Rocky Linux

ONTAP SAN Host Utilities

NetApp
January 30, 2026

Table of Contents

Rocky Linux . . . 1
Learn about ONTAP support and features for Rocky Linux . . . 1
What's next . . . 1
Configure Rocky Linux 10.x for NVMe-oF with ONTAP storage . . . 2
Step 1: Optionally, enable SAN booting . . . 2
Step 2: Install Rocky Linux and NVMe software and verify your configuration . . . 2
Step 3: Configure NVMe/FC and NVMe/TCP . . . 4
Step 4: Optionally, enable 1MB I/O for NVMe/FC . . . 12
Step 5: Verify NVMe boot services . . . 13
Step 6: Verify the multipathing configuration . . . 14
Step 7: Set up secure in-band authentication . . . 18
Step 8: Review the known issues . . . 25
Configure Rocky Linux 9.x for NVMe-oF with ONTAP storage . . . 25
Step 1: Optionally, enable SAN booting . . . 25
Step 2: Install Rocky Linux and NVMe software and verify your configuration . . . 25
Step 3: Configure NVMe/FC and NVMe/TCP . . . 27
Step 4: Optionally, enable 1MB I/O for NVMe/FC . . . 39
Step 5: Verify NVMe boot services . . . 40
Step 6: Verify the multipathing configuration . . . 41
Step 7: Set up secure in-band authentication . . . 45
Step 8: Review the known issues . . . 53
Configure Rocky Linux 8.x for NVMe-oF with ONTAP storage . . . 53
Step 1: Install Rocky Linux and NVMe software and verify your configuration . . . 53
Step 2: Configure NVMe/FC and NVMe/TCP . . . 55
Step 3: Optionally, enable 1MB I/O for NVMe/FC . . . 66
Step 4: Verify the multipathing configuration . . . 67
Step 5: Review the known issues . . . 71

Rocky Linux

Learn about ONTAP support and features for Rocky Linux

Features supported for host configuration with NVMe over Fabrics (NVMe-oF) varies based on your version of ONTAP and Rocky Linux.

Feature	Rocky Linux host version	ONTAP version
Secure in-band authentication is supported over NVMe/TCP between a RHEL host and an ONTAP controller	9.3 or later	9.12.1 or later
NVMe/TCP provides namespaces using the native `nvme-cli` package	8.2 or later	9.10.1 or later
NVMe/TCP is a fully supported enterprise feature	9.0 or later	9.10.1 or later
NVMe and SCSI traffic is supported on the same host using NVMe multipath for NVMe-oF namespaces and dm-multipath for SCSI LUNs	8.2 or later	9.4 or later

ONTAP supports the following SAN host features regardless of the ONTAP version running on your system setup.

Feature	Rocky Linux host version
Native NVMe multipathing is enabled by default	10.0 or later
SAN booting is enabled using the NVMe/FC protocol	9.4 or later
The `nvme-cli` package includes auto-connect scripts removing the need for third-party scripts	8.2 or later
The native udev rule in the `nvme-cli` package provides round-robin load balancing for NVMe multipathing	8.2 or later

For details on supported configurations, see the Interoperability Matrix Tool.

What's next

If your Rocky Linux version is ..	Learn about ..
10 series	Configuring NVMe for Rocky Linux 10.x
9 series	Configuring NVMe for Rocky Linux 9.x
8 series	Configuring NVMe for Rocky Linux 8.x

Related information

Configure Rocky Linux 10.x for NVMe-oF with ONTAP storage

Rocky Linux hosts support the NVMe over Fibre Channel (NVMe/FC) and NVMe over TCP (NVMe/TCP) protocols with Asymmetric Namespace Access (ANA). ANA provides multipathing functionality equivalent to asymmetric logical unit access (ALUA) in iSCSI and FCP environments.

Learn how to configure NVMe over Fabrics (NVMe-oF) hosts for Rocky Linux 10.x. For more support and feature information, see Rocky Linux ONTAP support and features.

NVMe-oF with Rocky Linux 10.x has the following known limitations:

- The `nvme disconnect-all` command disconnects both root and data filesystems and might lead to system instability. Do not issue this on systems booting from SAN over NVMe-TCP or NVMe-FC namespaces.

Step 1: Optionally, enable SAN booting

You can configure your host to use SAN booting to simplify deployment and improve scalability. Use the Interoperability Matrix Tool to verify that your Linux OS, host bus adapter (HBA), HBA firmware, HBA boot BIOS, and ONTAP version support SAN booting.

Steps

1. Create a NVMe namespace and map it to the host.
2. Enable SAN booting in the server BIOS for the ports to which the SAN boot namespace is mapped.

   For information on how to enable the HBA BIOS, see your vendor-specific documentation.

3. Reboot the host and verify that the OS is up and running.

Step 2: Install Rocky Linux and NVMe software and verify your configuration

To configure your host for NVMe-oF you need to install the host and NVMe software packages, enable multipathing, and verify your host NQN configuration.

Steps

1. Install Rocky Linux 10.x on the server. After the installation is complete, verify that you are running the required Rocky Linux 10.x kernel:

   ```
   uname -r
   ```

   Example Rocky Linux kernel version:

   ```
   6.12.0-55.9.1.el10_0.x86_64
   ```

2. Install the `nvme-cli` package:

```
rpm -qa|grep nvme-cli
```

The following example shows an `nvme-cli` package version:

```
nvme-cli-2.11-5.el10.x86_64
```

3. Install the `libnvme` package:

```
rpm -qa|grep libnvme
```

The following example shows an `libnvme` package version:

```
libnvme-1.11.1-1.el10.x86_64
```

4. On the host, check the hostnqn string at `/etc/nvme/hostnqn`:

```
cat /etc/nvme/hostnqn
```

The following example shows a `hostnqn` value:

```
nqn.2014-08.org.nvmexpress:uuid:4c4c4544-0056-5410-8048-b9c04f425633
```

5. On the ONTAP system, verify that the `hostnqn` string matches the `hostnqn` string for the corresponding subsystem on the ONTAP array:

```
::> vserver nvme subsystem host show -vserver vs_nvme_194_rockylinux10
```

Show example

```
Vserver Subsystem Priority  Host NQN
------- --------- --------
-------------------------------------------------
vs_nvme_194_rockylinux10
        nvme4
                  regular   nqn.2014-
08.org.nvmexpress:uuid:4c4c4544-0056-5410-8048-c7c04f425633
        nvme_1
                  regular   nqn.2014-
08.org.nvmexpress:uuid:4c4c4544-0056-5410-8048-c7c04f425633
        nvme_2
                  regular   nqn.2014-
08.org.nvmexpress:uuid:4c4c4544-0056-5410-8048-c7c04f425633
        nvme_3
                  regular   nqn.2014-
08.org.nvmexpress:uuid:4c4c4544-0056-5410-8048-c7c04f425633
4 entries were displayed.
```

If the `hostnqn` strings do not match, use the `vserver modify` command to update the `hostnqn` string on your corresponding ONTAP storage system subsystem to match the `hostnqn` string from `/etc/nvme/hostnqn` on the host.

Step 3: Configure NVMe/FC and NVMe/TCP

Configure NVMe/FC with Broadcom/Emulex or Marvell/QLogic adapters, or configure NVMe/TCP using manual discovery and connect operations.

NVMe/FC - Broadcom/Emulex

Configure NVMe/FC for a Broadcom/Emulex adapter.

Steps

1. Verify that you are using the supported adapter model:
   a. Display the model names:

```
cat /sys/class/scsi_host/host*/modelname
```

   You should see the following output:

```
LPe36002-M64
LPe36002-M64
```

   b. Display the model descriptions:

```
cat /sys/class/scsi_host/host*/modeldesc
```

   You should see an output similar to the following example:

```
Emulex LightPulse LPe36002-M64 2-Port 64Gb Fibre Channel Adapter
Emulex LightPulse LPe36002-M64 2-Port 64Gb Fibre Channel Adapter
```

2. Verify that you are using the recommended Broadcom `lpfc` firmware and inbox driver:
   a. Display the firmware version:

```
cat /sys/class/scsi_host/host*/fwrev
```

   The command returns the firmware versions:

```
14.0.539.16, sli-4:6:d
14.0.539.16, sli-4:6:d
```

   b. Display the inbox driver version:

```
cat /sys/module/lpfc/version
```

   The following example shows a driver version:

```
0:14.4.0.6
```

For the current list of supported adapter driver and firmware versions, see the Interoperability Matrix Tool.

3. Verify that `lpfc_enable_fc4_type` is set to `3`:

```
cat /sys/module/lpfc/parameters/lpfc_enable_fc4_type
```

4. Verify that you can view your initiator ports:

```
cat /sys/class/fc_host/host*/port_name
```

You should see an output similar to:

```
0x2100f4c7aa0cd7c2
0x2100f4c7aa0cd7c3
```

5. Verify that your initiator ports are online:

```
cat /sys/class/fc_host/host*/port_state
```

You should see the following output:

```
Online
Online
```

6. Verify that the NVMe/FC initiator ports are enabled and that the target ports are visible:

```
cat /sys/class/scsi_host/host*/nvme_info
```

Show example

```
NVME Initiator Enabled
XRI Dist lpfc2 Total 6144 IO 5894 ELS 250
NVME LPORT lpfc2 WWPN x100000109bf044b1 WWNN x200000109bf044b1
DID x022a00 ONLINE
NVME RPORT       WWPN x202fd039eaa7dfc8 WWNN x202cd039eaa7dfc8
DID x021310 TARGET DISCSRVC ONLINE
NVME RPORT       WWPN x202dd039eaa7dfc8 WWNN x202cd039eaa7dfc8
DID x020b10 TARGET DISCSRVC ONLINE

NVME Statistics
LS: Xmt 0000000810 Cmpl 0000000810 Abort 00000000
LS XMIT: Err 00000000  CMPL: xb 00000000 Err 00000000
Total FCP Cmpl 000000007b098f07 Issue 000000007aee27c4 OutIO
fffffffffe498bd
        abort 000013b4 noxri 00000000 nondlp 00000058 qdepth
00000000 wqerr 00000000 err 00000000
FCP CMPL: xb 000013b4 Err 00021443

NVME Initiator Enabled
XRI Dist lpfc3 Total 6144 IO 5894 ELS 250
NVME LPORT lpfc3 WWPN x100000109bf044b2 WWNN x200000109bf044b2
DID x021b00 ONLINE
NVME RPORT       WWPN x2033d039eaa7dfc8 WWNN x202cd039eaa7dfc8
DID x020110 TARGET DISCSRVC ONLINE
NVME RPORT       WWPN x2032d039eaa7dfc8 WWNN x202cd039eaa7dfc8
DID x022910 TARGET DISCSRVC ONLINE

NVME Statistics
LS: Xmt 0000000840 Cmpl 0000000840 Abort 00000000
LS XMIT: Err 00000000  CMPL: xb 00000000 Err 00000000
Total FCP Cmpl 000000007afd4434 Issue 000000007ae31b83 OutIO
fffffffffe5d74f
        abort 000014a5 noxri 00000000 nondlp 0000006a qdepth
00000000 wqerr 00000000 err 00000000
FCP CMPL: xb 000014a5 Err 0002149a
```

NVMe/FC - Marvell/QLogic

Configure NVMe/FC for a Marvell/QLogic adapter.

Steps

1. Verify that you are using the supported adapter driver and firmware versions:

```
cat /sys/class/fc_host/host*/symbolic_name
```

The following example shows driver and firmware versions:

```
QLE2872 FW:v9.15.00 DVR:v10.02.09.300-k
QLE2872 FW:v9.15.00 DVR:v10.02.09.300-k
```

2. Verify that `ql2xnvmeenable` is set. This enables the Marvell adapter to function as an NVMe/FC initiator:

```
cat /sys/module/qla2xxx/parameters/ql2xnvmeenable
```

The expected output is 1.

NVMe/TCP

The NVMe/TCP protocol doesn't support the auto-connect operation. Instead, you can discover the NVMe/TCP subsystems and namespaces by performing the NVMe/TCP `connect` or `connect-all` operations manually.

Steps

1. Check that the initiator port can get the discovery log page data across the supported NVMe/TCP LIFs:

```
nvme discover -t tcp -w host-traddr -a traddr
```

Show example

```
nvme discover -t tcp -w 192.168.20.1 -a 192.168.20.20

Discovery Log Number of Records 8, Generation counter 18
=====Discovery Log Entry 0======
trtype:  tcp
adrfam:  ipv4
subtype: current discovery subsystem
treq:    not specified
portid:  4
trsvcid: 8009
subnqn:  nqn.1992-
08.com.netapp:sn.64e65e6caae711ef9668d039ea951c46:discovery
traddr:  192.168.21.21
eflags:  explicit discovery connections, duplicate discovery
information
sectype: none
=====Discovery Log Entry 1======
trtype:  tcp
adrfam:  ipv4
subtype: current discovery subsystem
treq:    not specified
portid:  2
trsvcid: 8009
subnqn:  nqn.1992-
08.com.netapp:sn.64e65e6caae711ef9668d039ea951c46:discovery
traddr:  192.168.20.21
eflags:  explicit discovery connections, duplicate discovery
information
sectype: none
=====Discovery Log Entry 2======
trtype:  tcp
adrfam:  ipv4
subtype: current discovery subsystem
treq:    not specified
portid:  3
trsvcid: 8009
subnqn:  nqn.1992-
08.com.netapp:sn.64e65e6caae711ef9668d039ea951c46:discovery
traddr:  192.168.21.20
eflags:  explicit discovery connections, duplicate discovery
information
sectype: none
=====Discovery Log Entry 3======
trtype:  tcp
```

```
adrfam:  ipv4
subtype: current discovery subsystem
treq:    not specified
portid:  1
trsvcid: 8009
subnqn:  nqn.1992-
08.com.netapp:sn.64e65e6caae711ef9668d039ea951c46:discovery
traddr:  192.168.20.20
eflags:  explicit discovery connections, duplicate discovery
information
sectype: none
=====Discovery Log Entry 4======
trtype:  tcp
adrfam:  ipv4
subtype: nvme subsystem
treq:    not specified
portid:  4
trsvcid: 4420
subnqn:  nqn.1992-
08.com.netapp:sn.64e65e6caae711ef9668d039ea951c46:subsystem.rock
ylinux10_tcp_subsystem
traddr:  192.168.21.21
eflags:  none
sectype: none
=====Discovery Log Entry 5======
trtype:  tcp
adrfam:  ipv4
subtype: nvme subsystem
treq:    not specified
portid:  2
trsvcid: 4420
subnqn:  nqn.1992-
08.com.netapp:sn.64e65e6caae711ef9668d039ea951c46:subsystem.rock
ylinux10_tcp_subsystem
traddr:  192.168.20.21
eflags:  none
sectype: none
=====Discovery Log Entry 6======
trtype:  tcp
adrfam:  ipv4
subtype: nvme subsystem
treq:    not specified
portid:  3
trsvcid: 4420
subnqn:  nqn.1992-
08.com.netapp:sn.64e65e6caae711ef9668d039ea951c46:subsystem.rock
```

```
ylinux10_tcp_subsystem
traddr:  192.168.21.20
eflags:  none
sectype: none
=====Discovery Log Entry 7======
trtype:  tcp
adrfam:  ipv4
subtype: nvme subsystem
treq:    not specified
portid:  1
trsvcid: 4420
subnqn:  nqn.1992-
08.com.netapp:sn.64e65e6caae711ef9668d039ea951c46:subsystem.rock
ylinux10_tcp_subsystem
traddr:  192.168.20.20
eflags:  none
sectype: none
```

2. Verify that the other NVMe/TCP initiator-target LIF combinations can successfully retrieve discovery log page data:

```
nvme discover -t tcp -w host-traddr -a traddr
```

Show example

```
nvme discover -t tcp -w 192.168.20.1 -a 192.168.20.20
nvme discover -t tcp -w 192.168.21.1 -a 192.168.21.20
nvme discover -t tcp -w 192.168.20.1 -a 192.168.20.21
nvme discover -t tcp -w 192.168.21.1 -a 192.168.21.21
```

3. Run the `nvme connect-all` command across all the supported NVMe/TCP initiator-target LIFs across the nodes:

```
nvme connect-all -t tcp -w host-traddr -a traddr
```

Show example

```
nvme    connect-all -t  tcp -w  192.168.20.1    -a
192.168.20.20
nvme    connect-all -t  tcp -w  192.168.21.1    -a
192.168.21.20
nvme    connect-all -t  tcp -w  192.168.20.1    -a
192.168.20.21
nvme    connect-all -t  tcp -w  192.168.21.1    -a
192.168.21.21
```

Beginning with Rocky Linux 9.4, the setting for the NVMe/TCP `ctrl_loss_tmo timeout` is automatically set to "off". As a result:

- There are no limits on the number of retries (indefinite retry).
- You don't need to manually configure a specific `ctrl_loss_tmo timeout` duration when using the `nvme connect` or `nvme connect-all` commands (option -l).
- The NVMe/TCP controllers don't experience timeouts in the event of a path failure and remain connected indefinitely.

Step 4: Optionally, enable 1MB I/O for NVMe/FC

ONTAP reports a Max Data Transfer Size (MDTS) of 8 in the Identify Controller data. This means the maximum I/O request size can be up to 1MB. To issue I/O requests of size 1MB for a Broadcom NVMe/FC host, you should increase the `lpfc` value of the `lpfc_sg_seg_cnt` parameter to 256 from the default value of 64.

These steps don't apply to Qlogic NVMe/FC hosts.

Steps

1. Set the `lpfc_sg_seg_cnt` parameter to 256:

   ```
   cat /etc/modprobe.d/lpfc.conf
   ```

   You should see an output similar to the following example:

   ```
   options lpfc lpfc_sg_seg_cnt=256
   ```

2. Run the `dracut -f` command, and reboot the host.
3. Verify that the value for `lpfc_sg_seg_cnt` is 256:

```
cat /sys/module/lpfc/parameters/lpfc_sg_seg_cnt
```

Step 5: Verify NVMe boot services

The `nvmefc-boot-connections.service` and `nvmf-autoconnect.service` boot services included in the NVMe/FC `nvme-cli` package are automatically enabled when the system boots.

After booting completes, verify that the `nvmefc-boot-connections.service` and `nvmf-autoconnect.service` boot services are enabled.

Steps

1. Verify that `nvmf-autoconnect.service` is enabled:

```
systemctl status nvmf-autoconnect.service
```

Show example output

```
nvmf-autoconnect.service - Connect NVMe-oF subsystems automatically
during boot
     Loaded: loaded (/usr/lib/systemd/system/nvmf-
autoconnect.service; enabled; preset: disabled)
     Active: inactive (dead)

Jun 10 04:06:26 SR630-13-201.lab.eng.btc.netapp.in systemd[1]:
Starting Connect NVMe-oF subsystems automatically during boot...
Jun 10 04:06:26 SR630-13-201.lab.eng.btc.netapp.in systemd[1]: nvmf-
autoconnect.service: Deactivated successfully.
Jun 10 04:06:26 SR630-13-201.lab.eng.btc.netapp.in systemd[1]:
Finished Connect NVMe-oF subsystems automatically during boot.
```

2. Verify that `nvmefc-boot-connections.service` is enabled:

```
systemctl status nvmefc-boot-connections.service
```

Show example output

```
nvmefc-boot-connections.service - Auto-connect to subsystems on FC-
NVME devices found during boot
     Loaded: loaded (/usr/lib/systemd/system/nvmefc-boot-
connections.service; enabled; preset: enabled)
     Active: inactive (dead) since Tue 2025-06-10 01:08:36 EDT; 2h
59min ago
   Main PID: 7090 (code=exited, status=0/SUCCESS)
        CPU: 30ms

Jun 10 01:08:36 localhost systemd[1]: Starting Auto-connect to
subsystems on FC-NVME devices found during boot...
Jun 10 01:08:36 localhost systemd[1]: nvmefc-boot-
connections.service: Deactivated successfully.
Jun 10 01:08:36 localhost systemd[1]: Finished Auto-connect to
subsystems on FC-NVME devices found during boot.
```

Step 6: Verify the multipathing configuration

Verify that the in-kernel NVMe multipath status, ANA status, and ONTAP namespaces are correct for the NVMe-oF configuration.

Steps

1. Verify that the in-kernel NVMe multipath is enabled:

   ```
   cat /sys/module/nvme_core/parameters/multipath
   ```

   You should see the following output:

   ```
   Y
   ```

2. Verify that the appropriate NVMe-oF settings (such as, model set to NetApp ONTAP Controller and load balancing iopolicy set to round-robin) for the respective ONTAP namespaces correctly reflect on the host:

   a. Display the subsystems:

      ```
      cat /sys/class/nvme-subsystem/nvme-subsys*/model
      ```

      You should see the following output:

```
NetApp ONTAP Controller
NetApp ONTAP Controller
```

b. Display the policy:

```
cat /sys/class/nvme-subsystem/nvme-subsys*/iopolicy
```

You should see the following output:

```
round-robin
round-robin
```

3. Verify that the namespaces are created and correctly discovered on the host:

```
nvme list
```

Show example

```
Node         SN                   Model
------------------------------------------------------------
/dev/nvme4n1 81Ix2BVuekWcAAAAAAAB   NetApp ONTAP Controller


Namespace Usage    Format             FW             Rev
------------------------------------------------------------
1                 21.47 GB / 21.47 GB   4 KiB + 0 B   FFFFFFFF
```

4. Verify that the controller state of each path is live and has the correct ANA status:

NVMe/FC

```
nvme list-subsys /dev/nvme5n1
```

Show example

```
nvme-subsys5 - NQN=nqn.1992-
08.com.netapp:sn.f7565b15a66911ef9668d039ea951c46:subsystem.nvme
1
               hostnqn=nqn.2014-08.org.nvmexpress:uuid:4c4c4544-
0056-5410-8048-c7c04f425633
\
 +- nvme126 fc traddr=nn-0x2036d039ea951c45:pn-
0x2038d039ea951c45,host_traddr=nn-0x2000f4c7aa0cd7c3:pn-
0x2100f4c7aa0cd7c3 live optimized
 +- nvme176 fc traddr=nn-0x2036d039ea951c45:pn-
0x2037d039ea951c45,host_traddr=nn-0x2000f4c7aa0cd7c2:pn-
0x2100f4c7aa0cd7c2 live optimized
 +- nvme5 fc traddr=nn-0x2036d039ea951c45:pn-
0x2039d039ea951c45,host_traddr=nn-0x2000f4c7aa0cd7c2:pn-
0x2100f4c7aa0cd7c2 live non-optimized
 +- nvme71 fc traddr=nn-0x2036d039ea951c45:pn-
0x203ad039ea951c45,host_traddr=nn-0x2000f4c7aa0cd7c3:pn-
0x2100f4c7aa0cd7c3 live non-optimized
```

NVMe/TCP

```
nvme list-subsys /dev/nvme4n2
```

Show example

```
nvme-subsys4 - NQN=nqn.1992-
08.com.netapp:sn.64e65e6caae711ef9668d039ea951c46:subsystem.nvme
4
               hostnqn=nqn.2014-08.org.nvmexpress:uuid:4c4c4544-
0035-5910-804b-c2c04f444d33
\
+- nvme102 tcp
traddr=192.168.21.20,trsvcid=4420,host_traddr=192.168.21.1,src_a
ddr=192.168.21.1 live non-optimized
+- nvme151 tcp
traddr=192.168.21.21,trsvcid=4420,host_traddr=192.168.21.1,src_a
ddr=192.168.21.1 live optimized
+- nvme4 tcp
traddr=192.168.20.20,trsvcid=4420,host_traddr=192.168.20.1,src_a
ddr=192.168.20.1 live non-optimized
+- nvme53 tcp
traddr=192.168.20.21,trsvcid=4420,host_traddr=192.168.20.1,src_a
ddr=192.168.20.1 live optimized
```

5. Verify that the NetApp plug-in displays the correct values for each ONTAP namespace device:

Column

```
nvme netapp ontapdevices -o column
```

Show example

```
Device        Vserver   Namespace Path
---------------------- ------------------------------------
/dev/nvme10n1     vs_tcp_rockylinux10       /vol/vol10/ns10

NSID       UUID                                   Size
---------------------- ------------------------------------
1    bbf51146-fc64-4197-b8cf-8a24f6f359b3   21.47GB
```

JSON

```
nvme netapp ontapdevices -o json
```

Show example

```
{
  "ONTAPdevices":[
    {
      "Device":"/dev/nvme10n1",
      "Vserver":"vs_tcp_rockylinux10",
      "Namespace_Path":"/vol/vol10/ns10",
      "NSID":1,
      "UUID":"bbf51146-fc64-4197-b8cf-8a24f6f359b3",
      "Size":"21.47GB",
      "LBA_Data_Size":4096,
      "Namespace_Size":5242880
}
]
    }
```

Step 7: Set up secure in-band authentication

Secure in-band authentication is supported over NVMe/TCP between a Rocky Linux 10.x host and an ONTAP controller.

Each host or controller must be associated with a `DH-HMAC-CHAP` key to set up secure authentication. A `DH-HMAC-CHAP` key is a combination of the NQN of the NVMe host or controller and an authentication secret configured by the administrator. To authenticate its peer, an NVMe host or controller must recognize the key associated with the peer.

Steps

Set up secure in-band authentication using the CLI or a config JSON file. If you need to specify different dhchap keys for different subsystems, you must use a config JSON file.

CLI

Set up secure in-band authentication using the CLI.

1. Obtain the host NQN:

```
cat /etc/nvme/hostnqn
```

2. Generate the dhchap key for the Rocky Linux 10.x host.

   The following output describes the `gen-dhchap-key` command parameters:

```
nvme gen-dhchap-key -s optional_secret -l key_length {32|48|64} -m
HMAC_function {0|1|2|3} -n host_nqn
•   -s secret key in hexadecimal characters to be used to initialize
the host key
•   -l length of the resulting key in bytes
•   -m HMAC function to use for key transformation
0 = none, 1- SHA-256, 2 = SHA-384, 3=SHA-512
•   -n host NQN to use for key transformation
```

   In the following example, a random dhchap key with HMAC set to 3 (SHA-512) is generated.

```
nvme gen-dhchap-key -m 3 -n nqn.2014-
08.org.nvmexpress:uuid:4c4c4544-0035-5910-804b-c2c04f444d33
DHHC-
1:03:7zf8I9gaRcDWH3tCH5vLGaoyjzPIvwNWusBfKdpJa+hia1aKDKJQ2o53pX3wYM9
xdv5DtKNNhJInZ7X8wU2RQpQIngc=:
```

3. On the ONTAP controller, add the host and specify both dhchap keys:

```
vserver nvme subsystem host add -vserver <svm_name> -subsystem
<subsystem> -host-nqn <host_nqn> -dhchap-host-secret
<authentication_host_secret> -dhchap-controller-secret
<authentication_controller_secret> -dhchap-hash-function {sha-
256|sha-512} -dhchap-group {none|2048-bit|3072-bit|4096-bit|6144-
bit|8192-bit}
```

4. A host supports two types of authentication methods, unidirectional and bidirectional. On the host, connect to the ONTAP controller and specify dhchap keys based on the chosen authentication method:

```
nvme connect -t tcp -w <host-traddr> -a <tr-addr> -n <host_nqn> -S
<authentication_host_secret> -C <authentication_controller_secret>
```

5. Validate the `nvme connect authentication` command by verifying the host and controller dhchap keys:

   a. Verify the host dhchap keys:

   ```
   cat /sys/class/nvme-subsystem/<nvme-subsysX>/nvme*/dhchap_secret
   ```

   Show example output for a unidirectional configuration

   ```
   cat /sys/class/nvme-subsystem/nvme-subsys1/nvme*/dhchap_secret
   DHHC-
   1:03:fMCrJharXUOqRoIsOEaG6m2PH1yYvu5+z3jTmzEKUbcWu26I33b93b
   il2WR09XDho/ld3L45J+0FeCsStBEAfhYgkQU=:
   DHHC-
   1:03:fMCrJharXUOqRoIsOEaG6m2PH1yYvu5+z3jTmzEKUbcWu26I33b93b
   il2WR09XDho/ld3L45J+0FeCsStBEAfhYgkQU=:
   DHHC-
   1:03:fMCrJharXUOqRoIsOEaG6m2PH1yYvu5+z3jTmzEKUbcWu26I33b93b
   il2WR09XDho/ld3L45J+0FeCsStBEAfhYgkQU=:
   DHHC-
   1:03:fMCrJharXUOqRoIsOEaG6m2PH1yYvu5+z3jTmzEKUbcWu26I33b93b
   il2WR09XDho/ld3L45J+0FeCsStBEAfhYgkQU=:
   ```

   b. Verify the controller dhchap keys:

   ```
   cat /sys/class/nvme-subsystem/<nvme-
   subsysX>/nvme*/dhchap_ctrl_secret
   ```

Show example output for a bidirectional configuration

```
cat /sys/class/nvme-subsystem/nvme-
subsys6/nvme*/dhchap_ctrl_secret
DHHC- 1:03:7zf8I9gaRcDWH3tCH5vLGaoyjzPIvwNWusBfKdpJa+hia
1aKDKJQ2o53pX3wYM9xdv5DtKNNhJInZ7X8wU2RQpQIngc=:

DHHC- 1:03:7zf8I9gaRcDWH3tCH5vLGaoyjzPIvwNWusBfKdpJa+hia
1aKDKJQ2o53pX3wYM9xdv5DtKNNhJInZ7X8wU2RQpQIngc=:

DHHC- 1:03:7zf8I9gaRcDWH3tCH5vLGaoyjzPIvwNWusBfKdpJa+hia
1aKDKJQ2o53pX3wYM9xdv5DtKNNhJInZ7X8wU2RQpQIngc=:

DHHC- 1:03:7zf8I9gaRcDWH3tCH5vLGaoyjzPIvwNWusBfKdpJa+hia
1aKDKJQ2o53pX3wYM9xdv5DtKNNhJInZ7X8wU2RQpQIngc=:
```

JSON

When multiple NVMe subsystems are available on the ONTAP controller, you can use the `/etc/nvme/config.json` file with the `nvme connect-all` command.

Use the `-o` option to generate the JSON file. Refer to the NVMe connect-all man pages for more syntax options.

1. Configure the JSON file.

> In the following example, `dhchap_key` corresponds to `dhchap_secret` and `dhchap_ctrl_key` corresponds to `dhchap_ctrl_secret`.

Show example

```
cat /etc/nvme/config.json
[
  {
    "hostnqn":"nqn.2014-08.org.nvmexpress:uuid:4c4c4544-0035-
5910-804b-c2c04f444d33",
    "hostid":"4c4c4544-0035-5910-804b-c2c04f444d33",
    "dhchap_key":"DHHC-
1:03:7zf8I9gaRcDWH3tCH5vLGaoyjzPIvwNWusBfKdpJa+hia1aKDKJQ2o53pX3
wYM9xdv5DtKNNhJInZ7X8wU2RQpQIngc=:",
    "subsystems":[
      {
        "nqn":"nqn.1992-
08.com.netapp:sn.127ade26168811f0a50ed039eab69ad3:subsystem.inba
nd_unidirectional",
        "ports":[
          {
            "transport":"tcp",
            "traddr":"192.168.20.17",
            "host_traddr":"192.168.20.1",
            "trsvcid":"4420"
          },
          {
            "transport":"tcp",
            "traddr":"192.168.20.18",
            "host_traddr":"192.168.20.1",
            "trsvcid":"4420"
          },
          {
            "transport":"tcp",
            "traddr":"192.168.21.18",
            "host_traddr":"192.168.21.1",
            "trsvcid":"4420"
          },
          {
            "transport":"tcp",
            "traddr":"192.168.21.17",
            "host_traddr":"192.168.21.1",
            "trsvcid":"4420"
}
]
```

2. Connect to the ONTAP controller using the config JSON file:

```
nvme connect-all -J /etc/nvme/config.json
```

Show example

```
traddr=192.168.20.20 is already connected
traddr=192.168.20.20 is already connected
traddr=192.168.20.20 is already connected
traddr=192.168.20.20 is already connected
traddr=192.168.20.20 is already connected
traddr=192.168.20.20 is already connected
traddr=192.168.20.20 is already connected
traddr=192.168.20.20 is already connected
traddr=192.168.20.21 is already connected
traddr=192.168.20.21 is already connected
traddr=192.168.20.21 is already connected
traddr=192.168.20.21 is already connected
traddr=192.168.20.21 is already connected
traddr=192.168.20.21 is already connected
traddr=192.168.20.21 is already connected
traddr=192.168.20.21 is already connected
```

3. Verify that the dhchap secrets have been enabled for the respective controllers for each subsystem.
   a. Verify the host dhchap keys:

      ```
      cat /sys/class/nvme-subsystem/nvme-subsys0/nvme0/dhchap_secret
      ```

      The following example shows a dhchap key:

      ```
      DHHC-1:03:7zf8I9gaRcDWH3tCH5vLGaoyjzPIvwNWusBfKdpJa+hia1
      aKDKJQ2o53pX3wYM9xdv5DtKNNhJInZ7X8wU2RQpQIngc=:
      ```

   b. Verify the controller dhchap keys:

      ```
      cat /sys/class/nvme-subsystem/nvme-
      subsys0/nvme0/dhchap_ctrl_secret
      ```

      You should see an output similar to the following example:

```
DHHC-1:03:fMCrJharXUOqRoIsOEaG6m2PH1yYvu5+z3jT
mzEKUbcWu26I33b93bil2WR09XDho/ld3L45J+0FeCsStBEAfhYgkQU=:
```

Step 8: Review the known issues

There are no known issues.

Configure Rocky Linux 9.x for NVMe-oF with ONTAP storage

Rocky Linux hosts support the NVMe over Fibre Channel (NVMe/FC) and NVMe over TCP (NVMe/TCP) protocols with Asymmetric Namespace Access (ANA). ANA provides multipathing functionality equivalent to asymmetric logical unit access (ALUA) in iSCSI and FCP environments.

Learn how to configure NVMe over Fabrics (NVMe-oF) hosts for Rocky Linux 9.x. For more support and feature information, see Rocky Linux ONTAP support and features.

NVMe-oF with Rocky Linux 9.x has the following known limitations:

- The `nvme disconnect-all` command disconnects both root and data filesystems and might lead to system instability. Do not issue this on systems booting from SAN over NVMe-TCP or NVMe-FC namespaces.

Step 1: Optionally, enable SAN booting

You can configure your host to use SAN booting to simplify deployment and improve scalability. Use the Interoperability Matrix Tool to verify that your Linux OS, host bus adapter (HBA), HBA firmware, HBA boot BIOS, and ONTAP version support SAN booting.

Steps

1. Create a NVMe namespace and map it to the host.
2. Enable SAN booting in the server BIOS for the ports to which the SAN boot namespace is mapped.

   For information on how to enable the HBA BIOS, see your vendor-specific documentation.

3. Reboot the host and verify that the OS is up and running.

Step 2: Install Rocky Linux and NVMe software and verify your configuration

To configure your host for NVMe-oF you need to install the host and NVMe software packages, enable multipathing, and verify your host NQN configuration.

Steps

1. Install Rocky Linux 9.x on the server. After the installation is complete, verify that you are running the required Rocky Linux 9.x kernel:

```
uname -r
```

Example Rocky Linux kernel version:

```
5.14.0-570.12.1.el9_6.x86_64
```

2. Install the `nvme-cli` package:

```
rpm -qa|grep nvme-cli
```

The following example shows an nvme-cli package version:

```
nvme-cli-2.11-5.el9.x86_64
```

3. Install the `libnvme` package:

```
rpm -qa|grep libnvme
```

The following example shows an `libnvme` package version:

```
libnvme-1.11.1-1.el9.x86_64
```

4. On the Rocky Linux host, check the hostnqn string at `/etc/nvme/hostnqn`:

```
cat /etc/nvme/hostnqn
```

The following example shows an `hostnqn` version:

```
nqn.2014-08.org.nvmexpress:uuid:4c4c4544-0056-5410-8048-b9c04f425633
```

5. On the ONTAP system, verify that the `hostnqn` string matches the `hostnqn` string for the corresponding subsystem on the ONTAP array:

```
::> vserver nvme subsystem host show -vserver vs_coexistence_LPE36002
```

Show example

```
Vserver Subsystem Priority  Host NQN
------- --------- --------
-------------------------------------------------
vs_coexistence_LPE36002
        nvme
                  regular   nqn.2014-
08.org.nvmexpress:uuid:4c4c4544-0056-5410-8048-b9c04f425633
        nvme_1
                  regular   nqn.2014-
08.org.nvmexpress:uuid:4c4c4544-0056-5410-8048-b9c04f425633
        nvme_2
                  regular   nqn.2014-
08.org.nvmexpress:uuid:4c4c4544-0056-5410-8048-b9c04f425633
        nvme_3
                  regular   nqn.2014-
08.org.nvmexpress:uuid:4c4c4544-0056-5410-8048-b9c04f425633
4 entries were displayed.
```

If the `hostnqn` strings do not match, use the `vserver modify` command to update the `hostnqn` string on your corresponding ONTAP array subsystem to match the `hostnqn` string from `/etc/nvme/hostnqn` on the host.

Step 3: Configure NVMe/FC and NVMe/TCP

Configure NVMe/FC with Broadcom/Emulex or Marvell/QLogic adapters, or configure NVMe/TCP using manual discovery and connect operations.

NVMe/FC - Broadcom/Emulex

Configure NVMe/FC for a Broadcom/Emulex adapter.

Steps

1. Verify that you are using the supported adapter model:
   a. Display the model names:

```
cat /sys/class/scsi_host/host*/modelname
```

   You should see the following output:

```
LPe36002-M64
LPe36002-M64
```

   b. Display the model descriptions:

```
cat /sys/class/scsi_host/host*/modeldesc
```

   You should see an output similar to the following example:

```
Emulex LightPulse LPe36002-M64 2-Port 64Gb Fibre Channel Adapter
Emulex LightPulse LPe36002-M64 2-Port 64Gb Fibre Channel Adapter
```

2. Verify that you are using the recommended Broadcom `lpfc` firmware and inbox driver:
   a. Display the firmware version:

```
cat /sys/class/scsi_host/host*/fwrev
```

   The command returns the firmware versions:

```
14.0.539.16, sli-4:6:d
14.0.539.16, sli-4:6:d
```

   b. Display the inbox driver version:

```
cat /sys/module/lpfc/version
```

   The following example shows a driver version:

```
0:14.4.0.6
```

For the current list of supported adapter driver and firmware versions, see the Interoperability Matrix Tool.

3. Verify that `lpfc_enable_fc4_type` is set to `3`:

```
cat /sys/module/lpfc/parameters/lpfc_enable_fc4_type
```

4. Verify that you can view your initiator ports:

```
cat /sys/class/fc_host/host*/port_name
```

The following example shows port identities:

```
0x2100f4c7aa0cd7c2
0x2100f4c7aa0cd7c3
```

5. Verify that your initiator ports are online:

```
cat /sys/class/fc_host/host*/port_state
```

You should see the following output:

```
Online
Online
```

6. Verify that the NVMe/FC initiator ports are enabled and that the target ports are visible:

```
cat /sys/class/scsi_host/host*/nvme_info
```

Show example

```
NVME Initiator Enabled
XRI Dist lpfc0 Total 6144 IO 5894 ELS 250
NVME LPORT lpfc0 WWPN x100000109b954518 WWNN x200000109b954518
DID x000000 ONLINE

NVME Statistics
LS: Xmt 0000000000 Cmpl 0000000000 Abort 00000000
LS XMIT: Err 00000000  CMPL: xb 00000000 Err 00000000
Total FCP Cmpl 0000000000000000 Issue 0000000000000000 OutIO
0000000000000000
          abort 00000000 noxri 00000000 nondlp 00000000 qdepth
00000000 wqerr 00000000 err 00000000
FCP CMPL: xb 00000000 Err 00000000

NVME Initiator Enabled
XRI Dist lpfc1 Total 6144 IO 5894 ELS 250
NVME LPORT lpfc1 WWPN x100000109b954519 WWNN x200000109b954519
DID x020500 ONLINE

NVME Statistics
LS: Xmt 0000000000 Cmpl 0000000000 Abort 00000000
LS XMIT: Err 00000000  CMPL: xb 00000000 Err 00000000
Total FCP Cmpl 0000000000000000 Issue 0000000000000000 OutIO
0000000000000000
         abort 00000000 noxri 00000000 nondlp 00000000 qdepth
00000000 wqerr 00000000 err 00000000
FCP CMPL: xb 00000000 Err 00000000

NVME Initiator Enabled
XRI Dist lpfc2 Total 6144 IO 5894 ELS 250
NVME LPORT lpfc2 WWPN x100000109bf044b1 WWNN x200000109bf044b1
DID x022a00 ONLINE
NVME RPORT       WWPN x200bd039eaa7dfc8 WWNN x2008d039eaa7dfc8
DID x021319 TARGET DISCSRVC ONLINE
NVME RPORT       WWPN x2155d039eaa7dfc8 WWNN x2154d039eaa7dfc8
DID x02130f TARGET DISCSRVC ONLINE
NVME RPORT       WWPN x2001d039eaa7dfc8 WWNN x2000d039eaa7dfc8
DID x021310 TARGET DISCSRVC ONLINE
NVME RPORT       WWPN x200dd039eaa7dfc8 WWNN x2008d039eaa7dfc8
DID x020b15 TARGET DISCSRVC ONLINE
NVME RPORT       WWPN x2156d039eaa7dfc8 WWNN x2154d039eaa7dfc8
DID x020b0d TARGET DISCSRVC ONLINE
NVME RPORT       WWPN x2003d039eaa7dfc8 WWNN x2000d039eaa7dfc8
DID x020b10 TARGET DISCSRVC ONLINE
```

```
NVME Statistics
LS: Xmt 0000003049 Cmpl 0000003049 Abort 00000000
LS XMIT: Err 00000000  CMPL: xb 00000000 Err 00000000
Total FCP Cmpl 0000000018f9450b Issue 0000000018f5de57 OutIO
fffffffffffc994c
          abort 000036d3 noxri 00000313 nondlp 00000c8d qdepth
00000000 wqerr 00000064 err 00000000
FCP CMPL: xb 000036d1 Err 000fef0f

NVME Initiator Enabled
XRI Dist lpfc3 Total 6144 IO 5894 ELS 250
NVME LPORT lpfc3 WWPN x100000109bf044b2 WWNN x200000109bf044b2
DID x021b00 ONLINE
NVME RPORT       WWPN x2062d039eaa7dfc8 WWNN x2008d039eaa7dfc8
DID x022915 TARGET DISCSRVC ONLINE
NVME RPORT       WWPN x2157d039eaa7dfc8 WWNN x2154d039eaa7dfc8
DID x02290f TARGET DISCSRVC ONLINE
NVME RPORT       WWPN x2002d039eaa7dfc8 WWNN x2000d039eaa7dfc8
DID x022910 TARGET DISCSRVC ONLINE
NVME RPORT       WWPN x2065d039eaa7dfc8 WWNN x2008d039eaa7dfc8
DID x020119 TARGET DISCSRVC ONLINE
NVME RPORT       WWPN x2158d039eaa7dfc8 WWNN x2154d039eaa7dfc8
DID x02010d TARGET DISCSRVC ONLINE
NVME RPORT       WWPN x2004d039eaa7dfc8 WWNN x2000d039eaa7dfc8
DID x020110 TARGET DISCSRVC ONLINE

NVME Statistics
LS: Xmt 0000002f2c Cmpl 0000002f2c Abort 00000000
LS XMIT: Err 00000000  CMPL: xb 00000000 Err 00000000
Total FCP Cmpl 000000001aaf3eb5 Issue 000000001aab4373 OutIO
fffffffffffc04be
          abort 000035cc noxri 0000038c nondlp 000009e3 qdepth
00000000 wqerr 00000082 err 00000000
FCP CMPL: xb 000035cc Err 000fcfc0
```

NVMe/FC - Marvell/QLogic

Configure NVMe/FC for a Marvell/QLogic adapter.

Steps

1. Verify that you are using the supported adapter driver and firmware versions:

```
cat /sys/class/fc_host/host*/symbolic_name
```

The following example shows driver and firmware versions:

```
QLE2872 FW:v9.15.00 DVR:v10.02.09.300-k
QLE2872 FW:v9.15.00 DVR:v10.02.09.300-k
```

2. Verify that `ql2xnvmeenable` is set. This enables the Marvell adapter to function as an NVMe/FC initiator:

```
cat /sys/module/qla2xxx/parameters/ql2xnvmeenable
```

The expected output is 1.

NVMe/TCP

The NVMe/TCP protocol does not support the auto-connect operation. You must manually perform the NVMe/TCP connect or connect-all operations to discover the NVMe/TCP subsystems and namespaces.

Steps

1. Check that the initiator port can get the discovery log page data across the supported NVMe/TCP LIFs:

```
nvme discover -t tcp -w host-traddr -a traddr
```

Show example

```
nvme discover -t tcp -w 192.168.1.31 -a 192.168.1.24

Discovery Log Number of Records 20, Generation counter 25
=====Discovery Log Entry 0======
trtype:  tcp
adrfam:  ipv4
subtype: current discovery subsystem
treq:    not specified
portid:  4
trsvcid: 8009
subnqn:  nqn.1992-
08.com.netapp:sn.0f4ba1e74eb611ef9f50d039eab6cb6d:discovery
traddr:  192.168.2.25
eflags:  explicit discovery connections, duplicate discovery
information
sectype: none
=====Discovery Log Entry 1======
trtype:  tcp
adrfam:  ipv4
subtype: current discovery subsystem
treq:    not specified
portid:  2
trsvcid: 8009
subnqn:  nqn.1992-
08.com.netapp:sn.0f4ba1e74eb611ef9f50d039eab6cb6d:discovery
traddr:  192.168.1.25
eflags:  explicit discovery connections, duplicate discovery
information
sectype: none
=====Discovery Log Entry 2======
trtype:  tcp
adrfam:  ipv4
subtype: current discovery subsystem
treq:    not specified
portid:  5
trsvcid: 8009
subnqn:  nqn.1992-
08.com.netapp:sn.0f4ba1e74eb611ef9f50d039eab6cb6d:discovery
traddr:  192.168.2.24
eflags:  explicit discovery connections, duplicate discovery
information
sectype: none
=====Discovery Log Entry 3======
trtype:  tcp
```

```
adrfam:  ipv4
subtype: current discovery subsystem
treq:    not specified
portid:  1
trsvcid: 8009
subnqn:  nqn.1992-
08.com.netapp:sn.0f4ba1e74eb611ef9f50d039eab6cb6d:discovery
traddr:  192.168.1.24
eflags:  explicit discovery connections, duplicate discovery
information
sectype: none
=====Discovery Log Entry 4======
trtype:  tcp
adrfam:  ipv4
subtype: nvme subsystem
treq:    not specified
portid:  4
trsvcid: 4420
subnqn:  nqn.1992-
08.com.netapp:sn.0f4ba1e74eb611ef9f50d039eab6cb6d:subsystem.
Unidirectional_DHCP_NONE_1_3
traddr:  192.168.2.25
eflags:  none
sectype: none
=====Discovery Log Entry 5======
trtype:  tcp
adrfam:  ipv4
subtype: nvme subsystem
treq:    not specified
portid:  2
trsvcid: 4420
subnqn:  nqn.1992-
08.com.netapp:sn.0f4ba1e74eb611ef9f50d039eab6cb6d:subsystem.
Unidirectional_DHCP_NONE_1_4
traddr:  192.168.1.25
eflags:  none
sectype: none
=====Discovery Log Entry 6======
trtype:  tcp
adrfam:  ipv4
subtype: nvme subsystem
treq:    not specified
portid:  5
trsvcid: 4420
subnqn:  nqn.1992-
08.com.netapp:sn.0f4ba1e74eb611ef9f50d039eab6cb6d:subsystem.
```

```
Unidirectional_DHCP_NONE_1_5
traddr:  192.168.2.24
eflags:  none
sectype: none
=====Discovery Log Entry 7======
trtype:  tcp
adrfam:  ipv4
subtype: nvme subsystem
treq:    not specified
portid:  1
trsvcid: 4420
subnqn:  nqn.1992-
08.com.netapp:sn.0f4ba1e74eb611ef9f50d039eab6cb6d:subsystem.
Unidirectional_DHCP_2_2
traddr:  192.168.1.24
eflags:  none
sectype: none
=====Discovery Log Entry 8======
trtype:  tcp
adrfam:  ipv4
subtype: nvme subsystem
treq:    not specified
portid:  4
trsvcid: 4420
subnqn:  nqn.1992-
08.com.netapp:sn.0f4ba1e74eb611ef9f50d039eab6cb6d:subsystem.
Unidirectional_DHCP_2_3
traddr:  192.168.2.25
eflags:  none
sectype: none
=====Discovery Log Entry 9======
trtype:  tcp
adrfam:  ipv4
subtype: nvme subsystem
treq:    not specified
portid:  2
trsvcid: 4420
subnqn:  nqn.1992-
08.com.netapp:sn.0f4ba1e74eb611ef9f50d039eab6cb6d:subsystem.
Unidirectional_DHCP_2_5
traddr:  192.168.1.25
eflags:  none
sectype: none
=====Discovery Log Entry 10======
trtype:  tcp
adrfam:  ipv4
```

```
subtype: nvme subsystem
treq:    not specified
portid:  5
trsvcid: 4420
subnqn:  nqn.1992-
08.com.netapp:sn.0f4ba1e74eb611ef9f50d039eab6cb6d:subsystem.
Bidirectional_DHCP_2_2
traddr:  192.168.2.24
eflags:  none
sectype: none
=====Discovery Log Entry 11======
trtype:  tcp
adrfam:  ipv4
subtype: nvme subsystem
treq:    not specified
portid:  1
trsvcid: 4420
subnqn:  nqn.1992-
08.com.netapp:sn.0f4ba1e74eb611ef9f50d039eab6cb6d:subsystem.
Bidirectional_DHCP_2_3
traddr:  192.168.1.24
eflags:  none
sectype: none
=====Discovery Log Entry 12======
trtype:  tcp
adrfam:  ipv4
subtype: nvme subsystem
treq:    not specified
portid:  4
trsvcid: 4420
subnqn:  nqn.1992-
08.com.netapp:sn.0f4ba1e74eb611ef9f50d039eab6cb6d:subsystem.
Bidirectional_DHCP_2_3
traddr:  192.168.2.25
eflags:  none
sectype: none
=====Discovery Log Entry 13======
trtype:  tcp
adrfam:  ipv4
subtype: nvme subsystem
treq:    not specified
portid:  2
trsvcid: 4420
subnqn:  nqn.1992-
08.com.netapp:sn.0f4ba1e74eb611ef9f50d039eab6cb6d:subsystem.
Bidirectional_DHCP_NONE_2_4
```

```
traddr:  192.168.1.25
eflags:  none
sectype: none
=====Discovery Log Entry 14======
trtype:  tcp
adrfam:  ipv4
subtype: nvme subsystem
treq:    not specified
portid:  5
trsvcid: 4420
subnqn:  nqn.1992-
08.com.netapp:sn.0f4ba1e74eb611ef9f50d039eab6cb6d:subsystem.
Bidirectional_DHCP_NONE_2_5
traddr:  192.168.2.24
eflags:  none
sectype: none
=====Discovery Log Entry 15======
trtype:  tcp
adrfam:  ipv4
subtype: nvme subsystem
treq:    not specified
portid:  1
trsvcid: 4420
subnqn:  nqn.1992-
08.com.netapp:sn.0f4ba1e74eb611ef9f50d039eab6cb6d:subsystem.
Bidirectional_DHCP_NONE_2_6
traddr:  192.168.1.24
eflags:  none
sectype: none
=====Discovery Log Entry 16======
trtype:  tcp
adrfam:  ipv4
subtype: nvme subsystem
treq:    not specified
portid:  4
trsvcid: 4420
subnqn:  nqn.1992-
08.com.netapp:sn.0f4ba1e74eb611ef9f50d039eab6cb6d:subsystem.
Bidirectional_DHCP_NONE_2_7
traddr:  192.168.2.25
eflags:  none
sectype: none
=====Discovery Log Entry 17======
trtype:  tcp
adrfam:  ipv4
subtype: nvme subsystem
```

```
treq:    not specified
portid:  2
trsvcid: 4420
subnqn:  nqn.1992-
08.com.netapp:sn.0f4ba1e74eb611ef9f50d039eab6cb6d:subsystem.
Bidirectional_DHCP_NONE_2_8
traddr:  192.168.1.25
eflags:  none
sectype: none
=====Discovery Log Entry 18======
trtype:  tcp
adrfam:  ipv4
subtype: nvme subsystem
treq:    not specified
portid:  5
trsvcid: 4420
subnqn:  nqn.1992-
08.com.netapp:sn.0f4ba1e74eb611ef9f50d039eab6cb6d:subsystem.nvme
_tcp_2
traddr:  192.168.2.24
eflags:  none
sectype: none
=====Discovery Log Entry 19======
trtype:  tcp
adrfam:  ipv4
subtype: nvme subsystem
treq:    not specified
portid:  1
trsvcid: 4420
subnqn:  nqn.1992-
08.com.netapp:sn.0f4ba1e74eb611ef9f50d039eab6cb6d:subsystem.
Bidirectional_DHCP_NONE_2_9
traddr:  192.168.1.24
eflags:  none
sectype: none
```

2. Verify that the other NVMe/TCP initiator-target LIF combinations can successfully get discovery log page data:

```
nvme discover -t tcp -w host-traddr -a traddr
```

Show example

```
nvme discover -t tcp -w 192.168.1.31 -a 192.168.1.24
nvme discover -t tcp -w 192.168.2.31 -a 192.168.2.24
nvme discover -t tcp -w 192.168.1.31 -a 192.168.1.25
nvme discover -t tcp -w 192.168.2.31 -a 192.168.2.25
```

3. Run the `nvme connect-all` command across all the supported NVMe/TCP initiator-target LIFs across the nodes:

```
nvme connect-all -t tcp -w host-traddr -a traddr
```

Show example

```
nvme    connect-all -t  tcp -w  192.168.1.31    -a  192.168.1.24
nvme    connect-all -t  tcp -w  192.168.2.31    -a  192.168.2.24
nvme    connect-all -t  tcp -w  192.168.1.31    -a  192.168.1.25
nvme    connect-all -t  tcp -w  192.168.2.31    -a  192.168.2.25
```

Beginning with Rocky Linux 9.4, the setting for the NVMe/TCP `ctrl_loss_tmo timeout` is automatically set to "off". As a result:

- There are no limits on the number of retries (indefinite retry).
- You don't need to manually configure a specific `ctrl_loss_tmo timeout` duration when using the `nvme connect` or `nvme connect-all` commands (option -l).
- The NVMe/TCP controllers don't experience timeouts in the event of a path failure and remain connected indefinitely.

Step 4: Optionally, enable 1MB I/O for NVMe/FC

ONTAP reports a Max Data Transfer Size (MDTS) of 8 in the Identify Controller data. This means the maximum I/O request size can be up to 1MB. To issue I/O requests of size 1MB for a Broadcom NVMe/FC host, you should increase the `lpfc` value of the `lpfc_sg_seg_cnt` parameter to 256 from the default value of 64.

These steps don't apply to Qlogic NVMe/FC hosts.

Steps

1. Set the `lpfc_sg_seg_cnt` parameter to 256:

```
cat /etc/modprobe.d/lpfc.conf
```

You should see an output similar to the following example:

```
options lpfc lpfc_sg_seg_cnt=256
```

2. Run the `dracut -f` command, and reboot the host.
3. Verify that the value for `lpfc_sg_seg_cnt` is 256:

```
cat /sys/module/lpfc/parameters/lpfc_sg_seg_cnt
```

Step 5: Verify NVMe boot services

The `nvmefc-boot-connections.service` and `nvmf-autoconnect.service` boot services included in the NVMe/FC `nvme-cli` package are automatically enabled when the system boots.

After booting completes, verify that the `nvmefc-boot-connections.service` and `nvmf-autoconnect.service` boot services are enabled.

Steps

1. Verify that `nvmf-autoconnect.service` is enabled:

```
systemctl status nvmf-autoconnect.service
```

Show example output

```
nvmf-autoconnect.service - Connect NVMe-oF subsystems automatically
during boot
     Loaded: loaded (/usr/lib/systemd/system/nvmf-
autoconnect.service; enabled; preset: disabled)
     Active: inactive (dead)

Jun 10 04:06:26 SR630-13-201.lab.eng.btc.netapp.in systemd[1]:
Starting Connect NVMe-oF subsystems automatically during boot...
Jun 10 04:06:26 SR630-13-201.lab.eng.btc.netapp.in systemd[1]: nvmf-
autoconnect.service: Deactivated successfully.
Jun 10 04:06:26 SR630-13-201.lab.eng.btc.netapp.in systemd[1]:
Finished Connect NVMe-oF subsystems automatically during boot.
```

2. Verify that `nvmefc-boot-connections.service` is enabled:

```
systemctl status nvmefc-boot-connections.service
```

Show example output

```
nvmefc-boot-connections.service - Auto-connect to subsystems on FC-
NVME devices found during boot
     Loaded: loaded (/usr/lib/systemd/system/nvmefc-boot-
connections.service; enabled; preset: enabled)
     Active: inactive (dead) since Tue 2025-06-10 01:08:36 EDT; 2h
59min ago
   Main PID: 7090 (code=exited, status=0/SUCCESS)
        CPU: 30ms

Jun 10 01:08:36 localhost systemd[1]: Starting Auto-connect to
subsystems on FC-NVME devices found during boot...
Jun 10 01:08:36 localhost systemd[1]: nvmefc-boot-
connections.service: Deactivated successfully.
Jun 10 01:08:36 localhost systemd[1]: Finished Auto-connect to
subsystems on FC-NVME devices found during boot.
```

Step 6: Verify the multipathing configuration

Verify that the in-kernel NVMe multipath status, ANA status, and ONTAP namespaces are correct for the NVMe-oF configuration.

Steps

1. Verify that the in-kernel NVMe multipath is enabled:

   ```
   cat /sys/module/nvme_core/parameters/multipath
   ```

   You should see the following output:

   ```
   Y
   ```

2. Verify that the appropriate NVMe-oF settings (such as, model set to NetApp ONTAP Controller and load balancing iopolicy set to round-robin) for the respective ONTAP namespaces correctly reflect on the host:

   a. Display the subsystems:

      ```
      cat /sys/class/nvme-subsystem/nvme-subsys*/model
      ```

      You should see the following output:

```
NetApp ONTAP Controller
NetApp ONTAP Controller
```

b. Display the policy:

```
cat /sys/class/nvme-subsystem/nvme-subsys*/iopolicy
```

You should see the following output:

```
round-robin
round-robin
```

3. Verify that the namespaces are created and correctly discovered on the host:

```
nvme list
```

Show example

```
Node         SN                   Model
------------------------------------------------------------
/dev/nvme4n1 81Ix2BVuekWcAAAAAAAB   NetApp ONTAP Controller


Namespace Usage    Format             FW             Rev
------------------------------------------------------------
1                 21.47 GB / 21.47 GB   4 KiB + 0 B   FFFFFFFF
```

4. Verify that the controller state of each path is live and has the correct ANA status:

NVMe/FC

```
nvme list-subsys /dev/nvme4n5
```

Show example

```
nvme-subsys4 - NQN=nqn.1992-
08.com.netapp:sn.3a5d31f5502c11ef9f50d039eab6cb6d:subsystem.nvme
_1
               hostnqn=nqn.2014-08.org.nvmexpress:uuid:e6dade64-
216d-
11ec-b7bb-7ed30a5482c3
iopolicy=round-robin\
+- nvme1 fc traddr=nn-0x2082d039eaa7dfc8:pn-
0x2088d039eaa7dfc8,host_traddr=nn-0x20000024ff752e6d:pn-
0x21000024ff752e6d live optimized
+- nvme12 fc traddr=nn-0x2082d039eaa7dfc8:pn-
0x208ad039eaa7dfc8,host_traddr=nn-0x20000024ff752e6d:pn-
0x21000024ff752e6d live non-optimized
+- nvme10 fc traddr=nn-0x2082d039eaa7dfc8:pn-
0x2087d039eaa7dfc8,host_traddr=nn-0x20000024ff752e6c:pn-
0x21000024ff752e6c live non-optimized
+- nvme3 fc traddr=nn-0x2082d039eaa7dfc8:pn-
0x2083d039eaa7dfc8,host_traddr=nn-0x20000024ff752e6c:pn-
0x21000024ff752e6c live optimized
```

NVMe/TCP

```
nvme list-subsys /dev/nvme1n1
```

Show example

```
nvme-subsys5 - NQN=nqn.1992-
08.com.netapp:sn.0f4ba1e74eb611ef9f50d039eab6cb6d:subsystem.nvme
_tcp_3
hostnqn=nqn.2014-08.org.nvmexpress:uuid:4c4c4544-0035-5910-804b-
b5c04f444d33
iopolicy=round-robin
\
+- nvme13 tcp
traddr=192.168.2.25,trsvcid=4420,host_traddr=192.168.2.31,
src_addr=192.168.2.31 live optimized
+- nvme14 tcp
traddr=192.168.2.24,trsvcid=4420,host_traddr=192.168.2.31,
src_addr=192.168.2.31 live non-optimized
+- nvme5 tcp
traddr=192.168.1.25,trsvcid=4420,host_traddr=192.168.1.31,
src_addr=192.168.1.31 live optimized
+- nvme6 tcp
traddr=192.168.1.24,trsvcid=4420,host_traddr=192.168.1.31,
src_addr=192.168.1.31 live non-optimized
```

5. Verify that the NetApp plug-in displays the correct values for each ONTAP namespace device:

Column

```
nvme netapp ontapdevices -o column
```

Show example

```
Device        Vserver   Namespace Path
------------------------ ------------------------------
/dev/nvme1n1     linux_tcnvme_iscsi
/vol/tcpnvme_1_0_0/tcpnvme_ns

NSID       UUID                                   Size
------------------------------------------------------------
1    5f7f630d-8ea5-407f-a490-484b95b15dd6   21.47GB
```

JSON

```
nvme netapp ontapdevices -o json
```

Show example

```
{
  "ONTAPdevices":[
    {
      "Device":"/dev/nvme1n1",
      "Vserver":"linux_tcnvme_iscsi",
      "Namespace_Path":"/vol/tcpnvme_1_0_0/tcpnvme_ns",
      "NSID":1,
      "UUID":"5f7f630d-8ea5-407f-a490-484b95b15dd6",
      "Size":"21.47GB",
      "LBA_Data_Size":4096,
      "Namespace_Size":5242880
    },
]
}
```

Step 7: Set up secure in-band authentication

Secure in-band authentication is supported over NVMe/TCP between a Rocky Linux 9x host and an ONTAP controller.

Each host or controller must be associated with a `DH-HMAC-CHAP` key to set up secure authentication. A `DH-HMAC-CHAP` key is a combination of the NQN of the NVMe host or controller and an authentication secret configured by the administrator. To authenticate its peer, an NVMe host or controller must recognize the key associated with the peer.

Steps

Set up secure in-band authentication using the CLI or a config JSON file. If you need to specify different dhchap keys for different subsystems, you must use a config JSON file.

CLI

Set up secure in-band authentication using the CLI.

1. Obtain the host NQN:

```
cat /etc/nvme/hostnqn
```

2. Generate the dhchap key for the Rocky Linux 9.x host.

   The following output describes the `gen-dhchap-key` command parameters:

```
nvme gen-dhchap-key -s optional_secret -l key_length {32|48|64} -m
HMAC_function {0|1|2|3} -n host_nqn
•   -s secret key in hexadecimal characters to be used to initialize
the host key
•   -l length of the resulting key in bytes
•   -m HMAC function to use for key transformation
0 = none, 1- SHA-256, 2 = SHA-384, 3=SHA-512
•   -n host NQN to use for key transformation
```

   In the following example, a random dhchap key with HMAC set to 3 (SHA-512) is generated.

```
nvme gen-dhchap-key -m 3 -n nqn.2014-
08.org.nvmexpress:uuid:e6dade64-216d-11ec-b7bb-7ed30a5482c3
DHHC-
1:03:wSpuuKbBHTzC0W9JZxMBsYd9JFV8Si9aDh22k2BR/4m852vH7KGlrJeMpzhmyjD
WOo0PJJM6yZsTeEpGkDHMHQ255+g=:
```

3. On the ONTAP controller, add the host and specify both dhchap keys:

```
vserver nvme subsystem host add -vserver <svm_name> -subsystem
<subsystem> -host-nqn <host_nqn> -dhchap-host-secret
<authentication_host_secret> -dhchap-controller-secret
<authentication_controller_secret> -dhchap-hash-function {sha-
256|sha-512} -dhchap-group {none|2048-bit|3072-bit|4096-bit|6144-
bit|8192-bit}
```

4. A host supports two types of authentication methods, unidirectional and bidirectional. On the host, connect to the ONTAP controller and specify dhchap keys based on the chosen authentication method:

```
nvme connect -t tcp -w <host-traddr> -a <tr-addr> -n <host_nqn> -S
<authentication_host_secret> -C <authentication_controller_secret>
```

5. Validate the `nvme connect authentication` command by verifying the host and controller dhchap keys:

   a. Verify the host dhchap keys:

   ```
   cat /sys/class/nvme-subsystem/<nvme-subsysX>/nvme*/dhchap_secret
   ```

   Show example output for a unidirectional configuration

   ```
   cat /sys/class/nvme-subsystem/nvme-subsys1/nvme*/dhchap_secret
   DHHC-1:01:CNxTYq73T9vJk0JpOfDBZrhDCqpWBN4XVZI5WxwPgDUieHAi:
   DHHC-1:01:CNxTYq73T9vJk0JpOfDBZrhDCqpWBN4XVZI5WxwPgDUieHAi:
   DHHC-1:01:CNxTYq73T9vJk0JpOfDBZrhDCqpWBN4XVZI5WxwPgDUieHAi:
   DHHC-1:01:CNxTYq73T9vJk0JpOfDBZrhDCqpWBN4XVZI5WxwPgDUieHAi:
   ```

   b. Verify the controller dhchap keys:

   ```
   cat /sys/class/nvme-subsystem/<nvme-
   subsysX>/nvme*/dhchap_ctrl_secret
   ```

   Show example output for a bidirectional configuration

   ```
   cat /sys/class/nvme-subsystem/nvme-
   subsys6/nvme*/dhchap_ctrl_secret
   DHHC-
   1:03:wSpuuKbBHTzC0W9JZxMBsYd9JFV8Si9aDh22k2BR/4m852vH7KGlrJeMp
   zhmyjDWOo0PJJM6yZsTeEpGkDHMHQ255+g=:
   DHHC-
   1:03:wSpuuKbBHTzC0W9JZxMBsYd9JFV8Si9aDh22k2BR/4m852vH7KGlrJeMp
   zhmyjDWOo0PJJM6yZsTeEpGkDHMHQ255+g=:
   DHHC-
   1:03:wSpuuKbBHTzC0W9JZxMBsYd9JFV8Si9aDh22k2BR/4m852vH7KGlrJeMp
   zhmyjDWOo0PJJM6yZsTeEpGkDHMHQ255+g=:
   DHHC-
   1:03:wSpuuKbBHTzC0W9JZxMBsYd9JFV8Si9aDh22k2BR/4m852vH7KGlrJeMp
   zhmyjDWOo0PJJM6yZsTeEpGkDHMHQ255+g=:
   ```

JSON

When multiple NVMe subsystems are available on the ONTAP controller, you can use the `/etc/nvme/config.json` file with the `nvme connect-all` command.

Use the `-o` option to generate the JSON file. Refer to the NVMe connect-all man pages for more syntax options.

1. Configure the JSON file.

In the following example, `dhchap_key` corresponds to `dhchap_secret` and `dhchap_ctrl_key` corresponds to `dhchap_ctrl_secret`.

Show example

```
cat /etc/nvme/config.json
[
{
  "hostnqn":"nqn.2014-08.org.nvmexpress:uuid:9796c1ec-0d34-11eb-
  b6b2-3a68dd3bab57",
  "hostid":"b033cd4fd6db4724adb48655bfb55448",
  "dhchap_key":" DHHC-
1:01:CNxTYq73T9vJk0JpOfDBZrhDCqpWBN4XVZI5WxwPgDUieHAi:"
},
{
  "hostnqn":"nqn.2014-08.org.nvmexpress:uuid:4c4c4544-0035-5910-
  804b-b5c04f444d33",
  "subsystems":[
        {
          "nqn":"nqn.1992-

08.com.netapp:sn.0f4ba1e74eb611ef9f50d039eab6cb6d:subsystem.bidi
          r_DHCP",
          "ports":[
              {
                  "transport":"tcp",
                    "traddr":" 192.168.1.24 ",
                  "host_traddr":" 192.168.1.31 ",
                  "trsvcid":"4420",
                  "dhchap_ctrl_key":"DHHC-
                  1:03:
wSpuuKbBHTzC0W9JZxMBsYd9JFV8Si9aDh22k2BR/4m852vH7KGlrJeMpzhmyjDW
Oo0PJJM6yZsTeEpGkDHMHQ255+g=:"
              },
              {
                  "transport":"tcp",
                  "traddr":" 192.168.1.25 ",
                  "host_traddr":" 192.168.1.31",
                  "trsvcid":"4420",
                  "dhchap_ctrl_key":"DHHC-
                  1:03:
wSpuuKbBHTzC0W9JZxMBsYd9JFV8Si9aDh22k2BR/4m852vH7KGlrJeMpzhmyjDW
Oo0PJJM6yZsTeEpGkDHMHQ255+g=:"
              },
              {
                  "transport":"tcp",
                 "traddr":" 192.168.2.24 ",
                  "host_traddr":" 192.168.2.31",
                  "trsvcid":"4420",
```

```
                "dhchap_ctrl_key":"DHHC-
                1:03:
wSpuuKbBHTzC0W9JZxMBsYd9JFV8Si9aDh22k2BR/4m852vH7KGlrJeMpzhmyjDW
Oo0PJJM6yZsTeEpGkDHMHQ255+g=:"
            },
            {
                "transport":"tcp",
                "traddr":" 192.168.2.25 ",
                  "host_traddr":" 192.168.2.31",
                "trsvcid":"4420",
                "dhchap_ctrl_key":"DHHC-
                1:03:
wSpuuKbBHTzC0W9JZxMBsYd9JFV8Si9aDh22k2BR/4m852vH7KGlrJeMpzhmyjDW
Oo0PJJM6yZsTeEpGkDHMHQ255+g=:"
            }
        ]
    }
  ]
}
]
```

2. Connect to the ONTAP controller using the config JSON file:

```
nvme connect-all -J /etc/nvme/config.json
```

Show example

```
already connected to hostnqn=nqn.2014-
08.org.nvmexpress:uuid:4c4c4544-0035-5910-804b-
b5c04f444d33,nqn=nqn.1992-
08.com.netapp:sn.8dde3be2cc7c11efb777d039eab6cb6d:subsystem.
bidi
r_DHCP,transport=tcp,traddr=192.168.1.25,trsvcid=4420
already connected to hostnqn=nqn.2014-
08.org.nvmexpress:uuid:4c4c4544-0035-5910-804b-
b5c04f444d33,nqn=nqn.1992-
08.com.netapp:sn.8dde3be2cc7c11efb777d039eab6cb6d:subsystem.
bidi
r_DHCP,transport=tcp,traddr=192.168.2.25,trsvcid=4420
already connected to hostnqn=nqn.2014-
08.org.nvmexpress:uuid:4c4c4544-0035-5910-804b-
b5c04f444d33,nqn=nqn.1992-
08.com.netapp:sn.8dde3be2cc7c11efb777d039eab6cb6d:subsystem.
bidi
r_DHCP,transport=tcp,traddr=192.168.1.24,trsvcid=4420
already connected to hostnqn=nqn.2014-
08.org.nvmexpress:uuid:4c4c4544-0035-5910-804b-
b5c04f444d33,nqn=nqn.1992-
08.com.netapp:sn.8dde3be2cc7c11efb777d039eab6cb6d:subsystem.
bidi
r_DHCP,transport=tcp,traddr=192.168.2.24,trsvcid=4420
```

3. Verify that the dhchap secrets have been enabled for the respective controllers for each subsystem:
   a. Verify the host dhchap keys:

      ```
      cat /sys/class/nvme-subsystem/nvme-subsys0/nvme0/dhchap_secret
      ```

      The following example shows a dhchap key:

      ```
      DHHC-1:01:CNxTYq73T9vJk0JpOfDBZrhDCqpWBN4XVZI5WxwPgDUieHAi:
      ```

   b. Verify the controller dhchap keys:

      ```
      cat /sys/class/nvme-subsystem/nvme-
      subsys0/nvme0/dhchap_ctrl_secret
      ```

      You should see an output similar to the following example:

```
DHHC-
1:03:wSpuuKbBHTzC0W9JZxMBsYd9JFV8Si9aDh22k2BR/4m852vH7KGlrJeMpzhm
yjDWOo0PJJM6yZsTeEpGkDHMHQ255+g=:
```

Step 8: Review the known issues

There are no known issues.

Configure Rocky Linux 8.x for NVMe-oF with ONTAP storage

Rocky Linux hosts support the NVMe over Fibre Channel (NVMe/FC) and NVMe over TCP (NVMe/TCP) protocols with Asymmetric Namespace Access (ANA). ANA provides multipathing functionality equivalent to asymmetric logical unit access (ALUA) in iSCSI and FCP environments.

Learn how to configure NVMe over Fabrics (NVMe-oF) hosts for Rocky Linux 8.x. For more support and feature information, see Rocky Linux ONTAP support and features.

NVMe-oF with Rocky Linux 8.x has the following known limitations:

- SAN booting using the NVMe-oF protocol is not currently supported.
- In-kernel NVMe multipath is disabled by default on NVMe-oF hosts in Rocky Linux 8.x; you must enable it manually.
- NVMe/TCP is available as a technology preview due to known issues.

Step 1: Install Rocky Linux and NVMe software and verify your configuration

To configure your host for NVMe-oF you need to install the host and NVMe software packages, enable multipathing, and verify your host NQN configuration.

Steps

1. Install Rocky Linux 8.x on the server. After the installation is complete, verify that you are running the required Rocky Linux 8.x kernel:

   ```
   uname -r
   ```

   Example Rocky Linux kernel version:

   ```
   5.14.0-570.12.1.el9_6.x86_64
   ```

2. Install the `nvme-cli` package:

```
rpm -qa|grep nvme-cli
```

The following example shows an nvme-cli package version:

```
nvme-cli-2.11-5.el9.x86_64
```

3. Install the `libnvme` package:

```
rpm -qa|grep libnvme
```

The following example shows an `libnvme` package version:

```
libnvme-1.11.1-1.el9.x86_64
```

4. On the Rocky Linux host, check the hostnqn string at `/etc/nvme/hostnqn`:

```
cat /etc/nvme/hostnqn
```

The following example shows an `hostnqn` version:

```
nqn.2014-08.org.nvmexpress:uuid:4c4c4544-0056-5410-8048-b9c04f425633
```

5. On the ONTAP system, verify that the `hostnqn` string matches the `hostnqn` string for the corresponding subsystem on the ONTAP array:

```
::> vserver nvme subsystem host show -vserver vs_coexistence_LPE36002
```

Show example

```
Vserver Subsystem Priority  Host NQN
------- --------- --------
-------------------------------------------------
vs_coexistence_LPE36002
        nvme
                  regular   nqn.2014-
08.org.nvmexpress:uuid:4c4c4544-0056-5410-8048-b9c04f425633
        nvme_1
                  regular   nqn.2014-
08.org.nvmexpress:uuid:4c4c4544-0056-5410-8048-b9c04f425633
        nvme_2
                  regular   nqn.2014-
08.org.nvmexpress:uuid:4c4c4544-0056-5410-8048-b9c04f425633
        nvme_3
                  regular   nqn.2014-
08.org.nvmexpress:uuid:4c4c4544-0056-5410-8048-b9c04f425633
4 entries were displayed.
```

If the `hostnqn` strings do not match, use the `vserver modify` command to update the `hostnqn` string on your corresponding ONTAP array subsystem to match the `hostnqn` string from `/etc/nvme/hostnqn` on the host.

Step 2: Configure NVMe/FC and NVMe/TCP

Configure NVMe/FC with Broadcom/Emulex or Marvell/QLogic adapters, or configure NVMe/TCP using manual discovery and connect operations.

NVMe/FC - Broadcom/Emulex

Configure NVMe/FC for a Broadcom/Emulex adapter.

Steps

1. Verify that you are using the supported adapter model:
   a. Display the model names:

```
cat /sys/class/scsi_host/host*/modelname
```

   You should see the following output:

```
LPe36002-M64
LPe36002-M64
```

   b. Display the model descriptions:

```
cat /sys/class/scsi_host/host*/modeldesc
```

   You should see an output similar to the following example:

```
Emulex LightPulse LPe36002-M64 2-Port 64Gb Fibre Channel Adapter
Emulex LightPulse LPe36002-M64 2-Port 64Gb Fibre Channel Adapter
```

2. Verify that you are using the recommended Broadcom `lpfc` firmware and inbox driver:
   a. Display the firmware version:

```
cat /sys/class/scsi_host/host*/fwrev
```

   The command returns the firmware versions:

```
14.4.317.10, sli-4:6:d
14.4.317.10, sli-4:6:d
```

   b. Display the inbox driver version:

```
cat /sys/module/lpfc/version`
```

   The following example shows a driver version:

```
0:14.4.0.2
```

For the current list of supported adapter driver and firmware versions, see the Interoperability Matrix Tool.

3. Verify that the expected output of `lpfc_enable_fc4_type` is set to `3`:

```
cat /sys/module/lpfc/parameters/lpfc_enable_fc4_type
```

4. Verify that you can view your initiator ports:

```
cat /sys/class/fc_host/host*/port_name
```

The following example shows port identities:

```
0x100000109bf044b1
0x100000109bf044b2
```

5. Verify that your initiator ports are online:

```
cat /sys/class/fc_host/host*/port_state
```

You should see the following output:

```
Online
Online
```

6. Verify that the NVMe/FC initiator ports are enabled and that the target ports are visible:

```
cat /sys/class/scsi_host/host*/nvme_info
```

Show example

```
NVME Initiator Enabled
XRI Dist lpfc2 Total 6144 IO 5894 ELS 250
NVME LPORT lpfc2 WWPN x100000109bf044b1 WWNN x200000109bf044b1
DID x022a00 ONLINE
NVME RPORT       WWPN x202fd039eaa7dfc8 WWNN x202cd039eaa7dfc8
DID x021310 TARGET DISCSRVC ONLINE
NVME RPORT       WWPN x202dd039eaa7dfc8 WWNN x202cd039eaa7dfc8
DID x020b10 TARGET DISCSRVC ONLINE

NVME Statistics
LS: Xmt 0000000810 Cmpl 0000000810 Abort 00000000
LS XMIT: Err 00000000  CMPL: xb 00000000 Err 00000000
Total FCP Cmpl 000000007b098f07 Issue 000000007aee27c4 OutIO
fffffffffe498bd
        abort 000013b4 noxri 00000000 nondlp 00000058 qdepth
00000000 wqerr 00000000 err 00000000
FCP CMPL: xb 000013b4 Err 00021443

NVME Initiator Enabled
XRI Dist lpfc3 Total 6144 IO 5894 ELS 250
NVME LPORT lpfc3 WWPN x100000109bf044b2 WWNN x200000109bf044b2
DID x021b00 ONLINE
NVME RPORT       WWPN x2033d039eaa7dfc8 WWNN x202cd039eaa7dfc8
DID x020110 TARGET DISCSRVC ONLINE
NVME RPORT       WWPN x2032d039eaa7dfc8 WWNN x202cd039eaa7dfc8
DID x022910 TARGET DISCSRVC ONLINE

NVME Statistics
LS: Xmt 0000000840 Cmpl 0000000840 Abort 00000000
LS XMIT: Err 00000000  CMPL: xb 00000000 Err 00000000
Total FCP Cmpl 000000007afd4434 Issue 000000007ae31b83 OutIO
fffffffffe5d74f
        abort 000014a5 noxri 00000000 nondlp 0000006a qdepth
00000000 wqerr 00000000 err 00000000
FCP CMPL: xb 000014a5 Err 0002149a
```

NVMe/FC - Marvell/QLogic

Configure NVMe/FC for a Marvell/QLogic adapter.

Steps

1. Verify that you are running the supported adapter driver and firmware versions:

```
cat /sys/class/fc_host/host*/symbolic_name
```

The follow example shows driver and firmware versions:

```
QLE2742 FW:v9.14.00 DVR:v10.02.09.200-k
QLE2742 FW:v9.14.00 DVR:v10.02.09.200-k
```

2. Verify that `ql2xnvmeenable` is set. This enables the Marvell adapter to function as an NVMe/FC initiator:

```
cat /sys/module/qla2xxx/parameters/ql2xnvmeenable
```

The expected output is 1.

NVMe/TCP

The NVMe/TCP protocol doesn't support the auto-connect operation. Instead, you can discover the NVMe/TCP subsystems and namespaces by performing the NVMe/TCP `connect` or `connect-all` operations manually.

Steps

1. Check that the initiator port can get the discovery log page data across the supported NVMe/TCP LIFs:

```
nvme discover -t tcp -w host-traddr -a traddr
```

Show example

```
nvme discover -t tcp -w 192.168.1.31 -a 192.168.1.24
Discovery Log Number of Records 20, Generation counter 25
=====Discovery Log Entry 0======
trtype:  tcp
adrfam:  ipv4
subtype: current discovery subsystem
treq:    not specified
portid:  4
trsvcid: 8009
subnqn:  nqn.1992-
08.com.netapp:sn.0f4ba1e74eb611ef9f50d039eab6cb6d:discovery
traddr:  192.168.2.25
eflags:  explicit discovery connections, duplicate discovery
information
sectype: none
=====Discovery Log Entry 1======
trtype:  tcp
adrfam:  ipv4
subtype: current discovery subsystem
treq:    not specified
portid:  2
trsvcid: 8009
subnqn:  nqn.1992-
08.com.netapp:sn.0f4ba1e74eb611ef9f50d039eab6cb6d:discovery
traddr:  192.168.1.25
eflags:  explicit discovery connections, duplicate discovery
information
sectype: none
=====Discovery Log Entry 2======
trtype:  tcp
adrfam:  ipv4
subtype: current discovery subsystem
treq:    not specified
portid:  5
trsvcid: 8009
subnqn:  nqn.1992-
08.com.netapp:sn.0f4ba1e74eb611ef9f50d039eab6cb6d:discovery
traddr:  192.168.2.24
eflags:  explicit discovery connections, duplicate discovery
information
sectype: none
=====Discovery Log Entry 3======
trtype:  tcp
adrfam:  ipv4
```

```
subtype: current discovery subsystem
treq:    not specified
portid:  1
trsvcid: 8009
subnqn:  nqn.1992-
08.com.netapp:sn.0f4ba1e74eb611ef9f50d039eab6cb6d:discovery
traddr:  192.168.1.24
eflags:  explicit discovery connections, duplicate discovery
information
sectype: none
=====Discovery Log Entry 4======
trtype:  tcp
adrfam:  ipv4
subtype: nvme subsystem
treq:    not specified
portid:  4
trsvcid: 4420
subnqn:  nqn.1992-
08.com.netapp:sn.0f4ba1e74eb611ef9f50d039eab6cb6d:subsystem.nvme
_tcp_1
traddr:  192.168.2.25
eflags:  none
sectype: none
=====Discovery Log Entry 5======
trtype:  tcp
adrfam:  ipv4
subtype: nvme subsystem
treq:    not specified
portid:  2
trsvcid: 4420
subnqn:  nqn.1992-
08.com.netapp:sn.0f4ba1e74eb611ef9f50d039eab6cb6d:subsystem.nvme
_tcp_1
traddr:  192.168.1.25
eflags:  none
sectype: none
=====Discovery Log Entry 6======
trtype:  tcp
adrfam:  ipv4
subtype: nvme subsystem
treq:    not specified
portid:  5
trsvcid: 4420
subnqn:  nqn.1992-
08.com.netapp:sn.0f4ba1e74eb611ef9f50d039eab6cb6d:subsystem.nvme
_tcp_1
```

```
traddr:  192.168.2.24
eflags:  none
sectype: none
=====Discovery Log Entry 7======
trtype:  tcp
adrfam:  ipv4
subtype: nvme subsystem
treq:    not specified
portid:  1
trsvcid: 4420
subnqn:  nqn.1992-
08.com.netapp:sn.0f4ba1e74eb611ef9f50d039eab6cb6d:subsystem.nvme
_tcp_1
traddr:  192.168.1.24
eflags:  none
sectype: none
=====Discovery Log Entry 8======
trtype:  tcp
adrfam:  ipv4
subtype: nvme subsystem
treq:    not specified
portid:  4
trsvcid: 4420
subnqn:  nqn.1992-
08.com.netapp:sn.0f4ba1e74eb611ef9f50d039eab6cb6d:subsystem.nvme
_tcp_4
traddr:  192.168.2.25
eflags:  none
sectype: none
=====Discovery Log Entry 9======
trtype:  tcp
adrfam:  ipv4
subtype: nvme subsystem
treq:    not specified
portid:  2
trsvcid: 4420
subnqn:  nqn.1992-
08.com.netapp:sn.0f4ba1e74eb611ef9f50d039eab6cb6d:subsystem.nvme
_tcp_4
traddr:  192.168.1.25
eflags:  none
sectype: none
=====Discovery Log Entry 10======
trtype:  tcp
adrfam:  ipv4
subtype: nvme subsystem
```

```
treq:    not specified
portid:  5
trsvcid: 4420
subnqn:  nqn.1992-
08.com.netapp:sn.0f4ba1e74eb611ef9f50d039eab6cb6d:subsystem.nvme
_tcp_4
traddr:  192.168.2.24
eflags:  none
sectype: none
=====Discovery Log Entry 11======
trtype:  tcp
adrfam:  ipv4
subtype: nvme subsystem
treq:    not specified
portid:  1
trsvcid: 4420
subnqn:  nqn.1992-
08.com.netapp:sn.0f4ba1e74eb611ef9f50d039eab6cb6d:subsystem.nvme
_tcp_4
traddr:  192.168.1.24
eflags:  none
sectype: none
=====Discovery Log Entry 12======
trtype:  tcp
adrfam:  ipv4
subtype: nvme subsystem
treq:    not specified
portid:  4
trsvcid: 4420
subnqn:  nqn.1992-
08.com.netapp:sn.0f4ba1e74eb611ef9f50d039eab6cb6d:subsystem.nvme
_tcp_3
traddr:  192.168.2.25
eflags:  none
sectype: none
=====Discovery Log Entry 13======
trtype:  tcp
adrfam:  ipv4
subtype: nvme subsystem
treq:    not specified
portid:  2
trsvcid: 4420
subnqn:  nqn.1992-
08.com.netapp:sn.0f4ba1e74eb611ef9f50d039eab6cb6d:subsystem.nvme
_tcp_3
traddr:  192.168.1.25
```

```
eflags:  none
sectype: none
=====Discovery Log Entry 14======
trtype:  tcp
adrfam:  ipv4
subtype: nvme subsystem
treq:    not specified
portid:  5
trsvcid: 4420
subnqn:  nqn.1992-
08.com.netapp:sn.0f4ba1e74eb611ef9f50d039eab6cb6d:subsystem.nvme
_tcp_3
traddr:  192.168.2.24
eflags:  none
sectype: none
=====Discovery Log Entry 15======
trtype:  tcp
adrfam:  ipv4
subtype: nvme subsystem
treq:    not specified
portid:  1
trsvcid: 4420
subnqn:  nqn.1992-
08.com.netapp:sn.0f4ba1e74eb611ef9f50d039eab6cb6d:subsystem.nvme
_tcp_3
traddr:  192.168.1.24
eflags:  none
sectype: none
=====Discovery Log Entry 16======
trtype:  tcp
adrfam:  ipv4
subtype: nvme subsystem
treq:    not specified
portid:  4
trsvcid: 4420
subnqn:  nqn.1992-
08.com.netapp:sn.0f4ba1e74eb611ef9f50d039eab6cb6d:subsystem.nvme
_tcp_2
traddr:  192.168.2.25
eflags:  none
sectype: none
=====Discovery Log Entry 17======
trtype:  tcp
adrfam:  ipv4
subtype: nvme subsystem
treq:    not specified
```

```
portid:  2
trsvcid: 4420
subnqn:  nqn.1992-
08.com.netapp:sn.0f4ba1e74eb611ef9f50d039eab6cb6d:subsystem.nvme
_tcp_2
traddr:  192.168.1.25
eflags:  none
sectype: none
=====Discovery Log Entry 18======
trtype:  tcp
adrfam:  ipv4
subtype: nvme subsystem
treq:    not specified
portid:  5
trsvcid: 4420
subnqn:  nqn.1992-
08.com.netapp:sn.0f4ba1e74eb611ef9f50d039eab6cb6d:subsystem.nvme
_tcp_2
traddr:  192.168.2.24
eflags:  none
sectype: none
=====Discovery Log Entry 19======
trtype:  tcp
adrfam:  ipv4
subtype: nvme subsystem
treq:    not specified
portid:  1
trsvcid: 4420
subnqn:  nqn.1992-
08.com.netapp:sn.0f4ba1e74eb611ef9f50d039eab6cb6d:subsystem.nvme
_tcp_2
traddr:  192.168.1.24
eflags:  none
sectype: none
```

2. Verify that the other NVMe/TCP initiator-target LIF combinations are able to successfully fetch discovery log page data:

```
nvme discover -t tcp -w host-traddr -a traddr
```

Show example

```
nvme discover -t tcp -w 192.168.1.31 -a 192.168.1.24
nvme discover -t tcp -w 192.168.2.31 -a 192.168.2.24
nvme discover -t tcp -w 192.168.1.31 -a 192.168.1.25
nvme discover -t tcp -w 192.168.2.31 -a 192.168.2.25
```

3. Run the `nvme connect-all` command across all the supported NVMe/TCP initiator-target LIFs across the nodes:

```
nvme connect-all -t tcp -w host-traddr -a traddr
```

Show example

```
nvme    connect-all -t  tcp -w  192.168.1.31    -a  192.168.1.24
nvme    connect-all -t  tcp -w  192.168.2.31    -a  192.168.2.24
nvme    connect-all -t  tcp -w  192.168.1.31    -a  192.168.1.25
nvme    connect-all -t  tcp -w  192.168.2.31    -a  192.168.2.25
```

Step 3: Optionally, enable 1MB I/O for NVMe/FC

You can enable I/O requests of size 1MB for NVMe/FC configured with a Broadcom adapter. ONTAP reports a Max Data Transfer Size (MDTS) of 8 in the Identify Controller data. This means the maximum I/O request size can be up to 1MB. To issue I/O requests of size 1MB, you need to increase the lpfc value of the `lpfc_sg_seg_cnt` parameter to 256 from the default value of 64.

These steps don't apply to Qlogic NVMe/FC hosts.

Steps

1. Set the `lpfc_sg_seg_cnt` parameter to 256:

```
cat /etc/modprobe.d/lpfc.conf
```

```
options lpfc lpfc_sg_seg_cnt=256
```

2. Run the `dracut -f` command, and reboot the host.
3. Verify that the value for `lpfc_sg_seg_cnt` is 256:

```
cat /sys/module/lpfc/parameters/lpfc_sg_seg_cnt
```

Step 4: Verify the multipathing configuration

Verify that the in-kernel NVMe multipath status, ANA status, and ONTAP namespaces are correct for the NVMe-oF configuration.

Steps

1. Verify that the in-kernel NVMe multipath is enabled:

   ```
   cat /sys/module/nvme_core/parameters/multipath
   ```

   You should see the following output:

   ```
   Y
   ```

2. Verify that the appropriate NVMe-oF settings (such as, model set to NetApp ONTAP Controller and load balancing iopolicy set to round-robin) for the respective ONTAP namespaces correctly reflect on the host:

   a. Display the subsystems:

      ```
      cat /sys/class/nvme-subsystem/nvme-subsys*/model
      ```

      You should see the following output:

      ```
      NetApp ONTAP Controller
      NetApp ONTAP Controller
      ```

   b. Display the policy:

      ```
      cat /sys/class/nvme-subsystem/nvme-subsys*/iopolicy
      ```

      You should see the following output:

      ```
      round-robin
      round-robin
      ```

3. Verify that the namespaces are created and correctly discovered on the host:

```
nvme list
```

Show example

```
Node         SN                   Model
------------------------------------------------------------
/dev/nvme4n1 81Ix2BVuekWcAAAAAAAB   NetApp ONTAP Controller


Namespace Usage    Format             FW             Rev
------------------------------------------------------------
1                 21.47 GB / 21.47 GB   4 KiB + 0 B   FFFFFFFF
```

4. Verify that the controller state of each path is live and has the correct ANA status:

NVMe/FC

```
nvme list-subsys /dev/nvme4n5
```

Show example

```
nvme-subsys4 - NQN=nqn.1992-
08.com.netapp:sn.3a5d31f5502c11ef9f50d039eab6cb6d:subsystem.nvme
_1
               hostnqn=nqn.2014-08.org.nvmexpress:uuid:e6dade64-
216d-
11ec-b7bb-7ed30a5482c3
iopolicy=round-robin\
+- nvme1 fc traddr=nn-0x2082d039eaa7dfc8:pn-
0x2088d039eaa7dfc8,host_traddr=nn-0x20000024ff752e6d:pn-
0x21000024ff752e6d live optimized
+- nvme12 fc traddr=nn-0x2082d039eaa7dfc8:pn-
0x208ad039eaa7dfc8,host_traddr=nn-0x20000024ff752e6d:pn-
0x21000024ff752e6d live non-optimized
+- nvme10 fc traddr=nn-0x2082d039eaa7dfc8:pn-
0x2087d039eaa7dfc8,host_traddr=nn-0x20000024ff752e6c:pn-
0x21000024ff752e6c live non-optimized
+- nvme3 fc traddr=nn-0x2082d039eaa7dfc8:pn-
0x2083d039eaa7dfc8,host_traddr=nn-0x20000024ff752e6c:pn-
0x21000024ff752e6c live optimized
```

NVMe/TCP

```
nvme list-subsys /dev/nvme1n1
```

Show example

```
nvme-subsys5 - NQN=nqn.1992-
08.com.netapp:sn.0f4ba1e74eb611ef9f50d039eab6cb6d:subsystem.nvme
_tcp_3
hostnqn=nqn.2014-08.org.nvmexpress:uuid:4c4c4544-0035-5910-804b-
b5c04f444d33
iopolicy=round-robin
\
+- nvme13 tcp
traddr=192.168.2.25,trsvcid=4420,host_traddr=192.168.2.31,
src_addr=192.168.2.31 live optimized
+- nvme14 tcp
traddr=192.168.2.24,trsvcid=4420,host_traddr=192.168.2.31,
src_addr=192.168.2.31 live non-optimized
+- nvme5 tcp
traddr=192.168.1.25,trsvcid=4420,host_traddr=192.168.1.31,
src_addr=192.168.1.31 live optimized
+- nvme6 tcp
traddr=192.168.1.24,trsvcid=4420,host_traddr=192.168.1.31,
src_addr=192.168.1.31 live non-optimized
```

5. Verify that the NetApp plug-in displays the correct values for each ONTAP namespace device:

Column

```
nvme netapp ontapdevices -o column
```

Show example

```
Device        Vserver   Namespace Path
------------------------ ------------------------------
/dev/nvme1n1     linux_tcnvme_iscsi
/vol/tcpnvme_1_0_0/tcpnvme_ns

NSID       UUID                                   Size
--------------------------------------------------------------
1    5f7f630d-8ea5-407f-a490-484b95b15dd6   21.47GB
```

JSON

```
nvme netapp ontapdevices -o json
```

Show example

```
{
  "ONTAPdevices":[
    {
      "Device":"/dev/nvme1n1",
      "Vserver":"linux_tcnvme_iscsi",
      "Namespace_Path":"/vol/tcpnvme_1_0_0/tcpnvme_ns",
      "NSID":1,
      "UUID":"5f7f630d-8ea5-407f-a490-484b95b15dd6",
      "Size":"21.47GB",
      "LBA_Data_Size":4096,
      "Namespace_Size":5242880
    },
]
}
```

Step 5: Review the known issues

These are the known issues:

NetApp Bug ID	Title	Description
1479047	Rocky Linux 8.x NVMe-oF hosts create duplicate persistent discovery controllers	On NVMe-oF hosts, you can use the "nvme discover -p" command to create Persistent Discovery Controllers (PDCs). When this command is used, only one PDC should be created per initiator-target combination. However, if you are running Rocky Linux 8.x on an NVMe-oF host, a duplicate PDC is created each time "nvme discover -p" is executed. This leads to unnecessary usage of resources on both the host and the target.

Copyright information

Trademark information