Red Hat Enterprise Linux 10-beta

Securing networks

Configuring secured networks and network communication

Last Updated: 2025-03-13

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Legal Notice

Abstract

Learn the tools and techniques to improve the security of your networks and lower the risks of data breaches and intrusions.

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RHEL BETA RELEASE

Red Hat provides Red Hat Enterprise Linux Beta access to all subscribed Red Hat accounts. The purpose of Beta access is to:

- Provide an opportunity to customers to test major features and capabilities prior to the general availability release and provide feedback or report issues.
- Provide Beta product documentation as a preview. Beta product documentation is under development and is subject to substantial change.

Note that Red Hat does not support the usage of RHEL Beta releases in production use cases. For more information, see the Red Hat Knowledgebase solution What does Beta mean in Red Hat Enterprise Linux and can I upgrade a RHEL Beta installation to a General Availability (GA) release?.

CHAPTER 1. USING SECURE COMMUNICATIONS BETWEEN TWO SYSTEMS WITH OPENSSH

SSH (Secure Shell) is a protocol which provides secure communications between two systems using a client-server architecture and allows users to log in to server host systems remotely. Unlike other remote communication protocols, such as FTP or Telnet, SSH encrypts the login session, which prevents intruders from collecting unencrypted passwords from the connection.

1.1. SSH AND OPENSSH

SSH (Secure Shell) is a program for logging into a remote machine and executing commands on that machine. The SSH protocol provides secure encrypted communications between two untrusted hosts over an insecure network. You can also forward X11 connections and arbitrary TCP/IP ports over the secure channel.

The SSH protocol mitigates security threats, such as interception of communication between two systems and impersonation of a particular host, when you use it for remote shell login or file copying. This is because the SSH client and server use digital signatures to verify their identities. Additionally, all communication between the client and server systems is encrypted.

A host key authenticates hosts in the SSH protocol. Host keys are cryptographic keys that are generated automatically when OpenSSH is started for the first time or when the host boots for the first time.

OpenSSH is an implementation of the SSH protocol supported by Linux, UNIX, and similar operating systems. It includes the core files necessary for both the OpenSSH client and server. The OpenSSH suite consists of the following user-space tools:

- **ssh** is a remote login program (SSH client).
- **sshd** is an OpenSSH SSH daemon.
- **scp** is a secure remote file copy program.
- **sftp** is a secure file transfer program.
- **ssh-agent** is an authentication agent for caching private keys.
- **ssh-add** adds private key identities to **ssh-agent**.
- **ssh-keygen** generates, manages, and converts authentication keys for **ssh**.
- **ssh-copy-id** is a script that adds local public keys to the **authorized_keys** file on a remote SSH server.
- **ssh-keyscan** gathers SSH public host keys.

NOTE

In RHEL 9 and later, the Secure copy protocol (SCP) is replaced with the SSH File Transfer Protocol (SFTP) by default. This is because SCP has already caused security issues, for example CVE-2020-15778.

If SFTP is unavailable or incompatible in your scenario, you can use the **scp** command with the **-O** option to force the use of the original SCP/RCP protocol.

For additional information, see the OpenSSH SCP protocol deprecation in Red Hat Enterprise Linux 9 article.

The OpenSSH suite in RHEL supports only SSH version 2. It has an enhanced key-exchange algorithm that is not vulnerable to exploits known in the older version 1.

Red Hat Enterprise Linux includes the following **OpenSSH** packages: the general **openssh** package, the **openssh-server** package, and the **openssh-clients** package. The **OpenSSH** packages require the **OpenSSL** package **openssl-libs**, which installs several important cryptographic libraries that enable **OpenSSH** to provide encrypted communications.

OpenSSH, as one of core cryptographic subsystems of RHEL, uses system-wide crypto policies. This ensures that weak cipher suites and cryptographic algorithms are disabled in the default configuration. To modify the policy, the administrator must either use the **update-crypto-policies** command to adjust the settings or manually opt out of the system-wide crypto policies. See the Excluding an application from following system-wide crypto policies section for more information.

The OpenSSH suite uses two sets of configuration files: one for client programs (that is, **ssh**, **scp**, and **sftp**), and another for the server (the **sshd** daemon).

System-wide SSH configuration information is stored in the **/etc/ssh/** directory. The **/etc/ssh/ssh_config** file contains the client configuration, and the **/etc/ssh/sshd_config** file is the default OpenSSH server configuration file.

User-specific SSH configuration information is stored in **~/.ssh/** in the user's home directory. For a detailed list of OpenSSH configuration files, see the **FILES** section in the **sshd(8)** man page on your system.

Additional resources

- Man pages listed by using the **man -k ssh** command on your system
- Using system-wide cryptographic policies

1.2. GENERATING SSH KEY PAIRS

You can log in to an OpenSSH server without entering a password by generating an SSH key pair on a local system and copying the generated public key to the OpenSSH server. Each user who wants to create a key must run this procedure.

To preserve previously generated key pairs after you reinstall the system, back up the **~/.ssh/** directory before you create new keys. After reinstalling, copy it back to your home directory. You can do this for all users on your system, including **root**.

Prerequisites

- You are logged in as a user who wants to connect to the OpenSSH server by using keys.
- The OpenSSH server is configured to allow key-based authentication.

Procedure

1. Generate an ECDSA key pair:

```
$ ssh-keygen -t ecdsa
Generating public/private ecdsa key pair.
Enter file in which to save the key (/home/<username>/.ssh/id_ecdsa):
Enter passphrase (empty for no passphrase): <password>
Enter same passphrase again: <password>
Your identification has been saved in /home/<username>/.ssh/id_ecdsa.
Your public key has been saved in /home/<username>/.ssh/id_ecdsa.pub.
The key fingerprint is:
SHA256:Q/x+qms4j7PCQ0qFd09iZEFHA+SqwBKRNaU72oZfaCI
<username>@<localhost.example.com>
The key's randomart image is:
+---[ECDSA 256]---+
|.oo..o=++        |
|.. o .oo .       |
|. .. o. o        |
|....o.+...       |
|o.oo.o +S .      |
|.=.+.   .o       |
|E.*+.  .  . .    |
|.=..+ +..  o     |
|  .  oo*+o.      |
+----[SHA256]-----+
```

   You can also generate an RSA key pair by using the **ssh-keygen** command without any parameter or an Ed25519 key pair by entering the **ssh-keygen -t ed25519** command. Note that the Ed25519 algorithm is not FIPS-140-compliant, and OpenSSH does not work with Ed25519 keys in FIPS mode.

2. Copy the public key to a remote machine:

```
$ ssh-copy-id <username>@<ssh-server-example.com>
/usr/bin/ssh-copy-id: INFO: attempting to log in with the new key(s), to filter out any that are already installed
<username>@<ssh-server-example.com>'s password:
…
Number of key(s) added: 1

Now try logging into the machine, with: "ssh '<username>@<ssh-server-example.com>'" and check to make sure that only the key(s) you wanted were added.
```

   Replace ***<username>@<ssh-server-example.com>*** with your credentials.

   If you do not use the **ssh-agent** program in your session, the previous command copies the most recently modified **~/.ssh/id*.pub** public key if it is not yet installed. To specify another public-key file or to prioritize keys in files over keys cached in memory by **ssh-agent**, use the **ssh-copy-id** command with the **-i** option.

Verification

1. Log in to the OpenSSH server by using the key file:

```
$ ssh -o PreferredAuthentications=publickey <username>@<ssh-server-example.com>
```

Additional resources

- **ssh-keygen(1)** and **ssh-copy-id(1)** man pages on your system

1.3. SETTING KEY-BASED AUTHENTICATION AS THE ONLY METHOD ON AN OPENSSH SERVER

To improve system security, enforce key-based authentication by disabling password authentication on your OpenSSH server.

Prerequisites

- The **openssh-server** package is installed.
- The **sshd** daemon is running on the server.
- You can already connect to the OpenSSH server by using a key.
  See the Generating SSH key pairs section for details.

Procedure

1. Open the **/etc/ssh/sshd_config** configuration in a text editor, for example:

```
# vi /etc/ssh/sshd_config
```

2. Change the **PasswordAuthentication** option to **no**:

```
PasswordAuthentication no
```

3. On a system other than a new default installation, check that the **PubkeyAuthentication** parameter is either not set or set to **yes**.

4. Set the **KbdInteractiveAuthentication** directive to **no**.
   Note that the corresponding entry is commented out in the configuration file and the default value is **yes**.

5. To use key-based authentication with NFS-mounted home directories, enable the **use_nfs_home_dirs** SELinux boolean:

```
# setsebool -P use_nfs_home_dirs 1
```

6. If you are connected remotely, not using console or out-of-band access, test the key-based login process before disabling password authentication.

7. Reload the **sshd** daemon to apply the changes:

```
# systemctl reload sshd
```

Additional resources

- **sshd_config(5)** and **setsebool(8)** man pages on your system

1.4. 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

1. 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
```

2. 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>
```

3. 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] $
```

4. 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

1.5. MAKING OPENSSH MORE SECURE

You can tweak the system to increase security when using OpenSSH.

Note that changes in the **/etc/ssh/sshd_config** OpenSSH server configuration file require reloading the **sshd** daemon to take effect:

```
# systemctl reload sshd
```

WARNING

The majority of security hardening configuration changes reduce compatibility with clients that do not support up-to-date algorithms or cipher suites.

Disabling insecure connection protocols

To make SSH truly effective, prevent the use of insecure connection protocols that are replaced by the OpenSSH suite. Otherwise, a user's password might be protected using SSH for one session only to be captured later when logging in using Telnet.

Disabling password-based authentication

Disabling passwords for authentication and allowing only key pairs reduces the attack surface. See the Setting key-based authentication as the only method on an OpenSSH server section for more information.

Stronger key types

Although the **ssh-keygen** command generates a pair of RSA keys by default, you can instruct it to generate Elliptic Curve Digital Signature Algorithm (ECDSA) or Edwards-Curve 25519 (Ed25519) keys by using the **-t** option. The ECDSA offers better performance than RSA at the equivalent symmetric key strength. It also generates shorter keys. The Ed25519 public-key algorithm is an implementation of twisted Edwards curves that is more secure and also faster than RSA, DSA, and ECDSA.

OpenSSH creates RSA, ECDSA, and Ed25519 server host keys automatically if they are missing. To configure the host key creation in RHEL, use the **sshd-keygen@.service** instantiated service. For example, to disable the automatic creation of the RSA key type:

```
# systemctl mask sshd-keygen@rsa.service
# rm -f /etc/ssh/ssh_host_rsa_key*
# systemctl restart sshd
```

NOTE

In images with the **cloud-init** method enabled, the **ssh-keygen** units are automatically disabled. This is because the **ssh-keygen template** service can interfere with the **cloud-init** tool and cause problems with host key generation. To prevent these problems the **etc/systemd/system/sshd-keygen@.service.d/disable-sshd-keygen-if-cloud-init-active.conf** drop-in configuration file disables the **ssh-keygen** units if **cloud-init** is running.

To allow only a particular key type for SSH connections, remove a comment out at the beginning of the relevant line in **/etc/ssh/sshd_config**, and reload the **sshd** service. For example, to allow only Ed25519 host keys, the corresponding lines must be as follows:

```
# HostKey /etc/ssh/ssh_host_rsa_key
# HostKey /etc/ssh/ssh_host_ecdsa_key
HostKey /etc/ssh/ssh_host_ed25519_key
```

IMPORTANT

The Ed25519 algorithm is not FIPS-140-compliant, and OpenSSH does not work with Ed25519 keys in FIPS mode.

Non-default port

By default, the **sshd** daemon listens on TCP port 22. Changing the port reduces the exposure of the system to attacks based on automated network scanning on the default port and therefore increases security through obscurity. You can specify the port using the **Port** directive in the **/etc/ssh/sshd_config** configuration file.
You also have to update the default SELinux policy to allow the use of a non-default port. To do so, use the **semanage** tool from the **policycoreutils-python-utils** package:

```
# semanage port -a -t ssh_port_t -p tcp <port-number>
```

Furthermore, update **firewalld** configuration:

```
# firewall-cmd --add-port <port-number>/tcp
# firewall-cmd --remove-port=22/tcp
# firewall-cmd --runtime-to-permanent
```

In the previous commands, replace *<port-number>* with the new port number specified using the **Port** directive.

Root login

PermitRootLogin is set to **prohibit-password** by default. This enforces the use of key-based authentication instead of the use of passwords for logging in as root and reduces risks by preventing brute-force attacks.

WARNING

Enabling logging in as the root user is not a secure practice because the administrator cannot audit which users run which privileged commands. For using administrative commands, log in and use **sudo** instead.

Using the X Security extension

The X server in Red Hat Enterprise Linux clients does not provide the X Security extension. Therefore, clients cannot request another security layer when connecting to untrusted SSH servers with X11 forwarding. Most applications are not able to run with this extension enabled anyway.
By default, the **ForwardX11Trusted** option in the **/etc/ssh/ssh_config.d/50-redhat.conf** file is set to **yes**, and there is no difference between the **ssh -X remote_machine** (untrusted host) and **ssh -Y remote_machine** (trusted host) command.

If your scenario does not require the X11 forwarding feature at all, set the **X11Forwarding** directive in the **/etc/ssh/sshd_config** configuration file to **no**.

Restricting SSH access to specific users, groups, or IP ranges

The **AllowUsers** and **AllowGroups** directives in the **/etc/ssh/sshd_config** configuration file server enable you to permit only certain users, domains, or groups to connect to your OpenSSH server. You can combine **AllowUsers** and **AllowGroups** to restrict access more precisely, for example:

```
AllowUsers *@192.168.1.* *@10.0.0.* !*@192.168.1.2
AllowGroups example-group
```

This configuration allows only connections if all of the following conditions meet:

- The connection's source IP is within the 192.168.1.0/24 or 10.0.0.0/24 subnet.
- The source IP is not 192.168.1.2.
- The user is a member of the example-group group.

The OpenSSH server permits only connections that pass all Allow and Deny directives in **/etc/ssh/sshd_config**. For example, if the **AllowUsers** directive lists a user that is not part of a group listed in the **AllowGroups** directive, then the user cannot log in.

Note that using allowlists (directives starting with Allow) is more secure than using blocklists (options starting with Deny) because allowlists block also new unauthorized users or groups.

Changing system-wide cryptographic policies

OpenSSH uses RHEL system-wide cryptographic policies, and the default system-wide cryptographic policy level offers secure settings for current threat models. To make your cryptographic settings more strict, change the current policy level:

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

WARNING

If your system communicates with legacy systems, you might face interoperability problems due to the strict setting of the **FUTURE** policy.

You can also disable only specific ciphers for the SSH protocol through the system-wide cryptographic policies. See the Customizing system-wide cryptographic policies with subpolicies section in the Security hardening document for more information.

Opting out of system-wide cryptographic policies

To opt out of the system-wide cryptographic policies for your OpenSSH server, specify the cryptographic policy in a drop-in configuration file located in the **/etc/ssh/sshd_config.d/** directory, with a two-digit number prefix smaller than 50, so that it lexicographically precedes the **50-redhat.conf** file, and with a **.conf** suffix, for example, **49-crypto-policy-override.conf**.
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 50, so that it lexicographically precedes the **50-redhat.conf** file, and with a **.conf** suffix, for example, **49-crypto-policy-override.conf**.

Additional resources

- **sshd_config(5)**, **ssh-keygen(1)**, **crypto-policies(7)**, and **update-crypto-policies(8)** man pages on your system
- Using system-wide cryptographic policies in the Security hardening document
- How to disable specific algorithms and ciphers for ssh service only (Red Hat Knowledgebase)

1.6. CONNECTING TO A REMOTE SERVER THROUGH AN SSH JUMP HOST

You can connect from your local system to a remote server through an intermediary server, also called jump host. A jump server bridges hosts from different security zones and can manage multiple client-server connections.

Prerequisites

- A jump host accepts SSH connections from your local system.
- A remote server accepts SSH connections from the jump host.

Procedure

1. If you connect through a jump server or more intermediary servers once, use the **ssh -J** command and specify the jump servers directly, for example:

```
$ ssh -J <jump-1.example.com>,<jump-2.example.com>,<jump-3.example.com> <target-server-1.example.com>
```

Change the host name-only notation in the previous command if the user names or SSH ports on the jump servers differ from the names and ports on the remote server, for example:

```
$ ssh -J <example.user.1>@<jump-1.example.com>:<75>,<example.user.2>@<jump-2.example.com>:<75>,<example.user.3>@<jump-3.example.com>:<75> <example.user.f>@<target-server-1.example.com>:<220>
```

2. If you connect to a remote server through jump servers regularly, store the jump-server configuration in your SSH configuration file:

   a. Define the jump host by editing the ~/**.ssh**/**config** file on your local system, for example:

```
Host <jump-server-1>
  HostName <jump-1.example.com>
```

   - The **Host** parameter defines a name or alias for the host you can use in **ssh** commands. The value can match the real host name, but can also be any string.
   - The **HostName** parameter sets the actual host name or IP address of the jump host.

   b. Add the remote server jump configuration with the **ProxyJump** directive to ~/**.ssh**/**config** file on your local system, for example:

```
Host <remote-server-1>
  HostName <target-server-1.example.com>
  ProxyJump <jump-server-1>
```

   c. Use your local system to connect to the remote server through the jump server:

```
$ ssh <remote-server-1>
```

   This command is equivalent to the **ssh -J jump-server1 remote-server** command if you omit the previous configuration steps.

Additional resources

- **ssh_config(5)** and **ssh(1)** man pages on your system

1.7. CONFIGURING THE OPENSSH SERVER AND CLIENT BY USING RHEL SYSTEM ROLES

You can use the **sshd** RHEL system role to configure OpenSSH servers and the **ssh** RHEL system role to configure OpenSSH clients consistently, in an automated fashion, and on any number of RHEL systems at the same time. Such configurations are necessary for any system where secure remote interaction is needed, for example:

- Remote system administration: securely connecting to your machine from another computer by using an SSH client.
- Secure file transfers: the Secure File Transfer Protocol (SFTP) provided by OpenSSH enable you to securely transfer files between your local machine and a remote system.
- Automated DevOps pipelines: automating software deployments that require secure connection to remote servers (CI/CD pipelines).
- Tunneling and port forwarding: forwarding a local port to access a web service on a remote server behind a firewall. For example a remote database or a development server.
- Key-based authentication: more secure alternative to password-based logins.
- Certificate-based authentication: centralized trust management and better scalability.
- Enhanced security: disabling root logins, restricting user access, enforcing strong encryption and other such forms of hardening ensures stronger system security.

1.7.1. How the sshd RHEL system role maps settings from a playbook to the configuration file

In the **sshd** RHEL system role playbook, you can define the parameters for the server SSH configuration file.

If you do not specify these settings, the role produces the **sshd_config** file that matches the RHEL defaults.

In all cases, booleans correctly render as **yes** and **no** in the final configuration on your managed nodes. You can use lists to define multi-line configuration items. For example:

```
sshd_ListenAddress:
  - 0.0.0.0
  - '::'
```

renders as:

```
ListenAddress 0.0.0.0
ListenAddress ::
```

Additional resources

- **/usr/share/ansible/roles/rhel-system-roles.sshd/README.md** file
- **/usr/share/doc/rhel-system-roles/sshd/** directory

1.7.2. Configuring OpenSSH servers by using the sshd RHEL system role

You can use the **sshd** RHEL system role to configure multiple OpenSSH servers. These ensure secure communication environment for remote users by providing namely:

- Management of incoming SSH connections from remote clients
- Credentials verification

- Secure data transfer and command execution

NOTE

You can use the **sshd** RHEL system role alongside with other RHEL system roles that change SSHD configuration, for example the Identity Management RHEL system roles. To prevent the configuration from being overwritten, ensure the **sshd** RHEL system role uses namespaces (RHEL 8 and earlier versions) or a drop-in directory (RHEL 9).

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: SSH server configuration
  hosts: managed-node-01.example.com
  tasks:
    - name: Configure sshd to prevent root and password login except from particular subnet
      ansible.builtin.include_role:
        name: rhel-system-roles.sshd
      vars:
        sshd:
          PermitRootLogin: no
          PasswordAuthentication: no
          Match:
            - Condition: "Address 192.0.2.0/24"
              PermitRootLogin: yes
              PasswordAuthentication: yes
```

The settings specified in the example playbook include the following:

PasswordAuthentication: yes|no

Controls whether the OpenSSH server (**sshd**) accepts authentication from clients that use the username and password combination.

Match:

The match block allows the **root** user login by using password only from the subnet **192.0.2.0/24**.

For details about the role variables and the OpenSSH configuration options used in the playbook, see the **/usr/share/ansible/roles/rhel-system-roles.sshd/README.md** file and the **sshd_config(5)** manual page 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. Log in to the SSH server:

```
$ ssh <username>@<ssh_server>
```

2. Verify the contents of the **sshd_config** file on the SSH server:

```
$ cat /etc/ssh/sshd_config.d/00-ansible_system_role.conf
#
# Ansible managed
#
PasswordAuthentication no
PermitRootLogin no
Match Address 192.0.2.0/24
  PasswordAuthentication yes
  PermitRootLogin yes
```

3. Check that you can connect to the server as root from the **192.0.2.0/24** subnet:

   a. Determine your IP address:

```
$ hostname -I
192.0.2.1
```

   If the IP address is within the **192.0.2.1** - **192.0.2.254** range, you can connect to the server.

   b. Connect to the server as **root**:

```
$ ssh root@<ssh_server>
```

Additional resources

- **/usr/share/ansible/roles/rhel-system-roles.sshd/README.md** file
- **/usr/share/doc/rhel-system-roles/sshd/** directory

1.7.3. Using the sshd RHEL system role for non-exclusive configuration

By default, applying the **sshd** RHEL system role overwrites the entire configuration. This may be problematic if you have previously adjusted the configuration, for example, with a different RHEL system role or a playbook. To apply the **sshd** RHEL system role for only selected configuration options while keeping other options in place, you can use the non-exclusive configuration.

You can apply a non-exclusive configuration:

- In RHEL 8 and earlier by using a configuration snippet.

- In RHEL 9 and later by using files in a drop-in directory. The default configuration file is already placed in the drop-in directory as **/etc/ssh/sshd_config.d/00-ansible_system_role.conf**.

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:

   - For managed nodes that run RHEL 8 or earlier:

```
---
- name: Non-exclusive sshd configuration
  hosts: managed-node-01.example.com
  tasks:
    - name: Configure SSHD to accept environment variables
      ansible.builtin.include_role:
        name: rhel-system-roles.sshd
      vars:
        sshd_config_namespace: <my-application>
        sshd:
          # Environment variables to accept
          AcceptEnv:
            LANG
            LS_COLORS
            EDITOR
```

   - For managed nodes that run RHEL 9 or later:

```
- name: Non-exclusive sshd configuration
  hosts: managed-node-01.example.com
  tasks:
    - name: Configure sshd to accept environment variables
      ansible.builtin.include_role:
        name: rhel-system-roles.sshd
      vars:
        sshd_config_file: /etc/ssh/sshd_config.d/<42-my-application>.conf
        sshd:
          # Environment variables to accept
          AcceptEnv:
            LANG
            LS_COLORS
            EDITOR
```

   The settings specified in the example playbooks include the following:

   sshd_config_namespace: *<my-application>*

The role places the configuration that you specify in the playbook to configuration snippets in the existing configuration file under the given namespace. You need to select a different namespace when running the role from different context.

sshd_config_file: /etc/ssh/sshd_config.d/*<42-my-application>*.conf

In the **sshd_config_file** variable, define the **.conf** file into which the **sshd** system role writes the configuration options. Use a two-digit prefix, for example ***42-*** to specify the order in which the configuration files will be applied.

AcceptEnv:

Controls which environment variables the OpenSSH server (**sshd**) will accept from a client:

- **LANG**: defines the language and locale settings.
- **LS_COLORS**: defines the displaying color scheme for the **ls** command in the terminal.
- **EDITOR**: specifies the default text editor for the command-line programs that need to open an editor.

For details about the role variables and the OpenSSH configuration options used in the playbook, see the **/usr/share/ansible/roles/rhel-system-roles.sshd/README.md** file and the **sshd_config(5)** manual page 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

- Verify the configuration on the SSH server:
  - For managed nodes that run RHEL 8 or earlier:

```
# cat /etc/ssh/sshd_config
...
# BEGIN sshd system role managed block: namespace <my-application>
Match all
  AcceptEnv LANG LS_COLORS EDITOR
# END sshd system role managed block: namespace <my-application>
```

  - For managed nodes that run RHEL 9 or later:

```
# cat /etc/ssh/sshd_config.d/42-my-application.conf
# Ansible managed
#
AcceptEnv LANG LS_COLORS EDITOR
```

Additional resources

- **/usr/share/ansible/roles/rhel-system-roles.sshd/README.md** file
- **/usr/share/doc/rhel-system-roles/sshd/** directory
- **sshd_config(5)** manual page

1.7.4. Overriding the system-wide cryptographic policy on an SSH server by using the sshd RHEL system role

When the default cryptographic settings do not meet certain security or compatibility needs, you may want to override the system-wide cryptographic policy on the OpenSSH server by using the **sshd** RHEL system role. Especially, in the following notable situations:

- Compatibility with older clients: necessity to use weaker-than-default encryption algorithms, key exchange protocols, or ciphers.
- Enforcing stronger security policies: simultaneously, you can disable weaker algorithms. Such a measure could exceed the default system cryptographic policies, especially in the highly secure and regulated environments.
- Performance considerations: the system defaults could enforce stronger algorithms that can be computationally intensive for some systems.
- Customizing for specific security needs: adapting for unique requirements that are not covered by the default cryptographic policies.

WARNING

It is not possible to override all aspects of the cryptographic policies from the **sshd** RHEL system role. For example, SHA1 signatures might be forbidden on a different layer so for a more generic solution, see Setting a custom cryptographic policy by using RHEL system roles.

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 SSH configuration for OpenSSH server
  hosts: managed-node-01.example.com
  tasks:
    - name: Overriding the system-wide cryptographic policy
```

```
    ansible.builtin.include_role:
      name: rhel-system-roles.sshd
    vars:
      sshd_sysconfig: true
      sshd_sysconfig_override_crypto_policy: true
      sshd_KexAlgorithms: ecdh-sha2-nistp521
      sshd_Ciphers: aes256-ctr
      sshd_MACs: hmac-sha2-512-etm@openssh.com
      sshd_HostKeyAlgorithms: rsa-sha2-512,rsa-sha2-256
```

The settings specified in the example playbook include the following:

sshd_KexAlgorithms

You can choose key exchange algorithms, for example, **ecdh-sha2-nistp256**, **ecdh-sha2-nistp384**, **ecdh-sha2-nistp521**,**diffie-hellman-group14-sha1**, or **diffie-hellman-group-exchange-sha256**.

sshd_Ciphers

You can choose ciphers, for example, **aes128-ctr**, **aes192-ctr**, or **aes256-ctr**.

sshd_MACs

You can choose MACs, for example, **hmac-sha2-256**, **hmac-sha2-512**, or **hmac-sha1**.

sshd_HostKeyAlgorithms

You can choose a public key algorithm, for example, **ecdsa-sha2-nistp256**, **ecdsa-sha2-nistp384**, **ecdsa-sha2-nistp521**, or **ssh-rsa**.

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

On RHEL 9 managed nodes, the system role writes the configuration into the **/etc/ssh/sshd_config.d/00-ansible_system_role.conf** file, where cryptographic options are applied automatically. You can change the file by using the **sshd_config_file** variable. However, to ensure the configuration is effective, use a file name that lexicographically precedes the **/etc/ssh/sshd_config.d/50-redhat.conf** file, which includes the configured crypto policies.

On RHEL 8 managed nodes, you must enable override by setting the **sshd_sysconfig_override_crypto_policy** and **sshd_sysconfig** variables to **true**.

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

- You can verify the success of the procedure by using the verbose SSH connection and check the defined variables in the following output:

```
$ ssh -vvv <ssh_server>
```

```
...
debug2: peer server KEXINIT proposal
debug2: KEX algorithms: ecdh-sha2-nistp521
debug2: host key algorithms: rsa-sha2-512,rsa-sha2-256
debug2: ciphers ctos: aes256-ctr
debug2: ciphers stoc: aes256-ctr
debug2: MACs ctos: hmac-sha2-512-etm@openssh.com
debug2: MACs stoc: hmac-sha2-512-etm@openssh.com
...
```

Additional resources

- **/usr/share/ansible/roles/rhel-system-roles.sshd/README.md** file
- **/usr/share/doc/rhel-system-roles/sshd/** directory

1.7.5. How the ssh RHEL system role maps settings from a playbook to the configuration file

In the **ssh** RHEL system role playbook, you can define the parameters for the client SSH configuration file.

If you do not specify these settings, the role produces a global **ssh_config** file that matches the RHEL defaults.

In all the cases, booleans correctly render as **yes** or **no** in the final configuration on your managed nodes. You can use lists to define multi-line configuration items. For example:

```
LocalForward:
  - 22 localhost:2222
  - 403 localhost:4003
```

renders as:

```
LocalForward 22 localhost:2222
LocalForward 403 localhost:4003
```

NOTE

The configuration options are case sensitive.

Additional resources

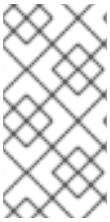
- **/usr/share/ansible/roles/rhel-system-roles.ssh/README.md** file
- **/usr/share/doc/rhel-system-roles/ssh/** directory

1.7.6. Configuring OpenSSH clients by using the ssh RHEL system role

You can use the **ssh** RHEL system role to configure multiple OpenSSH clients. These enable the local user to establish a secure connection with the remote OpenSSH server by ensuring namely:

- Secure connection initiation

- Credentials provision
- Negotiation with the OpenSSH server on the encryption method used for the secure communication channel
- Ability to send files securely to and from the OpenSSH server



NOTE

You can use the **ssh** RHEL system role alongside with other system roles that change SSH configuration, for example the Identity Management RHEL system roles. To prevent the configuration from being overwritten, make sure that the **ssh** RHEL system role uses a drop-in directory (default in RHEL 8 and later).

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: SSH client configuration
  hosts: managed-node-01.example.com
  tasks:
    - name: Configure ssh clients
      ansible.builtin.include_role:
        name: rhel-system-roles.ssh
      vars:
        ssh_user: root
        ssh:
          Compression: true
          GSSAPIAuthentication: no
          ControlMaster: auto
          ControlPath: ~/.ssh/.cm%C
          Host:
            - Condition: example
              Hostname: server.example.com
              User: user1
        ssh_ForwardX11: no
```

The settings specified in the example playbook include the following:

ssh_user: root

Configures the **root** user's SSH client preferences on the managed nodes with certain configuration specifics.

Compression: true

Compression is enabled.

ControlMaster: auto

ControlMaster multiplexing is set to **auto**.

Host

Creates alias **example** for connecting to the **server.example.com** host as a user called **user1**.

ssh_ForwardX11: no

X11 forwarding is disabled.

For details about the role variables and the OpenSSH configuration options used in the playbook, see the **/usr/share/ansible/roles/rhel-system-roles.ssh/README.md** file and the **ssh_config(5)** manual page 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

- Verify that the managed node has the correct configuration by displaying the SSH configuration file:

```
# cat ~/root/.ssh/config
# Ansible managed
Compression yes
ControlMaster auto
ControlPath ~/.ssh/.cm%C
ForwardX11 no
GSSAPIAuthentication no
Host example
  Hostname example.com
  User user1
```

Additional resources

- **/usr/share/ansible/roles/rhel-system-roles.ssh/README.md** file
- **/usr/share/doc/rhel-system-roles/ssh/** directory
- **ssh_config(5)** manual page

1.8. ADDITIONAL RESOURCES

- **sshd(8)**, **ssh(1)**, **scp(1)**, **sftp(1)**, **ssh-keygen(1)**, **ssh-copy-id(1)**, **ssh_config(5)**, **sshd_config(5)**, **update-crypto-policies(8)**, and **crypto-policies(7)** man pages on your system
- Configuring SELinux for applications and services with non-standard configurations

- Controlling network traffic using firewalld

CHAPTER 2. CREATING AND MANAGING TLS KEYS AND CERTIFICATES

You can encrypt communication transmitted between two systems by using the TLS (Transport Layer Security) protocol. This standard uses asymmetric cryptography with private and public keys, digital signatures, and certificates.

2.1. TLS CERTIFICATES

TLS (Transport Layer Security) is a protocol that enables client-server applications to pass information securely. TLS uses a system of public and private key pairs to encrypt communication transmitted between clients and servers. TLS is the successor protocol to SSL (Secure Sockets Layer).

TLS uses X.509 certificates to bind identities, such as hostnames or organizations, to public keys using digital signatures. X.509 is a standard that defines the format of public key certificates.

Authentication of a secure application depends on the integrity of the public key value in the application's certificate. If an attacker replaces the public key with its own public key, it can impersonate the true application and gain access to secure data. To prevent this type of attack, all certificates must be signed by a certification authority (CA). A CA is a trusted node that confirms the integrity of the public key value in a certificate.

A CA signs a public key by adding its digital signature and issues a certificate. A digital signature is a message encoded with the CA's private key. The CA's public key is made available to applications by distributing the certificate of the CA. Applications verify that certificates are validly signed by decoding the CA's digital signature with the CA's public key.

To have a certificate signed by a CA, you must generate a public key, and send it to a CA for signing. This is referred to as a certificate signing request (CSR). A CSR contains also a distinguished name (DN) for the certificate. The DN information that you can provide for either type of certificate can include a two-letter country code for your country, a full name of your state or province, your city or town, a name of your organization, your email address, and it can also be empty. Many current commercial CAs prefer the Subject Alternative Name extension and ignore DNs in CSRs.

RHEL provides two main toolkits for working with TLS certificates: GnuTLS and OpenSSL. You can create, read, sign, and verify certificates using the **openssl** utility from the **openssl** package. The **certtool** utility provided by the **gnutls-utils** package can do the same operations using a different syntax and above all a different set of libraries in the back end.

Additional resources

- RFC 5280: Internet X.509 Public Key Infrastructure Certificate and Certificate Revocation List (CRL) Profile
- **openssl(1)**, **x509(1)**, **ca(1)**, **req(1)**, and **certtool(1)** man pages on your system

2.2. CREATING A PRIVATE CA BY USING OPENSSL

Private certificate authorities (CA) are useful when your scenario requires verifying entities within your internal network. For example, use a private CA when you create a VPN gateway with authentication based on certificates signed by a CA under your control or when you do not want to pay a commercial CA. To sign certificates in such use cases, the private CA uses a self-signed certificate.

Prerequisites

- You have **root** privileges or permissions to enter administrative commands with **sudo**. Commands that require such privileges are marked with **#**.

Procedure

1. Generate a private key for your CA. For example, the following command creates a 256-bit Elliptic Curve Digital Signature Algorithm (ECDSA) key:

```
$ openssl genpkey -algorithm ec -pkeyopt ec_paramgen_curve:P-256 -out <ca.key>
```

   The time for the key-generation process depends on the hardware and entropy of the host, the selected algorithm, and the length of the key.

2. Create a certificate signed using the private key generated in the previous command:

```
$ openssl req -key <ca.key> -new -x509 -days 3650 -addext
keyUsage=critical,keyCertSign,cRLSign -subj "/CN=<Example CA>" -out <ca.crt>
```

   The generated **ca.crt** file is a self-signed CA certificate that you can use to sign other certificates for ten years. In the case of a private CA, you can replace *<Example CA>* with any string as the common name (CN).

3. Set secure permissions on the private key of your CA, for example:

```
# chown <root>:<root> <ca.key>
# chmod 600 <ca.key>
```

Next steps

- To use a self-signed CA certificate as a trust anchor on client systems, copy the CA certificate to the client and add it to the clients' system-wide truststore as **root**:

```
# trust anchor <ca.crt>
```

  See the Using shared system certificates chapter for more information.

Verification

1. Create a certificate signing request (CSR), and use your CA to sign the request. The CA must successfully create a certificate based on the CSR, for example:

```
$ openssl x509 -req -in <client-cert.csr> -CA <ca.crt> -CAkey <ca.key> -CAcreateserial -
days 365 -extfile <openssl.cnf> -extensions <client-cert> -out <client-cert.crt>
Signature ok
subject=C = US, O = Example Organization, CN = server.example.com
Getting CA Private Key
```

   See Section 2.5, “Using a private CA to issue certificates for CSRs with OpenSSL” for more information.

2. Display the basic information about your self-signed CA:

```
$ openssl x509 -in <ca.crt> -text -noout
Certificate:
```

```
…
        X509v3 extensions:
            …
            X509v3 Basic Constraints: critical
                CA:TRUE
            X509v3 Key Usage: critical
                Certificate Sign, CRL Sign
…
```

3. Verify the consistency of the private key:

```
$ openssl pkey -check -in <ca.key>
Key is valid
-----BEGIN PRIVATE KEY-----
MIGHAgEAMBMGByqGSM49AgEGCCqGSM49AwEHBG0wawIBAQQgcagSaTEBn74xZAwO

18wRpXoCVC9vcPki7WIT+gnmCI+hRANCAARb9NxIvkaVjFhOoZbGp/HtIQxbM78E
lwbDP0BI624xBJ8gK68ogSaq2x4SdezFdV1gNeKScDcU+Pj2pELldmdF
-----END PRIVATE KEY-----
```

Additional resources

- **openssl(1)**, **ca(1)**, **genpkey(1)**, **x509(1)**, and **req(1)** man pages on your system

2.3. CREATING A PRIVATE KEY AND A CSR FOR A TLS SERVER CERTIFICATE BY USING OPENSSL

You can use TLS-encrypted communication channels only if you have a valid TLS certificate from a certificate authority (CA). To obtain the certificate, you must create a private key and a certificate signing request (CSR) for your server first.

Procedure

1. Generate a private key on your server system, for example:

```
$ openssl genpkey -algorithm ec -pkeyopt ec_paramgen_curve:P-256 -out <server-private.key>
```

2. Optional: Use a text editor of your choice to prepare a configuration file that simplifies creating your CSR, for example:

```
$ vim <example_server.cnf>
[server-cert]
keyUsage = critical, digitalSignature, keyEncipherment, keyAgreement
extendedKeyUsage = serverAuth
subjectAltName = @alt_name

[req]
distinguished_name = dn
prompt = no

[dn]
C = <US>
```

```
O = <Example Organization>
CN = <server.example.com>

[alt_name]
DNS.1 = <example.com>
DNS.2 = <server.example.com>
IP.1 = <192.168.0.1>
IP.2 = <::1>
IP.3 = <127.0.0.1>
```

The **extendedKeyUsage = serverAuth** option limits the use of a certificate.

3. Create a CSR using the private key you created previously:

```
$ openssl req -key <server-private.key> -config <example_server.cnf> -new -out <server-cert.csr>
```

If you omit the **-config** option, the **req** utility prompts you for additional information, for example:

```
You are about to be asked to enter information that will be incorporated
into your certificate request.
What you are about to enter is what is called a Distinguished Name or a DN.
There are quite a few fields but you can leave some blank
For some fields there will be a default value,
If you enter '.', the field will be left blank.
-----
Country Name (2 letter code) [XX]: <US>
State or Province Name (full name) []: <Washington>
Locality Name (eg, city) [Default City]: <Seattle>
Organization Name (eg, company) [Default Company Ltd]: <Example Organization>
Organizational Unit Name (eg, section) []:
Common Name (eg, your name or your server's hostname) []: <server.example.com>
Email Address []: <server@example.com>
```

Next steps

- Submit the CSR to a CA of your choice for signing. Alternatively, for an internal use scenario within a trusted network, use your private CA for signing. See Section 2.5, “Using a private CA to issue certificates for CSRs with OpenSSL” for more information.

Verification

1. After you obtain the requested certificate from the CA, check that the human-readable parts of the certificate match your requirements, for example:

```
$ openssl x509 -text -noout -in <server-cert.crt>
Certificate:
…
        Issuer: CN = Example CA
        Validity
            Not Before: Feb  2 20:27:29 2023 GMT
            Not After : Feb  2 20:27:29 2024 GMT
        Subject: C = US, O = Example Organization, CN = server.example.com
        Subject Public Key Info:
```

```
            Public Key Algorithm: id-ecPublicKey
                Public-Key: (256 bit)
…
        X509v3 extensions:
            X509v3 Key Usage: critical
                Digital Signature, Key Encipherment, Key Agreement
            X509v3 Extended Key Usage:
                TLS Web Server Authentication
            X509v3 Subject Alternative Name:
                DNS:example.com, DNS:server.example.com, IP Address:192.168.0.1, IP
…
```

Additional resources

- **openssl(1)**, **x509(1)**, **genpkey(1)**, **req(1)**, and **config(5)** man pages on your system

2.4. CREATING A PRIVATE KEY AND A CSR FOR A TLS CLIENT CERTIFICATE BY USING OPENSSL

You can use TLS-encrypted communication channels only if you have a valid TLS certificate from a certificate authority (CA). To obtain the certificate, you must create a private key and a certificate signing request (CSR) for your client first.

Procedure

1. Generate a private key on your client system, for example:

```
$ openssl genpkey -algorithm ec -pkeyopt ec_paramgen_curve:P-256 -out <client-private.key>
```

2. Optional: Use a text editor of your choice to prepare a configuration file that simplifies creating your CSR, for example:

```
$ vim <example_client.cnf>
[client-cert]
keyUsage = critical, digitalSignature, keyEncipherment
extendedKeyUsage = clientAuth
subjectAltName = @alt_name

[req]
distinguished_name = dn
prompt = no

[dn]
CN = <client.example.com>

[clnt_alt_name]
email= <client@example.com>
```

   The **extendedKeyUsage = clientAuth** option limits the use of a certificate.

3. Create a CSR using the private key you created previously:

```
$ openssl req -key <client-private.key> -config <example_client.cnf> -new -out <client-cert.csr>
```

If you omit the **-config** option, the **req** utility prompts you for additional information, for example:

```
You are about to be asked to enter information that will be incorporated
into your certificate request.
…
Common Name (eg, your name or your server's hostname) []: <client.example.com>
Email Address []: <client@example.com>
```

Next steps

- Submit the CSR to a CA of your choice for signing. Alternatively, for an internal use scenario within a trusted network, use your private CA for signing. See Section 2.5, "Using a private CA to issue certificates for CSRs with OpenSSL" for more information.

Verification

1. Check that the human-readable parts of the certificate match your requirements, for example:

```
$ openssl x509 -text -noout -in <client-cert.crt>
Certificate:
…
            X509v3 Extended Key Usage:
                TLS Web Client Authentication
            X509v3 Subject Alternative Name:
                email:client@example.com
…
```

Additional resources

- **openssl(1)**, **x509(1)**, **genpkey(1)**, **req(1)**, and **config(5)** man pages on your system

2.5. USING A PRIVATE CA TO ISSUE CERTIFICATES FOR CSRS WITH OPENSSL

To enable systems to establish a TLS-encrypted communication channel, a certificate authority (CA) must provide valid certificates to them. If you have a private CA, you can create the requested certificates by signing certificate signing requests (CSRs) from the systems.

Prerequisites

- You have already configured a private CA. See Section 2.2, "Creating a private CA by using OpenSSL" for more information.
- You have a file containing a CSR. You can find an example of creating the CSR in Section 2.3, "Creating a private key and a CSR for a TLS server certificate by using OpenSSL" .

Procedure

1. Optional: Use a text editor of your choice to prepare an OpenSSL configuration file for adding extensions to certificates, for example:

```
$ vim <openssl.cnf>
[server-cert]
extendedKeyUsage = serverAuth

[client-cert]
extendedKeyUsage = clientAuth
```

Note that the previous example illustrates only the principle and **openssl** does not add all extensions to the certificate automatically. You must add the extensions you require either to the CNF file or append them to parameters of the **openssl** command.

2. Use the **x509** utility to create a certificate based on a CSR, for example:

```
$ openssl x509 -req -in <server-cert.csr> -CA <ca.crt> -CAkey <ca.key> -days 365 -extfile
<openssl.cnf> -extensions <server-cert> -out <server-cert.crt>
Signature ok
subject=C = US, O = Example Organization, CN = server.example.com
Getting CA Private Key
```

To increase security, delete the serial-number file before you create another certificate from a CSR. This way, you ensure that the serial number is always random. If you omit the **CAserial** option for specifying a custom file name, the serial-number file name is the same as the file name of the certificate, but its extension is replaced with the **.srl** extension (**server-cert.srl** in the previous example).

Additional resources

- **openssl(1)**, **ca(1)**, and **x509(1)** man pages on your system

2.6. CREATING A PRIVATE CA BY USING GNUTLS

Private certificate authorities (CA) are useful when your scenario requires verifying entities within your internal network. For example, use a private CA when you create a VPN gateway with authentication based on certificates signed by a CA under your control or when you do not want to pay a commercial CA. To sign certificates in such use cases, the private CA uses a self-signed certificate.

Prerequisites

- You have **root** privileges or permissions to enter administrative commands with **sudo**. Commands that require such privileges are marked with **#**.
- You have already installed GnuTLS on your system. If you did not, you can use this command:

```
$ dnf install gnutls-utils
```

Procedure

1. Generate a private key for your CA. For example, the following command creates a 256-bit ECDSA (Elliptic Curve Digital Signature Algorithm) key:

```
$ certtool --generate-privkey --sec-param High --key-type=ecdsa --outfile <ca.key>
```

The time for the key-generation process depends on the hardware and entropy of the host, the selected algorithm, and the length of the key.

2. Create a template file for a certificate.

   a. Create a file with a text editor of your choice, for example:

   ```
   $ vi <ca.cfg>
   ```

   b. Edit the file to include the necessary certification details:

   ```
   organization = "Example Inc."
   state = "Example"
   country = EX
   cn = "Example CA"
   serial = 007
   expiration_days = 365
   ca
   cert_signing_key
   crl_signing_key
   ```

3. Create a certificate signed using the private key generated in step 1:
   The generated *<ca.crt>* file is a self-signed CA certificate that you can use to sign other certificates for one year. *<ca.crt>* file is the public key (certificate). The loaded file *<ca.key>* is the private key. You should keep this file in safe location.

   ```
   $ certtool --generate-self-signed --load-privkey <ca.key> --template <ca.cfg> --outfile
   <ca.crt>
   ```

4. Set secure permissions on the private key of your CA, for example:

   ```
   # chown <root>:<root> <ca.key>
   # chmod 600 <ca.key>
   ```

Next steps

- To use a self-signed CA certificate as a trust anchor on client systems, copy the CA certificate to the client and add it to the clients' system-wide truststore as **root**:

  ```
  # trust anchor <ca.crt>
  ```

  See the Using shared system certificates chapter for more information.

Verification

1. Display the basic information about your self-signed CA:

   ```
   $ certtool --certificate-info --infile <ca.crt>
   Certificate:
   …
       X509v3 extensions:
           …
           X509v3 Basic Constraints: critical
   ```

```
    CA:TRUE
X509v3 Key Usage: critical
    Certificate Sign, CRL Sign
```

2. Create a certificate signing request (CSR), and use your CA to sign the request. The CA must successfully create a certificate based on the CSR, for example:

   a. Generate a private key for your CA:

   ```
   $ certtool --generate-privkey --outfile <example-server.key>
   ```

   b. Open a new configuration file in a text editor of your choice, for example:

   ```
   $ vi <example-server.cfg>
   ```

   c. Edit the file to include the necessary certification details:

   ```
   signing_key
   encryption_key
   key_agreement

   tls_www_server

   country = "US"
   organization = "Example Organization"
   cn = "server.example.com"

   dns_name = "example.com"
   dns_name = "server.example.com"
   ip_address = "192.168.0.1"
   ip_address = "::1"
   ip_address = "127.0.0.1"
   ```

   d. Generate a request with the previously created private key:

   ```
   $ certtool --generate-request --load-privkey <example-server.key> --template <example-server.cfg> --outfile <example-server.crq>
   ```

   e. Generate the certificate and sign it with the private key of the CA:

   ```
   $ certtool --generate-certificate --load-request <example-server.crq> --load-ca-certificate <ca.crt> --load-ca-privkey <ca.key> --outfile <example-server.crt>
   ```

   Additional resources

   - **certtool(1)** and **trust(1)** man pages on your system

2.7. CREATING A PRIVATE KEY AND A CSR FOR A TLS SERVER CERTIFICATE BY USING GNUTLS

To obtain the certificate, you must create a private key and a certificate signing request (CSR) for your server first.

Procedure

1. Generate a private key on your server system, for example:

```
$ certtool --generate-privkey --sec-param High --outfile <example-server.key>
```

2. Optional: Use a text editor of your choice to prepare a configuration file that simplifies creating your CSR, for example:

```
$ vim <example_server.cnf>
signing_key
encryption_key
key_agreement

tls_www_server

country = "US"
organization = "Example Organization"
cn = "server.example.com"

dns_name = "example.com"
dns_name = "server.example.com"
ip_address = "192.168.0.1"
ip_address = "::1"
ip_address = "127.0.0.1"
```

3. Create a CSR using the private key you created previously:

```
$ certtool --generate-request --template <example-server.cfg> --load-privkey <example-server.key> --outfile <example-server.crq>
```

If you omit the **--template** option, the **certool** utility prompts you for additional information, for example:

```
You are about to be asked to enter information that will be incorporated
into your certificate request.
What you are about to enter is what is called a Distinguished Name or a DN.
There are quite a few fields but you can leave some blank
For some fields there will be a default value,
If you enter '.', the field will be left blank.
-----
Generating a PKCS #10 certificate request...
Country name (2 chars): <US>
State or province name: <Washington>
Locality name: <Seattle>
Organization name: <Example Organization>
Organizational unit name:
Common name: <server.example.com>
```

Next steps

- Submit the CSR to a CA of your choice for signing. Alternatively, for an internal use scenario within a trusted network, use your private CA for signing. See Section 2.9, “Using a private CA to issue certificates for CSRs with GnuTLS” for more information.

Verification

1. After you obtain the requested certificate from the CA, check that the human-readable parts of the certificate match your requirements, for example:

```
$ certtool --certificate-info --infile <example-server.crt>
Certificate:
…
        Issuer: CN = Example CA
        Validity
            Not Before: Feb  2 20:27:29 2023 GMT
            Not After : Feb  2 20:27:29 2024 GMT
        Subject: C = US, O = Example Organization, CN = server.example.com
        Subject Public Key Info:
            Public Key Algorithm: id-ecPublicKey
                Public-Key: (256 bit)
…
        X509v3 extensions:
            X509v3 Key Usage: critical
                Digital Signature, Key Encipherment, Key Agreement
            X509v3 Extended Key Usage:
                TLS Web Server Authentication
            X509v3 Subject Alternative Name:
                DNS:example.com, DNS:server.example.com, IP Address:192.168.0.1, IP
…
```

Additional resources

- **certtool(1)** man page on your system

2.8. CREATING A PRIVATE KEY AND A CSR FOR A TLS CLIENT CERTIFICATE BY USING GNUTLS

To obtain the certificate, you must create a private key and a certificate signing request (CSR) for your client first.

Procedure

1. Generate a private key on your client system, for example:

```
$ certtool --generate-privkey --sec-param High --outfile <example-client.key>
```

2. Optional: Use a text editor of your choice to prepare a configuration file that simplifies creating your CSR, for example:

```
$ vim <example_client.cnf>
signing_key
encryption_key

tls_www_client

cn = "client.example.com"
email = "client@example.com"
```

3. Create a CSR using the private key you created previously:

```
$ certtool --generate-request --template <example-client.cfg> --load-privkey <example-client.key> --outfile <example-client.crq>
```

If you omit the **--template** option, the **certtool** utility prompts you for additional information, for example:

```
Generating a PKCS #10 certificate request...
Country name (2 chars): <US>
State or province name: <Washington>
Locality name: <Seattle>
Organization name: <Example Organization>
Organizational unit name:
Common name: <server.example.com>
```

Next steps

- Submit the CSR to a CA of your choice for signing. Alternatively, for an internal use scenario within a trusted network, use your private CA for signing. See Section 2.9, "Using a private CA to issue certificates for CSRs with GnuTLS" for more information.

Verification

1. Check that the human-readable parts of the certificate match your requirements, for example:

```
$ certtool --certificate-info --infile <example-client.crt>
Certificate:
…
        X509v3 Extended Key Usage:
            TLS Web Client Authentication
        X509v3 Subject Alternative Name:
            email:client@example.com
…
```

Additional resources

- **certtool(1)** man page on your system

2.9. USING A PRIVATE CA TO ISSUE CERTIFICATES FOR CSRS WITH GNUTLS

To enable systems to establish a TLS-encrypted communication channel, a certificate authority (CA) must provide valid certificates to them. If you have a private CA, you can create the requested certificates by signing certificate signing requests (CSRs) from the systems.

Prerequisites

- You have already configured a private CA. See Section 2.6, "Creating a private CA by using GnuTLS" for more information.
- You have a file containing a CSR. You can find an example of creating the CSR in Section 2.7, "Creating a private key and a CSR for a TLS server certificate by using GnuTLS" .

Procedure

1. Optional: Use a text editor of your choice to prepare an GnuTLS configuration file for adding extensions to certificates, for example:

```
$ vi <server-extensions.cfg>
honor_crq_extensions
ocsp_uri = "http://ocsp.example.com"
```

2. Use the **certtool** utility to create a certificate based on a CSR, for example:

```
$ certtool --generate-certificate --load-request <example-server.crq> --load-ca-privkey
<ca.key> --load-ca-certificate <ca.crt> --template <server-extensions.cfg> --outfile
<example-server.crt>
```

Additional resources

- **certtool(1)** man page on your system

CHAPTER 3. PLANNING AND IMPLEMENTING TLS

TLS (Transport Layer Security) is a cryptographic protocol used to secure network communications. When hardening system security settings by configuring preferred key-exchange protocols, authentication methods, and encryption algorithms, it is necessary to bear in mind that the broader the range of supported clients, the lower the resulting security. Conversely, strict security settings lead to limited compatibility with clients, which can result in some users being locked out of the system. Be sure to target the strictest available configuration and only relax it when it is required for compatibility reasons.

3.1. SSL AND TLS PROTOCOLS

The Secure Sockets Layer (SSL) protocol was originally developed by Netscape Corporation to provide a mechanism for secure communication over the Internet. Subsequently, the protocol was adopted by the Internet Engineering Task Force (IETF) and renamed to Transport Layer Security (TLS).

The TLS protocol sits between an application protocol layer and a reliable transport layer, such as TCP/IP. It is independent of the application protocol and can thus be layered underneath many different protocols, for example: HTTP, FTP, SMTP, and so on.

Protocol version	Usage recommendation
SSL v2	Do not use. Has serious security vulnerabilities. Removed from the core crypto libraries since RHEL 7.
SSL v3	Do not use. Has serious security vulnerabilities. Removed from the core crypto libraries since RHEL 8.
TLS 1.0	Not recommended to use. Has known issues that cannot be mitigated in a way that guarantees interoperability, and does not support modern cipher suites. In RHEL 10, disabled in all cryptographic policies.
TLS 1.1	Use for interoperability purposes where needed. Does not support modern cipher suites. In RHEL 10, disabled in all cryptographic policies.
TLS 1.2	Supports the modern AEAD cipher suites. This version is enabled in all system-wide crypto policies, but optional parts of this protocol contain vulnerabilities and TLS 1.2 also allows outdated algorithms.
TLS 1.3	Recommended version. TLS 1.3 removes known problematic options, provides additional privacy by encrypting more of the negotiation handshake and can be faster thanks usage of more efficient modern cryptographic algorithms. TLS 1.3 is also enabled in all system-wide cryptographic policies.

Additional resources

- IETF: The Transport Layer Security (TLS) Protocol Version 1.3

3.2. SECURITY CONSIDERATIONS FOR TLS IN RHEL 10

In RHEL 10, TLS configuration is performed using the system-wide cryptographic policies mechanism. TLS versions below 1.2 are not supported anymore. **DEFAULT**, **FUTURE**, and **LEGACY** cryptographic policies allow only TLS 1.2 and 1.3. See Using system-wide cryptographic policies for more information.

The default settings provided by libraries included in RHEL 10 are secure enough for most deployments. The TLS implementations use secure algorithms where possible while not preventing connections from or to legacy clients or servers. Apply hardened settings in environments with strict security requirements where legacy clients or servers that do not support secure algorithms or protocols are not expected or allowed to connect.

The most straightforward way to harden your TLS configuration is switching the system-wide cryptographic policy level to **FUTURE** using the **update-crypto-policies --set FUTURE** command.

WARNING

Algorithms disabled for the **LEGACY** cryptographic policy do not conform to Red Hat's vision of RHEL 10 security, and their security properties are not reliable. Consider moving away from using these algorithms instead of re-enabling them. If you do decide to re-enable them, for example for interoperability with old hardware, treat them as insecure and apply extra protection measures, such as isolating their network interactions to separate network segments. Do not use them across public networks.

If you decide to not follow RHEL system-wide crypto policies or create custom cryptographic policies tailored to your setup, use the following recommendations for preferred protocols, cipher suites, and key lengths on your custom configuration:

3.2.1. Protocols

The latest version of TLS provides the best security mechanism. TLS 1.2 is now the minimum version even when using the **LEGACY** cryptographic policy. Re-enabling older protocol versions is possible through either opting out of cryptographic policies or providing a custom policy, but the resulting configuration will not be supported.

Note that even though that RHEL 10 supports TLS version 1.3, not all features of this protocol are fully supported by RHEL 10 components. For example, the 0-RTT (Zero Round Trip Time) feature, which reduces connection latency, is not yet fully supported by the Apache web server.

WARNING

A RHEL 9.2 and later system running in FIPS mode enforces that any TLS 1.2 connection must use the Extended Master Secret (EMS) extension (RFC 7627) as requires the FIPS 140-3 standard. Thus, legacy clients not supporting EMS or TLS 1.3 cannot connect to RHEL 9 and 10 servers running in FIPS mode, RHEL 9 a 10 clients in FIPS mode cannot connect to servers that support only TLS 1.2 without EMS. See TLS Extension "Extended Master Secret" enforced with Red Hat Enterprise Linux 9.2

3.2.2. Cipher suites

Modern, more secure cipher suites should be preferred to old, insecure ones. Always disable the use of eNULL and aNULL cipher suites, which do not offer any encryption or authentication at all. If at all possible, ciphers suites based on RC4 or HMAC-MD5, which have serious shortcomings, should also be disabled. The same applies to the so-called export cipher suites, which have been intentionally made weaker, and thus are easy to break.

While not immediately insecure, cipher suites that offer less than 128 bits of security should not be considered for their short useful life. Algorithms that use 128 bits of security or more can be expected to be unbreakable for at least several years, and are thus strongly recommended. Note that while 3DES ciphers advertise the use of 168 bits, they actually offer 112 bits of security.

Always prefer cipher suites that support (perfect) forward secrecy (PFS), which ensures the confidentiality of encrypted data even in case the server key is compromised. This rules out the fast RSA key exchange, but allows for the use of ECDHE and DHE. Of the two, ECDHE is the faster and therefore the preferred choice.

You should also prefer AEAD ciphers, such as AES-GCM, over CBC-mode ciphers as they are not vulnerable to padding oracle attacks. Additionally, in many cases, AES-GCM is faster than AES in CBC mode, especially when the hardware has cryptographic accelerators for AES.

Note also that when using the ECDHE key exchange with ECDSA certificates, the transaction is even faster than a pure RSA key exchange. To provide support for legacy clients, you can install two pairs of certificates and keys on a server: one with ECDSA keys (for new clients) and one with RSA keys (for legacy ones).

3.2.3. Public key length

When using RSA keys, always prefer key lengths of at least 3072 bits signed by at least SHA-256, which is sufficiently large for true 128 bits of security.

WARNING

The security of your system is only as strong as the weakest link in the chain. For example, a strong cipher alone does not guarantee good security. The keys and the certificates are just as important, as well as the hash functions and keys used by the Certification Authority (CA) to sign your keys.

Additional resources

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

3.3. HARDENING TLS CONFIGURATION IN APPLICATIONS

In RHEL, system-wide crypto policies provide a convenient way to ensure that your applications that use cryptographic libraries do not allow known insecure protocols, ciphers, or algorithms.

If you want to harden your TLS-related configuration with your customized cryptographic settings, you can use the cryptographic configuration options described in this section, and override the system-wide crypto policies just in the minimum required amount.

Regardless of the configuration you choose to use, always ensure that your server application enforces *server-side cipher order*, so that the cipher suite to be used is determined by the order you configure.

3.3.1. Configuring the Apache HTTP server to use TLS

The **Apache HTTP Server** can use both **OpenSSL** and **NSS** libraries for its TLS needs. RHEL 10 provides the **mod_ssl** functionality through eponymous packages:

```
# dnf install mod_ssl
```

The **mod_ssl** package installs the **/etc/httpd/conf.d/ssl.conf** configuration file, which can be used to modify the TLS-related settings of the **Apache HTTP Server**.

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. Examples of various settings are described in the **/usr/share/httpd/manual/ssl/ssl_howto.html** file.

When modifying the settings in the **/etc/httpd/conf.d/ssl.conf** configuration file, be sure to consider the following three directives at the minimum:

SSLProtocol

Use this directive to specify the version of TLS or SSL you want to allow.

SSLCipherSuite

Use this directive to specify your preferred cipher suite or disable the ones you want to disallow.

SSLHonorCipherOrder

Uncomment and set this directive to **on** to ensure that the connecting clients adhere to the order of ciphers you specified.

For example, to use only the TLS 1.2 and 1.3 protocol:

```
SSLProtocol             all -SSLv3 -TLSv1 -TLSv1.1
```

See the Configuring TLS encryption on an Apache HTTP Server chapter in the Deploying web servers and reverse proxies document for more information.

3.3.2. Configuring the Nginx HTTP and proxy server to use TLS

To enable TLS 1.3 support in **Nginx**, add the **TLSv1.3** value to the **ssl_protocols** option in the **server** section of the **/etc/nginx/nginx.conf** configuration file:

```
server {
    listen 443 ssl http2;
    listen [::]:443 ssl http2;
    ....
    ssl_protocols TLSv1.2 TLSv1.3;
    ssl_ciphers
    ....
}
```

See the Adding TLS encryption to an Nginx web server chapter in the Deploying web servers and reverse proxies document for more information.

3.3.3. Configuring the Dovecot mail server to use TLS

To configure your installation of the **Dovecot** mail server to use TLS, modify the **/etc/dovecot/conf.d/10-ssl.conf** configuration file. You can find an explanation of some of the basic configuration directives available in that file in the **/usr/share/doc/dovecot/wiki/SSL.DovecotConfiguration.txt** file, which is installed along with the standard installation of **Dovecot**.

When modifying the settings in the **/etc/dovecot/conf.d/10-ssl.conf** configuration file, be sure to consider the following three directives at the minimum:

ssl_protocols

Use this directive to specify the version of TLS or SSL you want to allow or disable.

ssl_cipher_list

Use this directive to specify your preferred cipher suites or disable the ones you want to disallow.

ssl_prefer_server_ciphers

Uncomment and set this directive to **yes** to ensure that the connecting clients adhere to the order of ciphers you specified.

For example, the following line in **/etc/dovecot/conf.d/10-ssl.conf** allows only TLS 1.1 and later:

```
ssl_protocols = !SSLv2 !SSLv3 !TLSv1
```

Additional resources

- Deploying web servers and reverse proxies
- **config(5)** and **ciphers(1)** man pages on your system

- Recommendations for Secure Use of Transport Layer Security (TLS) and Datagram Transport Layer Security (DTLS)
- Mozilla SSL Configuration Generator.
- SSL Server Test

CHAPTER 4. SETTING UP AN IPSEC VPN

A virtual private network (VPN) is a way of connecting to a local network over the internet. **IPsec** provided by **Libreswan** is the preferred method for creating a VPN. **Libreswan** is a user-space **IPsec** implementation for VPN. A VPN enables the communication between your LAN, and another, remote LAN by setting up a tunnel across an intermediate network such as the internet. For security reasons, a VPN tunnel always uses authentication and encryption. For cryptographic operations, **Libreswan** uses the **NSS** library.

4.1. LIBRESWAN AS AN IPSEC VPN IMPLEMENTATION

In RHEL, you can configure a Virtual Private Network (VPN) by using the IPsec protocol, which is supported by the Libreswan application. Libreswan is a continuation of the Openswan application, and many examples from the Openswan documentation are interchangeable with Libreswan.

The IPsec protocol for a VPN is configured using the Internet Key Exchange (IKE) protocol. The terms IPsec and IKE are used interchangeably. An IPsec VPN is also called an IKE VPN, IKEv2 VPN, XAUTH VPN, Cisco VPN or IKE/IPsec VPN. A variant of an IPsec VPN that also uses the Layer 2 Tunneling Protocol (L2TP) is usually called an L2TP/IPsec VPN, which requires the **xl2tpd** package provided by the **optional** repository.

Libreswan is an open-source, user-space IKE implementation. IKE v1 and v2 are implemented as a user-level daemon. The IKE protocol is also encrypted. The IPsec protocol is implemented by the Linux kernel, and Libreswan configures the kernel to add and remove VPN tunnel configurations.

The IKE protocol uses UDP port 500 and 4500. The IPsec protocol consists of two protocols:

- Encapsulated Security Payload (ESP), which has protocol number 50.
- Authenticated Header (AH), which has protocol number 51.

The AH protocol is not recommended for use. Users of AH are recommended to migrate to ESP with null encryption.

The IPsec protocol provides two modes of operation:

- Tunnel Mode (the default)
- Transport Mode

You can configure the kernel with IPsec without IKE. This is called *manual keying*. You can also configure manual keying using the **ip xfrm** commands, however, this is strongly discouraged for security reasons. Libreswan communicates with the Linux kernel using the Netlink interface. The kernel performs packet encryption and decryption.

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

IMPORTANT

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

In RHEL, Libreswan follows **system-wide cryptographic policies** by default. This ensures that Libreswan uses secure settings for current threat models including IKEv2 as a default protocol. See Using system-wide crypto policies for more information.

Libreswan does not use the terms "source" and "destination" or "server" and "client" because IKE/IPsec are peer to peer protocols. Instead, it uses the terms "left" and "right" to refer to end points (the hosts). This also allows you to use the same configuration on both end points in most cases. However, administrators usually choose to always use "left" for the local host and "right" for the remote host.

The **leftid** and **rightid** options serve as identification of the respective hosts in the authentication process. See the **ipsec.conf(5)** man page for more information.

4.2. AUTHENTICATION METHODS IN LIBRESWAN

Libreswan supports several authentication methods, each of which fits a different scenario.

Pre-Shared key (PSK)

Pre-Shared Key (PSK) is the simplest authentication method. For security reasons, do not use PSKs shorter than 64 random characters. In FIPS mode, PSKs must comply with a minimum-strength requirement depending on the integrity algorithm used. You can set PSK by using the **authby=secret** connection.

Raw RSA keys

Raw RSA keys are commonly used for static host-to-host or subnet-to-subnet IPsec configurations. Each host is manually configured with the public RSA keys of all other hosts, and Libreswan sets up an IPsec tunnel between each pair of hosts. This method does not scale well for large numbers of hosts.

You can generate a raw RSA key on a host using the **ipsec newhostkey** command. You can list generated keys by using the **ipsec showhostkey** command. The **leftrsasigkey=** line is required for connection configurations that use CKA ID keys. Use the **authby=rsasig** connection option for raw RSA keys.

X.509 certificates

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

For example, you can generate X.509 certificates using the **openssl** command and the NSS **certutil** command. Because Libreswan reads user certificates from the NSS database using the certificates' nickname in the **leftcert=** configuration option, provide a nickname when you create a certificate.

If you use a custom CA certificate, you must import it to the Network Security Services (NSS) database. You can import any certificate in the PKCS #12 format to the Libreswan NSS database by using the **ipsec import** command.

WARNING

Libreswan requires an Internet Key Exchange (IKE) peer ID as a subject alternative name (SAN) for every peer certificate as described in section 3.1 of RFC 4945. Disabling this check by changing the **require-id-on-certificated=** option can make the system vulnerable to man-in-the-middle attacks.

Use the **authby=rsasig** connection option for authentication based on X.509 certificates using RSA with SHA-2. You can further limit it for ECDSA digital signatures using SHA-2 by setting **authby=** to **ecdsa** and RSA Probabilistic Signature Scheme (RSASSA-PSS) digital signatures based authentication with SHA-2 through **authby=rsa-sha2**. The default value is **authby=rsasig,ecdsa**.

The certificates and the **authby=** signature methods should match. This increases interoperability and preserves authentication in one digital signature system.

NULL authentication

NULL authentication is used to gain mesh encryption without authentication. It protects against passive attacks but not against active attacks. However, because IKEv2 allows asymmetric authentication methods, NULL authentication can also be used for internet-scale opportunistic IPsec. In this model, clients authenticate the server, but servers do not authenticate the client. This model is similar to secure websites using TLS. Use **authby=null** for NULL authentication.

Protection against quantum computers

In addition to the previously mentioned authentication methods, you can use the *Post-quantum Pre-shared Key* (PPK) method to protect against possible attacks by quantum computers. Individual clients or groups of clients can use their own PPK by specifying a PPK ID that corresponds to an out-of-band configured pre-shared key.

Using IKEv1 with pre-shared keys protects against quantum attackers. The redesign of IKEv2 does not offer this protection natively. Libreswan offers the use of a *Post-quantum Pre-shared Key* (PPK) to protect IKEv2 connections against quantum attacks.

To enable optional PPK support, add **ppk=yes** to the connection definition. To require PPK, add **ppk=insist**. Then, each client can be given a PPK ID with a secret value that is communicated out-of-band (and preferably quantum-safe). The PPK's should be very strong in randomness and not based on dictionary words. The PPK ID and PPK data are stored in the **ipsec.secrets** file, for example:

```
@west @east : PPKS "user1" "thestringismeanttobearandomstr"
```

The **PPKS** option refers to static PPKs. This experimental function uses one-time-pad-based Dynamic PPKs. Upon each connection, a new part of the one-time pad is used as the PPK. When used, that part of the dynamic PPK inside the file is overwritten with zeros to prevent re-use. If there is no more one-time-pad material left, the connection fails. See the **ipsec.secrets(5)** man page for more information.

WARNING

The implementation of dynamic PPKs is provided as an unsupported Technology Preview. Use with caution.

4.3. INSTALLING LIBRESWAN

Before you can set a VPN through the Libreswan IPsec/IKE implementation, you must install the corresponding packages, start the **ipsec** service, and allow the service in your firewall.

Prerequisites

- The **AppStream** repository is enabled.

Procedure

1. Install the **libreswan** packages:

```
# dnf install libreswan
```

2. If you are re-installing Libreswan, remove its old database files and create a new database:

```
# systemctl stop ipsec
# rm /var/lib/ipsec/nss/*db
# ipsec initnss
```

3. Start the **ipsec** service, and enable the service to be started automatically on boot:

```
# systemctl enable ipsec --now
```

4. Configure the firewall to allow 500 and 4500/UDP ports for the IKE, ESP, and AH protocols by adding the **ipsec** service:

```
# firewall-cmd --add-service="ipsec"
# firewall-cmd --runtime-to-permanent
```

4.4. CREATING A HOST-TO-HOST VPN

You can configure Libreswan to create a host-to-host IPsec VPN between two hosts referred to as *left* and *right* using authentication by raw RSA keys.

Prerequisites

- Libreswan is installed and the **ipsec** service is started on each node.

Procedure

1. Generate a raw RSA key pair on each host:

```
# ipsec newhostkey
```

2. The previous step returned the generated key's **ckaid**. Use that **ckaid** with the following command on *left*, for example:

```
# ipsec showhostkey --left --ckaid 2d3ea57b61c9419dfd6cf43a1eb6cb306c0e857d
```

The output of the previous command generated the **leftrsasigkey=** line required for the configuration. Do the same on the second host (*right*):

```
# ipsec showhostkey --right --ckaid a9e1f6ce9ecd3608c24e8f701318383f41798f03
```

3. In the /**etc**/**ipsec.d**/ directory, create a new **my_host-to-host.conf** file. Write the RSA host keys from the output of the **ipsec showhostkey** commands in the previous step to the new file. For example:

```
conn mytunnel
    leftid=@west
    left=192.1.2.23
    leftrsasigkey=0sAQOrlo+hOafUZDlCQmXFrje/oZm [...] W2n417C/4urYHQkCvuIQ==
    rightid=@east
    right=192.1.2.45
    rightrsasigkey=0sAQO3fwC6nSSGgt64DWiYZzuHbc4 [...] D/v8t5YTQ==
    authby=rsasig
```

4. After importing keys, restart the **ipsec** service:

```
# systemctl restart ipsec
```

5. Load the connection:

```
# ipsec auto --add mytunnel
```

6. Establish the tunnel:

```
# ipsec auto --up mytunnel
```

7. To automatically start the tunnel when the **ipsec** service is started, add the following line to the connection definition:

```
auto=start
```

4.5. CONFIGURING A SITE-TO-SITE VPN

To create a site-to-site IPsec VPN, by joining two networks, an IPsec tunnel between the two hosts is created. The hosts thus act as the end points, which are configured to permit traffic from one or more subnets to pass through. Therefore you can think of the host as gateways to the remote portion of the network.

The configuration of the site-to-site VPN only differs from the host-to-host VPN in that one or more networks or subnets must be specified in the configuration file.

Prerequisites

- A host-to-host VPN is already configured.

Procedure

1. Copy the file with the configuration of your host-to-host VPN to a new file, for example:

```
# cp /etc/ipsec.d/my_host-to-host.conf /etc/ipsec.d/my_site-to-site.conf
```

2. Add the subnet configuration to the file created in the previous step, for example:

```
conn mysubnet
    also=mytunnel
    leftsubnet=192.0.1.0/24
    rightsubnet=192.0.2.0/24
    auto=start

conn mysubnet6
    also=mytunnel
    leftsubnet=2001:db8:0:1::/64
    rightsubnet=2001:db8:0:2::/64
    auto=start

# the following part of the configuration file is the same for both host-to-host and site-to-site
connections:

conn mytunnel
   leftid=@west
   left=192.1.2.23
   leftrsasigkey=0sAQOrlo+hOafUZDlCQmXFrje/oZm [...] W2n417C/4urYHQkCvuIQ==
   rightid=@east
   right=192.1.2.45
   rightrsasigkey=0sAQO3fwC6nSSGgt64DWiYZzuHbc4 [...] D/v8t5YTQ==
   authby=rsasig
```

4.6. CONFIGURING A REMOTE ACCESS VPN

Road warriors are traveling users with mobile clients and a dynamically assigned IP address. The mobile clients authenticate using X.509 certificates.

The following example shows configuration for **IKEv2**, and it avoids using the **IKEv1** XAUTH protocol.

On the server:

```
conn roadwarriors
   ikev2=insist
   # support (roaming) MOBIKE clients (RFC 4555)
   mobike=yes
   fragmentation=yes
   left=1.2.3.4
   # if access to the LAN is given, enable this, otherwise use 0.0.0.0/0
   # leftsubnet=10.10.0.0/16
   leftsubnet=0.0.0.0/0
   leftcert=gw.example.com
```

```
    leftid=%fromcert
    leftxauthserver=yes
    leftmodecfgserver=yes
    right=%any
    # trust our own Certificate Agency
    rightca=%same
    # pick an IP address pool to assign to remote users
    # 100.64.0.0/16 prevents RFC1918 clashes when remote users are behind NAT
    rightaddresspool=100.64.13.100-100.64.13.254
    # if you want remote clients to use some local DNS zones and servers
    modecfgdns="1.2.3.4, 5.6.7.8"
    modecfgdomains="internal.company.com, corp"
    rightxauthclient=yes
    rightmodecfgclient=yes
    authby=rsasig
    # optionally, run the client X.509 ID through pam to allow or deny client
    # pam-authorize=yes
    # load connection, do not initiate
    auto=add
    # kill vanished roadwarriors
    dpddelay=1m
    dpdtimeout=5m
    dpdaction=clear
```

On the mobile client, the road warrior's device, use a slight variation of the previous configuration:

```
conn to-vpn-server
    ikev2=insist
    # pick up our dynamic IP
    left=%defaultroute
    leftsubnet=0.0.0.0/0
    leftcert=myname.example.com
    leftid=%fromcert
    leftmodecfgclient=yes
    # right can also be a DNS hostname
    right=1.2.3.4
    # if access to the remote LAN is required, enable this, otherwise use 0.0.0.0/0
    # rightsubnet=10.10.0.0/16
    rightsubnet=0.0.0.0/0
    fragmentation=yes
    # trust our own Certificate Agency
    rightca=%same
    authby=rsasig
    # allow narrowing to the server's suggested assigned IP and remote subnet
    narrowing=yes
    # support (roaming) MOBIKE clients (RFC 4555)
    mobike=yes
    # initiate connection
    auto=start
```

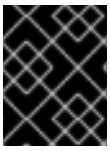
4.7. CONFIGURING A MESH VPN

A mesh VPN network, which is also known as an *any-to-any* VPN, is a network where all nodes communicate using IPsec. The configuration allows for exceptions for nodes that cannot use IPsec. The mesh VPN network can be configured in two ways:

- To require IPsec.
- To prefer IPsec but allow a fallback to clear-text communication.

Authentication between the nodes can be based on X.509 certificates or on DNS Security Extensions (DNSSEC).

You can use any regular IKEv2 authentication method for *opportunistic IPsec*, because these connections are regular Libreswan configurations, except for the opportunistic IPsec that is defined by **right=%opportunisticgroup** entry. A common authentication method is for hosts to authenticate each other based on X.509 certificates using a commonly shared certification authority (CA). Cloud deployments typically issue certificates for each node in the cloud as part of the standard procedure.



IMPORTANT

Do not use PreSharedKey (PSK) authentication because one compromised host would result in the group PSK secret being compromised as well.

You can use NULL authentication to deploy encryption between nodes without authentication, which protects only against passive attackers.

The following procedure uses X.509 certificates. You can generate these certificates by using any kind of CA management system, such as the Dogtag Certificate System. Dogtag assumes that the certificates for each node are available in the PKCS #12 format (**.p12** files), which contain the private key, the node certificate, and the Root CA certificate used to validate other nodes' X.509 certificates.

Each node has an identical configuration with the exception of its X.509 certificate. This allows for adding new nodes without reconfiguring any of the existing nodes in the network. The PKCS #12 files require a "friendly name", for which we use the name "node" so that the configuration files referencing the friendly name can be identical for all nodes.

Prerequisites

- Libreswan is installed, and the **ipsec** service is started on each node.
- A new NSS database is initialized.
  1. If you already have an old NSS database, remove the old database files:

     ```
     # systemctl stop ipsec
     # rm /var/lib/ipsec/nss/*db
     ```

  2. You can initialize a new database with the following command:

     ```
     # ipsec initnss
     ```

Procedure

1. On each node, import PKCS #12 files. This step requires the password used to generate the PKCS #12 files:

   ```
   # ipsec import nodeXXX.p12
   ```

2. Create the following three connection definitions for the **IPsec required** (private), **IPsec optional** (private-or-clear), and **No IPsec** (clear) profiles:

```
# cat /etc/ipsec.d/mesh.conf
conn clear
 auto=ondemand (1)
 type=passthrough
 authby=never
 left=%defaultroute
 right=%group

conn private
 auto=ondemand
 type=transport
 authby=rsasig
 failureshunt=drop
 negotiationshunt=drop
 ikev2=insist
 left=%defaultroute
 leftcert=nodeXXXX
 leftid=%fromcert (2)
 rightid=%fromcert
 right=%opportunisticgroup

conn private-or-clear
 auto=ondemand
 type=transport
 authby=rsasig
 failureshunt=passthrough
 negotiationshunt=passthrough
 # left
 left=%defaultroute
 leftcert=nodeXXXX (3)
 leftid=%fromcert
 leftrsasigkey=%cert
 # right
 rightrsasigkey=%cert
 rightid=%fromcert
 right=%opportunisticgroup
```

(1) The **auto** variable has several options:

You can use the **ondemand** connection option with opportunistic IPsec to initiate the IPsec connection, or for explicitly configured connections that do not need to be active all the time. This option sets up a trap XFRM policy in the kernel, enabling the IPsec connection to begin when it receives the first packet that matches that policy.

You can effectively configure and manage your IPsec connections, whether you use Opportunistic IPsec or explicitly configured connections, by using the following options:

The add option
: Loads the connection configuration and prepares it for responding to remote initiations. However, the connection is not automatically initiated from the local side. You can manually start the IPsec connection by using the command **ipsec auto --up**.

The start option

Loads the connection configuration and prepares it for responding to remote initiations. Additionally, it immediately initiates a connection to the remote peer. You can use this option for permanent and always active connections.

2 The **leftid** and **rightid** variables identify the right and the left channel of the IPsec tunnel connection. You can use these variables to obtain the value of the local IP address or the subject DN of the local certificate, if you have configured one.

3 The **leftcert** variable defines the nickname of the NSS database that you want to use.

3. Add the IP address of the network to the corresponding category. For example, if all nodes reside in the **10.15.0.0/16** network, and all nodes must use IPsec encryption:

```
# echo "10.15.0.0/16" >> /etc/ipsec.d/policies/private
```

4. To allow certain nodes, for example, **10.15.34.0/24**, to work with and without IPsec, add those nodes to the private-or-clear group:

```
# echo "10.15.34.0/24" >> /etc/ipsec.d/policies/private-or-clear
```

5. To define a host, for example, **10.15.1.2**, which is not capable of IPsec into the clear group, use:

```
# echo "10.15.1.2/32" >> /etc/ipsec.d/policies/clear
```

You can create the files in the **/etc/ipsec.d/policies** directory from a template for each new node, or you can provision them by using Puppet or Ansible.

Note that every node has the same list of exceptions or different traffic flow expectations. Two nodes, therefore, might not be able to communicate because one requires IPsec and the other cannot use IPsec.

6. Restart the node to add it to the configured mesh:

```
# systemctl restart ipsec
```

Verification

1. Open an IPsec tunnel by using the **ping** command:

```
# ping <nodeYYY>
```

2. Display the NSS database with the imported certification:

```
# certutil -L -d sql:/etc/ipsec.d

Certificate Nickname    Trust Attributes
                        SSL,S/MIME,JAR/XPI

west                     u,u,u
ca                      CT,,
```

3. See which tunnels are open on the node:

```
# ipsec trafficstatus
006 #2: "private#10.15.0.0/16"[1] ...<nodeYYY>, type=ESP, add_time=1691399301,
inBytes=512, outBytes=512, maxBytes=2^63B, id='C=US, ST=NC, O=Example
Organization, CN=east'
```

Additional resources

- **ipsec.conf(5)** man page on your system.
- For more information about the **authby** variable, see 6.2. Authentication methods in Libreswan .

4.8. DEPLOYING A FIPS-COMPLIANT IPSEC VPN

You can deploy a FIPS-compliant IPsec VPN solution with Libreswan. To do so, you can identify which cryptographic algorithms are available and which are disabled for Libreswan in FIPS mode.

Prerequisites

- The **AppStream** repository is enabled.
- Your system has been installed in FIPS mode

Procedure

1. Install the **libreswan** packages:

```
# dnf install libreswan
```

2. If you are re-installing Libreswan, remove its old NSS database:

```
# systemctl stop ipsec
# rm /var/lib/ipsec/nss/*db
```

3. Start the **ipsec** service, and enable the service to be started automatically on boot:

```
# systemctl enable ipsec --now
```

4. Configure the firewall to allow **500** and **4500** UDP ports for the IKE, ESP, and AH protocols by adding the **ipsec** service:

```
# firewall-cmd --add-service="ipsec"
# firewall-cmd --runtime-to-permanent
```

Verification

1. Confirm Libreswan is running in FIPS mode:

```
# ipsec whack --fipsstatus
000 FIPS mode enabled
```

2. Alternatively, check entries for the **ipsec** unit in the **systemd** journal:

```
$ journalctl -u ipsec
...
Jan 22 11:26:50 localhost.localdomain pluto[3076]: FIPS Mode: YES
```

3. To see the available algorithms in FIPS mode:

```
# ipsec pluto --selftest 2>&1 | head -6
Initializing NSS using read-write database "sql:/var/lib/ipsec/nss"
FIPS Mode: YES
NSS crypto library initialized
FIPS mode enabled for pluto daemon
NSS library is running in FIPS mode
FIPS HMAC integrity support [disabled]
```

4. To query disabled algorithms in FIPS mode:

```
# ipsec pluto --selftest 2>&1 | grep disabled
Encryption algorithm CAMELLIA_CTR disabled; not FIPS compliant
Encryption algorithm CAMELLIA_CBC disabled; not FIPS compliant
Encryption algorithm NULL disabled; not FIPS compliant
Encryption algorithm CHACHA20_POLY1305 disabled; not FIPS compliant
Hash algorithm MD5 disabled; not FIPS compliant
PRF algorithm HMAC_MD5 disabled; not FIPS compliant
PRF algorithm AES_XCBC disabled; not FIPS compliant
Integrity algorithm HMAC_MD5_96 disabled; not FIPS compliant
Integrity algorithm HMAC_SHA2_256_TRUNCBUG disabled; not FIPS compliant
Integrity algorithm AES_XCBC_96 disabled; not FIPS compliant
DH algorithm MODP1536 disabled; not FIPS compliant
DH algorithm DH31 disabled; not FIPS compliant
```

5. To list all allowed algorithms and ciphers in FIPS mode:

```
# ipsec pluto --selftest 2>&1 | grep ESP | grep FIPS | sed "s/^.*FIPS//"
aes_ccm, aes_ccm_c
aes_ccm_b
aes_ccm_a
NSS(CBC)  3des
NSS(GCM)  aes_gcm, aes_gcm_c
NSS(GCM)  aes_gcm_b
NSS(GCM)  aes_gcm_a
NSS(CTR)  aesctr
NSS(CBC)  aes
aes_gmac
NSS       sha, sha1, sha1_96, hmac_sha1
NSS       sha512, sha2_512, sha2_512_256, hmac_sha2_512
NSS       sha384, sha2_384, sha2_384_192, hmac_sha2_384
NSS       sha2, sha256, sha2_256, sha2_256_128, hmac_sha2_256
aes_cmac
null
NSS(MODP) null, dh0
NSS(MODP) dh14
NSS(MODP) dh15
NSS(MODP) dh16
NSS(MODP) dh17
NSS(MODP) dh18
```

```
NSS(ECP)  ecp_256, ecp256
NSS(ECP)  ecp_384, ecp384
NSS(ECP)  ecp_521, ecp521
```

Additional resources

- Using system-wide cryptographic policies .

4.9. PROTECTING THE IPSEC NSS DATABASE BY A PASSWORD

By default, the IPsec service creates its Network Security Services (NSS) database with an empty password during the first start. To enhance security, you can add password protection.

Prerequisites

- The **/var/lib/ipsec/nss/** directory contains NSS database files.

Procedure

1. Enable password protection for the **NSS** database for Libreswan:

```
# certutil -N -d sql:/var/lib/ipsec/nss
Enter Password or Pin for "NSS Certificate DB":
Enter a password which will be used to encrypt your keys.
The password should be at least 8 characters long,
and should contain at least one non-alphabetic character.

Enter new password:
```

2. Create the **/etc/ipsec.d/nsspassword** file that contains the password you have set in the previous step, for example:

```
# cat /etc/ipsec.d/nsspassword
NSS Certificate DB:<password>
```

   The **nsspassword** file use the following syntax:

```
<token_1>:<password1>
<token_2>:<password2>
```

   The default NSS software token is **NSS Certificate DB**. If your system is running in FIPS mode, the name of the token is **NSS FIPS 140-2 Certificate DB**.

3. Depending on your scenario, either start or restart the **ipsec** service after you finish the **nsspassword** file:

```
# systemctl restart ipsec
```

Verification

1. Check that the **ipsec** service is running after you have added a non-empty password to its NSS database:

```
# systemctl status ipsec
● ipsec.service - Internet Key Exchange (IKE) Protocol Daemon for IPsec
  Loaded: loaded (/usr/lib/systemd/system/ipsec.service; enabled; vendor preset: disable>
  Active: active (running)…
```

Verification

- Check that the **Journal** log contains entries that confirm a successful initialization:

```
# journalctl -u ipsec
…
pluto[6214]: Initializing NSS using read-write database "sql:/var/lib/ipsec/nss"
pluto[6214]: NSS Password from file "/etc/ipsec.d/nsspassword" for token "NSS Certificate
DB" with length 20 passed to NSS
pluto[6214]: NSS crypto library initialized
…
```

Additional resources

- **certutil(1)** man page on your system
- FIPS - Federal Information Processing Standards section on the Product compliance Red Hat Customer Portal page

4.10. CONFIGURING AN IPSEC VPN TO USE TCP

Libreswan supports TCP encapsulation of IKE and IPsec packets as described in RFC 8229. With this feature, you can establish IPsec VPNs on networks that prevent traffic transmitted via UDP and Encapsulating Security Payload (ESP). You can configure VPN servers and clients to use TCP either as a fallback or as the main VPN transport protocol. Because TCP encapsulation has bigger performance costs, use TCP as the main VPN protocol only if UDP is permanently blocked in your scenario.

Prerequisites

- A remote-access VPN is already configured.

Procedure

1. Add the following option to the **/etc/ipsec.conf** file in the **config setup** section:

```
listen-tcp=yes
```

2. To use TCP encapsulation as a fallback option when the first attempt over UDP fails, add the following two options to the client's connection definition:

```
enable-tcp=fallback
tcp-remoteport=4500
```

Alternatively, if you know that UDP is permanently blocked, use the following options in the client's connection configuration:

```
enable-tcp=yes
tcp-remoteport=4500
```

Additional resources

- IETF RFC 8229: TCP Encapsulation of IKE and IPsec Packets

4.11. CONFIGURING VPN CONNECTIONS WITH IPSEC BY USING THE RHEL SYSTEM ROLE

With the **vpn** system role, you can configure VPN connections on RHEL systems by using Red Hat Ansible Automation Platform. You can use it to set up host-to-host, network-to-network, VPN Remote Access Server, and mesh configurations.

For host-to-host connections, the role sets up a VPN tunnel between each pair of hosts in the list of **vpn_connections** using the default parameters, including generating keys as needed. Alternatively, you can configure it to create an opportunistic mesh configuration between all hosts listed. The role assumes that the names of the hosts under **hosts** are the same as the names of the hosts used in the Ansible inventory, and that you can use those names to configure the tunnels.

NOTE

The **vpn** RHEL system role currently supports only Libreswan, which is an IPsec implementation, as the VPN provider.

4.11.1. Creating a host-to-host VPN with IPsec by using the vpn RHEL system role

You can use the **vpn** system role to configure host-to-host connections by running an Ansible playbook on the control node, which configures all managed nodes listed in an inventory file.

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: Host to host VPN
  hosts: managed-node-01.example.com, managed-node-02.example.com
  roles:
    - rhel-system-roles.vpn
  vars:
    vpn_connections:
      - hosts:
          managed-node-01.example.com:
          managed-node-02.example.com:
    vpn_manage_firewall: true
    vpn_manage_selinux: true
```

This playbook configures the connection **managed-node-01.example.com-to-managed-node-**

02.example.com by using pre-shared key authentication with keys auto-generated by the system role. Because **vpn_manage_firewall** and **vpn_manage_selinux** are both set to **true**, the **vpn** role uses the **firewall** and **selinux** roles to manage the ports used by the **vpn** role.

To configure connections from managed hosts to external hosts that are not listed in the inventory file, add the following section to the **vpn_connections** list of hosts:

```
vpn_connections:
  - hosts:
      managed-node-01.example.com:
      <external_node>:
        hostname: <IP_address_or_hostname>
```

This configures one additional connection: **managed-node-01.example.com-to-*<external_node>***

NOTE

The connections are configured only on the managed nodes and not on the external node.

2. Optional: You can specify multiple VPN connections for the managed nodes by using additional sections within **vpn_connections**, for example, a control plane and a data plane:

```
- name: Multiple VPN
  hosts: managed-node-01.example.com, managed-node-02.example.com
  roles:
    - rhel-system-roles.vpn
  vars:
    vpn_connections:
      - name: control_plane_vpn
        hosts:
          managed-node-01.example.com:
            hostname: 192.0.2.0 # IP for the control plane
          managed-node-02.example.com:
            hostname: 192.0.2.1
      - name: data_plane_vpn
        hosts:
          managed-node-01.example.com:
            hostname: 10.0.0.1 # IP for the data plane
          managed-node-02.example.com:
            hostname: 10.0.0.2
```

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
```

Verification

1. On the managed nodes, confirm that the connection is successfully loaded:

```
# ipsec status | grep <connection_name>
```

Replace ***<connection_name>*** with the name of the connection from this node, for example **managed_node1-to-managed_node2**.

NOTE

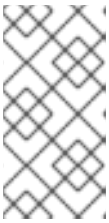
By default, the role generates a descriptive name for each connection it creates from the perspective of each system. For example, when creating a connection between **managed_node1** and **managed_node2**, the descriptive name of this connection on **managed_node1** is **managed_node1-to-managed_node2** but on **managed_node2** the connection is named **managed_node2-to-managed_node1**.

2. On the managed nodes, confirm that the connection is successfully started:

```
# ipsec trafficstatus | grep <connection_name>
```

3. Optional: If a connection does not successfully load, manually add the connection by entering the following command. This provides more specific information indicating why the connection failed to establish:

```
# ipsec auto --add <connection_name>
```



NOTE

Any errors that may occur during the process of loading and starting the connection are reported in the **/var/log/pluto.log** file. Because these logs are hard to parse, manually add the connection to obtain log messages from the standard output instead.

Additional resources

- **/usr/share/ansible/roles/rhel-system-roles.vpn/README.md** file
- **/usr/share/doc/rhel-system-roles/vpn/** directory

4.11.2. Creating an opportunistic mesh VPN connection with IPsec by using the vpn RHEL system role

You can use the **vpn** system role to configure an opportunistic mesh VPN connection that uses certificates for authentication by running an Ansible playbook on the control node, which will configure all the managed nodes listed in an inventory file.

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.
- The IPsec Network Security Services (NSS) crypto library in the **/etc/ipsec.d/** directory contains the necessary certificates.

Procedure

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

```
- name: _Mesh VPN_
  hosts: managed-node-01.example.com, managed-node-02.example.com, managed-node-03.example.com
  roles:
    - rhel-system-roles.vpn
  vars:
    vpn_connections:
      - opportunistic: true
        auth_method: cert
        policies:
          - policy: private
            cidr: default
          - policy: private-or-clear
            cidr: 198.51.100.0/24
          - policy: private
            cidr: 192.0.2.0/24
          - policy: clear
            cidr: 192.0.2.7/32
    vpn_manage_firewall: true
    vpn_manage_selinux: true
```

Authentication with certificates is configured by defining the **auth_method: cert** parameter in the playbook. By default, the node name is used as the certificate nickname. In this example, this is **managed-node-01.example.com**. You can define different certificate names by using the **cert_name** attribute in your inventory.

In this example procedure, the control node, which is the system from which you will run the Ansible playbook, shares the same classless inter-domain routing (CIDR) number as both of the managed nodes (192.0.2.0/24) and has the IP address 192.0.2.7. Therefore, the control node falls under the private policy which is automatically created for CIDR 192.0.2.0/24.

To prevent SSH connection loss during the play, a clear policy for the control node is included in the list of policies. Note that there is also an item in the policies list where the CIDR is equal to default. This is because this playbook overrides the rule from the default policy to make it private instead of private-or-clear.

Because **vpn_manage_firewall** and **vpn_manage_selinux** are both set to **true**, the **vpn** role uses the **firewall** and **selinux** roles to manage the ports used by the **vpn** role.

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
```

Additional resources

- **/usr/share/ansible/roles/rhel-system-roles.vpn/README.md** file
- **/usr/share/doc/rhel-system-roles/vpn/** directory

4.12. CONFIGURING IPSEC CONNECTIONS THAT OPT OUT OF THE SYSTEM-WIDE CRYPTO POLICIES

Overriding system-wide crypto-policies for a connection

The RHEL system-wide cryptographic policies create a special connection called **%default**. This connection contains the default values for the **ikev2**, **esp**, and **ike** options. However, you can override the default values by specifying the mentioned option in the connection configuration file.

For example, the following configuration allows connections that use IKEv1 with AES and SHA-1 or SHA-2, and IPsec (ESP) with either AES-GCM or AES-CBC:

```
conn MyExample
  ...
  ikev2=never
  ike=aes-sha2,aes-sha1;modp2048
  esp=aes_gcm,aes-sha2,aes-sha1
  ...
```

Note that AES-GCM is available for IPsec (ESP) and for IKEv2, but not for IKEv1.

Disabling system-wide crypto policies for all connections

To disable system-wide crypto policies for all IPsec connections, comment out the following line in the **/etc/ipsec.conf** file:

```
include /etc/crypto-policies/back-ends/libreswan.config
```

Then add the **ikev2=never** option to your connection configuration file.

Additional resources

- Using system-wide cryptographic policies .

4.13. TROUBLESHOOTING IPSEC VPN CONFIGURATIONS

Problems related to IPsec VPN configurations most commonly occur due to several main reasons. If you are encountering such problems, you can check if the cause of the problem corresponds to any of the following scenarios, and apply the corresponding solution.

Basic connection troubleshooting

Most problems with VPN connections occur in new deployments, where administrators configured endpoints with mismatched configuration options. Also, a working configuration can suddenly stop working, often due to newly introduced incompatible values. This could be the result of an administrator

changing the configuration. Alternatively, an administrator may have installed a firmware update or a package update with different default values for certain options, such as encryption algorithms.

To confirm that an IPsec VPN connection is established:

```
# ipsec trafficstatus
006 #8: "vpn.example.com"[1] 192.0.2.1, type=ESP, add_time=1595296930, inBytes=5999,
outBytes=3231, id='@vpn.example.com', lease=100.64.13.5/32
```

If the output is empty or does not show an entry with the connection name, the tunnel is broken.

To check that the problem is in the connection:

1. Reload the *vpn.example.com* connection:

```
# ipsec auto --add vpn.example.com
002 added connection description "vpn.example.com"
```

2. Next, initiate the VPN connection:

```
# ipsec auto --up vpn.example.com
```

Firewall-related problems

The most common problem is that a firewall on one of the IPsec endpoints or on a router between the endpoints is dropping all Internet Key Exchange (IKE) packets.

- For IKEv2, an output similar to the following example indicates a problem with a firewall:

```
# ipsec auto --up vpn.example.com
181 "vpn.example.com"[1] 192.0.2.2 #15: initiating IKEv2 IKE SA
181 "vpn.example.com"[1] 192.0.2.2 #15: STATE_PARENT_I1: sent v2I1, expected v2R1
010 "vpn.example.com"[1] 192.0.2.2 #15: STATE_PARENT_I1: retransmission; will wait 0.5
seconds for response
010 "vpn.example.com"[1] 192.0.2.2 #15: STATE_PARENT_I1: retransmission; will wait 1
seconds for response
010 "vpn.example.com"[1] 192.0.2.2 #15: STATE_PARENT_I1: retransmission; will wait 2
seconds for
...
```

- For IKEv1, the output of the initiating command looks like:

```
# ipsec auto --up vpn.example.com
002 "vpn.example.com" #9: initiating Main Mode
102 "vpn.example.com" #9: STATE_MAIN_I1: sent MI1, expecting MR1
010 "vpn.example.com" #9: STATE_MAIN_I1: retransmission; will wait 0.5 seconds for
response
010 "vpn.example.com" #9: STATE_MAIN_I1: retransmission; will wait 1 seconds for
response
010 "vpn.example.com" #9: STATE_MAIN_I1: retransmission; will wait 2 seconds for
response
...
```

Because the IKE protocol, which is used to set up IPsec, is encrypted, you can troubleshoot only a limited subset of problems using the **tcpdump** tool. If a firewall is dropping IKE or IPsec packets, you can try to

find the cause using the **tcpdump** utility. However, **tcpdump** cannot diagnose other problems with IPsec VPN connections.

- To capture the negotiation of the VPN and all encrypted data on the **eth0** interface:

```
# tcpdump -i eth0 -n -n esp or udp port 500 or udp port 4500 or tcp port 4500
```

Mismatched algorithms, protocols, and policies

VPN connections require that the endpoints have matching IKE algorithms, IPsec algorithms, and IP address ranges. If a mismatch occurs, the connection fails. If you identify a mismatch by using one of the following methods, fix it by aligning algorithms, protocols, or policies.

- If the remote endpoint is not running IKE/IPsec, you can see an ICMP packet indicating it. For example:

```
# ipsec auto --up vpn.example.com
...
000 "vpn.example.com"[1] 192.0.2.2 #16: ERROR: asynchronous network error report on
wlp2s0 (192.0.2.2:500), complainant 198.51.100.1: Connection refused [errno 111, origin
ICMP type 3 code 3 (not authenticated)]
...
```

- Example of mismatched IKE algorithms:

```
# ipsec auto --up vpn.example.com
...
003 "vpn.example.com"[1] 193.110.157.148 #3: dropping unexpected IKE_SA_INIT message
containing NO_PROPOSAL_CHOSEN notification; message payloads: N; missing payloads:
SA,KE,Ni
```

- Example of mismatched IPsec algorithms:

```
# ipsec auto --up vpn.example.com
...
182 "vpn.example.com"[1] 193.110.157.148 #5: STATE_PARENT_I2: sent v2I2, expected
v2R2 {auth=IKEv2 cipher=AES_GCM_16_256 integ=n/a prf=HMAC_SHA2_256
group=MODP2048}
002 "vpn.example.com"[1] 193.110.157.148 #6: IKE_AUTH response contained the error
notification NO_PROPOSAL_CHOSEN
```

  A mismatched IKE version could also result in the remote endpoint dropping the request without a response. This looks identical to a firewall dropping all IKE packets.

- Example of mismatched IP address ranges for IKEv2 (called Traffic Selectors - TS):

```
# ipsec auto --up vpn.example.com
...
1v2 "vpn.example.com" #1: STATE_PARENT_I2: sent v2I2, expected v2R2 {auth=IKEv2
cipher=AES_GCM_16_256 integ=n/a prf=HMAC_SHA2_512 group=MODP2048}
002 "vpn.example.com" #2: IKE_AUTH response contained the error notification
TS_UNACCEPTABLE
```

- Example of mismatched IP address ranges for IKEv1:

```
# ipsec auto --up vpn.example.com
...
031 "vpn.example.com" #2: STATE_QUICK_I1: 60 second timeout exceeded after 0
retransmits.  No acceptable response to our first Quick Mode message: perhaps peer likes
no proposal
```

- When using PreSharedKeys (PSK) in IKEv1, if both sides do not put in the same PSK, the entire IKE message becomes unreadable:

```
# ipsec auto --up vpn.example.com
...
003 "vpn.example.com" #1: received Hash Payload does not match computed value
223 "vpn.example.com" #1: sending notification INVALID_HASH_INFORMATION to
192.0.2.23:500
```

- In IKEv2, the mismatched-PSK error results in an AUTHENTICATION_FAILED message:

```
# ipsec auto --up vpn.example.com
...
002 "vpn.example.com" #1: IKE SA authentication request rejected by peer:
AUTHENTICATION_FAILED
```

Maximum transmission unit

Other than firewalls blocking IKE or IPsec packets, the most common cause of networking problems relates to an increased packet size of encrypted packets. Network hardware fragments packets larger than the maximum transmission unit (MTU), for example, 1500 bytes. Often, the fragments are lost and the packets fail to re-assemble. This leads to intermittent failures, when a ping test, which uses small-sized packets, works but other traffic fails. In this case, you can establish an SSH session but the terminal freezes as soon as you use it, for example, by entering the 'ls -al /usr' command on the remote host.

To work around the problem, reduce MTU size by adding the **mtu=1400** option to the tunnel configuration file.

Alternatively, for TCP connections, enable an iptables rule that changes the MSS value:

```
# iptables -I FORWARD -p tcp --tcp-flags SYN,RST SYN -j TCPMSS --clamp-mss-to-pmtu
```

If the previous command does not solve the problem in your scenario, directly specify a lower size in the **set-mss** parameter:

```
# iptables -I FORWARD -p tcp --tcp-flags SYN,RST SYN -j TCPMSS --set-mss 1380
```

Network address translation (NAT)

When an IPsec host also serves as a NAT router, it could accidentally remap packets. The following example configuration demonstrates the problem:

```
conn myvpn
    left=172.16.0.1
    leftsubnet=10.0.2.0/24
    right=172.16.0.2
    rightsubnet=192.168.0.0/16
…
```

The system with address 172.16.0.1 have a NAT rule:

```
iptables -t nat -I POSTROUTING -o eth0 -j MASQUERADE
```

If the system on address 10.0.2.33 sends a packet to 192.168.0.1, then the router translates the source 10.0.2.33 to 172.16.0.1 before it applies the IPsec encryption.

Then, the packet with the source address 10.0.2.33 no longer matches the **conn myvpn** configuration, and IPsec does not encrypt this packet.

To solve this problem, insert rules that exclude NAT for target IPsec subnet ranges on the router, in this example:

```
iptables -t nat -I POSTROUTING -s 10.0.2.0/24 -d 192.168.0.0/16 -j RETURN
```

Kernel IPsec subsystem bugs

The kernel IPsec subsystem might fail, for example, when a bug causes a desynchronizing of the IKE user space and the IPsec kernel. To check for such problems:

```
$ cat /proc/net/xfrm_stat
XfrmInError               0
XfrmInBufferError         0
...
```

Any non-zero value in the output of the previous command indicates a problem. If you encounter this problem, open a new support case, and attach the output of the previous command along with the corresponding IKE logs.

Libreswan logs

Libreswan logs using the **syslog** protocol by default. You can use the **journalctl** command to find log entries related to IPsec. Because the corresponding entries to the log are sent by the **pluto** IKE daemon, search for the "pluto" keyword, for example:

```
$ journalctl -b | grep pluto
```

To show a live log for the **ipsec** service:

```
$ journalctl -f -u ipsec
```

If the default level of logging does not reveal your configuration problem, enable debug logs by adding the **plutodebug=all** option to the **config setup** section in the **/etc/ipsec.conf** file.

Note that debug logging produces a lot of entries, and it is possible that either the **journald** or **syslogd** service rate-limits the **syslog** messages. To ensure you have complete logs, redirect the logging to a file. Edit the **/etc/ipsec.conf**, and add the **logfile=/var/log/pluto.log** in the **config setup** section.

Additional resources

- Troubleshooting problems by using log files
- **tcpdump(8)** and **ipsec.conf(5)** man pages on your system
- Using and configuring firewalld

4.14. CONFIGURING A VPN CONNECTION WITH CONTROL-CENTER

If you use Red Hat Enterprise Linux with a graphical interface, you can configure a VPN connection in the GNOME **control-center**.

Prerequisites

- The **NetworkManager-libreswan-gnome** package is installed.

Procedure

1. Press the **Super** key, type **Settings**, and press **Enter** to open the **control-center** application.
2. Select the **Network** entry on the left.
3. Click the **+** icon.
4. Select **VPN**.
5. Select the **Identity** menu entry to see the basic configuration options:
   General

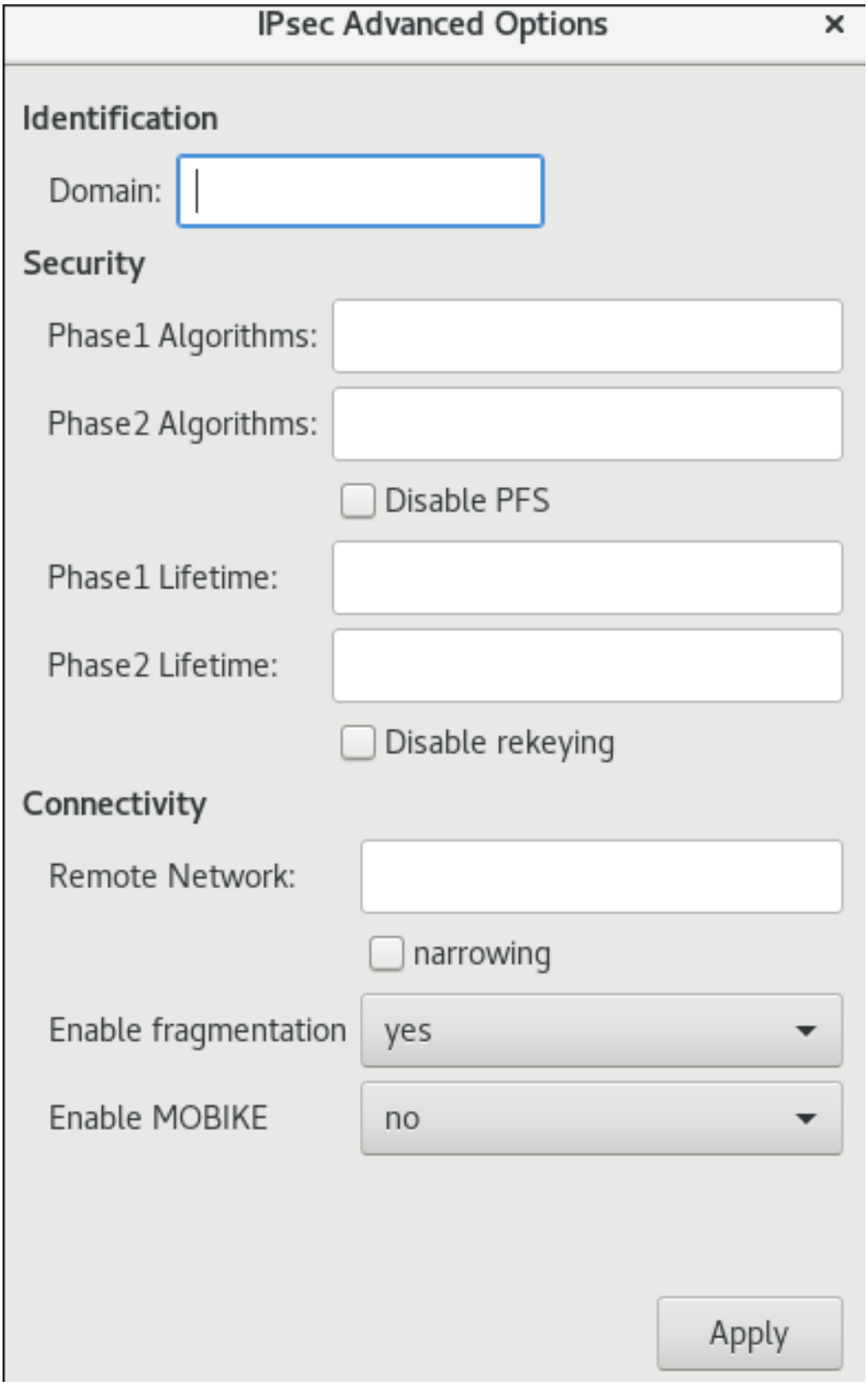
   Gateway – The name or **IP** address of the remote VPN gateway.

   Authentication

   Type

   - **IKEv2 (Certificate)**- client is authenticated by certificate. It is more secure (default).
   - **IKEv1 (XAUTH)** - client is authenticated by user name and password, or a pre-shared key (PSK).
     The following configuration settings are available under the **Advanced** section:

Figure 4.1. Advanced options of a VPN connection



WARNING

When configuring an IPsec-based VPN connection using the **gnome-control-center** application, the **Advanced** dialog displays the configuration, but it does not allow any changes. As a consequence, users cannot change any advanced IPsec options. Use the **nm-connection-editor** or **nmcli** tools instead to perform configuration of the advanced properties.

Identification

- **Domain** – If required, enter the Domain Name.
  Security
- **Phase1 Algorithms** – corresponds to the **ike** Libreswan parameter – enter the algorithms to be used to authenticate and set up an encrypted channel.
- **Phase2 Algorithms** – corresponds to the **esp** Libreswan parameter – enter the algorithms to be used for the **IPsec** negotiations.
  Check the **Disable PFS** field to turn off Perfect Forward Secrecy (PFS) to ensure compatibility with old servers that do not support PFS.
- **Phase1 Lifetime** – corresponds to the **ikelifetime** Libreswan parameter – how long the key used to encrypt the traffic will be valid.
- **Phase2 Lifetime** – corresponds to the **salifetime** Libreswan parameter – how long a particular instance of a connection should last before expiring.
  Note that the encryption key should be changed from time to time for security reasons.
- **Remote network** – corresponds to the **rightsubnet** Libreswan parameter – the destination private remote network that should be reached through the VPN.
  Check the **narrowing** field to enable narrowing. Note that it is only effective in IKEv2 negotiation.
- **Enable fragmentation** – corresponds to the **fragmentation** Libreswan parameter – whether or not to allow IKE fragmentation. Valid values are **yes** (default) or **no**.
- **Enable Mobike** – corresponds to the **mobike** Libreswan parameter – whether or not to allow Mobility and Multihoming Protocol (MOBIKE, RFC 4555) to enable a connection to migrate its endpoint without needing to restart the connection from scratch. This is used on mobile devices that switch between wired, wireless, or mobile data connections. The values are **no** (default) or **yes**.

6. Select the **IPv4** menu entry:
   IPv4 Method
   - **Automatic (DHCP)** – Choose this option if the network you are connecting to uses a **DHCP** server to assign dynamic **IP** addresses.
   - **Link-Local Only** – Choose this option if the network you are connecting to does not have a **DHCP** server and you do not want to assign **IP** addresses manually. Random addresses will be assigned as per *RFC 3927* with prefix **169.254/16**.

- **Manual** – Choose this option if you want to assign **IP** addresses manually.
- **Disable** – **IPv4** is disabled for this connection.

DNS

In the **DNS** section, when **Automatic** is **ON**, switch it to **OFF** to enter the IP address of a DNS server you want to use separating the IPs by comma.

Routes

Note that in the **Routes** section, when **Automatic** is **ON**, routes from DHCP are used, but you can also add additional static routes. When **OFF**, only static routes are used.

- **Address** – Enter the **IP** address of a remote network or host.
- **Netmask** – The netmask or prefix length of the **IP** address entered above.
- **Gateway** – The **IP** address of the gateway leading to the remote network or host entered above.
- **Metric** – A network cost, a preference value to give to this route. Lower values will be preferred over higher values.

Use this connection only for resources on its network

Select this check box to prevent the connection from becoming the default route. Selecting this option means that only traffic specifically destined for routes learned automatically over the connection or entered here manually is routed over the connection.

7. To configure **IPv6** settings in a **VPN** connection, select the **IPv6** menu entry:

IPv6 Method

- **Automatic** – Choose this option to use **IPv6** Stateless Address AutoConfiguration (SLAAC) to create an automatic, stateless configuration based on the hardware address and Router Advertisements (RA).
- **Automatic, DHCP only** – Choose this option to not use RA, but request information from **DHCPv6** directly to create a stateful configuration.
- **Link-Local Only** – Choose this option if the network you are connecting to does not have a **DHCP** server and you do not want to assign **IP** addresses manually. Random addresses will be assigned as per *RFC 4862* with prefix **FE80::0**.
- **Manual** – Choose this option if you want to assign **IP** addresses manually.
- **Disable** – **IPv6** is disabled for this connection.

Note that **DNS**, **Routes**, **Use this connection only for resources on its network** are common to **IPv4** settings.

8. Once you have finished editing the **VPN** connection, click the **Add** button to customize the configuration or the **Apply** button to save it for the existing one.
9. Switch the profile to **ON** to activate the **VPN** connection.

Additional resources

- **nm-settings-libreswan(5)** man page on your system

4.15. CONFIGURING AN IPSEC BASED VPN CONNECTION BY USING NMSTATECTL

IPsec (Internet Protocol Security) is a security protocol suite, provided by **Libreswan**, for implementation of VPN. IPsec includes protocols to initiate authentication at the time of connection establishment and manage keys during the data transfer. When an application deploys in a network and communicates by using the IP protocol, IPsec can protect data communication.

To manage an IPsec-based configuration for authenticating VPN connections, you can use the **nmstatectl** utility. This utility provides command line access to a declarative API for host network management. The following are the authentication types for the **host-to-subnet** and **host-to-host** communication modes:

- Host-to-subnet PKI authentication
- Host-to-subnet RSA authentication
- Host-to-subnet PSK authentication
- Host-to-host tunnel mode authentication
- Host-to-host transport mode authentication

4.15.1. Configuring a host-to-subnet IPSec VPN with PKI authentication and tunnel mode by using nmstatectl

If you want to use encryption based on the trusted entity authentication in IPsec, Public Key Infrastructure (PKI) provides secure communication by using cryptographic keys between two hosts. Both communicating hosts generate private and public keys where each host maintains a private key by sharing public key with the trusted entity Certificate Authority (CA). The CA generates a digital certificate after verifying the authenticity. In case of encryption and decryption, the host uses a private key for encryption and public key for decryption.

By using Nmstate, a declarative API for network management, you can configure a PKI authentication-based IPsec connection. After setting the configuration, the Nmstate API ensures that the result matches with the configuration file. If anything fails, **nmstate** automatically rolls back the changes to avoid an incorrect state of the system.

To establish encrypted communication in **host-to-subnet** configuration, remote IPsec end provides another IP to host by using parameter **dhcp: true**. In the case of defining systems for **IPsec** in nmstate, the **left**-named system is the local host while the **right**-named system is the remote host. The following procedure needs to run on both hosts.

Prerequisites

- By using a password, you have generated a PKCS #12 file that stores certificates and cryptographic keys.

Procedure

1. Install the required packages:

```
# dnf install nmstate libreswan NetworkManager-libreswan
```

2. Restart the NetworkManager service:

```
# systemctl restart NetworkManager
```

3. As **Libreswan** was already installed, remove its old database files and re-create them:

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

4. Enable and start the **ipsec** service:

```
# systemctl enable --now ipsec
```

5. Import the PKCS#12 file:

```
# ipsec import node-example.p12
```

When importing the PKCS#12 file, enter the password that was used to create the file.

6. Create a YAML file, for example **~/create-pki-authentication.yml**, with the following content:

```
---
interfaces:
- name: 'example_ipsec_conn1'                    (1)
  type: ipsec
  ipv4:
    enabled: true
    dhcp: true
  libreswan:
    ipsec-interface: 'yes'                       (2)
    left: '192.0.2.250'                          (3)
    leftid: '%fromcert'                          (4)
    leftcert: 'local-host.example.com'           (5)
    right: '192.0.2.150'                         (6)
    rightid: '%fromcert'                         (7)
    ikev2: 'insist'                              (8)
    ikelifetime: '24h'                           (9)
    salifetime: '24h'                            (10)
```

The YAML file defines the following settings:

(1) An IPsec connection name

(2) The value **yes** means **libreswan** creates an IPsec **xfrm** virtual interface **ipsec<number>** and automatically finds the next available number

(3) A static IPv4 address of public network interface for a local host

(4) On a local host, the value of **%fromcert** sets the ID to a Distinguished Name (DN) that is fetched from a loaded certificate

(5) A Distinguished Name (DN) of a local host's public key

(6) A static IPv4 address of public network interface for a remote host

7 On a remote host, the value of **%fromcert** sets the ID to a Distinguished Name (DN) that is fetched from a loaded certificate.

8 **insist** value accepts and receives only the Internet Key Exchange (IKEv2) protocol

9 The duration of IKE protocol

10 The duration of IPsec security association (SA)

7. Apply settings to the system:

```
# nmstatectl apply ~/create-pki-authentication.yml
```

Verification

1. Verify IPsec status:

```
# ip xfrm status
```

2. Verify IPsec policies:

```
# ip xfrm policy
```

Additional resources

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

4.15.2. Configuring a host-to-subnet IPSec VPN with RSA authentication and tunnel mode by using nmstatectl

If you want to use asymmetric cryptography-based key authentication in IPsec, the RSA algorithm provides secure communication by using either of private and public keys for encryption and decryption between two hosts. This method uses a private key for encryption, and a public key for decryption.

By using Nmstate, a declarative API for network management, you can configure RSA-based IPsec authentication. After setting the configuration, the Nmstate API ensures that the result matches with the configuration file. If anything fails, **nmstate** automatically rolls back the changes to avoid an incorrect state of the system.

To establish encrypted communication in **host-to-subnet** configuration, remote IPsec end provides another IP to host by using parameter **dhcp: true**. In the case of defining systems for **IPsec** in nmstate, the **left**-named system is the local host while the **right**-named system is the remote host. The following procedure needs to run on both hosts.

Procedure

1. Install the required packages:

```
# dnf install nmstate libreswan NetworkManager-libreswan
```

2. Restart the NetworkManager service:

```
# systemctl restart NetworkManager
```

3. If **Libreswan** was already installed, remove its old database files and re-create them:

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

4. Generate a RSA key pair on each host:

```
# ipsec newhostkey --output
```

5. Display the public keys:

```
# ipsec showhostkey --list
```

6. The previous step returned the generated key **ckaid**. Use that **ckaid** with the following command on left, for example:

```
# ipsec showhostkey --left --ckaid <0sAwEAAesFfVZqFzRA9F>
```

7. The output of the previous command generated the **leftrsasigkey=** line required for the configuration. Do the same on the second host (right):

```
# ipsec showhostkey --right --ckaid <0sAwEAAesFfVZqFzRA9E>
```

8. Enable the **ipsec** service to automatically start it on boot:

```
# systemctl enable --now ipsec
```

9. Create a YAML file, for example ~/**create-rsa-authentication.yml**, with the following content:

```
---
interfaces:
- name: 'example_ipsec_conn1'                    (1)
  type: ipsec                                    (2)
  ipv4:
    enabled: true
    dhcp: true
  libreswan:
    ipsec-interface: '99'                        (3)
    leftrsasigkey: '0sAwEAAesFfVZqFzRA9F'        (4)
    left: '192.0.2.250'                          (5)
    leftid: 'local-host-rsa.example.com'         (6)
    right: '192.0.2.150'                         (7)
    rightrsasigkey: '0sAwEAAesFfVZqFzRA9E'       (8)
    rightid: 'remote-host-rsa.example.com'       (9)
    ikev2: 'insist'                              (10)
```

The YAML file defines the following settings:

1. An IPsec connection name
2. An interface name
3. The value **99** means that **libreswan** creates an IPsec **xfrm** virtual interface **ipsec<number>** and automatically finds the next available number
4. The RSA public key of a local host
5. A static IPv4 address of public network interface of a local host
6. A Distinguished Name (DN) for a local host
7. The RSA public key of a remote host
8. A static IPv4 address of public network interface of a remote host
9. A Distinguished Name(DN) for a remote host
10. **insist** value accepts and receives only the Internet Key Exchange (IKEv2) protocol

10. Apply the settings to the system:

```
# nmstatectl apply ~/create-rsa-authentication.yml
```

Verification

1. Display the IP settings of the network interface:

```
# ip addr show example_ipsec_conn1
```

2. Verify IPsec status:

```
# ip xfrm status
```

3. Verify IPsec policies:

```
# ip xfrm policy
```

Additional resources

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

4.15.3. Configuring a host-to-subnet IPSec VPN with PSK authentication and tunnel mode by using nmstatectl

If you want to use encryption based on mutual authentication in IPsec, the Pre-Shared Key (PSK) method provides secure communication by using a secret key between two hosts. A file stores the secret key and the same key encrypts the data flowing through the tunnel.

By using Nmstate, a declarative API for network management, you can configure PSK-based IPsec authentication. After setting the configuration, the Nmstate API ensures that the result matches with the configuration file. If anything fails, **nmstate** automatically rolls back the changes to avoid incorrect

state of the system.

To establish encrypted communication in **host-to-subnet** configuration, remote IPsec end provides another IP to host by using parameter **dhcp: true**. In the case of defining systems for **IPsec** in nmstate, the **left**-named system is the local host while the **right**-named system is the remote host. The following procedure needs to run on both hosts.

NOTE

As this method uses static strings for authentication and encryption, use it only for testing/development purposes.

Procedure

1. Install the required packages:

```
# dnf install nmstate libreswan NetworkManager-libreswan
```

2. Restart the NetworkManager service:

```
# systemctl restart NetworkManager
```

3. If **Libreswan** was already installed, remove its old database files and re-create them:

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

4. Enable the **ipsec** service to automatically start it on boot:

```
# systemctl enable --now ipsec
```

5. Create a YAML file, for example **~/create-pks-authentication.yml**, with the following content:

```
---
interfaces:
- name: 'example_ipsec_conn1'          (1)
  type: ipsec
  ipv4:
    enabled: true
    dhcp: true
  libreswan:
    ipsec-interface: 'no'              (2)
    right: '192.0.2.250'               (3)
    rightid: 'remote-host.example.org' (4)
    left: '192.0.2.150'                (5)
    leftid: 'local-host.example.org'   (6)
    psk: "example_password"
    ikev2: 'insist'                    (7)
```

The YAML file defines the following settings:

1. An IPsec connection name
2. Setting **no** value indicates that **libreswan** creates only **xfrm** policies, and not a virtual **xfrm** interface
3. A static IPv4 address of public network interface of a remote host
4. A Distinguished Name (DN) for a remote host
5. A static IPv4 address of public network interface of a local host
6. A Distinguished Name (DN) for a local host
7. **insist** value accepts and receives only the Internet Key Exchange (IKEv2) protocol

6. Apply the settings to the system:

```
# nmstatectl apply ~/create-pks-authentication.yml
```

Verification

1. Display the IP settings of network interface:

```
# ip addr show example_ipsec_conn1
```

2. Verify IPsec status:

```
# ip xfrm status
```

3. Verify IPsec policies:

```
# ip xfrm policy
```

4.15.4. Configuring a host-to-host IPsec VPN with PKI authentication and tunnel mode by using nmstatectl

IPsec (Internet Protocol Security) is a security protocol suite to authenticate and encrypt IP communications within networks and devices. The **Libreswan** software provides an IPsec implementation for VPNs.

In tunnel mode, the source and destination IP address of communication is encrypted in the IPsec tunnel. External network sniffers can only get left IP and right IP. In general, for tunnel mode, it supports **host-to-host**, **host-to-subnet**, and **subnet-to-subnet**. In this mode, a new IP packet encapsulates an existing packet along with its payload and header. Encapsulation in this mode protects IP data, source, and destination headers over an unsecure network. This mode is useful to transfer data in **subnet-to-subnet**, remote access connections, and untrusted networks, such as open public Wi-Fi networks. By default, IPsec establishes a secure channel between two sites in tunnel mode. With the following configuration, you can establish a VPN connection as a **host-to-host** architecture.

By using Nmstate, a declarative API for network management, you can configure an IPsec VPN connection. After setting the configuration, the Nmstate API ensures that the result matches with the configuration file. If anything fails, **nmstate** automatically rolls back the changes to avoid incorrect state of the system.

In **host-to-host** configuration, you need to set **leftmodecfgclient: no** so that it can't receive network configuration from the server, hence the value **no**. In the case of defining systems for **IPsec** in nmstate, the **left**-named system is the local host while the **right**-named system is the remote host. The following procedure needs to run on both hosts.

Prerequisites

- By using a password, you have generated a PKCS #12 file that stores certificates and cryptographic keys.

Procedure

1. Install the required packages:

```
# dnf install nmstate libreswan NetworkManager-libreswan
```

2. Restart the NetworkManager service:

```
# systemctl restart NetworkManager
```

3. As **Libreswan** was already installed, remove its old database files and re-create them:

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

4. Import the PKCS#12 file:

```
# ipsec import node-example.p12
```

When importing the PKCS#12 file, enter the password that was used to generate the file.

5. Enable and start the **ipsec** service:

```
# systemctl enable --now ipsec
```

6. Create a YAML file, for example **~/create-p2p-vpn-authentication.yml**, with the following content:

```
---
interfaces:
- name: 'example_ipsec_conn1'                    (1)
  type: ipsec
  libreswan:
    left: '192.0.2.250'                          (2)
    leftid:  'local-host.example.com'            (3)
    leftcert: 'local-host.example.com'           (4)
    leftmodecfgclient: 'no'                      (5)
    right: '192.0.2.150'                         (6)
    rightid: 'remote-host.example.com'           (7)
    rightsubnet: '192.0.2.150/32'                (8)
    ikev2: 'insist'                              (9)
```

The YAML file defines the following settings:

1. An IPsec connection name
2. A static IPv4 address of public network interface for a local host
3. A distinguished Name (DN) of a local host
4. A certificate name installed on a local host
5. The value for not to retrieve client configuration from a remote host
6. A static IPv4 address of public network interface for a remote host
7. A distinguished Name (DN) of a remote host
8. The subnet range of a remote host - **192.0.2.150** with **32** IPv4 addresses
9. The value to accept and receive only the Internet Key Exchange (IKEv2) protocol

7. Apply the settings to the system:

```
# nmstatectl apply ~/create-p2p-vpn-authentication.yml
```

Verification

1. Display the created P2P policy:

```
# ip xfrm policy
```

2. Verify IPsec status:

```
# ip xfrm status
```

Additional resources

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

4.15.5. Configuring a host-to-host IPsec VPN with PSK authentication and transport mode by using nmstatectl

IPsec (Internet Protocol Security) is a security protocol suite to authenticate and encrypt IP communications within networks and devices. The **Libreswan** utility provides IPsec based implementation for VPN.

In transport mode, encryption works only for the payload of an IP packet. Also, a new IPsec header gets appended to the IP packet by keeping the original IP header as it is. Transport mode does not encrypt the source and destination IP of communication but copies them to an external IP header. Hence, encryption protects only IP data across the network. This mode is useful to transfer data in a **host-to-host** connection of a network. This mode is often used along with the GRE tunnel to save 20 bytes (IP header) of overheads. By default, the **IPsec** utility uses tunnel mode. To use transfer mode, set **type: transport** for **host-to-host** connection data transfer.

By using Nmstate, a declarative API for network management, you can configure an IPsec VPN

connection. After setting the configuration, the Nmstate API ensures that the result matches with the configuration file. If anything fails, **nmstate** automatically rolls back the changes to avoid incorrect state of the system. To override the default **tunnel** mode, specify **transport** mode.

In the case of defining systems for **IPsec** in nmstate, the **left**-named system is the local host while the **right**-named system is the remote host. The following procedure needs to run on both hosts.

Prerequisites

- By using a password, you have generated a PKCS #12 file that stores certificates and cryptographic keys.

Procedure

1. Install the required packages:

```
# dnf install nmstate libreswan NetworkManager-libreswan
```

2. Restart the NetworkManager service:

```
# systemctl restart NetworkManager
```

3. As **Libreswan** was already installed, remove its old database files and re-create them:

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

4. Import the PKCS#12 file:

```
# ipsec import node-example.p12
```

When importing the PKCS#12 file, enter the password that was used to create the file.

5. Enable and start the **ipsec** service:

```
# systemctl enable --now ipsec
```

6. Create a YAML file, for example **~/create-p2p-transport-authentication.yml**, with the following content:

```
---
interfaces:
- name: 'example_ipsec_conn1'          (1)
  type: ipsec
  libreswan:
    type: 'transport'                  (2)
    ipsec-interface: '99'              (3)
    left: '192.0.2.250'                (4)
    leftid: '%fromcert'                (5)
    leftcert: 'local-host.example.org' (6)
    right: '192.0.2.150'               (7)
    prefix-length: '32'                (8)
```

```
    rightid: '%fromcert'          9
    ikev2: 'insist'               10
    ikelifetime: '24h'            11
    salifetime: '24h'             12
```

The YAML file defines the following settings:

1. An IPsec connection name
2. An IPsec mode
3. The value **99** means that **libreswan** creates an IPsec **xfrm** virtual interface **ipsec<number>** and automatically finds the next available number
4. A static IPv4 address of public network interface for a local host
5. On a local host, the value of **%fromcert** sets the ID to a Distinguished Name (DN) which is fetched from a loaded certificate
6. A Distinguished Name (DN) of a local host's public key
7. A static IPv4 address of public network interface for a remote host
8. The subnet mask of a static IPv4 address of a local host
9. On a remote host, the value of **%fromcert** sets the ID to a Distinguished Name (DN) which is fetched from a loaded certificate
10. The value to accept and receive only the Internet Key Exchange (IKEv2) protocol
11. The duration of IKE protocol
12. The duration of IPsec security association (SA)

7. Apply the settings to the system:

```
# nmstatectl apply ~/create-p2p-transport-authentication.yml
```

Verification

1. Verify IPsec status:

```
# ip xfrm status
```

2. Verify IPsec policies:

```
# ip xfrm policy
```

Additional resources

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

4.16. ADDITIONAL RESOURCES

- **ipsec(8)**, **ipsec.conf(5)**, **ipsec.secrets(5)**, **ipsec_auto(8)**, and **ipsec_rsasigkey(8)** man pages on your system
- /**usr**/**share**/**doc**/**libreswan-*version***/ directory

CHAPTER 5. USING MACSEC TO ENCRYPT LAYER-2 TRAFFIC IN THE SAME PHYSICAL NETWORK

You can use MACsec to secure the communication between two devices (point-to-point). For example, your branch office is connected over a Metro-Ethernet connection with the central office, you can configure MACsec on the two hosts that connect the offices to increase the security.

5.1. HOW MACSEC INCREASES SECURITY

Media Access Control security (MACsec) is a layer-2 protocol that secures different traffic types over the Ethernet links, including:

- Dynamic host configuration protocol (DHCP)
- address resolution protocol (ARP)
- IPv4 and IPv6 traffic
- Any traffic over IP such as TCP or UDP

MACsec encrypts and authenticates all traffic in LANs, by default with the GCM-AES-128 algorithm, and uses a pre-shared key to establish the connection between the participant hosts. To change the pre-shared key, you must update the NM configuration on all network hosts that use MACsec.

A MACsec connection uses an Ethernet device, such as an Ethernet network card, VLAN, or tunnel device, as a parent. You can either set an IP configuration only on the MACsec device to communicate with other hosts only by using the encrypted connection, or you can also set an IP configuration on the parent device. In the latter case, you can use the parent device to communicate with other hosts using an unencrypted connection and the MACsec device for encrypted connections.

MACsec does not require any special hardware. For example, you can use any switch, except if you want to encrypt traffic only between a host and a switch. In this scenario, the switch must also support MACsec.

In other words, you can configure MACsec for two common scenarios:

- Host-to-host
- Host-to-switch and switch-to-other-hosts

IMPORTANT

You can use MACsec only between hosts being in the same physical or virtual LAN.

Additional resources

- MACsec: a different solution to encrypt network traffic

5.2. CONFIGURING A MACSEC CONNECTION BY USING NMCLI

You can use the **nmcli** utility to configure Ethernet interfaces to use MACsec. For example, you can create a MACsec connection between two hosts that are connected over Ethernet.

Procedure

1. On the first host on which you configure MACsec:
   - Create the connectivity association key (CAK) and connectivity-association key name (CKN) for the pre-shared key:
     a. Create a 16-byte hexadecimal CAK:

```
# dd if=/dev/urandom count=16 bs=1 2> /dev/null | hexdump -e '1/2 "%04x"'
50b71a8ef0bd5751ea76de6d6c98c03a
```

     b. Create a 32-byte hexadecimal CKN:

```
# dd if=/dev/urandom count=32 bs=1 2> /dev/null | hexdump -e '1/2 "%04x"'
f2b4297d39da7330910a74abc0449feb45b5c0b9fc23df1430e1898fcf1c4550
```

2. On both hosts you want to connect over a MACsec connection:
3. Create the MACsec connection:

```
# nmcli connection add type macsec con-name macsec0 ifname macsec0
connection.autoconnect yes macsec.parent enp1s0 macsec.mode psk macsec.mka-
cak 50b71a8ef0bd5751ea76de6d6c98c03a macsec.mka-ckn
f2b4297d39da7330910a74abc0449feb45b5c0b9fc23df1430e1898fcf1c4550
```

   Use the CAK and CKN generated in the previous step in the **macsec.mka-cak** and **macsec.mka-ckn** parameters. The values must be the same on every host in the MACsec-protected network.

4. Configure the IP settings on the MACsec connection.
   a. Configure the **IPv4** settings. For example, to set a static **IPv4** address, network mask, default gateway, and DNS server to the **macsec0** connection, enter:

```
# nmcli connection modify macsec0 ipv4.method manual ipv4.addresses
'192.0.2.1/24' ipv4.gateway '192.0.2.254' ipv4.dns '192.0.2.253'
```

   b. Configure the **IPv6** settings. For example, to set a static **IPv6** address, network mask, default gateway, and DNS server to the **macsec0** connection, enter:

```
# nmcli connection modify macsec0 ipv6.method manual ipv6.addresses
'2001:db8:1::1/32' ipv6.gateway '2001:db8:1::fffe' ipv6.dns '2001:db8:1::fffd'
```

5. Activate the connection:

```
# nmcli connection up macsec0
```

Verification

1. Verify that the traffic is encrypted:

```
# tcpdump -nn -i enp1s0
```

2. Optional: Display the unencrypted traffic:

```
# tcpdump -nn -i macsec0
```

3. Display MACsec statistics:

```
# ip macsec show
```

4. Display individual counters for each type of protection: integrity-only (encrypt off) and encryption (encrypt on)

```
# ip -s macsec show
```

Additional resources

- MACsec: a different solution to encrypt network traffic

5.3. CONFIGURING A MACSEC CONNECTION BY USING NMSTATECTL

You can configure Ethernet interfaces to use MACsec through the **nmstatectl** utility in a declarative way. For example, in a YAML file, you describe the desired state of your network, which is supposed to have a MACsec connection between two hosts connected over Ethernet. The **nmstatectl** utility interprets the YAML file and deploys persistent and consistent network configuration across the hosts.

Using the MACsec security standard for securing communication at the link layer, also known as layer 2 of the Open Systems Interconnection (OSI) model provides the following notable benefits:

- Encryption at layer 2 eliminates the need for encrypting individual services at layer 7. This reduces the overhead associated with managing a large number of certificates for each endpoint on each host.
- Point-to-point security between directly connected network devices such as routers and switches.
- No changes needed for applications and higher-layer protocols.

Prerequisites

- A physical or virtual Ethernet Network Interface Controller (NIC) exists in the server configuration.
- The **nmstate** package is installed.

Procedure

1. On the first host on which you configure MACsec, create the connectivity association key (CAK) and connectivity-association key name (CKN) for the pre-shared key:
   a. Create a 16-byte hexadecimal CAK:

```
# dd if=/dev/urandom count=16 bs=1 2> /dev/null | hexdump -e '1/2 "%04x"'
50b71a8ef0bd5751ea76de6d6c98c03a
```

   b. Create a 32-byte hexadecimal CKN:

```
# dd if=/dev/urandom count=32 bs=1 2> /dev/null | hexdump -e '1/2 "%04x"'
f2b4297d39da7330910a74abc0449feb45b5c0b9fc23df1430e1898fcf1c4550
```

2. On both hosts that you want to connect over a MACsec connection, complete the following steps:

   a. Create a YAML file, for example **create-macsec-connection.yml**, with the following settings:

```
---
routes:
  config:
  - destination: 0.0.0.0/0
    next-hop-interface: macsec0
    next-hop-address: 192.0.2.2
    table-id: 254
  - destination: 192.0.2.2/32
    next-hop-interface: macsec0
    next-hop-address: 0.0.0.0
    table-id: 254
dns-resolver:
  config:
    search:
    - example.com
    server:
    - 192.0.2.200
    - 2001:db8:1::ffbb
interfaces:
- name: macsec0
  type: macsec
  state: up
  ipv4:
    enabled: true
    address:
    - ip: 192.0.2.1
      prefix-length: 32
  ipv6:
    enabled: true
    address:
    - ip: 2001:db8:1::1
      prefix-length: 64
  macsec:
    encrypt: true
    base-iface: enp0s1
    mka-cak: 50b71a8ef0bd5751ea76de6d6c98c03a
    mka-ckn: f2b4297d39da7330910a74abc0449feb45b5c0b9fc23df1430e1898fcf1c4550
    port: 0
    validation: strict
    send-sci: true
```

   b. Use the CAK and CKN generated in the previous step in the **mka-cak** and **mka-ckn** parameters. The values must be the same on every host in the MACsec-protected network.

   c. Optional: In the same YAML configuration file, you can also configure the following settings:

      - A static IPv4 address - **192.0.2.1** with the /**32** subnet mask

- A static IPv6 address - **2001:db8:1::1** with the **/64** subnet mask
- An IPv4 default gateway - **192.0.2.2**
- An IPv4 DNS server - **192.0.2.200**
- An IPv6 DNS server - **2001:db8:1::ffbb**
- A DNS search domain - **example.com**

3. Apply the settings to the system:

```
# nmstatectl apply create-macsec-connection.yml
```

Verification

1. Display the current state in YAML format:

```
# nmstatectl show macsec0
```

2. Verify that the traffic is encrypted:

```
# tcpdump -nn -i enp0s1
```

3. Optional: Display the unencrypted traffic:

```
# tcpdump -nn -i macsec0
```

4. Display MACsec statistics:

```
# ip macsec show
```

5. Display individual counters for each type of protection: integrity-only (encrypt off) and encryption (encrypt on)

```
# ip -s macsec show
```

Additional resources

- MACsec: a different solution to encrypt network traffic

CHAPTER 6. SECURING NETWORK SERVICES

Red Hat Enterprise Linux supports many different types of network servers. Their network services can expose the system security to risks of various types of attacks, such as denial of service attacks (DoS), distributed denial of service attacks (DDoS), script vulnerability attacks, and buffer overflow attacks.

To increase the system security against attacks, it is important to monitor active network services that you use. For example, when a network service is running on a machine, its daemon listens for connections on network ports, and this can reduce the security. To limit exposure to attacks over the network, all services that are unused should be turned off.

6.1. SECURING THE RPCBIND SERVICE

The **rpcbind** service is a dynamic port-assignment daemon for remote procedure calls (RPC) services such as Network Information Service (NIS) and Network File System (NFS). Because it has weak authentication mechanisms and can assign a wide range of ports for the services it controls, it is important to secure **rpcbind**.

You can secure **rpcbind** by restricting access to all networks and defining specific exceptions using firewall rules on the server.

NOTE

- The **rpcbind** service is required on **NFSv3** servers.
- The **rpcbind** service is not required on **NFSv4**.

Prerequisites

- The **rpcbind** package is installed.
- The **firewalld** package is installed and the service is running.

Procedure

1. Add firewall rules, for example:
   - Limit TCP connection and accept packages only from the **192.168.0.0/24** host via the **111** port:

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

   - Limit TCP connection and accept packages only from local host via the **111** port:

     ```
     # firewall-cmd --add-rich-rule='rule family="ipv4" port port="111" protocol="tcp" source address="127.0.0.1" accept'
     ```

   - Limit UDP connection and accept packages only from the **192.168.0.0/24** host via the **111** port:

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

To make the firewall settings permanent, use the **--permanent** option when adding firewall rules.

2. Reload the firewall to apply the new rules:

```
# firewall-cmd --reload
```

Verification

- List the firewall rules:

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

Additional resources

- For more information about **NFSv4-only** servers, see Configuring an NFSv4-only server
- Using and configuring firewalld

6.2. SECURING THE RPC.MOUNTD SERVICE

The **rpc.mountd** daemon implements the server side of the NFS mount protocol. The NFS mount protocol is used by NFS version 3 (RFC 1813).

You can secure the **rpc.mountd** service by adding firewall rules to the server. You can restrict access to all networks and define specific exceptions using firewall rules.

Prerequisites

- The **rpc.mountd** package is installed.
- The **firewalld** package is installed and the service is running.

Procedure

1. Add firewall rules to the server, for example:
   - Accept **mountd** connections from the **192.168.0.0/24** host:

```
# firewall-cmd --add-rich-rule 'rule family="ipv4" service name="mountd" source
address="192.168.0.0/24" invert="True" drop'
```

   - Accept **mountd** connections from the local host:

```
# firewall-cmd --permanent --add-rich-rule 'rule family="ipv4" source address="127.0.0.1"
service name="mountd" accept'
```

     To make the firewall settings permanent, use the **--permanent** option when adding firewall rules.

2. Reload the firewall to apply the new rules:

```
# firewall-cmd --reload
```

Verification

- List the firewall rules:

```
# firewall-cmd --list-rich-rule
rule family="ipv4" service name="mountd" source address="192.168.0.0/24" invert="True"
drop
rule family="ipv4" source address="127.0.0.1" service name="mountd" accept
```

Additional resources

- Using and configuring firewalld

6.3. SECURING THE NFS SERVICE

You can secure Network File System version 4 (NFSv4) by authenticating and encrypting all file system operations using Kerberos. When using NFSv4 with Network Address Translation (NAT) or a firewall, you can turn off the delegations by modifying the **/etc/default/nfs** file. Delegation is a technique by which the server delegates the management of a file to a client. In contrast, NFSv3 do not use Kerberos for locking and mounting files.

The NFS service sends the traffic using TCP in all versions of NFS. The service supports Kerberos user and group authentication, as part of the **RPCSEC_GSS** kernel module.

NFS allows remote hosts to mount file systems over a network and interact with those file systems as if they are mounted locally. You can merge the resources on centralized servers and additionally customize NFS mount options in the **/etc/nfsmount.conf** file when sharing the file systems.

6.3.1. Export options for securing an NFS server

The NFS server determines a list structure of directories and hosts about which file systems to export to which hosts in the **/etc/exports** file.

You can use the following export options on the **/etc/exports** file:

ro

Exports the NFS volume as read-only.

rw

Allows read and write requests on the NFS volume. Use this option cautiously because allowing write access increases the risk of attacks. If your scenario requires mounting the directories with the **rw** option, make sure they are not writable for all users to reduce possible risks.

root_squash

Maps requests from **uid/gid** 0 to the anonymous **uid/gid**. This does not apply to any other **uids** or **gids** that might be equally sensitive, such as the **bin** user or the **staff** group.

no_root_squash

Turns off root squashing. By default, NFS shares change the **root** user to the **nobody** user, which is an unprivileged user account. This changes the owner of all the **root** created files to **nobody**, which prevents the uploading of programs with the **setuid** bit set. When using the **no_root_squash** option,

remote root users can change any file on the shared file system and leave applications infected by trojans for other users.

secure

Restricts exports to reserved ports. By default, the server allows client communication only through reserved ports. However, it is easy for anyone to become a **root** user on a client on many networks, so it is rarely safe for the server to assume that communication through a reserved port is privileged. Therefore the restriction to reserved ports is of limited value; it is better to rely on Kerberos, firewalls, and restriction of exports to particular clients.

WARNING

Extra spaces in the syntax of the **/etc/exports** file can lead to major changes in the configuration.

In the following example, the **/tmp/nfs/** directory is shared with the **bob.example.com** host and has read and write permissions.

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

The following example is the same as the previous one but shares the same directory to the **bob.example.com** host with read-only permissions and shares it to the *world* with read and write permissions due to a single space character after the hostname.

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

You can check the shared directories on your system by entering the **showmount -e *<hostname>*** command.

Additionally, consider the following best practices when exporting an NFS server:

- Exporting home directories is a risk because some applications store passwords in plain text or in a weakly encrypted format. You can reduce the risk by reviewing and improving the application code.
- Some users do not set passwords on SSH keys which again leads to risks with home directories. You can reduce these risks by enforcing the use of passwords or using Kerberos.
- Restrict the NFS exports only to required clients. Use the **showmount -e** command on the NFS server to review what the server is exporting. Do not export anything that is not specifically required.
- Do not allow unnecessary users to log in to a server to reduce the risk of attacks. You can periodically check who and what can access the server.

WARNING

Export an entire file system because exporting a subdirectory of a file system is not secure. An attacker might access the unexported part of a partially-exported file system.

Additional resources

- Using automount in IdM when using RHEL Identity Management
- **exports(5)** and **nfs(5)** man pages on your system

6.3.2. Mount options for securing an NFS client

You can pass the following options to the **mount** command to increase the security of NFS-based clients:

nosuid

Use the **nosuid** option to disable the **set-user-identifier** or **set-group-identifier** bits. This prevents remote users from gaining higher privileges by running a **setuid** program and you can use this option opposite to **setuid** option.

noexec

Use the **noexec** option to disable all executable files on the client. Use this to prevent users from accidentally executing files placed in the shared file system.

nodev

Use the **nodev** option to prevent the client's processing of device files as a hardware device.

resvport

Use the **resvport** option to restrict communication to a reserved port and you can use a privileged source port to communicate with the server. The reserved ports are reserved for privileged users and processes such as the **root** user.

sec

Use the **sec** option on the NFS server to choose the RPCGSS security flavor for accessing files on the mount point. Valid security flavors are **none**, **sys**, **krb5**, **krb5i**, and **krb5p**.

IMPORTANT

The MIT Kerberos libraries provided by the **krb5-libs** package do not support the Data Encryption Standard (DES) algorithm in new deployments. DES is deprecated and disabled by default in Kerberos libraries because of security and compatibility reasons. Use newer and more secure algorithms instead of DES, unless your environment requires DES for compatibility reasons.

Additional resources

- Frequently-used NFS mount options

6.3.3. Securing NFS with firewall

To secure the firewall on an NFS server, keep only the required ports open. Do not use the NFS connection port numbers for any other service.

Prerequisites

- The **nfs-utils** package is installed.
- The **firewalld** package is installed and running.

Procedure

- On NFSv4, the firewall must open TCP port **2049**.
- On NFSv3, open four additional ports with **2049**:
  1. **rpcbind** service assigns the NFS ports dynamically, which might cause problems when creating firewall rules. To simplify this process, use the **/etc/nfs.conf** file to specify which ports to use:
     a. Set TCP and UDP port for **mountd** (**rpc.mountd**) in the ` **section in `port=*<value>*** format.
     b. Set TCP and UDP port for **statd** (**rpc.statd**) in the ` **section in `port=*<value>*** format.
  2. Set the TCP and UDP port for the NFS lock manager (**nlockmgr**) in the **/etc/nfs.conf** file:
     a. Set TCP port for **nlockmgr** (**rpc.statd**) in the ` **section in `port=value** format. Alternatively, you can use the **nlm_tcpport** option in the **/etc/modprobe.d/lockd.conf** file.
     b. Set UDP port for **nlockmgr** (**rpc.statd**) in the ` **section in `udp-port=value** format. Alternatively, you can use the **nlm_udpport** option in the **/etc/modprobe.d/lockd.conf** file.

Verification

- List the active ports and RPC programs on the NFS server:

```
$ rpcinfo -p
```

6.4. SECURING THE FTP SERVICE

You can use the File Transfer Protocol (FTP) to transfer files over a network. Because all FTP transactions with the server, including user authentication, are unencrypted, make sure it is configured securely.

Red Hat Enterprise Linux provides two FTP servers:

Red Hat Content Accelerator (tux)

A kernel-space web server with FTP capabilities.

Very Secure FTP Daemon (vsftpd)

A standalone, security-oriented implementation of the FTP service.

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

6.4.1. Securing the FTP greeting banner

When a user connects to the FTP service, FTP shows a greeting banner, which by default includes version information. Attackers might use this information to identify weaknesses in the system. You can hide this information by changing the default banner.

You can define a custom banner by editing the **/etc/banners/ftp.msg** file to either directly include a single-line message, or to refer to a separate file, which can contain a multi-line message.

Procedure

- To define a single line message, add the following option to the **/etc/vsftpd/vsftpd.conf** file:

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

- To define a message in a separate file:
  - Create a **.msg** file which contains the banner message, for example **/etc/banners/*ftp*.msg**:

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

    To simplify the management of multiple banners, place all banners into the **/etc/banners/** directory.

  - Add the path to the banner file to the **banner_file** option in the **/etc/vsftpd/vsftpd.conf** file:

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

Verification

- Display the modified banner:

```
$ ftp localhost
Trying ::1…
Connected to localhost (::1).
Hello, all activity on ftp.example.com is logged.
```

6.4.2. Preventing anonymous access and uploads in FTP

By default, installing the **vsftpd** package creates the **/var/ftp/** directory and a directory tree for anonymous users with read-only permissions on the directories. Because anonymous users can access the data, do not store sensitive data in these directories.

To increase the security of the system, you can configure the FTP server to allow anonymous users to upload files to a specific directory and prevent anonymous users from reading data. In the following procedure, the anonymous user must be able to upload files in the directory owned by the **root** user but not change it.

Procedure

- Create a write-only directory in the **/var/ftp/pub/** directory:

```
# mkdir /var/ftp/pub/upload
# chmod 730 /var/ftp/pub/upload
```

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

- Add the following lines to the **/etc/vsftpd/vsftpd.conf** file:

```
anon_upload_enable=YES
anonymous_enable=YES
```

- Optional: If your system has SELinux enabled and enforcing, enable SELinux boolean attributes **allow_ftpd_anon_write** and **allow_ftpd_full_access**.

WARNING

Allowing anonymous users to read and write in directories might lead to the server becoming a repository for stolen software.

6.4.3. Securing user accounts for FTP

FTP transmits usernames and passwords unencrypted over insecure networks for authentication. You can improve the security of FTP by denying system users access to the server from their user accounts.

Perform as many of the following steps as applicable for your configuration.

Procedure

- Disable all user accounts in the **vsftpd** server, by adding the following line to the **/etc/vsftpd/vsftpd.conf** file:

```
local_enable=NO
```

- Disable FTP access for specific accounts or specific groups of accounts, such as the **root** user and users with **sudo** privileges, by adding the usernames to the **/etc/pam.d/vsftpd** PAM configuration file.
- Disable user accounts, by adding the usernames to the **/etc/vsftpd/ftpusers** file.

6.4.4. Additional resources

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

6.5. SECURING HTTP SERVERS

6.5.1. Security enhancements in httpd.conf

You can enhance the security of the Apache HTTP server by configuring security options in the **/etc/httpd/conf/httpd.conf** file.

Always verify that all scripts running on the system work correctly before putting them into production.

Ensure that only the **root** user has write permissions to any directory containing scripts or Common Gateway Interfaces (CGI). To change the directory ownership to **root** with write permissions, enter the following commands:

```
# chown root <directory_name>
# chmod 755 <directory_name>
```

In the **/etc/httpd/conf/httpd.conf** file, you can configure the following options:

FollowSymLinks

This directive is enabled by default and follows symbolic links in the directory.

Indexes

This directive is enabled by default. Disable this directive to prevent visitors from browsing files on the server.

UserDir

This directive is disabled by default because it can confirm the presence of a user account on the system. To activate user directory browsing for all user directories other than **/root/**, use the **UserDir enabled** and **UserDir disabled** root directives. To add users to the list of disabled accounts, add a space-delimited list of users on the **UserDir disabled** line.

ServerTokens

This directive controls the server response header field which is sent back to clients. You can use the following parameters to customize the information:

ServerTokens Full

Provides all available information such as web server version number, server operating system details, installed Apache modules, for example:

```
Apache/2.4.37 (Red Hat Enterprise Linux) MyMod/1.2
```

ServerTokens Full-Release

Provides all available information with release versions, for example:

```
Apache/2.4.37 (Red Hat Enterprise Linux) (Release 41.module+el8.5.0+11772+c8e0c271)
```

ServerTokens Prod / ServerTokens ProductOnly

Provides the web server name, for example:

```
Apache
```

ServerTokens Major

Provides the web server major release version, for example:

```
Apache/2
```

ServerTokens Minor

Provides the web server minor release version, for example:

```
Apache/2.4
```

ServerTokens Min / ServerTokens Minimal

Provides the web server minimal release version, for example:

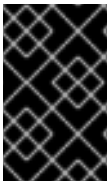
```
Apache/2.4.37
```

ServerTokens OS

Provides the web server release version and operating system, for example:

```
Apache/2.4.37 (Red Hat Enterprise Linux)
```

Use the **ServerTokens Prod** option to reduce the risk of attackers gaining any valuable information about your system.



IMPORTANT

Do not remove the **IncludesNoExec** directive. By default, the Server Side Includes (SSI) module cannot execute commands. Changing this can allow an attacker to enter commands on the system.

Removing httpd modules

You can remove the **httpd** modules to limit the functionality of the HTTP server. To do so, edit configuration files in the **/etc/httpd/conf.modules.d/** or **/etc/httpd/conf.d/** directory. For example, to remove the proxy module:

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

Additional resources

- The Apache HTTP server
- Customizing the SELinux policy for the Apache HTTP server

6.5.2. Securing the Nginx server configuration

Nginx is a high-performance HTTP and proxy server. You can harden your Nginx configuration with the following configuration options.

Procedure

- To disable version strings, modify the **server_tokens** configuration option:

  ```
  server_tokens off;
  ```

  This option stops displaying additional details such as server version number. This configuration displays only the server name in all requests served by Nginx, for example:

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

- Add extra security headers that mitigate certain known web application vulnerabilities in specific /**etc**/**nginx**/ conf files:
  - For example, the **X-Frame-Options** header option denies any page outside of your domain to frame any content served by Nginx, mitigating clickjacking attacks:

    ```
    add_header X-Frame-Options "SAMEORIGIN";
    ```

  - For example, the **x-content-type** header prevents MIME-type sniffing in certain older browsers:

    ```
    add_header X-Content-Type-Options nosniff;
    ```

  - For example, the **X-XSS-Protection** header enables Cross-Site Scripting (XSS) filtering, which prevents browsers from rendering potentially malicious content included in a response by Nginx:

    ```
    add_header X-XSS-Protection "1; mode=block";
    ```

- You can limit the services exposed to the public and limit what they do and accept from the visitors, for example:

  ```
  limit_except GET {
     allow 192.168.1.0/32;
     deny  all;
  }
  ```

  The snippet will limit access to all methods except **GET** and **HEAD**.

- You can disable HTTP methods, for example:

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

- You can configure SSL to protect the data served by your Nginx web server, consider serving it over HTTPS only. Furthermore, you can generate a secure configuration profile for enabling SSL in your Nginx server using the Mozilla SSL Configuration Generator. The generated configuration ensures that known vulnerable protocols (for example, SSLv2 and SSLv3), ciphers, and hashing algorithms (for example, 3DES and MD5) are disabled. You can also use the SSL Server Test to verify that your configuration meets modern security requirements.

Additional resources

- Mozilla SSL Configuration Generator
- SSL Server Test

6.6. SECURING POSTGRESQL BY LIMITING ACCESS TO AUTHENTICATED LOCAL USERS

PostgreSQL is an object-relational database management system (DBMS). In Red Hat Enterprise Linux, PostgreSQL is provided by the **postgresql-server** package.

You can reduce the risks of attacks by configuring client authentication. The **pg_hba.conf** configuration file stored in the database cluster's data directory controls the client authentication. Follow the procedure to configure PostgreSQL for host-based authentication.

Procedure

1. Install PostgreSQL:

```
# dnf install postgresql-server
```

2. Initialize a database storage area using one of the following options:

   a. Using the **initdb** utility:

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

   The **initdb** command with the **-D** option creates the directory you specify if it does not already exist, for example */**home**/**postgresql**/**db1**/*. This directory then contains all the data stored in the database and also the client authentication configuration file.

   b. Using the **postgresql-setup** script:

```
$ postgresql-setup --initdb
```

   By default, the script uses the /**var**/**lib**/**pgsql**/**data**/ directory. This script helps system administrators with basic database cluster administration.

3. To allow any authenticated local users to access any database with their usernames, modify the following line in the **pg_hba.conf** file:

```
local   all             all                                     trust
```

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

4. Restart the database to apply the changes:

```
# systemctl restart postgresql
```

   The previous command updates the database and also verifies the syntax of the configuration file.

6.7. SECURING THE MEMCACHED SERVICE

Memcached is an open source, high-performance, distributed memory object caching system. It can improve the performance of dynamic web applications by lowering database load.

Memcached is an in-memory key-value store for small chunks of arbitrary data, such as strings and objects, from results of database calls, API calls, or page rendering. Memcached allows assigning memory from underutilized areas to applications that require more memory.

In 2018, vulnerabilities of DDoS amplification attacks by exploiting Memcached servers exposed to the public internet were discovered. These attacks took advantage of Memcached communication using the UDP protocol for transport. The attack was effective because of the high amplification ratio where a request with the size of a few hundred bytes could generate a response of a few megabytes or even hundreds of megabytes in size.

In most situations, the **memcached** service does not need to be exposed to the public Internet. Such exposure may have its own security problems, allowing remote attackers to leak or modify information stored in Memcached.

6.7.1. Hardening Memcached against DDoS

To mitigate security risks, perform as many of the following steps as applicable for your configuration.

Procedure

- Configure a firewall in your LAN. If your Memcached server should be accessible only in your local network, do not route external traffic to ports used by the **memcached** service. For example, remove the default port **11211** from the list of allowed ports:

```
# firewall-cmd --remove-port=11211/udp
# firewall-cmd --runtime-to-permanent
```

- If you use a single Memcached server on the same machine as your application, set up **memcached** to listen to localhost traffic only. Modify the **OPTIONS** value in the **/etc/sysconfig/memcached** file:

```
OPTIONS="-l 127.0.0.1,::1"
```

- Enable Simple Authentication and Security Layer (SASL) authentication:

  1. Modify or add the **/etc/sasl2/memcached.conf** file:

```
sasldb_path: /path.to/memcached.sasldb
```

  2. Add an account in the SASL database:

```
# saslpasswd2 -a memcached -c cacheuser -f /path.to/memcached.sasldb
```

  3. Ensure that the database is accessible for the **memcached** user and group:

```
# chown memcached:memcached /path.to/memcached.sasldb
```

  4. Enable SASL support in Memcached by adding the **-S** value to the **OPTIONS** parameter in the **/etc/sysconfig/memcached** file:

```
OPTIONS="-S"
```

  5. Restart the Memcached server to apply the changes:

```
# systemctl restart memcached
```

6. Add the username and password created in the SASL database to the Memcached client configuration of your application.

- Encrypt communication between Memcached clients and servers with TLS:

1. Enable encrypted communication between Memcached clients and servers with TLS by adding the **-Z** value to the **OPTIONS** parameter in the **/etc/sysconfig/memcached** file:

```
OPTIONS="-Z"
```

2. Add the certificate chain file path in the PEM format using the **-o ssl_chain_cert** option.

3. Add a private key file path using the **-o ssl_key** option.

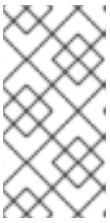
6.8. SECURING THE POSTFIX SERVICE

Postfix is a mail transfer agent (MTA) that uses the Simple Mail Transfer Protocol (SMTP) to deliver electronic messages between other MTAs and to email clients or delivery agents. Although MTAs can encrypt traffic between one another, they might not do so by default. You can also mitigate risks to various attacks by changing setting to more secure values.

6.8.1. Reducing Postfix network-related security risks

To reduce the risk of attackers invading your system through the network, perform as many of the following tasks as possible.

- Do not share the **/var/spool/postfix/** mail spool directory on a Network File System (NFS) shared volume. NFSv2 and NFSv3 do not maintain control over user and group IDs. Therefore, if two or more users have the same UID, they can receive and read each other's mail, which is a security risk.



NOTE

This rule does not apply to NFSv4 using Kerberos, because the **SECRPC_GSS** kernel module does not use UID-based authentication. However, to reduce the security risks, you should not put the mail spool directory on NFS shared volumes.

- To reduce the probability of Postfix server exploits, mail users must access the Postfix server using an email program. Do not allow shell accounts on the mail server, and set all user shells in the **/etc/passwd** file to **/sbin/nologin** (with the possible exception of the **root** user).

- To protect Postfix from a network attack, it is set up to only listen to the local loopback address by default. You can verify this by viewing the **inet_interfaces = localhost** line in the **/etc/postfix/main.cf** file. This ensures that Postfix only accepts mail messages (such as **cron** job reports) from the local system and not from the network. This is the default setting and protects Postfix from a network attack. To remove the localhost restriction and allow Postfix to listen on all interfaces, set the **inet_interfaces** parameter to **all** in **/etc/postfix/main.cf**.

6.8.2. Postfix configuration options for limiting DoS attacks

An attacker can flood the server with traffic, or send information that triggers a crash, causing a denial of service (DoS) attack. You can configure your system to reduce the risk of such attacks by setting limits in the **/etc/postfix/main.cf** file. You can change the value of the existing directives or you can add new

directives with custom values in the ***<directive> = <value>*** format.

Use the following list of directives for limiting a DoS attack:

smtpd_client_connection_rate_limit

Limits the maximum number of connection attempts any client can make to this service per time unit. The default value is **0**, which means a client can make as many connections per time unit as Postfix can accept. By default, the directive excludes clients in trusted networks.

anvil_rate_time_unit

Defines a time unit to calculate the rate limit. The default value is **60** seconds.

smtpd_client_event_limit_exceptions

Excludes clients from the connection and rate limit commands. By default, the directive excludes clients in trusted networks.

smtpd_client_message_rate_limit

Defines the maximum number of message deliveries from client to request per time unit (regardless of whether or not Postfix actually accepts those messages).

default_process_limit

Defines the default maximum number of Postfix child processes that provide a given service. You can ignore this rule for specific services in the **master.cf** file. By default, the value is **100**.

queue_minfree

Defines the minimum amount of free space required to receive mail in the queue file system. The directive is currently used by the Postfix SMTP server to decide if it accepts any mail at all. By default, the Postfix SMTP server rejects **MAIL FROM** commands when the amount of free space is less than 1.5 times the **message_size_limit**. To specify a higher minimum free space limit, specify a **queue_minfree** value that is at least 1.5 times the **message_size_limit**. By default, the **queue_minfree** value is **0**.

header_size_limit

Defines the maximum amount of memory in bytes for storing a message header. If a header is large, it discards the excess header. By default, the value is **102400** bytes.

message_size_limit

Defines the maximum size of a message including the envelope information in bytes. By default, the value is **10240000** bytes.

6.8.3. Configuring Postfix to use SASL

Postfix supports Simple Authentication and Security Layer (SASL) based SMTP Authentication (AUTH). SMTP AUTH is an extension of the Simple Mail Transfer Protocol. Currently, the Postfix SMTP server supports the SASL implementations in the following ways:

Dovecot SASL

The Postfix SMTP server can communicate with the Dovecot SASL implementation using either a UNIX-domain socket or a TCP socket. Use this method if Postfix and Dovecot applications are running on separate machines.

Cyrus SASL

When enabled, SMTP clients must authenticate with the SMTP server using an authentication method supported and accepted by both the server and the client.

Prerequisites

- The **dovecot** package is installed on the system

Procedure

1. Set up Dovecot:

   a. Include the following lines in the **/etc/dovecot/conf.d/10-master.conf** file:

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

   The previous example uses UNIX-domain sockets for communication between Postfix and Dovecot. The example also assumes default Postfix SMTP server settings, which include the mail queue located in the **/var/spool/postfix/** directory, and the application running under the **postfix** user and group.

   b. Optional: Set up Dovecot to listen for Postfix authentication requests through TCP:

   ```
   service auth {
     inet_listener {
         port = port-number
     }
   }
   ```

   c. Specify the method that the email client uses to authenticate with Dovecot by editing the **auth_mechanisms** parameter in **/etc/dovecot/conf.d/10-auth.conf** file:

   ```
   auth_mechanisms = plain login
   ```

   The **auth_mechanisms** parameter supports different plaintext and non-plaintext authentication methods.

2. Set up Postfix by modifying the **/etc/postfix/main.cf** file:

   a. Enable SMTP Authentication on the Postfix SMTP server:

   ```
   smtpd_sasl_auth_enable = yes
   ```

   b. Enable the use of Dovecot SASL implementation for SMTP Authentication:

   ```
   smtpd_sasl_type = dovecot
   ```

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

   ```
   smtpd_sasl_path = private/auth
   ```

   This step uses UNIX-domain sockets for communication between Postfix and Dovecot.

To configure Postfix to look for Dovecot on a different machine in case you use TCP sockets for communication, use configuration values similar to the following:

```
smtpd_sasl_path = inet: ip-address : port-number
```

In the previous example, replace the *ip-address* with the IP address of the Dovecot machine and *port-number* with the port number specified in Dovecot's **/etc/dovecot/conf.d/10-master.conf** file.

d. Specify SASL mechanisms that the Postfix SMTP server makes available to clients. Note that you can specify different mechanisms for encrypted and unencrypted sessions.

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

The previous directives specify that during unencrypted sessions, no anonymous authentication is allowed and no mechanisms that transmit unencrypted user names or passwords are allowed. For encrypted sessions that use TLS, only non-anonymous authentication mechanisms are allowed.

Additional resources

- Postfix SMTP server policy - SASL mechanism properties
- Postfix and Dovecot SASL
- Configuring SASL authentication in the Postfix SMTP server