**, and add the values you want to dynamically assign to the hosts:

```
clients:
  managed-node-01.example.com:
    ip_v4: 192.0.2.1
    gateway_v4: 192.0.2.254
    netmask_v4: 255.255.255.0
    interface: enp1s0
  managed-node-02.example.com:
    ip_v4: 192.0.2.2
    gateway_v4: 192.0.2.254
    netmask_v4: 255.255.255.0
    interface: enp1s0
```

2. Create a playbook file, for example, **~/playbook.yml**, with the following content:

```
- name: Configure clients for unlocking of encrypted volumes by Tang servers
  hosts: managed-node-01.example.com,managed-node-02.example.com
  vars_files:
    - ~/static-ip-settings-clients.yml
  tasks:
    - name: Create NBDE client bindings
      ansible.builtin.include_role:
        name: redhat.rhel_system_roles.network
      vars:
        nbde_client_bindings:
          - device: /dev/rhel/root
            encryption_key_src: /etc/luks/keyfile
            servers:
              - http://server1.example.com
              - http://server2.example.com
          - device: /dev/rhel/swap
            encryption_key_src: /etc/luks/keyfile
            servers:
              - http://server1.example.com
              - http://server2.example.com

    - name: Configure a Clevis client with static IP address during early boot
      ansible.builtin.include_role:
        name: redhat.rhel_system_roles.bootloader
      vars:
        bootloader_settings:
          - kernel: ALL
          options:
            - name: ip
              value: "{{ clients[inventory_hostname]['ip_v4'] }}::{{ clients[inventory_hostname]
['gateway_v4'] }}::{{ clients[inventory_hostname]['netmask_v4'] }}::{{
clients[inventory_hostname]['interface'] }}:none"
```

This playbook reads certain values dynamically for each host listed in the **~/static-ip-settings-clients.yml** file.

For details about all variables used in the playbook, see the **/usr/share/ansible/roles/rhel-system-roles.network/README.md** file on the control node.

3. Validate the playbook syntax:

```
$ ansible-playbook --syntax-check ~/playbook.yml
```

Note that this command only validates the syntax and does not protect against a wrong but valid configuration.

4. Run the playbook:

```
$ ansible-playbook ~/playbook.yml
```

Additional resources

- **/usr/share/ansible/roles/rhel-system-roles.nbde_client/README.md** file
- **/usr/share/doc/rhel-system-roles/nbde_client/** directory
- [Looking forward to Linux network configuration in the initial ramdisk \(initrd\)](#) (Red Hat Enable Sysadmin)

CHAPTER 11. AUDITING THE SYSTEM

Although Audit does not provide additional security to your system, you can use it to discover violations of security policies on your system. Then, you can prevent future such violations by configuring additional security measures such as SELinux.

11.1. LINUX AUDIT

The Linux Audit system provides a way to track security-relevant information about 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.

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).

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 several 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 **nftables**, **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.

11.2. 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 following filters: **user**, **task**, **fstype**, or **exit**.

After 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.

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:

- The **auditctl** Audit control utility interacts with the kernel Audit component to manage rules and to control many 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.

In RHEL 8, the Audit dispatcher daemon (**audisp**) functionality is integrated in the Audit daemon (**auditd**). Configuration files of plugins for the interaction of real-time analytical programs with Audit events are located in the **/etc/audit/plugins.d/** directory by default.

11.3. CONFIGURING AUDITD FOR A SECURE ENVIRONMENT

The default **auditd** configuration should be suitable for most environments. However, if your environment must meet strict security policies, you can change the following settings 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. The **max_log_file** parameter specifies the maximum file size in megabytes. The value given must be numeric.

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. If the value of **space_left** is specified as a whole number, it is interpreted as an absolute size in megabytes (MiB). If the value is specified as a number between 1 and 99 followed by a percentage sign (for example, 5%), the Audit daemon calculates the absolute size in megabytes based on the size of the file system containing **log_file**.

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. The numeric value for this parameter should be lower than the number for **space_left**. You can also append a percent sign (for example, 1%) to the number to have the audit daemon calculate the number based on the disk partition size.

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.

11.4. STARTING AND CONTROLLING AUDITD

After **auditd** is configured, start the service to collect Audit information and store it in the log files. Use the following command as the root user to start **auditd**:

```
# service auditd start
```

To configure **auditd** to start at boot time:

```
# systemctl enable auditd
```

You can temporarily disable **auditd** with the **# auditctl -e 0** command and re-enable it with **# auditctl -e 1**.

You can perform other actions on **auditd** by 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**.



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 **audit** value is properly recorded. You can use the **systemctl** command only for two actions: **enable** and **status**.

11.5. 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.

Add the following Audit rule to log every attempt to read or modify the `/etc/ssh/sshd_config` file:

```
# auditctl -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
nametype=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 start 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.

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 a 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 PATH 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.

audit=1000

The **audit** 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 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.

oid=0

The **oid** 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.

nametype=NORMAL

The **nametype** 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 **cat /etc/ssh/sshd_config**.

11.6. USING AUDITCTL FOR DEFINING AND EXECUTING AUDIT RULES

The Audit system operates on a set of rules that define what is captured in the log files. Audit rules can be set either on the command line using the **auditctl** utility or in the **/etc/audit/rules.d/** directory.

The **auditctl** command enables you to control the basic functionality of the Audit system and to define rules that decide which Audit events are logged.

File-system rules examples

1. To define a rule that logs all write access to, and every attribute change of, the **/etc/passwd** file:

```
# auditctl -w /etc/passwd -p wa -k passwd_changes
```

2. To define a rule that logs all write access to, and every attribute change of, all the files in the **/etc/selinux/** directory:

```
# auditctl -w /etc/selinux/ -p wa -k selinux_changes
```

System-call rules examples

1. 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:

```
# auditctl -a always,exit -F arch=b64 -S adjtimex -S settimeofday -k time_change
```

2. 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:

```
# 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.

Executable-file rules

To define a rule that logs all execution of the **/bin/id** program, execute the following command:

```
# auditctl -a always,exit -F exe=/bin/id -F arch=b64 -S execve -k execution_bin_id
```

Additional resources

- **auditctl(8)** man page on your system

11.7. DEFINING PERSISTENT AUDIT RULES

To define Audit rules that are persistent across reboots, you must either directly include them in the **/etc/audit/rules.d/audit.rules** file or use the **augenrules** program that reads rules located in the **/etc/audit/rules.d/** directory.

Note that the **/etc/audit/audit.rules** file is generated whenever the **auditd** service starts. Files in **/etc/audit/rules.d/** use the same **auditctl** command-line syntax to specify the rules. Empty lines and text following a hash sign (**#**) are ignored.

Furthermore, you can use the **auditctl** command to read rules from a specified file using the **-R** option, for example:

```
# auditctl -R /usr/share/audit/sample-rules/30-stig.rules
```

11.8. PRE-CONFIGURED AUDIT RULES FILES FOR COMPLIANCE WITH STANDARDS

To configure Audit for compliance with a specific certification standard, such as OSPP, PCI DSS, or STIG, you can use the set of pre-configured rules files installed with the **audit** package as a starting point. The sample rules are located in the **/usr/share/audit/sample-rules** directory.



WARNING

The Audit sample rules in the **sample-rules** directory are not exhaustive nor up to date because security standards are dynamic and subject to change. These rules are provided only to demonstrate how Audit rules can be structured and written. They do not ensure immediate compliance with the latest security standards. To bring your system into compliance with the latest security standards according to specific security guidelines, use the [SCAP-based security compliance tools](#).

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-ospp-v42*.rules

Audit rule configuration that meets the requirements defined in the OSPP (Protection Profile for General Purpose Operating Systems) profile version 4.2.

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, copy them to the `/etc/audit/rules.d/` directory and use the **augenrules** **--load** command, for example:

```
# cd /usr/share/audit/sample-rules/
# cp 10-base-config.rules 30-stig.rules 31-privileged.rules 99-finalize.rules /etc/audit/rules.d/
# augenrules --load
```

You can order Audit rules using a numbering scheme. See the `/usr/share/audit/sample-rules/README-rules` file for more information.

Additional resources

- **audit.rules(7)** man page on your system

11.9. 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 end with **.rules** in a specific order based on their natural sort order. The files in this directory are organized into groups with the 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
/sbin/augenrules: No change
No rules
enabled 1
```

```
failure 1
pid 742
rate_limit 0
...
```

Additional resources

- **audit.rules(8)** and **augenrules(8)** man pages on your system

11.10. DISABLING AUGENRULES

Use the following steps to disable the **augenrules** utility. This switches Audit to use rules defined in the **/etc/audit/audit.rules** file.

Procedure

1. Copy the **/usr/lib/systemd/system/auditd.service** file to the **/etc/systemd/system/** directory:

```
# cp -f /usr/lib/systemd/system/auditd.service /etc/systemd/system/
```

2. Edit the **/etc/systemd/system/auditd.service** file in a text editor of your choice, for example:

```
# vi /etc/systemd/system/auditd.service
```

3. Comment out the line containing **augenrules**, and uncomment the line containing the **auditctl -R** command:

```
#ExecStartPost=/sbin/augenrules --load
ExecStartPost=/sbin/auditctl -R /etc/audit/audit.rules
```

4. Reload the **systemd** daemon to fetch changes in the **auditd.service** file:

```
# systemctl daemon-reload
```

5. Restart the **auditd** service:

```
# service auditd restart
```

Additional resources

- **augenrules(8)** and **audit.rules(8)** man pages on your system
- [Auditd service restart overrides changes made to /etc/audit/audit.rules](#) (Red Hat Knowledgebase)

11.11. SETTING UP AUDIT TO MONITOR SOFTWARE UPDATES

In RHEL 8.6 and later versions, you can use the pre-configured rule **44-installers.rules** to configure Audit to monitor the following utilities that install software:

- **dnf** [3]

- **yum**
- **pip**
- **npm**
- **cpan**
- **gem**
- **luarocks**

By default, **rpm** already provides audit **SOFTWARE_UPDATE** events when it installs or updates a package. You can list them by entering **ausearch -m SOFTWARE_UPDATE** on the command line.

In RHEL 8.5 and earlier versions, you can manually add rules to monitor utilities that install software into a **.rules** file within the **/etc/audit/rules.d/** directory.



NOTE

Pre-configured rule files cannot be used on systems with the **ppc64le** and **aarch64** architectures.

Prerequisites

- **auditd** is configured in accordance with the settings provided in [Configuring auditd for a secure environment](#).

Procedure

1. On RHEL 8.6 and later, copy the pre-configured rule file **44-installers.rules** from the **/usr/share/audit/sample-rules/** directory to the **/etc/audit/rules.d/** directory:

```
# cp /usr/share/audit/sample-rules/44-installers.rules /etc/audit/rules.d/
```

On RHEL 8.5 and earlier, create a new file in the **/etc/audit/rules.d/** directory named **44-installers.rules**, and insert the following rules:

```
-a always,exit -F perm=x -F path=/usr/bin/dnf-3 -F key=software-installer
-a always,exit -F perm=x -F path=/usr/bin/yum -F
```

You can add additional rules for other utilities that install software, for example **pip** and **npm**, using the same syntax.

2. Load the audit rules:

```
# augenrules --load
```

Verification

1. List the loaded rules:

```
# auditctl -l
-p x-w /usr/bin/dnf-3 -k software-installer
```

```
-p x-w /usr/bin/yum -k software-installer
-p x-w /usr/bin/pip -k software-installer
-p x-w /usr/bin/npm -k software-installer
-p x-w /usr/bin/cpan -k software-installer
-p x-w /usr/bin/gem -k software-installer
-p x-w /usr/bin/luarocks -k software-installer
```

2. Perform an installation, for example:

```
# yum reinstall -y vim-enhanced
```

3. Search the Audit log for recent installation events, for example:

```
# ausearch -ts recent -k software-installer
_____
time->Thu Dec 16 10:33:46 2021
type=PROCTITLE msg=audit(1639668826.074:298):
proctitle=2F7573722F6C69626578656332F706C61746666F726D2D707974686F6E002F75737
22F62696E2F646E66007265696E7374616C6C002D790076696D2D656E68616E636564
type=PATH msg=audit(1639668826.074:298): item=2 name="/lib64/ld-linux-x86-64.so.2"
inode=10092 dev=fd:01 mode=0100755 ouid=0 ogid=0 rdev=00:00
obj=system_u:object_r:ld_so_t:s0 nametype=NORMAL cap_fp=0 cap_fi=0 cap_fe=0
cap_fver=0 cap_frootid=0
type=PATH msg=audit(1639668826.074:298): item=1 name="/usr/libexec/platform-python"
inode=4618433 dev=fd:01 mode=0100755 ouid=0 ogid=0 rdev=00:00
obj=system_u:object_r:bin_t:s0 nametype=NORMAL cap_fp=0 cap_fi=0 cap_fe=0
cap_fver=0 cap_frootid=0
type=PATH msg=audit(1639668826.074:298): item=0 name="/usr/bin/dnf" inode=6886099
dev=fd:01 mode=0100755 ouid=0 ogid=0 rdev=00:00 obj=system_u:object_r:rpm_exec_t:s0
nametype=NORMAL cap_fp=0 cap_fi=0 cap_fe=0 cap_fver=0 cap_frootid=0
type=CWD msg=audit(1639668826.074:298): cwd="/root"
type=EXECVE msg=audit(1639668826.074:298): argc=5 a0="/usr/libexec/platform-python"
a1="/usr/bin/dnf" a2="reinstall" a3="-y" a4="vim-enhanced"
type=SYSCALL msg=audit(1639668826.074:298): arch=c000003e syscall=59 success=yes
exit=0 a0=55c437f22b20 a1=55c437f2c9d0 a2=55c437f2aeb0 a3=8 items=3 ppid=5256
pid=5375 auid=0 uid=0 gid=0 euid=0 suid=0 fsuid=0 egid=0 sgid=0 fsgid=0 tty=pts0 ses=3
comm="dnf" exe="/usr/libexec/platform-python3.6"
subj=unconfined_u:unconfined_r:unconfined_t:s0-s0:c0.c1023 key="software-installer"
```

11.12. MONITORING USER LOGIN TIMES WITH AUDIT

To monitor which users logged in at specific times, you do not need to configure Audit in any special way. You can use the **ausearch** or **aureport** tools, which provide different ways of presenting the same information.

Prerequisites

- **auditd** is configured in accordance with the settings provided in [Configuring auditd for a secure environment](#).

Procedure

To display user log in times, use any one of the following commands:

- Search the audit log for the **USER_LOGIN** message type:

```
# ausearch -m USER_LOGIN -ts '12/02/2020' '18:00:00' -sv no
time->Mon Nov 22 07:33:22 2021
type=USER_LOGIN msg=audit(1637584402.416:92): pid=1939 uid=0 auid=4294967295
ses=4294967295 subj=system_u:system_r:sshd_t:s0-s0:c0.c1023 msg='op=login acct="
(unknown)" exe="/usr/sbin/sshd" hostname=? addr=10.37.128.108 terminal=ssh res=failed'
```

- You can specify the date and time with the **-ts** option. If you do not use this option, **ausearch** provides results from today, and if you omit time, **ausearch** provides results from midnight.
- You can use the **-sv yes** option to filter out successful login attempts and **-sv no** for unsuccessful login attempts.
- Pipe the raw output of the **ausearch** command into the **aulast** utility, which displays the output in a format similar to the output of the **last** command. For example:

```
# ausearch --raw | aulast --stdin
root  ssh      10.37.128.108  Mon Nov 22 07:33 - 07:33 (00:00)
root  ssh      10.37.128.108  Mon Nov 22 07:33 - 07:33 (00:00)
root  ssh      10.22.16.106  Mon Nov 22 07:40 - 07:40 (00:00)
reboot system boot 4.18.0-348.6.el8 Mon Nov 22 07:33
```

- Display the list of login events by using the **aureport** command with the **--login -i** options.

```
# aureport --login -i

Login Report
=====
# date time auid host term exe success event
=====
1. 11/16/2021 13:11:30 root 10.40.192.190 ssh /usr/sbin/sshd yes 6920
2. 11/16/2021 13:11:31 root 10.40.192.190 ssh /usr/sbin/sshd yes 6925
3. 11/16/2021 13:11:31 root 10.40.192.190 ssh /usr/sbin/sshd yes 6930
4. 11/16/2021 13:11:31 root 10.40.192.190 ssh /usr/sbin/sshd yes 6935
5. 11/16/2021 13:11:33 root 10.40.192.190 ssh /usr/sbin/sshd yes 6940
6. 11/16/2021 13:11:33 root 10.40.192.190 /dev/pts/0 /usr/sbin/sshd yes 6945
```

Additional resources

- **ausearch(8)**, **aulast(8)**, and **aureport(8)** man pages on your system

11.13. ADDITIONAL RESOURCES

- [RHEL Audit System Reference](#) (Red Hat Knowledgebase)
- [Auditd execution options in a container](#) (Red Hat Knowledgebase)
- [Linux Audit Documentation Project page](#) (Github.com)
- Documentation in the **/usr/share/doc/audit/** directory provided by the **audit** package
- **auditd(8)**, **auditctl(8)**, **ausearch(8)**, **audit.rules(7)**, **audispd.conf(5)**, **audispd(8)**, **auditd.conf(5)**, **ausearch-expression(5)**, **aulast(8)**, **aulastlog(8)**, **aureport(8)**, **ausyscall(8)**, **autrace(8)**, and **auvirt(8)** man pages on your system

[3] Because **dnf** is a symlink in RHEL, the path in the **dnf** Audit rule must include the target of the symlink. To receive correct Audit events, modify the **44-installers.rules** file by changing the **path=/usr/bin/dnf** path to **/usr/bin/dnf-3**.

CHAPTER 12. BLOCKING AND ALLOWING APPLICATIONS BY USING FAPOLICYD

Setting and enforcing a policy that either allows or denies application execution based on a rule set efficiently prevents the execution of unknown and potentially malicious software.

12.1. INTRODUCTION TO FAPOLICYD

The **fapolicyd** software framework controls the execution of applications based on a user-defined policy. This is one of the most efficient ways to prevent running untrusted and possibly malicious applications on the system.

The **fapolicyd** framework provides the following components:

- **fapolicyd** service
- **fapolicyd** command-line utilities
- **fapolicyd** RPM plugin
- **fapolicyd** rule language
- **fagenrules** script

The administrator can define the **allow** and **deny** execution rules for any application with the possibility of auditing based on a path, hash, MIME type, or trust.

The **fapolicyd** framework introduces the concept of trust. An application is trusted when it is properly installed by the system package manager, and therefore it is registered in the system RPM database. The **fapolicyd** daemon uses the RPM database as a list of trusted binaries and scripts. The **fapolicyd** RPM plugin registers any system update that is handled by either the YUM package manager or the RPM Package Manager. The plugin notifies the **fapolicyd** daemon about changes in this database. Other ways of adding applications require the creation of custom rules and restarting the **fapolicyd** service.

The **fapolicyd** service configuration is located in the `/etc/fapolicyd/` directory with the following structure:

- The `/etc/fapolicyd/fapolicyd.trust` file contains a list of trusted files. You can also use multiple trust files in the `/etc/fapolicyd/trust.d/` directory.
- The `/etc/fapolicyd/rules.d/` directory for files containing **allow** and **deny** execution rules. The **fagenrules** script merges these component rules files to the `/etc/fapolicyd/compiled.rules` file.
- The `fapolicyd.conf` file contains the daemon's configuration options. This file is useful primarily for performance-tuning purposes.

Rules in `/etc/fapolicyd/rules.d/` are organized in several files, each representing a different policy goal. The numbers at the beginning of the corresponding file names determine the order in `/etc/fapolicyd/compiled.rules`:

10

Language rules.

20

Dracut-related Rules.

21

rules for updaters.

30

Patterns.

40

ELF rules.

41

Shared objects rules.

42

Trusted ELF rules.

70

Trusted language rules.

72

Shell rules.

90

Deny execute rules.

95

Allow open rules.

You can use one of the following ways for **fapolicyd** integrity checking:

- File-size checking
- Comparing SHA-256 hashes
- Integrity Measurement Architecture (IMA) subsystem

By default, **fapolicyd** does no integrity checking. Integrity checking based on the file size is fast, but an attacker can replace the content of the file and preserve its byte size. Computing and checking SHA-256 checksums is more secure, but it affects the performance of the system. The **integrity = ima** option in **fapolicyd.conf** requires support for files extended attributes (also known as **xattr**) on all file systems containing executable files.

Additional resources

- **fapolicyd(8)**, **fapolicyd.rules(5)**, **fapolicyd.conf(5)**, **fapolicyd.trust(13)**, **fagenrules(8)**, and **fapolicyd-cli(1)** man pages.
- The [Enhancing security with the kernel integrity subsystem](#) chapter in the [Managing, monitoring, and updating the kernel](#) document.
- The documentation installed with the **fapolicyd** package in the **/usr/share/doc/fapolicyd/** directory and the **/usr/share/fapolicyd/sample-rules/README-rules** file.

12.2. DEPLOYING FAPOLICYD

When deploying the **fapolicyd** application allowlisting framework, you can either try your configuration in permissive mode first or directly enable the service in the default configuration.

Procedure

1. Install the **fapolicyd** package:

```
# yum install fapolicyd
```

2. Optional: To try your configuration first, change mode to permissive.

- a. Open the **/etc/fapolicyd/fapolicyd.conf** file in a text editor of your choice, for example:

```
# vi /etc/fapolicyd/fapolicyd.conf
```

- b. Change the value of the **permissive** option from **0** to **1**, save the file, and exit the editor:

```
permissive = 1
```

Alternatively, you can debug your configuration by using the **fapolicyd --debug-deny --permissive** command before you start the service. See the [Troubleshooting problems related to fapolicyd](#) section for more information.

3. Enable and start the **fapolicyd** service:

```
# systemctl enable --now fapolicyd
```

4. If you enabled permissive mode through **/etc/fapolicyd/fapolicyd.conf**:

- a. Set the Audit service for recording **fapolicyd** events:

```
# auditctl -w /etc/fapolicyd/ -p wa -k fapolicyd_changes
# service try-restart auditd
```

- b. Use your applications.

- c. Check Audit logs for **fanotify** denials, for example:

```
# ausearch -ts recent -m fanotify
```

- d. When debugged, disable permissive mode by changing the corresponding value back to **permissive = 0**, and restart the service:

```
# systemctl restart fapolicyd
```

Verification

1. Verify that the **fapolicyd** service is running correctly:

```
# systemctl status fapolicyd
● fapolicyd.service - File Access Policy Daemon
   Loaded: loaded (/usr/lib/systemd/system/fapolicyd.service; enabled; preset: disabled)
   Active: active (running) since Tue 2024-10-08 05:53:50 EDT; 11s ago
     ...
Oct 08 05:53:51 machine1.example.com fapolicyd[4974]: Loading trust data from rpmdb
backend
```

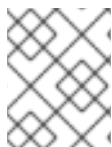
```
Oct 08 05:53:51 machine1.example.com fapolicyd[4974]: Loading trust data from file
backend
Oct 08 05:53:51 machine1.example.com fapolicyd[4974]: Starting to listen for events
```

2. Log in as a user without root privileges, and check that **fapolicyd** is working, for example:

```
$ cp /bin/ls /tmp
$ /tmp/ls
bash: /tmp/ls: Operation not permitted
```

12.3. MARKING FILES AS TRUSTED USING AN ADDITIONAL SOURCE OF TRUST

The **fapolicyd** framework trusts files contained in the RPM database. You can mark additional files as trusted by adding the corresponding entries to the **/etc/fapolicyd/fapolicyd.trust** plain-text file or the **/etc/fapolicyd/trust.d/** directory, which supports separating a list of trusted files into more files. You can modify **fapolicyd.trust** or the files in **/etc/fapolicyd/trust.d** either directly using a text editor or through **fapolicyd-cli** commands.



NOTE

Marking files as trusted using **fapolicyd.trust** or **trust.d/** is better than writing custom **fapolicyd** rules due to performance reasons.

Prerequisites

- The **fapolicyd** framework is deployed on your system.

Procedure

1. Copy your custom binary to the required directory, for example:

```
$ cp /bin/ls /tmp
$ /tmp/ls
bash: /tmp/ls: Operation not permitted
```

2. Mark your custom binary as trusted, and store the corresponding entry to the **myapp** file in **/etc/fapolicyd/trust.d/**:

```
# fapolicyd-cli --file add /tmp/ls --trust-file myapp
```

- If you skip the **--trust-file** option, then the previous command adds the corresponding line to **/etc/fapolicyd/fapolicyd.trust**.
 - To mark all existing files in a directory as trusted, provide the directory path as an argument of the **--file** option, for example: **fapolicyd-cli --file add /tmp/my_bin_dir/ --trust-file myapp**.
3. Update the **fapolicyd** database:

```
# fapolicyd-cli --update
```



NOTE

Changing the content of a trusted file or directory changes their checksum, and therefore **fapolicyd** no longer considers them trusted.

To make the new content trusted again, refresh the file trust database by using the **fapolicyd-cli --file update** command. If you do not provide any argument, the entire database refreshes. Alternatively, you can specify a path to a specific file or directory. Then, update the database by using **fapolicyd-cli --update**.

Verification

1. Check that your custom binary can be now executed, for example:

```
$ /tmp/ls
ls
```

Additional resources

- **fapolicyd.trust(13)** man page on your system

12.4. ADDING CUSTOM ALLOW AND DENY RULES FOR FAPOLICYD

The default set of rules in the **fapolicyd** package does not affect system functions. For custom scenarios, such as storing binaries and scripts in a non-standard directory or adding applications without the **yum** or **rpm** installers, you must either mark additional files as trusted or add new custom rules.

For basic scenarios, prefer [Marking files as trusted using an additional source of trust](#) . In more advanced scenarios such as allowing to execute a custom binary only for specific user and group identifiers, add new custom rules to the **/etc/fapolicyd/rules.d/** directory.

The following steps demonstrate adding a new rule to allow a custom binary.

Prerequisites

- The **fapolicyd** framework is deployed on your system.

Procedure

1. Copy your custom binary to the required directory, for example:

```
$ cp /bin/ls /tmp
$ /tmp/ls
bash: /tmp/ls: Operation not permitted
```

2. Stop the **fapolicyd** service:

```
# systemctl stop fapolicyd
```

3. Use debug mode to identify a corresponding rule. Because the output of the **fapolicyd --debug** command is verbose and you can stop it only by pressing **Ctrl+C** or killing the corresponding process, redirect the error output to a file. In this case, you can limit the output only to access denials by using the **--debug-deny** option instead of **--debug**:

```
# fapolicyd --debug-deny 2> fapolicy.output &
[1] 51341
```

Alternatively, you can run **fapolicyd** debug mode in another terminal.

4. Repeat the command that **fapolicyd** denied:

```
$ /tmp/ls
bash: /tmp/ls: Operation not permitted
```

5. Stop debug mode by resuming it in the foreground and pressing **Ctrl+C**:

```
# fg
fapolicyd --debug 2> fapolicy.output
^C
...
```

Alternatively, kill the process of **fapolicyd** debug mode:

```
# kill 51341
```

6. Find a rule that denies the execution of your application:

```
# cat fapolicy.output | grep 'deny_audit'
...
rule=13 dec=deny_audit perm=execute auid=0 pid=6855 exe=/usr/bin/bash : path=/tmp/ls
ftype=application/x-executable trust=0
```

7. Locate the file that contains a rule that prevented the execution of your custom binary. In this case, the **deny_audit perm=execute** rule belongs to the **90-deny-execute.rules** file:

```
# ls /etc/fapolicyd/rules.d/
10-languages.rules 40-bad-elf.rules 72-shell.rules
20-dracut.rules 41-shared-obj.rules 90-deny-execute.rules
21-updaters.rules 42-trusted-elf.rules 95-allow-open.rules
30-patterns.rules 70-trusted-lang.rules

# cat /etc/fapolicyd/rules.d/90-deny-execute.rules
# Deny execution for anything untrusted

deny_audit perm=execute all : all
```

8. Add a new **allow** rule to the file that lexically *precedes* the rule file that contains the rule that denied the execution of your custom binary in the **/etc/fapolicyd/rules.d/** directory:

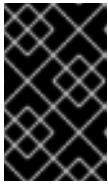
```
# touch /etc/fapolicyd/rules.d/80-myapps.rules
# vi /etc/fapolicyd/rules.d/80-myapps.rules
```

Insert the following rule to the **80-myapps.rules** file:

```
allow perm=execute exe=/usr/bin/bash trust=1 : path=/tmp/ls ftype=application/x-executable
trust=0
```

Alternatively, you can allow executions of all binaries in the **/tmp** directory by adding the following rule to the rule file in **/etc/fapolicyd/rules.d/**:

```
allow perm=execute exe=/usr/bin/bash trust=1 : dir=/tmp/ trust=0
```



IMPORTANT

To make a rule effective recursively on all directories under the specified directory, add a trailing slash to the value of the **dir=** parameter in the rule (**/tmp/** in the previous example).

- To prevent changes in the content of your custom binary, define the required rule using an SHA-256 checksum:

```
$ sha256sum /tmp/ls
780b75c90b2d41ea41679fcb358c892b1251b68d1927c80fbc0d9d148b25e836 ls
```

Change the rule to the following definition:

```
allow perm=execute exe=/usr/bin/bash trust=1 :
sha256hash=780b75c90b2d41ea41679fcb358c892b1251b68d1927c80fbc0d9d148b25e836
```

- Check that the list of compiled differs from the rule set in **/etc/fapolicyd/rules.d/**, and update the list, which is stored in the **/etc/fapolicyd/compiled.rules** file:

```
# fagenrules --check
/usr/sbin/fagenrules: Rules have changed and should be updated
# fagenrules --load
```

- Check that your custom rule is in the list of **fapolicyd** rules before the rule that prevented the execution:

```
# fapolicyd-cli --list
...
13. allow perm=execute exe=/usr/bin/bash trust=1 : path=/tmp/ls ftype=application/x-
executable trust=0
14. deny_audit perm=execute all : all
...
```

- Start the **fapolicyd** service:

```
# systemctl start fapolicyd
```

Verification

- Check that your custom binary can be now executed, for example:

```
$ /tmp/ls
ls
```

Additional resources

- **fapolicyd.rules(5)** and **fapolicyd-cli(1)** man pages on your system
- The documentation installed with the **fapolicyd** package in the **/usr/share/fapolicyd/sample-rules/README-rules** file.

12.5. ENABLING FAPOLICYD INTEGRITY CHECKS

By default, **fapolicyd** does not perform integrity checking. You can configure **fapolicyd** to perform integrity checks by comparing either file sizes or SHA-256 hashes. You can also set integrity checks by using the Integrity Measurement Architecture (IMA) subsystem.

Prerequisites

- The **fapolicyd** framework is deployed on your system.

Procedure

1. Open the **/etc/fapolicyd/fapolicyd.conf** file in a text editor of your choice, for example:

```
# vi /etc/fapolicyd/fapolicyd.conf
```

2. Change the value of the **integrity** option from **none** to **sha256**, save the file, and exit the editor:

```
integrity = sha256
```

3. Restart the **fapolicyd** service:

```
# systemctl restart fapolicyd
```

Verification

1. Back up the file used for the verification:

```
# cp /bin/more /bin/more.bak
```

2. Change the content of the **/bin/more** binary:

```
# cat /bin/less > /bin/more
```

3. Use the changed binary as a regular user:

```
# su example.user
$ /bin/more /etc/redhat-release
bash: /bin/more: Operation not permitted
```

4. Revert the changes:

```
# mv -f /bin/more.bak /bin/more
```

12.6. TROUBLESHOOTING PROBLEMS RELATED TO FAPOLICYD

The **fapolicyd** application framework provides tools for troubleshooting the most common problems and you can also add applications installed with the **rpm** command to the trust database.

Installing applications by using rpm

- If you install an application by using the **rpm** command, you have to perform a manual refresh of the **fapolicyd** RPM database:

1. Install your *application*:

```
# rpm -i application.rpm
```

2. Refresh the database:

```
# fapolicyd-cli --update
```

If you skip this step, the system can freeze and must be restarted.

Service status

- If **fapolicyd** does not work correctly, check the service status:

```
# systemctl status fapolicyd
```

fapolicyd-cli checks and listings

- The **--check-config**, **--check-watch_fs**, and **--check-trustdb** options help you find syntax errors, not-yet-watched file systems, and file mismatches, for example:

```
# fapolicyd-cli --check-config
Daemon config is OK

# fapolicyd-cli --check-trustdb
/etc/selinux/targeted/contexts/files/file_contexts mismatches: size sha256
/etc/selinux/targeted/policy/policy.31 mismatches: size sha256
```

- Use the **--list** option to check the current list of rules and their order:

```
# fapolicyd-cli --list
...
9. allow perm=execute all : trust=1
10. allow perm=open all : ftype=%languages trust=1
11. deny_audit perm=any all : ftype=%languages
12. allow perm=any all : ftype=text/x-shellscrip
13. deny_audit perm=execute all : all
...
```

Debug mode

- Debug mode provides detailed information about matched rules, database status, and more. To switch **fapolicyd** to debug mode:

1. Stop the **fapolicyd** service:

```
■
```

```
# systemctl stop fapolicyd
```

2. Use debug mode to identify a corresponding rule:

```
# fapolicyd --debug
```

Because the output of the **fapolicyd --debug** command is verbose, you can redirect the error output to a file:

```
# fapolicyd --debug 2> fapolicy.output
```

Alternatively, to limit the output only to entries when **fapolicyd** denies access, use the **--debug-deny** option:

```
# fapolicyd --debug-deny
```

You can also use permissive mode, which does not prevent running your application but only records the matched **fapolicyd** rule:

```
# fapolicyd --debug-deny --permissive
```

Removing the **fapolicyd** database

- To solve problems related to the **fapolicyd** database, try to remove the database file:

```
# systemctl stop fapolicyd
# fapolicyd-cli --delete-db
```



WARNING

Do not remove the **/var/lib/fapolicyd/** directory. The **fapolicyd** framework automatically restores only the database file in this directory.

Dumping the **fapolicyd** database

- The **fapolicyd** contains entries from all enabled trust sources. You can check the entries after dumping the database:

```
# fapolicyd-cli --dump-db
```

Application pipe

- In rare cases, removing the **fapolicyd** pipe file can solve a lockup:

```
# rm -f /var/run/fapolicyd/fapolicyd.fifo
```

Additional resources

- **fapolicyd-cli(1)** man page on your system

12.7. PREVENTING USERS FROM EXECUTING UNTRUSTWORTHY CODE BY USING THE FAPOLICYD RHEL SYSTEM ROLE

You can automate the installation and configuration of the **fapolicyd** service by using the **fapolicyd** RHEL system role. With this role, you can remotely configure the service to allow users to execute only trusted applications, for example, the ones which are listed in the RPM database and in an allow list. Additionally, the service can perform integrity checks before it executes an allowed application.

Prerequisites

- You have prepared the control node and the managed nodes
- You are logged in to the control node as a user who can run playbooks on the managed nodes.
- The account you use to connect to the managed nodes has **sudo** permissions on them.

Procedure

1. Create a playbook file, for example `~/playbook.yml`, with the following content:

```
---
- name: Configuring fapolicyd
  hosts: managed-node-01.example.com
  tasks:
    - name: Allow only executables installed from RPM database and specific files
      ansible.builtin.include_role:
        name: redhat.rhel_system_roles.fapolicyd
      vars:
        fapolicyd_setup_permissive: false
        fapolicyd_setup_integrity: sha256
        fapolicyd_setup_trust: rpmdb,file
        fapolicyd_add_trusted_file:
          - <path_to_allowed_command>
          - <path_to_allowed_service>
```

The settings specified in the example playbook include the following:

fapolicyd_setup_permissive: <true/false>

Enables or disables sending policy decisions to the kernel for enforcement. Set this variable for debugging and testing purposes to **false**.

fapolicyd_setup_integrity: <type_type>

Defines the integrity checking method. You can set one of the following values:

- **none** (default): Disables integrity checking.
- **size**: The service compares only the file sizes of allowed applications.
- **ima**: The service checks the SHA-256 hash that the kernel's Integrity Measurement Architecture (IMA) stored in a file's extended attribute. Additionally, the service performs a size check. Note that the role does not configure the IMA kernel subsystem. To use this option, you must manually configure the IMA subsystem.

- **sha256**: The service compares the SHA-256 hash of allowed applications.

fapolicyd_setup_trust: <trust_backends>

Defines the list of trust backends. If you include the **file** backend, specify the allowed executable files in the **fapolicyd_add_trusted_file** list.

For details about all variables used in the playbook, see the **/usr/share/ansible/roles/rhel-system-roles.fapolicyd.README.md** file on the control node.

2. Validate the playbook syntax:

```
$ ansible-playbook ~/playbook.yml --syntax-check
```

Note that this command only validates the syntax and does not protect against a wrong but valid configuration.

3. Run the playbook:

```
$ ansible-playbook ~/playbook.yml
```

Verification

- Execute a binary application that is not on the allow list as a user:

```
$ ansible managed-node-01.example.com -m command -a 'su -c  
"/bin/not_authorized_application " <user_name>  
bash: line 1: /bin/not_authorized_application: Operation not permitted non-zero return code
```

Additional resources

- **/usr/share/ansible/roles/rhel-system-roles.fapolicyd/README.md** file
- **/usr/share/doc/rhel-system-roles/fapolicyd/** directory

12.8. ADDITIONAL RESOURCES

- **fapolicyd**-related man pages listed by using the **man -k fapolicyd** command on your system
- [FOSDEM 2020 fapolicyd](#) presentation

CHAPTER 13. PROTECTING SYSTEMS AGAINST INTRUSIVE USB DEVICES

USB devices can be loaded with spyware, malware, or trojans, which can steal your data or damage your system. As a Red Hat Enterprise Linux administrator, you can prevent such USB attacks with **USBGuard**.

13.1. USBGUARD

With the USBGuard software framework, you can protect your systems against intrusive USB devices by using basic lists of permitted and forbidden devices based on the USB device authorization feature in the kernel.

The USBGuard framework provides the following components:

- The system service component with an inter-process communication (IPC) interface for dynamic interaction and policy enforcement
- The command line to interact with a running **usbguard** system service
- The rule language for writing USB device authorization policies
- The C++ API for interacting with the system service component implemented in a shared library

The **usbguard** system service configuration file (`/etc/usbguard/usbguard-daemon.conf`) includes the options to authorize the users and groups to use the IPC interface.



IMPORTANT

The system service provides the USBGuard public IPC interface. In Red Hat Enterprise Linux, the access to this interface is limited to the root user only by default.

Consider setting either the **IPCAccessControlFiles** option (recommended) or the **IPCAccessControlFiles** and **IPCAccessControlFiles** options to limit access to the IPC interface.

Ensure that you do not leave the Access Control List (ACL) unconfigured as this exposes the IPC interface to all local users and allows them to manipulate the authorization state of USB devices and modify the USBGuard policy.

13.2. INSTALLING USBGUARD

Use this procedure to install and initiate the USBGuard framework.

Procedure

1. Install the **usbguard** package:

```
# yum install usbguard
```

2. Create an initial rule set:

```
# usbguard generate-policy > /etc/usbguard/rules.conf
```

3. Start the **usbguard** daemon and ensure that it starts automatically on boot:

```
# systemctl enable --now usbguard
```

Verification

1. Verify that the **usbguard** service is running:

```
# systemctl status usbguard
● usbguard.service - USBGuard daemon
   Loaded: loaded (/usr/lib/systemd/system/usbguard.service; enabled; vendor preset: disabled)
   Active: active (running) since Thu 2019-11-07 09:44:07 CET; 3min 16s ago
     Docs: man:usbguard-daemon(8)
    Main PID: 6122 (usbguard-daemon)
      Tasks: 3 (limit: 11493)
     Memory: 1.2M
    CGroup: /system.slice/usbguard.service
            └─6122 /usr/sbin/usbguard-daemon -f -s -c /etc/usbguard/usbguard-daemon.conf

Nov 07 09:44:06 localhost.localdomain systemd[1]: Starting USBGuard daemon...
Nov 07 09:44:07 localhost.localdomain systemd[1]: Started USBGuard daemon.
```

2. List USB devices recognized by USBGuard:

```
# usbguard list-devices
4: allow id 1d6b:0002 serial "0000:02:00.0" name "xHCI Host Controller" hash...
```

Additional resources

- **usbguard(1)** and **usbguard-daemon.conf(5)** man pages.

13.3. BLOCKING AND AUTHORIZING A USB DEVICE BY USING CLI

You can set USBGuard to authorize and block a USB device by using the **usbguard** command in your terminal.

Prerequisites

- The **usbguard** service is installed and running.

Procedure

1. List USB devices recognized by USBGuard, for example:

```
# usbguard list-devices
1: allow id 1d6b:0002 serial "0000:00:06.7" name "EHCI Host Controller" hash
"JDOb0BiktYs2ct3mSQKopnOOV2h9MGYADwhT+oUtF2s=" parent-hash
"4PHGcaDKWtPjKDwYpIRG722cB9SIGz9l9lea93+Gt9c=" via-port "usb1" with-interface
09:00:00
...
6: block id 1b1c:1ab1 serial "000024937962" name "Voyager" hash
"CrXgjaWlf2bZAU+5WkzOE7y0rdSO82XMzubn7HDb95Q=" parent-hash
"JDOb0BiktYs2ct3mSQKopnOOV2h9MGYADwhT+oUtF2s=" via-port "1-3" with-interface
08:06:50
```

2. Authorize the device <6> to interact with the system:

```
# usbguard allow-device <6>
```

3. Deauthorize and remove the device <6>:

```
# usbguard reject-device <6>
```

4. Deauthorize and retain the device <6>:

```
# usbguard block-device <6>
```



NOTE

USBGuard uses the terms **block** and **reject** with the following meanings:

block

Do not interact with this device for now.

reject

Ignore this device as if it does not exist.

Additional resources

- **usbguard(1)** man page on your system
- **usbguard --help** command

13.4. PERMANENTLY BLOCKING AND AUTHORIZING A USB DEVICE

You can permanently block and authorize a USB device by using the **-p** option. This adds a device-specific rule to the current policy.

Prerequisites

- The **usbguard** service is installed and running.

Procedure

1. Configure SELinux to allow the **usbguard** daemon to write rules.

- a. Display the **semanage** Booleans relevant to **usbguard**.

```
# semanage boolean -l | grep usbguard
usbguard_daemon_write_conf (off , off) Allow usbguard to daemon write conf
usbguard_daemon_write_rules (on , on) Allow usbguard to daemon write rules
```

- b. Optional: If the **usbguard_daemon_write_rules** Boolean is turned off, turn it on.

```
# semanage boolean -m --on usbguard_daemon_write_rules
```

2. List USB devices recognized by USBGuard:

■

```
# usbguard list-devices
1: allow id 1d6b:0002 serial "0000:00:06.7" name "EHCI Host Controller" hash
"JDOb0BiktYs2ct3mSQKopnOOV2h9MGYADwhT+oUtF2s=" parent-hash
"4PHGcaDKWtPjKDwYpIRG722cB9SIGz9l9lea93+Gt9c=" via-port "usb1" with-interface
09:00:00
...
6: block id 1b1c:1ab1 serial "000024937962" name "Voyager" hash
"CrXgiaWlf2bZAU+5WkzOE7y0rdSO82XMzubn7HDb95Q=" parent-hash
"JDOb0BiktYs2ct3mSQKopnOOV2h9MGYADwhT+oUtF2s=" via-port "1-3" with-interface
08:06:50
```

3. Permanently authorize device **6** to interact with the system:

```
# usbguard allow-device 6 -p
```

4. Permanently deauthorize and remove device **6**:

```
# usbguard reject-device 6 -p
```

5. Permanently deauthorize and retain device **6**:

```
# usbguard block-device 6 -p
```



NOTE

USBGuard uses the terms ***block*** and ***reject*** with the following meanings:

block

Do not interact with this device for now.

reject

Ignore this device as if it does not exist.

Verification

1. Check that USBGuard rules include the changes you made.

```
# usbguard list-rules
```

Additional resources

- **usbguard(1)** man page on your system
- Built-in help listed by using the **usbguard --help** command.

13.5. CREATING A CUSTOM POLICY FOR USB DEVICES

The following procedure contains steps for creating a rule set for USB devices that reflects the requirements of your scenario.

Prerequisites

- The **usbguard** service is installed and running.

- The **/etc/usbguard/rules.conf** file contains an initial rule set generated by the **usbguard generate-policy** command.

Procedure

1. Create a policy which authorizes the currently connected USB devices, and store the generated rules to the **rules.conf** file:

```
# usbguard generate-policy --no-hashes > ./rules.conf
```

The **--no-hashes** option does not generate hash attributes for devices. Avoid hash attributes in your configuration settings because they might not be persistent.

2. Edit the **rules.conf** file with a text editor of your choice, for example:

```
# vi ./rules.conf
```

3. Add, remove, or edit the rules as required. For example, the following rule allows only devices with a single mass storage interface to interact with the system:

```
allow with-interface equals { 08:*:* }
```

See the **usbguard-rules.conf(5)** man page for a detailed rule-language description and more examples.

4. Install the updated policy:

```
# install -m 0600 -o root -g root rules.conf /etc/usbguard/rules.conf
```

5. Restart the **usbguard** daemon to apply your changes:

```
# systemctl restart usbguard
```

Verification

1. Check that your custom rules are in the active policy, for example:

```
# usbguard list-rules
...
4: allow with-interface 08:*:*
...
```

Additional resources

- **usbguard-rules.conf(5)** man page on your system

13.6. CREATING A STRUCTURED CUSTOM POLICY FOR USB DEVICES

You can organize your custom USBGuard policy in several **.conf** files within the **/etc/usbguard/rules.d/** directory. The **usbguard-daemon** then combines the main **rules.conf** file with the **.conf** files within the directory in alphabetical order.

Prerequisites

- The **usbguard** service is installed and running.

Procedure

1. Create a policy which authorizes the currently connected USB devices, and store the generated rules to a new **.conf** file, for example, **policy.conf**.

```
# usbguard generate-policy --no-hashes > ./policy.conf
```

The **--no-hashes** option does not generate hash attributes for devices. Avoid hash attributes in your configuration settings because they might not be persistent.

2. Display the **policy.conf** file with a text editor of your choice, for example:

```
# vi ./policy.conf
...
allow id 04f2:0833 serial "" name "USB Keyboard" via-port "7-2" with-interface { 03:01:01
03:00:00 } with-connect-type "unknown"
...
```

3. Move selected lines into a separate **.conf** file.



NOTE

The two digits at the beginning of the file name specify the order in which the daemon reads the configuration files.

For example, copy the rules for your keyboards into a new **.conf** file.

```
# grep "USB Keyboard" ./policy.conf > ./10keyboards.conf
```

4. Install the new policy to the **/etc/usbguard/rules.d/** directory.

```
# install -m 0600 -o root -g root 10keyboards.conf /etc/usbguard/rules.d/10keyboards.conf
```

5. Move the rest of the lines to a main **rules.conf** file.

```
# grep -v "USB Keyboard" ./policy.conf > ./rules.conf
```

6. Install the remaining rules.

```
# install -m 0600 -o root -g root rules.conf /etc/usbguard/rules.conf
```

7. Restart the **usbguard** daemon to apply your changes.

```
# systemctl restart usbguard
```

Verification

1. Display all active USBGuard rules.

```
# usbguard list-rules
...
15: allow id 04f2:0833 serial "" name "USB Keyboard" hash
"KxM/iddRe/WSCocgiuQIVs6Dn0VEza7KiHoDeTz0fyg=" parent-hash
"2i6ZBJfTI5BakXF7Gba84/Cp1gslnNc1DM6vWQpie3s=" via-port "7-2" with-interface {
03:01:01 03:00:00 } with-connect-type "unknown"
...
```

2. Display the contents of the **rules.conf** file and all the **.conf** files in the **/etc/usbguard/rules.d/** directory.

```
# cat /etc/usbguard/rules.conf /etc/usbguard/rules.d/*.conf
```

3. Verify that the active rules contain all the rules from the files and are in the correct order.

Additional resources

- **usbguard-rules.conf(5)** man page on your system

13.7. AUTHORIZING USERS AND GROUPS TO USE THE USBGUARD IPC INTERFACE

Use this procedure to authorize a specific user or a group to use the USBGuard public IPC interface. By default, only the root user can use this interface.

Prerequisites

- The **usbguard** service is installed and running.
- The **/etc/usbguard/rules.conf** file contains an initial rule set generated by the **usbguard generate-policy** command.

Procedure

1. Edit the **/etc/usbguard/usbguard-daemon.conf** file with a text editor of your choice:

```
# vi /etc/usbguard/usbguard-daemon.conf
```

2. For example, add a line with a rule that allows all users in the **wheel** group to use the IPC interface, and save the file:

```
IPCAllowGroups=wheel
```

3. You can add users or groups also with the **usbguard** command. For example, the following command enables the **joesec** user to have full access to the **Devices** and **Exceptions** sections. Furthermore, **joesec** can list and modify the current policy:

```
# usbguard add-user joesec --devices ALL --policy modify,list --exceptions ALL
```

To remove the granted permissions for the **joesec** user, use the **usbguard remove-user joesec** command.

4. Restart the **usbguard** daemon to apply your changes:

```
# systemctl restart usbguard
```

Additional resources

- **usbguard(1)** and **usbguard-rules.conf(5)** man pages.

13.8. LOGGING USBGUARD AUTHORIZATION EVENTS TO THE LINUX AUDIT LOG

Use the following steps to integrate logging of USBguard authorization events to the standard Linux Audit log. By default, the **usbguard** daemon logs events to the **/var/log/usbguard/usbguard-audit.log** file.

Prerequisites

- The **usbguard** service is installed and running.
- The **auditd** service is running.

Procedure

1. Edit the **usbguard-daemon.conf** file with a text editor of your choice:

```
# vi /etc/usbguard/usbguard-daemon.conf
```

2. Change the **AuditBackend** option from **FileAudit** to **LinuxAudit**:

```
AuditBackend=LinuxAudit
```

3. Restart the **usbguard** daemon to apply the configuration change:

```
# systemctl restart usbguard
```

Verification

1. Query the **audit** daemon log for a USB authorization event, for example:

```
# ausearch -ts recent -m USER_DEVICE
```

Additional resources

- **usbguard-daemon.conf(5)** man page on your system

13.9. ADDITIONAL RESOURCES

- **usbguard(1)**, **usbguard-rules.conf(5)**, **usbguard-daemon(8)**, and **usbguard-daemon.conf(5)** man pages.
- [USBGuard Homepage](#).

