Red Hat Enterprise Linux 8

Configuring InfiniBand and RDMA networks

A guide to configuring InfiniBand and RDMA networks on Red Hat Enterprise Linux 8

Last Updated: 2022-11-16

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Abstract

This document describes what InfiniBand and remote direct memory access (RDMA) are and how to configure InfiniBand hardware. Additionally, this documentation explains how to configure InfiniBand-related services.

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MAKING OPEN SOURCE MORE INCLUSIVE

Red Hat is committed to replacing problematic language in our code, documentation, and web properties. We are beginning with these four terms: master, slave, blacklist, and whitelist. Because of the enormity of this endeavor, these changes will be implemented gradually over several upcoming releases. For more details, see our CTO Chris Wright's message .

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CHAPTER 1. UNDERSTANDING INFINIBAND AND RDMA

InfiniBand refers to two distinct things:

- The physical link-layer protocol for InfiniBand networks
- The InfiniBand Verbs API, an implementation of the remote direct memory access (RDMA) technology

RDMA provides access between the main memory of two computers without involving an operating system, cache, or storage. Using RDMA, data transfers with high-throughput, low-latency, and 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 actions happen on the receiving end:

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 internal memory space of the kernel 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 some context switches to switch between the kernel and application. These context switches can cause a higher CPU load with high traffic rates while slowing down the other tasks.

Unlike traditional IP communication, RDMA communication bypasses the kernel intervention in the communication process. This reduces the CPU overhead. The RDMA protocol enables the host adapter to decide after a packet enters the network which application should receive it and where to store it in the memory space of that application. Instead of sending the packet for processing to the kernel and copying it into the memory of the user application, the host adapter directly places the packet contents in the application buffer. This process requires a separate API, the InfiniBand Verbs API, and applications need to implement the InfiniBand Verbs API to use RDMA.

Red Hat Enterprise Linux supports both the InfiniBand hardware and the InfiniBand Verbs API. Additionally, it supports the following technologies 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

Additional resources

- Configuring RoCE

CHAPTER 2. CONFIGURING ROCE

This section explains background information about RDMA over Converged Ethernet (RoCE), as well as how to change the default RoCE version. Also, how to configure a software RoCE adapter.

Note that there are different vendors, such as Mellanox, Broadcom, and QLogic, who provide RoCE hardware.

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 the communication between any two hosts in the same Ethernet broadcast domain.

RoCE v2

The RoCE version 2 protocol exists on the top of either the UDP over IPv4 or the UDP over IPv6 protocol. For RoCE v2, the UDP destination port number is **4791**.

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 message-based data transfers.

IMPORTANT

Using different versions like RoCE v2 on the client and RoCE v1 on the server is not supported. In such a case, configure both the server and client to communicate over RoCE v1.

Additional resources

- Temporarily changing the default RoCE version

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 with RoCE v2 protocol
- The server uses an InfiniBand device that only supports RoCE v1

Procedure

1. Create the **/sys/kernel/config/rdma_cm/*mlx5_0*/** directory:

```
# mkdir /sys/kernel/config/rdma_cm/mlx5_0/
```

2. Display the default RoCE mode:

```
# cat /sys/kernel/config/rdma_cm/mlx5_0/ports/1/default_roce_mode

RoCE v2
```

3. Change the default RoCE mode to version 1:

```
# echo "IB/RoCE v1" > /sys/kernel/config/rdma_cm/mlx5_0/ports/1/default_roce_mode
```

2.3. CONFIGURING SOFT-ROCE

Soft-RoCE is a software implementation of remote direct memory access (RDMA) over Ethernet, which is also called RXE. Use Soft-RoCE on hosts without RoCE host channel adapters (HCA).

IMPORTANT

The Soft-RoCE feature is provided as a Technology Preview only. Technology Preview features are not supported with Red Hat production Service Level Agreements (SLAs), might not be functionally complete, and Red Hat does not recommend using them for production. These previews provide early access to upcoming product features, enabling customers to test functionality and provide feedback during the development process.

See Technology Preview Features Support Scope on the Red Hat Customer Portal for information about the support scope for Technology Preview features.

Prerequisites

- An Ethernet adapter is installed

Procedure

1. Install the **iproute**, **libibverbs**, **libibverbs-utils**, and **infiniband-diags** packages:

```
# yum install iproute libibverbs libibverbs-utils infiniband-diags
```

2. Display the RDMA links:

```
# rdma link show
```

3. Load the **rdma_rxe** kernel module and add a new **rxe** device named **rxe0** that uses the **enp0s1** interface:

```
# rdma link add rxe0 type rxe netdev enp1s0
```

Verification

1. View the state of all RDMA links:

```
# rdma link show

link rxe0/1 state ACTIVE physical_state LINK_UP netdev enp1s0
```

2. List the available RDMA devices:

```
# ibv_devices

    device          node GUID
    ------       ----------------
    rxe0          505400fffed5e0fb
```

3. You can 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
```

CHAPTER 3. CONFIGURING SOFT-IWARP

This section explains background information about iWARP, Soft-iWARP and configuration of Soft-iWARP.

3.1. OVERVIEW OF IWARP AND SOFT-IWARP

Remote direct memory access (RDMA) uses the Internet Wide-area RDMA Protocol (iWARP) over Ethernet for converged and low latency data transmission over TCP. Using standard Ethernet switches and the TCP/IP stack, iWARP routes traffic across the IP subnets. This provides flexibility to efficiently use the existing infrastructure. In Red Hat Enterprise Linux, multiple providers implement iWARP in their hardware network interface cards. For example, **cxgb4**, **irdma**, **qedr** etc.

Soft-iWARP (siw) is a software-based iWARP kernel driver and user library for Linux. It is a software-based RDMA device that provides a programming interface to RDMA hardware when attached to network interface cards. It provides an easy way to test and validate the RDMA environment.

3.2. CONFIGURING SOFT-IWARP

Soft-iWARP (siw) implements the Internet Wide-area RDMA Protocol (iWARP) Remote direct memory access (RDMA) transport over the Linux TCP/IP network stack. It enables a system with a standard Ethernet adapter to interoperate with an iWARP adapter or with another system running the Soft-iWARP driver or a host with the hardware that supports iWARP.

IMPORTANT

The Soft-iWARP feature is provided as a Technology Preview only. Technology Preview features are not supported with Red Hat production Service Level Agreements (SLAs), might not be functionally complete, and Red Hat does not recommend using them for production. These previews provide early access to upcoming product features, enabling customers to test functionality and provide feedback during the development process.

See Technology Preview Features Support Scope on the Red Hat Customer Portal for information about the support scope for Technology Preview features.

To configure Soft-iWARP, you can use this procedure in a script to run automatically when the system boots.

Prerequisites

- An Ethernet adapter is installed

Procedure

1. Install the **iproute**, **libibverbs**, **libibverbs-utils**, and **infiniband-diags** packages:

```
# yum install iproute libibverbs libibverbs-utils infiniband-diags
```

2. Display the RDMA links:

```
# rdma link show
```

3. Load the **siw** kernel module:

```
# modprobe siw
```

4. Add a new **siw** device named **siw0** that uses the **enp0s1** interface:

```
# rdma link add siw0 type siw netdev enp0s1
```

Verification

1. View the state of all RDMA links:

```
# rdma link show

link siw0/1 state ACTIVE physical_state LINK_UP netdev enp0s1
```

2. List the available RDMA devices:

```
# ibv_devices

 device                 node GUID
 ------              ----------------
 siw0                 0250b6fffea19d61
```

3. You can use the **ibv_devinfo** utility to display a detailed status:

```
# ibv_devinfo siw0

   hca_id:               siw0
   transport:            iWARP (1)
   fw_ver:               0.0.0
   node_guid:            0250:b6ff:fea1:9d61
   sys_image_guid:       0250:b6ff:fea1:9d61
   vendor_id:            0x626d74
   vendor_part_id:       1
   hw_ver:               0x0
   phys_port_cnt:        1
      port:              1
         state:          PORT_ACTIVE (4)
         max_mtu:        1024 (3)
         active_mtu:     1024 (3)
         sm_lid:         0
         port_lid:       0
         port_lmc:       0x00
         link_layer:     Ethernet
```

CHAPTER 4. 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.

4.1. RENAMING IPOIB DEVICES

By default, the kernel names Internet Protocol 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

Procedure

1. Display the hardware address of the device **ib0**:

   ```
   # 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:12:40:1b:ff:ff:00:00:00:00:00:00:ff:ff:ff:ff
   ```

   The last eight bytes of the address are required to create a **udev** rule in the next step.

2. To configure a rule that renames the device with the **00:02:c9:03:00:31:78:f2** hardware address to **mlx4_ib0**, edit the **/etc/udev/rules.d/70-persistent-ipoib.rules** file and add an **ACTION** rule:

   ```
   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

- **udev(7)** man page
- Understanding IPoIB hardware addresses

4.2. INCREASING THE AMOUNT OF MEMORY THAT USERS ARE ALLOWED TO PIN IN THE SYSTEM

Remote direct memory access (RDMA) operations require the pinning of physical memory. As a consequence, 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 to free up more memory. Hence, memory pinning is a privileged operation.

If non-root users run large RDMA applications, it is 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 file **/etc/security/limits.conf** with following contents:

```
@rdma soft memlock unlimited
@rdma hard memlock unlimited
```

Verification

1. Log in as a member of the **rdma** group after editing the **/etc/security/limits.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

- **limits.conf(5)** man page

4.3. CONFIGURING THE RDMA SERVICE

The **rdma** service manages the stack in the kernel. If Red Hat Enterprise Linux detects InfiniBand, iWARP, or RoCE devices and configuration file of the same reside at the **/etc/rdma/modules/***, the **udev** device manager instructs **systemd** to start the **rdma** service. By default, **/etc/rdma/modules/rdma.conf** configures and loads these services.

Procedure

1. Edit the **/etc/rdma/modules/rdma.conf** file and set the variable to **yes** that you want to enable:

```
# Load IPoIB
IPOIB_LOAD=yes
# Load SRP (SCSI Remote Protocol initiator support) module
SRP_LOAD=yes
# Load SRPT (SCSI Remote Protocol target support) module
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
```

4.4. ENABLING NFS OVER RDMA (NFSORDMA)

Remote direct memory access (RDMA) service works automatically on RDMA-capable hardware in Red Hat Enterprise Linux 8.

Procedure

1. Install the **rdma-core** package:

```
# yum install rdma-core
```

2. Verify the lines with **xprtrdma** and **svcrdma** are commented out in the **/etc/rdma/modules/rdma.conf** file:

```
# NFS over RDMA client support
xprtrdma
# NFS over RDMA server support
svcrdma
```

3. On the NFS server, create directory **/mnt/nfsordma** and export it to **/etc/exports**:

```
# mkdir /mnt/nfsordma
# echo "/mnt/nfsordma *(fsid=0,rw,async,insecure,no_root_squash)" >> /etc/exports
```

4. On the NFS client, mount the nfs-share with server IP address, for example, **172.31.0.186**:

```
# mount -o rdma,port=20049 172.31.0.186:/mnt/nfs-share /mnt/nfs
```

5. Restart the **nfs-server** service:

```
# systemctl restart nfs-server
```

Additional resources

- The RFC 5667 standard

CHAPTER 5. 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.

5.1. 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 in case the default installation does not match your environment.
With only one InfiniBand port, the host acts as the master subnet manager that does not require any custom changes. The default configuration works without any modification.

3. Enable and start the **opensm** service:

```
# systemctl enable --now opensm
```

Additional resources

- **opensm(8)** man page

5.2. CONFIGURING OPENSM USING THE SIMPLE METHOD

This section describes how to configure OpenSM without customized settings.

Prerequisites

- One or more InfiniBand ports are installed on the server

Procedure

1. Obtain the GUIDs for the ports using the **ibstat** utility:

```
# ibstat -d mlx4_0

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: 0xf65214fffe7be132
  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. You can set the **PRIORITY** parameter if multiple subnet managers are available in your subnet. For example:

```
PRIORITY=15
```

Additional resources

- **/etc/sysconfig/opensm**

5.3. 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 on the server

Procedure

1. Edit the **/etc/rdma/opensm.conf** file and customize the settings to match your environment. After updating an **opensm** package, the **yum** utility overrides the **/etc/rdma/opensm.conf** and creates a copy which is the new OpenSM configuration file **/etc/rdma/opensm.conf.rpmnew**. So, you can compare the previous and new files to identify changes and incorporate them manually in file **opensm.conf**.

2. Restart the **opensm** service:

   ```
   # systemctl restart opensm
   ```

5.4. CONFIGURING MULTIPLE OPENSM INSTANCES

This section describes how to set up multiple instances of OpenSM.

Prerequisites

- One or more InfiniBand ports are installed on the server

Procedure

1. 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, compare the previous and new files 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.

   After updating the **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.

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.

5.5. CREATING A PARTITION CONFIGURATION

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 this speed minimum. If a host does not meet the speed requirements, it can't 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 on the server

Procedure

1. Edit the **/etc/rdma/partitions.conf** file to configure the partitions as follows:

   NOTE

   All fabrics must contain the **0x7fff** partition, and all switches and all hosts must belong to that fabric.

   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
    mgid=ff12:401b::fc          # IPv4 Multicast Link Local Name Resolution group
    mgid=ff12:401b::101         # IPv4 NTP group
    mgid=ff12:401b::202         # IPv4 Sun RPC
    mgid=ff12:601b::1           # IPv6 All Hosts group
    mgid=ff12:601b::2           # IPv6 All Routers group
    mgid=ff12:601b::16          # IPv6 MLDv2-capable Routers group
    mgid=ff12:601b::fb          # IPv6 mDNS group
    mgid=ff12:601b::101         # IPv6 NTP group
    mgid=ff12:601b::202         # IPv6 Sun RPC group
    mgid=ff12:601b::1:3         # IPv6 Multicast Link Local Name Resolution group
    ALL=full, ALL_SWITCHES=full;

ib0_2=0x0002, rate=7, mtu=4, scope=2, defmember=full:
        ALL, ALL_SWITCHES=full;
ib0_2=0x0002, ipoib, rate=7, 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
    mgid=ff12:401b::fc          # IPv4 Multicast Link Local Name Resolution group
    mgid=ff12:401b::101         # IPv4 NTP group
    mgid=ff12:401b::202         # IPv4 Sun RPC
    mgid=ff12:601b::1           # IPv6 All Hosts group
    mgid=ff12:601b::2           # IPv6 All Routers group
    mgid=ff12:601b::16          # IPv6 MLDv2-capable Routers group
    mgid=ff12:601b::fb          # IPv6 mDNS group
    mgid=ff12:601b::101         # IPv6 NTP group
    mgid=ff12:601b::202         # IPv6 Sun RPC group
    mgid=ff12:601b::1:3         # IPv6 Multicast Link Local Name Resolution group
    ALL=full, ALL_SWITCHES=full;
```

CHAPTER 6. 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

The Mellanox devices, starting from ConnectX-4 and above, on RHEL 8 and later use Enhanced IPoIB mode by default (datagram only). Connected mode is not supported on these devices.

6.1. THE IPOIB COMMUNICATION MODES

An IPoIB device is configurable in either **Datagram** or **Connected** mode. The difference is the 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 Maximum Transmission Unit (MTU) of the InfiniBand link layer. During transmission of data, the IPoIB layer adds a 4-byte IPoIB header on top of the IP packet. As a result, the IPoIB MTU is 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. The host adapter handles packet segmentation and reassembly. As a result, in the **Connected** mode, the messages sent from Infiniband adapters have no size limits. However, there are limited IP packets due to the **data** field and TCP/IP **header** field. For this reason, the IPoIB MTU in the **Connected** mode is **65520** bytes.

  The **Connected** mode has a higher performance but consumes more kernel memory.

Though a system is configured to use the **Connected** mode, a system still sends multicast traffic using the **Datagram** mode because InfiniBand switches and fabric cannot pass multicast traffic in the **Connected** mode. Also, when the host is not configured to use the **Connected** mode, the system falls back to the **Datagram** mode.

While running an application that sends multicast data up to MTU on the interface, configures the interface in **Datagram** mode or configure the application to cap the send size of a packet that will fit in datagram-sized packets.

6.2. 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 with the configured subnet manager.

- The last 8 bytes are the Globally Unique Identifier (GUID) of the InfiniBand port that attaches to the IPoIB device

> **NOTE**
>
> As the first 12 bytes can change, don’t use them in the **udev** device manager rules.

6.3. CONFIGURING AN IPOIB CONNECTION USING NMCLI COMMANDS

The **nmcli** command-line utility controls the NetworkManager and reports network status using CLI.

Prerequisites

- An InfiniBand device is installed on the server
- The corresponding kernel module is loaded

Procedure

1. Create the InfiniBand connection to use the **mlx4_ib0** interface in the **Connected** transport mode and the maximum MTU of **65520** bytes:

   ```
   # nmcli connection add type infiniband con-name mlx4_ib0 ifname mlx4_ib0 transport-mode Connected mtu 65520
   ```

2. You can also set **0x8002** as a **P_Key** interface of the **mlx4_ib0** connection:

   ```
   # nmcli connection modify mlx4_ib0 infiniband.p-key 0x8002
   ```

3. To configure the IPv4 settings set a static IPv4 address, network mask, default gateway, and DNS server of the **mlx4_ib0** connection:

   ```
   # 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. To configure the IPv6 settings set a static IPv6 address, network mask, default gateway, and DNS server of the **mlx4_ib0** connection:

   ```
   # nmcli connection modify mlx4_ib0 ipv6.addresses 2001:db8:1::1/32
   # nmcli connection modify mlx4_ib0 ipv6.gateway 2001:db8:1::fffe
   # nmcli connection modify mlx4_ib0 ipv6.dns 2001:db8:1::fffd
   # nmcli connection modify mlx4_ib0 ipv6.method manual
   ```

5. To activate the **mlx4_ib0** connection:

   ```
   # nmcli connection up mlx4_ib0
   ```

6.4. CONFIGURING AN IPOIB CONNECTION USING THE NETWORK RHEL SYSTEM ROLE

You can use the **network** RHEL System Role to remotely create NetworkManager connection profiles for IP over InfiniBand (IPoIB) devices.

Prerequisites

- You have prepared the control node and the managed nodes
- You are logged in to the control node as a user who can run playbooks on the managed nodes.
- The account you use to connect to the managed nodes has **sudo** permissions on them.
- The hosts or host groups on which you want to run this playbook are listed in the Ansible inventory file.
- An InfiniBand device named **mlx4_ib0** is installed in the managed nodes.
- The managed nodes use NetworkManager to configure the network.

Procedure

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

```
---
- name: Configure the network
  hosts: managed-node-01.example.com
  tasks:
  - name: Configure IPoIB
    include_role:
      name: rhel-system-roles.network

    vars:
      network_connections:

        # InfiniBand connection mlx4_ib0
        - name: mlx4_ib0
          interface_name: mlx4_ib0
          type: infiniband

        # IPoIB device mlx4_ib0.8002 on top of mlx4_ib0
        - name: mlx4_ib0.8002
          type: infiniband
          autoconnect: yes
          infiniband:
            p_key: 0x8002
            transport_mode: datagram
          parent: mlx4_ib0
          ip:
            address:
              - 192.0.2.1/24
              - 2001:db8:1::1/64
          state: up
```

   If you set a **p_key** parameter as in this example, do not set an **interface_name** parameter on the IPoIB device.

2. Run the playbook:

```
# ansible-playbook ~/IPoIB.yml
```

Verification

1. On the **managed-node-01.example.com** host, display the IP settings of the **mlx4_ib0.8002** device:

```
# ip address show mlx4_ib0.8002
...
inet 192.0.2.1/24 brd 192.0.2.255 scope global noprefixroute ib0.8002
   valid_lft forever preferred_lft forever
inet6 2001:db8:1::1/64 scope link tentative noprefixroute
   valid_lft forever preferred_lft forever
```

2. Display the partition key (P_Key) of the **mlx4_ib0.8002** device:

```
# cat /sys/class/net/mlx4_ib0.8002/pkey
0x8002
```

3. Display the mode of the **mlx4_ib0.8002** device:

```
# cat /sys/class/net/mlx4_ib0.8002/mode
datagram
```

Additional resources

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

6.5. CONFIGURING AN IPOIB CONNECTION USING NM-CONNECTION-EDITOR

The **nmcli-connection-editor** application configures and manages network connections stored by NetworkManager using GUI.

Prerequisites

- An InfiniBand device is installed on the server
- Corresponding kernel module is loaded
- The **nm-connection-editor** package is installed

Procedure

1. Enter the command:

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

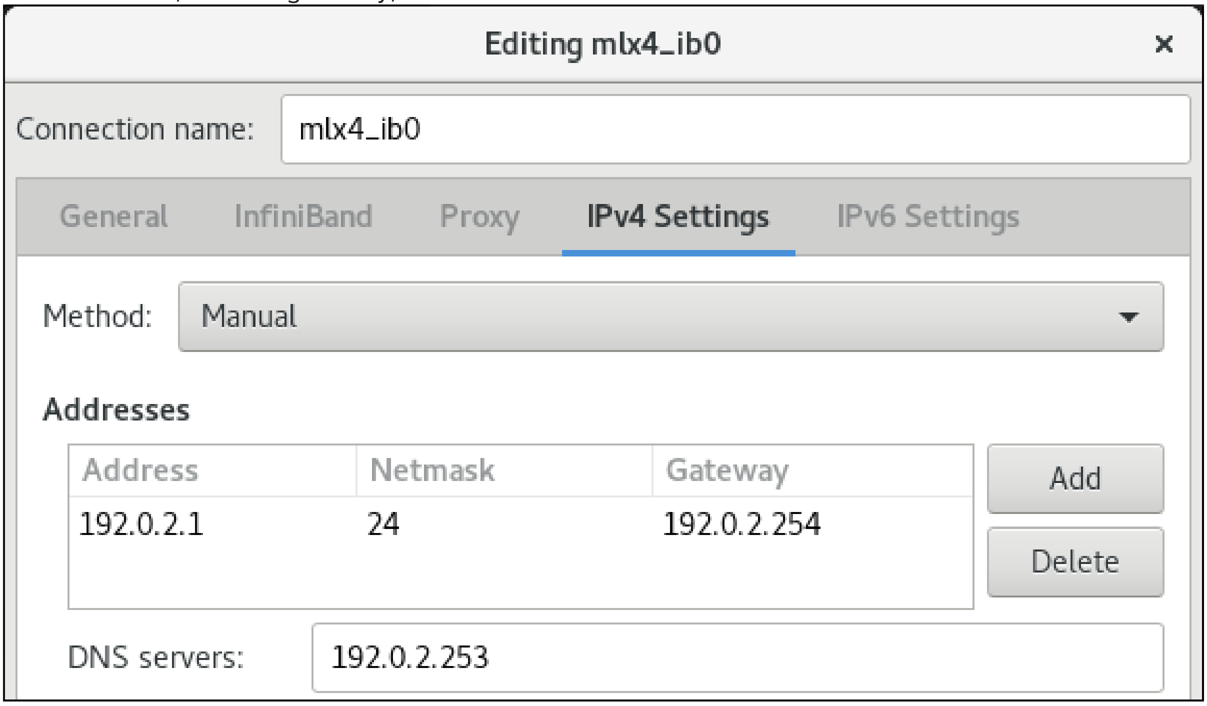
2. Click the **+** button to add a new connection.
3. Select the **InfiniBand** connection type and click **Create**.
4. On the **InfiniBand** tab:
   a. Change the connection name if you want to.

b. Select the transport mode.

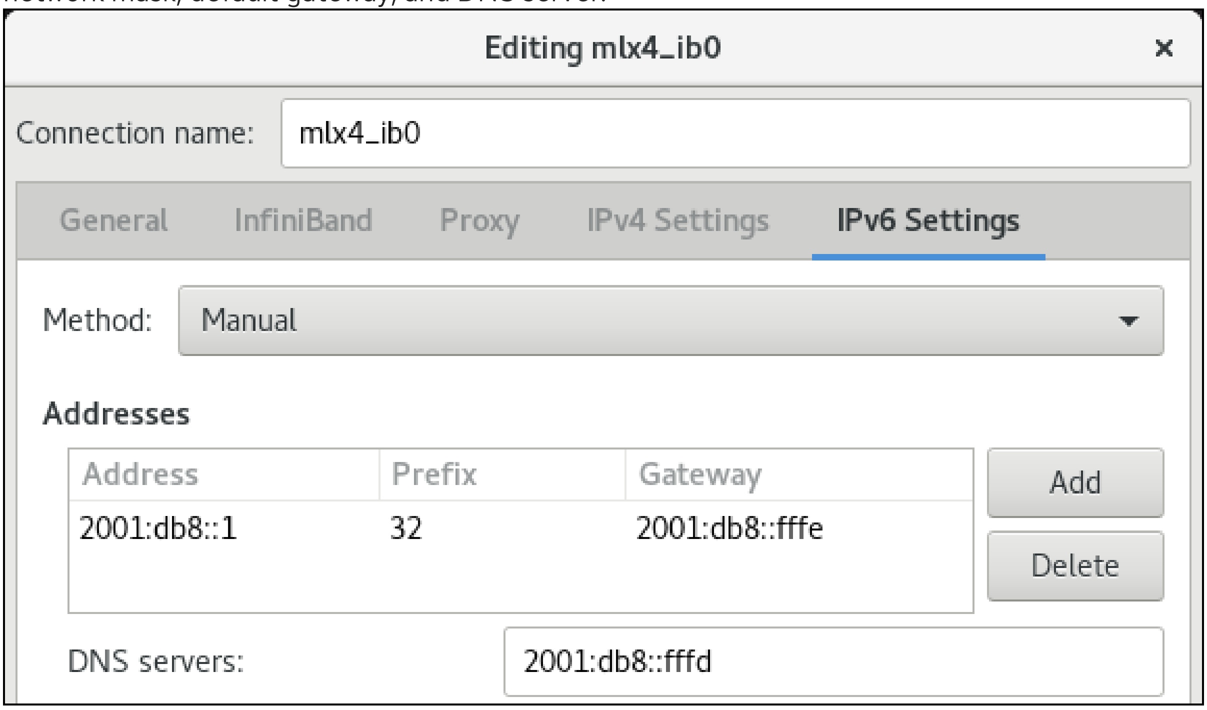
c. Select the device.

d. Set an MTU if needed.

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:



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

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

9. You can set a **P_Key** interface. As this setting is not available in **nm-connection-editor**, you must set this parameter on the command line.
   For example, to set **0x8002** as **P_Key** interface of the **mlx4_ib0** connection:

   ```
   # nmcli connection modify mlx4_ib0 infiniband.p-key 0x8002
   ```

CHAPTER 7. TESTING INFINIBAND NETWORKS

This section provides procedures how to test InfiniBand networks.

7.1. 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 IP-based devices such as Internet Wide-area Remote Protocol(iWARP) or RDMA over Converged Ethernet (RoCE) or InfiniBand over Ethernet (IBoE) devices, see:

- Testing an IPoIB using the ping utility
- Testing an RDMA network using qperf after IPoIB is configured

Prerequisites

- The **rdma** service 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. To display the information of the **mlx4_1** device:

```
# 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. To display the status of the **mlx4_1** device:

```
# 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: 0xf65214fffe7bcba2
        Link layer: Ethernet
```

4. The **ibping** utility pings an InfiniBand address and runs as a client/server.

   a. To start server mode on a host, use the **-S** parameter on port number **-P** with **-C** InfiniBand certificate authority (CA) name:

   ```
   # ibping -S -C mlx4_1 -P 1
   ```

   b. To start client mode on another host, send some packets **-c** on port number **-P** using **-C** InfiniBand certificate authority (CA) name with **-L** Local Identifier (LID):

```
# ibping -c 50 -C mlx4_0 -P 1 -L 2
```

Additional resources

- **ibping(8)** man page

7.2. TESTING AN IPOIB USING THE PING UTILITY

After you configured IP over InfiniBand (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

- Use the **ping** utility to send five ICMP packets to the remote host's InfiniBand adapter:

```
# ping -c5 192.0.2.1
```

7.3. TESTING AN RDMA NETWORK USING QPERF AFTER IPOIB IS CONFIGURED

The **qperf** utility measures RDMA and IP performance between two nodes in terms of bandwidth, latency, and CPU utilization.

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:

```
# 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:

```
# 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:

```
# 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:

```
# 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

- **qperf(1)** man page