BCM957608

Ethernet Networking Guide for NVIDIA H100 GPU Clusters

Application Note

Table of Contents

Chapter 1: Introduction

Broadcom© Ethernet network interface controllers (NICs) support remote direct memory access (RDMA) over Converged Ethernet (RoCE). RoCE enables Direct Memory Transfer across GPU or CPU memory on two different hosts, bypassing the CPU on the hosts. RoCE is completely offloaded to the NIC hardware. It, therefore, provides high bandwidth, low latency, and low-overhead communication to applications.

RoCE is extensively used in Artificial Intelligence (AI), Machine Learning (ML), and High Performance Computing (HPC) applications. AI/ML and HPC applications follow a distributed and parallel computing paradigm where computations are performed across a large number of GPUs or CPUs spread across a large number of hosts, connected through an Ethernet network. These applications move massive amounts of data across hosts and require high-bandwidth and low-latency transport. RoCE-capable Broadcom NICs provide such a transport, which is completely offloaded to the NIC hardware.

1.1 Intended Audience

This document describes:

- How to use Broadcom NICs and NVIDIA GPUs for Data Flow Path with Peer Memory Direct on Linux-based hosts.
- How to configure Ethernet switches for RoCE/Peer Memory Direct
- How to run benchmark tests with collective communications libraries such as NCCL.

The intended audience of this document are those looking to deploy AI/ML clusters using Linux-based hosts over an Ethernet network and then run GPU-based collectives and training/inference models on the cluster.

Specifically, this document focuses on the use of Broadcom 400G BCM957608 NICs and NVIDIA H100 GPUs in a clustered environment over an Ethernet network. The cluster can consist of multiple hosts and multiple Ethernet switches. Each host contains multiple NICs and multiple GPUs.

The document provides details on how to:

- Install and Configure Software and Firmware for Broadcom NICs
- Install GPU Software:
  - CUDA and NCCL for NVIDIA GPUs
- Configure routing on the hosts for RoCE/Peer Mem Direct
- Configure Ethernet switches for RoCE/Peer Mem Direct
- Run RDMA perftest with CUDA support on NVIDIA GPUs and Broadcom NICs
- Install OpenMPI and UCX with CUDA support
- Run NCCL collectives on NVIDIA GPUs and Broadcom NICs

For more information on CUDA and NCCL, please refer to the following links:

- CUDA: https://developer.nvidia.com/cuda-downloads
- NCCL: https://developer.nvidia.com/nccl/nccl-download

NVIDIA GPU-related tests mentioned in this document have been verified on:

- Ubuntu 22.04 running 6.5 kernel.

The Broadcom BCM957608 (Thor2) family of NICs support RoCE and Peer Memory Direct. The BCM957608 family supports a max speed of 400Gbps. These NICs are available in the PCIe and the OCP3.0 Form Factor. Table 1 provides a list of Broadcom Thor2 NIC part numbers.

Table 1: Broadcom 400G NIC Part Numbers

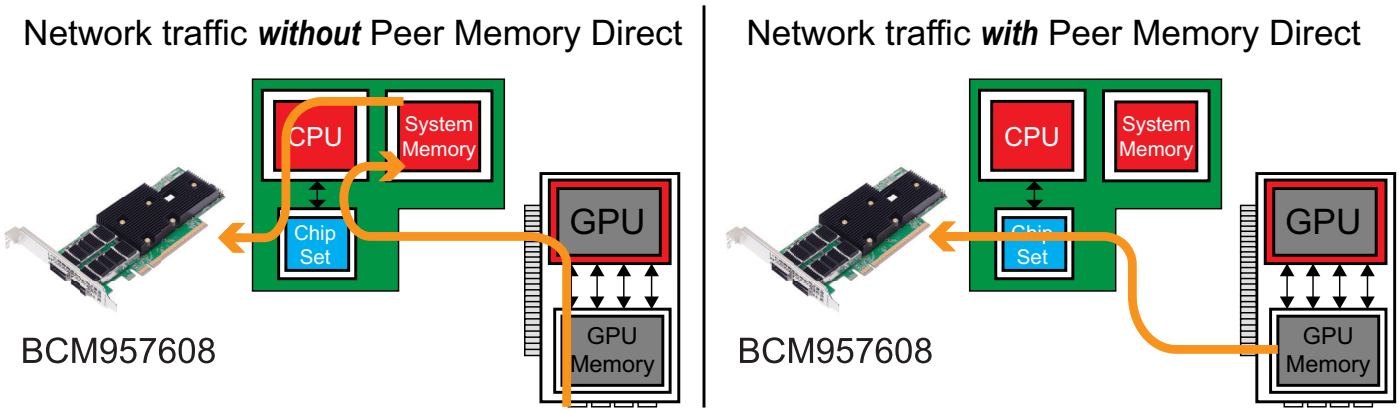
Part Number	Form Factor	Ports	Connector
BCM957608-P1400GD	PCIe	1x 400G	QSFP112-DD
BCM957608-N1400GD	OCP3.0	1x 400G	QSFP112-DD
BCM957608-P2200G	PCIe	2x 200G (default) Can be configured as 1x400G	QSFP112
BCM957608-N2200G	OCP3.0	2x 200G (default) Can be configured as 1x400G	QSFP112

1.2 Data Flow Path with Peer Memory Direct

AI/ML training and inference models require a large number of GPUs for computation and consume massive amounts of data. These GPUs are spread across several hosts in a cluster and connected via Ethernet NICs and Ethernet switches. Using the Peer Memory Direct feature, which is based on RoCE, GPUs on different hosts can exchange data from each other's GPU memory without any CPU involvement.

Without Peer Memory Direct, RoCE can still be used to transfer data across CPU memory on different hosts without any CPU involvement, but the CPU would then have to transfer the data from its memory to the GPU memory. Peer Memory Direct makes use of PCIe peer-to-peer transfers to transfer data between the NIC and the GPU directly, bypassing the CPU.

Figure 1: Data Flow Path with and without Peer Memory Direct



1.3 Host PCIe Topology for Peer Memory Direct

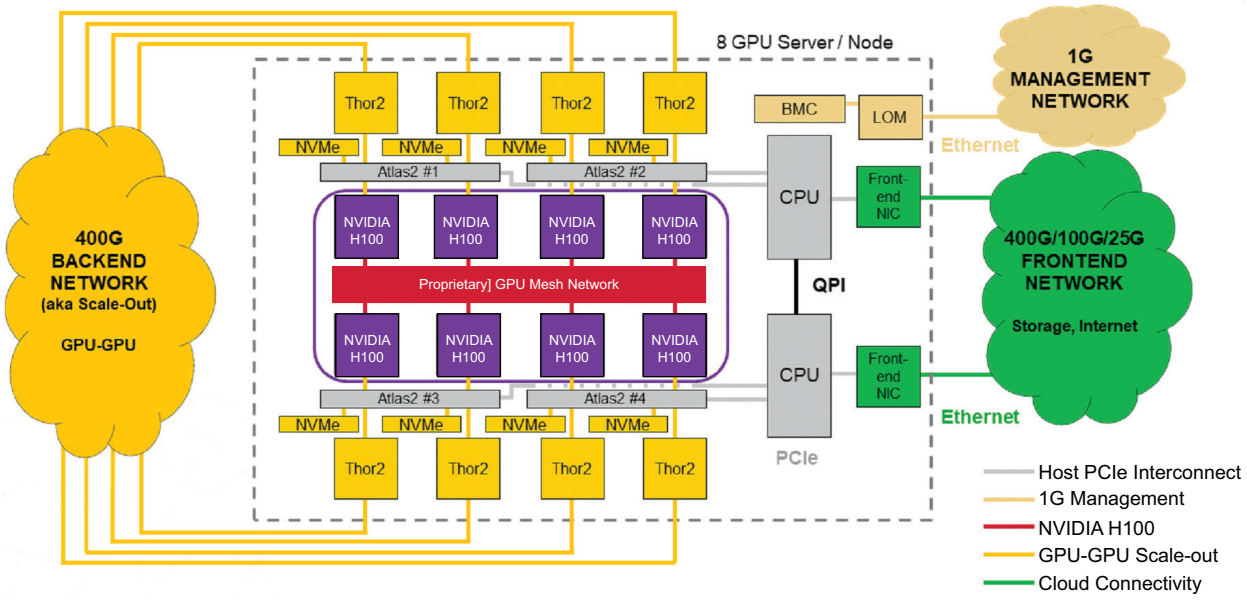
To get the best performance for Peer Memory Direct, the PCIe slot selection for the GPU and the NIC on a host is essential. Peer Memory Direct works via PCIe peer-to-peer transfers, where data is directly transferred between the GPU and the NIC over the PCIe bus.

A typical host used in AI/ML clusters has multiple NICs, multiple GPUs, and multiple PCIe switches per host.

For PCIe peer-to-peer transfers to work, the GPU and the NIC should be connected to the same PCIe switch and the PCIe Access Control Service (ACS) should be disabled on the PCIe switch. If this is not true, then the data is transferred across the NIC and the GPU via the CPU root complex and the benefit of Peer Memory Direct is lost.

A typical NIC, GPU, and PCIe switch configuration inside an AI/ML host is shown in Figure 2. In this host, there are eight NICs (Thor2), eight GPUs (H100), and four PCIe switches (Atlas2). Each NIC is paired with a GPU, and two NICs and two GPUs share a PCIe switch.

Figure 2: Typical NIC, GPU, and PCIe Switch Configuration Inside a AI/ML Host



1.4 Quick Start Guide and Document Overview

This user guide summarizes the essential steps for configuring Broadcom BCM957608 NICs and NVIDIA H100 GPUs for Peer Memory Direct on Linux-based hosts, as described in this document.

IMPORTANT: Always perform Final Checks and Settings for Optimal Performance to ensure the installation and configuration is correct.

1. Install the NVIDIA GPU software:
   a. Follow the NVIDIA GPU Driver Installation instructions by downloading and installing the CUDA toolkit installer.
   b. Follow the Installing NVIDIA GPU drivers, NCCL, and Fabric Manager from the Package Manager instructions by installing the library using an installation package for the specific Linux distribution.
   c. Follow the Installing NVIDIA GPU drivers, NCCL, and Fabric Manager from the Package Manager instructions using NVLink-capable GPUs connected by an NVswitch and install and enable the fabric manager service.
2. Install the Broadcom Ethernet NIC software and firmware as follows:
   a. Follow the Using the Broadcom NIC_Wizard to Update Software and Firmware for Peer Memory Direct instructions (Recommended). Use the -g option to install the Peer Memory Direct drivers.

   Example: Using PCIe BDF sudo bash ./install.sh -v -i 1d:00.0 -f -g or ./nic_wizard installer install -v -i 1d:00.0 -f -g

   Replaced `1d:00.0` with the actual BDF.
   b. Follow the Manually Compiling the Broadcom Host Software from Source Code for Peer Memory Direct instructions (Alternative):

   If the `nic_wizard` installer cannot be used, manually compile, install, and configure the following:
   - Ethernet driver
   - RoCE driver and library
   - Peer Memory Direct driver
   - RoCE QOS Configuration package
   - NIC firmware
3. Configure the host and switch settings for Peer Memory Direct as follows:
   a. To disable PCIe ACS, follow the Broadcom Ethernet NIC Software Installation with Peer Memory Direct instructions by ensuring that the PCIe Access Control Service (ACS) is disabled on the PCIe switch connecting the NIC and the GPU for optimal performance. A script for disabling ACS is provided in Appendix B, Script for Disabling ACS.
   b. To configure IOMMU by disabling IOMMU or set it to Pass Through (PT) mode via the kernel command line or BIOS for optimal performance, follow the Broadcom Ethernet NIC Software Installation with Peer Memory Direct instructions.
   c. Configure Routing for Backend Network by configuring a routing scheme (using Configuring Routing for the Back-End Network), such as using 24-bit or 31-bit subnets, to avoid the ARP flux problem when a host has multiple NICs in the same IP subnet.
   d. To configure Ethernet Switch for QoS and Congestion Control follow the Ethernet Switch Configuration for QoS and Congestion Control instructions by configuring the switch for Priority Flow Control (PFC) and DCQCN-P Congestion Control, ensuring settings match those on the NICs. The default values are:
      - RoCE v2 packets use DSCP 26 and Priority 3.
      - CNP packets use DSCP 48 and Priority 7.
      - PFC should be enabled for Priority 3 traffic.

4. Perform final checks to ensure that the software, the firmware, the tools, and other settings are configured correctly for optimal Peer Memory Direct performance by using the instructions in Final Checks and Settings for Optimal Performance.
5. Validate Peer Memory Direct Support using the following steps:
   a. Installing and Compiling Perftest with NVIDIA GPU Support: Clone the perftest repository and compile it with CUDA support.
   b. Validating Peer Memory Direct Support with Perftest: Execute an `ib_write_bw` test to validate Peer Memory Direct.

Chapter 2: Peer Memory Direct Configuration with BCM957608

This section provides configuration information for Peer Memory Direct with the BCM957608.

2.1 NVIDIA H100 GPU

This section provides information on configuring the BCM957608 with NVIDIA H100.

2.1.1 NVIDIA GPU Driver Installation

See https://developer.nvidia.com/cuda-13-0-2-download-archive and download the CUDA tool kit installer based on the OS type, architecture, distribution, and installer type.

See https://docs.nvidia.com/cuda/cuda-installation-guide-linux/#driver-installation for CUDA installation with the driver.

The NVIDIA GPU driver package provides a kernel module, `nvidia-peermem`, which provides direct peer-to-peer read and write access to the NVIDIA GPU's video memory. It allows GPUDirect RDMA-based applications to use GPU computing power with the RDMA interconnect without needing to copy data to host memory.

Currently, there is no service to automatically load `nvidia-peermem`. Load the module manually using the following command:

```
sudo modprobe nvidia-peermem
```

2.1.2 NCCL Library Installation

Installation of the NCCL library can be performed by downloading an installation package for your Linux distribution. The library can also be compiled from source. Compiling the library from source is outside the scope of this document.

Download the installation package. This requires to have an NVIDIA developer account. Use the following instructions:

```
sudo dpkg -i nccl-local-repo-ubuntu2204-2.22.3-cuda12.6_1.0-1_amd64.deb
sudo cp /var/nccl-local-repo-ubuntu2204-2.22.3-cuda12.6/nccl-local-8EF36A6C-keyring.gpg
/usr/share/keyrings /
sudo dpkg -i nccl-local-repo-ubuntu2204-2.22.3-cuda12.6_1.0-1_amd64.deb
sudo apt update
sudo apt install libnccl2 libnccl-i
sudo /usr/local/cuda/bin/nvcc --version
```

2.1.3 NVIDIA Fabric Manager Installation

If the server has an NVswitch that connects multiple NVLink-capable GPUs, the Fabric Manager package must be installed. To enable NVLink peer-to-peer support, the GPUs must register with the NVLink fabric. The Fabric Manager installation package installs the required core components and registers the daemon as a system service called `nvidia-fabricmanager`.

GPU fabric registration status can be found by using the following command:

```
nvidia-smi -q -i 0 | grep -i -A 2 Fabric
    Fabric
```

```
        State                           : In Progress
        Status                          : N/A
```

Download the `nvidia-fabricmanager` pkg from the following link. The Fabric Manager must correspond to the OS and the GPU driver version that is running on the system. See the following link:

https://developer.download.nvidia.com/compute/cuda/repos/

```
dpkg -i nvidia-fabricmanager-560_560.28.03-1_amd64.deb
systemctl enable nvidia-fabricmanager
systemctl start nvidia-fabricmanager

nvidia-smi -q -i 0 | grep -i -A 2 Fabric
    Fabric

        State                           : Complete
        Status                          : Success
```

2.1.4 Installing NVIDIA GPU drivers, NCCL, and Fabric Manager from the Package Manager

In addition to the previous method for installing NVIDIA GPU drivers, NCCL, and NVIDIA Fabric Manager software. Using the package manager like apt, install NVIDIA GPU drivers, NCCL, and NVIDIA Fabric Manager using the following steps.

The following steps apply to Ubuntu 22.04:

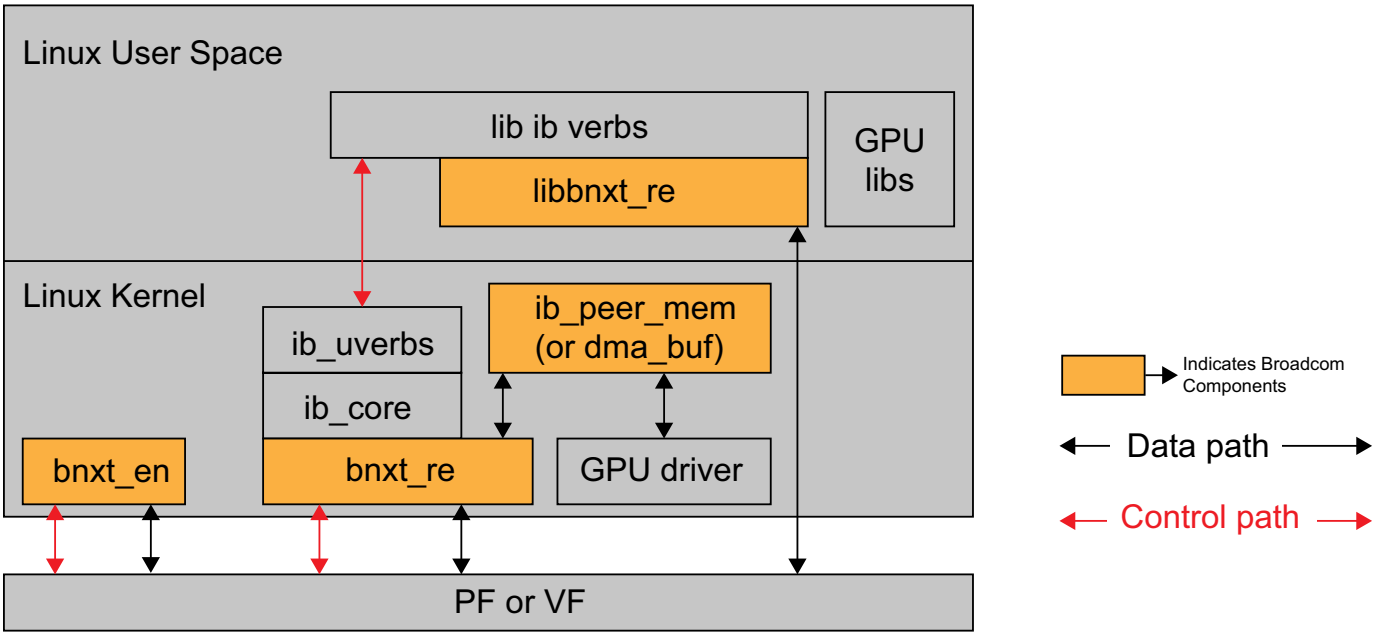
```
sudo apt-get install linux-headers-$(uname -r)
wget
https://developer.download.nvidia.com/compute/cuda/repos/ubuntu2204/x86_64/cuda-keyring_1.1-1_all.de
b
sudo dpkg -i cuda-keyring_1.1-1_all.deb
sudo apt update
sudo apt install cuda-toolkit-12-6           #or just cuda-toolkit to allow auto upgrades
sudo apt install nvidia-open
sudo apt install nvidia-gds

#add the following to .bashrc
export PATH=${PATH:+:${PATH}}:/usr/local/cuda/bin
export LD_LIBRARY_PATH=/usr/local/cuda/lib64/${LD_LIBRARY_PATH:+:${LD_LIBRARY_PATH}}
sudo apt install -y libnccl2 libnccl-i
sudo apt install nvidia-fabricmanager-560sudo systemctl enable nvidia-fabricmanagersudo systemctl
start nvidia-fabricmanager
```

2.2 Broadcom Ethernet NIC Software Installation with Peer Memory Direct

The host software components required for Broadcom RoCE are as follows:

- Ethernet kernel driver (`bnxt_en`)
- RoCE kernel driver (`bnxt_re`)
- RoCE userspace library (`libbnxt_re`)
- RoCE QOS configuration pkg (`bnxt_re_conf`)

For Peer Memory Direct, an additional kernel driver (`ib_peer_mem`) is required. The `ib_peer_mem` driver interfaces with the GPU driver for Peer Memory Direct.



The Broadcom Ethernet NIC software can be distributed and installed in a variety of approaches:

- Automated installer: Installs all required software and firmware using a single command line
- Dynamic Kernel Module Support (DKMS) format for the kernel drivers
- Source RPM and Binary RPM format for the kernel drivers
- Source Code for the kernel drivers and the RoCE userspace library
- Debian, RPM, and Source Tarball for `bnxt_re_conf` (udev rules and scripts for setting up RoCE QoS parameters – PFC, CC, RoCE and CNP DSCP values, and so forth)

2.2.1 Using the Broadcom NIC_Wizard to Update Software and Firmware for Peer Memory Direct

Broadcom provides a tarball for every NIC GA release. The release tarball contains all required software and firmware for every NIC part number, and an automated installer that can be used to install the required software and firmware.

The tarball for the latest GA release is publicly available from the downloads tab of the following links:

https://www.broadcom.com/products/ethernet-connectivity/network-adapters/p1400g

or

https://www.broadcom.com/products/ethernet-connectivity/network-adapters/p2200g

Besides the public location, customers can contact Broadcom for the GA version of any release not available on the public website.

In `NIC_Wizard`, the installer namespace provides different install options including assigning an IP address, netmask, and MTU size for an Ethernet interface. The installer requires Internet access to download any prerequisite packages from the Linux distribution's package manager for building the required NIC host software.

Installer Options

```
-h, --help show this help message and exit
-v, --verbose Show all commands run and status information
-U, --uninstall Uninstall packages and boot-time configuration of the specified devices (-i)
-i DEVICES [DEVICES ...]
Specify a network interface. PCI addresses or interface names ( ens4f1np1,eno1np0,eno2np1,ens4f0np0
)are allowed. Supports comma-separated
values for multiple interfaces. syntax: -i <intf1>,<intf2>
-A, --all Apply on all supported network interfaces. All interface names (
ens4f1np1,eno1np0,eno2np1,ens4f0np0 )are selected.
-a IP_ADDRESS [IP_ADDRESS ...]
Specify an IPv4 or IPv6 IP address for the previous interface
-n NETMASK [NETMASK ...]
Specify the netmask/prefix for the previous interface. For IPv4: dotted decimal (e.g., 255.255.255.0)
or CIDR (e.g., 24). For IPv6: prefix
length (e.g., 64). Default IPv4: 255.255.255.0, Default IPv6: 64. syntax: -a <address> -n
<netmask/prefix>
-l IP_ADDRESS_PREFIX Configure interface IP address as <prefix>. For IPv4: first 3 octets (e.g.,
"192.168.1"). For IPv6: network prefix, first 4 hextets (e.g.,
"2001:db8::", "fd00:1234:5678::"). Supports comma-separated values for multiple interfaces. syntax:
-i <intf1>,<intf2> -l <prefix1>,<prefix2>
-m MTU, --mtu MTU Interface MTU. Default: 1500. syntax: -i <interface name> ( -a <address> or -l
<ip_prefix> ) -m <MTU>
-w, --no-firmware Do not install firmware
-s RELEASE_SOURCE, --source RELEASE_SOURCE
Path to release files. Default: ../
-o {ECN,PFC,ECNPFC,NOOP} [{ECN,PFC,ECNPFC,NOOP} ...], --cc_mode {ECN,PFC,ECNPFC,NOOP}
[{ECN,PFC,ECNPFC,NOOP} ...]
RoCE congestion control mode. Default: NOOP
-r ROCE_PRI, --roce_pri ROCE_PRI
RoCE priority. Must set -o to take effect. Default: 3
-d ROCE_DSCP, --roce_dscp ROCE_DSCP
RoCE Packet DSCP value. Must set -o to take effect. Default: 26
-c CNP_PRI, --cnp_pri CNP_PRI
RoCE CNP Packet Priority. Must set -o to take effect. Default: 7
-p CNP_DSCP, --cnp_dscp CNP_DSCP
RoCE CNP DSCP value. Must set -o to take effect. Default: 48
-b ROCE_PCT, --roce_pct ROCE_PCT
RoCE Bandwidth
```

The installer README.md is located inside the release zip file in the directory: `utils/nic_wizard`. The README provides info on the different installer options.

The following example shows how to use the installer for the NIC 237 GA release.

The main option used by the installer is "-i" which refers to the interface on which the software and firmware must be installed. The interface argument can be specified either as:

- Ethernet interface name
- BDF (Bus, Device, Function) of the PCIe interface for the NIC

The PCIe BDF is useful in cases when no Broadcom Ethernet driver (`bnxt_en`) exists on a host and therefore the NIC interface does not have a name.

The `-g` option of the installer is used to install Peer Memory Direct drivers.

NOTE: If kernel stack already supports peer memory APIs, the installer skips installing the Broadcom peer memory module.

2.2.1.1 Example On Using the NIC Wizard

```
cd $HOME


# Download the tarball

BCM_TARBALL=bcm_234.1.124.0b.tar.gz
# Highlighted item will change depending on the release

tar -xf ${BCM_TARBALL}

cd $HOME/bcm_234.1.124.0b/utils/nic_wizard

./install.sh -v -i 1d:00.0 -f -g or ./nic_wizard installer install -v -i 1d:00.0 -f -g
# Highlighted item will change depending on PCIe BDF of the NIC (check with lspci)
```

2.2.1.2 Verifying the Correct Driver and Firmware Versions

The output of the `nic_wizard` installer install command is logged in the file install.log. The log file can be checked to see if any error occurred during the installation. After the installer has completed successfully, the version of the drivers loaded in the kernel and the version of the firmware flashed on the NIC should be checked. The best way to check the version of the drivers loaded into the kernel is to check the dmesg logs using the following commands:

```
sudo dmesg | grep -i bnx | grep -i ver

modinfo bnxt_en | grep -i ver

modinfo bnxt_re | grep -i ver

modinfo ib_peer_mem | grep -i ver

dkms status
```

The firmware version running on the card can be checked via the Broadcom-provided NICCLI tool.

```
sudo niccli --list_devices
# This command will list available Broadcom NICs and index for each

sudo niccli --dev <index | pci b:d:f | mac | nic interface> show -p
# Highlighted item will change depending on the index or PCIe BDF or MAC

# Example:
sudo niccli --dev 1 show -p
```

In general, reboot the host after the installer has run and re-check the driver version and the FW version. This ensures the correct version of the drivers load after every reboot of the host and the initramfs/ramdisk of the host is correctly updated by the installer.

2.2.1.3 Verifying the Correct RoCE QOS Configuration

The correct RoCE QOS CFG pkg (`bnxt_re_conf`) installation can be verified via the presence of the `/etc/bnxt_re/bnxt_re.conf` file. The file contents should match the configured QOS values. The default values are as follows:

```
cat /etc/bnxt_re/bnxt_re.conf
ENABLE_FC=1
FC_MODE=3
ROCE_PRI=3
ROCE_DSCP=26
CNP_PRI=7
CNP_DSCP=48
ROCE_BW=50
UTILITY=4
```

The correct RoCE QOS application on each RoCE NIC can be verified via the following Broadcom-provided NICCLI tool commands:

```
sudo niccli --list_devices
# This command will list available Broadcom NICs and index for each

sudo niccli --dev <index | pci b:d:f | mac> qos --ets --show
# Highlighted item will change depending on the index or PCIE BDF or MAC

# Example:
sudo niccli --dev 1 qos --ets --show

IEEE 8021QAZ ETS Configuration TLV:
         PRIO_MAP: 0:0 1:0 2:0 3:1 4:0 5:0 6:0 7:2
         TC Bandwidth: 50% 50% 0%
         TSA_MAP: 0:ets 1:ets 2:strict
IEEE 8021QAZ PFC TLV:
         PFC enabled: 3
IEEE 8021QAZ APP TLV:
         APP#0:
          Priority: 7
          Sel: 5
          DSCP: 48

         APP#1:
          Priority: 3
          Sel: 5
          DSCP: 26

         APP#2:
          Priority: 3
          Sel: 3
          UDP or DCCP: 4791

TC Rate Limit: 100% 100% 100% 0% 0% 0% 0% 0%
```

In general, reboot the host after the installer has run and re-check the driver version, the firmware version, and the RoCE QOS settings. This ensures the correct version of the drivers load after every reboot of the host and the `initramfs/ramdisk` of the host is correctly updated by the installer.

2.2.1.4 Using the Broadcom NIC_Wizard on a Host with Multiple NICs

Most of the hosts used for Peer Memory Direct use multiple NICs and multiple GPUs per host. From the NIC perspective, a single host driver instance is interfacing with the firmware on all the NICs. To flash or upgrade firmware on multiple NICs on the same host, the installer supports specifying multiple interfaces or multiple PCIe Bus, Device, Function. Each interface or PCIe Bus, Device, Function specifies a NIC on which the firmware is to be flashed.

```
cd $HOME

ls bcm_234.1.124.0b.tar.gz
# Highlighted item will change depending on the release

tar xf bcm_234.1.124.0b.tar.gz
# Highlighted item will change depending on the release

cd $HOME/bcm_234.1.124.0b/utils/nic_wizard
# Highlighted item will change depending on the release

sudo bash ./install.sh -v -i 1d:00.0 -i 43:0.0 -i 56:0.0 -i 69:0.0 -i 9f:0.0 -i c3:0.0 -i d5:0.0 -i
e7:0.0 -f -g
```

(or)

```
./nic_wizard installer install -v -i 1d:00.0 -i 43:0.0 -i 56:0.0 -i 69:0.0 -i 9f:0.0 -i c3:0.0 -i
d5:0.0 -i e7:0.0 -f -g
```

(or)

To select all of the supported NICs:

```
./nic_wizard installer install -A -f -g

# Highlighted items will change depending on the PCIe BDF of each NIC
```

Reboot the host and check the driver versions and the firmware versions on each NIC as described in Verifying the Correct Driver and Firmware Versions.

2.2.2 Manually Compiling the Broadcom Host Software from Source Code for Peer Memory Direct

The NIC Wizard installer automatically installs the peer mem driver required for the NIC if the driver is not available as part of the kernel. Check Frequently Asked Questions and Troubleshooting on how to check if the peer mem driver is already part of the kernel. This section outlines the manual compilation of the peer mem driver if a user wants to manually compile the peer mem driver.

The source code required for the kernel drivers is distributed in a tarball with a name that indicates the software release the tarball belongs to. For example, the tarball `netxtreme-peer-mem-a.b.c.d.tar.gz` contains all the kernel driver source code and Makefiles to build the `a.b.c.d` release version of the kernel drivers.

The source code for the libbnxt_re library is distributed in a tarball with a name that indicates the software release the tarball belongs to. For example, the `libbnxt_re-234.0.154.0.tar.gz` contains all the software source code and Makefiles to build the 234.0.154.0 release version of the `libbnxt_re` library.

To summarize, the following two source code tarballs are required to be built and installed for the NIC software on any given host:

- `netxtreme-peer-mem-a.b.c.d.tar.gz`
- `libbnxt_re-a.b.c.d.tar.gz`

The highlighted items change depending on the release version.

Appendix A, Compiling Broadcom NIC Software from Source provides Linux shell scripts that can be used to build and install the required software. Two separate scripts are provided for Ubuntu and RHEL-based hosts. The script, along with `netxtreme-peer-mem-a.b.c.d.tar.gz` and `libbnxt_re-a.b.c.d.tar.gz` should be placed in a directory before executing the script. The content of the scripts can be followed to understand the various steps used to build and install the NIC software.

2.2.2.1 Installing the RoCE QOS Configuration (bnxt_re_conf) pkg Manually

NOTE: If the Broadcom automated installer is used, then the RoCE QOS Configuration pkg (`bnxt_re_conf`) is automatically installed by the `nic_wizard` when using the install command.

Beginning with the Broadcom 2.31 release, the RoCE QOS CFG package is a standalone pkg. Before the 2.31 release, RoCE QOS CFG was part of the RoCE driver `bnxt_re`. The `bnxt_re_conf` pkg is distributed in a variety of formats (debian, RPM, and source tarball). Depending on the OS distro being used, the appropriate pkg format can be used.

```
cd $HOME

ls bcm_234.1.124.0b.tar.gz
# Highlighted item will change depending on the release

tar xf bcm_234.1.124.0b.tar.gz
# Highlighted item will change depending on the release

cd $HOME/bcm_234.1.124.0b.tar.gz/drivers_linux/bnxt_re/bnxt_re_conf
# Highlighted item will change depending on the release

dpkg -i bnxt_re_conf_234.0.154.0-1_all.deb
# Highlighted item will change depending on the release
or
rpm -Uvh bnxt_re_conf-234.0.154.0-1.noarch.rpm
# Highlighted item will change depending on the release
```

It is recommended to reboot the host if the `bnxt_re_conf` pkg is installed the first time or the contents of the `/etc/bnxt_re/bnxt_re.conf` file are modified. This allows the RoCE QOS settings to be applied correctly to each NIC. After installing the `bnxt_re_conf` pkg, ensure the pkg is correctly installed as shown in Verifying the Correct RoCE QOS Configuration.

2.2.3 Configuring the Peer Memory Driver on Kernels that Do Not Have Inbox Peer Memory Driver Support

Certain Ubuntu kernels have built-in `ib_peer_mem` APIs. These kernels do not require an `ib_peer_mem` module built via the Broadcom Peer Memory Direct Driver pkg. The Driver Pkg Makefile can detect the presence of `ib_peer_mem` APIs in the kernel and skip building the `ib_peer_mem` kernel module. For such kernels, the `nvidia_peermem` module provided via the kernel or the CUDA installation is sufficient. To check if the kernel has inbox peer me support refer to step 3 in Frequently Asked Questions and Troubleshooting.

For the kernels that do not have inbox peer memory driver support, use the following instructions to patch the NVIDIA GPU driver to work with the Broadcom peer memory direct driver.

1. Retrieve and patch the NVIDIA source open-gpu-kernel-modules using the following commands:

```
wget https://github.com/NVIDIA/open-gpu-kernel-modules/archive/refs/tags/$NVIDIA_VERSION.tar.gz
tar xf open-gpu-kernel-modules-$NVIDIA_VERSION.tar.gz
cd open-gpu-kernel-modules-$NVIDIA_VERSION/
```

2. Patch the `kernel-open/conftest.sh` and `nvidia-peermem.Kbuild` file by adding the following line to `compile_test()` in the kernel-open/conftest.sh file.

```
check_for_ib_peer_memory_symbols "$BNXT_PEER_MEM_INC" || \
```

3. Replace the definition of `MLNX_OFED_KERNEL` in file `nvidia-peermem.Kbuild` with the following:

```
MLNX_OFED_KERNEL := $(shell echo /lib/modules/`uname -r`/build)
```

4. Replace the definition of `KBUILD_EXTRA_SYMBOLS` in file `nvidia-peermem.Kbuild` with the following:

```
KBUILD_EXTRA_SYMBOLS := $(BNXT_PEER_MEM_INC)/Module.symvers
```

5. Recompile and install the `open-gpu-kernel-modules` using the following commands:

```
dkms remove nvidia/$NVIDIA_VERSION

export $REL_DIR/drivers_linux/peer_mem/netxtreme-peer-mem-x.y.z/peer_mem ##point to the location
of the source of peer_mem driver

make modules -j
sudo make modules_install
sudo depmod -a
sudo update-initramfs -u
sudo modprobe ib_peer_mem
sudo modprobe nvidia-peermem
```

2.2.3.1 Installing the NIC Firmware Manually

NOTE: If the Broadcom `nic_wizard` is used, then the firmware is automatically installed by the installer.

The Broadcom NIC firmware is provided in a ".pkg" file and a single file contains all the required firmware for a NIC. The firmware pkg file name contains the NIC part number.

For example, the BCM957608-P1400GD card firmware file is named `BCM957608-P1400GDF00.pkg`.

To list the interface name of all the Broadcom NICs available on a host, use the NICCLI tool provided by Broadcom.

```
sudo niccli --list_devices
# List the interfaces where Broadcom Ethernet cards are recognized
```

To install the FW on a Broadcom NIC, use the following NICCLI command:

```
sudo niccli --dev <index | pci b:d:f | mac> fw --update -f <FW.pkg> --yes
# Highlighted item will change depending on the index or PCIe BDF or MAC

# Example:
sudo niccli --dev 1 install BCM957608-P1400GQF00.pkg
```

A reboot is required when a NIC firmware is flashed. The NICCLI tool output indicates a reboot is required.

2.2.3.2 Verifying the Correct Driver and Firmware Version

After manually installing the drivers from source code and/or installing the NIC firmware on a NIC, it's a good idea to check and ensure the proper versions of the driver are loaded into the kernel and the correct firmware version is installed on the NICs. See Verifying the Correct Driver and Firmware Versions for the required steps.

2.2.4 Configuring RoCE Support

The NICs are default configured for RoCE/Peer Memory Direct. The following NVM CFG parameters control RoCE operation on an NIC and can be verified using the NICCLI tool.

2.2.4.1 Enable RDMA Option on the NIC

To check the option value:

```
sudo niccli --dev <index|pci b:d:f> nvm --getoption support_rdma --scope <pf number>
# First highlighted item will change depending on the index or PCIe BDF or MAC
# Second highlighted item will change depending on the PF

# Example:
sudo niccli --dev 1 nvm --getoption support_rdma --scope 0
```

To enable the option:

```
sudo niccli --dev <index|pci b:d:f> nvm --setoption support_rdma --scope <pf number> --value 1
# First highlighted item will change depending on the index or PCIe BDF or MAC
# Second highlighted item will change depending on the PF

# Example:
sudo niccli --dev 1 nvm --setoption support_rdma --scope 0 --value 1
```

2.2.4.2 Enable RoCE Performance Profile on the NIC

The default performance profile on the NICs is non-ROCE. The default profile is optimized for scenarios where the majority of the traffic handled by the NIC is L2. If the NIC needs to handle a traffic mix where the RoCE traffic is greater than 50% of all traffic (as would be the case for Peer Memory Direct), then the performance profile should be changed to RoCE.

To check the option value:

```
sudo niccli --dev <index | pci b:d:f | mac> nvm --getoption performance_profile
# Highlighted item will change depending on the index or PCIe BDF or MAC

# Example:
sudo niccli --dev 1 nvm --getoption performance_profile
```

To enable the option:

```
sudo niccli --dev <index|pci b:d:f> nvm --setoption performance_profile --value 1
# Highlighted item will change depending on the index or PCIe BDF or MAC
#value 0: Default
#value 1: RoCE
# Example:
```

```
sudo niccli --dev 1 nvm --setoption performance_profile --value 1
```

2.2.4.3 Enable PCIe Relaxed Ordering on the NIC

PCIe Relaxed ordering allows PCIe transactions to be completed out of order and results in a performance boost for applications when enabled. However, care should be taken before Relaxed ordering is enabled as it can lead to data corruption for some applications.

To check the option value:

```
sudo niccli --dev <index | pci b:d:f | mac> nvm --getoption pcie_relaxed_ordering
# Highlighted item will change depending on the index or PCIe BDF or MAC

# Example:
sudo niccli --dev 1 nvm --getoption pcie_relaxed_ordering
```

To enable the option:

```
sudo niccli --dev <index|pci b:d:f> nvm --setoption pcie_relaxed_ordering --value 1
# Highlighted item will change depending on the index or PCIe BDF or MAC

# Example:
sudo niccli --dev 1 nvm --setoption pcie_relaxed_ordering --value 1
```

2.2.4.4 Firmware Based DCBx NVM CFG on NIC

The Broadcom RoCE driver (`bnxt_re`) configures the QOS defaults for the NIC upon loading. However, if the firmware-based DCBX or the FW-based LLDP is enabled via NVM CFG, the RoCE driver does not configure the QOS on the NIC interface.

NOTE: Firmware-based DCBX and FW-based LLDP should be disabled if the RoCE driver needs to configure the QOS for the interface.

To check the option values:

```
sudo niccli --dev <index | pci b:d:f | mac> nvm --getoption dcbx_mode --scope <pf number>
# First highlighted item will change depending on the index or PCIe BDF or MAC
# Second highlighted item will change depending on the PF

# Example:
niccli --dev 3 nvm --getoption dcbx_mode --scope 0

sudo niccli --dev <index | pci b:d:f | mac> nvm --getoption lldp_nearest_bridge --scope <pf number>
# First highlighted item will change depending on the index or PCIe BDF or MAC
# Second highlighted item will change depending on the PF

# Example:
sudo niccli --dev 1 nvm --getoption lldp_nearest_bridge --scope 0

sudo niccli --dev <index | pci b:d:f | mac> nvm --getoption lldp_nearest_non_tpmr_bridge --scope <pf
number>
# First highlighted item will change depending on the index or PCIe BDF or MAC
# Second highlighted item will change depending on the PF

# Example:
sudo niccli --dev 1 nvm --getoption lldp_nearest_non_tpmr_bridge --scope 0
```

To disable the options:

```
sudo niccli --dev <index | pci b:d:f | mac> nvm --setoption dcbx_mode --scope <pf number> --value 0
# First highlighted item will change depending on the index or PCIe BDF or MAC
# Second highlighted item will change depending on the PF

# Example:
$ sudo niccli --dev 1 nvm --setoption dcbx_mode --scope 0 --value 0

$ sudo niccli --dev <index | pci b:d:f | mac> nvm --setoption lldp_nearest_bridge --scope <pf number>
--value 0
# First highlighted item will change depending on the index or PCIe BDF or MAC
# Second highlighted item will change depending on the PF

# Example:
$ sudo niccli --dev 1 nvm --getoption lldp_nearest_bridge --scope 0 --value 0

$ sudo niccli --dev <index | pci b:d:f | mac> nvm --setoption lldp_nearest_non_tpmr_bridge --scope <pf
number> --value 0
# First highlighted item will change depending on the index or PCIe BDF or MAC
# Second highlighted item will change depending on the PF

# Example:
$ sudo niccli --dev 1 nvm --getoption lldp_nearest_non_tpmr_bridge --scope 0 --value 0
```

2.3 ACS and IOMMU Settings

For Peer Memory Direct to work optimally, PCIe Access Control Services (ACS) needs to be disabled. ACS is a PCIe switch setting and needs to be disabled on the PCIe switch connecting the NIC and the GPU.

Additionally, for optimum Peer Memory Direct performance, the IOMMU on the host needs to be disabled or put in the Pass Through (PT) mode.

2.3.1 Hosts with AMD CPUs

The IOMMU should be configured in PT mode via the kernel command line. The kernel parameters to use with AMD CPU-based hosts are `amd_iommu=on iommu=pt`.

Sample kernel command line for hosts with AMD CPU and IOMMU in PT mode:

```
BOOT_IMAGE=/boot/vmlinuz-5.15.0-102-generic root=UUID=8d0ffb16-6f01-44c2-8e16-18bb37d87392 ro
pci=realloc=off amd_iommu=on iommu=pt
```

2.3.2 Hosts with Intel CPUs

The IOMMU can be configured in PT mode via the kernel command line. The kernel parameters to use with Intel CPU-based hosts are `intel_iommu=on iommu=pt`.

Sample kernel command line for hosts with Intel CPU and IOMMU in PT mode:

```
BOOT_IMAGE=/boot/vmlinuz-5.15.0-102-generic root=UUID=8d0ffb16-6f01-44c2-8e16-18bb37d87392 ro
pci=realloc=off intel_iommu=on iommu=pt
```

On some hosts, ACS and IOMMU can be disabled via the BIOS as well. Check with the host/BIOS vendor on how ACS and IOMMU can be configured via the BIOS.

See Appendix B, Script for Disabling ACS for a bash shell script that can be used to disable ACS on a host.

If the host does not support disabling ACS via the BIOS, then ACS must be disabled after every host reboot and the shell script in Appendix B, Script for Disabling ACS can be used.

2.3.3 Host Memory

AI/ML and HPC applications typically require a lot of RAM. 2 Terabytes or more of RAM is typically recommended.

2.4 Configuring Routing for the Back-End Network

Most hosts used for AI/ML training, inference as well as AI/ML applications have multiple NICs and multiple GPUs per host. GPU collectives such as NCCL require that any NIC on any host should be able to communicate with any other NIC on any host in the cluster.

When a host has multiple NICs in the same IP subnet, an Address Resolution Protocol (ARP) flux problem can happen on Linux-based hosts. Linux can respond to an ARP request on a different interface (IP address) than the IP address carried in the ARP request. This causes the RDMA stack to incorrectly map the remote IP address to the wrong RDMA device.

There are a few solutions to this problem.

Using the `arp_ignore` and `arp_announce` sysctl settings as follows, one can instruct Linux to send ARP replies on the interface targeted in the ARP request.

```
sudo sysctl -w net.ipv4.conf.all.arp_announce=1
sudo sysctl -w net.ipv4.conf.all.arp_ignore=2
```

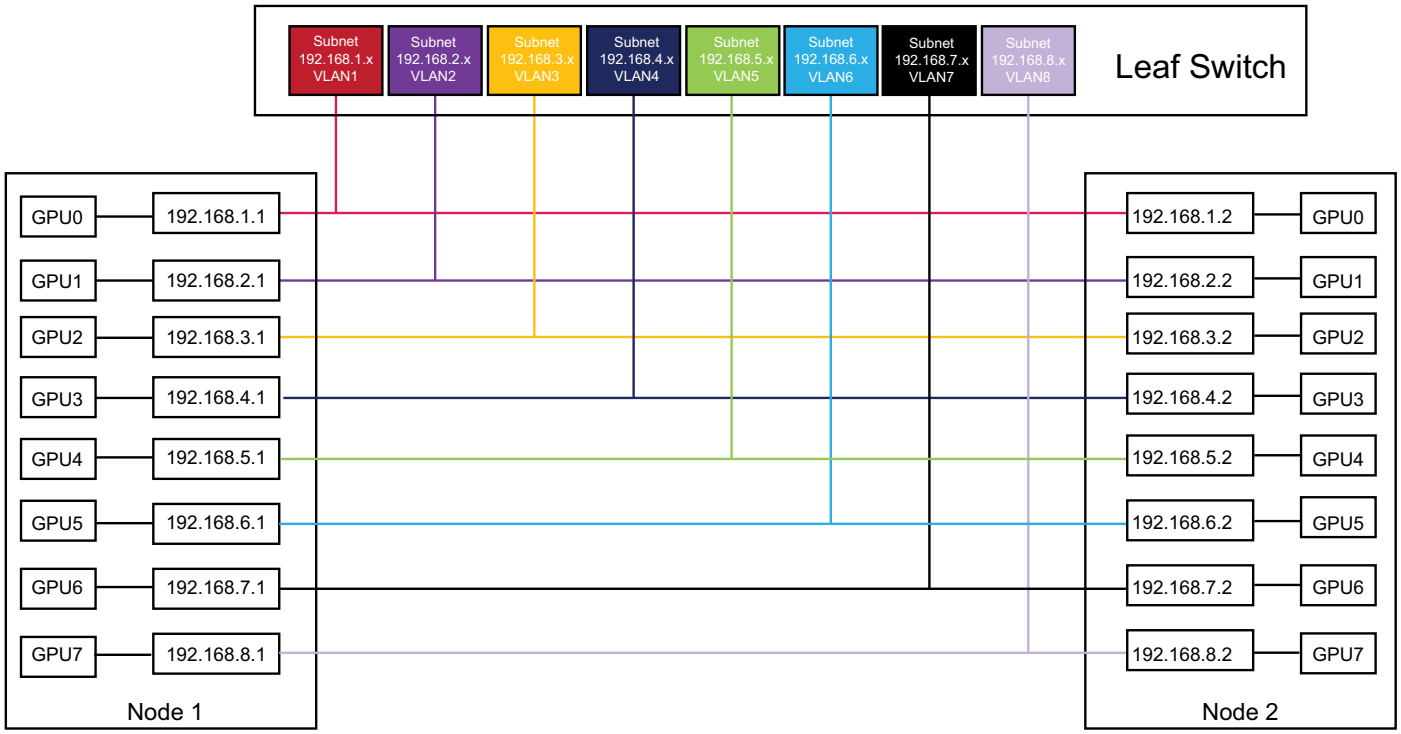
However, a better approach to the ARP flux problem is to configure each NIC on a host in a separate subnet. There are multiple approaches possible here depending on the size of the cluster being configured.

2.4.1 Single Leaf Switch Topology with 24-bit Subnets

The approach used in the section makes use of the 24-bit IP subnets and a Layer 3 switch. The topology referenced in this section is that of multiple hosts connecting to the same leaf switch.

1. Each host has eight NICs and eight GPUs per host.
2. The leaf switch is a Layer 3 switch and can route packets based on the IPv4 address.
3. A total of 8 IP subnets and eight VLANs are used in the network. The VLANs are only configured on the switch ports. The VLANs are not configured on the NICs.
4. Each VLAN on the switch has an IP address assigned in a unique subnet from the set of eight subnets used in the network.
5. Inter VLAN routing is used on the switch.
6. Each of the eight NICs on a host belongs to a unique subnet from the set of eight subnets used in the network. For symmetry, NIC1 on each host is connected to a switch port in the same VLAN, NIC2 on each host is connected to a switch port in the same VLAN, and so on.
7. Source-Based Routing is applied to each NIC, with the default gateway set to the IP address of the switch port VLAN to which the NIC is connected. A total of eight additional routing tables (101 through 108) are used.

Figure 3: 24-bit Subnet Scheme



The following is a sample netplan file for two of the hosts on the cluster. Other hosts can follow a similar addressing scheme.

The netplan file has 8 Ethernet interfaces. The interfaces are named eth1 through eth8 just for reference and should be replaced with the actual interface Ethernet names on the host. Each interface has an IP address with a 24-bit subnet mask.

2.4.1.1 Host 1 netplan file:/etc/netplan/00-installer-config-24bit-subnet-host1.yaml

```
network:
  version: 2
  renderer: networkd
  ethernets: eth1:
      mtu: 9000
      addresses:
      - 192.168.1.1/24
      routes:
      - to: default
        via: 192.168.1.254
        table: 101
      routing-policy:
      - from: 192.168.1.1
        table: 101
    eth2:
      mtu: 9000
      addresses:
- 192.168.2.1/24
      routes:
      - to: default
        via: 192.168.2.254
        table: 102
```

```
    routing-policy:
    - from: 192.168.2.1
      table: 102
  eth3:
    mtu: 9000
    addresses:
    - 192.168.3.1/24
    routes:
    - to: default
      via: 192.168.3.254
      table: 103
    routing-policy:
    - from: 192.168.3.1
      table: 103
  eth4:
    mtu: 9000
    addresses:
    - 192.168.4.1/24
    routes:
    - to: default
      via: 192.168.4.254
      table: 104
    routing-policy:
    - from: 192.168.4.1
      table: 104
  eth5:
    mtu: 9000
    addresses:
    - 192.168.5.1/24
    routes:
    - to: default
      via: 192.168.5.254
      table: 105
    routing-policy:
    - from: 192.168.5.1
      table: 105
  eth6:
    mtu: 9000
    addresses:
    - 192.168.6.1/24
    routes:
    - to: default
      via: 192.168.6.254
      table: 106
    routing-policy:
    - from: 192.168.6.1
      table: 106
  eth7:
    mtu: 9000
    addresses:
    - 192.168.7.1/24
    routes:
    - to: default
      via: 192.168.7.254
      table: 107
    routing-policy:
    - from: 192.168.7.1
      table: 107
```

```
    eth8:
      mtu: 9000
      addresses:
      - 192.168.8.1/24
      routes:
      - to: default
        via: 192.168.8.254
        table: 108
      routing-policy:
      - from: 192.168.8.1
        table: 108
```

After the previous netplan file is applied, ensure to start and enable networked service. This disables any prior network configuration performed with network manager.

```
sudo systemctl enable systemd-networkd
sudo systemctl start systemd-networkd
```

After the previous netplan file is applied, the `ip rule show` command should list eight additional rules and eight additional routing tables should be populated.

```
$ ip rule show
0:      from all lookup local
32758:  from 192.168.7.1 lookup 107 proto static
32759:  from 192.168.5.1 lookup 105 proto static
32760:  from 192.168.6.1 lookup 106 proto static
32761:  from 192.168.8.1 lookup 108 proto static
32762:  from 192.168.1.1 lookup 101 proto static
32763:  from 192.168.2.1 lookup 102 proto static
32764:  from 192.168.3.1 lookup 103 proto static
32765:  from 192.168.4.1 lookup 104 proto static
32766:  from all lookup main
32767:  from all lookup default

$ ip route list table 101
default via 192.168.1.254 dev eth1 proto static

$ ip route list table 102
default via 192.168.2.254 dev eth2 proto static

$ ip route list table 103
default via 192.168.3.254 dev eth3 proto static

$ ip route list table 104
default via 192.168.4.254 dev eth4 proto static

$ ip route list table 105
default via 192.168.5.254 dev eth5 proto static

$ ip route list table 106
default via 192.168.6.254 dev eth6 proto static

$ ip route list table 107
default via 192.168.7.254 dev eth7 proto static

$ ip route list table 108
default via 192.168.8.254 dev eth8 proto static
```

2.4.1.2 Host 2 netplan file:/etc/netplan/00-installer-config-24bit-subnet-host2.yaml

```
network:
  version: 2
  renderer: networkd
  ethernets:
    eth1:
      mtu: 9000
      addresses:
      - 192.168.1.2/24
      routes:
      - to: default
        via: 192.168.1.254
        table: 101
      routing-policy:
      - from: 192.168.1.2
        table: 101
    eth2:
      mtu: 9000
      addresses:
      - 192.168.2.2/24
      routes:
      - to: default
        via: 192.168.2.254
        table: 102
      routing-policy:
      - from: 192.168.2.2
        table: 102
    eth3:
      mtu: 9000
      addresses:
      - 192.168.3.2/24
      routes:
      - to: default
        via: 192.168.3.254
        table: 103
      routing-policy:
      - from: 192.168.3.2
        table: 103
    eth4:
      mtu: 9000
      addresses:
      - 192.168.4.2/24
      routes:
      - to: default
        via: 192.168.4.254
        table: 104
      routing-policy:
      - from: 192.168.4.2
        table: 104
    eth5:
      mtu: 9000
      addresses:
      - 192.168.5.2/24
      routes:
      - to: default
        via: 192.168.5.254
        table: 105
```

```
      routing-policy:
      - from: 192.168.5.2
        table: 105
    eth6:
      mtu: 9000
      addresses:
      - 192.168.6.2/24
      routes:
      - to: default
        via: 192.168.6.254
        table: 106
      routing-policy:
      - from: 192.168.6.2
        table: 106
    eth7:
      mtu: 9000
      addresses:
      - 192.168.7.2/24
      routes:
      - to: default
        via: 192.168.7.254
        table: 107
      routing-policy:
      - from: 192.168.7.2
        table: 107
    eth8:
      mtu: 9000
      addresses:
      - 192.168.8.2/24
      routes:
      - to: default
        via: 192.168.8.254
        table: 108
      routing-policy:
      - from: 192.168.8.2
        table: 108
```

After the previous netplan file is applied, ensure to start and enable networked service. This disables any prior network configuration performed with network manager.

```
sudo systemctl enable systemd-networkd
sudo systemctl start systemd-networkd
```

After the previous netplan file is applied, the `ip rule show` command should list eight additional rules and eight additional routing tables should be populated.

```
$ ip rule show
0:      from all lookup local
32758:  from 192.168.7.2 lookup 107 proto static
32759:  from 192.168.5.2 lookup 105 proto static
32760:  from 192.168.6.2 lookup 106 proto static
32761:  from 192.168.8.2 lookup 108 proto static
32762:  from 192.168.1.2 lookup 101 proto static
32763:  from 192.168.2.2 lookup 102 proto static
32764:  from 192.168.3.2 lookup 103 proto static
32765:  from 192.168.4.2 lookup 104 proto static
32766:  from all lookup main
```

```
32767:  from all lookup default

$ ip route list table 101
default via 192.168.1.254 dev eth1 proto static

$ ip route list table 102
default via 192.168.2.254 dev eth2 proto static

$ ip route list table 103
default via 192.168.3.254 dev eth3 proto static

$ ip route list table 104
default via 192.168.4.254 dev eth4 proto static

$ ip route list table 105
default via 192.168.5.254 dev eth5 proto static

$ ip route list table 106
default via 192.168.6.254 dev eth6 proto static

$ ip route list table 107
default via 192.168.7.254 dev eth7 proto static

$ ip route list table 108
default via 192.168.8.254 dev eth8 proto static
```

The corresponding sample Ethernet switch configuration with respect to configuring the VLAN, the subnets, and the routing on the switch are shown in the following example. The sample configuration is based on a Dell Z9664 Ethernet switch and a Supermicro SSE-T8032 Ethernet switch running SONiC. Only the configuration pertinent to the routing scheme outlined in this section is presented.

2.4.1.3 Ethernet Leaf Switch Port Configuration for 24-bit Subnet Scheme on Dell Z9664 Switch and Supermicro SSE-T8032 Switch Running SONiC OS

```
interface Vlan1
 description nic1_vlan
 ip address 192.168.1.254/24
!
interface Vlan2
 description nic2_vlan
 ip address 192.168.2.254/24
!
interface Vlan3
 description nic3_vlan
 ip address 192.168.3.254/24
!
interface Vlan4
 description nic4_vlan
 ip address 192.168.4.254/24
!
interface Vlan5
 description nic5_vlan
 ip address 192.168.5.254/24
!
interface Vlan6
 description nic6_vlan
 ip address 192.168.6.254/24
!
interface Vlan7
 description nic7_vlan
 ip address 192.168.7.254/24
!
interface Vlan8
 description nic8_vlan
 ip address 192.168.8.254/24
!
```

```
interface Eth1/1
 description "Node1 NIC1"
 mtu 9100
 speed 400000
 fec RS
 standalone-link-training
 unreliable-los auto
 no shutdown
 switchport access Vlan 1
!
interface Eth1/2
 description "Node2 NIC1"
 mtu 9100
 speed 400000
 fec RS
 standalone-link-training
```

```
 unreliable-los auto
 no shutdown
 switchport access Vlan 1
!
interface Eth1/3
 description "Node1 NIC2"
 mtu 9100
 speed 400000
 fec RS
 standalone-link-training
 unreliable-los auto
 no shutdown
 switchport access Vlan 2
!
interface Eth1/4
 description "Node2 NIC2"
 mtu 9100
 speed 400000
 fec RS
 standalone-link-training
 unreliable-los auto
 no shutdown
 switchport access Vlan 2
!
interface Eth1/5
 description "Node1 NIC3"
 mtu 9100
 speed 400000
 fec RS
 standalone-link-training
 unreliable-los auto
 no shutdown
 switchport access Vlan 3
!
interface Eth1/6
 description "Node2 NIC3"
 mtu 9100
 speed 400000
 fec RS
 standalone-link-training
 unreliable-los auto
 no shutdown
 switchport access Vlan 3
!
interface Eth1/7
 description "Node1 NIC4"
 mtu 9100
 speed 400000
 fec RS
 standalone-link-training
 unreliable-los auto
 no shutdown
 switchport access Vlan 4
!
interface Eth1/8
 description "Node2 NIC4"
 mtu 9100
 speed 400000
```

```
 fec RS
 standalone-link-training
 unreliable-los auto
 no shutdown
 switchport access Vlan 4
!
interface Eth1/9
 description "Node1 NIC5"
 mtu 9100
 speed 400000
 fec RS
 standalone-link-training
 unreliable-los auto
 no shutdown
 switchport access Vlan 5
!
interface Eth1/10
 description "Node2 NIC5"
 mtu 9100
 speed 400000
 fec RS
 standalone-link-training
 unreliable-los auto
 no shutdown
 switchport access Vlan 5
!
interface Eth1/11
 description "Node1 NIC6"
 mtu 9100
 speed 400000
 fec RS
 standalone-link-training
 unreliable-los auto
 no shutdown
 switchport access Vlan 6
!
interface Eth1/12
 description "Node2 NIC6"
 mtu 9100
 speed 400000
 fec RS
 standalone-link-training
 unreliable-los auto
 no shutdown
 switchport access Vlan 6
!
interface Eth1/13
 description "Node1 NIC7"
 mtu 9100
 speed 400000
 fec RS
 standalone-link-training
 unreliable-los auto
 no shutdown
 switchport access Vlan 7
!
interface Eth1/14
 description "Node2 NIC7"
```

```
 mtu 9100
 speed 400000
 fec RS
 standalone-link-training
 unreliable-los auto
 no shutdown
 switchport access Vlan 7
!
interface Eth1/15
 description "Node1 NIC8"
 mtu 9100
 speed 400000
 fec RS
 standalone-link-training
 unreliable-los auto
 no shutdown
 switchport access Vlan 8
!
interface Eth1/16
 description "Node2 NIC8"
 mtu 9100
 speed 400000
 fec RS
 standalone-link-training
 unreliable-los auto
 no shutdown
 switchport access Vlan 8
!
```

2.4.1.4 Ethernet Leaf Switch Port Configuration for 24-bit Subnet Scheme on Juniper QFX5240 Switch

```
interfaces {
    et-0/0/1 {
        description "Breakout et-0/0/1";
        number-of-sub-ports 2;
        speed 400g;
    }
    et-0/0/1:0 {
        description to.node-02;
        native-vlan-id 2;
        mtu 9216;
        unit 0 {
            family ethernet-switching {
                interface-mode trunk;
                vlan {
                    members vn2;
                }
            }
        }
    }
    et-0/0/1:1 {
        description to.node-03;
        native-vlan-id 3;
        mtu 9216;
        unit 0 {
            family ethernet-switching {
```

```
            interface-mode trunk;
            vlan {
                members vn3;
            }
        }
    }
}
et-0/0/2 {
    description "Breakout et-0/0/2";
    number-of-sub-ports 2;
    speed 400g;
}
et-0/0/2:0 {
    description to.AMD-ML3100-04;
    native-vlan-id 4;
    mtu 9216;
    unit 0 {
        family ethernet-switching {
            interface-mode trunk;
            vlan {
                members vn4;
            }
        }
    }
}
et-0/0/2:1 {
    description to.AMD-ML3100-05;
    native-vlan-id 5;
    mtu 9216;
    unit 0 {
        family ethernet-switching {
            interface-mode trunk;
            vlan {
                members vn5;
            }
        }
    }
}
et-0/0/3 {
    description "Breakout et-0/0/3";
    number-of-sub-ports 2;
    speed 400g;
}
et-0/0/3:0 {
    description to.AMD-ML3100-06;
    native-vlan-id 6;
    mtu 9216;
    unit 0 {
        family ethernet-switching {
            interface-mode trunk;
            vlan {
                members vn6;
            }
        }
    }
}
et-0/0/3:1 {
    description to.AMD-ML3100-07;
```

```
        native-vlan-id 7;
        mtu 9216;
        unit 0 {
            family ethernet-switching {
                interface-mode trunk;
                vlan {
                    members vn7;
                }
            }
        }
    }
    et-0/0/4 {
        description "Breakout et-0/0/1";
        number-of-sub-ports 2;
        speed 400g;
    }
    et-0/0/4:0 {
        description to.AMD-ML3100-08;
        native-vlan-id 8;
        mtu 9216;
        unit 0 {
            family ethernet-switching {
                interface-mode trunk;
                vlan {
                    members vn8;
                }
            }
        }
    }
    et-0/0/4:1 {
        description to.AMD-ML3100-09;
        native-vlan-id 9;
        mtu 9216;
        unit 0 {
            family ethernet-switching {
                interface-mode trunk;
                vlan {
                    members vn9;
                }
            }
        }
    }
    irb {
        mtu 9216;
        unit 2 {
            family inet {
                mtu 9000;
                address 192.168.2.254/24;
            }
        }
        unit 3 {
            family inet {
                mtu 9000;
                address 192.168.3.254/24;
            }
        }
        unit 4 {
            family inet {
```

```
                mtu 9000;
                address 192.168.4.254/24;
            }
        }
        unit 5 {
            family inet {
                mtu 9000;
                address 192.168.5.254/24;
            }
        }
        unit 6 {
            family inet {
                mtu 9000;
                address 192.168.6.254/24;
            }
        }
        unit 7 {
            family inet {
                mtu 9000;
                address 192.168.7.254/24;
            }
        }
        unit 8 {
            family inet {
                mtu 9000;
                address 192.168.8.254/24;
            }
        }
        unit 9 {
            family inet {
                mtu 9000;
                address 192.168.9.254/24;
            }
        }
    }
}
vlans {
    vn2 {
        description stripe1_leaf1_vlan2;
        vlan-id 2;
        l3-interface irb.2;
    }
    vn3 {
        description stripe1_leaf1_vlan3;
        vlan-id 3;
        l3-interface irb.3;
    }
    vn4 {
        description stripe1_leaf1_vlan4;
        vlan-id 4;
        l3-interface irb.4;
    }
    vn5 {
        description stripe1_leaf1_vlan5;
        vlan-id 5;
        l3-interface irb.5;
    }
    vn6 {
```

```
        description stripe1_leaf1_vlan6;
        vlan-id 6;
        l3-interface irb.6;
    }
    vn7 {
        description stripe1_leaf1_vlan7;
        vlan-id 7;
        l3-interface irb.7;
    }
    vn8 {
        description stripe1_leaf1_vlan8;
        vlan-id 8;
        l3-interface irb.8;
    }
    vn9 {
        description stripe1_leaf1_vlan9;
        vlan-id 9;
        l3-interface irb.9;
    }
}
```

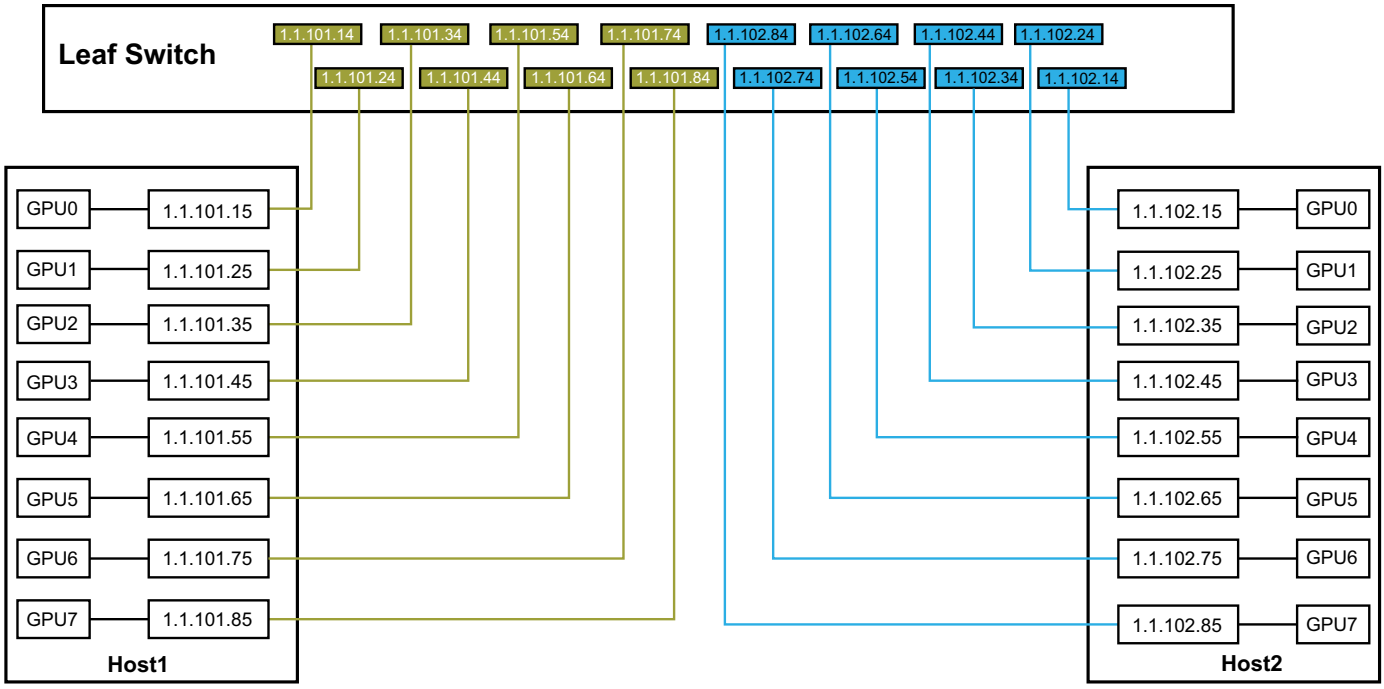
2.4.2 Single Leaf Switch Topology with 31-bit Subnets

The approach used in this section makes use of the 31-bit IP subnets and a Layer 3 switch. The 31-bit subnets enable point-to-point links as the 31-bit subnet allows only 2 addresses in the subnet. These two addresses form each end of the point-to-point link.

The topology referenced in this section is that of multiple hosts connecting to the same leaf switch.

1. Each host has eight NICs and eight GPUs per host.
2. Each NIC in the network is in a unique subnet (31-bit subnet mask). The NIC IP address forms one end of the point-to-point connection. The other IP address of the subnet is assigned to the Ethernet switch port to which the NIC connects. The switch port forms the other end of the point-to-point connection.
3. Source Based Routing is used for each NIC where the default gateway of each NIC is the IP address of the switch port to which it connects. A total of eight additional routing tables (101 through 108) are used.

Figure 4: 31-bit Subnet Scheme



The following is a sample netplan file for two of the hosts on the cluster. Other hosts can follow a similar addressing scheme.

The netplan file has eight Ethernet interfaces. The interfaces are named eth1 through eth8 just for reference and should be replaced with the actual interface Ethernet names on the host. Each interface has an IP address with a 31-bit subnet mask.

2.4.2.1 Host 1 netplan file:/etc/netplan/00-installer-config-host1.yaml

```
network:
    version: 2
    renderer: networkd
    ethernets:
    eth1:
    mtu: 9000
       addresses:
       - 1.1.101.15/31
       routes:
       - to: default
         via: 1.1.101.14
         table: 101
         scope: global
       routing-policy:
       - from: 1.1.101.14/31
         table: 101
         priority: 0
       - to: 1.1.101.14/16
         table: 101
         priority: 1
     eth2:
       mtu: 9000
       addresses:
       - 1.1.101.25/31
       routes:
       - to: default
         via: 1.1.101.24
         table: 102
         scope: global
       routing-policy:
       - from: 1.1.101.24/31
         table: 102
         priority: 0
       - to: 1.1.101.24/16
         table: 102
         priority: 1
     eth3:
       mtu: 9000
       addresses:
       - 1.1.101.35/31
       routes:
       - to: default
         via: 1.1.101.34
         table: 103
         scope: global
       routing-policy:
       - from: 1.1.101.34/31
         table: 103
         priority: 0
       - to: 1.1.101.34/16
         table: 103
         priority: 1
     eth4:
       mtu: 9000
       addresses:
       - 1.1.101.45/31
```

```
      routes:
      - to: default
        via: 1.1.101.44
        table: 104
        scope: global
      routing-policy:
      - from: 1.1.101.44/31
        table: 104
        priority: 0
      - to: 1.1.101.44/16
        table: 104
        priority: 1
    eth5:
      mtu: 9000
      addresses:
      - 1.1.101.55/31
      routes:
      - to: default
        via: 1.1.101.54
        table: 105
        scope: global
      routing-policy:
      - from: 1.1.101.54/31
        table: 105
        priority: 0
      - to: 1.1.101.54/16
        table: 105
        priority: 1
    eth6:
      mtu: 9000
      addresses:
      - 1.1.101.65/31
      routes:
      - to: default
        via: 1.1.101.64
        table: 106
        scope: global
      routing-policy:
      - from: 1.1.101.64/31
        table: 106
        priority: 0
      - to: 1.1.101.64/16
        table: 106
        priority: 1
    eth7:
      mtu: 9000
      addresses:
      - 1.1.101.75/31
      routes:
      - to: default
        via: 1.1.101.74
        table: 107
        scope: global
      routing-policy:
      - from: 1.1.101.74/31
        table: 107
        priority: 0
      - to: 1.1.101.74/16
```

```
        table: 107
        priority: 1
    eth8:
      mtu: 9000
      addresses:
      - 1.1.101.85/31
      routes:
      - to: default
        via: 1.1.101.84
        table: 108
        scope: global
      routing-policy:
      - from: 1.1.101.84/31
        table: 108
        priority: 0
      - to: 1.1.101.84/16
        table: 108
        priority: 1
```

After the previous netplan file is applied, ensure to start and enable networked service. This disables any prior network configuration performed with the network manager.

```
sudo systemctl enable systemd-networkd
sudo systemctl start systemd-networkd
```

After the previous netplan file is applied, the `ip rule show` command should list eight additional rules and eight additional routing tables should be populated.

```
$ ip rule show
0:      from all lookup local
0:      from 1.1.101.14/31 lookup 101 proto static
0:      from 1.1.101.24/31 lookup 102 proto static
1:      from all to 1.1.101.14/16 lookup 101 proto static
1:      from all to 1.1.101.24/16 lookup 102 proto static
0:      from 1.1.101.34/31 lookup 103 proto static
0:      from 1.1.101.44/31 lookup 104 proto static
1:      from all to 1.1.101.34/16 lookup 103 proto static
1:      from all to 1.1.101.44/16 lookup 104 proto static
0:      from 1.1.101.54/31 lookup 105 proto static
0:      from 1.1.101.64/31 lookup 106 proto static
1:      from all to 1.1.101.54/16 lookup 105 proto static
1:      from all to 1.1.101.64/16 lookup 106 proto static
0:      from 1.1.101.74/31 lookup 107 proto static
0:      from 1.1.101.84/31 lookup 108 proto static
1:      from all to 1.1.101.74/16 lookup 107 proto static
1:      from all to 1.1.101.84/16 lookup 108 proto static
32766:  from all lookup main
32767:  from all lookup default

$ ip route show table 101
default via 1.1.101.14 dev eth1 proto static

$ ip route show table 102
default via 1.1.101.24 dev eth2 proto static

$ ip route show table 103
default via 1.1.101.34 dev eth3 proto static
```

```
$ ip route show table 104
default via 1.1.101.44 dev eth4 proto static

$ ip route show table 105
default via 1.1.101.54 dev eth5 proto static

$ ip route show table 106
default via 1.1.101.64 dev eth6 proto static

$ ip route show table 107
default via 1.1.101.74 dev eth7 proto static

$ ip route show table 108
default via 1.1.101.84 dev eth8 proto static
```

2.4.2.2 Host 2 netplan file:/etc/netplan/00-installer-config-host2.yaml

```
network:
   version: 2
   renderer: networkd
   ethernets:
   eth1:
      mtu: 9000
      addresses:
      - 1.1.102.15/31
      routes:
      - to: default
        via: 1.1.102.14
        table: 101
        scope: global
      routing-policy:
      - from: 1.1.102.14/31
        table: 101
        priority: 0
      - to: 1.1.102.14/16
        table: 101
        priority: 1
    eth2:
      mtu: 9000
      addresses:
      - 1.1.102.25/31
      routes:
      - to: default
        via: 1.1.102.24
        table: 102
        scope: global
      routing-policy:
      - from: 1.1.102.24/31
        table: 102
        priority: 0
      - to: 1.1.102.24/16
        table: 102
        priority: 1
    eth3:
      mtu: 9000
      addresses:
```

```
      - 1.1.102.35/31
      routes:
      - to: default
        via: 1.1.102.34
        table: 103
        scope: global
      routing-policy:
      - from: 1.1.102.34/31
        table: 103
        priority: 0
      - to: 1.1.102.34/16
        table: 103
        priority: 1
    eth4:
      mtu: 9000
      addresses:
      - 1.1.102.45/31
      routes:
      - to: default
        via: 1.1.102.44
        table: 104
        scope: global
      routing-policy:
      - from: 1.1.102.44/31
        table: 104
        priority: 0
      - to: 1.1.102.44/16
        table: 104
        priority: 1
    eth5:
      mtu: 9000
      addresses:
      - 1.1.102.55/31
      routes:
      - to: default
        via: 1.1.102.54
        table: 105
        scope: global
      routing-policy:
      - from: 1.1.102.54/31
        table: 105
        priority: 0
      - to: 1.1.102.54/16
        table: 105
        priority: 1
    eth6:
      mtu: 9000
      addresses:
      - 1.1.102.65/31
      routes:
      - to: default
        via: 1.1.102.64
        table: 106
        scope: global
      routing-policy:
      - from: 1.1.102.64/31
        table: 106
        priority: 0
```

```
      - to: 1.1.102.64/16
        table: 106
        priority: 1
    eth7:
      mtu: 9000
      addresses:
      - 1.1.102.75/31
      routes:
      - to: default
        via: 1.1.102.74
        table: 107
        scope: global
      routing-policy:
      - from: 1.1.102.74/31
        table: 107
        priority: 0
      - to: 1.1.102.74/16
        table: 107
        priority: 1
    eth8:
      mtu: 9000
      addresses:
      - 1.1.102.85/31
      routes:
      - to: default
        via: 1.1.102.84
        table: 108
        scope: global
      routing-policy:
      - from: 1.1.102.84/31
        table: 108
        priority: 0
      - to: 1.1.102.84/16
        table: 108
        priority: 1
```

After the previous netplan file is applied, ensure to start and enable networked service. This disables any prior network configuration performed with the network manager.

```
sudo systemctl enable systemd-networkd
sudo systemctl start systemd-networkd
```

After the previous netplan file is applied, the `ip rule show` command should list 16 additional rules and 8 additional routing tables should be populated.

```
$ ip rule show
0:      from all lookup local
0:      from 1.1.102.14/31 lookup 101 proto static
0:      from 1.1.102.24/31 lookup 102 proto static
1:      from all to 1.1.102.14/16 lookup 101 proto static
1:      from all to 1.1.102.24/16 lookup 102 proto static
0:      from 1.1.102.34/31 lookup 103 proto static
0:      from 1.1.102.44/31 lookup 104 proto static
1:      from all to 1.1.102.34/16 lookup 103 proto static
1:      from all to 1.1.102.44/16 lookup 104 proto static
0:      from 1.1.102.54/31 lookup 105 proto static
0:      from 1.1.102.64/31 lookup 106 proto static
```

```
1:      from all to 1.1.102.54/16 lookup 105 proto static
1:      from all to 1.1.102.64/16 lookup 106 proto static
0:      from 1.1.102.74/31 lookup 107 proto static
0:      from 1.1.102.84/31 lookup 108 proto static
1:      from all to 1.1.102.74/16 lookup 107 proto static
1:      from all to 1.1.102.84/16 lookup 108 proto static
32766:  from all lookup main
32767:  from all lookup default

$ ip route show table 101
default via 1.1.102.14 dev eth1 proto static

$ ip route show table 102
default via 1.1.102.24 dev eth2 proto static

$ ip route show table 103
default via 1.1.102.34 dev eth3 proto static

$ ip route show table 104
default via 1.1.102.44 dev eth4 proto static

$ ip route show table 105
default via 1.1.102.54 dev eth5 proto static

$ ip route show table 106
default via 1.1.102.64 dev eth6 proto static

$ ip route show table 107
default via 1.1.102.74 dev eth7 proto static

$ ip route show table 108
default via 1.1.102.84 dev eth8 proto static
```

The corresponding sample Ethernet switch configuration with respect to configuring the IP addresses and the routing on the switch is shown in the following example. The sample configuration is based on a Dell Z9664 Ethernet switch and a Supermicro SSE-T8032 Ethernet switch running SONiC. Only the configuration pertinent to the routing scheme outlined in this section is presented.

NOTE: The following example uses a port scheme where the different NICs of the same host are connected to the consecutive front panel Ethernet switch ports. However, it's also possible to connect NIC1 of each host to the consecutive front panel switch ports and so on.

2.4.2.3 Ethernet Leaf Switch Port Configuration for 31-bit Subnet Scheme on Dell Z9664 Switch Running SONiC OS

```
interface Eth1/1
 description node1_eth1
 mtu 9100
 speed 400000
 fec RS
 standalone-link-training
 no shutdown
 ip address 1.1.101.14/31
!
interface Eth1/2
 description node1_eth2
 mtu 9100
 speed 400000
 fec RS
 standalone-link-training
 no shutdown
 ip address 1.1.101.24/31
!
interface Eth1/3
 description node1_eth3
 mtu 9100
 speed 400000
 fec RS
 standalone-link-training
 no shutdown
 ip address 1.1.101.34/31
!
interface Eth1/4
 description node1_eth4
 mtu 9100
 speed 400000
 fec RS
 standalone-link-training
 no shutdown
 ip address 1.1.101.44/31
!
interface Eth1/5
 description node1_eth5
 mtu 9100
 speed 400000
 fec RS
 standalone-link-training
 no shutdown
 ip address 1.1.101.54/31
!
interface Eth1/6
 description node1_eth6
 mtu 9100
 speed 400000
 fec RS
 standalone-link-training

 no shutdown
 ip address 1.1.101.64/31
```

```
!
interface Eth1/7
 description node1_eth7
 mtu 9100
 speed 400000
 fec RS
 standalone-link-training
 no shutdown
 ip address 1.1.101.74/31
!
interface Eth1/8
 description node1_eth8
 mtu 9100
 speed 400000
 fec RS
 standalone-link-training
 no shutdown
 ip address 1.1.101.84/31
!
interface Eth1/9
 description node2_eth1
 mtu 9100
 speed 400000
 fec RS
 standalone-link-training
 no shutdown
 ip address 1.1.102.14/31
!
interface Eth1/10
 description node2_eth2
 mtu 9100
 speed 400000
 fec RS
 standalone-link-training
 no shutdown
 ip address 1.1.102.24/31
!
interface Eth1/11
 description node2_eth3
 mtu 9100
 speed 400000
 fec RS
 standalone-link-training
 no shutdown
 ip address 1.1.102.34/31
!
interface Eth1/12
 description node2_eth4
 mtu 9100
 speed 400000
 fec RS
 standalone-link-training
 no shutdown
 ip address 1.1.102.44/31
!
interface Eth1/13
 description node2_eth5
 mtu 9100
```

```
 speed 400000
 fec RS
 standalone-link-training
 no shutdown
 ip address 1.1.102.54/31
!
interface Eth1/14
 description node2_eth6
 mtu 9100
 speed 400000
 fec RS
 standalone-link-training
 no shutdown
 ip address 1.1.102.64/31
!
interface Eth1/15
 description node2_eth7
 mtu 9100
 speed 400000
 fec RS
 standalone-link-training
 no shutdown
 ip address 1.1.102.74/31
!
interface Eth1/16
 description node2_eth8
 mtu 9100
 speed 400000
 fec RS
 standalone-link-training
 no shutdown
 ip address 1.1.102.84/31
!
```

2.4.2.4 Ethernet Leaf Switch Port Configuration for 31-bit Subnet Scheme on Juniper QFX5240 Switch

```
interfaces {
    et-0/0/1 {
        description "Breakout et-0/0/1";
        number-of-sub-ports 2;
        speed 400g;
    }
    et-0/0/1:0 {
        description to.AMD-ML3100-01;
        mtu 9216;
        unit 0 {
            family inet {
                mtu 9170;
                address 192.168.2.1/31;
            }
        }
    }
    et-0/0/1:1 {
        description to.AMD-ML3100-02;
        mtu 9216;
```

```
        unit 0 {
            family inet {
                mtu 9170;
                address 192.168.2.3/31;
            }
        }
    }
    et-0/0/2 {
        description "Breakout et-0/0/2";
        number-of-sub-ports 2;
        speed 400g;
    }
    et-0/0/2:0 {
        description to.AMD-ML3100-03;
        mtu 9216;
        unit 0 {
            family inet {
                mtu 9170;
                address 192.168.2.5/31;
            }
        }
    }
    et-0/0/2:1 {
        description to.AMD-ML3100-ML3100-04;
        mtu 9216;
        unit 0 {
            family inet {
                mtu 9170;
                address 192.168.2.7/31;
            }
        }
    }
    et-0/0/3 {
        description "Breakout et-0/0/3";
        number-of-sub-ports 2;
        speed 400g;
    }
    et-0/0/3:0 {
        description to.AMD-ML3100-ML3100-05;
        mtu 9216;
        unit 0 {
            family inet {
                mtu 9170;
                address 192.168.2.9/31;
            }
        }
    }
    et-0/0/3:1 {
        description to.AMD-ML3100-ML3100-06;
        mtu 9216;
        unit 0 {
            family inet {
                mtu 9170;
                address 192.168.2.11/31;
            }
        }
    }
    et-0/0/4 {
```

```
        description "Breakout et-0/0/4";
        number-of-sub-ports 2;
        speed 400g;
    }
    et-0/0/3:0 {
        description to.AMD-ML3100-ML3100-07;
        mtu 9216;
        unit 0 {
            family inet {
                mtu 9170;
                address 192.168.2.13/31;
            }
        }
    }
    et-0/0/3:1 {
        description to.AMD-ML3100-ML3100-08;
        mtu 9216;
        unit 0 {
            family inet {
                mtu 9170;
                address 192.168.2.15/31;
            }
        }
    }
}
```

2.4.3 Confirm Routing Between Different NICs Across Different Hosts

With the routing configured in the back-end network as shown in Configuring Host Routing for the Back-end Network, ping and trace route tests can be used to confirm that any NIC on any host can reach any other NIC on any other host.

```
# Example: ping Host1,NIC1 to Host2,NIC7
ping -I 192.168.1.1 192.168.7.2
traceroute -i eth1 192.168.7.2

# Example: ping Host1,NIC6 to Host2,NIC2
ping -I 192.168.6.1 192.168.2.2
traceroute -i eth6 192.168.2.2

# All highlighted items above will depend on netplan setup
```

The following shell script can be used to test the full mesh ping across all the NICs of two given hosts. The script runs ping tests from each NIC of host1 to each NIC of host2.

```
#!/bin/bash

host1_ip_list=(192.168.1.15 192.168.2.15 192.168.3.15 192.168.4.15 192.168.5.15 192.168.6.15
192.168.7.15 192.168.8.15)

host2_ip_list=(192.168.1.14 192.168.2.14 192.168.3.14 192.168.4.14 192.168.5.14 192.168.6.14
192.168.7.14 142.168.8.15)

for i in ${host1_ip_list[@]}
do
    for j in ${host2_ip_list[@]}
    do
        echo -e "\nping -I $i $j\n====================================\n"
```

```
        ping -I $i -c 1 $j > /dev/null
        if [ $? == 0 ]; then

            echo "Ping Passed"
        else
            echo -e "Ping Failed\n\n\n\n"
            exit 5
        fi
    done
done


# All highlighted items above will depend on netplan setup
```

2.5 Ethernet Switch Configuration for QoS and Congestion Control

Every GPU cluster and HPC Cluster has a single or multi-tier Ethernet switch architecture to connect all the NICs on all the hosts in the cluster. With multiple NICs and multiple hosts in the cluster communicating with each other all the time, and flows starting and stopping asynchronously, congestion in the network becomes inevitable. NCCL collectives also involve many-to-many and many-to-one communication patterns leading to congestion on various network paths.

RoCE provides a very high bandwidth and low latency transport, but it is sensitive to packet drops. Any packet drop incurred due to congestion in the switches or the NICs impacts RoCE performance. Therefore, to handle congestion, the NICs and the switches in the cluster need to be configured for Congestion Control.

Broadcom NICs implement the DCQCN-P Congestion Control Algorithm. DCQCN stands for Data Center Quantized Congestion Notification and DCQCN-P stands for DCQCN- Probabilistic. With the NICs using the DCQCN-P Congestion Control Algorithm, the switches in the network need to be configured for DCQCN-P as well.

In simple terms, the DCQCN algorithm relies on the switches marking the ECN field in the IP header of the RoCE v2 packets when the switch buffers rise beyond a configured threshold. The NIC receiving an ECN-marked packet sends a Congestion Notification Packet (CNP) to the NIC that sent the RoCE v2 packet that was ECN marked by the switch. The NIC, upon receiving a CNP regulates its sending rate to alleviate the congestion in the network. An important thing to note is that the Congestion Control Algorithm operates at the RoCE Connection or the RoCE Queue Pair(QP) level, with the RoCE v2 and the CNP packets carrying the QP number in them.

The DCQCN-P algorithm uses the probabilistic ECN marking. In probabilistic marking, minimum and maximum marking thresholds are specified at the switch together with maximum marking probability. When the switch egress port queue crosses the minimum threshold, marking starts at low probability which linearly increases between 0 and max probability in the range between min. and max. marking thresholds. After the maximum threshold is reached, every packet is marked (for example, 100% marking).

Congestion Control Algorithms help with Congestion in the network but do not make the network lossless. Even with Congestion Control configured in the network, packets can be dropped with flows starting asynchronously or due to an incast. To make the network lossless, Priority Flow Control (PFC) needs to be configured in the network.

When the NIC is configured for RoCE on a host along with the RoCE QOS configuration pkg (`bnxt_re_conf`), the NIC is automatically configured for DCQCN-P along with the following settings:

- RoCE v2 packets are marked with a DSCP value of 26 and use Priority 3 internally
- CNP packets are marked with a DSCP value of 48 and use Priority 7 internally
- PFC is enabled for Priority 3 traffic
- Three Traffic classes are set up, TC0 for non-RoCE traffic, TC1 for RoCE traffic, and TC2 for CNP traffic

- RoCE and non-RoCE traffic share ETS bandwidth of 50% each. The ETS bandwidth share applies only when the actual traffic is available to use the bandwidth share. In the absence of non-RoCE traffic, all the available bandwidth will be used by RoCE and conversely.
- CNP traffic is treated as ETS Strict Priority.

```
$ niccli -i 1 qos --ets --show

IEEE 8021QAZ ETS Configuration TLV:
         PRIO_MAP: 0:0 1:0 2:0 3:1 4:0 5:0 6:0 7:2
         TC Bandwidth: 50% 50% 0% 0% 0% 0% 0% 0%
         TSA_MAP: 0:ets 1:ets 2:strict 3:strict 4:strict 5:strict 6:strict 7:strict
IEEE 8021QAZ PFC TLV:
         PFC enabled: 3
IEEE 8021QAZ APP TLV:
         APP#0:
          Priority: 7
          Sel: 5
          DSCP: 48


         APP#1:
          Priority: 3
          Sel: 5
          DSCP: 26


         APP#2:
          Priority: 3
          Sel: 3
          UDP or DCCP: 4791


TC Rate Limit: 100% 100% 100% 0% 0% 0% 0% 0%


$ sudo niccli -i 1 qos --listmap --pri2cos

Base Queue is 0 for port 0.
------------------------
Priority   TC HW Queue ID
------------------------
 0         0    4
 1         0    4
 2         0    4
 3         1    0
 4         0    4
 5         0    4
 6         0    4
 7         2    5


$ sudo niccli -i 1 qos --dscp2prio

dscp2prio mapping:
          priority:7  dscp:48,
          priority:3  dscp:26,
```

Broadcom provides tools NICCLI and bnxtsetupcc.sh that allow changing the DSCP values, the Priority values, the ETS settings, and the PFC settings.

NOTE: The important thing to note is that the settings on the NIC and the Ethernet switches match each other.

Most network switches used for RoCE are based on Broadcom Ethernet switch silicon. The switch silicon provides the ability to configure PFC and Congestion Control settings. Prominent switch vendors such as Dell, Arista, Supermicro, Juniper Networks and so forth, implement their own Software Stacks for Ethernet switches. Each vendor provides their own command line interface (CLI) to configure the switches. The following sections describe how to configure popular Dell, Arista, Juniper Networks, and Supermicro switch models for PFC and DCQCN-P.

The switch configuration elements required are as follows:

- Map DSCP traffic priorities for RoCE and CNP traffic to traffic classes
- Enable PFC
- Enable ECN
- Configure ECN marking algorithm and ECN marking threshold

2.5.1 Example: Arista 7060CX (DCQCN-P at 400G) and 31-bit Subnet Scheme

```
qos map traffic-class 3 to dscp 26
qos map traffic-class 7 to dscp 48


qos profile QOS_ROCE_DCQCN
   qos trust dscp
   priority-flow-control on
   priority-flow-control priority 3 no-drop
   !
   uc-tx-queue 0
      no priority
   !
   uc-tx-queue 1
      no priority
   !
   uc-tx-queue 3
      no priority
      random-detect ecn minimum-threshold 1000 kbytes maximum-threshold 3000 kbytes
max-mark-probability 20 weight 0
!


interface Ethernet1/1
   mtu 9200
   flowcontrol send off
   flowcontrol receive off
   speed 400g-8
   error-correction encoding reed-solomon
   phy link training
   service-profile QOS_ROCE_DCQCN
   ip address 1.1.101.14/31
!


interface Ethernet2/1
   mtu 9200
```

```
   flowcontrol send off
   flowcontrol receive off
   speed 400g-8
   error-correction encoding reed-solomon
   phy link training
   service-profile QOS_ROCE_DCQCN
   ip address 1.1.101.24/31
!
```

2.5.2 Example: Dell Z9664 Switch and Supermicro SSE-T8032 Switch Running SONiC OS and 31-bit Subnet Scheme

```
qos wred-policy ROCE
 green minimum-threshold 1048 maximum-threshold 2097 drop-probability 5
 ecn green
!
qos scheduler-policy ROCE
 !
 queue 0
  type dwrr
  weight 50
 !
 queue 3
  type dwrr
  weight 50
 !
 queue 4
  type dwrr
  weight 50
 !
 queue 6
  type strict
!


qos map dscp-tc ROCE
 dscp 0-3,5-23,25,27-47,49-63 traffic-class 0
 dscp 24,26 traffic-class 3
 dscp 4 traffic-class 4
 dscp 48 traffic-class 6
!
qos map dot1p-tc ROCE
 dot1p 0-2,5-7 traffic-class 0
 dot1p 3 traffic-class 3
 dot1p 4 traffic-class 4
!
qos map tc-queue ROCE
 traffic-class 0 queue 0
 traffic-class 1 queue 1
 traffic-class 2 queue 2
 traffic-class 3 queue 3
 traffic-class 4 queue 4
 traffic-class 5 queue 5
 traffic-class 6 queue 6
 traffic-class 7 queue 7
!
```

```
qos map tc-pg ROCE
 traffic-class 3 priority-group 3
 traffic-class 4 priority-group 4
 traffic-class 0-2,5-7 priority-group 7
!
qos map pfc-priority-queue ROCE
 pfc-priority 0 queue 0
 pfc-priority 1 queue 1
 pfc-priority 2 queue 2
 pfc-priority 3 queue 3
 pfc-priority 4 queue 4
 pfc-priority 5 queue 5
 pfc-priority 6 queue 6
 pfc-priority 7 queue 7
!


interface Eth1/1
 description node1_eth2
 mtu 9100
 speed 400000
 fec RS
 standalone-link-training
 unreliable-los auto
 no shutdown
 ip address 1.1.101.14/31
 queue 3 wred-policy ROCE
 scheduler-policy ROCE
 qos-map dscp-tc ROCE
 qos-map dot1p-tc ROCE
 qos-map tc-queue ROCE
 qos-map tc-pg ROCE
 qos-map pfc-priority-queue ROCE
 priority-flow-control priority 3
 priority-flow-control priority 4
 priority-flow-control watchdog action drop
 priority-flow-control watchdog on detect-time 200
 priority-flow-control watchdog restore-time 400
!
```

```
interface Eth1/2
 description node1_eth2
 mtu 9100
 speed 400000
 fec RS
 standalone-link-training
 unreliable-los auto
 no shutdown
 ip address 1.1.101.24/31
 queue 3 wred-policy ROCE
 scheduler-policy ROCE
 qos-map dscp-tc ROCE
 qos-map dot1p-tc ROCE
 qos-map tc-queue ROCE
 qos-map tc-pg ROCE
 qos-map pfc-priority-queue ROCE
 priority-flow-control priority 3
 priority-flow-control priority 4
 priority-flow-control watchdog action drop
 priority-flow-control watchdog on detect-time 200
 priority-flow-control watchdog restore-time 400
!
```

2.5.3 Example: Juniper QFX5240 Switch and 31-bit Subnet Scheme

```
forwarding-options {
    hash-key {
        family inet {
            layer-3;
            layer-4;
        }
    }
    enhanced-hash-key {
        ecmp-dlb {
            flowlet {
                inactivity-interval 256;
                flowset-table-size 2048;
                reassignment {
                    prob-threshold 3;
                    quality-delta 6;
                }
            }
            ether-type {
                ipv4;
            }
            sampling-rate 1000000;
        }
    }
}
class-of-service {
    classifiers {
        dscp mydscp {
            forwarding-class CNP {
                loss-priority low code-points 110000;
            }
            forwarding-class NO-LOSS {
```

```
                loss-priority low code-points 011010;
            }
        }
    }
    drop-profiles {
        dp1 {
            interpolate {
                fill-level [ 55 90 ];
                drop-probability [ 0 100 ];
            }
        }
    }
    shared-buffer {
        ingress {
            buffer-partition lossless {
                percent 80;
            }
            buffer-partition lossless-headroom {
                percent 10;
            }
            buffer-partition lossy {
                percent 10;
            }
        }
        egress {
            buffer-partition lossless {
                percent 80;
            }
            buffer-partition lossy {
                percent 10;
            }
        }
    }
    forwarding-classes {
        class CNP queue-num 3;
        class NO-LOSS queue-num 4 no-loss pfc-priority 3;
    }
    congestion-notification-profile {
        cnp {
            input {
                dscp {
                    code-point 011010 {
                        pfc;
                    }
                }
            }
            output {
                ieee-802.1 {
                    code-point 011 {
                        flow-control-queue 4;
                    }
                }
            }
        }
    }
    interfaces {
        et-* {
            congestion-notification-profile cnp;
```

```
            scheduler-map sm1;
            unit * {
                classifiers {
                    dscp mydscp;
                }
            }
        }
    }
    scheduler-maps {
        sm1 {
            forwarding-class CNP scheduler s2-cnp;
            forwarding-class NO-LOSS scheduler s1;
        }
    }
    schedulers {
        s1 {
            drop-profile-map loss-priority any protocol any drop-profile dp1;
            explicit-congestion-notification;
        }
        s2-cnp {
            transmit-rate percent 5;
            priority strict-high;
        }
    }
}
```

2.6 Final Checks and Settings for Optimal Performance

The following final checks can be made to ensure that the software, the firmware, the tools, and other settings are configured correctly for optimal Peer Memory Direct performance.

1. Ensure the `bnxt_en.ko`, `bnxt_re.ko`, and `ib_peer_mem.ko` kernel modules are loaded and are the correct version.

NOTE: Certain Ubuntu kernels have built-in `ib_peer_mem` support; these kernels do not require `ib_peer_mem` to be built and loaded from the Broadcom-provided release. The kernel driver Makefile can detect if `ib_peer_mem` is required to be built or not and act accordingly.

2. Ensure that the file `/etc/bnxt_re/bnxt_re.conf` has the correct RoCE QOS values and each NIC has the correct QOS settings. The QOS settings on each NIC can be confirmed via the following `niccli qos --ets --show` command:

```
niccli --dev <index | pci b:d:f | mac> qos --ets --show
```

3. Make sure nvidia-peermem module is loaded when using NVIDIA GPUs.

```
lsmod | grep peer
nvidia_peermem         16384  0
nvidia               9744384  3 nvidia_uvm,nvidia_peermem,nvidia_modeset
ib_uverbs             196608  3 nvidia_peermem,bnxt_re,rdma_ucm
```

4. PCIe Access Control Service (ACS) is disabled on the PCIe switch connecting the NIC and the GPU to allow PCIe Peer to Peer Transactions between the GPU and the NIC. If ACS is enabled, performance will degrade.
5. IOMMU is disabled or is in Pass Through (PT) mode.
6. The following tandard InfiniBand Commands work correctly. These commands are part of the infiniband-diags package which can be downloaded by the OS distro's package manager:

- `ibstatus`
- `ibv_devinfo -vvv`
- `ibdev2netdev`

7. NIC NVM Configuration (to enable RDMA, performance profile, and PCIe Relaxed Ordering) is set to enabled.
8. The NIC interface shows the NIC link is up and linked at the correct speed. This can be verified using one of the following commands.
   - `ibstatus`
   - `ethtool <ifname>`
9. An IP address is assigned to the NIC interface and the IP address is visible as GID 3 for IPv4 addresses or IPv6 addresses in the `ibv_devinfo -vvv` command:
   - `rdma link show`
   - `ibv_devinfo -vvv`
   - `ibv_devinfo -vvv -d  <roce_interface_name>`
     (example, `ibv_devinfo -vvv -d bnxt_re0`)
10. Interface MTU size is set to 9000 bytes on the host for maximum throughput.
11. The Ethernet switch port to which the NIC connects has its MTU set to 9000.
12. The PCIe slot for the NIC shows correct PCIe GEN speed and width.
    - `lspci -vvv  -s <B:D:F>`
13. Firewall is disabled on the communicating hosts in case it prevents RDMA connections from being set up.
14. There are no NIC and GPU-related errors in the Linux dmesg logs.
15. For NCCL testing, NUMA balancing is disabled on each host participating in the NCCL tests.

```
echo 0 >   /proc/sys/kernel/numa_balancing or
sysctl -w kernel.numa_balancing=0
```

Another option is to add the following entry to file `/etc/sysctl.d/99-sysctl.conf` so that the setting takes effect automatically after a reboot.

```
kernel.numa_balancing=0
```

2.7 Installing and Compiling Perftest with NVIDIA GPU Support

NOTE: The following instructions are intended for recompiled perftest utility that can be run directly from the home directory. The instructions assume CUDA toolkit is already installed.

```
sudo apt install libibumad-i
sudo apt install pciutils
sudo apt install libpci*
sudo apt install automake autoconf libtool libibverbs-i ibverbs-utils infiniband-diags  ethtool
librdmacm-i
git clone https://github.com/linux-rdma/perftest.git
cd perftest/
./autogen.sh
./configure CUDA_H_PATH=/usr/local/cuda/include/cuda.h
make

./ib_write_bw -h | grep -i cuda
--use_cuda=<cuda device id> Use CUDA specific device for GPUDirect RDMA testing
--use_cuda_bus_id=<cuda full BUS id> Use CUDA specific device, based on its full PCIe address
```

2.8 Validating Peer Memory Direct Support with Perftest

This section provides information on validating Peer Memory Direct Support with Perftest.

2.8.1 Using an NVIDIA GPU

```
$HOME/perftest/ib_write_bw -d <roce-interface-name> --use_cuda=<gpu-id> -a -F -x 3 --report_gbits -q
2 -b
```

With the routing configured in the back-end network as shown in Configuring Routing for the Back-End Network, perftest can be used for RDMA tests across different NICs on different hosts.

2.8.2 Example – ib_write_bw test using Broadcom NIC with NVIDIA GPU

The following example of running `ib_write_bw` test using a Broadcom NIC with an NVIDIA GPU across Host1, NIC0, and Host2, NIC0. For the best `peer_memory` direct performance, the GPUs used for this test should be the one closest to the NIC on the PCIe Bus.

```
# Start Server on Host1

$ $HOME/perftest/bin/ib_write_bw -d bnxt_re0 --use_cuda=0 -a -F -x 3 -q 4 --report_gbits

# Start Client on Host2

$ $HOME/perftest/bin/ib_write_bw -d bnxt_re0 --use_cuda=0 -a -F -x 3 -q 4 --report_gbits 1.1.102.15

Perftest doesn't supports CUDA tests with inline messages: inline size set to 0
initializing CUDA
Listing all CUDA devices in system:
CUDA device 0: PCIe address is 18:00
CUDA device 1: PCIe address is 2B:00
CUDA device 2: PCIe address is 3A:00
CUDA device 3: PCIe address is 5E:00
CUDA device 4: PCIe address is 84:00
CUDA device 5: PCIe address is 9D:00
CUDA device 6: PCIe address is B0:00
CUDA device 7: PCIe address is D7:00

Picking device No. 0
[pid = 7710, dev = 0] device name = [NVIDIA H100 80GB HBM3]
creating CUDA Ctx
making it the current CUDA Ctx
CUDA device integrated: 0
cuMemAlloc() of a 67108864 bytes GPU buffer
allocated GPU buffer address at 000074ddf0000000 pointer=0x74ddf0000000
---------------------------------------------------------------------------------------
                    RDMA_Write BW Test
 Dual-port       : OFF          Device         : bnxt_re0
 Number of qps   : 4            Transport type : IB
 Connection type : RC           Using SRQ      : OFF
 PCIe relax order: ON
 ibv_wr* API     : OFF
 TX depth        : 128
 CQ Moderation   : 100
 Mtu             : 4096[B]
 Link type       : Ethernet
 GID index       : 3
 Max inline data : 0[B]
 rdma_cm QPs     : OFF
 Data ex. method : Ethernet
---------------------------------------------------------------------------------------
 local address: LID 0000 QPN 0x2c01 PSN 0xee4161 RKey 0x2000001 VAddr 0x0074ddf2000000
 GID: 00:00:00:00:00:00:00:00:00:00:255:255:01:01:101:15
 local address: LID 0000 QPN 0x2c02 PSN 0x626637 RKey 0x2000001 VAddr 0x0074ddf2800000
 GID: 00:00:00:00:00:00:00:00:00:00:255:255:01:01:101:15
 local address: LID 0000 QPN 0x2c03 PSN 0xe070b5 RKey 0x2000001 VAddr 0x0074ddf3000000
 GID: 00:00:00:00:00:00:00:00:00:00:255:255:01:01:101:15
 local address: LID 0000 QPN 0x2c04 PSN 0xd53a60 RKey 0x2000001 VAddr 0x0074ddf3800000
 GID: 00:00:00:00:00:00:00:00:00:00:255:255:01:01:101:15
```

```
 remote address: LID 0000 QPN 0x2c01 PSN 0xb642de RKey 0x2000001 VAddr 0x00739cf6000000
 GID: 00:00:00:00:00:00:00:00:00:00:255:255:01:01:102:15
 remote address: LID 0000 QPN 0x2c02 PSN 0x93c9a7 RKey 0x2000001 VAddr 0x00739cf6800000
 GID: 00:00:00:00:00:00:00:00:00:00:255:255:01:01:102:15
 remote address: LID 0000 QPN 0x2c03 PSN 0x7f42f RKey 0x2000001 VAddr 0x00739cf7000000
 GID: 00:00:00:00:00:00:00:00:00:00:255:255:01:01:102:15
 remote address: LID 0000 QPN 0x2c04 PSN 0xc95e1b RKey 0x2000001 VAddr 0x00739cf7800000
 GID: 00:00:00:00:00:00:00:00:00:00:255:255:01:01:102:15
---------------------------------------------------------------------------------------
 #bytes     #iterations    BW peak[Gb/sec]    BW average[Gb/sec]   MsgRate[Mpps]
 2          20000           0.071589           0.071102            4.443871
 4          20000            0.13              0.13                3.955896
 8          20000            0.28              0.28                4.302460
 16         20000            0.52              0.52                4.040328
 32         20000            0.95              0.95                3.704634
 64         20000            1.73              1.73                3.370019
 128        20000            3.81              3.71                3.621056
 256        20000            6.91              6.91                3.371592
 512        20000            14.42             13.92               3.399008
 1024       20000            27.63             27.57               3.365319
 2048       20000            55.26             55.16               3.366869
 4096       20000            111.27            111.15              3.392172
 8192       20000            222.53            221.91              3.386064
 16384      20000            387.79            387.59              2.957057
 32768      20000            390.10            389.81              1.487013
 65536      20000            391.12            390.98              0.745735
 131072     20000            391.63            391.61              0.373472
 262144     20000            391.89            391.85              0.186850
 524288     20000            392.01            392.00              0.093461
 1048576    20000            392.08            392.07              0.046739
 2097152    20000            392.11            392.11              0.023371
 4194304    20000            392.12            392.12              0.011686
 8388608    20000            392.13            392.13              0.005843
---------------------------------------------------------------------------------------
deallocating GPU buffer 000074ddf0000000
destroying current CUDA Ctx
```

NOTE: The GPU buffers are allocated before the start of the test and deallocated after test completion. This confirms that perftest is running with Peer Mem.

Chapter 3: System BIOS

3.1 BIOS Setting Recommendations

The following BIOS settings (see Table 2) are recommended by Dell for their XE9680 AI//ML server. The BIOS settings disable IOMMU and ACS on the host as well.

Table 2: BIOS Settings Recommendations

UEFI/BIOS Area	Value
BIOS -> Processor Settings	Logical Processor = Disable
	Virtualization Technology = Disable
	SubNumaCluster = Disable
	MADt Core cluster = Linear
BIOS -> Integrated Devices	Global SRIOV = Disable
BIOS -> System Profile Setting	Server System Profile = Performance
	Workload = Not Configured
BIOS -> System Security	AC Recovery Delay = Random (highly recommended)

Chapter 4: Atlas2 PCIe Switch Configuration

There are four switches in the system. Each switch is partitioned into two virtual switches. Each VS has 4 to 5 downstream ports. Station 0 is configured as 4 x 4 and other stations are all x16.

See Appendix C, PCIe Link Speed and Width Related Scripts for a bash shell script that can be used to disable ACS on a host.

Chapter 5: Debugging Thor2 NIC

5.1 Frequently Asked Questions and Troubleshooting

1. RoCE interface names on a host do not have names like `bnx_re0`, `bnxt_re1`, and so forth.

   This is due to the setting `NAME_FALLBACK` in file `/usr/lib/udev/rules.d/60-rdma-persistent-naming.rules` as follows:

   ```
   ACTION=="add", SUBSYSTEM=="infiniband", PROGRAM="rdma_rename %k NAME_FALLBACK"
   ```

   With `NAME_FALLBACK`, the RoCE interfaces are named based on the PCIe ID of the PCIe slot used for the NIC. Replacing `NAME_FALLBACK` with `NAME_KERNEL` will rename the RoCE interfaces to the `bnxt_reX` format.

2. RoCE perftests (`ib_write_bw`, `ib_read_bw`, `ib_send_bw`) fail with status 12 as shown in the following example:

   ```
   ib_write_bw -d roceo3811 -F -x 3 192.168.1.11

   ---------------------------------------------------------------------------------------
                       RDMA_Write BW Test
    Dual-port       : OFF          Device         : roceo3811
    Number of qps   : 1            Transport type : IB
    Connection type : RC           Using SRQ      : OFF
    PCIe relax order: ON
    ibv_wr* API     : OFF
    TX depth        : 128
    CQ Moderation   : 100
    Mtu             : 4096[B]
    Link type       : Ethernet
    GID index       : 3
    Max inline data : 0[B]
    rdma_cm QPs     : OFF
    Data ex. method : Ethernet
   ---------------------------------------------------------------------------------------
    local address: LID 0000 QPN 0x2c02 PSN 0xab5dfe RKey 0x2000007 VAddr 0x007ff32cb4a000
    GID: 00:00:00:00:00:00:00:00:00:00:255:255:192:168:01:13
    remote address: LID 0000 QPN 0x2c02 PSN 0x987205 RKey 0x2000207 VAddr 0x007fee3ba00000
    GID: 00:00:00:00:00:00:00:00:00:00:255:255:192:168:01:11
   ---------------------------------------------------------------------------------------
    Completion with error at client
    Failed status 12: wr_id 0 syndrom 0xa
   scnt=128, ccnt=0
    Failed to complete run_iter_bw function successfully
   ```

   Failed Status 12 means that the RoCE packets cannot be transferred across the connection and point to a networking error. Often (not always) this is due to the switch MTU not being set to 9000. On some switches, if the switch port belongs to a VLAN, the VLAN MTU size must be set to 9000 as well. By default, perftest uses a 64 KB msg size which requires multiple 4096 byte MTUs to transfer. Therefore, if the switch MTU is not configured to 9000, the switch drops 4096 byte RoCE packets.

3. How to check if `ib_peer_mem` is part of the kernel or if it must be loaded as `ib_peer_mem.ko` kernel module. Use the following command:

   ```
   cat /proc/kallsyms | grep -i ib_register_peer_memory_client
   ```

If the `ib_register_peer_memory_client` symbol is provided by `ib_uverbs`, then `ib_peer_mem` is part of the kernel. Installing the Broadcom software stack will not install and load the `ib_peer_mem.ko` kernel module. If the output of the cat command shows that the `ib_register_peer_memory_client` symbol is provided by `ib_peer_mem`, it means that the Broadcom `ib_peer_mem` kernel module is loaded into the kernel. If the cat command returns empty, the `ib_peer_mem` is not yet loaded into the kernel. Installing the Broadcom stack should load the module.

```
$ cat /proc/kallsyms | grep -i ib_register_peer_memory_client
0000000000000000 r __kstrtab_ib_register_peer_memory_client     [ib_uverbs]
0000000000000000 r __kstrtabns_ib_register_peer_memory_client   [ib_uverbs]
0000000000000000 r __ksymtab_ib_register_peer_memory_client     [ib_uverbs]
0000000000000000 r __crc_ib_register_peer_memory_client [ib_uverbs]
0000000000000000 r __export_symbol_ib_register_peer_memory_client       [ib_uverbs]
0000000000000000 t __pfx_ib_register_peer_memory_client [ib_uverbs]
0000000000000000 T ib_register_peer_memory_client       [ib_uverbs]
```

4. Make sure nvidia-peermem module is loaded when using NVIDIA GPUs.

```
lsmod | grep peer
nvidia_peermem         16384  0
nvidia               9744384  3 nvidia_uvm,nvidia_peermem,nvidia_modeset
ib_uverbs             196608  3 nvidia_peermem,bnxt_re,rdma_ucm
```

5. QOS (PFC, DSCP, ETS) is not configured after RoCE driver load or host reboot.

   If the NICCLI `getqos` command shows an output similar to the following, the QOS for RoCE is not configured.

```
$ sudo niccli -i <index | pci b:d:f | mac> qos --ets --show
IEEE 8021QAZ ETS Configuration TLV:
         PRIO_MAP: 0:0 1:0 2:0 3:0 4:0 5:0 6:0 7:0
         TC Bandwidth: 0% 0% 0% 0% 0% 0% 0% 0%
         TSA_MAP: 0:strict 1:strict 2:strict 3:strict 4:strict 5:strict 6:strict 7:strict
IEEE 8021QAZ PFC TLV:
         PFC enabled: none
```

   This generally means that firmware-based DCBX or firmware-based LLDP is enabled and the RoCE driver (`bnxt_re`) did not configure the QOS for the given NIC interface. The dmesg logs have errors similar to the following:

```
infiniband bnxt_re2: Fail to setets rc:-22
infiniband bnxt_re2: Fail to initialize Flow control
```

   Ensure that the following NVM CFGs are disabled. See Firmware Based DCBx NVM CFG on NIC.

   a. dcbx_mode
   b. lldp_nearest_bridge
   c. lldp_nearest_non_tpmr_bridge

6. The following error is seen when running RDMA-related commands such as:

```
$ ibv_devinfo -vvv
libibverbs: Warning: Driver bnxt_re does not support the kernel ABI of 6 (supports 1 to 1) for
device /sys/class/infiniband/bnxt_re0
libibverbs: Warning: Driver bnxt_re does not support the kernel ABI of 6 (supports 1 to 1) for
device /sys/class/infiniband/bnxt_re0
```

   This means the inbox `libbnxt_re` library is being used. We need to use the out of box `libbnxt_re` library. This can happen if the out of box library has not been installed or the rdma-core package on the host has been updated. Use the command `strace ibv_devinfo 2>&1 | grep libbnxt_re | grep -v 'No such file'` identify the path of the current `libbnxt_re` library and rename or delete it.

```
$ strace ibv_devinfo 2>&1 | grep libbnxt_re | grep -v 'No such file'
openat(AT_FDCWD, "/usr/lib/x86_64-linux-gnu/libibverbs/libbnxt_re-rdmav34.so",
O_RDONLY|O_CLOEXEC) = 3
```

7. Broadcom software installation fails due to errors similar to:

```
bnxt_re: disagrees about version of symbol ib_umem_release
bnxt_re: Unknown symbol ib_umem_release (err -22)
bnxt_re: disagrees about version of symbol ib_modify_qp_is_ok
bnxt_re: Unknown symbol ib_modify_qp_is_ok (err -22)
```

   Check if the MLNX OFED is installed on the host. MLNX OFED install removes the standard `RDMA/ib_core` kernel modules and rdma-core user space libraries from the host and installs MLNX OFED specific variants. After that, the install of the Broadcom RoCE software stack fails. Check for the presence of `/usr/sbin/ofed_uninstall.sh` shell script. If the script exists, it indicates MLNX OFED is installed on the host. Execute `/usr/sbin/ofed_uninstall.sh` which uninstalls MLNX OFED from the host, then reboot the host. After reboot, the `/user/sbin/ofed_uninstall.sh` script no longer exists and the Broadcom stack installs.

8. RoCE (non-GPU) performance using perftest (`ib_write_bw`) is low (~235 Gbps) but GPU based perftest (`ib_write_bw`) performance is at line rate (~320 Gbps).

   One of the reasons for low RoCE (non-GPU) performance, but good GPU based RoCE performance is the **Memory Interleaving** BIOS setting on some hosts. The **Memory Interleaving** option should not be disabled and set to **Auto**. If disabled, RoCE (non-GPU) performance suffers due to Host Memory BW limitation.

9. How to capture RoCE packets on a host using tcpdump.

   For debug purposes, RoCE packets can be captured on a host via tcpdump. RoCE packet capture is not a production feature as it has its side effects, but can be very useful in debugging certain problems. The following two NVM CFG options must be modified to enable RoCE packet capture.

   a. `enable_sriov` should be set to value 0 (Disabled)

   b. `default_evb_mode`s should be set to value 3 (none)

   To check the option values, use the following commands:

```
sudo niccli -i <index | pci b:d:f | mac> nvm --getoption enable_sriov
# The highlighted item will change depending on the index or PCIE BDF or MAC


# Example:
sudo niccli -i 1 nvm --getoption enable_sriov

sudo niccli -i <index | pci b:d:f | mac> nvm --getoption default_evb_mode --scope <pf number>
# First highlighted item will change depending on the index or PCIE BDF or MAC
# Second highlighted item will change depending on the PF

# Example:
sudo niccli -i 1 nvm --getoption default_evb_mode --scope 0
```

   To set the value of the options, use the following commands:

```
sudo niccli -i <index | pci b:d:f | mac> nvm --setoption enable_sriov --value 0
# The highlighted item will change depending on the index or PCIE BDF or MAC
```

```
# Example:
$ sudo niccli -i 1 nvm --setoption enable_sriov --value 0


$ sudo niccli  -i <index | pci b:d:f | mac> nvm --setoption default_evb_mode --scope <pf number>
--value 3
# First highlighted item will change depending on the index or PCIE BDF or MAC
# Second highlighted item will change depending on the PF

# Example:
$ sudo niccli -i 1 nvm --setoption default_evb_mode --scope 0 --value 3
```

A reboot is required for the modified NVM CFGs to take effect. After the reboot, tcpdump must be run on the Ethernet interface name (not the RoCE interface name). See the following example:

```
$ rdma link show
link bnxt_re0/1 state ACTIVE physical_state LINK_UP netdev enp30s0np0
link bnxt_re1/1 state ACTIVE physical_state LINK_UP netdev enp67s0np0
link bnxt_re2/1 state ACTIVE physical_state LINK_UP netdev enp86s0np0
link bnxt_re3/1 state ACTIVE physical_state LINK_UP netdev enp105s0np0
link bnxt_re4/1 state ACTIVE physical_state LINK_UP netdev enp160s0np0
link bnxt_re5/1 state ACTIVE physical_state LINK_UP netdev enp195s0np0
link bnxt_re6/1 state ACTIVE physical_state LINK_UP netdev enp213s0np0
link bnxt_re7/1 state ACTIVE physical_state LINK_UP netdev enp231s0np0


$ tcpdump -i enp30s0np0 udp
```

Starting with the 2.34 release, roce pkt capture via tcpdump requires tcpdump to be executed on the RoCE interface name instead of the ethernet interface name.

```
$ tcpdump -i bnxt_re0 udp
```

5.2 BCM_SOSREPORT

The Broadcom SOS reporting tool builds on the open source `sosreport` tool to collect system information for support purposes. The following sections describe how to create the `bcm_sosreport` package and how to install and run the tool. The report that is generated can be sent to a Broadcom support representative for analysis.

On a Ubuntu host, the tool can be installed and executed as follows:

```
To install the tool on a Ubuntu Host
$ dpkg -i bcm_sosreport_<version>.deb

To execute the tool
$ bcm_sosreport
```

See the following link for additional details on `bcm_sosreport`.

Chapter 6: Installing NVIDIA GPU Drivers

The NVIDIA GPU driver installation process, outlined in the NVIDIA GPU Driver Installation section, sets up the NVIDIA GPU driver.

Chapter 7: Running NCCL Collectives

Install NCCL as described in Peer Memory Direct Configuration with BCM957608.

To run NCCL across multiple nodes in a cluster, Open MPI installation is required. Open MPI is only used to launch the NCCL tests or processes across multiple nodes. Additionally, UCX can be used along with Open MPI to launch the NCCL tests/processes across multiple nodes. NCCL itself does not use Open MPI or UCX for its operation. See Table 3 for the software component versions used for AI/ML/HPC applications. It is recommended to install and execute Open MPI, UCX, and nccl-tests as a non-root user. Passwordless SSH should be set up for the non-root user as well.

Table 3: NVIDIA GPU

Component Name	Component Version
Cuda version	13.0.2
UCX	1.19
OpenMPI	5.0.8
NCCL version	2.28.7
GDRCOPY git clone	https://github.com/NVIDIA/gdrcopy.git (current version GDR-Copy 2.5.1)

7.1 Setting Up the Environmental Variable

To set up environment variables, use the following commands:

```
export UCX_VER=vXXX
export OMPI_VER=vXXX
```

NOTE: See Table 3 for the correct version numbers.

7.2 Installing UCX for NVIDIA GPUs

To install UCX for NVIDIA GPUs, use the following examples:

```
cd $HOME
git clone --recursive -b ${UCX_VER} https://github.com/openucx/ucx.git
cd ucx
./autogen.sh
mkdir ucx_install
mkdir build
cd build
../configure --with-cuda=/usr/local/cuda --with-verbs --with-go=no --enable-debug
--prefix=$HOME/ucx/ucx_install
make -j ${nproc}
make -j $(nproc) install

# Verify by running
$HOME/ucx/ucx_install/bin/ucx_info -d
```

7.3 Installing Open MPI for NVIDIA GPUs

To install Open MPI for NVIDIA GPUs, use the following commands:

```
# The Open MPI build needs to point to the UCX installation $HOME/ucx/ucx_install
# as shown in the steps below.

# On Ubuntu please install flex
sudo apt install flex

cd $HOME
git clone --recursive -b $OMPI_VER  https://github.com/open-mpi/ompi.git
cd ompi

./autogen.pl
mkdir build
mkdir ompi_install

cd build

../configure --prefix=$HOME/ompi/ompi_install --with-cuda=/usr/local/cuda
--with-cuda-libdir=/usr/local/cuda/targets/x86_64-linux/lib/stubs --with-verbs
--with-ucx=$HOME/ucx/ucx_install --enable-debug

make -j $(nproc)
make -j $(nproc) install


# Verify by running
$HOME/ompi/ompi_install/bin/ompi_info --parsable --all | grep mpi_built_with_cuda_support:value

$HOME/ompi/ompi_install/bin/ompi_info | grep "MPI extensions"
```

Open MPI BTL openib requires Broadcom NIC PCIE vendor_part_id 0x1760 to be added to the file `$HOME/ompi/ompi_install/share/openmpi/mca-btl-openib-device-params.ini`, under section.

```
[Broadcom BCM57XXX]
vendor_id = 0x14e4
```

The file `mca-btl-openib-device-params.ini` is installed as part of the Open MPI installation.

7.4 Compiling NCCL Tests

The NCCL tests are located on GitHub. Clone the repo and build as follows. Note there is no need to install the binaries as they can be run directly from the home directory. If CUDA is not installed in `/usr/local/cuda, you may specify CUDA_HOME`. Similarly, if NCCL is not installed in `/usr`, you can specify `NCCL_HOME` while trying to do `make`.

In this example, the CUDA and NCCL libraries are in the appropriate folders as the NCCL test expects.

```
git clone https://github.com/NVIDIA/nccl-tests.git
cd nccl-tests/
make MPI=1 MPI_HOME=$HOME/ompi/ompi_install
```

With tests compiled, the following collectives can be tested:

- all_gather
- all_reduce
- all_to_all
- all_to_allv
- broadcast
- gather
- reduce
- reduce_scatter
- scatter.
- send_recv

7.5 Single Node NCCL Collectives

Single Node NCCL collectives do not use RoCE by default and can be exercised with the Broadcom `bnxt_en` and `bnxt_re` drivers removed as well.

The `LD_LIBRARY_PATH` should be set correctly for a single node run though.

```
export LD_LIBRARY_PATH=$HOME/ompi/ompi_install/lib:$HOME/ucx/ucx_install/lib:$LD_LIBRARY_PATH

$ $HOME/nccl-tests/build/all_reduce_perf -b 8 -e 16g -f 2 -g 8
--------------------------------------------------------------------------
WARNING: There was an error initializing an OpenFabrics device.

  Local host:   COS-AI-R1C2S1
  Local device: bnxt_re0
--------------------------------------------------------------------------
# nThread 1 nGpus 8 minBytes 8 maxBytes 17179869184 step: 2(factor) warmup iters: 5 iters: 20 agg iters: 1 validation: 1 graph: 0
#
# Using devices
#  Rank  0 Group  0 Pid 234319 on COS-AI-R1C2S1 device  0 [0x18] NVIDIA H100 80GB HBM3
#  Rank  1 Group  0 Pid 234319 on COS-AI-R1C2S1 device  1 [0x2b] NVIDIA H100 80GB HBM3
#  Rank  2 Group  0 Pid 234319 on COS-AI-R1C2S1 device  2 [0x3a] NVIDIA H100 80GB HBM3
#  Rank  3 Group  0 Pid 234319 on COS-AI-R1C2S1 device  3 [0x5e] NVIDIA H100 80GB HBM3
#  Rank  4 Group  0 Pid 234319 on COS-AI-R1C2S1 device  4 [0x84] NVIDIA H100 80GB HBM3
#  Rank  5 Group  0 Pid 234319 on COS-AI-R1C2S1 device  5 [0x9b] NVIDIA H100 80GB HBM3
#  Rank  6 Group  0 Pid 234319 on COS-AI-R1C2S1 device  6 [0xae] NVIDIA H100 80GB HBM3
#  Rank  7 Group  0 Pid 234319 on COS-AI-R1C2S1 device  7 [0xd7] NVIDIA H100 80GB HBM3
```

```
#
#                                                              out-of-place                  in-place
#       size         count      type   redop    root     time   algbw   busbw #wrong     time   algbw   busbw #wrong
#        (B)    (elements)                               (us)  (GB/s)  (GB/s)            (us)  (GB/s)  (GB/s)
           8             2     float     sum      -1    65.51    0.00    0.00      0    51.92    0.00    0.00      0
          16             4     float     sum      -1    50.13    0.00    0.00      0    49.43    0.00    0.00      0
          32             8     float     sum      -1    70.35    0.00    0.00      0    51.07    0.00    0.00      0
          64            16     float     sum      -1    53.06    0.00    0.00      0    52.94    0.00    0.00      0
         128            32     float     sum      -1    53.20    0.00    0.00      0    54.17    0.00    0.00      0
         256            64     float     sum      -1    56.01    0.00    0.01      0    56.37    0.00    0.01      0
         512           128     float     sum      -1    57.17    0.01    0.02      0    59.80    0.01    0.01      0
        1024           256     float     sum      -1    60.11    0.02    0.03      0    59.23    0.02    0.03      0
        2048           512     float     sum      -1    59.78    0.03    0.06      0    60.17    0.03    0.06      0
        4096          1024     float     sum      -1    60.10    0.07    0.12      0    60.19    0.07    0.12      0
        8192          2048     float     sum      -1    60.66    0.14    0.24      0    60.04    0.14    0.24      0
       16384          4096     float     sum      -1    60.24    0.27    0.48      0    61.71    0.27    0.46      0
       32768          8192     float     sum      -1    60.81    0.54    0.94      0    61.19    0.54    0.94      0
       65536         16384     float     sum      -1    56.92    1.15    2.01      0    53.13    1.23    2.16      0
      131072         32768     float     sum      -1    51.56    2.54    4.45      0    52.34    2.50    4.38      0
      262144         65536     float     sum      -1    64.98    4.03    7.06      0    65.13    4.02    7.04      0
      524288        131072     float     sum      -1    67.22    7.80   13.65      0    67.69    7.74   13.55      0
     1048576        262144     float     sum      -1    70.47   14.88   26.04      0    69.98   14.98   26.22      0
     2097152        524288     float     sum      -1    68.44   30.64   53.62      0    69.10   30.35   53.11      0
     4194304       1048576     float     sum      -1    68.42   61.31  107.29      0    68.78   60.98  106.72      0
     8388608       2097152     float     sum      -1    85.71   97.87  171.27      0    84.71   99.02  173.29      0
    16777216       4194304     float     sum      -1   127.5   131.54  230.19      0   125.9   133.22  233.14      0
    33554432       8388608     float     sum      -1   200.1   167.65  293.40      0   200.2   167.60  293.31      0
    67108864      16777216     float     sum      -1   326.3   205.69  359.95      0   325.8   205.99  360.49      0
   134217728      33554432     float     sum      -1   591.6   226.86  397.00      0   592.0   226.74  396.79      0
   268435456      67108864     float     sum      -1  1120.0   239.68  419.43      0  1120.1   239.65  419.39      0
   536870912     134217728     float     sum      -1  2161.9   248.33  434.57      0  2159.8   248.58  435.01      0
  1073741824     268435456     float     sum      -1  4031.4   266.34  466.10      0  4032.3   266.29  466.00      0
  2147483648     536870912     float     sum      -1  7974.0   269.31  471.30      0  7978.1   269.17  471.05      0
  4294967296    1073741824     float     sum      -1   15822   271.46  475.05      0   15836   271.22  474.63      0
  8589934592    2147483648     float     sum      -1   31436   273.25  478.18      0   31421   273.38  478.42      0
 17179869184    4294967296     float     sum      -1   62563   274.60  480.55      0   62579   274.53  480.43      0
# Out of bounds values : 0 OK
# Avg bus bandwidth    : 152.97
#
```

7.6 MultiNode NCCL Collectives using Open MPI

Ensure the following prechecks are complete:

- NIC IP addresses and routing are configured
- Passwordless SSH has been setup between the hosts
- NUMA balancing is disabled on every host. This can be done at runtime using `echo 0 > /proc/sys/kernel/numa_balancing` or via `sysctl -w kernel.numa_balancing=0`. Another option is to add the following entry to the file `/etc/sysctl.d/99-sysctl.conf` so that the setting takes effect automatically after a reboot
- Each node used for the test has the `PATH` and `LD_LIBRARY_PATH` set correctly using the `.bashrc` file as follows:

```
export LD_LIBRARY_PATH=$HOME/ompi/ompi_install/lib:$HOME/ucx/ucx_install/lib:$LD_LIBRARY_PATH
export PATH=$HOME/ompi/ompi_install/bin:$HOME/ucx/ucx_install/bin:$PATH
```

In the following NCCL test, two nodes are used to run the `all_reduce` collective. Each node has eight GPUs and eight NICs. Passwordless ssh is set up for this interface. Both the Hosts connect to the same leaf switch.

```
$ $HOME/ompi/ompi_install/bin/mpirun --np 16 -H COS-AI-R1C1S1:8,COS-AI-R1C2S1:8 \
-x NCCL_DEBUG=VERSION --mca pml ucx --mca btl ^openib \
-x NCCL_SOCKET_IFNAME=enp25s0np0 -x NCCL_IB_DISABLE=0 \
-x NCCL_IB_HCA=bnxt_re0:1,bnxt_re1:1,bnxt_re2:1,bnxt_re3:1,bnxt_re4:1,bnxt_re5:1,bnxt_re6:1,bnxt_re7:1  \
-x NCCL_IB_GID_INDEX=3 \
-x NCCL_P2P_NET_CHUNKSIZE=262144 \
$HOME/nccl-tests/build/all_reduce_perf -b 8 -e 16g -f 2 -g 1
# nThread 1 nGpus 1 minBytes 8 maxBytes 17179869184 step: 2(factor) warmup iters: 5 iters: 20 agg iters: 1 validation: 1 graph: 0
#
# Using devices
#  Rank  0 Group  0 Pid 220894 on COS-AI-R1C2S1 device  0 [0x18] NVIDIA H100 80GB HBM3
#  Rank  1 Group  0 Pid 220895 on COS-AI-R1C2S1 device  1 [0x2b] NVIDIA H100 80GB HBM3
#  Rank  2 Group  0 Pid 220896 on COS-AI-R1C2S1 device  2 [0x3a] NVIDIA H100 80GB HBM3
#  Rank  3 Group  0 Pid 220898 on COS-AI-R1C2S1 device  3 [0x5e] NVIDIA H100 80GB HBM3
#  Rank  4 Group  0 Pid 220901 on COS-AI-R1C2S1 device  4 [0x84] NVIDIA H100 80GB HBM3
#  Rank  5 Group  0 Pid 220904 on COS-AI-R1C2S1 device  5 [0x9b] NVIDIA H100 80GB HBM3
#  Rank  6 Group  0 Pid 220906 on COS-AI-R1C2S1 device  6 [0xae] NVIDIA H100 80GB HBM3
#  Rank  7 Group  0 Pid 220909 on COS-AI-R1C2S1 device  7 [0xd7] NVIDIA H100 80GB HBM3
#  Rank  8 Group  0 Pid 249511 on COS-AI-R1C1S1 device  0 [0x18] NVIDIA H100 80GB HBM3
#  Rank  9 Group  0 Pid 249512 on COS-AI-R1C1S1 device  1 [0x2b] NVIDIA H100 80GB HBM3
#  Rank 10 Group  0 Pid 249513 on COS-AI-R1C1S1 device  2 [0x3a] NVIDIA H100 80GB HBM3
#  Rank 11 Group  0 Pid 249514 on COS-AI-R1C1S1 device  3 [0x5e] NVIDIA H100 80GB HBM3
#  Rank 12 Group  0 Pid 249515 on COS-AI-R1C1S1 device  4 [0x84] NVIDIA H100 80GB HBM3
#  Rank 13 Group  0 Pid 249518 on COS-AI-R1C1S1 device  5 [0x9d] NVIDIA H100 80GB HBM3
#  Rank 14 Group  0 Pid 249521 on COS-AI-R1C1S1 device  6 [0xb0] NVIDIA H100 80GB HBM3
#  Rank 15 Group  0 Pid 249524 on COS-AI-R1C1S1 device  7 [0xd7] NVIDIA H100 80GB HBM3
NCCL version 2.22.3+cuda12.6
#
#
#                                                              out-of-place                       in-place
#       size         count      type   redop    root     time   algbw   busbw #wrong     time   algbw   busbw #wrong
#        (B)    (elements)                               (us)  (GB/s)  (GB/s)            (us)  (GB/s)  (GB/s)
           8             2     float     sum      -1    98.30    0.00    0.00      0    38.03    0.00    0.00      0
          16             4     float     sum      -1    40.04    0.00    0.00      0    38.92    0.00    0.00      0
          32             8     float     sum      -1    41.82    0.00    0.00      0    42.26    0.00    0.00      0
          64            16     float     sum      -1    42.65    0.00    0.00      0    41.01    0.00    0.00      0
         128            32     float     sum      -1    44.18    0.00    0.01      0    40.38    0.00    0.01      0
         256            64     float     sum      -1    99.02    0.00    0.00      0    42.38    0.01    0.01      0
         512           128     float     sum      -1    45.28    0.01    0.02      0    33.07    0.02    0.03      0
        1024           256     float     sum      -1    46.54    0.02    0.04      0    42.05    0.02    0.05      0
        2048           512     float     sum      -1    46.79    0.04    0.08      0    43.89    0.05    0.09      0
        4096          1024     float     sum      -1    50.99    0.08    0.15      0    46.98    0.09    0.16      0
        8192          2048     float     sum      -1    50.92    0.16    0.30      0    51.34    0.16    0.30      0
       16384          4096     float     sum      -1    53.48    0.31    0.57      0    44.46    0.37    0.69      0
       32768          8192     float     sum      -1    58.73    0.56    1.05      0    54.03    0.61    1.14      0
       65536         16384     float     sum      -1    57.14    1.15    2.15      0    55.40    1.18    2.22      0
      131072         32768     float     sum      -1    62.14    2.11    3.95      0    66.29    1.98    3.71      0
      262144         65536     float     sum      -1    70.03    3.74    7.02      0    68.48    3.83    7.18      0
      524288        131072     float     sum      -1    165.6    3.17    5.94      0    139.4    3.76    7.05      0
     1048576        262144     float     sum      -1    141.7    7.40   13.87      0    151.7    6.91   12.96      0
     2097152        524288     float     sum      -1    153.8   13.63   25.56      0    153.6   13.65   25.59      0
     4194304       1048576     float     sum      -1    180.3   23.26   43.62      0    192.8   21.75   40.79      0
     8388608       2097152     float     sum      -1    203.5   41.22   77.30      0    230.4   36.41   68.26      0
```

```
    16777216       4194304     float     sum      -1    281.3   59.64  111.82      0    279.8   59.97  112.44      0
    33554432       8388608     float     sum      -1    410.6   81.71  153.21      0    411.1   81.63  153.05      0
    67108864      16777216     float     sum      -1    528.4  127.01  238.15      0    530.1  126.60  237.38      0
   134217728      33554432     float     sum      -1    872.1  153.90  288.57      0    852.6  157.43  295.18      0
   268435456      67108864     float     sum      -1   1429.1  187.84  352.19      0   1433.1  187.32  351.22      0
   536870912     134217728     float     sum      -1   2539.5  211.41  396.40      0   2416.4  222.18  416.58      0
  1073741824     268435456     float     sum      -1   4493.3  238.96  448.06      0   4478.9  239.73  449.50      0
  2147483648     536870912     float     sum      -1   8745.0  245.57  460.44      0   8747.1  245.51  460.33      0
  4294967296    1073741824     float     sum      -1    17241  249.11  467.09      0    17256  248.90  466.69      0
  8589934592    2147483648     float     sum      -1    34313  250.34  469.38      0    34337  250.16  469.06      0
 17179869184    4294967296     float     sum      -1    68552  250.61  469.89      0    68595  250.45  469.60      0
# Out of bounds values : 0 OK
# Avg bus bandwidth    : 126.377
```

Chapter 8: NIC and Ethernet Switch Configuration

Broadcom publishes an Ethernet NIC user guide that is publicly available. This guide contains detailed information on how to configure and use Broadcom NICs, including how to use the NIC for RoCE and Peer Memory Direct:

- Broadcom Ethernet Network Adapter User Guide
- RDMA over Converged Ethernet (RoCE)

Broadcom and Arista jointly publish a Broadcom RoCE Deployment guide that has more details on how to configure Arista switches for RoCE and RoCE congestion Control:

- Lossless Network for AI/ML/Storage/HPC with RDMA

Appendix A: Compiling Broadcom NIC Software from Source

NOTE: The Broadcom `nic_wizard`'s installer install command installs the necessary packages automatically. To install by compiling the source code manually, use the following script.

This appendix shows example Linux shell scripts that can be used to compile and install Broadcom RoCE Kernel drivers and the user-space library `libbnxt_re` from source code. The script examples use the 232 release and the 232 release pkg file names as an example. Depending on the actual release and release pkg names being used, the script can be updated. Assuming the following scripts are placed in a file named `brcm_sw_compile_install.sh`, execute the script as follows:

```
chmod 777 brcm_sw_compile_install.sh

sudo ./brcm_sw_compile_install.sh | tee build_log.txt
# or
sudo bash ./brcm_sw_compile_install.sh | tee build_log.txt
```

A.1 Ubuntu: Install Script for NIC Software (Compiling from Source Code)

Install the NIC software using the following script:

```
#!/bin/bash

echo -e "\n\n============Installing required pkgs============\n\n"
sudo apt install linux-headers-"$(uname -r)"  libelf-i
sudo apt install gcc make libtool autoconf librdmacm-dev rdmacm-utils infiniband-diags ibverbs-utils
perftest ethtool libibverbs-dev rdma-core strace

echo -e "\n\n============Compiling and installing L2 and RoCE kernel drivers============\n\n"
# Highlighted item will change depending on the release
tar -xf netxtreme-peer-mem-234.0.154.0.tar.gz
cd netxtreme-peer-mem-234.0.154.0
make
sudo make install
sudo depmod -a
cd ..
echo  -e "\n\n====================L2 and RoCE Kernel Driver Compile Complete====================\n\n"


echo -e "\n\n====================Loading built modules into the kernel====================\n\n"



#Unload the current version of the loaded drivers in case they are loaded.
sudo rmdir  /sys/kernel/config/bnxt_re/* 2> /dev/null
sudo modprobe -r bnxt_re
sudo modprobe -r ib_peer_mem
sudo modprobe ib_peer_mem
#Make sure the 2 commands below, seperated by ";" are executed together in a single line
sudo rmmod bnxt_en; sudo modprobe bnxt_en
sudo modprobe bnxt_re
```

```
sudo update-initramfs -u -k `uname -r`


echo -e "\n\n=================== Checking and updating /etc/security/limit.conf
file================== \n\n"

if [[ $(grep '^* soft memlock unlimited$' /etc/security/limits.conf) ]]; then
    echo "Soft MemLock ok"
else
    echo "Adding soft memlock unlimited to  /etc/security/limits.conf"
    sudo sh -c "echo '* soft memlock unlimited' >> /etc/security/limits.conf"
fi

if [[ $(grep '^* hard memlock unlimited$' /etc/security/limits.conf) ]]; then
    echo "Hard MemLock ok"
else
    echo "Adding hard memlock unlimited to  /etc/security/limits.conf"
    sudo sh -c "echo '* hard memlock unlimited' >> /etc/security/limits.conf"
fi



echo -e "\n\n============Compiling RoCE Lib now============\n\n"
# Highlighted item will change depending on the release
tar -xf libbnxt_re-234.0.154.0.tar.gz
cd libbnxt_re-234.0.154.0
sh autogen.sh
./configure
make
find /usr/lib64/  /usr/lib -name "libbnxt_re-rdmav*.so"  -exec mv {} {}.inbox \;
sudo make install all
sudo sh -c "echo /usr/local/lib >> /etc/ld.so.conf"
sudo ldconfig
sudo cp -f bnxt_re.driver /etc/libibverbs.d/

find . -name "*.so" -exec md5sum {} \;
BUILT_MD5SUM=$(find . -name "libbnxt_re-rdmav*.so" -exec md5sum {} \; |  cut -d " " -f 1)
echo -e "\n\nmd5sum of the built libbnxt_re is $BUILT_MD5SUM"

echo  -e "\n\n===================RoCE userlib compile complete===================\n\n"
cd ..
echo -e "\nRunning strace"
strace ibv_devinfo 2>&1 | grep libbnxt_re | grep -v 'No such file'
INSTALLED_LIB_PATH=$(strace ibv_devinfo 2>&1 | grep libbnxt_re | grep -v 'No such file' | cut  -d ","
-f 2 | tr -d "\"")
echo -e "\n\nInstalled libbnxt_re is at path $INSTALLED_LIB_PATH\n"


if [[ -z "$INSTALLED_LIB_PATH" ]]; then
    echo -e "Failed to find location of installed libbnxt_re, exiting....\n\n\n"
    exit 4
fi



md5sum $INSTALLED_LIB_PATH
INSTALLED_MD5SUM=$(md5sum $INSTALLED_LIB_PATH  | cut -d " " -f 1)
```

```
echo -e "md5sum of the installed library is $INSTALLED_MD5SUM"

echo -e "\n\nlibbnxt_re BUILT_MD5SUM=$BUILT_MD5SUM, INSTALLED_MD5SUM=$INSTALLED_MD5SUM \n\n"

if [[ -z "$BUILT_MD5SUM" ]]; then
    echo -e "Failed to get the md5sum of the built libbnxt_re lib\n\n\n"
    exit 1
elif  [[ -z "$INSTALLED_MD5SUM" ]]; then
    echo "Failed to get the md5sum of the installed libbnxt_re lib\n\n\n"
    exit 2
elif  [[ "$BUILT_MD5SUM" = "$INSTALLED_MD5SUM" ]]; then
    echo -e "MD5Sum of the built and installed libbnxt_re match"
else
    echo -e "MD5Sum of the built and installed libbnxt_re do not match \n\n\n"
    exit 3
fi

echo -e "\n\n\n"
```

A.2 RHEL: Install Script for NIC Software (Compiling from Source Code)

Install the NIC software using the following script:

```
#!/bin/bash

echo -e "\n\n============Installing required pkgs============\n\n"
sudo yum install -y "kernel-devel-uname-r == $(uname -r)"  elfutils-libelf-devel
sudo yum install -y libibverbs-devel qperf perftest infiniband-diags make gcc kernel-devel autoconf
libtool libibverbs-utils rdma-core-devel librdmacm-utils strace

echo -e "\n\n============Compiling and installing L2 and RoCE kernel drivers============\n\n"
# Highlighted item will change depending on the release
tar -xf netxtreme-peer-mem-234.0.154.0.tar.gz
cd netxtreme-peer-mem-234.0.154.0
make
sudo make install
sudo depmod -a
cd ..
echo  -e "\n\n====================L2 and RoCE Kernel Driver Compile Complete====================\n\n"


echo -e "\n\n====================Loading built modules into the kernel====================\n\n"
#Unload the current version of the loaded drivers in case they are loaded.
sudo rmdir  /sys/kernel/config/bnxt_re/* 2> /dev/null
sudo modprobe -r bnxt_re
sudo modprobe -r ib_peer_mem
sudo modprobe ib_peer_mem
#Make sure the 2 commands below, seperated by ";" are executed together in a single line
sudo rmmod bnxt_en; sudo modprobe bnxt_en
sudo modprobe bnxt_re

sudo dracut -f


echo -e "\n\n==================== Checking and updating /etc/security/limit.conf
file==================== \n\n"
```

```
if [[ $(grep '^* soft memlock unlimited$' /etc/security/limits.conf) ]]; then
    echo "Soft MemLock ok"
else
    echo "Adding soft memlock unlimited to  /etc/security/limits.conf"
    sudo sh -c "echo '* soft memlock unlimited' >> /etc/security/limits.conf"
fi

if [[ $(grep '^* hard memlock unlimited$' /etc/security/limits.conf) ]]; then
    echo "Hard MemLock ok"
else
    echo "Adding hard memlock unlimited to  /etc/security/limits.conf"
    sudo sh -c "echo '* hard memlock unlimited' >> /etc/security/limits.conf"
fi



echo -e "\n\n============Compiling RoCE Lib now============\n\n"
# Highlighted item will change depending on the release
tar -xf libbnxt_re-234.0.154.0.tar.gz
cd libbnxt_re-234.0.154.0
sh autogen.sh
./configure
make
find /usr/lib64/  /usr/lib -name "libbnxt_re-rdmav*.so"  -exec mv {} {}.inbox \;
make install all
sudo sh -c "echo /usr/local/lib >> /etc/ld.so.conf"
sudo ldconfig
cp -f bnxt_re.driver /etc/libibverbs.d/

find . -name "*.so" -exec md5sum {} \;
BUILT_MD5SUM=$(find . -name "libbnxt_re-rdmav*.so" -exec md5sum {} \; |  cut -d " " -f 1)
echo -e "\n\nmd5sum of the built libbnxt_re is $BUILT_MD5SUM"

echo  -e "\n\n====================RoCE userlib compile complete====================\n\n"
cd ..
echo -e "\nRunning strace"
strace ibv_devinfo 2>&1 | grep libbnxt_re | grep -v 'No such file'
INSTALLED_LIB_PATH=$(strace ibv_devinfo 2>&1 | grep libbnxt_re | grep -v 'No such file' | cut  -d ","
-f 2 | tr -d "\"")
echo -e "\n\nInstalled libbnxt_re is at path $INSTALLED_LIB_PATH\n"


if [[ -z "$INSTALLED_LIB_PATH" ]]; then
    echo -e "Failed to find location of installed libbnxt_re, exiting....\n\n\n"
    exit 4
fi


md5sum $INSTALLED_LIB_PATH
INSTALLED_MD5SUM=$(md5sum $INSTALLED_LIB_PATH  | cut -d " " -f 1)

echo -e "md5sum of the installed library is $INSTALLED_MD5SUM"

echo -e "\n\nlibbnxt_re BUILT_MD5SUM=$BUILT_MD5SUM, INSTALLED_MD5SUM=$INSTALLED_MD5SUM \n\n"

if [[ -z "$BUILT_MD5SUM" ]]; then
    echo -e "Failed to get the md5sum of the built libbnxt_re lib\n\n\n"
```

```
    exit 1
elif  [[ -z "$INSTALLED_MD5SUM" ]]; then
    echo "Failed to get the md5sum of the installed libbnxt_re lib\n\n\n"
    exit 2
elif  [[ "$BUILT_MD5SUM" = "$INSTALLED_MD5SUM" ]]; then
    echo -e "MD5Sum of the built and installed libbnxt_re match"
else
    echo -e "MD5Sum of the built and installed libbnxt_re do not match \n\n\n"
    exit 3
fi

echo -e "\n\n\n"
```

Appendix B: Script for Disabling ACS

The following shell script can be used to disable ACS on a host that does not disable ACS by default via the BIOS. The script disables ACS on all ports that support ACS..

B.1 Disable PCIe ACS

To disable PCIe ACS, use the following commands:

```
#!/bin/bash
#
# Disable ACS on every device that supports it
#
PLATFORM=$(dmidecode --string system-product-name)
logger "PLATFORM=${PLATFORM}"
# Enforce platform check here.
#case "${PLATFORM}" in
    #"OAM"*)
        #logger "INFO: Disabling ACS is no longer necessary for ${PLATFORM}"
        #exit 0
        #;;
    #*)
        #;;
#esac
# must be root to access extended PCI config space
if [ "$EUID" -ne 0 ]; then
    echo "ERROR: $0 must be run as root"
    exit 1
fi
for BDF in `lspci -d "*:*:*" | awk '{print $1}'`; do
    # skip if it doesn't support ACS
    setpci -v -s ${BDF} ECAP_ACS+0x6.w > /dev/null 2>&1
    if [ $? -ne 0 ]; then
        #echo "${BDF} does not support ACS, skipping"
        continue
    fi
     logger "Disabling ACS on `lspci -s ${BDF}`"
    setpci -v -s ${BDF} ECAP_ACS+0x6.w=0000
    if [ $? -ne 0 ]; then
        logger "Error enabling directTrans ACS on ${BDF}"
        continue
    fi
    NEW_VAL=`setpci -v -s ${BDF} ECAP_ACS+0x6.w | awk '{print $NF}'`
    if [ "${NEW_VAL}" != "0000" ]; then
        logger "Failed to enabling directTrans ACS on ${BDF}"
        continue
    fi
done
exit 0
```

B.2 List all PCIe Devices that Support ACS

To list all PCIe devices, use the following commands:

```
#!/bin/bash
#
for BDF in `lspci -n | awk '{print $1}'`; do
    if lspci -vvv -s "$BDF"  | grep -qi ACSCtl;  then
        lspci -vvv -s "$BDF" | head -1
       lspci -vvv -s "$BDF" | grep -i ACSCtl

   fi
done
```

B.3 List all PCIe Devices with ACS Enabled

To list all PCIe devices with ACS enabled, use the following commands:

```
#!/bin/bash
#
for BDF in `lspci -n | awk '{print $1}'`; do
    if lspci -vvv -s "$BDF"  | grep -i ACSCtl | grep -qi SrcValid+;  then
        lspci -vvv -s "$BDF" | head -1
       lspci -vvv -s "$BDF" | grep -i ACSCtl

   fi
done
```

B.4 List all PCIe Devices with ACS Disabled

To list all PCIe devices with ACS disabled, use the following commands:

```
#!/bin/bash
#
for BDF in `lspci -n | awk '{print $1}'`; do
    if lspci -vvv -s "$BDF"  | grep -i ACSCtl | grep -qi SrcValid-;  then
        lspci -vvv -s "$BDF" | head -1
       lspci -vvv -s "$BDF" | grep -i ACSCtl

   fi
done
```

Appendix C: PCIe Link Speed and Width Related Scripts

This section provides scripts to get the PCIe link speed and width scripts.

C.1 Displaying the Link Speed and Link Width of Every PCIe Component

To display the link speed and link width, use the following commands:

```
#!/bin/bash
#
for BDF in `lspci -d "*:*:*" | awk '{print $1}'`; do
    if lspci -vvv -s "$BDF"  | grep -q LnkSta:;  then
        lspci -vvv -s "$BDF" | head -1
       lspci -vvv -s "$BDF" | grep LnkSta:

   fi
done
```

C.2 Display Every PCIe Component with Downgraded Speed or Downgraded Width

To display every PCIe component with downgraded speed and width, use the following commands:

```
#!/bin/bash
#
for BDF in `lspci -d "*:*:*" | awk '{print $1}'`; do
    if lspci -vvv -s "$BDF"  | grep -q downgraded;  then
        lspci -vvv -s "$BDF" | head -1
       lspci -vvv -s "$BDF" | grep -i downgraded

   fi
done
```

Appendix D: References

D.1 Broadcom Ethernet Network Adapter User Guide

https://techdocs.broadcom.com/us/en/storage-and-ethernet-connectivity/ethernet-nic-controllers/bcm957xxx/adapters.html

Appendix E: Terminology

This section provides terminology definitions for terms used in this document.

Table 4: Terminology

Acronym	Meaning
ACS	PCIe Access Control Service
ARP	Address Resolution Protocol
BTL	Byte Transfer Layer
CNP	Congestion Notification Packet
DCBX	Data Center Bridging Exchange protocol
DCQCN	Data Centre quantized Congestion Notification
DCQCN-P	Data Centre quantized Congestion Notification-Probabilistic
DCQCN-D	Data Centre quantized Congestion Notification-Deterministic
DKMS	Dynamic Kernel Module Support
DSCP	Differentiated Services Code Point
ECN	Explicit Congestion Notification
ETS	Enhanced Transmission Selection
IOMMU	Input Output Memory Management Unit
L2	Ethernet as Layer 2 protocol in the OSI model
LLDP	Link Layer Discovery Protocol
MLNX_OFED	Mellanox OFED driver pkg
MTU	Maximum Transmission Unit
NUMA	Non Uniform Memory Access
NCCL	NVIDIA Communications Collective Library
OCP	Open Compute Project
Open MPI	Open Message Passing Interface
PFC	Priority Flow Control
RDMA	Remote Direct Memory Access
NIC	Network Interface Card
RoCE	RDMA over Converged Ethernet
SONiC	Software for Open Networking in the cloud
UCX	Unified Communication X
VLAN	Virtual Local Area Network
XGMI	AMD Infinity Fabric

Revision History

957608-AN306; April 13, 2026

Updated:

- Table 3, NVIDIA GPU

Added:

- Quick Start Guide and Document Overview

957608-AN305; December 12, 2025

Updated:

- Chapter 7, Running NCCL Collectives

Added:

- Quick Start Guide and Document Overview

957608-AN304; July 29, 2025

Updated:

- Updated formatting issue.

957608-AN303; July 9, 2025

Updated:

- Updated for 234 version of software.

957608-AN302; April 15, 2025

Updated:

- Replaced NICCLI getoption -name commands with nvm-getoption commands throughout.

957608-AN301; March 20, 2025

Updated:

- Broadcom Ethernet NIC Software Installation with Peer Memory Direct
- Debugging Thor2 NIC

Added:

- Verifying the Correct RoCE QOS Configuration
- Ethernet Leaf Switch Port Configuration for 24-bit Subnet Scheme on Juniper QFX5240 Switch
- Ethernet Leaf Switch Port Configuration for 31-bit Subnet Scheme on Juniper QFX5240 Switch
- Example: Juniper QFX5240 Switch and 31-bit Subnet Scheme

957608-AN300; October 22, 2024

Initial release.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