A guide to configuring and managing networking in Red Hat Enterprise Linux 8
Abstract

This document describes how to manage networking on Red Hat Enterprise Linux 8. The current version of the document contains only selected preview user stories.
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PROVIDING FEEDBACK ON RED HAT DOCUMENTATION

We appreciate your input on our documentation. Please let us know how we could make it better. To do so:

- For simple comments on specific passages:
  1. Make sure you are viewing the documentation in the *Multi-page HTML* format. In addition, ensure you see the Feedback button in the upper right corner of the document.
  2. Use your mouse cursor to highlight the part of text that you want to comment on.
  3. Click the Add Feedback pop-up that appears below the highlighted text.
  4. Follow the displayed instructions.

- For submitting more complex feedback, create a Bugzilla ticket:
  1. Go to the Bugzilla website.
  2. As the Component, use Documentation.
  3. Fill in the Description field with your suggestion for improvement. Include a link to the relevant part(s) of documentation.
  4. Click Submit Bug.
NOTE

The following sections mention some commands to be performed. The commands that need to be entered by the root user have \texttt{~\textbackslash #} in the prompt, while the commands that can be performed by a regular user, have \texttt{~\textbackslash $} in their prompt.

1.1. IP VERSUS NON-IP NETWORKS

A network is a system of interconnected devices that can communicate sharing information and resources, such as files, printers, applications, and Internet connection. Each of these devices has a unique Internet Protocol (IP) address to send and receive messages between two or more devices using a set of rules called protocol.

Categories of network communication

IP networks

Networks that communicate through IP addresses. An IP network is implemented in the Internet and most internal networks. Ethernet, cable modems, DSL modems, dial-up modems, wireless networks, and VPN connections are typical examples.

non-IP networks

Networks that are used to communicate through a lower layer rather than the transport layer. Note that these networks are rarely used. InfiniBand is a non-IP network.

1.2. STATIC VERSUS DYNAMIC IP ADDRESSING

Static IP addressing

When a device is assigned a static IP address, the address does not change over time unless changed manually. Use static IP addressing if you want:

- To ensure network address consistency for servers such as DNS, and authentication servers.
- To use out-of-band management devices that work independently of other network infrastructure.

All the configuration tools listed in Section 5.1, “Selecting network configuration methods” allow assigning static IP addresses manually.

Dynamic IP addressing

When a device is assigned a dynamic IP address, the address changes over time. For this reason, it is recommended for devices that connect to the network occasionally because IP address might be changed after rebooting the machine.

Dynamic IP addresses are more flexible, easier to set up and administer. The Dynamic Host Control Protocol (DHCP) is a traditional method of dynamically assigning network configurations to hosts.

NOTE

There is no strict rule defining when to use static or dynamic IP address. It depends on user’s needs, preferences and the network environment.
1.3. CONFIGURING THE DHCP CLIENT BEHAVIOR

A Dynamic Host Configuration Protocol (DHCP) client requests the dynamic IP address and corresponding configuration information from a DHCP server each time a client connects to the network.

Configuring the DHCP timeout
When a DHCP connection is started, a dhcp client requests an IP address from a DHCP server. The time that a dhcp client waits for this request to be completed is 45 seconds by default. This procedure describes how you can configure the ipv4.dhcp-timeout property using the nmcli tool or the IPV4_DHCP_TIMEOUT option in the /etc/sysconfig/network-scripts/ifcfg-<ifname> file. For example, using nmcli:

```
~# nmcli connection modify enp1s0 ipv4.dhcp-timeout 10
```

If an address cannot be obtained during this interval, the IPv4 configuration fails. The whole connection may fail, too, and this depends on the ipv4.may-fail property:

- If ipv4.may-fail is set to yes (default), the state of the connection depends on IPv6 configuration:
  - a. If the IPv6 configuration is enabled and successful, the connection is activated, but the IPv4 configuration can never be retried again.
  - b. If the IPv6 configuration is disabled or does not get configured, the connection fails.
- If ipv4.may-fail is set to no the connection is deactivated. In this case:
  - a. If the autoconnect property of the connection is enabled, NetworkManager retries to activate the connection as many times as set in the autoconnect-retries property. The default is 4.
  - b. If the connection still cannot acquire the dhcp address, auto-activation fails.
    Note that after 5 minutes, the auto-connection process starts again and the dhcp client retries to acquire an address from the dhcp server.

Lease renewal and expiration
After a DHCP lease is acquired successfully, NetworkManager configures the interface with parameters received from the DHCP server for the given time, and tries to renew the lease periodically. When the lease expires and cannot be renewed, NetworkManager continues trying to contact the server up to 8 minutes. If the other IP configuration, either IPv4 or IPv6 is successful, DHCP requests continue as long as the connection is active.

1.3.1. Making DHCPv4 persistent

To make DHCPv4 persistent both at startup and during the lease renewal processes, set the ipv4.dhcp-timeout property either to the maximum for a 32-bit integer (MAXINT32), which is 2147483647, or to the infinity value:

```
~$ nmcli connection modify enp1s0 ipv4.dhcp-timeout infinity
```

As a result, NetworkManager never stops trying to get or renew a lease from a DHCP server until it is successful.
To ensure a DHCP persistent behavior only during the lease renewal process, you can manually add a static IP to the `IPADDR` property in the `/etc/sysconfig/network-scripts/ifcfg-device_name` configuration file or by using `nmcli`:

```
~]$ nmcli connection modify enp1s0 ipv4.address 192.168.122.88/24
```

When an IP address lease expires, the static IP preserves the IP state as configured or partially configured - you can have an IP address, but you are not connected to the Internet.

### 1.4. SETTING THE WIRELESS REGULATORY DOMAIN

In Red Hat Enterprise Linux, the `crda` package contains the Central Regulatory Domain Agent that provides the kernel with the wireless regulatory rules for a given jurisdiction. It is used by certain `udev` scripts and should not be run manually unless debugging `udev` scripts. The kernel runs `crda` by sending a `udev` event upon a new regulatory domain change. Regulatory domain changes are triggered by the Linux wireless subsystem (IEEE-802.11). This subsystem uses the `regulatory.bin` file to keep its regulatory database information.

The `setregdomain` utility sets the regulatory domain for your system. `Setregdomain` takes no arguments and is usually called through system script such as `udev` rather than manually by the administrator. If a country code look-up fails, the system administrator can define the `COUNTRY` environment variable in the `/etc/sysconfig/regdomain` file.

**Additional resources**

See the following man pages for more information about the regulatory domain:

- `setregdomain(1)` man page – Sets regulatory domain based on country code.
- `crda(8)` man page – Sends to the kernel a wireless regulatory domain for a given ISO or IEC 3166 alpha2.
- `regulatory.bin(5)` man page – Shows the Linux wireless regulatory database.
- `iw(8)` man page – Shows or manipulates wireless devices and their configuration.

### 1.5. USING NETWORK KERNEL TUNABLES WITH SYSCTL

Using certain kernel tunables through the `sysctl` utility, you can adjust network configuration on a running system and directly affect the networking performance.

To change network settings, use the `sysctl` commands. For permanent changes that persist across system restarts, add lines to the `/etc/sysctl.conf` file.

To display a list of all available `sysctl` parameters, enter as `root`:

```
~]$ sysctl -a
```

### 1.6. MANAGING DATA USING THE NCAT UTILITY

The `ncat` networking utility replaces `netcat` in Red Hat Enterprise Linux 7. `ncat` is a reliable back-end tool that provides network connectivity to other applications and users. It reads and writes data across the network from the command line, and uses Transmission Control Protocol (TCP), User Datagram
Protocol (UDP), Stream Control Transmission Protocol (SCTP) or Unix sockets for communication. `ncat` can deal with both IPv4 and IPv6, open connections, send packets, perform port scanning, and supports higher-level features such as SSL, and connection broker.

The `nc` command can also be entered as `ncat`, using the identical options. For more information about the `ncat` options, see the New networking utility (ncat) section in the Migration Planning Guide and the `ncat(1)` man page.

### Installing ncat

To install the `ncat` package, enter as `root`:

```bash
~$ yum install nmap-ncat
```

### Brief selection of ncat use cases

#### Example 1.1. Enabling communication between a client and a server

1. Set a client machine to listen for connections on TCP port 8080:
   ```bash
   ~$ ncat -l 8080
   ```

2. On a server machine, specify the IP address of the client and use the same port number:
   ```bash
   ~$ ncat 10.0.11.60 8080
   ```

You can send messages on either side of the connection and they appear on both local and remote machines.

3. Press `Ctrl+D` to close the TCP connection.

#### NOTE

To check a UDP port, use the same `nc` commands with the `–u` option. For example:

```bash
~$ ncat -u -l 8080
```

#### Example 1.2. Sending files

Instead of printing information on the screen, as mentioned in the previous example, you can send all information to a file. For example, to send a file over TCP port 8080 from a client to a server:

1. On a client machine, to listen a specific port transferring a file to the server machine:
   ```bash
   ~$ ncat -l 8080 > outputfile
   ```

2. On a server machine, specify the IP address of the client, the port and the file which is to be transferred:
   ```bash
   ~$ ncat -l 10.0.11.60 8080 < inputfile
   ```

After the file is transferred, the connection closes automatically.
NOTE
You can transfer a file in the other direction as well:

```
~]$ ncat -l 8080 < inputfile
~]$ ncat -l 10.0.11.60 8080 > outputfile
```

Example 1.3. Creating an HTTP proxy server
To create an HTTP proxy server on localhost port 8080:

```
~]$ ncat -l --proxy-type http localhost 8080
```

Example 1.4. Port scanning
To view which ports are open, use the `--z` option and specify a range of ports to scan:

```
~]$ ncat -z 10.0.11.60 80-90
Connection to 192.168.0.1 80 port [tcp/http] succeeded!
```

Example 1.5. Setting up secure client-server communication using SSL
Set up SSL on a server:

```
~]$ ncat -e /bin/bash -k -l 8080 --ssl
```

On a client machine:

```
~]$ ncat --ssl 10.0.11.60 8080
```

NOTE
To ensure true confidentiality of the SSL connection, the server requires the `--ssl-cert` and `--ssl-key` options, and the client requires the `--ssl-verify` and `--ssl-trustfile` options.

Additional resources
For more examples, see the `ncat(1)` man page.
CHAPTER 2. CONSISTENT NETWORK INTERFACE DEVICE NAMING

Red Hat Enterprise Linux 8 provides methods for consistent and predictable device naming for network interfaces. These features help locating and differentiating network interfaces.

The kernel assigns names to network interfaces by concatenating a fixed prefix and a number that increases as the kernel initialize the network devices. For instance, eth0 would represent the first device being probed on start-up. However, these names do not necessarily correspond to labels on the chassis. Modern server platforms with multiple network adapters can encounter non-deterministic and counter-intuitive naming of these interfaces. This affects both network adapters embedded on the system board and add-in adapters.

In Red Hat Enterprise Linux 8, the udev device manager supports a number of different naming schemes. By default, udev assigns fixed names based on firmware, topology, and location information. This has the following advantages:

- Device names are fully predictable.
- Device names stay fixed even if you add or remove hardware, because no re-enumeration takes places.
- Defective hardware can be seamlessly replaced.

2.1. NETWORK INTERFACE DEVICE NAMING HIERARCHY

If consistent device naming is enabled, which is the default in Red Hat Enterprise Linux 8, the udev device manager generates device names based on the following schemes:

<table>
<thead>
<tr>
<th>Scheme</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Device names incorporate firmware or BIOS-provided index numbers for onboard devices. If this information is not available or applicable, udev uses scheme 2.</td>
<td>eno1</td>
</tr>
<tr>
<td>2</td>
<td>Device names incorporate firmware or BIOS-provided PCI Express (PCIe) hot plug slot index numbers. If this information is not available or applicable, udev uses scheme 3.</td>
<td>ens1</td>
</tr>
<tr>
<td>3</td>
<td>Device names incorporate the physical location of the connector of the hardware. If this information is not available or applicable, udev uses scheme 5.</td>
<td>enp2s0</td>
</tr>
<tr>
<td>4</td>
<td>Device names incorporate the MAC address. Red Hat Enterprise Linux does not use this scheme by default, but administrators can optionally use it.</td>
<td>enx525400d5e0fb</td>
</tr>
<tr>
<td>5</td>
<td>The traditional unpredictable kernel naming scheme. If udev cannot apply any of the other schemes, the device manager uses this scheme.</td>
<td>eth0</td>
</tr>
</tbody>
</table>

By default, Red Hat Enterprise Linux selects the device name based on the NamePolicy setting in the /usr/lib/systemd/network/99-default.link file. The order of the values in NamePolicy is important.
Red Hat Enterprise Linux uses the first device name that is both specified in the file and that `udev` generated.

If you manually configured `udev` rules to change the name of kernel devices, those rules take precedence.

### 2.2. HOW THE NETWORK DEVICE RENAMING WORKS

By default, consistent device naming is enabled in Red Hat Enterprise Linux 8. The `udev` device manager processes different rules to rename the devices. The following list describes the order in which `udev` processes these rules and what actions these rules are responsible for:

1. The `/usr/lib/udev/rules.d/60-net.rules` file defines that the `/lib/udev/rename_device` helper utility searches for the `HWADDR` parameter in `/etc/sysconfig/network-scripts/ifcfg-*` files. If the value set in the variable matches the MAC address of an interface, the helper utility renames the interface to the name set in the `DEVICE` parameter of the file.

2. The `/usr/lib/udev/rules.d/71-biosdevname.rules` file defines that the `biosdevname` utility renames the interface according to its naming policy, provided that it was not renamed in the previous step.

3. The `/usr/lib/udev/rules.d/75-net-description.rules` file defines that `udev` examines the network interface device and sets the properties in `udev`-internal variables, that will be processed in the next step. Note that some of these properties might be undefined.

4. The `/usr/lib/udev/rules.d/80-net-setup-link.rules` file calls the `net_setup_link` `udev` built-in which then applies the policy. The following is the default policy that is stored in the `/usr/lib/systemd/network/99-default.link` file:

   ```
   [Link]
   NamePolicy=kernel database onboard slot path
   MACAddressPolicy=persistent
   ```

   With this policy, if the kernel uses a persistent name, `udev` does not rename the interface. If the kernel does not use a persistent name, `udev` renames the interface to the name provided by the hardware database of `udev`. If this database is not available, Red Hat Enterprise Linux falls back to the mechanisms described above.

   Alternatively, set the `NamePolicy` parameter in this file to `mac` for media access control (MAC) address-based interface names.

5. The `/usr/lib/udev/rules.d/80-net-setup-link.rules` file defines that `udev` renames the interface based on the `udev`-internal parameters in the following order:
   a. `ID_NET_NAME_ONBOARD`
   b. `ID_NET_NAME_SLOT`
   c. `ID_NET_NAME_PATH`

   If one parameter is not set, `udev` uses the next one. If none of the parameters are set, the interface is not renamed.

Steps 3 and 4 implement the naming schemes 1 to 4 described in Section 2.1, “Network interface device naming hierarchy”.

---

---
2.3. PREDICTABLE NETWORK INTERFACE DEVICE NAMES ON THE X86_64 PLATFORM EXPLAINED

When the consistent network device name feature is enabled, the `udev` device manager creates the names of devices based on different criteria. This section describes the naming scheme when Red Hat Enterprise Linux 8 is installed on a x86_64 platform.

The interface name starts with a two-character prefix based on the type of interface:

- **en** for Ethernet
- **wl** for wireless LAN (WLAN)
- **ww** for wireless wide area network (WWAN)

Additionally, one of the following is appended to one of the above-mentioned prefix based on the schema the `udev` device manager applies:

- **o<on-board_index_number>**
- **s<hot_plug_slot_index_number>[f<function>][d<device_id>]**
  Note that all multi-function PCI devices have the `[f<function>]` number in the device name, including the function 0 device.
- **x<MAC_address>**
- **[P<domain_number>][p<bus>s<slot>[f<function>][d<device_id>]**
  The `[P<domain_number>]` part defines the PCI geographical location. This part is only set if the domain number is not 0.
- **[P<domain_number>][p<bus>s<slot>[f<function>][u<usb_port>][...][c<config>][i<interface>]**
  For USB devices, the full chain of port numbers of hubs is composed. If the name is longer than the maximum (15 characters), the name is not exported. If there are multiple USB devices in the chain, `udev` suppresses the default values for USB configuration descriptors (`c1`) and USB interface descriptors (`i0`).

2.4. PREDICTABLE NETWORK INTERFACE DEVICE NAMES ON THE SYSTEM Z PLATFORM EXPLAINED

When the consistent network device name feature is enabled, the `udev` device manager on the System Z platform creates the names of devices based on the bus ID. The bus ID identifies a device in the s390 channel subsystem.

For a channel command word (CCW) device, the bus ID is the device number with a leading 0.n prefix where n is the subchannel set ID.

Ethernet interfaces are named, for example, `enccw0.0.1234`. Serial Line Internet Protocol (SLIP) channel-to-channel (CTC) network devices are named, for example, `slccw0.0.1234`.

Additional resources

- For details about setting custom prefixes for consistent naming, see Section 2.7, “Using `prefixdevname` for naming of Ethernet network interfaces”.
- For details about the `NamePolicy` parameter, see the `systemd.link(5)` man page.
Use the `znetconf -c` or the `lsccs -a` commands to display available network devices and their bus IDs.

### 2.5. DISABLING CONSISTENT INTERFACE DEVICE NAMING DURING THE INSTALLATION

This section describes how to disable consistent interface device naming during the installation.

**WARNING**

Red Hat recommends not to disable consistent device naming. Disabling consistent device naming can cause different kind of problems. For example, if you add another network interface card to the system, the assignment of the kernel device names, such as `eth0`, is no longer fixed. Consequently, after a reboot, the Kernel can name the device differently.

**Procedure**

1. Boot the Red Hat Enterprise Linux 8 installation media.

2. In the boot manager, select *Install Red Hat Enterprise Linux 8*, and press the *Tab* key to edit the entry.

3. Append the `net.ifnames=0` parameter to the kernel command line:

   ```
   vmlinuz... net.ifnames=0
   ```

4. Press *Enter* to start the installation.

**Additional resources**

- Is it safe to set `net.ifnames=0` in RHEL 7 and RHEL 8?
- How to perform an in-place upgrade to RHEL 8 when using kernel NIC names on RHEL 7

### 2.6. DISABLING CONSISTENT INTERFACE DEVICE NAMING ON AN INSTALLED SYSTEM

This section describes how to disable consistent interface device naming on a system that is already installed.
WARNING

Red Hat recommends not to disable consistent device naming. Disabling consistent device naming can cause different kind of problems. For example, if you add another network interface card to the system, the assignment of the kernel device names, such as eth0, is no longer fixed. Consequently, after a reboot, the Kernel can name the device differently.

Prerequisites

- The system uses consistent interface device naming, which is the default.

Procedure

1. Edit the /etc/default/grub file and append the net.ifnames=0 parameter to the GRUB_CMDLINE_LINUX variable:
   
   
   GRUB_CMDLINE_LINUX="... *net.ifnames=0

2. Rebuild the grub.cfg file:
   
   - On a system with UEFI boot mode:
     
     # grub2-mkconfig -o /boot/efi/EFI/redhat/grub.cfg
   
   - On a system with legacy boot mode:
     
     # grub2-mkconfig -o /boot/grub2/grub.cfg

3. If you use interface names in configuration files or scripts, you must manually update them.

4. Reboot the host:

   # reboot

2.7. USING PREFIXDEVNAME FOR NAMING OF ETHERNET NETWORK INTERFACES

This documentation describes how to set the prefixes for consistent naming of Ethernet network interfaces in case that you do not want to use the default naming scheme of such interfaces.

However, Red Hat recommends to use the default naming scheme, which is the same as in Red Hat Enterprise Linux 7.

For more details about this scheme, see Consistent Network Device Naming.

2.7.1. Introduction to prefixdevname
The **prefixdevname** tool is a udev helper utility that enables you to define your own prefix used for naming of the Ethernet network interfaces.

### 2.7.2. Setting prefixdevname

The setting of the prefix with **prefixdevname** is done during system installation.

To set and activate the required prefix for your Ethernet network interfaces, use the following procedure.

**Procedure**

- Add the following string on the kernel command line:

  ```
  net.ifnames.prefix=<required prefix>
  ```

**WARNING**

Red Hat does not support the use of **prefixdevname** on already deployed systems.

After the prefix was once set, and the operating system was rebooted, the prefix is effective every time when a new network interface appears. The new device is assigned a name in the form of `<PREFIX><INDEX>`. For example, if your selected prefix is `net`, and the interfaces with `net0` and `net1` prefixes already exist on the system, the new interface is named `net2`. The **prefixdevname** utility then generates the new `.link` file in the `/etc/systemd/network` directory that applies the name to the interface with the MAC address that just appeared. The configuration is persistent across reboots.

### 2.7.3. Limitations of prefixdevname

There are certain limitations for prefixes of Ethernet network interfaces.

The prefix that you choose must meet the following requirements:

- Be ASCII string
- Be alphanumeric string
- Be shorter than 16 characters

**WARNING**

The prefix cannot conflict with any other well-known prefix used for network interface naming on Linux. Specifically, you cannot use these prefixes: `eth`, `eno`, `ens`, `em`. 
2.8. RELATED INFORMATION

- See the udev(7) man page for details about the udev device manager.
CHAPTER 3. NETCONSOLE

The netconsole kernel module enables logging of kernel messages over the network to another computer. It allows kernel debugging when disk logging fails or when using the serial console is not possible.

3.1. CONFIGURING NETCONSOLE

This procedure describes how you can configure netconsole in Red Hat Enterprise Linux (RHEL) 8.

Prerequisites

The `netconsole-service` package is installed.

```
~]# yum install netconsole-service
```

Procedure

1. Set the `SYSLOGADDR` to the IP address of the `syslogd` server in the `/etc/sysconfig/netconsole` file to match the IP address of the `syslogd` server. For example:

   ```
   SYSLOGADDR=192.168.0.1
   ```

2. Restart the `netconsole.service`.

   ```
   ~]# systemctl restart netconsole.service
   ```

3. Enable `netconsole.service` to run after rebooting the system.

   ```
   ~]# systemctl enable netconsole.service
   ```

4. View the `netconsole` messages from the client in the `/var/log/messages` file (default) or in the file specified in `rsyslog.conf`.

   ```
   ~]# cat /var/log/messages
   ```

Additional resources

How to configure netconsole under Red Hat Enterprise Linux 8?
CHAPTER 4. GETTING STARTED WITH MANAGING NETWORKING WITH NETWORKMANAGER

4.1. OVERVIEW OF NETWORKMANAGER

Red Hat Enterprise Linux 8 uses the default networking service, NetworkManager, which is a dynamic network control and configuration daemon to keep network devices and connections up and active when they are available. The traditional ifcfg type configuration files are still supported.

Each network device corresponds to a NetworkManager device. The configuration of a network device is completely stored in a single NetworkManager connection. You can perform a network configuration applying a NetworkManager connection to a NetworkManager device.

4.1.1. Benefits of using NetworkManager

The main benefits of using NetworkManager are:

- Offering an API through D-Bus which allows to query and control network configuration and state. In this way, networking can be checked and configured by multiple applications ensuring a synced and up-to-date networking status. For example, the RHEL web console, which monitors and configures servers through a web browser, uses the NetworkManager D-BUS interface to configure networking, as well as the Gnome GUI, the nmcli and the nm-connection-editor tools. Each change made in one of these tools is detected by all the others.

- Making Network management easier: NetworkManager ensures that network connectivity works. When it detects that there is no network configuration in a system but there are network devices, NetworkManager creates temporary connections to provide connectivity.

- Providing easy setup of connection to the user: NetworkManager offers management through different tools – GUI, nmtui, nmcli.

- Supporting configuration flexibility. For example, configuring a WiFi interface, NetworkManager scans and shows the available wifi networks. You can select an interface, and NetworkManager displays the required credentials providing automatic connection after the reboot process. NetworkManager can configure network aliases, IP addresses, static routes, DNS information, and VPN connections, as well as many connection-specific parameters. You can modify the configuration options to reflect your needs.

- Maintaining the state of devices after the reboot process and taking over interfaces which are set into managed mode during restart.

- Handling devices which are not explicitly set unmanaged but controlled manually by the user or another network service.

Additional resources

- Section 4.5, “NetworkManager tools”

- For more information on installing and using the RHEL 8 web console, see Managing systems using the RHEL 8 web console.

4.2. INSTALLING NETWORKMANAGER

NetworkManager is installed by default on Red Hat Enterprise Linux 8. If it is not, enter as root.
-]# yum install NetworkManager

Additional resources

- Section 4.1, “Overview of NetworkManager”
- Section 4.1.1, “Benefits of using NetworkManager”

4.3. CHECKING THE STATUS OF NETWORKMANAGER

To check whether NetworkManager is running:

-]$
$ systemctl status NetworkManager
NetworkManager.service - Network Manager
 Loaded: loaded (/lib/systemd/system/NetworkManager.service; enabled)
 Active: active (running) since Fri, 08 Mar 2013 12:50:04 +0100; 3 days ago

Note that the systemctl status command displays Active: inactive (dead) when NetworkManager is
not running.

4.4. STARTING NETWORKMANAGER

To start NetworkManager:

-]$
$ systemctl start NetworkManager

To enable NetworkManager automatically at boot time:

-]$
$ systemctl enable NetworkManager

4.5. NETWORKMANAGER TOOLS

Table 4.1. A summary of NetworkManager tools and applications

<table>
<thead>
<tr>
<th>Application or Tool</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>nmcli</td>
<td>A command-line tool which enables users and scripts to interact with NetworkManager. Note that nmcli can be used on systems without a GUI such as servers to control all aspects of NetworkManager. It provides a deeper functionality as GUI tools.</td>
</tr>
<tr>
<td>nmtui</td>
<td>A simple curses-based text user interface (TUI) for NetworkManager</td>
</tr>
</tbody>
</table>
### Application or Tool

<table>
<thead>
<tr>
<th>Application or Tool</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>nm-connection-editor</td>
<td>A graphical user interface tool for certain tasks not yet handled by the control-center utility such as configuring bonds and teaming connections. You can add, remove, and modify network connections stored by NetworkManager. To start it, enter <code>nm-connection-editor</code> in a terminal.</td>
</tr>
<tr>
<td>control-center</td>
<td>A graphical user interface tool provided by the GNOME Shell, available for desktop users. It incorporates a Network settings tool. To start it, press the Super key to enter the Activities Overview, type Network and then press Enter. The Network settings tool appears.</td>
</tr>
<tr>
<td>network connection icon</td>
<td>A graphical user interface tool provided by the GNOME Shell representing network connection states as reported by NetworkManager. The icon has multiple states that serve as visual indicators for the type of connection you are currently using.</td>
</tr>
</tbody>
</table>

### Additional resources

- Chapter 6, Configuring IP networking with nmtui
- Chapter 7, Getting started with nmcli
- Chapter 8, Getting started with configuring networking using the GNOME GUI

### 4.6. RUNNING DISPATCHER SCRIPTS

NetworkManager provides a way to run additional custom scripts to start or stop services based on the connection status. By default, the `/etc/NetworkManager/dispatcher.d/` directory exists and NetworkManager runs scripts there, in alphabetical order. Each script must be an executable file owned by root and must have write permission only for the file owner.

### Additional resources

- For more information about running NetworkManager dispatcher scripts, see the Red Hat Knowledgebase solution How to write a NetworkManager dispatcher script to apply ethtool commands.

### 4.7. USING NETWORKMANAGER WITH SYSCONFIG FILES

The `/etc/sysconfig/` directory is a location for configuration files and scripts. Most network configuration information is stored there, with the exception of VPN, mobile broadband and PPPoE configuration, which are stored in the `/etc/NetworkManager/` subdirectories. For example, interface-specific information is stored in the `ifcfg` files in the `/etc/sysconfig/network-scripts/` directory.

Information for VPNs, mobile broadband and PPPoE connections is stored in `/etc/NetworkManager/system-connections/`.
In Red Hat Enterprise Linux 8, if you edit an ifcfg file, NetworkManager is not automatically aware of the change and has to be prompted to notice the change. If you use one of the tools to update NetworkManager profile settings, NetworkManager does not implement those changes until you reconnect using that profile. For example, if configuration files have been changed using an editor, NetworkManager must read the configuration files again.

To ensure this, enter as root to reload all connection profiles:

```
~# nmcli connection reload
```

Alternatively, to reload only one changed file, ifcfg-ifname.

```
~# nmcli con load /etc/sysconfig/network-scripts/ifcfg-ifname
```

Note that you can specify multiple file names using the above command.

To restart the connection after changes are made, use:

```
~# nmcli con up connection-name
```

### 4.7.1. Legacy network scripts support

Network scripts are deprecated in Red Hat Enterprise Linux 8 and are no longer provided by default. The basic installation provides a new version of the ifup and ifdown scripts which call NetworkManager through the nmcli tool. In Red Hat Enterprise Linux 8, to run the ifup and the ifdown scripts, NetworkManager must be running.

**NOTE**

Custom commands in /sbin/ifup-local, ifdown-pre-local and ifdown-local scripts are not executed.

If any of these scripts are required, the installation of the deprecated network scripts in the system is still possible with the following command:

```
~# yum install network-scripts
```

The ifup and the ifdown scripts link to the installed legacy network scripts.

Calling the legacy network scripts shows a warning about their deprecation.

**Additional resources**

- NetworkManager(8) man page — Describes the network management daemon.
- NetworkManager.conf(5) man page — Describes the NetworkManager configuration file.
- /usr/share/doc/initscripts/sysconfig.txt — Describes ifcfg configuration files and their directives as understood by the legacy network service.
- ifcfg(8) man page — Describes briefly the ifcfg command.
CHAPTER 5. OVERVIEW OF NETWORK CONFIGURATION METHODS

The following section provides an overview of network configuration methods that are available in Red Hat Enterprise Linux 8.

5.1. SELECTING NETWORK CONFIGURATION METHODS

- To configure a network interface using NetworkManager, use one of the following tools:
  - the text user interface tool, nmtui.
  - the command-line tool, nmcli.
  - the graphical user interface tools, GNOME GUI.

- To configure a network interface without using NetworkManager:
  - edit the ifcfg files manually.

- To configure the network settings when the root filesystem is not local:
  - use the kernel command-line.

Additional resources

- Chapter 6, Configuring IP networking with nmtui
- Chapter 7, Getting started with nmcli
- Chapter 8, Getting started with configuring networking using the GNOME GUI
CHAPTER 6. CONFIGURING IP NETWORKING WITH NMTUI

The following section provides how you can configure a network interface using the NetworkManager's tool, nmtui.

6.1. GETTING STARTED WITH NMTUI

nmtui is a simple curses-based text user interface (TUI) for NetworkManager.

This procedure describes how to start the text user interface tool, nmtui.

Prerequisites

- The nmtui tool is used in a terminal window. It is contained in the NetworkManager-tui package, but it is not installed along with NetworkManager by default. To install NetworkManager-tui:

  ```
  ~]# yum install NetworkManager-tui
  ```

- To verify that NetworkManager is running, see Section 4.3, “Checking the status of NetworkManager”

Procedure

1. Start the nmtui tool:

  ```
  ~]$ nmtui
  ```

  The text user interface appears.

2. To navigate, use the arrow keys or press Tab to step forwards and press Shift+Tab to step back through the options. Press Enter to select an option. The Space bar toggles the status of a check box.
6.1.1. Adding a connection profile using nmtui

The nmtui application provides a text user interface to NetworkManager. This procedure describes how to add a new connection profile.

Prerequisites

- The NetworkManager-tui package is installed.

Procedure

1. Start the NetworkManager text user interface utility:
   
   # nmtui

2. Select the Edit a connection menu entry, and press Enter.

3. Select the Add button, and press Enter.

4. Select Ethernet, and press Enter.

5. Fill the fields with the connection details.
6. Select **OK** to save the changes.

7. Select **Back** to return to the main menu.

8. Select **Activate a connection**, and press **Enter**.

9. Select the new connection entry, and press **Enter** to activate the connection.

10. Select **Back** to return to the main menu.

11. Select **Quit**.

**Verification steps**
1. Display the status of the devices and connections:

```
# nmcli device status
DEVICE    TYPE      STATE      CONNECTION
enp7s0    ethernet  connected  Example-Connection
```

2. To display all settings of the connection profile:

```
# nmcli connection show Example-Connection
connection.id: Example-Connection
connection.uuid: b6cdfa1c-e4ad-46e5-af8b-a75f06b79f76
connection.stable-id: --
connection.type: 802-3-ethernet
connection.interface-name: enp7s0
```

Additional resources

- For further details about the `nmtui` application, see the `nmtui(1)` man page.

6.1.2. Applying changes to a modified connection with nmtui

To apply changes after a modified connection which is already active requires a reactivation of the connection. In this case, follow the procedure below:

**Prerequisites**

- Section 6.1, “Getting started with nmtui”

**Procedure**

1. Select the **Activate a connection** menu entry.
2. Select the modified connection. On the right, click the **Deactivate** button.
3. Choose the connection again and click the **Activate** button.
The following commands are also available:

```
~$ nmtui edit connection-name
```

If no connection name is supplied, the selection menu appears. If the connection name is supplied and correctly identified, the relevant **Edit connection** screen appears.

```
~$ nmtui connect connection-name
```

If no connection name is supplied, the selection menu appears. If the connection name is supplied and correctly identified, the relevant connection is activated. Any invalid command prints a usage message.

Note that **nmtui** does not support all types of connections. In particular, you cannot edit VPNs, wireless network connections using WPA Enterprise, or Ethernet connections using **802.1X**.

**Additional resources**

- For more information about the **NetworkManager’s** tools, see **Section 4.5, “NetworkManager tools”**
CHAPTER 7. GETTING STARTED WITH NMCLI

This section describes general information about the nmcli utility.

7.1. UNDERSTANDING NMCLI

nmcli (NetworkManager Command Line Interface) is the command-line utility to configure networking through NetworkManager. nmcli is used to create, display, edit, delete, activate, and deactivate network connections, as well as control and display network device status.

The nmcli utility can be used by both users and scripts:

- For servers, headless machines, and terminals, nmcli can be used to control NetworkManager directly, without GUI.
- For scripts, nmcli supports options to change the output to a format better suited for script processing.

Each network device corresponds to a NetworkManager device. The configuration of a network device is completely stored in a single NetworkManager connection. You can perform a network configuration applying a NetworkManager connection to a NetworkManager device.

To get started with nmcli the most common nmcli commands are nmcli device and nmcli connection:

- The nmcli device command lists the available network devices in the system.

A device can be:

1. managed - under the NetworkManager control. A managed device may be connected, meaning that it is activated and configured, or disconnected, meaning that it is not configured but ready to be activated again.
2. unmanaged - NetworkManager does not control it.

For more details on setting a managed or unmanaged device, see Section 7.4, “Setting a device managed or unmanaged with nmcli”.

The nmcli device command can take many arguments. Most notable are: status, show, set, connect, disconnect, modify, delete, wifi. Enter the nmcli device help command to see the full list.

- The nmcli connection command lists the available connection profiles in NetworkManager.

Every connection that is active is displayed as green on top of the list. The inactive connections are displayed as white. The DEVICE field identifies the device on which the connection is applied on.

The nmcli connection command can take many arguments to manage connection profiles. Most notable are: show, up, down, add, modify, delete. Enter the nmcli connection help command to see the full list.
IMPORTANT

If you use the `nmcli` commands, it is recommended to type a partial `nmcli` command, and then press the Tab key to auto-complete the command sequence. If multiple completions are possible, then Tab lists them all. This helps users to type commands faster and easier. To enable the `nmcli` auto-complete feature be sure to install the `bash-completion` package:

```bash
~]# yum install bash-completion
```

After the package installation, `nmcli auto-complete` will be available next time you login into a console. To activate it also in the current console, enter:

```bash
~]$ source /etc/profile.d/bash_completion.sh
```

The basic format of using `nmcli` is:

```
nmcli [OPTIONS] OBJECT { COMMAND | help }
```

- where `[OPTIONS]` can be optional options, such as:
  
  **-t, terse**
  This mode can be used for computer script processing as you can see a terse output displaying only the values.

  **Example 7.1. Viewing a terse output**

  ```bash
  ~]$ nmcli -t device
  ens3:ethernet:connected:Profile 1
  lo:loopback:unmanaged:
  ```

  **-f, field**
  This option specifies what fields can be displayed in output. For example, `NAME,UUID,TYPE,AUTOCONNECT,ACTIVE,DEVICE,STATE`. You can use one or more fields. If you want to use more, do not use space after comma to separate the fields.

  **Example 7.2. Specifying fields in the output**

  ```bash
  ~]$ nmcli -f DEVICE,TYPE device
  DEVICE  TYPE
  ens3    ethernet
  lo      loopback
  ```

  or even better for scripting:

  ```bash
  ~]$ nmcli -t -f DEVICE,TYPE device
  ens3:ethernet
  lo:loopback
  ```

  **-p, pretty**
This option causes `nmcli` to produce human-readable output. For example, values are aligned and headers are printed.

**Example 7.3. Viewing an output in pretty mode**

```
~]$ nmcli -p device
===================== Status of devices
===================== DEVICE TYPE STATE CONNECTION
ens3 ethernet connected Profile 1
lo loopback unmanaged --
```

-h, help

Prints help information.

- where OBJECT can be one of the following options: `general`, `networking`, `radio`, `connection`, `device`, `agent`, and `monitor`.

**NOTE**

You can use any prefix of the above options in your commands. For example, `nmcli con help`, `nmcli c help`, `nmcli connection help` generate the same output.

- where COMMAND, the required `nmcli` command.

- where `help` is to list available actions related to a specified object:

```
~]$ nmcli OBJECT help
```

For example,

```
~]$ nmcli c help
```

Additional resources

- Section 4.5, “NetworkManager tools”
- the `nmcli(1)` man page.
- Section 7.3, “Brief selection of `nmcli` commands”
- Section 7.5, “Creating a connection profile with `nmcli`”

### 7.2. OVERVIEW OF NMCLI PROPERTY NAMES AND ALIASES

**Prerequisites**

Property names are specific names that NetworkManager uses to identify a common option. Following are some of the important `nmcli property` names:
**connection.type**

A type of a specific connection. Allowed values are: `adsl, bond, bond-slave, bridge, bridge-slave, bluetooth, cdma, ethernet, gsm, infiniband, olpc-mesh, team, team-slave, vlan, wifi, wimax`. Each connection type has type-specific command options. You can see the `TYPE_SPECIFIC_OPTIONS` list in the `nmcli(1)` man page. For example, a `gsm` connection requires the access point name specified in an `apn`. A `wifi` device requires the service set identifier specified in a `ssid`.

**connection.interface-name**

A device name relevant for the connection. For example, `enp1s0`.

**connection.id**

A name used for the connection profile. If you do not specify a connection name, one will be generated as follows:

```
connection.type -connection.interface-name
```

The `connection.id` is the name of a `connection profile` and should not be confused with the interface name which denotes a device (`wlan0, ens3, em1`). However, users can name the connections after interfaces, but they are not the same thing. There can be multiple connection profiles available for a device. This is particularly useful for mobile devices or when switching a network cable back and forth between different devices. Rather than edit the configuration, create different profiles and apply them to the interface as needed. The `id` option also refers to the connection profile name.

The most important options for `nmcli` commands such as `show, up, down` are:

**id**

An identification string assigned by the user to a connection profile. Id can be used in `nmcli` connection commands to identify a connection. The `NAME` field in the command output always denotes the connection id. It refers to the same connection profile name that the `con-name` does.

**uuid**

A unique identification string assigned by the system to a connection profile. The `uuid` can be used in `nmcli connection` commands to identify a connection.

**Aliases and property names**

An alias is an alternative name for a `property` name — aliases are translated to properties internally in `nmcli`. **Aliases** are more readable but **property names** are preferable to use. Both can be used interchangeably.

<table>
<thead>
<tr>
<th>Alias</th>
<th>Example</th>
<th>Property</th>
<th>Example</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>type</td>
<td>type bond</td>
<td>connection.type</td>
<td>connection.type</td>
<td>type of a specific connection. Some of the connection types are: <code>bond, bridge, ethernet, wifi, infiniband, vlan</code></td>
</tr>
<tr>
<td>ifname</td>
<td>iface enp1s0</td>
<td>connection.iface-name</td>
<td>connection.iface-name enp1s0</td>
<td>name of the device to which a connection belongs to</td>
</tr>
</tbody>
</table>
### 7.3. BRIEF SELECTION OF NMCLI COMMANDS

**IMPORTANT**

If you use the `nmcli` commands, it is recommended to type a partial `nmcli` command, and then press the Tab key to auto-complete the command sequence. If multiple completions are possible, then Tab lists them all. This helps users to type commands faster and easier. To enable the `nmcli` auto-complete feature be sure to install the `bash-completion` package:

```bash
~$ yum install bash-completion
```

After the package installation, `nmcli auto-complete` will be available next time you login into a console. To activate it also in the current console, enter:

```bash
~$ source /etc/profile.d/bash_completion.sh
```

The following examples show how to use `nmcli` in specific use cases:

**Example 7.4. Viewing all connections**

```bash
~$ nmcli connection show
NAME   UUID                                TYPE      DEVICE
Profile 1  db1060e9-c164-476f-b2b5-caec62dc1b05  ethernet    ens3
bond0    aaf6eb56-73e5-4746-9037-eed42caa8a65  ethernet    --
```

**Example 7.5. Viewing only currently active connections**

```bash
~$ nmcli connection show --active
NAME   UUID                                TYPE      DEVICE
Profile 1  db1060e9-c164-476f-b2b5-caec62dc1b05  ethernet    ens3
```

**Example 7.6. Activating a connection**

Use the `up` argument to activate a connection.

```bash
~$ nmcli connection show
NAME   UUID                                TYPE      DEVICE
Profile 1  db1060e9-c164-476f-b2b5-caec62dc1b05  ethernet    ens3
bond0    aaf6eb56-73e5-4746-9037-eed42caa8a65  ethernet    --
```
Example 7.7. Deactivating a specific active connection

Use the `down` argument to deactivate a specific active connection:

```
$ nmcli connection down id bond0
```

```
$ nmcli connection show
NAME  UUID                    TYPE  DEVICE
Profile 1 db1060e9-c164-476f-b2b5-caec62dc1b05 ethernet ens3
bond0  aaf6eb56-73e5-4746-9037-eed42caa8a65 ethernet bond0
```

Example 7.8. Disconnecting a device preventing it from automatically started again

```
$ nmcli device disconnect id bond0
```

**NOTE**

The `nmcli connection down` command, deactivates a connection from a device without preventing the device from further auto-activation. The `nmcli device disconnect` command, disconnects a device and prevent the device from automatically activating further connections without manual intervention. If the connection has the `connection.autoconnect` flag set to `yes`, the connection automatically starts on the disconnected device again. In this case, use the `nmcli device disconnect` command instead of the `nmcli connection down` command.

Example 7.9. Viewing only devices recognized by NetworkManager and their state

```
$ nmcli device status
DEVICE  TYPE      STATE      CONNECTION
ens3    ethernet  connected  Profile 1
lo      loopback  unmanaged  --
```

Example 7.10. Viewing general information for a device

```
$ nmcli device show
GENERAL.DEVICE: ens3
GENERAL.TYPE: ethernet
```
Example 7.11. Checking the overall status of NetworkManager

```bash
~]$ nmcli general status
STATE CONNECTIVITY WIFI-HW WIFI WWAN-HW WWAN
connected full enabled enabled enabled enabled
```

In terse mode:

```bash
~]$ nmcli -t -f STATE general
connected
```

Example 7.12. Viewing NetworkManager logging status

```bash
~]$ nmcli general logging
LEVEL DOMAINS
INFO PLATFORM,RFKILL,ETHER,WIFI,BT,MB,DHCP4,DHCP6,PPP,WIFI_SCAN,IP4,IP6,AUTOIP4,DNS,VPN,SHARING,SUPPLICANT,AGENTS,SETTINGS,SUSPEND,CORE,DEVICE,OLPC,WIMAX,INFINIBAND,Firewall,ADSL,BOND,VLAN,BRIDGE,DBUS_PROPS,TEAM,CONCHECK,DC,B,DISPATCH
```

You can also use the following abbreviations of the `nmcli` commands:

<table>
<thead>
<tr>
<th>nmcli command</th>
<th>abbreviation</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>nmcli general status</code></td>
<td><code>nmcli g</code></td>
</tr>
<tr>
<td><code>nmcli general logging</code></td>
<td><code>nmcli g log</code></td>
</tr>
<tr>
<td><code>nmcli connection show</code></td>
<td><code>nmcli con show</code></td>
</tr>
<tr>
<td><code>nmcli connection show --active</code></td>
<td><code>nmcli con show -a</code></td>
</tr>
<tr>
<td><code>nmcli device status</code></td>
<td><code>nmcli dev</code></td>
</tr>
<tr>
<td><code>nmcli device show</code></td>
<td><code>nmcli dev show</code></td>
</tr>
</tbody>
</table>

**Table 7.1. Abbreviations of some nmcli commands**

Additional resources
For more information on the comprehensive list of `nmcli` options, see the `nmcli(1)` man page.

For more examples, see the `nmcli-examples(5)` man page.

Section 7.5, “Creating a connection profile with nmcli”

7.4. SETTING A DEVICE MANAGED OR UNMANAGED WITH NMCLI

Prerequisites

- Section 7.1, “Understanding nmcli”
- Section 7.2, “Overview of nmcli property names and aliases”

Procedure

1. To list the currently available network connections:

   ```
   ~]$ nmcli con show
   NAME       UUID                                  TYPE            DEVICE
   Auto Ethernet  9b7f2511-5432-40ae-b091-af2457dfd988  802-3-ethernet  --
   ens3        fb157a65-ad32-47ed-858c-102a48e064a2  802-3-ethernet  ens3
   MyWiFi      91451385-4eb8-4080-8b82-720aab8328dd  802-11-wireless wlan0
   ```

   Note that the `NAME` field in the output always denotes the connection ID (name). It is not the interface name even though it might look the same. In the second connection shown above, `ens3` in the `NAME` field is the connection ID given by the user to the profile applied to the interface `ens3`. In the last connection shown, the user has assigned the connection ID `MyWiFi` to the interface `wlan0`.

   Adding an Ethernet connection means creating a configuration profile which is then assigned to a device. Before creating a new profile, review the available devices as follows:

   ```
   ~]$ nmcli device status
   DEVICE  TYPE      STATE         CONNECTION
   ens3    ethernet  disconnected  --
   ens9    ethernet  disconnected  --
   lo      loopback  unmanaged     --
   ```

   2. To set the device unmanaged by the NetworkManager:

   ```
   ~]$ nmcli device set ifname managed no
   ```

   For example, to set `enp1s0` unmanaged:

   ```
   ~]$ nmcli device status
   DEVICE  TYPE      STATE         CONNECTION
   bond0   bond       connected bond0
   virbr0  bridge     connected virbr0
   enp7s0  ethernet   connected bond-slave-enp7s0
   enp1s0  ethernet   connected bond-slave-enp1s0
   enp8s0  ethernet   unmanaged --
   ```
NOTE

When you set the device unmanaged, NetworkManager does not control it. If the device you want to configure is listed as unmanaged, no nmcli command has any effect on this device. However, the device is still connected.

Additional resources

- For more information, see the nmcli(1) man page.

7.5. CREATING A CONNECTION PROFILE WITH NMCLI

You can create a connection profile to be associated with a device.

Prerequisites

- Section 7.1, “Understanding nmcli”
- Section 7.2, “Overview of nmcli property names and aliases”

IMPORTANT

If you use the nmcli commands, it is recommended to type a partial nmcli command, and then press the Tab key to auto-complete the command sequence. If multiple completions are possible, then Tab lists them all. This helps users to type commands faster and easier. To enable the nmcli auto-complete feature be sure to install the bash-completion package:

```
~$ yum install bash-completion
```

After the package installation, nmcli auto-complete will be available next time you login into a console. To activate it also in the current console, enter:

```
~$ source /etc/profile.d/bash_completion.sh
```

Procedure

The basic format to create a new profile for NetworkManager using nmcli:

```
nmcli c add {COMMON_OPTIONS} [IP_OPTIONS]/[NETMASK] [GATEWAY]
```
a. where \{COMMON\_OPTIONS\} are the aliases or property names, see Aliases and Property names.

b. where \{IP\_OPTIONS\} are the IP addresses:
   - For IPv4 addresses: `ip4`
   - For IPv6 addresses: `ip6`

c. where \{NETMASK\} is the network mask width. For example, `255.255.255.0` is the network mask for the prefix `198.51.100.0/24`.

d. where \{GATEWAY\} is the gateway information:
   - For IPv4 addresses: `gw4`
   - For IPv6 addresses: `gw6`

```
nmcli connection add type ethernet con-name connection-name ifname interface-name ip4 address/network mask gw4 address
```

1. To create a connection profile with an IPv4 address:
```
~]$ nmcli c add type ethernet ifname enp1s0 con-name "My Connection" ip4 192.168.2.100/24 gw4 192.168.2.1
Connection 'My Connection' (f0c23472-1aec-4e84-8f1b-be8a2ebbeade) successfully added.
```

2. To activate the created connection:
```
~]$ nmcli c up _"My Connection"
```

3. To view the created connection:
```
~]$ nmcli c show "My Connection"
```

Note that the `nmcli c show con-name` command displays all the properties present in the connection, even those that are empty or have a default value. If the output is longer than a terminal page, `nmcli` generates a pager to allow an easy navigation on the output. In the pager, use arrows to move up and down and the `q` key to quit.

For a more compact display of the connection, use the `-o` option:
```
~]$ nmcli -o c show "My Connection"
```

The `nmcli -o c show con-name` command still displays the connection content, but omits empty properties or those that are set to a default value. This usually results in a shorter output that is more readable.

Additional resources
- See the `nm-settings(5)` man page for more information on properties and their settings.

7.6. USING THE NMCLI INTERACTIVE CONNECTION EDITOR
The `nmcli` tool has an interactive connection editor. It allows you to change connection parameters according to your needs. To use it:

```bash
~$ nmcli con edit
```

You should enter a valid **connection type** from the list displayed. Then, you are able to modify its parameters.

```bash
~$ nmcli con edit
Valid connection types: generic, 802-3-ethernet (ethernet), pppoe, 802-11-wireless (wifi), wimax, gsm, cdma, infiniband, adsl, bluetooth, vpn, 802-11-olpc-mesh (olpc-mesh), vlan, bond, team, bridge, bond-slave, team-slave, bridge-slave, no-slave, tun, ip-tunnel, macsec, macvlan, vxlan, dummy
Enter connection type: ethernet
```

Adding a new '802-11-wireless' connection

Type 'help' or '?' for available commands.
Type 'describe [setting].<prop>' for detailed property description.

You may edit the following settings: connection, 802-11-wireless (wifi), 802-11-wireless-security (wifi-sec), 802-1x, ipv4, ipv6, proxy

```
nmcli>
```

It is possible now to edit the **ethernet** connection settings. To get the list of available commands, type `help` or `?`:

```
nmcli> ?
```

---[ Main menu ]---

goto   [setting] | [prop]  :: go to a setting or property
remove <setting>.[prop]  | [prop] :: remove setting or reset property value
set    [setting].<prop> <value>  :: set property value
describe [setting].<prop> :: describe property
print   [all] | [setting].[prop] :: print the connection
verify  [all] | fix  :: verify the connection
save    [persistent] | [temporary] :: save the connection
activate [ifname] [/ap]|<nsp>  :: activate the connection
back    :: go one level up (back)
help/?  [command]  :: print this help
nmcli   <conf-option> <value> :: nmcli configuration
quit    :: exit nmcli

```
nmcli>
```

To exit, enter the `quit` command.

**Example 7.13. Adding a new Ethernet connection using the `nmcli` interactive connection editor**

```bash
~$ nmcli con edit
Valid connection types: generic, 802-3-ethernet (ethernet), pppoe, 802-11-wireless (wifi), wimax, gsm, cdma, infiniband, adsl, bluetooth, vpn, 802-11-olpc-mesh (olpc-mesh), vlan, bond, team, bridge, bond-slave, team-slave, bridge-slave, no-slave, tun, ip-tunnel, macsec, macvlan, vxlan,
```

---
dummy
Enter connection type: ethernet

===| nmcli interactive connection editor |===

Adding a new '802-3-ethernet' connection

Type 'help' or '? for available commands.
Type 'describe [<setting>.<prop>]' for detailed property description.

You may edit the following settings: connection, 802-3-ethernet (ethernet), 802-1x, dcb, ipv4, ipv6, proxy

nmcli> set connection.id new_enp7s0
nmcli> set connection.interface-name enp7s0
nmcli> set connection.autoconnect yes
nmcli> save

Saving the connection with 'autoconnect=yes'. That might result in an immediate activation of the connection.
Do you still want to save? (yes/no) [yes] yes
Connection 'new_enp7s0' (34ac8f9a-e9d8-4e0b-9751-d5dc87cc0467) successfully saved.

nmcli> quit

A new network interface configuration file is created in the /etc/sysconfig/network-scripts directory:

```bash
~]# ls -lrt /etc/sysconfig/network-scripts/ifcfg*
-rw-r--r--. 1 root root 254 Aug 15  2017 /etc/sysconfig/network-scripts/ifcfg-lo
-rw-r--r--. 1 root root 304 Apr 26 22:14 /etc/sysconfig/network-scripts/ifcfg-ens3
-rw-r--r--. 1 root root 266 Aug  6 11:03 /etc/sysconfig/network-scripts/ifcfg-new_enp7s0
```

7.7. MODIFYING A CONNECTION PROFILE WITH NMCLI

You can modify the existing configuration of a connection profile.

Prerequisites

- Section 7.1, “Understanding nmcli”
- Section 7.2, “Overview of nmcli property names and aliases”
- Section 7.5, “Creating a connection profile with nmcli”
If you use the `nmcli` commands, it is recommended to type a partial `nmcli` command, and then press the Tab key to auto-complete the command sequence. If multiple completions are possible, then Tab lists them all. This helps users to type commands faster and easier. To enable the `nmcli` auto-complete feature be sure to install the `bash-completion` package:

```bash
~]# yum install bash-completion
```

After the package installation, `nmcli auto-complete` will be available next time you login into a console. To activate it also in the current console, enter:

```bash
~]$ source /etc/profile.d/bash_completion.sh
```

### Procedure

1. To modify one or more properties of a connection profile, use the following command:

   ```bash
   ~> nmcli c modify
   ```

   For example, to change the `connection.id` from "My Connection" to "My favorite connection" and the `connection.interface-name` to `enp7s0`:

   ```bash
   ~> nmcli c modify "My Connection" connection.id "My favorite connection"
   connection.interface-name enp7s0
   ```

2. To apply changes after a modified connection using `nmcli`, activate again the connection by entering:

   ```bash
   ~> nmcli con up "My favorite connection"
   Connection successfully activated (D-Bus active path: /org/freedesktop/NetworkManager/ActiveConnection/16)
   ```

3. To view the modified connection, enter the `nmcli con show con-name` command.
CHAPTER 8. GETTING STARTED WITH CONFIGURING NETWORKING USING THE GNOME GUI

You can configure a network interface using the following Graphical User Interface (GUI) ways:

- the GNOME Shell network connection icon on the top right of the desktop
- the GNOME control-center application
- the GNOME nm-connection-editor application

8.1. CONNECTING TO A NETWORK USING THE GNOME SHELL NETWORK CONNECTION ICON

To access the Network settings, click on the GNOME Shell network connection icon in the top right-hand corner of the screen to open its menu:

Figure 8.1. The network connection icon menu

When you click on the GNOME Shell network connection icon, you can see:

- A list of categorized networks you are currently connected to (such as Wired and Wi-Fi).
- A list of all Available Networks that NetworkManager has detected. If you are connected to a network, this is indicated on the left of the connection name.
• Options for connecting to any configured Virtual Private Networks (VPNs) and
• An option for selecting the **Network Settings** menu entry.

### 8.2. CREATING A NETWORK CONNECTION USING CONTROL-CENTER

You can create a network connection through the GNOME **control-center** application, which is a graphical user interface that provides a view of available network devices and their current configuration.

This procedures describes how to create a new **wired**, **wireless**, **vpn** connection using **control-center**:

**Procedure**

1. Press the **Super** key to enter the Activities Overview, type **Settings**, and press **Enter**. Then, select the **Network** tab on the left-hand side, and the **Network** settings tool appears:

   ![Network settings window](image)

   **Figure 8.2. Opening the network settings window**

2. Click the plus button to add a new connection:
   - For **Wired** connections, click the plus button next to **Wired** entry and configure the connection.
   - For **VPN** connections, click the plus button next to **VPN** entry. If you want to add an **IPsec VPN**, click on **IPsec based VPN** and configure the connection.
   - For **Wi-Fi** connections, click the **Wi-Fi** entry on the left-hand side in the **Settings** menu and configure the connection.
CHAPTER 9. CONFIGURING AN ETHERNET CONNECTION

This section describes how to configure an Ethernet connection with static and dynamic IP addresses.

9.1. ADDING A STATIC ETHERNET CONNECTION USING NMCLI

This procedure describes adding an Ethernet connection with the following settings:

- A static IPv4 address - 192.0.2.1 with a /24 subnet mask
- A static IPv6 address - 2001:db8::1 with a /32 subnet mask
- An IPv4 default gateway - 192.0.2.254
- An IPv6 default gateway - 2001:db8::ffe
- An IPv4 DNS server - 192.0.2.200
- An IPv6 DNS server - 2001:db8::ffbb
- A DNS search domain - example.com

Procedure

1. Add a new NetworkManager connection profile for the Ethernet connection:
   ```
   # nmcli connection add con-name Example-Connection ifname enp7s0 type ethernet ipv4.addresses 192.0.2.1/24
   ```
   The further steps modify the `Example-Connection` connection profile you created.

2. Set the IPv6 address:
   ```
   # nmcli connection modify Example-Connection ipv6.addresses 2001:db8::1/32
   ```

3. Set the IPv4 and IPv6 connection method to manual:
   ```
   # nmcli connection modify Example-Connection ipv4.method manual
   # nmcli connection modify Example-Connection ipv6.method manual
   ```

4. Set the IPv4 and IPv6 default gateways:
   ```
   # nmcli connection modify Example-Connection ipv4.gateway 192.0.2.254
   # nmcli connection modify Example-Connection ipv6.gateway 2001:db8::ffe
   ```

5. Set the IPv4 and IPv6 DNS server addresses:
   ```
   # nmcli connection modify Example-Connection ipv4.dns "192.0.2.200"
   # nmcli connection modify Example-Connection ipv6.dns "2001:db8::ffbb"
   ```
   To set multiple DNS servers, specify them space-separated and enclosed in quotes.

6. Set the DNS search domain for the IPv4 and IPv6 connection:
# nmcli connection modify Example-Connection ipv4.dns-search example.com  
# nmcli connection modify Example-Connection ipv6.dns-search example.com

7. Active the connection profile:

# nmcli connection up Example-Connection  
Connection successfully activated (D-Bus active path: /org/freedesktop/NetworkManager/ActiveConnection/13)

Verification steps

1. Display the status of the devices and connections:

# nmcli device status  

DEVICE      TYPE      STATE      CONNECTION  
enp7s0        ethernet    connected     Example-Connection

2. To display all settings of the connection profile:

# nmcli connection show Example-Connection  
connection.id: Example-Connection  
connection.uuid: b6cdfa1c-e4ad-46e5-af8b-a75f06b79f76  
connection.stable-id: --  
connection.type: 802-3-ethernet  
connection.interface-name: enp7s0  
...

Additional resources

- See the `nm-settings(5)` man page for more information on connection profile properties and their settings.

- For further details about the `nmcli` utility, see the `nmcli(1)` man page.

9.2. CONFIGURING A STATIC ETHERNET CONNECTION USING THE NMCLI INTERACTIVE EDITOR

To configure a static Ethernet connection using the `nmcli` interactive editor:

```
$ nmcli con edit type ethernet con-name ens3

===| nmcli interactive connection editor |===

Adding a new '802-3-ethernet' connection

Type 'help' or '?' for available commands.  
Type 'describe [>setting<.>prop<'] for detailed property description.

You may edit the following settings: connection, 802-3-ethernet (ethernet), 802-1x, ipv4, ipv6, dcb
nmcli> set ipv4.addresses 192.168.122.88/24  
Do you also want to set 'ipv4.method' to 'manual'? [yes]: yes
nmcli> set ipv4.dns 192.168.122.1  
nmcli> set ipv4.dns-search example.com
```
nmcli> save persistent
Saving the connection with 'autoconnect=yes'. That might result in an immediate activation of the
connection.
Do you still want to save? [yes] yes
Connection 'ens3' (704a5666-8cbd-4d89-b5f9-fa65a3dbc916) successfully saved.
nmcli> quit

The default action is to save the connection profile as persistent. If required, the profile can be held in
memory only, until the next restart, by means of the save temporary command.

9.3. CONFIGURING A DYNAMIC ETHERNET CONNECTION WITH
NMCLI

Prerequisites

- Section 7.1, “Understanding nmcli”
- Section 7.5, “Creating a connection profile with nmcli”

Procedure

1. To change the host name sent by a host to a DHCP server, modify the dhcp-hostname property:

   ```bash
   ~]$ nmcli con modify my-office my-office ipv4.dhcp-hostname host-name ipv6.dhcp-hostname host-name
   ```

2. To change the IPv4 client ID sent by a host to a DHCP server, modify the dhcp-client-id property:

   ```bash
   ~]$ nmcli con modify my-office my-office ipv4.dhcp-client-id client-ID-string
   ```

   There is no dhcp-client-id property for IPv6, dhclient to create an identifier for IPv6. See the
dhclient(8) man page for details.

3. To ignore the DNS servers sent to a host by a DHCP server, modify the ignore-auto-dns property:

   ```bash
   ```

9.4. CONFIGURING A DYNAMIC ETHERNET CONNECTION USING THE
INTERACTIVE EDITOR

To configure a dynamic Ethernet connection using the interactive editor:

```bash
~]$ nmcli con edit type ethernet con-name ens3

===| nmcli interactive connection editor |===

Adding a new '802-3-ethernet' connection
```
You may edit the following settings: connection, 802-3-ethernet (ethernet), 802-1x, ipv4, ipv6, dcb
nmcli> describe ipv4.method

=== [method] ===
[NM property description]
IPv4 configuration method. If 'auto' is specified then the appropriate automatic method (DHCP, PPP, etc) is used for the interface and most other properties can be left unset. If 'link-local' is specified, then a link-local address in the 169.254/16 range will be assigned to the interface. If 'manual' is specified, static IP addressing is used and at least one IP address must be given in the 'addresses' property. If 'shared' is specified (indicating that this connection will provide network access to other computers) then the interface is assigned an address in the 10.42.x.1/24 range and a DHCP and forwarding DNS server are started, and the interface is NAT-ed to the current default network connection. 'disabled' means IPv4 will not be used on this connection. This property must be set.

nmcli> set ipv4.method auto
nmcli> save
Saving the connection with 'autoconnect=yes'. That might result in an immediate activation of the connection.
Do you still want to save? [yes] yes
Connection 'ens3' (090b61f7-540f-4dd6-bf1f-a905831fc287) successfully saved.

The default action is to save the connection profile as persistent. If required, the profile can be held in memory only, until the next restart, by means of the save temporary command.

Additional resources
- See the nm-settings(5) man page for more information on properties and their settings.

9.5. CONFIGURING AN ETHERNET CONNECTION USING CONTROL-CENTER

You can configure a network connection through the GNOME control-center application.

Procedure

1. Press the Super key to enter the Activities Overview, type Settings and press Enter. Then, select the Network menu entry on the left-hand side, and the Network settings tool appears, see Opening the Network Settings Window

2. Select the Wired network interface
   The system creates and configures a single wired connection profile called Wired by default. More than one profile can be created for an interface and applied as needed. The default profile cannot be deleted but its settings can be changed.

3. Edit the default Wired profile by clicking the gear wheel icon to edit an existing connection or click the plus button and then set the configuration options for a new connection.
NOTE

When you add a new connection by clicking the plus 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.

Basic configuration options
You can see the following configuration settings in the Wired dialog, by selecting the Identity menu entry:

Figure 9.1. Basic configuration options of a wired connection

- **Name** – Enter a descriptive name for your network connection. This name will be used to list this connection in the menu of the Network window.

- **MAC Address** – Select the MAC address of the interface this profile must be applied to.

- **Cloned Address** – If required, enter a different MAC address to use.

- **MTU** – If required, enter a specific maximum transmission unit (MTU) to use. The MTU value represents the size in bytes of the largest packet that the link layer will transmit. This value defaults to 1500 and does not generally need to be specified or changed.

Configuring IPv4 settings for wired with control-center
You can further configure IPv4 settings in a wired connection. In the Wired dialog, click the IPv4 menu entry:
Figure 9.2. Configuring IPv4 Settings

The IPv4 menu entry allows you to configure:

- the IPv4 Method used to connect to a network
- DNS and
- Routes

### IPv4 Method

**Automatic (DHCP)** – Choose this option if the network you are connecting to uses Router Advertisements (RA) or 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 Automatic to OFF to enter the IP address of a DNS server you want to use separating the IPs by comma.

### Routes

- Use this connection only for resources on its network.
NOTE

In the Routes section, when Automatic is ON, routes from Router Advertisements (RA) or 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, sub-net, 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, sub-net, 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. Typical examples are where a connection is a VPN tunnel or a leased line to a head office and you do not want any Internet-bound traffic to pass over the connection. Selecting this option means that only traffic specifically destined for routes learned automatically over the connection or entered here manually will be routed over the connection.

**Configuring IPv6 settings for wired with control center**

Alternatively, to configure IPv6 settings in a wired connection, click the IPv6 menu entry:
The IPv6 menu entry allows you to configure:

- the IPv6 Method used to connect to a network
- DNS and
- Routes

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.

**Disabled** — IPv6 is disabled for this connection.

Configuring 802.1X security for wired with control-center
802.1X security is the name of the IEEE standard for port-based Network Access Control (PNAC). It is also called WPA Enterprise. 802.1X security is a way of controlling access to a logical network from a physical one. All clients who want to join the logical network must authenticate with the server (a router, for example) using the correct 802.1X authentication method.

To configure 802.1X Security settings in a wired connection, click the Security menu entry:

Figure 9.4. Configuring 802.1X security for a wired with control-center

To enable settings configuration, set the symbolic power button to ON, and select from one of following authentication methods:

- **TLS** for Transport Layer Security and proceed to Configuring TLS Settings
- **PWD** for Password and proceed to Configuring PWD Settings
- **FAST** for Flexible Authentication through Secure Tunneling and proceed to Configuring FAST Settings
- Select Tunneled TLS for Tunneled Transport Layer Security, otherwise known as TTLS, or EAP-TTLS and proceed to Configuring Tunneled TLS Settings
- Select Protected EAP (PEAP) for Protected Extensible Authentication Protocol and proceed to Configuring Protected EAP PEAP Settings

**Configuring TLS settings**

With Transport Layer Security (TLS), the client and server mutually authenticate using the TLS protocol.
Using TLS security requires the overhead of a public key infrastructure (PKI) to manage certificates. The benefit of using TLS security is that a compromised password does not allow access to the (W)LAN: an intruder must also have access to the authenticating client’s private key.

NetworkManager does not determine the version of TLS supported. NetworkManager gathers the parameters entered by the user and passes them to the daemon, wpa_supplicant, that handles the procedure. It in turn uses OpenSSL to establish the TLS tunnel. OpenSSL itself negotiates the SSL/TLS protocol version. It uses the highest version both ends support.

To configure TLS settings, follow the procedure described in Section 9.5, “Configuring an Ethernet connection using control-center”. The following configuration settings are available:

Identity
   Provide the identity of this server.

User certificate
   Click to browse for, and select, a personal X.509 certificate file encoded with Distinguished Encoding Rules (DER) or Privacy Enhanced Mail (PEM).

CA certificate
   Click to browse for, and select, an X.509 certificate authority certificate file encoded with Distinguished Encoding Rules (DER) or Privacy Enhanced Mail (PEM).

Private key
   Click to browse for, and select, a private key file encoded with Distinguished Encoding Rules (DER), Privacy Enhanced Mail (PEM), or the Personal Information Exchange Syntax Standard (PKCS #12).

Private key password
   Enter the password for the private key in the Private key field. Select Show password to make the password visible as you type it.

Configuring PWD settings
With Password (PWD), you can specify the username and the password.

Username
   Enter the user name to be used in the authentication process.

Password
   Enter the password to be used in the authentication process.

Configuring FAST settings
To configure FAST settings, follow the procedure described in Section 9.5, “Configuring an Ethernet connection using control-center”. The following configuration settings are available:

Anonymous Identity
   Provide the identity of this server.

Allow automatic PAC provisioning
   Select the check box to enable and then select from Anonymous, Authenticated, and Both.

PAC file
   Click to browse for, and select, a protected access credential (PAC) file.

Inner authentication
   GTC – Generic Token Card.
Username
Enter the user name to be used in the authentication process.

Password
Enter the password to be used in the authentication process.

Configuring tunneled TLS settings
To configure Tunneled TLS settings, follow the procedure described in Section 9.5, “Configuring an Ethernet connection using control-center”. The following configuration settings are available:

Anonymous identity
This value is used as the unencrypted identity.

CA certificate
Click to browse for, and select, a Certificate Authority’s certificate.

Inner authentication
- **PAP** — Password Authentication Protocol.
- **MSCHAP** — Challenge Handshake Authentication Protocol.
- **MSCHAPv2** — Microsoft Challenge Handshake Authentication Protocol version 2.
- **CHAP** — Challenge Handshake Authentication Protocol.
- **MD5** — Message Digest 5, a cryptographic hash function.
- **GTC** — Generic Token Card.

Username
Enter the user name to be used in the authentication process.

Password
Enter the password to be used in the authentication process.

Configuring protected EAP (PEAP) settings
To configure Protected EAP (PEAP) settings, follow the procedure described in Section 9.5, “Configuring an Ethernet connection using control-center”. The following configuration settings are available:

Anonymous Identity
This value is used as the unencrypted identity.

CA certificate
Click to browse for, and select, a Certificate Authority’s certificate.

PEAP version
The version of Protected EAP to use. Automatic, 0 or 1.

Inner authentication
- **MSCHAPv2** — Microsoft Challenge Handshake Authentication Protocol version 2.
- **MD5** — Message Digest 5, a cryptographic hash function.
- **GTC** — Generic Token Card.
**Username**

Enter the user name to be used in the authentication process.

**Password**

Enter the password to be used in the authentication process.

### 9.6. Configuring an Ethernet Connection Using NM-Connection-editor

Ethernet connections are the most frequently used connection types in physical or virtual servers. This section describes how to configure this connection type in Red Hat Enterprise Linux.

**Prerequisites**

- A physical or virtual Ethernet device exists in the server’s configuration.

**Procedure**

1. Open a terminal, and enter:

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

2. Click the + button to add a new connection.

3. Select the **Ethernet** connection type, and click **Create**.

4. On the **Ethernet** tab, select a device and, optionally, further Ethernet-related settings.
5. On the **IPv4 Settings** tab, configure the IPv4 settings. For example, set a static IPv4 address, network mask, default gateway, and DNS server:

   ![IPv4 Settings Table]

   - Addresses:
     - **Address**: 192.0.2.1, **Netmask**: 24, **Gateway**: 192.0.2.254
     - DNS servers: 192.0.2.1

6. On the **IPv6 Settings** tab, configure the IPv6 settings. For example, set a static IPv6 address, network mask, default gateway, and DNS server:

   ![IPv6 Settings Table]

   - Addresses:
     - **Address**: 2001:db8::1, **Prefix**: 32, **Gateway**: 2001:db8::fff3
     - DNS servers: 2001:db8::fff0

7. Save the connection.

8. Close **nm-connection-editor**.
CHAPTER 10. MANAGING WI-FI CONNECTIONS

This section describes how to configure and manage Wi-Fi connections.

10.1. CONFIGURING A WI-FI CONNECTION USING NMCLI

Prerequisites

- The nmcli utility to be installed.
- Make sure that the WiFi radio is on (default):

  ~]$ nmcli radio wifi on

Procedure

1. To create a Wi-Fi connection profile with static IP configuration:

  ~]$ nmcli con add con-name MyCafe ifname wlan0 type wifi ssid MyCafe ` `ip4 192.168.100.101/24 gw4 192.168.100.1

2. Set a DNS server. For example, to set 192.160.100.1 as the DNS server:

  ~]$ nmcli con modify con-name MyCafe ipv4.dns "192.160.100.1"

3. Optionally, set a DNS search domain. For example, to set the search domain to example.com:

  ~]$ nmcli con modify con-name MyCafe ipv4.dns-search "example.com"

4. To check a specific property, for example mtu:

  ~]$ nmcli connection show id MyCafe | grep mtu
  802-11-wireless.mtu: auto

5. To change the property of a setting:

  ~]$ nmcli connection modify id MyCafe 802-11-wireless.mtu 1350

6. To verify the change:

  ~]$ nmcli connection show id MyCafe | grep mtu
  802-11-wireless.mtu: 1350

Additional resources

See the nm-settings(5) man page for more information on properties and their settings.

10.2. CONFIGURING A WI-FI CONNECTION USING CONTROL-CENTER
When you connect to a **Wi-Fi**, the network settings are prefilled depending on the current network connection. This means that the settings will be detected automatically when the interface connects to a network.

This procedure describes how to use **control-center** to manually configure the **Wi-Fi** settings.

**Procedure**

1. Press the **Super** key to enter the **Activities Overview**, type **Wi-Fi** and press **Enter**. In the left-hand-side menu entry you see the list of available networks.

2. Select the gear wheel icon to the right of the **Wi-Fi** connection name that you want to edit, and the editing connection dialog appears. The **Details** menu window shows the connection details where you can make further configuration.

**Options**

a. If you select **Connect automatically**, **NetworkManager** auto-connects to this connection whenever **NetworkManager** detects that it is available. If you do not want **NetworkManager** to connect automatically, clear the check box. Note that when the check box is clear, you have to select that connection manually in the network connection icon’s menu to cause it to connect.

b. To make a connection available to other users, select the **Make available to other users** check box.

c. You can also control the background data usage. If you leave **Restrict background data usage** unspecified (default), then **NetworkManager** tries to download data that you are actively using. Otherwise, select the check box and **NetworkManager** sets the connection as metered, and applies restriction on the background data usage.

**NOTE**

To delete a **Wi-Fi** connection, click the **Forget Connection** red box.

3. Select the **Identity** menu entry to see the basic configuration options.

   **SSID** – The **Service Set Identifier** (SSID) of the access point (AP).

   **BSSID** – The **Basic Service Set Identifier** (BSSID) is the MAC address, also known as a **hardware address**, of the specific wireless access point you are connecting to when in **Infrastructure** mode. This field is blank by default, and you are able to connect to a wireless access point by **SSID** without having to specify its **BSSID**. If the BSSID is specified, it will force the system to associate to a specific access point only. For ad-hoc networks, the **BSSID** is generated randomly by the **mac80211** subsystem when the ad-hoc network is created. It is not displayed by **NetworkManager**.

   **MAC address** – The **MAC address** allows you to associate a specific wireless adapter with a specific connection (or connections).

   **Cloned Address** – A cloned MAC address to use in place of the real hardware address. Leave blank unless required.

4. For further IP address configuration, select the **IPv4** and **IPv6** menu entries.

   By default, both **IPv4** and **IPv6** are set to automatic configuration depending on current network settings. This means that addresses such as the local IP address, DNS address, and other settings will be detected automatically when the interface connects to a network. If a
DHCP server assigns the IP configuration in this network, this is sufficient, but you can also provide static configuration in the IPv4 and IPv6 Settings. In the IPv4 and IPv6 menu entries, you can see the following settings:

- **IPv4 Method**
  - **Automatic (DHCP)** – Choose this option if the network you are connecting to uses Router Advertisements (RA) or a DHCP server to assign dynamic IP addresses. You can see the assigned IP address in the Details menu entry.
  - **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**
  If **Automatic** is **ON**, and no DHCP server is available that assigns DNS servers to this connection, switch it to **OFF** to enter the IP address of a DNS server separating the IPs by comma.

- **Routes**
  Note that in the Routes section, when **Automatic** is **ON**, routes from Router Advertisements (RA) or 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, sub-net, 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, sub-net, 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.

Alternatively, to configure IPv6 settings in a Wi-Fi 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.
- The DNS, Routes, Use this connection only for resources on its network fields are common to IPv4 settings.

5. To configure Security settings in a Wi-Fi connection, select the Security menu entry. The following configuration options are available:

- Security
  - None – Do not encrypt the Wi-Fi connection.
  - WEP 40/128-bit Key – Wired Equivalent Privacy (WEP), from the IEEE 802.11 standard. Uses a single pre-shared key (PSK).
  - WEP 128-bit Passphrase – An MD5 hash of the passphrase to derive a WEP key.

![WARNING]
If the Wi-Fi use no encryption, WEP, or WPA, do not use the network because it is insecure and everyone can read the data you send over this network.

- Dynamic WEP (802.1X) – WEP keys are changed dynamically.
- WPA & WPA2 Personal – Wi-Fi Protected Access (WPA), from the draft IEEE 802.11i standard. A replacement for WEP. Wi-Fi Protected Access II (WPA2), from the 802.11i-2004 standard. Personal mode uses a pre-shared key (WPA-PSK).
- WPA & WPA2 Enterprise – WPA for use with a RADIUS authentication server to provide IEEE 802.1X network access control.

- Password – Enter the password to be used in the authentication process.

6. Once you have finished the configuration, click the Apply button to save it.

![NOTE]
When you add a new connection by clicking the plus 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.

**10.3. CONNECTING TO A WI-FI NETWORK WITH NMCLI**

This procedure describes how to connect to a wireless connection using the nmcli utility.

**Prerequisites**
The *nmcli* utility to be installed.

Make sure that the WiFi radio is on (default):

```
~$ nmcli radio wifi on
```

**Procedure**

1. To refresh the available Wi-Fi connection list:

```
~$ nmcli device wifi rescan
```

2. To view the available Wi-Fi access points:

```
~$ nmcli dev wifi list
```

<table>
<thead>
<tr>
<th>IN-USE</th>
<th>SSID</th>
<th>MODE</th>
<th>CHAN</th>
<th>RATE</th>
<th>SIGNAL</th>
<th>BARS</th>
<th>SECURITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>...</td>
<td>MyCafe</td>
<td>Infra</td>
<td>3</td>
<td>405 Mbit/s</td>
<td>85</td>
<td>▂▄▆▆█</td>
<td>WPA1 WPA2</td>
</tr>
</tbody>
</table>

3. To connect to a Wi-Fi connection using *nmcli*:

```
~$ nmcli dev wifi connect SSID-Name password wireless-password
```

For example:

```
~$ nmcli dev wifi connect MyCafe password wireless-password
```

Note that if you want to disable the Wi-Fi state:

```
~$ nmcli radio wifi off
```

### 10.4. CONNECTING TO A HIDDEN WI-FI NETWORK USING NMCLI

All access points have a Service Set Identifier (SSID) to identify them. However, an access point may be configured not to broadcast its SSID, in which case it is hidden, and will not show up in NetworkManager’s list of Available networks.

This procedure shows how you can connect to a hidden network using the *nmcli* tool.

**Prerequisites**

- The *nmcli* utility to be installed.
- To know the SSID, and password of the Wi-Fi connection.
- Make sure that the WiFi radio is on (default):

```
~$ nmcli radio wifi on
```

**Procedure**
Connect to the SSID that is hidden:

```
~$ nmcli dev wifi connect SSID_Name password wireless_password hidden yes
```

### 10.5. CONNECTING TO A WI-FI NETWORK USING THE GNOME GUI

This procedure describes how you can connect to a wireless network to get access to the internet.

**Procedure**

1. Open the GNOME Shell network connection icon menu from the top right-hand corner of the screen.
2. Select *Wi-Fi Not Connected*.
3. Click the *Select Network* option.
4. Click the name of the network to which you want to connect, and then click *Connect*. Note that if you do not see the network, the network might be hidden.
5. If the network is protected by a password or encryption keys are required, enter the password and click *Connect*. Note that if you do not know the password, contact the administrator of the Wi-Fi network.
6. If the connection is successful, the name of the network is visible in the connection icon menu and the wireless indicator is on the top right-hand corner of the screen.

**Additional resources**

- Configuring a Wi-Fi connection using control center.

### 10.6. CONFIGURING 802.1X SECURITY FOR WI-FI WITH NMCLI

This procedure describes how to set the network security settings in a *wireless* or a *Wired* connection using the *nmcli* utility.

**Prerequisites**

- The *nmcli* utility is installed.

**Procedure**

1. For a *wireless* connection, set the authenticated key-mgmt (key management) protocol. It configures the keying mechanism for a secure *wifi* connection.
2. Configure the 802-1x authentication settings.

**Table 10.1. The 802-1x authentication settings**

<table>
<thead>
<tr>
<th>802-1x authentication setting</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>802-1x.identity</td>
<td>Identity</td>
</tr>
</tbody>
</table>
For example, to configure WPA2 Enterprise using the EAP-TLS authentication method, apply the following settings:

```bash
-]$ nmcli c add type wifi ifname wlan0 con-name 'My Wifi Network'
   802-11-wireless.ssid 'My Wifi'
   802-11-wireless-security.key-mgmt wpa-eap
   802-1x.identity identity@example.com
   802-1x.ca-cert /etc/pki/my-wifi/ca.crt
   802-1x.client-cert /etc/pki/my-wifi/client.crt
   802-1x.private-key /etc/pki/my-wifi/client.key
   802-1x.private-key-password s3cr3t
```

**NOTE**

To configure a wired connection using the `nmcli` tool, follow the same procedure as for a wireless connection, except the `802-11-wireless.ssid` and `802-11-wireless-security` key-mgmt settings.
CHAPTER 11. SETTING A DEFAULT GATEWAY IN AN EXISTING CONNECTION PROFILE

In most situations, administrators set the default gateway when they create a connection. However, you can also set the default gateway after creating the connection.

This section describes how to set the default gateway in an existing network connection profile.

11.1. SETTING THE DEFAULT GATEWAY ON AN EXISTING CONNECTION USING NMCLI

In most situations, administrators set the default gateway when they create a connection as explained in, for example, Section 9.1, “Adding a static Ethernet connection using nmcli”.

This section describes how to set or update the default gateway on a previously created connection using the nmcli utility.

Prerequisites

- At least one static IP address must be configured on the connection on which the default gateway will be set.
- If the user is logged in on a physical console, user permissions are sufficient. Otherwise, user must have root permissions.

Procedure

1. Set the IP address of the default gateway.
   For example, to set the IPv4 address of the default gateway on the example connection to 192.0.2.1:

   $ sudo nmcli connection modify example ipv4.gateway "192.0.2.1"

   For example, to set the IPv6 address of the default gateway on the example connection to 2001:db8::1:

   $ sudo nmcli connection modify example ipv6.gateway "2001:db8::1"

2. Restart the network connection for changes to take effect. For example, to restart the example connection using the command line:

   $ sudo nmcli connection up example

WARNING

All connections currently using this network connection are temporarily interrupted during the restart.
3. Optionally, verify that the route is active.
   To display the IPv4 default gateway:
   
   ```
   $ ip -4 route
default via 192.0.2.1 dev example proto static metric 100
   ```

   To display the IPv6 default gateway:
   
   ```
   $ ip -6 route
default via 2001:db8::1 dev example proto static metric 100 pref medium
   ```

   Additional resources
   
   - Section 9.1, “Adding a static Ethernet connection using nmcli”

11.2. SETTING THE DEFAULT GATEWAY ON AN EXISTING CONNECTION USING THE NMCLI INTERACTIVE MODE

In most situations, administrators set the default gateway when they create a connection as explained in, for example, Section 9.4, “Configuring a dynamic Ethernet connection using the interactive editor”.

This section describes how to set or update the default gateway on a previously created connection using the interactive mode of the `nmcli` utility.

Prerequisites

- At least one static IP address must be configured on the connection on which the default gateway will be set.
- If the user is logged in on a physical console, user permissions are sufficient. Otherwise, the user must have `root` permissions.

Procedure

1. Open the `nmcli` interactive mode for the required connection. For example, to open the `nmcli` interactive mode for the `example` connection:
   
   ```
   $ sudo nmcli connection edit example
   ```

2. Set the default gateway.
   For example, to set the IPv4 address of the default gateway on the `example` connection to `192.0.2.1`:
   
   ```
   nmcli> set ipv4.gateway 192.0.2.1
   ```
   
   For example, to set the IPv6 address of the default gateway on the `example` connection to `2001:db8::1`:
   
   ```
   nmcli> set ipv6.gateway 2001:db8::1
   ```

3. Optionally, verify that the default gateway was set correctly:
nmcli> print
...
ipv4.gateway: 192.0.2.1
... 
ipv6.gateway: 2001:db8::1
...
4. Save the configuration:

   nmcli> save persistent

5. Restart the network connection for changes to take effect:

   nmcli> activate example

   **WARNING**
   
   All connections currently using this network connection are temporarily interrupted during the restart.

6. Leave the *nmcli* interactive mode:

   nmcli> quit

7. Optionally, verify that the route is active.
   To display the IPv4 default gateway:

   $ ip -4 route
default via 192.0.2.1 dev example proto static metric 100

   To display the IPv6 default gateway:

   $ ip -6 route
default via 2001:db8::1 dev example proto static metric 100 pref medium

**Additional resources**

- Section 9.4, “Configuring a dynamic Ethernet connection using the interactive editor”

### 11.3. SETTING THE DEFAULT GATEWAY ON AN EXISTING CONNECTION USING NM-CONNECTION-EDITOR

In most situations, administrators set the default gateway when they create a connection as explained in, for example, Section 9.5, “Configuring an Ethernet connection using control-center”.

This section describes how to set or update the default gateway on a previously created connection using the *nm-connection-editor* application.
Prerequisites

- At least one static IP address must be configured on the connection on which the default gateway will be set.

Procedure

1. Open a terminal, and enter `nm-connection-editor`:

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

2. Select the connection to modify, and click the gear wheel icon to edit the existing connection.

3. Set the IPv4 default gateway. For example, to set the IPv4 address of the default gateway on the connection to 192.0.2.1:

   a. Open the IPv4 Settings tab.

   b. Enter the address in the gateway field next to the IP range the gateway’s address is within:

   ![IPv4 Settings tab](image)

4. Set the IPv6 default gateway. For example, to set the IPv6 address of the default gateway on the connection to 2001:db8::1:

   a. Open the IPv6 tab.

   b. Enter the address in the gateway field next to the IP range the gateway’s address is within:

   ![IPv6 tab](image)

5. Click OK.

6. Click Save.

7. Restart the network connection for changes to take effect. For example, to restart the example connection using the command line:

   ```
   $ sudo nmcli connection up example
   ```

   **WARNING**

   All connections currently using this network connection are temporarily interrupted during the restart.
8. Optionally, verify that the route is active. To display the IPv4 default gateway:

```
$ ip -4 route
default via 192.0.2.1 dev example proto static metric 100
```

To display the IPv6 default gateway:

```
$ ip -6 route
default via 2001:db8::1 dev example proto static metric 100 pref medium
```

Additional resources

- Section 9.5, “Configuring an Ethernet connection using control-center”

### 11.4. SETTING THE DEFAULT GATEWAY ON AN EXISTING CONNECTION USING CONTROL-CENTER

In most situations, administrators set the default gateway when they create a connection as explained in, for example, Section 9.5, “Configuring an Ethernet connection using control-center”.

This section describes how to set or update the default gateway on a previously created connection using the control-center application.

**Prerequisites**

- At least one static IP address must be configured on the connection on which the default gateway will be set.

- The network configuration of the connection is open in the control-center application. See Section 9.5, “Configuring an Ethernet connection using control-center”.

**Procedure**

1. Set the IPv4 default gateway. For example, to set the IPv4 address of the default gateway on the connection to `192.0.2.1`:
   a. Open the IPv4 tab.
   b. Enter the address in the gateway field next to the IP range the gateway’s address is within:

<table>
<thead>
<tr>
<th>Address</th>
<th>Netmask</th>
<th>Gateway</th>
</tr>
</thead>
<tbody>
<tr>
<td>192.0.2.123</td>
<td>255.255.255.0</td>
<td>192.0.2.1</td>
</tr>
</tbody>
</table>

2. Set the IPv6 default gateway. For example, to set the IPv6 address of the default gateway on the connection to `2001:db8::1`:
   a. Open the IPv6 tab.
   b. Enter the address in the gateway field next to the IP range the gateway’s address is within:
3. Click **Apply**.

4. Back in the **Network** window, disable and re-enable the connection by switching the button for the connection to **Off** and back to **On** for changes to take effect.

![WARNING]

**WARNING**

All connections currently using this network connection are temporarily interrupted during the restart.

5. Optionally, verify that the route is active.

To display the IPv4 default gateway:

```bash
$ ip -4 route
default via 192.0.2.1 dev example proto static metric 100
```

To display the IPv6 default gateway:

```bash
$ ip -6 route
default via 2001:db8::1 dev example proto static metric 100 pref medium
```

**Additional resources**

- Section 9.5, “Configuring an Ethernet connection using control-center”
CHAPTER 12. CONFIGURING A STATIC ROUTE

By default, and if a default gateway is configured, Red Hat Enterprise Linux forwards traffic for networks that are not directly connected to the host to the default gateway. Using a static route, you can configure that Red Hat Enterprise Linux forwards the traffic for a specific host or network to a different router than the default gateway. This section describes how to configure a static route.

12.1. HOW TO USE THE NMCLI COMMAND TO CONFIGURE A STATIC ROUTE

To configure a static route, use the `nmcli` utility with the following syntax:

```bash
$ nmcli connection modify connection_name ipv4.routes "ip[/prefix] [next_hop] [metric] [attribute=value] [attribute=value] ..."
```

The command supports the following route attributes:

- `table=n`
- `src=address`
- `tos=n`
- `onlink=true|false`
- `window=n`
- `cwnd=n`
- `mtu=n`
- `lock-window=true|false`
- `lock-cwnd=true|false`
- `lock-mtu=true|false`

If you use the `ipv4.routes` sub-command, `nmcli` overrides all current settings of this parameter. To add an additional route, use the `nmcli connection modify connection_name +ipv4.routes "..."` command. In a similar way, you can use `nmcli connection modify connection_name -ipv4.routes "..."` to remove a specific route.

12.2. CONFIGURING A STATIC ROUTE USING A NMCLI COMMAND

You can add a static route to the configuration of a network connection using the `nmcli connection modify` command.

The procedure in this section describes how to add a route to the `192.0.2.0/24` network that uses the gateway running on `198.51.100.1`, which is reachable through the `example` connection.

Prerequisites

- The network is configured
- The gateway for the static route must be directly reachable on the interface.
If the user is logged in on a physical console, user permissions are sufficient. Otherwise, the command requires root permissions.

Procedure

1. Add the static route to the example connection:

```bash
$ sudo nmcli connection modify example +ipv4.routes "192.0.2.0/24 198.51.100.1"
```

To set multiple routes in one step, pass the individual routes comma-separated to the command. For example, to add a route to the 192.0.2.0/24 and 203.0.113.0/24 networks, both routed through the 198.51.100.1 gateway, enter:

```bash
$ sudo nmcli connection modify example +ipv4.routes "192.0.2.0/24 198.51.100.1, 203.0.113.0/24 198.51.100.1"
```

2. Optionally, verify that the routes were added correctly to the configuration:

```bash
$ nmcli connection show example
...  
ipv4.routes:   { ip = 192.0.2.1/24, nh = 198.51.100.1 }
...
```

3. Restart the network connection:

```bash
$ sudo nmcli connection up example
```

![WARNING]

Restarting the connection briefly disrupts connectivity on that interface.

4. Optionally, verify that the route is active:

```bash
$ ip route
...  
192.0.2.0/24 via 198.51.100.1 dev example proto static metric 100
```

Additional resources

- For further details about nmcli, see the nmcli(1) man page.

12.3. CONFIGURING A STATIC ROUTE USING CONTROL-CENTER

You can use control-center in GNOME to add a static route to the configuration of a network connection.

The procedure in this section describes how to add a route to the 192.0.2.0/24 network that uses the gateway running on 198.51.100.1.
Prerequisites

- The network is configured.
- The gateway for the static route must be directly reachable on the interface.
- The network configuration of the connection is opened in the control-center application. See Section 9.5, “Configuring an Ethernet connection using control-center”.

Procedure

1. Open the IPv4 tab.

2. Optionally, disable automatic routes by clicking the On button in the Routes section of the IPv4 tab to use only static routes. If automatic routes are enabled, Red Hat Enterprise Linux uses static routes and routes received from a DHCP server.

3. Enter the address, netmask, gateway, and optionally a metric value:

<table>
<thead>
<tr>
<th>Routes</th>
<th>Automatic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Address</td>
<td>Netmask</td>
</tr>
<tr>
<td>192.0.2.0</td>
<td>24</td>
</tr>
</tbody>
</table>

4. Click Apply.

5. Back in the Network window, disable and re-enable the connection by switching the button for the connection to Off and back to On for changes to take effect.

   **WARNING**
   
   Restarting the connection briefly disrupts connectivity on that interface.

6. Optionally, verify that the route is active:

   ```
   $ ip route
   ...
   192.0.2.0/24 via 198.51.100.1 dev example proto static metric 100
   ```

12.4. CONFIGURING A STATIC ROUTE USING NM-CONNECTION-EDITOR

You can use the nm-connection-editor application to add a static route to the configuration of a network connection.

The procedure in this section describes how to add a route to the 192.0.2.0/24 network that uses the gateway running on 198.51.100.1, which is reachable through the example connection.
Prerequisites

- The network is configured.
- The gateway for the static route must be directly reachable on the interface.

Procedure

1. Open a terminal and enter `nm-connection-editor`:

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

2. Select the `example` connection and click the gear wheel icon to edit the existing connection.

3. Open the IPv4 tab.

4. Click the Routes button.

5. Click the Add button and enter the address, netmask, gateway, and optionally a metric value.

6. Click OK.

7. Click Save.

8. Restart the network connection for changes to take effect. For example, to restart the example connection using the command line:

   ```
   $ sudo nmcli connection up example
   ```

9. Optionally, verify that the route is active:

   ```
   $ ip route
   ...
   192.0.2.0/24 via 198.51.100.1 dev example proto static metric 100
   ```

12.5. CONFIGURING A STATIC ROUTE USING THE NMCLl INTERACTIVE MODE

You can use the interactive mode of the `nmcli` utility to add a static route to the configuration of a network connection.

The procedure in this section describes how to add a route to the 192.0.2.0/24 network that uses the gateway running on 198.51.100.1, which is reachable through the example connection.

Prerequisites
The network is configured

The gateway for the static route must be directly reachable on the interface.

If the user is logged in on a physical console, user permissions are sufficient. Otherwise, the command requires root permissions.

Procedure

1. Open the nmcli interactive mode for the example connection:

   ```
   $ sudo nmcli connection edit example
   ```

2. Add the static route:

   ```
   nmcli> set ipv4.routes 192.0.2.0/24 198.51.100.1
   ```

3. Optionally, verify that the routes were added correctly to the configuration:

   ```
   nmcli> print
   ...
   ipv4.routes:     { ip = 192.0.2.1/24, nh = 198.51.100.1 }  
   ...
   ```

   The ip attribute displays the network to route and the nh attribute the gateway (next hop).

4. Save the configuration:

   ```
   nmcli> save persistent
   ```

5. Restart the network connection:

   ```
   nmcli> activate example
   ```

   **WARNING**

   When you restart the connection, all connections currently using this connection will be temporarily interrupted.

6. Leave the nmcli interactive mode:

   ```
   nmcli> quit
   ```

7. Optionally, verify that the route is active:

   ```
   $ ip route
   ...
   192.0.2.0/24 via 198.51.100.1 dev example proto static metric 100
   ```
Additional resources

- For the list of commands available in the interactive mode, enter `help` in the interactive shell.
CHAPTER 13. CONFIGURING POLICY-BASED ROUTING TO DEFINE ALTERNATIVE ROUTES

By default, the kernel in RHEL decides where to forward network packets based on the destination address using a routing table. Policy-based routing enables you to configure complex routing scenarios. For example, you can route packets based on various criteria, such as the source address, packet metadata, or protocol.

This section describes how to configure policy-based routing using NetworkManager.

NOTE

On systems that use NetworkManager, only the nmcli utility supports setting routing rules and assigning routes to specific tables.

13.1. ROUTING TRAFFIC FROM A SPECIFIC SUBNET TO A DIFFERENT DEFAULT GATEWAY

This section describes how to configure RHEL as a router that, by default, routes all traffic to internet provider A using the default route. Using policy-based routing, RHEL routes traffic received from the internal workstations subnet to provider B.

The procedure assumes the following network topology:

Prerequisites

- The RHEL router you want to set up in the procedure has four network interfaces:
  - The enp7s0 interface is connected to the network of provider A. The gateway IP in the provider’s network is 198.51.100.2, and the network uses a /30 network mask.
  - The enp1s0 interface is connected to the network of provider B. The gateway IP in the provider’s network is 192.0.2.2, and the network uses a /30 network mask.
  - The enp8s0 interface is connected to the 10.0.0.0/24 subnet with internal workstations.
The enp9s0 interface is connected to the 203.0.113.0/24 subnet with the company’s servers.

- Hosts in the internal workstations subnet use 10.0.0.1 as default gateway. In the procedure, you assign this IP address to the enp8s0 network interface of the router.

- Hosts in the server subnet use 203.0.113.1 as default gateway. In the procedure, you assign this IP address to the enp9s0 network interface of the router.

- The firewalld service is enabled and active, which is the default.

Procedure

1. Configure the network interface to provider A:

```
# nmcli connection add type ethernet con-name Provider-A ifname enp7s0 ipv4.method manual ipv4.addresses 198.51.100.1/30 ipv4.gateway 198.51.100.2 ipv4.dns 198.51.100.200 connection.zone external
```

The nmcli connection add command creates a NetworkManager connection profile. The following list describes the options of the command:

- **type ethernet**: Defines that the connection type is Ethernet.
- **con-name connection_name**: Sets the name of the profile. Use a meaningful name to avoid confusion.
- **ifname network_device**: Sets the network interface.
- **ipv4.method manual**: Enables to configure a static IP address.
- **ipv4.addresses IP_address/subnet_mask**: Sets the IPv4 addresses and subnet mask.
- **ipv4.gateway IP_address**: Sets the default gateway address.
- **ipv4.dns IP_of_DNS_server**: Sets the IPv4 address of the DNS server.
- **connection.zone firewalld_zone**: Assigns the network interface to the defined firewalld zone. Note that firewalld automatically enables masquerading interfaces assigned to the external zone.

2. Configure the network interface to provider B:

```
# nmcli connection add type ethernet con-name Provider-B ifname enp1s0 ipv4.method manual ipv4.addresses 192.0.2.1/30 ipv4.routes "0.0.0.0/1 192.0.2.2 table=5000, 128.0.0.0/1 192.0.2.2 table=5000" connection.zone external
```

This command uses the ipv4.routes parameter instead of ipv4.gateway to set the default gateway. This is required to assign the default gateway for this connection to a different routing table (5000) than the default. NetworkManager automatically creates this new routing table when the connection is activated.
NOTE

The `nmcli` utility does not support using `0.0.0.0/0` for the default gateway in `ipv4.gateway`. To work around this problem, the command creates separate routes for both the `0.0.0.0/1` and `128.0.0.0/1` subnets, which covers also the full IPv4 address space.

3. Configure the network interface to the internal workstations subnet:

```bash
# nmcli connection add type ethernet con-name Internal-Workstations ifname enp8s0 ipv4.method manual ipv4.addresses 10.0.0.1/24 ipv4.routes "10.0.0.0/24 src=192.0.2.1 table=5000" ipv4.routing-rules "priority 5 from 10.0.0.0/24 table 5000" connection.zone internal
```

This command uses the `ipv4.routes` parameter to add a static route to the routing table with ID `5000`. This static route for the `10.0.0.0/24` subnet uses the IP of the local network interface to provider B (`192.0.2.1`) as next hop.

Additionally, the command uses the `ipv4.routing-rules` parameter to add a routing rule with priority `5` that routes traffic from the `10.0.0.0/24` subnet to table `5000`. Low values have a high priority.

Note that the syntax in the `ipv4.routing-rules` parameter is the same as in an `ip route add` command, except that `ipv4.routing-rules` always requires specifying a priority.

4. Configure the network interface to the server subnet:

```bash
# nmcli connection add type ethernet con-name Servers ifname enp9s0 ipv4.method manual ipv4.addresses 203.0.113.1/24 connection.zone internal
```

Verification steps

1. On a RHEL host in the internal workstation subnet:
   a. Install the `traceroute` package:

      ```bash
      # yum install traceroute
      ```

   b. Use the `traceroute` utility to display the route to a host on the internet:

      ```bash
      # traceroute redhat.com
      traceroute to redhat.com (209.132.183.105), 30 hops max, 60 byte packets
      1  10.0.0.1 (10.0.0.1)  0.337 ms  0.260 ms  0.223 ms
      2  192.0.2.1 (192.0.2.1)  0.884 ms  1.066 ms  1.248 ms
      ...
      ```

      The output of the command displays that the router sends packets over `192.0.2.1`, which is the network of provider B.

2. On a RHEL host in the server subnet:
   a. Install the `traceroute` package:

      ```bash
      # yum install traceroute
      ```
b. Use the `traceroute` utility to display the route to a host on the internet:

```
# traceroute redhat.com
traceroute to redhat.com (209.132.183.105), 30 hops max, 60 byte packets
 1  203.0.113.1 (203.0.113.1)    2.179 ms  2.073 ms  1.944 ms
 2  198.51.100.2 (198.51.100.2) 1.868 ms  1.798 ms  1.549 ms
...
```

The output of the command displays that the router sends packets over `198.51.100.2`, which is the network of provider A.

### Troubleshooting steps

On the RHEL router:

1. Display the rule list:

```
# ip rule list
0: from all lookup local
5: from 10.0.0.0/24 lookup 5000
 32766: from all lookup main
 32767: from all lookup default
```

By default, RHEL contains rules for the tables `local`, `main`, and `default`.

2. Display the routes in table `5000`:

```
# ip route list table 5000
0.0.0.0/1 via 192.0.2.2 dev enp1s0 proto static metric 100
10.0.0.0/24 dev enp8s0 proto static scope link src 192.0.2.1 metric 102
128.0.0.0/1 via 192.0.2.2 dev enp1s0 proto static metric 100
```

3. Display which interfaces are assigned to which firewall zones:

```
# firewall-cmd --get-active-zones
external interfaces: enp1s0 enp7s0
internal interfaces: enp8s0 enp9s0
```

4. Verify that the `external` zone has masquerading enabled:

```
# firewall-cmd --info-zone=external
external (active)
target: default
icmp-block-inversion: no
interfaces: enp1s0 enp7s0
sources:
services: ssh
ports:
protocols:
masquerade: yes
```

### Additional resources

Red Hat Enterprise Linux 8 Configuring and managing networking
• For further details about the **ipv4**.* parameters you can set in the `nmcli connection add` command, see the **IPv4 settings** section in the `nm-settings(5)` man page.

• For further details about the **connection**.* parameters you can set in the `nmcli connection add` command, see the **Connection settings** section in the `nm-settings(5)` man page.

• For further details about managing NetworkManager connections using `nmcli`, see the **Connection management commands** section in the `nmcli(1)` man page.
CHAPTER 14. CONFIGURING VLAN TAGGING

This section describes how to configure Virtual Local Area Network (VLAN). A VLAN is a logical network within a physical network. The VLAN interface tags packets with the VLAN ID as they pass through the interface, and removes tags of returning packets.

You create a VLAN interface on top of another interface, such as Ethernet, bond, team, or bridge. This interface is called the parent interface.

14.1. CONFIGURING VLAN TAGGING USING NM-CONNECTION-EDITOR

This section describes how to configure Virtual Local Area Network (VLAN) tagging using the nm-connection-editor application.

Prerequisites

- The interface you plan to use as a parent to the virtual VLAN interface supports VLAN tags.
- If you configure the VLAN on top of a bond interface:
  - The slaves of the bond are up.
  - The bond is not configured with the fail_over_mac=follow option. A VLAN virtual device cannot change its MAC address to match the parent’s new MAC address. In such a case, the traffic would still be sent with the then incorrect source MAC address.
- The switch the host is connected to is configured to support VLAN tags. For details, see the documentation of your switch.

Procedure

1. Open a terminal, and enter nm-connection-editor:

   $ nm-connection-editor

2. Click the + button to add a new connection.

3. Select the VLAN connection type, and click Create.

4. On the VLAN tab:
   a. Select the parent interface.
   b. Select the VLAN id. Note that the VLAN must be within the range from 0 to 4094.
   c. By default, the VLAN connection inherits the maximum transmission unit (MTU) from the parent interface. Optionally, set a different MTU value.
   d. Optionally, set the name of the VLAN interface and further VLAN-specific options.
5. On the IPv4 Settings tab, configure the IPv4 settings. For example, set a static IPv4 address, network mask, default gateway, and DNS server:
6. On the **IPv6 Settings** tab, configure the IPv6 settings. For example, set a static IPv6 address, network mask, default gateway, and DNS server:

<table>
<thead>
<tr>
<th>Address</th>
<th>Prefix</th>
<th>Gateway</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001:db8::1</td>
<td>32</td>
<td>2001:db8::ffe</td>
</tr>
</tbody>
</table>

**DNS servers:** 2001:db8::fffd

7. Click **Save** to save the VLAN connection.

8. Close **nm-connection-editor**.

9. Optionally, verify the settings:

```
# ip -d addr show vlan10
4: vlan10@enp1s0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc noqueue
  state UP group default qlen 1000
  link/ether 52:54:00:d5:e0:fb brd ff:ff:ff:ff:ff:ff promiscuity 0
  vlan protocol 802.1Q id 10 <REORDER_HDR> numtxqueues 1 numrxqueues 1
gso_max_size 65536 gso_max_segs 65535
  inet 192.0.2.1/24 brd 192.0.2.255 scope global noprefixroute vlan10
    valid_lft forever preferred_lft forever
  inet6 fe80::8dd7:9030:6f8e:89e6/64 scope link noprefixroute
    valid_lft forever preferred_lft forever
```

### 14.2. CONFIGURING VLAN TAGGING USING NMCLi COMMANDS

This section describes how to configure Virtual Local Area Network (VLAN) tagging using **nmcli** commands.

**Prerequisites**

- The interface you plan to use as a parent to the virtual VLAN interface supports VLAN tags.

- If you configure the VLAN on top of a bond interface:
  - The slaves of the bond are up.
  - The bond is not configured with the **fail_over_mac=follow** option. A VLAN virtual device cannot change its MAC address to match the parent’s new MAC address. In such a case, the traffic would still be sent with the then incorrect source MAC address.
The switch the host is connected to is configured to support VLAN tags. For details, see the documentation of your switch.

Procedure

1. Optionally, display the available network interfaces:

   ```
   # ip address show
   1: lo: <LOOPBACK,UP,LOWER_UP> mtu 65536 qdisc noqueue state UNKNOWN group default qlen 1000
     link/loopback 00:00:00:00:00:00 brd 00:00:00:00:00:00
     inet 127.0.0.1/8 scope host lo
       valid_lft forever preferred_lft forever
     inet6 ::1/128 scope host
       valid_lft forever preferred_lft forever
   2: enp1s0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc fq_codel state UP group default qlen 1000
     link/ether 52:54:00:d5:e0:fb brd ff:ff:ff:ff:ff:ff
   ```

2. Create the VLAN interface. For example, to create a VLAN interface named `vlan10` that uses `enp1s0` as its parent interface and that tags packets with VLAN ID 10, enter:

   ```
   # nmcli connection add type vlan con-name vlan10 ifname vlan10 vlan.parent enp1s0 vlan.id 10
   ```

   Note that the VLAN must be within the range from 0 to 4094.

3. By default, the VLAN connection inherits the maximum transmission unit (MTU) from the parent interface. Optionally, set a different MTU value:

   ```
   # nmcli connection modify vlan10 802-3-ethernet.mtu 2000
   ```

4. Configure the IPv4 settings. For example, to set a static IPv4 address, network mask, default gateway, and DNS server to the `vlan10` connection, enter:

   ```
   # nmcli connection modify vlan10 ipv4.addresses '192.0.2.1/24'
   # nmcli connection modify vlan10 ipv4.gateway '192.0.2.254'
   # nmcli connection modify vlan10 ipv4.dns '192.0.2.253'
   # nmcli connection modify vlan10 ipv4.method manual
   ```

5. Configure the IPv6 settings. For example, to set a static IPv6 address, network mask, default gateway, and DNS server to the `vlan10` connection, enter:

   ```
   # nmcli connection modify vlan10 ipv6.addresses '2001:db8::1/32'
   # nmcli connection modify vlan10 ipv6.gateway '2001:db8::ffffe'
   # nmcli connection modify vlan10 ipv6.dns '2001:db8::fffd'
   # nmcli connection modify vlan10 ipv6.method manual
   ```

6. Optionally, verify the settings:

   ```
   # ip -d addr show vlan10
   4: vlan10@enp1s0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc noqueue state UP group default qlen 1000
     link/ether 52:54:00:d5:e0:fb brd ff:ff:ff:ff:ff promiscuity 0
   ```
Additional resources

- For `nmcli` examples, see the `nmcli-examples(7)` man page.
- For all vlan properties you can set, see the `vlan setting` section in the `nm-settings(5)` man page.
CHAPTER 15. CONFIGURING A NETWORK BRIDGE

A network bridge is a link-layer device which forwards traffic between networks based on MAC addresses. The bridge device decides on forwarding packages based on a table of MAC addresses. The bridge builds the MAC addresses table by listening to network traffic and thereby learning what hosts are connected to each network.

For example, you can use a software bridge on a Red Hat Enterprise Linux 8 host:

- To emulate a hardware bridge
- In virtualization environments, to integrate virtual machines (VM) to the same network as the host

Due to the IEEE 802.11 standard which specifies the use of 3-address frames in Wi-Fi for the efficient use of airtime, you cannot configure a bridge over Wi-Fi networks operating in Ad-Hoc or Infrastructure modes.

15.1. CONFIGURING A NETWORK BRIDGE USING NMCLI COMMANDS

This section explains how to configure a network bridge using the `nmcli` utility.

Prerequisites

- Two or more physical or virtual network devices are installed in the server.
- You are logged in as the `root` user.

Procedure

1. Create a bridge interface. For example, to create the bridge interface named `bridge0`, enter:

   ```bash
   # nmcli connection add type bridge con-name bridge0 ifname bridge0
   ```

2. Configure the IPv4 settings. For example, to set a static IPv4 address, network mask, default gateway, DNS server, and DNS search domain of the `bridge0` connection, enter:

   ```bash
   # nmcli connection modify bridge0 ipv4.addresses '192.0.2.1/24'
   # nmcli connection modify bridge0 ipv4.gateway '192.0.2.254'
   # nmcli connection modify bridge0 ipv4.dns '192.0.2.253'
   # nmcli connection modify bridge0 ipv4.dns-search 'example.com'
   # nmcli connection modify bridge0 ipv4.method manual
   ```

3. Configure the IPv6 settings. For example, to set a static IPv6 address, network mask, default gateway, DNS server, and DNS search domain of the `bridge0` connection, enter:

   ```bash
   # nmcli connection modify bridge0 ipv6.addresses '2001:db8::1/32'
   # nmcli connection modify bridge0 ipv6.gateway '2001:db8::ffe'
   # nmcli connection modify bridge0 ipv6.dns '2001:db8::fffd'
   # nmcli connection modify bridge0 ipv6.dns-search 'example.com'
   # nmcli connection modify bridge0 ipv6.method manual
   ```

4. Optionally, configure further properties of the bridge. For example, to set the Spanning Tree Protocol (STP) priority of `bridge0` to 16384, enter:

   ```bash
   # nmcli connection modify bridge0 stp.priority 16384
   ```
# nmcli connection modify bridge0 bridge.priority '16384'

By default, STP is enabled.

5. Optionally, display the network interfaces, and note the names of the interfaces you want to add to the bridge as a slave in the next step:

   # nmcli device

   DEVICE  TYPE      STATE         CONNECTION
   enp1s0  ethernet  connected     enp1s0
   enp7s0  ethernet  disconnected  --
   enp8s0  ethernet  disconnected  --
   lo      loopback  unmanaged     --

6. Assign the port interfaces to the bridge’s connection. For example, to add the interfaces named enp7s0 and enp8s0 to the bridge0 connection, enter:

   # nmcli connection add type ethernet slave-type bridge con-name bridge0-port1 ifname enp7s0 master bridge0
   # nmcli connection add type ethernet slave-type bridge con-name bridge0-port2 ifname enp8s0 master bridge0

7. Activate the connection. For example, to activate the bridge0 connection, enter:

   # nmcli connection up bridge0

8. Verify that the slave devices are connected, and the CONNECTION column displays the slave’s connection name:

   # nmcli device

   DEVICE   TYPE      STATE      CONNECTION
   ...
   enp7s0   ethernet  connected  bridge0-port1
   enp8s0   ethernet  connected  bridge0-port2

Red Hat Enterprise Linux activates master and slave devices when the system boots. By activating any slave connection, the master is also activated. However, in this case, only one slave connection is activated. By default, activating the master does not automatically activate the slaves. However, you can enable this behavior by setting:

   a. Enable the connection.autoconnect-slaves parameter of the bridge connection:

      # nmcli connection modify bridge0 connection.autoconnect-slaves 1

   b. Reactivate the bridge:

      # nmcli connection up bridge0

Verification steps

- Display the link status of Ethernet devices that are slaves of a specific bridge:

   # ip link show master bridge0
Display the status of Ethernet devices that are slaves to any bridge device:

```
# bridge link show
3: enp7s0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 master bridge0 state forwarding priority 32 cost 100
  link/ether 52:54:00:62:61:0e brd ff:ff:ff:ff:ff:ff
4: enp8s0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 master bridge0 state listening priority 32 cost 100
  link/ether 52:54:00:9e:f1:ce brd ff:ff:ff:ff:ff:ff
5: enp9s0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 master bridge1 state forwarding priority 32 cost 100
6: enp11s0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 master bridge1 state blocking priority 32 cost 100
...
```

To display the status for a specific Ethernet device, use the `bridge link show dev ethernet_device_name` command.

Additional resources

- For `nmcli` examples, see the `nmcli-examples(7)` man page.
- For all bridge properties you can set, see the `bridge settings` section in the `nm-settings(5)` man page.
- For all bridge port properties you can set, see the `bridge-port settings` section in the `nm-settings(5)` man page.
- For details about the `bridge` utility, see the `bridge(8)` man page.

### 15.2. CONFIGURING A NETWORK BRIDGE USING NM-CONNECTION-EDITOR

This section explains how to configure a network bridge using the `nm-connection-editor` application.

**Prerequisites**

- Two or more physical or virtual network devices are installed in the server.

**Procedure**

1. Open a terminal, and enter `nm-connection-editor`:

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

2. Click the + button to add a new connection.

3. Select the **Bridge** connection type, and click **Create**.
a. Optionally, set the name of the bridge interface in the **Interface name** field.

b. Click the **Add** button to add a network interface as a slave to the bridge.
   
   i. Select the connection type of the interface. For example, select **Ethernet** for a wired connection.

   ii. Optionally, set a connection name for the slave device.

   iii. In the **Device** field on the **Ethernet** tab, select the network interface you want to add as a slave to the bridge.

   iv. Click **Save**.

c. Repeat the previous step for each interface you want to add to the bridge.

   ![Editing Bridge connection 1](image)

   - **Connection name:** Bridge connection 1
   - **Interface name:** bridge0
   - **Bridged connections:**
     - bridge0 slave 1
     - bridge0 slave 2

   - **Add**
   - **Edit**

d. Optionally, configure further bridge settings, such as Spanning Tree Protocol (STP) options.
4. On the **IPv4 Settings** tab, configure the IPv4 settings. For example, set a static IPv4 address, network mask, default gateway, DNS server, and DNS search domain:

![IPv4 Settings screenshot](image1)

5. On the **IPv6 Settings** tab, configure the IPv6 settings. For example, set a static IPv6 address, network mask, default gateway, DNS server, and DNS search domain:

![IPv6 Settings screenshot](image2)

6. Save the bridge connection.

**Verification steps**

- Display the link status of Ethernet devices that are slaves of a specific bridge:

  ```bash
  # ip link show master bridge0
  3: enp7s0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc fq_codel master
    bridge0 state UP mode DEFAULT group default qlen 1000
    link/ether 52:54:00:62:61:0e brd ff:ff:ff:ff:ff:ff
  4: enp8s0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc fq_codel master
    bridge0 state UP mode DEFAULT group default qlen 1000
    link/ether 52:54:00:9e:f1:ce brd ff:ff:ff:ff:ff:ff
  ```

- Display the status of Ethernet devices that are slaves to any bridge device:

  ```bash
  # bridge link show
  3: enp7s0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 master bridge0 state forwarding priority 32 cost 100
  4: enp8s0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 master bridge0 state listening priority 32 cost 100
  5: enp9s0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 master bridge1 state forwarding priority 32 cost 100
  6: enp11s0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 master bridge1 state blocking priority 32 cost 100
  ...
  ```

To display the status for a specific Ethernet device, use the `bridge link show dev ethernet_device_name` command.
CHAPTER 16. CONFIGURING NETWORK TEAMING

This section describes the basics of network teaming, the differences between bonding and teaming, and how to configure a network team on Red Hat Enterprise Linux 8.

Prerequisites

- Red Hat Enterprise Linux 8 is installed.
- The system has an active subscription assigned.

16.1. UNDERSTANDING NETWORK TEAMING

Network teaming is a feature that combines or aggregates network interfaces to provide a logical interface with higher throughput or redundancy.

Network teaming uses a kernel driver to implement fast handling of packet flows, as well as user-space libraries and services for other tasks. This way, network teaming is an easily extensible and scalable solution for load-balancing and redundancy requirements.

Note that in the context of network teaming, the term *port* is also known as *slave*. In the *teamd* service, the term *port* is preferred while in the *NetworkManager* service, the term *slave* refers to interfaces which create a team.

**IMPORTANT**

Certain network teaming features, such as the fail-over mechanism, do not support direct cable connections without a network switch. For further details, see Is bonding supported with direct connection using crossover cables?

16.2. UNDERSTANDING THE DEFAULT BEHAVIOR OF MASTER AND SLAVE INTERFACES

Consider the following default behavior of, when managing or troubleshooting team or bond port interfaces using the *NetworkManager* service:

- Starting the master interface does not automatically start the port interfaces.
- Starting a port interface always starts the master interface.
- Stopping the master interface also stops the port interface.
- A master without ports can start static IP connections.
- A master without ports waits for ports when starting DHCP connections.
- A master with a DHCP connection waiting for ports completes when you add a port with a carrier.
- A master with a DHCP connection waiting for ports continues waiting when you add a port without carrier.
## 16.3. COMPARISON OF NETWORK TEAMING AND BONDING FEATURES

The following table compares features supported in network teams and network bonds:

<table>
<thead>
<tr>
<th>Feature</th>
<th>Network bond</th>
<th>Network team</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broadcast Tx policy</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Round-robin Tx policy</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Active-backup Tx policy</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>LACP (802.3ad) support</td>
<td>Yes (active only)</td>
<td>Yes</td>
</tr>
<tr>
<td>Hash-based Tx policy</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>User can set hash function</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Tx load-balancing support (TLB)</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>LACP hash port select</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Load-balancing for LACP support</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Ethtool link monitoring</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>ARP link monitoring</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>NS/NA (IPv6) link monitoring</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Ports up/down delays</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Port priorities and stickiness (“primary” option enhancement)</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Separate per-port link monitoring setup</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Multiple link monitoring setup</td>
<td>Limited</td>
<td>Yes</td>
</tr>
<tr>
<td>Lockless Tx/Rx path</td>
<td>No (rwlock)</td>
<td>Yes (RCU)</td>
</tr>
<tr>
<td>VLAN support</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>User-space runtime control</td>
<td>Limited</td>
<td>Yes</td>
</tr>
<tr>
<td>Logic in user-space</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>
### 16.4. UNDERSTANDING THE TEAMD SERVICE, RUNNERS, AND LINK-WATCHERS

The team service, **teamd**, controls one instance of the team driver. This instance of the driver adds instances of a hardware device driver to form a team of network interfaces. The team driver presents a network interface, for example **team0**, to the kernel.

The **teamd** service implements the common logic to all methods of teaming. Those functions are unique to the different load sharing and backup methods, such as round-robin, and implemented by separate units of code referred to as **runners**. Administrators specify runners in JavaScript Object Notation (JSON) format, and the JSON code is compiled into an instance of **teamd** when the instance is created. Alternatively, when using **NetworkManager**, you can set the runner in the **team.runner** parameter, and **NetworkManager** auto-creates the corresponding JSON code.

The following runners are available:

- **broadcast**: Transmits data over all ports.
- **roundrobin**: Transmits data over all ports in turn.
- **activebackup**: Transmits data over one port while the others are kept as a backup.
- **loadbalance**: Transmits data over all ports with active Tx load balancing and Berkeley Packet Filter (BPF)-based Tx port selectors.
- **random**: Transmits data on a randomly selected port.
- **lacp**: Implements the 802.3ad Link Aggregation Control Protocol (LACP).

The **teamd** services uses a link watcher to monitor the state of subordinate devices. The following link-watchers are available:

- **ethtool**: The **libteam** library uses the **ethtool** utility to watch for link state changes. This is the default link-watcher.
- **arp_ping**: The *libteam* library uses the *arp_ping* utility to monitor the presence of a far-end hardware address using Address Resolution Protocol (ARP).

- **nsna_ping**: On IPv6 connections, the *libteam* library uses the Neighbor Advertisement and Neighbor Solicitation features from the IPv6 Neighbor Discovery protocol to monitor the presence of a neighbor's interface.

Each runner can use any link watcher, with the exception of *lacp*. This runner can only use the *ethtool* link watcher.

### 16.5. INSTALLING THE TEAMD SERVICE

To configure a network team in **NetworkManager**, you require the *teamd* service and the team plug-in for **NetworkManager**. Both are installed on Red Hat Enterprise Linux 8 by default. This section describes how you install the required packages in case that you remove them.

**Prerequisites**

- An active Red Hat subscription is assigned to the host.

**Procedure**

1. Install the *teamd* and *NetworkManager-team* packages:

   ```bash
   # yum install teamd NetworkManager-team
   ```

### 16.6. CONFIGURING A NETWORK TEAM USING NMCLI COMMANDS

This section describes how you configure a network team using **nmcli** commands.

**Prerequisites**

- Two or more network cards are installed in the server.
- The network cards are connected to a switch.

**Procedure**

1. Create the team interface. For example, to create a team interface that uses the *activebackup* runner and both the interface and connection named *team0*, enter:

   ```bash
   # nmcli connection add type team con-name team0 ifname team0 team.runner activebackup
   ```

2. Optionally, set a link watcher. For example, to set the *ethtool* link watcher, modify the *team0* connection:

   ```bash
   # nmcli connection modify team0 team.link-watchers "name=ethtool"
   ```

Link watchers support different parameters. To set parameters for a link watcher, specify them space-separated in the *name* property. Note that the name property must be surrounded by quotes. For example, to use the *ethtool* link watcher and set its *delay-up* parameter to 2500 milliseconds (2.5 seconds):
To set multiple link watchers and each of them with specific parameters, the link watchers must be separated by a comma. The following example sets the `ethtool` link watcher with the `delay-up` parameter and the `arp_ping` link watcher with the `source-host` and `target-host` parameter:

```bash
# nmcli connection modify team0 team.link-watchers "name=ethtool delay-up=2500"
# nmcli connection modify team0 team.link-watchers "name=ethtool delay-up=2,
name=arp_ping source-host=192.0.2.1 target-host=192.0.2.2"
```

3. Configure the IPv4 settings. For example, to set a static IPv4 address, network mask, default gateway, DNS server, and DNS search domain the `team0` connection, enter:

```bash
# nmcli connection modify team0 ipv4.addresses '192.0.2.1/24'
# nmcli connection modify team0 ipv4.gateway '192.0.2.254'
# nmcli connection modify team0 ipv4.dns '192.0.2.253'
# nmcli connection modify team0 ipv4.dns-search 'example.com'
# nmcli connection modify team0 ipv4.method manual
```

4. Configure the IPv6 settings. For example, to set a static IPv6 address, network mask, default gateway, DNS server, and DNS search domain of the `team0` connection, enter:

```bash
# nmcli connection modify team0 ipv6.addresses '2001:db8::1/32'
# nmcli connection modify team0 ipv6.gateway '2001:db8::ffe'
# nmcli connection modify team0 ipv6.dns '2001:db8::fffd'
# nmcli connection modify team0 ipv6.dns-search 'example.com'
# nmcli connection modify team0 ipv6.method manual
```

5. Optionally, display the network interfaces, and note the names of the interfaces you want to add to the team in the next step:

```bash
# nmcli device
DEVICE  TYPE      STATE         CONNECTION
enp1s0  ethernet  connected     enp1s0
enp7s0  ethernet  disconnected  --
enp8s0  ethernet  disconnected  --
lo      loopback  unmanaged     --
```

**IMPORTANT**

You can only use network interfaces in a team that are not assigned to any connection. In the above example, you can only use the `enp7s0` and `enp8s0` interfaces.

6. Assign the port interfaces to the team’s connection. For example, to add the interfaces named `enp7s0` and `enp8s0` to the `team0` connection:

```bash
# nmcli connection add type ethernet slave-type team con-name team0-port1 ifname enp7s0
master team0
# nmcli connection add type ethernet slave-type team con-name team0-port2 ifname enp8s0
master team0
```

7. Activate the connection. For example, to activate the `team0` connection:
# nmcli connection up team0

8. Optionally, display the status of the team:

```
# teamdctl team0 state
setup:
  runner: activebackup
ports:
  enp7s0
    link watches:
      link summary: up
      instance[link_watch_0]:
        name: ethtool
        link: up
        down count: 0
  enp8s0
    link watches:
      link summary: up
      instance[link_watch_0]:
        name: ethtool
        link: up
        down count: 0
  runner:
    active port: enp7s0
```

In the example, both ports are up.

Additional resources

- Section 16.4, "Understanding the teamd service, runners, and link-watchers".
- For **nmcli** examples, see the **nmcli-examples(7)** man page.
- For all team properties you can set, see the **team** section in the **nm-settings(5)** man page.
- For parameters you can set in the JSON configuration, as well as JSON examples, see the **teamd.conf(5)** man page.

### 16.7. CONFIGURING A NETWORK TEAM USING NM-CONNECTION-EDITOR

This section describes how you configure a network team using the **nm-connection-editor** application.

**Prerequisites**

- Two or more network cards are installed in the server.
- The network cards are connected to a switch.

**Procedure**

1. Open a terminal, and enter **nm-connection-editor**:

```
$ nm-connection-editor
```
2. Click the + button to add a new connection.

3. Select the Team connection type, and click Create.

4. On the Team tab:
   a. Optionally, set the name of the team interface in the Interface name field.
   b. Click the Add button to add a network interface as a slave to the team.
      i. Select the connection type of the interface. For example, select Ethernet for a wired connection.
      ii. Optionally, set a connection name for the slave device.
      iii. In the Device field on the Ethernet tab, select the network interface you want to add as a slave to the team.

      **IMPORTANT**
      
      You can only use network interfaces in a team that are not configured.

      iv. Click Save.

   c. Repeat the previous step for each interface you want to add to the team.

   d. Click the Advanced button to set advanced options to the team connection.
      i. On the Runner tab, select the runner.
      ii. On the Link Watcher tab, set the link link watcher and its optional settings.
      iii. Click OK.

5. On the IPv4 Settings tab, configure the IPv4 settings. For example, set a static IPv4 address,
5. On the **IPv4 Settings** tab, configure the IPv4 settings. For example, set a static IPv4 address, network mask, default gateway, DNS server, and DNS search domain:

![IPv4 Settings](image1)

6. On the **IPv6 Settings** tab, configure the IPv6 settings. For example, set a static IPv6 address, network mask, default gateway, DNS server, and DNS search domain:

![IPv6 Settings](image2)

7. Click **Save** to save the team connection.
8. Close **nm-connection-editor**.

9. Optionally, display the status of the team:

   ```
   # teamdctl team0 state
   setup:
   runner: activebackup
   ports:
   enp7s0
   link watches:
   link summary: up
   instance[link_watch_0]:
   name: ethtool
   link: up
   down count: 0
   enp8s0
   link watches:
   link summary: up
   instance[link_watch_0]:
   name: ethtool
   link: up
   down count: 0
   runner:
   active port: enp7s0
   ```

**Additional resources**

- Section 16.4, "Understanding the teamd service, runners, and link-watchers".
CHAPTER 17. CONFIGURING NETWORK BONDING

This section describes the basics of network bonding, the differences between bonding and teaming, and how to configure a network bond on Red Hat Enterprise Linux 8.

17.1. UNDERSTANDING NETWORK BONDING

Network bonding is a method to combine or aggregate network interfaces to provide a logical interface with higher throughput or redundancy.

The active-backup, balance-tlb, and balance-alb modes do not require any specific configuration of the network switch. However, other bonding modes require configuring the switch to aggregate the links. For example, Cisco switches requires EtherChannel for modes 0, 2, and 3, but for mode 4, the Link Aggregation Control Protocol (LACP) and EtherChannel are required.

For further details, see the documentation of your switch and https://www.kernel.org/doc/Documentation/networking/bonding.txt.

IMPORTANT

Certain network bonding features, such as the fail-over mechanism, do not support direct cable connections without a network switch. For further details, see the Is bonding supported with direct connection using crossover cables? KCS solution.

17.2. UNDERSTANDING THE DEFAULT BEHAVIOR OF MASTER AND SLAVE INTERFACES

Consider the following default behavior of, when managing or troubleshooting team or bond port interfaces using the NetworkManager service:

- Starting the master interface does not automatically start the port interfaces.
- Starting a port interface always starts the master interface.
- Stopping the master interface also stops the port interface.
- A master without ports can start static IP connections.
- A master without ports waits for ports when starting DHCP connections.
- A master with a DHCP connection waiting for ports completes when you add a port with a carrier.
- A master with a DHCP connection waiting for ports continues waiting when you add a port without carrier.

17.3. COMPARISON OF NETWORK TEAMING AND BONDING FEATURES

The following table compares features supported in network teams and network bonds:
<table>
<thead>
<tr>
<th>Feature</th>
<th>Network bond</th>
<th>Network team</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broadcast Tx policy</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Round-robin Tx policy</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Active-backup Tx policy</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>LACP (802.3ad) support</td>
<td>Yes (active only)</td>
<td>Yes</td>
</tr>
<tr>
<td>Hash-based Tx policy</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>User can set hash function</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Tx load-balancing support (TLB)</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>LACP hash port select</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Load-balancing for LACP support</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Ethtool link monitoring</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>ARP link monitoring</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>NS/NA (IPv6) link monitoring</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Ports up/down delays</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Port priorities and stickiness (&quot;primary&quot; option enhancement)</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Separate per-port link monitoring setup</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Multiple link monitoring setup</td>
<td>Limited</td>
<td>Yes</td>
</tr>
<tr>
<td>Lockless Tx/Rx path</td>
<td>No (rwlock)</td>
<td>Yes (RCU)</td>
</tr>
<tr>
<td>VLAN support</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>User-space runtime control</td>
<td>Limited</td>
<td>Yes</td>
</tr>
<tr>
<td>Logic in user-space</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Extensibility</td>
<td>Hard</td>
<td>Easy</td>
</tr>
<tr>
<td>Modular design</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>
### 17.4. Upstream Switch Configuration Depending on the Bonding Modes

The following table describes which settings you must apply to the upstream switch depending on the bonding mode:

<table>
<thead>
<tr>
<th>Bonding mode</th>
<th>Configuration on the switch</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - <code>balance-rr</code></td>
<td>Requires static Etherchannel enabled (not LACP-negotiated)</td>
</tr>
<tr>
<td>1 - <code>active-backup</code></td>
<td>Requires autonomous ports</td>
</tr>
<tr>
<td>2 - <code>balance-xor</code></td>
<td>Requires static Etherchannel enabled (not LACP-negotiated)</td>
</tr>
<tr>
<td>3 - <code>broadcast</code></td>
<td>Requires static Etherchannel enabled (not LACP-negotiated)</td>
</tr>
<tr>
<td>4 - <code>802.3ad</code></td>
<td>Requires LACP-negotiated Etherchannel enabled</td>
</tr>
<tr>
<td>5 - <code>balance-tlb</code></td>
<td>Requires autonomous ports</td>
</tr>
<tr>
<td>6 - <code>balance-alb</code></td>
<td>Requires autonomous ports</td>
</tr>
</tbody>
</table>

For configuring these settings on your switch, see the switch documentation.

### 17.5. Configuring a Network Bond Using `nmcli` Commands

This section describes how to configure a network bond using `nmcli` commands.

**Prerequisites**

- Two or more network cards are installed in the server.
- The network cards are connected to a switch.

**Procedure**
1. Create a bond interface. For example, to create a bond interface that uses the `active-backup` mode and both the interface and the connection are named `bond0`, enter:

```
# nmcli connection add type bond con-name bond0 ifname bond0 bond.options "mode=active-backup"
```

To additionally set a Media Independent Interface (MII) monitoring interval, add the `miimon=interval` option to the `bond.options` property. For example, to use the same command but, additionally, set the MII monitoring interval to 1000 milliseconds (1 second), enter:

```
# nmcli connection add type bond con-name bond0 ifname bond0 bond.options "mode=active-backup,miimon=1000"
```

2. Configure the IPv4 settings. For example, to set a static IPv4 address, network mask, default gateway, DNS server, and DNS search domain to the `bond0` connection, enter:

```
# nmcli connection modify bond0 ipv4.addresses '192.0.2.1/24'
# nmcli connection modify bond0 ipv4.gateway '192.0.2.254'
# nmcli connection modify bond0 ipv4.dns '192.0.2.253'
# nmcli connection modify bond0 ipv4.dns-search 'example.com'
# nmcli connection modify bond0 ipv4.method manual
```

3. Configure the IPv6 settings. For example, to set a static IPv6 address, network mask, default gateway, DNS server, and DNS search domain to the `bond0` connection, enter:

```
# nmcli connection modify bond0 ipv6.addresses '2001:db8::1/32'
# nmcli connection modify bond0 ipv6.gateway '2001:db8::ffe'
# nmcli connection modify bond0 ipv6.dns '2001:db8::fffd'
# nmcli connection modify bond0 ipv6.dns-search 'example.com'
# nmcli connection modify bond0 ipv6.method manual
```

4. Optionally, display the network interfaces, and note names of interfaces you plan to add to the bond:

```
# nmcli device
```

```
DEVICE    TYPE      STATE         CONNECTION
enp1s0    ethernet  connected     enp1s0
enp7s0    ethernet  disconnected  --
enp8s0    ethernet  disconnected  --
lo    loopback unmanaged     --
```

5. Assign port interfaces to the bond’s connection. For example, to add the interfaces named `enp7s0` and `enp8s0` to the `bond0` connection:

```
# nmcli connection add type ethernet slave-type bond con-name bond0-port1 ifname enp7s0 master bond0
# nmcli connection add type ethernet slave-type bond con-name bond0-port2 ifname enp8s0 master bond0
```

6. Activate the connection. For example, to activate the `bond0` connection:

```
# nmcli connection up bond0
```
7. Verify that the slave devices are connected, and the CONNECTION column displays the slave’s connection name:

```
# nmcli device
DEVICE   TYPE      STATE      CONNECTION
...  
enp7s0   ethernet  connected  bond0-port1
enp8s0   ethernet  connected  bond0-port2
```

Red Hat Enterprise Linux activates master and slave devices when the system boots. By activating any slave connection, the master is also activated. However, in this case, only one slave connection is activated. By default, activating the master does not automatically activate the slaves. However, you can enable this behavior by setting:

a. Enable the `connection.autoconnect-slaves` parameter of the bond’s connection:

```
# nmcli connection modify bond0 connection.autoconnect-slaves 1
```

b. Reactivate the bridge:

```
# nmcli connection up bond0
```

8. Optionally, display the status of the bond:

```
# cat /proc/net/bonding/bond0
Ethernet Channel Bonding Driver: v3.7.1 (April 27, 2011)

Bonding Mode: fault-tolerance (active-backup)
Primary Slave: None
Currently Active Slave: enp7s0
MII Status: up
MII Polling Interval (ms): 100
Up Delay (ms): 0
Down Delay (ms): 0

Slave Interface: enp7s0
MII Status: up
Speed: Unknown
Duplex: Unknown
Link Failure Count: 0
Permanent HW addr: 52:54:00:d5:e0:fb
Slave queue ID: 0

Slave Interface: enp8s0
MII Status: up
Speed: Unknown
Duplex: Unknown
Link Failure Count: 0
Permanent HW addr: 52:54:00:b2:e2:63
Slave queue ID: 0
```

In the example, both ports are up.

**Additional resources**
17.6. CONFIGURING A NETWORK BOND USING NM-CONNECTION-EDITOR

This section describes how to configure a network bond using the nm-connection-editor application.

Prerequisites

- Two or more network cards are installed in the server.
- The network cards are connected to a switch.

Procedure

1. Open a terminal, and enter `nm-connection-editor`:

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

2. Click the `+` button to add a new connection.

3. Select the Bond connection type, and click Create.

4. On the Bond tab:
   a. Optionally, set the name of the bond interface in the Interface name field.
   b. Click the Add button to add a network interface as a slave to the bond.
      i. Select the connection type of the interface. For example, select Ethernet for a wired connection.
      ii. Optionally, set a connection name for the slave device.
      iii. In the Device field on the Ethernet tab, select the network interface you want to add as a slave to the bond.

   IMPORTANT

   You can only use network interfaces in a bond that are not configured.

   iv. Click Save.

   c. Repeat the previous step for each interface you want to add to the bond:
d. Optionally, set other options, such as the Media Independent Interface (MII) monitoring interval.

5. On the **IPv4 Settings** tab, configure the IPv4 settings. For example, set a static IPv4 address, network mask, default gateway, DNS server, and DNS search domain:

6. On the **IPv6 Settings** tab, configure the IPv6 settings. For example, set a static IPv6 address, network mask, default gateway, DNS server, and DNS search domain:
7. Click **Save** to save the bond connection.

8. Close **nm-connection-editor**.

9. Optionally, display the status of the bond:

   ```bash
   $ cat /proc/net/bonding/_bond0_
   Ethernet Channel Bonding Driver: v3.7.1 (April 27, 2011)
   Bonding Mode: fault-tolerance (active-backup)
   Primary Slave: None
   Currently Active Slave: enp7s0
   MII Status: up
   MII Polling Interval (ms): 100
   Up Delay (ms): 0
   Down Delay (ms): 0
   Slave Interface: enp7s0
   MII Status: up
   Speed: Unknown
   Duplex: Unknown
   Link Failure Count: 0
   Permanent HW addr: 52:54:00:d5:e0:fb
   Slave queue ID: 0
   Slave Interface: enp8s0
   MII Status: up
   Speed: Unknown
   Duplex: Unknown
   ```
Link Failure Count: 0
Permanent HW addr: 52:54:00:b2:e2:63
Slave queue ID: 0

In the example, both ports are up.
CHAPTER 18. CONFIGURING A VPN CONNECTION

This section explains how to configure a VPN connection.

18.1. CONFIGURING A VPN CONNECTION WITH CONTROL-CENTER

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 an open-source, user-space **IPsec** implementation for VPN. A Virtual Private Network (VPN) enables communication between your Local Area Network (LAN), and another, remote LAN. This is done by setting up a tunnel across an intermediate network such as the Internet. The VPN tunnel that is set up typically uses authentication and encryption.

This procedure describes how to configure a VPN connection using **control-center**.

Prerequisites

- The **NetworkManager-libreswan-gnome** package is installed.
- Start for adding a **VPN** connection as explained **Section 8.2, “Creating a network connection using control-center”**.

Procedure

1. 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 username and password, or secret (PSK).

The following configuration settings are available under the **Advanced** section:
Figure 18.1. Advanced options of a VPN connection
WARNING

When configuring an IPsec based VPN connection using the `gnome-control-center` application, the Advanced dialog will only display the configuration, but will not allow doing any change. 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 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 to allow 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.

2. For further configuration, select the IPv4 menu entry:

   - **IPv4 Method**
     - **Automatic (DHCP)** — Choose this option if the network you are connecting to uses Router Advertisements (RA) or 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 Router Advertisements (RA) or 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, sub-net, 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, sub-net, 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 will be routed over the connection.

3. Alternatively, 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.

4. 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.

5. Switch the profile to **ON** to active the VPN connection.
NOTE

When you add a new connection by clicking the plus 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

- For more details on the supported Libreswan parameters, see the nm-settings-libreswan man page.

18.2. CONFIGURING A VPN CONNECTION USING NM-CONNECTION-EDITOR

This procedure describes how to configure a VPN connection using nm-connection-editor

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 (Certificate) 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
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.

![Editing VPN connection 1](image)

- Optionally, 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 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](image)

6. Save the connection.

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

**Additional resources**

- For further details on the supported IPsec parameters, see the **nm-settings-libreswan(5)** man page.
CHAPTER 19. CONFIGURING THE ORDER OF DNS SERVERS

Most applications use the `getaddrinfo()` function of the `glibc` library to resolve DNS requests. By default, `glibc` sends all DNS requests to the first DNS server specified in the `/etc/resolv.conf` file. If this server does not reply, Red Hat Enterprise Linux uses the next server in this file.

This section describes how to customize the order of DNS servers.

19.1. HOW NETWORKMANAGER ORDERS DNS SERVERS IN `/ETC/RESOLV.CONF`

NetworkManager orders DNS servers in the `/etc/resolv.conf` file based on the following rules:

- If only one connection profile exists, NetworkManager uses the order of IPv4 and IPv6 DNS server specified in that connection.

- If multiple connection profiles are activated, NetworkManager orders DNS servers based on a DNS priority value. If you set DNS priorities, the behavior of NetworkManager depends on the value set in the `dns` parameter. You can set this parameter in the `[main]` section in the `/etc/NetworkManager/NetworkManager.conf` file:
  - `dns=default` or if the `dns` parameter is not set:
    NetworkManager orders the DNS servers from different connections based on the `ipv4.dns-priority` and `ipv6.dns-priority` parameter in each connection.
    
    If you set no value or you set `ipv4.dns-priority` and `ipv6.dns-priority` to 0, NetworkManager uses the global default value. See the section called “Default values of DNS priority parameters”.

  - `dns=dnsmasq` or `dns=systemd-resolved`:
    When you use one of these settings, NetworkManager sets either 127.0.0.1 for `dnsmasq` or 127.0.0.53 as nameserver entry in the `/etc/resolv.conf` file.
    
    Both the `dnsmasq` and `systemd-resolved` services forward queries for the search domain set in a NetworkManager connection to the DNS server specified in that connection, and forwardes queries to other domains to the connection with the default route. When multiple connections have the same search domain set, `dnsmasq` and `systemd-resolved` forward queries for this domain to the DNS server set in the connection with the lowest priority value.

Default values of DNS priority parameters

NetworkManager uses the following default values for connections:

- 50 for VPN connections
- 100 for other connections

Valid DNS priority values:

You can set both the global default and connection-specific `ipv4.dns-priority` and `ipv6.dns-priority` parameters to a value between -2147483647 and 2147483647.

- A lower value has a higher priority.
- Negative values have the special effect of excluding other configurations with a greater value. For example, if at least one connection with a negative priority value exists, NetworkManager uses only the DNS servers specified in the connection profile with the lowest priority.
If multiple connections have the same DNS priority, NetworkManager prioritizes the DNS in the following order:

- VPN connections
- Connection with an active default route. The active default route is the default route the lowest metric.

Additional resources

- For further details about how NetworkManager orders DNS server entries in the `/etc/resolv.conf` file, see the `dns-priority` parameter description in the `ipv4` and `ipv6` sections in the `nm-settings(5)` man page.
- For details about using `systemd-resolved` to use different DNS servers for different domains, see Chapter 26, Using different DNS servers for different domains.

19.2. SETTING A NETWORKMANAGER-WIDE DEFAULT DNS SERVER PRIORITY VALUE

NetworkManager uses the following DNS priority default values for connections:

- **50** for VPN connections
- **100** for other connections

This section describes how to override these system-wide defaults with a custom default value for IPv4 and IPv6 connections.

**Procedure**

1. Edit the `/etc/NetworkManager/NetworkManager.conf` file:
   a. Add the `[connection]` section, if it does not exist:

   ```
   [connection]
   ```

   b. Add the custom default values to the `[connection]` section. For example, to set the new default for both IPv4 and IPv6 to **200**, add:

   ```
   ipv4.dns-priority=200
   ipv6.dns-priority=200
   ```

   You can set the parameters to a value between **-2147483647** and **2147483647**. Note that setting the parameters to **0** enables the built-in defaults (**50** for VPN connections and **100** for other connections).

2. Reload the **NetworkManager** service:

   ```
   # systemctl reload NetworkManager
   ```

Additional resources
19.3. SETTING THE DNS PRIORITY OF A NETWORKMANAGER CONNECTION

This section describes how to define the order of DNS servers when NetworkManager creates or updates the \texttt{/etc/resolv.conf} file.

Note that setting DNS priorities makes only sense if you have multiple connections with different DNS servers configured. If you have only one connection with multiple DNS servers configured, manually set the DNS servers in the preferred order in the connection profile.

Prerequisites

- The system has multiple NetworkManager connections configured.

- The system either has no \texttt{dns} parameter set in the \texttt{/etc/NetworkManager/NetworkManager.conf} file or the parameter is set to \texttt{default}.

Procedure

1. Optionally, display the available connections:

   ```
   # nmcli connection show
   NAME           UUID                                  TYPE      DEVICE
   Example_con_1  d17ee488-4665-4de2-b28a-48befab0cd43  ethernet  enp1s0
   Example_con_2  916e4f67-7145-3ffa-9f7b-e7cada8f6bf7  ethernet  enp7s0
   ...
   ```

2. Set the \texttt{ipv4.dns-priority} and \texttt{ipv6.dns-priority} parameters. For example, to set both parameters to \texttt{10} for the \texttt{Example_con_1} connection:

   ```
   # nmcli connection modify Example_con_1 ipv4.dns-priority 10 ipv6.dns-priority 10
   ```

3. Optionally, repeat the previous step for other connections.

4. Re-activate the connection you updated:

   ```
   # nmcli connection up Example_con_1
   ```

Verification steps

- Display the contents of the \texttt{/etc/resolv.conf} file to verify that the DNS server order is correct:

   ```
   # cat /etc/resolv.conf
   ```
CHAPTER 20. CONFIGURING IP NETWORKING WITH IFCFG FILES

This section describes how to configure a network interface manually by editing the ifcfg files.

Interface configuration (ifcfg) files control the software interfaces for individual network devices. As the system boots, it uses these files to determine what interfaces to bring up and how to configure them. These files are usually named ifcfg-name, where the suffix name refers to the name of the device that the configuration file controls. By convention, the ifcfg file’s suffix is the same as the string given by the DEVICE directive in the configuration file itself.

20.1. CONFIGURING AN INTERFACE WITH STATIC NETWORK SETTINGS USING IFCFG FILES

This procedure describes how to configure a network interface using ifcfg files.

Procedure

To configure an interface with static network settings using ifcfg files, for an interface with the name enp1s0, create a file with the name ifcfg-enp1s0 in the /etc/sysconfig/network-scripts/ directory that contains:

- For IPv4 configuration:

  DEVICE=enp1s0
  BOOTPROTO=none
  ONBOOT=yes
  PREFIX=24
  IPADDR=10.0.1.27
  GATEWAY=10.0.1.1

- For IPv6 configuration:

  DEVICE=enp1s0
  BOOTPROTO=none
  ONBOOT=yes
  IPV6INIT=yes
  IPV6ADDR=2001:db8::2/48

  Gateways for IPv6 networks can be configured using the command /etc/iproute2/rt_tables.

  For more IPv6 ifcfg configuration options, see nm-settings-ifcfg-rh(5) man page.

20.2. CONFIGURING AN INTERFACE WITH DYNAMIC NETWORK SETTINGS USING IFCFG FILES

This procedure describes how to configure a network interface with dynamic network settings using ifcfg files.

Procedure

1. To configure an interface named em1 with dynamic network settings using ifcfg files, create a file with the name ifcfg-em1 in the /etc/sysconfig/network-scripts/ directory that contains:
2. To configure an interface to send a different host name to the **DHCP** server, add the following line to the **ifcfg** file:

```
DHCP_HOSTNAME=hostname
```

3. To configure an interface to send a different fully qualified domain name (FQDN) to the **DHCP** server, add the following line to the **ifcfg** file:

```
DHCP_FQDN=fully.qualified.domain.name
```

**NOTE**

Only one directive, either `DHCP_HOSTNAME` or `DHCP_FQDN`, should be used in a given **ifcfg** file. In case both `DHCP_HOSTNAME` and `DHCP_FQDN` are specified, only the latter is used.

4. To configure an interface to use particular **DNS** servers, add the following lines to the **ifcfg** file:

```
PEERDNS=no
DNS1=ip-address
DNS2=ip-address
```

where `ip-address` is the address of a **DNS** server. This will cause the network service to update `/etc/resolv.conf` with the specified **DNS** servers specified. Only one **DNS** server address is necessary, the other is optional.

### 20.3. MANAGING SYSTEM-WIDE AND PRIVATE CONNECTION PROFILES WITH **IFCFG** FILES

This procedure describes how to configure **ifcfg** files to manage the system-wide and private connection profiles.

**Procedure**

The permissions correspond to the **USERS** directive in the **ifcfg** files. If the **USERS** directive is not present, the network profile will be available to all users.

1. As an example, modify the **ifcfg** file with the following row, which will make the connection available only to the users listed:

```
USERS="joe bob alice"
```
CHAPTER 21. DISABLING IPV6 ON A SYSTEM THAT USES NETWORKMANAGER

This section describes how to disable the IPv6 protocol on a system that uses NetworkManager to manage network interfaces. If you disable IPv6, NetworkManager automatically sets the corresponding `sysctl` values in the Kernel.

**NOTE**

The NetworkManager service sets certain `sysctl` values when it starts a connection. To avoid unexpected behavior, do not manually set `sysctl` values to disable IPv6.

**Prerequisites**

- The system uses NetworkManager to manage network interfaces, which is the default on Red Hat Enterprise Linux 8.
- The system runs Red Hat Enterprise Linux 8.1 or later.

### 21.1. DISABLING IPV6 ON A CONNECTION USING NMCLI

Use this section to disable the IPv6 protocol using the `nmcli` utility.

**Procedure**

1. Optionally, display the list of network connections:

   ```bash
   # nmcli connection show
   NAME        UUID                                  TYPE      DEVICE
   Example 7a7e0151-9c18-4e6f-89ee-65bb2d64d365  ethernet  enp1s0
   ...
   ```

2. Set the `ipv6.method` parameter of the connection to `disabled`:

   ```bash
   # nmcli connection modify Example ipv6.method "disabled"
   ```

3. Restart the network connection:

   ```bash
   # nmcli connection up Example
   ```

**Verification steps**

1. Enter the `ip address show` command to display the IP settings of the device:

   ```bash
   # ip address show enp1s0
   2: enp1s0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc fq_codel state UP
   group default qlen 1000
   link/ether 52:54:00:6b:74:be brd ff:ff:ff:ff:ff:ff
   inet 192.0.2.1/24 brd 192.10.2.255 scope global noprefixroute enp1s0
   valid_lft forever preferred_lft forever
   ```

   If no `inet6` entry is displayed, IPv6 is disabled on the device.
2. Verify that the `/proc/sys/net/ipv6/conf/enp1s0/disable_ipv6` file now contains the value 1:

```bash
# cat /proc/sys/net/ipv6/conf/enp1s0/disable_ipv6
1
```

The value 1 means that IPv6 is disabled for the device.
CHAPTER 22. MANUALLY CONFIGURING THE /ETC/RESOLV.CONF FILE

By default, NetworkManager on Red Hat Enterprise Linux (RHEL) 8 dynamically updates the /etc/resolv.conf file with the DNS settings from active NetworkManager connection profiles. This section describes different options on how to disable this feature to manually configure DNS settings in /etc/resolv.conf.

22.1. DISABLING DNS PROCESSING IN THE NETWORKMANAGER CONFIGURATION

This section describes how to disable DNS processing in the NetworkManager configuration to manually configure the /etc/resolv.conf file.

Procedure

1. Create the /etc/NetworkManager/conf.d/90-dns-none.conf file with the following content:

```
[main]
dns=none
```

2. Reload the NetworkManager service:

```
# systemctl reload NetworkManager
```

**NOTE**

After you reload the service, NetworkManager no longer updates the /etc/resolv.conf file. However, the last contents of the file are preserved.

3. Optionally, remove the Generated by NetworkManager comment from /etc/resolv.conf to avoid confusion.

Verification steps

1. Edit the /etc/resolv.conf file and manually update the configuration.

2. Reload the NetworkManager service:

```
# systemctl reload NetworkManager
```

3. Display the /etc/resolv.conf file:

```
# cat /etc/resolv.conf
```

If you successfully disabled DNS processing, NetworkManager did not override the manually configured settings.

Additional resources
For further details, see the description of the **dns** parameter in the *NetworkManager.conf(5)* man page.

### 22.2. REPLACING /ETC/RESOLV.CONF WITH A SYMBOLIC LINK TO MANUALLY CONFIGURE DNS SETTINGS

NetworkManager does not automatically update the DNS configuration if `/etc/resolv.conf` is a symbolic link. This section describes how to replace `/etc/resolv.conf` with a symbolic link to an alternative file with the DNS configuration.

**Prerequisites**

- The `rc-manager` option is not set to `file`. To verify, use the `NetworkManager --print-config` command.

**Procedure**

1. Create a file, such as `/etc/resolv.conf.manually-configured`, and add the DNS configuration for your environment to it. Use the same parameters and syntax as in the original `/etc/resolv.conf`.

2. Remove the `/etc/resolv.conf` file:

   ```bash
   # rm /etc/resolv.conf
   ```

3. Create a symbolic link named `/etc/resolv.conf` that refers to `/etc/resolv.conf.manually-configured`:

   ```bash
   # ln -s /etc/resolv.conf.manually-configured /etc/resolv.conf
   ```

**Additional resources**

- For details about parameters you can set in `/etc/resolv.conf`, see the *resolv.conf(5)* man page.

- For further details about why NetworkManager does not process DNS settings if `/etc/resolv.conf` is a symbolic link, see the description of the `rc-manager` parameter in the *NetworkManager.conf(5)* man page.
CHAPTER 23. CONFIGURING 802.3 LINK SETTINGS

You can configure the 802.3 link settings of an Ethernet connection by modifying the following configuration parameters:

- `802-3-ethernet.auto-negotiate`
- `802-3-ethernet.speed`
- `802-3-ethernet.duplex`

You can configure the 802.3 link settings to the following main modes:

- Ignore link negotiation
- Enforce the auto-negotiation activation
- Manually set the **speed** and **duplex** link settings

### 23.1. CONFIGURING 802.3 LINK SETTINGS WITH NMCLI TOOL

This procedure describes how to configure 802.3 link settings using the `nmcli` tool.

**Prerequisites**

- The NetworkManager must be installed and running.

**Procedure**

1. To ignore link negotiation, set the following parameters:

   ```shell
   ~\# nmcli connection modify connection_name 802-3-ethernet.auto-negotiate no 802-3-ethernet.speed 0 802-3-ethernet.duplex ""
   ```

   Note, that the auto-negotiation parameter is not disabled even if the speed and duplex parameters are not set and the auto-negotiation parameter is set to no.

2. To enforce the auto-negotiation activation, enter the following command:

   ```shell
   ~\# nmcli connection modify connection_name 802-3-ethernet.auto-negotiate yes 802-3-ethernet.speed 0 802-3-ethernet.duplex ""
   ```

   That allows to negotiate all the available speed and duplex modes supported by the NIC.

   You can also enable auto-negotiation while advertising and allowing only one speed/duplex mode. This can be useful if you want to enforce **1000BASE-T** and **10GBASE-T** Ethernet link configuration, as these standards mandate auto-negotiation enabled. To enforce **1000BASE-T** standard:

   ```shell
   ~\# nmcli connection modify connection_name 802-3-ethernet.auto-negotiate yes 802-3-ethernet.speed 1000 802-3-ethernet.duplex full
   ```

3. To manually set the speed and duplex link settings, enter the following command:

   ```shell
   ~\# nmcli connection modify connection_name 802-3-ethernet.auto-negotiate no 802-3-ethernet.speed 1000 802-3-ethernet.duplex full
   ```
~]# nmcli connection modify connection_name 802-3-ethernet.auto-negotiate no 802-3-ethernet.speed [speed in Mbit/s] 802-3-ethernet.duplex [full|half]
CHAPTER 24. CONFIGURING ETHTOOL OFFLOAD FEATURES USING NETWORKMANAGER

Network interface cards can use the TCP offload engine (TOE) to offload processing certain operations to the network controller to improve the network throughput.

This section describes what offload features NetworkManager supports and how to set them.

24.1. OFFLOAD FEATURES SUPPORTED BY NETWORKMANAGER

You can set the following `ethtool` offload features using NetworkManager:

- `ethtool.feature-esp-hw-offload`
- `ethtool.feature-esp-tx-csum-hw-offload`
- `ethtool.feature-fcoe-mtu`
- `ethtool.feature-gro`
- `ethtool.feature-gso`
- `ethtool.feature-highdma`
- `ethtool.feature-hw-tc-offload`
- `ethtool.feature-l2-fwd-offload`
- `ethtool.feature-loopback`
- `ethtool.feature-lro`
- `ethtool.feature-ntuple`
- `ethtool.feature-rx`
- `ethtool.feature-rx-all`
- `ethtool.feature-rx-fcs`
- `ethtool.feature-rx-gro-hw`
- `ethtool.feature-rx-udp_tunnel-port-offload`
- `ethtool.feature-rx-vlan-filter`
- `ethtool.feature-rx-vlan-stag-filter`
- `ethtool.feature-rx-vlan-stag-hw-parse`
- `ethtool.feature-rxhash`
- `ethtool.feature-rxvlan`
- `ethtool.feature-sg`
- ethtool.feature-tls-hw-record
- ethtool.feature-tls-hw-tx-offload
- ethtool.feature-tso
- ethtool.feature-tx
- ethtool.feature-tx-checksum-fcoe-crc
- ethtool.feature-tx-checksum-ip-generic
- ethtool.feature-tx-checksum-ipv4
- ethtool.feature-tx-checksum-ipv6
- ethtool.feature-tx-checksum-sctp
- ethtool.feature-tx-esp-segmentation
- ethtool.feature-tx-fcoe-segmentation
- ethtool.feature-tx-gre-csum-segmentation
- ethtool.feature-tx-gre-segmentation
- ethtool.feature-tx-gso-partial
- ethtool.feature-tx-gso-robust
- ethtool.feature-tx-ipxip4-segmentation
- ethtool.feature-tx-ipxip6-segmentation
- ethtool.feature-tx-nocache-copy
- ethtool.feature-tx-scatter-gather
- ethtool.feature-tx-scatter-gather-fraglist
- ethtool.feature-tx-sctp-segmentation
- ethtool.feature-tx-tcp-ecn-segmentation
- ethtool.feature-tx-tcp-mangleid-segmentation
- ethtool.feature-tx-tcp-segmentation
- ethtool.feature-tx-tcp6-segmentation
- ethtool.feature-tx-udp-segmentation
- ethtool.feature-tx-udp_tnl-csum-segmentation
- ethtool.feature-tx-udp_tnl-segmentation
- ethtool.feature-tx-vlan-stag-hw-insert
For details about the individual offload features, see the documentation of the `ethtool` utility and the kernel documentation.

## 24.2. CONFIGURING AN ETHTOOL OFFLOAD FEATURE USING NETWORKMANAGER

This section describes how you enable and disable `ethtool` offload features using NetworkManager, as well as how you remove the setting for a feature from a NetworkManager connection profile.

**Procedure**

1. For example, to enable the RX offload feature and disable TX offload in the `enp0s1` connection profile, enter:
   ```
   # nmcli con modify enp0s1 ethtool.feature-rx on ethtool.feature-tx off
   ```
   This command explicitly enables RX offload and disables TX offload.

2. To remove the setting of an offload feature that you previously enabled or disabled, set the feature's parameter to `ignore`. For example, to remove the configuration for TX offload, enter:
   ```
   # nmcli con modify enp0s1 ethtool.feature-tx ignore
   ```

3. Reactivate the network profile:
   ```
   # nmcli connection up enp0s1
   ```

**Verification steps**

1. Use the `ethtool -k` command to display the current offload features of a network device:
   ```
   # ethtool -k network_device
   ```

**Additional resources**

- For a list of `ethtool` offload features NetworkManager supports, see Section 24.1, “Offload features supported by NetworkManager”.

CHAPTER 25. CONFIGURING MACSEC

The following section provides information on how to configure Media Control Access Security (MACsec), which is an 802.1AE IEEE standard security technology for secure communication in all traffic on Ethernet links.

25.1. INTRODUCTION TO MACSEC

Media Access Control Security (MACsec, IEEE 802.1AE) encrypts and authenticates all traffic in LANs with the GCM-AES-128 algorithm. MACsec can protect not only IP but also Address Resolution Protocol (ARP), Neighbor Discovery (ND), or DHCP. While IPsec operates on the network layer (layer 3) and SSL or TLS on the application layer (layer 7), MACsec operates in the data link layer (layer 2). Combine MACsec with security protocols for other networking layers to take advantage of different security features that these standards provide.

25.2. USING MACSEC WITH NMCLI TOOL

This procedure shows how to configure MACsec with nmcli tool.

Prerequisites

- The NetworkManager must be running.
- You already have a 16-byte hexadecimal CAK ($MKA_CAK) and a 32-byte hexadecimal CKN ($MKA_CKN).

Procedure

```bash
~$ nmcli connection add type macsec \
  con-name test-macsec+ ifname macsec0 \
  connection.autoconnect no \
  macsec.parent enp1s0 macsec.mode psk \
  macsec.mka-cak $MKA_CAK \ 
  macsec.mka-ckn $MKA_CKN

~$ nmcli connection up test-macsec+
```

After this step, the macsec0 device is configured and can be used for networking.

25.3. USING MACSEC WITH WPA_SUPPLICANT

This procedure shows how to enable MACsec with a switch that performs authentication using a pre-shared Connectivity Association Key/CAK Name (CAK/CKN) pair.

Procedure

1. Create a CAK/CKN pair. For example, the following command generates a 16-byte key in hexadecimal notation:

   ```bash
   ~$ dd if=/dev/urandom count=16 bs=1 2> /dev/null | hexdump -e '1/2 "%02x"'
   ```

2. Create the wpa_supplicant.conf configuration file and add the following lines to it:
Use the values from the previous step to complete the `mka_cak` and `mka_ckn` lines in the `wpa_supplicant.conf` configuration file.

For more information, see the `wpa_supplicant.conf(5)` man page.

3. Assuming you are using `wlp61s0` to connect to your network, start `wpa_supplicant` using the following command:

```
~]$# wpa_supplicant -i wlp61s0 -Dmacsec_linux -c wpa_supplicant.conf
```

### 25.4. RELATED INFORMATION

For more details, see the [What’s new in MACsec: setting up MACsec using wpa_supplicant and (optionally) NetworkManager](#) article. In addition, see the [MACsec: a different solution to encrypt network traffic](#) article for more information about the architecture of a MACsec network, use case scenarios, and configuration examples.
CHAPTER 26. USING DIFFERENT DNS SERVERS FOR DIFFERENT DOMAINS

By default, Red Hat Enterprise Linux (RHEL) sends all DNS requests to the first DNS server specified in the /etc/resolv.conf file. If this server does not reply, RHEL uses the next server in this file.

In environments where one DNS server cannot resolve all domains, administrators can configure RHEL to send DNS requests for a specific domain to a selected DNS server. For example, you can configure one DNS server to resolve queries for example.com and another DNS server to resolve queries for example.net. For all other DNS requests, RHEL uses the DNS server configured in the connection with the default gateway.

26.1. SENDING DNS REQUESTS FOR A SPECIFIC DOMAIN TO A SELECTED DNS SERVER

This section configures systemd-resolved service and NetworkManager to send DNS queries for a specific domain to a selected DNS server.

If you complete the procedure in this section, RHEL uses the DNS service provided by systemd-resolved in the /etc/resolv.conf file. The systemd-resolved service starts a DNS service that listens on port 53 IP address 127.0.0.53. The service dynamically routes DNS requests to the corresponding DNS servers specified in NetworkManager.

NOTE
The 127.0.0.53 address is only reachable from the local system and not from the network.

Prerequisites

- The system has multiple NetworkManager connections configured.
- A DNS server and search domain are configured in the NetworkManager connections that are responsible for resolving a specific domain.
  For example, if the DNS server specified in a VPN connection should resolve queries for the example.com domain, the VPN connection profile must have:
  - Configured a DNS server that can resolve example.com
  - Configured the search domain to example.com in the ipv4.dns-search and ipv6.dns-search parameters

Procedure

1. Start and enable the systemd-resolved service:

   # systemctl --now enable systemd-resolved

2. Edit the /etc/NetworkManager/NetworkManager.conf file, and set the following entry in the [main] section:

   dns-systemd-resolved

3. Reload the NetworkManager service:
# systemctl reload NetworkManager

Verification steps

1. Verify that the `nameserver` entry in the `/etc/resolv.conf` file refers to `127.0.0.53`:

```bash
# cat /etc/resolv.conf
nameserver 127.0.0.53
```

2. Verify that the `systemd-resolved` service listens on port `53` on the local IP address `127.0.0.53`:

```bash
# netstat -tulpn | grep "127.0.0.53:53"
```

Additional resources

- For further details, see the description of the `dns` parameter in the `NetworkManager.conf(5)` man page.
CHAPTER 27. CONFIGURING INFINIBAND AND RDMA NETWORKS

This section describes what InfiniBand and remote direct memory access (RDMA) are and how to configure InfiniBand hardware. Additionally, the section explains how to configure InfiniBand-related services.

27.1. UNDERSTANDING INFINIBAND AND RDMA

InfiniBand refers to two distinct things:

- The physical link-layer protocol for InfiniBand networks
- The InfiniBand Verbs API, which is an implementation of the remote direct memory access (RDMA) technology

RDMA provides access to the memory from one computer to the memory of another computer without involving either computer’s operating system. This technology enables high-throughput and low-latency networking with low CPU utilization.

In a typical IP data transfer, when an application on one machine sends data to an application on another machine, the following happens on the receiving side:

1. The kernel must receive the data.
2. The kernel must determine that the data belongs to the application.
3. The kernel wakes up the application.
4. The kernel waits for the application to perform a system call into the kernel.
5. The application copies the data from the kernel’s own internal memory space into the buffer provided by the application.

This process means that most network traffic is copied across the main memory of the system if the host adapter uses direct memory access (DMA), or otherwise at least twice. Additionally, the computer executes a number of context switches to switch between the kernel and application context. Both context switches can cause a high CPU load at high traffic rates and slow down other tasks.

RDMA communication bypasses the kernel intervention in the communication process, unlike the normal IP communication. This reduces the CPU overhead. The RDMA protocol enables the host adapter to know when a packet comes in from the network, which application should receive it, and where in the application’s memory space, the packet should be stored. Instead of sending the packet to the kernel to be processed and then copied into the user application’s memory, with InfiniBand, the host adapter places the contents of the packet directly in the application’s buffer. This process requires a separate API, the InfiniBand Verbs API, and applications must support this API before they can use RDMA.

Red Hat Enterprise Linux 8 supports both the InfiniBand hardware and the InfiniBand Verbs API. Additionally, Red Hat Enterprise Linux supports the following technologies that allow to use the InfiniBand Verbs API on non-InfiniBand hardware:

- Internet Wide Area RDMA Protocol (iWARP): A network protocol that implements RDMA over IP networks.
- RDMA over Converged Ethernet (RoCE), which is also known as InfiniBand over Ethernet (IBoE): A network protocol that implements RDMA over Ethernet networks.
27.2. CONFIGURING ROCE

This section explains background information about RDMA over Converged Ethernet (RoCE), as well as how to change the default RoCE version, and how to configure a software RoCE adapter.

Note that there are different vendors, such as Mellanox, Broadcom, and QLogic, who provide RoCE hardware.

27.2.1. Overview of RoCE protocol versions

RoCE is a network protocol that enables remote direct memory access (RDMA) over Ethernet.

The following are the different RoCE versions:

RoCE v1

The RoCE version 1 protocol is an Ethernet link layer protocol with ethertype 0x8915 that enables communication between any two hosts in the same Ethernet broadcast domain.

By default, when using a Mellanox ConnectX-3 network adapter, Red Hat Enterprise Linux uses RoCE v1 for the RDMA Connection Manager (RDMA_CM).

RoCE v2

The RoCE version 2 protocol exists on top of either the UDP over IPv4 or the UDP over IPv6 protocol. The UDP destination port number 4791 is reserved for RoCE v2.

By default, when using a Mellanox ConnectX-3 Pro, ConnectX-4 Lx, or ConnectX-5 network adapter, Red Hat Enterprise Linux uses RoCE v2 for the RDMA_CM, but the hardware supports both RoCE v1 and RoCE v2.

The RDMA_CM sets up a reliable connection between a client and a server for transferring data. RDMA_CM provides an RDMA transport-neutral interface for establishing connections. The communication uses a specific RDMA device, and data transfers are message-based.

IMPORTANT

Using RoCE v2 on the client and RoCE v1 on the server is not supported. In this case, configure both the server and client to communicate over RoCE v1.

Additional resources

- Section 27.2.2, "Temporarily changing the default RoCE version"

27.2.2. Temporarily changing the default RoCE version

Using the RoCE v2 protocol on the client and RoCE v1 on the server is not supported. If the hardware in your server only supports RoCE v1, configure your clients to communicate with the server using RoCE v1. This section describes how to enforce RoCE v1 on the client that uses the mlx5_0 driver for the Mellanox ConnectX-5 Infiniband device. Note that the changes described in this section are only temporary until you reboot the host.
Prerequisites

- The client uses an InfiniBand device that uses, by default, the RoCE v2 protocol.
- The InfiniBand device in the server only supports RoCE v1.

Procedure

1. Create the `/sys/kernel/config/rdma_cm/mlx5_0` directory:
   ```bash
   # mkdir /sys/kernel/config/rdma_cm/mlx5_0/
   ```
2. Display the default RoCE mode. For example, to display the mode for port 1:
   ```bash
   # cat /sys/kernel/config/rdma_cm/mlx5_0/ports/1/default_roce_mode
   ```
   RoCE v2
3. Change the default RoCE mode to version 1:
   ```bash
   # echo "IB/RoCE v1" > /sys/kernel/config/rdma_cm/mlx5_0/ports/1/default_roce_mode
   ```

27.2.3. Configuring Soft-RoCE

Soft-RoCE is a software implementation of remote direct memory access (RDMA) over Ethernet, which is also called RXE. This section describes how to configure Soft-RoCE.

Use Soft-RoCE on hosts without RoCE host channel adapters (HCA).

Prerequisites

- An Ethernet adapter is installed in the system.

Procedure

1. Install the `libibverbs`, `libibverbs-utils`, and `infiniband-diags` packages:
   ```bash
   # yum install libibverbs libibverbs-utils infiniband-diags
   ```
2. Load the `rdma_rxe` kernel module and display the current configuration:
   ```bash
   # rxe_cfg start
   Name    Link  Driver      Speed  NMTU  IPv4_addr        RDEV  RMTU
   enp7s0  yes   virtio_net         1500
   ```
3. Add a new RXE device. For example, to add the `enp7s0` Ethernet device as an RXE device, enter:
   ```bash
   # rxe_cfg add enp7s0
   ```
4. Display the RXE device status:
In the **RDEV** column, you see that the *enp7s0* is mapped to the *rxe0* device.

5. Optional: list the available RDMA devices in the system:

```
# ibv_devices
device node GUID
------ ----------------
      
rxe0 505400fffed5e0fb
```

Alternatively, use the **ibstat** utility to display a detailed status:

```
# ibstat rxe0
CA 'rxe0'
CA type:
Number of ports: 1
Firmware version:
Hardware version:
Node GUID: 0x505400fffed5e0fb
System image GUID: 0x0000000000000000
Port 1:
State: Active
Physical state: LinkUp
Rate: 100
Base lid: 0
LMC: 0
SM lid: 0
Capability mask: 0x00890000
Port GUID: 0x505400fffed5e0fb
Link layer: Ethernet
```

### 27.3. CONFIGURING THE CORE RDMA SUBSYSTEM

This section describes how to configure the **rdma** service and increase the amount of memory that users are allowed to pin in the system.

#### 27.3.1. Configuring the rdma service

The **rdma** service manages the RDMA stack in the kernel. If Red Hat Enterprise Linux detects InfiniBand, iWARP, or RoCE devices, the **udev** device manager instructs **systemd** to start the **rdma** service.

**Procedure**

1. Edit the `/etc/rdma/rdma.conf` file, and set the variables of the modules you want to enable to `yes`. The following is the default `/etc/rdma/rdma.conf` on Red Hat Enterprise Linux 8:

```
# Load IPoIB
IPoIB_LOAD=yes
# Load SRP (SCSI Remote Protocol initiator support) module
SRP_LOAD=yes
# Load SRPT (SCSI Remote Protocol target support) module
```

---

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SRPT_LOAD=yes
# Load iSER (iSCSI over RDMA initiator support) module
ISER_LOAD=yes
# Load iSERT (iSCSI over RDMA target support) module
ISERT_LOAD=yes
# Load RDS (Reliable Datagram Service) network protocol
RDS_LOAD=no
# Load NFSoRDMA client transport module
XPRTRDMA_LOAD=yes
# Load NFSoRDMA server transport module
SVCRDMA_LOAD=no
# Load Tech Preview device driver modules
TECH_PREVIEW_LOAD=no

2. Restart the rdma service:

```
# systemctl restart rdma
```

### 27.3.2. Renaming IPoIB devices

By default, the kernel names IP over InfiniBand (IPoIB) devices, for example, *ib0*, *ib1*, and so on. To avoid conflicts, Red Hat recommends creating a rule in the *udev* device manager to create persistent and meaningful names, such as *mlx4_ib0*.

**Prerequisites**

- An InfiniBand device is installed in the host.

**Procedure**

1. Display the hardware address of the device. For example, to display the address for the device named *ib0*, enter:

   ```
   # ip link show ib0
   8: ib0: >BROADCAST,MULTICAST,UP,LOWER_UP< mtu 65520 qdisc pfifo_fast state UP
   mode DEFAULT qlen 256
   link/infiniband 80:00:02:00:fe:80:00:00:00:00:00:00:00:02:c9:03:00:31:78:f2 brd
   00:ff:ff:ff:ff:ff:ff:ff:ff:ff:ff:ff:ff:ff:ff:ff:
   
   The last eight bytes of the address, marked in bold in the example, are required to create a *udev* rule in the next step.
   ```

2. Edit the `/etc/udev/rules.d/70-persistent-ipoib.rules` file, and append an `ACTION` rule. For example, to configure a rule that renames the device with the *00:02:c9:03:00:31:78:f2* hardware address to *mlx4_ib0*, append the following line:

   ```
   ACTION=="add", SUBSYSTEM=="net", DRIVERS=="*", ATTR{type}=="32",
   ATTR{address}=="00:02:c9:03:00:31:78:f2", NAME="mlx4_ib0"
   ```

3. Reboot the host:

   ```
   # reboot
   ```

**Additional resources**

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For details about `udev` rules, see the `udev(7)` man page.

For details, why the first 12 bytes of the hardware address are not used in the `udev` rule, see Section 27.5.2, "Understanding IPoIB hardware addresses".

27.3.3. Increasing the amount of memory that users are allowed to pin in the system

RDMA operations require pinning of physical memory. This means that the kernel is not allowed to write memory into the swap space. If a user pins too much memory, the system can run out of memory, and the kernel terminates processes in order to free up more memory. For this reason, memory pinning is a privileged operation.

If non-root users run large RDMA applications, it can be necessary to increase the amount of memory these users can pin in the system. This section describes how to configure an unlimited amount of memory for the `rdma` group.

Procedure

- As the `root` user, create the `/etc/security/limits.d/rdma.conf` file with the following content:

  @rdma    soft    memlock     unlimited
  @rdma    hard    memlock     unlimited

Verification steps

1. Log in as a member of the `rdma` group after you edited the `/etc/security/limits.d/rdma.conf` file.
   Note that Red Hat Enterprise Linux applies updated `ulimit` settings when the user logs in.

2. Use the `ulimit -l` command to display the limit:

   $ ulimit -l
   unlimited

   If the command returns `unlimited`, the user can pin an unlimited amount of memory.

Additional resources

- For further details about limiting system resources, see the `limits.conf(5)` man page.

27.4. CONFIGURING AN INFINIBAND SUBNET MANAGER

All InfiniBand networks must have a subnet manager running for the network to function. This is true even if two machines are connected directly with no switch involved.

It is possible to have more than one subnet manager. In that case one acts as a master and another subnet manager acts as a slave that will take over in case the master subnet manager fails.

Most InfiniBand switches contain an embedded subnet manager. However, if you need a more up-to-date subnet manager or if you require more control, use the OpenSM subnet manager provided by Red Hat Enterprise Linux.

27.4.1. Installing the OpenSM subnet manager
This section describes how to install the OpenSM subnet manager.

Procedure

1. Install the opensm package:
   
   ```
   # yum install opensm
   ```

2. Configure OpenSM if the default installation does not match your environment.
   If only one InfiniBand port is installed, the host should act as the master subnet manager, and no custom changes are needed. The default configuration works without any modification.

3. Enable and start the opensm service:
   
   ```
   # systemctl enable --now opensm
   ```

Additional resources

- For a list of command line options for the opensm service, as well as additional descriptions of the partitions configurations, Quality of Service (QoS), and other advanced topics, see the opensm(8) man page.

27.4.2. Configuring OpenSM using the simple method

This section describes how to configure OpenSM if you do not need any customized settings.

Prerequisites

- One or more InfiniBand ports are installed in the server.

Procedure

1. Obtain the GUIDs for the ports using the ibstat utility:
   
   ```
   # ibstat -d device_name
   CA 'mlx4_0'
   CA type: MT4099
   Number of ports: 2
   Firmware version: 2.42.5000
   Hardware version: 1
   Node GUID: 0xf4521403007be130
   System image GUID: 0xf4521403007be133
   Port 1:
   State: Active
   Physical state: LinkUp
   Rate: 56
   Base lid: 3
   LMC: 0
   SM lid: 1
   Capability mask: 0x02594868
   Port GUID: 0xf4521403007be131
   Link layer: InfiniBand
   Port 2:
   State: Down
   ```
Physical state: Disabled
Rate: 10
Base lid: 0
LMC: 0
SM lid: 0
Capability mask: 0x04010000
Port GUID: 0xf65214ffe7be132
Link layer: Ethernet

NOTE

Some InfiniBand adapters use the same GUID for the node, system, and port.

2. Edit the `/etc/sysconfig/opensm` file and set the GUIDs in the **GUIDS** parameter:

   GUIDS="GUID_1 GUID_2"

3. Optionally, set the **PRIORITY** parameter if multiple subnet managers are available in your subnet. For example:

   PRIORITY=15

**Additional resources**

- For additional information on the parameters you can set in `/etc/sysconfig/opensm`, see the documentation in that file.

### 27.4.3. Configuring OpenSM by editing the opensm.conf file

This section describes how to configure OpenSM by editing the `/etc/rdma/opensm.conf` file. Use this method to customize the OpenSM configuration if only one InfiniBand port is available.

**Prerequisites**

- Only one InfiniBand port is installed in the server.

**Procedure**

1. Edit the `/etc/rdma/opensm.conf` file and customize the settings to match your environment.

2. Restart the **opensm** service:

   ```
   # systemctl restart opensm
   ```

**Additional resources**

- When you install an updated **opensm** package, the **yum** utility stores the new OpenSM configuration file as `/etc/rdma/opensm.conf.rpmnew`. Compare this file with your customized `/etc/rdma/opensm.conf` file and manually incorporate the changes.

### 27.4.4. Configuring multiple OpenSM instances
This section describes how to set up multiple instances of OpenSM.

Prerequisites

- One or more InfiniBand ports are installed in the server.

Procedure

1. Optionally, copy the `/etc/rdma/opensm.conf` file to `/etc/rdma/opensm.conf.orig` file:

   ```
   # cp /etc/rdma/opensm.conf /etc/rdma/opensm.conf.orig
   ```

   When you install an updated `opensm` package, the `yum` utility overrides the `/etc/rdma/opensm.conf`. With the copy created in this step, you can compare the previous and new file to identify changes and incorporate them manually in the instance-specific `opensm.conf` files.

2. Create a copy of the `/etc/rdma/opensm.conf` file:

   ```
   # cp /etc/rdma/opensm.conf /etc/rdma/opensm.conf.1
   ```

   For each instance you create, append a unique and continuous number to the copy of the configuration file.

3. Edit the copy you created in the previous step, and customize the settings for the instance to match your environment. For example, set the `guid`, `subnet_prefix`, and `logdir` parameters.

4. Optionally, create a `partitions.conf` file with a unique name specifically for this subnet and reference that file in the `partition_config_file` parameter in the corresponding copy of the `opensm.conf` file.

5. Repeat the previous steps for each instance you want to create.

6. Start the `opensm` service:

   ```
   # systemctl start opensm
   ```

   The `opensm` service automatically starts a unique instance for each `opensm.conf.*` file in the `/etc/rdma/` directory. If multiple `opensm.conf.*` files exist, the service ignores settings in the `/etc/sysconfig/opensm` file as well as in the base `/etc/rdma/opensm.conf` file.

Additional resources

- When you install an updated `opensm` package, the `yum` utility stores the new OpenSM configuration file as `/etc/rdma/opensm.conf.rpmnew`. Compare this file with your customized `/etc/rdma/opensm.conf.*` files and manually incorporate the changes.

### 27.4.5. Creating a partition configuration

This section describes how to create InfiniBand partition configurations for OpenSM. Partitions enable administrators to create subnets on InfiniBand similar to Ethernet VLANs.
IMPORTANT

If you define a partition with a specific speed, such as 40 Gbps, all hosts within this partition must support at least this speed. If a host does not meet the speed requirements, it cannot join the partition. Therefore, set the speed of a partition to the lowest speed supported by any host with permission to join the partition.

Prerequisites

- One or more InfiniBand ports are installed in the server.

Procedure

1. Edit the `etc/rdma/partitions.conf` file and configure the partitions.

   **NOTE**

   All fabrics must contain the 0x7fff partition, and all switches and all hosts must belong to that fabric.

   For example, add the following content to the file to create the 0x7fff default partition at a reduced speed of 10 Gbps, and a partition 0x0002 with a speed of 40 Gbps:

   ```
   # For reference:
   # IPv4 IANA reserved multicast addresses:
   #   http://www.iana.org/assignments/multicast-addresses/multicast-addresses.txt
   # IPv6 IANA reserved multicast addresses:
   #   http://www.iana.org/assignments/ipv6-multicast-addresses/ipv6-multicast-addresses.xml
   #
   # mtu =
   #   1 = 256
   #   2 = 512
   #   3 = 1024
   #   4 = 2048
   #   5 = 4096
   #
   # rate =
   #   2  =   2.5 GBit/s
   #   3  =  10   GBit/s
   #   4  =  30   GBit/s
   #   5  =   5   GBit/s
   #   6  =  20   GBit/s
   #   7  =  40   GBit/s
   #   8  =  60   GBit/s
   #   9  =  80   GBit/s
   #   10 = 120   GBit/s
   Default=0x7fff, rate=3, mtu=4, scope=2, defmember=full:
   ALL, ALL_SWITCHES=full;
   Default=0x7fff, ipoib, rate=3, mtu=4, scope=2:
   mgid=ff12:401b::ffff:ffff   # IPv4 Broadcast address
   mgid=ff12:401b::1           # IPv4 All Hosts group
   mgid=ff12:401b::2           # IPv4 All Routers group
   mgid=ff12:401b::16          # IPv4 IGMP group
   mgid=ff12:401b::fb          # IPv4 mDNS group
   ```
27.5. CONFIGURING IPOIB

By default, InfiniBand does not use the internet protocol (IP) for communication. However, IP over InfiniBand (IPoIB) provides an IP network emulation layer on top of InfiniBand remote direct memory access (RDMA) networks. This allows existing unmodified applications to transmit data over InfiniBand networks, but the performance is lower than if the application would use RDMA natively.

**NOTE**

Internet Wide Area RDMA Protocol (iWARP) and RoCE networks are already IP-based. Therefore, you cannot create an IPoIB device on top of iWARP or RoCE devices.

### 27.5.1. The IPoIB communication modes

You can configure an IPoIB device either in **Datagram** or **Connected** mode. The difference is what type of queue pair the IPoIB layer attempts to open with the machine at the other end of the communication:

- **In the Datagram mode**, the system opens an unreliable, disconnected queue pair. This mode does not support packages larger than the InfiniBand link-layer’s Maximum Transmission Unit (MTU). The IPoIB layer adds a 4 byte IPoIB header on top of the IP packet being transmitted. As a result, the IPoIB MTU must be 4 bytes less than the InfiniBand link-layer MTU. As 2048 is a common InfiniBand link-layer MTU, the common IPoIB device MTU in **Datagram** mode is 2044.
In the **Connected** mode, the system opens a reliable, connected queue pair. This mode allows messages larger than the InfiniBand link-layer MTU, and the host adapter handles packet segmentation and reassembly. As a result, there is no size limit imposed on the size of IPoIB messages that can be sent by InfiniBand adapters in **Connected** mode. However, IP packets are limited because of the **size** field and TCP/IP headers. For this reason, the IPoIB MTU in **Connected** mode is **65520** bytes maximum.

The **Connected** mode has a higher performance, but consumes more kernel memory.

If a system is configured to use the **Connected** mode, it still sends multicast traffic in the **Datagram** mode, because InfiniBand switches and fabric cannot pass multicast traffic in **Connected** mode. Additionally, the system falls back to **Datagram** mode, when communicating with any host that is not configured in the **Connected** mode.

While running application that sends multicast data up to the maximum MTU on the interface, you must configure the interface in **Datagram** mode or configure the application to cap the packet send size at a size that will fit in datagram-sized packets.

### 27.5.2. Understanding IPoIB hardware addresses

IPoIB devices have a 20 byte hardware address that consists of the following parts:

- The first 4 bytes are flags and queue pair numbers.
- The next 8 bytes are the subnet prefix. The default subnet prefix is **0xfe:80:00:00:00:00:00:00**. After the device connects to the subnet manager, the device changes this prefix to match the one configured in the subnet manager.
- The last 8 bytes are the Globally Unique Identifier (GUID) of the InfiniBand port that the IPoIB device is attached to.

**NOTE**

Because the first 12 bytes can change, don’t use them in **udev** device manager rules.

Additional resources

- For details about renaming IPoIB devices, see Section 27.3.2, “Renaming IPoIB devices”.

### 27.5.3. Configuring an IPoIB connection using nmcli commands

This procedure describes how to configure an IPoIB connection using **nmcli** commands.

**Prerequisites**

- An InfiniBand device is installed in the server, and the corresponding kernel module is loaded.

**Procedure**

1. Create the InfiniBand connection. For example, to create a connection that uses the **mlx4_ib0** interface in the **Connected** transport mode and the maximum MTU of **65520** bytes, enter:

```
# nmcli connection add type infiniband con-name mlx4_ib0 ifname mlx4_ib0 transport-mode Connected mtu 65520
```
2. Optional: set a **P-Key** interface. For example, to set `0x8002` as **P-Key** interface of the `mlx4_ib0` connection, enter:

```bash
# nmcli connection modify mlx4_ib0 infiniband.p-key 0x8002
```

3. Configure the IPv4 settings. For example, to set a static IPv4 address, network mask, default gateway, and DNS server of the `mlx4_ib0` connection, enter:

```bash
# nmcli connection modify mlx4_ib0 ipv4.addresses '192.0.2.1/24'
# nmcli connection modify mlx4_ib0 ipv4.gateway '192.0.2.254'
# nmcli connection modify mlx4_ib0 ipv4.dns '192.0.2.253'
# nmcli connection modify mlx4_ib0 ipv4.method manual
```

4. Configure the IPv6 settings. For example, to set a static IPv6 address, network mask, default gateway, and DNS server of the `mlx4_ib0` connection, enter:

```bash
# nmcli connection modify mlx4_ib0 ipv6.addresses '2001:db8::1/32'
# nmcli connection modify mlx4_ib0 ipv6.gateway '2001:db8::fffe'
# nmcli connection modify mlx4_ib0 ipv6.dns '2001:db8::fffd'
# nmcli connection modify mlx4_ib0 ipv6.method manual
```

5. Activate the connection. For example, to activate the `mlx4_ib0` connection:

```bash
# nmcli connection up mlx4_ib0
```

### 27.5.4. Configuring an IPoIB connection using `nm-connection-editor`

This procedure describes how to configure an IPoIB connection using the `nm-connection-editor` application.

**Prerequisites**

- An InfiniBand device is installed in the server, and the corresponding kernel module is loaded.
- The **nm-connection-editor** package is installed.

**Procedure**

1. Open a terminal, and enter:

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

2. Click the `*` button to add a new connection.

3. Select the **InfiniBand** connection type, and click **Create**.

4. On the **InfiniBand** tab:
   a. Optionally, change the connection name.
   b. Select the transport mode.
   c. Select the device.
   d. Optional: set an MTU.
5. On the IPv4 Settings tab, configure the IPv4 settings. For example, set a static IPv4 address, network mask, default gateway, and DNS server:

![IPv4 Settings Tab](image)

- **Connection name:** mlx4_ib0
- **Method:** Manual
- **Addresses**
  - **Address:** 192.0.2.1
  - **Netmask:** 24
  - **Gateway:** 192.0.2.254

  **DNS servers:** 192.0.2.253

6. On the IPv6 Settings tab, configure the IPv6 settings. For example, set a static IPv6 address, network mask, default gateway, and DNS server:

![IPv6 Settings Tab](image)

- **Connection name:** mlx4_ib0
- **Method:** Manual
- **Addresses**
  - **Address:** 2001:db8::1
  - **Prefix:** 32
  - **Gateway:** 2001:db8::fffe

  **DNS servers:** 2001:db8::fffd

7. Click **Save** to save the team connection.

8. Close **nm-connection-editor**.

9. Optional: set a P_Key interface. Note that you must set this parameter on the command line, because the setting is not available in **nm-connection-editor**.
   - For example, to set 0x8002 as P_Key interface of the mlx4_ib0 connection, enter:

   ```bash
   # nmcli connection modify mlx4_ib0 infiniband.p-key 0x8002
   ```
27.6. TESTING INFINIBAND NETWORKS

This section provides procedures how to test InfiniBand networks.

27.6.1. Testing early InfiniBand RDMA operations

This section describes how to test InfiniBand remote direct memory access (RDMA) operations.

**NOTE**

This section applies only to InfiniBand devices. If you use iWARP or RoCE/IBoE devices, which are IP-based, see:

- Section 27.6.2, “Testing an IPoIB using the ping utility”
- Section 27.6.3, “Testing an RDMA network using qperf after IPoIB is configured”

**Prerequisites**

- RDMA is configured.
- The `libibverbs-utils` and `infiniband-diags` packages are installed.

**Procedure**

1. List the available InfiniBand devices:

   ```
   # ibv_devices
   device   node GUID
   ------              ----------------
   mlx4_0              0002c903003178f0
   mlx4_1              f4521403007bcba0
   ```

2. Display the information for a specific InfiniBand device. For example, to display the information of the `mlx4_1` device, enter:

   ```
   # ibv_devinfo -d mlx4_1
   hca_id: mlx4_1
   transport: InfiniBand (0)
   fw_ver: 2.30.8000
   node_guid: f452:1403:007b:cba0
   sys_image_guid: f452:1403:007b:cba3
   vendor_id: 0x02c9
   vendor_part_id: 4099
   hw_ver: 0x0
   board_id: MT_1090120019
   phys_port_cnt: 2
   port: 1
     state: PORT_ACTIVE (4)
     max_mtu: 4096 (5)
     active_mtu: 2048 (4)
     sm_lid: 2
     port_lid: 2
     port_lmc: 0x01
     link_layer: InfiniBand
   ```
port: 2
  state: PORT_ACTIVE (4)
  max_mtu: 4096 (5)
  active_mtu: 4096 (5)
  sm_lid: 0
  port_lid: 0
  port_lmc: 0x00
  link_layer: Ethernet

3. Display the basic status of an InfiniBand device. For example, to display the status of the mlx4_1 device, enter:

```bash
# ibstat mlx4_1
```

CA 'mlx4_1'
  CA type: MT4099
  Number of ports: 2
  Firmware version: 2.30.8000
  Hardware version: 0
  Node GUID: 0xf4521403007bcba0
  System image GUID: 0xf4521403007bcba3
  Port 1:
    State: Active
    Physical state: LinkUp
    Rate: 56
    Base lid: 2
    LMC: 1
    SM lid: 2
    Capability mask: 0x0251486a
    Port GUID: 0xf4521403007bcba1
    Link layer: InfiniBand
  Port 2:
    State: Active
    Physical state: LinkUp
    Rate: 40
    Base lid: 0
    LMC: 0
    SM lid: 0
    Capability mask: 0x04010000
    Port GUID: 0xf65214ffe7bcba2
    Link layer: Ethernet

4. Use the ibping utility to ping from a client to a server using InfiniBand:

   a. On the host that acts as a server, start ibping in server mode:

   ```bash
   # ibping -S -C mlx4_1 -P 1
   ```

   This command uses the following parameters:
   
   - **-S**: Enables the server mode.
   - **-C InfiniBand_CA_name**: Set's the CA name to use.
   - **-P port_number**: Sets the port number to use, if the InfiniBand provides multiple ports.
b. On the host that acts as client, use `ibping` as follows:

```bash
# ibping -c 50 -C mlx4_0 -P 1 -L 2
```

- `-c number`: Sends these number of packets to the server.
- `-C InfiniBand_CA_name`: Set's the CA name to use.
- `-P port_number`: Sets the port number to use, if the InfiniBand provides multiple ports.
- `-L port_LID`: Sets the Local Identifier (LID) to use.

Additional resources

- For further details about `ibping` parameters, see the `ibping(8)` man page.

27.6.2. Testing an IPoIB using the ping utility

After you configured IPoIB, use the `ping` utility to send ICMP packets to test the IPoIB connection.

Prerequisites

- The two RDMA hosts are connected in the same InfiniBand fabric with RDMA ports.
- The IPoIB interfaces in both hosts are configured with IP addresses within the same subnet.

Procedure

1. Use the `ping` utility to send ICMP packets to the remote host’s InfiniBand adapter:

```bash
# ping -c5 192.0.2.1
```

This command sends five ICMP packets to the IP address `192.0.2.1`.

27.6.3. Testing an RDMA network using qperf after IPoIB is configured

This procedure describes examples how to display the InfiniBand adapter configuration and measure the bandwidth and latency between two hosts using the `qperf` utility.

Prerequisites

- The `qperf` package is installed on both hosts.
- IPoIB is configured on both hosts.

Procedure

1. Start `qperf` on one of the hosts without any options to act as a server:

```bash
# qperf
```

2. Use the following commands on the client. The commands use port 1 of the `mlx4_0` host channel adapter in the client to connect to IP address `192.0.2.1` assigned to the InfiniBand adapter in the server.
a. To display the configuration, enter:

```bash
qperf -v -i mlx4_0:1 192.0.2.1 conf

conf:
loc_node   = rdma-dev-01.lab.bos.redhat.com
loc_cpu    = 12 Cores: Mixed CPUs
loc_os     = Linux 4.18.0-187.el8.x86_64
loc_qperf  = 0.4.11
rem_node   = rdma-dev-00.lab.bos.redhat.com
rem_cpu    = 12 Cores: Mixed CPUs
rem_os     = Linux 4.18.0-187.el8.x86_64
rem_qperf  = 0.4.11
```

b. To display the Reliable Connection (RC) streaming two-way bandwidth, enter:

```bash
# qperf -v -i mlx4_0:1 192.0.2.1 rc_bi_bw

rc_bi_bw:
bw             = 10.7 GB/sec
msg_rate       = 163 K/sec
loc_id         = mlx4_0
rem_id         = mlx4_0:1
loc_cpus_used  = 65 % cpus
rem_cpus_used  = 62 % cpus
```

c. To display the RC streaming one-way bandwidth, enter:

```bash
# qperf -v -i mlx4_0:1 192.0.2.1 rc_bw

rc_bw:
bw              = 6.19 GB/sec
msg_rate        = 94.4 K/sec
loc_id          = mlx4_0
rem_id          = mlx4_0:1
send_cost       = 63.5 ms/GB
recv_cost       = 63 ms/GB
send_cpus_used  = 39.5 % cpus
recv_cpus_used  = 39 % cpus
```

**Additional resources**

- For further details about `qperf`, see the `qperf(1)` man page.
CHAPTER 28. GETTING STARTED WITH IPVLAN

This document describes the IPVLAN driver.

28.1. IPVLAN OVERVIEW

IPVLAN is a driver for a virtual network device that can be used in container environment to access the host network. IPVLAN exposes a single MAC address to the external network regardless the number of IPVLAN device created inside the host network. This means that a user can have multiple IPVLAN devices in multiple containers and the corresponding switch reads a single MAC address. IPVLAN driver is useful when the local switch imposes constraints on the total number of MAC addresses that it can manage.

28.2. IPVLAN MODES

The following modes are available for IPVLAN:

- **L2 mode**
  In IPVLAN L2 mode, virtual devices receive and respond to Address Resolution Protocol (ARP) requests. The netfilter framework runs only inside the container that owns the virtual device. No netfilter chains are executed in the default namespace on the containerized traffic. Using L2 mode provides good performance, but less control on the network traffic.

- **L3 mode**
  In L3 mode, virtual devices process only L3 traffic and above. Virtual devices do not respond to ARP request and users must configure the neighbour entries for the IPVLAN IP addresses on the relevant peers manually. The egress traffic of a relevant container is landed on the netfilter POSTROUTING and OUTPUT chains in the default namespace while the ingress traffic is threaded in the same way as L2 mode. Using L3 mode provides good control but decreases the network traffic performance.

- **L3S mode**
  In L3S mode, virtual devices process the same way as in L3 mode, except that both egress and ingress traffics of a relevant container are landed on netfilter chain in the default namespace. L3S mode behaves in a similar way to L3 mode but provides greater control of the network.

NOTE

The IPVLAN virtual device does not receive broadcast and multicast traffic in case of L3 and L3S modes.

28.3. OVERVIEW OF MACVLAN

The MACVLAN driver allows to create multiple virtual network devices on top of a single NIC, each of them identified by its own unique MAC address. Packets which land on the physical NIC are demultiplexed towards the relevant MACVLAN device via MAC address of the destination. MACVLAN devices do not add any level of encapsulation.

28.4. COMPARISON OF IPVLAN AND MACVLAN

The following table shows the major differences between MACVLAN and IPVLAN.
### MACVLAN vs. IPVLAN

<table>
<thead>
<tr>
<th>MACVLAN</th>
<th>IPVLAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uses MAC address for each MACVLAN device. The overlimit of MAC addresses of MAC table in switch might cause loosing the connectivity.</td>
<td>Uses single MAC address which does not limit the number of IPVLAN devices.</td>
</tr>
<tr>
<td>Netfilter rules for global namespace cannot affect traffic to or from MACVLAN device in a child namespace.</td>
<td>It is possible to control traffic to or from IPVLAN device in <strong>L3 mode</strong> and <strong>L3S mode</strong>.</td>
</tr>
</tbody>
</table>

Note that both IPVLAN and MACVLAN do not require any level of encapsulation.

### 28.5. CONFIGURING IPVLAN NETWORK

#### 28.5.1. Creating and configuring the IPVLAN device using iproute2

This procedure shows how to set up the IPVLAN device using iproute2.

**Procedure**

1. To create an IPVLAN device, enter the following command:

   ```sh
   ~
   ]# ip link add link real_NIC_device name IPVLAN_device type ipvlan mode l2
   ```

   Note that network interface controller (NIC) is a hardware component which connects a computer to a network.

   **Example 28.1. Creating an IPVLAN device**

   ```sh
   ~
   ]# ip link add link enp0s31f6 name my_ipvlan type ipvlan mode l2
   ~
   ]# ip link
   47: my_ipvlan@enp0s31f6: <BROADCAST,MULTICAST> mtu 1500 qdisc noop state DOWN mode DEFAULT group default qlen 1000 link/ether e8:6a:6e:8a:a2:44 brd ff:ff:ff:ff:ff:ff
   ```

2. To assign an IPv4 or IPv6 address to the interface, enter the following command:

   ```sh
   ~
   ]# ip addr add dev IPVLAN_device IP_address/subnet_mask_prefix
   ```

3. In case of configuring an IPVLAN device in **L3 mode** or **L3S mode**, make the following setups:

   a. Configure the neighbor setup for the remote peer on the remote host:

      ```sh
      ~
      ]# ip neigh add dev peer_device IPVLAN_device_IP_address lladdr MAC_address
      ```

      where `MAC_address` is the MAC address of the real NIC on which an IPVLAN device is based on.

   b. Configure an IPVLAN device for **L3 mode** with the following command:
For L3S mode:

```bash
~$ ip route dev add real_NIC_device peer_IP_address/32
```

where IP-address represents the address of the remote peer.

4. To set an IPVLAN device active, enter the following command:

```bash
~$ ip link set dev IPVLAN_device up
```

5. To check if the IPVLAN device is active, execute the following command on the remote host:

```bash
~$ ping IP_address
```

where the IP_address uses the IP address of the IPVLAN device.
CHAPTER 29. CONFIGURING VIRTUAL ROUTING AND FORWARDING (VRF)

With Virtual routing and forwarding (VRF), Administrators can use multiple routing tables simultaneously on the same host. For that, VRF partitions a network at layer 3. This enables the administrator to isolate traffic using separate and independent route tables per VRF domain. This technique is similar to virtual LANs (VLAN), which partitions a network at layer 2, where the operating system uses different VLAN tags to isolate traffic sharing the same physical medium.

One benefit of VRF over partitioning on layer 2 is that routing scales better considering the number of peers involved.

Red Hat Enterprise Linux uses a virtual vrf device for each VRF domain and adds routes to a VRF domain by enslaving existing network devices to a VRF device. Addresses and routes previously attached to the enslaved device will be moved inside the VRF domain.

Note that each VRF domain is isolated from each other.

29.1. TEMPORARILY REUSING THE SAME IP ADDRESS ON DIFFERENT INTERFACES

The procedure in this section describes how to temporarily use the same IP address on different interfaces in one server by using the virtual routing and forwarding (VRF) feature. Use this procedure only for testing purposes, because the configuration is temporary and lost after you reboot the system.

IMPORTANT

To enable remote peers to contact both VRF interfaces while reusing the same IP address, the network interfaces must belong to different broadcasting domains. A broadcast domain in a network is a set of nodes which receive broadcast traffic sent by any of them. In most configurations, all nodes connected to the same switch belong to the same broadcasting domain.

Prerequisites

- You are logged in as the root user.
- The network interfaces are not configured.

Procedure

1. Create and configure the first VRF device:
   a. Create the VRF device and assign it to a routing table. For example, to create a VRF device named blue that is assigned to the 1001 routing table:

   ```
   # ip link add dev blue type vrf table 1001
   ```
   
   b. Enable the blue device:

   ```
   # ip link set dev blue up
   ```
c. Assign a network device to the VRF device. For example, to add the `enp1s0` Ethernet device to the blue VRF device:

```
# ip link set dev enp1s0 master blue
```

d. Enable the `enp1s0` device:

```
# ip link set dev enp1s0 up
```

e. Assign an IP address and subnet mask to the `enp1s0` device. For example, to set it to `192.0.2.1/24`:

```
# ip addr add dev enp1s0 192.0.2.1/24
```

2. Create and configure the next VRF device:

a. Create the VRF device and assign it to a routing table. For example, to create a VRF device named `red` that is assigned to the 1002 routing table:

```
# ip link add dev red type vrf table 1002
```

b. Enable the `red` device:

```
# ip link set dev red up
```

c. Assign a network device to the VRF device. For example, to add the `enp7s0` Ethernet device to the red VRF device:

```
# ip link set dev enp7s0 master red
```

d. Enable the `enp7s0` device:

```
# ip link set dev enp7s0 up
```

e. Assign the same IP address and subnet mask to the `enp7s0` device as you used for `enp1s0` in the blue VRF domain:

```
# ip addr add dev enp7s0 192.0.2.1/24
```

3. Optionally, create further VRF devices as described above.

### 29.2. RELATED INFORMATION

CHAPTER 30. SETTING THE ROUTING PROTOCOLS FOR YOUR SYSTEM

This section describes how to use the Free Range Routing (FRRouting, or FRR) feature to enable and set the required routing protocols for your system.

30.1. INTRODUCTION TO FRRROUTING

Free Range Routing (FRRouting, or FRR) is a routing protocol stack, which is provided by the frr package available in the AppStream repository.

FRR replaces Quagga that was used on previous RHEL versions. As such, FRR provides TCP/IP-based routing services with support for multiple IPv4 and IPv6 routing protocols.

The supported protocols are:

- Border Gateway Protocol (BGP)
- Intermediate System to Intermediate System (IS-IS)
- Open Shortest Path First (OSPF)
- Protocol-Independent Multicast (PIM)
- Routing Information Protocol (RIP)
- Routing Information Protocol next generation (RIPng)
- Enhanced Interior Gateway Routing Protocol (EIGRP)
- Next Hop Resolution Protocol (NHRP)
- Bidirectional Forwarding Detection (BFD)
- Policy-based Routing (PBR)

FRR is a collection of the following services:

- zebra
- bgpd
- isisd
- ospfd
- ospf6d
- pimd
- ripd
- ripngd
- eigrpd
If \texttt{frr} is installed, the system can act as a dedicated router, which exchanges routing information with other routers in either internal or external network using the routing protocols.

### 30.2. SETTING UP FRROUTING

**Prerequisites**

- Make sure that the \texttt{frr} package is installed on your system:

\[
\text{# yum install frr}
\]

**Procedure**

1. Edit the \texttt{/etc/frr/daemons} configuration file, and enable the required daemons for your system. For example, to enable the \texttt{ripd} daemon, include the following line:

\[
\text{ripd=yes}
\]

**WARNING**

The \texttt{zebra} daemon must always be enabled, so that you must set \texttt{zebra=yes} to be able to use FRR.

**IMPORTANT**

By default, \texttt{/etc/frr/daemons} contains \texttt{[daemon_name]=no} entries for all daemons. Therefore, all daemons are disabled, and starting FRR after a new installation of the system has no effect.

2. Start the \texttt{frr} service:

\[
\text{# systemctl start frr}
\]

3. Optionally, you can also set FRR to start automatically on boot:

\[
\text{# systemctl enable frr}
\]
30.3. MODIFYING THE CONFIGURATION OF FRR

This section describes:

- How to enable an additional daemon after you set up FRR
- How to disable a daemon after you set up FRR

Enabling an additional daemon

Prerequisites

- FRR is set up as described in Section 30.2, “Setting up FRRouting”.

Procedure

To enable one or more additional daemons:

1. Edit the `/etc/frr/daemons` configuration file, and modify the line for the required daemons to state `yes` instead of `no`.
   For example, to enable the `ripd` daemon:

   ```
   ripd=yes
   ```

2. Reload the `frr` service:

   ```
   # systemctl reload frr
   ```

Disabling a daemon

Prerequisites

- FRR is set up as described in Section 30.2, “Setting up FRRouting”.

Procedure

To disable one or more daemons:

1. Edit the `/etc/frr/daemons` configuration file, and modify the line for the required daemons to state `no` instead of `yes`.
   For example, to disable the `ripd` daemon:

   ```
   ripd=no
   ```

2. Reload the `frr` service:

   ```
   # systemctl reload frr
   ```

30.4. MODIFYING A CONFIGURATION OF A PARTICULAR DAEMON

With the default configuration, every routing daemon in FRR can only act as a plain router.

For any additional configuration of a daemon, use the following procedure.
Procedure

1. Within the /etc/frr/ directory, create a configuration file for the required daemon, and name the file as follows:

   [daemon_name].conf

   For example, to further configure the eigrpd daemon, create the eigrpd.conf file in the mentioned directory.

2. Populate the new file with the required content.
   For configuration examples of particular FRR daemons, see the /usr/share/doc/frr/ directory.

3. Reload the frr service:

   # systemctl reload frr
CHAPTER 31. PROVIDING DHCP SERVICES

The Dynamic Host Configuration Protocol (DHCP) is a network protocol that automatically assigns IP information to clients.

This section explains general information on the `dhcpd` service, as well as how to set up a DHCP server and DHCP relay.

If a procedure requires different steps for providing DHCP in IPv4 and IPv6 networks, the sections in this chapter contain procedures for both protocols.

31.1. THE DIFFERENCES WHEN USING DHCPD FOR DHCPV4 AND DHCPV6

The `dhcpd` service supports providing both DHCPv4 and DHCPv6 on one server. However, you need a separate instance of `dhcpd` with separate configuration files to provide DHCP for each protocol.

**DHCPv4**

- Configuration file: `/etc/dhcp/dhcpd.conf`
- Systemd service name: `dhcpd`

**DHCPv6**

- Configuration file: `/etc/dhcp/dhcpd6.conf`
- Systemd service name: `dhcpd6`

31.2. THE LEASE DATABASE OF THE DHCPD SERVICE

A DHCP lease is the time period for which the `dhcpd` service allocates a network address to a client. The `dhcpd` service stores the DHCP leases in the following databases:

- For DHCPv4: `/var/lib/dhcp/dhcpd.leases`
- For DHCPv6: `/var/lib/dhcp/dhcpd6.leases`

**WARNING**

Manually updating the database files can corrupt the databases.

The lease databases contain information about the allocated leases, such as the IP address assigned to a media access control (MAC) address or the time stamp when the lease expires. Note that all time stamps in the lease databases are in Coordinated Universal Time (UTC).

The `dhcpd` service recreates the databases periodically:

1. The service renames the existing files:
2. The service writes all known leases to the newly created `/var/lib/dhcpd/dhcpd.leases` and `/var/lib/dhcpd/dhcpd6.leases` files.

Additional resources

- For further details about what is stored in the lease database, see the `dhcpd.leases(5)` man page.
- Section 31.9, “Restoring a corrupt lease database”

### 31.3. DYNAMIC IP ADDRESS ASSIGNMENT IN IPV6 NETWORKS

In an IPv6 network, only router advertisement messages provide information on an IPv6 default gateway. As a consequence, if you want to use DHCPv6 in subnets that require a default gateway setting, you must additionally configure a router advertisement service, such as Router Advertisement Daemon (`radvd`).

The `radvd` service uses flags in router advertisement packets to announce the availability of a DHCPv6 server.

This section compares DHCPv6 and `radvd`, and provides information about configuring `radvd`.

#### 31.3.1. Comparison of DHCPv6 to radvd

<table>
<thead>
<tr>
<th></th>
<th>DHCPv6</th>
<th>radvd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provides information on the default gateway</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>Guarantees random addresses to protect privacy</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Sends further network configuration options</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Maps media access control (MAC) addresses to IPv6 addresses</td>
<td>yes</td>
<td>no</td>
</tr>
</tbody>
</table>

#### 31.3.2. Configuring the radvd service for IPv6 routers

The router advertisement daemon (`radvd`) sends router advertisement messages that are required for IPv6 stateless autoconfiguration. This enables users to automatically configure their addresses, settings, routes, and to choose a default router based on these advertisements.

The procedure in this section explains how to configure `radvd`.

**Prerequisites**

- You are logged in as the `root` user.

**Procedure**
1. Install the `radvd` package:

   ```sh
   # yum install radvd
   ```

2. Edit the `/etc/radvd.conf` file, and add the following configuration:

   ```conf
   interface enp1s0
   {
   AdvSendAdvert on;
   AdvManagedFlag on;
   AdvOtherConfigFlag on;
   
   prefix 2001:db8:0:1::/64 {
   };
   };
   ```

   These settings configures `radvd` to send router advertisement messages on the `enp1s0` device for the `2001:db8:0:1::/64` subnet. The `AdvManagedFlag on` setting defines that the client should receive the IP address from a DHCP server, and the `AdvOtherConfigFlag` parameter set to `on` defines that clients should receive non-address information from the DHCP server as well.

3. Optionally, configure that `radvd` automatically starts when the system boots:

   ```sh
   # systemctl enable radvd
   ```

4. Start the `radvd` service:

   ```sh
   # systemctl start radvd
   ```

5. Optionally, display the content of router advertisement packages and the configured values `radvd` sends:

   ```sh
   # radvdump
   ```

**Additional resources**

- For further details about configuring `radvd`, see the `radvd.conf(5)` man page.
- For an example configuration of `radvd`, see the `/usr/share/doc/radvd/radvd.conf.example` file.

## 31.4. SETTING NETWORK INTERFACES FOR THE DHCP SERVERS

By default, the `dhcpd` service processes requests only on network interfaces that have an IP address in the subnet defined in the configuration file of the service.

For example, in the following scenario, `dhcpd` listens only on the `enp0s1` network interface:

- You have only a **subnet** definition for the 192.0.2.0/24 network in the `/etc/dhcp/dhcppd.conf` file.

- The **enp0s1** network interface is connected to the 192.0.2.0/24 subnet.

- The **enp7s0** interface is connected to a different subnet.
Only follow the procedure in this section if the DHCP server contains multiple network interfaces connected to the same network but the service should listen only on specific interfaces.

Depending on whether you want to provide DHCP for IPv4, IPv6, or both protocols, see the procedure for:

- IPv4 networks
- IPv6 networks

Prerequisites

- You are logged in as the root user.
- The dhcp-server package is installed.

For IPv4 networks

1. Copy the /usr/lib/systemd/system/dhcpd.service file to the /etc/systemd/system/ directory:

   ```bash
   # cp /usr/lib/systemd/system/dhcpd.service /etc/systemd/system/
   ```

   Do not edit the /usr/lib/systemd/system/dhcpd.service file. Future updates of the dhcp-server package can override the changes.

2. Edit the /etc/systemd/system/dhcpd.service file, and append the names of the interface, that dhcpd should listen on to the command in the ExecStart parameter:

   ```bash
   ExecStart=/usr/sbin/dhcpd -f -cf /etc/dhcp/dhcpd.conf -user dhcpd -group dhcpd --no-pid $DHCPDARGS
   ```

   This example configures that dhcpd listens only on the enp0s1 and enp7s0 interfaces.

3. Reload the systemd manager configuration:

   ```bash
   # systemctl daemon-reload
   ```

4. Restart the dhcpd service:

   ```bash
   # systemctl restart dhcpd.service
   ```

For IPv6 networks

1. Copy the /usr/lib/systemd/system/dhcpd6.service file to the /etc/systemd/system/ directory:

   ```bash
   # cp /usr/lib/systemd/system/dhcpd6.service /etc/systemd/system/
   ```

   Do not edit the /usr/lib/systemd/system/dhcpd6.service file. Future updates of the dhcp-server package can override the changes.

2. Edit the /etc/systemd/system/dhcpd6.service file, and append the names of the interface, that dhcpd should listen on to the command in the ExecStart parameter:

   ```bash
   ExecStart=/usr/sbin/dhcpd -f -6 -cf /etc/dhcp/dhcpd.conf -user dhcpd -group dhcpd --no-pid $DHCPDARGS enp0s1 enp7s0
   ```

   This example configures that dhcpd listens only on the enp0s1 and enp7s0 interfaces.
3. Reload the `systemd` manager configuration:

```
# systemctl daemon-reload
```

4. Restart the `dhcpd` service:

```
# systemctl restart dhcpd.service
```

### 31.5. Setting up the DHCP service for subnets directly connected to the DHCP server

Use the following procedure if the DHCP server is directly connected to the subnet for which the server should answer DHCP requests. This is the case if a network interface of the server has an IP address of this subnet assigned.

Depending on whether you want to provide DHCP for IPv4, IPv6, or both protocols, see the procedure for:

- IPv4 networks
- IPv6 networks

**Prerequisites**

- You are logged in as the root user.
- The `dhcpd-server` package is installed.

**For IPv4 networks**

1. Edit the `/etc/dhcp/dhcpd.conf` file:

   a. Optionally, add global parameters that `dhcpd` uses as default if no other directives contain these settings:

   ```
   option domain-name "example.com";
   default-lease-time 86400;
   ```

   This example sets the default domain name for the connection to `example.com`, and the default lease time to 86400 seconds (1 day).

   b. Add the `authoritative` statement on a new line:

   ```
   authoritative;
   ```

   **IMPORTANT**

   Without the `authoritative` statement, the `dhcpd` service does not answer `DHCPREQUEST` messages with `DHCPNAK` if a client asks for an address that is outside of the pool.
c. For each IPv4 subnet directly connected to an interface of the server, add a subnet declaration:

```plaintext
subnet 192.0.2.0 netmask 255.255.255.0 {
    range 192.0.2.20 192.0.2.100;
    option domain-name-servers 192.0.2.1;
    option routers 192.0.2.1;
    option broadcast-address 192.0.2.255;
    max-lease-time 172800;
}
```

This example adds a subnet declaration for the 192.0.2.0/24 network. With this configuration, the DHCP server assigns the following settings to a client that sends a DHCP request from this subnet:

- A free IPv4 address from the range defined in the range parameter
- IP of the DNS server for this subnet: **192.0.2.1**
- Default gateway for this subnet: **192.0.2.1**
- Broadcast address for this subnet: **192.0.2.255**
- The maximum lease time, after which clients in this subnet release the IP and send a new request to the server: **172800** seconds (2 days)

2. Optionally, configure that `dhcppd` starts automatically when the system boots:

```plaintext
# systemctl enable dhcppd
```

3. Start the `dhcppd` service:

```plaintext
# systemctl start dhcppd
```

**For IPv6 networks**

1. Edit the `/etc/dhcp/dhcppd6.conf` file:

   a. Optionally, add global parameters that `dhcppd` uses as default if no other directives contain these settings:

   ```plaintext
   option dhcp6.domain-search "example.com";
   default-lease-time 86400;
   ```

   This example sets the default domain name for the connection to `example.com`, and the default lease time to **86400** seconds (1 day).

   b. Add the authoritative statement on a new line:

   ```plaintext
   authoritative;
   ```
c. For each IPv6 subnet directly connected to an interface of the server, add a subnet declaration:

```
subnet6 2001:db8:0:1::/64 {
    range6 2001:db8:0:1::20 2001:db8:0:1::100;
    option dhcp6.name-servers 2001:db8:0:1::1;
    max-lease-time 172800;
}
```

This example adds a subnet declaration for the 2001:db8:0:1::/64 network. With this configuration, the DHCP server assigns the following settings to a client that sends a DHCP request from this subnet:

- A free IPv6 address from the range defined in the range6 parameter.
- The IP of the DNS server for this subnet is 2001:db8:0:1::1.
- The maximum lease time, after which clients in this subnet release the IP and send a new request to the server is 172800 seconds (2 days).

Note that IPv6 requires uses router advertisement messages to identify the default gateway.

2. Optionally, configure that dhcpd6 starts automatically when the system boots:

```
# systemctl enable dhcpd6
```

3. Start the dhcpd6 service:

```
# systemctl start dhcpd6
```

Additional resources:

- For a list of all parameters you can set in `/etc/dhcp/dhcpd.conf` and `/etc/dhcp/dhcpd6.conf`, see the dhcp-options(5) man page.
- For further details about the authoritative statement, see The authoritative statement section in the dhcpd.conf(5) man page.
- For example configurations, see the `/usr/share/doc/dhcp-server/dhcpd.conf.example` and `/usr/share/doc/dhcp-server/dhcpd6.conf.example` files.
- For details about configuring the radvd service for IPv6 router advertisement, see Section 31.3.2, “Configuring the radvd service for IPv6 routers”

### 31.6. SETTING UP THE DHCP SERVICE FOR SUBNETS THAT ARE NOT DIRECTLY CONNECTED TO THE DHCP SERVER

Use the following procedure if the DHCP server is not directly connected to the subnet for which the
server should answer DHCP requests. This is the case if a DHCP relay agent forwards requests to the DHCP server, because none of the DHCP server's interfaces is directly connected to the subnet the server should serve.

Depending on whether you want to provide DHCP for IPv4, IPv6, or both protocols, see the procedure for:

- IPv4 networks
- IPv6 networks

**Prerequisites**

- You are logged in as the root user.
- The dhcpd-server package is installed.

**For IPv4 networks**

1. Edit the `/etc/dhcp/dhcpd.conf` file:
   
   a. Optionally, add global parameters that `dhcpd` uses as default if no other directives contain these settings:

   ```
   option domain-name "example.com";
   default-lease-time 86400;
   ```

   This example sets the default domain name for the connection to example.com, and the default lease time to 86400 seconds (1 day).

   b. Add the authoritative statement on a new line:

   ```
   authoritative;
   ```

   **IMPORTANT**

   Without the authoritative statement, the dhcpd service does not answer DHCPREQUEST messages with DHCPNAK if a client asks for an address that is outside of the pool.

   c. Add a shared-network declaration, such as the following, for IPv4 subnets that are not directly connected to an interface of the server:

   ```
   shared-network example {
   option domain-name-servers 192.0.2.1;
   ...

   subnet 192.0.2.0 netmask 255.255.255.0 {
   range 192.0.2.20 192.0.2.100;
   option routers 192.0.2.1;
   }

   subnet 198.51.100.0 netmask 255.255.255.0 {
   range 198.51.100.20 198.51.100.100;
   option routers 198.51.100.1;
   }
   ```
This example adds a shared network declaration, that contains a subnet declaration for both the 192.0.2.0/24 and 198.51.100.0/24 networks. With this configuration, the DHCP server assigns the following settings to a client that sends a DHCP request from one of these subnets:

- The IP of the DNS server for clients from both subnets is: **192.0.2.1**.
- A free IPv4 address from the range defined in the range parameter, depending on from which subnet the client sent the request.
- The default gateway is either **192.0.2.1** or **198.51.100.1** depending on from which subnet the client sent the request.

d. Add a **subnet** declaration for the subnet the server is directly connected to and that is used to reach the remote subnets specified in **shared-network** above:

```
subnet 203.0.113.0 netmask 255.255.255.0 {
}
```

**NOTE**

If the server does not provide DHCP service to this subnet, the subnet declaration must be empty as shown in the example. Without a declaration for the directly connected subnet, **dhcpd** does not start.

2. Optionally, configure that **dhcpd** starts automatically when the system boots:

```
# systemctl enable dhcpd
```

3. Start the **dhcpd** service:

```
# systemctl start dhcpd
```

For IPv6 networks

1. Edit the /etc/dhcp/dhcpd6.conf file:

   a. Optionally, add global parameters that **dhcpd** uses as default if no other directives contain these settings:

   ```
   option dhcp6.domain-search "example.com";
   default-lease-time 86400;
   ```

   This example sets the default domain name for the connection to **example.com**, and the default lease time to **86400** seconds (1 day).

   b. Add the **authoritative** statement on a new line:

   ```
   authoritative;
   ```
IMPORTANT

Without the authoritative statement, the dhcpd service does not answer DHCPREQUEST messages with DHCPNAK if a client asks for an address that is outside of the pool.

c. Add a shared-network declaration, such as the following, for IPv6 subnets that are not directly connected to an interface of the server:

```plaintext
shared-network example {
  option domain-name-servers 2001:db8:0:1::1:1
  ...

  subnet6 2001:db8:0:1::1:0/120 {
    range6 2001:db8:0:1::1:20 2001:db8:0:1::1:100
  }

  subnet6 2001:db8:0:1::2:0/120 {
    range6 2001:db8:0:1::2:20 2001:db8:0:1::2:100
  }
  ...
}
```

This example adds a shared network declaration that contains a subnet6 declaration for both the 2001:db8:0:1::1:0/120 and 2001:db8:0:1::2:0/120 networks. With this configuration, the DHCP server assigns the following settings to a client that sends a DHCP request from one of these subnets:

- The IP of the DNS server for clients from both subnets is \texttt{2001:db8:0:1::1:1}.
- A free IPv6 address from the range defined in the range6 parameter, depending on from which subnet the client sent the request.
  Note that IPv6 requires uses router advertisement messages to identify the default gateway.

d. Add a subnet6 declaration for the subnet the server is directly connected to and that is used to reach the remote subnets specified in shared-network above:

```plaintext
subnet6 2001:db8:0:1::50:0/120 {
}
```

\textbf{NOTE}

If the server does not provide DHCP service to this subnet, the subnet6 declaration must be empty as shown in the example. Without a declaration for the directly connected subnet, dhcpd does not start.

2. Optionally, configure that dhcpd6 starts automatically when the system boots:

```plaintext
# systemctl enable dhcpd6
```

3. Start the dhcpd6 service:

```plaintext
# systemctl start dhcpd6
```
31.7. ASSIGNING A STATIC ADDRESS TO A HOST USING DHCP

Using a host declaration, you can configure the DHCP server to assign a fixed IP address to a media access control (MAC) address of a host. For example, use this method to always assign the same IP address to a server or network device.

**IMPORTANT**

If you configure a fixed IP address for a MAC address, the IP address must be outside of the address pool you specified in the fixed-address and fixed-address6 parameters.

Depending on whether you want to configure fixed addresses for IPv4, IPv6, or both protocols, see the procedure for:

- IPv4 networks
- IPv6 networks

Prerequisites

- The dhcpd service is configured and running.
- You are logged in as the root user.

For IPv4 networks

1. Edit the /etc/dhcp/dhcpd.conf file:
   a. Add a host declaration:

   ```
   host server.example.com {
     hardware ethernet 52:54:00:72:2f:6e;
     fixed-address 192.0.2.130;
   }
   ```

   This example configures the DHCP server to always assigns the 192.0.2.130 IP address to the host with the 52:54:00:72:2f:6e MAC address.

   The dhcpd service identifies systems by the MAC address specified in the fixed-address parameter, and not by the name in the host declaration. As a consequence, you can set this...
name to any string that does not match other host declarations. To configure the same system for multiple networks, use a different name, otherwise, dhcpd fails to start.

b. Optionally, add further settings to the host declaration that are specific for this host.

2. Restart the dhcpd service:

```
# systemctl start dhcpd
```

For IPv6 networks

1. Edit the /etc/dhcp/dhcpd6.conf file:

   a. Add a host declaration:

   ```
   host server.example.com {
     hardware ethernet 52:54:00:72:2f:6e;
     fixed-address6 2001:db8:0:1::20;
   }
   
   This example configures the DHCP server to always assign the 2001:db8:0:1::20 IP address to the host with the 52:54:00:72:2f:6e MAC address.
   
   The dhcpd service identifies systems by the MAC address specified in the fixed-address6 parameter, and not by the name in the host declaration. As a consequence, you can set this name to any string, as long as it is unique to other host declarations. To configure the same system for multiple networks, use a different name because, otherwise, dhcpd fails to start.

   b. Optionally, add further settings to the host declaration that are specific for this host.

2. Restart the dhcpd6 service:

```
# systemctl start dhcpd6
```

Additional resources

- For a list of all parameters you can set in /etc/dhcp/dhcpd.conf and /etc/dhcp/dhcpd6.conf, see the dhcp-options(5) man page.

- For example configurations, see the /usr/share/doc/dhcp-server/dhcpd.conf.example and /usr/share/doc/dhcp-server/dhcpd6.conf.example files.

31.8. USING A GROUP DECLARATION TO APPLY PARAMETERS TO MULTIPLE HOSTS, SUBNETS, AND SHARED NETWORKS AT THE SAME TIME

Using a group declaration, you can apply the same parameters to multiple hosts, subnets, and shared networks.

Note that the procedure in this section describes using a group declaration for hosts, but the steps are the same for subnets and shared networks.

Depending on whether you want to configure a group for IPv4, IPv6, or both protocols, see the procedure for:
Prerequisites

- The `dhcpd` service is configured and running.
- You are logged in as the `root` user.

For IPv4 networks

1. Edit the `/etc/dhcp/dhcpd.conf` file:
   
   a. Add a `group` declaration:

   ```
   group {
     option domain-name-servers 192.0.2.1;
     host server1.example.com {
       hardware ethernet 52:54:00:72:2f:6e;
       fixed-address 192.0.2.130;
     }
     host server2.example.com {
       hardware ethernet 52:54:00:1b:f3:cf;
       fixed-address 192.0.2.140;
     }
   }
   ```

   This `group` definition groups two `host` entries. The `dhcpd` service applies the value set in the `option domain-name-servers` parameter to both hosts in the group.

   b. Optionally, add further settings to the `group` declaration that are specific for these hosts.

2. Restart the `dhcpd` service:

   ```
   # systemctl start dhcpd
   ```

For IPv6 networks

1. Edit the `/etc/dhcp/dhcpd6.conf` file:

   a. Add a `group` declaration:

   ```
   group {
     option dhcp6.domain-search "example.com";
     host server1.example.com {
       hardware ethernet 52:54:00:72:2f:6e;
       fixed-address 2001:db8:0:1::200;
     }
     host server2.example.com {
       hardware ethernet 52:54:00:1b:f3:cf;
     }
   }
   ```
This **group** definition groups two **host** entries. The **dhcpd** service applies the value set in the **option dhcp6.domain-search** parameter to both hosts in the group.

b. Optionally, add further settings to the **group** declaration that are specific for these hosts.

2. Restart the **dhcpd6** service:

```
# systemctl start dhcpd6
```

### Additional resources

- For a list of all parameters you can set in `/etc/dhcp/dhcpd.conf` and `/etc/dhcp/dhcpd6.conf`, see the **dhcp-options(5)** man page.
- For example configurations, see the `/usr/share/doc/dhcp-server/dhcpd.conf.example` and `/usr/share/doc/dhcp-server/dhcpd6.conf.example` files.

### 31.9. RESTORING A CORRUPT LEASE DATABASE

If the DHCP server logs an error that is related to the lease database, such as **Corrupt lease file - possible data loss!**, you can restore the lease database from the copy the **dhcpd** service created. Note that this copy might not reflect the latest status of the database.

![WARNING]

If you remove the lease database instead of replacing it with a backup, you lose all information about the currently assigned leases. As a consequence, the DHCP server could assign leases to clients that have been previously assigned to other hosts and are not expired yet. This leads to IP conflicts.

Depending on whether you want to restore the DHCPv4, DHCPv6, or both databases, see the procedure for:

- **Restoring the DHCPv4 lease database**
- **Restoring the DHCPv6 lease database**

### Prerequisites

- You are logged in as the **root** user.
- The lease database is corrupt.

**Restoring the DHCPv4 lease database**

1. Stop the **dhcpd** service:
# systemctl stop dhcpd

2. Rename the corrupt lease database:

```bash
# mv /var/lib/dhcpd/dhcpd.leases /var/lib/dhcpd/dhcpd.leases.corrupt
```

3. Restore the copy of the lease database that the `dhcp` service created when it refreshed the lease database:

```bash
# cp -p /var/lib/dhcpd/dhcpd.leases~ /var/lib/dhcpd/dhcpd.leases
```

**IMPORTANT**

If you have a more recent backup of the lease database, restore this backup instead.

4. Start the `dhcp` service:

```bash
# systemctl start dhcpd
```

---

**Restoring the DHCPv6 lease database**

1. Stop the `dhcpp6` service:

```bash
# systemctl stop dhcpp6
```

2. Rename the corrupt lease database:

```bash
# mv /var/lib/dhcpd/dhcpd6.leases /var/lib/dhcpd/dhcpd6.leases.corrupt
```

3. Restore the copy of the lease database that the `dhcp` service created when it refreshed the lease database:

```bash
# cp -p /var/lib/dhcpd/dhcpd6.leases~ /var/lib/dhcpd/dhcpd6.leases
```

**IMPORTANT**

If you have a more recent backup of the lease database, restore this backup instead.

4. Start the `dhcpp6` service:

```bash
# systemctl start dhcpp6
```

---

**Additional resources**

- Section 31.2, “The lease database of the dhcpd service”

---

**31.10. SETTING UP A DHCP RELAY AGENT**
The DHCP Relay Agent (dhcrelay) enables the relay of DHCP and BOOTP requests from a subnet with no DHCP server on it to one or more DHCP servers on other subnets. When a DHCP client requests information, the DHCP Relay Agent forwards the request to the list of DHCP servers specified. When a DHCP server returns a reply, the DHCP Relay Agent forwards this request to the client.

Depending on whether you want to set up a DHCP relay for IPv4, IPv6, or both protocols, see the procedure for:

- IPv4 networks
- IPv6 networks

Prerequisites

- You are logged in as the root user.

For IPv4 networks

1. Install the dhcp-relay package:

   ```bash
   # yum install dhcp-relay
   ```

2. Copy the `/lib/systemd/system/dhcrelay.service` file to the `/etc/systemd/system/` directory:

   ```bash
   # cp /lib/systemd/system/dhcrelay.service /etc/systemd/system/
   ```

   Do not edit the `/usr/lib/systemd/system/dhcrelay.service` file. Future updates of the dhcp-relay package can override the changes.

3. Edit the `/etc/systemd/system/dhcrelay.service` file, and append the `-i interface` parameter, together with a list of IP addresses of DHCPv4 servers that are responsible for the subnet:

   ```bash
   ExecStart=/usr/sbin/dhcrelay -d --no-pid -i enp1s0 192.0.2.1
   ```

   With these additional parameters, dhcrelay listens for DHCPv4 requests on the enp1s0 interface and forwards them to the DHCP server with the IP 192.0.2.1.

4. Reload the systemd manager configuration:

   ```bash
   # systemctl daemon-reload
   ```

5. Optionally, configure that the dhcrelay service starts when the system boots:

   ```bash
   # systemctl enable dhcrelay.service
   ```

6. Start the dhcrelay service:

   ```bash
   # systemctl start dhcrelay.service
   ```

For IPv6 networks

1. Install the dhcp-relay package:

   ```bash
   # yum install dhcp-relay
   ```
2. Copy the `/lib/systemd/system/dhcrelay.service` file to the `/etc/systemd/system/` directory and name the file `dhcrelay6.service`:

```bash
# cp /lib/systemd/system/dhcrelay.service /etc/systemd/system/dhcrelay6.service
```

Do not edit the `/usr/lib/systemd/system/dhcrelay.service` file. Future updates of the `dhcp-relay` package can override the changes.

3. Edit the `/etc/systemd/system/dhcrelay6.service` file, and append the `-l receiving_interface` and `-u outgoing_interface` parameters:

```bash
ExecStart=/usr/sbin/dhcrelay -d --no-pid -l enp1s0 -u enp7s0
```

With these additional parameters, `dhcrelay` listens for DHCPv6 requests on the `enp1s0` interface and forwards them to the network connected to the `enp7s0` interface.

4. Reload the `systemd` manager configuration:

```bash
# systemctl daemon-reload
```

5. Optionally, configure that the `dhcrelay6` service starts when the system boots:

```bash
# systemctl enable dhcrelay6.service
```

6. Start the `dhcrelay6` service:

```bash
# systemctl start dhcrelay6.service
```

### Additional resources
- For further details about `dhcrelay`, see the `dhcrelay(8)` man page.

### Additional resources
- Section 31.1, "The differences when using dhcpd for DHCPv4 and DHCPv6"
CHAPTER 32. USING AND CONFIGURING FIREWALLS

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.

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

32.1. 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 to configure a firewall on workstations. The utility is easy to use and covers the typical use cases for this scenario.

- **nftables**: Use the nftables utility to set up complex firewalls, such as for a whole network.

- **iptables**: The iptables utility is deprecated in Red Hat Enterprise Linux 8. Use instead nftables.

**IMPORTANT**

To avoid that the different firewall services influence each other, run only one of them on a RHEL host, and disable the other services.

32.2. GETTING STARTED WITH FIREWALLD

32.2.1. firewalld

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.

**Additional resources**

- firewalld(1) man page

32.2.2. Zones

Firewalld can be used to separate networks into different zones according to the level of trust that the user has decided to place on the interfaces and traffic within that network. A connection can only be part of one zone, but a zone can be used for many network connections.
NetworkManager notifies firewalld of the zone of an interface. You can assign zones to interfaces with:

- NetworkManager
- firewall-config tool
- firewall-cmd command-line tool
- The RHEL web console

The latter three 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 predefined zones are stored in the /usr/lib/firewalld/zones/ directory and can be instantly applied to any available network interface. These files are copied to the /etc/firewalld/zones/ directory only after they are modified. The default settings of the predefined zones are as follows:

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

**dmz**
- For computers in your demilitarized zone that are publicly-accessible with limited access to your internal network. Only selected incoming connections are accepted.

**drop**
- Any incoming network packets are dropped without any notification. Only outgoing network connections are possible.

**external**
- For use on external networks with masquerading enabled, especially for routers. You do not trust the other computers on the network to not harm your computer. Only selected incoming connections are accepted.

**home**
- For use at home when you mostly trust the other computers on the network. Only selected incoming connections are accepted.

**internal**
- For use on internal networks when you mostly trust the other computers on the network. Only selected incoming connections are accepted.

**public**
- For use in public areas where you do not trust other computers on the network. Only selected incoming connections are accepted.

**trusted**
- All network connections are accepted.

**work**
- For use at work where you mostly trust the other computers on the network. Only selected incoming connections are accepted.

One of these zones is set as the default zone. When interface connections are added to NetworkManager, they are assigned to the default zone. On installation, the default zone in firewalld is set to be the public zone. The default zone can be changed.
NOTE

The network zone names have been chosen to be self-explanatory and to allow users to quickly make a reasonable decision. To avoid any security problems, review the default zone configuration and disable any unnecessary services according to your needs and risk assessments.

Additional resources

`firewalld.zone(5)` man page

32.2.3. Predefined services

A service can be a list of local ports, protocols, source ports, and destinations, as well as a list of firewall helper modules automatically loaded if a service is enabled. Using services saves users time because they can achieve several tasks, such as opening ports, defining protocols, enabling packet forwarding and more, in a single step, rather than setting up everything one after another.

Service configuration options and generic file information are described in the `firewalld.service(5)` man page. The services are specified by means of individual XML configuration files, which are named in the following format: `service-name.xml`. Protocol names are preferred over service or application names in `firewalld`.

Services can be added and removed using the graphical `firewall-config` tool, `firewall-cmd`, and `firewall-offline-cmd`.

Alternatively, you can edit the XML files in the `/etc/firewalld/services/` directory. If a service is not added or changed by the user, then no corresponding XML file is found in `/etc/firewalld/services/`. The files in the `/usr/lib/firewalld/services/` directory can be used as templates if you want to add or change a service.

Additional resources

- `firewalld.service(5)` man page

32.3. INSTALLING THE FIREWALL-CONFIG GUI CONFIGURATION TOOL

To use the `firewall-config` GUI configuration tool, install the `firewall-config` package.

Procedure

1. Enter the following command as root:

   ```
   # yum install firewall-config
   ```

   Alternatively, in GNOME, use the Super key and type `Software Sources` to launch the `Software Sources` application. Type `firewall` to the search box, which appears after selecting the search button in the top-right corner. Select the `Firewall` item from the search results, and click on the `Install` button.

2. To run `firewall-config`, use either the `firewall-config` command or press the Super key to enter the Activities Overview, type `firewall`, and press Enter.

32.4. VIEWING THE CURRENT STATUS AND SETTINGS OF FIREWALLD
32.4.1. Viewing the current status of firewalld

The firewall service, firewalld, is installed on the system by default. Use the firewalld CLI interface to check that the service is running.

Procedure

1. To see the status of the service:

   # firewall-cmd --state

2. For more information about the service status, use the systemctl status sub-command:

   # systemctl status firewalld

   firewalld.service - firewalld - dynamic firewall daemon
   Loaded: loaded (/usr/lib/systemd/system/firewalld.service; enabled; vendor provided)
   Active: active (running) since Mon 2017-12-18 16:05:15 CET; 50min ago
   Docs: man:firewalld(1)
   Main PID: 705 (firewalld)
   Tasks: 2 (limit: 4915)
   CGroup: /system.slice/firewalld.service
   └─ 705 /usr/bin/python3 -Es /usr/sbin/firewalld --nofork --nopid

Additional resources

It is important to know how firewalld is set up and which rules are in force before you try to edit the settings. To display the firewall settings, see Section 32.4.2, “Viewing current firewalld settings”

32.4.2. Viewing current firewalld settings

32.4.2.1. Viewing allowed services using GUI

To view the list of services using the graphical firewall-config tool, press the Super key to enter the Activities Overview, type firewall, and press Enter. The firewall-config tool appears. You can now view the list of services under the Services tab.

Alternatively, to start the graphical firewall configuration tool using the command-line, enter the following command:

$ firewall-config

The Firewall Configuration window opens. Note that this command can be run as a normal user, but you are prompted for an administrator password occasionally.

32.4.2.2. Viewing firewalld settings using CLI

With the CLI client, it is possible to get different views of the current firewall settings. The --list-all option shows a complete overview of the firewalld settings.

firewalld uses zones to manage the traffic. If a zone is not specified by the --zone option, the command is effective in the default zone assigned to the active network interface and connection.

To list all the relevant information for the default zone:
To specify the zone for which to display the settings, add the `--zone=zone-name` argument to the `firewall-cmd --list-all` command, for example:

```
# firewall-cmd --list-all --zone=home
home
target: default
icmp-block-inversion: no
interfaces:
sources:
services: ssh mdns samba-client dhcpv6-client
... [trimmed for clarity]
```

To see the settings for particular information, such as services or ports, use a specific option. See the `firewalld` manual pages or get a list of the options using the command `help`:

```
# firewall-cmd --help
Usage: firewall-cmd [OPTIONS...]

General Options
  -h, --help          Prints a short help text and exists
  -V, --version       Print the version string of firewalld
  -q, --quiet         Do not print status messages

Status Options
  --state            Return and print firewalld state
  --reload           Reload firewall and keep state information
  ... [trimmed for clarity]
```

For example, to see which services are allowed in the current zone:

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

Listing the settings for a certain subpart using the CLI tool can sometimes be difficult to interpret. For example, you allow the SSH service and firewalld opens the necessary port (22) for the service. Later, if you list the allowed services, the list shows the SSH service, but if you list open ports, it does not show any. Therefore, it is recommended to use the --list-all option to make sure you receive a complete information.

32.5. STARTING FIREWALLD

Procedure

1. To start firewalld, enter the following command as root:

   # systemctl unmask firewalld
   # systemctl start firewalld

2. To ensure firewalld starts automatically at system start, enter the following command as root:

   # systemctl enable firewalld

32.6. STOPPING FIREWALLD

Procedure

1. To stop firewalld, enter the following command as root:

   # systemctl stop firewalld

2. To prevent firewalld from starting automatically at system start:

   # systemctl disable firewalld

3. To make sure firewalld is not started by accessing the firewalld D-Bus interface and also if other services require firewalld:

   # systemctl mask firewalld

32.7. RUNTIME AND PERMANENT SETTINGS

Any changes committed in runtime mode only apply while firewalld is running. When firewalld is restarted, the settings revert to their permanent values.

To make the changes persistent across reboots, apply them again using the --permanent option. Alternatively, to make changes persistent while firewalld is running, use the --runtime-to-permanent firewall-cmd option.

If you set the rules while firewalld is running using only the --permanent option, they do not become effective before firewalld is restarted. However, restarting firewalld closes all open ports and stops the networking traffic.

Modifying settings in runtime and permanent configuration using CLI
Using the CLI, you do not modify the firewall settings in both modes at the same time. You only modify either runtime or permanent mode. To modify the firewall settings in the permanent mode, use the `--permanent` option with the `firewall-cmd` command.

```sh
# firewall-cmd --permanent <other options>
```

Without this option, the command modifies runtime mode.

To change settings in both modes, you can use two methods:

1. Change runtime settings and then make them permanent as follows:

   ```sh
   # firewall-cmd <other options>
   # firewall-cmd --runtime-to-permanent
   ```

2. Set permanent settings and reload the settings into runtime mode:

   ```sh
   # firewall-cmd --permanent <other options>
   # firewall-cmd --reload
   ```

The first method allows you to test the settings before you apply them to the permanent mode.

**NOTE**

It is possible, especially on remote systems, that an incorrect setting results in a user locking themselves out of a machine. To prevent such situations, use the `--timeout` option. After a specified amount of time, any change reverts to its previous state. Using this options excludes the `--permanent` option.

For example, to add the `SSH` service for 15 minutes:

```sh
# firewall-cmd --add-service=ssh --timeout 15m
```

### 32.8. VERIFYING THE PERMANENT FIREWALLD CONFIGURATION

In certain situations, for example after manually editing `firewalld` configuration files, administrators want to verify that the changes are correct. This section describes how to verify the permanent configuration of the `firewalld` service.

**Prerequisites**

- The `firewalld` service is running.

**Procedure**

1. Verify the permanent configuration of the `firewalld` service:

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

   If the permanent configuration is valid, the command returns `success`. In other cases, the command returns an error with further details, such as the following:
### 32.9. CONTROLLING NETWORK TRAFFIC USING FIREWALLD

#### 32.9.1. Disabling all traffic in case of emergency using CLI

In an emergency situation, such as a system attack, it is possible to disable all network traffic and cut off the attacker.

**Procedure**

1. To immediately disable networking traffic, switch panic mode on:

   ```bash
   # firewall-cmd --panic-on
   ```

   **IMPORTANT**

   Enabling panic mode stops all networking traffic. From this reason, it should be used only when you have the physical access to the machine or if you are logged in using a serial console.

   Switching off panic mode reverts the firewall to its permanent settings. To switch panic mode off:

   ```bash
   # firewall-cmd --panic-off
   ```

   To see whether panic mode is switched on or off, use:

   ```bash
   # firewall-cmd --query-panic
   ```

#### 32.9.2. Controlling traffic with predefined services using CLI

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

**Procedure**

1. Check that the service is not already allowed:

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

2. List all predefined services:

   ```bash
   # 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 ...  
   [trimmed for clarity]
   ```

3. Add the service to the allowed services:
# firewall-cmd --add-service=<service-name>

4. Make the new settings persistent:

# firewall-cmd --runtime-to-permanent

### 32.9.3. Controlling traffic with predefined services using GUI

To enable or disable a predefined or custom service:

1. Start the `firewall-config` tool and select the network zone whose services are to be configured.

2. Select the **Services** tab.

3. Select the check box for each type of service you want to trust or clear the check box to block a service.

To edit a service:

1. Start the `firewall-config` tool.

2. Select **Permanent** from the menu labeled **Configuration**. Additional icons and menu buttons appear at the bottom of the **Services** window.

3. Select the service you want to configure.

The **Ports**, **Protocols**, and **Source Port** tabs enable adding, changing, and removing of ports, protocols, and source port for the selected service. The modules tab is for configuring **Netfilter** helper modules. The **Destination** tab enables limiting traffic to a particular destination address and Internet Protocol (IPv4 or IPv6).

**NOTE**

It is not possible to alter service settings in **Runtime** mode.

### 32.9.4. Adding new services

Services can be added and removed using the graphical `firewall-config` tool, `firewall-cmd`, and `firewall-offline-cmd`. Alternatively, you can edit the XML files in `/etc/firewalld/services/`. If a service is not added or changed by the user, then no corresponding XML file are found in `/etc/firewalld/services/`. The files `/usr/lib/firewalld/services/` can be used as templates if you want to add or change a service.

**NOTE**

Service names must be alphanumeric and can, additionally, include only _ (underscore) and - (dash) characters.

**Procedure**

To add a new service in a terminal, use `firewall-cmd`, or `firewall-offline-cmd` in case of not active `firewalld`.

1. Enter the following command to add a new and empty service:
$ firewall-cmd --new-service=service-name --permanent

2. To add a new service using a local file, use the following command:

    $ firewall-cmd --new-service-from-file=service-name.xml --permanent

You can change the service name with the additional --name=service-name option.

3. As soon as service settings are changed, an updated copy of the service is placed into 
   /etc/firewalld/services/.
   
   As root, you can enter the following command to copy a service manually:

   # cp /usr/lib/firewalld/services/service-name.xml /etc/firewalld/services/service-name.xml

firewalld loads files from /usr/lib/firewalld/services in the first place. If files are placed in
/etc/firewalld/services and they are valid, then these will override the matching files from
/usr/lib/firewalld/services. The overridden files in /usr/lib/firewalld/services are used as soon as the
matching files in /etc/firewalld/services have been removed or if firewalld has been asked to load the
defaults of the services. This applies to the permanent environment only. A reload is needed to get
these fallbacks also in the runtime environment.

32.9.5. Controlling ports using CLI

Ports are logical devices that enable an operating system to receive and distinguish network traffic and
forward it accordingly to system services. These are usually represented by a daemon that listens on the
port, that is it waits for any traffic coming to this port.

Normally, system services listen on standard ports that are reserved for them. The httpd daemon, for
example, listens on port 80. However, system administrators by default configure daemons to listen on
different ports to enhance security or for other reasons.

32.9.5.1. Opening a port

Through open ports, the system is accessible from the outside, which represents a security risk.
Generally, keep ports closed and only open them if they are required for certain services.

Procedure

To get a list of open ports in the current zone:

1. List all allowed ports:

   # firewall-cmd --list-ports

2. Add a port to the allowed ports to open it for incoming traffic:

   # firewall-cmd --add-port=port-number/port-type

3. Make the new settings persistent:

   # firewall-cmd --runtime-to-permanent
The port types are either tcp, udp, sctp, or dccp. The type must match the type of network communication.

32.9.5.2. Closing a port

When an open port is no longer needed, close that port in firewalld. It is highly recommended to close all unnecessary ports as soon as they are not used because leaving a port open represents a security risk.

Procedure

To close a port, remove it from the list of allowed ports:

1. List all allowed ports:
   
   ```
   # firewall-cmd --list-ports
   [WARNING]
   ====
   This command will only give you a list of ports that have been opened as ports. You will not be able to see any open ports that have been opened as a service. Therefore, you should consider using the --list-all option instead of --list-ports.
   ====
   ```

2. Remove the port from the allowed ports to close it for the incoming traffic:

   ```
   # firewall-cmd --remove-port=port-number/port-type
   ```

3. Make the new settings persistent:

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

32.9.6. Opening ports using GUI

To permit traffic through the firewall to a certain port:

1. Start the firewall-config tool and select the network zone whose settings you want to change.

2. Select the Ports tab and click the Add button on the right-hand side. The Port and Protocol window opens.

3. Enter the port number or range of ports to permit.

4. Select tcp or udp from the list.

32.9.7. Controlling traffic with protocols using GUI

To permit traffic through the firewall using a certain protocol:

1. Start the firewall-config tool and select the network zone whose settings you want to change.

2. Select the Protocols tab and click the Add button on the right-hand side. The Protocol window opens.

3. Either select a protocol from the list or select the Other Protocol check box and enter the protocol in the field.
32.9.8. Opening source ports using GUI

To permit traffic through the firewall from a certain port:

1. Start the firewall-config tool and select the network zone whose settings you want to change.

2. Select the Source Port tab and click the Add button on the right-hand side. The Source Port window opens.

3. Enter the port number or range of ports to permit. Select tcp or udp from the list.

32.10. 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.

32.10.1. Listing zones

Procedure

1. To see which zones are available on your system:

   # firewall-cmd --get-zones

   The firewall-cmd --get-zones command displays all zones that are available on the system, but it does not show any details for particular zones.

2. To see detailed information for all zones:

   # firewall-cmd --list-all-zones

3. To see detailed information for a specific zone:

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

32.10.2. Modifying firewalld settings for a certain zone

The Section 32.9.2, “Controlling traffic with predefined services using CLI” and Section 32.9.5, “Controlling ports using CLI” explain how to add services or modify ports in the scope of the current working zone. Sometimes, it is required to set up rules in a different zone.

Procedure

1. To work in a different zone, use the --zone=zone-name option. For example, to allow the SSH service in the zone public:

   # firewall-cmd --add-service=ssh --zone=public

32.10.3. Changing the default zone

System administrators assign a zone to a networking interface in its configuration files. If an interface is
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.

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.

32.10.4. Assigning a network interface to a zone

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

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>
   ```

   **NOTE**

   You do not have to use the `--permanent` option to make the setting persistent across restarts. If you set a new default zone, the setting becomes permanent.

32.10.5. Assigning a default zone to a network connection

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

Procedure
1. To set a default zone for an Internet connection, use either the NetworkManager GUI or edit the `/etc/sysconfig/network-scripts/ifcfg-connection-name` file and add a line that assigns a zone to this connection:

   ```
   ZONE=zone-name
   ```

32.10.6. Creating a new zone

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

Procedure

To create a new zone:

1. Create a new zone:

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

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

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

3. Make the new settings persistent:

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

32.10.7. Zone configuration files

Zones can also be created using a zone configuration file. This approach can be helpful when you need to create a new zone, but want to reuse the settings from a different zone and only alter them a little.

A firewalld zone configuration file contains the information for a zone. These are the zone description, services, ports, protocols, icmp-blocks, masquerade, forward-ports and rich language rules in an XML file format. The file name has to be `zone-name.xml` where the length of `zone-name` is currently limited to 17 chars. The zone configuration files are located in the `/usr/lib/firewalld/zones/` and `/etc/firewalld/zones/` directories.

The following example shows a configuration that allows one service (SSH) and one port range, for both the TCP and UDP protocols:

```xml
<?xml version="1.0" encoding="utf-8"?>
<zone>
  <short>My zone</short>
  <description>Here you can describe the characteristic features of the zone.</description>
  <service name="ssh"/>
  <port protocol="tcp" port="1025-65535"/>
  <port protocol="udp" port="1025-65535"/>
</zone>
```

To change settings for that zone, add or remove sections to add ports, forward ports, services, and so on.

Additional resources
32.10.8. Using zone targets to set default behavior for incoming traffic

For every zone, you can set a default behavior that handles incoming traffic that is not further specified. Such behaviour is defined by setting the target of the zone. There are three options - *default*, *ACCEPT*, *REJECT*, and *DROP*. By setting the target to *ACCEPT*, you accept all incoming packets except those disabled by a specific rule. If you set the target to *REJECT* or *DROP*, you disable all incoming packets except those that you have allowed in specific rules. When packets are rejected, the source machine is informed about the rejection, while there is no information sent when the packets are dropped.

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 --zone=zone-name --set-target=<default|ACCEPT|REJECT|DROP>
   ```

32.11. USING ZONES TO MANAGE INCOMING TRAFFIC DEPENDING ON A SOURCE

32.11.1. Using zones to manage incoming traffic depending on a source

You can use zones to manage incoming traffic based on its source. That enables you to sort incoming traffic and route it through different zones to allow or disallow services that can be reached by that traffic.

If you add a source to a zone, the zone becomes active and any incoming traffic from that source will be directed through it. You can specify different settings for each zone, which is applied to the traffic from the given sources accordingly. You can use more zones even if you only have one network interface.

32.11.2. Adding a source

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

- 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:
1. List all available zones:
   
   ```bash
   # firewall-cmd --get-zones
   ```

2. Add the source IP to the trusted zone in the permanent mode:
   
   ```bash
   # firewall-cmd --zone=trusted --add-source=192.168.2.15
   ```

3. Make the new settings persistent:
   
   ```bash
   # firewall-cmd --runtime-to-permanent
   ```

### 32.11.3. Removing a source

Removing a source from the zone cuts off the traffic coming from it.

**Procedure**

1. List allowed sources for the required zone:
   
   ```bash
   # firewall-cmd --zone=zone-name --list-sources
   ```

2. Remove the source from the zone permanently:
   
   ```bash
   # firewall-cmd --zone=zone-name --remove-source=<source>
   ```

3. Make the new settings persistent:
   
   ```bash
   # firewall-cmd --runtime-to-permanent
   ```

### 32.11.4. Adding a source port

To enable sorting the traffic based on a port of origin, specify a source port using the `--add-source-port` option. You can also combine this with the `--add-source` option to limit the traffic to a certain IP address or IP range.

**Procedure**

1. To add a source port:
   
   ```bash
   # firewall-cmd --zone=zone-name --add-source-port=<port-name>/<tcp|udp|sctp|dccp>
   ```

### 32.11.5. Removing a source port

By removing a source port you disable sorting the traffic based on a port of origin.

**Procedure**

1. To remove a source port:
   
   ```bash
   # firewall-cmd --zone=zone-name --remove-source-port=<port-name>/<tcp|udp|sctp|dccp>
   ```
32.11.6. Using zones and sources to allow a service for only a specific domain

To allow traffic from a specific network to use a service on a machine, use zones and source. The following procedure allows traffic from 192.168.1.0/24 to be able to reach the HTTP service while any other traffic is blocked.

Procedure

1. List all available zones:
   ```bash
   # firewall-cmd --get-zones
   block dmz drop external home internal public trusted work
   ```

2. Add the source to the trusted zone to route the traffic originating from the source through the zone:
   ```bash
   # firewall-cmd --zone=trusted --add-source=192.168.1.0/24
   ```

3. Add the `http` service in the trusted zone:
   ```bash
   # firewall-cmd --zone=trusted --add-service=http
   ```

4. Make the new settings persistent:
   ```bash
   # firewall-cmd --runtime-to-permanent
   ```

5. Check that the trusted zone is active and that the service is allowed in it:
   ```bash
   # firewall-cmd --zone=trusted --list-all
   trusted (active)
   target: ACCEPT
   sources: 192.168.1.0/24
   services: http
   ```

32.11.7. Configuring traffic accepted by a zone based on a protocol

You can allow incoming traffic to be accepted by a zone based on a protocol. All traffic using the specified protocol is accepted by a zone, in which you can apply further rules and filtering.

32.11.7.1. Adding a protocol to a zone

By adding a protocol to a certain zone, you allow all traffic with this protocol to be accepted by this zone.

Procedure

1. To add a protocol to a zone:
   ```bash
   # firewall-cmd --zone=zone-name --add-protocol=port-name/tcp|udp|sctp|dccp|igmp
   ```

**NOTE**

To receive multicast traffic, use the `igmp` value with the `--add-protocol` option.
32.11.7.2. Removing a protocol from a zone

By removing a protocol from a certain zone, you stop accepting all traffic based on this protocol by the zone.

Procedure

1. To remove a protocol from a zone:

   # firewall-cmd --zone=zone-name --remove-protocol=port-name/tcp|udp|sctp|dccp|igmp

32.12. CONFIGURING IP ADDRESS MASQUERADING

The following procedure describes how to 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, repeat the command adding the --permanent option.

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

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

32.13. PORT FORWARDING

Redirecting ports using this method only works for IPv4-based traffic. For IPv6 redirecting setup, you must use rich rules.

To redirect to an external system, it is necessary to enable masquerading. For more information, see Configuring IP address masquerading.

32.13.1. Adding a port to redirect

Using firewalld, you can set up ports redirection so that any incoming traffic that reaches a certain port on your system is delivered to another internal port of your choice or to an external port on another machine.

Prerequisites
Before you redirect traffic from one port to another port, or another address, you have to know three things: which port the packets arrive at, what protocol is used, and where you want to redirect them.

**Procedure**

To redirect a port to another port:

```bash
# firewall-cmd --add-forward-port=port=port-number:proto=tcp|udp|sctp|dccp:toport=port-number
```

To redirect a port to another port at a different IP address:

1. Add the port to be forwarded:

```bash
# firewall-cmd --add-forward-port=port=port-number:proto=tcp|udp:toport=port-number:toaddr=IP/mask
```

2. Enable masquerade:

```bash
# firewall-cmd --add-masquerade
```

### 32.13.2. Redirecting TCP port 80 to port 88 on the same machine

Follow the steps to redirect the TCP port 80 to port 88.

**Procedure**

1. Redirect the port 80 to port 88 for TCP traffic:

```bash
# firewall-cmd --add-forward-port=port=80:proto=tcp:toport=88
```

2. Make the new settings persistent:

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

3. Check that the port is redirected:

```bash
# firewall-cmd --list-all
```

### 32.13.3. Removing a redirected port

To remove a redirected port:

```bash
~]# firewall-cmd --remove-forward-port=port=port-number:proto=<tcp|udp>:toport=port-number:toaddr=<IP/mask>
```

To remove a forwarded port redirected to a different address, use the following procedure.

**Procedure**

1. Remove the forwarded port:
2. Disable masquerade:

```
~]# firewall-cmd --remove-masquerade
```

### 32.13.4. Removing TCP port 80 forwarded to port 88 on the same machine

To remove the port redirection:

**Procedure**

1. List redirected ports:

```
~]# firewall-cmd --list-forward-ports
```

2. Remove the redirected port from the firewall:

```
~]# firewall-cmd --remove-forward-port=port=80:proto=tcp:toport=88:toaddr=
```

3. Make the new settings persistent:

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

### 32.14. MANAGING ICMP REQUESTS

The Internet Control Message Protocol (ICMP) is a supporting protocol that is used by various network devices to send error messages and operational information indicating a connection problem, for example, that a requested service is not available. ICMP differs from transport protocols such as TCP and UDP because it is not used to exchange data between systems.

Unfortunately, it is possible to use the ICMP messages, especially **echo-request** and **echo-reply**, to reveal information about your network and misuse such information for various kinds of fraudulent activities. Therefore, firewalld enables blocking the ICMP requests to protect your network information.

#### 32.14.1. Listing and blocking ICMP requests

**Listing ICMP requests**

The ICMP requests are described in individual XML files that are located in the `/usr/lib/firewalld/icmptypes/` directory. You can read these files to see a description of the request. The firewall-cmd command controls the ICMP requests manipulation.

- To list all available ICMP types:

```
# firewall-cmd --get-icmptypes
```

- The ICMP request can be used by IPv4, IPv6, or by both protocols. To see for which protocol the ICMP request is used:
The status of an ICMP request shows **yes** if the request is currently blocked or **no** if it is not. To see if an ICMP request is currently blocked:

```bash
# firewall-cmd --query-icmp-block=<icmptype>
```

### Blocking or unblocking ICMP requests

When your server blocks ICMP requests, it does not provide the information that it normally would. However, that does not mean that no information is given at all. The clients receive information that the particular ICMP request is being blocked (rejected). Blocking the ICMP requests should be considered carefully, because it can cause communication problems, especially with IPv6 traffic.

- To see if an ICMP request is currently blocked:
  ```bash
  # firewall-cmd --query-icmp-block=<icmptype>
  ```

- To block an ICMP request:
  ```bash
  # firewall-cmd --add-icmp-block=<icmptype>
  ```

- To remove the block for an ICMP request:
  ```bash
  # firewall-cmd --remove-icmp-block=<icmptype>
  ```

### Blocking ICMP requests without providing any information at all

Normally, if you block ICMP requests, clients know that you are blocking it. So, a potential attacker who is sniffing for live IP addresses is still able to see that your IP address is online. To hide this information completely, you have to drop all ICMP requests.

- To block and drop all ICMP requests:
  1. Set the target of your zone to **DROP**:
     ```bash
     # firewall-cmd --set-target=DROP
     ```
  2. Make the new settings persistent:
     ```bash
     # firewall-cmd --runtime-to-permanent
     ```

Now, all traffic, including ICMP requests, is dropped, except traffic which you have explicitly allowed.

- To block and drop certain ICMP requests and allow others:
  1. Set the target of your zone to **DROP**:
     ```bash
     # firewall-cmd --set-target=DROP
     ```
  2. Add the ICMP block inversion to block all ICMP requests at once:
     ```bash
     # firewall-cmd --add-icmp-block-inversion
     ```
3. Add the ICMP block for those ICMP requests that you want to allow:

   # firewall-cmd --add-icmp-block=<icmptype>

4. Make the new settings persistent:

   # firewall-cmd --runtime-to-permanent

The block inversion inverts the setting of the ICMP requests blocks, so all requests, that were not previously blocked, are blocked. Those that were blocked are not blocked. Which means that if you need to unblock a request, you must use the blocking command.

- To revert the block inversion to a fully permissive setting:

  1. Set the target of your zone to default or ACCEPT:

     # firewall-cmd --set-target=default

  2. Remove all added blocks for ICMP requests:

     # firewall-cmd --remove-icmp-block=<icmptype>

  3. Remove the ICMP block inversion:

     # firewall-cmd --remove-icmp-block-inversion

  4. Make the new settings persistent:

     # firewall-cmd --runtime-to-permanent

32.14.2. Configuring the ICMP filter using GUI

- To enable or disable an ICMP filter, start the firewall-config tool and select the network zone whose messages are to be filtered. Select the ICMP Filter tab and select the check box for each type of ICMP message you want to filter. Clear the check box to disable a filter. This setting is per direction and the default allows everything.

- To edit an ICMP type, start the firewall-config tool and select Permanent mode from the menu labeled Configuration. Additional icons appear at the bottom of the Services window. Select Yes in the following dialog to enable masquerading and to make forwarding to another machine working.

- To enable inverting the ICMP Filter, click the Invert Filter check box on the right. Only marked ICMP types are now accepted, all other are rejected. In a zone using the DROP target, they are dropped.

32.15. SETTING AND CONTROLLING IP SETS USING FIREWALLD

To see the list of IP set types supported by firewalld, enter the following command as root.
# Configuring IP set options using CLI

IP sets can be used in `firewalld` zones as sources and also as sources in rich rules. In Red Hat Enterprise Linux, the preferred method is to use the IP sets created with `firewalld` in a direct rule.

- To list the IP sets known to `firewalld` in the permanent environment, use the following command as **root**:

  ```bash
  # firewall-cmd --permanent --get-ipsets
  ```

- To add a new IP set, use the following command using the permanent environment as **root**:

  ```bash
  # firewall-cmd --permanent --new-ipset=test --type=hash:net
  success
  ```

  The previous command creates a new IP set with the name `test` and the `hash:net` type for IPv4. To create an IP set for use with IPv6, add the `--option=family=inet6` option. To make the new setting effective in the runtime environment, reload `firewalld`.

- List the new IP set with the following command as **root**:

  ```bash
  # firewall-cmd --permanent --get-ipsets
  test
  ```

- To get more information about the IP set, use the following command as **root**:

  ```bash
  # firewall-cmd --permanent --info-ipset=test
  test
type: hash:net
options:
entries:
  ```

  Note that the IP set does not have any entries at the moment.

- To add an entry to the `test` IP set, use the following command as **root**:

  ```bash
  # firewall-cmd --permanent --ipset=test --add-entry=192.168.0.1
  success
  ```

  The previous command adds the IP address `192.168.0.1` to the IP set.

- To get the list of current entries in the IP set, use the following command as **root**:

  ```bash
  # firewall-cmd --permanent --ipset=test --get-entries
  192.168.0.1
  ```

- Generate a file containing a list of IP addresses, for example:

  ```bash
  # cat > iplist.txt <<EOL
  ```
The file with the list of IP addresses for an IP set should contain an entry per line. Lines starting with a hash, a semi-colon, or empty lines are ignored.

- To add the addresses from the `iplist.txt` file, use the following command as `root`:

  ```shell
  # firewall-cmd --permanent --ipset=test --add-entries-from-file=iplist.txt
  success
  ```

- To see the extended entries list of the IP set, use the following command as `root`:

  ```shell
  # firewall-cmd --permanent --ipset=test --get-entries
  192.168.0.1
  192.168.0.2
  192.168.0.3
  192.168.1.0/24
  192.168.2.254
  ```

- To remove the addresses from the IP set and to check the updated entries list, use the following commands as `root`:

  ```shell
  # firewall-cmd --permanent --ipset=test --remove-entries-from-file=iplist.txt
  success
  # firewall-cmd --permanent --ipset=test --get-entries
  192.168.0.1
  ```

- You can add the IP set as a source to a zone to handle all traffic coming in from any of the addresses listed in the IP set with a zone. For example, to add the `test` IP set as a source to the `drop` zone to drop all packets coming from all entries listed in the `test` IP set, use the following command as `root`:

  ```shell
  # firewall-cmd --permanent --zone=drop --add-source=ipset:test
  success
  ```

  The `ipset:` prefix in the source shows `firewalld` that the source is an IP set and not an IP address or an address range.

Only the creation and removal of IP sets is limited to the permanent environment, all other IP set options can be used also in the runtime environment without the `--permanent` option.
32.16. PRIORITIZING RICH RULES

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.

32.16.1. How the priority parameter organizes rules into different chains

You can set the `priority` parameter in a rich rule to any number between -32768 and 32767, and lower 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.

32.16.2. Setting the priority of a rich rule

The procedure describes 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

1. 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.

2. Optionally, display the `nftables` rule that the command in the previous step created:

   ```
   # nft list chain inet firewalld filter_IN_public_post
   table inet firewalld {
   ```
32.17. CONFIGURING FIREWALL LOCKDOWN

Local applications or services are able to change the firewall configuration if they are running as root (for example, libvirt). With this feature, the administrator can lock the firewall configuration so that either no applications or only applications that are added to the lockdown whitelist are able to request firewall changes. The lockdown settings default to disabled. If enabled, the user can be sure that there are no unwanted configuration changes made to the firewall by local applications or services.

32.17.1. Configuring lockdown with using CLI

- To query whether lockdown is enabled, use the following command as root:
  
  ```
  # firewall-cmd --query-lockdown
  ```

  The command prints yes with exit status 0 if lockdown is enabled. It prints no with exit status 1 otherwise.

- To enable lockdown, enter the following command as root:
  
  ```
  # firewall-cmd --lockdown-on
  ```

- To disable lockdown, use the following command as root:
  
  ```
  # firewall-cmd --lockdown-off
  ```

32.17.2. Configuring lockdown whitelist options using CLI

The lockdown whitelist can contain commands, security contexts, users and user IDs. If a command entry on the whitelist ends with an asterisk "*", then all command lines starting with that command will match. If the "*" is not there then the absolute command including arguments must match.

- The context is the security (SELinux) context of a running application or service. To get the context of a running application use the following command:
  
  ```
  $ ps -e --context
  ```

  That command returns all running applications. Pipe the output through the grep tool to get the application of interest. For example:

  ```
  $ ps -e --context | grep example_program
  ```

- To list all command lines that are on the whitelist, enter the following command as root:
  
  ```
  # firewall-cmd --list-lockdown-whitelist-commands
  ```

- To add a command command to the whitelist, enter the following command as root:
# firewall-cmd --add-lockdown-whitelist-command='/usr/bin/python3 -Es /usr/bin/command'

- To remove a command command from the whitelist, enter the following command as root:

  # firewall-cmd --remove-lockdown-whitelist-command='/usr/bin/python3 -Es /usr/bin/command'

- To query whether the command command is on the whitelist, enter the following command as root:

  # firewall-cmd --query-lockdown-whitelist-command='/usr/bin/python3 -Es /usr/bin/command'

  The command prints yes with exit status 0 if true. It prints no with exit status 1 otherwise.

- To list all security contexts that are on the whitelist, enter the following command as root:

  # firewall-cmd --list-lockdown-whitelist-contexts

- To add a context context to the whitelist, enter the following command as root:

  # firewall-cmd --add-lockdown-whitelist-context=context

- To remove a context context from the whitelist, enter the following command as root:

  # firewall-cmd --remove-lockdown-whitelist-context=context

- To query whether the context context is on the whitelist, enter the following command as root:

  # firewall-cmd --query-lockdown-whitelist-context=context

  Prints yes with exit status 0, if true, prints no with exit status 1 otherwise.

- To list all user IDs that are on the whitelist, enter the following command as root:

  # firewall-cmd --list-lockdown-whitelist-uids

- To add a user ID uid to the whitelist, enter the following command as root:

  # firewall-cmd --add-lockdown-whitelist-uid=uid

- To remove a user ID uid from the whitelist, enter the following command as root:

  # firewall-cmd --remove-lockdown-whitelist-uid=uid

- To query whether the user ID uid is on the whitelist, enter the following command:

  $ firewall-cmd --query-lockdown-whitelist-uid=uid

  Prints yes with exit status 0, if true, prints no with exit status 1 otherwise.

- To list all user names that are on the whitelist, enter the following command as root:
To add a user name `user` to the whitelist, enter the following command as `root`:

```
# firewall-cmd --add-lockdown-whitelist-user=user
```

To remove a user name `user` from the whitelist, enter the following command as `root`:

```
# firewall-cmd --remove-lockdown-whitelist-user=user
```

To query whether the user name `user` is on the whitelist, enter the following command:

```
$ firewall-cmd --query-lockdown-whitelist-user=user
```

Prints `yes` with exit status 0, if true, prints `no` with exit status 1 otherwise.

### 32.17.3. Configuring lockdown whitelist options using configuration files

The default whitelist configuration file contains the `NetworkManager` context and the default context of `libvirt`. The user ID 0 is also on the list.

```xml
<?xml version="1.0" encoding="utf-8"?>
<whitelist>
  <selinux context="system_u:system_r:NetworkManager_t:s0"/>
  <selinux context="system_u:system_r:virtd_t:s0-s0:c0.c1023"/>
  <user id="0"/>
</whitelist>
```

Following is an example whitelist configuration file enabling all commands for the `firewall-cmd` utility, for a user called `user` whose user ID is 815:

```xml
<?xml version="1.0" encoding="utf-8"?>
<whitelist>
  <command name="/usr/libexec/platform-python -s /bin/firewall-cmd"/>
  <selinux context="system_u:system_r:NetworkManager_t:s0"/>
  <user id="815"/>
  <user name="user"/>
</whitelist>
```

This example shows both `user id` and `user name`, but only one option is required. Python is the interpreter and is prepended to the command line. You can also use a specific command, for example:

```
/usr/bin/python3 /bin/firewall-cmd --lockdown-on
```

In that example, only the `--lockdown-on` command is allowed.

In Red Hat Enterprise Linux, all utilities are placed in the `/usr/bin/` directory and the `/bin/` directory is sym-linked to the `/usr/bin/` directory. In other words, although the path for `firewall-cmd` when entered as `root` might resolve to `/bin/firewall-cmd`, `/usr/bin/firewall-cmd` can now be used. All new scripts should use the new location. But be aware that if scripts that run as `root` are written to use the `/bin/firewall-cmd` path, then that command path must be whitelisted in addition to the `/usr/bin/firewall-cmd` path traditionally used only for non- `root` users.
The * at the end of the name attribute of a command means that all commands that start with this string match. If the * is not there then the absolute command including arguments must match.

### 32.18. LOG FOR DENIED PACKETS

With the **LogDenied** option in the **firewalld**, it is possible to add a simple logging mechanism for denied packets. These are the packets that are rejected or dropped. To change the setting of the logging, edit the `/etc/firewalld/firewalld.conf` file or use the command-line or GUI configuration tool.

If **LogDenied** is enabled, logging rules are added right before the reject and drop rules in the INPUT, FORWARD and OUTPUT chains for the default rules and also the final reject and drop rules in zones. The possible values for this setting are: **all**, **unicast**, **broadcast**, **multicast**, and **off**. The default setting is **off**. With the **unicast**, **broadcast**, and **multicast** setting, the **pkttype** match is used to match the link-layer packet type. With **all**, all packets are logged.

To list the actual **LogDenied** setting with firewall-cmd, use the following command as **root**:

```bash
# firewall-cmd --get-log-denied
off
```

To change the **LogDenied** setting, use the following command as **root**:

```bash
# firewall-cmd --set-log-denied=all
success
```

To change the **LogDenied** setting with the **firewalld** GUI configuration tool, start **firewall-config**, click the **Options** menu and select **Change Log Denied**. The **LogDenied** window appears. Select the new **LogDenied** setting from the menu and click OK.

### 32.19. RELATED INFORMATION

The following sources of information provide additional resources regarding **firewalld**.

**Installed documentation**

- **firewalld(1)** man page — describes command options for **firewalld**.
- **firewalld.conf(5)** man page — contains information to configure **firewalld**.
- **firewall-cmd(1)** man page — describes command options for the **firewalld** command-line client.
- **firewall-config(1)** man page — describes settings for the **firewall-config** tool.
- **firewall-offline-cmd(1)** man page — describes command options for the **firewalld** offline command-line client.
- **firewalld.icmptype(5)** man page — describes XML configuration files for **ICMP** filtering.
- **firewalld.ipset(5)** man page — describes XML configuration files for the **firewalld** IP sets.
- **firewalld.service(5)** man page — describes XML configuration files for **firewalld** service.
- **firewalld.zone(5)** man page — describes XML configuration files for **firewalld** zone configuration.
• `firewalld.direct(5)` man page – describes the `firewalld` direct interface configuration file.

• `firewalld.lockdown-whitelist(5)` man page – describes the `firewalld` lockdown whitelist configuration file.

• `firewalld.richlanguage(5)` man page – describes the `firewalld` rich language rule syntax.

• `firewalld.zones(5)` man page – general description of what zones are and how to configure them.

• `firewalld.dbus(5)` man page – describes the D-Bus interface of `firewalld`.

Online documentation

CHAPTER 33. GETTING STARTED WITH NFTABLES

The **nftables** framework enables administrators to configure packet-filtering rules used by the Linux kernel firewall.

### 33.1. INTRODUCTION TO NFTABLES

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

- lookup tables instead of linear processing
- a single framework for both the **IPv4** and **IPv6** protocols
- rules all 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

Similarly to **iptables**, **nftables** use tables for storing chains. The chains contain individual rules for performing actions. The **nft** tool replaces all tools from the previous packet-filtering frameworks. The **libnftnl** library can be used for low-level interaction with **nftables** Netlink API over the **libmnl** library.

Effect of the modules on the **nftables** rules set can be observed using the **nft** list rule set command. Since these tools 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 formerly separate legacy commands.

**Additional resources**

- The **nft**(8) man page provides a comprehensive reference documentation for configuring and inspecting packet filtering with nftables using the **nft** command-line tool.

### 33.2. 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 to configure a firewall on workstations. The utility is easy to use and covers the typical use cases for this scenario.

- **nftables**: Use the **nftables** utility to set up complex firewalls, such as for a whole network.

- **iptables**: The **iptables** utility is deprecated in Red Hat Enterprise Linux 8. Use instead **nftables**.

**IMPORTANT**

To avoid that the different firewall services influence each other, run only one of them on a RHEL host, and disable the other services.
33.3. CONVERTING IPTABLES RULES TO NFTABLES RULES

Red Hat Enterprise Linux 8 provides the `iptables-translate` and `ip6tables-translate` tools to convert existing `iptables` or `ip6tables` rules into the equivalent ones for `nftables`.

Note that some extensions lack translation support. If such an extension exists, the tool prints the untranslated rule prefixed with the `#` sign. For example:

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

Additionally, users can use the `iptables-restore-translate` and `ip6tables-restore-translate` tools to translate a dump of rules. Note that before that, users can use the `iptables-save` or `ip6tables-save` commands to print a dump of current rules. For example:

```plaintext
# iptables-save >/tmp/iptables.dump
# iptables-restore-translate -f /tmp/iptables.dump

# Translated by iptables-restore-translate v1.8.0 on Wed Oct 17 17:00:13 2018
add table ip nat
...```

For more information and a list of possible options and values, enter the `iptables-translate --help` command.

33.4. WRITING AND EXECUTING NFTABLES SCRIPTS

The `nftables` framework provides a native scripting environment that brings a major benefit over using shell scripts to maintain firewall rules: 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, the `nftables` script environment enables administrators to:

- add comments
- define variables
- include other rule set files

This section explains how to use these features, as well as creating and executing `nftables` scripts.

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. You can either extend these files or write your scripts.

33.4.1. The required script header in nftables script

Similar to other scripts, `nftables` scripts require a shebang sequence in the first line of the script that sets the interpreter directive.

An `nftables` script must always start with the following line:

```plaintext
#!/usr/sbin/nft -f
```
33.4.2. Supported nftables script formats

The nftables scripting environment supports scripts in the following formats:

- You can write a script in 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
    }
  }
  ```

- You can use the same syntax for commands as in `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
  ```

33.4.3. Running nftables scripts

To run an nftables script, the script must be executable. Only if the script is included in another script, it does not require to be executable. The procedure describes how to make a script executable and run the script.

**Prerequisites**

- The procedure of this section assumes that you stored an nftables script in the `/etc/nftables/example_firewall.nft` file.
Procedure

1. Steps that are required only once:
   a. Optionally, set the owner of the script to `root`:
      
      ```
      # chown root /etc/nftables/example_firewall.nft
      ```
   
   b. Make the script executable for the owner:
      
      ```
      # chmod u+x /etc/nftables/example_firewall.nft
      ```

2. Run the script:

   ```
   # /etc/nftables/example_firewall.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

- For details about setting the owner of a file, see the `chown(1)` man page.
- For details about setting permissions of a file, see the `chmod(1)` man page.
- Section 33.4.7, “Automatically loading nftables rules when the system boots”

### 33.4.4. Using comments in nftables scripts

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

#### Example 33.1. Comments in an nftables script

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

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

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

### 33.4.5. Using variables in an 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`:

```bash
define INET_DEV = enp1s0
```

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

```bash
... 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:

```bash
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:

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

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

Additional resources
- For details about sets, see Section 33.11, “Using sets in nftables commands”.
- For details about verdict maps, see Section 33.12, “Using verdict maps in nftables commands”.

33.4.6. Including files in an nftables script
The `nftables` scripting environment enables administrators to 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 33.2. Including files from the default search directory
To include a file from the default search directory:

```bash
include "example.nft"
```

Example 33.3. Including all *.nft files from a directory
To include all files ending in `*.nft` that are stored in the `/etc/nftables/rulesets/` directory:

```bash
include "/etc/nftables/rulesets/* .nft"
```
Note that the `include` statement does not match files beginning with a dot.

### Additional resources

- For further details, see the `Include files` section in the `nft(8)` man page.

### 33.4.7. 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. This section explains how to load firewall rules when the system boots.

#### Prerequisites

- The `nftables` scripts are stored in the `/etc/nftables/` directory.

#### Procedure

1. Edit the `/etc/sysconfig/nftables.conf` file.
   
   - If you enhance `*.nft` scripts created in `/etc/nftables/` when you installed the `nftables` package, uncomment the `include` statement for these scripts.
   
   - If you write scripts from scratch, 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. Enable the `nftables` service.
   
   ```
   # systemctl enable nftables
   ```

3. Optionally, start the `nftables` service to load the firewall rules without rebooting the system:
   
   ```
   # systemctl start nftables
   ```

### Additional resources

- Section 33.4.2, “Supported nftables script formats”

### 33.5. DISPLAYING NFTABLES RULE SETS

Rule sets of `nftables` contain tables, chains, and rules. This section explains how to display these rule sets.

#### Procedure

1. To display all rule sets, enter:
   
   ```
   # nft list ruleset
   table inet example_table {
     chain example_chain { type filter hook input priority 0; policy accept;
   ```
By default, `nftables` does not pre-create tables. As a consequence, displaying the rule set on a host without any tables, the `nft list ruleset` command shows no output.

### 33.6. CREATING AN NFTABLES TABLE

A table in `nftables` is a name space that contains a collection of chains, rules, sets, and other objects. This section explains how to create a table.

Each table must have an address family defined. The address family of a table defines what address types the 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**: MatchesIPv4 address resolution protocol (ARP) packets.
- **bridge**: Matches packets that traverse a bridge device.
- **netdev**: Matches packets from ingress.

**Procedure**

1. Use the `nft add table` command to create a new table. For example, to create a table named `example_table` that processes IPv4 and IPv6 packets:

   ```
   # nft add table inet example_table
   ```

2. Optionally, list all tables in the rule set:

   ```
   # nft list tables
table inet example_table
   ```

**Additional resources**

- For further details about address families, see the `Address families` section in the `nft(8)` man page.

- For details on other actions you can run on tables, see the `Tables` section in the `nft(8)` man page.

### 33.7. CREATING AN NFTABLES CHAIN

Chains 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 and to better organize rules.

The procedure describes how to add a base chain to an existing table.

Prerequisites

• The table to which you want to add the new chain exists.

Procedure

1. Use the `nft add chain` command to create a new chain. For example, to create a chain named `example_chain` in `example_table`:

   ```
   # nft add chain inet example_table example_chain { type filter hook input priority 0; policy accept; }
   ```

   **IMPORTANT**

   To avoid that the shell interprets the semicolons as the end of the command, you must escape the semicolons with a backslash.

   This chain filters incoming packets. The `priority` parameter specifies the order in which nftables processes chains with the same hook value. A lower priority value has precedence over higher ones. The `policy` parameter sets the default action for rules in this chain. Note that if you are logged in to the server remotely and you set the default policy to `drop`, you are disconnected immediately if no other rule allows the remote access.

2. Optionally, display all chains:

   ```
   # nft list chains
   table inet example_table {
   chain example_chain {
   type filter hook input priority 0; policy accept;
   }
   }
   ```

Additional resources

• For further details about address families, see the Address families section in the `nft(8)` man page.

• For details on other actions you can run on chains, see the Chains section in the `nft(8)` man page.

### 33.8. ADDING A RULE TO AN NFTABLES CHAIN

This section explains how to add a rule to an existing nftables chain. By default, the `nftables add rule` command appends a new rule to the end of the chain.

If you instead want to insert a rule at the beginning of the chain, see Section 33.9, “Inserting a rule into an nftables chain”.
Prerequisites

- The chain to which you want to add the rule exists.

Procedure

1. To add a new rule, use the `nft add rule` command. For example, to add a rule to the `example_chain` in the `example_table` that allows TCP traffic on port 22:

   ```
   # nft add rule inet example_table example_chain tcp dport 22 accept
   ```

   Instead of the port number, you can alternatively specify the name of the service. In the example, you could use `ssh` instead of the port number `22`. Note that a service name is resolved to a port number based on its entry in the `/etc/services` file.

2. Optionally, 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 0; policy accept;
       ...
       tcp dport ssh accept
     }
   }
   ```

Additional resources

- For further details about address families, see the **Address families** section in the `nft(8)` man page.

- For details on other actions you can run on rules, see the **Rules** section in the `nft(8)` man page.

33.9. INSERTING A RULE INTO AN NFTABLES CHAIN

This section explains how to insert a rule at the beginning of an existing `nftables` chain using the `nftables insert rule` command. If you instead want to add a rule to the end of a chain, see Section 33.8, “Adding a rule to an nftables chain”.

Prerequisites

- The chain to which you want to add the rule exists.

Procedure

1. To insert a new rule, use the `nft insert rule` command. For example, to insert a rule to the `example_chain` in the `example_table` that allows TCP traffic on port 22:

   ```
   # nft add rule inet example_table example_chain tcp dport 22 accept
   ```

   You can alternatively specify the name of the service instead of the port number. In the example, you could use `ssh` instead of the port number `22`. Note that a service name is resolved to a port number based on its entry in the `/etc/services` file.
2. Optionally, display all chains and their rules in `example_table`:

```bash
# nft list table inet example_table
table inet example_table {
  chain example_chain {
    type filter hook input priority 0; policy accept;
tcp dport ssh accept
  }
}
```

Additional resources

- For further details about address families, see the `Address families` section in the `nft(8)` man page.
- For details on other actions you can run on rules, see the `Rules` section in the `nft(8)` man page.

### 33.10. CONFIGURING NAT USING NFTABLES

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

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

#### 33.10.1. The different NAT types: masquerading, source NAT, and destination NAT

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 providers do not route reserved IP ranges, such as `10.0.0.0/8`. If you use reserved 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.

Both masquerading and SNAT are very similar. 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 route incoming traffic to a different host. For example, if your web server uses an IP address from a reserved 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.

#### 33.10.2. 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.

The following procedure describes how to replace the source IP of packets leaving the host through the `ens3` interface to the IP set on `ens3`.

**Procedure**

1. Create a table:
   ```bash
   # nft add table nat
   ```
2. Add the **prerouting** and **postrouting** chains to the table:
   ```bash
   # 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 **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 avoid that the shell interprets 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:
   ```bash
   # nft add rule nat postrouting oifname "ens3" masquerade
   ```

### 33.10.3. 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 following procedure describes how to replace the source IP of packets leaving the router through the `ens3` interface to **192.0.2.1**.

**Procedure**

1. Create a table:
   ```bash
   # nft add table nat
   ```
2. Add the **prerouting** and **postrouting** chains to the table:
   ```bash
   # 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 avoid that the shell interprets 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`:

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

Additional resources

- Section 33.13.2, “Forwarding incoming packets on a specific local port to a different host”

### 33.10.4. Configuring destination NAT using nftables

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

The following procedure describes how to redirect incoming traffic sent to port `80` and `443` of the router to the host with the `192.0.2.1` IP address.

**Procedure**

1. Create a table:

   ```bash
   # nft add table nat
   ```

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

   ```bash
   # 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 avoid that the shell interprets the negative priority value as an option of the `nft` command.

3. Add a rule to the `prerouting` chain that redirects incoming traffic on the `ens3` interface sent to port `80` and `443` to the host with the `192.0.2.1` IP:

   ```bash
   # nft add rule nat prerouting ifname 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:

   a. If the `ens3` interface used dynamic IP addresses, add a masquerading rule:
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 ofname "ens3" snat to 198.51.100.1
```

Additional resources

- Section 33.10.1, “The different NAT types: masquerading, source NAT, and destination NAT”

### 33.11. 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.

#### 33.11.1. Using an anonymous sets in nftables

An anonymous set contain comma-separated values enclosed in curly brackets, such as `{22, 80, 443}`, that you use directly in a rule. You can also use anonymous sets also for IP addresses or 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 Section 33.11.2, “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. Optionally, 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 0; policy accept;
    tcp dport { ssh, http, https } accept
  }
}
```

#### 33.11.2. 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` or `2001:db8::1/24`.
- **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:
     ```bash
     # nft add set inet example_table example_set { type ipv4_addr ; }
     ```
   - To create a set that can store IPv4 address ranges:
     ```bash
     # nft add set inet example_table example_set { type ipv4_addr ; flags interval ; }
     ```

   **IMPORTANT**
   To avoid that the shell interprets the semicolons as the end of the command, you must escape the semicolons with a backslash.

2. Optionally, 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.
   ```bash
   # 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:
     ```bash
     # 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:
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.

33.11.3. Related information

- For further details about sets, see the Sets section in the `nft(8)` man page.

### 33.12. 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.

#### 33.12.1. Using literal maps in nftables

A literal 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 a literal map is that if you want to change the map, you must replace the rule. For a dynamic solution, use named verdict maps as described in Section 33.12.2, "Using mutable verdict maps in nftables".

The example describes how to use a literal 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 the `example_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 a literal map to `incoming_traffic`:

```
# nft add rule inet example_table incoming_traffic ip protocol vmap { tcp : jump tcp_packets, udp : jump udp_packets }
```

The literal 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 0; 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.

### 33.12.2. Using mutable verdict maps in nftables

The `nftables` framework supports mutable verdict maps. You can use these maps in multiple rules within a table. Another benefit over literal maps is that you can update a mutable map without replacing the rules that use it.

When you create a mutable verdict 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`.
- `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.

The example describes how to allow or drop incoming packets based on their source IP address. Using a
mutable verdict map, you require only a single rule to configure this scenario while the IP addresses and
actions are dynamically stored in the map. The procedure also describes how to add and remove entries
from 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 avoid that the shell interprets 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. 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. Optionally, 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. Optionally, remove an entry from the map:

   ```
   # nft delete element ip example_table example_map { 192.0.2.1 }
   ```

8. Optionally, 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 0; policy accept;
    ip saddr vmap @example_map
  }
}

33.12.3. Related information

- For further details about verdict maps, see the Maps section in the nft(8) man page.

33.13. CONFIGURING PORT FORWARDING USING NFTABLES

Port forwarding enables administrators to forward packets sent to a specific destination port to a different local or remote port.

For example, if your web server does not have a public IP address, you can set a port forwarding rule on your firewall that forwards incoming packets on port 80 and 443 on the firewall to the web server. With this firewall rule, users on the internet can access the web server using the IP or host name of the firewall.

33.13.1. Forwarding incoming packets to a different local port

This section describes an example of how to forward incoming IPv4 packets on port 8022 to port 22 on the local system.

Procedure

1. Create a table named nat with the ip address family:

   # nft add table ip nat

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

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

   NOTE

   Pass the -- option to the nft command to avoid that the shell interprets the negative priority value as an option of the nft command.

3. Add a rule to the prerouting chain that redirects incoming packets on port 8022 to the local port 22:

   # nft add rule ip nat prerouting tcp dport 8022 redirect to :22

33.13.2. Forwarding incoming packets on a specific local port to a different host
You can use a destination network address translation (DNAT) rule to forward incoming packets on a local port to a remote host. This enables users on the internet to access a service that runs on a host with a private IP address.

The procedure describes how to forward incoming IPv4 packets on the local port 443 to the same port number on the remote system with the 192.0.2.1 IP address.

Prerequisite

- You are logged in as the root user on the system that should forward the packets.

Procedure

1. Create a table named nat with the ip address family:
   
   ```bash
   # nft add table ip nat
   ```

2. Add the prerouting and postrouting chains to the table:
   
   ```bash
   # nft -- add chain ip nat prerouting { type nat hook prerouting priority -100 ; }
   # nft add chain ip nat postrouting { type nat hook postrouting priority 100 ; }
   ```

   **NOTE**
   
   Pass the -- option to the nft command to avoid that the shell interprets the negative priority value as an option of the nft command.

3. Add a rule to the prerouting chain that redirects incoming packets on port 443 to the same port on 192.0.2.1:
   
   ```bash
   # nft add rule ip nat prerouting tcp dport 443 dnat to 192.0.2.1
   ```

4. Add a rule to the postrouting chain to masquerade outgoing traffic:
   
   ```bash
   # nft add rule ip daddr 192.0.2.1 masquerade
   ```

5. Enable packet forwarding:

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

33.14. LIMITING THE NUMBER OF CONNECTIONS USING NFTABLES

The ct count parameter of the nft utility enables administrators to limit the number of connections. The procedure describes a basic example of how to limit incoming connections.

Prerequisites

- The base example_chain in example_table exists.

Procedure
1. Add a rule that allows only two simultaneous connections to the SSH port (22) from an IPv4 address and rejects all further connections from the same IP:

   ```
   # nft add rule ip example_table example_chain tcp dport ssh meter example_meter { ip saddr ct count over 2 } counter reject
   ```

2. Optionally, display the meter created in the previous step:

   ```
   # nft list meter ip example_table example_meter
   table ip example_table {
      meter example_meter {
         type ipv4_addr
         size 65535
         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.

### 33.15. Blocking IP Addresses That Attempt More Than Ten New Incoming TCP Connections Within One Minute

The `nftables` framework enables administrators to dynamically update sets. This section explains how you use this feature to temporarily block hosts that are establishing more than ten IPv4 TCP connections within one minute. After five minutes, `nftables` automatically removes the IP address from the blacklist.

#### 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 set named `blacklist` to the `filter` table:

   ```
   # nft add set ip filter blacklist { type ipv4_addr ; flags dynamic, timeout ; timeout 5m ; }
   ```

   This command creates a dynamic set for IPv4 addresses. The `timeout 5m` parameter defines that `nftables` automatically removes entries after 5 minutes from the set.

4. Add a rule that automatically adds the source IP address of hosts that attempt to establish more than ten new TCP connections within one minute to the `blacklist` set:

   ```
   # nft add rule ip filter input ip protocol tcp ct state new, untracked limit rate over 10/minute add @blacklist { ip saddr }
   ```

5. Add a rule that drops all connections from IP addresses in the `blacklist` set:
33.16. DEBUGGING NFTABLES RULES

The nftables framework provides different options for administrators to debug rules and if packets match them. This section describes these options.

33.16.1. Creating a rule with a counter

To identify if a rule is matched, you can use a counter. This section describes how to create a new rule with a counter.

For a procedure that adds a counter to an existing rule, see Section 33.16.2, “Adding a counter to an existing rule”.

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 0; policy accept;
   tcp dport ssh counter packets 6872 bytes 105448565 accept
   }
   }
   ```

33.16.2. Adding a counter to an existing rule

To identify if a rule is matched, you can use a counter. This section describes how to add a counter to an existing rule.

For a procedure to add a new rule with a counter, see Section 33.16.1, “Creating a rule with a counter”.

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 0; 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 0; policy accept;
       tcp dport ssh counter packets 6872 bytes 105448565 accept
     }
   }
   ```

33.16.3. 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. The procedure describes how to enable tracing for a rule as well as 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 0; 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`:

```bash
# 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.

### 33.17. BACKING UP AND RESTORING NFTABLES RULE SETS

This section describes how to backup `nftables` rules to a file, as well as restoring rules from a file.

Administrators can use a file with the rules to, for example, transfer the rules to a different server.

#### 33.17.1. Backing up nftables rule sets to a file

This section describes how to back up `nftables` rule sets to a file.

**Procedure**

1. To backup `nftables` rules:
   - In `nft list ruleset` format:
     ```bash
     # nft list ruleset > file.nft
     ```
   - In JSON format:
     ```bash
     # nft -j list ruleset > file.json
     ```

#### 33.17.2. Restoring nftables rule sets from a file

This section describes how to restore `nftables` rule sets.

**Procedure**

1. To restore `nftables` rules:
- If the file to restore is in **nft list ruleset** format or contains **nft** commands:
  
  ```
  # nft -f file.nft
  ```

- If the file to restore is in JSON format:

  ```
  # nft -j -f file.json
  ```

### 33.18. RELATED INFORMATION

- The [Using nftables in Red Hat Enterprise Linux 8](#) blog post provides an overview about using **nftables** features.

- The [What comes after iptables? Its successor, of course: nftables](#) article explains why **nftables** replaces **iptables**.

- The [Firewalld: The Future is nftables](#) article provides additional information on **nftables** as a default back end for **firewalld**.
CHAPTER 34. GETTING STARTED WITH DPDK

The Data Plane Development Kit (DPDK) provides libraries and network drivers to accelerate package processing in user space.

Administrators use DPDK, for example, in virtual machines to use Single Root I/O Virtualization (SR-IOV) to reduce latencies and increase I/O throughput.

NOTE

Red Hat does not support experimental DPDK APIs.

34.1. INSTALLING THE DPDK PACKAGE

This section describes how to install the dpdk package.

Prerequisites

- Red Hat Enterprise Linux is installed.
- A valid subscription is assigned to the host.

Procedure

1. Use the yum utility to install the dpdk package:

```
# yum install dpdk
```

34.2. RELATED INFORMATION

- For a list of network adapters that support SR-IOV on Red Hat Enterprise Linux 8, see Network Adapter Fast Datapath Feature Support Matrix.
CHAPTER 35. NETWORK TRACING USING THE BPF COMPILER COLLECTION

This section explains what the BPF Compiler Collection (BCC) is, how you install the BCC, as well as how to perform different network tracing operations using the pre-created scripts provided by the bcc-tools package. All of these scripts support the --ebpf parameter to display the eBPF code the utility uploads to the kernel. You can use the code to learn more about writing eBPF scripts.

35.1. A BRIEF INTRODUCTION TO BCC

BPF Compiler Collection (BCC) is a library, which facilitates the creation of the extended Berkeley Packet Filter (eBPF) programs. The main utility of eBPF programs is analyzing OS performance and network performance without experiencing overhead or security issues.

BCC removes the need for users to know deep technical details of eBPF, and provides many out-of-the-box starting points, such as the bcc-tools package with pre-created eBPF programs.

NOTE

The eBPF programs are triggered on events, such as disk I/O, TCP connections, and process creations. It is unlikely that the programs should cause the kernel to crash, loop or become unresponsive because they run in a safe virtual machine in the kernel.

Additional resources

- For more information about BCC, see the /usr/share/doc/bcc/README.md file.

35.2. INSTALLING THE BCC-TOOLS PACKAGE

This section describes how to install the bcc-tools package, which also installs the BPF Compiler Collection (BCC) library as a dependency.

Prerequisites

- An active Red Hat Enterprise Linux subscription
- An enabled repository containing the bcc-tools package
- Introduction to yum package manager
- Updated kernel

Procedure

1. Install bcc-tools:

   # yum install bcc-tools

   Once installed, the tools are placed in the /usr/share/bcc/tools/ directory.

2. Optionally, inspect the tools:

   # lI /usr/share/bcc/tools/
35.3. DISPLAYING TCP CONNECTIONS ADDED TO THE KERNEL’S ACCEPT QUEUE

After the kernel receives the **ACK** packet in a TCP 3-way handshake, the kernel moves the connection from the **SYN** queue to the **accept** queue after the connection’s state changes to **ESTABLISHED**. Therefore, only successful TCP connections are visible in this queue.

The **tcpaccept** utility uses eBPF features to display all connections the kernel adds to the **accept** queue. The utility is lightweight because it traces the **accept()** function of the kernel instead of capturing packets and filtering them. For example, use **tcpaccept** for general troubleshooting to display new connections the server has accepted.

**Procedure**

1. Enter the following command to start the tracing the kernel **accept** queue:

   ```bash
   # /usr/share/bcc/tools/tcpaccept
   PID   COMM      IP RADDR         RPORT  LADDR    LPORT
   843   sshd      4  192.0.2.17    50598  192.0.2.1  22
   1107  ns-slapd  4  198.51.100.6  38772  192.0.2.1  389
   1107  ns-slapd  4  203.0.113.85  38774  192.0.2.1  389
   ...```

   Each time the kernel accepts a connection, **tcpaccept** displays the details of the connections.

2. Press **Ctrl+C** to stop the tracing process.

**Additional resources**

- For further details, see the **tcpaccept**(8) man page.

- For further details about **tcpaccept** and examples, see the `/usr/share/bcc/tools/doc/tcpaccept_example.txt` file.

- To display the eBPF script **tcpaccept8**) uploads to the kernel, use the `/usr/share/bcc/tools/tcpaccept --ebpf` command.

35.4. TRACING OUTGOING TCP CONNECTION ATTEMPTS

The **tcpconnect** utility uses eBPF features to trace outgoing TCP connection attempts. The output of the utility also includes connections that failed.
The `tcpconnect` utility is lightweight because it traces, for example, the connect() function of the kernel instead of capturing packets and filtering them.

**Procedure**

1. Enter the following command to start the tracing process that displays all outgoing connections:

   ```bash
   # /usr/share/bcc/tools/tcpconnect
   PID  COMM         IP   SADDR      DADDR          DPORT
   31346 curl         4   192.0.2.1  198.51.100.16  80
   31348 telnet       4   192.0.2.1  203.0.113.231  23
   31361 isc-worker00 4   192.0.2.1  192.0.2.254    53
   ...
   ```

   Each time the kernel processes an outgoing connection, **tcpconnect** displays the details of the connections.

2. Press **Ctrl+C** to stop the tracing process.

**Additional resources**

- For further details, see the `tcpconnect(8)` man page.
- For further details about `tcpconnect` and examples, see the `/usr/share/bcc/tools/doc/tcpconnect_example.txt` file.
- To display the eBPF script `tcpconnect(8)` uploads to the kernel, use the `/usr/share/bcc/tools/tcpconnect --ebpf` command.

### 35.5. MEASURING THE LATENCY OF OUTGOING TCP CONNECTIONS

The TCP connection latency is the time taken to establish a connection. This typically involves the kernel TCP/IP processing and network round trip time, and not the application runtime.

The `tcpconnlat` utility uses eBPF features to measure the time between a sent **SYN** packet and the received response packet.

**Procedure**

1. Start measuring the latency of outgoing connections:

   ```bash
   # /usr/share/bcc/tools/tcpconnlat
   PID  COMM         IP   SADDR      DADDR          DPORT LAT(ms)
   32151 isc-worker00 4   192.0.2.1  192.0.2.254    53   0.60
   32155 ssh          4   192.0.2.1  203.0.113.190  22   26.34
   32319 curl         4   192.0.2.1  198.51.100.59  443   188.96
   ...
   ```

   Each time the kernel processes an outgoing connection, **tcpconnlat** displays the details of the connection after the kernel receives the response packet.

2. Press **Ctrl+C** to stop the tracing process.

**Additional resources**
35.6. DISPLAYING DETAILS ABOUT TCP PACKETS AND SEGMENTS THAT WERE DROPPED BY THE KERNEL

The tcpdrop utility enables administrators to display details about TCP packets and segments that were dropped by the kernel. Use this utility to debug high rates of dropped packets that can cause the remote system to send timer-based retransmits. High rates of dropped packets and segments can impact the performance of a server.

Instead of capturing and filtering packets, which is resource-intensive, the tcpdrop utility uses eBPF features to retrieve the information directly from the kernel.

Procedure

1. Enter the following command to start displaying details about dropped TCP packets and segments:

   ```
   # /usr/share/bcc/tools/tcpdrop
   TIME     PID    IP SADDR:SPORT       > DADDR:DPORT   STATE (FLAGS)
   13:28:39 32253  4  192.0.2.85:51616  > 192.0.2.1:22  CLOSE_WAIT (FIN|ACK)
   b'tcp_drop+0x1'
   b'tcp_data_queue+0x2b9'
   ...
   13:28:39 1      4  192.0.2.85:51616  > 192.0.2.1:22   CLOSE (ACK)
   b'tcp_drop+0x1'
   b'tcp_rcv_state_process+0xe2'
   ...
   ```

   Each time the kernel drops TCP packets and segments, tcpdrop displays the details of the connection, including the kernel stack trace that led to the dropped package.

2. Press Ctrl+C to stop the tracing process.

Additional resources

- For further details, see the tcpdrop(8) man page.
- For further details about tcpdrop and examples, see the /usr/share/bcc/tools/doc/tcpdrop_example.txt file.
- To display the eBPF script tcpdrop(8) uploads to the kernel, use the /usr/share/bcc/tools/tcpdrop --ebpf command.

35.7. TRACING TCP SESSIONS
The **tcplife** utility uses eBPF to trace TCP sessions that open and close, and prints a line of output to summarize each one. Administrators can use **tcplife** to identify connections and the amount of transferred traffic.

The example in this section describes how to display connections to port **22** (SSH) to retrieve the following information:

- The local process ID (PID)
- The local process name
- The local IP address and port number
- The remote IP address and port number
- The amount of received and transmitted traffic in KB.
- The time in milliseconds the connection was active

**Procedure**

1. Enter the following command to start the tracing of connections to the local port **22**:

   ```bash
   /usr/share/bcc/tools/tcplife -L 22
   PID   COMM    LADDR      LPORT RADDR       RPORT TX_KB  RX_KB      MS
   19392 sshd    192.0.2.1  22    192.0.2.17  43892    53     52 6681.95
   19431 sshd    192.0.2.1  22    192.0.2.245 43902    81 249381 7585.09
   19487 sshd    192.0.2.1  22    192.0.2.121 43970  6998     7 16740.35
   ...  
   ```

   Each time a connection is closed, **tcplife** displays the details of the connections.

2. Press **Ctrl+C** to stop the tracing process.

**Additional resources**

- For further details, see the **tcplife(8)** man page.
- For further details about **tcplife** and examples, see the `/usr/share/bcc/tools/doc/tcplife_example.txt` file.
- To display the eBPF script **tcplife(8)** uploads to the kernel, use the `/usr/share/bcc/tools/tcplife --ebpf` command.

### 35.8. TRACING TCP RETRANSMISSIONS

The **tcpretrans** utility displays details about TCP retransmissions, such as the local and remote IP address and port number, as well as the TCP state at the time of the retransmissions.

The utility uses eBPF features and, therefore, has a very low overhead.

**Procedure**

1. Use the following command to start displaying TCP retransmission details:
Each time the kernel calls the TCP retransmit function, `tcpretrans` displays the details of the connection.

2. Press `Ctrl+C` to stop the tracing process.

Additional resources

- For further details, see the `tcpretrans(8)` man page.
- For further details about `tcpretrans` and examples, see the `/usr/share/bcc/tools/doc/tcpretrans_example.txt` file.
- To display the eBPF script `tcpretrans(8)` uploads to the kernel, use the `/usr/share/bcc/tools/tcpretrans --ebpf` command.

### 35.9. Displaying TCP State Change Information

During a TCP session, the TCP state changes. The `tcpstates` utility uses eBPF functions to trace these state changes, and prints details including the duration in each state. For example, use `tcpstates` to identify if connections spend too much time in the initialization state.

**Procedure**

1. Use the following command to start to start tracing TCP state changes:

```bash
# /usr/share/bcc/tools/tcpstates
SKADDR C-PID C-COMM LADDR LPORT RADDR RPORT OLDSTATE -> NEWSTATE MS
ffff9cd377b3af80 0 swapper/1 0.0.0.0 22 0.0.0.0 0 LISTEN -> SYN_RECV 0.000
ffff9cd377b3af80 0 swapper/1 192.0.2.1 22 192.0.2.45 53152 SYN_RECV -> ESTABLISHED 0.067
ffff9cd377b3af80 818 sssd_nss 192.0.2.1 22 192.0.2.45 53152 ESTABLISHED -> CLOSE_WAIT 65636.773
ffff9cd377b3af80 1432 sshd 192.0.2.1 22 192.0.2.45 53152 CLOSE_WAIT -> LAST_ACK 24.409
ffff9cd377b3af80 1267 pulseaudio 192.0.2.1 22 192.0.2.45 53152 LAST_ACK -> CLOSE 0.376
```

Each time a connection changes its state, `tcpstates` displays a new line with updated connection details.

If multiple connections change their state at the same time, use the socket address in the first column (`SKADDR`) to determine which entries belong to the same connection.

2. Press `Ctrl+C` to stop the tracing process.
Additional resources

- For further details, see the tcpstates(8) man page.
- For further details about tcpstates and examples, see the /usr/share/bcc/tools/doc/tcpstates_example.txt file.
- To display the eBPF script tcpstates(8) uploads to the kernel, use the /usr/share/bcc/tools/tcpstates --ebpf command.

35.10. SUMMARIZING AND AGGREGATING TCP TRAFFIC SENT TO SPECIFIC SUBNETS

The tcpsubnet utility summarizes and aggregates IPv4 TCP traffic that the local host sends to subnets and displays the output on a fixed interval. The utility uses eBPF features to collect and summarize the data to reduce the overhead.

By default, tcpsubnet summarizes traffic for the following subnets:

- 127.0.0.1/32
- 10.0.0.0/8
- 172.16.0.0/12
- 192.0.2.0/24/16
- 0.0.0.0/0

Note that the last subnet (0.0.0.0/0) is a catch-all option. The tcpsubnet utility counts all traffic for subnets different than the first four in this catch-all entry.

Follow the procedure to count the traffic for the 192.0.2.0/24 and 198.51.100.0/24 subnets. Traffic to other subnets will be tracked in the 0.0.0.0/0 catch-all subnet entry.

Procedure

1. Start monitoring the amount of traffic sent to the 192.0.2.0/24, 198.51.100.0/24, and other subnets:

```
# /usr/share/bcc/tools/tcpsubnet 192.0.2.0/24,198.51.100.0/24,0.0.0.0/0
Tracing... Output every 1 secs. Hit Ctrl-C to end
[02/21/20 10:04:50]
192.0.2.0/24      856
198.51.100.0/24   7467
[02/21/20 10:04:51]
192.0.2.0/24      1200
198.51.100.0/24   8763
0.0.0.0/0         673
...
```

This command displays the traffic in bytes for the specified subnets once per second.

2. Press Ctrl+C to stop the tracing process.
Additional resources

- For further details, see the `tcpsubnet(8)` man page.
- For further details about `tcpsubnet` and examples, see the `/usr/share/bcc/tools/doc/tcpsubnet.txt` file.
- To display the eBPF script `tcpsubnet(8)` uploads to the kernel, use the `/usr/share/bcc/tools/tcpsubnet --ebpf` command.

35.11. DISPLAYING THE NETWORK THROUGHPUT BY IP ADDRESS AND PORT

The `tcptop` utility displays TCP traffic the host sends and receives in kilobytes. The report automatically refreshes and contains only active TCP connections. The utility uses eBPF features and, therefore, has only a very low overhead.

Procedure

1. To monitor the sent and received traffic, enter:

```
# /usr/share/bcc/tools/tcptop
13:46:29 loadavg: 0.10 0.03 0.01 1/215 3875

    PID  COMM       LADDR           RADDR              RX_KB   TX_KB
3853  3853       192.0.2.1:22    192.0.2.165:41838  32     102626
1285  sshd       192.0.2.1:22    192.0.2.45:39240   0           0

...```

The output of the command includes only active TCP connections. If the local or remote system closes a connection, the connection is no longer visible in the output.

2. Press `Ctrl+C` to stop the tracing process.

Additional resources

- For further details, see the `tcptop(8)` man page.
- For further details about `tcptop` and examples, see the `/usr/share/bcc/tools/doc/tcptop.txt` file.
- To display the eBPF script `tcptop(8)` uploads to the kernel, use the `/usr/share/bcc/tools/tcptop --ebpf` command.

35.12. TRACING ESTABLISHED TCP CONNECTIONS

The `tcptracer` utility traces the kernel functions that connect, accept, and close TCP connections. The utility uses eBPF features and, therefore, has a very low overhead.

Procedure

1. Use the following command to start the tracing process:

```
# /usr/share/bcc/tools/tcptracer
```
Tracing TCP established connections. Ctrl-C to end.

<table>
<thead>
<tr>
<th>T</th>
<th>PID</th>
<th>COMM</th>
<th>IP</th>
<th>SADDR</th>
<th>DADDR</th>
<th>SPORT</th>
<th>DPORT</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1088</td>
<td>ns-slapd</td>
<td>4</td>
<td>192.0.2.153</td>
<td>192.0.2.1</td>
<td>0</td>
<td>65535</td>
</tr>
<tr>
<td>A</td>
<td>845</td>
<td>sshd</td>
<td>4</td>
<td>192.0.2.1</td>
<td>192.0.2.67</td>
<td>22</td>
<td>42302</td>
</tr>
<tr>
<td>X</td>
<td>4502</td>
<td>sshd</td>
<td>4</td>
<td>192.0.2.1</td>
<td>192.0.2.67</td>
<td>22</td>
<td>42302</td>
</tr>
</tbody>
</table>

Each time the kernel connects, accepts, or closes a connection, tcptracer displays the details of the connections.

2. Press **Ctrl+C** to stop the tracing process.

Additional resources

- For further details, see the **tcptracer(8)** man page.
- For further details about tcptracer and examples, see the `/usr/share/bcc/tools/doc/tcptracer_example.txt` file.
- To display the eBPF script tcptracer(8) uploads to the kernel, use the `/usr/share/bcc/tools/tcptracer --ebpf` command.

35.13. ADDITIONAL RESOURCES

- For further information about BCC, see the `/usr/share/doc/bcc/README.md` file.