Oracle Linux

ONTAP SAN Host Utilities

NetApp
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Configure Oracle Linux 9.5 with NVMe-oF for ONTAP storage

NetApp SAN host configurations support the NVMe over Fabrics (NVMe-oF) protocol with Asymmetric Namespace Access (ANA). In NVMe-oF environments, ANA is equivalent to asymmetric logical unit access (ALUA) multipathing in iSCSI and FCP environments. ANA is implemented using the in-kernel NVMe multipath feature.

About this task

The following support and features are available with the NVMe-oF host configuration for Oracle Linux 9.5 with ONTAP storage.

- Support available:
  - Support for NVMe over TCP (NVMe/TCP) in addition to NVMe over Fibre Channel (NVMe/FC). The NetApp plug-in in the native nvme-cli package displays ONTAP details for both NVMe/FC and NVMe/TCP namespaces.
  - Running both NVMe and SCSI traffic on the same host. For example, you can configure dm-multipath on SCSI mpath devices for SCSI LUNs and use NVMe multipath to configure NVMe-oF namespace devices on the host.
  - Oracle Linux 9.5 enables in-kernel NVMe multipath for NVMe namespaces by default, removing the need for explicit settings.
  - Beginning with ONTAP 9.12.1, support for secure in-band authentication is introduced for NVMe/TCP. You can use secure in-band authentication for NVMe/TCP with Oracle Linux 9.5.

  > The NetApp `sanlun` host utility isn't supported for NVMe-oF. Instead, you can use the NetApp plug-in included in the native `nvme-cli` for all NVMe-oF transports.

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

- Features available:
  - There are no new features in this release.
- Known limitations:
  - Avoid issuing the `nvme disconnect-all` command on systems booting from SAN over NVMe-TCP or NVMe-FC namespaces because it disconnects both root and data filesystems and might lead to system instability.

Step 1: Optionally, enable SAN booting

You can configure your host to use SAN booting to simplify deployment and improve scalability.

Before you begin

Use the Interoperability Matrix Tool to verify that your Linux OS, host bus adapter (HBA), HBA firmware, HBA boot BIOS, and ONTAP version support SAN booting.

Steps

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

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

3. Verify that the configuration was successful by rebooting the host and verifying that the OS is up and running.

Step 2: Validate software versions

Use the following procedure to validate the minimum supported Oracle Linux 9.5 software versions.

Steps

1. Install Oracle Linux 9.5 on the server. After the installation is complete, verify that you are running the specified Oracle Linux 9.5 kernel.

   ```
   uname -r
   ```

   The following example shows an Oracle Linux kernel version:

   ```
   5.15.0-302.167.6.el9uek.x86_64
   ```

2. Install the `nvme-cli` package:

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

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

   ```
   nvme-cli-2.9.1-6.el9.x86_64
   ```

3. Install the `libnvme` package:

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

   The following example shows an `libnvme` package version:

   ```
   libnvme-1.9-3.el9.x86_64
   ```

4. On the Oracle Linux 9.5 host, check the `hostnqn` string at `/etc/nvme/hostnqn`:

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

The following example shows an `hostnqn` version:

```
nqn.2014-08.org.nvmexpress:uuid:4c4c4544-0050-3410-8035-c2c04f4a5933
```

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

```
vserver nvme subsystem host show -vserver vs_213_36002
```

Show example

```
Vserver Subsystem Priority  Host NQN
------- --------- --------
-----------------------------------------------
vs_coexistence_LPE36002
        nvme1
                  regular   nqn.2014-
08.org.nvmexpress:uuid:4c4c4544-0050-3410-8035-c2c04f4a5933
        nvme2
                  regular   nqn.2014-
08.org.nvmexpress:uuid:4c4c4544-0050-3410-8035-c2c04f4a5933
        nvme3
                  regular   nqn.2014-
08.org.nvmexpress:uuid:4c4c4544-0050-3410-8035-c2c04f4a5933
        nvme4
                  regular   nqn.2014-
08.org.nvmexpress:uuid:4c4c4544-0050-3410-8035-c2c04f4a5933
4 entries were displayed.
```

If the `hostnqn` strings don't match, you can use the `vserver modify` command to update the `hostnqn` string on your corresponding ONTAP array subsystem to match the `hostnqn` string from `/etc/nvme/hostnqn` on the host.

Step 3: Configure NVMe/FC

Configure NVMe/FC with Broadcom/Emulex FC or Marvell/Qlogic FC adapters.

Broadcom/Emulex

Configure NVMe/FC for a Broadcom/Emulex adapter.

Steps

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

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

   You should see the following output:

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

   b. Display the model descriptions:

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

   You should see an output similar to the following example:

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

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

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

   The following example shows firmware versions:

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

   b. Display the inbox driver version:

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

   The following example shows a driver version:

```
0:14.4.0.2
```

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

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

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

4. Verify that you can view your initiator ports:

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

The following example shows port identities:

```
0x100000620b3c089c
0x100000620b3c089d
```

5. Verify that your initiator ports are online:

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

You should see the following output:

```
Online
Online
```

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

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

Show example

```
NVME Initiator Enabled
XRI Dist lpfc0 Total 6144 IO 5894 ELS 250
NVME LPORT lpfc0 WWPN x100000620b3c089c WWNN x200000620b3c089c
DID x081300 ONLINE
NVME RPORT       WWPN x2001d039eab0dadc WWNN x2000d039eab0dadc
DID x080101 TARGET DISCSRVC ONLINE
NVME RPORT       WWPN x2003d039eab0dadc WWNN x2000d039eab0dadc
DID x080401 TARGET DISCSRVC ONLINE

NVME Statistics
LS: Xmt 00000002e9 Cmpl 00000002e9 Abort 00000000
LS XMIT: Err 00000000  CMPL: xb 00000000 Err 00000000
Total FCP Cmpl 0000000000078742 Issue 0000000000078740 OutIO
fffffffffffffffe
        abort 000000c2 noxri 00000000 nondlp 00000a23 qdepth
00000000 wqerr 00000000 err 00000000
FCP CMPL: xb 000000c2 Err 00000238

NVME Initiator Enabled
XRI Dist lpfc1 Total 6144 IO 5894 ELS 250
NVME LPORT lpfc1 WWPN x100000620b3c089d WWNN x200000620b3c089d
DID x081900 ONLINE
NVME RPORT       WWPN x2002d039eab0dadc WWNN x2000d039eab0dadc
DID x080201 TARGET DISCSRVC ONLINE
NVME RPORT       WWPN x2004d039eab0dadc WWNN x2000d039eab0dadc
DID x080301 TARGET DISCSRVC ONLINE

NVME Statistics
LS: Xmt 00000002d9 Cmpl 00000002d9 Abort 00000000
LS XMIT: Err 00000000  CMPL: xb 00000000 Err 00000000
Total FCP Cmpl 000000000007754f Issue 000000000007754f OutIO
0000000000000000
        abort 000000c2 noxri 00000000 nondlp 00000719 qdepth
00000000 wqerr 00000000 err 00000000
FCP CMPL: xb 000000c2 Err 0000023d
```

Marvell/QLogic

Configure NVMe/FC for a Marvell/QLogic adapter.

Steps

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

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

The follow example shows driver and firware versions:

```
QLE2772 FW:v9.15.03 DVR:v10.02.09.300-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
```

The value `1` verifies that `ql2xnvmeenable` is set.

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

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

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

Steps

1. Set the `lpfc_sg_seg_cnt` parameter to 256:

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

You should see an output similar to the following example:

```
options lpfc lpfc_sg_seg_cnt=256
```

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

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

Step 5: Verify NVMe boot services

With Oracle Linux 9.5, the `nvmefc-boot-connections.service` and `nvmf-autoconnect.service` boot services included in the NVMe/FC `nvme-cli` package are automatically enabled when the system boots.

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

Steps

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

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

Show example output

```
nvmf-autoconnect.service - Connect NVMe-oF subsystems automatically
during boot
Loaded: loaded (/usr/lib/systemd/system/nvmf-autoconnect.service;
enabled; preset: disabled)
Active: inactive (dead) since Wed 2025-07-02 16:46:37 IST; 1 day 3h
ago
Main PID: 2129 (code=exited, status=0/SUCCESS)
CPU: 121ms

Jul 02 16:46:37 interop-13-175 nvme[2129]: Failed to write to
/dev/nvme-fabrics: Invalid argument
Jul 02 16:46:37 interop-13-175 nvme[2129]: Failed to write to
/dev/nvme-fabrics: Invalid argument
Jul 02 16:46:37 interop-13-175 nvme[2129]: Failed to write to
/dev/nvme-fabrics: Invalid argument
Jul 02 16:46:37 interop-13-175 nvme[2129]: Failed to write to
/dev/nvme-fabrics: Invalid argument
Jul 02 16:46:37 interop-13-175 nvme[2129]: Failed to write to
/dev/nvme-fabrics: Invalid argument
Jul 02 16:46:37 interop-13-175 nvme[2129]: Failed to write to
/dev/nvme-fabrics: Invalid argument
Jul 02 16:46:37 interop-13-175 nvme[2129]: Failed to open ctrl
nvme0, errno 2
Jul 02 16:46:37 interop-13-175 nvme[2129]: failed to get discovery
log: Bad file descriptor
Jul 02 16:46:37 interop-13-175 systemd[1]: nvmf-autoconnect.service:
Deactivated successfully.
Jul 02 16:46:37 interop-13-175 systemd[1]: Finished Connect NVMe-oF
subsystems automatically during boot.
```

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

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

Show example output

```
nvmefc-boot-connections.service - Auto-connect to subsystems on FC-
NVME devices found during boot
Loaded: loaded (/usr/lib/systemd/system/nvmefc-boot-
connections.service; enabled; preset: enabled)
Active: inactive (dead) since Wed 2025-07-02 16:45:46 IST; 1 day 3h
ago
Main PID: 1604 (code=exited, status=0/SUCCESS)
CPU: 32ms

Jul 02 16:45:46 interop-13-175 systemd[1]: Starting Auto-connect to
subsystems on FC-NVME devices found during boot...
Jul 02 16:45:46 interop-13-175 systemd[1]: nvmefc-boot-
connections.service: Deactivated successfully.
Jul 02 16:45:46 interop-13-175 systemd[1]: Finished Auto-connect to
subsystems on FC-NVME devices found during boot.
```

Step 6: Configure NVMe/TCP

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

Steps

1. 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
```

Show example

```
nvme discover -t tcp -w 192.168.165.3 -a 192.168.165.8
Discovery Log Number of Records 8, Generation counter 8
=====Discovery Log Entry 0======
trtype:  tcp
adrfam:  ipv4
subtype: current discovery subsystem
treq:    not specified
portid:  4
trsvcid: 8009
subnqn:  nqn.1992-
08.com.netapp:sn.4f7af2bd221811f0afadd039eab0dadd:discovery
traddr:  192.168.166.9
eflags:  explicit discovery connections, duplicate discovery
information
sectype: none
=====Discovery Log Entry 1======
trtype:  tcp
adrfam:  ipv4
subtype: current discovery subsystem
treq:    not specified
portid:  2
trsvcid: 8009
subnqn:  nqn.1992-
08.com.netapp:sn.4f7af2bd221811f0afadd039eab0dadd:discovery
traddr:  192.168.165.9
eflags:  explicit discovery connections, duplicate discovery
information
sectype: none
=====Discovery Log Entry 2======
trtype:  tcp
adrfam:  ipv4
subtype: current discovery subsystem
treq:    not specified
portid:  3
trsvcid: 8009
subnqn:  nqn.1992-
08.com.netapp:sn.4f7af2bd221811f0afadd039eab0dadd:discovery
traddr:  192.168.166.8
eflags:  explicit discovery connections, duplicate discovery
information
sectype: none
=====Discovery Log Entry 3======
trtype:  tcp
adrfam:  ipv4
```

```
subtype: current discovery subsystem
treq:    not specified
portid:  1
trsvcid: 8009
subnqn:  nqn.1992-
08.com.netapp:sn.4f7af2bd221811f0afadd039eab0dadd:discovery
traddr:  192.168.165.8
eflags:  explicit discovery connections, duplicate discovery
information
sectype: none
=====Discovery Log Entry 4======
trtype:  tcp
adrfam:  ipv4
subtype: nvme subsystem
treq:    not specified
portid:  4
trsvcid: 4420
subnqn:  nqn.1992-
08.com.netapp:sn.4f7af2bd221811f0afadd039eab0dadd:subsystem.nvme
traddr:  192.168.166.9
eflags:  none
sectype: none
=====Discovery Log Entry 5======
trtype:  tcp
adrfam:  ipv4
subtype: nvme subsystem
treq:    not specified
portid:  2
trsvcid: 4420
subnqn:  nqn.1992-
08.com.netapp:sn.4f7af2bd221811f0afadd039eab0dadd:subsystem.nvme
traddr:  192.168.165.9
eflags:  none
sectype: none
=====Discovery Log Entry 6======
trtype:  tcp
adrfam:  ipv4
subtype: nvme subsystem
treq:    not specified
portid:  3
trsvcid: 4420
subnqn:  nqn.1992-
08.com.netapp:sn.4f7af2bd221811f0afadd039eab0dadd:subsystem.nvme
traddr:  192.168.166.8
eflags:  none
sectype: none
```

```
=====Discovery Log Entry 7======
trtype:  tcp
adrfam:  ipv4
subtype: nvme subsystem
treq:    not specified
portid:  1
trsvcid: 4420
subnqn:  nqn.1992-
08.com.netapp:sn.4f7af2bd221811f0afadd039eab0dadd:subsystem.nvme
traddr:  192.168.165.8
eflags:  none
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
```

You should see an output similar to the following example:

```
nvme discover -t tcp -w 192.168.166.4 -a 192.168.166.8
nvme discover -t tcp -w 192.168.165.3 -a 192.168.165.8
nvme discover -t tcp -w 192.168.166.4 -a 192.168.166.9
nvme discover -t tcp -w 192.168.165.3 -a 192.168.165.9
```

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

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

You should see an output similar to the following example:

```
nvme connect-all -t tcp -w 192.168.165.3 -a 192.168.165.8
nvme connect-all -t tcp -w 192.168.165.3 -a 192.168.165.9
nvme connect-all -t tcp -w 192.168.166.4 -a 192.168.166.8
nvme connect-all -t tcp -w 192.168.166.4 -a 192.168.166.9
```

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

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

Step 7: Validate NVMe-oF

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

Steps

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

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

You should see the following output:

```
Y
```

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

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

You should see the following output:

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

   b. Display the policy:

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

You should see the following output:

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

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

```
nvme list
```

Show example

```
Node          Generic       SN                   Model
Namespace  Usage                    Format         FW Rev
------------- ------------- --------------------
------------------------- ---------- ----------------------
-------------- --------
/dev/nvme1n1  /dev/ng1n1    81Mc4FXd1tocAAAAAAAC NetApp ONTAP
Controller   0x1        0.00   B /  10.74  GB   4 KiB +  0 B
9.16.1
```

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

NVMe/FC

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

Show example

```
nvme-subsys7 - NQN=nqn.1992-
08.com.netapp:sn.7d37987be3cb11ef8948d039eab0dadd:subsystem.nvme
6
               hostnqn=nqn.2014-08.org.nvmexpress:uuid:2831093d-
fa7f-4714-a6bf-548796e82053
               iopolicy=round-robin
\
 +- nvme103 fc traddr=nn-0x202cd039eab0dadc:pn-
0x202fd039eab0dadc,host_traddr=nn-0x200034800d767bb0:pn-
0x210034800d767bb0 live optimized
 +- nvme153 fc traddr=nn-0x202cd039eab0dadc:pn-
0x202ed039eab0dadc,host_traddr=nn-0x200034800d767bb1:pn-
0x210034800d767bb1 live non-optimized
 +- nvme55 fc traddr=nn-0x202cd039eab0dadc:pn-
0x202dd039eab0dadc,host_traddr=nn-0x200034800d767bb0:pn-
0x210034800d767bb0 live non-optimized
 +- nvme7 fc traddr=nn-0x202cd039eab0dadc:pn-
0x2030d039eab0dadc,host_traddr=nn-0x200034800d767bb1:pn-
0x210034800d767bb1 live optimized
```

NVMe/TCP

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

Show example

```
nvme-subsys1 - NQN=nqn.1992-
08.com.netapp:sn.4f7af2bd221811f0afadd039eab0dadd:subsystem.nvme
               hostnqn=nqn.2014-08.org.nvmexpress:uuid:9796c1ec-
0d34-11eb-b6b2-3a68dd3bab57
               iopolicy=round-robin\
+- nvme1 tcp
traddr=192.168.165.8,trsvcid=4420,host_traddr=192.168.165.3,
src_addr=192.168.165.3 live optimized
+- nvme2 tcp
traddr=192.168.165.9,trsvcid=4420,host_traddr=192.168.165.3,
src_addr=192.168.165.3 live non-optimized
+- nvme3 tcp
traddr=192.168.166.8,trsvcid=4420,host_traddr=192.168.166.4,
src_addr=192.168.166.4 live optimized
+- nvme4 tcp
traddr=192.168.166.9,trsvcid=4420,host_traddr=192.168.166.4,
src_addr=192.168.166.4 live non-optimized
```

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

Column

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

Show example

```
Device           Vserver                   Namespace Path
NSID UUID                                   Size
---------------- ------------------------
------------------------------------------------ ----
---------------------------------------- ---------
/dev/nvme1n1     vs_tcpinband              /vol/volpdc/ns1
1    80eec226-6987-4eb4-bf86-65bf48c5372d   10.74GB
```

JSON

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

Show example

```
{
  "ONTAPdevices":[
    {
      "Device":"/dev/nvme1n1",
      "Vserver":"vs_tcpinband",
      "Namespace_Path":"/vol/volpdc/ns1",
      "NSID":1,
      "UUID":"80eec226-6987-4eb4-bf86-65bf48c5372d",
      "Size":"10.74GB",
      "LBA_Data_Size":4096,
      "Namespace_Size":2621440
    }
  ]
}
```

Step 8: Set up secure in-band authentication

Beginning with ONTAP 9.12.1, secure in-band authentication is supported over NVMe/TCP between an Oracle Linux 9.5 host and an ONTAP controller.

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

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

CLI

Set up secure in-band authentication using the CLI.

Steps

1. Obtain the host NQN:

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

2. Generate the dhchap key for the Linux host.

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

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

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

```
# nvme gen-dhchap-key -m 3 -n nqn.2014-
08.org.nvmexpress:uuid:9796c1ec-0d34-11eb-b6b2-3a68dd3bab57
DHHC-
1:03:Y5VkkESgmtTGNdX842qemNpFK6BXYVwwnqErgt3IQKP5Fbjje\/JSBOjG5Ea3NB
LRfuiAuUSDUto6eY\/GwKoRp6AwGkw=:
```

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

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

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

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

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

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

   Show example output for a unidirectional configuration

   ```
   cat /sys/class/nvme-subsystem/nvme-subsys1/nvme*/dhchap_secret
   DHHC-
   1:03:Y5VkkESgmtTGNdX842qemNpFK6BXYVwwnqErgt3IQKP5Fbjje\/JSBOjG
   5Ea3NBLRfuiAuUSDUto6eY\/GwKoRp6AwGkw=:
   DHHC-
   1:03:Y5VkkESgmtTGNdX842qemNpFK6BXYVwwnqErgt3IQKP5Fbjje\/JSBOjG
   5Ea3NBLRfuiAuUSDUto6eY\/GwKoRp6AwGkw=:
   DHHC-
   1:03:Y5VkkESgmtTGNdX842qemNpFK6BXYVwwnqErgt3IQKP5Fbjje\/JSBOjG
   5Ea3NBLRfuiAuUSDUto6eY\/GwKoRp6AwGkw=:
     DHHC-
   1:03:Y5VkkESgmtTGNdX842qemNpFK6BXYVwwnqErgt3IQKP5Fbjje\/JSBOjG
   5Ea3NBLRfuiAuUSDUto6eY\/GwKoRp6AwGkw=:
   ```

   b. Verify the controller dhchap keys:

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

Show example output for a bidirectional configuration

```
cat /sys/class/nvme-subsystem/nvme-
subsys6/nvme*/dhchap_ctrl_secret
DHHC-
1:03:frpLlTrnOYtcWDxPzq4ccxU1UrH2FjV7hYw5s2XEDB+lo+TjMsOwHR\/N
FtM0nBBidx+gdoyUcC5s6hOOtTLDGcz0Kbs=:
DHHC-
1:03:frpLlTrnOYtcWDxPzq4ccxU1UrH2FjV7hYw5s2XEDB+lo+TjMsOwHR\/N
FtM0nBBidx+gdoyUcC5s6hOOtTLDGcz0Kbs=:
DHHC-
1:03:frpLlTrnOYtcWDxPzq4ccxU1UrH2FjV7hYw5s2XEDB+lo+TjMsOwHR\/N
FtM0nBBidx+gdoyUcC5s6hOOtTLDGcz0Kbs=:
DHHC-
1:03:frpLlTrnOYtcWDxPzq4ccxU1UrH2FjV7hYw5s2XEDB+lo+TjMsOwHR\/N
FtM0nBBidx+gdoyUcC5s6hOOtTLDGcz0Kbs=:
```

JSON file

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

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

Steps

1. Configure the JSON file:

Show example

```
 cat /etc/nvme/config.json
[
  {
    "hostnqn":"nqn.2014-08.org.nvmexpress:uuid:9796c1ec-0d34-
11eb-b6b2-3a68dd3bab57",
    "hostid":"9796c1ec-0d34-11eb-b6b2-3a68dd3bab57",
    "dhchap_key":"DHHC-
1:03:Y5VkkESgmtTGNdX842qemNpFK6BXYVwwnqErgt3IQKP5Fbjje\/JSBOjG5E
a3NBLRfuiAuUSDUto6eY\/GwKoRp6AwGkw=:",
    "subsystems":[
      {
        "nqn":"nqn.1992-
08.com.netapp:sn.4f7af2bd221811f0afadd039eab0dadd:subsystem.nvme
",
        "ports":[
          {
            "transport":"tcp",
            "traddr":"192.168.165.9",
            "host_traddr":"192.168.165.3",
            "trsvcid":"4420",
            "dhchap_key":"DHHC-
1:03:Y5VkkESgmtTGNdX842qemNpFK6BXYVwwnqErgt3IQKP5Fbjje\/JSBOjG5E
a3NBLRfuiAuUSDUto6eY\/GwKoRp6AwGkw=:",
            "dhchap_ctrl_key":"DHHC-
1:03:frpLlTrnOYtcWDxPzq4ccxU1UrH2FjV7hYw5s2XEDB+lo+TjMsOwHR\/NFt
M0nBBidx+gdoyUcC5s6hOOtTLDGcz0Kbs=:"          },
          {
            "transport":"tcp",
            "traddr":"192.168.166.9",
            "host_traddr":"192.168.166.4",
            "trsvcid":"4420",
                        "dhchap_key":"DHHC-
1:03:Y5VkkESgmtTGNdX842qemNpFK6BXYVwwnqErgt3IQKP5Fbjje\/JSBOjG5E
a3NBLRfuiAuUSDUto6eY\/GwKoRp6AwGkw=:",
            "dhchap_ctrl_key":"DHHC-
1:03:frpLlTrnOYtcWDxPzq4ccxU1UrH2FjV7hYw5s2XEDB+lo+TjMsOwHR\/NFt
M0nBBidx+gdoyUcC5s6hOOtTLDGcz0Kbs=:"
          },
          {
            "transport":"tcp",
            "traddr":"192.168.166.8",
            "host_traddr":"192.168.166.4",
            "trsvcid":"4420",
                        "dhchap_key":"DHHC-
```

```
1:03:Y5VkkESgmtTGNdX842qemNpFK6BXYVwwnqErgt3IQKP5Fbjje\/JSBOjG5E
a3NBLRfuiAuUSDUto6eY\/GwKoRp6AwGkw=:",
            "dhchap_ctrl_key":"DHHC-
1:03:frpLlTrnOYtcWDxPzq4ccxU1UrH2FjV7hYw5s2XEDB+lo+TjMsOwHR\/NFt
M0nBBidx+gdoyUcC5s6hOOtTLDGcz0Kbs=:"
          },
          {
            "transport":"tcp",
            "traddr":"192.168.165.8",
            "host_traddr":"192.168.165.3",
            "trsvcid":"4420",
                        "dhchap_key":"DHHC-
1:03:Y5VkkESgmtTGNdX842qemNpFK6BXYVwwnqErgt3IQKP5Fbjje\/JSBOjG5E
a3NBLRfuiAuUSDUto6eY\/GwKoRp6AwGkw=:",
            "dhchap_ctrl_key":"DHHC-
1:03:frpLlTrnOYtcWDxPzq4ccxU1UrH2FjV7hYw5s2XEDB+lo+TjMsOwHR\/NFt
M0nBBidx+gdoyUcC5s6hOOtTLDGcz0Kbs=:"
          }
        ]
      }
    ]
  }
]
```

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

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

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

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

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

   The following example shows a dhchap key:

```
DHHC-
1:03:Y5VkkESgmtTGNdX842qemNpFK6BXYVwwnqErgt3IQKP5Fbjje\/JSBOjG5Ea
3NBLRfuiAuUSDUto6eY\/GwKoRp6AwGkw=:
```

b. Verify the controller dhchap keys:

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

You should see an output similar to the following example:

```
DHHC-
1:03:frpLlTrnOYtcWDxPzq4ccxU1UrH2FjV7hYw5s2XEDB+lo+TjMsOwHR\/NFtM
0nBBidx+gdoyUcC5s6hOOtTLDGcz0Kbs=:
```

Step 9: Review the known issues

There are no known issues.

NVMe-oF Host Configuration for Oracle Linux 9.4 with ONTAP

NetApp SAN host configurations support the NVMe over Fabrics (NVMe-oF) protocol with Asymmetric Namespace Access (ANA). In NVMe-oF environments, ANA is equivalent to asymmetric logical unit access (ALUA) multipathing in iSCSI and FCP environments. ANA is implemented using the in-kernel NVMe multipath feature.

About this task

The following support and features are available with the NVMe-oF host configuration for Oracle Linux 9.4 with ONTAP storage. You should also review the known limitations before starting the configuration process.

- Support available:
  - Support for NVMe over TCP (NVMe/TCP) in addition to NVMe over Fibre Channel (NVMe/FC). The NetApp plug-in in the native nvme-cli package displays ONTAP details for both NVMe/FC and NVMe/TCP namespaces.
  - Running both NVMe and SCSI traffic on the same host. For example, you can configure dm-multipath for SCSI mpath devices on SCSI LUNs and use NVMe multipath to configure NVMe-oF namespace devices on the host.

    For additional details on supported configurations, see the Interoperability Matrix Tool.
- Features available:
  - Beginning with ONTAP 9.12.1, support for secure in-band authentication is introduced for NVMe/TCP. You can use secure in-band authentication for NVMe/TCP with Oracle Linux 9.4
  - Support for in-kernel NVMe multipath enabled for NVMe namespaces by default, therefore, there is no need for explicit settings.
- Known limitations:
  - SAN booting using the NVMe-oF protocol is currently not supported.

Validate software versions

You can use the following procedure to validate the minimum supported Oracle Linux 9.4 software versions.

Steps

1. Install Oracle Linux 9.4 GA on the server. After the installation is complete, verify that you are running the specified Oracle Linux 9.4 GA kernel.

```
uname -r
```

```
5.15.0-205.149.5.1.el9uek.x86_64
```

2. Install the `nvme-cli` package:

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

```
nvme-cli-2.6-5.el9.x86_64
```

3. Install the `libnvme` package:

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

```
libnvme-1.6-1.el9.x86_64
```

4. On the Oracle Linux 9.4 host, check the `hostnqn` string at `/etc/nvme/hostnqn`:

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

```
nqn.2014-08.org.nvmexpress:uuid:9c5d23fe-21c5-472f-9aa4-dc68de0882e9
```

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

```
vserver nvme subsystem host show -vserver vs_coexistence_149
```

Show example

```
Vserver Subsystem Priority  Host NQN
------- --------- --------
-------------------------------------------------
vs_coexistence_149
        nvme
                  regular   nqn.2014-
08.org.nvmexpress:uuid:9c5d23fe-21c5-472f-9aa4-dc68de0882e9
        nvme_1
                  regular   nqn.2014-
08.org.nvmexpress:uuid:9c5d23fe-21c5-472f-9aa4-dc68de0882e9
        nvme_2
                  regular   nqn.2014-
08.org.nvmexpress:uuid:9c5d23fe-21c5-472f-9aa4-dc68de0882e9
        nvme_3
                  regular   nqn.2014-
08.org.nvmexpress:uuid:9c5d23fe-21c5-472f-9aa4-dc68de0882e9
4 entries were displayed.
```

If the `hostnqn` strings don't match, you can use the `vserver modify` command to update the `hostnqn` string on your corresponding ONTAP array subsystem to match the `hostnqn` string from `/etc/nvme/hostnqn` on the host.

Configure NVMe/FC

You can configure NVMe/FC with Broadcom/Emulex FC or Marvell/Qlogic FC adapters. For NVMe/FC configured with a Broadcom adapter, you can enable I/O requests of size 1MB.

Broadcom/Emulex

Configure NVMe/FC for a Broadcom/Emulex adapter.

Steps

1. Verify that you are using the supported adapter model:
   a. `cat /sys/class/scsi_host/host*/modelname`

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

   b. `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:
   a. `cat /sys/class/scsi_host/host*/fwrev`

   ```
   14.4.317.7, sli-4:2:c
   14.4.317.7, sli-4:2:c
   ```

   b. `cat /sys/module/lpfc/version`

   ```
   0:14.2.0.13
   ```

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

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

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

   ```
   3
   ```

4. Verify that you can view your initiator ports:

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

   ```
   0x100000109b3c081f
   0x100000109b3c0820
   ```

5. Verify that your initiator ports are online:

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

```
Online
Online
```

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

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

Show example

```
NVME Initiator Enabled
XRI Dist lpfc0 Total 6144 IO 5894 ELS 250
NVME LPORT lpfc0 WWPN x100000109b3c081f WWNN x200000109b3c081f
DID x081600 ONLINE
NVME RPORT       WWPN x2020d039eab0dadc WWNN x201fd039eab0dadc
DID x08010c TARGET DISCSRVC ONLINE
NVME RPORT       WWPN x2024d039eab0dadc WWNN x201fd039eab0dadc
DID x08030c TARGET DISCSRVC ONLINE

NVME Statistics
LS: Xmt 00000027d8 Cmpl 00000027d8 Abort 00000000
LS XMIT: Err 00000000  CMPL: xb 00000000 Err 00000000
Total FCP Cmpl 00000000315454fa Issue 00000000314de6a4 OutIO
fffffffffff991aa
        abort 00000be4 noxri 00000000 nondlp 00001903 qdepth
00000000 wqerr 00000000 err 00000000
FCP CMPL: xb 00000c92 Err 0000bda4

NVME Initiator Enabled
XRI Dist lpfc1 Total 6144 IO 5894 ELS 250
NVME LPORT lpfc1 WWPN x100000109b3c0820 WWNN x200000109b3c0820
DID x081b00 ONLINE
NVME RPORT       WWPN x2027d039eab0dadc WWNN x201fd039eab0dadc
DID x08020c TARGET DISCSRVC ONLINE
NVME RPORT       WWPN x2025d039eab0dadc WWNN x201fd039eab0dadc
DID x08040c TARGET DISCSRVC ONLINE

NVME Statistics
LS: Xmt 00000026ac Cmpl 00000026ac Abort 00000000
LS XMIT: Err 00000000  CMPL: xb 00000000 Err 00000000
Total FCP Cmpl 00000000312a5478 Issue 00000000312465a2 OutIO
fffffffffffa112a
        abort 00000b01 noxri 00000000 nondlp 00001ae4 qdepth
00000000 wqerr 00000000 err 00000000
FCP CMPL: xb 00000b53 Err 0000ba63
```

Marvell/QLogic

Configure NVMe/FC for a Marvell/QLogic adapter.

> The native inbox qla2xxx driver included in the Oracle Linux 9.4 GA kernel has the latest fixes. These fixes 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
```

```
QLE2872 FW:v9.15.00 DVR:v10.02.09.100-k
QLE2872 FW:v9.15.00 DVR:v10.02.09.100-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 size (Optional)

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

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

Steps

1. Set the `lpfc_sg_seg_cnt` parameter to 256:

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

You should see an output similar to the following example:

```
options lpfc lpfc_sg_seg_cnt=256
```

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

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

Configure NVMe/TCP

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

Steps

1. 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
```

Show example

```
nvme discover -t tcp -w 192.168.166.4 -a 192.168.166.56

Discovery Log Number of Records 10, Generation counter 15
=====Discovery Log Entry 0======
trtype:  tcp
adrfam:  ipv4
subtype: current discovery subsystem
treq:    not specified
portid:  13
trsvcid: 8009
subnqn:  nqn.1992-
08.com.netapp:sn.cf84a53c81b111ef8446d039ea9ea481:discovery
traddr:  192.168.165.56
eflags:  explicit discovery connections, duplicate discovery
information
sectype: none
=====Discovery Log Entry 1======
trtype:  tcp
adrfam:  ipv4
subtype: current discovery subsystem
treq:    not specified
portid:  9
trsvcid: 8009
subnqn:  nqn.1992-
08.com.netapp:sn.cf84a53c81b111ef8446d039ea9ea481:discovery
traddr:  192.168.166.56
eflags:  explicit discovery connections, duplicate discovery
information
sectype: none
=====Discovery Log Entry 2======
trtype:  tcp
adrfam:  ipv4
subtype: nvme subsystem
treq:    not specified
portid:  13
trsvcid: 4420
subnqn:  nqn.1992-
08.com.netapp:sn.cf84a53c81b111ef8446d039ea9ea481:subsystem.nvme_tcp
_2
traddr:  192.168.165.56
eflags:  none
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
```

```
nvme discover -t tcp -w 192.168.166.4 -a 192.168.166.56
nvme discover -t tcp -w 192.168.165.3 -a 192.168.165.56
```

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

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

```
nvme connect-all -t tcp -w 192.168.166.4 -a 192.168.166.56
nvme connect-all -t tcp -w 192.168.165.3 -a 192.168.165.56
```

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

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

Validate NVMe-oF

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

Steps

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

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

You should see the following output:

```
Y
```

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

a. Display the subsystems:

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

You should see the following output:

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

b. Display the policy:

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

You should see the following output:

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

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

```
nvme list
```

Show example

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


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

Steps

1. Verify the following NVMe/FC settings on the Oracle Liniux 9.4 host:

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

```
Y
```

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

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

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

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

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

```
nvme list
```

Show example

```
Node         SN                   Model
------------------------------------------------------------
/dev/nvme0n1 81K2iBXAYSG6AAAAAAAB NetApp ONTAP Controller
/dev/nvme0n2 81K2iBXAYSG6AAAAAAAB NetApp ONTAP Controller
/dev/nvme0n3 81K2iBXAYSG6AAAAAAAB NetApp ONTAP Controller


Namespace Usage    Format             FW             Rev
-------------------------------------------------------------
1                 3.78GB/10.74GB 4 KiB + 0 B       FFFFFFFF
2                 3.78GB/10.74GB 4 KiB +  0 B      FFFFFFFF
3                 3.78GB/10.74GB 4 KiB + 0 B       FFFFFFFF
```

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

NVMe/FC

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

Show example

```
nvme-subsys0 - NQN=nqn.1992-
08.com.netapp:sn.5f074d527b7011ef8446d039ea9ea481:subsystem.nvme
               hostnqn=nqn.2014-08.org.nvmexpress:uuid:060fd513-
83be-4c3e-aba1-52e169056dcf
               iopolicy=round-robin
\
 +- nvme10 fc traddr=nn-0x201fd039eab0dadc:pn-
0x2024d039eab0dadc,host_traddr=nn-0x200000109b3c081f:pn-
0x100000109b3c081f live non-optimized
 +- nvme15 fc traddr=nn-0x201fd039eab0dadc:pn-
0x2020d039eab0dadc,host_traddr=nn-0x200000109b3c081f:pn-
0x100000109b3c081f live optimized
 +- nvme7 fc traddr=nn-0x201fd039eab0dadc:pn-
0x2025d039eab0dadc,host_traddr=nn-0x200000109b3c0820:pn-
0x100000109b3c0820 live non-optimized
 +- nvme9 fc traddr=nn-0x201fd039eab0dadc:pn-
0x2027d039eab0dadc,host_traddr=nn-0x200000109b3c0820:pn-
0x100000109b3c0820 live optimized
```

NVMe/TCP

```
nvme list-subsys /dev/nvme1n22
```

Show example

```
nvme-subsys0 - NQN=nqn.1992-
08.com.netapp:sn.cf84a53c81b111ef8446d039ea9ea481:subsystem.nvme
_tcp_1
               hostnqn=nqn.2014-08.org.nvmexpress:uuid:9796c1ec-
0d34-11eb-b6b2-3a68dd3bab57
               iopolicy=round-robin
\
 +- nvme2 tcp
traddr=192.168.166.56,trsvcid=4420,host_traddr=192.168.166.4,src
_addr=192.168.166.4 live optimized
 +- nvme4 tcp
traddr=192.168.165.56,trsvcid=4420,host_traddr=192.168.165.3,src
_addr=192.168.165.3 live non-optimized
```

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

Column

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

Show example

```
Device        Vserver   Namespace Path
---------------------- ------------------------------
/dev/nvme0n1     vs_coexistence_147 /vol/fcnvme_1_1_0/fcnvme_ns
/dev/nvme0n2     vs_coexistence_147 /vol/fcnvme_1_1_1/fcnvme_ns
/dev/nvme0n3     vs_coexistence_147 /vol/fcnvme_1_1_2/fcnvme_ns



NSID       UUID                                   Size
--------------------------------------------------------------
1   e605babf-1b54-417d-843b-bc14355b70c5    10.74GB
2   b8dbecc7-14c5-4d84-b948-73c7abf5af43    10.74GB
3   ba24d1a3-1911-4351-83a9-1c843d04633c    10.74GB
```

JSON

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

Show example


```
{
  "ONTAPdevices":[
    {
      "Device":"/dev/nvme0n1",
      "Vserver":"vs_coexistence_147",
      "Namespace_Path":"/vol/fcnvme_1_1_0/fcnvme_ns",
      "NSID":1,
      "UUID":"e605babf-1b54-417d-843b-bc14355b70c5",
      "Size":"10.74GB",
      "LBA_Data_Size":4096,
      "Namespace_Size":2621440
    },
    {
      "Device":"/dev/nvme0n2",
      "Vserver":"vs_coexistence_147",
      "Namespace_Path":"/vol/fcnvme_1_1_1/fcnvme_ns",
      "NSID":2,
      "UUID":"b8dbecc7-14c5-4d84-b948-73c7abf5af43",
      "Size":"10.74GB",
      "LBA_Data_Size":4096,
      "Namespace_Size":2621440
    },
    {
      "Device":"/dev/nvme0n3",
      "Vserver":"vs_coexistence_147",
      "Namespace_Path":"/vol/fcnvme_1_1_2/fcnvme_ns",
      "NSID":3,
      "UUID":"c236905d-a335-47c4-a4b1-89ae30de45ae",
      "Size":"10.74GB",
      "LBA_Data_Size":4096,
      "Namespace_Size":2621440
    },
    ]
}
```


Set up secure in-band authentication

Beginning with ONTAP 9.12.1, secure in-band authentication is supported over NVMe/TCP between an Oracle Linux 9.4 host and an ONTAP controller.

To set up secure authentication, each host or controller must be associated with a `DH-HMAC-CHAP` key, which is a combination of the NQN of the NVMe host or controller and an authentication secret configured by the

administrator. To authenticate its peer, an NVMe host or controller must recognize the key associated with the peer.

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

CLI

Set up secure in-band authentication using the CLI.

Steps

1. Obtain the host NQN:

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

2. Generate the dhchap key for the OL 9.4 host.

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

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

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

```
# nvme gen-dhchap-key -m 3 -n nqn.2014-
08.org.nvmexpress:uuid:9796c1ec-0d34-11eb-b6b2-3a68dd3bab57
DHHC-
1:03:zSq3+upTmknih8+6Ro0yw6KBQNAXjHFrOxQJaE5i916YdM/xsUSTdLkHw2MMmdF
uGEslj6+LhNdf5HF0qfroFPgoQpU=:
```

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

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

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

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

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

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

Show example output for a unidirectional configuration

```
cat /sys/class/nvme-subsystem/nvme-subsys0/nvme*/dhchap_secret
DHHC-1:01:OKIc4l+fs+fmpAj0hMK7ay8tTIzjccUWSCak/G2XjgJpKZeK:
DHHC-1:01:OKIc4l+fs+fmpAj0hMK7ay8tTIzjccUWSCak/G2XjgJpKZeK:
```

   b. Verify the controller dhchap keys:

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

Show example output for a bidirectional configuration

```
cat /sys/class/nvme-subsystem/nvme-
subsys0/nvme*/dhchap_ctrl_secret
DHHC-
1:03:zSq3+upTmknih8+6Ro0yw6KBQNAXjHFrOxQJaE5i916YdM/xsUSTdLkHw
2MMmdFuGEslj6+LhNdf5HF0qfroFPgoQpU=:
DHHC-
1:03:zSq3+upTmknih8+6Ro0yw6KBQNAXjHFrOxQJaE5i916YdM/xsUSTdLkHw
2MMmdFuGEslj6+LhNdf5HF0qfroFPgoQpU=:
```

JSON file

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

To generate the JSON file, you can use the `-o` option. See the NVMe connect-all manual pages for more syntax options.

Steps

1. Configure the JSON file:

Show example

```
cat /etc/nvme/config.json
[
  {
    "hostnqn":"nqn.2014-08.org.nvmexpress:uuid:9796c1ec-0d34-
11eb-b6b2-3a68dd3bab57",
    "hostid":"9796c1ec-0d34-11eb-b6b2-3a68dd3bab57",
    "dhchap_key":"DHHC-
1:01:OKIc4l+fs+fmpAj0hMK7ay8tTIzjccUWSCak\/G2XjgJpKZeK:",
    "subsystems":[
      {
        "nqn":"nqn.1992-
08.com.netapp:sn.cf84a53c81b111ef8446d039ea9ea481:subsystem.nvme
_tcp_1",
        "ports":[
          {
            "transport":"tcp",
            "traddr":"192.168.165.56",
            "host_traddr":"192.168.165.3",
            "trsvcid":"4420",
            "dhchap_key":"DHHC-
1:01:OKIc4l+fs+fmpAj0hMK7ay8tTIzjccUWSCak\/G2XjgJpKZeK:",
            "dhchap_ctrl_key":"DHHC-
1:03:zSq3+upTmknih8+6Ro0yw6KBQNAXjHFrOxQJaE5i916YdM\/xsUSTdLkHw2
MMmdFuGEslj6+LhNdf5HF0qfroFPgoQpU=:"
          },
          {
            "transport":"tcp",
            "traddr":"192.168.166.56",
            "host_traddr":"192.168.166.4",
            "trsvcid":"4420",
            "dhchap_key":"DHHC-
1:01:OKIc4l+fs+fmpAj0hMK7ay8tTIzjccUWSCak\/G2XjgJpKZeK:",
            "dhchap_ctrl_key":"DHHC-
1:03:zSq3+upTmknih8+6Ro0yw6KBQNAXjHFrOxQJaE5i916YdM\/xsUSTdLkHw2
MMmdFuGEslj6+LhNdf5HF0qfroFPgoQpU=:"
          }
        ]
      }
    ]
  }
]
```

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

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

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

Show example

```
traddr=192.168.165.56 is already connected
traddr=192.168.165.56 is already connected
traddr=192.168.165.56 is already connected
traddr=192.168.165.56 is already connected
traddr=192.168.165.56 is already connected
traddr=192.168.165.56 is already connected
traddr=192.168.166.56 is already connected
traddr=192.168.166.56 is already connected
traddr=192.168.166.56 is already connected
traddr=192.168.166.56 is already connected
traddr=192.168.166.56 is already connected
traddr=192.168.166.56 is already connected
```

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

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

```
DHHC-1:01:OKIc4l+fs+fmpAj0hMK7ay8tTIzjccUWSCak/G2XjgJpKZeK:
```

   b. Verify the controller dhchap keys:

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

```
DHHC-
1:03:zSq3+upTmknih8+6Ro0yw6KBQNAXjHFrOxQJaE5i916YdM/xsUSTdLkHw2MM
mdFuGEslj6+LhNdf5HF0qfroFPgoQpU=:
```

Known issues

There are no known issues for the Oracle Linux 9.4 with ONTAP release.

NVMe-oF Host Configuration for Oracle Linux 9.3 with ONTAP

NVMe over Fabrics (NVMe-oF), including NVMe over Fibre Channel (NVMe/FC) and other transports, is supported with Oracle Linux (OL) 9.3 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 OL 9.3 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.
- Use of NVMe and SCSI co-existent traffic on the same host on a given host bus adapter (HBA), without the explicit dm-multipath settings to prevent claiming NVMe namespaces.

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

Features

Oracle Linux 9.3 has in-kernel NVMe multipath enabled for NVMe namespaces by default, therefore, there is no need for explicit settings.

Known limitations

SAN booting using the NVMe-oF protocol is currently not supported.

Validate software versions

You can use the following procedure to validate the minimum supported OL 9.3 software versions.

Steps

1. Install OL 9.3 GA on the server. After the installation is complete, verify that you are running the specified OL 9.3 GA kernel.

   ```
   # uname -r
   ```

   Example output:

   ```
   5.15.0-200.131.27.el9uek.x86_64
   ```

2. Install the `nvme-cli` package:

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

   Example output:

```
nvme-cli-2.4-10.el9.x86_64
```

3. Install the `libnvme` package:

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

Example output

```
libnvme-1.4-7.el9.x86_64
```

4. On the Oracle Linux 9.3 host, check the `hostnqn` string at `/etc/nvme/hostnqn`:

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

Example output:

```
nqn.2014-08.org.nvmexpress:uuid:2831093d-fa7f-4714-a6bf-548796e82053
```

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

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

Example output:

```
Vserver     Subsystem          Host NQN
----------- ---------------
------------------------------------------------------------
vs_ol_nvme   nvme              nqn.2014-08.org.nvmexpress:uuid:2831093d-
fa7f-4714-a6bf-548796e82053
```

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

Configure NVMe/FC

You can configure NVMe/FC for Broadcom/Emulex adapters 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:

```
LPe36002-M2
LPe36002-M2
```

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

Example output:

```
Emulex LightPulse LPe36002-M2 2-Port 64Gb Fibre Channel Adapter
Emulex LightPulse LPe36002-M2 2-Port 64Gb Fibre Channel Adapter
```

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

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

```
# cat /sys/module/lpfc/version
0:14.2.0.13
```

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

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

```
# cat /sys/module/lpfc/parameters/lpfc_enable_fc4_type
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
0x100000620b3c089c
0x100000620b3c089d
```

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

Show example output

```
# cat /sys/class/scsi_host/host*/nvme_info
NVME Initiator Enabled
XRI Dist lpfc0 Total 6144 IO 5894 ELS 250
NVME LPORT lpfc0 WWPN x100000620b3c089c WWNN x200000620b3c089c
DID x062f00 ONLINE
NVME RPORT       WWPN x2019d039ea9ea480 WWNN x2018d039ea9ea480
DID x061b06 TARGET DISCSRVC ONLINE
NVME RPORT       WWPN x201cd039ea9ea480 WWNN x2018d039ea9ea480
DID x062706 TARGET DISCSRVC ONLINE

NVME Statistics
LS: Xmt 0000000f03 Cmpl 0000000efa Abort 0000004a
LS XMIT: Err 00000009  CMPL: xb 0000004a Err 0000004a
Total FCP Cmpl 00000000b9b3486a Issue 00000000b97ba0d2 OutIO
fffffffffc85868
abort 00000afc noxri 00000000 nondlp 00002e34 qdepth 00000000
wqerr 00000000 err 00000000
FCP CMPL: xb 0000138c Err 00014750

NVME Initiator Enabled
XRI Dist lpfc1 Total 6144 IO 5894 ELS 250
NVME LPORT lpfc1 WWPN x100000620b3c089d WWNN x200000620b3c089d
DID x062400 ONLINE
NVME RPORT       WWPN x201ad039ea9ea480 WWNN x2018d039ea9ea480
DID x060206 TARGET DISCSRVC ONLINE
NVME RPORT       WWPN x201dd039ea9ea480 WWNN x2018d039ea9ea480
DID x061305 TARGET DISCSRVC ONLINE

NVME Statistics
LS: Xmt 0000000b40 Cmpl 0000000b40 Abort 00000000
LS XMIT: Err 00000000  CMPL: xb 00000000 Err 00000000
Total FCP Cmpl 00000000b9a9f03f Issue 00000000b96e622e OutIO
fffffffffc471ef
abort 0000090d noxri 00000000 nondlp 00003b3f qdepth 00000000
wqerr 00000000 err 00000000
FCP CMPL: xb 000010a5 Err 000147e4
```

Marvell/QLogic FC Adapter for NVMe/FC

The native inbox qla2xxx driver included in the OL 9.3 GA kernel has the latest upstream fixes. These fixes 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
QLE2872 FW:v9.14.02 DVR:v 10.02.09.100-k
QLE2872 FW:v9.14.02 DVR:v 10.02.09.100-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 size (Optional)

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

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

Steps

1. Set the `lpfc_sg_seg_cnt` parameter to 256:

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

You should see an output similar to the following example:

```
options lpfc lpfc_sg_seg_cnt=256
```

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

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

Configure NVMe/TCP

NVMe/TCP does not have an auto-connect functionality. Therefore, you need to perform the NVMe/TCP connect or connect-all functionality manually to discover the NVMe/TCP subsystems and namespaces. You can use the following procedure to configure NVMe/TCP.

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
```

Show example

```
# nvme discover -t tcp -w 192.168.166.4 -a 192.168.166.56

Discovery Log Number of Records 4, Generation counter 10
=====Discovery Log Entry 0======
trtype:  tcp
adrfam:  ipv4
subtype: current discovery subsystem
treq:    not specified
portid:  2
trsvcid: 8009
subnqn:  nqn.1992-
08.com.netapp:sn.337a0392d58011ee9764d039eab0dadd:discovery
traddr:  192.168.165.56
eflags:  explicit discovery connections, duplicate discovery
information
sectype: none
=====Discovery Log Entry 1======
trtype:  tcp
adrfam:  ipv4
subtype: current discovery subsystem
treq:    not specified
portid:  1
trsvcid: 8009
subnqn:  nqn.1992-
08.com.netapp:sn.337a0392d58011ee9764d039eab0dadd:discovery
traddr:  192.168.166.56
eflags:  explicit discovery connections, duplicate discovery
information
sectype: none
=====Discovery Log Entry 2======
trtype:  tcp
adrfam:  ipv4
subtype: nvme subsystem
treq:    not specified
portid:  2
trsvcid: 4420
subnqn:  nqn.1992-
08.com.netapp:sn.337a0392d58011ee9764d039eab0dadd:subsystem.rhel_95
traddr:  192.168.165.56
eflags:  none
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 discover -t tcp -w 192.168.166.4 -a 192.168.166.56
# nvme discover -t tcp -w 192.168.165.3 -a 192.168.165.56
```

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

```
nvme connect-all -t tcp -w host-traddr -a traddr -l
<ctrl_loss_timeout_in_seconds>
```

Example output:

```
# nvme connect-all -t tcp -w 192.168.166.4 -a 192.168.166.56 -l -1
# nvme connect-all -t tcp -w 192.168.165.3 -a 192.168.165.56 -l -1
```

NetApp recommends setting the `ctrl-loss-tmo` option to `-1` so that the NVMe/TCP initiator attempts to reconnect indefinitely in the event of a path loss.

Validate NVMe-oF

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

Steps

1. Verify the following NVMe/FC settings on the OL 9.3 host:

```
# 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 correctly discovered on the host:

```
# nvme list
```

Example output:

```
Node         SN                   Model
------------------------------------------------------------
/dev/nvme0n1 814vWBNRwf9HAAAAAAAB NetApp ONTAP Controller
/dev/nvme0n2 814vWBNRwf9HAAAAAAAB NetApp ONTAP Controller
/dev/nvme0n3 814vWBNRwf9HAAAAAAAB NetApp ONTAP Controller


Namespace Usage    Format             FW             Rev
-------------------------------------------------------------
1                 21.47 GB / 21.47 GB  4 KiB + 0 B   FFFFFFFF
2                 21.47 GB / 21.47 GB  4 KiB + 0 B  FFFFFFFF
3                   21.47 GB/ 21.47 GB 4 KiB + 0 B   FFFFFFFF
```

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

NVMe/FC

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

Example output:

```
nvme-subsys5 - NQN=nqn.1992-
08.com.netapp:sn.4aa0fa76c92c11eeb301d039eab0dadd:subsystem.rhel_213
\
 +- nvme3 fc traddr=nn-0x2018d039ea9ea480:pn-
0x201dd039ea9ea480,host_traddr=nn-0x200000620b3c089d:pn-
0x100000620b3c089d live non-optimized
 +- nvme4 fc traddr=nn-0x2018d039ea9ea480:pn-
0x201cd039ea9ea480,host_traddr=nn-0x200000620b3c089c:pn-
0x100000620b3c089c live non-optimized
 +- nvme6 fc traddr=nn-0x2018d039ea9ea480:pn-
0x2019d039ea9ea480,host_traddr=nn-0x200000620b3c089c:pn-
0x100000620b3c089c live optimized
 +- nvme7 fc traddr=nn-0x2018d039ea9ea480:pn-
0x201ad039ea9ea480,host_traddr=nn-0x200000620b3c089d:pn-
0x100000620b3c089d live optimized
```

NVMe/TCP

```
nvme list-subsys /dev/nvme1n22
```

Example output

```
nvme-subsys1 - NQN=nqn.1992-
08.com.netapp:sn.337a0392d58011ee9764d039eab0dadd:subsystem.rhel_95
\
 +- nvme2 tcp
traddr=192.168.166.56,trsvcid=4420,host_traddr=192.168.166.4,src_add
r=192.168.166.4 live optimized
 +- nvme3 tcp
traddr=192.168.165.56,trsvcid=4420,host_traddr=192.168.165.3,src_add
r=192.168.165.3 live non-optimized
```

4. 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/nvme5n6     vs_nvme175                /vol/vol6/ns
/dev/nvme5n7     vs_nvme175                /vol/vol7/ns
/dev/nvme5n8     vs_nvme175                /vol/vol8/ns



NSID       UUID                                   Size
-------------------------------------------------------------
6          72b887b1-5fb6-47b8-be0b-33326e2542e2   21.47GB
7          04bf9f6e-9031-40ea-99c7-a1a61b2d7d08   21.47GB
8          264823b1-8e03-4155-80dd-e904237014a4   21.47GB
```

JSON

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

Example output

```
{
  "ONTAPdevices":[
    {
      "Device":"/dev/nvme5n1",
      "Vserver":"vs_nvme175",
      "Namespace_Path":"/vol/vol1/ns",
      "NSID":1,
      "UUID":"d4791955-07c9-44fc-b41c-d1c39d3d9b5b",
      "Size":"21.47GB",
      "LBA_Data_Size":4096,
      "Namespace_Size":5242880
    },
    {
      "Device":"/dev/nvme5n10",
      "Vserver":"vs_nvme175",
      "Namespace_Path":"/vol/vol10/ns",
      "NSID":10,
      "UUID":"f3a4ce94-bcc5-4ff0-9e52-e59030bbc97f",
      "Size":"21.47GB",
      "LBA_Data_Size":4096,
      "Namespace_Size":5242880
    },
    {
      "Device":"/dev/nvme5n11",
      "Vserver":"vs_nvme175",
      "Namespace_Path":"/vol/vol11/ns",
      "NSID":11,
      "UUID":"0bf171d2-51f7-4a00-8f6a-0ea2190885a2",
      "Size":"21.47GB",
      "LBA_Data_Size":4096,
      "Namespace_Size":5242880
    },
  ]
}
```


Known issues

There are no known issues for the Oracle Linux 9.3 with ONTAP release.

NVMe-oF Host Configuration for Oracle Linux 9.2 with ONTAP

NVMe over Fabrics (NVMe-oF), including NVMe over Fibre Channel (NVMe/FC) and other transports, is supported with Oracle Linux (OL) 9.2 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 OL 9.2 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.
- Use of NVMe and SCSI co-existent traffic on the same host on a given host bus adapter (HBA), without the explicit dm-multipath settings to prevent claiming NVMe namespaces.

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

Features

- Oracle Linux 9.2 has in-kernel NVMe multipath enabled for NVMe namespaces by default, therefore, there is no need for explicit settings.

Known limitations

SAN booting using the NVMe-oF protocol is currently not supported.

Validate software versions

You can use the following procedure to validate the minimum supported OL 9.2 software versions.

Steps

1. Install OL 9.2 GA on the server. After the installation is complete, verify that you are running the specified OL 9.2 GA kernel.

```
# uname -r
```

Example output:

```
5.15.0-101.103.2.1.el9uek.x86_64
```

2. Install the `nvme-cli` package:

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

Example output:

```
nvme-cli-2.2.1-2.el9.x86_64
```

3. Install the `libnvme` package:

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

Example output

```
libnvme-1.2-2.el9.x86_64
```

4. On the Oracle Linux 9.2 host, check the `hostnqn` string at `/etc/nvme/hostnqn`:

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

Example output:

```
nqn.2014-08.org.nvmexpress:uuid:bc59d14c-47f3-11eb-b93c-3a68dd48673f
```

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

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

Example output:

```
Vserver     Subsystem          Host NQN
----------- ---------------
------------------------------------------------------------
vs_nvme207   nvme_ss_ol_1    nqn.2014-08.org.nvmexpress:uuid:bc59d14c-
47f3-11eb-b93c-3a68dd48673f
```

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

Configure NVMe/FC

You can configure NVMe/FC for Broadcom/Emulex adapters 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
14.2.455.11, sli-4:2:c
14.2.455.11, sli-4:2:c
```

```
# cat /sys/module/lpfc/version
0:14.2.0.5
```

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

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

```
# cat /sys/module/lpfc/parameters/lpfc_enable_fc4_type
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
0x100000109b3c081f
0x100000109b3c0820
```

```
# 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 OL 9.2 GA kernel has the latest upstream fixes. These fixes 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:v9.12.00 DVR:v10.02.08.100-k
QLE2742 FW:v9.12.00 DVR:v10.02.08.100-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 size (Optional)

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

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

Steps

1. Set the `lpfc_sg_seg_cnt` parameter to 256:

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

You should see an output similar to the following example:

```
options lpfc lpfc_sg_seg_cnt=256
```

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

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

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 192.168.167.5 -a 192.168.167.22

Discovery Log Number of Records 8, Generation counter 18
=====Discovery Log Entry 0======
trtype:  tcp
adrfam:  ipv4
subtype: current discovery subsystem
treq:    not specified
portid:  0
trsvcid: 8009
subnqn:  nqn.1992-
08.com.netapp:sn.c680f5bcae1411ed8639d039ea951c46:discovery
traddr:  192.168.166.23
eflags:  explicit discovery connections, duplicate discovery information
sectype: none
=====Discovery Log Entry 1======
trtype:  tcp
adrfam:  ipv4
subtype: current discovery subsystem
treq:    not specified
portid:  1
trsvcid: 8009
subnqn:  nqn.1992-
08.com.netapp:sn.c680f5bcae1411ed8639d039ea951c46:discovery
traddr:  192.168.166.22
eflags:  explicit discovery connections, duplicate discovery information
sectype: none
=====Discovery Log Entry 2======
trtype:  tcp
adrfam:  ipv4
subtype: current discovery subsystem
treq:    not specified
portid:  2
trsvcid: 8009
subnqn:  nqn.1992-
08.com.netapp:sn.c680f5bcae1411ed8639d039ea951c46:discovery
traddr:  192.168.167.23
eflags:  explicit discovery connections, duplicate discovery information
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 discover -t tcp -w 192.168.8.1 -a 192.168.8.48
# nvme discover -t tcp -w 192.168.8.1 -a 192.168.8.49
# nvme discover -t tcp -w 192.168.9.1 -a 192.168.9.48
# nvme discover -t tcp -w 192.168.9.1 -a 192.168.9.49
```

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 192.168.8.1 -a 192.168.8.48 -l 1800
# nvme connect-all -t tcp -w 192.168.8.1 -a 192.168.8.49 -l 1800
# nvme connect-all -t tcp -w 192.168.9.1 -a 192.168.9.48 -l 1800
# nvme connect-all -t tcp -w 192.168.9.1 -a 192.168.9.49 -l 1800
```

Validate NVMe-oF

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

Steps

1. Verify the following NVMe/FC settings on the OL 9.2 host:

```
# 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 correctly discovered on the host:

```
# nvme list
```

Example output:

```
Node         SN                   Model
------------------------------------------------------------
/dev/nvme0n1 814vWBNRwf9HAAAAAAAB NetApp ONTAP Controller
/dev/nvme0n2 814vWBNRwf9HAAAAAAAB NetApp ONTAP Controller
/dev/nvme0n3 814vWBNRwf9HAAAAAAAB NetApp ONTAP Controller



Namespace Usage    Format             FW             Rev
-----------------------------------------------------------
1                 85.90 GB / 85.90 GB  4 KiB + 0 B   FFFFFFFF
2                 85.90 GB / 85.90 GB  24 KiB + 0 B  FFFFFFFF
3                   85.90 GB / 85.90 GB  4 KiB + 0 B   FFFFFFFF
```

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

NVMe/FC

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

Example output:

```
nvme-subsys0 - NQN=nqn.1992-
08.com.netapp:sn.5f5f2c4aa73b11e9967e00a098df41bd:subsystem.nvme_ss_
ol_1
\
+- nvme0 fc traddr=nn-0x203700a098dfdd91:pn-0x203800a098dfdd91
host_traddr=nn-0x200000109b1c1204:pn-0x100000109b1c1204 live non-
optimized
+- nvme1 fc traddr=nn-0x203700a098dfdd91:pn-0x203900a098dfdd91
host_traddr=nn-0x200000109b1c1204:pn-0x100000109b1c1204 live non-
optimized
+- 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
```

NVMe/TCP

```
nvme list-subsys /dev/nvme1n22
```

Example output

```
nvme-subsys1 - NQN=nqn.1992-
08.com.netapp:sn.68c036aaa3cf11edbb95d039ea243511:subsystem.tcp
\
 +- nvme2 tcp
traddr=192.168.8.49,trsvcid=4420,host_traddr=192.168.8.1 live
optimized
 +- nvme3 tcp
traddr=192.168.8.48,trsvcid=4420,host_traddr=192.168.8.1 live
optimized
 +- nvme6 tcp
traddr=192.168.9.49,trsvcid=4420,host_traddr=192.168.9.1 live non-
optimized
 +- nvme7 tcp
traddr=192.168.9.48,trsvcid=4420,host_traddr=192.168.9.1 live non-
optimized
```

4. 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_ol_nvme  /vol/ol_nvme_vol_1_1_0/ol_nvme_ns
/dev/nvme0n2   vs_ol_nvme  /vol/ol_nvme_vol_1_0_0/ol_nvme_ns
/dev/nvme0n3   vs_ol_nvme  /vol/ol_nvme_vol_1_1_1/ol_nvme_ns



NSID       UUID                                   Size
-------------------------------------------------------------
1          72b887b1-5fb6-47b8-be0b-33326e2542e2   85.90GB
2          04bf9f6e-9031-40ea-99c7-a1a61b2d7d08   85.90GB
3          264823b1-8e03-4155-80dd-e904237014a4   85.90GB
```

JSON

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

Example output

```
{
"ONTAPdevices" : [
    {
        "Device" : "/dev/nvme0n1",
        "Vserver" : "vs_ol_nvme",
        "Namespace_Path" : "/vol/ol_nvme_vol_1_1_0/ol_nvme_ns",
        "NSID" : 1,
        "UUID" : "72b887b1-5fb6-47b8-be0b-33326e2542e2",
        "Size" : "85.90GB",
        "LBA_Data_Size" : 4096,
        "Namespace_Size" : 20971520
    },
    {
        "Device" : "/dev/nvme0n2",
        "Vserver" : "vs_ol_nvme",
        "Namespace_Path" : "/vol/ol_nvme_vol_1_0_0/ol_nvme_ns",
        "NSID" : 2,
        "UUID" : "04bf9f6e-9031-40ea-99c7-a1a61b2d7d08",
        "Size" : "85.90GB",
        "LBA_Data_Size" : 4096,
        "Namespace_Size" : 20971520
      },
      {
         "Device" : "/dev/nvme0n3",
         "Vserver" : "vs_ol_nvme",
         "Namespace_Path" : "/vol/ol_nvme_vol_1_1_1/ol_nvme_ns",
         "NSID" : 3,
         "UUID" : "264823b1-8e03-4155-80dd-e904237014a4",
         "Size" : "85.90GB",
         "LBA_Data_Size" : 4096,
         "Namespace_Size" : 20971520
       },
  ]
}
```


Known issues

There are no known issues.

NVMe-oF Host Configuration for Oracle Linux 9.1 with ONTAP

NVMe over Fabrics (NVMe-oF), including NVMe over Fibre Channel (NVMe/FC) and other transports, is supported with Oracle Linux (OL) 9.1 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 OL 9.1 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.
- Use of NVMe and SCSI co-existent traffic on the same host on a given host bus adapter (HBA), without the explicit dm-multipath settings to prevent claiming NVMe namespaces.

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

Features

- Oracle Linux 9.1 has in-kernel NVMe multipath enabled for NVMe namespaces by default, therefore, there is no need for explicit settings.

Known limitations

SAN booting using the NVMe-oF protocol is currently not supported.

Validate software versions

You can use the following procedure to validate the minimum supported OL 9.1 software versions.

Steps

1. Install OL 9.1 GA on the server. After the installation is complete, verify that you are running the specified OL 9.1 GA kernel.

```
# uname -r
```

Example output:

```
5.15.0-3.60.5.1.el9uek.x86_64
```

2. Install the `nvme-cli` package:

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

Example output:

```
nvme-cli-2.0-4.el9.x86_64
```

3. Install the `libnvme` package:

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

Example output

```
libnvme-1.0-5.el9.x86_64.rpm
```

4. On the Oracle Linux 9.1 host, check the `hostnqn` string at `/etc/nvme/hostnqn`:

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

Example output:

```
nqn.2014-08.org.nvmexpress:uuid:bc59d14c-47f3-11eb-b93c-3a68dd48673f
```

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

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

Example output:

```
Vserver     Subsystem          Host NQN
----------- ---------------
------------------------------------------------------------
vs_ol_nvme  nvme_ss_ol_1    nqn.2014-08.org.nvmexpress:uuid:bc59d14c-
47f3-11eb-b93c-3a68dd48673f
```

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

Configure NVMe/FC

You can configure NVMe/FC for Broadcom/Emulex adapters 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
12.8.614.23, sli-4:2:c
12.8.614.23, sli-4:2:c


# cat /sys/module/lpfc/version
0:14.0.0.1
```

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

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

```
# cat /sys/module/lpfc/parameters/lpfc_enable_fc4_type
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
0x100000109b3c081f
0x100000109b3c0820

# cat /sys/class/fc_host/host*/port_state
Online
Online
# cat /sys/class/scsi_host/host*/nvme_info
# 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 OL 9.1 GA kernel has the latest upstream fixes. These fixes 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:v9.18.02 DVR:v10.02.00.106-k
QLE2742 FW:v9.18.02 DVR:v10.02.00.106-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 size (Optional)

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

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

Steps

1. Set the `lpfc_sg_seg_cnt` parameter to 256:

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

You should see an output similar to the following example:

```
options lpfc lpfc_sg_seg_cnt=256
```

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

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

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 192.168.6.13 -a 192.168.6.15
Discovery Log Number of Records 6, Generation counter 8
=====Discovery Log Entry 0======
trtype: tcp
adrfam: ipv4
subtype: unrecognized
treq: not specified
portid: 0
trsvcid: 8009
subnqn: nqn.1992-
08.com.netapp:sn.1c6ac66338e711eda41dd039ea3ad566:discovery
traddr: 192.168.6.17
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.1c6ac66338e711eda41dd039ea3ad566:discovery
traddr: 192.168.5.17
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.1c6ac66338e711eda41dd039ea3ad566:discovery
traddr: 192.168.6.15
sectype: none
=====Discovery Log Entry 3======
trtype: tcp
adrfam: ipv4
```

```
subtype: nvme subsystem
treq: not specified
portid: 0
trsvcid: 4420
subnqn: nqn.1992-
08.com.netapp:sn.1c6ac66338e711eda41dd039ea3ad566:subsystem.host_95
traddr: 192.168.6.17
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 discover -t tcp -w 192.168.5.13 -a 192.168.5.15
# nvme discover -t tcp -w 192.168.5.13 -a 192.168.5.17
# nvme discover -t tcp -w 192.168.6.13 -a 192.168.6.15
# nvme discover -t tcp -w 192.168.6.13 -a 192.168.6.17
```

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 192.168.5.13 -a 192.168.5.15 -l 1800
# nvme connect-all -t tcp -w 192.168.5.13 -a 192.168.5.17 -l 1800
# nvme connect-all -t tcp -w 192.168.6.13 -a 192.168.6.15 -l 1800
# nvme connect-all -t tcp -w 192.168.6.13 -a 192.168.6.17 -l 1800
```

Validate NVMe-oF

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

Steps

1. Verify the following NVMe/FC settings on the OL 9.1 host:

```
# 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 correctly discovered on the host:

```
# nvme list
```

Example output:

```
Node         SN                   Model
------------------------------------------------------------
/dev/nvme0n1 814vWBNRwf9HAAAAAAAB NetApp ONTAP Controller
/dev/nvme0n2 814vWBNRwf9HAAAAAAAB NetApp ONTAP Controller
/dev/nvme0n3 814vWBNRwf9HAAAAAAAB NetApp ONTAP Controller


Namespace Usage    Format             FW             Rev
-------------------------------------------------------------
1                 85.90 GB / 85.90 GB  4 KiB + 0 B   FFFFFFFF
2                 85.90 GB / 85.90 GB  24 KiB + 0 B  FFFFFFFF
3                 85.90 GB / 85.90 GB  4 KiB + 0 B   FFFFFFFF
```

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

NVMe/FC

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

Example output:

```
nvme-subsys0 - NQN=nqn.1992-
08.com.netapp:sn.5f5f2c4aa73b11e9967e00a098df41bd:subsystem.nvme_ss_
ol_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
```

NVMe/TCP

```
nvme list-subsys /dev/nvme1n22
```

Example output

```
nvme-subsys1 - NQN=nqn.1992-
08.com.netapp:sn.68c036aaa3cf11edbb95d039ea243511:subsystem.tcp
\
+- nvme2 tcp
traddr=192.168.8.49,trsvcid=4420,host_traddr=192.168.8.1 live
optimized
+- nvme3 tcp
traddr=192.168.8.48,trsvcid=4420,host_traddr=192.168.8.1 live
optimized
+- nvme6 tcp
traddr=192.168.9.49,trsvcid=4420,host_traddr=192.168.9.1 live non-
optimized
+- nvme7 tcp
traddr=192.168.9.48,trsvcid=4420,host_traddr=192.168.9.1 live non-
optimized
```

4. 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_ol_nvme  /vol/ol_nvme_vol_1_1_0/ol_nvme_ns
/dev/nvme0n2   vs_ol_nvme  /vol/ol_nvme_vol_1_0_0/ol_nvme_ns
/dev/nvme0n3   vs_ol_nvme  /vol/ol_nvme_vol_1_1_1/ol_nvme_ns


NSID       UUID                                   Size
--------------------------------------------------------------
1          72b887b1-5fb6-47b8-be0b-33326e2542e2   85.90GB
2          04bf9f6e-9031-40ea-99c7-a1a61b2d7d08   85.90GB
3          264823b1-8e03-4155-80dd-e904237014a4   85.90GB
```

JSON

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

Example output

```
{
"ONTAPdevices" : [
    {
        "Device" : "/dev/nvme0n1",
        "Vserver" : "vs_ol_nvme",
        "Namespace_Path" : "/vol/ol_nvme_vol_1_1_0/ol_nvme_ns",
        "NSID" : 1,
        "UUID" : "72b887b1-5fb6-47b8-be0b-33326e2542e2",
        "Size" : "85.90GB",
        "LBA_Data_Size" : 4096,
        "Namespace_Size" : 20971520
    },
    {
        "Device" : "/dev/nvme0n2",
        "Vserver" : "vs_ol_nvme",
        "Namespace_Path" : "/vol/ol_nvme_vol_1_0_0/ol_nvme_ns",
        "NSID" : 2,
        "UUID" : "04bf9f6e-9031-40ea-99c7-a1a61b2d7d08",
        "Size" : "85.90GB",
        "LBA_Data_Size" : 4096,
        "Namespace_Size" : 20971520
      },
      {
         "Device" : "/dev/nvme0n3",
         "Vserver" : "vs_ol_nvme",
         "Namespace_Path" : "/vol/ol_nvme_vol_1_1_1/ol_nvme_ns",
         "NSID" : 3,
         "UUID" : "264823b1-8e03-4155-80dd-e904237014a4",
         "Size" : "85.90GB",
         "LBA_Data_Size" : 4096,
         "Namespace_Size" : 20971520
       },
  ]
}
```


Known issues

The NVMe-oF host configuration for OL 9.1 with ONTAP release has the following known issues:

NetApp Bug ID	Title	Description
1536937	`nvme list-subsys` command prints repeated NVMe controllers for a subsystem	The `nvme list-subsys` command should return a unique list of NVMe controllers associated with a given subsystem. In Oracle Linux 9.1, the `nvme list-subsys` command returns NVMe controllers with the respective asymmetric namespace access (ANA) state for all namespaces that belong to a given subsystem. However, it would be useful to display unique NVMe controller entries with the path state if you list the subsystem command syntax for a given namespace because the ANA state is a per-namespace attribute.
1539101	Oracle Linux 9.1 NVMe-oF hosts fail to create a persistent discovery controller	On Oracle Linux 9.1 NVMe-oF hosts, you can use the `nvme discover -p` command to create Persistent Discovery Controllers (PDCs). When this command is used, one PDC should be created per initiator-target combination. However, if you are running Oracle Linux 9.1 on an NVMe-oF host, PDC creation fails when the `nvme discover -p` command is executed.

NVMe/FC Host Configuration for Oracle Linux 9.0 with ONTAP

NVMe over Fabrics (NVMe-oF), including NVMe/FC and other transports, is supported with Oracle Linux (OL) 9.0 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.

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

Features

- Oracle Linux 9.0 has in-kernel NVMe multipath enabled for NVMe namespaces by default, therefore, there is no need for explicit settings.

Known limitations

SAN booting using the NVMe-oF protocol is currently not supported.

Validate software versions

You can validate the minimum supported OL 9.0 software versions using the following procedure.

Steps

1. Install OL 9.0 GA on the server. After the installation is complete, verify that you are running the specified OL 9.0 GA kernel.

```
# uname -r
```

Example output:

```
5.15.0-0.30.19.el9uek.x86_64
```

2. Install the `nvme-cli` package:

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

Example output:

```
nvme-cli-1.16-3.el9.x86_64
```

3. On the Oracle Linux 9.0 host, check the `hostnqn` string at `/etc/nvme/hostnqn`:

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

Example output:

```
nqn.2014-08.org.nvmexpress:uuid:4c4c4544-0032-3310-8033-b8c04f4c5132
```

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

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

Example output:

```
Vserver     Subsystem          Host NQN
----------- ---------------
------------------------------------------------------------
vs_ol_nvme  nvme_ss_ol_1    nqn.2014-08.org.nvmexpress:uuid:4c4c4544-
0032-3310-8033-b8c04f4c5132
```

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

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
14.0.505.11, sli-4:2:c
14.0.505.11, sli-4:2:c

# cat /sys/module/lpfc/version
0:12.8.0.11
```

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

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

```
# cat /sys/module/lpfc/parameters/lpfc_enable_fc4_type
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 OL 9.0 GA kernel has the latest upstream fixes. These fixes 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:v9.08.02 DVR:v10.02.00.106-k
QLE2742 FW:v9.08.02 DVR:v10.02.00.106-k
```

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

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

Enable 1MB I/O size (Optional)

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

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

Steps

1. Set the `lpfc_sg_seg_cnt` parameter to 256:

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

You should see an output similar to the following example:

```
options lpfc lpfc_sg_seg_cnt=256
```

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

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

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 192.168.6.13 -a 192.168.6.15
Discovery Log Number of Records 6, Generation counter 8
=====Discovery Log Entry 0======
trtype: tcp
adrfam: ipv4
subtype: unrecognized
treq: not specified
portid: 0
trsvcid: 8009
subnqn: nqn.1992-
08.com.netapp:sn.1c6ac66338e711eda41dd039ea3ad566:discovery
traddr: 192.168.6.17
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.1c6ac66338e711eda41dd039ea3ad566:discovery
traddr: 192.168.5.17
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.1c6ac66338e711eda41dd039ea3ad566:discovery
traddr: 192.168.6.15
sectype: none
=====Discovery Log Entry 3======
trtype: tcp
adrfam: ipv4
```

```
subtype: nvme subsystem
treq: not specified
portid: 0
trsvcid: 4420
subnqn: nqn.1992-
08.com.netapp:sn.1c6ac66338e711eda41dd039ea3ad566:subsystem.host_95
traddr: 192.168.6.17
sectype: none
..........
```

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

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

Example output:

```
# nvme discover -t tcp -w 192.168.5.13 -a 192.168.5.15
# nvme discover -t tcp -w 192.168.5.13 -a 192.168.5.17
# nvme discover -t tcp -w 192.168.6.13 -a 192.168.6.15
# nvme discover -t tcp -w 192.168.6.13 -a 192.168.6.17
```

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 192.168.5.13 -a 192.168.5.15 -l 1800
# nvme connect-all -t tcp -w 192.168.5.13 -a 192.168.5.17 -l 1800
# nvme connect-all -t tcp -w 192.168.6.13 -a 192.168.6.15 -l 1800
# nvme connect-all -t tcp -w 192.168.6.13 -a 192.168.6.17 -l 1800
```

Validate NVMe-oF

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

Steps

1. Verify the following NVMe/FC settings on the OL 9.0 host:

```
# 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 correctly discovered on the host:

```
# nvme list
```

Example output:

```
Node         SN                   Model
------------------------------------------------------------
/dev/nvme0n1 814vWBNRwf9HAAAAAAAB NetApp ONTAP Controller
/dev/nvme0n2 814vWBNRwf9HAAAAAAAB NetApp ONTAP Controller
/dev/nvme0n3 814vWBNRwf9HAAAAAAAB NetApp ONTAP Controller


Namespace Usage    Format             FW             Rev
-------------------------------------------------------------
1                 85.90 GB / 85.90 GB  4 KiB + 0 B   FFFFFFFF
2                 85.90 GB / 85.90 GB  24 KiB + 0 B  FFFFFFFF
3                 85.90 GB / 85.90 GB  4 KiB + 0 B   FFFFFFFF
```

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

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

Example output:

```
nvme-subsys0 - NQN=nqn.1992-
08.com.netapp:sn.5f5f2c4aa73b11e9967e00a098df41bd:subsystem.nvme_ss_ol_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 that the NetApp plug-in displays the correct values for each ONTAP namespace device:

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

Example output:

```
Device        Vserver   Namespace Path
---------------------- ------------------------------
/dev/nvme0n1   vs_ol_nvme  /vol/ol_nvme_vol_1_1_0/ol_nvme_ns
/dev/nvme0n2   vs_ol_nvme  /vol/ol_nvme_vol_1_0_0/ol_nvme_ns
/dev/nvme0n3   vs_ol_nvme  /vol/ol_nvme_vol_1_1_1/ol_nvme_ns


NSID       UUID                                   Size
------------------------------------------------------------
1          72b887b1-5fb6-47b8-be0b-33326e2542e2   85.90GB
2          04bf9f6e-9031-40ea-99c7-a1a61b2d7d08   85.90GB
3          264823b1-8e03-4155-80dd-e904237014a4   85.90GB
```

```
# nvme netapp ontapdevices -o json
{
"ONTAPdevices" : [
    {
        "Device" : "/dev/nvme0n1",
        "Vserver" : "vs_ol_nvme",
        "Namespace_Path" : "/vol/ol_nvme_vol_1_1_0/ol_nvme_ns",
        "NSID" : 1,
        "UUID" : "72b887b1-5fb6-47b8-be0b-33326e2542e2",
        "Size" : "85.90GB",
        "LBA_Data_Size" : 4096,
        "Namespace_Size" : 20971520
    },
    {
        "Device" : "/dev/nvme0n2",
        "Vserver" : "vs_ol_nvme",
        "Namespace_Path" : "/vol/ol_nvme_vol_1_0_0/ol_nvme_ns",
        "NSID" : 2,
        "UUID" : "04bf9f6e-9031-40ea-99c7-a1a61b2d7d08",
        "Size" : "85.90GB",
        "LBA_Data_Size" : 4096,
        "Namespace_Size" : 20971520
      },
      {
         "Device" : "/dev/nvme0n3",
         "Vserver" : "vs_ol_nvme",
         "Namespace_Path" : "/vol/ol_nvme_vol_1_1_1/ol_nvme_ns",
         "NSID" : 3,
         "UUID" : "264823b1-8e03-4155-80dd-e904237014a4",
         "Size" : "85.90GB",
         "LBA_Data_Size" : 4096,
         "Namespace_Size" : 20971520
       },
  ]
}
```

Known issues

The NVMe-oF host configuration for Oracle Linux 9.0 with ONTAP has the following known issues:

NetApp Bug ID	Title	Description
1517321	Oracle Linux 9.0 NVMe-oF Hosts create duplicate Persistent Discovery Controllers	On Oracle Linux 9.0 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 Oracle Linux 9.0 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.

Oracle Linux 8

NVMe-oF Host Configuration for Oracle Linux 8.10 with ONTAP

NetApp SAN host configurations support the NVMe over Fabrics (NVMe-oF) protocol with Asymmetric Namespace Access (ANA). In NVMe-oF environments, ANA is equivalent to asymmetric logical unit access (ALUA) multipathing in iSCSI and FCP environments. ANA is implemented using the in-kernel NVMe multipath feature.

About this task

You can use the following support and features with the NVMe-oF host configuration for Oracle Linux 8.10. You should also review the known limitations before starting the configuration process.

- Support available:
  - Support for NVMe over TCP (NVMe/TCP) and NVMe over Fibre Channel (NVMe/FC). This gives the NetApp plug-in in the native nvme-cli package the capability to display the ONTAP information for both NVMe/FC and NVMe/TCP namespaces.

    Depending on your host configuration, you configure NNMe/FC, NVMe/TCP, or both protocols.
  - Running NVMe and SCSI traffic simultaneously on the same host. For example, you can configure dm-multipath for SCSI `mpath` devices for SCSI LUNs and use NVMe multipath to configure NVMe-oF namespace devices on the host.

  For additional details on supported configurations, see the Interoperability Matrix Tool.
- Features available:
  - The in-kernel NVMe multipath feature is enabled for NVMe namespaces by default in Oracle Linux 8.10. You don’t need to configure explicit settings.
- Known limitations:
  - SAN booting using the NVMe-oF protocol is currently not supported.

- NetApp sanlun host utility support isn't available for NVMe-oF on an Oracle Linux 8.10 host. Instead, you can rely on the NetApp plug-in included in the native `nvme-cli` package for all NVMe-oF transports.

Validate software versions

Validate the minimum supported software versions for Oracle Linux 8.10.

Steps

1. Install Oracle Linux 8.10 GA on the server. After the installation is complete, verify that you are running the specified Oracle Linux 8.10 GA kernel:

```
uname -r
```

```
5.15.0-206.153.7.1.el8uek.x86_64
```

2. Install the `nvme-cli` package:

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

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

3. On the Oracle Linux 8.10 host, check the `hostnqn` string at `/etc/nvme/hostnqn`:

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

```
nqn.2014-08.org.nvmexpress:uuid:edd38060-00f7-47aa-a9dc-4d8ae0cd969a
```

4. Verify that `hostnqn` on the Oracle Linux 8.10 host matches `hostnqn` for the corresponding subsystem on the ONTAP array:

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

Show example

```
Vserver Subsystem Priority  Host NQN
------- --------- --------
-------------------------------------------------
vs_coexistence_LPE36002
        nvme
                  regular   nqn.2014-
08.org.nvmexpress:uuid:edd38060-00f7-47aa-a9dc-4d8ae0cd969a
        nvme1
                  regular   nqn.2014-
08.org.nvmexpress:uuid:edd38060-00f7-47aa-a9dc-4d8ae0cd969a
        nvme2
                  regular   nqn.2014-
08.org.nvmexpress:uuid:edd38060-00f7-47aa-a9dc-4d8ae0cd969a
        nvme3
                  regular   nqn.2014-
08.org.nvmexpress:uuid:edd38060-00f7-47aa-a9dc-4d8ae0cd969a
4 entries were displayed.
```

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

5. 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 the ONTAP namespace devices:

   a. Add the `enable_foreign` setting to the `/etc/multipath.conf` file:

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

   b. Restart the `multipathd` daemon to apply the new setting:

   ```
   systemctl restart multipathd
   ```

Configure NVMe/FC

You can configure NVMe/FC with Broadcom/Emulex FC or Marvell/Qlogic FC adapters. For NVMe/FC configured with a Broadcom adapter, you can enable I/O requests of size 1MB.

Broadcom/Emulex

Configure NVMe/FC for a Broadcom/Emulex adapter.

Steps

1. Verify that you are using the supported adapter model:
   a. `cat /sys/class/scsi_host/host*/modelname`

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

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

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

2. Verify that you are using the recommended Broadcom `lpfc` firmware and inbox driver:
   a. `cat /sys/class/scsi_host/host*/fwrev`

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

   b. `cat /sys/module/lpfc/version`

   ```
   0:14.2.0.13
   ```

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

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

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

4. Verify that the initiator ports are up and running and that you can see the target LIFs:
   a. `cat /sys/class/fc_host/host*/port_name`

   ```
   0x100000109bf0449c
   0x100000109bf0449d
   ```

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

```
Online
Online
```

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

Show example

```
NVME Initiator Enabled
XRI Dist lpfc0 Total 6144 IO 5894 ELS 250
NVME LPORT lpfc0 WWPN x100000109bf0449c WWNN x200000109bf0449c
DID x061500 ONLINE
NVME RPORT       WWPN x200bd039eab31e9c WWNN x2005d039eab31e9c
DID x020e06 TARGET DISCSRVC ONLINE
NVME RPORT       WWPN x2006d039eab31e9c WWNN x2005d039eab31e9c
DID x020a0a TARGET DISCSRVC ONLINE
NVME Statistics
LS: Xmt 000000002c Cmpl 000000002c Abort 00000000
LS XMIT: Err 00000000  CMPL: xb 00000000 Err 00000000
Total FCP Cmpl 000000000008ffe8 Issue 000000000008ffb9 OutIO
fffffffffffffd1
        abort 0000000c noxri 00000000 nondlp 00000000 qdepth
00000000 wqerr 00000000 err 00000000
FCP CMPL: xb 0000000c Err 0000000c
NVME Initiator Enabled
XRI Dist lpfc1 Total 6144 IO 5894 ELS 250
NVME LPORT lpfc1 WWPN x100000109bf0449d WWNN x200000109bf0449d
DID x062d00 ONLINE
NVME RPORT       WWPN x201fd039eab31e9c WWNN x2005d039eab31e9c
DID x02090a TARGET DISCSRVC ONLINE
NVME RPORT       WWPN x200cd039eab31e9c WWNN x2005d039eab31e9c
DID x020d06 TARGET DISCSRVC ONLINE
NVME Statistics
LS: Xmt 0000000041 Cmpl 0000000041 Abort 00000000
LS XMIT: Err 00000000  CMPL: xb 00000000 Err 00000000
Total FCP Cmpl 00000000000936bf Issue 000000000009369a OutIO
fffffffffffffdb
        abort 00000016 noxri 00000000 nondlp 00000000 qdepth
00000000 wqerr 00000000 err 00000000
FCP CMPL: xb 00000016 Err 00000016
```

Marvell/QLogic

Configure NVMe/FC for a Marvell/QLogic adapter.

The native inbox qla2xxx driver included in the Oracle Linux 10 GA kernel has the latest fixes. These fixes 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
   ```

   ```
   QLE2772 FW:v9.15.00 DVR:v10.02.09.100-k
   QLE2772 FW:v9.15.00 DVR:v10.02.09.100-k
   ```

2. Verify that `ql2xnvmeenable` is set to "1". This enables the Marvell adapter to function as an NVMe/FC initiator:

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

Enable 1MB I/O size (Optional)

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

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

Steps

1. Set the `lpfc_sg_seg_cnt` parameter to 256:

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

   You should see an output similar to the following example:

   ```
   options lpfc lpfc_sg_seg_cnt=256
   ```

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

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

Configure NVMe/TCP

The NVMe/TCP protocol doesn't support the `auto-connect` operation. Instead, you can discover the

NVMe/TCP subsystems and namespaces by performing the NVMe/TCP `connect` or `connect-all` operations manually.

Steps

1. 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>
```

Show example

```
#   nvme discover -t tcp -w 192.168.6.1 -a 192.168.6.24 Discovery
Log Number of Records 20, Generation counter 45
=====Discovery Log Entry 0======
trtype:  tcp
adrfam:  ipv4
subtype: unrecognized
treq:    not specified
portid:  6
trsvcid: 8009
subnqn:  nqn.1992-
08.com.netapp:sn.e6c438e66ac211ef9ab8d039eab31e9d:discovery
traddr:  192.168.6.25
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.e6c438e66ac211ef9ab8d039eab31e9d:discovery
traddr:  192.168.5.24
sectype: none
=====Discovery Log Entry 2======
trtype:  tcp
adrfam:  ipv4
subtype: unrecognized
treq:    not specified
portid:  4
trsvcid: 8009
subnqn:  nqn.1992-
08.com.netapp:sn.e6c438e66ac211ef9ab8d039eab31e9d:discovery
traddr:  192.168.6.24
sectype: none
=====Discovery Log Entry 3======
trtype:  tcp
adrfam:  ipv4
subtype: unrecognized
treq:    not specified
portid:  2
trsvcid: 8009
subnqn:  nqn.1992-
08.com.netapp:sn.e6c438e66ac211ef9ab8d039eab31e9d:discovery
```

```
traddr:  192.168.5.25
sectype: none
=====Discovery Log Entry 4======
trtype:  tcp
adrfam:  ipv4
subtype: nvme subsystem
treq:    not specified
portid:  6
trsvcid: 4420
subnqn:  nqn.1992-
08.com.netapp:sn.e6c438e66ac211ef9ab8d039eab31e9d:subsystem.nvme_tcp
_4
traddr:  192.168.6.25
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.e6c438e66ac211ef9ab8d039eab31e9d:subsystem.nvme_tcp
_4
..........
```

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

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

Show example

```
# nvme discover -t tcp -w 192.168.6.1 -a 192.168.6.24
# nvme discover -t tcp -w 192.168.6.1 -a 192.168.6.25
# nvme discover -t tcp -w 192.168.5.1 -a 192.168.5.24
# nvme discover -t tcp -w 192.168.5.1 -a 192.168.5.25
```

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

```
nvme connect-all -t tcp -w <host-traddr> -a <traddr> -l
<ctrl_loss_timeout_in_seconds>
```

Show example

```
#   nvme    connect-all -t  tcp -w  192.168.5.1 -a  192.168.5.24
-l -1
#   nvme    connect-all -t  tcp -w  192.168.5.1 -a  192.168.5.25
-l -1
#   nvme    connect-all -t  tcp -w  192.168.6.1 -a  192.168.6.24
-l -1
#   nvme    connect-all -t  tcp -w  192.168.6.1 -a  192.168.6.25
-l -1
```

NetApp recommends setting the `ctrl-loss-tmo` option to "-1" so that the NVMe/TCP initiator attempts to reconnect indefinitely in the event of a path loss.

Validate NVMe-oF

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

Steps

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

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

You should see the following output:

```
Y
```

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

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

You should see the following output:

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

b. Display the policy:

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

You should see the following output:

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

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

```
nvme list
```

Show example

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


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

Steps

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

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

Y
```

2. Verify that the 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 display on the host:

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

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

b. `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`

Show example

```
Node         SN                   Model
------------------------------------------------------------
/dev/nvme0n1 814vWBNRwf9HAAAAAAAB NetApp ONTAP Controller
/dev/nvme0n2 814vWBNRwf9HAAAAAAAB NetApp ONTAP Controller
/dev/nvme0n3 814vWBNRwf9HAAAAAAAB NetApp ONTAP Controller

Namespace Usage   Format               FW            Rev
------------------------------------------------------------
1                 85.90 GB / 85.90 GB  4 KiB + 0 B   FFFFFFFF
2                 85.90 GB / 85.90 GB  24 KiB + 0 B  FFFFFFFF
3                   85.90 GB / 85.90 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/nvme0n1
```

Show example

```
nvme-subsys0 - NQN=nqn.1992- 08.com.netapp:
4b4d82566aab11ef9ab8d039eab31e9d:subsystem.nvme\
+-  nvme1 fc traddr=nn-0x2038d039eab31e9c:pn-0x203ad039eab31e9c
host_traddr=nn-0x200034800d756a89:pn-0x210034800d756a89 live
optimized
+-  nvme2 fc traddr=nn-0x2038d039eab31e9c:pn-0x203cd039eab31e9c
host_traddr=nn-0x200034800d756a88:pn-0x210034800d756a88 live
optimized
+- nvme3 fc traddr=nn-0x2038d039eab31e9c:pn-0x203ed039eab31e9c
host_traddr=nn-0x200034800d756a89:pn-0x210034800d756a89 live
non-optimized
+-  nvme7 fc traddr=nn-0x2038d039eab31e9c:pn-0x2039d039eab31e9c
host_traddr=nn-0x200034800d756a88:pn-0x210034800d756a88 live
non-optimized
```

NVMe/TCP

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

Show example

```
nvme-subsys0 - NQN=nqn.1992- 08.com.netapp:
sn.e6c438e66ac211ef9ab8d039eab31e9d:subsystem.nvme_tcp_4
\
+- nvme1 tcp traddr=192.168.5.25 trsvcid=4420
host_traddr=192.168.5.1 src_addr=192.168.5.1 live optimized
+- nvme10 tcp traddr=192.168.6.24 trsvcid=4420
host_traddr=192.168.6.1 src_addr=192.168.6.1 live optimized
+- nvme2 tcp traddr=192.168.5.24 trsvcid=4420
host_traddr=192.168.5.1 src_addr=192.168.5.1 live non-optimized
+- nvme9 tcp traddr=192.168.6.25 trsvcid=4420
host_traddr=192.168.6.1 src_addr=192.168.6.1 live non-optimized
```

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

Column

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

Show example

```
Device         Vserver                   Namespace Path
NSID UUID                                   Size
-------------- ------------------------
------------------------------ ----
------------------------------------ ---------
/dev/nvme0n1   vs_coexistence_QLE2772
/vol/fcnvme_1_1_0/fcnvme_ns   1    159f9f88-be00-4828-aef6-
197d289d4bd9  10.74GB
/dev/nvme0n2   vs_coexistence_QLE2772
/vol/fcnvme_1_1_1/fcnvme_ns   2    2c1ef769-10c0-497d-86d7-
e84811ed2df6  10.74GB
/dev/nvme0n3   vs_coexistence_QLE2772
/vol/fcnvme_1_1_2/fcnvme_ns   3    9b49bf1a-8a08-4fa8-baf0-
6ec6332ad5a4  10.74GB
```

JSON

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

Show example

```
{
  "ONTAPdevices" : [
    {
      "Device" : "/dev/nvme0n1",
      "Vserver" : "vs_coexistence_QLE2772",
      "Namespace_Path" : "/vol/fcnvme_1_1_0/fcnvme_ns",
      "NSID" : 1,
      "UUID" : "159f9f88-be00-4828-aef6-197d289d4bd9",
      "Size" : "10.74GB",
      "LBA_Data_Size" : 4096,
      "Namespace_Size" : 2621440
    },
    {
      "Device" : "/dev/nvme0n2",
      "Vserver" : "vs_coexistence_QLE2772",
      "Namespace_Path" : "/vol/fcnvme_1_1_1/fcnvme_ns",
      "NSID" : 2,
      "UUID" : "2c1ef769-10c0-497d-86d7-e84811ed2df6",
      "Size" : "10.74GB",
      "LBA_Data_Size" : 4096,
      "Namespace_Size" : 2621440
    },
    {
      "Device" : "/dev/nvme0n4",
      "Vserver" : "vs_coexistence_QLE2772",
      "Namespace_Path" : "/vol/fcnvme_1_1_3/fcnvme_ns",
      "NSID" : 4,
      "UUID" : "f3572189-2968-41bc-972a-9ee442dfaed7",
      "Size" : "10.74GB",
      "LBA_Data_Size" : 4096,
      "Namespace_Size" : 2621440
    },
```

Known issues

The NVMe-oF host configuration for Oracle Linux 8.10 with ONTAP release has the following known issue:

NetApp Bug ID	Title	Description
CONTAPEXT-1082	Oracle Linux 8.10 NVMe-oF hosts create duplicate PDCs	On Oracle Linux 8.10 NVMe-oF hosts, Persistent Discovery Controllers (PDCs) are created by using the `-p` option with the `nvme discover` command. For a given initiator-target combination, each execution of the `nvme discover` command is expected to create one PDC. However, beginning with Oracle Linux 8.x, NVMe-oF hosts create a duplicate PDC. This wastes resources on both the host and the target.

NVMe-oF Host Configuration for Oracle Linux 8.9 with ONTAP

NVMe over Fabrics (NVMe-oF), including NVMe over Fibre Channel (NVMe/FC) and other transports, is supported with Oracle Linux 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 the NVMe-oF host configuration for Oracle Linux 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 the ONTAP details for both NVMe/FC and NVMe/TCP namespaces.
- Both NVMe and SCSI traffic can be run on the same host. Therefore, you can configure dm-multipath for SCSI mpath devices for SCSI LUNs, whereas you might use NVMe multipath to configure NVMe-oF namespace devices on the host.
- There is no sanlun support for NVMe-oF. Therefore, there is no host utility support for NVMe-oF on an Oracle Linux 8.9 host. You can rely on the NetApp plug-in included in the native `nvme-cli` package for all NVMe-oF transports.

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

Features

Oracle Linux 8.9 has in-kernel NVMe multipath enabled for NVMe namespaces by default; therefore, there is no need for explicit settings.

Known limitations

SAN booting using the NVMe-oF protocol is currently not supported.

Validate software versions

Validate the minimum supported Oracle Linux 8.9 software versions.

Steps

1. Install Oracle Linux 8.9 GA on the server. After the installation is complete, verify that you are running the specified Oracle Linux 8.9 GA kernel:

```
# uname -r
```

Example output:

```
5.15.0-200.131.27.el8uek.x86_64
```

2. Install the `nvme-cli` package:

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

Example output:

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

3. On the Oracle Linux 8.9 host, check the `hostnqn` string at `/etc/nvme/hostnqn`:

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

Example output:

```
nqn.2014-08.org.nvmexpress:uuid:edd38060-00f7-47aa-a9dc-4d8ae0cd969a
```

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

```
::> vserver nvme subsystem host show -vserver vs_nvme177
```

Example output:

```
Vserver     Subsystem          Host NQN
----------- ---------------
-------------------------------------------------------------
vs_nvme177  nvme_ss_ol_1       nqn.2014-08.org.nvmexpress:uuid:edd38060-
00f7-47aa-a9dc-4d8ae0cd969a
```

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

5. 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. You can add 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. This allows the new setting to take effect.

Configure NVMe/FC

Configure NVMe/FC for Broadcom/Emulex adapters 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
0:14.2.0.5
```

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

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

```
# cat /sys/module/lpfc/parameters/lpfc_enable_fc4_type
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
0x100000109b3c081f
0x100000109b3c0820
```

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

Show example

```
# 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 Oracle Linux 8.9 GA kernel has the latest fixes. These fixes 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:v9.12.00 DVR:v10.02.08.100-k
QLE2742 FW:v9.12.00 DVR:v10.02.08.100-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 size (Optional)

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

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

Steps

1. Set the `lpfc_sg_seg_cnt` parameter to 256:

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

You should see an output similar to the following example:

```
options lpfc lpfc_sg_seg_cnt=256
```

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

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

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 avoid this scenario, you should set the retry period for storage failover events by using the following procedure.

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
```

Show example output

```
#  nvme discover -t tcp -w 192.168.6.13 -a 192.168.6.15
Discovery Log Number of Records 6, Generation counter 8
=====Discovery Log Entry 0======
trtype: tcp
adrfam: ipv4
subtype: unrecognized
treq: not specified
portid: 0
trsvcid: 8009
subnqn: nqn.1992-
08.com.netapp:sn.1c6ac66338e711eda41dd039ea3ad566:discovery
traddr: 192.168.6.17
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.1c6ac66338e711eda41dd039ea3ad566:discovery
traddr: 192.168.5.17
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.1c6ac66338e711eda41dd039ea3ad566:discovery
traddr: 192.168.6.15
sectype: none
=====Discovery Log Entry 3======
trtype: tcp
adrfam: ipv4
subtype: nvme subsystem
treq: not specified
portid: 0
trsvcid: 4420
subnqn: nqn.1992-
08.com.netapp:sn.1c6ac66338e711eda41dd039ea3ad566:subsystem.host_95
```

```
traddr: 192.168.6.17
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 discover -t tcp -w 192.168.6.1 -a 192.168.6.10
# nvme discover -t tcp -w 192.168.6.1 -a 192.168.6.11
# nvme discover -t tcp -w 192.168.5.1 -a 192.168.5.10
# nvme discover -t tcp -w 192.168.5.1 -a 192.168.5.11
```

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

```
nvme connect-all -t tcp -w host-traddr -a traddr -l
<ctrl_loss_timeout_in_seconds>
```

Example output:

```
#   nvme    connect-all -t  tcp -w  192.168.5.1 -a  192.168.5.10    -l
-1
#   nvme    connect-all -t  tcp -w  192.168.5.1 -a  192.168.5.11    -l
-1
#   nvme    connect-all -t  tcp -w  192.168.6.1 -a  192.168.6.10    -l
-1
#   nvme    connect-all -t  tcp -w  192.168.6.1 -a  192.168.6.11    -l
-1
```

NetApp recommends setting the `ctrl-loss-tmo` option to `-1` so that the NVMe/TCP initiator attempts to reconnect indefinitely in the event of a path loss.

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 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 814vWBNRwf9HAAAAAAAB NetApp ONTAP Controller
/dev/nvme0n2 814vWBNRwf9HAAAAAAAB NetApp ONTAP Controller
/dev/nvme0n3 814vWBNRwf9HAAAAAAAB NetApp ONTAP Controller



Namespace Usage    Format             FW             Rev
------------------------------------------------------------
1                 85.90 GB / 85.90 GB  4 KiB + 0 B   FFFFFFFF
2                 85.90 GB / 85.90 GB  24 KiB + 0 B  FFFFFFFF
3                   85.90 GB / 85.90 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/nvme0n1
```

Example output:

```
nvme-subsys0 - NQN=nqn.1992-
08.com.netapp:sn.5f5f2c4aa73b11e9967e00a098df41bd:subsystem.nvme_ss_
ol_1
\
+- nvme0 fc traddr=nn-0x203700a098dfdd91:pn-0x203800a098dfdd91
host_traddr=nn-0x200000109b1c1204:pn-0x100000109b1c1204 live non-
optimized
+- nvme1 fc traddr=nn-0x203700a098dfdd91:pn-0x203900a098dfdd91
host_traddr=nn-0x200000109b1c1204:pn-0x100000109b1c1204 live non-
optimized
+- 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
```

NVMe/TCP

```
nvme list-subsys /dev/nvme1n22
```

Example output

```
nvme-subsys0 - NQN=nqn.1992- 08.com.netapp:
sn.44986b09cadc11eeb309d039eab31e9d:subsystem.ol_nvme
\
+- nvme1 tcp traddr=192.168.5.11 trsvcid=4420
host_traddr=192.168.5.1 src_addr=192.168.5.1 live non-optimized
+- nvme2 tcp traddr=192.168.5.10 trsvcid=4420
host_traddr=192.168.5.1 src_addr=192.168.5.1 live optimized
+- nvme3 tcp traddr=192.168.6.11 trsvcid=4420
host_traddr=192.168.6.1 src_addr=192.168.6.1 live non-optimized
+- nvme4 tcp traddr=192.168.6.10 trsvcid=4420
host_traddr=192.168.6.1 src_addr=192.168.6.1 live  optimized
```

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

Column

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

Example output:

```
Device        Vserver     Namespace Path
------------  ----------  ------------------
/dev/nvme0n1    vs_nvme177  /vol/vol1/ns1
/dev/nvme0n2    vs_nvme177  /vol/vol2/ns2
/dev/nvme0n3    vs_nvme177  /vol/vol3/ns3



NSID     UUID                                   Size
-------- -------------------------------------- ------------
1          72b887b1-5fb6-47b8-be0b-33326e2542e2   85.90GB
2          04bf9f6e-9031-40ea-99c7-a1a61b2d7d08   85.90GB
3          264823b1-8e03-4155-80dd-e904237014a4   85.90GB
```

JSON

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

Example output

```
{
"ONTAPdevices" : [
{
"Device" : "/dev/nvme0n1", "Vserver" : "vs_nvme177",
"Namespace_Path" : "/vol/vol1/ns1",
"NSID" : 1,
"UUID" : "72b887b1-5fb6-47b8-be0b-33326e2542e2", "Size" : "85.90GB",
"LBA_Data_Size" : 4096,
"Namespace_Size" : 5242880
},
{
"Device" : "/dev/nvme0n2", "Vserver" : "vs_nvme177",
"Namespace_Path" : "/vol/vol2/ns2",
 "NSID" : 2,
"UUID" : "04bf9f6e-9031-40ea-99c7-a1a61b2d7d08", "Size" : "85.90GB",
"LBA_Data_Size" : 4096,
"Namespace_Size" : 20971520
},
{
"Device" : "/dev/nvme0n3", "Vserver" : "vs_nvme177",
"Namespace_Path" : "/vol/vol3/ns3",
 "NSID" : 3,
"UUID" : "264823b1-8e03-4155-80dd-e904237014a4", "Size" : "85.90GB",
"LBA_Data_Size" : 4096,
"Namespace_Size" : 20971520
},
]
}
```


Known issues

The NVMe-oF host configuration for Oracle Linux 8.9 with ONTAP release has the following known issues:

NetApp Bug ID	Title	Description

1517321	Oracle Linux 8.9 NVMe-oF hosts create duplicate PDCs	On Oracle Linux 8.9 NVMe-oF hosts, Persistent Discovery Controllers (PDCs) are created by passing the `-p` option to the `nvme discover` command. For a given initiator-target combination, each execution of the `nvme discover` command is expected to create one PDC. However, beginning with Oracle Linux 8.x, NVMe-oF hosts create duplicate. This wastes resources on both the host and the target.

NVMe-oF Host Configuration for Oracle Linux 8.8 with ONTAP

NVMe over Fabrics (NVMe-oF), including NVMe over Fibre Channel (NVMe/FC) and other transports, is supported with Oracle Linux (OL) 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 OL 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.
- Both NVMe and SCSI traffic can be run on the same host. Therefore, for SCSI LUNs, you can configure dm-multipath for SCSI mpath devices, whereas you might use NVMe multipath to configure NVMe-oF namespace devices on the host.
- There is no sanlun support for NVMe-oF. Therefore, there is no host utility support for NVMe-oF on an OL 8.8 host. You can rely on the NetApp plug-in included in the native `nvme-cli` package for all NVMe-oF transports.

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

Features

Oracle Linux 8.8 has in-kernel NVMe multipath enabled for NVMe namespaces by default, therefore, there is no need for explicit settings.

Known limitations

SAN booting using the NVMe-oF protocol is currently not supported.

Validate software versions

You can use the following procedure to validate the minimum supported OL 8.8 software versions.

Steps

1. Install OL 8.8 GA on the server. After the installation is complete, verify that you are running the specified OL 8.8 GA kernel.

```
# uname -r
```

Example output:

```
5.15.0-101.103.2.1.el8uek.x86_64
```

2. Install the `nvme-cli` package:

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

Example output:

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

3. On the Oracle Linux 8.8 host, check the `hostnqn` string at `/etc/nvme/hostnqn`:

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

Example output:

```
nqn.2014-08.org.nvmexpress:uuid:bc59d14c-47f3-11eb-b93c-3a68dd48673f
```

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

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

Example output:

```
Vserver     Subsystem          Host NQN
----------- ---------------
-------------------------------------------------------------
vs_nvme207   nvme_ss_ol_1    nqn.2014-08.org.nvmexpress:uuid:bc59d14c-
47f3-11eb-b93c-3a68dd48673f
```

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

5. 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. You can add 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. This allows the new setting to take effect.

Configure NVMe/FC

You can configure NVMe/FC for Broadcom/Emulex adapters 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
0:14.2.0.5
```

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

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

```
# cat /sys/module/lpfc/parameters/lpfc_enable_fc4_type
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
0x100000109b3c081f
0x100000109b3c0820
```

```
# 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 OL 8.8 GA kernel has the latest fixes. These fixes 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:v9.12.00 DVR:v10.02.08.100-k
QLE2742 FW:v9.12.00 DVR:v10.02.08.100-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 size (Optional)

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

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

Steps

1. Set the `lpfc_sg_seg_cnt` parameter to 256:

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

You should see an output similar to the following example:

```
options lpfc lpfc_sg_seg_cnt=256
```

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

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

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 192.168.6.13 -a 192.168.6.15
Discovery Log Number of Records 6, Generation counter 8
=====Discovery Log Entry 0======
trtype: tcp
adrfam: ipv4
subtype: unrecognized
treq: not specified
portid: 0
trsvcid: 8009
subnqn: nqn.1992-
08.com.netapp:sn.1c6ac66338e711eda41dd039ea3ad566:discovery
traddr: 192.168.6.17
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.1c6ac66338e711eda41dd039ea3ad566:discovery
traddr: 192.168.5.17
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.1c6ac66338e711eda41dd039ea3ad566:discovery
```

```
traddr: 192.168.6.15
sectype: none
=====Discovery Log Entry 3======
trtype: tcp
adrfam: ipv4
subtype: nvme subsystem
treq: not specified
portid: 0
trsvcid: 4420
subnqn: nqn.1992-
08.com.netapp:sn.1c6ac66338e711eda41dd039ea3ad566:subsystem.host_95
traddr: 192.168.6.17
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 discover -t tcp -w 192.168.5.13 -a 192.168.5.15
# nvme discover -t tcp -w 192.168.5.13 -a 192.168.5.17
# nvme discover -t tcp -w 192.168.6.13 -a 192.168.6.15
# nvme discover -t tcp -w 192.168.6.13 -a 192.168.6.17
```

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 192.168.5.13 -a 192.168.5.15 -l 1800
# nvme connect-all -t tcp -w 192.168.5.13 -a 192.168.5.17 -l 1800
# nvme connect-all -t tcp -w 192.168.6.13 -a 192.168.6.15 -l 1800
# nvme connect-all -t tcp -w 192.168.6.13 -a 192.168.6.17 -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 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 814vWBNRwf9HAAAAAAAB NetApp ONTAP Controller
/dev/nvme0n2 814vWBNRwf9HAAAAAAAB NetApp ONTAP Controller
/dev/nvme0n3 814vWBNRwf9HAAAAAAAB NetApp ONTAP Controller



Namespace Usage    Format             FW             Rev
-------------------------------------------------------------
1                 85.90 GB / 85.90 GB  4 KiB + 0 B   FFFFFFFF
2                 85.90 GB / 85.90 GB  24 KiB + 0 B  FFFFFFFF
3                   85.90 GB / 85.90 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/nvme0n1
```

Example output:

```
nvme-subsys0 - NQN=nqn.1992-
08.com.netapp:sn.5f5f2c4aa73b11e9967e00a098df41bd:subsystem.nvme_ss_
ol_1
\
+- nvme0 fc traddr=nn-0x203700a098dfdd91:pn-0x203800a098dfdd91
host_traddr=nn-0x200000109b1c1204:pn-0x100000109b1c1204 live non-
optimized
+- nvme1 fc traddr=nn-0x203700a098dfdd91:pn-0x203900a098dfdd91
host_traddr=nn-0x200000109b1c1204:pn-0x100000109b1c1204 live non-
optimized
+- 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
```

NVMe/TCP

```
nvme list-subsys /dev/nvme1n22
```

Example output

```
nvme-subsys1 - NQN=nqn.1992-
08.com.netapp:sn.68c036aaa3cf11edbb95d039ea243511:subsystem.tcp
\
+- nvme2 tcp
traddr=192.168.8.49,trsvcid=4420,host_traddr=192.168.8.1 live non-
optimized
+- nvme3 tcp
traddr=192.168.8.48,trsvcid=4420,host_traddr=192.168.8.1 live non-
optimized
+- nvme6 tcp
traddr=192.168.9.49,trsvcid=4420,host_traddr=192.168.9.1 live
optimized
+- nvme7 tcp
traddr=192.168.9.48,trsvcid=4420,host_traddr=192.168.9.1 live
optimized
```

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

Column

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

Example output:

```
Device        Vserver   Namespace Path
------------------------ ------------------------------
/dev/nvme0n1   vs_ol_nvme  /vol/ol_nvme_vol_1_1_0/ol_nvme_ns
/dev/nvme0n2   vs_ol_nvme  /vol/ol_nvme_vol_1_0_0/ol_nvme_ns
/dev/nvme0n3   vs_ol_nvme  /vol/ol_nvme_vol_1_1_1/ol_nvme_ns




NSID       UUID                                   Size
-------------------------------------------------------------
1          72b887b1-5fb6-47b8-be0b-33326e2542e2   85.90GB
2          04bf9f6e-9031-40ea-99c7-a1a61b2d7d08   85.90GB
3          264823b1-8e03-4155-80dd-e904237014a4   85.90GB
```

JSON

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

Example output

```
{
"ONTAPdevices" : [
    {
        "Device" : "/dev/nvme0n1",
        "Vserver" : "vs_ol_nvme",
        "Namespace_Path" : "/vol/ol_nvme_vol_1_1_0/ol_nvme_ns",
        "NSID" : 1,
        "UUID" : "72b887b1-5fb6-47b8-be0b-33326e2542e2",
        "Size" : "85.90GB",
        "LBA_Data_Size" : 4096,
        "Namespace_Size" : 20971520
    },
    {
        "Device" : "/dev/nvme0n2",
        "Vserver" : "vs_ol_nvme",
        "Namespace_Path" : "/vol/ol_nvme_vol_1_0_0/ol_nvme_ns",
        "NSID" : 2,
        "UUID" : "04bf9f6e-9031-40ea-99c7-a1a61b2d7d08",
        "Size" : "85.90GB",
        "LBA_Data_Size" : 4096,
        "Namespace_Size" : 20971520
      },
      {
         "Device" : "/dev/nvme0n3",
         "Vserver" : "vs_ol_nvme",
         "Namespace_Path" : "/vol/ol_nvme_vol_1_1_1/ol_nvme_ns",
         "NSID" : 3,
         "UUID" : "264823b1-8e03-4155-80dd-e904237014a4",
         "Size" : "85.90GB",
         "LBA_Data_Size" : 4096,
         "Namespace_Size" : 20971520
       },
  ]
}
```


Known issues

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

NetApp Bug ID	Title	Description
1517321	Oracle Linux 8.8 NVMe-oF hosts create duplicate PDCs	On OL 8.8 NVMe-oF hosts, Persistent Discovery Controllers (PDCs) are created by passing the `-p` option to the `nvme discover` command. For a given initiator-target combination, each execution of the `nvme discover` command is expected to create one PDC. However, beginning with OL 8.x, NVMe-oF hosts create duplicate PDCs. This wastes resources on both the host and the target.

NVMe-oF Host Configuration for Oracle Linux 8.7 with ONTAP

NVMe over Fabrics (NVMe-oF), including NVMe over Fibre Channel (NVMe/FC) and other transports, is supported with Oracle Linux (OL) 8.7 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/FC host configuration for OL 8.7 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.
- Use of NVMe and SCSI co-existent traffic on the same host on a given host bus adapter (HBA), without the explicit dm-multipath settings to prevent claiming NVMe namespaces.

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

Features

- OL 8.7 has in-kernel NVMe multipath enabled for NVMe namespaces by default, therefore, there is no need for explicit settings.

Known limitations

SAN booting using the NVMe-oF protocol is currently not supported.

Validate software versions

You can use the following procedure to validate the minimum supported OL 8.7 software versions.

Steps

1. Install OL 8.7 GA on the server. After the installation is complete, verify that you are running the specified OL 8.7 GA kernel.

```
# uname -r
```

Example output:

```
5.15.0-3.60.5.1.el8uek.x86_64
```

2. Install the `nvme-cli` package:

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

Example output:

```
nvme-cli-1.16-5.el8.x86_64
```

3. On the Oracle Linux 8.7 host, check the `hostnqn` string at `/etc/nvme/hostnqn`:

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

Example output:

```
nqn.2014-08.org.nvmexpress:uuid:791c54eb-545d-4ed3-8d41-91a0a53d4b24
```

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

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

Example output:

```
Vserver     Subsystem          Host NQN
----------- ---------------
------------------------------------------------------------
vs_ol_nvme  nvme_ss_ol_1    nqn.2014-08.org.nvmexpress:uuid:791c54eb-
545d-4ed3-8d41-91a0a53d4b24
```

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

5. Reboot the host.

If you intend to run both NVMe and SCSI traffic on the same Oracle Linux 8.7 host, NetApp recommends using the in-kernel NVMe multipath for ONTAP namespaces and dm-multipath for ONTAP LUNs respectively. This also means the ONTAP namespaces should be blacklisted 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` file:

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

Restart the multipathd daemon by running the `systemctl restart multipathd` command to apply the new settings.

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
12.8.614.23, sli-4:2:c
12.8.614.23, sli-4:2:c


# cat /sys/module/lpfc/version
0:14.0.0.1
```

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

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

```
# cat /sys/module/lpfc/parameters/lpfc_enable_fc4_type
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
0x100000109b3c081f
0x100000109b3c0820
```

```
# 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 x100000109b3c081f WWNN x200000109b3c081f DID
x060300 ONLINE
NVME RPORT WWPN x2010d039ea2c3e2d WWNN x200fd039ea2c3e2d DID x061f0e
TARGET DISCSRVC ONLINE
NVME RPORT WWPN x2011d039ea2c3e2d WWNN x200fd039ea2c3e2d DID x06270f
TARGET DISCSRVC ONLINE
NVME Statistics
LS: Xmt 0000000a71 Cmpl 0000000a71 Abort 00000000
LS XMIT: Err 00000000 CMPL: xb 00000000 Err 00000000
Total FCP Cmpl 00000000558611c6 Issue 0000000005578bb69 OutIO
fffffffffff2a9a3
abort 0000007a noxri 00000000 nondlp 00000447 qdepth 00000000 wqerr
00000000 err 00000000
FCP CMPL: xb 00000a8e Err 0000e2a8
NVME Initiator Enabled
XRI Dist lpfc1 Total 6144 IO 5894 ELS 250
NVME LPORT lpfc1 WWPN x100000109b3c0820 WWNN x200000109b3c0820 DID
x060200 ONLINE
NVME RPORT WWPN x2015d039ea2c3e2d WWNN x200fd039ea2c3e2d DID x062e0c
TARGET DISCSRVC ONLINE
NVME RPORT WWPN x2014d039ea2c3e2d WWNN x200fd039ea2c3e2d DID x06290f
TARGET DISCSRVC ONLINE
NVME Statistics
LS: Xmt 0000000a69 Cmpl 0000000a69 Abort 00000000
LS XMIT: Err 00000000 CMPL: xb 00000000 Err 00000000
Total FCP Cmpl 0000000055814701 Issue 0000000055744b1c OutIO
fffffffffff3041b
abort 00000046 noxri 00000000 nondlp 0000043f qdepth 00000000 wqerr
00000000 err 00000000
FCP CMPL: xb 00000a89 Err 0000e2f3
```

Marvell/Qlogic FC Adapter for NVMe/FC

The native inbox qla2xxx driver included in the OL 8.7 GA kernel has the latest upstream fixes. These fixes 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
```

Example output

```
QLE2742 FW:v9.10.11 DVR:v10.02.06.200-k
QLE2742 FW:v9.10.11 DVR:v10.02.06.200-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. This means the maximum I/O request size can be up to 1MB. To issue I/O requests of size 1MB for a Broadcom NVMe/FC host, you should increase the `lpfc` value of the `lpfc_sg_seg_cnt` parameter to 256 from the default value of 64.

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

Steps

1. Set the `lpfc_sg_seg_cnt` parameter to 256:

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

You should see an output similar to the following example:

```
options lpfc lpfc_sg_seg_cnt=256
```

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

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

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 192.168.6.13 -a 192.168.6.15
   Discovery Log Number of Records 6, Generation counter 8
   =====Discovery Log Entry 0======
   trtype: tcp
   adrfam: ipv4
   subtype: unrecognized
   treq: not specified
   portid: 0
   trsvcid: 8009
   subnqn: nqn.1992-
   08.com.netapp:sn.1c6ac66338e711eda41dd039ea3ad566:discovery
   traddr: 192.168.6.17
   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.1c6ac66338e711eda41dd039ea3ad566:discovery
   traddr: 192.168.5.17
   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.1c6ac66338e711eda41dd039ea3ad566:discovery
traddr: 192.168.6.15
sectype: none
=====Discovery Log Entry 3======
trtype: tcp
adrfam: ipv4
subtype: nvme subsystem
treq: not specified
portid: 0
trsvcid: 4420
subnqn: nqn.1992-
08.com.netapp:sn.1c6ac66338e711eda41dd039ea3ad566:subsystem.host_95
traddr: 192.168.6.17
sectype: none
..........
```

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

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

Example output:

```
# nvme discover -t tcp -w 192.168.5.13 -a 192.168.5.15
# nvme discover -t tcp -w 192.168.5.13 -a 192.168.5.17
# nvme discover -t tcp -w 192.168.6.13 -a 192.168.6.15
# nvme discover -t tcp -w 192.168.6.13 -a 192.168.6.17
```

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 192.168.5.13 -a 192.168.5.15 -l 1800
# nvme connect-all -t tcp -w 192.168.5.13 -a 192.168.5.17 -l 1800
# nvme connect-all -t tcp -w 192.168.6.13 -a 192.168.6.15 -l 1800
# nvme connect-all -t tcp -w 192.168.6.13 -a 192.168.6.17 -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 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 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 814vWBNRwf9HAAAAAAAB NetApp ONTAP Controller
/dev/nvme0n2 814vWBNRwf9HAAAAAAAB NetApp ONTAP Controller
/dev/nvme0n3 814vWBNRwf9HAAAAAAAB NetApp ONTAP Controller


Namespace Usage    Format             FW             Rev
-------------------------------------------------------------
1                 85.90 GB / 85.90 GB  4 KiB + 0 B   FFFFFFFF
2                 85.90 GB / 85.90 GB  24 KiB + 0 B  FFFFFFFF
3                 85.90 GB / 85.90 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/nvme0n1
```

Example output:

```
nvme-subsys0 - NQN=nqn.1992-
08.com.netapp:sn.5f5f2c4aa73b11e9967e00a098df41bd:subsystem.nvme_ss_
ol_1
\
+- nvme0 fc traddr=nn-0x203700a098dfdd91:pn-0x203800a098dfdd91
host_traddr=nn-0x200000109b1c1204:pn-0x100000109b1c1204 live non-
optimized
+- nvme1 fc traddr=nn-0x203700a098dfdd91:pn-0x203900a098dfdd91
host_traddr=nn-0x200000109b1c1204:pn-0x100000109b1c1204 live non-
optimized
+- 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
```

NVMe/TCP

```
# nvme list-subsys /dev/nvme1n40
```

Example output:

```
nvme-subsys1 - NQN=nqn.1992-
08.com.netapp:sn.68c036aaa3cf11edbb95d039ea243511:subsystem.tcp
\
+- nvme2 tcp
traddr=192.168.8.49,trsvcid=4420,host_traddr=192.168.8.1 live non-
optimized
+- nvme3 tcp
traddr=192.168.8.48,trsvcid=4420,host_traddr=192.168.8.1 live non-
optimized
+- nvme6 tcp
traddr=192.168.9.49,trsvcid=4420,host_traddr=192.168.9.1 live
optimized
+- nvme7 tcp
traddr=192.168.9.48,trsvcid=4420,host_traddr=192.168.9.1 live
optimized
```

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

Column

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

Example output:

```
Device        Vserver   Namespace Path
--------------------- ------------------------------
/dev/nvme0n1   vs_ol_nvme  /vol/ol_nvme_vol_1_1_0/ol_nvme_ns
/dev/nvme0n2   vs_ol_nvme  /vol/ol_nvme_vol_1_0_0/ol_nvme_ns
/dev/nvme0n3   vs_ol_nvme  /vol/ol_nvme_vol_1_1_1/ol_nvme_ns


NSID       UUID                                   Size
-------------------------------------------------------------
1          72b887b1-5fb6-47b8-be0b-33326e2542e2   85.90GB
2          04bf9f6e-9031-40ea-99c7-a1a61b2d7d08   85.90GB
3          264823b1-8e03-4155-80dd-e904237014a4   85.90GB
```

JSON

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

Example output

```
{
"ONTAPdevices" : [
    {
        "Device" : "/dev/nvme0n1",
        "Vserver" : "vs_ol_nvme",
        "Namespace_Path" : "/vol/ol_nvme_vol_1_1_0/ol_nvme_ns",
        "NSID" : 1,
        "UUID" : "72b887b1-5fb6-47b8-be0b-33326e2542e2",
        "Size" : "85.90GB",
        "LBA_Data_Size" : 4096,
        "Namespace_Size" : 20971520
    },
    {
        "Device" : "/dev/nvme0n2",
        "Vserver" : "vs_ol_nvme",
        "Namespace_Path" : "/vol/ol_nvme_vol_1_0_0/ol_nvme_ns",
        "NSID" : 2,
        "UUID" : "04bf9f6e-9031-40ea-99c7-a1a61b2d7d08",
        "Size" : "85.90GB",
        "LBA_Data_Size" : 4096,
        "Namespace_Size" : 20971520
      },
      {
         "Device" : "/dev/nvme0n3",
         "Vserver" : "vs_ol_nvme",
         "Namespace_Path" : "/vol/ol_nvme_vol_1_1_1/ol_nvme_ns",
         "NSID" : 3,
         "UUID" : "264823b1-8e03-4155-80dd-e904237014a4",
         "Size" : "85.90GB",
         "LBA_Data_Size" : 4096,
         "Namespace_Size" : 20971520
       },
  ]
}
```


Known issues

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

NetApp Bug ID	Title	Description
1517321	Oracle Linux 8.7 NVMe-oF Hosts create duplicate Persistent Discovery Controllers	On OL 8.7 NVMe-oF hosts, Persistent Discovery Controllers (PDCs) are created by passing the `-p` option to the `nvme discover` command. For a given initiator-target combination, each execution of the `nvme discover` command is expected to create one PDC. However, beginning with OL 8.x, NVMe-oF hosts create duplicate PDCs. This wastes resources on both the host and the target.

NVMe/FC Host Configuration for Oracle Linux 8.6 with ONTAP

You can configure NVMe over Fibre Channel (NVMe/FC) on initiator hosts running Oracle Linux 8.6 and ONTAP as the target.

Supportability

NVMe over Fabrics or NVMe-oF (including NVMe/FC and NVMe/TCP) is supported with Oracle Linux 8.6 with Asymmetric Namespace Access (ANA) that is required for surviving storage failovers (SFOs) on the ONTAP array. ANA is the asymmetric logical unit access (ALUA) equivalent in the NVMe-oF environment, and is currently implemented with in-kernel NVMe Multipath. Using this procedure, you can enable NVMe-oF with in-kernel NVMe Multipath using ANA on Oracle Linux 8.6 and ONTAP as the target.

You can use the configuration settings provided in this procedure to configure cloud clients connected to Cloud Volumes ONTAP and Amazon FSx for ONTAP.

Features

- Oracle Linux 8.6 has in-kernel NVMe multipath enabled by default for NVMe namepsaces.
- With Oracle Linux 8.6, `nvme-fc auto-connect` scripts are included in the native `nvme-cli` package. You can use these native auto-connect scripts instead of installing external vendor provided outbox auto-connect scripts.
- With Oracle Linux 8.6, a native `udev` rule is provided as part of the `nvme-cli` package which enables round-robin load balancing for NVMe multipath. Therefore, you need not manually create this rule anymore.
- With Oracle Linux 8.6, both NVMe and SCSI traffic can be run on the same host. This is the commonly deployed host configuration. You can configure dm-multipath as usual for SCSI LUNs resulting in mpath devices and also use NVMe multipath to configure NVMe-oF multipath devices (for example, `/dev/nvmeXnY`) on the host.
- With Oracle Linux 8.6, the NetApp plug-in in the native `nvme-cli` package is capable of displaying ONTAP details as well as ONTAP namespaces.

Known limitations

SAN booting using the NVMe-oF protocol is currently not supported.

Configuration requirements

Refer to the Interoperability Matrix Tool for exact details regarding supported configurations.

Enable NVMe/FC with Oracle Linux 8.6

Steps

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

```
# uname -r
5.4.17-2136.307.3.1.el8uek.x86_64
```

2. Install the `nvme-cli` package:

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

3. On the Oracle Linux 8.6 host, check the `hostnqn` string at `/etc/nvme/hostnqn` and verify that it matches the hostnqn string for the corresponding subsystem on the ONTAP array.

```
# cat /etc/nvme/hostnqn
nqn.2014-08.org.nvmexpress:uuid:4c4c4544-0032-3310-8033-b8c04f4c5132
::> vserver nvme subsystem host show -vserver vs_ol_nvme
Vserver     Subsystem          Host NQN
----------- ---------------
------------------------------------------------------------
vs_ol_nvme  nvme_ss_ol_1    nqn.2014-08.org.nvmexpress:uuid:9ed5b327-
b9fc-4cf5-97b3-1b5d986345d1
```

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

4. Reboot the host.

If you intend to run both NVMe and SCSI traffic on the same Oracle Linux 8.6 host, NetApp recommends using the in-kernel NVMe multipath for ONTAP namespaces and dm-multipath for ONTAP LUNs respectively. This also means the ONTAP namespaces should be blacklisted in 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 the `systemctl restart multipathd` command to let the new setting take effect.

Configure Broadcom FC adapter for NVMe/FC

Steps

1. Verify that you are using the supported adapter. For the current list of supported adapters see the Interoperability Matrix Tool:

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

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

# cat /sys/module/lpfc/version
0:12.8.0.11
```

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
```

Enable 1MB I/O size

ONTAP reports an MDTS (Max Data Transfer Size) of 8 in the Identify Controller data. This means the

maximum I/O request size can be up to 1MB. To issue I/O requests of size 1MB for a Broadcom NVMe/FC host, you should increase the `lpfc` value of the `lpfc_sg_seg_cnt` parameter to 256 from the default value of 64.

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

Steps

1. Set the `lpfc_sg_seg_cnt` parameter to 256:

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

You should see an output similar to the following example:

```
options lpfc lpfc_sg_seg_cnt=256
```

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

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

Configure the Marvell/QLogic FC Adapter for NVMe/FC

The native inbox qla2xxx driver included in the OL 8.6 GA kernel has the latest upstream fixes. These fixes 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:v9.08.02 DVR:v10.02.00.106-k
QLE2742 FW:v9.08.02 DVR:v10.02.00.106-k
```

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

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

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 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. Similarly, verify that the other NVMe/TCP initiator-target LIF combinations are able to successfully fetch discovery log page data.
   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. Now run the `nvme connect-all` command across all the supported NVMe/TCP initiator-target LIFs across the nodes. MAke sure you pass a longer `ctrl_loss_tmo` period (such as, say 30 minutes, which can be set through `-l 1800`) during the `connect-all` so that it would retry for a longer period 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/FC

Steps

1. Verify the following NVMe/FC settings on the Oracle Linux 8.6 host:

```
# 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 correctly discovered on the host:

```
# nvme list
Node         SN                    Model
------------------------------------------------------------
/dev/nvme0n1 814vWBNRwf9HAAAAAAAB NetApp ONTAP Controller
/dev/nvme0n2 814vWBNRwf9HAAAAAAAB NetApp ONTAP Controller
/dev/nvme0n3 814vWBNRwf9HAAAAAAAB NetApp ONTAP Controller


Namespace Usage    Format             FW             Rev
-----------------------------------------------------------
1                 85.90 GB / 85.90 GB  4 KiB + 0 B   FFFFFFFF
2                 85.90 GB / 85.90 GB  24 KiB + 0 B  FFFFFFFF
3                 85.90 GB / 85.90 GB  4 KiB + 0 B   FFFFFFFF
```

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

```
# nvme list-subsys /dev/nvme0n1
nvme-subsys0 - NQN=nqn.1992-
08.com.netapp:sn.5f5f2c4aa73b11e9967e00a098df41bd:subsystem.nvme_ss_ol_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 that the NetApp plug-in displays the correct values for each ONTAP namespace device:

```
# nvme netapp ontapdevices -o column

Device        Vserver   Namespace Path
--------------------- ------------------------------
/dev/nvme0n1   vs_ol_nvme  /vol/ol_nvme_vol_1_1_0/ol_nvme_ns
/dev/nvme0n2   vs_ol_nvme  /vol/ol_nvme_vol_1_0_0/ol_nvme_ns
/dev/nvme0n3   vs_ol_nvme  /vol/ol_nvme_vol_1_1_1/ol_nvme_ns


NSID       UUID                                   Size
-------------------------------------------------------------
1          72b887b1-5fb6-47b8-be0b-33326e2542e2   85.90GB
2          04bf9f6e-9031-40ea-99c7-a1a61b2d7d08   85.90GB
3          264823b1-8e03-4155-80dd-e904237014a4   85.90GB
```

```
# nvme netapp ontapdevices -o json
{
"ONTAPdevices" : [
    {
        "Device" : "/dev/nvme0n1",
        "Vserver" : "vs_ol_nvme",
        "Namespace_Path" : "/vol/ol_nvme_vol_1_1_0/ol_nvme_ns",
        "NSID" : 1,
        "UUID" : "72b887b1-5fb6-47b8-be0b-33326e2542e2",
        "Size" : "85.90GB",
        "LBA_Data_Size" : 4096,
        "Namespace_Size" : 20971520
    },
    {
        "Device" : "/dev/nvme0n2",
        "Vserver" : "vs_ol_nvme",
        "Namespace_Path" : "/vol/ol_nvme_vol_1_0_0/ol_nvme_ns",
        "NSID" : 2,
        "UUID" : "04bf9f6e-9031-40ea-99c7-a1a61b2d7d08",
        "Size" : "85.90GB",
        "LBA_Data_Size" : 4096,
        "Namespace_Size" : 20971520
      },
      {
         "Device" : "/dev/nvme0n3",
         "Vserver" : "vs_ol_nvme",
         "Namespace_Path" : "/vol/ol_nvme_vol_1_1_1/ol_nvme_ns",
         "NSID" : 3,
         "UUID" : "264823b1-8e03-4155-80dd-e904237014a4",
         "Size" : "85.90GB",
         "LBA_Data_Size" : 4096,
         "Namespace_Size" : 20971520
       },
  ]
}
```

Known issues

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

NetApp Bug ID	Title	Description
1517321	Oracle Linux 8.6 NVMe-oF Hosts create duplicate Persistent Discovery Controllers	On Oracle Linux 8.6 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 Oracle Linux 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.

NVMe/FC Host Configuration for Oracle Linux 8.5 with ONTAP

You can configure NVMe over Fibre Channel (NVMe/FC) on initiator hosts running Oracle Linux 8.5 and ONTAP as the target.

Supportability

NVMe over Fabrics or NVMe-oF (including NVMe/FC and NVMe/TCP) is supported with Oracle Linux 8.5 with Asymmetric Namespace Access (ANA) that is required for surviving storage failovers (SFOs) on the ONTAP array. ANA is the asymmetric logical unit access (ALUA) equivalent in the NVMe-oF environment, and is currently implemented with in-kernel NVMe Multipath. Using this procedure, you can enable NVMe-oF with in-kernel NVMe Multipath using ANA on Oracle Linux 8.5 and ONTAP as the target.

You can use the configuration settings provided in this procedure to configure cloud clients connected to Cloud Volumes ONTAP and Amazon FSx for ONTAP.

Features

- Oracle Linux 8.5 has in-kernel NVMe multipath enabled by default for NVMe namepsaces.
- With Oracle Linux 8.5, `nvme-fc auto-connect` scripts are included in the native `nvme-cli` package. You can use these native auto-connect scripts instead of installing external vendor provided outbox auto-connect scripts.
- With Oracle Linux 8.5, a native `udev` rule is provided as part of the `nvme-cli` package which enables round-robin load balancing for NVMe multipath. Therefore, you do not need to manually create this rule anymore.
- With Oracle Linux 8.5, both NVMe and SCSI traffic can be run on the same host. This is the commonly deployed host configuration. You can configure dm-multipath as usual for SCSI LUNs resulting in mpath devices and also use NVMe multipath to configure NVMe-oF multipath devices (for example, `/dev/nvmeXnY`) on the host.
- With Oracle Linux 8.5, the NetApp plugin in the native `nvme-cli` package is capable of displaying ONTAP details as well as ONTAP namespaces.

Known limitations

SAN booting using the NVMe-oF protocol is currently not supported.

Configuration requirements

Refer to the Interoperability Matrix Tool for exact details regarding supported configurations.

Enable NVMe/FC with Oracle Linux 8.5

Steps

1. Install Oracle Linux 8.5 General Availability (GA) on the server. After the installation is complete, verify that you are running the specified Oracle Linux 8.5 GA kernel. See the Interoperability Matrix Tool for the current list of supported versions.

```
# uname -r
5.4.17-2136.309.4.el8uek.x86_64
```

2. Install the `nvme-cli` package.

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

3. On the Oracle Linux 8.5 host, check the `hostnqn` string at `/etc/nvme/hostnqn` and verify that it matches the `hostnqn` 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_ol_nvme

Vserver    Subsystem      Host NQN
-------------------------------------------
vs_ol_nvme nvme_ss_ol_1   nqn.2014-08.org.nvmexpress:uuid:9ed5b327-b9fc-
4cf5-97b3-1b5d986345d1
```

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

4. Reboot the host.

If you intend to run both NVMe and SCSI traffic on the same Oracle Linux 8.5 host, NetApp recommends using the in-kernel NVMe multipath for ONTAP namespaces and dm-multipath for ONTAP LUNs respectively. This also means the ONTAP namespaces should be blacklisted in 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 the `systemctl restart multipathd` command to let the new setting take effect.

Configure the Broadcom FC adapter for NVMe/FC

Steps

1. Verify that you are using the supported adapter. For the current list of supported adapters, see the Interoperability Matrix Tool.

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

```
# cat /sys/class/scsi_host/host*/fwrev
14.0.505.11, sli-4:2:c
14.0.505.11, 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 can see the target LIFs.

```
# cat /sys/class/fc_host/host*/port_name
0x100000109b213a00
0x100000109b2139ff
# 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 x100000109b213a00 WWNN x200000109b213a00 DID
x031700     ONLINE
NVME RPORT WWPN x208cd039ea243510 WWNN x208bd039ea243510 DID x03180a
TARGET DISCSRVC ONLINE
NVME RPORT WWPN x2090d039ea243510 WWNN x208bd039ea243510 DID x03140a
TARGET DISCSRVC ONLINE
NVME Statistics
LS: Xmt 000000000e Cmpl 000000000e Abort 00000000
LS XMIT: Err 00000000 CMPL: xb 00000000 Err 00000000
Total FCP Cmpl 0000000000079efc Issue 0000000000079eeb OutIO
fffffffffffffef
abort 00000002 noxri 00000000 nondlp 00000000 qdepth 00000000 wqerr
00000000 err   00000000
FCP CMPL: xb 00000002 Err 00000004

NVME Initiator Enabled
XRI Dist lpfc0 Total 6144 IO 5894 ELS 250
NVME LPORT lpfc0 WWPN x100000109b2139ff WWNN x200000109b2139ff DID
x031300 ONLINE
NVME RPORT WWPN x208ed039ea243510 WWNN x208bd039ea243510 DID x03230c
TARGET DISCSRVC ONLINE
NVME RPORT WWPN x2092d039ea243510 WWNN x208bd039ea243510 DID x03120c
TARGET DISCSRVC ONLINE

NVME Statistics
LS: Xmt 000000000e Cmpl 000000000e Abort 00000000
LS XMIT: Err 00000000 CMPL: xb 00000000 Err 00000000
Total FCP Cmpl 0000000000029ba0 Issue 0000000000029ba2 OutIO
0000000000000002
abort 00000002 noxri 00000000 nondlp 00000000 qdepth 00000000 wqerr
00000000 err 00000000
FCP CMPL: xb 00000002 Err 00000004
```

Enable 1MB I/O size

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

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

Steps

1. Set the `lpfc_sg_seg_cnt` parameter to 256:

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

You should see an output similar to the following example:

```
options lpfc lpfc_sg_seg_cnt=256
```

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

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

Configure the Marvell/QLogic FC adapter for NVMe/FC

The native inbox qla2xxx driver included in the OL 8.5 GA kernel has the latest upstream fixes. These fixes 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 an NVMe/FC initiator.

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

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 is able to fetch 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. Similarly, verify that the other NVMe/TCP initiator-target LIF combinations are able to successfully fetch discovery log page data.
   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. Now run the `nvme connect-all` command across all the supported NVMe/TCP initiator-target LIFs across the nodes. Make sure you provide a longer `ctrl_loss_tmo` timer period (such as say 30 minutes, which can be set adding `-l 1800`) during `connect-all` so that it would retry for a longer period in the event of a path loss.
   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/FC

Steps

1. Verify the following NVMe/FC settings on the Oracle Linux 8.5 host.

```
# 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 correctly discovered on the host.

```
# nvme list
Node         SN                    Model
------------------------------------------------------------
/dev/nvme0n1 814vWBNRwf9HAAAAAAAB  NetApp ONTAP Controller
/dev/nvme0n2 814vWBNRwf9HAAAAAAAB  NetApp ONTAP Controller
/dev/nvme0n3 814vWBNRwf9HAAAAAAAB  NetApp ONTAP Controller

Namespace Usage  Format                  FW            Rev
-------------------------------------------------------------
1                85.90 GB / 85.90 GB     4 KiB + 0 B   FFFFFFFF
2                85.90 GB / 85.90 GB     4 KiB + 0 B   FFFFFFFF
3                85.90 GB / 85.90 GB     4 KiB + 0 B   FFFFFFFF
```

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

```
# nvme list-subsys /dev/nvme0n1
nvme-subsys0 - NQN=nqn.1992-
08.com.netapp:sn.5f5f2c4aa73b11e9967e00a098df41bd:subsystem.nvme_ss_ol_1
\
+- nvme0 fc traddr=nn-0x203700a098dfdd91:pn-0x203800a098dfdd91
host_traddr=nn-0x200000109b1c1204:pn-0x100000109b1c1204 live non-
optimized
+- nvme1 fc traddr=nn-0x203700a098dfdd91:pn-0x203900a098dfdd91
host_traddr=nn-0x200000109b1c1204:pn-0x100000109b1c1204 live non-
optimized
+- 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 displays correct values for each ONTAP namespace device.

```
# nvme netapp ontapdevices -o column
Device       Vserver  Namespace Path
---------------------------------
/dev/nvme0n1  vs_ol_nvme  /vol/ol_nvme_vol_1_1_0/ol_nvme_ns
/dev/nvme0n2  vs_ol_nvme  /vol/ol_nvme_vol_1_0_0/ol_nvme_ns
/dev/nvme0n3  vs_ol_nvme  /vol/ol_nvme_vol_1_1_1/ol_nvme_ns

NSID    UUID                                   Size
-------------------------------------------------
1       72b887b1-5fb6-47b8-be0b-33326e2542e2   85.90GB
2       04bf9f6e-9031-40ea-99c7-a1a61b2d7d08   85.90GB
3       264823b1-8e03-4155-80dd-e904237014a4   85.90GB
```

```
# nvme netapp ontapdevices -o json
{
"ONTAPdevices" : [
    {
        "Device" : "/dev/nvme0n1",
        "Vserver" : "vs_ol_nvme",
        "Namespace_Path" : "/vol/ol_nvme_vol_1_1_0/ol_nvme_ns",
        "NSID" : 1,
        "UUID" : "72b887b1-5fb6-47b8-be0b-33326e2542e2",
        "Size" : "85.90GB",
        "LBA_Data_Size" : 4096,
        "Namespace_Size" : 20971520
    },
    {
        "Device" : "/dev/nvme0n2",
        "Vserver" : "vs_ol_nvme",
        "Namespace_Path" : "/vol/ol_nvme_vol_1_0_0/ol_nvme_ns",
        "NSID" : 2,
        "UUID" : "04bf9f6e-9031-40ea-99c7-a1a61b2d7d08",
        "Size" : "85.90GB",
        "LBA_Data_Size" : 4096,
        "Namespace_Size" : 20971520
      },
      {
         "Device" : "/dev/nvme0n3",
         "Vserver" : "vs_ol_nvme",
         "Namespace_Path" : "/vol/ol_nvme_vol_1_1_1/ol_nvme_ns",
         "NSID" : 3,
         "UUID" : "264823b1-8e03-4155-80dd-e904237014a4",
         "Size" : "85.90GB",
         "LBA_Data_Size" : 4096,
         "Namespace_Size" : 20971520
       },
  ]
}
```

Known issues

The NVMe-oF host configuration for OL 8.5 with ONTAP has the following known issues:

NetApp Bug ID	Title	Description
1517321	Oracle Linux 8.5 NVMe-oF Hosts create duplicate Persistent Discovery Controllers	On Oracle Linux 8.5 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 Oracle Linux 8.5 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.

NVMe/FC Host Configuration for Oracle Linux 8.4 with ONTAP

You can configure NVMe over Fibre Channel (NVMe/FC) on initiator hosts running Oracle Linux 8.4 and ONTAP as the target.

Supportability

NVMe over Fabrics or NVMe-oF (including NVMe/FC and NVMe/TCP) is supported with Oracle Linux 8.4 with Asymmetric Namespace Access (ANA), which is required for surviving storage failovers (SFOs) on the ONTAP array. ANA is the asymmetric logical unit access (ALUA) equivalent in the NVMe-oF environment, and is currently implemented with in-kernel NVMe Multipath. This topic details how to enable NVMe-oF with in-kernel NVMe Multipath using ANA on Oracle Linux 8.4 with ONTAP as the target.

You can use the configuration settings provided in this procedure to configure cloud clients connected to Cloud Volumes ONTAP and Amazon FSx for ONTAP.

Features

- Oracle Linux 8.4 has in-kernel NVMe multipath enabled by default for NVMe namepsaces.
- With Oracle Linux 8.4, `nvme-fc auto-connect` scripts are included in the native `nvme-cli` package. You can use these native auto-connect scripts instead of installing external vendor provided outbox auto-connect scripts.
- With Oracle Linux 8.4, a native `udev` rule is provided as part of the `nvme-cli` package which enables round-robin load balancing for NVMe multipath. Therefore, you do not need to manually create this rule anymore.
- With Oracle Linux 8.4, both NVMe and SCSI traffic can be run on the same host. This is the commonly deployed host configuration. You can configure dm-multipath as usual for SCSI LUNs resulting in mpath devices and also use NVMe multipath to configure NVMe-oF multipath devices (for example, `/dev/nvmeXnY`) on the host.
- With Oracle Linux 8.4, the NetApp plugin in the native `nvme-cli` package is capable of displaying ONTAP details as well as ONTAP namespaces.

Known limitations

SAN booting using the NVMe-oF protocol is currently not supported.

Configuration requirements

Refer to the NetApp Interoperability Matrix (IMT) for exact details on supported configurations.

Enable NVMe/FC

Steps

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

```
# uname -r
5.4.17-2102.206.1.el8uek.x86_64
```

2. Install the `nvme-cli` package.

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

3. On the Oracle Linux 8.4 host, check the hostnqn string at `/etc/nvme/hostnqn` and verify that it matches the hostnqn string for the corresponding subsystem on the ONTAP array.

```
# cat /etc/nvme/hostnqn
nqn.2014-08.org.nvmexpress:uuid:8b43c7c6-e98d-4cc7-a699-d66a69aa714e
::> vserver nvme subsystem host show -vserver vs_coexistance_2

Vserver         Subsystem Host NQN
-------
------------------------------------------------------------------------
vs_coexistance_2 nvme_1   nqn.2014-08.org.nvmexpress:uuid:753881b6-3163-
46f9-8145-0d1653d99389
```

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

4. Reboot the host.

If you intend to run both NVMe and SCSI traffic on the same Oracle Linux 8.4 host, NetApp recommends using the in-kernel NVMe multipath for ONTAP namespaces and dm-multipath for ONTAP LUNs respectively. This also means the ONTAP namespaces should be blacklisted in 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 the `systemctl restart multipathd` command to let the new setting take effect.

Configuring the Broadcom FC adapter for NVMe/FC

Steps

1. Verify that you are using the supported adapter. For the current list of supported adapters, see the Interoperability Matrix Tool.

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

```
# cat /sys/class/scsi_host/host*/fwrev
14.0.505.11, sli-4:2:c
14.0.505.11, 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 can see the target LIFs.

```
# cat /sys/class/fc_host/host*/port_name
0x100000109b213a00
0x100000109b2139ff

# 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 x100000109b213a00 WWNN x200000109b213a00 DID
x031700     ONLINE
NVME RPORT WWPN x208cd039ea243510 WWNN x208bd039ea243510 DID x03180a
TARGET DISCSRVC ONLINE
NVME RPORT WWPN x2090d039ea243510 WWNN x208bd039ea243510 DID x03140a
TARGET DISCSRVC ONLINE

NVME Statistics
LS: Xmt 000000000e Cmpl 000000000e Abort 00000000
LS XMIT: Err 00000000 CMPL: xb 00000000 Err 00000000
Total FCP Cmpl 0000000000079efc Issue 0000000000079eeb OutIO
fffffffffffffef
abort 00000002 noxri 00000000 nondlp 00000000 qdepth 00000000 wqerr
00000000 err   00000000
FCP CMPL: xb 00000002 Err 00000004

NVME Initiator Enabled
XRI Dist lpfc0 Total 6144 IO 5894 ELS 250
NVME LPORT lpfc0 WWPN x100000109b2139ff WWNN x200000109b2139ff DID
x031300 ONLINE
NVME RPORT WWPN x208ed039ea243510 WWNN x208bd039ea243510 DID x03230c
TARGET DISCSRVC ONLINE
NVME RPORT WWPN x2092d039ea243510 WWNN x208bd039ea243510 DID x03120c
TARGET DISCSRVC ONLINE

NVME Statistics
LS: Xmt 000000000e Cmpl 000000000e Abort 00000000
LS XMIT: Err 00000000 CMPL: xb 00000000 Err 00000000
Total FCP Cmpl 0000000000029ba0 Issue 0000000000029ba2 OutIO
0000000000000002
abort 00000002 noxri 00000000 nondlp 00000000 qdepth 00000000 wqerr
00000000 err 00000000
FCP CMPL: xb 00000002 Err 00000004
```

Enabling 1MB I/O size

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

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

Steps

1. Set the `lpfc_sg_seg_cnt` parameter to 256:

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

You should see an output similar to the following example:

```
options lpfc lpfc_sg_seg_cnt=256
```

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

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

Configure the Marvell/QLogic FC adapter for NVMe/FC

The native inbox qla2xxx driver included in the OL 8.4 GA kernel has the latest upstream fixes. These fixes 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:v9.08.02 DVR:v10.02.00.103-k
QLE2742 FW:v9.08.02 DVR:v10.02.00.103-k
```

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

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

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 is able to fetch 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. Similarly, verify that other NVMe/TCP initiator-target LIF combinations are able to successfully fetch discovery log page data.
   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. Now run the `nvme connect-all` command across all the supported NVMe/TCP initiator-target LIFs across the nodes. Make sure you provide a longer `ctrl_loss_tmo` timer period (30 minutes or more, which can be set adding `-l 1800`) during `connect-all` so that it would retry for a longer period in the event of a path loss.
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/FC

Steps

1. Verify the following NVMe/FC settings on the Oracle Linux 8.4 host:

```
# 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 correctly discoverd on the host:

```
# nvme list
Node                  SN              Model
Namespace
------------------------------------------------------------------------
-----------------
/dev/nvme0n1     814vWBNRwf9HAAAAAAAB  NetApp ONTAP Controller
1
/dev/nvme0n2     814vWBNRwf9HAAAAAAAB  NetApp ONTAP Controller
2
/dev/nvme0n3     814vWBNRwf9HAAAAAAAB  NetApp ONTAP Controller
3

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

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

```
# nvme list-subsys /dev/nvme0n1
nvme-subsys0 - NQN=nqn.1992-
08.com.netapp:sn.5f5f2c4aa73b11e9967e00a098df41bd:subsystem.nvme_ss_ol_1
\
+- nvme0 fc traddr=nn-0x203700a098dfdd91:pn-0x203800a098dfdd91
host_traddr=nn-0x200000109b1c1204:pn-0x100000109b1c1204 live non-
optimized
+- nvme1 fc traddr=nn-0x203700a098dfdd91:pn-0x203900a098dfdd91
host_traddr=nn-0x200000109b1c1204:pn-0x100000109b1c1204 live non-
optimized
+- 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 that the NetApp plug-in displays correct values for each ONTAP namespace devices.

```
# nvme netapp ontapdevices -o column
Device                  Vserver          Namespace Path
----------------------- ------------------------------
------------------------------------------------------------------------
--------- --
/dev/nvme0n1      vs_ol_nvme
/vol/ol_nvme_vol_1_1_0/ol_nvme_ns
/dev/nvme0n2      vs_ol_nvme
/vol/ol_nvme_vol_1_0_0/ol_nvme_ns
/dev/nvme0n3      vs_ol_nvme
/vol/ol_nvme_vol_1_1_1/ol_nvme_ns

NSID        UUID                                          Size
------------------------------------------------------------------
1          72b887b1-5fb6-47b8-be0b-33326e2542e2   85.90GB
2          04bf9f6e-9031-40ea-99c7-a1a61b2d7d08   85.90GB
3          264823b1-8e03-4155-80dd-e904237014a4   85.90GB
```

```
# nvme netapp ontapdevices -o json
{
"ONTAPdevices" : [
    {
        "Device" : "/dev/nvme0n1",
        "Vserver" : "vs_ol_nvme",
        "Namespace_Path" : "/vol/ol_nvme_vol_1_1_0/ol_nvme_ns",
        "NSID" : 1,
        "UUID" : "72b887b1-5fb6-47b8-be0b-33326e2542e2",
        "Size" : "85.90GB",
        "LBA_Data_Size" : 4096,
        "Namespace_Size" : 20971520
    },
    {
        "Device" : "/dev/nvme0n2",
        "Vserver" : "vs_ol_nvme",
        "Namespace_Path" : "/vol/ol_nvme_vol_1_0_0/ol_nvme_ns",
        "NSID" : 2,
        "UUID" : "04bf9f6e-9031-40ea-99c7-a1a61b2d7d08",
        "Size" : "85.90GB",
        "LBA_Data_Size" : 4096,
        "Namespace_Size" : 20971520
      },
      {
         "Device" : "/dev/nvme0n3",
         "Vserver" : "vs_ol_nvme",
         "Namespace_Path" : "/vol/ol_nvme_vol_1_1_1/ol_nvme_ns",
         "NSID" : 3,
         "UUID" : "264823b1-8e03-4155-80dd-e904237014a4",
         "Size" : "85.90GB",
         "LBA_Data_Size" : 4096,
         "Namespace_Size" : 20971520
       },
  ]
}
```

Known issues

The NVMe-oF host configuration for OL 8.4 with ONTAP has the following known issues:

NetApp Bug ID	Title	Description
1517321	Oracle Linux 8.4 NVMe-oF hosts create duplicate Persistent Discovery Controllers	On Oracle Linux 8.4 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 Oracle Linux 8.4 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.

NVMe/FC Host Configuration for Oracle Linux 8.3 with ONTAP

You can configure NVMe over Fibre Channel (NVMe/FC) on initiator hosts running Oracle Linux 8.3 and ONTAP as the target.

Supportability

NVMe over Fabrics or NVMe-oF (including NVMe/FC) is supported with Oracle Linux 8.3 with Asymmetric Namespace Access (ANA) required for surviving storage failovers (SFOs) on the ONTAP array. ANA is the ALUA equivalent in the NVMe-oF environment and is currently implemented with in-kernel NVMe Multipath. Using this procedure, you can enable NVMe-oF with in-kernel NVMe Multipath using ANA on OL 8.3 and ONTAP as the target.

You can use the configuration settings provided in this procedure to configure cloud clients connected to Cloud Volumes ONTAP and Amazon FSx for ONTAP.

Features

- Oracle Linux 8.3 has in-kernel NVMe multipath enabled by default for NVMe namespaces.
- With Oracle Linux 8.3, `nvme-fc auto-connect` scripts are included in the native nvme-cli package. You can use these native auto-connect scripts instead of installing external vendor provided outbox auto-connect scripts.
- With Oracle Linux 8.3, a native `udev` rule is provided as part of the `nvme-cli` package which enables round-robin load balancing for NVMe multipath. Therefore, you do not need to manually create this rule anymore.
- With Oracle Linux 8.3, both NVMe and SCSI traffic can be run on the same host. This is the commonly deployed host configuration. You can configure dm-multipath as usual for SCSI LUNs resulting in mpath devices and also use NVMe multipath to configure NVMe-oF multipath devices (for example, `/dev/nvmeXnY`) on the host.
- With Oracle Linux 8.3, the NetApp plugin in the native `nvme-cli` package is capable of displaying ONTAP details as well as ONTAP namespaces.

Known limitations

SAN booting using the NVMe-oF protocol is currently not supported.

Configuration requirements

Refer to the Interoperability Matrix Tool (IMT) for the current list of supported configurations.

Enable NVMe/FC with Oracle Linux 8.3

Steps

1. Install Oracle Linux 8.3 GA on the server. After the installation is complete, verify that you are running the specified Oracle Linux 8.3 GA kernel. See the Interoperability Matrix Tool for the current list of supported versions.

```
# uname -r
5.4.17-2011.7.4.el8uek.x86_64
```

2. Install the `nvme-cli` package.

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

nvme-cli-1.12-2.el8.x86_64_
```

3. On the Oracle Linux 8.3 host, check the hostnqn string at `/etc/nvme/hostnqn` and verify that it matches the `hostnqn` string for the corresponding subsystem on the ONTAP array.

```
#cat /etc/nvme/hostnqn
nqn.2014-08.org.nvmexpress:uuid:446c21ab-f4c1-47ed-9a8f-1def96f3fed2

::> vserver nvme subsystem host show -vserver vs_coexistance_2
Vserver   Subsystem      Host NQN
------- ---------
------------------------------------------------------------
vs_coexistance_2 nvme_1 nqn.2014-08.org.nvmexpress:uuid:446c21ab-f4c1-
47ed-9a8f-1def96f3fed2
```

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

4. Reboot the host.

If you intend to run both NVMe and SCSI traffic on the same Oracle Linux 8.3 host, NetApp recommends using the in-kernel NVMe multipath for ONTAP namespaces and `dm-multipath` for ONTAP LUNs respectively. This also means the ONTAP namespaces should be blacklisted in `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 the *systemctl restart multipathd* command to let the new setting take effect.

Configure the Broadcom FC adapter for NVMe/FC

Steps

1. Verify that you are using the supported adapter. For the current list of supported adapters, see the Interoperability Matrix Tool.

```
#cat /sys/class/scsi_host/host*/modelname
LPe36002-M2
LPe36002-M2
```

```
#cat /sys/class/scsi_host/host*/modeldesc
Emulex LPe36002-M64 2-Port 64Gb Fibre Channel Adapter
Emulex LPe36002-M64 2-Port 64Gb Fibre Channel Adapter
```

2. Verify that you are using the recommended Broadcom lpfc firmware and inbox driver. For the current list of supported adapter drivers and firmware versions, see the Interoperability Matrix Tool.

```
#cat /sys/class/scsi_host/host*/fwrev
12.8.351.49, sli-4:6:d
12.8.351.49, sli-4:6:d
```

```
#cat /sys/module/lpfc/version
0:12.6.0.3
```

3. Verify that the `lpfc_enable_fc4_type` parameter 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
0x100000109bf0447b
0x100000109bf0447c
```

```
#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 x100000109bf0447b WWNN x200000109bf0447b DID
x022400 ONLINE
NVME RPORT WWPN x20e1d039ea243510 WWNN x20e0d039ea243510 DID x0a0314
TARGET DISCSRVC ONLINE
NVME RPORT WWPN x20e4d039ea243510 WWNN x20e0d039ea243510 DID x0a0713
TARGET DISCSRVC ONLINE

NVME Statistics
LS: Xmt 00000003b6 Cmpl 00000003b6 Abort 00000000
LS XMIT: Err 00000000 CMPL: xb 00000000 Err 00000000
Total FCP Cmpl 00000000be1425e8 Issue 00000000be1425f2 OutIO
000000000000000a
abort 00000251 noxri 00000000 nondlp 00000000 qdepth 00000000 wqerr
00000000 err 00000000
FCP CMPL: xb 00000c5b Err 0000d176

NVME Initiator Enabled
XRI Dist lpfc1 Total 6144 IO 5894 ELS 250
NVME LPORT lpfc1 WWPN x100000109bf0447c WWNN x200000109bf0447c DID
x021600 ONLINE
NVME RPORT WWPN x20e2d039ea243510 WWNN x20e0d039ea243510 DID x0a0213
TARGET DISCSRVC ONLINE
NVME RPORT WWPN x20e3d039ea243510 WWNN x20e0d039ea243510 DID x0a0614
TARGET DISCSRVC ONLINE

NVME Statistics
LS: Xmt 0000000419 Cmpl 0000000419 Abort 00000000
LS XMIT: Err 00000000 CMPL: xb 00000000 Err 00000000
Total FCP Cmpl 00000000be37ff65 Issue 00000000be37ff84 OutIO
000000000000001f
abort 0000025a noxri 00000000 nondlp 00000000 qdepth 00000000 wqerr
00000000 err 00000000
FCP CMPL: xb 00000c89 Err 0000cd87
```

Enable 1MB I/O size

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

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

Steps

1. Set the `lpfc_sg_seg_cnt` parameter to 256:

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

You should see an output similar to the following example:

```
options lpfc lpfc_sg_seg_cnt=256
```

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

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

Configure the Marvell/QLogic FC adapter for NVMe/FC

The native inbox qla2xxx driver included in the OL 8.3 GA kernel has the latest upstream fixes. These fixes 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:v9.10.11 DVR:v10.01.00.25-k
QLE2742 FW:v9.10.11 DVR:v10.01.00.25-k
```

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

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

Validate NVMe/FC

Steps

1. Verify the following NVMe/FC settings on the Oracle Linux 8.3 host.

```
#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 correctly discoverd on the host.

```
# nvme list
Node         SN                    Model                    Namespace Usage
Format FW Rev
---------------- --------------------
---------------------------------------- --------- ------------------
/dev/nvme0n1 81Ec-JRMlkL9AAAAAAAB NetApp ONTAP Controller 1        37.58
GB / 37.58 GB 4 KiB + 0 B FFFFFFFF
/dev/nvme0n10 81Ec-JRMlkL9AAAAAAAB NetApp ONTAP Controller 10      37.58
GB / 37.58 GB 4 KiB + 0 B FFFFFFFF
/dev/nvme0n11 81Ec-JRMlkL9AAAAAAAB NetApp ONTAP Controller 11      37.58
GB / 37.58 GB 4 KiB + 0 B FFFFFFFF
/dev/nvme0n12 81Ec-JRMlkL9AAAAAAAB NetApp ONTAP Controller 12      37.58
GB / 37.58 GB 4 KiB + 0 B FFFFFFFF
/dev/nvme0n13 81Ec-JRMlkL9AAAAAAAB NetApp ONTAP Controller 13      37.58
GB / 37.58 GB 4 KiB + 0 B FFFFFFFF
/dev/nvme0n14 81Ec-JRMlkL9AAAAAAAB NetApp ONTAP Controller 14      37.58
GB / 37.58 GB 4 KiB + 0 B FFFFFFFF
/dev/nvme0n15 81Ec-JRMlkL9AAAAAAAB NetApp ONTAP Controller 15      37.58
GB / 37.58 GB 4 KiB + 0 B FFFFFFFF
/dev/nvme0n16 81Ec-JRMlkL9AAAAAAAB NetApp ONTAP Controller 16      37.58
GB / 37.58 GB 4 KiB + 0 B FFFFFFFF
/dev/nvme0n17 81Ec-JRMlkL9AAAAAAAB NetApp ONTAP Controller 17      37.58
GB / 37.58 GB 4 KiB + 0 B FFFFFFFF
/dev/nvme0n18 81Ec-JRMlkL9AAAAAAAB NetApp ONTAP Controller 18      37.58
GB / 37.58 GB 4 KiB + 0 B FFFFFFFF
/dev/nvme0n19 81Ec-JRMlkL9AAAAAAAB NetApp ONTAP Controller 19      37.58
GB / 37.58 GB 4 KiB + 0 B FFFFFFFF
/dev/nvme0n2 81Ec-JRMlkL9AAAAAAAB NetApp ONTAP Controller 2        37.58
GB / 37.58 GB 4 KiB + 0 B FFFFFFFF
/dev/nvme0n20 81Ec-JRMlkL9AAAAAAAB NetApp ONTAP Controller 20      37.58
GB / 37.58 GB 4 KiB + 0 B FFFFFFFF
/dev/nvme0n3 81Ec-JRMlkL9AAAAAAAB NetApp ONTAP Controller 3        37.58
GB / 37.58 GB 4 KiB + 0 B FFFFFFFF
/dev/nvme0n4 81Ec-JRMlkL9AAAAAAAB NetApp ONTAP Controller 4        37.58
GB / 37.58 GB 4 KiB + 0 B FFFFFFFF
/dev/nvme0n5 81Ec-JRMlkL9AAAAAAAB NetApp ONTAP Controller 5        37.58
GB / 37.58 GB 4 KiB + 0 B FFFFFFFF
/dev/nvme0n6 81Ec-JRMlkL9AAAAAAAB NetApp ONTAP Controller 6        37.58
GB / 37.58 GB 4 KiB + 0 B FFFFFFFF
/dev/nvme0n7 81Ec-JRMlkL9AAAAAAAB NetApp ONTAP Controller 7        37.58
GB / 37.58 GB 4 KiB + 0 B FFFFFFFF
/dev/nvme0n8 81Ec-JRMlkL9AAAAAAAB NetApp ONTAP Controller 8        37.58
GB / 37.58 GB 4 KiB + 0 B FFFFFFFF
/dev/nvme0n9 81Ec-JRMlkL9AAAAAAAB NetApp ONTAP Controller 9        37.58
GB / 37.58 GB 4 KiB + 0 B FFFFFFFF
```

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

```
# nvme list-subsys /dev/nvme0n1
nvme-subsys0 - NQN=nqn.1992-
08.com.netapp:sn.b79f5c6e4d0911edb3a0d039ea243511:subsystem.nvme_1
\ +
+- nvme214 fc traddr=nn-0x20e0d039ea243510:pn-0x20e4d039ea243510
host_traddr=nn-0x200000109bf0447b:pn-0x100000109bf0447b live non-
optimized
+- nvme219 fc traddr=nn-0x20e0d039ea243510:pn-0x20e2d039ea243510
host_traddr=nn-0x200000109bf0447c:pn-0x100000109bf0447c live optimized
+- nvme223 fc traddr=nn-0x20e0d039ea243510:pn-0x20e1d039ea243510
host_traddr=nn-0x200000109bf0447b:pn-0x100000109bf0447b live optimized
+- nvme228 fc traddr=nn-0x20e0d039ea243510:pn-0x20e3d039ea243510
host_traddr=nn-0x200000109bf0447c:pn-0x100000109bf0447c live non-
optimized
```

4. Verify the NetApp plug-in displays correct values for each ONTAP namespace devices.

```
#nvme netapp ontapdevices -o column
Device      Vserver         Namespace Path             NSID UUID
Size
--------------- ------------------------
------------------------------------------------- ---- ---------
/dev/nvme0n1 LPE36002_ASA_BL /vol/fcnvme_1_0_0/fcnvme_ns 1 ae10e16d-
1fa4-49c2-8594-02bf6f3b1af1 37.58GB
/dev/nvme0n10 LPE36002_ASA_BL /vol/fcnvme_1_0_9/fcnvme_ns 10 2cf00782-
e2bf-40fe-8495-63e4501727cd 37.58GB
/dev/nvme0n11 LPE36002_ASA_BL /vol/fcnvme_1_1_9/fcnvme_ns 11 fbefbe6c-
90fe-46a2-8a51-47bad9e2eb95 37.58GB
/dev/nvme0n12 LPE36002_ASA_BL /vol/fcnvme_1_1_0/fcnvme_ns 12 0e9cc8fa-
d821-4f1c-8944-3003dcded864 37.58GB
/dev/nvme0n13 LPE36002_ASA_BL /vol/fcnvme_1_1_1/fcnvme_ns 13 31f03b13-
aaf9-4a3f-826b-d126ef007991 37.58GB
/dev/nvme0n14 LPE36002_ASA_BL /vol/fcnvme_1_1_8/fcnvme_ns 14 bcf4627c-
5bf9-4a51-a920-5da174ec9876 37.58GB
/dev/nvme0n15 LPE36002_ASA_BL /vol/fcnvme_1_1_7/fcnvme_ns 15 239fd09d-
11db-46a3-8e94-b5ebe6eb2421 37.58GB
/dev/nvme0n16 LPE36002_ASA_BL /vol/fcnvme_1_1_2/fcnvme_ns 16 1d8004df-
f2e8-48c8-8ccb-ce45f18a15ae 37.58GB
/dev/nvme0n17 LPE36002_ASA_BL /vol/fcnvme_1_1_3/fcnvme_ns 17 4f7afbcf-
3ace-4e6c-9245-cbf5bd155ef4 37.58GB
/dev/nvme0n18 LPE36002_ASA_BL /vol/fcnvme_1_1_4/fcnvme_ns 18 b022c944-
6ebf-4986-a28c-8d9e8ec130c9 37.58GB
/dev/nvme0n19 LPE36002_ASA_BL /vol/fcnvme_1_1_5/fcnvme_ns 19 c457d0c7-
bfea-43aa-97ef-c749d8612a72 37.58GB
/dev/nvme0n2 LPE36002_ASA_BL /vol/fcnvme_1_0_1/fcnvme_ns 2 d2413d8b-
e82e-4412-89d3-c9a751ed7716 37.58GB
/dev/nvme0n20 LPE36002_ASA_BL /vol/fcnvme_1_1_6/fcnvme_ns 20 650e0d93-
967d-4415-874a-36bf9c93c952 37.58GB
/dev/nvme0n3 LPE36002_ASA_BL /vol/fcnvme_1_0_2/fcnvme_ns 3 09d89d9a-
7835-423f-93e7-f6f3ece1dcbc 37.58GB
/dev/nvme0n4 LPE36002_ASA_BL /vol/fcnvme_1_0_3/fcnvme_ns 4 d8e99326-
a67c-469f-b3e9-e0e4a38c8a76 37.58GB
/dev/nvme0n5 LPE36002_ASA_BL /vol/fcnvme_1_0_4/fcnvme_ns 5 c91c71f9-
3e04-4844-b376-30acab6311f1 37.58GB
/dev/nvme0n6 LPE36002_ASA_BL /vol/fcnvme_1_0_5/fcnvme_ns 6 4e8b4345-
e5b1-4aa4-ae1a-adf0de2879ea 37.58GB
/dev/nvme0n7 LPE36002_ASA_BL /vol/fcnvme_1_0_6/fcnvme_ns 7 ef715a16-
a946-4bb8-8735-74f214785874 37.58GB
/dev/nvme0n8 LPE36002_ASA_BL /vol/fcnvme_1_0_7/fcnvme_ns 8 4b038502-
966c-49fd-9631-a17f23478ae0 37.58GB
/dev/nvme0n9 LPE36002_ASA_BL /vol/fcnvme_1_0_8/fcnvme_ns 9 f565724c-
992f-41f6-83b5-da1fe741c09b 37.58GB
```

```
#nvme netapp ontapdevices -o json
{
"ONTAPdevices" : [
{
"Device" : "/dev/nvme0n1",
"Vserver" : "LPE36002_ASA_BL",
"Namespace_Path" : "/vol/fcnvme_1_0_0/fcnvme_ns",
"NSID" : 1,
"UUID" : "ae10e16d-1fa4-49c2-8594-02bf6f3b1af1",
"Size" : "37.58GB",
"LBA_Data_Size" : 4096,
"Namespace_Size" : 9175040
},
{
"Device" : "/dev/nvme0n10",
"Vserver" : "LPE36002_ASA_BL",
"Namespace_Path" : "/vol/fcnvme_1_0_9/fcnvme_ns",
"NSID" : 10,
"UUID" : "2cf00782-e2bf-40fe-8495-63e4501727cd",
"Size" : "37.58GB",
"LBA_Data_Size" : 4096,
"Namespace_Size" : 9175040
},
{
"Device" : "/dev/nvme0n11",
"Vserver" : "LPE36002_ASA_BL",
"Namespace_Path" : "/vol/fcnvme_1_1_9/fcnvme_ns",
"NSID" : 11,
"UUID" : "fbefbe6c-90fe-46a2-8a51-47bad9e2eb95",
"Size" : "37.58GB",
"LBA_Data_Size" : 4096,
"Namespace_Size" : 9175040
},
{
"Device" : "/dev/nvme0n12",
"Vserver" : "LPE36002_ASA_BL",
"Namespace_Path" : "/vol/fcnvme_1_1_0/fcnvme_ns",
"NSID" : 12,
"UUID" : "0e9cc8fa-d821-4f1c-8944-3003dcded864",
"Size" : "37.58GB",
"LBA_Data_Size" : 4096,
"Namespace_Size" : 9175040
},
{
"Device" : "/dev/nvme0n13",
```

```
"Vserver" : "LPE36002_ASA_BL",
"Namespace_Path" : "/vol/fcnvme_1_1_1/fcnvme_ns",
"NSID" : 13,
"UUID" : "31f03b13-aaf9-4a3f-826b-d126ef007991",
"Size" : "37.58GB",
"LBA_Data_Size" : 4096,
"Namespace_Size" : 9175040
},
```


Known issues

The NVMe-oF host configuration for OL 8.3 with ONTAP has the following known issues:

NetApp Bug ID	Title	Description
1517321	Oracle Linux 8.3 NVMe-oF Hosts create duplicate Persistent Discovery Controllers	On Oracle Linux 8.3 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 Oracle Linux 8.3 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.

NVMe/FC Host Configuration for Oracle Linux 8.2 with ONTAP

You can configure NVMe over Fibre Channel (NVMe/FC) on initiator hosts running Oracle Linux 8.2 and ONTAP as the target.

Supportability

Beginning with ONTAP 9.6, NVMe/FC is supported for Oracle Linux 8.2. The Oracle Linux 8.2 host can run both NVMe/FC and FCP traffic through the same fibre channel (FC) initiator adapter ports. See the Hardware Universe for a list of supported FC adapters and controllers. For the current list of supported configurations see the Interoperability Matrix Tool.

> You can use the configuration settings provided in this procedure to configure cloud clients connected to Cloud Volumes ONTAP and Amazon FSx for ONTAP.

Known limitations

SAN booting using the NVMe-oF protocol is currently not supported.

Enable NVMe/FC

1. Install Oracle Linux 8.2 on the server.
2. After the installation is complete, verify that you are running the supported Unbreakable Enterprise kernel. See the Interoperability Matrix Tool.

```
# uname -r
5.4.17-2011.1.2.el8uek.x86_64
```

3. Upgrade the nvme-cli package. The native nvme-cli package contains the NVMe/FC auto-connect scripts, ONTAP udev rule which enables round-robin load balancing for NVMe Multipath as well as the NetApp plug-in for ONTAP namespaces.

```
# rpm -qa|grep nvme-cli
nvme-cli-1.9-5.el8.x86_64
```

4. On the Oracle Linux 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_ol_nvme
Vserver  Subsystem Host NQN
---------- ---------------
------------------------------------------------------------
vs_ol_nvme
              nvme_ss_ol_1
                                  nqn.2014-
08.org.nvmexpress:uuid:9ed5b327-b9fc-4cf5-97b3-1b5d986345d1
```

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

Configure the Broadcom FC Adapter for NVMe/FC

1. Verify that you are using the supported adapter. For the current list of supported adapters, see the Interoperability Matrix Tool.

```
# 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. NVMe support in lpfc is already enabled by default:

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

Newer lpfc drivers (both inbox and outbox) have lpfc_enable_fc4_type default set to 3. Therefore, you do not need to set this explicitly in the /etc/modprobe.d/lpfc.conf.

3. Verify that the NVMe/FC initiator ports are enabled and able to see the target ports, and all are up and running.

In the example below, only a single initiator port has been enabled and connected with two target LIFs as seen in the below output:

```
# 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
```

Validate NVMe/FC

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
```

In the above example, two namespaces are mapped to the Oracle Linux 8.2 ANA host. These are visible through four target LIFs: two local node LIFs and two other partner/remote node LIFs. This setup shows as two ANA Optimized and two ANA Inaccessible paths for each namespace on the host.

2. Verify that the namespaces are created.

```
# nvme list
Node                  SN
Model                                                Namespace Usage
Format          FW Rev
--------------------   ----------------------------------------
-------------------------------------------------- -----------------
-------------------------------- ---------------- ---------------
/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_ss_ol_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.

```
# nvme netapp ontapdevices -o column
Device                 Vserver                         Namespace Path
NSID    UUID
Size
---------------------- ------------------------------
-------------------------------------------------------------------------
--------- ------------------------------------------------------------
---------
/dev/nvme0n1      vs_ol_nvme
/vol/ol_nvme_vol_1_1_0/ol_nvme_ns             1          72b887b1-5fb6-
47b8-be0b-33326e2542e2   85.90GB
/dev/nvme0n2      vs_ol_nvme
/vol/ol_nvme_vol_1_0_0/ol_nvme_ns             2          04bf9f6e-9031-
40ea-99c7-a1a61b2d7d08    85.90GB
/dev/nvme0n3      vs_ol_nvme
/vol/ol_nvme_vol_1_1_1/ol_nvme_ns             3          264823b1-8e03-
4155-80dd-e904237014a4  85.90GB

# nvme netapp ontapdevices -o json
{
"ONTAPdevices" : [
    {
        "Device" : "/dev/nvme0n1",
        "Vserver" : "vs_ol_nvme",
        "Namespace_Path" : "/vol/ol_nvme_vol_1_1_0/ol_nvme_ns",
        "NSID" : 1,
        "UUID" : "72b887b1-5fb6-47b8-be0b-33326e2542e2",
        "Size" : "85.90GB",
```

```
        "LBA_Data_Size" : 4096,
        "Namespace_Size" : 20971520
    },
    {
        "Device" : "/dev/nvme0n2",
        "Vserver" : "vs_ol_nvme",
        "Namespace_Path" : "/vol/ol_nvme_vol_1_0_0/ol_nvme_ns",
        "NSID" : 2,
        "UUID" : "04bf9f6e-9031-40ea-99c7-a1a61b2d7d08",
        "Size" : "85.90GB",
        "LBA_Data_Size" : 4096,
        "Namespace_Size" : 20971520
      },
      {
         "Device" : "/dev/nvme0n3",
         "Vserver" : "vs_ol_nvme",
         "Namespace_Path" : "/vol/ol_nvme_vol_1_1_1/ol_nvme_ns",
         "NSID" : 3,
         "UUID" : "264823b1-8e03-4155-80dd-e904237014a4",
         "Size" : "85.90GB",
         "LBA_Data_Size" : 4096,
         "Namespace_Size" : 20971520
       },
  ]
}
```

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

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

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

Steps

1. Set the `lpfc_sg_seg_cnt` parameter to 256:

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

You should see an output similar to the following example:

```
options lpfc lpfc_sg_seg_cnt=256
```

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

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

NVMe/FC Host Configuration for Oracle Linux 8.1 with ONTAP

You can configure NVMe over Fibre Channel (NVMe/FC) on initiator hosts running Oracle Linux 8.1 and ONTAP as the target.

Supportability

Beginning with ONTAP 9.6, NVMe/FC is supported for Oracle Linux 8.1. The Oracle Linux 8.1 host can run both NVMe and SCSI traffic through the same fibre channel (FC) initiator adapter ports. Note that the Broadcom initiator can serve both NVMe/FC and FCP traffic through the same FC adapter ports. See the Hardware Universe for a list of supported FC adapters and controllers. For the current list of supported configurations see the Interoperability Matrix Tool.

You can use the configuration settings provided in this procedure to configure cloud clients connected to Cloud Volumes ONTAP and Amazon FSx for ONTAP.

Known limitations

- Native NVMe/FC auto-connect scripts are not available in the nvme-cli package. Use the HBA vendor provided external auto-connect scripts.
- By default, round-robin load balancing is not enabled in NVMe Multipath. You must write a udev rule to enable this functionality. Steps are provided in the section on Enabling NVMe/FC on Oracle Linux 8.1.
- There is no sanlun support for NVMe/FC and, as a consequence, no Linux Host Utilities support for NVMe/FC on Oracle Linux 8.1. Use the ONTAP command output available as part of the NetApp plug-in included in the native nvme-cli.
- SAN booting using the NVMe-oF protocol is currently not supported.

Enable NVMe/FC

1. Install Oracle Linux 8.1 on the server.
2. After the installation is complete, verify that you are running the supported Unbreakable Enterprise kernel. See the Interoperability Matrix Tool.

```
# uname -r
5.4.17-2011.0.7.el8uek.x86_64
```

3. Upgrade the nvme-cli package.

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

4. Add the string below 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.

```
# cat /lib/udev/rules.d/71-nvme-iopolicy-netapp-ONTAP.rules
# Enable round-robin for NetApp ONTAP
ACTION=="add", SUBSYSTEM=="nvme-subsystem", ATTR{model}=="NetApp ONTAP
Controller", ATTR{iopolicy}="round-robin"
```

5. On the Oracle Linux 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
------- ---------
------------------------------------------------------------
Oracle Linux_141_nvme_ss_10_0
nqn.2014-08.org.nvmexpress:uuid:75953f3b-77fe-4e03-bf3c-09d5a156fbcd
```

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

6. Reboot the host.

Configure the Broadcom FC Adapter for NVMe/FC

1. Verify that you are using the supported adapter. For the current list of supported adapters, see the Interoperability Matrix Tool.

```
# 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. NVMe support in lpfc is already enabled by default:

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

Newer lpfc drivers (both inbox and outbox) have lpfc_enable_fc4_type default set to 3. Therefore, you do not need to set this explicitly in the /etc/modprobe.d/lpfc.conf.

3. Next, install the recommended lpfc auto-connect scripts:

```
# rpm -ivh nvmefc-connect-12.6.61.0-1.noarch.rpm
```

4. Verify that the auto-connect scripts are installed.

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

5. 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
```

6. Verify that the NVMe/FC initiator ports are enabled and able to see the target ports, and all are up and running.

In the example below, only a single initiator port has been enabled and connected with two target LIFs as seen in the below output:

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

NVME Initiator Enabled
XRI Dist lpfc0 Total 6144 NVME 2947 SCSI 2947 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
```

Validate NVMe/FC

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
```

   In the above example, two namespaces are mapped to the Oracle Linux 8.1 ANA host. These are visible through four target LIFs: two local node LIFs and two other partner/remote node LIFs. This setup shows as two ANA Optimized and two ANA Inaccessible paths for each namespace on the host.

2. Verify that the namespaces are created.

```
# nvme list
Node                 SN                                          Model
Namespace Usage                              Format           FW Rev
-------------------- ----------------------------------------
---------------------------------------- ----------------
------------------------------  ----------------  -------------
/dev/nvme0n1  814vWBNRwfBCAAAAAAAB NetApp ONTAP Controller        2
107.37 GB / 107.37 GB  4 KiB + 0 B   FFFFFFFF
/dev/nvme0n2  814vWBNRwfBCAAAAAAAB NetApp ONTAP Controller        3
107.37 GB / 107.37 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.5a32407351c711eaaa4800a098df41bd:subsystem.test
\
+- nvme0 fc traddr=nn-0x207300a098dfdd91:pn-0x207400a098dfdd91
host_traddr=nn-0x200000109b1c1204:pn-0x100000109b1c1204 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/ol_157_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/ol_157_ns_10_0",
         "NSID" : 1,
         "UUID" : "55baf453-f629-4a18-9364-b6aee3f50dad",
         "Size" : "53.69GB",
         "LBA_Data_Size" : 4096,
         "Namespace_Size" : 13107200
    }
]
```

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

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

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

Steps

1. Set the `lpfc_sg_seg_cnt` parameter to 256:

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

   You should see an output similar to the following example:

   ```
   options lpfc lpfc_sg_seg_cnt=256
   ```

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

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

Oracle Linux 7

NVMe/FC Host Configuration for Oracle Linux 7.9 with ONTAP

You can configure NVMe over Fibre Channel (NVMe/FC) on initiator hosts running Oracle Linux 7.9 and ONTAP as the target.

Supportability

Beginning with ONTAP 9.6, NVMe/FC is supported for Oracle Linux 7.9. The Oracle Linux 7.9 host can run 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. For the current list of supported configurations see the Interoperability Matrix Tool.

You can use the configuration settings provided in this procedure to configure cloud clients connected to Cloud Volumes ONTAP and Amazon FSx for ONTAP.

Known limitations

- Native NVMe/FC auto-connect scripts are not available in the `nvme-cli` package. Use the HBA vendor provided external auto-connect scripts.
- By default, round-robin load balancing is not enabled in NVMe Multipath. You must write a udev rule to enable this functionality. Steps are provided in the section on Enabling NVMe/FC on Oracle Linux 7.9.
- There is no sanlun support for NVMe/FC and, as a consequence, no Linux Host Utilities support for NVMe/FC on Oracle Linux 7.9. Use the ONTAP command output available as part of the NetApp plug-in included in the native nvme-cli.
- SAN booting using the NVMe-oF protocol is currently not supported.

Enable NVMe/FC

1. Install Oracle Linux 7.9 on the server.
2. After the installation is complete, verify that you are running the supported Unbreakable Enterprise kernel. See the Interoperability Matrix Tool.

```
# uname -r
5.4.17-2011.6.2.el7uek.x86_64
```

3. Upgrade the `nvme-cli` package.

```
# rpm -qa | grep nvme-cli
nvme-cli-1.8.1-3.el7.x86_64
```

4. Add the string below 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.

```
# cat /lib/udev/rules.d/71-nvme-iopolicy-netapp-ONTAP.rules
# Enable round-robin for NetApp ONTAP
ACTION=="add", SUBSYSTEMS=="nvme-subsystem", ATTRS{model}=="NetApp ONTAP
Controller          ", ATTR{iopolicy}="round-robin"
```

5. On the Oracle Linux L 7.9 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:497ad959-e6d0-4987-8dc2-a89267400874
```

```
*> vserver nvme subsystem host show -vserver vs_nvme_10
Vserver Subsystem Host NQN
------- --------- ------------------------------------ -----------
ol_157_nvme_ss_10_0
nqn.2014-08.org.nvmexpress:uuid:497ad959-e6d0-4987-8dc2-a89267400874
```

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

6. Reboot the host.

Configure the Broadcom FC Adapter for NVMe/FC

1. Verify that you are using the supported adapter. For the current list of supported adapters, see the Interoperability Matrix Tool.

```
# 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. NVMe support in lpfc is already enabled by default:

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

Newer lpfc drivers (both inbox and outbox) have lpfc_enable_fc4_type default set to 3. Therefore, you do not need to set this explicitly in the `/etc/modprobe.d/lpfc.conf`.

3. Next, install the recommended lpfc auto-connect scripts:

```
# rpm -ivh nvmefc-connect-12.8.264.0-1.noarch.rpm
```

4. Verify that the auto-connect scripts are installed.

```
# rpm -qa | grep nvmefc
nvmefc-connect-12.8.264.0-1.noarch
```

5. 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
```

6. Verify that the NVMe/FC initiator ports are enabled and able to see the target ports, and all are up and running.

   In the example below, only a single initiator port has been enabled and connected with two target LIFs as seen in the below output:

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

NVME Initiator Enabled
XRI Dist lpfc0 Total 6144 NVME 2947 SCSI 2947 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
```

Validate NVMe/FC

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
```

   In the above example, two namespaces are mapped to the Oracle Linux 7.9 ANA host. These are visible through four target LIFs: two local node LIFs and two other partner/remote node LIFs. This setup shows as two ANA Optimized and two ANA Inaccessible paths for each namespace on the host.

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.ol_157_nvme_
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/ol_157_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/ol_157_ns_10_0",
         "NSID" : 1,
         "UUID" : "55baf453-f629-4a18-9364-b6aee3f50dad",
         "Size" : "53.69GB",
         "LBA_Data_Size" : 4096,
         "Namespace_Size" : 13107200
    }
]
```

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

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

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

Steps

1. Set the `lpfc_sg_seg_cnt` parameter to 256:

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

You should see an output similar to the following example:

```
options lpfc lpfc_sg_seg_cnt=256
```

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

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

NVMe/FC Host Configuration for Oracle Linux 7.8 with ONTAP

You can configure NVMe over Fibre Channel (NVMe/FC) on initiator hosts running Oracle Linux 7.8 and ONTAP as the target.

Supportability

Beginning with ONTAP 9.6, NVMe/FC is supported for Oracle Linux 7.8. The Oracle Linux 7.8 host can run both NVMe and SCSI traffic through the same fibre channel (FC) initiator adapter ports. Note that the Broadcom initiator can serve both NVMe/FC and FCP traffic through the same FC adapter ports. See the Hardware Universe for a list of supported FC adapters and controllers. For the current list of supported configurations see the Interoperability Matrix Tool.

You can use the configuration settings provided in this procedure to configure cloud clients connected to Cloud Volumes ONTAP and Amazon FSx for ONTAP.

Known limitations

- Native NVMe/FC auto-connect scripts are not available in the nvme-cli package. Use the HBA vendor provided external auto-connect scripts.
- By default, round-robin load balancing is not enabled in NVMe Multipath. You must write a udev rule to enable this functionality. Steps are provided in the section on Enabling NVMe/FC on Oracle Linux 7.8.
- There is no sanlun support for NVMe/FC and, as a consequence, no Linux Host Utilities support for NVMe/FC on Oracle Linux 7.8. Use the ONTAP command output available as part of the NetApp plug-in included in the native nvme-cli.
- SAN booting using the NVMe-oF protocol is currently not supported.

Enabling NVMe/FC

1. Install Oracle Linux 7.8 on the server.
2. After the installation is complete, verify that you are running the supported Unbreakable Enterprise kernel. See the Interoperability Matrix Tool.

```
# uname -r
4.14.35-1902.9.2.el7uek
```

3. Upgrade the nvme-cli package.

```
# rpm -qa | grep nvme-cli
nvme-cli-1.8.1-3.el7.x86_64
```

4. Add the string below 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.

```
# cat /lib/udev/rules.d/71-nvme-iopolicy-netapp-ONTAP.rules
# Enable round-robin for NetApp ONTAP
ACTION=="add", SUBSYSTEM=="nvme-subsystem", ATTR{model}=="NetApp ONTAP
Controller", ATTR{iopolicy}="round-robin"
```

5. On the Oracle Linux L 7.8 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
------- --------- ------------------------------------ -----------
ol_157_nvme_ss_10_0
nqn.2014-08.org.nvmexpress:uuid:75953f3b-77fe-4e03-bf3c-09d5a156fbcd
```

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

6. Reboot the host.

Configuring the Broadcom FC Adapter for NVMe/FC

1. Verify that you are using the supported adapter. For the current list of supported adapters, see the Interoperability Matrix Tool.

```
# 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. NVMe support in lpfc is already enabled by default:

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

Newer lpfc drivers (both inbox and outbox) have lpfc_enable_fc4_type default set to 3. Therefore, you do not need to set this explicitly in the /etc/modprobe.d/lpfc.conf.

3. Next, install the recommended lpfc auto-connect scripts:

```
# rpm -ivh nvmefc-connect-12.4.65.0-1.noarch.rpm
```

4. Verify that the auto-connect scripts are installed.

```
# rpm -qa | grep nvmefc
nvmefc-connect-12.4.65.0-1.noarch
```

5. 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
```

6. Verify that the NVMe/FC initiator ports are enabled and able to see the target ports, and all are up and running.

In the example below, only a single initiator port has been enabled and connected with two target LIFs as seen in the below output:

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

NVME Initiator Enabled
XRI Dist lpfc0 Total 6144 NVME 2947 SCSI 2947 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
```

Validating NVMe/FC

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
```

   In the above example, two namespaces are mapped to the Oracle Linux 7.8 ANA host. These are visible through four target LIFs: two local node LIFs and two other partner/remote node LIFs. This setup shows as two ANA Optimized and two ANA Inaccessible paths for each namespace on the host.

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.ol_157_nvme_
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/ol_157_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/ol_157_ns_10_0",
         "NSID" : 1,
         "UUID" : "55baf453-f629-4a18-9364-b6aee3f50dad",
         "Size" : "53.69GB",
         "LBA_Data_Size" : 4096,
         "Namespace_Size" : 13107200
    }
]
```

Enabling 1MB I/O size for Broadcom NVMe/FC

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

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

Steps

1. Set the `lpfc_sg_seg_cnt` parameter to 256:

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

You should see an output similar to the following example:

```
options lpfc lpfc_sg_seg_cnt=256
```

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

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

NVMe/FC Host Configuration for Oracle Linux 7.7 with ONTAP

You can configure NVMe over Fibre Channel (NVMe/FC) on initiator hosts running Oracle Linux 7.7 and ONTAP as the target.

Supportability

Beginning with ONTAP 9.6, NVMe/FC is supported for Oracle Linux 7.7. The Oracle Linux 7.7 host can run both NVMe and SCSI traffic through the same fibre channel initiator adapter ports. See the Hardware Universe for a list of supported FC adapters and controllers. For the current list of supported configurations see the Interoperability Matrix Tool.

You can use the configuration settings provided in this procedure to configure cloud clients connected to Cloud Volumes ONTAP and Amazon FSx for ONTAP.

Known limitations

- Native NVMe/FC auto-connect scripts are not available in the nvme-cli package.
  You can use the HBA vendor provided external auto-connect scripts.
- By default, round-robin load balancing is not enabled.
  You must write a udev rule to enable this functionality. Steps are provided in the section on Enabling NVMe/FC on OL 7.7.
- SAN booting using the NVMe-oF protocol is currently not supported.

Enabling NVMe on OL 7.7

1. Ensure the default Oracle Linux 7.7 kernel is installed.
2. Reboot the host and verify that it boots into specified OL 7.7 kernel.

```
# uname -r
4.14.35-1902.9.2.el7uek
```

3. Upgrade to the nvme-cli-1.8.1-3.el7 package.

```
# rpm -qa|grep nvme-cli
nvme-cli-1.8.1-3.el7.x86_64
```

4. Add the string below 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
```

5. On the OL 7.7 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
------- --------- ------------------------------------ -----------
ol_157_nvme_ss_10_0
nqn.2014-08.org.nvmexpress:uuid:75953f3b-77fe-4e03-bf3c-09d5a156fbcd
```

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 array subsystem to match to host NQN string from `/etc/nvme/hostnqn` on the host.

1. Reboot the host.

Configuring the Broadcom FC Adapter for NVMe/FC

1. Verify that you are using a supported adapter. For the current list of supported adapters see the Interoperability Matrix Tool.

```
# 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 outbox auto-connect scripts package.

```
# rpm -ivh nvmefc-connect-12.4.65.0-1.noarch.rpm
```

3. Reboot the host.
4. Verify that you are using the recommended Broadcom lpfc firmware, native inbox driver and outbox auto-connect package versions. For a list of supported versions, see the Interoperability Matrix Tool.

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

# cat /sys/module/lpfc/version
0:12.0.0.10

# rpm -qa | grep nvmefc
nvmefc-connect-12.4.65.0-1.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 able to 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
…
```

Validating NVMe/FC

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.ol_157_nvme_
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/ol_157_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/ol_157_ns_10_0",
         "NSID" : 1,
         "UUID" : "55baf453-f629-4a18-9364-b6aee3f50dad",
         "Size" : "53.69GB",
         "LBA_Data_Size" : 4096,
         "Namespace_Size" : 13107200
    }
]
```

Enabling 1MB I/O size for Broadcom NVMe/FC

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

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

Steps

1. Set the `lpfc_sg_seg_cnt` parameter to 256:

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

You should see an output similar to the following example:

```
options lpfc lpfc_sg_seg_cnt=256
```

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

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

LPFC verbose logging

Set the lpfc driver for NVMe/FC.

Steps

1. Set the `lpfc_log_verbose` driver setting to any of the following values to log NVMe/FC events.

```
#define LOG_NVME 0x00100000 /* NVME general events. */
#define LOG_NVME_DISC 0x00200000 /* NVME Discovery/Connect events. */
#define LOG_NVME_ABTS 0x00400000 /* NVME ABTS events. */
#define LOG_NVME_IOERR 0x00800000 /* NVME IO Error events. */
```

2. After setting the values, run the `dracut-f` command and reboot the host.
3. Verify the settings.

```
# cat /etc/modprobe.d/lpfc.conf options lpfc lpfc_log_verbose=0xf00083

# cat /sys/module/lpfc/parameters/lpfc_log_verbose 15728771
```

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