RHEL 8

SAN hosts and cloud clients

NetApp
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NVMe-oF host configuration for RHEL 8.9 with ONTAP

NVMe over Fabrics (NVMe-oF), including NVMe over Fibre Channel (NVMe/FC) and other transports, is supported with Red Hat Enterprise Linux (RHEL) 8.9 with Asymmetric Namespace Access (ANA). In NVMe-oF environments, ANA is the equivalent of ALUA multipathing in iSCSI and FC environments and is implemented with in-kernel NVMe multipath.

The following support is available for NVMe-oF host configuration for RHEL 8.9 with ONTAP:

- Support for NVMe over TCP (NVMe/TCP) in addition to NVMe/FC. The NetApp plug-in in the native nvme-cli package displays ONTAP details for both NVMe/FC and NVMe/TCP namespaces.

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

Known limitations

- In-kernel NVMe multipath is disabled by default for RHEL 8.9 NVMe-oF hosts. Therefore, you need to enable it manually.
- On RHEL 8.9 hosts, NVMe/TCP is a technology preview feature due to open issues.
- SAN booting using the NVMe-oF protocol is currently not supported.

Enable in-kernel multipath

You can use the following procedure to enable in-kernel multipath.

Steps

1. Install RHEL 8.9 on the host server.
2. After the installation is complete, verify that you are running the specified RHEL 8.9 kernel:

   ```
   # uname -r
   ```

   Example output

   ```
   4.18.0-513.5.1.el8_9.x86_64
   ```

3. Install the nvme-cli package:

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

   Example output

```
nvme-cli-1.16-9.el8.x86_64
```

4. Enable in -kernel NVMe multipath:

```
# grubby --args=nvme_core.multipath=Y --update-kernel /boot/vmlinuz-
4.18.0-513.5.1.el8_9.x86_64
```

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

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

Example output

```
nqn.2014-08.org.nvmexpress:uuid:4c4c4544-0032-3410-8035-b8c04f4c5132
```

6. Verify that the `hostnqn` string matches the `hostnqn` string for the corresponding subsystem on the ONTAP array:

```
::> vserver nvme subsystem host show -vserver vs_fcnvme_141
```

Example output

```
Vserver     Subsystem       Host NQN
----------- ---------------
------------------------------------------------------------
vs_nvme101 rhel_101_QLe2772    nqn.2014-08.org.nvmexpress:
uuid:4c4c4544-0032-3410-8035-b8c04f4c5132
```

> If the host NQN strings do not match, you can use the `vserver modify` command to update the host NQN string on your corresponding ONTAP NVMe subsystem to match the host NQN string `/etc/nvme/hostnqn` on the host.

7. Reboot the host.

If you intend to run both NVMe and SCSI co-existent traffic on the same host, NetApp recommends using the in-kernel NVMe multipath for ONTAP namespaces and dm-multipath for ONTAP LUNs respectively. This should exclude the ONTAP namespaces from dm-multipath and prevent dm-multipath from claiming these namespace devices. You can do this by adding the `enable_foreign` setting to the `/etc/multipath.conf` file:

```
# cat /etc/multipath.conf
defaults {
  enable_foreign  NONE
}
```

Configure NVMe/FC

You can configure NVMe/FC for Broadcom/Emulex or Marvell/Qlogic adapters.

Broadcom/Emulex

Steps

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

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

Example output:

```
LPe32002-M2
LPe32002-M2
```

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

Example output:

```
Emulex LightPulse LPe32002-M2 2-Port 32Gb Fibre Channel Adapter
Emulex LightPulse LPe32002-M2 2-Port 32Gb Fibre Channel Adapter
```

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

```
# cat /sys/class/scsi_host/host*/fwrev
14.2.539.16, sli-4:2:c
14.2.539.16, sli-4:2:c
```

```
# cat /sys/module/lpfc/version
0:14.0.0.21
```

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

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

```
# cat /sys/module/lpfc/parameters/lpfc_enable_fc4_type
3
```

4. Verify that the initiator ports are up and running and that you can see the target LIFs:

```
# cat /sys/class/fc_host/host*/port_name
0x10000090fae0ec88
0x10000090fae0ec89
```

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

```
# cat /sys/class/scsi_host/host*/nvme_info
NVME Initiator Enabled
XRI Dist lpfc0 Total 6144 IO 5894 ELS 250
NVME LPORT lpfc0 WWPN x10000090fae0ec88 WWNN x20000090fae0ec88 DID
x0a1300 ONLINE
NVME RPORT       WWPN x2049d039ea36a105 WWNN x2048d039ea36a105 DID
x0a0c0a TARGET DISCSRVC ONLINE
NVME Statistics
LS: Xmt 0000000024 Cmpl 0000000024 Abort 00000000
LS XMIT: Err 00000000 CMPL: xb 00000000 Err 00000000
Total FCP Cmpl 00000000000001aa Issue 00000000000001ab OutIO
0000000000000001
        abort 00000002 noxri 00000000 nondlp 00000000 qdepth
00000000 wqerr 00000000 err 00000000
FCP CMPL: xb 00000002 Err 00000003
NVME Initiator Enabled
XRI Dist lpfc1 Total 6144 IO 5894 ELS 250
NVME LPORT lpfc1 WWPN x10000090fae0ec89 WWNN x20000090fae0ec89 DID
x0a1200 ONLINE
NVME RPORT       WWPN x204ad039ea36a105 WWNN x2048d039ea36a105 DID
x0a080a TARGET DISCSRVC ONLINE
NVME Statistics
LS: Xmt 0000000024 Cmpl 0000000024 Abort 00000000
LS XMIT: Err 00000000 CMPL: xb 00000000 Err 00000000
Total FCP Cmpl 00000000000001ac Issue 00000000000001ad OutIO
0000000000000001
        abort 00000002 noxri 00000000 nondlp 00000000 qdepth
00000000 wqerr 00000000 err 00000000
FCP CMPL: xb 00000002 Err 00000003
```

Marvell/QLogic FC Adapter for NVMe/FC

Steps

1. The native inbox qla2xxx driver included in the RHEL 8.9 GA kernel has the latest upstream fixes essential for ONTAP support. Verify that you are running the supported adapter driver and firmware

versions:

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

Example output

```
QLE2742 FW: v9.10.11 DVR: v10.02.08.200-k
QLE2742 FW: v9.10.11 DVR: v10.02.08.200-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
1
```

Enable 1MB I/O (Optional)

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

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 a `dracut -f` command, and reboot the host.
3. Verify that `lpfc_sg_seg_cnt` is 256.

```
# cat /sys/module/lpfc/parameters/lpfc_sg_seg_cnt
256
```

This is not applicable to Qlogic NVMe/FC hosts.

Configure NVMe/TCP

NVMe/TCP does not have auto-connect functionality. Therefore, if a path goes down and is not reinstated within the default time out period of 10 minutes, NVMe/TCP cannot automatically reconnect. To prevent a time out, you should set the retry period for failover events to at least 30 minutes.

Steps

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

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

Example output:

```
# nvme discover -t tcp -w 192.168.111.79 -a 192.168.111.14 -l 1800

Discovery Log Number of Records 8, Generation counter 18
=====Discovery Log Entry 0======
trtype:  tcp
adrfam:  ipv4
subtype: unrecognized
treq:    not specified.
portid:  0
trsvcid: 8009
subnqn:  nqn.1992-08.com.netapp:sn.154a5833c78c11ecb069d039ea359e4b:
discovery
traddr:  192.168.211.15
sectype: none
=====Discovery Log Entry 1======
trtype:  tcp
adrfam:  ipv4
subtype: unrecognized
treq:    not specified.
portid:  1
trsvcid: 8009
subnqn:  nqn.1992-08.com.netapp:sn.154a5833c78c11ecb069d039ea359e4b:
discovery
traddr:  192.168.111.15
sectype: none ..........
```

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

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

Example output:

```
# nvme  discovery   -t   tcp    -w  192.168.111.79   -a 192.168.111.14
# nvme  discovery   -t   tcp    -w  192.168.111.79   -a 192.168.111.15
# nvme  discovery   -t   tcp    -w  192.168.211.79   -a 192.168.211.14
# nvme  discovery   -t   tcp    -w  192.168.211.79   -a 192.168.211.15
```

3. Run the `nvme connect-all` command across all the supported NVMe/TCP initiator-target LIFs across the nodes, and set the controller loss timeout period for at least 30 minutes or 1800 seconds:

```
nvme connect-all -t tcp -w host-traddr -a traddr -l 1800
```

Example output:

```
# nvme  connect-all -t  tcp -w  192.168.111.79  -a  192.168.111.14  -l
1800
# nvme  connect-all -t  tcp -w  192.168.111.79  -a  192.168.111.15  -l
1800
# nvme  connect-all -t  tcp -w  192.168.211.79  -a  192.168.211.14  -l
1800
# nvme  connect-all -t  tcp -w  192.168.211.79  -a  192.168.211.15  -l
1800
```

Validate NVMe-oF

You can use the following procedure to validate NVMe-oF.

Steps

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

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

```
# cat /sys/class/nvme-subsystem/nvme-subsys*/model
NetApp ONTAP Controller
NetApp ONTAP Controller
```

```
# cat /sys/class/nvme-subsystem/nvme-subsys*/iopolicy
round-robin
round-robin
```

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

```
# nvme list
```

Example output:

```
Node         SN                   Model
----------------------------------------------------------
/dev/nvme0n1 81Gx7NSiKSQqAAAAAAAB   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/nvme3n1
```

Example output:

```
nvme-subsys0 - NQN=nqn.1992-
08.com.netapp:sn.8e501f8ebafa11ec9b99d039ea359e4b:subsystem.rhel_163
_Qle2742
+- nvme0 fc traddr=nn-0x204dd039ea36a105:pn-0x2050d039ea36a105
host_traddr=nn-0x20000024ff7f4994:pn-0x21000024ff7f4994 live non-
optimized
+- nvme1 fc traddr=nn-0x204dd039ea36a105:pn-0x2050d039ea36a105
host_traddr=nn-0x20000024ff7f4994:pn-0x21000024ff7f4994 live non-
optimized
+- nvme2 fc traddr=nn-0x204dd039ea36a105:pn-0x204fd039ea36a105
host_traddr=nn-0x20000024ff7f4995:pn-0x21000024ff7f4995 live
optimized
+- nvme3 fc traddr=nn-0x204dd039ea36a105:pn-0x204ed039ea36a105
host_traddr=nn-0x20000024ff7f4994:pn-0x21000024ff7f4994 live
optimized
```

NVMe/TCP

```
# nvme list-subsys /dev/nvme0n1
```

Example output:

```
nvme-subsys0 - NQN=nqn.1992-
08.com.netapp:sn.154a5833c78c11ecb069d039ea359e4b:subsystem.rhel_tcp
_165\
+- nvme0 tcp traddr=192.168.111.15 trsvcid=4420
host_traddr=192.168.111.79 live non-optimized
+- nvme1 tcp traddr=192.168.111.14 trsvcid=4420
host_traddr=192.168.111.79 live optimized
+- nvme2 tcp traddr=192.168.211.15 trsvcid=4420
host_traddr=192.168.211.79 live non-optimized
+- nvme3 tcp traddr=192.168.211.14 trsvcid=4420
host_traddr=192.168.211.79 live optimized
```

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

Column

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

Example output:

```
Device        Vserver   Namespace Path
----------------------- ------------------------------
/dev/nvme0n1 vs_tcp79           /vol/vol1/ns


NSID       UUID                                   Size
--------------------------------------------------------------
1          aa197984-3f62-4a80-97de-e89436360cec 21.47GB
```

JSON

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

Example output

```
{
  "ONTAPdevices”: [
    {
      "Device”: "/dev/nvme0n1",
      "Vserver”: "vs_tcp79",
      "Namespace Path”: "/vol/vol1/ns",
      "NSID”: 1,
      "UUID”: "aa197984-3f62-4a80-97de-e89436360cec",
      "Size”: "21.47GB",
      "LBA_Data_Size”: 4096,
      "Namespace Size" : 5242880
    },
]

}
```

Known issues

The NVMe-oF host configuration for RHEL 8.9 with ONTAP release has the following known issue:

NetApp Bug ID	Title	Description	Bugzilla ID
1479047	RHEL 8.9 NVMe-oF hosts create duplicate persistent discovery controllers	On NVMe over Fabrics (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 Red Hat Enterprise Linux (RHEL) 8.9 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.	2087000

NVMe-oF host configuration for RHEL 8.8 with ONTAP

NVMe over Fabrics (NVMe-oF), including NVMe over Fibre Channel (NVMe/FC) and other transports, is supported with Red Hat Enterprise Linux (RHEL) 8.8 with Asymmetric Namespace Access (ANA). In NVMe-oF environments, ANA is the equivalent of ALUA multipathing in iSCSI and FC environments and is implemented with in-kernel NVMe multipath.

The following support is available for the NVMe-oF host configuration for RHEL 8.8 with ONTAP:

- Support for NVMe over TCP (NVMe/TCP) in addition to NVMe/FC. The NetApp plug-in in the native nvme-cli package displays ONTAP details for both NVMe/FC and NVMe/TCP namespaces.

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

Known limitations

- In-kernel NVMe multipath is disabled by default for RHEL 8.8 NVMe-oF hosts. Therefore, you need to enable it manually.
- On RHEL 8.8 hosts, NVMe/TCP is a technology preview feature due to open issues.
- SAN booting using the NVMe-oF protocol is currently not supported.

Enable in-kernel multipath

You can use the following procedure to enable in-kernal multipath.

Steps

1. Install RHEL 8.8 on the host server.
2. After the installation is complete, verify that you are running the specified RHEL 8.8 kernel.

```
# uname -r
```

Example output

```
4.18.0-477.10.1.el8_8.x86_64
```

3. Install the nvme-cli package:

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

Example output

```
nvme-cli-1.16-7.el8.x86_64
```

4. Enable in -kernel NVMe multipath:

```
# grubby --args=nvme_core.multipath=Y --update-kernel /boot/vmlinuz-
4.18.0-477.10.1.el8_8.x86_64
```

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

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

Example output

```
nqn.2014-08.org.nvmexpress:uuid:f6517cae-3133-11e8-bbff-7ed30aef123f
```

6. Verify that the `hostnqn` string matches the `hostnqn` string for the corresponding subsystem on the ONTAP array:

```
::> vserver nvme subsystem host show -vserver vs_fcnvme_141
```

Example output

```
Vserver     Subsystem       Host NQN
----------- ---------------
------------------------------------------------------------
vs_nvme161 rhel_161_LPe32002    nqn.2014-
08.org.nvmexpress:uuid:f6517cae-3133-11e8-bbff-7ed30aef123f
```

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

7. Reboot the host.

If you intend to run both NVMe and SCSI co-existent traffic on the same host, NetApp recommends using the in-kernel NVMe multipath for ONTAP namespaces and dm-multipath for ONTAP LUNs respectively. This means that the ONTAP namespaces should be excluded from dm-multipath to prevent dm-multipath from claiming these namespace devices. This can be done by adding the `enable_foreign` setting to the `/etc/multipath.conf` file:

```
# cat /etc/multipath.conf
defaults {
  enable_foreign  NONE
}
```

Configure NVMe/FC

You can configure NVMe/FC for Broadcom/Emulex or Marvell/Qlogic adapters.

Broadcom/Emulex

Steps

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

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

Example output:

```
LPe32002-M2
LPe32002-M2
```

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

Example output:

```
Emulex LightPulse LPe32002-M2 2-Port 32Gb Fibre Channel Adapter
Emulex LightPulse LPe32002-M2 2-Port 32Gb Fibre Channel Adapter
```

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

```
# cat /sys/class/scsi_host/host*/fwrev
14.0.639.18, sli-4:2:c
14.0.639.18, sli-4:2:c
```

```
# cat /sys/module/lpfc/version
0:14.0.0.18
```

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

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

```
# cat /sys/module/lpfc/parameters/lpfc_enable_fc4_type
3
```

4. Verify that the initiator ports are up and running and that you can see the target LIFs:

```
# cat /sys/class/fc_host/host*/port_name
0x100000109b1c1204
0x100000109b1c1205
```

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

```
# cat /sys/class/scsi_host/host*/nvme_info NVME Initiator Enabled
XRI Dist lpfc0 Total 6144 IO 5894 ELS 250
NVME LPORT lpfc0 WWPN x10000090fae0ec88 WWNN x20000090fae0ec88 DID
x0a1300 ONLINE
NVME RPORT       WWPN x2049d039ea36a105 WWNN x2048d039ea36a105 DID
x0a0c0a TARGET DISCSRVC ONLINE
NVME RPORT       WWPN x204bd039ea36a105 WWNN x2048d039ea36a105 DID
x0a100a TARGET DISCSRVC ONLINE
NVME Statistics
LS: Xmt 0000000134 Cmpl 0000000134 Abort 00000000
LS XMIT: Err 00000000  CMPL: xb 00000000 Err 00000000
Total FCP Cmpl 000000000825e567 Issue 000000000825d7ed OutIO
ffffffffffffff286
abort 0000027c noxri 00000000 nondlp 00000a02 qdepth 00000000 wqerr
00000000 err 00000000
FCP CMPL: xb 00000782 Err 000130fa

NVME Initiator Enabled
XRI Dist lpfc1 Total 6144 IO 5894 ELS 250
NVME LPORT lpfc1 WWPN x10000090fae0ec89 WWNN x20000090fae0ec89 DID
x0a1200 ONLINE
NVME RPORT       WWPN x204ad039ea36a105 WWNN x2048d039ea36a105 DID
x0a080a TARGET DISCSRVC ONLINE
NVME RPORT       WWPN x204cd039ea36a105 WWNN x2048d039ea36a105 DID
x0a090a TARGET DISCSRVC ONLINE
NVME Statistics
LS: Xmt 0000000134 Cmpl 0000000134 Abort 00000000
LS XMIT: Err 00000000  CMPL: xb 00000000 Err 00000000
Total FCP Cmpl 000000000826ced5 Issue 000000000826c226 OutIO
ffffffffffffff351
        abort 0000029d noxri 00000000 nondlp 000008df qdepth
00000000 wqerr 00000000 err 00000000
FCP CMPL: xb 00000821 Err 00012fcd
```

Marvell/QLogic FC Adapter for NVMe/FC

Steps

1. The native inbox qla2xxx driver included in the RHEL 8.8 GA kernel has the latest upstream fixes essential for ONTAP support. Verify that you are running the supported adapter driver and firmware versions:

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

   Example output

   ```
   QLE2772 FW:v9.10.11 DVR:v10.02.07.900-k-debug
   QLE2772 FW:v9.10.11 DVR:v10.02.07.900-k-debug
   ```

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

   ```
   # cat /sys/module/qla2xxx/parameters/ql2xnvmeenable
   1
   ```

Enable 1MB I/O (Optional)

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

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 a `dracut -f` command, and reboot the host.
3. Verify that `lpfc_sg_seg_cnt` is 256.

   ```
   # cat /sys/module/lpfc/parameters/lpfc_sg_seg_cnt
   256
   ```

This is not applicable to Qlogic NVMe/FC hosts.

Configure NVMe/TCP

NVMe/TCP does not have auto-connect functionality. Therefore, if a path goes down and is not reinstated within the default time out period of 10 minutes, NVMe/TCP cannot automatically reconnect. To prevent a time out, you should set the retry period for failover events to at least 30 minutes.

Steps

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

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

   Example output:

```
# nvme discover -t tcp -w 192.168.111.79 -a 192.168.111.14

Discovery Log Number of Records 8, Generation counter 10
=====Discovery Log Entry 0======
trtype:  tcp
adrfam:  ipv4
subtype: unrecognized
treq:    not specified
portid:  0
trsvcid: 8009
subnqn:  nqn.1992-
08.com.netapp:sn.154a5833c78c11ecb069d039ea359e4b:discovery
traddr:  192.168.211.15
sectype: none
=====Discovery Log Entry 1======
trtype:  tcp
adrfam:  ipv4
subtype: unrecognized
treq:    not specified
portid:  1
trsvcid: 8009
subnqn:  nqn.1992-
08.com.netapp:sn.154a5833c78c11ecb069d039ea359e4b:discovery
traddr:  192.168.111.15
sectype: none
=====Discovery Log Entry 2======
trtype:  tcp
adrfam:  ipv4
subtype: unrecognized
treq:    not specified
portid:  2
trsvcid: 8009
subnqn:  nqn.1992-
08.com.netapp:sn.154a5833c78c11ecb069d039ea359e4b:discovery
traddr:  192.168.211.14
sectype: none
..........
```

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

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

Example output:

```
# nvme  discovery   -t   tcp    -w  192.168.111.79   -a 192.168.111.14
# nvme  discovery   -t   tcp    -w  192.168.111.79   -a 192.168.111.15
# nvme  discovery   -t   tcp    -w  192.168.211.79   -a 192.168.211.14
# nvme  discovery   -t   tcp    -w  192.168.211.79   -a 192.168.211.15
```

3. Run the `nvme connect-all` command across all the supported NVMe/TCP initiator-target LIFs across the nodes, and set the controller loss timeout period for at least 30 minutes or 1800 seconds:

```
nvme connect-all -t tcp -w host-traddr -a traddr -l 1800
```

Example output:

```
# nvme  connect-all -t  tcp -w  192.168.111.79  -a  192.168.111.14  -l
1800
# nvme  connect-all -t  tcp -w  192.168.111.79  -a  192.168.111.15  -l
1800
# nvme  connect-all -t  tcp -w  192.168.211.79  -a  192.168.211.14  -l
1800
# nvme  connect-all -t  tcp -w  192.168.211.79  -a  192.168.211.15  -l
1800
```

Validate NVMe-oF

You can use the following procedure to validate NVME-oF.

Steps

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

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

```
# cat /sys/class/nvme-subsystem/nvme-subsys*/model
NetApp ONTAP Controller
NetApp ONTAP Controller
```

```
# cat /sys/class/nvme-subsystem/nvme-subsys*/iopolicy
round-robin
round-robin
```

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

```
# nvme list
```

Example output:

```
Node         SN                   Model
----------------------------------------------------------
/dev/nvme3n1 81Gx7NSiKSQeAAAAAAAB   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/nvme3n1
```

Example output:

```
nvme-subsys3 - NQN=nqn.1992-
08.com.netapp:sn.ab4fa6a5ba8b11ecbe3dd039ea359e4b:subsystem.rhel_161
_Lpe32002
\
 +- nvme0 fc traddr=nn-0x2048d039ea36a105:pn-0x204cd039ea36a105
host_traddr=nn-0x20000090fae0ec89:pn-0x10000090fae0ec89 live non-
optimized
 +- nvme1 fc traddr=nn-0x2048d039ea36a105:pn-0x204ad039ea36a105
host_traddr=nn-0x20000090fae0ec89:pn-0x10000090fae0ec89 live
optimized
 +- nvme2 fc traddr=nn-0x2048d039ea36a105:pn-0x204bd039ea36a105
host_traddr=nn-0x20000090fae0ec88:pn-0x10000090fae0ec88 live non-
optimized
 +- nvme4 fc traddr=nn-0x2048d039ea36a105:pn-0x2049d039ea36a105
host_traddr=nn-0x20000090fae0ec88:pn-0x10000090fae0ec88 live
optimized
```

NVMe/TCP

```
# nvme list-subsys /dev/nvme0n1
```

Example output:

```
nvme-subsys0 - NQN=nqn.1992-
08.com.netapp:sn.154a5833c78c11ecb069d039ea359e4b:subsystem.rhel_tcp
_165
\
 +- nvme0 tcp traddr=192.168.111.15 trsvcid=4420
host_traddr=192.168.111.79 live non-optimized
 +- nvme1 tcp traddr=192.168.111.14 trsvcid=4420
host_traddr=192.168.111.79 live optimized
 +- nvme2 tcp traddr=192.168.211.15 trsvcid=4420
host_traddr=192.168.211.79 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
```

Example output:

```
Device        Vserver   Namespace Path
----------------------- ------------------------------
/dev/nvme0n1 vs_tcp           /vol/vol1/ns1



NSID       UUID                                   Size
----------------------------------------------------------------
1          338d73ce-b5a8-4847-9cc9-b127c75d8855 21.47GB
```

JSON

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

Example output

```
{
  "ONTAPdevices" : [
    {
      "Device" : "/dev/nvme0n1",
      "Vserver" : "vs_tcp79",
      "Namespace_Path" : "/vol/vol1/ns1",
      "NSID" : 1,
      "UUID" : "338d73ce-b5a8-4847-9cc9-b127c75d8855",
      "Size" : "21.47GB",
      "LBA_Data_Size" : 4096,
      "Namespace_Size" : 5242880
    },
]

}
```

Known issues

The NVMe-oF host configuration for RHEL 8.8 with ONTAP release has the following known issues:

NetApp Bug ID	Title	Description	Bugzilla ID
1479047	RHEL 8.8 NVMe-oF hosts create duplicate persistent discovery controllers	On NVMe over Fabrics (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 Red Hat Enterprise Linux (RHEL) 8.8 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.	2087000

NVMe-oF host configuration for RHEL 8.7 with ONTAP

NVMe over Fabrics or NVMe-oF (including NVMe/FC and other transports) is supported with Red Hat Enterprise Linux (RHEL) 8.7 with ANA (Asymmetric Namespace Access). ANA is the asymmetric logical unit access (ALUA) equivalent in the NVMe-oF environment, and is currently implemented with in-kernel NVMe Multipath. During this procedure, you enable NVMe-oF with in-kernel NVMe Multipath using ANA on RHEL 8.7 and ONTAP as the target.

See the NetApp Interoperability Matrix Tool for accurate details regarding supported configurations.

Features

RHEL 8.7 includes support for NVMe/TCP (as a Technology Preview feature) in addition to NVMe/FC. The NetApp plugin in the native nvme-cli package is capable of displaying ONTAP details for both NVMe/FC and NVMe/TCP namespaces.

Known limitations

- For RHEL 8.7, in-kernel NVMe multipath remains disabled by default. Therefore, you need to enable it manually.
- NVMe/TCP on RHEL 8.7 remains a Technology Preview feature due to open issues. Refer to the RHEL 8.7 release notes for details.
- SAN booting using the NVMe-oF protocol is currently not supported.

Enable in-kernel NVMe Multipath

You can use the following procedure to enable in-kernel NVMe multipath.

Steps

1. Install RHEL 8.7 on the server.
2. After the installation is complete, verify that you are running the specified RHEL 8.7 kernel. See the NetApp

Interoperability Matrix for the most current list of supported versions.

Example:

```
# uname -r
4.18.0-425.3.1.el8.x86_64
```

3. Install the `nvme-cli` package:

   Example:

```
# rpm -qa|grep nvme-cli
nvme-cli-1.16-5.el8.x86_64
```

4. Enable in-kernel NVMe multipath:

```
# grubby --args=nvme_core.multipath=Y --update-kernel /boot/vmlinuz-
4.18.0-425.3.1.el8.x86_64
```

5. On the host, check the host NQN string at `/etc/nvme/hostnqn` and verify that it matches the host NQN string for the corresponding subsystem on the ONTAP array. Example:

```
# cat /etc/nvme/hostnqn

          nqn.2014-08.org.nvmexpress:uuid:a7f7a1d4-311a-11e8-b634-
7ed30aef10b7

::> vserver nvme subsystem host show -vserver vs_nvme167
Vserver     Subsystem       Host NQN
----------- --------------- ----------------
vs_nvme167 rhel_167_LPe35002  nqn.2014-08.org.nvmexpress:uuid: a7f7a1d4-
311a-11e8-b634-7ed30aef10b7
```

> If the host NQN strings do not match, you should use the `vserver modify` command to update the host NQN string on your corresponding ONTAP NVMe subsystem to match the host NQN string `/etc/nvme/hostnqn` on the host.

6. Reboot the host.

If you intend to run both NVMe and SCSI co-existent traffic on the same host, NetApp recommends using in-kernel NVMe multipath for ONTAP namespaces and dm-multipath for ONTAP LUNs respectively. This means that the ONTAP namespaces should be excluded from dm-multipath to prevent dm-multipath from claiming these namespace devices. You can do this by adding the enable_foreign setting to the `/etc/multipath.conf` file:

```
# cat /etc/multipath.conf
defaults {
        enable_foreign     NONE
}
```

Restart the multipathd daemon by running a `systemctl restart multipathd` command to allow the new setting to take effect.

Configure NVMe/FC

You can configure NVMe/FC for Broadcom/Emulex or Marvell/Qlogic adapters.

Broadcom/Emulex

Steps

1. Verify that you are using the supported adapter. See the NetApp Interoperability Matrix for the most current list of supported adapters.

```
# cat /sys/class/scsi_host/host*/modelname
LPe35002-M2
LPe35002-M2
# cat /sys/class/scsi_host/host*/modeldesc
Emulex LightPulse LPe35002-M2 2-Port 32Gb Fibre Channel Adapter
Emulex LightPulse LPe35002-M2 2-Port 32Gb Fibre Channel Adapter
```

2. Verify that you are using the recommended Broadcom lpfc firmware and inbox driver. See the NetApp Interoperability Matrix for the most current list of supported adapter driver and firmware versions.

```
# cat /sys/class/scsi_host/host*/fwrev
14.0.505.12, sli-4:6:d
14.0.505.12, sli-4:6:d
# cat /sys/module/lpfc/version
0:14.0.0.15
```

3. Verify that `lpfc_enable_fc4_type` is set to 3

```
# cat /sys/module/lpfc/parameters/lpfc_enable_fc4_type
3
```

4. Verify that the initiator ports are up and running, and that you can see the target LIFs.

```
# cat /sys/class/fc_host/host*/port_name
0x100000109b95467c
0x100000109b95467b
# cat /sys/class/fc_host/host*/port_state
Online
Online
# cat /sys/class/scsi_host/host*/nvme_info
NVME Initiator Enabled
XRI Dist lpfc1 Total 6144 IO 5894 ELS 250
NVME LPORT lpfc1 WWPN x100000109b95467c WWNN x200000109b95467c DID
x0a1500 ONLINE
NVME RPORT       WWPN x2071d039ea36a105 WWNN x206ed039ea36a105 DID
x0a0907 TARGET DISCSRVC ONLINE
NVME RPORT       WWPN x2072d039ea36a105 WWNN x206ed039ea36a105 DID
x0a0805 TARGET DISCSRVC ONLINE

NVME Statistics
LS: Xmt 00000001c7 Cmpl 00000001c7 Abort 00000000
LS XMIT: Err 00000000  CMPL: xb 00000000 Err 00000000
Total FCP Cmpl 0000000004909837 Issue 0000000004908cfc OutIO
fffffffffffff4c5
abort 0000004a noxri 00000000 nondlp 00000458 qdepth 00000000 wqerr
00000000 err 00000000
FCP CMPL: xb 00000061 Err 00017f43

NVME Initiator Enabled
XRI Dist lpfc0 Total 6144 IO 5894 ELS 250
NVME LPORT lpfc0 WWPN x100000109b95467b WWNN x200000109b95467b DID
x0a1100 ONLINE
NVME RPORT       WWPN x2070d039ea36a105 WWNN x206ed039ea36a105 DID
x0a1007 TARGET DISCSRVC ONLINE
NVME RPORT       WWPN x206fd039ea36a105 WWNN x206ed039ea36a105 DID
x0a0c05 TARGET DISCSRVC ONLINE

NVME Statistics
LS: Xmt 00000001c7 Cmpl 00000001c7 Abort 00000000
LS XMIT: Err 00000000  CMPL: xb 00000000 Err 00000000
Total FCP Cmpl 0000000004909464 Issue 0000000004908531 OutIO
fffffffffffff0cd
abort 0000004f noxri 00000000 nondlp 00000361 qdepth 00000000 wqerr
00000000 err 00000000
FCP CMPL: xb 0000006b Err 00017f99
```

Marvell/QLogic FC adapter for NVMe/FC

The native inbox `qla2xxx` driver included in the RHEL 8.7 kernel has the latest fixes which are essential for ONTAP support.

Steps

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

```
# cat /sys/class/fc_host/host*/symbolic_name
QLE2772 FW:v9.08.02 DVR:v10.02.07.400-k-debug
QLE2772 FW:v9.08.02 DVR:v10.02.07.400-k-debug
```

2. Verify `ql2xnvmeenable` is set, which enables the Marvell adapter to function as a NVMe/FC initiator using the following command:

```
# cat /sys/module/qla2xxx/parameters/ql2xnvmeenable
1
```

Enable 1MB I/O (Optional)

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

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 a `dracut -f` command, and reboot the host.
3. Verify that `lpfc_sg_seg_cnt` is 256.

```
# cat /sys/module/lpfc/parameters/lpfc_sg_seg_cnt
256
```

This is not applicable to Qlogic NVMe/FC hosts.

Configure NVMe/TCP

NVMe/TCP does not have auto-connect functionality. Therefore, if a path goes down and is not reinstated within the default time out period of 10 minutes, NVMe/TCP cannot automatically reconnect. To prevent a time

out, you should set the retry period for failover events to at least 30 minutes.

Steps

1. Verify whether the initiator port can fetch the discovery log page data across the supported NVMe/TCP LIFs:

```
# nvme discover -t tcp -w 192.168.211.5 -a 192.168.211.14

Discovery Log Number of Records 8, Generation counter 10

=====Discovery Log Entry 0======
trtype:  tcp
adrfam:  ipv4
subtype: unrecognized
treq:    not specified
portid:  0
trsvcid: 8009
subnqn:
nqn.199208.com.netapp:sn.154a5833c78c11ecb069d039ea359e4b:discovery
traddr:  192.168.211.15
sectype: none
=====Discovery Log Entry 1======
trtype:  tcp
adrfam:  ipv4
subtype: unrecognized
treq:    not specified
portid:  1
trsvcid: 8009
subnqn:  nqn.1992-
08.com.netapp:sn.154a5833c78c11ecb069d039ea359e4b:discovery
traddr:  192.168.111.15
sectype: none
=====Discovery Log Entry 2======
trtype:  tcp
adrfam:  ipv4
subtype: unrecognized
treq:    not specified
portid:  2
trsvcid: 8009
subnqn:  nqn.1992-
08.com.netapp:sn.154a5833c78c11ecb069d039ea359e4b:discovery
traddr:  192.168.211.14
sectype: none
=====Discovery Log Entry 3======
trtype:  tcp
adrfam:  ipv4
```

```
subtype: unrecognized
treq:    not specified
portid:  3
trsvcid: 8009
subnqn:  nqn.1992-
08.com.netapp:sn.154a5833c78c11ecb069d039ea359e4b:discovery
traddr:  192.168.111.14
sectype: none
=====Discovery Log Entry 4======
trtype:  tcp
adrfam:  ipv4
subtype: nvme subsystem
treq:    not specified
portid:  0
trsvcid: 4420
subnqn:  nqn.1992-
08.com.netapp:sn.154a5833c78c11ecb069d039ea359e4b:subsystem.rhel_tcp_165
traddr:  192.168.211.15
sectype: none
=====Discovery Log Entry 5======
trtype:  tcp
adrfam:  ipv4
subtype: nvme subsystem
treq:    not specified
portid:  1
trsvcid: 4420
subnqn:  nqn.1992-
08.com.netapp:sn.154a5833c78c11ecb069d039ea359e4b:subsystem.rhel_tcp_165
traddr:  192.168.111.15
sectype: none
=====Discovery Log Entry 6======

trtype:  tcp
adrfam:  ipv4
subtype: nvme subsystem
treq:    not specified
portid:  2
trsvcid: 4420
subnqn:  nqn.1992-
08.com.netapp:sn.154a5833c78c11ecb069d039ea359e4b:subsystem.rhel_tcp_165
traddr:  192.168.211.14
sectype: none

=====Discovery Log Entry 7======
trtype:  tcp
adrfam:  ipv4
```

```
subtype: nvme subsystem
treq:    not specified

   portid:  3

trsvcid: 4420
subnqn:  nqn.1992-
08.com.netapp:sn.154a5833c78c11ecb069d039ea359e4b:subsystem.rhel_tcp_165
traddr:  192.168.111.14
sectype: none
[root@R650-13-79 ~]#
```

2. Verify that other NVMe/TCP initiator-target LIF combos can successfully fetch discovery log page data. For example:

```
# nvme discover -t tcp -w 192.168.211.5 -a 192.168.211.14
# nvme discover -t tcp -w 192.168.211.5 -a 192.168.211.15
# nvme discover -t tcp -w 192.168.111.5 -a 192.168.111.14
# nvme discover -t tcp -w 192.168.111.5 -a 192.168.111.15
```

3. Run `nvme connect-all` command across all the supported NVMe/TCP initiator-target LIFs across the nodes. Ensure you set a longer `ctrl_loss_tmo` timer retry period (for example, 30 minutes, which can be set through `-l 1800`) during the connect-all so that it would retry for a longer period of time in the event of a path loss. For example:

```
# nvme connect-all -t tcp -w 192.168.211.5-a 192.168.211.14 -l 1800
# nvme connect-all -t tcp -w 192.168.211.5 -a 192.168.211.15 -l 1800
# nvme connect-all -t tcp -w 192.168.111.5 -a 192.168.111.14 -l 1800
# nvme connect-all -t tcp -w 192.168.111.5 -a 192.168.111.15 -l 1800
```

Validate NVMe-oF

You can use the following procedure to validate NVMe-oF.

Steps

1. Verify that in-kernel NVMe multipath is indeed enabled by checking:

```
# cat /sys/module/nvme_core/parameters/multipath
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 properly reflect on the host:

```
# cat /sys/class/nvme-subsystem/nvme-subsys*/model
NetApp ONTAP Controller
NetApp ONTAP Controller

# cat /sys/class/nvme-subsystem/nvme-subsys*/iopolicy
round-robin
round-robin
```

3. Verify that the ONTAP namespaces properly reflect on the host. For example:

```
# nvme list
Node           SN                    Model                    Namespace
------------   --------------------- ---------------------------------
/dev/nvme0n1   81Gx7NSiKSRNAAAAAAAB   NetApp ONTAP Controller   1

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

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

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

nvme-subsys0 - NQN=nqn.1992-
08.com.netapp:sn.154a5833c78c11ecb069d039ea359e4b:subsystem.rhel_tcp_165

\

 +- nvme0 tcp traddr=192.168.211.15 trsvcid=4420
host_traddr=192.168.211.5 live non-optimized

 +- nvme1 tcp traddr=192.168.211.14 trsvcid=4420
host_traddr=192.168.211.5 live optimized

 +- nvme2 tcp traddr=192.168.111.15 trsvcid=4420
host_traddr=192.168.111.5 live non-optimized

 +- nvme3 tcp traddr=192.168.111.14 trsvcid=4420
host_traddr=192.168.111.5 live optimized
```

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

```
# nvme netapp ontapdevices -o column
Device       Vserver          Namespace Path
---------    -------
----------------------------------------------------
/dev/nvme0n1 vs_tcp79     /vol/vol1/ns1

NSID  UUID                                   Size
----  ------------------------------         ------
1     79c2c569-b7fa-42d5-b870-d9d6d7e5fa84  21.47GB


# nvme netapp ontapdevices -o json
{

  "ONTAPdevices" : [
  {

      "Device" : "/dev/nvme0n1",
      "Vserver" : "vs_tcp79",
      "Namespace_Path" : "/vol/vol1/ns1",
      "NSID" : 1,
      "UUID" : "79c2c569-b7fa-42d5-b870-d9d6d7e5fa84",
      "Size" : "21.47GB",
      "LBA_Data_Size" : 4096,
      "Namespace_Size" : 5242880
    },

]

}
```

Known issues

The NVMe-oF host configuration for RHEL 8.7 with ONTAP has the following known issues:

NetApp Bug ID	Title	Description	Bugzilla ID
1479047	RHEL 8.7 NVMe-oF hosts create duplicate Persistent Discovery Controllers	On NVMe over Fabrics (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 ONTAP 9.10.1 and Red Hat Enterprise Linux (RHEL) 8.7 with 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.	2087000

NVMe-oF host configuration for RHEL 8.6 with ONTAP

NVMe over Fabrics or NVMe-oF (including NVMe/FC and other transports) is supported with Red Hat Enterprise Linux (RHEL) 8.6 with ANA (Asymmetric Namespace Access). ANA is the asymmetric logical unit access (ALUA) equivalent in the NVMe-oF environment, and is currently implemented with in-kernel NVMe Multipath. During this procedure, you enable NVMe-oF with in-kernel NVMe Multipath using ANA on RHEL 8.6 and ONTAP as the target

See the NetApp Interoperability Matrix Tool for accurate details regarding supported configurations.

Features

- RHEL 8.6 includes support for NVMe/TCP (as a Technology Preview feature) in addition to NVMe/FC. The NetApp plugin in the native nvme-cli package is capable of displaying ONTAP details for both NVMe/FC and NVMe/TCP namespaces.

Known limitations

- For RHEL 8.6, in-kernel NVMe multipath remains disabled by default. Therefore, you need to enable it manually.
- NVMe/TCP on RHEL 8.6 remains a Technology Preview feature due to open issues. Refer to the RHEL 8.6 Release Notes for details.
- SAN booting using the NVMe-oF protocol is currently not supported.

Enable in-kernel NVMe Multipath

You can use the following procedure to enable in-kernel NVMe multipath.

Steps

1. Install RHEL 8.6 on the server. After the installation is complete, verify that you are running the specified RHEL 8.6 kernel. See the NetApp Interoperability Matrix for the most current list of supported versions.

2. After the installation is complete, verify that you are running the specified RHEL 8.6 kernel. See the NetApp Interoperability Matrix for the most current list of supported versions.

   Example:

```
# uname -r
4.18.0-372.9.1.el8.x86_64
```

3. Install the `nvme-cli` package:

   Example:

```
# rpm -qa|grep nvme-cli
nvme-cli-1.16-3.el8.x86_64
```

4. Enable in-kernel NVMe multipath:

```
# grubby --args=nvme_core.multipath=Y --update-kernel /boot/vmlinuz-
4.18.0-372.9.1.el8.x86_64
```

5. On the host, check the host NQN string at `/etc/nvme/hostnqn` and verify that it matches the host NQN string for the corresponding subsystem on the ONTAP array. Example:

```
# cat /etc/nvme/hostnqn
nqn.2014-08.org.nvmexpress:uuid:9ed5b327-b9fc-4cf5-97b3-1b5d986345d1
::> vserver nvme subsystem host show -vserver vs_fcnvme_141
Vserver     Subsystem       Host NQN
----------- ---------------
------------------------------------------------------------
vs_fcnvme_14 nvme_141_1     nqn.2014-08.org.nvmexpress:uuid:9ed5b327-
b9fc-4cf5-97b3-1b5d986345d1
```

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

6. Reboot the host.

If you intend to run both NVMe and SCSI co-existent traffic on the same host, NetApp recommends using in-kernel NVMe multipath for ONTAP namespaces and dm-multipath for ONTAP LUNs respectively. This means that the ONTAP namespaces should be excluded from dm-multipath to prevent dm-multipath from claiming these namespace devices. This can be done by adding the enable_foreign setting to the `/etc/multipath.conf` file:

```
# cat /etc/multipath.conf
defaults {
        enable_foreign     NONE
}
```

Restart the multipathd daemon by running a `systemctl restart multipathd` command to allow the new setting to take effect.

Configure NVMe/FC

You can configure NVMe/FC for Broadcom/Emulex or Marvell/Qlogic adapters.

Broadcom/Emulex

Steps

1. Verify that you are using the supported adapter. See the NetApp Interoperability Matrix for the most current list of supported adapters.

```
# cat /sys/class/scsi_host/host*/modelname
LPe32002-M2
LPe32002-M2
# cat /sys/class/scsi_host/host*/modeldesc
Emulex LightPulse LPe32002-M2 2-Port 32Gb Fibre Channel Adapter
Emulex LightPulse LPe32002-M2 2-Port 32Gb Fibre Channel Adapter
```

2. Verify that you are using the recommended Broadcom lpfc firmware and inbox driver. See the NetApp Interoperability Matrix for the most current list of supported adapter driver and firmware versions.

```
# cat /sys/class/scsi_host/host*/fwrev
12.8.351.47, sli-4:2:c
12.8.351.47, sli-4:2:c
# cat /sys/module/lpfc/version
0:14.0.0.4
```

3. Verify that `lpfc_enable_fc4_type` is set to 3

```
# cat /sys/module/lpfc/parameters/lpfc_enable_fc4_type
3
```

4. Verify that the initiator ports are up and running, and that you can see the target LIFs.

```
# cat /sys/class/fc_host/host*/port_name
0x100000109b1c1204
0x100000109b1c1205
# cat /sys/class/fc_host/host*/port_state
Online
Online
# cat /sys/class/scsi_host/host*/nvme_info
NVME Initiator Enabled
XRI Dist lpfc0 Total 6144 IO 5894 ELS 250
NVME LPORT lpfc0 WWPN x100000109b1c1204 WWNN x200000109b1c1204 DID
x011d00 ONLINE
NVME RPORT WWPN x203800a098dfdd91 WWNN x203700a098dfdd91 DID x010c07
TARGET DISCSRVC ONLINE
NVME RPORT WWPN x203900a098dfdd91 WWNN x203700a098dfdd91 DID x011507
TARGET DISCSRVC ONLINE

NVME Statistics
LS: Xmt 0000000f78 Cmpl 0000000f78 Abort 00000000
LS XMIT: Err 00000000 CMPL: xb 00000000 Err 00000000
Total FCP Cmpl 000000002fe29bba Issue 000000002fe29bc4 OutIO
000000000000000a
abort 00001bc7 noxri 00000000 nondlp 00000000 qdepth 00000000 wqerr
00000000 err 00000000
FCP CMPL: xb 00001e15 Err 0000d906

NVME Initiator Enabled
XRI Dist lpfc1 Total 6144 IO 5894 ELS 250
NVME LPORT lpfc1 WWPN x100000109b1c1205 WWNN x200000109b1c1205 DID
x011900 ONLINE
NVME RPORT WWPN x203d00a098dfdd91 WWNN x203700a098dfdd91 DID x010007
TARGET DISCSRVC ONLINE
NVME RPORT WWPN x203a00a098dfdd91 WWNN x203700a098dfdd91 DID x012a07
TARGET DISCSRVC ONLINE

NVME Statistics
LS: Xmt 0000000fa8 Cmpl 0000000fa8 Abort 00000000
LS XMIT: Err 00000000 CMPL: xb 00000000 Err 00000000
Total FCP Cmpl 000000002e14f170 Issue 000000002e14f17a OutIO
000000000000000a
abort 000016bb noxri 00000000 nondlp 00000000 qdepth 00000000 wqerr
00000000 err 00000000
FCP CMPL: xb 00001f50 Err 0000d9f8
```

Marvell/QLogic FC adapter for NVMe/FC

The native inbox `qla2xxx` driver included in the RHEL 8.6 kernel has the latest upstream fixes which are essential for ONTAP support.

Steps

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

```
# cat /sys/class/fc_host/host*/symbolic_name
QLE2742 FW:v9.06.02 DVR:v10.02.00.200-k
QLE2742 FW:v9.06.02 DVR:v10.02.00.200-k
```

2. Verify `ql2xnvmeenable` is set which enables the Marvell adapter to function as a NVMe/FC initiator using the following command:

```
# cat /sys/module/qla2xxx/parameters/ql2xnvmeenable
1
```

Enable 1MB I/O (Optional)

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

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 a `dracut -f` command, and reboot the host.
3. Verify that `lpfc_sg_seg_cnt` is 256.

```
# cat /sys/module/lpfc/parameters/lpfc_sg_seg_cnt
256
```

This is not applicable to Qlogic NVMe/FC hosts.

Configure NVMe/TCP

NVMe/TCP does not have auto-connect functionality. Therefore, if a path goes down and is not reinstated within the default time out period of 10 minutes, NVMe/TCP cannot automatically reconnect. To prevent a time out, you should set the retry period for failover events to at least 30 minutes.

Steps

1. Verify whether the initiator port can fetch the discovery log page data across the supported NVMe/TCP LIFs:

```
# nvme discover -t tcp -w 192.168.1.8 -a 192.168.1.51
Discovery Log Number of Records 10, Generation counter 119
=====Discovery Log Entry 0======
trtype: tcp
adrfam: ipv4
subtype: nvme subsystem
treq: not specified
portid: 0
trsvcid: 4420
subnqn: nqn.1992-
08.com.netapp:sn.56e362e9bb4f11ebbaded039ea165abc:subsystem.nvme_118_tcp
_1
traddr: 192.168.2.56
sectype: none
=====Discovery Log Entry 1======
trtype: tcp
adrfam: ipv4
subtype: nvme subsystem
treq: not specified
portid: 1
trsvcid: 4420
subnqn: nqn.1992-
08.com.netapp:sn.56e362e9bb4f11ebbaded039ea165abc:subsystem.nvme_118_tcp
_1
traddr: 192.168.1.51
sectype: none
=====Discovery Log Entry 2======
trtype: tcp
adrfam: ipv4
subtype: nvme subsystem
treq: not specified
portid: 0
trsvcid: 4420
subnqn: nqn.1992-
08.com.netapp:sn.56e362e9bb4f11ebbaded039ea165abc:subsystem.nvme_118_tcp
_2
traddr: 192.168.2.56
sectype: none
...
```

2. Verify that other NVMe/TCP initiator-target LIF combos can successfully fetch discovery log page data. For example:

```
# nvme discover -t tcp -w 192.168.1.8 -a 192.168.1.51
# nvme discover -t tcp -w 192.168.1.8 -a 192.168.1.52
# nvme discover -t tcp -w 192.168.2.9 -a 192.168.2.56
# nvme discover -t tcp -w 192.168.2.9 -a 192.168.2.57
```

3. Run `nvme connect-all` command across all the supported NVMe/TCP initiator-target LIFs across the nodes. Ensure you set a longer `ctrl_loss_tmo` timer retry period (for example, 30 minutes, which can be set through `-l 1800`) during the connect-all so that it would retry for a longer period of time in the event of a path loss. For example:

```
# nvme connect-all -t tcp -w 192.168.1.8 -a 192.168.1.51 -l 1800
# nvme connect-all -t tcp -w 192.168.1.8 -a 192.168.1.52 -l 1800
# nvme connect-all -t tcp -w 192.168.2.9 -a 192.168.2.56 -l 1800
# nvme connect-all -t tcp -w 192.168.2.9 -a 192.168.2.57 -l 1800
```

Validate NVMe-oF

You can use the following procedure to validate NVMe-oF.

Steps

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

```
# cat /sys/module/nvme_core/parameters/multipath
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 properly reflect on the host:

```
# cat /sys/class/nvme-subsystem/nvme-subsys*/model
NetApp ONTAP Controller
NetApp ONTAP Controller

# cat /sys/class/nvme-subsystem/nvme-subsys*/iopolicy
round-robin
round-robin
```

3. Verify that the ONTAP namespaces properly reflect on the host. For example:

```
# nvme list
Node           SN                    Model                    Namespace
------------   --------------------- ---------------------------------
/dev/nvme0n1   814vWBNRwf9HAAAAAAAB   NetApp ONTAP Controller   1

Usage                Format         FW Rev
-------------------  -----------    --------
85.90 GB / 85.90 GB  4 KiB + 0 B    FFFFFFFF
```

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

```
# nvme list-subsys /dev/nvme1n1
nvme-subsys1 - nvme-subsys0 - NQN=nqn.1992-
08.com.netapp:sn.5f5f2c4aa73b11e9967e00a098df41bd:subsystem.nvme_141_1
\
+- nvme0 fc traddr=nn-0x203700a098dfdd91:pn-0x203800a098dfdd91
host_traddr=nn-0x200000109b1c1204:pn-0x100000109b1c1204 live
inaccessible
+- nvme1 fc traddr=nn-0x203700a098dfdd91:pn-0x203900a098dfdd91
host_traddr=nn-0x200000109b1c1204:pn-0x100000109b1c1204 live
inaccessible
+- nvme2 fc traddr=nn-0x203700a098dfdd91:pn-0x203a00a098dfdd91
host_traddr=nn-0x200000109b1c1205:pn-0x100000109b1c1205 live optimized
+- nvme3 fc traddr=nn-0x203700a098dfdd91:pn-0x203d00a098dfdd91
host_traddr=nn-0x200000109b1c1205:pn-0x100000109b1c1205 live optimized
```

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

```
# nvme netapp ontapdevices -o column
Device       Vserver          Namespace Path
---------    -------
----------------------------------------------------
/dev/nvme0n1 vs_fcnvme_141    /vol/fcnvme_141_vol_1_1_0/fcnvme_141_ns

NSID  UUID                                   Size
----  ------------------------------         ------
1     72b887b1-5fb6-47b8-be0b-33326e2542e2  85.90GB


# nvme netapp ontapdevices -o json
{
"ONTAPdevices" : [
    {
        "Device" : "/dev/nvme0n1",
        "Vserver" : "vs_fcnvme_141",
        "Namespace_Path" : "/vol/fcnvme_141_vol_1_1_0/fcnvme_141_ns",
        "NSID" : 1,
        "UUID" : "72b887b1-5fb6-47b8-be0b-33326e2542e2",
        "Size" : "85.90GB",
        "LBA_Data_Size" : 4096,
        "Namespace_Size" : 20971520
    }
  ]
}
```

Known issues

The NVMe-oF host configuration for RHEL 8.6 with ONTAP has the following known issues:

NetApp Bug ID	Title	Description	Bugzilla ID
1479047	RHEL 8.6 NVMe-oF hosts create duplicate Persistent Discovery Controllers	On NVMe over Fabrics (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 ONTAP 9.10.1 and Red Hat Enterprise Linux (RHEL) 8.6 with 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.	2087000

NVMe-oF host configuration for RHEL 8.5 with ONTAP

NVMe over Fabrics or NVMe-oF (including NVMe/FC and other transports) is supported with Red Hat Enterprise Linux (RHEL) 8.5 with ANA (Asymmetric Namespace Access). ANA is the asymmetric logical unit access (ALUA) equivalent in the NVMe-oF environment, and is currently implemented with in-kernel NVMe Multipath. During this procedure, you enable NVMe-oF with in-kernel NVMe Multipath using ANA on RHEL 8.5 and ONTAP as the target.

See the NetApp Interoperability Matrix Tool for accurate details regarding supported configurations.

Features

RHEL 8.5 includes support for NVMe/TCP (as a Technology Preview feature) in addition to NVMe/FC. The NetApp plugin in the native nvme-cli package can display ONTAP details for both NVMe/FC and NVMe/TCP namespaces.

Known limitations

- For RHEL 8.5, in-kernel NVMe multipath remains disabled by default. Therefore, you need to enable it manually.
- NVMe/TCP on RHEL 8.5 remains a Technology Preview feature due to open issues. Refer to the RHEL 8.5 Release Notes for details.
- SAN booting using the NVMe-oF protocol is currently not supported.

Enable in-kernel NVMe Multipath

You can use the following procedure to enable in-kernel NVMe multipath.

Steps

1. Install RHEL 8.5 GA on the server. After the installation is complete, verify that you are running the specified RHEL 8.5 GA kernel. See the NetApp Interoperability Matrix for the most current list of supported

versions.

Example:

```
# uname -r
4.18.0-348.el8.x86_64
```

2. Install the `nvme-cli` package:

   Example:

```
# rpm -qa|grep nvme-cli
nvme-cli-1.14-3.el8.x86_64
```

3. Enable in-kernel NVMe multipath:

```
# grubby --args=nvme_core.multipath=Y --update-kernel /boot/vmlinuz-
4.18.0-348.el8.x86_64
```

4. On the host, check the host NQN string at `/etc/nvme/hostnqn` and verify that it matches the host NQN string for the corresponding subsystem on the ONTAP array. Example:

```
# cat /etc/nvme/hostnqn
nqn.2014-08.org.nvmexpress:uuid:9ed5b327-b9fc-4cf5-97b3-1b5d986345d1
::> vserver nvme subsystem host show -vserver vs_fcnvme_141
Vserver     Subsystem       Host NQN
----------- ---------------
------------------------------------------------------------
vs_fcnvme_14 nvme_141_1     nqn.2014-08.org.nvmexpress:uuid:9ed5b327-
b9fc-4cf5-97b3-1b5d986345d1
```

> If the host NQN strings do not match, you should use the `vserver modify` command to update the host NQN string on your corresponding ONTAP NVMe subsystem to match the host NQN string `/etc/nvme/hostnqn` on the host.

5. Reboot the host.

If you intend to run both NVMe and SCSI co-existent traffic on the same host, NetApp recommends using in-kernel NVMe multipath for ONTAP namespaces and dm-multipath for ONTAP LUNs respectively. This means that the ONTAP namespaces should be excluded from dm-multipath to prevent dm-multipath from claiming these namespace devices. You can do this by adding the enable_foreign setting to the `/etc/multipath.conf` file:

```
# cat /etc/multipath.conf
defaults {
        enable_foreign     NONE
}
```

Restart the multipathd daemon by running a `systemctl restart multipathd` command to allow the new setting to take effect.

Configure NVMe/FC

You can configure NVMe/FC for Broadcom/Emulex or Marvell/Qlogic adapters.

Broadcom/Emulex

Steps

1. Verify that you are using the supported adapter. See the NetApp Interoperability Matrix for the most current list of supported adapters.

```
# cat /sys/class/scsi_host/host*/modelname
LPe32002-M2
LPe32002-M2
# cat /sys/class/scsi_host/host*/modeldesc
Emulex LightPulse LPe32002-M2 2-Port 32Gb Fibre Channel Adapter
Emulex LightPulse LPe32002-M2 2-Port 32Gb Fibre Channel Adapter
```

2. Verify that you are using the recommended Broadcom lpfc firmware and inbox driver. See the NetApp Interoperability Matrix for the most current list of supported adapter driver and firmware versions.

```
# cat /sys/class/scsi_host/host*/fwrev
12.8.351.47, sli-4:2:c
12.8.351.47, sli-4:2:c
# cat /sys/module/lpfc/version
0:12.8.0.10
```

3. Verify that `lpfc_enable_fc4_type` is set to 3

```
# cat /sys/module/lpfc/parameters/lpfc_enable_fc4_type
3
```

4. Verify that the initiator ports are up and running, and that you can see the target LIFs.

```
# cat /sys/class/fc_host/host*/port_name
0x100000109b1c1204
0x100000109b1c1205

# cat /sys/class/fc_host/host*/port_state
Online
Online

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

NVME Initiator Enabled
XRI Dist lpfc0 Total 6144 IO 5894 ELS 250
NVME LPORT lpfc0 WWPN x100000109b1c1204 WWNN x200000109b1c1204 DID
x011d00 ONLINE
NVME RPORT WWPN x203800a098dfdd91 WWNN x203700a098dfdd91 DID x010c07
TARGET DISCSRVC ONLINE
NVME RPORT WWPN x203900a098dfdd91 WWNN x203700a098dfdd91 DID x011507
TARGET DISCSRVC ONLINE

NVME Statistics
LS: Xmt 0000000f78 Cmpl 0000000f78 Abort 00000000
LS XMIT: Err 00000000 CMPL: xb 00000000 Err 00000000
Total FCP Cmpl 000000002fe29bba Issue 000000002fe29bc4 OutIO
000000000000000a
abort 00001bc7 noxri 00000000 nondlp 00000000 qdepth 00000000 wqerr
00000000 err 00000000
FCP CMPL: xb 00001e15 Err 0000d906

NVME Initiator Enabled
XRI Dist lpfc1 Total 6144 IO 5894 ELS 250
NVME LPORT lpfc1 WWPN x100000109b1c1205 WWNN x200000109b1c1205 DID
x011900 ONLINE
NVME RPORT WWPN x203d00a098dfdd91 WWNN x203700a098dfdd91 DID x010007
TARGET DISCSRVC ONLINE
NVME RPORT WWPN x203a00a098dfdd91 WWNN x203700a098dfdd91 DID x012a07
TARGET DISCSRVC ONLINE

NVME Statistics
LS: Xmt 0000000fa8 Cmpl 0000000fa8 Abort 00000000
LS XMIT: Err 00000000 CMPL: xb 00000000 Err 00000000
Total FCP Cmpl 000000002e14f170 Issue 000000002e14f17a OutIO
000000000000000a
abort 000016bb noxri 00000000 nondlp 00000000 qdepth 00000000 wqerr
00000000 err 00000000
FCP CMPL: xb 00001f50 Err 0000d9f8
```

Marvell/QLogic

The native inbox `qla2xxx` driver included in the RHEL 8.5 GA kernel has the latest fixes which are essential for ONTAP support.

Steps

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

```
# cat /sys/class/fc_host/host*/symbolic_name
QLE2742 FW:v9.06.02 DVR:v10.02.00.106-k
QLE2742 FW:v9.06.02 DVR:v10.02.00.106-k
```

2. Verify `ql2xnvmeenable` is set which enables the Marvell adapter to function as a NVMe/FC initiator:

```
# cat /sys/module/qla2xxx/parameters/ql2xnvmeenable
1
```

Enable 1MB I/O (Optional)

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

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 a `dracut -f` command, and reboot the host.
3. Verify that `lpfc_sg_seg_cnt` is 256.

```
# cat /sys/module/lpfc/parameters/lpfc_sg_seg_cnt
256
```

This is not applicable to Qlogic NVMe/FC hosts.

Configure NVMe/TCP

NVMe/TCP does not have auto-connect functionality. Therefore, if a path goes down and is not reinstated within the default time out period of 10 minutes, NVMe/TCP cannot automatically reconnect. To prevent a time out, you should set the retry period for failover events to at least 30 minutes.

Steps

1. Verify whether the initiator port can fetch the discovery log page data across the supported NVMe/TCP LIFs:

```
# nvme discover -t tcp -w 192.168.1.8 -a 192.168.1.51
Discovery Log Number of Records 10, Generation counter 119
=====Discovery Log Entry 0======
trtype: tcp
adrfam: ipv4
subtype: nvme subsystem
treq: not specified
portid: 0
trsvcid: 4420
subnqn: nqn.1992-
08.com.netapp:sn.56e362e9bb4f11ebbaded039ea165abc:subsystem.nvme_118_tcp
_1
traddr: 192.168.2.56
sectype: none
=====Discovery Log Entry 1======
trtype: tcp
adrfam: ipv4
subtype: nvme subsystem
treq: not specified
portid: 1
trsvcid: 4420
subnqn: nqn.1992-
08.com.netapp:sn.56e362e9bb4f11ebbaded039ea165abc:subsystem.nvme_118_tcp
_1
traddr: 192.168.1.51
sectype: none
=====Discovery Log Entry 2======
trtype: tcp
adrfam: ipv4
subtype: nvme subsystem
treq: not specified
portid: 0
trsvcid: 4420
subnqn: nqn.1992-
08.com.netapp:sn.56e362e9bb4f11ebbaded039ea165abc:subsystem.nvme_118_tcp
_2
traddr: 192.168.2.56
sectype: none
...
```

2. Verify that other NVMe/TCP initiator-target LIF combos can successfully fetch discovery log page data. For example:

```
# nvme discover -t tcp -w 192.168.1.8 -a 192.168.1.51
# nvme discover -t tcp -w 192.168.1.8 -a 192.168.1.52
# nvme discover -t tcp -w 192.168.2.9 -a 192.168.2.56
# nvme discover -t tcp -w 192.168.2.9 -a 192.168.2.57
```

3. Run the `nvme connect-all` command across all the supported NVMe/TCP initiator-target LIFs across the nodes. Ensure you set a longer `ctrl_loss_tmo` timer retry period (for example, 30 minutes, which can be set through `-l 1800`) during the connect-all so that it retries for a longer period of time in the event of a path loss. For example:

```
# nvme connect-all -t tcp -w 192.168.1.8 -a 192.168.1.51 -l 1800
# nvme connect-all -t tcp -w 192.168.1.8 -a 192.168.1.52 -l 1800
# nvme connect-all -t tcp -w 192.168.2.9 -a 192.168.2.56 -l 1800
# nvme connect-all -t tcp -w 192.168.2.9 -a 192.168.2.57 -l 1800
```

Validate NVMe-oF

You can use the following procedure to validate NVMe-oF.

Steps

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

```
# cat /sys/module/nvme_core/parameters/multipath
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 properly reflect on the host:

```
# cat /sys/class/nvme-subsystem/nvme-subsys*/model
NetApp ONTAP Controller
NetApp ONTAP Controller

# cat /sys/class/nvme-subsystem/nvme-subsys*/iopolicy
round-robin
round-robin
```

3. Verify that the ONTAP namespaces properly reflect on the host. For example:

```
# nvme list
Node           SN                    Model                    Namespace
------------   --------------------- ---------------------------------
/dev/nvme0n1    814vWBNRwf9HAAAAAAAB  NetApp ONTAP Controller   1

Usage                Format         FW Rev
-------------------  -----------    --------
85.90 GB / 85.90 GB  4 KiB + 0 B    FFFFFFFF
```

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

```
# nvme list-subsys /dev/nvme0n1
nvme-subsys0 - NQN=nqn.1992-
08.com.netapp:sn.5f5f2c4aa73b11e9967e00a098df41bd:subsystem.nvme_141_1
\
+- nvme0 fc traddr=nn-0x203700a098dfdd91:pn-0x203800a098dfdd91
host_traddr=nn-0x200000109b1c1204:pn-0x100000109b1c1204 live
inaccessible
+- nvme1 fc traddr=nn-0x203700a098dfdd91:pn-0x203900a098dfdd91
host_traddr=nn-0x200000109b1c1204:pn-0x100000109b1c1204 live
inaccessible
+- nvme2 fc traddr=nn-0x203700a098dfdd91:pn-0x203a00a098dfdd91
host_traddr=nn-0x200000109b1c1205:pn-0x100000109b1c1205 live optimized
+- nvme3 fc traddr=nn-0x203700a098dfdd91:pn-0x203d00a098dfdd91
host_traddr=nn-0x200000109b1c1205:pn-0x100000109b1c1205 live optimized
```

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

```
# nvme netapp ontapdevices -o column
Device       Vserver          Namespace Path
---------    -------
----------------------------------------------------
/dev/nvme0n1 vs_fcnvme_141  vol/fcnvme_141_vol_1_1_0/fcnvme_141_ns

NSID  UUID                                   Size
----  ------------------------------         ------
1     72b887b1-5fb6-47b8-be0b-33326e2542e2  85.90GB


# nvme netapp ontapdevices -o json
{
"ONTAPdevices" : [
    {
        "Device" : "/dev/nvme0n1",
        "Vserver" : "vs_fcnvme_141",
        "Namespace_Path" : "/vol/fcnvme_141_vol_1_1_0/fcnvme_141_ns",
        "NSID" : 1,
        "UUID" : "72b887b1-5fb6-47b8-be0b-33326e2542e2",
        "Size" : "85.90GB",
        "LBA_Data_Size" : 4096,
        "Namespace_Size" : 20971520
    }
  ]
}
```

Known issues

There are no known issues.

NVMe-oF Host Configuration for RHEL 8.4 with ONTAP

NVMe over Fabrics or NVMe-oF (including NVMe/FC and other transports) is supported with Red Hat Enterprise Linux (RHEL) 8.4 with ANA (Asymmetric Namespace Access). ANA is the asymmetric logical unit access (ALUA) equivalent in the NVMe-oF environment, and is currently implemented with in-kernel NVMe Multipath. You can enable NVMe-oF with in-kernel NVMe Multipath using ANA on RHEL 8.4 and ONTAP as the target.

Features

There are no new features in this release.

Known limitations

- For RHEL 8.4, in-kernel NVMe multipath is disabled by default. Therefore, you need to enable it manually.
- NVMe/TCP on RHEL 8.4 remains a Technology Preview feature due to open issues. Refer to the RHEL 8.4 Release Notes for details.
- SAN booting using the NVMe-oF protocol is currently not supported.

Enable in-kernel NVMe multipath

You can use the following procedure to enable in-kernel NVMe multipath.

Steps

1. Install RHEL 8.4 GA on the server.
2. After the installation is complete, verify that you are running the specified RHEL 8.4 kernel. See the NetApp Interoperability Matrix for the most current list of supported versions.

   Example:

   ```
   # uname -r
   4.18.0-305.el8.x86_64
   ```

3. Install the `nvme-cli` package:

   Example:

   ```
   # rpm -qa|grep nvme-cli
   nvme-cli-1.12-3.el8.x86_64
   ```

4. Enable in-kernel NVMe multipath:

   ```
   # grubby --args=nvme_core.multipath=Y --update-kernel /boot/vmlinuz-
   4.18.0-305.el8.x86_64
   ```

5. On the host, check the host NQN string at `/etc/nvme/hostnqn` and verify that it matches the host NQN string for the corresponding subsystem on the ONTAP array. Example:

   ```
   # cat /etc/nvme/hostnqn
   nqn.2014-08.org.nvmexpress:uuid:9ed5b327-b9fc-4cf5-97b3-1b5d986345d1
   ::> vserver nvme subsystem host show -vserver vs_fcnvme_141
   Vserver     Subsystem       Host NQN
   ----------- ---------------
   ------------------------------------------------------------
   vs_fcnvme_14 nvme_141_1     nqn.2014-08.org.nvmexpress:uuid:9ed5b327-
   b9fc-4cf5-97b3-1b5d986345d1
   ```

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

6. Reboot the host.

If you intend to run both NVMe & SCSI co-existent traffic on the same host, it is recommended to use in-kernel NVMe multipath for ONTAP namespaces and dm-multipath for ONTAP LUNs respectively. This means that the ONTAP namespaces should be excluded from dm-multipath to prevent dm-multipath from claiming these namespace devices. This can be done by adding the enable_foreign setting to the `/etc/multipath.conf` file:

```
# cat /etc/multipath.conf
defaults {
        enable_foreign     NONE
}
```

Restart the multipathd daemon by running a `systemctl restart multipathd` command to allow the new setting to take effect.

Configure NVMe/FC

You can configure NVMe/FC for Broadcom/Emulex or Marvell/Qlogic adapters.

Broadcom/Emulex

Steps

1. Verify that you are using the supported adapter. See the NetApp Interoperability Matrix Tool for the most current list of supported adapters.

```
# cat /sys/class/scsi_host/host*/modelname
LPe32002-M2
LPe32002-M2
# cat /sys/class/scsi_host/host*/modeldesc
Emulex LightPulse LPe32002-M2 2-Port 32Gb Fibre Channel Adapter
Emulex LightPulse LPe32002-M2 2-Port 32Gb Fibre Channel Adapter
```

2. Verify that you are using the recommended Broadcom lpfc firmware and inbox driver. See the NetApp Interoperability Matrix Tool for the most current list of supported adapter driver and firmware versions.

```
# cat /sys/class/scsi_host/host*/fwrev
12.8.340.8, sli-4:2:c
12.8.340.8, sli-4:2:c
# cat /sys/module/lpfc/version
0:12.8.0.5
```

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

```
# cat /sys/module/lpfc/parameters/lpfc_enable_fc4_type
3
```

4. Verify that the initiator ports are up and running, and you are able to see the target LIFs.

```
# cat /sys/class/fc_host/host*/port_name
0x100000109b1c1204
0x100000109b1c1205
# cat /sys/class/fc_host/host*/port_state
Online
Online
# cat /sys/class/scsi_host/host*/nvme_info
NVME Initiator Enabled
XRI Dist lpfc0 Total 6144 IO 5894 ELS 250
NVME LPORT lpfc0 WWPN x100000109b1c1204 WWNN x200000109b1c1204 DID
x011d00 ONLINE
NVME RPORT WWPN x203800a098dfdd91 WWNN x203700a098dfdd91 DID x010c07
TARGET DISCSRVC ONLINE
NVME RPORT WWPN x203900a098dfdd91 WWNN x203700a098dfdd91 DID x011507
TARGET DISCSRVC ONLINE
NVME Statistics
LS: Xmt 0000000f78 Cmpl 0000000f78 Abort 00000000
LS XMIT: Err 00000000 CMPL: xb 00000000 Err 00000000
Total FCP Cmpl 000000002fe29bba Issue 000000002fe29bc4 OutIO
000000000000000a
abort 00001bc7 noxri 00000000 nondlp 00000000 qdepth 00000000 wqerr
00000000 err 00000000
FCP CMPL: xb 00001e15 Err 0000d906
NVME Initiator Enabled
XRI Dist lpfc1 Total 6144 IO 5894 ELS 250
NVME LPORT lpfc1 WWPN x100000109b1c1205 WWNN x200000109b1c1205 DID
x011900 ONLINE
NVME RPORT WWPN x203d00a098dfdd91 WWNN x203700a098dfdd91 DID x010007
TARGET DISCSRVC ONLINE
NVME RPORT WWPN x203a00a098dfdd91 WWNN x203700a098dfdd91 DID x012a07
TARGET DISCSRVC ONLINE
NVME Statistics
LS: Xmt 0000000fa8 Cmpl 0000000fa8 Abort 00000000
LS XMIT: Err 00000000 CMPL: xb 00000000 Err 00000000
Total FCP Cmpl 000000002e14f170 Issue 000000002e14f17a OutIO
000000000000000a
abort 000016bb noxri 00000000 nondlp 00000000 qdepth 00000000 wqerr
00000000 err 00000000
FCP CMPL: xb 00001f50 Err 0000d9f8
```

Marvell/QLogic FC adapter for NVMe/FC

The native inbox `qla2xxx` driver included in the RHEL 8.4 GA kernel has the latest fixes which are essential for ONTAP support.

Steps

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

```
# cat /sys/class/fc_host/host*/symbolic_name
QLE2742 FW:v9.06.02 DVR:v10.02.00.104-k
QLE2742 FW:v9.06.02 DVR:v10.02.00.104-k
```

2. Verify `ql2xnvmeenable` is set which enables the Marvell adapter to function as a NVMe/FC initiator using the following command:

```
# cat /sys/module/qla2xxx/parameters/ql2xnvmeenable
1
```

Enable 1MB I/O (Optional)

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

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 a `dracut -f` command, and reboot the host.
3. Verify that `lpfc_sg_seg_cnt` is 256.

```
# cat /sys/module/lpfc/parameters/lpfc_sg_seg_cnt
256
```

This is not applicable to Qlogic NVMe/FC hosts.

Configure NVMe/TCP

NVMe/TCP does not have auto-connect functionality. Therefore, if a path goes down and is not reinstated within the default time out period of 10 minutes, NVMe/TCP cannot automatically reconnect. To prevent a time out, you should set the retry period for failover events to at least 30 minutes.

Steps

1. Verify whether the initiator port can fetch the discovery log page data across the supported NVMe/TCP

LIFs:

```
# nvme discover -t tcp -w 192.168.1.8 -a 192.168.1.51
Discovery Log Number of Records 10, Generation counter 119
=====Discovery Log Entry 0======
trtype: tcp
adrfam: ipv4
subtype: nvme subsystem
treq: not specified
portid: 0
trsvcid: 4420
subnqn: nqn.1992-
08.com.netapp:sn.56e362e9bb4f11ebbaded039ea165abc:subsystem.nvme_118_tcp
_1
traddr: 192.168.2.56
sectype: none
=====Discovery Log Entry 1======
trtype: tcp
adrfam: ipv4
subtype: nvme subsystem
treq: not specified
portid: 1
trsvcid: 4420
subnqn: nqn.1992-
08.com.netapp:sn.56e362e9bb4f11ebbaded039ea165abc:subsystem.nvme_118_tcp
_1
traddr: 192.168.1.51
sectype: none
=====Discovery Log Entry 2======
trtype: tcp
adrfam: ipv4
subtype: nvme subsystem
treq: not specified
portid: 0
trsvcid: 4420
subnqn: nqn.1992-
08.com.netapp:sn.56e362e9bb4f11ebbaded039ea165abc:subsystem.nvme_118_tcp
_2
traddr: 192.168.2.56
sectype: none
...
```

2. Verify that other NVMe/TCP initiator-target LIF combos are able to successfully fetch discovery log page data. For example,

```
# nvme discover -t tcp -w 192.168.1.8 -a 192.168.1.52
# nvme discover -t tcp -w 192.168.2.9 -a 192.168.2.56
# nvme discover -t tcp -w 192.168.2.9 -a 192.168.2.57
```

3. Run `nvme connect-all` command across all the supported NVMe/TCP initiator-target LIFs across the nodes. Ensure you set a longer `ctrl_loss_tmo` timer retry period (for example, 30 minutes, which can be set through `-l 1800`) during the connect-all so that it would retry for a longer period of time in the event of a path loss. For example,

```
# nvme connect-all -t tcp -w 192.168.1.8 -a 192.168.1.51 -l 1800
# nvme connect-all -t tcp -w 192.168.1.8 -a 192.168.1.52 -l 1800
# nvme connect-all -t tcp -w 192.168.2.9 -a 192.168.2.56 -l 1800
# nvme connect-all -t tcp -w 192.168.2.9 -a 192.168.2.57 -l 1800
```

Validate NVMe-oF

You can use the following procedure to validate NVMe-oF.

Steps

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

```
# cat /sys/module/nvme_core/parameters/multipath
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 properly reflect on the host:

```
# cat /sys/class/nvme-subsystem/nvme-subsys*/model
NetApp ONTAP Controller
NetApp ONTAP Controller

# cat /sys/class/nvme-subsystem/nvme-subsys*/iopolicy
round-robin
round-robin
```

3. Verify that the ONTAP namespaces properly reflect on the host. For example,

   Example (a):

```
# nvme list
Node           SN                    Model                    Namespace
------------   --------------------- ---------------------------------
/dev/nvme0n1   81CZ5BQuUNfGAAAAAAAB  NetApp ONTAP Controller   1

Usage                Format         FW Rev
-------------------  -----------    --------
85.90 GB / 85.90 GB  4 KiB + 0 B    FFFFFFFF
```

Example (b):

```
# nvme list
Node           SN                    Model                    Namespace
------------   --------------------- ---------------------------------
/dev/nvme0n1   81CYrBQuTHQFAAAAAAAC  NetApp ONTAP Controller   1

Usage                Format         FW Rev
-------------------  -----------    --------
85.90 GB / 85.90 GB  4 KiB + 0 B    FFFFFFFF
```

4. Verify that the controller state of each path is live and has proper ANA status. For example,

   Example (a):

```
# nvme list-subsys /dev/nvme1n1
nvme-subsys1 - NQN=nqn.1992-
08.com.netapp:sn.04ba0732530911ea8e8300a098dfdd91:subsystem.nvme_145_1
\
+- nvme2 fc traddr=nn-0x208100a098dfdd91:pn-0x208200a098dfdd91
host_traddr=nn-0x200000109b579d5f:pn-0x100000109b579d5f live non-
optimized
+- nvme3 fc traddr=nn-0x208100a098dfdd91:pn-0x208500a098dfdd91
host_traddr=nn-0x200000109b579d5e:pn-0x100000109b579d5e live non-
optimized
+- nvme4 fc traddr=nn-0x208100a098dfdd91:pn-0x208400a098dfdd91
host_traddr=nn-0x200000109b579d5e:pn-0x100000109b579d5e live optimized
+- nvme6 fc traddr=nn-0x208100a098dfdd91:pn-0x208300a098dfdd91
host_traddr=nn-0x200000109b579d5f:pn-0x100000109b579d5f live optimized
```

   Example (b):

```
#nvme list-subsys /dev/nvme0n1
nvme-subsys0 - NQN=nqn.1992-
08.com.netapp:sn.37ba7d9cbfba11eba35dd039ea165514:subsystem.nvme_114_tcp
_1
\
+- nvme0 tcp traddr=192.168.2.36 trsvcid=4420 host_traddr=192.168.1.4
live optimized
+- nvme1 tcp traddr=192.168.1.31 trsvcid=4420 host_traddr=192.168.1.4
live optimized
+- nvme10 tcp traddr=192.168.2.37 trsvcid=4420 host_traddr=192.168.1.4
live non-optimized
+- nvme11 tcp traddr=192.168.1.32 trsvcid=4420 host_traddr=192.168.1.4
live non-optimized
+- nvme20 tcp traddr=192.168.2.36 trsvcid=4420 host_traddr=192.168.2.5
live optimized
+- nvme21 tcp traddr=192.168.1.31 trsvcid=4420 host_traddr=192.168.2.5
live optimized
+- nvme30 tcp traddr=192.168.2.37 trsvcid=4420 host_traddr=192.168.2.5
live non-optimized
+- nvme31 tcp traddr=192.168.1.32 trsvcid=4420 host_traddr=192.168.2.5
live non-optimized
```

5. Verify that the NetApp plug-in displays proper values for each ONTAP namespace device. For example,

   Example (a):

```
# nvme netapp ontapdevices -o column
Device       Vserver          Namespace Path
---------    -------
----------------------------------------------------
/dev/nvme1n1 vserver_fcnvme_145 /vol/fcnvme_145_vol_1_0_0/fcnvme_145_ns

NSID  UUID                                   Size
-------  ------------------------------     --------------------
1      23766b68-e261-444e-b378-2e84dbe0e5e1  85.90GB


# nvme netapp ontapdevices -o json
{
"ONTAPdevices" : [
     {
       "Device" : "/dev/nvme1n1",
       "Vserver" : "vserver_fcnvme_145",
       "Namespace_Path" : "/vol/fcnvme_145_vol_1_0_0/fcnvme_145_ns",
       "NSID" : 1,
       "UUID" : "23766b68-e261-444e-b378-2e84dbe0e5e1",
       "Size" : "85.90GB",
       "LBA_Data_Size" : 4096,
       "Namespace_Size" : 20971520
     }
  ]
}
```

Example (b):

```
# nvme netapp ontapdevices -o column
Device       Vserver          Namespace Path
---------    -------
----------------------------------------------------
/dev/nvme0n1 vs_tcp_114       /vol/tcpnvme_114_1_0_1/tcpnvme_114_ns

NSID  UUID                                   Size
-------  ------------------------------         ---------------
1      a6aee036-e12f-4b07-8e79-4d38a9165686  85.90GB


# nvme netapp ontapdevices -o json
{
     "ONTAPdevices" : [
     {
          "Device" : "/dev/nvme0n1",
           "Vserver" : "vs_tcp_114",
          "Namespace_Path" : "/vol/tcpnvme_114_1_0_1/tcpnvme_114_ns",
          "NSID" : 1,
          "UUID" : "a6aee036-e12f-4b07-8e79-4d38a9165686",
          "Size" : "85.90GB",
          "LBA_Data_Size" : 4096,
          "Namespace_Size" : 20971520
       }
  ]

}
```

Known issues

There are no known issues.

NVMe/FC host configuration for RHEL 8.3 with ONTAP

NVMe/FC is supported on ONTAP 9.6 or later for Red Hat Enterprise Linux (RHEL) 8.3. The RHEL 8.3 host runs both NVMe and SCSI traffic through the same FC initiator adapter ports. See the Hardware Universe for a list of supported FC adapters and controllers.

See the NetApp Interoperability Matrix Tool for the most current list of supported configurations.

Features

There are no new features in this release.

Known limitations

- For RHEL 8.3, in-kernel NVMe multipath is disabled by default. You can enable it manually.
- SAN booting using the NVMe-oF protocol is currently not supported.

Enable NVMe/FC on RHEL 8.3

You can use the following procedure to enable NVMe/FC.

Steps

1. Install Red Hat Enterprise Linux 8.3 GA on the server.
2. If you are upgrading from RHEL 8.2 to RHEL 8.3 using the `yum update/upgrade` command, your `/etc/nvme/host*` files might be lost. To avoid file loss, use the following procedure:

   Steps

   a. Backup your `/etc/nvme/host*` files.

   b. If you have a manually edited `udev` rule, remove it:

   ```
   /lib/udev/rules.d/71-nvme-iopolicy-netapp-ONTAP.rules
   ```

   c. Perform the upgrade.

   d. After the upgrade is complete, run the following command:

   ```
   yum remove nvme-cli
   ```

   e. Restore the host files at `/etc/nvme/`.

   ```
   yum install nvmecli
   ```

   f. Copy the original `/etc/nvme/host*` contents from the backup to the actual host files at `/etc/nvme/`.

3. After the installation is complete, verify that you're running the specified RHEL kernel:

   ```
   # uname -r
   4.18.0-240.el8.x86_64
   ```

   See the NetApp Interoperability Matrix Tool for the most current list of supported versions.

4. Install the nvme-cli package:

```
# rpm -qa|grep nvme-cli
nvme-cli-1.12-2.el8.x86_64
```

5. Enable in-kernel NVMe multipath.

```
# grubby --args=nvme_core.multipath=Y --update-kernel /boot/vmlinuz-
4.18.0-240.el8.x86_64
```

6. On the RHEL 8.3 host, check the host NQN string at `/etc/nvme/hostnqn` verify that it matches the host NQN string for the corresponding subsystem on the ONTAP array:

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

Example output:

```
# cat /etc/nvme/hostnqn
nqn.2014-08.org.nvmexpress:uuid:9ed5b327-b9fc-4cf5-97b3-1b5d986345d1
```

7. Verify that the `hostnqn` string matches the hostnqn string for the corresponding subsystem on the ONTAP array:

```
vserver nvme subsystem host show -vserver vs_fcnvme_141
```

Example output

```
::> vserver nvme subsystem host show -vserver vs_fcnvme_141
Vserver         Subsystem        Host           NQN
-----------     --------------- ----------- ---------------
vs_fcnvme_141    nvme_141_1                 nqn.2014-
08.org.nvmexpress:uuid:9ed5b327-b9fc-4cf5-97b3-1b5d986345d1
```

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

8. Reboot the host.
9. Optionally, update the `enable_foreign` setting.

If you intend to run both NVMe and SCSI traffic on the same RHEL 8.3 co-existent host, NetApp recommends that you use in-kernel NVMe multipath for ONTAP namespaces and dm-multipath for ONTAP LUNs, respectively. You should also blacklist the ONTAP namespaces in dm-multipath to prevent dm-multipath from claiming these namespace devices. You can do this by adding the `enable_foreign` setting to the /etc/multipath.conf, as shown below:

```
# cat /etc/multipath.conf
defaults {
   enable_foreign NONE
}
```

Restart the multipathd daemon by running a `systemctl restart multipathd`.

Validate NVMe/FC

You can use the following procedure to validate NVMe/FC.

Steps

1. Verify the following NVMe/FC settings:

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

```
# cat /sys/class/nvme-subsystem/nvme-subsys*/model
NetApp ONTAP Controller
NetApp ONTAP Controller
```

```
# cat /sys/class/nvme-subsystem/nvme-subsys*/iopolicy
round-robin
round-robin
```

2. Verify that the namespaces are created and properly discovered on the host.

```
/dev/nvme0n1     814vWBNRwf9HAAAAAAAB  NetApp ONTAP Controller
1                  85.90 GB / 85.90 GB     4 KiB + 0 B   FFFFFFFF
/dev/nvme0n2     814vWBNRwf9HAAAAAAAB  NetApp ONTAP Controller
2                  85.90 GB / 85.90 GB     4 KiB + 0 B   FFFFFFFF
/dev/nvme0n3     814vWBNRwf9HAAAAAAAB  NetApp ONTAP Controller
3                  85.90 GB / 85.90 GB     4 KiB + 0 B   FFFFFFFF
```

3. Verify the status of the ANA paths.

```
# nvme list-subsys /dev/nvme0n1
nvme-subsys0 - NQN=nqn.1992-
08.com.netapp:sn.5f5f2c4aa73b11e9967e00a098df41bd:subsystem.nvme_141_1
\
+- nvme0 fc traddr=nn-0x203700a098dfdd91:pn-0x203800a098dfdd91
host_traddr=nn-0x200000109b1c1204:pn-0x100000109b1c1204 live
inaccessible
+- nvme1 fc traddr=nn-0x203700a098dfdd91:pn-0x203900a098dfdd91
host_traddr=nn-0x200000109b1c1204:pn-0x100000109b1c1204 live
inaccessible
+- nvme2 fc traddr=nn-0x203700a098dfdd91:pn-0x203a00a098dfdd91
host_traddr=nn-0x200000109b1c1205:pn-0x100000109b1c1205 live optimized
+- nvme3 fc traddr=nn-0x203700a098dfdd91:pn-0x203d00a098dfdd91
host_traddr=nn-0x200000109b1c1205:pn-0x100000109b1c1205 live optimized
```

4. Verify the NetApp plug-in for ONTAP devices:

Column

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

Example output

```
Device                Vserver            Namespace Path
NSID                      UUID                      Size
--------------- ---------------
----------------------------------------------  --------
--------------------------------------  ---------
/dev/nvme0n1      vs_fcnvme_141
/vol/fcnvme_141_vol_1_1_0/fcnvme_141_ns        1      72b887b1-5fb6-
47b8-be0b-33326e2542e2    85.90GB
/dev/nvme0n2      vs_fcnvme_141
/vol/fcnvme_141_vol_1_0_0/fcnvme_141_ns        2      04bf9f6e-9031-
40ea-99c7-a1a61b2d7d08    85.90GB
/dev/nvme0n3      vs_fcnvme_141
/vol/fcnvme_141_vol_1_1_1/fcnvme_141_ns        3      264823b1-8e03-
4155-80dd-e904237014a4    85.90GB
```

JSON

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

Example output

```
{
"ONTAPdevices" : [
    {
        "Device" : "/dev/nvme0n1",
        "Vserver" : "vs_fcnvme_141",
        "Namespace_Path" :
"/vol/fcnvme_141_vol_1_1_0/fcnvme_141_ns",
        "NSID" : 1,
        "UUID" : "72b887b1-5fb6-47b8-be0b-33326e2542e2",
        "Size" : "85.90GB",
        "LBA_Data_Size" : 4096,
        "Namespace_Size" : 20971520
    },
    {
        "Device" : "/dev/nvme0n2",
        "Vserver" : "vs_fcnvme_141",
        "Namespace_Path" :
"/vol/fcnvme_141_vol_1_0_0/fcnvme_141_ns",
        "NSID" : 2,
        "UUID" : "04bf9f6e-9031-40ea-99c7-a1a61b2d7d08",
        "Size" : "85.90GB",
        "LBA_Data_Size" : 4096,
        "Namespace_Size" : 20971520
      },
      {
         "Device" : "/dev/nvme0n3",
         "Vserver" : "vs_fcnvme_141",
         "Namespace_Path" :
"/vol/fcnvme_141_vol_1_1_1/fcnvme_141_ns",
         "NSID" : 3,
         "UUID" : "264823b1-8e03-4155-80dd-e904237014a4",
         "Size" : "85.90GB",
         "LBA_Data_Size" : 4096,
         "Namespace_Size" : 20971520
       },
  ]
```

Configure the Broadcom FC adapter for NVMe/FC

You can use the following procedure to configure a Broadcom FC adapter.

For the most current list of supported adapters, see the NetApp Interoperability Matrix Tool.

Steps

1. Verify that you are using the supported adapter.

```
# cat /sys/class/scsi_host/host*/modelname
LPe32002-M2
LPe32002-M2
```

```
# cat /sys/class/scsi_host/host*/modeldesc
Emulex LightPulse LPe32002-M2 2-Port 32Gb Fibre Channel Adapter
Emulex LightPulse LPe32002-M2 2-Port 32Gb Fibre Channel Adapter
```

2. Verify that `lpfc_enable_fc4_type` is set to "**3**".

```
# cat /sys/module/lpfc/parameters/lpfc_enable_fc4_type
3
```

3. Verify that the initiator ports are up and running and can see the target LIFs.

```
# cat /sys/class/fc_host/host*/port_name
0x100000109b1c1204
0x100000109b1c1205
```

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

```
# cat /sys/class/scsi_host/host*/nvme_info
NVME Initiator Enabled
XRI Dist lpfc0 Total 6144 IO 5894 ELS 250
NVME LPORT lpfc0 WWPN x100000109b1c1204 WWNN x200000109b1c1204 DID
x011d00 ONLINE
NVME RPORT WWPN x203800a098dfdd91 WWNN x203700a098dfdd91 DID x010c07
TARGET DISCSRVC ONLINE
NVME RPORT WWPN x203900a098dfdd91 WWNN x203700a098dfdd91 DID x011507
TARGET DISCSRVC ONLINE
NVME Statistics
LS: Xmt 0000000f78 Cmpl 0000000f78 Abort 00000000
LS XMIT: Err 00000000 CMPL: xb 00000000 Err 00000000
Total FCP Cmpl 000000002fe29bba Issue 000000002fe29bc4 OutIO
000000000000000a
abort 00001bc7 noxri 00000000 nondlp 00000000 qdepth 00000000 wqerr
00000000 err 00000000
FCP CMPL: xb 00001e15 Err 0000d906
NVME Initiator Enabled
XRI Dist lpfc1 Total 6144 IO 5894 ELS 250
NVME LPORT lpfc1 WWPN x100000109b1c1205 WWNN x200000109b1c1205 DID
x011900 ONLINE
NVME RPORT WWPN x203d00a098dfdd91 WWNN x203700a098dfdd91 DID x010007
TARGET DISCSRVC ONLINE
NVME RPORT WWPN x203a00a098dfdd91 WWNN x203700a098dfdd91 DID x012a07
TARGET DISCSRVC ONLINE
NVME Statistics
LS: Xmt 0000000fa8 Cmpl 0000000fa8 Abort 00000000
LS XMIT: Err 00000000 CMPL: xb 00000000 Err 00000000
Total FCP Cmpl 000000002e14f170 Issue 000000002e14f17a OutIO
000000000000000a
abort 000016bb noxri 00000000 nondlp 00000000 qdepth 00000000 wqerr
00000000 err 00000000
FCP CMPL: xb 00001f50 Err 0000d9f8
```

4. Enable 1 MB I/O size *(optional)*.

   The `lpfc_sg_seg_cnt` parameter needs to be set to 256 for the lpfc driver to issue I/O requests up to 1 MB in size.

```
# cat /etc/modprobe.d/lpfc.conf
options lpfc lpfc_sg_seg_cnt=256
```

5. Run a `dracut -f` command and then reboot the host.
6. After the host boots up, verify that lpfc_sg_seg_cnt is set to 256.

```
# cat /sys/module/lpfc/parameters/lpfc_sg_seg_cnt
256
```

7. Verify that you are using the recommended Broadcom lpfc firmware as well as the inbox driver:

```
# cat /sys/class/scsi_host/host*/fwrev
12.8.340.8, sli-4:2:c
12.8.340.8, sli-4:2:c
```

```
# cat /sys/module/lpfc/version
0:12.8.0.1
```

NVMe/FC host configuration for RHEL 8.2 with ONTAP

NVMe/FC is supported on ONTAP 9.6 or later for Red Hat Enterprise Linux (RHEL) 8.2. The RHEL 8.2 host runs both NVMe and SCSI traffic through the same fibre channel (FC) initiator adapter ports. See the Hardware Universe for a list of supported FC adapters and controllers.

See the NetApp Interoperability Matrix Tool for the most current list of supported configurations.

Features

- Beginning with RHEL 8.2, `nvme-fc auto-connect` scripts are included in the native `nvme-cli` package. You can rely on these native auto-connect scripts instead of having to install the external vendor provided outbox auto-connect scripts.
- Beginning with RHEL 8.2, a native `udev` rule is already provided as part of the `nvme-cli` package which enables round-robin load balancing for NVMe multipath. You need not manually create this rule any more (as was done in RHEL 8.1).
- Beginning with RHEL 8.2, both NVMe and SCSI traffic can be run on the same co-existent host. In fact, this is the expected deployed host configuration. Therefore, for SCSI, you can configure `dm-multipath` as usual for SCSI LUNs resulting in `mpath` devices, whereas NVMe multipath can be used to configure NVMe-oF multipath devices on the host.
- Beginning with RHEL 8.2, the NetApp plug-in in the native `nvme-cli` package is capable of displaying ONTAP details for ONTAP namespaces.

Known limitations

- For RHEL 8.2, in-kernel NVMe multipath is disabled by default. Therefore, you need to enable it manually.
- SAN booting using the NVMe-oF protocol is currently not supported.

Enable NVMe/FC

You can use the following procedure to enable NVMe/FC.

Steps

1. Install Red Hat Enterprise Linux 8.2 GA on the server.
2. If you are upgrading from RHEL 8.1 to RHEL 8.2 using `yum update/upgrade`, your `/etc/nvme/host*` files might be lost. To avoid the file loss, do the following:
   a. Backup your `/etc/nvme/host*` files.
   b. If you have a manually edited `udev` rule, remove it:

   ```
   /lib/udev/rules.d/71-nvme-iopolicy-netapp-ONTAP.rules
   ```

   c. Perform the upgrade.
   d. After the upgrade is complete, run the following command:

   ```
   yum remove nvme-cli
   ```

   e. Restore the host files at `/etc/nvme/`.

   ```
   yum install nvmecli
   ```

   f. Copy the original `/etc/nvme/host*` contents from the backup to the actual host files at `/etc/nvme/`.
3. After the installation is complete, verify that you are running the specified Red Hat Enterprise Linux kernel.

   ```
   # uname -r
   4.18.0-193.el8.x86_64
   ```

   See the NetApp Interoperability Matrix Tool for the most current list of supported versions.
4. Install the nvme-cli package.

   ```
   # rpm -qa|grep nvme-cli
   nvme-cli-1.9.5.el8.x86_64
   ```

5. Enable in-kernel NVMe multipath.

   ```
   # grubby –args=nvme_core.multipath=Y –update-kernel /boot/vmlinuz-
   4.18.0-193.el8.x86_64
   ```

6. On the RHEL 8.2 host, check the host NQN string at `/etc/nvme/hostnqn` and verify that it matches the host NQN string for the corresponding subsystem on the ONTAP array.

```
# cat /etc/nvme/hostnqn
nqn.2014-08.org.nvmexpress:uuid:9ed5b327-b9fc-4cf5-97b3-1b5d986345d1


::> vserver nvme subsystem host show -vserver vs_fcnvme_141
Vserver      Subsystem        Host           NQN
----------- --------------- ----------- ---------------
  vs_fcnvme_141
    nvme_141_1
        nqn.2014-08.org.nvmexpress:uuid:9ed5b327-b9fc-4cf5-97b3-
1b5d986345d1
```

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

7. Reboot the host.
8. Update the `enable_foreign` setting *(optional)*.

   If you intend to run both NVMe and SCSI traffic on the same RHEL 8.2 co-existent host, NetApp recommends using in-kernel NVMe multipath for ONTAP namespaces and dm-multipath for ONTAP LUNs respectively. You should also blacklist the ONTAP namespaces in dm-multipath to prevent dm-multipath from claiming these namespace devices. You can do this by adding the `enable_foreign` setting to the `/etc/multipath.conf`, as shown below.

```
# cat /etc/multipath.conf
defaults {
   enable_foreign NONE
}
```

9. Restart the multipathd daemon by running a `systemctl restart multipathd`.

Configure the Broadcom FC adapter for NVMe/FC

You can use the following procedure to configure a Broadcom FC adapter.

For the most current list of supported adapters, see the NetApp Interoperability Matrix Tool.

Steps

1. Verify that you are using the supported adapter.

```
# cat /sys/class/scsi_host/host*/modelname
LPe32002-M2
LPe32002-M2
```

```
# cat /sys/class/scsi_host/host*/modeldesc
Emulex LightPulse LPe32002-M2 2-Port 32Gb Fibre Channel Adapter
Emulex LightPulse LPe32002-M2 2-Port 32Gb Fibre Channel Adapter
```

2. Verify that `lpfc_enable_fc4_type` is set to "**3**".

```
# cat /sys/module/lpfc/parameters/lpfc_enable_fc4_type
3
```

3. Verify that the initiator ports are up and running and can see the target LIFs.

```
# cat /sys/class/fc_host/host*/port_name
0x100000109b1c1204
0x100000109b1c1205
```

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

```
# cat /sys/class/scsi_host/host*/nvme_info
NVME Initiator Enabled
XRI Dist lpfc0 Total 6144 IO 5894 ELS 250
NVME LPORT lpfc0 WWPN x100000109b1c1204 WWNN x200000109b1c1204 DID
x011d00 ONLINE
NVME RPORT WWPN x203800a098dfdd91 WWNN x203700a098dfdd91 DID x010c07
TARGET DISCSRVC ONLINE
NVME RPORT WWPN x203900a098dfdd91 WWNN x203700a098dfdd91 DID x011507
TARGET DISCSRVC ONLINE
NVME Statistics
LS: Xmt 0000000f78 Cmpl 0000000f78 Abort 00000000
LS XMIT: Err 00000000 CMPL: xb 00000000 Err 00000000
Total FCP Cmpl 000000002fe29bba Issue 000000002fe29bc4 OutIO
000000000000000a
abort 00001bc7 noxri 00000000 nondlp 00000000 qdepth 00000000 wqerr
00000000 err 00000000
FCP CMPL: xb 00001e15 Err 0000d906
NVME Initiator Enabled
XRI Dist lpfc1 Total 6144 IO 5894 ELS 250
NVME LPORT lpfc1 WWPN x100000109b1c1205 WWNN x200000109b1c1205 DID
x011900 ONLINE
NVME RPORT WWPN x203d00a098dfdd91 WWNN x203700a098dfdd91 DID x010007
TARGET DISCSRVC ONLINE
NVME RPORT WWPN x203a00a098dfdd91 WWNN x203700a098dfdd91 DID x012a07
TARGET DISCSRVC ONLINE
NVME Statistics
LS: Xmt 0000000fa8 Cmpl 0000000fa8 Abort 00000000
LS XMIT: Err 00000000 CMPL: xb 00000000 Err 00000000
Total FCP Cmpl 000000002e14f170 Issue 000000002e14f17a OutIO
000000000000000a
abort 000016bb noxri 00000000 nondlp 00000000 qdepth 00000000 wqerr
00000000 err 00000000
FCP CMPL: xb 00001f50 Err 0000d9f8
```

4. Enable 1 MB I/O size *(optional)*.

   The `lpfc_sg_seg_cnt` parameter needs to be set to 256 for the lpfc driver to issue I/O requests up to 1 MB in size.

```
# cat /etc/modprobe.d/lpfc.conf
options lpfc lpfc_sg_seg_cnt=256
```

5. Run a `dracut -f` command and then reboot the host.
6. After the host boots up, verify that lpfc_sg_seg_cnt is set to 256.

```
# cat /sys/module/lpfc/parameters/lpfc_sg_seg_cnt
256
```

7. Verify that you are using the recommended Broadcom lpfc firmware as well as the inbox driver.

```
# cat /sys/class/scsi_host/host*/fwrev
12.6.182.8, sli-4:2:c
12.6.182.8, sli-4:2:c
```

```
# cat /sys/module/lpfc/version
0:12.6.0.2
```

8. Verify that `lpfc_enable_fc4_type` is set to "**3**".

```
# cat /sys/module/lpfc/parameters/lpfc_enable_fc4_type
3
```

9. Verify that the initiator ports are up and running and can see the target LIFs.

```
# cat /sys/class/fc_host/host*/port_name
0x100000109b1c1204
0x100000109b1c1205
```

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

```
# cat /sys/class/scsi_host/host*/nvme_info
NVME Initiator Enabled
XRI Dist lpfc0 Total 6144 IO 5894 ELS 250
NVME LPORT lpfc0 WWPN x100000109b1c1204 WWNN x200000109b1c1204 DID
x011d00 ONLINE
NVME RPORT WWPN x203800a098dfdd91 WWNN x203700a098dfdd91 DID x010c07
TARGET DISCSRVC ONLINE
NVME RPORT WWPN x203900a098dfdd91 WWNN x203700a098dfdd91 DID x011507
TARGET DISCSRVC ONLINE
NVME Statistics
LS: Xmt 0000000f78 Cmpl 0000000f78 Abort 00000000
LS XMIT: Err 00000000 CMPL: xb 00000000 Err 00000000
Total FCP Cmpl 000000002fe29bba Issue 000000002fe29bc4 OutIO
000000000000000a
abort 00001bc7 noxri 00000000 nondlp 00000000 qdepth 00000000 wqerr
00000000 err 00000000
FCP CMPL: xb 00001e15 Err 0000d906
NVME Initiator Enabled
XRI Dist lpfc1 Total 6144 IO 5894 ELS 250
NVME LPORT lpfc1 WWPN x100000109b1c1205 WWNN x200000109b1c1205 DID
x011900 ONLINE
NVME RPORT WWPN x203d00a098dfdd91 WWNN x203700a098dfdd91 DID x010007
TARGET DISCSRVC ONLINE
NVME RPORT WWPN x203a00a098dfdd91 WWNN x203700a098dfdd91 DID x012a07
TARGET DISCSRVC ONLINE
NVME Statistics
LS: Xmt 0000000fa8 Cmpl 0000000fa8 Abort 00000000
LS XMIT: Err 00000000 CMPL: xb 00000000 Err 00000000
Total FCP Cmpl 000000002e14f170 Issue 000000002e14f17a OutIO
000000000000000a
abort 000016bb noxri 00000000 nondlp 00000000 qdepth 00000000 wqerr
00000000 err 00000000
FCP CMPL: xb 00001f50 Err 0000d9f8
```

10. Enable 1 MB I/O size *(optional)*.

    The `lpfc_sg_seg_cnt` parameter needs to be set to 256 for the lpfc driver to issue I/O requests up to 1 MB in size.

```
# cat /etc/modprobe.d/lpfc.conf
options lpfc lpfc_sg_seg_cnt=256
```

11. Run a `dracut -f` command and then reboot the host.
12. After the host boots up, verify that lpfc_sg_seg_cnt is set to 256.

```
# cat /sys/module/lpfc/parameters/lpfc_sg_seg_cnt
256
```

Validate NVMe/FC

You can use the following procedure to validate NVMe/FC.

Steps

1. Verify the following NVMe/FC settings.

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

```
# cat /sys/class/nvme-subsystem/nvme-subsys*/model
NetApp ONTAP Controller
NetApp ONTAP Controller
```

```
# cat /sys/class/nvme-subsystem/nvme-subsys*/iopolicy
round-robin
round-robin
```

2. Verify that the namespaces are created.

```
# nvme list
Node SN Model Namespace Usage Format FW Rev
---------------- -------------------- ----------------------
/dev/nvme0n1 80BADBKnB/JvAAAAAAAC NetApp ONTAP Controller 1 53.69 GB /
53.69 GB 4 KiB + 0 B FFFFFFFF
```

3. Verify the status of the ANA paths.

```
# nvme list-subsys/dev/nvme0n1
Nvme-subsysf0 - NQN=nqn.1992-
08.com.netapp:sn.341541339b9511e8a9b500a098c80f09:subsystem.rhel_141_nvm
e_ss_10_0
\
+- nvme0 fc traddr=nn-0x202c00a098c80f09:pn-0x202d00a098c80f09
host_traddr=nn-0x20000090fae0ec61:pn-0x10000090fae0ec61 live optimized
+- nvme1 fc traddr=nn-0x207300a098dfdd91:pn-0x207600a098dfdd91
host_traddr=nn-0x200000109b1c1204:pn-0x100000109b1c1204 live
inaccessible
+- nvme2 fc traddr=nn-0x207300a098dfdd91:pn-0x207500a098dfdd91
host_traddr=nn-0x200000109b1c1205:pn-0x100000109b1c1205 live optimized
+- nvme3 fc traddr=nn-0x207300a098dfdd91:pn-0x207700a098dfdd91 host
traddr=nn-0x200000109b1c1205:pn-0x100000109b1c1205 live inaccessible
```

4. Verify the NetApp plug-in for ONTAP devices.

```
# nvme netapp ontapdevices -o column
Device   Vserver  Namespace Path             NSID   UUID   Size
-------  -------- -------------------------  ------ ----- -----
/dev/nvme0n1   vs_nvme_10       /vol/rhel_141_vol_10_0/rhel_141_ns_10_0
1        55baf453-f629-4a18-9364-b6aee3f50dad   53.69GB

# nvme netapp ontapdevices -o json
{
   "ONTAPdevices" : [
   {
        Device" : "/dev/nvme0n1",
        "Vserver" : "vs_nvme_10",
        "Namespace_Path" : "/vol/rhel_141_vol_10_0/rhel_141_ns_10_0",
         "NSID" : 1,
         "UUID" : "55baf453-f629-4a18-9364-b6aee3f50dad",
         "Size" : "53.69GB",
         "LBA_Data_Size" : 4096,
         "Namespace_Size" : 13107200
    }
]
```

NVMe/FC host configuration for RHEL 8.1 with ONTAP

NVMe/FC is supported on ONTAP 9.6 or later for Red Hat Enterprise Linux (RHEL) 8.1. A RHEL 8.1 host can run both NVMe and SCSI traffic through the same FC initiator adapter ports. See the Hardware Universe for a list of supported FC adapters and controllers.

See the NetApp Interoperability Matrix Tool for the most current list of supported configurations.

Known limitations

- Native NVMe/FC auto-connect scripts are not available in the `nvme-cli` package. You can use the host bus adapter (HBA) vendor-provided external auto-connect script.
- NVMe multipath is disabled by default. Therefore, you need to enable it manually.
- By default, round-robin load balancing is not enabled. You can enable this functionality by writing a `udev` rule.
- SAN booting using the NVMe-oF protocol is currently not supported.

Enable NVMe/FC

You can use the following procedure to enable NVMe/FC.

Steps

1. Install Red Hat Enterprise Linux 8.1 on the server.
2. After the installation is complete, verify that you are running the specified RHEL kernel:

   ```
   # uname -r
   4.18.0-147.el8.x86_64
   ```

   See the NetApp Interoperability Matrix Tool for the most current list of supported versions.

3. Install the `nvme-cli-1.8.1-3.el8` package:

   ```
   # rpm -qa|grep nvme-cli
   nvme-cli-1.8.1-3.el8.x86_64
   ```

4. Enable in-kernel NVMe multipath:

   ```
   # grubby –args=nvme_core.multipath=Y –update-kernel /boot/vmlinuz-
   4.18.0-147.el8.x86_64
   ```

5. Add the following string as a separate udev rule at `/lib/udev/rules.d/71-nvme-iopolicy-netapp-ONTAP.rules`. This enables round-robin load balancing for NVMe multipath:

   ```
   # Enable round-robin for NetApp ONTAP
   ACTION==”add”, SUBSYSTEM==”nvme-subsystem”, ATTR{model}==”NetApp ONTAP
   Controller”, ATTR{iopolicy}=”round-robin
   ```

6. On the RHEL 8.1 host, check the host NQN string at `/etc/nvme/hostnqn` and verify that it matches the host NQN string for the corresponding subsystem on the ONTAP array:

```
# cat /etc/nvme/hostnqn
nqn.2014-08.org.nvmexpress:uuid:75953f3b-77fe-4e03-bf3c-09d5a156fbcd
```

```
*> vserver nvme subsystem host show -vserver vs_nvme_10
Vserver Subsystem Host NQN
------- --------- ------------------------------------- -----------
rhel_141_nvme_ss_10_0
nqn.2014-08.org.nvmexpress:uuid:75953f3b-77fe-4e03-bf3c-09d5a156fbcd
```

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

7. Reboot the host.

Configure the Broadcom FC adapter for NVMe/FC

You can use the following procedure to configure a Broadcom FC adapter.

Steps

1. Verify that you are using the supported adapter. See the NetApp Interoperability Matrix Tool for the most current list of supported adapters.

```
# cat /sys/class/scsi_host/host*/modelname
LPe32002-M2
LPe32002-M2
```

```
# cat /sys/class/scsi_host/host*/modeldesc
Emulex LightPulse LPe32002-M2 2-Port 32Gb Fibre Channel Adapter
Emulex LightPulse LPe32002-M2 2-Port 32Gb Fibre Channel Adapter
```

2. Copy and install the Broadcom lpfc outbox driver and auto-connect scripts:

```
# tar -xvzf elx-lpfc-dd-rhel8-12.4.243.20-ds-1.tar.gz
# cd elx-lpfc-dd-rhel8-12.4.2453.20-ds-1
# ./elx_lpfc_install-sh -i -n
```

> The native drivers that are bundled with the OS are called the inbox drivers. If you download the outbox drivers (drivers that are not included with an OS release), an auto-connect script is included in the download and should be installed as part of the driver installation process.

3. Reboot the host.
4. Verify that you are using the recommended Broadcom lpfc firmware, outbox driver, and auto-connect package versions:

```
# cat /sys/class/scsi_host/host*/fwrev
12.4.243.20, sil-4.2.c
12.4.243.20, sil-4.2.c
```

```
# cat /sys/module/lpfc/version
0:12.4.243.20
```

```
# rpm -qa | grep nvmefc
nvmefc-connect-12.6.61.0-1.noarch
```

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

```
# cat /sys/module/lpfc/parameters/lpfc_enable_fc4_type
3
```

6. Verify that the initiator ports are up and running:

```
# cat /sys/class/fc_host/host*/port_name
0x10000090fae0ec61
0x10000090fae0ec62
```

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

7. Verify that the NVMe/FC initiator ports are enabled, running, and you can see the target LIFs:

```
# cat /sys/class/scsi_host/host*/nvme_info
NVME Initiator Enabled
XRI Dist lpfc0 Total 6144 NVME 2947 SCSI 2977 ELS 250
NVME LPORT lpfc0 WWPN x10000090fae0ec61 WWNN x20000090fae0ec61 DID
x012000 ONLINE
NVME RPORT WWPN x202d00a098c80f09 WWNN x202c00a098c80f09 DID x010201
TARGET DISCSRVC ONLINE
NVME RPORT WWPN x203100a098c80f09 WWNN x202c00a098c80f09 DID x010601
TARGET DISCSRVC ONLINE
NVME Statistics
…
```

Enable 1MB I/O Size for Broadcom NVMe/FC

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

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 a `dracut -f` command, and reboot the host.
3. Verify that `lpfc_sg_seg_cnt` is 256.

```
# cat /sys/module/lpfc/parameters/lpfc_sg_seg_cnt
256
```

This is not applicable to Qlogic NVMe/FC hosts.

Validate NVMe/FC

You can use the following procedure to validate NVMe/FC.

Steps

1. Verify the following NVMe/FC settings.

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

```
# cat /sys/class/nvme-subsystem/nvme-subsys*/model
NetApp ONTAP Controller
NetApp ONTAP Controller
```

```
# cat /sys/class/nvme-subsystem/nvme-subsys*/iopolicy
round-robin
round-robin
```

2. Verify that the namespaces are created.

```
# nvme list
Node SN Model Namespace Usage Format FW Rev
---------------- -------------------- ----------------------
/dev/nvme0n1 80BADBKnB/JvAAAAAAAC NetApp ONTAP Controller 1 53.69 GB /
53.69 GB 4 KiB + 0 B FFFFFFFF
```

3. Verify the status of the ANA paths.

```
# nvme list-subsys/dev/nvme0n1
Nvme-subsysf0 - NQN=nqn.1992-
08.com.netapp:sn.341541339b9511e8a9b500a098c80f09:subsystem.rhel_141_nvm
e_ss_10_0
\
+- nvme0 fc traddr=nn-0x202c00a098c80f09:pn-0x202d00a098c80f09
host_traddr=nn-0x20000090fae0ec61:pn-0x10000090fae0ec61 live optimized
+- nvme1 fc traddr=nn-0x207300a098dfdd91:pn-0x207600a098dfdd91
host_traddr=nn-0x200000109b1c1204:pn-0x100000109b1c1204 live
inaccessible
+- nvme2 fc traddr=nn-0x207300a098dfdd91:pn-0x207500a098dfdd91
host_traddr=nn-0x200000109b1c1205:pn-0x100000109b1c1205 live optimized
+- nvme3 fc traddr=nn-0x207300a098dfdd91:pn-0x207700a098dfdd91 host
traddr=nn-0x200000109b1c1205:pn-0x100000109b1c1205 live inaccessible
```

4. Verify the NetApp plug-in for ONTAP devices.

```
# nvme netapp ontapdevices -o column
Device   Vserver  Namespace Path             NSID   UUID   Size
-------  -------- -------------------------  ------ ----- -----
/dev/nvme0n1   vs_nvme_10       /vol/rhel_141_vol_10_0/rhel_141_ns_10_0
1        55baf453-f629-4a18-9364-b6aee3f50dad   53.69GB

# nvme netapp ontapdevices -o json
{
   "ONTAPdevices" : [
   {
        Device" : "/dev/nvme0n1",
        "Vserver" : "vs_nvme_10",
        "Namespace_Path" : "/vol/rhel_141_vol_10_0/rhel_141_ns_10_0",
         "NSID" : 1,
         "UUID" : "55baf453-f629-4a18-9364-b6aee3f50dad",
         "Size" : "53.69GB",
         "LBA_Data_Size" : 4096,
         "Namespace_Size" : 13107200
    }
]
```