# Red Hat Enterprise Linux 8

## Securing networks

Configuring secured networks and network communication

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## 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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# 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.

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

- 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 **ChallengeResponseAuthentication** 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. CACHING YOUR SSH CREDENTIALS BY USING SSH-AGENT

To avoid entering a passphrase each time you initiate an SSH connection, you can use the **ssh-agent** utility to cache the private SSH key for a login session. If the agent is running and your keys are unlocked, you can log in to SSH servers by using these keys but without having to enter the key's password again. The private key and the passphrase remain secure.

### Prerequisites

- You have a remote host with the SSH daemon running and reachable through the network.
- You know the IP address or hostname and credentials to log in to the remote host.
- You have generated an SSH key pair with a passphrase and transferred the public key to the remote machine.

See the Generating SSH key pairs section for details.

### Procedure

1. Add the command for automatically starting **ssh-agent** in your session to the **~/.bashrc** file:
    a. Open **~/.bashrc** in a text editor of your choice, for example:

    ```
    $ vi ~/.bashrc
    ```

    b. Add the following line to the file:

    ```
    eval $(ssh-agent)
    ```

    c. Save the changes, and quit the editor.
2. Add the following line to the **~/.ssh/config** file:

    ```
    AddKeysToAgent yes
    ```

    With this option and **ssh-agent** started in your session, the agent prompts for a password only for the first time when you connect to a host.

### Verification

- Log in to a host which uses the corresponding public key of the cached private key in the agent, for example:

    ```
    $ ssh <example.user>@<ssh-server@example.com>
    ```

    Note that you did not have to enter the passphrase.

## 1.5. 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

## 1.6. 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.

### No root login

If your particular use case does not require the possibility of logging in as the root user, you can set the **PermitRootLogin** configuration directive to **no** in the **/etc/ssh/sshd_config** file. By disabling the possibility of logging in as the root user, the administrator can audit which users run what privileged commands after they log in as regular users and then gain root rights.
Alternatively, set **PermitRootLogin** to **prohibit-password**:

```
PermitRootLogin prohibit-password
```

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.

### 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/05-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, uncomment the line with the **CRYPTO_POLICY=** variable in the **/etc/sysconfig/sshd** file. After this change, values that you specify in the **Ciphers**, **MACs**, **KexAlgoritms**, and **GSSAPIKexAlgorithms** sections in the **/etc/ssh/sshd_config** file are not overridden.
See the **sshd_config(5)** man page for more information.

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

- For a given user, override the global **ssh_config** with a user-specific configuration in the **~/.ssh/config** file.

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

### 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)

## 1.7. 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

## 1.8. CONFIGURING SECURE COMMUNICATION WITH THE SSH SYSTEM ROLES

As an administrator, you can use the **sshd** system role to configure SSH servers and the **ssh** system role to configure SSH clients consistently on any number of RHEL systems at the same time by using Red Hat Ansible Automation Platform.

### 1.8.1. 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

### 1.8.2. 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: redhat.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 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
...
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

### 1.8.3. 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

### 1.8.4. 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: redhat.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

## 1.8.5. 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: redhat.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: redhat.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

- **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)** man page on your system

## 1.9. 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 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 Chapter 3, *Using shared system certificates* 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 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 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 the Creating a private CA by using OpenSSL section for more information.
- You have a file containing a CSR. You can find an example of creating the CSR in the Section 2.3, “Creating a private key and a CSR for a TLS server certificate using OpenSSL” section.

### 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> -CAcreateserial -
   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 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:

  ```
  $ yum 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 Chapter 3, *Using shared system certificates* 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 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 the Using a private CA to issue certificates for CSRs with GnuTLS section 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 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 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 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. USING SHARED SYSTEM CERTIFICATES

The shared system certificates storage enables NSS, GnuTLS, OpenSSL, and Java to share a default source for retrieving system certificate anchors and block-list information. By default, the truststore contains the Mozilla CA list, including positive and negative trust. The system allows updating the core Mozilla CA list or choosing another certificate list.

## 3.1. THE SYSTEM-WIDE TRUSTSTORE

In RHEL, the consolidated system-wide truststore is located in the **/etc/pki/ca-trust/** and **/usr/share/pki/ca-trust-source/** directories. The trust settings in **/usr/share/pki/ca-trust-source/** are processed with lower priority than settings in **/etc/pki/ca-trust/**.

Certificate files are treated depending on the subdirectory they are installed to. For example, trust anchors belong to the **/usr/share/pki/ca-trust-source/anchors/** or **/etc/pki/ca-trust/source/anchors/** directory.

NOTE

In a hierarchical cryptographic system, a trust anchor is an authoritative entity that other parties consider trustworthy. In the X.509 architecture, a root certificate is a trust anchor from which a chain of trust is derived. To enable chain validation, the trusting party must have access to the trust anchor first.

### Additional resources

- **update-ca-trust(8)** and **trust(1)** man pages on your system

## 3.2. ADDING NEW CERTIFICATES

To acknowledge applications on your system with a new source of trust, add the corresponding certificate to the system-wide store, and use the **update-ca-trust** command.

### Prerequisites

- The **ca-certificates** package is present on the system.

### Procedure

1. To add a certificate in the simple PEM or DER file formats to the list of CAs trusted on the system, copy the certificate file to the **/usr/share/pki/ca-trust-source/anchors/** or **/etc/pki/ca-trust/source/anchors/** directory, for example:

```
# cp ~/certificate-trust-examples/Cert-trust-test-ca.pem /usr/share/pki/ca-trust-source/anchors/
```

2. To update the system-wide trust store configuration, use the **update-ca-trust** command:

```
# update-ca-trust extract
```

NOTE

Even though the Firefox browser can use an added certificate without a prior execution of **update-ca-trust**, enter the **update-ca-trust** command after every CA change. Also note that browsers, such as Firefox, Chromium, and GNOME Web cache files, and you might have to clear your browser's cache or restart your browser to load the current system certificate configuration.

**Additional resources**

- **update-ca-trust(8)** and **trust(1)** man pages on your system

## 3.3. MANAGING TRUSTED SYSTEM CERTIFICATES

The **trust** command provides a convenient way for managing certificates in the shared system-wide truststore.

- To list, extract, add, remove, or change trust anchors, use the **trust** command. To see the built-in help for this command, enter it without any arguments or with the **--help** directive:

```
$ trust
usage: trust command <args>...

Common trust commands are:
  list             List trust or certificates
  extract          Extract certificates and trust
  extract-compat   Extract trust compatibility bundles
  anchor           Add, remove, change trust anchors
  dump             Dump trust objects in internal format

See 'trust <command> --help' for more information
```

- To list all system trust anchors and certificates, use the **trust list** command:

```
$ trust list
pkcs11:id=%d2%87%b4%e3%df%37%27%93%55%f6%56%ea%81%e5%36%cc%8c%1e%3
f%bd;type=cert
    type: certificate
    label: ACCVRAIZ1
    trust: anchor
    category: authority

pkcs11:id=%a6%b3%e1%2b%2b%49%b6%d7%73%a1%aa%94%f5%01%e7%73%65%4c%
ac%50;type=cert
    type: certificate
    label: ACEDICOM Root
    trust: anchor
    category: authority
...
```

- To store a trust anchor into the system-wide truststore, use the **trust anchor** sub-command and specify a path to a certificate. Replace *<path.to/certificate.crt>* by a path to your certificate and its file name:

```
# trust anchor <path.to/certificate.crt>
```

▪

- To remove a certificate, use either a path to a certificate or an ID of a certificate:

```
# trust anchor --remove <path.to/certificate.crt>
# trust anchor --remove "pkcs11:id=<%AA%BB%CC%DD%EE>;type=cert"
```

### Additional resources

- All sub-commands of the **trust** commands offer a detailed built-in help, for example:

```
$ trust list --help
usage: trust list --filter=<what>

  --filter=<what>     filter of what to export
                        ca-anchors        certificate anchors
...
  --purpose=<usage>   limit to certificates usable for the purpose
                        server-auth       for authenticating servers
...
```

### Additional resources

- **update-ca-trust(8)** and **trust(1)** man pages on your system

# CHAPTER 4. 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.

## 4.1. 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 8, enabled only in the **LEGACY** system-wide cryptographic policy profile. |
| TLS 1.1 | Use for interoperability purposes where needed. Does not support modern cipher suites. In RHEL 8, enabled only in the **LEGACY** policy. |
| 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

## 4.2. SECURITY CONSIDERATIONS FOR TLS IN RHEL 8

In RHEL 8, cryptography-related considerations are significantly simplified thanks to the system-wide crypto policies. The **DEFAULT** crypto policy allows only TLS 1.2 and 1.3. To allow your system to negotiate connections using the earlier versions of TLS, you need to either opt out from following crypto policies in an application or switch to the **LEGACY** policy with the **update-crypto-policies** command. See Using system-wide cryptographic policies for more information.

The default settings provided by libraries included in RHEL 8 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 8 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:

### 4.2.1. Protocols

The latest version of TLS provides the best security mechanism. Unless you have a compelling reason to include support for older versions of TLS, allow your systems to negotiate connections using at least TLS version 1.2.

Note that even though RHEL 8 supports TLS version 1.3, not all features of this protocol are fully supported by RHEL 8 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.

### 4.2.2. 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).

### 4.2.3. 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**

- System-wide crypto policies in RHEL 8
- **update-crypto-policies(8)** man page on your system

## 4.3. 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.

### 4.3.1. Configuring the Apache HTTP server to use TLS

The **Apache HTTP Server** can use both **OpenSSL** and **NSS** libraries for its TLS needs. RHEL 8 provides the **mod_ssl** functionality through eponymous packages:

```
# yum install mod_ssl
```

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

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 different types of servers document for more information.

### 4.3.2. 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 different types of servers document for more information.

### 4.3.3. 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 different types of servers on RHEL 8
- **config(5)** and **ciphers(1)** man pages.
- Recommendations for Secure Use of Transport Layer Security (TLS) and Datagram Transport Layer Security (DTLS).
- Mozilla SSL Configuration Generator.
- SSL Server Test.

# CHAPTER 5. 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.

## 5.1. 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.

## 5.2. 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 setting the **require-id-on-certificate=no** connection 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-1 and 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.

## 5.3. 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:

```
# yum install libreswan
```

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

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

## 5.4. 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
   ```

8. If you use this host in a network with DHCP or Stateless Address Autoconfiguration (SLAAC), the connection can be vulnerable to being redirected. For details and mitigation steps, see Assigning a VPN connection to a dedicated routing table to prevent the connection from bypassing the tunnel.

## 5.5. 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
```

3. If you use this host in a network with DHCP or Stateless Address Autoconfiguration (SLAAC), the connection can be vulnerable to being redirected. For details and mitigation steps, see Assigning a VPN connection to a dedicated routing table to prevent the connection from bypassing the tunnel.

## 5.6. 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
```

NOTE

If you use this host in a network with DHCP or Stateless Address Autoconfiguration (SLAAC), the connection can be vulnerable to being redirected. For details and mitigation steps, see Assigning a VPN connection to a dedicated routing table to prevent the connection from bypassing the tunnel.

## 5.7. 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 /etc/ipsec.d/*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
```

7. If you use this host in a network with DHCP or Stateless Address Autoconfiguration (SLAAC), the connection can be vulnerable to being redirected. For details and mitigation steps, see Assigning a VPN connection to a dedicated routing table to prevent the connection from bypassing the tunnel.

### 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 Authentication methods in Libreswan.

## 5.8. 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.

### Procedure

1. Install the **libreswan** packages:

```
# yum install libreswan
```

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

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

5. Switch the system to FIPS mode:

```
# fips-mode-setup --enable
```

6. Restart your system to allow the kernel to switch to FIPS mode:

```
# reboot
```

## 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 Product: YES
Jan 22 11:26:50 localhost.localdomain pluto[3076]: FIPS Kernel: YES
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 -11
FIPS Product: YES
FIPS Kernel: YES
FIPS Mode: YES
NSS DB directory: sql:/etc/ipsec.d
Initializing NSS
Opening NSS database "sql:/etc/ipsec.d" read-only
NSS initialized
NSS crypto library initialized
FIPS HMAC integrity support [enabled]
FIPS mode enabled for pluto daemon
NSS library is running in FIPS mode
FIPS HMAC integrity verification self-test passed
```

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 SERPENT_CBC disabled; not FIPS compliant
Encryption algorithm TWOFISH_CBC disabled; not FIPS compliant
Encryption algorithm TWOFISH_SSH 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 MODP1024 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//"
{256,192,*128}  aes_ccm, aes_ccm_c
{256,192,*128}  aes_ccm_b
{256,192,*128}  aes_ccm_a
[*192]  3des
{256,192,*128}  aes_gcm, aes_gcm_c
{256,192,*128}  aes_gcm_b
{256,192,*128}  aes_gcm_a
{256,192,*128}  aesctr
{256,192,*128}  aes
{256,192,*128}  aes_gmac
sha, sha1, sha1_96, hmac_sha1
sha512, sha2_512, sha2_512_256, hmac_sha2_512
sha384, sha2_384, sha2_384_192, hmac_sha2_384
sha2, sha256, sha2_256, sha2_256_128, hmac_sha2_256
aes_cmac
null
null, dh0
dh14
dh15
dh16
dh17
dh18
ecp_256, ecp256
ecp_384, ecp384
ecp_521, ecp521
```

**Additional resources**

- Using system-wide cryptographic policies

## 5.9. 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.

NOTE

In the previous releases of RHEL up to version 6.6, you had to protect the IPsec NSS database with a password to meet the FIPS 140-2 requirements because the NSS cryptographic libraries were certified for the FIPS 140-2 Level 2 standard. In RHEL 8, NIST certified NSS to Level 1 of this standard, and this status does not require password protection for the database.

### Prerequisites

- The **/etc/ipsec.d/** directory contains NSS database files.

### Procedure

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

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

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

```
# journalctl -u ipsec
...
pluto[6214]: Initializing NSS using read-write database "sql:/etc/ipsec.d"
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 140-2 and FIPS 140-3 in the Compliance Activities and Government Standards Knowledgebase article.

## 5.10. 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

## 5.11. CONFIGURING AUTOMATIC DETECTION AND USAGE OF ESP HARDWARE OFFLOAD TO ACCELERATE AN IPSEC CONNECTION

Offloading Encapsulating Security Payload (ESP) to the hardware accelerates IPsec connections over Ethernet. By default, Libreswan detects if hardware supports this feature and, as a result, enables ESP hardware offload. In case that the feature was disabled or explicitly enabled, you can switch back to automatic detection.

**Prerequisites**

- The network card supports ESP hardware offload.
- The network driver supports ESP hardware offload.
- The IPsec connection is configured and works.

**Procedure**

1. Edit the Libreswan configuration file in the **/etc/ipsec.d/** directory of the connection that should use automatic detection of ESP hardware offload support.
2. Ensure the **nic-offload** parameter is not set in the connection's settings.
3. If you removed **nic-offload**, restart the **ipsec** service:

```
# systemctl restart ipsec
```

**Verification**

1. Display the **tx_ipsec** and **rx_ipsec** counters of the Ethernet device the IPsec connection uses:

```
# ethtool -S enp1s0 | grep -E "_ipsec"
     tx_ipsec: 10
     rx_ipsec: 10
```

2. Send traffic through the IPsec tunnel. For example, ping a remote IP address:

```
# ping -c 5 remote_ip_address
```

3. Display the **tx_ipsec** and **rx_ipsec** counters of the Ethernet device again:

```
# ethtool -S enp1s0 | grep -E "_ipsec"
     tx_ipsec: 15
     rx_ipsec: 15
```

If the counter values have increased, ESP hardware offload works.

**Additional resources**

- Configuring a VPN with IPsec

## 5.12. CONFIGURING ESP HARDWARE OFFLOAD ON A BOND TO ACCELERATE AN IPSEC CONNECTION

Offloading Encapsulating Security Payload (ESP) to the hardware accelerates IPsec connections. If you use a network bond for fail-over reasons, the requirements and the procedure to configure ESP hardware offload are different from those using a regular Ethernet device. For example, in this scenario, you enable the offload support on the bond, and the kernel applies the settings to the ports of the bond.

### Prerequisites

- All network cards in the bond support ESP hardware offload. Use the **ethtool -k *<interface_name>* | grep "esp-hw-offload"** command to verify whether each bond port supports this feature.
- The bond is configured and works.
- The bond uses the **active-backup** mode. The bonding driver does not support any other modes for this feature.
- The IPsec connection is configured and works.

### Procedure

1. Enable ESP hardware offload support on the network bond:

   ```
   # nmcli connection modify bond0 ethtool.feature-esp-hw-offload on
   ```

   This command enables ESP hardware offload support on the **bond0** connection.

2. Reactivate the **bond0** connection:

   ```
   # nmcli connection up bond0
   ```

3. Edit the Libreswan configuration file in the **/etc/ipsec.d/** directory of the connection that should use ESP hardware offload, and append the **nic-offload=yes** statement to the connection entry:

   ```
   conn example
       ...
       nic-offload=yes
   ```

4. Restart the **ipsec** service:

   ```
   # systemctl restart ipsec
   ```

## Verification

The verification methods depend on various aspects, such as the kernel version and driver. For example, certain drivers provide counters, but their names can vary. See the documentation of your network driver for details.

The following verification steps work for the **ixgbe** driver on Red Hat Enterprise Linux 8:

1. Display the active port of the bond:

   ```
   # grep "Currently Active Slave" /proc/net/bonding/bond0
   Currently Active Slave: enp1s0
   ```

2. Display the **tx_ipsec** and **rx_ipsec** counters of the active port:

```
# ethtool -S enp1s0 | grep -E "_ipsec"
    tx_ipsec: 10
    rx_ipsec: 10
```

3. Send traffic through the IPsec tunnel. For example, ping a remote IP address:

```
# ping -c 5 remote_ip_address
```

4. Display the **tx_ipsec** and **rx_ipsec** counters of the active port again:

```
# ethtool -S enp1s0 | grep -E "_ipsec"
    tx_ipsec: 15
    rx_ipsec: 15
```

If the counter values have increased, ESP hardware offload works.

**Additional resources**

- Configuring a network bond
- Setting up an IPsec VPN

## 5.13. CONFIGURING VPN CONNECTIONS BY USING RHEL SYSTEM ROLES

A VPN is an encrypted connection to securely transmit traffic over untrusted networks. By using the **vpn** RHEL system role, you can automate the process of creating VPN configurations.

**NOTE**

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

### 5.13.1. Creating a host-to-host IPsec VPN with PSK authentication by using the vpn RHEL system role

You can use IPsec to directly connect hosts to each other through a VPN. The hosts can use a pre-shared key (PSK) to authenticate to each other. By using the **vpn** RHEL system role, you can automate the process of creating IPsec host-to-host connections with PSK authentication.

By default, the role creates a tunnel-based VPN.

**Prerequisites**

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

**Procedure**

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

```
---
- name: Configuring VPN
  hosts: managed-node-01.example.com, managed-node-02.example.com
  tasks:
    - name: IPsec VPN with PSK authentication
      ansible.builtin.include_role:
        name: redhat.rhel_system_roles.vpn
      vars:
        vpn_connections:
          - hosts:
              managed-node-01.example.com:
              managed-node-02.example.com:
            auth_method: psk
            auto: start
        vpn_manage_firewall: true
        vpn_manage_selinux: true
```

The settings specified in the example playbook include the following:

**hosts: *<list>***

Defines a YAML dictionary with the hosts between which you want to configure a VPN. If an entry is not an Ansible managed node, you must specify its fully-qualified domain name (FQDN) or IP address in the **hostname** parameter, for example:

```
        ...
        - hosts:
            ...
            external-host.example.com:
              hostname: 192.0.2.1
```

The role configures the VPN connection on each managed node. The connections are named ***<host_A>*-to-*<host_B>***, for example, **managed-node-01.example.com-to-managed-node-02.example.com**. Note that the role can not configure Libreswan on external (unmanaged) nodes. You must manually create the configuration on these hosts.

**auth_method: psk**

Enables PSK authentication between the hosts. The role uses **openssl** on the control node to create the PSK.

**auto: *<start-up_method>***

Specifies the start-up method of the connection. Valid values are **add**, **ondemand**, **start**, and **ignore**. For details, see the **ipsec.conf(5)** man page on a system with Libreswan installed. The default value of this variable is null, which means no automatic startup operation.

**vpn_manage_firewall: true**

Defines that the role opens the required ports in the **firewalld** service on the managed nodes.

**vpn_manage_selinux: true**

Defines that the role sets the required SELinux port type on the IPsec ports.

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

2. Validate the playbook syntax:

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

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

3. Run the playbook:

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

### Verification

- Confirm that the connections are successfully started, for example:

```
# ansible managed-node-01.example.com -m shell -a 'ipsec trafficstatus | grep
"managed-node-01.example.com-to-managed-node-02.example.com"'
...
006 #3: "managed-node-01.example.com-to-managed-node-02.example.com", type=ESP,
add_time=1741857153, inBytes=38622, outBytes=324626, maxBytes=2^63B,
id='@managed-node-02.example.com'
```

Note that this command only succeeds if the VPN connection is active. If you set the **auto** variable in the playbook to a value other than **start**, you might need to manually activate the connection on the managed nodes first.

### Additional resources

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

## 5.13.2. Creating a host-to-host IPsec VPN with PSK authentication and separate data and control planes by using the vpn RHEL system role

You can use IPsec to directly connect hosts to each other through a VPN. For example, to enhance the security by minimizing the risk of control messages being intercepted or disrupted, you can configure separate connections for both the data traffic and the control traffic. By using the **vpn** RHEL system role, you can automate the process of creating IPsec host-to-host connections with a separate data and control plane and PSK authentication.

### Prerequisites

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

### Procedure

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

```
---
- name: Configuring VPN
  hosts: managed-node-01.example.com, managed-node-02.example.com
```

```
tasks:
  - name: IPsec VPN with PSK authentication
    ansible.builtin.include_role:
      name: redhat.rhel_system_roles.vpn
    vars:
      vpn_connections:
        - name: control_plane_vpn
          hosts:
            managed-node-01.example.com:
              hostname: 203.0.113.1  # IP address for the control plane
            managed-node-02.example.com:
              hostname: 198.51.100.2 # IP address for the control plane
          auth_method: psk
          auto: start
        - name: data_plane_vpn
          hosts:
            managed-node-01.example.com:
              hostname: 10.0.0.1   # IP address for the data plane
            managed-node-02.example.com:
              hostname: 172.16.0.2 # IP address for the data plane
          auth_method: psk
          auto: start
      vpn_manage_firewall: true
      vpn_manage_selinux: true
```

The settings specified in the example playbook include the following:

**hosts: *<list>***

Defines a YAML dictionary with the hosts between which you want to configure a VPN. The connections are named ***<name>*-*<IP_address_A>*-to-*<IP_address_B>***, for example **control_plane_vpn-203.0.113.1-to-198.51.100.2**.
The role configures the VPN connection on each managed node. Note that the role can not configure Libreswan on external (unmanaged) nodes. You must manually create the configuration on these hosts.

**auth_method: psk**

Enables PSK authentication between the hosts. The role uses **openssl** on the control node to create the pre-shared key.

**auto: *<start-up_method>***

Specifies the start-up method of the connection. Valid values are **add**, **ondemand**, **start**, and **ignore**. For details, see the **ipsec.conf(5)** man page on a system with Libreswan installed. The default value of this variable is null, which means no automatic startup operation.

**vpn_manage_firewall: true**

Defines that the role opens the required ports in the **firewalld** service on the managed nodes.

**vpn_manage_selinux: true**

Defines that the role sets the required SELinux port type on the IPsec ports.

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

2. Validate the playbook syntax:

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

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

3. Run the playbook:

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

### Verification

- Confirm that the connections are successfully started, for example:

```
# ansible managed-node-01.example.com -m shell -a 'ipsec trafficstatus | grep
"control_plane_vpn-203.0.113.1-to-198.51.100.2"'
...
006 #3: "control_plane_vpn-203.0.113.1-to-198.51.100.2", type=ESP,
add_time=1741860073, inBytes=0, outBytes=0, maxBytes=2^63B, id='198.51.100.2'
```

Note that this command only succeeds if the VPN connection is active. If you set the **auto** variable in the playbook to a value other than **start**, you might need to manually activate the connection on the managed nodes first.

### Additional resources

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

## 5.13.3. Creating an IPsec mesh VPN among multiple hosts with certificate-based authentication by using the vpn RHEL system role

Libreswan supports creating an opportunistic mesh to establish IPsec connections among a large number of hosts with a single configuration on each host. Adding hosts to the mesh does not require updating the configuration on existing hosts. For enhanced security, use certificate-based authentication in Libreswan.

By using the **vpn** RHEL system role, you can automate configuring a VPN mesh with certificate-based authentication among managed nodes.

### 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.
- You prepared a PKCS #12 file for each managed node:
  - Each file contains:
    - The certificate authority (CA) certificate
    - The node's private key

    - The node’s client certificate
  - The files are named ***<managed_node_name_as_in_the_inventory>*.p12**.
  - The files are stored in the same directory as the playbook.

**Procedure**

1. Edit the **~/inventory** file, and append the **cert_name** variable:

   ```
   managed-node-01.example.com cert_name=managed-node-01.example.com
   managed-node-02.example.com cert_name=managed-node-02.example.com
   managed-node-03.example.com cert_name=managed-node-03.example.com
   ```

   Set the **cert_name** variable to the value of the common name (CN) field used in the certificate for each host. Typically, the CN field is set to the fully-qualified domain name (FQDN).

2. Store your sensitive variables in an encrypted file:

   a. Create the vault:

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

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

      ```
      pkcs12_pwd: <password>
      ```

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

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

   ```
   - name: Configuring VPN
     hosts: managed-node-01.example.com, managed-node-02.example.com, managed-node-
   03.example.com
     vars_files:
       - ~/vault.yml
     tasks:
       - name: Install LibreSwan
         ansible.builtin.package:
           name: libreswan
           state: present

       - name: Identify the path to IPsec NSS database
         ansible.builtin.set_fact:
           nss_db_dir: "{{ '/etc/ipsec.d/' if
             ansible_distribution in ['CentOS', 'RedHat']
             and ansible_distribution_major_version is version('8', '=')
             else '/var/lib/ipsec/nss/' }}"

       - name: Locate IPsec NSS database files
         ansible.builtin.find:
           paths: "{{ nss_db_dir }}"
   ```

```
      patterns: "*.db"
    register: db_files

  - name: Remove IPsec NSS database files
    ansible.builtin.file:
      path: "{{ item.path }}"
      state: absent
    loop: "{{ db_files.files }}"
    when: db_files.matched > 0

  - name: Initialize IPsec NSS database
    ansible.builtin.command:
      cmd: ipsec initnss

  - name: Copy PKCS #12 file to the managed node
    ansible.builtin.copy:
      src: "~/{{ inventory_hostname }}.p12"
      dest: "/etc/ipsec.d/{{ inventory_hostname }}.p12"
      mode: 0600

  - name: Import PKCS #12 file in IPsec NSS database
    ansible.builtin.shell:
      cmd: 'pk12util -d {{ nss_db_dir }} -i /etc/ipsec.d/{{ inventory_hostname }}.p12 -W "{{
pkcs12_pwd }}"'

  - name: Remove PKCS #12 file
    ansible.builtin.file:
      path: "/etc/ipsec.d/{{ inventory_hostname }}.p12"
      state: absent

  - name: Opportunistic mesh IPsec VPN with certificate-based authentication
    ansible.builtin.include_role:
      name: redhat.rhel_system_roles.vpn
    vars:
      vpn_connections:
        - opportunistic: true
          auth_method: cert
          policies:
            - policy: private
              cidr: default
            - policy: private
              cidr: 192.0.2.0/24
            - policy: clear
              cidr: 192.0.2.1/32
      vpn_manage_firewall: true
      vpn_manage_selinux: true
```

The settings specified in the example playbook include the following:

**opportunistic: true**

Enables an opportunistic mesh among multiple hosts. The **policies** variable defines for which subnets and hosts traffic must or or can be encrypted and which of them should continue using clear text connections.

**auth_method: cert**

Enables certificate-based authentication. This requires that you specified the nickname of each managed node's certificate in the inventory.

**policies: *<list_of_policies>***

Defines the Libreswan policies in YAML list format.
The default policy is **private-or-clear**. To change it to **private**, the above playbook contains an according policy for the default **cidr** entry.

To prevent a loss of the SSH connection during the execution of the playbook if the Ansible control node is in the same IP subnet as the managed nodes, add a **clear** policy for the control node's IP address. For example, if the mesh should be configured for the **192.0.2.0/24** subnet and the control node uses the IP address **192.0.2.1**, you require a **clear** policy for **192.0.2.1/32** as shown in the playbook.

For details about policies, see the **ipsec.conf(5)** man page on a system with Libreswan installed.

**vpn_manage_firewall: true**

Defines that the role opens the required ports in the **firewalld** service on the managed nodes.

**vpn_manage_selinux: true**

Defines that the role sets the required SELinux port type on the IPsec ports.

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

4. Validate the playbook syntax:

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

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

5. Run the playbook:

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

## Verification

1. On a node in the mesh, ping another node to activate the connection:

```
[root@managed-node-01]# ping managed-node-02.example.com
```

2. Confirm that the connections is active:

```
[root@managed-node-01]# ipsec trafficstatus
006 #2: "private#192.0.2.0/24"[1] ...192.0.2.2, type=ESP, add_time=1741938929,
inBytes=372408, outBytes=545728, maxBytes=2^63B, id='CN=managed-node-
02.example.com'
```

## Additional resources

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

- **/usr/share/doc/rhel-system-roles/vpn/** directory

## 5.14. 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

## 5.15. 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.
- Using and configuring firewalld

## 5.16. 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

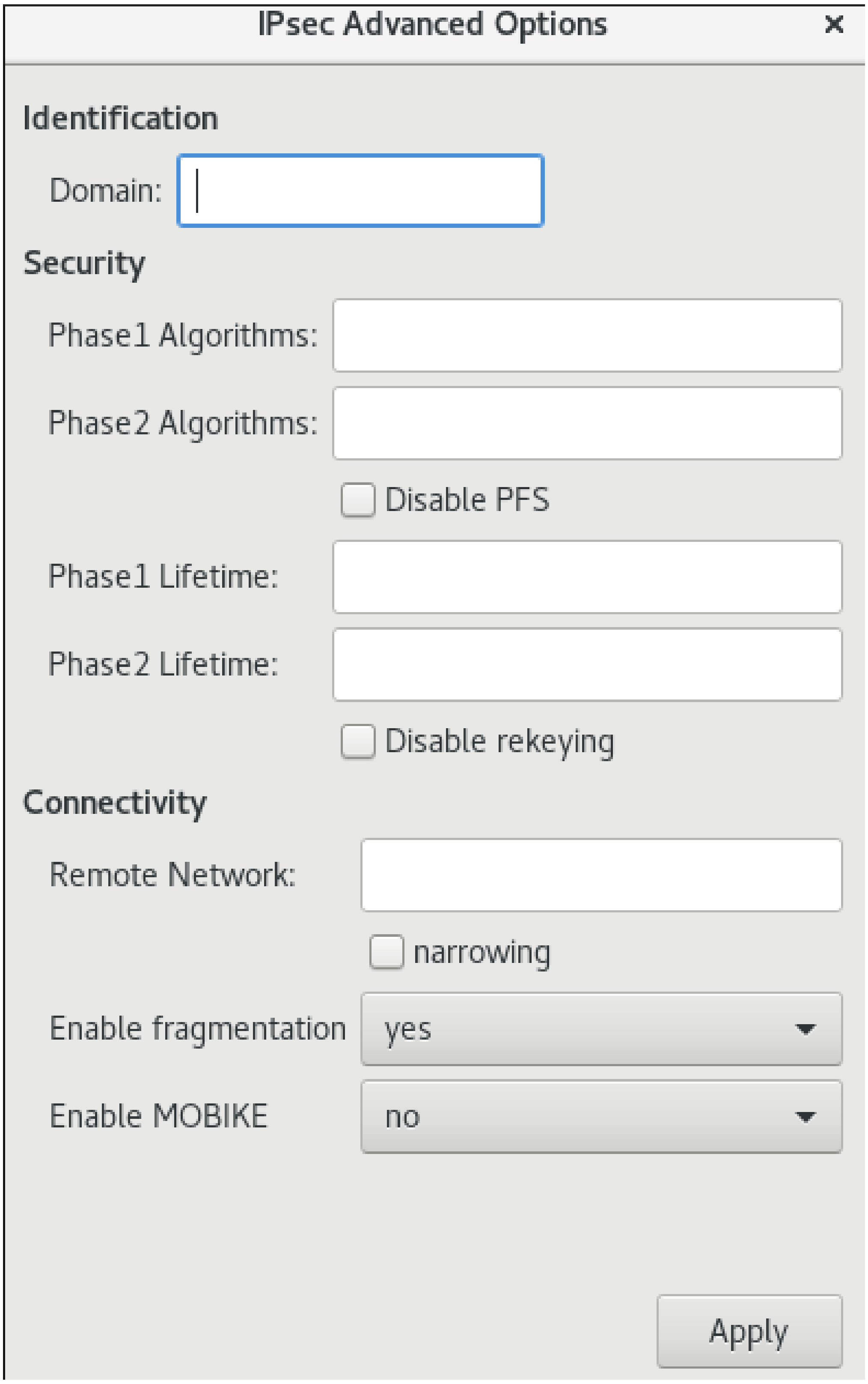
   **Gateway** — The name or **IP** address of the remote VPN gateway.

   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 5.1. Advanced options of a VPN connection



IPsec Advanced Options

Identification

Domain:

Security

Phase1 Algorithms:

Phase2 Algorithms:

☐ Disable PFS

Phase1 Lifetime:

Phase2 Lifetime:

☐ Disable rekeying

Connectivity

Remote Network:

☐ narrowing

Enable fragmentation: yes

Enable MOBIKE: no

> **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.
10. If you use this host in a network with DHCP or Stateless Address Autoconfiguration (SLAAC), the connection can be vulnerable to being redirected. For details and mitigation steps, see Assigning a VPN connection to a dedicated routing table to prevent the connection from bypassing the tunnel.

Additional resources

- **nm-settings-libreswan(5)**

## 5.17. CONFIGURING A VPN CONNECTION USING NM-CONNECTION-EDITOR

If you use Red Hat Enterprise Linux with a graphical interface, you can configure a VPN connection in the **nm-connection-editor** application.

Prerequisites

- The **NetworkManager-libreswan-gnome** package is installed.
- If you configure an Internet Key Exchange version 2 (IKEv2) connection:
  - The certificate is imported into the IPsec network security services (NSS) database.
  - The nickname of the certificate in the NSS database is known.

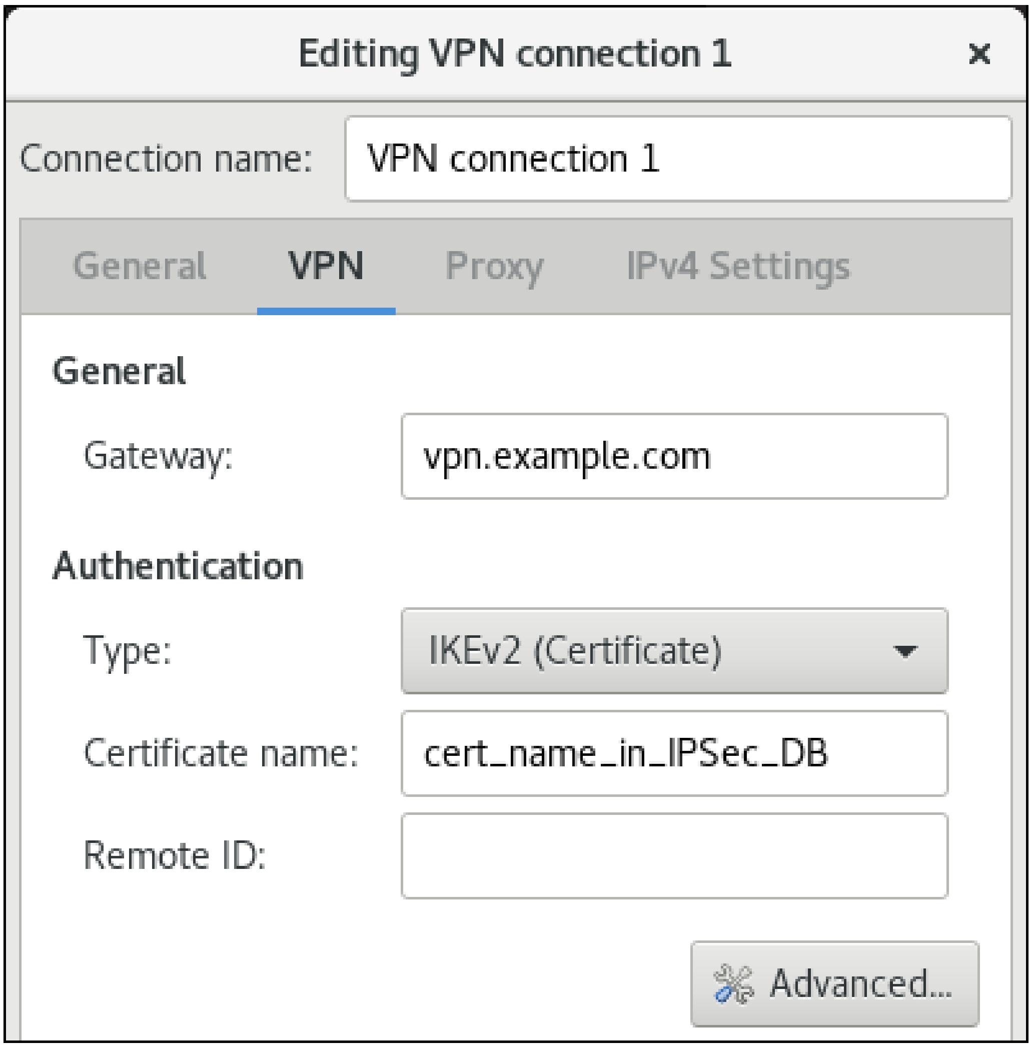
Procedure

1. Open a terminal, and enter:

   ```
   $ nm-connection-editor
   ```

2. Click the **+** button to add a new connection.
3. Select the **IPsec based VPN** connection type, and click **Create**.
4. On the **VPN** tab:
   a. Enter the host name or IP address of the VPN gateway into the **Gateway** field, and select an authentication type. Based on the authentication type, you must enter different additional information:
      - **IKEv2 (Certifiate)** authenticates the client by using a certificate, which is more secure. This setting requires the nickname of the certificate in the IPsec NSS database
      - **IKEv1 (XAUTH)** authenticates the user by using a user name and password (pre-shared key). This setting requires that you enter the following values:
        - User name
        - Password
        - Group name
        - Secret

   b. If the remote server specifies a local identifier for the IKE exchange, enter the exact string in the **Remote ID** field. In the remote server runs Libreswan, this value is set in the server's **leftid** parameter.



Connection name: VPN connection 1

General

Gateway: vpn.example.com

Authentication

Type: IKEv2 (Certificate)

Certificate name: cert_name_in_IPSec_DB

Remote ID:

c. Optional: Configure additional settings by clicking the **Advanced** button. You can configure the following settings:

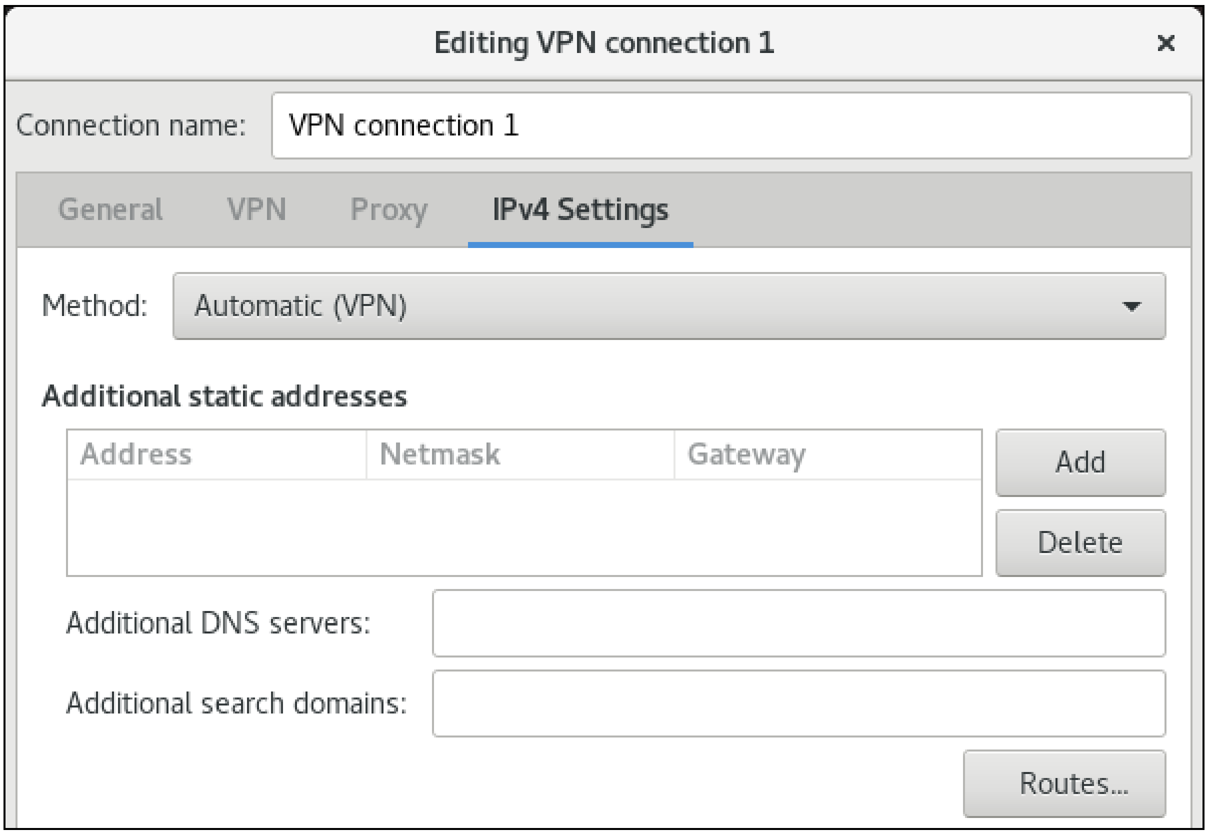
- Identification
    - **Domain** – If required, enter the domain name.
- Security
    - **Phase1 Algorithms** corresponds to the **ike** Libreswan parameter. Enter the algorithms to be used to authenticate and set up an encrypted channel.
    - **Phase2 Algorithms** corresponds to the **esp** Libreswan 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. This parameter defines how long the key used to encrypt the traffic is valid.
    - **Phase2 Lifetime** corresponds to the **salifetime** Libreswan parameter. This parameter defines how long a security association is valid.
- Connectivity

- **Remote network** corresponds to the **rightsubnet** Libreswan parameter and defines 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 the IKEv2 negotiation.

- **Enable fragmentation** corresponds to the **fragmentation** Libreswan parameter and defines whether or not to allow IKE fragmentation. Valid values are **yes** (default) or **no**.

- **Enable Mobike** corresponds to the **mobike** Libreswan parameter. The parameter defines 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**.

5. On the **IPv4 Settings** tab, select the IP assignment method and, optionally, set additional static addresses, DNS servers, search domains, and routes.


Editing VPN connection 1

Connection name: VPN connection 1

Method: Automatic (VPN)

Additional static addresses

| Address | Netmask | Gateway |
|---|---|---|

Additional DNS servers:

Additional search domains:

6. Save the connection.

7. Close **nm-connection-editor**.

8. If you use this host in a network with DHCP or Stateless Address Autoconfiguration (SLAAC), the connection can be vulnerable to being redirected. For details and mitigation steps, see Assigning a VPN connection to a dedicated routing table to prevent the connection from bypassing the tunnel.

NOTE

When you add a new connection by clicking the **+** button, **NetworkManager** creates a new configuration file for that connection and then opens the same dialog that is used for editing an existing connection. The difference between these dialogs is that an existing connection profile has a **Details** menu entry.

**Additional resources**

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

## 5.18. ASSIGNING A VPN CONNECTION TO A DEDICATED ROUTING TABLE TO PREVENT THE CONNECTION FROM BYPASSING THE TUNNEL

Both a DHCP server and Stateless Address Autoconfiguration (SLAAC) can add routes to a client's routing table. For example, a malicious DHCP server can use this feature to force a host with VPN connection to redirect traffic through a physical interface instead of the VPN tunnel. This vulnerability is also known as TunnelVision and described in the CVE-2024-3661 vulnerability article.

To mitigate this vulnerability, you can assign the VPN connection to a dedicated routing table. This prevents the DHCP configuration or SLAAC to manipulate routing decisions for network packets intended for the VPN tunnel.

Follow the steps if at least one of the conditions applies to your environment:

- At least one network interface uses DHCP or SLAAC.
- Your network does not use mechanisms, such as DHCP snooping, that prevent a rogue DHCP server.

IMPORTANT

Routing the entire traffic through the VPN prevents the host from accessing local network resources.

**Prerequisites**

- You use NetworkManager 1.40.16-18 or later.

**Procedure**

1. Decide which routing table you want to use. The following steps use table 75. By default, RHEL does not use the tables 1-254, and you can use any of them.
2. Configure the VPN connection profile to place the VPN routes in a dedicated routing table:

```
# nmcli connection modify <vpn_connection_profile> ipv4.route-table 75 ipv6.route-table 75
```

3. Set a low priority value for the table you used in the previous command:

```
# nmcli connection modify <vpn_connection_profile> ipv4.routing-rules "priority 32345 from all table 75" ipv6.routing-rules "priority 32345 from all table 75"
```

–

The priority value can be any value between 1 and 32766. The lower the value, the higher the priority.

4. Reconnect the VPN connection:

```
# nmcli connection down <vpn_connection_profile>
# nmcli connection up <vpn_connection_profile>
```

### Verification

1. Display the IPv4 routes in table 75:

```
# ip route show table 75
...
192.0.2.0/24 via 192.0.2.254 dev vpn_device proto static metric 50
default dev vpn_device proto static scope link metric 50
```

The output confirms that both the route to the remote network and the default gateway are assigned to routing table 75 and, therefore, all traffic is routed through the tunnel. If you set **ipv4.never-default true** in the VPN connection profile, a default route is not created and, therefore, not visible in this output.

2. Display the IPv6 routes in table 75:

```
# ip -6 route show table 75
...
2001:db8:1::/64 dev vpn_device proto kernel metric 50 pref medium
default dev vpn_device proto static metric 50 pref medium
```

The output confirms that both the route to the remote network and the default gateway are assigned to routing table 75 and, therefore, all traffic is routed through the tunnel. If you set **ipv4.never-default true** in the VPN connection profile, a default route is not created and, therefore, not visible in this output.

### Additional resources

- CVE-2024-3661

## 5.19. ADDITIONAL RESOURCES

- **ipsec(8)**, **ipsec.conf(5)**, **ipsec.secrets(5)**, **ipsec_auto(8)**, and **ipsec_rsasigkey(8)** man pages.
- **/usr/share/doc/libreswan-*version*/** directory.
- The Libreswan Project Wiki.
- All Libreswan man pages.
- NIST Special Publication 800-77: Guide to IPsec VPNs .

# CHAPTER 6. 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.

## 6.1. 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.

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.

### Additional resources

- MACsec: a different solution to encrypt network traffic

## 6.2. 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

# CHAPTER 7. USING AND CONFIGURING FIREWALLD

A *firewall* is a way to protect machines from any unwanted traffic from outside. It enables users to control incoming network traffic on host machines by defining a set of *firewall rules*. These rules are used to sort the incoming traffic and either block it or allow through.

**firewalld** is a firewall service daemon that provides a dynamic customizable host-based firewall with a D-Bus interface. Being dynamic, it enables creating, changing, and deleting the rules without the necessity to restart the firewall daemon each time the rules are changed.

**firewalld** uses the concepts of zones and services, that simplify the traffic management. Zones are predefined sets of rules. Network interfaces and sources can be assigned to a zone. The traffic allowed depends on the network your computer is connected to and the security level this network is assigned. Firewall services are predefined rules that cover all necessary settings to allow incoming traffic for a specific service and they apply within a zone.

Services use one or more ports or addresses for network communication. Firewalls filter communication based on ports. To allow network traffic for a service, its ports must be open. **firewalld** blocks all traffic on ports that are not explicitly set as open. Some zones, such as trusted, allow all traffic by default.

Note that **firewalld** with **nftables** backend does not support passing custom **nftables** rules to **firewalld**, using the **--direct** option.

## 7.1. WHEN TO USE FIREWALLD, NFTABLES, OR IPTABLES

The following is a brief overview in which scenario you should use one of the following utilities:

- **firewalld**: Use the **firewalld** utility for simple firewall use cases. The utility is easy to use and covers the typical use cases for these scenarios.
- **nftables**: Use the **nftables** utility to set up complex and performance-critical firewalls, such as for a whole network.
- **iptables**: The **iptables** utility on Red Hat Enterprise Linux uses the **nf_tables** kernel API instead of the **legacy** back end. The **nf_tables** API provides backward compatibility so that scripts that use **iptables** commands still work on Red Hat Enterprise Linux. For new firewall scripts, Red Hat recommends to use **nftables**.

IMPORTANT

To prevent the different firewall-related services (**firewalld**, **nftables**, or **iptables**) from influencing each other, run only one of them on a RHEL host, and disable the other services.

## 7.2. FIREWALL ZONES

You can use the **firewalld** utility to separate networks into different zones according to the level of trust that you have with the interfaces and traffic within that network. A connection can only be part of one zone, but you can use that zone for many network connections.

**firewalld** follows strict principles in regards to zones:

1. Traffic ingresses only one zone.
2. Traffic egresses only one zone.

3. A zone defines a level of trust.
4. Intrazone traffic (within the same zone) is allowed by default.
5. Interzone traffic (from zone to zone) is denied by default.

Principles 4 and 5 are a consequence of principle 3.

Principle 4 is configurable through the zone option **--remove-forward**. Principle 5 is configurable by adding new policies.

**NetworkManager** notifies **firewalld** of the zone of an interface. You can assign zones to interfaces with the following utilities:

- **NetworkManager**
- **firewall-config** utility
- **firewall-cmd** utility
- The RHEL web console

The RHEL web console, **firewall-config**, and **firewall-cmd** can only edit the appropriate **NetworkManager** configuration files. If you change the zone of the interface using the web console, **firewall-cmd**, or **firewall-config**, the request is forwarded to **NetworkManager** and is not handled by **firewalld**.

The **/usr/lib/firewalld/zones/** directory stores the predefined zones, and you can instantly apply them to any available network interface. These files are copied to the **/etc/firewalld/zones/** directory only after they are modified. The default settings of the predefined zones are as follows:

**block**

- Suitable for: Any incoming network connections are rejected with an icmp-host-prohibited message for **IPv4** and icmp6-adm-prohibited for **IPv6**.
- Accepts: Only network connections initiated from within the system.

**dmz**

- Suitable for: Computers in your DMZ that are publicly-accessible with limited access to your internal network.
- Accepts: Only selected incoming connections.

**drop**

Suitable for: Any incoming network packets are dropped without any notification.

- Accepts: Only outgoing network connections.

**external**

- Suitable for: External networks with masquerading enabled, especially for routers. Situations when you do not trust the other computers on the network.
- Accepts: Only selected incoming connections.

**home**

- Suitable for: Home environment where you mostly trust the other computers on the network.
- Accepts: Only selected incoming connections.

**internal**

- Suitable for: Internal networks where you mostly trust the other computers on the network.
- Accepts: Only selected incoming connections.

**public**

- Suitable for: Public areas where you do not trust other computers on the network.
- Accepts: Only selected incoming connections.

**trusted**

- Accepts: All network connections.

**work**

Suitable for: Work environment where you mostly trust the other computers on the network.

- Accepts: Only selected incoming connections.

One of these zones is set as the *default* zone. When interface connections are added to **NetworkManager**, they are assigned to the default zone. On installation, the default zone in **firewalld** is the **public** zone. You can change the default zone.

NOTE

Make network zone names self-explanatory to help users understand them quickly.

To avoid any security problems, review the default zone configuration and disable any unnecessary services according to your needs and risk assessments.

**Additional resources**

- **firewalld.zone(5)** man page on your system

## 7.3. FIREWALL POLICIES

The firewall policies specify the desired security state of your network. They outline rules and actions to take for different types of traffic. Typically, the policies contain rules for the following types of traffic:

- Incoming traffic
- Outgoing traffic
- Forward traffic
- Specific services and applications

- Network address translations (NAT)

Firewall policies use the concept of firewall zones. Each zone is associated with a specific set of firewall rules that determine the traffic allowed. Policies apply firewall rules in a stateful, unidirectional manner. This means you only consider one direction of the traffic. The traffic return path is implicitly allowed due to stateful filtering of **firewalld**.

Policies are associated with an ingress zone and an egress zone. The ingress zone is where the traffic originated (received). The egress zone is where the traffic leaves (sent).

The firewall rules defined in a policy can reference the firewall zones to apply consistent configurations across multiple network interfaces.

## 7.4. FIREWALL RULES

You can use the firewall rules to implement specific configurations for allowing or blocking network traffic. As a result, you can control the flow of network traffic to protect your system from security threats.

Firewall rules typically define certain criteria based on various attributes. The attributes can be as:

- Source IP addresses
- Destination IP addresses
- Transfer Protocols (TCP, UDP, …)
- Ports
- Network interfaces

The **firewalld** utility organizes the firewall rules into zones (such as **public**, **internal**, and others) and policies. Each zone has its own set of rules that determine the level of traffic freedom for network interfaces associated with a particular zone.

## 7.5. FIREWALL DIRECT RULES

The **firewalld** service provides multiple ways with which to configure rules, including:

- regular rules
- direct rules

One difference between these is how each method interacts with the underlying backend (**iptables** or **nftables**).

The direct rules are advanced, low-level rules that allow direct interaction with **iptables**. They bypass the structured zone-based management of **firewalld** to give you more control. You manually define the direct rules with the **firewall-cmd** command by using the raw **iptables** syntax. For example, **firewall-cmd --direct --add-rule ipv4 filter INPUT 0 -s 198.51.100.1 -j DROP**. This command adds an **iptables** rule to drop traffic from the 198.51.100.1 source IP address.

However, using the direct rules also has its drawbacks. Especially when **nftables** is your primary firewall backend. For example:

- The direct rules are harder to maintain and can conflict with **nftables** based **firewalld** configurations.
- The direct rules do not support advanced features that you can find in **nftables** such as raw expressions and stateful objects.
- Direct rules are not future-proof. The **iptables** component is deprecated and will eventually be removed from RHEL.

For the previous reasons, you might consider replacing **firewalld** direct rules with **nftables**. Review the knowledgebase solution How to replace firewalld direct rules with nftables? to see more details.

## 7.6. PREDEFINED FIREWALLD SERVICES

The predefined **firewalld** services provide a built-in abstraction layer over the low-level firewall rules. It is achieved by mapping commonly used network services, such as SSH or HTTP to their corresponding ports and protocols. Instead of manually specifying these each time, you can refer to a named predefined service. This makes firewall management simpler, less error-prone, and more intuitive.

- To see available predefined services:

```
# firewall-cmd --get-services
RH-Satellite-6 RH-Satellite-6-capsule afp amanda-client amanda-k5-client amqp amqps
apcupsd audit ausweisapp2 bacula bacula-client bareos-director bareos-filedaemon bareos-
storage bb bgp bitcoin bitcoin-rpc bitcoin-testnet bitcoin-testnet-rpc bittorrent-lsd ceph ceph-
exporter ceph-mon cfengine checkmk-agent cockpit collectd condor-collector cratedb ctdb
dds...
```

- To further inspect a particular predefined service:

```
# sudo firewall-cmd --info-service=RH-Satellite-6
RH-Satellite-6
  ports: 5000/tcp 5646-5647/tcp 5671/tcp 8000/tcp 8080/tcp 9090/tcp
  protocols:
  source-ports:
  modules:
  destination:
  includes: foreman
  helpers:
```

  The example output shows that the **RH-Satellite-6** predefined service listens on ports 5000/tcp 5646-5647/tcp 5671/tcp 8000/tcp 8080/tcp 9090/tcp. Additionally, **RH-Satellite-6** inherits rules from another predefined service. In this case **foreman.**

Each predefined service is stored as an XML file with the same name in the **/usr/lib/firewalld/services/** directory.

### Additional resources

- **firewall-cmd(1)**, **firewalld(1)** manual pages

## 7.7. WORKING WITH FIREWALLD ZONES

Zones represent a concept to manage incoming traffic more transparently. The zones are connected to networking interfaces or assigned a range of source addresses. You manage firewall rules for each zone independently, which enables you to define complex firewall settings and apply them to the traffic.

## 7.7.1. Customizing firewall settings for a specific zone to enhance security

You can strengthen your network security by modifying the firewall settings and associating a specific network interface or connection with a particular firewall zone. By defining granular rules and restrictions for a zone, you can control inbound and outbound traffic based on your intended security levels.

For example, you can achieve the following benefits:

- Protection of sensitive data
- Prevention of unauthorized access
- Mitigation of potential network threats

### Prerequisites

- The **firewalld** service is running.

### Procedure

1. List the available firewall zones:

   ```
   # firewall-cmd --get-zones
   ```

   The **firewall-cmd --get-zones** command displays all zones that are available on the system, but it does not show any details for particular zones. To see more detailed information for all zones, use the **firewall-cmd --list-all-zones** command.

2. Choose the zone you want to use for this configuration.

3. Modify firewall settings for the chosen zone. For example, to allow the **SSH** service and remove the **ftp** service:

   ```
   # firewall-cmd --add-service=ssh --zone=<your_chosen_zone>
   # firewall-cmd --remove-service=ftp --zone=<same_chosen_zone>
   ```

4. Assign a network interface to the firewall zone:

   a. List the available network interfaces:

      ```
      # firewall-cmd --get-active-zones
      ```

      Activity of a zone is determined by the presence of network interfaces or source address ranges that match its configuration. The default zone is active for unclassified traffic but is not always active if no traffic matches its rules.

   b. Assign a network interface to the chosen zone:

      ```
      # firewall-cmd --zone=<your_chosen_zone> --change-interface=<interface_name> -
      -permanent
      ```

Assigning a network interface to a zone is more suitable for applying consistent firewall settings to all traffic on a particular interface (physical or virtual).

The **firewall-cmd** command, when used with the **--permanent** option, often involves updating NetworkManager connection profiles to make changes to the firewall configuration permanent. This integration between **firewalld** and NetworkManager ensures consistent network and firewall settings.

#### Verification

1. Display the updated settings for your chosen zone:

```
# firewall-cmd --zone=<your_chosen_zone> --list-all
```

   The command output displays all zone settings including the assigned services, network interface, and network connections (sources).

### 7.7.2. Changing the default zone

System administrators assign a zone to a networking interface in its configuration files. If an interface is not assigned to a specific zone, it is assigned to the default zone. After each restart of the **firewalld** service, **firewalld** loads the settings for the default zone and makes it active. Note that settings for all other zones are preserved and ready to be used.

Typically, zones are assigned to interfaces by NetworkManager according to the **connection.zone** setting in NetworkManager connection profiles. Also, after a reboot NetworkManager manages assignments for "activating" those zones.

#### Prerequisites

- The **firewalld** service is running.

#### Procedure

To set up the default zone:

1. Display the current default zone:

```
# firewall-cmd --get-default-zone
```

2. Set the new default zone:

```
# firewall-cmd --set-default-zone <zone_name>
```

NOTE

Following this procedure, the setting is a permanent setting, even without the **--permanent** option.

### 7.7.3. Assigning a network interface to a zone

It is possible to define different sets of rules for different zones and then change the settings quickly by changing the zone for the interface that is being used. With multiple interfaces, a specific zone can be set for each of them to distinguish traffic that is coming through them.

### Procedure

To assign the zone to a specific interface:

1. List the active zones and the interfaces assigned to them:

   ```
   # firewall-cmd --get-active-zones
   ```

2. Assign the interface to a different zone:

   ```
   # firewall-cmd --zone=zone_name --change-interface=interface_name --permanent
   ```

## 7.7.4. Adding a source

To route incoming traffic into a specific zone, add the source to that zone. The source can be an IP address or an IP mask in the classless inter-domain routing (CIDR) notation.

NOTE

In case you add multiple zones with an overlapping network range, they are ordered alphanumerically by zone name and only the first one is considered.

- To set the source in the current zone:

  ```
  # firewall-cmd --add-source=<source>
  ```

- To set the source IP address for a specific zone:

  ```
  # firewall-cmd --zone=zone-name --add-source=<source>
  ```

The following procedure allows all incoming traffic from *192.168.2.15* in the **trusted** zone:

### Procedure

1. List all available zones:

   ```
   # firewall-cmd --get-zones
   ```

2. Add the source IP to the trusted zone in the permanent mode:

   ```
   # firewall-cmd --zone=trusted --add-source=192.168.2.15
   ```

3. Make the new settings persistent:

   ```
   # firewall-cmd --runtime-to-permanent
   ```

## 7.7.5. Removing a source

When you remove a source from a zone, the traffic which originates from the source is no longer directed through the rules specified for that source. Instead, the traffic falls back to the rules and settings of the zone associated with the interface from which it originates, or goes to the default zone.

**Procedure**

1. List allowed sources for the required zone:

   ```
   # firewall-cmd --zone=zone-name --list-sources
   ```

2. Remove the source from the zone permanently:

   ```
   # firewall-cmd --zone=zone-name --remove-source=<source>
   ```

3. Make the new settings persistent:

   ```
   # firewall-cmd --runtime-to-permanent
   ```

### 7.7.6. Assigning a zone to a connection using nmcli

You can add a **firewalld** zone to a **NetworkManager** connection using the **nmcli** utility.

**Procedure**

1. Assign the zone to the **NetworkManager** connection profile:

   ```
   # nmcli connection modify profile connection.zone zone_name
   ```

2. Activate the connection:

   ```
   # nmcli connection up profile
   ```

### 7.7.7. Manually assigning a zone to a network connection in an ifcfg file

When the connection is managed by **NetworkManager**, it must be aware of a zone that it uses. For every network connection profile, a zone can be specified, which provides the flexibility of various firewall settings according to the location of the computer with portable devices. Thus, zones and settings can be specified for different locations, such as company or home.

**Procedure**

- To set a zone for a connection, edit the **/etc/sysconfig/network-scripts/ifcfg-*connection_name*** file and add a line that assigns a zone to this connection:

  ```
  ZONE=zone_name
  ```

### 7.7.8. Creating a new zone

To use custom zones, create a new zone and use it just like a predefined zone. New zones require the **--permanent** option, otherwise the command does not work.

**Prerequisites**

- The **firewalld** service is running.

### Procedure

1. Create a new zone:

```
# firewall-cmd --permanent --new-zone=zone-name
```

2. Make the new zone usable:

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

The command applies recent changes to the firewall configuration without interrupting network services that are already running.

### Verification

- Check if the new zone is added to your permanent settings:

```
# firewall-cmd --get-zones --permanent
```

## 7.7.9. Enabling zones by using the web console

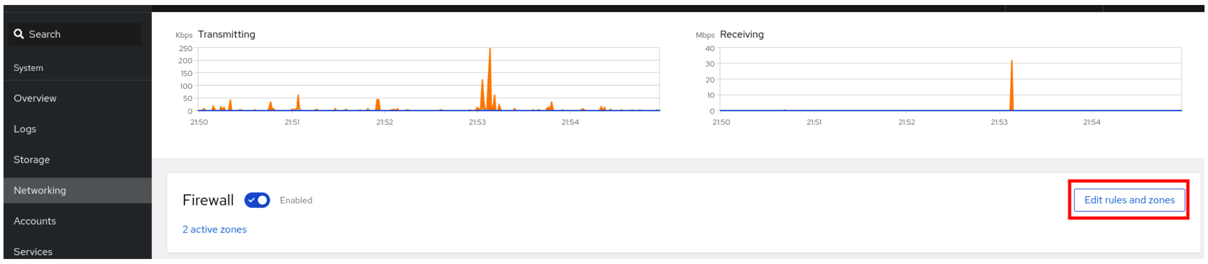
You can apply predefined and existing firewall zones on a particular interface or a range of IP addresses through the RHEL web console.

### Prerequisites

- You have installed the RHEL 8 web console.
- You have enabled the cockpit service.
- Your user account is allowed to log in to the web console.
  For instructions, see Installing and enabling the web console .

### Procedure

1. Log in to the RHEL 8 web console.
   For details, see Logging in to the web console .
2. Click **Networking**.
3. Click on the **Edit rules and zones** button.



If you do not see the **Edit rules and zones** button, log in to the web console with the administrator privileges.

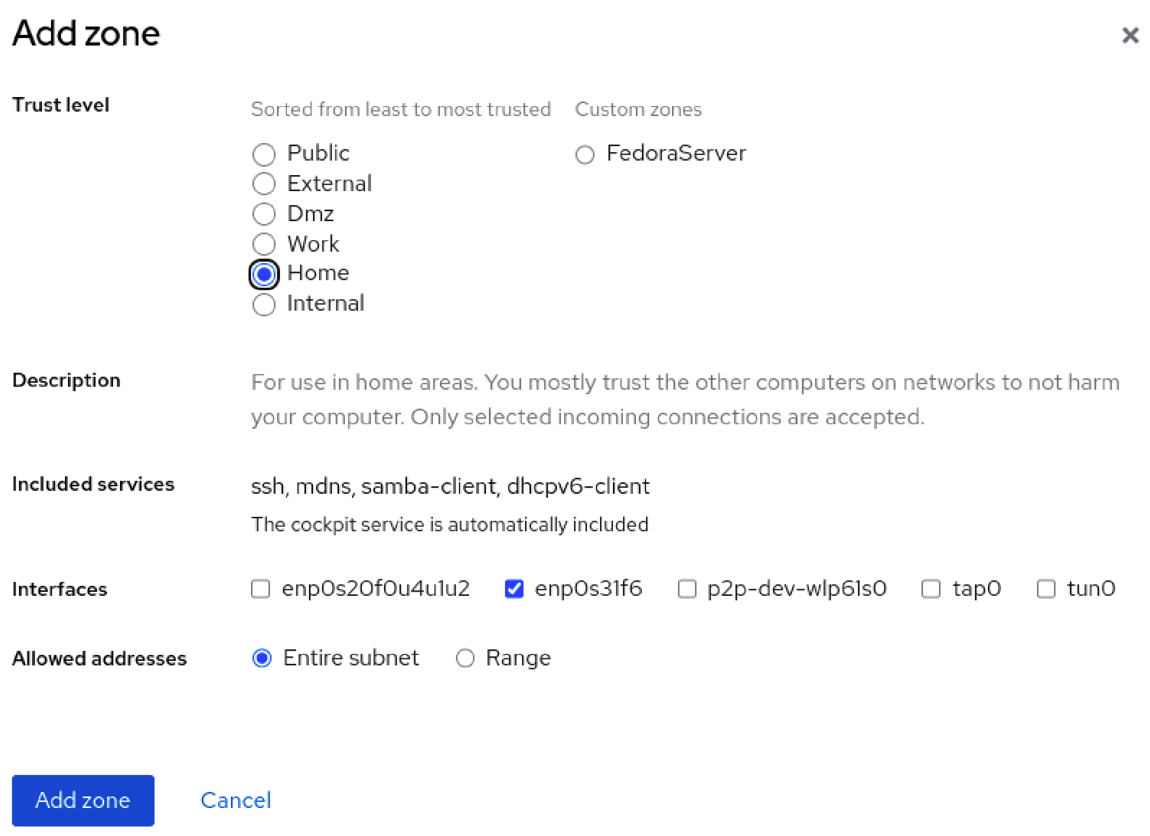
4. In the **Firewall** section, click **Add new zone**.

5. In the **Add zone** dialog box, select a zone from the **Trust level** options.
   The web console displays all zones predefined in the **firewalld** service.

6. In the **Interfaces** part, select an interface or interfaces on which the selected zone is applied.

7. In the **Allowed Addresses** part, you can select whether the zone is applied on:
   - the whole subnet
   - or a range of IP addresses in the following format:
     - 192.168.1.0
     - 192.168.1.0/24
     - 192.168.1.0/24, 192.168.1.0

8. Click on the **Add zone** button.


Add zone

Trust level: Sorted from least to most trusted — Public, External, Dmz, Work, [✓ Home], Internal. Custom zones — FedoraServer

Description: For use in home areas. You mostly trust the other computers on networks to not harm your computer. Only selected incoming connections are accepted.

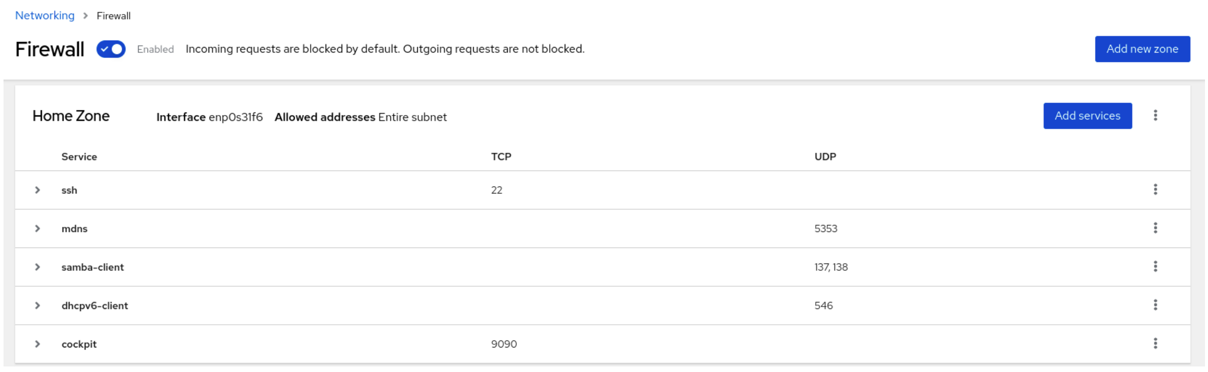
Included services: ssh, mdns, samba-client, dhcpv6-client
The cockpit service is automatically included

Interfaces: enp0s20f0u4u1u2, [✓ enp0s31f6], p2p-dev-wlp61s0, tap0, tun0

Allowed addresses: [✓ Entire subnet] Range

## Verification

- Check the configuration in the **Firewall** section:


Networking > Firewall

Firewall Enabled Incoming requests are blocked by default. Outgoing requests are not blocked. Add new zone

Home Zone **Interface** enp0s31f6 **Allowed addresses** Entire subnet Add services

| Service | TCP | UDP |
|---|---|---|
| ssh | 22 | |
| mdns | | 5353 |
| samba-client | | 137, 138 |
| dhcpv6-client | | 546 |
| cockpit | 9090 | |

## 7.7.10. Disabling zones by using the web console

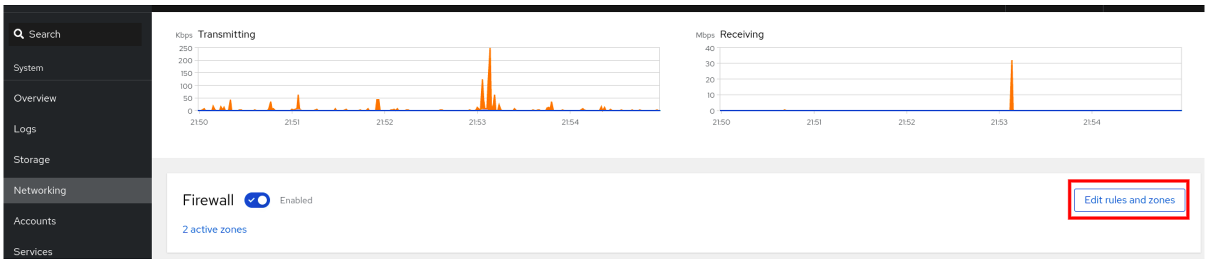
You can disable a firewall zone in your firewall configuration by using the web console.

### Prerequisites

- You have installed the RHEL 8 web console.
- You have enabled the cockpit service.
- Your user account is allowed to log in to the web console.
  For instructions, see Installing and enabling the web console .

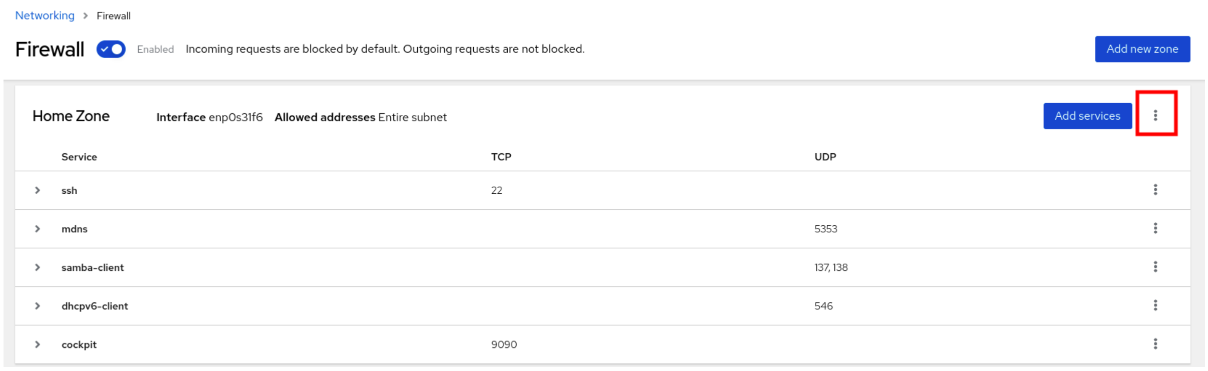
### Procedure

1. Log in to the RHEL 8 web console.
   For details, see Logging in to the web console .
2. Click **Networking**.
3. Click on the **Edit rules and zones** button.



If you do not see the **Edit rules and zones** button, log in to the web console with the administrator privileges.

4. Click on the **Options** icon at the zone you want to remove.


Networking > Firewall

Firewall Enabled Incoming requests are blocked by default. Outgoing requests are not blocked. Add new zone

Home Zone **Interface** enp0s31f6 **Allowed addresses** Entire subnet Add services

| Service | TCP | UDP |
|---|---|---|
| ssh | 22 | |
| mdns | | 5353 |
| samba-client | | 137, 138 |
| dhcpv6-client | | 546 |
| cockpit | 9090 | |

5. Click **Delete**.

The zone is now disabled and the interface does not include opened services and ports which were configured in the zone.

### 7.7.11. Using zone targets to set default behavior for incoming traffic

For every zone, you can set a default behavior that handles incoming traffic that is not further specified. Such behavior is defined by setting the target of the zone. There are four options:

- **ACCEPT**: Accepts all incoming packets except those disallowed by specific rules.
- **REJECT**: Rejects all incoming packets except those allowed by specific rules. When **firewalld** rejects packets, the source machine is informed about the rejection.
- **DROP**: Drops all incoming packets except those allowed by specific rules. When **firewalld** drops packets, the source machine is not informed about the packet drop.
- **default**: Similar behavior as for **REJECT**, but with special meanings in certain scenarios.

#### Prerequisites

- The **firewalld** service is running.

#### Procedure

To set a target for a zone:

1. List the information for the specific zone to see the default target:

```
# firewall-cmd --zone=zone-name --list-all
```

2. Set a new target in the zone:

```
# firewall-cmd --permanent --zone=zone-name --set-target=
<default|ACCEPT|REJECT|DROP>
```

#### Additional resources

- **firewall-cmd(1)** man page on your system

### 7.7.12. Configuring dynamic updates for allowlisting with IP sets

You can make near real-time updates to flexibly allow specific IP addresses or ranges in the IP sets even in unpredictable conditions. These updates can be triggered by various events, such as detection of security threats or changes in the network behavior. Typically, such a solution leverages automation to reduce manual effort and improve security by responding quickly to the situation.

#### Prerequisites

- The **firewalld** service is running.

#### Procedure

1. Create an IP set with a meaningful name:

   ```
   # firewall-cmd --permanent --new-ipset=allowlist --type=hash:ip
   ```

   The new IP set called **allowlist** contains IP addresses that you want your firewall to allow.

2. Add a dynamic update to the IP set:

   ```
   # firewall-cmd --permanent --ipset=allowlist --add-entry=198.51.100.10
   ```

   This configuration updates the **allowlist** IP set with a newly added IP address that is allowed to pass network traffic by your firewall.

3. Create a firewall rule that references the previously created IP set:

   ```
   # firewall-cmd --permanent --zone=public --add-source=ipset:allowlist
   ```

   Without this rule, the IP set would not have any impact on network traffic. The default firewall policy would prevail.

4. Reload the firewall configuration to apply the changes:

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

## Verification

1. List all IP sets:

   ```
   # firewall-cmd --get-ipsets
   allowlist
   ```

2. List the active rules:

   ```
   # firewall-cmd --list-all
   public (active)
     target: default
     icmp-block-inversion: no
     interfaces: enp0s1
     sources: ipset:allowlist
     services: cockpit dhcpv6-client ssh
     ports:
     protocols:
     ...
   ```

   The **sources** section of the command-line output provides insights to what origins of traffic (hostnames, interfaces, IP sets, subnets, and others) are permitted or denied access to a particular firewall zone. In this case, the IP addresses contained in the **allowlist** IP set are allowed to pass traffic through the firewall for the **public** zone.

3. Explore the contents of your IP set:

   ```
   # cat /etc/firewalld/ipsets/allowlist.xml
   <?xml version="1.0" encoding="utf-8"?>
   <ipset type="hash:ip">
   ```

```
  <entry>198.51.100.10</entry>
</ipset>
```

**Next steps**

- Use a script or a security utility to fetch your threat intelligence feeds and update **allowlist** accordingly in an automated fashion.

**Additional resources**

- **firewall-cmd(1)** manual page

## 7.8. CONTROLLING NETWORK TRAFFIC USING FIREWALLD

The **firewalld** package installs a large number of predefined service files and you can add more or customize them. You can then use these service definitions to open or close ports for services without knowing the protocol and port numbers they use.

### 7.8.1. Controlling traffic with predefined services using the CLI

The most straightforward method to control traffic is to add a predefined service to **firewalld**. This opens all necessary ports and modifies other settings according to the *service definition file* .

**Prerequisites**

- The **firewalld** service is running.

**Procedure**

1. Check that the service in **firewalld** is not already allowed:

   ```
   # firewall-cmd --list-services
   ssh dhcpv6-client
   ```

   The command lists the services that are enabled in the default zone.

2. List all predefined services in **firewalld**:

   ```
   # firewall-cmd --get-services
   RH-Satellite-6 amanda-client amanda-k5-client bacula bacula-client bitcoin bitcoin-rpc
   bitcoin-testnet bitcoin-testnet-rpc ceph ceph-mon cfengine condor-collector ctdb dhcp dhcpv6
   dhcpv6-client dns docker-registry ...
   ```

   The command displays a list of available services for the default zone.

3. Add the service to the list of services that **firewalld** allows:

   ```
   # firewall-cmd --add-service=<service_name>
   ```

   The command adds the specified service to the default zone.

4. Make the new settings persistent:

```
# firewall-cmd --runtime-to-permanent
```

The command applies these runtime changes to the permanent configuration of the firewall. By default, it applies these changes to the configuration of the default zone.

### Verification

1. List all permanent firewall rules:

   ```
   # firewall-cmd --list-all --permanent
   public
     target: default
     icmp-block-inversion: no
     interfaces:
     sources:
     services: cockpit dhcpv6-client ssh
     ports:
     protocols:
     forward: no
     masquerade: no
     forward-ports:
     source-ports:
     icmp-blocks:
     rich rules:
   ```

   The command displays complete configuration with the permanent firewall rules of the default firewall zone (**public**).

2. Check the validity of the permanent configuration of the **firewalld** service.

   ```
   # firewall-cmd --check-config
   success
   ```

   If the permanent configuration is invalid, the command returns an error with further details:

   ```
   # firewall-cmd --check-config
   Error: INVALID_PROTOCOL: 'public.xml': 'tcpx' not from {'tcp'|'udp'|'sctp'|'dccp'}
   ```

   You can also manually inspect the permanent configuration files to verify the settings. The main configuration file is **/etc/firewalld/firewalld.conf**. The zone-specific configuration files are in the **/etc/firewalld/zones/** directory and the policies are in the **/etc/firewalld/policies/** directory.

## 7.8.2. Enabling services on the firewall by using the web console

By default, services are added to the default firewall zone. If you use more firewall zones on more network interfaces, you must select a zone first and then add the service with port.

The RHEL 8 web console displays predefined **firewalld** services and you can add them to active firewall zones.

**IMPORTANT**

The RHEL 8 web console configures the **firewalld** service.

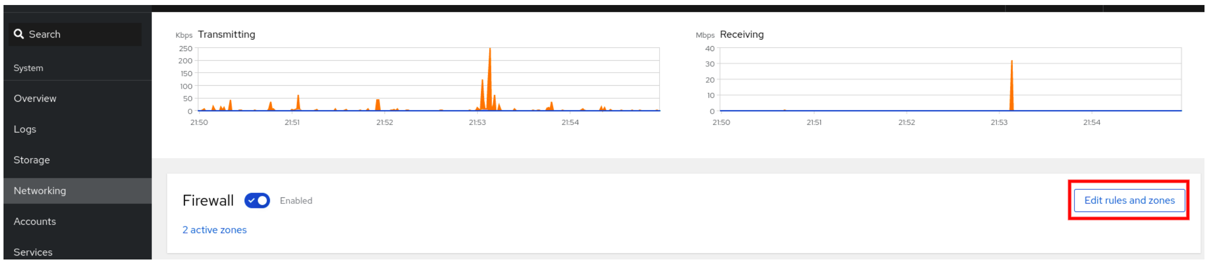
The web console does not allow generic **firewalld** rules which are not listed in the web console.

## Prerequisites

- You have installed the RHEL 8 web console.
- You have enabled the cockpit service.
- Your user account is allowed to log in to the web console.
  For instructions, see Installing and enabling the web console .

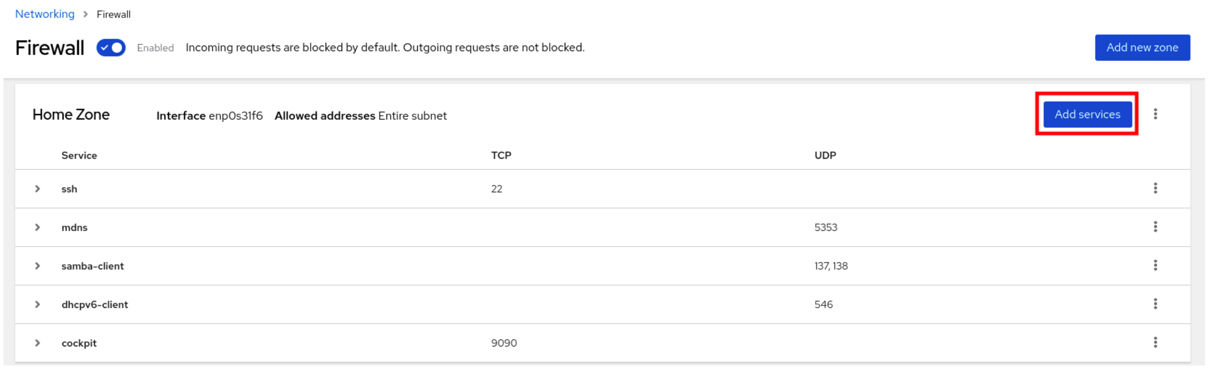
## Procedure

1. Log in to the RHEL 8 web console.
   For details, see Logging in to the web console .
2. Click **Networking**.
3. Click on the **Edit rules and zones** button.



   If you do not see the **Edit rules and zones** button, log in to the web console with the administrator privileges.

4. In the **Firewall** section, select a zone for which you want to add the service and click **Add Services**.

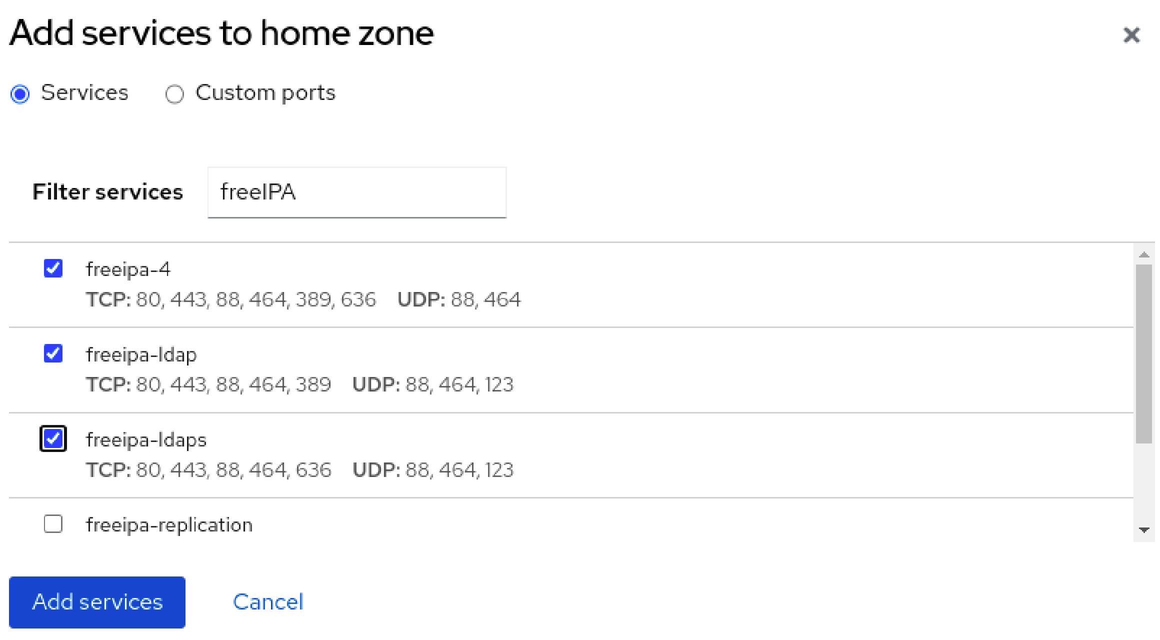


Incoming requests are blocked by default. Outgoing requests are not blocked.

Home Zone **Interface** enp0s31f6 **Allowed addresses** Entire subnet

| Service | TCP | UDP |
|---|---|---|
| ssh | 22 | |
| mdns | | 5353 |
| samba-client | | 137, 138 |
| dhcpv6-client | | 546 |
| cockpit | 9090 | |

5. In the **Add Services** dialog box, find the service you want to enable on the firewall.
6. Enable services according to your scenario:



Add services to home zone ×

● Services ○ Custom ports

**Filter services** freeIPA

✓ freeipa-4
**TCP:** 80, 443, 88, 464, 389, 636 **UDP:** 88, 464

✓ freeipa-ldap
**TCP:** 80, 443, 88, 464, 389 **UDP:** 88, 464, 123

✓ freeipa-ldaps
**TCP:** 80, 443, 88, 464, 636 **UDP:** 88, 464, 123

☐ freeipa-replication

Add services Cancel

7. Click **Add Services**.

At this point, the RHEL 8 web console displays the service in the zone's list of **Services**.

## 7.8.3. Configuring custom ports by using the web console

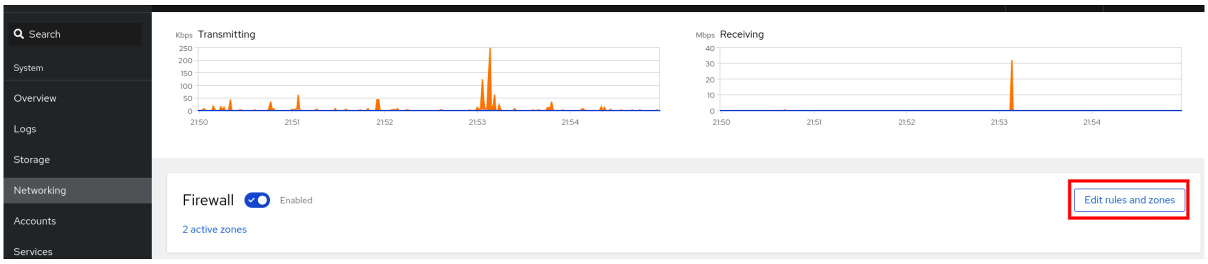
You can add configure custom ports for services through the RHEL web console.

### Prerequisites

- You have installed the RHEL 8 web console.
- You have enabled the cockpit service.
- Your user account is allowed to log in to the web console.
  For instructions, see Installing and enabling the web console .
- The **firewalld** service is running.

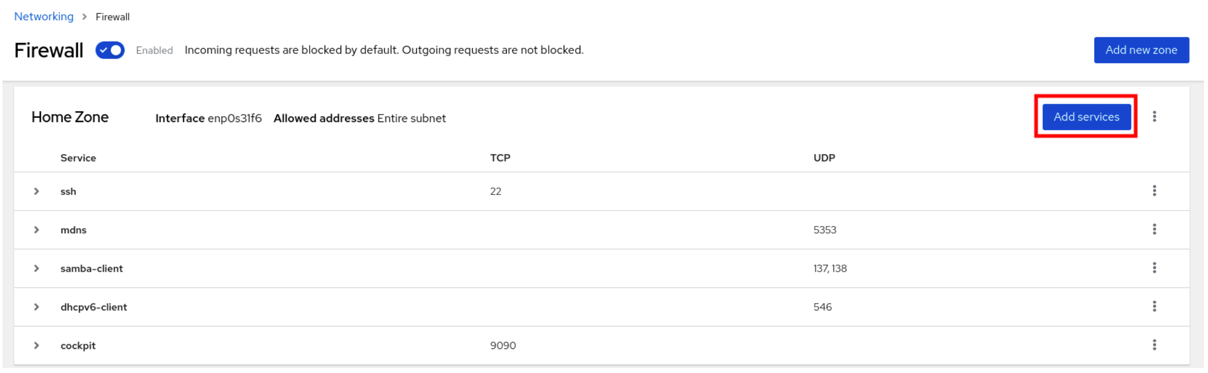
### Procedure

1. Log in to the RHEL 8 web console.
   For details, see Logging in to the web console .
2. Click **Networking**.
3. Click on the **Edit rules and zones** button.



If you do not see the **Edit rules and zones** button, log in to the web console with the administrative privileges.

4. In the **Firewall** section, select a zone for which you want to configure a custom port and click **Add Services**.



Firewall Enabled Incoming requests are blocked by default. Outgoing requests are not blocked.

Home Zone **Interface** enp0s31f6 **Allowed addresses** Entire subnet

| Service | TCP | UDP |
|---|---|---|
| ssh | 22 | |
| mdns | | 5353 |
| samba-client | | 137, 138 |
| dhcpv6-client | | 546 |
| cockpit | 9090 | |

5. In the **Add services** dialog box, click on the **Custom Ports** radio button.

6. In the TCP and UDP fields, add ports according to examples. You can add ports in the following formats:

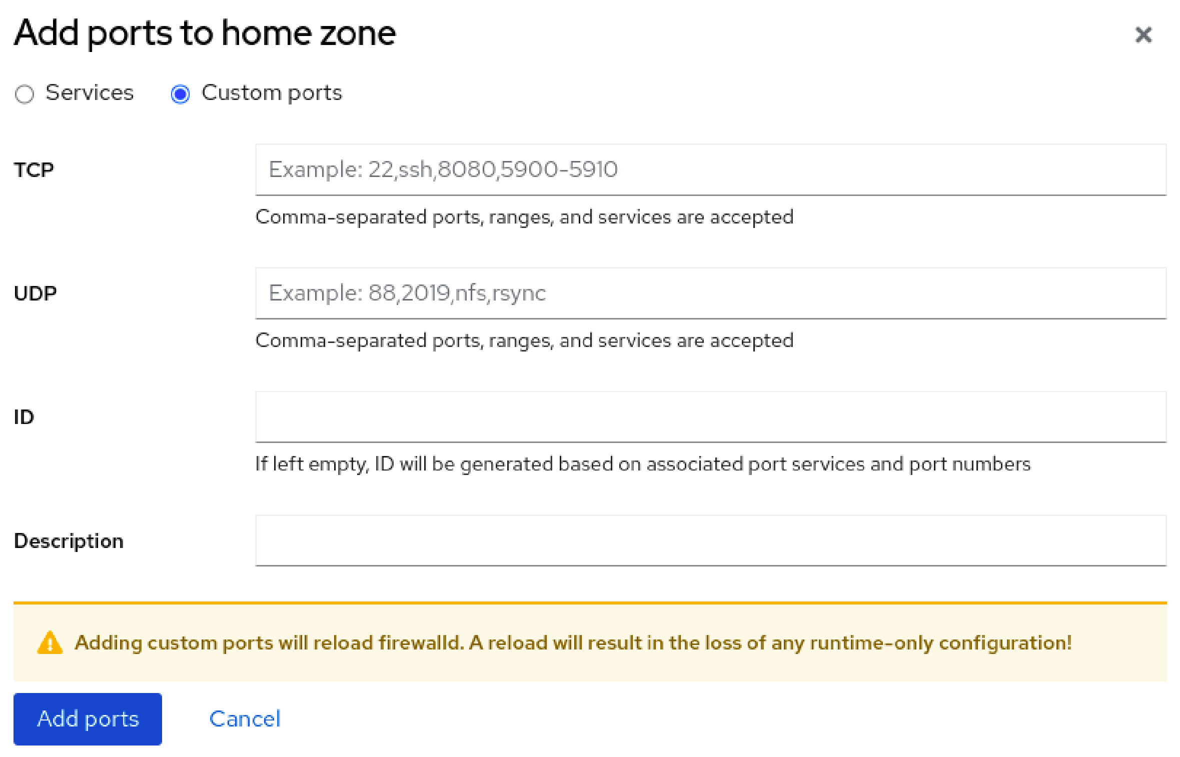
   - Port numbers such as 22
   - Range of port numbers such as 5900-5910
   - Aliases such as nfs, rsync

> **NOTE**
>
> You can add multiple values into each field. Values must be separated with the comma and without the space, for example: 8080,8081,http

7. After adding the port number in the **TCP** filed, the **UDP** filed, or both, verify the service name in the **Name** field.
   The **Name** field displays the name of the service for which is this port reserved. You can rewrite the name if you are sure that this port is free to use and no server needs to communicate on this port.

8. In the **Name** field, add a name for the service including defined ports.

9. Click on the **Add Ports** button.



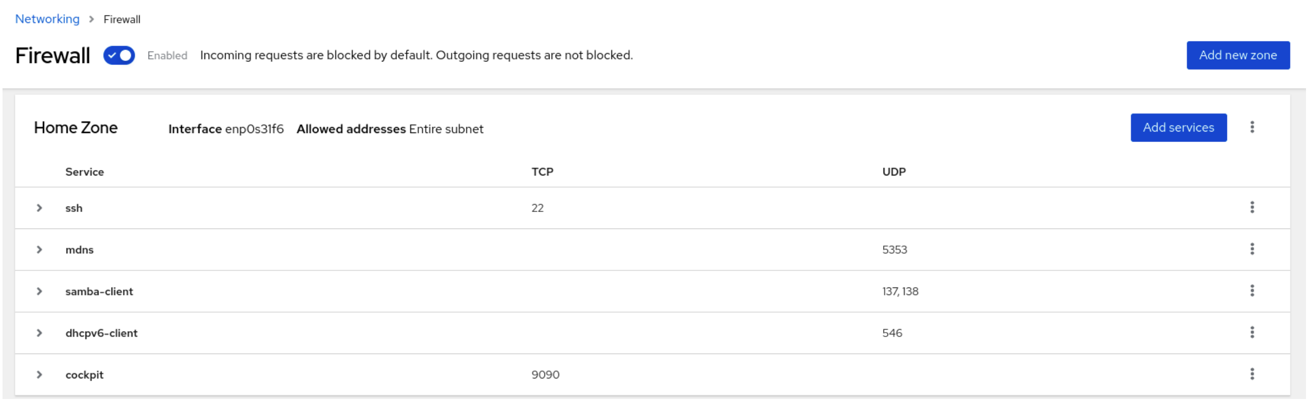
Add ports to home zone

Services [✓ Custom ports]

| | |
|---|---|
| TCP | Example: 22,ssh,8080,5900-5910 — Comma-separated ports, ranges, and services are accepted |
| UDP | Example: 88,2019,nfs,rsync — Comma-separated ports, ranges, and services are accepted |
| ID | If left empty, ID will be generated based on associated port services and port numbers |
| Description | |

Adding custom ports will reload firewalld. A reload will result in the loss of any runtime-only configuration!

To verify the settings, go to the **Firewall** page and find the service in the list of zone’s **Services**.



Firewall Enabled Incoming requests are blocked by default. Outgoing requests are not blocked.

Home Zone Interface enp0s31f6 Allowed addresses Entire subnet

| Service | TCP | UDP |
|---|---|---|
| ssh | 22 | |
| mdns | | 5353 |
| samba-client | | 137, 138 |
| dhcpv6-client | | 546 |
| cockpit | 9090 | |

## 7.9. FILTERING FORWARDED TRAFFIC BETWEEN ZONES

**firewalld** enables you to control the flow of network data between different **firewalld** zones. By defining rules and policies, you can manage how traffic is allowed or blocked when it moves between these zones.

The policy objects feature provides forward and output filtering in **firewalld**. You can use **firewalld** to filter traffic between different zones to allow access to locally hosted VMs to connect the host.

### 7.9.1. The relationship between policy objects and zones

Policy objects allow the user to attach firewalld’s primitives such as services, ports, and rich rules to the policy. You can apply the policy objects to traffic that passes between zones in a stateful and unidirectional manner.

```
# firewall-cmd --permanent --new-policy myOutputPolicy

# firewall-cmd --permanent --policy myOutputPolicy --add-ingress-zone HOST
# firewall-cmd --permanent --policy myOutputPolicy --add-egress-zone ANY
```

**HOST** and **ANY** are the symbolic zones used in the ingress and egress zone lists.

- The **HOST** symbolic zone allows policies for the traffic originating from or has a destination to the host running firewalld.
- The **ANY** symbolic zone applies policy to all the current and future zones. **ANY** symbolic zone acts as a wildcard for all zones.

### 7.9.2. Using priorities to sort policies

Multiple policies can apply to the same set of traffic, therefore, priorities should be used to create an order of precedence for the policies that may be applied.

To set a priority to sort the policies:

```
# firewall-cmd --permanent --policy mypolicy --set-priority -500
```

In the above example *-500* is a lower priority value but has higher precedence. Thus, -500 will execute before -100.

Lower numerical priority values have higher precedence and are applied first.

### 7.9.3. Using policy objects to filter traffic between locally hosted containers and a network physically connected to the host

The policy objects feature allows users to filter traffic between Podman and firewalld zones.

NOTE

Red Hat recommends blocking all traffic by default and opening the selective services needed for the Podman utility.

**Procedure**

1. Create a new firewall policy:

   ```
   # firewall-cmd --permanent --new-policy podmanToAny
   ```

2. Block all traffic from Podman to other zones and allow only necessary services on Podman:

   ```
   # firewall-cmd --permanent --policy podmanToAny --set-target REJECT
   # firewall-cmd --permanent --policy podmanToAny --add-service dhcp
   # firewall-cmd --permanent --policy podmanToAny --add-service dns
   # firewall-cmd --permanent --policy podmanToAny --add-service https
   ```

3. Create a new Podman zone:

   ```
   # firewall-cmd --permanent --new-zone=podman
   ```

4. Define the ingress zone for the policy:

```
# firewall-cmd --permanent --policy podmanToHost --add-ingress-zone podman
```

5. Define the egress zone for all other zones:

   ```
   # firewall-cmd --permanent --policy podmanToHost --add-egress-zone ANY
   ```

   Setting the egress zone to ANY means that you filter from Podman to other zones. If you want to filter to the host, then set the egress zone to HOST.

6. Restart the firewalld service:

   ```
   # systemctl restart firewalld
   ```

**Verification**

- Verify the Podman firewall policy to other zones:

  ```
  # firewall-cmd --info-policy podmanToAny
  podmanToAny (active)
    ...
    target: REJECT
    ingress-zones: podman
    egress-zones: ANY
    services: dhcp dns https
    ...
  ```

### 7.9.4. Setting the default target of policy objects

You can specify --set-target options for policies. The following targets are available:

- **ACCEPT** - accepts the packet
- **DROP** - drops the unwanted packets
- **REJECT** - rejects unwanted packets with an ICMP reply
- **CONTINUE** (default) - packets will be subject to rules in following policies and zones.

  ```
  # firewall-cmd --permanent --policy mypolicy --set-target CONTINUE
  ```

**Verification**

- Verify information about the policy

  ```
  # firewall-cmd --info-policy mypolicy
  ```

## 7.10. CONFIGURING NAT USING FIREWALLD

With **firewalld**, you can configure the following network address translation (NAT) types:

- Masquerading

- Destination NAT (DNAT)
- Redirect

### 7.10.1. Network address translation types

These are the different network address translation (NAT) types:

**Masquerading**

Use one of these NAT types to change the source IP address of packets. For example, Internet Service Providers (ISPs) do not route private IP ranges, such as **10.0.0.0/8**. If you use private IP ranges in your network and users should be able to reach servers on the internet, map the source IP address of packets from these ranges to a public IP address.
Masquerading automatically uses the IP address of the outgoing interface. Therefore, use masquerading if the outgoing interface uses a dynamic IP address.

**Destination NAT (DNAT)**

Use this NAT type to rewrite the destination address and port of incoming packets. For example, if your web server uses an IP address from a private IP range and is, therefore, not directly accessible from the internet, you can set a DNAT rule on the router to redirect incoming traffic to this server.

**Redirect**

This type is a special case of DNAT that redirects packets to a different port on the local machine. For example, if a service runs on a different port than its standard port, you can redirect incoming traffic from the standard port to this specific port.

### 7.10.2. Configuring IP address masquerading

You can enable IP masquerading on your system. IP masquerading hides individual machines behind a gateway when accessing the internet.

**Procedure**

1. To check if IP masquerading is enabled (for example, for the **external** zone), enter the following command as **root**:

   ```
   # firewall-cmd --zone=external --query-masquerade
   ```

   The command prints **yes** with exit status **0** if enabled. It prints **no** with exit status **1** otherwise. If **zone** is omitted, the default zone will be used.

2. To enable IP masquerading, enter the following command as **root**:

   ```
   # firewall-cmd --zone=external --add-masquerade
   ```

3. To make this setting persistent, pass the **--permanent** option to the command.

4. To disable IP masquerading, enter the following command as **root**:

   ```
   # firewall-cmd --zone=external --remove-masquerade
   ```

   To make this setting permanent, pass the **--permanent** option to the command.

### 7.10.3. Using DNAT to forward incoming HTTP traffic

You can use destination network address translation (DNAT) to direct incoming traffic from one destination address and port to another. Typically, this is useful for redirecting incoming requests from an external network interface to specific internal servers or services.

#### Prerequisites

- The **firewalld** service is running.

#### Procedure

1. Forward incoming HTTP traffic:

   ```
   # firewall-cmd --zone=public --add-forward-port=port=80:proto=tcp:toaddr=198.51.100.10:toport=8080 --permanent
   ```

   The previous command defines a DNAT rule with the following settings:

   - **--zone=public** - The firewall zone for which you configure the DNAT rule. You can adjust this to whatever zone you need.
   - **--add-forward-port** - The option that indicates you are adding a port-forwarding rule.
   - **port=80** - The external destination port.
   - **proto=tcp** - The protocol indicating that you forward TCP traffic.
   - **toaddr=198.51.100.10** - The destination IP address.
   - **toport=8080** - The destination port of the internal server.
   - **--permanent** - The option that makes the DNAT rule persistent across reboots.

2. Reload the firewall configuration to apply the changes:

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

#### Verification

- Verify the DNAT rule for the firewall zone that you used:

  ```
  # firewall-cmd --list-forward-ports --zone=public
  port=80:proto=tcp:toport=8080:toaddr=198.51.100.10
  ```

  Alternatively, view the corresponding XML configuration file:

  ```
  # cat /etc/firewalld/zones/public.xml
  <?xml version="1.0" encoding="utf-8"?>
  <zone>
    <short>Public</short>
    <description>For use in public areas. You do not trust the other computers on networks to not harm your computer. Only selected incoming connections are accepted.</description>
    <service name="ssh"/>
    <service name="dhcpv6-client"/>
  ```

```
  <service name="cockpit"/>
  <forward-port port="80" protocol="tcp" to-port="8080" to-addr="198.51.100.10"/>
  <forward/>
</zone>
```

### Additional resources

- Configuring kernel parameters at runtime
- **firewall-cmd(1)** manual page

### 7.10.4. Redirecting traffic from a non-standard port to make the web service accessible on a standard port

You can use the redirect mechanism to make the web service that internally runs on a non-standard port accessible without requiring users to specify the port in the URL. As a result, the URLs are simpler and provide better browsing experience, while a non-standard port is still used internally or for specific requirements.

#### Prerequisites

- The **firewalld** service is running.

#### Procedure

1. Create the NAT redirect rule:

   ```
   # firewall-cmd --zone=public --add-forward-
   port=port=<standard_port>:proto=tcp:toport=<non_standard_port> --permanent
   ```

   The previous command defines the NAT redirect rule with the following settings:

   - **--zone=public** - The firewall zone, for which you configure the rule. You can adjust this to whatever zone you need.
   - **--add-forward-port=port=*<non_standard_port>*** - The option that indicates you are adding a port-forwarding (redirecting) rule with source port on which you initially receive the incoming traffic.
   - **proto=tcp** - The protocol indicating that you redirect TCP traffic.
   - **toport=*<standard_port>*** - The destination port, to which the incoming traffic should be redirected after being received on the source port.
   - **--permanent** - The option that makes the rule persist across reboots.

2. Reload the firewall configuration to apply the changes:

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

#### Verification

- Verify the redirect rule for the firewall zone that you used:

```
# firewall-cmd --list-forward-ports
port=8080:proto=tcp:toport=80:toaddr=
```

Alternatively, view the corresponding XML configuration file:

```
# cat /etc/firewalld/zones/public.xml
<?xml version="1.0" encoding="utf-8"?>
<zone>
  <short>Public</short>
  <description>For use in public areas. You do not trust the other computers on networks to
not harm your computer. Only selected incoming connections are accepted.</description>
  <service name="ssh"/>
  <service name="dhcpv6-client"/>
  <service name="cockpit"/>
  <forward-port port="8080" protocol="tcp" to-port="80"/>
  <forward/>
</zone>
```

**Additional resources**

- Configuring kernel parameters at runtime
- **firewall-cmd(1)** manual page

## 7.11. PRIORITIZING RICH RULES

Rich rules provide a more advanced and flexible way to define firewall rules. Rich rules are particularly useful where services, ports, and so on are not enough to express complex firewall rules.

Concepts behind rich rules:

**granularity and flexibility**

You can define detailed conditions for network traffic based on more specific criteria.

**rule structure**

A rich rule consists of a family (IPv4 or IPv6), followed by conditions and actions.

```
rule family="ipv4|ipv6" [conditions] [actions]
```

**conditions**

They allow rich rules to apply only when certain criteria are met.

**actions**

You can define what happens to network traffic that matches the conditions.

**combining multiple conditions**

You can create more specific and complex filtering.

**hierarchical control and reusability**

You can combine rich rules with other firewall mechanisms such as zones or services.

By default, rich rules are organized based on their rule action. For example, **deny** rules have precedence over **allow** rules. The **priority** parameter in rich rules provides administrators fine-grained control over rich rules and their execution order. When using the **priority** parameter, rules are sorted first by their priority values in ascending order. When more rules have the same **priority**, their order is determined by the rule action, and if the action is also the same, the order may be undefined.

### 7.11.1. How the priority parameter organizes rules into different chains

You can set the **priority** parameter in a rule to any number between **-32768** and **32767**, and lower numerical values have higher precedence.

The **firewalld** service organizes rules based on their priority value into different chains:

- Priority lower than 0: the rule is redirected into a chain with the **_pre** suffix.
- Priority higher than 0: the rule is redirected into a chain with the **_post** suffix.
- Priority equals 0: based on the action, the rule is redirected into a chain with the **_log**, **_deny**, or **_allow** the action.

Inside these sub-chains, **firewalld** sorts the rules based on their priority value.

#### Additional resources

- `firewalld.richlanguage(5)

### 7.11.2. Setting the priority of a rich rule

The following is an example of how to create a rich rule that uses the **priority** parameter to log all traffic that is not allowed or denied by other rules. You can use this rule to flag unexpected traffic.

#### Procedure

- Add a rich rule with a very low precedence to log all traffic that has not been matched by other rules:

  ```
  # firewall-cmd --add-rich-rule='rule priority=32767 log prefix="UNEXPECTED: " limit
  value="5/m"'
  ```

  The command additionally limits the number of log entries to **5** per minute.

#### Verification

- Display the **nftables** rule that the command in the previous step created:

  ```
  # nft list chain inet firewalld filter_IN_public_post
  table inet firewalld {
    chain filter_IN_public_post {
      log prefix "UNEXPECTED: " limit rate 5/minute
    }
  }
  ```

#### Additional resources

- `firewalld.richlanguage(5)

## 7.12. ENABLING TRAFFIC FORWARDING BETWEEN DIFFERENT INTERFACES OR SOURCES WITHIN A FIREWALLD ZONE

Intra-zone forwarding is a **firewalld** feature that enables traffic forwarding between interfaces or sources within a **firewalld** zone.

### 7.12.1. The difference between intra-zone forwarding and zones with the default target set to ACCEPT

With intra-zone forwarding enabled, the traffic within a single **firewalld** zone can flow from one interface or source to another interface or source. The zone specifies the trust level of interfaces and sources. If the trust level is the same, the traffic stays inside the same zone.

NOTE

Enabling intra-zone forwarding in the default zone of **firewalld**, applies only to the interfaces and sources added to the current default zone.

**firewalld** uses different zones to manage incoming and outgoing traffic. Each zone has its own set of rules and behaviors. For example, the **trusted** zone, allows all forwarded traffic by default.

Other zones can have different default behaviors. In standard zones, forwarded traffic is typically dropped by default when the target of the zone is set to **default**.

To control how the traffic is forwarded between different interfaces or sources within a zone, make sure you understand and configure the target of the zone accordingly.

### 7.12.2. Using intra-zone forwarding to forward traffic between an Ethernet and Wi-Fi network

You can use intra-zone forwarding to forward traffic between interfaces and sources within the same **firewalld** zone. This feature brings the following benefits:

- Seamless connectivity between wired and wireless devices (you can forward traffic between an Ethernet network connected to **enp1s0** and a Wi-Fi network connected to **wlp0s20**)
- Support for flexible work environments
- Shared resources that are accessible and used by multiple devices or users within a network (such as printers, databases, network-attached storage, and others)
- Efficient internal networking (such as smooth communication, reduced latency, resource accessibility, and others)

You can enable this functionality for individual **firewalld** zones.

**Procedure**

1. Enable packet forwarding in the kernel:

```
# echo "net.ipv4.ip_forward=1" > /etc/sysctl.d/95-IPv4-forwarding.conf
# sysctl -p /etc/sysctl.d/95-IPv4-forwarding.conf
```

2. Ensure that interfaces between which you want to enable intra-zone forwarding are assigned only to the **internal** zone:

   ```
   # firewall-cmd --get-active-zones
   ```

3. If the interface is currently assigned to a zone other than **internal**, reassign it:

   ```
   # firewall-cmd --zone=internal --change-interface=interface_name --permanent
   ```

4. Add the **enp1s0** and **wlp0s20** interfaces to the **internal** zone:

   ```
   # firewall-cmd --zone=internal --add-interface=enp1s0 --add-interface=wlp0s20
   ```

5. Enable intra-zone forwarding:

   ```
   # firewall-cmd --zone=internal --add-forward
   ```

### Verification

The following Verification require that the **nmap-ncat** package is installed on both hosts.

1. Log in to a host that is on the same network as the **enp1s0** interface of the host on which you enabled zone forwarding.
2. Start an echo service with **ncat** to test connectivity:

   ```
   # ncat -e /usr/bin/cat -l 12345
   ```

3. Log in to a host that is in the same network as the **wlp0s20** interface.
4. Connect to the echo server running on the host that is in the same network as the **enp1s0**:

   ```
   # ncat <other_host> 12345
   ```

5. Type something and press **Enter**. Verify the text is sent back.

### Additional resources

- **firewalld.zones(5)** man page on your system

## 7.13. CONFIGURING FIREWALLD BY USING RHEL SYSTEM ROLES

RHEL system roles is a set of contents for the Ansible automation utility. This content together with the Ansible automation utility provides a consistent configuration interface to remotely manage multiple systems at once.

The **rhel-system-roles** package contains the **rhel-system-roles.firewall** RHEL system role. This role was introduced for automated configurations of the **firewalld** service.

With the **firewall** RHEL system role you can configure many different **firewalld** parameters, for example:

- Zones

- The services for which packets should be allowed
- Granting, rejection, or dropping of traffic access to ports
- Forwarding of ports or port ranges for a zone

### 7.13.1. Resetting the firewalld settings by using the firewall RHEL system role

Over time, updates to your firewall configuration can accumulate to the point, where they could lead to unintended security risks. With the **firewall** RHEL system role, you can reset the **firewalld** settings to their default state in an automated fashion. This way you can efficiently remove any unintentional or insecure firewall rules and simplify their management.

#### 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: Reset firewalld example
     hosts: managed-node-01.example.com
     tasks:
       - name: Reset firewalld
         ansible.builtin.include_role:
           name: redhat.rhel_system_roles.firewall
         vars:
           firewall:
             - previous: replaced
   ```

   The settings specified in the example playbook include the following:

   **previous: replaced**

   Removes all existing user-defined settings and resets the **firewalld** settings to defaults. If you combine the **previous:replaced** parameter with other settings, the **firewall** role removes all existing settings before applying new ones.
   For details about all variables used in the playbook, see the **/usr/share/ansible/roles/rhel-system-roles.firewall/README.md** file on the control node.

2. Validate the playbook syntax:

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

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

3. Run the playbook:

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

### Verification

- Run this command on the control node to remotely check that all firewall configuration on your managed node was reset to its default values:

  ```
  # ansible managed-node-01.example.com -m ansible.builtin.command -a 'firewall-cmd --list-all-zones'
  ```

### Additional resources

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

## 7.13.2. Forwarding incoming traffic in firewalld from one local port to a different local port by using the firewall RHEL system role

You can use the **firewall** RHEL system role to remotely configure forwarding of incoming traffic from one local port to a different local port.

For example, if you have an environment where multiple services co-exist on the same machine and need the same default port, there are likely to become port conflicts. These conflicts can disrupt services and cause a downtime. With the **firewall** RHEL system role, you can efficiently forward traffic to alternative ports to ensure that your services can run simultaneously without modification to their configuration.

### Prerequisites

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

### Procedure

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

   ```
   ---
   - name: Configure firewalld
     hosts: managed-node-01.example.com
     tasks:
       - name: Forward incoming traffic on port 8080 to 443
         ansible.builtin.include_role:
           name: redhat.rhel_system_roles.firewall
         vars:
           firewall:
             - forward_port: 8080/tcp;443;
               state: enabled
               runtime: true
               permanent: true
   ```

The settings specified in the example playbook include the following:

**forward_port: 8080/tcp;443**
: Traffic coming to the local port 8080 using the TCP protocol is forwarded to the port 443.

**runtime: true**
: Enables changes in the runtime configuration. The default is set to **true**.
For details about all variables used in the playbook, see the **/usr/share/ansible/roles/rhel-system-roles.firewall/README.md** file on the control node.

2. Validate the playbook syntax:

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

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

3. Run the playbook:

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

### Verification

- On the control node, run the following command to remotely check the forwarded-ports on your managed node:

```
# ansible managed-node-01.example.com -m ansible.builtin.command -a 'firewall-cmd
--list-forward-ports'
managed-node-01.example.com | CHANGED | rc=0 >>
port=8080:proto=tcp:toport=443:toaddr=
```

### Additional resources

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

## 7.13.3. Configuring a firewalld DMZ zone by using the firewall RHEL system role

As a system administrator, you can use the **firewall** RHEL system role to configure a **dmz** zone on the **enp1s0** interface to permit **HTTPS** traffic to the zone. In this way, you enable external users to access your web servers.

### Prerequisites

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

### Procedure

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

```
---
- name: Configure firewalld
  hosts: managed-node-01.example.com
  tasks:
    - name: Creating a DMZ with access to HTTPS port and masquerading for hosts in DMZ
      ansible.builtin.include_role:
        name: redhat.rhel_system_roles.firewall
      vars:
        firewall:
          - zone: dmz
            interface: enp1s0
            service: https
            state: enabled
            runtime: true
            permanent: true
```

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

2. Validate the playbook syntax:

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

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

3. Run the playbook:

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

## Verification

- On the control node, run the following command to remotely check the information about the **dmz** zone on your managed node:

```
# ansible managed-node-01.example.com -m ansible.builtin.command -a 'firewall-cmd
--zone=dmz --list-all'
managed-node-01.example.com | CHANGED | rc=0 >>
dmz (active)
  target: default
  icmp-block-inversion: no
  interfaces: enp1s0
  sources:
  services: https ssh
  ports:
  protocols:
  forward: no
  masquerade: no
  forward-ports:
  source-ports:
  icmp-blocks:
```

## Additional resources

Additional resources

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

# CHAPTER 8. GETTING STARTED WITH NFTABLES

The **nftables** framework classifies packets and it is the successor to the **iptables**, **ip6tables**, **arptables**, **ebtables**, and **ipset** utilities. It offers numerous improvements in convenience, features, and performance over previous packet-filtering tools, most notably:

- Built-in lookup tables instead of linear processing
- A single framework for both the **IPv4** and **IPv6** protocols
- All rules applied atomically instead of fetching, updating, and storing a complete rule set
- Support for debugging and tracing in the rule set (**nftrace**) and monitoring trace events (in the **nft** tool)
- More consistent and compact syntax, no protocol-specific extensions
- A Netlink API for third-party applications

The **nftables** framework uses tables to store chains. The chains contain individual rules for performing actions. The **nft** utility replaces all tools from the previous packet-filtering frameworks. You can use the **libnftnl** library for low-level interaction with **nftables** Netlink API through the **libmnl** library.

To display the effect of rule set changes, use the **nft list ruleset** command. Because these utilities add tables, chains, rules, sets, and other objects to the **nftables** rule set, be aware that **nftables** rule-set operations, such as the **nft flush ruleset** command, might affect rule sets installed using the **iptables** command.

## 8.1. CREATING AND MANAGING NFTABLES TABLES, CHAINS, AND RULES

You can display **nftables** rule sets and manage them.

### 8.1.1. Basics of nftables tables

A table in **nftables** is a namespace that contains a collection of chains, rules, sets, and other objects.

Each table must have an address family assigned. The address family defines the packet types that this table processes. You can set one of the following address families when you create a table:

- **ip**: Matches only IPv4 packets. This is the default if you do not specify an address family.
- **ip6**: Matches only IPv6 packets.
- **inet**: Matches both IPv4 and IPv6 packets.
- **arp**: Matches IPv4 address resolution protocol (ARP) packets.
- **bridge**: Matches packets that pass through a bridge device.
- **netdev**: Matches packets from ingress.

If you want to add a table, the format to use depends on your firewall script:

- In scripts in native syntax, use:

```
table <table_address_family> <table_name> {
}
```

- In shell scripts, use:

```
nft add table <table_address_family> <table_name>
```

### 8.1.2. Basics of nftables chains

Tables consist of chains which in turn are containers for rules. The following two rule types exists:

- **Base chain**: You can use base chains as an entry point for packets from the networking stack.
- **Regular chain**: You can use regular chains as a **jump** target to better organize rules.

If you want to add a base chain to a table, the format to use depends on your firewall script:

- In scripts in native syntax, use:

```
table <table_address_family> <table_name> {
  chain <chain_name> {
    type <type> hook <hook> priority <priority>
    policy <policy> ;
  }
}
```

- In shell scripts, use:

```
nft add chain <table_address_family> <table_name> <chain_name> { type <type> hook
<hook> priority <priority> \; policy <policy> \; }
```

  To avoid that the shell interprets the semicolons as the end of the command, place the \ escape character in front of the semicolons.

Both examples create **base chains**. To create a **regular chain**, do not set any parameters in the curly brackets.

**Chain types**

The following are the chain types and an overview with which address families and hooks you can use them:

| Type | Address families | Hooks | Description |
|---|---|---|---|
| **filter** | all | all | Standard chain type |
| **nat** | **ip**, **ip6**, **inet** | **prerouting**, **input**, **output**, **postrouting** | Chains of this type perform native address translation based on connection tracking entries. Only the first packet traverses this chain type. |

| Type | Address families | Hooks | Description |
|---|---|---|---|
| **route** | **ip**, **ip6** | **output** | Accepted packets that traverse this chain type cause a new route lookup if relevant parts of the IP header have changed. |

**Chain priorities**

The priority parameter specifies the order in which packets traverse chains with the same hook value. You can set this parameter to an integer value or use a standard priority name.

The following matrix is an overview of the standard priority names and their numeric values, and with which address families and hooks you can use them:

| Textual value | Numeric value | Address families | Hooks |
|---|---|---|---|
| **raw** | **-300** | **ip**, **ip6**, **inet** | all |
| **mangle** | **-150** | **ip**, **ip6**, **inet** | all |
| **dstnat** | **-100** | **ip**, **ip6**, **inet** | **prerouting** |
|  | **-300** | **bridge** | **prerouting** |
| **filter** | **0** | **ip**, **ip6**, **inet**, **arp**, **netdev** | all |
|  | **-200** | **bridge** | all |
| **security** | **50** | **ip**, **ip6**, **inet** | all |
| **srcnat** | **100** | **ip**, **ip6**, **inet** | **postrouting** |
|  | **300** | **bridge** | **postrouting** |
| **out** | **100** | **bridge** | **output** |

**Chain policies**

The chain policy defines whether **nftables** should accept or drop packets if rules in this chain do not specify any action. You can set one of the following policies in a chain:

- **accept** (default)
- **drop**

## 8.1.3. Basics of nftables rules

Rules define actions to perform on packets that pass a chain that contains this rule. If the rule also contains matching expressions, **nftables** performs the actions only if all previous expressions apply.

If you want to add a rule to a chain, the format to use depends on your firewall script:

- In scripts in native syntax, use:

```
table <table_address_family> <table_name> {
  chain <chain_name> {
    type <type> hook <hook> priority <priority> ; policy <policy> ;
      <rule>
  }
}
```

- In shell scripts, use:

```
nft add rule <table_address_family> <table_name> <chain_name> <rule>
```

This shell command appends the new rule at the end of the chain. If you prefer to add a rule at the beginning of the chain, use the **nft insert** command instead of **nft add**.

### 8.1.4. Managing tables, chains, and rules using nft commands

To manage an **nftables** firewall on the command line or in shell scripts, use the **nft** utility.

IMPORTANT

The commands in this procedure do not represent a typical workflow and are not optimized. This procedure only demonstrates how to use **nft** commands to manage tables, chains, and rules in general.

#### Procedure

1. Create a table named **nftables_svc** with the **inet** address family so that the table can process both IPv4 and IPv6 packets:

```
# nft add table inet nftables_svc
```

2. Add a base chain named **INPUT**, that processes incoming network traffic, to the **inet nftables_svc** table:

```
# nft add chain inet nftables_svc INPUT { type filter hook input priority filter \; policy
accept \; }
```

To avoid that the shell interprets the semicolons as the end of the command, escape the semicolons using the \ character.

3. Add rules to the **INPUT** chain. For example, allow incoming TCP traffic on port 22 and 443, and, as the last rule of the **INPUT** chain, reject other incoming traffic with an Internet Control Message Protocol (ICMP) port unreachable message:

```
# nft add rule inet nftables_svc INPUT tcp dport 22 accept
# nft add rule inet nftables_svc INPUT tcp dport 443 accept
# nft add rule inet nftables_svc INPUT reject with icmpx type port-unreachable
```

If you enter the **nft add rule** commands as shown, **nft** adds the rules in the same order to the chain as you run the commands.

4. Display the current rule set including handles:

```
# nft -a list table inet nftables_svc
table inet nftables_svc { # handle 13
  chain INPUT { # handle 1
    type filter hook input priority filter; policy accept;
    tcp dport 22 accept # handle 2
    tcp dport 443 accept # handle 3
    reject # handle 4
  }
}
```

5. Insert a rule before the existing rule with handle 3. For example, to insert a rule that allows TCP traffic on port 636, enter:

   ```
   # nft insert rule inet nftables_svc INPUT position 3 tcp dport 636 accept
   ```

6. Append a rule after the existing rule with handle 3. For example, to insert a rule that allows TCP traffic on port 80, enter:

   ```
   # nft add rule inet nftables_svc INPUT position 3 tcp dport 80 accept
   ```

7. Display the rule set again with handles. Verify that the later added rules have been added to the specified positions:

   ```
   # nft -a list table inet nftables_svc
   table inet nftables_svc { # handle 13
     chain INPUT { # handle 1
       type filter hook input priority filter; policy accept;
       tcp dport 22 accept # handle 2
       tcp dport 636 accept # handle 5
       tcp dport 443 accept # handle 3
       tcp dport 80 accept # handle 6
       reject # handle 4
     }
   }
   ```

8. Remove the rule with handle 6:

   ```
   # nft delete rule inet nftables_svc INPUT handle 6
   ```

   To remove a rule, you must specify the handle.

9. Display the rule set, and verify that the removed rule is no longer present:

   ```
   # nft -a list table inet nftables_svc
   table inet nftables_svc { # handle 13
     chain INPUT { # handle 1
       type filter hook input priority filter; policy accept;
       tcp dport 22 accept # handle 2
       tcp dport 636 accept # handle 5
       tcp dport 443 accept # handle 3
       reject # handle 4
     }
   }
   ```

10. Remove all remaining rules from the **INPUT** chain:

    ```
    # nft flush chain inet nftables_svc INPUT
    ```

11. Display the rule set, and verify that the **INPUT** chain is empty:

    ```
    # nft list table inet nftables_svc
    table inet nftables_svc {
      chain INPUT {
        type filter hook input priority filter; policy accept
      }
    }
    ```

12. Delete the **INPUT** chain:

    ```
    # nft delete chain inet nftables_svc INPUT
    ```

    You can also use this command to delete chains that still contain rules.

13. Display the rule set, and verify that the **INPUT** chain has been deleted:

    ```
    # nft list table inet nftables_svc
    table inet nftables_svc {
    }
    ```

14. Delete the **nftables_svc** table:

    ```
    # nft delete table inet nftables_svc
    ```

    You can also use this command to delete tables that still contain chains.

> NOTE
>
> To delete the entire rule set, use the **nft flush ruleset** command instead of manually deleting all rules, chains, and tables in separate commands.

**Additional resources**

**nft(8)** man page on your system

## 8.2. MIGRATING FROM IPTABLES TO NFTABLES

If your firewall configuration still uses **iptables** rules, you can migrate your **iptables** rules to **nftables**.

### 8.2.1. When to use firewalld, nftables, or iptables

The following is a brief overview in which scenario you should use one of the following utilities:

- **firewalld**: Use the **firewalld** utility for simple firewall use cases. The utility is easy to use and covers the typical use cases for these scenarios.
- **nftables**: Use the **nftables** utility to set up complex and performance-critical firewalls, such as for a whole network.

- **iptables**: The **iptables** utility on Red Hat Enterprise Linux uses the **nf_tables** kernel API instead of the **legacy** back end. The **nf_tables** API provides backward compatibility so that scripts that use **iptables** commands still work on Red Hat Enterprise Linux. For new firewall scripts, Red Hat recommends to use **nftables**.

IMPORTANT

To prevent the different firewall-related services (**firewalld**, **nftables**, or **iptables**) from influencing each other, run only one of them on a RHEL host, and disable the other services.

### 8.2.2. Concepts in the nftables framework

Compared to the **iptables** framework, **nftables** offers a more modern, efficient, and flexible alternative. There are several concepts and features that provide advanced capabilities and improvements over **iptables**. These enhancements simplify the rule management and improve performance to make **nftables** a modern alternative for complex and high-performance networking environments.

The **nftables** framework contains the following components:

Tables and namespaces

In **nftables**, tables represent organizational units or namespaces that group together related firewall chains, sets, flowtables, and other objects. In **nftables**, tables provide a more flexible way to structure firewall rules and related components. While in **iptables**, the tables were more rigidly defined with specific purposes.

Table families

Each table in **nftables** is associated with a specific family ( **ip**, **ip6**, **inet**, **arp**, **bridge**, or **netdev**). This association determines which packets the table can process. For example, a table in the **ip** family handles only IPv4 packets. On the other hand, **inet** is a special case of table family. It offers a unified approach across protocols, because it can process both IPv4 and IPv6 packets. Another case of a special table family is **netdev**, because it is used for rules that apply directly to network devices, enabling filtering at the device level.

Base chains

Base chains in **nftables** are highly configurable entry-points in the packet processing pipeline that enable users to specify the following:

- Type of chain, for example "filter"
- The hook point in the packet processing path, for example "input", "output", "forward"
- Priority of the chain

This flexibility enables precise control over when and how the rules are applied to packets as they pass through the network stack. A special case of a chain is the **route** chain, which is used to influence the routing decisions made by the kernel, based on packet headers.

Virtual machine for rule processing

The **nftables** framework uses an internal virtual machine to process rules. This virtual machine executes instructions that are similar to assembly language operations (loading data into registers, performing comparisons, and so on). Such a mechanism allows for highly flexible and efficient rule processing.

Enhancements in **nftables** can be introduced as new instructions for that virtual machine. This typically requires a new kernel module and updates to the **libnftnl** library and the **nft** command-line utility.

Alternatively, you can introduce new features by combining existing instructions in innovative ways without a need for kernel modifications. The syntax of **nftables** rules reflects the flexibility of the underlying virtual machine. For example, the rule **meta mark set tcp dport map { 22: 1, 80: 2 }** sets a packet's firewall mark to 1 if the TCP destination port is 22, and to 2 if the port is 80. This demonstrates how complex logic can be expressed concisely.

Lessons learned and enhancements

The **nftables** framework integrates and extends the functionality of the **ipset** utility, which is used in **iptables** for bulk matching on IP addresses, ports, other data types and, most importantly, combinations thereof. This integration makes it easier to manage large and dynamic sets of data directly within **nftables**. Next, **nftables** natively supports matching packets based on multiple values or ranges for any data type, which enhances its capability to handle complex filtering requirements. With **nftables** you can manipulate any field within a packet.

In **nftables**, sets can be either named or anonymous. The named sets can be referenced by multiple rules and modified dynamically. The anonymous sets are defined inline within a rule and are immutable. Sets can contain elements that are combinations of different types, for example IP address and port number pairs. This feature provides greater flexibility in matching complex criteria. To manage sets, the kernel can select the most appropriate backend based on the specific requirements (performance, memory efficiency, and others). Sets can also function as maps with key-value pairs. The value part can be used as data points (values to write into packet headers), or as verdicts or chains to jump to. This enables complex and dynamic rule behaviors, known as "verdict maps".

Flexible rule format

The structure of **nftables** rules is straightforward. The conditions and actions are applied sequentially from left to right. This intuitive format simplifies rule creating and troubleshooting.

Conditions in a rule are logically connected (with the AND operator) together, which means that all conditions must be evaluated as "true" for the rule to match. If any condition fails, the evaluation moves to the next rule.

Actions in **nftables** can be final, such as **drop** or **accept**, which stop further rule processing for the packet. Non-terminal actions, such as **counter log meta mark set 0x3**, perform specific tasks (counting packets, logging, setting a mark, and others), but allow subsequent rules to be evaluated.

#### Additional resources

- **nft(8)** man page
- What comes after iptables? Its successor, of course: nftables
- Firewalld: The Future is nftables

### 8.2.3. Concepts in the deprecated iptables framework

Similar to the actively-maintained **nftables** framework, the deprecated **iptables** framework enables you to perform a variety of packet filtering tasks, logging and auditing, NAT-related configuration tasks, and more.

The **iptables** framework is structured into multiple tables, where each table is designed for a specific purpose:

**filter**

The default table, ensures general packet filtering

**nat**

For Network Address Translation (NAT), includes altering the source and destination addresses of packets

**mangle**

For specific packet alteration, enables you to do modification of packet headers for advanced routing decisions

**raw**

For configurations that need to happen before connection tracking

These tables are implemented as separate kernel modules, where each table offers a fixed set of builtin chains such as **INPUT**, **OUTPUT**, and **FORWARD**. A chain is a sequence of rules that packets are evaluated against. These chains hook into specific points in the packet processing flow in the kernel. The chains have the same names across different tables, however their order of execution is determined by their respective hook priorities. The priorities are managed internally by the kernel to make sure that the rules are applied in the correct sequence.

Originally, **iptables** was designed to process IPv4 traffic. However, with the inception of the IPv6 protocol, the **ip6tables** utility needed to be introduced to provide comparable functionality (as **iptables**) and enable users to create and manage firewall rules for IPv6 packets. With the same logic, the **arptables** utility was created to process Address Resolution Protocol (ARP) and the **ebtables** utility was developed to handle Ethernet bridging frames. These tools ensure that you can apply the packet filtering abilities of **iptables** across various network protocols and provide comprehensive network coverage.

To enhance the functionality of **iptables**, the extensions started to be developed. The functionality extensions are typically implemented as kernel modules that are paired with user-space dynamic shared objects (DSOs). The extensions introduce "matches" and "targets" that you can use in firewall rules to perform more sophisticated operations. Extensions can enable complex matches and targets. For instance you can match on, or manipulate specific layer 4 protocol header values, perform rate-limiting, enforce quotas, and so on. Some extensions are designed to address limitations in the default **iptables** syntax, for example the "multiport" match extension. This extension allows a single rule to match multiple, non-consecutive ports to simplify rule definitions, and thereby reducing the number of individual rules required.

An **ipset** is a special kind of functionality extension to **iptables**. It is a kernel-level data structure that is used together with **iptables** to create collections of IP addresses, port numbers, and other network-related elements that you can match against packets. These sets significantly streamline, optimize, and accelerate the process of writing and managing firewall rules.

#### Additional resources

- **iptables(8)** man page

### 8.2.4. Converting iptables and ip6tables rule sets to nftables

Use the **iptables-restore-translate** and **ip6tables-restore-translate** utilities to translate **iptables** and **ip6tables** rule sets to **nftables**.

#### Prerequisites

- The **nftables** and **iptables** packages are installed.
- The system has **iptables** and **ip6tables** rules configured.

#### Procedure

1. Write the **iptables** and **ip6tables** rules to a file:

   ```
   # iptables-save >/root/iptables.dump
   # ip6tables-save >/root/ip6tables.dump
   ```

2. Convert the dump files to **nftables** instructions:

   ```
   # iptables-restore-translate -f /root/iptables.dump > /etc/nftables/ruleset-migrated-from-iptables.nft
   # ip6tables-restore-translate -f /root/ip6tables.dump > /etc/nftables/ruleset-migrated-from-ip6tables.nft
   ```

3. Review and, if needed, manually update the generated **nftables** rules.

4. To enable the **nftables** service to load the generated files, add the following to the **/etc/sysconfig/nftables.conf** file:

   ```
   include "/etc/nftables/ruleset-migrated-from-iptables.nft"
   include "/etc/nftables/ruleset-migrated-from-ip6tables.nft"
   ```

5. Stop and disable the **iptables** service:

   ```
   # systemctl disable --now iptables
   ```

   If you used a custom script to load the **iptables** rules, ensure that the script no longer starts automatically and reboot to flush all tables.

6. Enable and start the **nftables** service:

   ```
   # systemctl enable --now nftables
   ```

#### Verification

- Display the **nftables** rule set:

  ```
  # nft list ruleset
  ```

#### Additional resources

- Automatically loading nftables rules when the system boots

### 8.2.5. Converting single iptables and ip6tables rules to nftables

Red Hat Enterprise Linux provides the **iptables-translate** and **ip6tables-translate** utilities to convert an **iptables** or **ip6tables** rule into the equivalent one for **nftables**.

#### Prerequisites

- The **nftables** package is installed.

#### Procedure

- Use the **iptables-translate** or **ip6tables-translate** utility instead of **iptables** or **ip6tables** to display the corresponding **nftables** rule, for example:

  ```
  # iptables-translate -A INPUT -s 192.0.2.0/24 -j ACCEPT
  nft add rule ip filter INPUT ip saddr 192.0.2.0/24 counter accept
  ```

  Note that some extensions lack translation support. In these cases, the utility prints the untranslated rule prefixed with the **#** sign, for example:

  ```
  # iptables-translate -A INPUT -j CHECKSUM --checksum-fill
  nft # -A INPUT -j CHECKSUM --checksum-fill
  ```

**Additional resources**

- **iptables-translate --help**

### 8.2.6. Comparison of common iptables and nftables commands

The following is a comparison of common **iptables** and **nftables** commands:

- Listing all rules:

| iptables | nftables |
|---|---|
| **iptables-save** | **nft list ruleset** |

- Listing a certain table and chain:

| iptables | nftables |
|---|---|
| **iptables -L** | **nft list table ip filter** |
| **iptables -L INPUT** | **nft list chain ip filter INPUT** |
| **iptables -t nat -L PREROUTING** | **nft list chain ip nat PREROUTING** |

  The **nft** command does not pre-create tables and chains. They exist only if a user created them manually.

  Listing rules generated by firewalld:

  ```
  # nft list table inet firewalld
  # nft list table ip firewalld
  # nft list table ip6 firewalld
  ```

## 8.3. CONFIGURING NAT USING NFTABLES

With **nftables**, you can configure the following network address translation (NAT) types:

- Masquerading

- Source NAT (SNAT)
- Destination NAT (DNAT)
- Redirect

IMPORTANT

You can only use real interface names in **iifname** and **oifname** parameters, and alternative names (**altname**) are not supported.

### 8.3.1. NAT types

These are the different network address translation (NAT) types:

**Masquerading and source NAT (SNAT)**

Use one of these NAT types to change the source IP address of packets. For example, Internet Service Providers (ISPs) do not route private IP ranges, such as **10.0.0.0/8**. If you use private IP ranges in your network and users should be able to reach servers on the internet, map the source IP address of packets from these ranges to a public IP address.
Masquerading and SNAT are very similar to one another. The differences are:

- Masquerading automatically uses the IP address of the outgoing interface. Therefore, use masquerading if the outgoing interface uses a dynamic IP address.
- SNAT sets the source IP address of packets to a specified IP and does not dynamically look up the IP of the outgoing interface. Therefore, SNAT is faster than masquerading. Use SNAT if the outgoing interface uses a fixed IP address.

**Destination NAT (DNAT)**

Use this NAT type to rewrite the destination address and port of incoming packets. For example, if your web server uses an IP address from a private IP range and is, therefore, not directly accessible from the internet, you can set a DNAT rule on the router to redirect incoming traffic to this server.

**Redirect**

This type is a special case of DNAT that redirects packets to the local machine depending on the chain hook. For example, if a service runs on a different port than its standard port, you can redirect incoming traffic from the standard port to this specific port.

### 8.3.2. Configuring masquerading using nftables

Masquerading enables a router to dynamically change the source IP of packets sent through an interface to the IP address of the interface. This means that if the interface gets a new IP assigned, **nftables** automatically uses the new IP when replacing the source IP.

Replace the source IP of packets leaving the host through the **ens3** interface to the IP set on **ens3**.

**Procedure**

1. Create a table:

```
# nft add table nat
```

2. Add the **prerouting** and **postrouting** chains to the table:

```
# nft add chain nat postrouting { type nat hook postrouting priority 100 \; }
```

IMPORTANT

Even if you do not add a rule to the **prerouting** chain, the **nftables** framework requires this chain to match incoming packet replies.

Note that you must pass the **--** option to the **nft** command to prevent the shell from interpreting the negative priority value as an option of the **nft** command.

3. Add a rule to the **postrouting** chain that matches outgoing packets on the **ens3** interface:

```
# nft add rule nat postrouting oifname "ens3" masquerade
```

### 8.3.3. Configuring source NAT using nftables

On a router, Source NAT (SNAT) enables you to change the IP of packets sent through an interface to a specific IP address. The router then replaces the source IP of outgoing packets.

#### Procedure

1. Create a table:

```
# nft add table nat
```

2. Add the **prerouting** and **postrouting** chains to the table:

```
# nft add chain nat postrouting { type nat hook postrouting priority 100 \; }
```

IMPORTANT

Even if you do not add a rule to the **postrouting** chain, the **nftables** framework requires this chain to match outgoing packet replies.

Note that you must pass the **--** option to the **nft** command to prevent the shell from interpreting the negative priority value as an option of the **nft** command.

3. Add a rule to the **postrouting** chain that replaces the source IP of outgoing packets through **ens3** with **192.0.2.1**:

```
# nft add rule nat postrouting oifname "ens3" snat to 192.0.2.1
```

### 8.3.4. Configuring destination NAT using nftables

Destination NAT (DNAT) enables you to redirect traffic on a router to a host that is not directly accessible from the internet.

For example, with DNAT the router redirects incoming traffic sent to port **80** and **443** to a web server with the IP address **192.0.2.1**.

#### Procedure

1. Create a table:

   ```
   # nft add table nat
   ```

2. Add the **prerouting** and **postrouting** chains to the table:

   ```
   # nft -- add chain nat prerouting { type nat hook prerouting priority -100 \; }
   # nft add chain nat postrouting { type nat hook postrouting priority 100 \; }
   ```

   IMPORTANT

   Even if you do not add a rule to the **postrouting** chain, the **nftables** framework requires this chain to match outgoing packet replies.

   Note that you must pass the **--** option to the **nft** command to prevent the shell from interpreting the negative priority value as an option of the **nft** command.

3. Add a rule to the **prerouting** chain that redirects incoming traffic to port **80** and **443** on the **ens3** interface of the router to the web server with the IP address **192.0.2.1**:

   ```
   # nft add rule nat prerouting iifname ens3 tcp dport { 80, 443 } dnat to 192.0.2.1
   ```

4. Depending on your environment, add either a SNAT or masquerading rule to change the source address for packets returning from the web server to the sender:

   a. If the **ens3** interface uses a dynamic IP addresses, add a masquerading rule:

      ```
      # nft add rule nat postrouting oifname "ens3" masquerade
      ```

   b. If the **ens3** interface uses a static IP address, add a SNAT rule. For example, if the **ens3** uses the **198.51.100.1** IP address:

      ```
      # nft add rule nat postrouting oifname "ens3" snat to 198.51.100.1
      ```

5. Enable packet forwarding:

   ```
   # echo "net.ipv4.ip_forward=1" > /etc/sysctl.d/95-IPv4-forwarding.conf
   # sysctl -p /etc/sysctl.d/95-IPv4-forwarding.conf
   ```

**Additional resources**

- NAT types

### 8.3.5. Configuring a redirect using nftables

The **redirect** feature is a special case of destination network address translation (DNAT) that redirects packets to the local machine depending on the chain hook.

For example, you can redirect incoming and forwarded traffic sent to port **22** of the local host to port **2222**.

**Procedure**

1. Create a table:

   ```
   # nft add table nat
   ```

2. Add the **prerouting** chain to the table:

   ```
   # nft -- add chain nat prerouting { type nat hook prerouting priority -100 \; }
   ```

   Note that you must pass the **--** option to the **nft** command to prevent the shell from interpreting the negative priority value as an option of the **nft** command.

3. Add a rule to the **prerouting** chain that redirects incoming traffic on port **22** to port **2222**:

   ```
   # nft add rule nat prerouting tcp dport 22 redirect to 2222
   ```

**Additional resources**

- NAT types

## 8.4. WRITING AND EXECUTING NFTABLES SCRIPTS

The major benefit of using the **nftables** framework is that the execution of scripts is atomic. This means that the system either applies the whole script or prevents the execution if an error occurs. This guarantees that the firewall is always in a consistent state.

Additionally, with the **nftables** script environment, you can:

- Add comments
- Define variables
- Include other rule-set files

When you install the **nftables** package, Red Hat Enterprise Linux automatically creates ***.nft** scripts in the **/etc/nftables/** directory. These scripts contain commands that create tables and empty chains for different purposes.

### 8.4.1. Supported nftables script formats

You can write scripts in the **nftables** scripting environment in the following formats:

- The same format as the **nft list ruleset** command displays the rule set:

  ```
  #!/usr/sbin/nft -f

  # Flush the rule set
  flush ruleset

  table inet example_table {
    chain example_chain {
      # Chain for incoming packets that drops all packets that
      # are not explicitly allowed by any rule in this chain
      type filter hook input priority 0; policy drop;
  ```

```
    # Accept connections to port 22 (ssh)
    tcp dport ssh accept
  }
}
```

- The same syntax as for **nft** commands:

```
#!/usr/sbin/nft -f

# Flush the rule set
flush ruleset

# Create a table
add table inet example_table

# Create a chain for incoming packets that drops all packets
# that are not explicitly allowed by any rule in this chain
add chain inet example_table example_chain { type filter hook input priority 0 ; policy drop ; }

# Add a rule that accepts connections to port 22 (ssh)
add rule inet example_table example_chain tcp dport ssh accept
```

## 8.4.2. Running nftables scripts

You can run an **nftables** script either by passing it to the **nft** utility or by executing the script directly.

### Procedure

- To run an **nftables** script by passing it to the **nft** utility, enter:

```
# nft -f /etc/nftables/<example_firewall_script>.nft
```

- To run an **nftables** script directly:

  a. For the single time that you perform this:

     i. Ensure that the script starts with the following shebang sequence:

```
#!/usr/sbin/nft -f
```

> **IMPORTANT**
>
> If you omit the **-f** parameter, the **nft** utility does not read the script and displays: **Error: syntax error, unexpected newline, expecting string**.

     ii. Optional: Set the owner of the script to **root**:

```
# chown root /etc/nftables/<example_firewall_script>.nft
```

     iii. Make the script executable for the owner:

```
# chmod u+x /etc/nftables/<example_firewall_script>.nft
```

b. Run the script:

```
# /etc/nftables/<example_firewall_script>.nft
```

If no output is displayed, the system executed the script successfully.

IMPORTANT

Even if **nft** executes the script successfully, incorrectly placed rules, missing parameters, or other problems in the script can cause that the firewall behaves not as expected.

**Additional resources**

- **chown(1)** and **chmod(1)** man pages on your system
- Automatically loading nftables rules when the system boots

## 8.4.3. Using comments in nftables scripts

The **nftables** scripting environment interprets everything to the right of a **#** character to the end of a line as a comment.

Comments can start at the beginning of a line, or next to a command:

```
...
# Flush the rule set
flush ruleset

add table inet example_table  # Create a table
...
```

## 8.4.4. Using variables in nftables script

To define a variable in an **nftables** script, use the **define** keyword. You can store single values and anonymous sets in a variable. For more complex scenarios, use sets or verdict maps.

**Variables with a single value**

The following example defines a variable named **INET_DEV** with the value **enp1s0**:

```
define INET_DEV = enp1s0
```

You can use the variable in the script by entering the **$** sign followed by the variable name:

```
...
add rule inet example_table example_chain iifname $INET_DEV tcp dport ssh accept
...
```

**Variables that contain an anonymous set**

The following example defines a variable that contains an anonymous set:

```
define DNS_SERVERS = { 192.0.2.1, 192.0.2.2 }
```

You can use the variable in the script by writing the **$** sign followed by the variable name:

```
add rule inet example_table example_chain ip daddr $DNS_SERVERS accept
```

NOTE

Curly braces have special semantics when you use them in a rule because they indicate that the variable represents a set.

### Additional resources

- Using sets in nftables commands
- Using verdict maps in nftables commands

### 8.4.5. Including files in nftables scripts

In the **nftables** scripting environment, you can include other scripts by using the **include** statement.

If you specify only a file name without an absolute or relative path, **nftables** includes files from the default search path, which is set to **/etc** on Red Hat Enterprise Linux.

**Example 8.1. Including files from the default search directory**

To include a file from the default search directory:

```
include "example.nft"
```

**Example 8.2. Including all *.nft files from a directory**

To include all files ending with ***.nft** that are stored in the **/etc/nftables/rulesets/** directory:

```
include "/etc/nftables/rulesets/*.nft"
```

Note that the **include** statement does not match files beginning with a dot.

### Additional resources

- The **Include files** section in the **nft(8)** man page on your system

### 8.4.6. Automatically loading nftables rules when the system boots

The **nftables** systemd service loads firewall scripts that are included in the **/etc/sysconfig/nftables.conf** file.

### Prerequisites

- The **nftables** scripts are stored in the **/etc/nftables/** directory.

### Procedure

1. Edit the **/etc/sysconfig/nftables.conf** file.

   - If you modified the ***.nft** scripts that were created in **/etc/nftables/** with the installation of the **nftables** package, uncomment the **include** statement for these scripts.
   - If you wrote new scripts, add **include** statements to include these scripts. For example, to load the **/etc/nftables/*example*.nft** script when the **nftables** service starts, add:

     ```
     include "/etc/nftables/_example_.nft"
     ```

2. Optional: Start the **nftables** service to load the firewall rules without rebooting the system:

   ```
   # systemctl start nftables
   ```

3. Enable the **nftables** service.

   ```
   # systemctl enable nftables
   ```

### Additional resources

- Supported nftables script formats

## 8.5. USING SETS IN NFTABLES COMMANDS

The **nftables** framework natively supports sets. You can use sets, for example, if a rule should match multiple IP addresses, port numbers, interfaces, or any other match criteria.

### 8.5.1. Using anonymous sets in nftables

An anonymous set contains comma-separated values enclosed in curly brackets, such as **{ 22, 80, 443 }**, that you use directly in a rule. You can use anonymous sets also for IP addresses and any other match criteria.

The drawback of anonymous sets is that if you want to change the set, you must replace the rule. For a dynamic solution, use named sets as described in Using named sets in nftables .

#### Prerequisites

- The **example_chain** chain and the **example_table** table in the **inet** family exists.

#### Procedure

1. For example, to add a rule to **example_chain** in **example_table** that allows incoming traffic to port **22**, **80**, and **443**:

   ```
   # nft add rule inet example_table example_chain tcp dport { 22, 80, 443 } accept
   ```

2. Optional: Display all chains and their rules in **example_table**:

   ```
   # nft list table inet example_table
   table inet example_table {
   ```

```
  chain example_chain {
    type filter hook input priority filter; policy accept;
    tcp dport { ssh, http, https } accept
  }
}
```

### 8.5.2. Using named sets in nftables

The **nftables** framework supports mutable named sets. A named set is a list or range of elements that you can use in multiple rules within a table. Another benefit over anonymous sets is that you can update a named set without replacing the rules that use the set.

When you create a named set, you must specify the type of elements the set contains. You can set the following types:

- **ipv4_addr** for a set that contains IPv4 addresses or ranges, such as **192.0.2.1** or **192.0.2.0/24**.
- **ipv6_addr** for a set that contains IPv6 addresses or ranges, such as **2001:db8:1::1** or **2001:db8:1::1/64**.
- **ether_addr** for a set that contains a list of media access control (MAC) addresses, such as **52:54:00:6b:66:42**.
- **inet_proto** for a set that contains a list of internet protocol types, such as **tcp**.
- **inet_service** for a set that contains a list of internet services, such as **ssh**.
- **mark** for a set that contains a list of packet marks. Packet marks can be any positive 32-bit integer value (**0** to **2147483647**).

#### Prerequisites

- The **example_chain** chain and the **example_table** table exists.

#### Procedure

1. Create an empty set. The following examples create a set for IPv4 addresses:
   - To create a set that can store multiple individual IPv4 addresses:

     ```
     # nft add set inet example_table example_set { type ipv4_addr \; }
     ```

   - To create a set that can store IPv4 address ranges:

     ```
     # nft add set inet example_table example_set { type ipv4_addr \; flags interval \; }
     ```

   **IMPORTANT**

   To prevent the shell from interpreting the semicolons as the end of the command, you must escape the semicolons with a backslash.

2. Optional: Create rules that use the set. For example, the following command adds a rule to the **example_chain** in the **example_table** that will drop all packets from IPv4 addresses in **example_set**.

```
# nft add rule inet example_table example_chain ip saddr @example_set drop
```

Because **example_set** is still empty, the rule has currently no effect.

3. Add IPv4 addresses to **example_set**:
   - If you create a set that stores individual IPv4 addresses, enter:

     ```
     # nft add element inet example_table example_set { 192.0.2.1, 192.0.2.2 }
     ```

   - If you create a set that stores IPv4 ranges, enter:

     ```
     # nft add element inet example_table example_set { 192.0.2.0-192.0.2.255 }
     ```

     When you specify an IP address range, you can alternatively use the Classless Inter-Domain Routing (CIDR) notation, such as **192.0.2.0/24** in the above example.

### 8.5.3. Using dynamic sets to add entries from the packet path

Dynamic sets in the **nftables** framework allow automatic addition of elements from packet data. For example, IP addresses, destination ports, MAC addresses, and others. This functionality enables you to collect those elements in real-time and use them to create deny lists, ban lists, and others so that you can instantly react to security threats.

#### Prerequisites

- The **example_chain** chain and the **example_table** table in the **inet** family exist.

#### Procedure

1. Create an empty set. The following examples create a set for IPv4 addresses:
   - To create a set that can store multiple individual IPv4 addresses:

     ```
     # nft add set inet example_table example_set { type ipv4_addr \; }
     ```

   - To create a set that can store IPv4 address ranges:

     ```
     # nft add set inet example_table example_set { type ipv4_addr \; flags interval \; }
     ```

   IMPORTANT

   To prevent the shell from interpreting the semicolons as the end of the command, you must escape the semicolons with a backslash.

2. Create a rule for dynamically adding the source IPv4 addresses of incoming packets to the **example_set** set:

   ```
   # nft add rule inet example_table example_chain set add ip saddr @example_set
   ```

   The command creates a new rule within the **example_chain** rule chain and the **example_table** to dynamically add the source IPv4 address of the packet to the **example_set**.

#### Verification

- Ensure the rule was added:

```
# nft list ruleset
...
table ip example_table {
 set example_set {
  type ipv4_addr
  elements = { 192.0.2.250, 192.0.2.251 }
 }

 chain example_chain {
    type filter hook input priority 0
  add @example_set { ip saddr }
 }
}
```

  The command displays the entire ruleset currently loaded in **nftables**. It shows that IPs are actively triggering the rule, and **example_set** is being updated with the relevant addresses.

#### Next steps

Once you have a dynamic set of IPs, you can use it for various security, filtering, and traffic control purposes. For example:

- block, limit, or log network traffic
- combine with allow-listing to avoid banning trusted users
- use automatic timeouts to prevent over-blocking

### 8.5.4. Additional resources

- The **Sets** section in the **nft(8)** man page on your system

## 8.6. USING VERDICT MAPS IN NFTABLES COMMANDS

Verdict maps, which are also known as dictionaries, enable **nft** to perform an action based on packet information by mapping match criteria to an action.

### 8.6.1. Using anonymous maps in nftables

An anonymous map is a **{ *match_criteria* : *action* }** statement that you use directly in a rule. The statement can contain multiple comma-separated mappings.

The drawback of an anonymous map is that if you want to change the map, you must replace the rule. For a dynamic solution, use named maps as described in Using named maps in nftables .

For example, you can use an anonymous map to route both TCP and UDP packets of the IPv4 and IPv6 protocol to different chains to count incoming TCP and UDP packets separately.

#### Procedure

1. Create a new table:

```
# nft add table inet example_table
```

2. Create the **tcp_packets** chain in **example_table**:

```
# nft add chain inet example_table tcp_packets
```

3. Add a rule to **tcp_packets** that counts the traffic in this chain:

```
# nft add rule inet example_table tcp_packets counter
```

4. Create the **udp_packets** chain in **example_table**

```
# nft add chain inet example_table udp_packets
```

5. Add a rule to **udp_packets** that counts the traffic in this chain:

```
# nft add rule inet example_table udp_packets counter
```

6. Create a chain for incoming traffic. For example, to create a chain named **incoming_traffic** in **example_table** that filters incoming traffic:

```
# nft add chain inet example_table incoming_traffic { type filter hook input priority 0 \;
}
```

7. Add a rule with an anonymous map to **incoming_traffic**:

```
# nft add rule inet example_table incoming_traffic ip protocol vmap { tcp : jump
tcp_packets, udp : jump udp_packets }
```

The anonymous map distinguishes the packets and sends them to the different counter chains based on their protocol.

8. To list the traffic counters, display **example_table**:

```
# nft list table inet example_table
table inet example_table {
  chain tcp_packets {
    counter packets 36379 bytes 2103816
  }

  chain udp_packets {
    counter packets 10 bytes 1559
  }

  chain incoming_traffic {
    type filter hook input priority filter; policy accept;
    ip protocol vmap { tcp : jump tcp_packets, udp : jump udp_packets }
  }
}
```

The counters in the **tcp_packets** and **udp_packets** chain display both the number of received packets and bytes.

## 8.6.2. Using named maps in nftables

The **nftables** framework supports named maps. You can use these maps in multiple rules within a table. Another benefit over anonymous maps is that you can update a named map without replacing the rules that use it.

When you create a named map, you must specify the type of elements:

- **ipv4_addr** for a map whose match part contains an IPv4 address, such as **192.0.2.1**.
- **ipv6_addr** for a map whose match part contains an IPv6 address, such as **2001:db8:1::1**.
- **ether_addr** for a map whose match part contains a media access control (MAC) address, such as **52:54:00:6b:66:42**.
- **inet_proto** for a map whose match part contains an internet protocol type, such as **tcp**.
- **inet_service** for a map whose match part contains an internet services name port number, such as **ssh** or **22**.
- **mark** for a map whose match part contains a packet mark. A packet mark can be any positive 32-bit integer value (**0** to **2147483647**).
- **counter** for a map whose match part contains a counter value. The counter value can be any positive 64-bit integer value.
- **quota** for a map whose match part contains a quota value. The quota value can be any positive 64-bit integer value.

For example, you can allow or drop incoming packets based on their source IP address. Using a named map, you require only a single rule to configure this scenario while the IP addresses and actions are dynamically stored in the map.

### Procedure

1. Create a table. For example, to create a table named **example_table** that processes IPv4 packets:

   ```
   # nft add table ip example_table
   ```

2. Create a chain. For example, to create a chain named **example_chain** in **example_table**:

   ```
   # nft add chain ip example_table example_chain { type filter hook input priority 0 \; }
   ```

   **IMPORTANT**

   To prevent the shell from interpreting the semicolons as the end of the command, you must escape the semicolons with a backslash.

3. Create an empty map. For example, to create a map for IPv4 addresses:

   ```
   # nft add map ip example_table example_map { type ipv4_addr : verdict \; }
   ```

4. [illegible]

4. Create rules that use the map. For example, the following command adds a rule to **example_chain** in **example_table** that applies actions to IPv4 addresses which are both defined in **example_map**:

   ```
   # nft add rule example_table example_chain ip saddr vmap @example_map
   ```

5. Add IPv4 addresses and corresponding actions to **example_map**:

   ```
   # nft add element ip example_table example_map { 192.0.2.1 : accept, 192.0.2.2 : drop }
   ```

   This example defines the mappings of IPv4 addresses to actions. In combination with the rule created above, the firewall accepts packet from **192.0.2.1** and drops packets from **192.0.2.2**.

6. Optional: Enhance the map by adding another IP address and action statement:

   ```
   # nft add element ip example_table example_map { 192.0.2.3 : accept }
   ```

7. Optional: Remove an entry from the map:

   ```
   # nft delete element ip example_table example_map { 192.0.2.1 }
   ```

8. Optional: Display the rule set:

   ```
   # nft list ruleset
   table ip example_table {
     map example_map {
       type ipv4_addr : verdict
       elements = { 192.0.2.2 : drop, 192.0.2.3 : accept }
     }

     chain example_chain {
       type filter hook input priority filter; policy accept;
       ip saddr vmap @example_map
     }
   }
   ```

### 8.6.3. Additional resources

- The **Maps** section in the **nft(8)** man page on your system

## 8.7. EXAMPLE: PROTECTING A LAN AND DMZ USING AN NFTABLES SCRIPT

Use the **nftables** framework on a RHEL router to write and install a firewall script that protects the network clients in an internal LAN and a web server in a DMZ from unauthorized access from the internet and from other networks.

IMPORTANT

This example is only for demonstration purposes and describes a scenario with specific requirements.

Firewall scripts highly depend on the network infrastructure and security requirements. Use this example to learn the concepts of **nftables** firewalls when you write scripts for your own environment.

### 8.7.1. Network conditions

The network in this example has the following conditions:

- The router is connected to the following networks:
  - The internet through interface **enp1s0**
  - The internal LAN through interface **enp7s0**
  - The DMZ through **enp8s0**
- The internet interface of the router has both a static IPv4 address (**203.0.113.1**) and IPv6 address (**2001:db8:a::1**) assigned.
- The clients in the internal LAN use only private IPv4 addresses from the range **10.0.0.0/24**. Consequently, traffic from the LAN to the internet requires source network address translation (SNAT).
- The administrator PCs in the internal LAN use the IP addresses **10.0.0.100** and **10.0.0.200**.
- The DMZ uses public IP addresses from the ranges **198.51.100.0/24** and **2001:db8:b::/56**.
- The web server in the DMZ uses the IP addresses **198.51.100.5** and **2001:db8:b::5**.
- The router acts as a caching DNS server for hosts in the LAN and DMZ.

### 8.7.2. Security requirements to the firewall script

The following are the requirements to the **nftables** firewall in the example network:

- The router must be able to:
  - Recursively resolve DNS queries.
  - Perform all connections on the loopback interface.
- Clients in the internal LAN must be able to:
  - Query the caching DNS server running on the router.
  - Access the HTTPS server in the DMZ.
  - Access any HTTPS server on the internet.
- The PCs of the administrators must be able to access the router and every server in the DMZ using SSH.

- The web server in the DMZ must be able to:
  - Query the caching DNS server running on the router.
  - Access HTTPS servers on the internet to download updates.
- Hosts on the internet must be able to:
  - Access the HTTPS servers in the DMZ.
- Additionally, the following security requirements exists:
  - Connection attempts that are not explicitly allowed should be dropped.
  - Dropped packets should be logged.

### 8.7.3. Configuring logging of dropped packets to a file

By default, **systemd** logs kernel messages, such as for dropped packets, to the journal. Additionally, you can configure the **rsyslog** service to log such entries to a separate file. To ensure that the log file does not grow infinitely, configure a rotation policy.

#### Prerequisites

- The **rsyslog** package is installed.
- The **rsyslog** service is running.

#### Procedure

1. Create the **/etc/rsyslog.d/nftables.conf** file with the following content:

   ```
   :msg, startswith, "nft drop" -/var/log/nftables.log
   & stop
   ```

   Using this configuration, the **rsyslog** service logs dropped packets to the **/var/log/nftables.log** file instead of **/var/log/messages**.

2. Restart the **rsyslog** service:

   ```
   # systemctl restart rsyslog
   ```

3. Create the **/etc/logrotate.d/nftables** file with the following content to rotate **/var/log/nftables.log** if the size exceeds 10 MB:

   ```
   /var/log/nftables.log {
     size +10M
     maxage 30
     sharedscripts
     postrotate
       /usr/bin/systemctl kill -s HUP rsyslog.service >/dev/null 2>&1 || true
     endscript
   }
   ```

The **maxage 30** setting defines that **logrotate** removes rotated logs older than 30 days during the next rotation operation.

**Additional resources**

- **rsyslog.conf(5)** and **logrotate(8)** man pages on your system

### 8.7.4. Writing and activating the nftables script

This example is an **nftables** firewall script that runs on a RHEL router and protects the clients in an internal LAN and a web server in a DMZ. For details about the network and the requirements for the firewall used in the example, see Network conditions and Security requirements to the firewall script .

**WARNING**

This **nftables** firewall script is only for demonstration purposes. Do not use it without adapting it to your environments and security requirements.

**Prerequisites**

- The network is configured as described in Network conditions.

**Procedure**

1. Create the **/etc/nftables/firewall.nft** script with the following content:

```
# Remove all rules
flush ruleset


# Table for both IPv4 and IPv6 rules
table inet nftables_svc {

  # Define variables for the interface name
  define INET_DEV = enp1s0
  define LAN_DEV  = enp7s0
  define DMZ_DEV  = enp8s0


  # Set with the IPv4 addresses of admin PCs
  set admin_pc_ipv4 {
    type ipv4_addr
    elements = { 10.0.0.100, 10.0.0.200 }
  }


  # Chain for incoming trafic. Default policy: drop
  chain INPUT {
    type filter hook input priority filter
    policy drop
  # Accept packets in established and related state, drop invalid packets
  ct state vmap { established:accept, related:accept, invalid:drop }

  # Accept incoming traffic on loopback interface
  iifname lo accept

  # Allow request from LAN and DMZ to local DNS server
  iifname { $LAN_DEV, $DMZ_DEV } meta l4proto { tcp, udp } th dport 53 accept

  # Allow admins PCs to access the router using SSH
  iifname $LAN_DEV ip saddr @admin_pc_ipv4 tcp dport 22 accept

  # Last action: Log blocked packets
  # (packets that were not accepted in previous rules in this chain)
  log prefix "nft drop IN : "
 }


 # Chain for outgoing traffic. Default policy: drop
 chain OUTPUT {
  type filter hook output priority filter
  policy drop

  # Accept packets in established and related state, drop invalid packets
  ct state vmap { established:accept, related:accept, invalid:drop }

  # Accept outgoing traffic on loopback interface
  oifname lo accept

  # Allow local DNS server to recursively resolve queries
  oifname $INET_DEV meta l4proto { tcp, udp } th dport 53 accept

  # Last action: Log blocked packets
  log prefix "nft drop OUT: "
 }


 # Chain for forwarding traffic. Default policy: drop
 chain FORWARD {
  type filter hook forward priority filter
  policy drop

  # Accept packets in established and related state, drop invalid packets
  ct state vmap { established:accept, related:accept, invalid:drop }

  # IPv4 access from LAN and internet to the HTTPS server in the DMZ
  iifname { $LAN_DEV, $INET_DEV } oifname $DMZ_DEV ip daddr 198.51.100.5 tcp dport
443 accept

  # IPv6 access from internet to the HTTPS server in the DMZ
  iifname $INET_DEV oifname $DMZ_DEV ip6 daddr 2001:db8:b::5 tcp dport 443 accept

  # Access from LAN and DMZ to HTTPS servers on the internet
  iifname { $LAN_DEV, $DMZ_DEV } oifname $INET_DEV tcp dport 443 accept
```

```
    # Last action: Log blocked packets
    log prefix "nft drop FWD: "
  }


  # Postrouting chain to handle SNAT
  chain postrouting {
    type nat hook postrouting priority srcnat; policy accept;

    # SNAT for IPv4 traffic from LAN to internet
    iifname $LAN_DEV oifname $INET_DEV snat ip to 203.0.113.1
  }
}
```

2. Include the **/etc/nftables/firewall.nft** script in the **/etc/sysconfig/nftables.conf** file:

```
include "/etc/nftables/firewall.nft"
```

3. Enable IPv4 forwarding:

```
# echo "net.ipv4.ip_forward=1" > /etc/sysctl.d/95-IPv4-forwarding.conf
# sysctl -p /etc/sysctl.d/95-IPv4-forwarding.conf
```

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

```
# systemctl enable --now nftables
```

**Verification**

1. Optional: Verify the **nftables** rule set:

```
# nft list ruleset
...
```

2. Try to perform an access that the firewall prevents. For example, try to access the router using SSH from the DMZ:

```
# ssh router.example.com
ssh: connect to host router.example.com port 22: Network is unreachable
```

3. Depending on your logging settings, search:
   - The **systemd** journal for the blocked packets:

   ```
   # journalctl -k -g "nft drop"
   Oct 14 17:27:18 router kernel: nft drop IN : IN=enp8s0 OUT= MAC=...
   SRC=198.51.100.5 DST=198.51.100.1 ... PROTO=TCP SPT=40464 DPT=22 ... SYN ...
   ```

   - The **/var/log/nftables.log** file for the blocked packets:

   ```
   Oct 14 17:27:18 router kernel: nft drop IN : IN=enp8s0 OUT= MAC=...
   SRC=198.51.100.5 DST=198.51.100.1 ... PROTO=TCP SPT=40464 DPT=22 ... SYN ...
   ```

## 8.8. USING NFTABLES TO LIMIT THE AMOUNT OF CONNECTIONS

You can use **nftables** to limit the number of connections or to block IP addresses that attempt to establish a given amount of connections to prevent them from using too many system resources.

### 8.8.1. Limiting the number of connections by using nftables

By using the **ct count** parameter of the **nft** utility, you can limit the number of simultaneous connections per IP address. For example, you can use this feature to configure that each source IP address can only establish two parallel SSH connections to a host.

#### Procedure

1. Create the **filter** table with the **inet** address family:

```
# nft add table inet filter
```

2. Add the **input** chain to the **inet filter** table:

```
# nft add chain inet filter input { type filter hook input priority 0 \; }
```

3. Create a dynamic set for IPv4 addresses:

```
# nft add set inet filter limit-ssh { type ipv4_addr\; flags dynamic \;}
```

4. Add a rule to the **input** chain that allows only two simultaneous incoming connections to the SSH port (22) from an IPv4 address and rejects all further connections from the same IP:

```
# nft add rule inet filter input tcp dport ssh ct state new add @limit-ssh { ip saddr ct
count over 2 } counter reject
```

#### Verification

1. Establish more than two new simultaneous SSH connections from the same IP address to the host. Nftables refuses connections to the SSH port if two connections are already established.

2. Display the **limit-ssh** dynamic set:

```
# nft list set inet filter limit-ssh
table inet filter {
  set limit-ssh {
    type ipv4_addr
    size 65535
    flags dynamic
    elements = { 192.0.2.1 ct count over 2 , 192.0.2.2 ct count over 2 }
  }
}
```

The **elements** entry displays addresses that currently match the rule. In this example, **elements** lists IP addresses that have active connections to the SSH port. Note that the output does not display the number of active connections or if connections were rejected.

### 8.8.2. Blocking IP addresses that attempt more than ten new incoming TCP connections within one minute

You can temporarily block hosts that are establishing more than ten IPv4 TCP connections within one minute.

**Procedure**

1. Create the **filter** table with the **ip** address family:

   ```
   # nft add table ip filter
   ```

2. Add the **input** chain to the **filter** table:

   ```
   # nft add chain ip filter input { type filter hook input priority 0 \; }
   ```

3. Add a rule that drops all packets from source addresses that attempt to establish more than ten TCP connections within one minute:

   ```
   # nft add rule ip filter input ip protocol tcp ct state new, untracked meter ratemeter { ip
   saddr timeout 5m limit rate over 10/minute } drop
   ```

   The **timeout 5m** parameter defines that **nftables** automatically removes entries after five minutes to prevent that the meter fills up with stale entries.

**Verification**

- To display the meter's content, enter:

  ```
  # nft list meter ip filter ratemeter
  table ip filter {
    meter ratemeter {
      type ipv4_addr
      size 65535
      flags dynamic,timeout
      elements = { 192.0.2.1 limit rate over 10/minute timeout 5m expires 4m58s224ms }
    }
  }
  ```

## 8.9. DEBUGGING NFTABLES RULES

The **nftables** framework provides different options for administrators to debug rules and if packets match them.

### 8.9.1. Creating a rule with a counter

To identify if a rule is matched, you can use a counter.

- For more information about a procedure that adds a counter to an existing rule, see Adding a counter to an existing rule in **Configuring and managing networking**

**Prerequisites**

- The chain to which you want to add the rule exists.

**Procedure**

1. Add a new rule with the **counter** parameter to the chain. The following example adds a rule with a counter that allows TCP traffic on port 22 and counts the packets and traffic that match this rule:

```
# nft add rule inet example_table example_chain tcp dport 22 counter accept
```

2. To display the counter values:

```
# nft list ruleset
table inet example_table {
  chain example_chain {
    type filter hook input priority filter; policy accept;
    tcp dport ssh counter packets 6872 bytes 105448565 accept
  }
}
```

### 8.9.2. Adding a counter to an existing rule

To identify if a rule is matched, you can use a counter.

- For more information about a procedure that adds a new rule with a counter, see Creating a rule with the counter in **Configuring and managing networking**

**Prerequisites**

- The rule to which you want to add the counter exists.

**Procedure**

1. Display the rules in the chain including their handles:

```
# nft --handle list chain inet example_table example_chain
table inet example_table {
  chain example_chain { # handle 1
    type filter hook input priority filter; policy accept;
    tcp dport ssh accept # handle 4
  }
}
```

2. Add the counter by replacing the rule but with the **counter** parameter. The following example replaces the rule displayed in the previous step and adds a counter:

```
# nft replace rule inet example_table example_chain handle 4 tcp dport 22 counter
accept
```

3. To display the counter values:

```
# nft list ruleset
table inet example_table {
  chain example_chain {
    type filter hook input priority filter; policy accept;
    tcp dport ssh counter packets 6872 bytes 105448565 accept
  }
}
```

## 8.9.3. Monitoring packets that match an existing rule

The tracing feature in **nftables** in combination with the **nft monitor** command enables administrators to display packets that match a rule. You can enable tracing for a rule an use it to monitoring packets that match this rule.

### Prerequisites

- The rule to which you want to add the counter exists.

### Procedure

1. Display the rules in the chain including their handles:

```
# nft --handle list chain inet example_table example_chain
table inet example_table {
  chain example_chain { # handle 1
    type filter hook input priority filter; policy accept;
    tcp dport ssh accept # handle 4
  }
}
```

2. Add the tracing feature by replacing the rule but with the **meta nftrace set 1** parameters. The following example replaces the rule displayed in the previous step and enables tracing:

```
# nft replace rule inet example_table example_chain handle 4 tcp dport 22 meta nftrace set 1 accept
```

3. Use the **nft monitor** command to display the tracing. The following example filters the output of the command to display only entries that contain **inet example_table example_chain**:

```
# nft monitor | grep "inet example_table example_chain"
trace id 3c5eb15e inet example_table example_chain packet: iif "enp1s0" ether saddr
52:54:00:17:ff:e4 ether daddr 52:54:00:72:2f:6e ip saddr 192.0.2.1 ip daddr 192.0.2.2 ip dscp
cs0 ip ecn not-ect ip ttl 64 ip id 49710 ip protocol tcp ip length 60 tcp sport 56728 tcp dport
ssh tcp flags == syn tcp window 64240
trace id 3c5eb15e inet example_table example_chain rule tcp dport ssh nftrace set 1 accept
(verdict accept)
...
```

WARNING

Depending on the number of rules with tracing enabled and the amount of matching traffic, the **nft monitor** command can display a lot of output. Use **grep** or other utilities to filter the output.

## 8.10. BACKING UP AND RESTORING THE NFTABLES RULE SET

You can backup **nftables** rules to a file and later restoring them. Also, administrators can use a file with the rules to, for example, transfer the rules to a different server.

### 8.10.1. Backing up the nftables rule set to a file

You can use the **nft** utility to back up the **nftables** rule set to a file.

**Procedure**

- To backup **nftables** rules:
  - In a format produced by **nft list ruleset** format:

    ```
    # nft list ruleset > file.nft
    ```

  - In JSON format:

    ```
    # nft -j list ruleset > file.json
    ```

### 8.10.2. Restoring the nftables rule set from a file

You can restore the **nftables** rule set from a file.

**Procedure**

- To restore **nftables** rules:
  - If the file to restore is in the format produced by **nft list ruleset** or contains **nft** commands directly:

    ```
    # nft -f file.nft
    ```

  - If the file to restore is in JSON format:

    ```
    # nft -j -f file.json
    ```

## 8.11. ADDITIONAL RESOURCES

- Using nftables in Red Hat Enterprise Linux 8

- What comes after iptables? Its successor, of course: nftables
- Firewalld: The Future is nftables

# CHAPTER 9. SECURING NETWORK SERVICES

Red Hat Enterprise Linux 8 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.

## 9.1. 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 **NFSv2** and **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

## 9.2. 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 2 (RFC 1904) and 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

## 9.3. 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, NFSv2 and 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.

### 9.3.1. 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

### 9.3.2. 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

### 9.3.3. 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 **[mountd]** section in **port=*<value>*** format.
     b. Set TCP and UDP port for **statd** (**rpc.statd**) in the **[statd]** 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 **[lockd]** 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 **[lockd]** 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
```

## 9.4. 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.

RHEL 8 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.

### 9.4.1. 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.
  ```

### 9.4.2. 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.

### 9.4.3. 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.

### 9.4.4. Additional resources

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

## 9.5. SECURING HTTP SERVERS

### 9.5.1. 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

## 9.5.2. 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

## 9.6. 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:

   ```
   # yum 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.

## 9.7. 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.

### 9.7.1. 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.