



SAN storage management

ONTAP 9

NetApp
April 04, 2023

This PDF was generated from <https://docs.netapp.com/us-en/ontap/san-admin/index.html> on April 04, 2023. Always check docs.netapp.com for the latest.

Table of Contents

SAN storage management	1
SAN administration	1

SAN storage management

SAN administration

SAN provisioning

SAN management overview

The content in this section shows you how to configure and manage SAN environments with the ONTAP command line interface (CLI) and System Manager in ONTAP 9.7 and later releases.

If you are using the classic System Manager (available only in ONTAP 9.7 and earlier), see these topics:

- [iSCSI protocol](#)
- [FC/FCoE protocol](#)

You can use the iSCSI and FC protocols to provide storage in a SAN environment.



With iSCSI and FC, storage targets are called LUNs (logical units) and are presented to hosts as standard

block devices. You create LUNs and then map them to initiator groups (igroups). Initiator groups are tables of FC host WWPNs and iSCSI host node names and control which initiators have access to which LUNs.

FC targets connect to the network through FC switches and host-side adapters and are identified by world-wide port names (WWPNs). iSCSI targets connect to the network through standard Ethernet network adapters (NICs), TCP offload engine (TOE) cards with software initiators, converged network adapters (CNAs) or dedicated host bus adapters (HBAs) and are identified by iSCSI qualified names (IQNs).

Configure switches for FCoE

You must configure your switches for FCoE before your FC service can run over the existing Ethernet infrastructure.

What you'll need

- Your SAN configuration must be supported.

For more information about supported configurations, see the [NetApp Interoperability Matrix Tool](#).

- A Unified Target Adapter (UTA) must be installed on your storage system.

If you are using a UTA2, it must be set to `cna` mode.

- A converged network adapter (CNA) must be installed on your host.

Steps

1. Use your switch documentation to configure your switches for FCoE.
2. Use the `dcb show` command to verify that the DCB settings for each node in the cluster have been correctly configured.

```
run -node node1 -command dcb show
```

DCB settings are configured on the switch. Consult your switch documentation if the settings are incorrect.

3. Use the `fcp adapter show` command to verify that the FCoE login is working when the FC target port online status is `true`.

```
cluster1::> fcp adapter show -fields node,adapter,status,state,speed,fabric-established,physical-protocol
```

If the FC target port online status is `false`, consult your switch documentation.

Related information

[NetApp Interoperability Matrix Tool](#)

[NetApp Technical Report 3800: Fibre Channel over Ethernet \(FCoE\) End-to-End Deployment Guide](#)

[Cisco MDS 9000 NX-OS and SAN-OS Software Configuration Guides](#)

[Brocade products](#)

System Requirements

Setting up LUNs involves creating a LUN, creating an igroup, and mapping the LUN to the igroup. Your system must meet certain prerequisites before you can set up your LUNs.

- The Interoperability Matrix must list your SAN configuration as supported.
- Your SAN environment must meet the SAN host and controller configuration limits specified in [NetApp Hardware Universe](#) for your version of the ONTAP software.
- A supported version of Host Utilities must be installed.

The Host Utilities documentation provides more information.

- You must have SAN LIFs on the LUN owning node and the owning node's HA partner.

Related information

[NetApp Interoperability Matrix Tool](#)

[ONTAP SAN Host Configuration](#)

[NetApp Technical Report 4017: Fibre Channel SAN Best Practices](#)

What to know before you create a LUN

Why actual LUN sizes slightly vary

You should be aware of the following regarding the size of your LUNs.

- When you create a LUN, the actual size of the LUN might vary slightly based on the OS type of the LUN. The LUN OS type cannot be modified after the LUN is created.
- If you create a LUN at the max 16 TB size, be aware that the actual size of the LUN might be slightly less. ONTAP rounds down the limit to be slightly less.
- The metadata for each LUN requires approximately 64 KB of space in the containing aggregate. When you create a LUN, you must ensure that the containing aggregate has enough space for the LUN's metadata. If the aggregate does not contain enough space for the LUN's metadata, some hosts might not be able to access the LUN.

Guidelines for assigning LUN IDs

Typically, the default LUN ID begins with 0 and is assigned in increments of 1 for each additional mapped LUN. The host associates the LUN ID with the location and path name of the LUN. The range of valid LUN ID numbers depends on the host. For detailed information, see the documentation provided with your Host Utilities.

Guidelines for mapping LUNs to igroups

- You can map a LUN only once to an igroup.
- You can map a LUN to only one specific initiator through the igroup.
- You can add a single initiator to multiple igroups, but the initiator can be mapped to only one LUN.
- You cannot use the same LUN ID for two LUNs mapped to the same igroup.

- You should use the same protocol type for igroups and port sets.

Verify and add your protocol FC or iSCSI license

Before you can enable block access for a storage virtual machine (SVM) with FC or iSCSI, you must have a license.

Example 1. Steps

System Manager

Verify and add your FC or iSCSI license with ONTAP System Manager (9.7 and later).

1. In System Manager, click **Cluster > Settings > Licenses**
2. If the license is not listed, click  and enter the license key.
3. Click **Add**.

CLI

Verify and add your FC or iSCSI license with the ONTAP CLI.

1. Verify that you have a active license for FC or iSCSI.

```
system license show
```

Package	Type	Description	Expiration
-----	-----	-----	
Base	site	Cluster Base License	-
NFS	site	NFS License	-
CIFS	site	CIFS License	-
iSCSI	site	iSCSI License	-
FCP	site	FCP License	-

2. If you do not have a active license for FC or iSCSI, add your license code.

```
license add -license-code your_license_code
```

= Provision SAN storage for VMware datastores

```
:toc: macro
```

```
:toclevels: 1
```

```
:hardbreaks:
```

```
:icons: font
```

```
:linkattrs:
```

```
:relative_path: ./
```

```
:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/
```

This procedure creates new LUNs on an existing storage VM which already has the FC or iSCSI protocol configured.

If you need to create a new storage VM and configure the FC or iSCSI protocol, see [Configure an SVM for FC](#) or [Configure an SVM for iSCSI](#).



Asymmetric logical unit access (ALUA) is always enabled during LUN creation. You cannot change the ALUA setting.

Beginning with ONTAP 9.8, when you provision storage, QoS is enabled by default. You can disable QoS

or choose a custom QoS policy during the provisioning process or at a later time.

When you have completed this procedure, you can manage VMware datastores with Virtual Storage Console (VSC) for VMware vSphere. Beginning with VSC 7.0, VSC is part of the [ONTAP Tools for VMware vSphere virtual appliance](#), which includes VSC, vStorage APIs for Storage Awareness (VASA) Provider, and Storage Replication Adapter (SRA) for VMware vSphere capabilities.

Be sure to check the [NetApp Interoperability Matrix](#) to confirm compatibility between your current ONTAP and VSC releases.

For more information, see [TR-4597: VMware vSphere for ONTAP](#) and the documentation for your VSC release.

System Manager

Create LUNs to provide storage with System Manager for ONTAP 9.7 or later.

LUNs appear as disks to the ESXi host.

To set up SAN protocol access for ESXi hosts to datastores using System Manager Classic (for ONTAP 9.7 and earlier releases), see the following topics:

- [FC configuration for ESXi using VSC overview](#)
- [iSCSI configuration for ESXi using VSC overview](#)



Asymmetric logical unit access (ALUA) is always enabled during LUN creation. You cannot change the ALUA setting.

Steps

1. In System Manager, click **Storage > LUNs** and then click **Add**.
2. Enter the required information to create the LUN.
3. You can click **More Options** to do any of the following, depending upon your version of ONTAP.

Option	Available beginning with
<ul style="list-style-type: none">• Assign QoS policy to LUNs instead of parent volume<ul style="list-style-type: none">◦ More Options > Storage and Optimization◦ Select Performance Service Level.◦ To apply the QoS policy to individual LUNs instead of the entire volume, select Apply these performance limits enforcements to each LUN. <p>By default, performance limits are applied at the volume level.</p>	ONTAP 9.10.1

<ul style="list-style-type: none"> • Create a new initiator group using existing initiator groups <ul style="list-style-type: none"> ◦ More Options > HOST INFORMATION ◦ Select New initiator group using existing initiator groups. <p>NOTE: The OS type for an igroup containing other igroups cannot be changed after it has been created.</p> 	ONTAP 9.9.1
<ul style="list-style-type: none"> • Add a description to your igroup or host initiator <p>The description serves as an alias for the igroup or host initiator.</p> <ul style="list-style-type: none"> ◦ More Options > HOST INFORMATION 	ONTAP 9.9.1
<ul style="list-style-type: none"> • Create your LUN on an existing volume <p>By default, a new LUN is created in a new volume.</p> <ul style="list-style-type: none"> ◦ More Options > Add LUNs ◦ Select Group related LUNs. 	ONTAP 9.9.1
<ul style="list-style-type: none"> • Disable QoS or choose a custom QoS policy <ul style="list-style-type: none"> ◦ More Options > Storage and Optimization ◦ Select Performance Service Level. <p>NOTE: In ONTAP 9.9.1 and later, if you select a custom QoS policy, you can also select manual placement on a specified local tier.</p> 	ONTAP 9.8

4. For FC, zone your FC switches by WWPN. Use one zone per initiator and include all target ports in each zone.
5. Use Virtual Storage Console (VSC) for VMware vSphere, to discover and initialize the LUN.
6. Verify that the ESXi hosts can write and read data on the LUN.

CLI

Create LUNs to provide storage with the ONTAP CLI.

1. Use the `system license show` command to verify that you have a license for FC or iSCSI.

```
system license show
```

Package	Type	Description	Expiration
Base	site	Cluster Base License	-
NFS	site	NFS License	-
CIFS	site	CIFS License	-
iSCSI	site	iSCSI License	-
FCP	site	FCP License	-

- If you do not have a license for FC or iSCSI, use the `license add` command.

```
license add -license-code your_license_code
```

- Enable your protocol service on the SVM:

For iSCSI: `vserver iscsi create -vserver vserver_name -target-alias vserver_name`

For FC: `vserver fcp create -vserver vserver_name -status-admin up`

- Create two LIFs for the SVMs on each node:

```
network interface create -vserver vserver_name -lif lif_name -role data -data
-protocol iscsi|fc -home-node node_name -home-port port_name -address
ip_address -netmask netmask
```

NetApp supports a minimum of one iSCSI or FC LIF per node for each SVM serving data. However, two LIFS per node are required for redundancy.

- Verify that your LIFs have been created and that their operational status is online:

```
network interface show -vserver vserver_name lif_name
```

- Create your LUNs:

```
lun create -vserver vserver_name -volume volume_name -lun lun_name -size
lun_size -ostype linux -space-reserve enabled|disabled
```

Your LUN name cannot exceed 255 characters and cannot contain spaces.



The NVFAIL option is automatically enabled when a LUN is created in a volume.

- Create your igroups:

```
igroup create -vserver vserver_name -igroup igroup_name -protocol
fcp|iscsi|mixed -ostype linux -initiator initiator_name
```

- Map your LUNs to igroups:

```
lun mapping create -vserver vserver_name -volume volume_name -lun lun_name
-igroup igroup_name
```

9. Verify that your LUNs are configured correctly:

```
lun show -vserver vservice_name
```

10. [Create a port set and bind to an igroup](#) (optional).

11. Follow steps in your host documentation for enabling block access on your specific hosts.

12. Use the Host Utilities to complete the FC or iSCSI mapping and to discover your LUNs on the host.

Related information

[ONTAP SAN Host Configuration](#)

[SAN Administration overview](#)

[View and manage SAN initiator groups in System Manager](#)

[NetApp Technical Report 4017: Fibre Channel SAN Best Practices](#)

= Provision SAN storage for Linux servers

:toc: macro

:toclevels: 1

:hardbreaks:

:icons: font

:linkattrs:

:relative_path: ./

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

This procedure creates new LUNs on an existing storage VM which already has the FC or iSCSI protocol configured.

If you need to create a new storage VM and configure the FC or iSCSI protocol, see [Configure an SVM for FC](#) or [Configure an SVM for iSCSI](#).

LUNs appear to Linux as SCSI disk devices.



Asymmetric logical unit access (ALUA) is always enabled during LUN creation. You cannot change the ALUA setting.

You must have an FC license and it must be enabled. If the FC license is not enabled, the LIFs and SVMs appear to be online but the operational status is down. The FC service must be enabled for your LIFs and SVMs to be operational. You must use single initiator zoning for all of the FC LIFs in the SVM to host the initiators.

You need to know the initiator identifiers (FC WWPN or iSCSI iqn) for your Linux server.

Beginning with ONTAP 9.8, when you provision storage, QoS is enabled by default. You can disable QoS or choose a custom QoS policy during the provisioning process or at a later time.

System Manager

Create LUNs to provide storage for a Linux server using the FC or iSCSI SAN protocol with ONTAP System Manager (9.7 and later).

To complete this task using System Manager Classic (available with 9.7 and earlier) refer to [iSCSI configuration for Red Hat Enterprise Linux](#)

1. On your Linux server, install the [NetApp Linux Host Utilities](#) package.
2. In System Manager, click **Storage > LUNs** and then click **Add**.
3. Enter the required information to create the LUN.
4. You can click **More Options** to do any of the following, depending upon your version of ONTAP.

Option	Available beginning with
<ul style="list-style-type: none"> • Assign QoS policy to LUNs instead of parent volume <ul style="list-style-type: none"> ◦ More Options > Storage and Optimization ◦ Select Performance Service Level. ◦ To apply the QoS policy to individual LUNs instead of the entire volume, select Apply these performance limits enforcements to each LUN. <p>By default, performance limits are applied at the volume level.</p> 	ONTAP 9.10.1
<ul style="list-style-type: none"> • Create a new initiator group using existing initiator groups <ul style="list-style-type: none"> ◦ More Options > HOST INFORMATION ◦ Select New initiator group using existing initiator groups. <p>NOTE: The OS type for an igroup containing other igroups cannot be changed after it has been created.</p> 	ONTAP 9.9.1
<ul style="list-style-type: none"> • Add a description to your igroup or host initiator <p>The description serves as an alias for the igroup or host initiator.</p> <ul style="list-style-type: none"> ◦ More Options > HOST INFORMATION 	ONTAP 9.9.1
<ul style="list-style-type: none"> • Create your LUN on an existing volume <p>By default, a new LUN is created in a new volume.</p> <ul style="list-style-type: none"> ◦ More Options > Add LUNs ◦ Select Group related LUNs. 	ONTAP 9.9.1
<ul style="list-style-type: none"> • Disable QoS or choose a custom QoS policy <ul style="list-style-type: none"> ◦ More Options > Storage and Optimization ◦ Select Performance Service Level. <p>NOTE: In ONTAP 9.9.1 and later, if you select a custom QoS policy, you can also select manual placement on a specified local tier.</p> 	ONTAP 9.8

5. For FC, zone your FC switches by WWPN. Use one zone per initiator and include all target ports in each zone.

6. On your Linux server, discover the new LUNs:

```
/usr/bin/rescan-scsi-bus.sh
```



Optionally partition the LUNs and create file systems.

7. Verify the Linux server can write and read data on the LUN.

CLI

Create LUNs to provide storage for a Linux server using the FC or iSCSI SAN protocol with ONTAP CLI.

1. Use the `system license show` command to verify that you have a license for FC or iSCSI.

```
system license show
```

Package	Type	Description	Expiration
Base	site	Cluster Base License	-
NFS	site	NFS License	-
CIFS	site	CIFS License	-
iSCSI	site	iSCSI License	-
FCP	site	FCP License	-

2. If you do not have a license for FC or iSCSI, use the `license add` command.

```
license add -license-code your_license_code
```

3. Enable your protocol service on the SVM:

For iSCSI: `vserver iscsi create -vserver vserver_name -target-alias vserver_name`

For FC: `vserver fcp create -vserver vserver_name -status-admin up`

4. Create two LIFs for the SVMs on each node:

```
network interface create -vserver vserver_name -lif lif_name -role data -data  
-protocol iscsi|fc -home-node node_name -home-port port_name -address  
ip_address -netmask netmask
```

NetApp supports a minimum of one iSCSI or FC LIF per node for each SVM serving data. However, two LIFS per node are required for redundancy.

5. Verify that your LIFs have been created and that their operational status is online:

```
network interface show -vserver vserver_name lif_name
```

6. Create your LUNs:

```
lun create -vserver vserver_name -volume volume_name -lun lun_name -size  
lun_size -ostype linux -space-reserve enabled|disabled
```

Your LUN name cannot exceed 255 characters and cannot contain spaces.



The NVFAIL option is automatically enabled when a LUN is created in a volume.

7. Create your igroups:

```
igroup create -vserver vserver_name -igroup igroup_name -protocol  
fc|iscsi|mixed -ostype linux -initiator initiator_name
```

8. Map your LUNs to igroups:

```
lun mapping create -vserver vserver_name -volume volume_name -lun lun_name  
-igroup igroup_name
```

9. Verify that your LUNs are configured correctly:

```
lun show -vserver vserver_name
```

10. [Create a port set and bind to an igroup](#) (optional).

11. Follow steps in your host documentation for enabling block access on your specific hosts.

12. Use the Host Utilities to complete the FC or iSCSI mapping and to discover your LUNs on the host.

Related information

[SAN Administration overview](#)

[ONTAP SAN Host Configuration](#)

[View and manage SAN initiator groups in System Manager](#)

[NetApp Technical Report 4017: Fibre Channel SAN Best Practices](#)

= Provision SAN storage for Windows servers

:toc: macro

:toclevels: 1

:hardbreaks:

:icons: font

:linkattrs:

:relative_path: ./

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

This procedure creates new LUNs on an existing storage VM which already has the FC or iSCSI protocol configured.

If you need to create a new storage VM and configure the FC or iSCSI protocol, see [Configure an SVM for FC](#) or [Configure an SVM for iSCSI](#).

LUNs appear as disks to the Windows host.



Asymmetric logical unit access (ALUA) is always enabled during LUN creation. You cannot change the ALUA setting.

Beginning with ONTAP 9.8, when you provision storage, QoS is enabled by default. You can disable QoS or choose a custom QoS policy during the provisioning process or at a later time.

System Manager

Create LUNs to provide storage for a Windows server using the FC or iSCSI SAN protocol with ONTAP System Manager (9.7 and later)

To complete this task using System Manager Classic (available with 9.7 and earlier) refer to [iSCSI configuration for Windows](#)

Steps

1. On your Windows server, install the native DSM for Windows MPIO.
2. In System Manager, click **Storage > LUNs** and then click **Add**.
3. Enter the required information to create the LUN.
4. You can click **More Options** to do any of the following, depending upon your version of ONTAP.

Option	Available beginning with
<ul style="list-style-type: none">• Assign QoS policy to LUNs instead of parent volume<ul style="list-style-type: none">◦ More Options > Storage and Optimization◦ Select Performance Service Level.◦ To apply the QoS policy to individual LUNs instead of the entire volume, select Apply these performance limits enforcements to each LUN.<p>By default, performance limits are applied at the volume level.</p>	ONTAP 9.10.1
<ul style="list-style-type: none">• Create a new initiator group using existing initiator groups<ul style="list-style-type: none">◦ More Options > HOST INFORMATION◦ Select New initiator group using existing initiator groups.<p>NOTE: The OS type for an igroup containing other igroups cannot be changed after it has been created.</p>	ONTAP 9.9.1
<ul style="list-style-type: none">• Add a description to your igroup or host initiator <p>The description serves as an alias for the igroup or host initiator.</p> <ul style="list-style-type: none">◦ More Options > HOST INFORMATION	ONTAP 9.9.1
<ul style="list-style-type: none">• Create your LUN on an existing volume <p>By default, a new LUN is created in a new volume.</p> <ul style="list-style-type: none">◦ More Options > Add LUNs◦ Select Group related LUNs.	ONTAP 9.9.1

- Disable QoS or choose a custom QoS policy
 - **More Options > Storage and Optimization**
 - Select **Performance Service Level**.

ONTAP 9.8

NOTE: In ONTAP 9.9.1 and later, if you select a custom QoS policy, you can also select manual placement on a specified local tier.

5. For FC, zone your FC switches by WWPN. Use one zone per initiator and include all target ports in each zone.
6. On your Windows server, discover the new LUN.
7. Initialize the LUN and optionally format it with a file system.
8. Verify the Windows server can write and read data on the LUN.

CLI

Create LUNs to provide storage for a Windows server using the FC or iSCSI SAN protocol with the ONTAP CLI.

1. Use the `system license show` command to verify that you have a license for FC or iSCSI.

```
system license show
```

Package	Type	Description	Expiration
Base	site	Cluster Base License	-
NFS	site	NFS License	-
CIFS	site	CIFS License	-
iSCSI	site	iSCSI License	-
FCP	site	FCP License	-

2. If you do not have a license for FC or iSCSI, use the `license add` command.

```
license add -license-code your_license_code
```

3. Enable your protocol service on the SVM:

For iSCSI: `vserver iscsi create -vserver vserver_name -target-alias vserver_name`

For FC: `vserver fcp create -vserver vserver_name -status-admin up`

4. Create two LIFs for the SVMs on each node:

```
network interface create -vserver vserver_name -lif lif_name -role data -data
-protocol iscsi|fc -home-node node_name -home-port port_name -address
ip_address -netmask netmask
```

NetApp supports a minimum of one iSCSI or FC LIF per node for each SVM serving data. However, two

LIFS per node are required for redundancy.

5. Verify that your LIFs have been created and that their operational status is online:

```
network interface show -vserver vservice_name lif_name
```

6. Create your LUNs:

```
lun create -vserver vservice_name -volume volume_name -lun lun_name -size  
lun_size -ostype linux -space-reserve enabled|disabled
```

Your LUN name cannot exceed 255 characters and cannot contain spaces.



The NVFAIL option is automatically enabled when a LUN is created in a volume.

7. Create your igroups:

```
igroup create -vserver vservice_name -igroup igroup_name -protocol  
fc|iscsi|mixed -ostype linux -initiator initiator_name
```

8. Map your LUNs to igroups:

```
lun mapping create -vserver vservice_name -volume volume_name -lun lun_name  
-igroup igroup_name
```

9. Verify that your LUNs are configured correctly:

```
lun show -vserver vservice_name
```

10. [Create a port set and bind to an igroup](#) (optional).
11. Follow steps in your host documentation for enabling block access on your specific hosts.
12. Use the Host Utilities to complete the FC or iSCSI mapping and to discover your LUNs on the host.

Related information

[ONTAP SAN Host Configuration](#)

[SAN Administration overview](#)

[View and manage SAN initiator groups in System Manager](#)

[NetApp Technical Report 4017: Fibre Channel SAN Best Practices](#)

= Provision SAN storage

:toc: macro

:toclevels: 1

:hardbreaks:

:icons: font

:linkattrs:

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

If a procedure for your specific host is not available, you can use these steps to provision storage for any support SAN host.

This procedure creates new LUNs on an existing storage VM which already has the FC or iSCSI protocol configured.

If you need to create a new storage VM and configure the FC or iSCSI protocol, see [Configure an SVM for FC](#) or [Configure an SVM for iSCSI](#).

If the FC license is not enabled, the LIFs and SVMs appear to be online but the operational status is down.

LUNs appear to your host as disk devices.



Asymmetric logical unit access (ALUA) is always enabled during LUN creation. You cannot change the ALUA setting.

You must use single initiator zoning for all of the FC LIFs in the SVM to host the initiators.

Unresolved directive in san-admin/provision-storage.adoc -
include::_include/98_qos_enabled_by_default.adoc[]

System Manager

Create LUNs to provide storage for a SAN host using the FC or iSCSI protocol with ONTAP System Manager (9.7 and later).

To complete this task using System Manager Classic (available with 9.7 and earlier) refer to [iSCSI configuration for Red Hat Enterprise Linux](#)

Steps

1. Install the appropriate [SAN host utilities](#) on your host.
2. In System Manager, click **Storage > LUNs** and then click **Add**.
3. Enter the required information to create the LUN.

Unresolved directive in san-admin/provision-storage.adoc -

include::_include/san_add_lun_more_options.adoc[]

5. For FC, zone your FC switches by WWPN. Use one zone per initiator and include all target ports in each zone.
6. Discover LUNs on your host.
7. Verify that the host can write and read data on the LUN.

CLI

Create LUNs to provide storage for a SAN host using the FC or iSCSI protocol with the ONTAP CLI.

1. Use the `system license show` command to verify that you have a license for FC or iSCSI.

```
system license show
```

Package	Type	Description	Expiration
-----	-----	-----	-----
Base	site	Cluster Base License	-
NFS	site	NFS License	-
CIFS	site	CIFS License	-
iSCSI	site	iSCSI License	-
FCP	site	FCP License	-

2. If you do not have a license for FC or iSCSI, use the `license add` command.

```
license add -license-code your_license_code
```

3. Enable your protocol service on the SVM:

For iSCSI: `vserver iscsi create -vserver vserver_name -target-alias vserver_name`

For FC: `vserver fcp create -vserver vserver_name -status-admin up`

4. Create two LIFs for the SVMs on each node:

```
network interface create -vserver vserver_name -lif lif_name -role data -data  
-protocol iscsi|fc -home-node node_name -home-port port_name -address  
ip_address -netmask netmask
```

NetApp supports a minimum of one iSCSI or FC LIF per node for each SVM serving data. However, two LIFS per node are required for redundancy.

5. Verify that your LIFs have been created and that their operational status is online:

```
network interface show -vserver vserver_name lif_name
```

6. Create your LUNs:

```
lun create -vserver vserver_name -volume volume_name -lun lun_name -size  
lun_size -ostype linux -space-reserve enabled|disabled
```

Your LUN name cannot exceed 255 characters and cannot contain spaces.



The NVFAIL option is automatically enabled when a LUN is created in a volume.

7. Create your igroups:

```
igroup create -vserver vserver_name -igroup igroup_name -protocol  
fc|iscsi|mixed -ostype linux -initiator initiator_name
```

8. Map your LUNs to igroups:

```
lun mapping create -vserver vserver_name -volume volume_name -lun lun_name  
-igroup igroup_name
```

9. Verify that your LUNs are configured correctly:

```
lun show -vserver vserver_name
```

10. [Create a port set and bind to an igroup](#) (optional).

11. Follow steps in your host documentation for enabling block access on your specific hosts.

12. Use the Host Utilities to complete the FC or iSCSI mapping and to discover your LUNs on the host.

Related information

[SAN Administration overview](#)

[ONTAP SAN Host Configuration](#)

[View and manage SAN initiator groups in System Manager](#)

[NetApp Technical Report 4017: Fibre Channel SAN Best Practices](#)

= NVMe provisioning

= NVMe Overview

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You can use the non-volatile memory express (NVMe) protocol to provide storage in a SAN environment. The NVMe protocol is optimized for performance with solid state storage.

For NVMe, storage targets are called namespaces. An NVMe namespace is a quantity of non-volatile storage that can be formatted into logical blocks and presented to a host as a standard block device. You create namespaces and subsystems, and then map the namespaces to the subsystems, similar to the way LUNs are provisioned and mapped to igroups for FC and iSCSI.

NVMe targets are connected to the network through a standard FC infrastructure using FC switches or a standard TCP infrastructure using Ethernet switches and host-side adapters.

Support for NVMe varies based on your version of ONTAP. See [NVMe support and limitations](#) for details.

== What NVMe is

The nonvolatile memory express (NVMe) protocol is a transport protocol used for accessing nonvolatile storage media.

NVMe over Fabrics (NVMeoF) is a specification-defined extension to NVMe that enables NVMe-based communication over connections other than PCIe. This interface allows for external storage enclosures to be connected to a server.

NVMe is designed to provide efficient access to storage devices built with non-volatile memory, from flash technology to higher performing, persistent memory technologies. As such, it does not have the same limitations as storage protocols designed for hard disk drives. Flash and solid state devices (SSDs) are a type of non-volatile memory (NVM). NVM is a type of memory that keeps its content during a power outage. NVMe is a way that you can access that memory.

The benefits of NVMe include increased speeds, productivity, throughput, and capacity for data transfer. Specific characteristics include the following:

- NVMe is designed to have up to 64 thousand queues.

Each queue in turn can have up to 64 thousand concurrent commands.

- NVMe is supported by multiple hardware and software vendors
- NVMe is more productive with Flash technologies enabling faster response times
- NVMe allows for multiple data requests for each “request” sent to the SSD.

NVMe takes less time to decode a “request” and does not require thread locking in a multithreaded program.

- NVMe supports functionality that prevents bottlenecking at the CPU level and enables massive scalability as systems expand.

== About NVMe namespaces

An NVMe namespace is a quantity of non-volatile memory (NVM) that can be formatted into logical blocks. Namespaces are used when a storage virtual machine is configured with the NVMe protocol and are the equivalent of LUNs for FC and iSCSI protocols.

One or more namespaces are provisioned and connected to an NVMe host. Each namespace can support various block sizes.

The NVMe protocol provides access to namespaces through multiple controllers. Using NVMe drivers, which are supported on most operating systems, solid state drive (SSD) namespaces appear as standard-block devices on which file systems and applications can be deployed without any modification.

A namespace ID (NSID) is an identifier used by a controller to provide access to a namespace. When setting the NSID for a host or host group, you also configure the accessibility to a volume by a host. A logical block can only be mapped to a single host group at a time, and a given host group does not have any duplicate NSIDs.

== About NVMe subsystems

An NVMe subsystem includes one or more NVMe controllers, namespaces, NVM subsystem ports, an NVM storage medium, and an interface between the controller and the NVM storage medium. When you create an NVMe namespace, by default it is not mapped to a subsystem. You can also choose to map it a new or existing subsystem.

Related information

- [Provision NVMe storage for SUSE Linux](#)
- [Provisioin NVMe storage for other hosts](#)
- [Map an NVMe namespace to a subsystem](#)

= NVMe license requirements

:icons: font

:relative_path: ./nvme/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

Beginning with ONTAP 9.5 a license is required to support NVMe. If NVMe is enabled in ONTAP 9.4, a 90 day grace period is given to acquire the license after upgrading to ONTAP 9.5.

You can enable the license using the following command:

```
system license add -license-code NVMe_license_key
```

= NVMe support and limitations

:icons: font

:relative_path: ./nvme/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

NVMe support and limitations varies based on your version of ONTAP, your platform and your configuration.

== Protocol support

Protocol	Beginning with ...	Allowed by...
TCP	ONTAP 9.10.1	Default
FCP	ONTAP 9.4	Default

== Platform and configuration support and limitations

Support for NVMe-oF protocol varies by platform and configuration. For details on your specific configuration, see the [NetApp Interoperability Matrix Tool](#).



Beginning with ONTAP 9.12.1, 4-node MetroCluster IP configurations are supported on NVMe/FC. MetroCluster configurations are not supported for NVMe prior to 9.12.1.

Beginning with ONTAP...	Platforms
9.12.1	<ul style="list-style-type: none">• FAS• All Flash FAS (AFF)• All SAN Array (ASA) platforms
9.9.1	<ul style="list-style-type: none">• AFF• ASA
9.4	AFF platforms only

== Namespace support and limitations

To set up the NVMe protocol in your SAN environment, you must configure an SVM for NVMe, create namespaces and subsystems, configure an NVMe/FC LIF, and then map the namespaces to the subsystems. When working with NVMe namespaces you should be aware of the following:

- Beginning with ONTAP 9.10.1, you can [resize a namespace](#). Resizing a namespace is not supported in releases prior to ONTAP 9.10.1.
- Beginning with ONTAP 9.6, namespaces support 512 byte blocks and 4096 byte blocks.

4096 is the default value. 512 should only be used if the host operating system does not support 4096 byte blocks.

- If you lose data in a LUN, it cannot be restored from a namespace, or vice versa.
- The space guarantee for namespaces is the same as the space guarantee of the containing volume.
- Namespaces do not support the following:
 - Renaming

You cannot rename a namespace.

- Inter-volume move
- Inter-volume copy

= Configure a storage VM for NVMe

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

If you want to use the NVMe protocol on a node, you must configure your SVM specifically for NVMe.

What you'll need

Your FC or Ethernet adapters must support NVMe. Supported adapters are listed in the [NetApp Hardware Universe](#).

System Manager

Configure an storage VM for NVMe with ONTAP System Manager (9.7 and later).

To configure NVMe on a new storage VM	To configure NVMe on an existing storage VM
<ol style="list-style-type: none"> 1. In System Manager, click Storage > Storage VMs and then click Add. 2. Enter a name for the storage VM. 3. Select NVMe for the Access Protocol. 4. Select Enable NVMe/FC or Enable NVMe/TCP and Save. 	<ol style="list-style-type: none"> 1. In System Manager, click Storage > Storage VMs. 2. Click on the storage VM you want to configure. 3. Click on the Settings tab, and then click  next to the NVMe protocol. 4. Select Enable NVMe/FC or Enable NVMe/TCP and Save.

CLI

Configure an storage VM for NVMe with the ONTAP CLI.

1. If you do not want to use an existing SVM, create one:

```
vserver create -vserver SVM_name
```

- a. Verify that the SVM is created:

```
vserver show
```

2. Verify that you have NVMe or TCP capable adapters installed in your cluster:

For NVMe: `network fcp adapter show -data-protocols-supported fc-nvme`

For TCP: `network port show`

3. If you are running ONTAP 9.7 or earlier, remove all protocols from the SVM:

```
vserver remove-protocols -vserver SVM_name -protocols iscsi,fcp,nfs,cifs,ndmp
```

Beginning with ONTAP 9.8, it is not necessary to remove other protocols when adding NVMe.

4. Add the NVMe protocol to the SVM:

```
vserver add-protocols -vserver SVM_name -protocols nvme
```

5. If you are running ONTAP 9.7 or earlier, verify that NVMe is the only protocol allowed on the SVM:

```
vserver show -vserver SVM_name -fields allowed-protocols
```

NVMe should be the only protocol displayed under the `allowed protocols` column.

6. Create the NVMe service:

```
vserver nvme create -vserver SVM_name
```

7. Verify that the NVMe service was created:

```
vserver nvme show -vserver SVM_name
```

The `Administrative Status` of the SVM should be listed as `up`.

8. Create an NVMe/FC LIF:

ONTAP version	Applicable protocols	Command
ONTAP 9.9.1 or earlier	FC	<pre>network interface create -vserver <i>SVM_name</i> -lif lif_name -role data -data -protocol fc-nvme -home -node home_node -home -port home_port</pre>
ONTAP 9.10.1	FC or TCP	<pre>network interface create -vserver <i>SVM_name</i> -lif lif_name -service-policy {default-data-nvme-tcp default-data-nvme-fc} -home-node home_node -home-port home_port -status admin up -failover-policy disabled -firewall-policy data -auto-revert false -failover-group failover_group -is-dns -update-enabled false</pre>

9. Create an NVMe/FC LIF on the HA partner node:

ONTAP version	Applicable protocols	Command
ONTAP 9.9.1 or earlier	FC	<pre>network interface create -vserver SVM_name -lif lif_name -role data -data -protocol fc-nvme -home -node home_node -home -port home_port</pre>
ONTAP 9.10.1 or later	FC or TCP	<pre>network interface create -vserver SVM_name -lif lif_name -service-policy {default-data-nvme-tcp default-data-nvme-fc} -home-node home_node -home-port home_port -status admin up -failover-policy disabled -firewall-policy data -auto-revert false -failover-group failover_group -is-dns -update-enabled false</pre>

10. Verify the NVMe/FC LIFs were created:

```
network interface show -vserver SVM_name
```

11. Create volume on the same node as the LIF:

```
vol create -vserver SVM_name -volume vol_name -aggregate aggregate_name -size
volume_size
```

If a warning message is displayed about the auto efficiency policy, it can be safely ignored.

```
= Provision NVMe storage for SUSE Linux
:toc: macro
:toclevels: 1
:hardbreaks:
:icons: font
:linkattrs:
:relative_path: ./
:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/
```

Create namespaces to provide storage for a SUSE Linux server using the NVMe protocol. Namespaces appear to Linux as SCSI disk devices.

This procedure creates new namespaces on an existing storage VM. Your storage VM must be configured for NVME, and your FC or TCP transport should already be set up.

Beginning with ONTAP 9.8, when you provision storage, QoS is enabled by default. You can disable QoS or choose a custom QoS policy during the provisioning process or at a later time.

System Manager

Create namespaces to provide storage using the NVMe protocol with ONTAP System Manager (9.7 and later).

1. In System Manager, click **Storage > NVMe Namespaces** and then click **Add**.
 - a. If you need to create a new subsystem, click **More Options**.
 - b. If you are running ONTAP 9.8 or later and you want to disable QoS or choose a custom QoS policy, click **More Options** and then, under **Storage and Optimization** select **Performance Service Level**.
2. Zone your FC switches by WWPN. Use one zone per initiator and include all target ports in each zone.
3. On your Linux server, discover the new namespaces.
4. Initialize the namespace and format it with a file system.
5. Verify the Linux server can write and read data on the namespace.

CLI

Create namespaces to provide storage using the NVMe protocol with the ONTAP CLI.

This procedure creates an NVMe namespace and subsystem on an existing storage VM which has already been configured for the NVMe protocol, then maps the namespace to the subsystem to allow data access from your host system.

If you need to configure the storage VM for NVMe, see [Configure an SVM for NVMe](#).

Steps

1. Verify that the SVM is configured for NVMe:

```
vserver show -vserver SVM_name -fields allowed-protocols
```

NVMe should be displayed under the allowed-protocols column.

2. Create the NVMe namespace:

```
vserver nvme namespace create -vserver SVM_name -path path -size  
size_of_namespace -ostype OS_type
```

3. Create the NVMe subsystem:

```
vserver nvme subsystem create -vserver SVM_name -subsystem name_of_subsystem  
-ostype OS_type
```

The NVMe subsystem name is case sensitive. It must contain 1 to 96 characters. Special characters are allowed.

4. Verify that the subsystem was created:

```
vserver nvme subsystem show -vserver SVM_name
```

The `nvme` subsystem should be displayed under the `Subsystem` column.

5. Obtain the NQN from the host.

6. Add the host NQN to the subsystem:

```
vserver nvme subsystem host add -vserver SVM_name -subsystem subsystem_name  
-host-nqn Host_NQN:subsystem.subsystem_name
```

7. Map the namespace to the subsystem:

```
vserver nvme subsystem map add -vserver SVM_name -subsystem subsystem_name  
-path path
```

A namespace can only be mapped to a single subsystem.

8. Verify that the namespace is mapped to the subsystem:

```
vserver nvme namespace show -vserver SVM_name -instance
```

The subsystem should be listed as the `Attached` subsystem.

```
= Provision NVMe storage  
:icons: font  
:relative_path: ./san-admin/  
:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/
```

If a procedure for your specific host is not available, you can use these steps to create namespaces and provision storage for any NVMe supported host.

Namespaces appear to Linux as SCSI disk devices.

This procedure creates new namespaces on an existing storage VM. Your storage VM must be configured for NVME, and your FC or TCP transport should already be set up.

Beginning with ONTAP 9.8, when you provision storage, QoS is enabled by default. You can disable QoS or choose a custom QoS policy during the provisioning process or at a later time.

System Manager

Using ONTAP System Manager (9.7 and later), create namespaces to provide storage using the NVMe protocol.

Steps

1. In System Manager, click **Storage > NVMe Namespaces** and then click **Add**.

If you need to create a new subsystem, click **More Options**.

2. If you are running ONTAP 9.8 or later and you want to disable QoS or choose a custom QoS policy, click **More Options** and then, under **Storage and Optimization** select **Performance Service Level**.
2. Zone your FC switches by WWPN. Use one zone per initiator and include all target ports in each zone.
3. On your host, discover the new namespaces.
4. Initialize the namespace and format it with a file system.
5. Verify that your host can write and read data on the namespace.

CLI

Using the ONTAP CLI, create namespaces to provide storage using the NVMe protocol.

This procedure creates an NVMe namespace and subsystem on an existing storage VM which has already been configured for the NVMe protocol, then maps the namespace to the subsystem to allow data access from your host system.

If you need to configure the storage VM for NVMe, see [Configure an SVM for NVMe](#).

Steps

1. Verify that the SVM is configured for NVMe:

```
vserver show -vserver SVM_name -fields allowed-protocols
```

NVMe should be displayed under the allowed-protocols column.

2. Create the NVMe namespace:

```
vserver nvme namespace create -vserver SVM_name -path path -size  
size_of_namespace -ostype OS_type
```

3. Create the NVMe subsystem:

```
vserver nvme subsystem create -vserver SVM_name -subsystem name_of_subsystem  
-ostype OS_type
```

The NVMe subsystem name is case sensitive. It must contain 1 to 96 characters. Special characters are allowed.

4. Verify that the subsystem was created:

```
vserver nvme subsystem show -vserver SVM_name
```

The `nvme` subsystem should be displayed under the `Subsystem` column.

5. Obtain the NQN from the host.

6. Add the host NQN to the subsystem:

```
vserver nvme subsystem host add -vserver SVM_name -subsystem subsystem_name  
-host-nqn Host_NQN:subsystem.subsystem_name
```

7. Map the namespace to the subsystem:

```
vserver nvme subsystem map add -vserver SVM_name -subsystem subsystem_name  
-path path
```

A namespace can only be mapped to a single subsystem.

8. Verify that the namespace is mapped to the subsystem:

```
vserver nvme namespace show -vserver SVM_name -instance
```

The subsystem should be listed as the Attached subsystem.

= Map an NVMe namespace to a subsystem

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

This procedure maps an existing NVMe namespace to an existing NVMe subsystem using the ONTAP CLI.

Your namespace and subsystem should already be created. If you need to create a namespace and subsystem, see [Provision NVMe storage](#).

Steps

1. Obtain the NQN from the host.
2. Add the host NQN to the subsystem:

```
vserver nvme subsystem host add -vserver SVM_name -subsystem subsystem_name
-host-nqn Host_NQN:subsystem.subsystem_name
```

3. Map the namespace to the subsystem:

```
vserver nvme subsystem map add -vserver SVM_name -subsystem subsystem_name
-path path
```

A namespace can only be mapped to a single subsystem.

4. Verify that the namespace is mapped to the subsystem:

```
vserver nvme namespace show -vserver SVM_name -instance
```

The subsystem should be listed as the `Attached` subsystem.

= Manage LUNs

= Edit LUN QoS policy group

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

Beginning with ONTAP 9.10.1, you can use System Manager to assign or remove Quality of Service (QoS) policies on multiple LUNs at the same time.



If the QoS policy is assigned at the volume level, it must be changed at the volume level. You can only edit the QoS policy at the LUN level if it was originally assigned at the LUN level.

Steps

1. In System Manager, click **Storage > LUNs**.
2. Select the LUN or LUNs you want to edit.

If you are editing more than one LUN at a time, the LUNs must belong to the same Storage Virtual

Machine (SVM). If you select LUNs that do not belong to the same SVM, the option to edit the QoS Policy Group is not displayed.

3. Click **More** and select **Edit QoS Policy Group**.

= Convert a LUN into a namespace

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

Beginning with ONTAP 9.11.1, you can use the ONTAP CLI to in-place convert an existing LUN to an NVMe namespace.

What you'll need

- Specified LUN should not have any existing maps to an igroup.
- LUN should not be in a MetroCluster configured SVM or in an SM-BC relationship.
- LUN should not be a protocol endpoint or bound to a protocol endpoint.
- LUN should not have non-zero prefix and/or suffix stream.
- LUN should not be part of a snapshot or on the destination side of SnapMirror relationship as a read-only LUN.

Steps

1. You enter the following command to convert a LUN to an NVMe namespace:

```
vserver nvme namespace convert-from-lun -vserver -lun-path
```

= Take a LUN offline

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

Beginning with ONTAP 9.10.1 you can use System Manager to take LUNs offline. Prior to ONTAP 9.10.1, you must use the ONTAP CLI to take LUNs offline.

System Manager

Steps

1. In System Manager, click **Storage>LUNs**.
2. Take a single LUN or multiple LUNs offline

If you want to...	Do this...
Take a single LUN offline	Next to the LUN name, click  and select Take Offline .
Take multiple LUNs offline	a. Select the LUNs you want to take offline. b. Click More and select Take Offline .

CLI

You can only take one LUN offline at a time when using the CLI.

Step

- 1. Take the LUN offline: `lun offline lun_name -vserver SVM_name`

```
= Resize a LUN
:icons: font
:relative_path: ./san-admin/
:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/
```

You can increase or decrease the size of a LUN.

Solaris LUNs cannot be resized.

== Increase the size of a LUN

The size to which you can increase your LUN varies depending upon your version of ONTAP.


ONTAP version	Maximum LUN size
ONTAP 9.8 and later	<ul style="list-style-type: none">• 128 TB for All SAN Arrays (ASAs)• 16 TB for non-ASAs
ONTAP 9.5, 9.6, 9.7	16TB
ONTAP 9.4 or earlier	<p>10 times the original LUN size, but not greater than 16TB, which is the maximum LUN size.</p> <p>For example, if you create a 100 GB LUN, you can only grow it to 1,000 GB.</p> <p>The actual maximum size of the LUN might not be exactly 16TB. ONTAP rounds down the limit to be slightly less.</p>

You do not need to take the LUN offline to increase the size. However, after you have increased the size, you must rescan the LUN on the host for the host to recognize the change in size.

See the Command Reference page for the `lun resize` command for more information about resizing a LUN.

System Manager

Increase the size of a LUN with ONTAP System Manager (9.7 and later).

- 1. In System Manager, click **Storage > LUNs**.
- 2. Click  and select **Edit**.
- 3. Under **Storage and Optimization** increase the size of the LUN and **Save**.

CLI

Increase the size of a LUN with the ONTAP CLI.

1. Increase the size of the LUN:

```
lun resize -vserver vservice_name -volume volume_name -lun lun_name -size  
lun_size
```

2. Verify the increased LUN size:

```
lun show -vserver vservice_name
```



ONTAP operations round down the actual maximum size of the LUN so it is slightly less than the expected value. Also, actual LUN size might vary slightly based on the OS type of the LUN. To obtain the exact resized value, run the following commands in advanced mode:

```
set -unit B
```

```
lun show -fields max-resize-size -volume volume_name -lun lun_name
```

3. Rescan the LUN on the host.
4. Follow your host documentation to make the newly created LUN size visible to the host file system.

== Decrease the size of a LUN

Before you decrease the size of a LUN, the host needs to migrate the blocks containing the LUN data into the boundary of the smaller LUN size. You should use a tool such as SnapDrive for Windows to ensure that the LUN is properly decreased without truncating blocks containing LUN data. Manually decreasing the size of your LUN is not recommended.

After you decrease the size of your LUN, ONTAP automatically notifies the initiator that the LUN size has decreased. However, additional steps might be required on your host for the host to recognize the new LUN size. Check your host documentation for specific information about decreasing the size of the host file structure.

= Move a LUN

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You can move a LUN across volumes within a storage virtual machine (SVM), but you cannot move a LUN across SVMs. LUNs moved across volumes within an SVM are moved immediately and without loss of connectivity.

What you'll need

If your LUN is using Selective LUN Map (SLM), the SLM reporting nodes must have been modified to include the destination node and its HA partner.

About this task

Storage efficiency features, such as deduplication, compression, and compaction are not preserved during a LUN move. They must be reapplied after the LUN move is completed.

Data protection through Snapshot copies occurs at the volume level. Therefore, when you move a LUN, it falls under the data protection scheme of the destination volume. If you do not have Snapshot copies established for the destination volume, Snapshot copies of the LUN are not created. Also, all of the Snapshot copies of the LUN stay in the original volume until those Snapshot copies are deleted.

You cannot move a LUN to the following volumes:

- A SnapMirror destination volume
- The SVM root volume

You cannot move the following types of LUNs:

- A LUN that has been created from a file
- A LUN that is in NVFail state
- A LUN that is in a load-sharing relationship
- A protocol-endpoint class LUN

For Solaris os_type LUNs that are 1 TB or larger, the host might experience a timeout during the LUN move. For this LUN type, you should unmount the LUN before initiating the move.

System Manager

Move a LUN with ONTAP System Manager (9.7 and later).

Beginning with ONTAP 9.10.1, you can use System Manager to create a new volume when you move a single LUN. In ONTAP 9.8 and 9.9.1, the volume to which you are moving your LUN must exist before you begin the LUN move.

Steps

1. In System Manager, click **Storage>LUNs**.
2. Right click the LUN you want to move, then click  and select **Move LUN**.

In ONTAP 9.10.1, select to move the LUN to **An existing volume** or to a **New volume**.

If you select to create a new volume, provide the volume specifications.

3. Click **Move**.

CLI

Move a LUN with the ONTAP CLI.

1. Move the LUN:

```
lun move start.
```

During a very brief period, the LUN is visible on both the origin and destination volume. This is expected and is resolved upon completion of the move.

2. Track the status of the move and verify successful completion:

```
lun move show.
```

Related information

- [Selective LUN Map](#)
- [Modifying the SLM reporting-nodes list](#)

= Delete LUNs

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You can delete a LUN from a storage virtual machine (SVM) if you no longer need the LUN.

What you'll need

The LUN must be unmapped from its igrp before you can delete it.

Steps

1. Verify that the application or host is not using the LUN.
2. Unmap the LUN from the igrp:

```
lun mapping delete
```

```
lun mapping delete -vserver vs5 -volume vo5 -lun lun5 -igroup igr5
```

3. Delete the LUN:

```
lun delete
```

```
lun delete -vserver vs5 -volume vol5 -lun lun5
```

4. Verify that you deleted the LUN:

```
lun show
```

```
lun show -vserver vs5
```

Vserver	Path	State	Mapped	Type	Size
vs5	/vol/vol16/lun8	online	mapped	windows	10.00GB

= What to know before copying LUNs

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You should be aware of certain things before copying a LUN.

Cluster administrators can copy a LUN across storage virtual machines (SVMs) within the cluster by using the `lun copy` command. Cluster administrators must establish the storage virtual machine (SVM)

peering relationship using the `vserver peer create` command before an inter-SVM LUN copy operation is performed. There must be enough space in the source volume for a SIS clone.

LUNs in Snapshot copies can be used as source LUNs for the `lun copy` command. When you copy a LUN using the `lun copy` command, the LUN copy is immediately available for read and write access. The source LUN is unchanged by creation of a LUN copy. Both the source LUN and the LUN copy exist as unique LUNs with different LUN serial numbers. Changes made to the source LUN are not reflected in the LUN copy, and changes made to the LUN copy are not reflected in the source LUN. The LUN mapping of the source LUN is not copied to the new LUN; the LUN copy must be mapped.

Data protection through Snapshot copies occurs at the volume level. Therefore, if you copy a LUN to a volume different from the volume of the source LUN, the destination LUN falls under the data protection scheme of the destination volume. If you do not have Snapshot copies established for the destination volume, Snapshot copies are not created of the LUN copy.

Copying LUNs is a nondisruptive operation.

You cannot copy the following types of LUNs:

- A LUN that has been created from a file
- A LUN that is in NVFAIL state
- A LUN that is in a load-sharing relationship
- A protocol-endpoint class LUN

= Examine configured and used space of a LUN

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

Knowing the configured space and actual space used for your LUNs can help you determine the amount of space that can be reclaimed when doing space reclamation, the amount of reserved space that contains data, and the total configured size versus the actual size used for a LUN.

Step

1. View the configured space versus the actual space used for a LUN:

```
lun show
```

The following example show the configured space versus the actual space used by the LUNs in the vs3 storage virtual machine (SVM):

```
lun show -vserver vs3 -fields path, size, size-used, space-reserve
```

vserver	path	size	space-reserve	size-used
vs3	/vol/vol0/lun1	50.01GB	disabled	25.00GB
vs3	/vol/vol0/lun1_backup	50.01GB	disabled	32.15GB
vs3	/vol/vol0/lun2	75.00GB	disabled	0B
vs3	/vol/volspace/lun0	5.00GB	enabled	4.50GB

4 entries were displayed.

= Control and monitor I/O performance to LUNs by using Storage QoS

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You can control input/output (I/O) performance to LUNs by assigning LUNs to Storage QoS policy groups. You might control I/O performance to ensure that workloads achieve specific performance objectives or to throttle a workload that negatively impacts other workloads.

About this task

Policy groups enforce a maximum throughput limit (for example, 100 MB/s). You can create a policy group without specifying a maximum throughput, which enables you to monitor performance before you control the workload.

You can also assign storage virtual machines (SVMs) with FlexVol volumes and LUNs to policy groups.

Note the following requirements about assigning a LUN to a policy group:

- The LUN must be contained by the SVM to which the policy group belongs.

You specify the SVM when you create the policy group.

- If you assign a LUN to a policy group, then you cannot assign the LUN's containing volume or SVM to a policy group.

For more information about how to use Storage QoS, see the [System administration reference](#).

Steps

1. Use the `qos policy-group create` command to create a policy group.
2. Use the `lun create` command or the `lun modify` command with the `-qos-policy-group` parameter to assign a LUN to a policy group.
3. Use the `qos statistics` commands to view performance data.
4. If necessary, use the `qos policy-group modify` command to adjust the policy group's maximum throughput limit.

= Tools available to effectively monitor your LUNs

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

Tools are available to help you effectively monitor your LUNs and avoid running out of space.

- Active IQ Unified Manager is a free tool that enables you to manage all storage across all clusters in your environment.
- System Manager is a graphical user interface built into ONTAP that enables you to manually manage storage needs at the cluster level.
- OnCommand Insight presents a single view of your storage infrastructure and enables you to set up automatic monitoring, alerts, and reporting when your LUNs, volumes, and aggregates are running out of storage space.

= Capabilities and restrictions of transitioned LUNs

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

In a SAN environment, a disruption in service is required during the transition of a 7-Mode volume to ONTAP. You need to shut down your hosts to complete the transition. After transition, you must update your host configurations before you can begin serving data in ONTAP

You need to schedule a maintenance window during which you can shut down your hosts and complete the transition.

LUNs that have been transitioned from Data ONTAP operating in 7-Mode to ONTAP have certain capabilities and restrictions that affect the way the LUNs can be managed.

You can do the following with transitioned LUNs:

- View the LUN using the `lun show` command
- View the inventory of LUNs transitioned from the 7-Mode volume using the `transition 7-mode show` command
- Restore a volume from a 7-Mode Snapshot copy

Restoring the volume transitions all of the LUNs captured in the Snapshot copy

- Restore a single LUN from a 7-Mode Snapshot copy using the `snapshot restore-file` command
- Create a clone of a LUN in a 7-Mode Snapshot copy
- Restore a range of blocks from a LUN captured in a 7-Mode Snapshot copy
- Create a FlexClone of the volume using a 7-Mode Snapshot copy

You cannot do the following with transitioned LUNs:

- Access Snapshot copy-backed LUN clones captured in the volume

Related information

[Copy-based transition](#)

= I/O misalignments on properly aligned LUNs overview

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

ONTAP might report I/O misalignments on properly aligned LUNs. In general, these misalignment warnings can be disregarded as long as you are confident that your LUN is properly provisioned and your partitioning table is correct.

LUNs and hard disks both provide storage as blocks. Because the block size for disks on the host is 512 bytes, LUNs present blocks of that size to the host while actually using larger, 4-KB blocks to store data. The 512-byte data block used by the host is referred to as a logical block. The 4-KB data block used by the LUN to store data is referred to as a physical block. This means that there are eight 512-byte logical blocks in each 4-KB physical block.



The host operating system can begin a read or write I/O operation at any logical block. I/O operations are only considered aligned when they begin at the first logical block in the physical block. If an I/O operation begins at a logical block that is not also the start of a physical block, the I/O is considered misaligned. ONTAP automatically detects the misalignment and reports it on the LUN. However, the presence of misaligned I/O does not necessarily mean that the LUN is also misaligned. It is possible for misaligned I/O to be reported on properly aligned LUNs.

If you require further investigation, see the Knowledge Base article [How to identify unaligned IO on LUNs?](#)

For more information about tools for correcting alignment problems, see the following documentation: +

- [Windows Unified Host Utilities 7.1](#)
- [Virtual Storage Console for VMware vSphere Installation and Administration Guide](#)

== Achieve I/O alignment using LUN OS types

To achieve I/O alignment with your OS partitioning scheme, you should use the recommended ONTAP LUN `ostype` value that most closely matches your operating system.

The partition scheme employed by the host operating system is a major contributing factor to I/O misalignments. Some ONTAP LUN `ostype` values use a special offset known as a “prefix” to enable the default partitioning scheme used by the host operating system to be aligned.

In some circumstances, a custom partitioning table might be required to achieve I/O alignment. However, for `ostype` values with a “prefix” value greater than 0, a custom partition might create misaligned I/O.

The LUN `ostype` values in the following table should be used based on your operating system.

LUN <code>ostype</code>	Prefix (bytes)	Prefix (sectors)	Operating system
windows	32,256	63	Windows 2000, 2003 (MBR format)
windows_gpt	17,408	34	Windows 2003 (GPT format)
windows_2008	0	0	Windows 2008 and later
linux	0	0	All Linux distributions
xen	0	0	Citrix XenServer
vmware	0	0	VMware ESX
solaris	1MB	2,048	Solaris
solaris_efi	17,408	34	Solaris
hpux	0	0	HP-UX
aix	0	0	AIX

== Special I/O alignment considerations for Linux

Linux distributions offer a wide variety of ways to use a LUN including as raw devices for databases, various volume managers, and file systems. It is not necessary to create partitions on a LUN when used as a raw device or as physical volume in a logical volume.

For RHEL 5 and earlier and SLES 10 and earlier, if the LUN will be used without a volume manager, you should partition the LUN to have one partition that begins at an aligned offset, which is a sector that is an even multiple of eight logical blocks.

== Special I/O alignment considerations for Solaris LUNs

You need to consider various factors when determining whether you should use the `solaris` `ostype` or the `solaris_efi` `ostype`.

See the [Solaris Host Utilities Installation and Administration Guide](#) for detailed information.

== ESX boot LUNs report as misaligned

LUNs used as ESX boot LUNs are typically reported by ONTAP as misaligned. ESX creates multiple partitions on the boot LUN, making it very difficult to align. Misaligned ESX boot LUNs are not typically a performance problem because the total amount of misaligned I/O is small. Assuming that the LUN was

correctly provisioned with the VMware `ostype`, no action is needed.

Related information

[Guest VM file system partition/disk alignment for VMware vSphere, other virtual environments, and NetApp storage systems](#)

= Ways to address issues when LUNs go offline

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

When no space is available for writes, LUNs go offline to preserve data integrity. LUNs can run out of space and go offline for various reasons, and there are several ways you can address the issue.

If the...	You can...
Aggregate is full	<ul style="list-style-type: none">• Add more disks.• Use the <code>volume modify</code> command to shrink a volume that has available space.• If you have space-guarantee volumes that have available space, change the volume space guarantee to none with the <code>volume modify</code> command.
Volume is full but there is space available in the containing aggregate	<ul style="list-style-type: none">• For space guarantee volumes, use the <code>volume modify</code> command to increase the size of your volume.• For thinly provisioned volumes, use the <code>volume modify</code> command to increase the maximum size of your volume. <p>If volume autogrow is not enabled, use <code>volume modify -autogrow-mode</code> to enable it.</p> <ul style="list-style-type: none">• Delete Snapshot copies manually with the <code>volume snapshot delete</code> command, or use the <code>volume snapshot autodelete modify</code> command to automatically delete Snapshot copies.

Related information

[Disk and aggregate management](#)

[Logical storage management](#)

= Troubleshoot iSCSI LUNs not visible on the host

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

The iSCSI LUNs appear as local disks to the host. If the storage system LUNs are not available as disks on the host, you should verify the configuration settings.

Configuration setting	What to do
Cabling	Verify that the cables between the host and storage system are properly connected.
Network connectivity	<p>Verify that there is TCP/IP connectivity between the host and storage system.</p> <ul style="list-style-type: none">From the storage system command line, ping the host interfaces that are being used for iSCSI: <pre>ping -node node_name -destination host_ip_address_for_iSCSI</pre>From the host command line, ping the storage system interfaces that are being used for iSCSI: <pre>ping -node node_name -destination host_ip_address_for_iSCSI</pre>
System requirements	Verify that the components of your configuration are qualified. Also, verify that you have the correct host operating system (OS) service pack level, initiator version, ONTAP version, and other system requirements. The Interoperability Matrix contains the most up-to-date system requirements.
Jumbo frames	If you are using jumbo frames in your configuration, verify that jumbo frames are enabled on all devices in the network path: the host Ethernet NIC, the storage system, and any switches.
iSCSI service status	Verify that the iSCSI service is licensed and started on the storage system.
Initiator login	Verify that the initiator is logged in to the storage system. If the <code>iscsi initiator show</code> command output shows no initiators are logged in, check the initiator configuration on the host. Also verify that the storage system is configured as a target of the initiator.
iSCSI node names (IQNs)	Verify that you are using the correct initiator node names in the <code>igroup</code> configuration. On the host, you can use the initiator tools and commands to display the initiator node name. The initiator node names configured in the <code>igroup</code> and on the host must match.

Configuration setting	What to do
LUN mappings	<p>Verify that the LUNs are mapped to an igroup. On the storage system console, you can use one of the following commands:</p> <ul style="list-style-type: none"> • <code>lun mapping show</code> displays all LUNs and the igroups to which they are mapped. • <code>lun mapping show -igroup</code> displays the LUNs mapped to a specific igroup.
iSCSI LIFs enable	Verify that the iSCSI logical interfaces are enabled.

Related information

[NetApp Interoperability Matrix Tool](#)

= Manage igroups and portsets

= Ways to limit LUN access with portsets and igroups

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

In addition to using Selective LUN Map (SLM), you can limit access to your LUNs through igroups and portsets.

Portsets can be used with SLM to further restrict access of certain targets to certain initiators. When using SLM with portsets, LUNs will be accessible on the set of LIFs in the portset on the node that owns the LUN and on that node's HA partner.

In the following example, initiator1 does not have a portset. Without a portset, initiator1 can access LUN1 through both LIF1 and LIF2.



You can limit access to LUN1 by using a portset. In the following example, initiator1 can access LUN1 only through LIF1. However, initiator1 cannot access LUN1 through LIF2 because LIF2 is not in portset1.



Related information

- [Selective LUN Map](#)

- [Create a portset and bind to an igroup](#)

= View and manage SAN initiators and igroups

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You can use System Manager to view and manage initiator groups (igroups) and initiators.

About this task

- The initiator groups identify which hosts are able to access specific LUNs on the storage system.
- After an initiator and initiator groups are created, you can also edit them or delete them.
- To manage SAN initiators groups and initiators, you can perform the following tasks:
 - [\[view-manage-san-igroups\]](#)
 - [\[view-manage-san-inits\]](#)

== View and manage SAN initiator groups

You can use System Manager to view a list of initiator groups (igroups). From the list, you can perform additional operations.

Steps

1. In System Manager, click **Hosts > SAN Initiator Groups**.

The page displays a list of initiator groups (igroups). If the list is large, you can view additional pages of the list by clicking the page numbers at the lower right corner of the page.

The columns display various information about the igroups. Beginning with 9.11.1, the connection status of the igroup is also displayed. Hover over status alerts to view details.

2. (Optional): You can perform the following tasks by clicking the icons at the upper right corner of the list:
 - **Search**
 - **Download** the list.
 - **Show** or **Hide** columns in the list.
 - **Filter** the data in the list.

3. You can perform operations from the list:

- Click  **Add** to add an igroup.
- Click the igroup name to view the **Overview** page that shows details about the igroup.

On the **Overview** page, you can view the LUNs associated with the igroup, and you can initiate the operations to create LUNs and map the LUNs. Click **All SAN Initiators** to return to the main list.

- Hover over the igroup, then click  next to an igroup name to edit or delete the igroup.
- Hover over the area to the left of the igroup name, then check the check box. If you click **+Add to Initiator Group**, you can add that igroup to another igroup.

- In the **Storage VM** column, click the name of a storage VM to view details about it.

== View and manage SAN initiators

You can use System Manager to view a list of initiators. From the list, you can perform additional operations.

Steps

1. In System Manager, click **Hosts > SAN Initiator Groups**.

The page displays a list of initiator groups (igroups).

2. To view initiators, perform the following:

- Click the **FC Initiators** tab to view a list of FC initiators.
- Click the **iSCSI Initiators** tab to view a list of iSCSI initiators.

The columns display various information about the initiators.

Beginning with 9.11.1, the connection status of the initiator is also displayed. Hover over status alerts to view details.

3. (Optional): You can perform the following tasks by clicking the icons at the upper right corner of the list:

- **Search** the list for particular initiators.
- **Download** the list.
- **Show** or **Hide** columns in the list.
- **Filter** the data in the list.

= Create nested igroup

:toc: macro

:toclevels: 1

:hardbreaks:

:icons: font

:linkattrs:

:relative_path: ./

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

Beginning with ONTAP 9.9.1, you can create an igroup that consists of other existing igroups.

1. In System Manager, click **Host > SAN Initiator Groups**, and then click **Add**.
2. Enter the igroup **Name** and **Description**.

The description serves as the igroup alias.

3. Select the **Storage VM** and **Host Operating System**.



The OS type of a nested igroup cannot be changed after the igroup is created.

4. Under **Initiator Group Members** select **Existing initiator group**.

You can use **Search** to find and select the initiator groups you want to add.

= Map igroups to multiple LUNs

:toc: macro

:toclevels: 1

:hardbreaks:

:icons: font

:linkattrs:

:relative_path: ./

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

Beginning with ONTAP 9.9.1, you can map igroups to two or more LUNs simultaneously.

1. In System Manager, click **Storage > LUNs**.
2. Select the LUNs you want to map.
3. Click **More**, then click **Map To Initiator Groups**.



The selected igroups are added to the selected LUNs. The pre-existing mappings are not overwritten.

= Create a portsets and bind to an igroup

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

In addition to using [Selective LUN Map \(SLM\)](#), you can create a portset and bind the portset to an igroup to further limit which LIFs can be used by an initiator to access a LUN.

If you do not bind a portset to an igroup, then all of the initiators in the igroup can access mapped LUNs through all of the LIFs on the node owning the LUN and the owning node's HA partner.

What you'll need

You must have at least one LIF and one igroup.

Unless you are using interface groups, two LIFs are recommended for redundancy for both iSCSI and FC. Only one LIF is recommended for interface groups.

About this task

It is advantageous to use portsets with SLM when you have more than two LIFs on a node and you want to restrict a certain initiator to a subset of LIFs. Without portsets, all targets on the node will be accessible by all of the initiators with access to the LUN through the node owning the LUN and the owning node's HA partner.

System Manager

Beginning with ONTAP 9.10.1, you can use System Manager to create portsets and bind them to igroups.

If you need to create a portset and bind it to an igroup in an ONTAP release earlier than 9.10.1 you must use the ONTAP CLI procedure.

1. In System Manager, click **Network > Overview > Portsets**, and click **Add**.
2. Enter the information for the new portset and click **Add**.
3. Click **Hosts > SAN Initiator Groups**.
4. To bind the portset to a new igroup, click **Add**.

To bind the portset to an existing igroup, select the igroup, click , and then click **Edit Initiator Group**.

Related information

[View and manage initiators and igroups](#)

CLI

1. Create a port set containing the appropriate LIFs:

```
portset create -vserver vs3 -portset portset0 -protocol iscsi  
-port-name lif0,lif1
```

If you are using FC, specify the `protocol` parameter as `fc`. If you are using iSCSI, specify the `protocol` parameter as `iscsi`.

2. Bind the igroup to the port set:

```
lun igroup bind -vserver vs3 -igroup igroup1 -portset  
portset0
```

3. Verify that your port sets and LIFs are correct:

```
portset show -vserver vs3
```

Vserver	Portset	Protocol	Port Names	Igroups
vs3	portset0	iscsi	lif0,lif1	igroup1

= Manage portsets

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

In addition to [Selective LUN Map \(SLM\)](#), you can use portsets to further limit which LIFs can be used by an initiator to access a LUN.

Beginning with ONTAP 9.10.1, you can use System Manager to change the network interfaces associated with portsets and to delete portsets.

== Change network interfaces associated with a portset

1. In System Manager, click **Network > Overview > Portsets**.
2. Select the portset you want to edit and click , then select **Edit Portset**.

== Delete a portset

1. In System Manager, click **Network > Overview > Portsets**.
2. To delete a single portset, select the portset, click  and then select **Delete Portsets**.

To delete multiple portsets, select the portsets, and click **Delete**.

= Selective LUN Map

= Selective LUN Map overview

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

Selective LUN Map (SLM) reduces the number of paths from the host to the LUN. With SLM, when a new LUN map is created, the LUN is accessible only through paths on the node owning the LUN and its HA partner.

SLM enables management of a single igroup per host and also supports nondisruptive LUN move operations that do not require portset manipulation or LUN remapping.

Portsets can be used with SLM just as in previous versions of ONTAP to further restrict access of certain targets to certain initiators. When using SLM with portsets, LUNs will be accessible on the set of LIFs in the portset on the node that owns the LUN and on that node's HA partner.

SLM is enabled by default on all new LUN maps.

= Determine whether SLM is enabled on a LUN map

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

If your environment has a combination of LUNs created in ONTAP and LUNs transitioned from previous versions, you might need to determine whether Selective LUN Map (SLM) is enabled on a specific LUN.

You can use the information displayed in the output of the `lun mapping show -fields reporting-nodes` command to determine whether SLM is enabled on your LUN map. If SLM is not enabled, "-" is displayed in the cells under the `reporting-nodes` column of the command output. If SLM is enabled, the list of nodes displayed under the `nodes` column is duplicated in the `reporting-nodes` column.

= Modify the SLM reporting-nodes list

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

If you are moving a LUN or a volume containing LUNs to another high availability (HA) pair within the same cluster, you should modify the Selective LUN Map (SLM) reporting-nodes list before initiating the move to ensure that active, optimized LUN paths are maintained.

Steps

1. Add the destination node and its partner node to the reporting-nodes list of the aggregate or volume:

```
lun mapping add-reporting-nodes -vserver vservice_name -path lun_path
-igroup igroup_name [-destination-aggregate aggregate_name|-destination-
volume volume_name]
```

If you have a consistent naming convention, you can modify multiple LUN mappings at the same time by using **-igroup** instead of `igroup`.

2. Rescan the host to discover the newly added paths.
3. If your OS requires it, add the new paths to your multipath network I/O (MPIO) configuration.
4. Run the command for the needed move operation and wait for the operation to finish.
5. Verify that I/O is being serviced through the Active/Optimized path:

```
lun mapping show -fields reporting-nodes
```

6. Remove the previous LUN owner and its partner node from the reporting-nodes list:

```
lun mapping remove-reporting-nodes -vserver vservice_name -path lun_path
-igroup igroup_name -remote-nodes
```

7. Verify that the LUN has been removed from the existing LUN map:

```
lun mapping show -fields reporting-nodes
```

8. Remove any stale device entries for the host OS.
9. Change any multipathing configuration files if required.
10. Rescan the host to verify removal of old paths.
See your host documentation for specific steps to rescan your hosts.

= Manage iSCSI protocol

= Configure your network for best performance

```
:icons: font
:relative_path: ./san-admin/
:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/
```

Ethernet networks vary greatly in performance. You can maximize the performance of the network used for iSCSI by selecting specific configuration values.

Steps

1. Connect the host and storage ports to the same network.

It is best to connect to the same switches. Routing should never be used.

2. Select the highest speed ports available, and dedicate them to iSCSI.

10 GbE ports are best. 1 GbE ports are the minimum.

3. Disable Ethernet flow control for all ports.

You should see [Network management](#) for using the CLI to configure Ethernet port flow control.

4. Enable jumbo frames (typically MTU of 9000).

All devices in the data path, including initiators, targets, and switches, must support jumbo frames. Otherwise, enabling jumbo frames actually reduces network performance substantially.

= Configure an SVM for iSCSI

```
:icons: font
:relative_path: ./san-admin/
:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/
```

To configure a storage virtual machine (SVM) for iSCSI, you must create LIFs for the SVM and assign the iSCSI protocol to those LIFs.

About this task

You need a minimum of one iSCSI LIF per node for each SVM serving data with the iSCSI protocol. For redundancy, you should create at least two LIFs per node.

System Manager

Configure an storage VM for iSCSI with ONTAP System Manager (9.7 and later).

To configure iSCSI on a new storage VM	To configure iSCSI on an existing storage VM
<ol style="list-style-type: none"> 1. In System Manager, click Storage > Storage VMs and then click Add. 2. Enter a name for the storage VM. 3. Select iSCSI for the Access Protocol. 4. Click Enable iSCSI and enter the IP address and subnet mask for the network interface. + Each node should have at least two network interfaces. 5. Click Save. 	<ol style="list-style-type: none"> 1. In System Manager, click Storage > Storage VMs. 2. Click on the storage VM you want to configure. 3. Click on the Settings tab, and then click  next to the iSCSI protocol. 4. Click Enable iSCSI and enter the IP address and subnet mask for the network interface. + Each node should have at least two network interfaces. 5. Click Save.

CLI

Configure an storage VM for iSCSI with the ONTAP CLI.

1. Enable the SVMs to listen for iSCSI traffic:

```
vserver iscsi create -vserver vserver_name -target-alias vserver_name
```

2. Create a LIF for the SVMs on each node to use for iSCSI:

- For ONTAP 9.6 and later:

```
network interface create -vserver vserver_name -lif lif_name -data-protocol
iscsi -service-policy default-data-iscsi -home-node node_name -home-port
port_name -address ip_address -netmask netmask
```

- For ONTAP 9.5 and earlier:

```
network interface create -vserver vserver_name -lif lif_name -role data
-data-protocol iscsi -home-node node_name -home-port port_name -address
ip_address -netmask netmask
```

3. Verify that you set up your LIFs correctly:

```
network interface show -vserver vserver_name
```

4. Verify that iSCSI is up and running and the target IQN for that SVM:

```
vserver iscsi show -vserver vserver_name
```

5. From your host, create iSCSI sessions to your LIFs.

Related information

[NetApp Technical Report 4080: Best practices for modern SAN](#)

= Define a security policy method for an initiator

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You can define a list of initiators and their authentication methods. You can also modify the default authentication method that applies to initiators that do not have a user-defined authentication method.

About this task

You can generate unique passwords using security policy algorithms in the product or you can manually specify the passwords that you want to use.

Not all initiators support hexadecimal CHAP secret passwords.

Steps

1. Use the `vserver iscsi security create` command to create a security policy method for an initiator.

```
vserver iscsi security create -vserver vs2 -initiator iqn.1991-05.com.microsoft:host1 -auth-type CHAP -user-name bob1 -outbound-user-name bob2
```

2. Follow the screen commands to add the passwords.

Creates a security policy method for initiator `iqn.1991-05.com.microsoft:host1` with inbound and outbound CHAP user names and passwords.

Related information

- [How iSCSI authentication works](#)
- [CHAP authentication](#)

= Delete an iSCSI service for an SVM

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You can delete an iSCSI service for a storage virtual machine (SVM) if it is no longer required.

What you'll need

The administration status of the iSCSI service must be in the “down” state before you can delete an iSCSI service. You can move the administration status to down with the `vserver iscsi modify` command.

Steps

1. Use the `vserver iscsi modify` command to stop the I/O to the LUN.

```
vserver iscsi modify -vserver vs1 -status-admin down
```

2. Use the `vserver iscsi delete` command to remove the iscsi service from the SVM.

```
vserver iscsi delete -vserver vs_1
```

3. Use the `vserver iscsi show` command to verify that you deleted the iSCSI service from the SVM.

```
vserver iscsi show -vserver vs1
```

= Get more details in iSCSI session error recoveries

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

Increasing the iSCSI session error recovery level enables you to receive more detailed information about iSCSI error recoveries. Using a higher error recovery level

might cause a minor reduction in iSCSI session performance.

About this task

By default, ONTAP is configured to use error recovery level 0 for iSCSI sessions. If you are using an initiator that has been qualified for error recovery level 1 or 2, you can choose to increase the error recovery level. The modified session error recovery level affects only the newly created sessions and does not affect existing sessions.

Beginning with ONTAP 9.4, the `max-error-recovery-level` option is not supported in the `iscsi show` and `iscsi modify` commands.

Steps

1. Enter advanced mode:

```
set -privilege advanced
```

2. Verify the current setting by using the `iscsi show` command.

```
iscsi show -vserver vs3 -fields max-error-recovery-level
```

```
vserver max-error-recovery-level
-----
vs3      0
```

3. Change the error recovery level by using the `iscsi modify` command.

```
iscsi modify -vserver vs3 -max-error-recovery-level 2
```

= Register the SVM with an iSNS server

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You can use the `vserver iscsi isns` command to configure the storage virtual machine (SVM) to register with an iSNS server.

About this task

The `vserver iscsi isns create` command configures the SVM to register with the iSNS server. The SVM does not provide commands that enable you to configure or manage the iSNS server. To manage the iSNS server, you can use the server administration tools or the interface provided by the vendor for the iSNS server.

Steps

1. On your iSNS server, ensure that your iSNS service is up and available for service.
2. Create the SVM management LIF on a data port:

```
network interface create -vserver SVM_name -lif lif_name -role data -data
-protocol none -home-node home_node_name -home-port home_port -address
IP_address -netmask network_mask
```

3. Create an iSCSI service on your SVM if one does not already exist:

```
vserver iscsi create -vserver SVM_name
```

4. Verify that the iSCSI service was created successfully:

```
iscsi show -vserver SVM_name
```

5. Verify that a default route exists for the SVM:

```
network route show -vserver SVM_name
```

6. If a default route does not exist for the SVM, create a default route:

```
network route create -vserver SVM_name -destination destination -gateway  
gateway
```

7. Configure the SVM to register with the iSNS service:

```
vserver iscsi isns create -vserver SVM_name -address IP_address
```

Both IPv4 and IPv6 address families are supported. The address family of the iSNS server must be the same as that of the SVM management LIF.

For example, you cannot connect an SVM management LIF with an IPv4 address to an iSNS server with an IPv6 address.

8. Verify that the iSNS service is running:

```
vserver iscsi isns show -vserver SVM_name
```

9. If the iSNS service is not running, start it:

```
vserver iscsi isns start -vserver SVM_name
```

= Resolve iSCSI error messages on the storage system

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

There are a number of common iSCSI-related error messages that you can view with the `event log show` command. You need to know what these messages mean and what you can do to resolve the issues they identify.

The following table contains the most common error messages, and instructions for resolving them:

Message	Explanation	What to do
ISCSI: network interface identifier disabled for use; incoming connection discarded	The iSCSI service is not enabled on the interface.	You can use the <code>iscsi interface enable</code> command to enable the iSCSI service on the interface. For example: <code>iscsi interface enable -vserver vs1 -lif lif1</code>
ISCSI: Authentication failed for initiator nodename	CHAP is not configured correctly for the specified initiator.	You should check the CHAP settings; you cannot use the same user name and password for inbound and outbound settings on the storage system: <ul style="list-style-type: none"> • Inbound credentials on the storage system must match outbound credentials on the initiator. • Outbound credentials on the storage system must match inbound credentials on the initiator.

= iSCSI LIF failover for ASA platforms

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

Beginning with ONTAP 9.11.1 on All SAN Array (ASA) platforms, the iSCSI LIF failover feature supports automatic and manual migration of iSCSI LIFs in an SFO partner failover (when an iSCSI LIF moves from its home node/port to its HA partner node/port and back again) and in a local failover (when an iSCSI LIF moves from its unhealthy port to a healthy port on its current home node and back again). This feature provides faster I/O resumption for SAN workloads running on iSCSI.

== About enabling iSCSI LIF failover

You should familiarize yourself with aspects of when iSCSI LIF failover is automatically enabled and when you must manually enable it, including how newly created iSCSI LIFs and existing iSCSI LIFs are affected.

- The automatic migration of an iSCSI LIF is a LIF failover and auto-revert, which is triggered in certain events, such as planned or unplanned failover, a physical ethernet link down, or a node dropping out of replicated database (RDB) quorum.
 - After upgrading your ASA HA pair to ONTAP 9.11.1, this feature is automatically enabled on newly created iSCSI LIFs if no iSCSI LIFs exist in the specified storage VM or if all existing iSCSI LIFs in the specified storage VM are already enabled with iSCSI LIF failover.
 - For iSCSI LIFs created prior to upgrading to ONTAP 9.11.1, to use the iSCSI LIF failover feature,

you must enable it using the ONTAP CLI. (Enabling the failover feature and auto-revert capability means changing the failover policy to `sfo-partner-only` and designating the auto-revert value to `true`.)

[Manage iSCSI LIFs using the ONTAP CLI]

If you do not enable iSCSI LIF failover on the existing iSCSI LIFs, when there is a failover event, the iSCSI LIFs will not failover.

Additionally, if after upgrading to ONTAP 9.11.1 or later you have existing iSCSI LIFs in a storage VM that have not been enabled with the iSCSI LIF failover feature and you create new iSCSI LIFs in the same storage VM, the new iSCSI LIFs assume the same failover policy (`disabled`) of the existing iSCSI LIFs in the storage VM.

- The manual migration of an iSCSI LIF is a LIF migrate and revert, which is initiated by the cluster admin using the ONTAP CLI or System Manager.

[Migrate and revert an iSCSI LIF]

You manually migrate and revert an iSCSI LIF under the following circumstances:

- When scheduled maintenance or replacement is needed.
- When you have a pre-existing iSCSI LIF, meaning that the iSCSI LIF was created before you upgraded your HA pair to ONTAP 9.11.1 or later, and you have not enabled the iSCSI LIF failover feature on the LIF.

== How iSCSI LIF failover works

For LIFs with iSCSI LIF failover enabled (either automatically or manually), the following applies.

- For LIFs using the `data-iscsi` service policy, the failover-policy is restricted to `sfo-partner-only`, `local-only`, and `disabled`.
- iSCSI LIFs can failover only to the HA partner when their failover policy is set to `sfo-partner-only`.
- Auto-revert of LIFs happens when the auto-revert is set to `true` and when the LIF's home port is healthy and able to host the LIF.
- On a planned or unplanned node takeover, the iSCSI LIF on the node which is taken-over fails over to the HA partner. The port on which the LIF fails over is determined by VIF Manager.
- Once the failover is complete, the iSCSI LIF operates normally.
- When a giveback is initiated, the iSCSI LIF reverts back to its home node and port, if auto-revert is set to `true`.
- When an ethernet link goes down on a port hosting one or more iSCSI LIFs, VIF Manager migrates the LIFs from the down port to a different port in the same broadcast domain. The new port could be in the same node or its HA partner. Once the link is restored and if auto-revert is set to `true`, VIF Manager reverts the iSCSI LIFs back to their home node and home port.
- When a node drops out of replicated database (RDB) quorum, VIF Manager migrates the iSCSI LIFs from the out of quorum node to its HA partner. Once the node comes back into quorum and if auto-revert is set to `true`, VIF Manager reverts the iSCSI LIFs back to their home node and home port.

== Migrate and revert an iSCSI LIF

You can use System Manager or the ONTAP CLI to manually migrate an iSCSI LIF to a different port on the same node or to a different port on the HA partner, and then revert the LIF back to its home node and home port.

=== Migrate and revert an iSCSI LIF using System Manager

You can use System Manager to manually migrate and revert one or more iSCSI LIFs (network interfaces) to another port on the same node or to a port on the HA partner.

Before you begin

You must have an ASA platform HA pair and it must be running ONTAP 9.11.1 or later.

==== Migrate a LIF

Steps

1. In System Manager, click **Network > Overview > Network Interfaces**
2. Select the LIF you want to migrate, click , and then click **Migrate**.
3. In the **Migrate Interface** dialog box, select the destination node and port of the HA partner.



You have the option of permanently migrating the iSCSI LIF by checking the checkbox. Understand that the iSCSI LIF must be offline before it is permanently migrated. Additionally, once an iSCSI LIF is permanently migrated, it cannot be undone. There is no revert option.

4. Click **Migrate**.

==== Revert a LIF

Steps

1. In System Manager, click **Network > Overview > Network Interfaces**.
2. Select the LIF you want to revert, click  and then click **Revert Network Interface**.
3. In the **Revert Network Interface** dialog box, click **Revert**.

=== Migrate and revert an iSCSI LIF using the ONTAP CLI

You can use the ONTAP CLI to manually migrate and revert one or more iSCSI LIFs to another port on the same node or to a port on the HA partner.

Before you begin

You must have an ASA platform HA pair and it must be running ONTAP 9.11.1 or later.

If you want to...	Use this command...
Migrate an iSCSI LIF to another node/port	See Migrate a LIF for the available commands.
Revert an iSCSI LIF back to its home node/port	See Revert a LIF to its home port for the available commands.

== Manage iSCSI LIFs using the ONTAP CLI

You can use the ONTAP CLI to manage iSCSI LIFs, including creating new iSCSI LIFs and enabling the iSCSI LIF failover feature for pre-existing LIFs.

Before you Begin

You must have an ASA platform HA pair and it must be running ONTAP 9.11.1 or later.

About this task

See the [ONTAP Command Reference](#) for a full list of `network interface` commands.

If you want to...	Use this command...
Create an iSCSI LIF	<pre>network interface create -vserver SVM_name -lif iscsi_lif -service -policy default-data-blocks -data -protocol iscsi -home-node node_name -home-port port_name -address IP_address -netmask netmask_value</pre> <p>If needed, see Create a LIF for more information.</p>
Verify that the LIF was created successfully	<pre>network interface show -vserver SVM_name -fields failover-policy,failover-group,auto-revert,is-home</pre>
Verify if you can override the auto-revert default on iSCSI LIFs	<pre>network interface modify -vserver SVM_name -lif iscsi_lif -auto-revert false</pre>
Perform a storage failover on an iSCSI LIF	<pre>storage failover takeover -ofnode node_name -option normal</pre> <p>You receive a warning: A takeover will be initiated. Once the partner node reboots, a giveback will be automatically initiated. Do you want to continue? {y/n}:</p> <p>A y response displays a takeover message from its HA partner.</p>
Enable iSCSI LIF failover feature for pre-existing LIFs	<p>For iSCSI LIFs created before you upgraded your cluster to ONTAP 9.11.1 or later, you can enable the iSCSI LIF failover feature (by modifying the failover policy to <code>sfo-partner-only</code> and by modifying the auto-revert capability to <code>true</code>):</p> <pre>network interface modify -vserver SVM_name -lif iscsi_lif -failover-policy sfo-partner-only -auto-revert true</pre> <p>This command can be run on all the iSCSI LIFs in a Storage VM by specifying “-lif*” and keeping all other parameters the same.</p>

Disable iSCSI LIF failover feature for pre-existing LIFs

For iSCSI LIFs created before you upgraded your cluster to ONTAP 9.11.1 or later, you can disable the iSCSI LIF failover feature and the auto-revert capability:

```
network interface modify -vserver  
SVM_name -lif iscsi_lif -failover-  
policy disabled -auto-revert false
```

This command can be run on all the iSCSI LIFs in a storage VM by specifying “-lif*” and keeping all other parameters the same.

= Manage FC protocol

= Configure an SVM for FC

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

To configure a storage virtual machine (SVM) for FC, you must create LIFs for the SVM and assign the FC protocol to those LIFs.

Before you begin

You must have an FC license and it must be enabled. If the FC license is not enabled, the LIFs and SVMs appear to be online but the operational status is `down`. The FC service must be enabled for your LIFs and SVMs to be operational. You must use single initiator zoning for all of the FC LIFs in the SVM to host the initiators.

About this task

NetApp supports a minimum of one FC LIF per node for each SVM serving data with the FC protocol. You must use two LIFs per node and two fabrics, with one LIF per node attached. This provides for redundancy at the node layer and the fabric.

System Manager

Configure an storage VM for iSCSI with ONTAP System Manager (9.7 and later).

To configure FC on a new storage VM	To configure FC on an existing storage VM
<ol style="list-style-type: none">1. In System Manager, click Storage > Storage VMs and then click Add.2. Enter a name for the storage VM.3. Select FC for the Access Protocol.4. Click Enable FC. + The FC ports are automatically assigned.5. Click Save.	<ol style="list-style-type: none">1. In System Manager, click Storage > Storage VMs.2. Click on the storage VM you want to configure.3. Click on the Settings tab, and then click  next to the FC protocol.4. Click Enable FC and enter the IP address and subnet mask for the network interface. + The FC ports are automatically assigned.5. Click Save.

CLI

1. Enable FC service on the SVM:

```
vserver fcp create -vserver vserver_name -status-admin up
```

2. Create two LIFs for the SVMs on each node serving FC:

- For ONTAP 9.6 and later:

```
network interface create -vserver vserver_name -lif lif_name -data-protocol  
fcp -service-policy default-data-fcp -home-node node_name -home-port  
port_name -address ip_address -netmask netmask
```

- For ONTAP 9.5 and earlier:

```
network interface create -vserver vserver_name -lif lif_name -role data  
-data-protocol fcp -home-node node_name -home-port port
```

3. Verify that your LIFs have been created and that their operational status is online:

```
network interface show -vserver vserver_name lif_name
```


Related information

[NetApp Support](#)

[NetApp Interoperability Matrix Tool](#)

[Considerations for LIFs in cluster SAN environments](#)

= Delete an FC service for an SVM

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You can delete an FC service for a storage virtual machine (SVM) if it is no longer required.

What you'll need

The administration status must be “down” before you can delete a FC service for an SVM. You can set the administration status to down with either the `vserver fcp modify` command or the `vserver fcp stop` command.

Steps

1. Use the `vserver fcp stop` command to stop the I/O to the LUN.

```
vserver fcp stop -vserver vs_1
```

2. Use the `vserver fcp delete` command to remove the service from the SVM.

```
vserver fcp delete -vserver vs_1
```

3. Use the `vserver fcp show` to verify that you deleted the FC service from your SVM:

```
vserver fcp show -vserver vs_1
```

= Recommended MTU configurations for FCoE jumbo frames

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

For Fibre Channel over Ethernet (FCoE), jumbo frames for the Ethernet adapter portion of the CNA should be configured at 9000 MTU. Jumbo frames for the FCoE adapter portion of the CNA should be configured at greater than 1500 MTU. Only configure jumbo frames if the initiator, target, and all intervening switches support and are configured for jumbo frames.

= Manage NVMe protocol

= Start the NVMe service for an SVM

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

Before you can use the NVMe protocol on your storage virtual machine (SVM), you must start the NVMe service on the SVM.

Before you begin

NVMe must be allowed as a protocol on your system.

The following NVMe protocols are supported:

Protocol	Beginning with ...	Allowed by...
TCP	ONTAP 9.10.1	Default
FCP	ONTAP 9.4	Default

Steps

1. Change the privilege setting to advanced:

```
set -privilege advanced
```

2. Verify that NVMe is allowed as a protocol:

```
vserver nvme show
```

3. Create the NVMe protocol service:

```
vserver nvme create
```

4. Start the NVMe protocol service on the SVM:

```
vserver nvme modify -status -admin up
```

= Delete NVMe service from an SVM

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

If needed, you can delete the NVMe service from your storage virtual machine (SVM).

Steps

1. Change the privilege setting to advanced:

```
set -privilege advanced
```

2. Stop the NVMe service on the SVM:

```
vserver nvme modify -status -admin down
```

3. Delete the NVMe service:

```
vserver nvme delete
```

= Resize a namespace

:icons: font

:relative_path: ./nvme/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

Beginning with ONTAP 9.10.1, you can use the ONTAP CLI to increase or decrease the size of a NVMe namespace. You can use System Manager to increase the size of a NVMe namespace.

== Increase the size of a namespace

System Manager

1. Click **Storage > NVMe Namespaces**.
2. Hoover over the namespace you want to increase, click , and then click **Edit**.
3. Under **CAPACITY**, change the size of the namespace.

CLI

1. Enter the following command: `vserver nvme namespace modify -vserver SVM_name -path path -size new_size_of_namespace`

== Decrease the size of a namespace

You must use the ONTAP CLI to decrease the size of a NVMe namespace.

1. Change the privilege setting to advanced:

```
set -privilege advanced
```

2. Decrease the size of the namespace:

```
vserver nvme namespace modify -vserver SVM_name -path namespace_path -size new_size_of_namespace
```

= Convert a namespace into a LUN

:icons: font

:relative_path: ./nvme/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

Beginning with ONTAP 9.11.1, you can use the ONTAP CLI to in-place convert an existing NVMe namespace to a LUN.

== Before you start

- * Specified NVMe namespace should not have any existing maps to a Subsystem.
- * Namespace should not be part of a snapshot or on the destination side of SnapMirror relationship as a read-only namespace.
- * Since NVMe namespaces are only supported with specific platforms and network cards, this feature only works with specific hardware.

Steps

1. You enter the following command to convert an NVMe namespace to a LUN:

```
lun convert-from-namespace -vserver -namespace-path
```

= Set up secure authentication over NVMe/TCP

:icons: font

:relative_path: ./nvme/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

Beginning with ONTAP 9.12.1 secure, bidirectional and unidirectional authentication between an NVMe host and controller is supported over NVMe/TCP using the DH-HMAC-CHAP authentication protocol.

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. In order for an NVMe host or controller to authenticate its peer, it must know the key associated with the peer. SHA-256 is the the default hash function and 2048-bit is the default DH group.

Steps

1. Add DH-HMAC-CHAP authentication to your NVMe subsystem:

```
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}
```

2. Verify that the DH-HMAC CHAP authentication protocol is added to your host:

```
vserver nvme subsystem host show
```

```
[ -dhchap-hash-function {sha-256|sha-512} ] Authentication Hash
Function
[ -dhchap-group {none|2048-bit|3072-bit|4096-bit|6144-bit|8192-
bit} ]
Diffie-Hellman
Group
[ -dhchap-mode {none|unidirectional|bidirectional} ]
Authentication Mode
```

3. Verify that the DH-HMAC CHAP authentication was performed during NVMe controller creation:

```
vserver nvme subsystem controller show
```

```
[ -dhchap-hash-function {sha-256|sha-512} ] Authentication Hash
Function
[ -dhchap-group {none|2048-bit|3072-bit|4096-bit|6144-bit|8192-bit}
]
Diffie-Hellman
Group
[ -dhchap-mode {none|unidirectional|bidirectional} ]
Authentication Mode
```

= Disable secure authentication over NVMe/TCP

:icons: font

:relative_path: ./nvme/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

If you are running the NVMe/TCP protocol and you have established secure authentication using DH-HMAC-CHAP, you can choose to disable it at any time.

However, if you are reverting from ONTAP 9.12.1 or later to ONTAP 9.12.0 or earlier you must disable secure authentication before you revert. If secure authentication using DH-HMAC-CHAP is not disabled, revert will fail.

Steps

1. Remove the host from the subsystem to disable DH-HMAC-CHAP authentication:

```
vserver nvme subsystem host remove -vserver svm_name -subsystem subsystem
-host-nqn host_nqn
```

2. Verify that the DH-HMAC-CHAP authentication protocol is removed from the host:

```
vserver nvme subsystem host show
```

3. Add the host back to the subsystem without authentication:

```
vserver nvme subsystem host add -vserver svm_name -subsystem subsystem
-host-nqn host_nqn
```

= Manage systems with FC adapters

= Manage systems with FC adapters

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

Commands are available to manage onboard FC adapters and FC adapter cards. These commands can be used to configure the adapter mode, display adapter information, and change the speed.

Most storage systems have onboard FC adapters that can be configured as initiators or targets. You can also use FC adapter cards configured as initiators or targets. Initiators connect to back-end disk shelves, and possibly foreign storage arrays (FlexArray). Targets connect only to FC switches. Both the FC target HBA ports and the switch port speed should be set to the same value and should not be set to auto.

Related information

[SAN configuration](#)

= Commands for managing FC adapters

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You can use FC commands to manage FC target adapters, FC initiator adapters, and onboard FC adapters for your storage controller. The same commands are used to manage FC adapters for the FC protocol and the FC-NVMe protocol.

FC initiator adapter commands work only at the node level. You must use the `run -node node_name` command before you can use the FC initiator adapter commands.

== Commands for managing FC target adapters

If you want to...	Use this command...
Display FC adapter information on a node	<code>network fcp adapter show</code>

If you want to...	Use this command...
Modify FC target adapter parameters	<code>network fcp adapter modify</code>
Display FC protocol traffic information	<code>run -node <i>node_name</i> sysstat -f</code>
Display how long the FC protocol has been running	<code>run -node <i>node_name</i> uptime</code>
Display adapter configuration and status	<code>run -node <i>node_name</i> sysconfig -v <i>adapter</i></code>
Verify which expansion cards are installed and whether there are any configuration errors	<code>run -node <i>node_name</i> sysconfig -ac</code>
View a man page for a command	<code>man <i>command_name</i></code>

== Commands for managing FC initiator adapters

If you want to...	Use this command...
Display information for all initiators and their adapters in a node	<code>run -node <i>node_name</i> storage show adapter</code>
Display adapter configuration and status	<code>run -node <i>node_name</i> sysconfig -v <i>adapter</i></code>
Verify which expansion cards are installed and whether there are any configuration errors	<code>run -node <i>node_name</i> sysconfig -ac</code>

== Commands for managing onboard FC adapters

If you want to...	Use this command...
Display the status of the onboard FC ports	<code>run -node <i>node_name</i> system hardware unified-connect show</code>

= Configure FC adapters

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

Each onboard FC port can be individually configured as an initiator or a target. Ports on certain FC adapters can also be individually configured as either a target port or an initiator port, just like the onboard FC ports. A list of adapters that can be configured for target mode is available in the [NetApp Hardware Universe](#).

Target mode is used to connect the ports to FC initiators. Initiator mode is used to connect the ports to

tape drives, tape libraries, or third-party storage with FlexArray Virtualization or Foreign LUN Import (FLI).

The same steps are used when configuring FC adapters for the FC protocol and the FC-NVMe protocol. However, only certain FC adapters support FC-NVMe. See the [NetApp Hardware Universe](#) for a list of adapters that support the FC-NVMe protocol.

== Configure FC adapters for target mode

Steps

1. Take the adapter offline:

```
node run -node node_name storage disable adapter adapter_name
```

If the adapter does not go offline, you can also remove the cable from the appropriate adapter port on the system.

2. Change the adapter from initiator to target:

```
system hardware unified-connect modify -t target -node node_name adapter  
adapter_name
```

3. Reboot the node hosting the adapter you changed.
4. Verify that the target port has the correct configuration:

```
network fcp adapter show -node node_name
```

5. Bring your adapter online:

```
network fcp adapter modify -node node_name -adapter adapter_port -state up
```

== Configure FC adapters for initiator mode

What you'll need

- LIFs on the adapter must be removed from any port sets of which they are members.
- All LIF's from every storage virtual machine (SVM) using the physical port to be modified must be migrated or destroyed before changing the personality of the physical port from target to initiator.

NVMe/FC does support initiator mode.

Steps

1. Remove all LIFs from the adapter:

```
network interface delete -vserver SVM_name -lif LIF_name,LIF_name
```

2. Take your adapter offline:

```
network fcp adapter modify -node node_name -adapter adapter_port -status  
-admin down
```

If the adapter does not go offline, you can also remove the cable from the appropriate adapter port on the system.

3. Change the adapter from target to initiator:

```
system hardware unified-connect modify -t initiator adapter_port
```

4. Reboot the node hosting the adapter you changed.
5. Verify that the FC ports are configured in the correct state for your configuration:

```
system hardware unified-connect show
```

6. Bring the adapter back online:

```
node run -node node_name storage enable adapter adapter_port
```

= View adapter settings

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You can use specific commands to view information about your FC/UTA adapters.

== FC target adapter

Step

1. Use the `network fcp adapter show` command to display adapter information: `network fcp adapter show -instance -node node1 -adapter 0a`

The output displays system configuration information and adapter information for each slot that is used.

== Unified Target Adapter (UTA) X1143A-R6

Steps

1. Boot your controller without the cables attached.
2. Run the `system hardware unified-connect show` command to see the port configuration and modules.
3. View the port information before configuring the CNA and ports.

```
= Change the UTA2 port from CNA mode to FC mode
:icons: font
:relative_path: ./san-admin/
:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/
```

You should change the UTA2 port from Converged Network Adapter (CNA) mode to Fibre Channel (FC) mode to support the FC initiator and FC target mode. You should change the personality from CNA mode to FC mode when you need to change the physical medium that connects the port to its network.

Steps

1. Take the adapter offline:

```
network fcp adapter modify -node node_name -adapter adapter_name -status
-admin down
```

2. Change the port mode:

```
ucadmin modify -node node_name -adapter adapter_name -mode fcp
```

3. Reboot the node, and then bring the adapter online:

```
network fcp adapter modify -node node_name -adapter adapter_name -status
-admin up
```

4. Notify your admin or VIF manager to delete or remove the port, as applicable:

- If the port is used as a home port of a LIF, is a member of an interface group (ifgrp), or hosts VLANs, then an admin should do the following:
 - i. Move the LIFs, remove the port from the ifgrp, or delete the VLANs, respectively.
 - ii. Manually delete the port by running the `network port delete` command.

If the `network port delete` command fails, the admin should address the errors, and then run the command again.

- If the port is not used as the home port of a LIF, is not a member of an ifgrp, and does not host VLANs, then the VIF manager should remove the port from its records at the time of reboot.

If the VIF manager does not remove the port, then the admin must remove it manually after the reboot by using the `network port delete` command.

```
net-f8040-34::> network port show
```

```
Node: net-f8040-34-01

Health                                                                    Speed (Mbps)
Port      IPspace      Broadcast Domain Link MTU      Admin/Oper
Status
-----
-----
```

```

...
e0i      Default      Default      down 1500  auto/10  -
e0f      Default      Default      down 1500  auto/10  -
...

```

```

net-f8040-34::> ucadmin show

```

		Current	Current	Pending	Pending
Admin					
Node	Adapter	Mode	Type	Mode	Type
Status					
-----	-----	-----	-----	-----	-----
net-f8040-34-01	0e	cna	target	-	-
offline					
net-f8040-34-01	0f	cna	target	-	-
offline					
...					

```

net-f8040-34::> network interface create -vs net-f8040-34 -lif m
-role
node-mgmt-home-node net-f8040-34-01 -home-port e0e -address 10.1.1.1
-netmask 255.255.255.0

```

```

net-f8040-34::> network interface show -fields home-port, curr-
port

```

vserver	lif	home-port	curr-port
-----	-----	-----	-----
Cluster net-f8040-34-01_clus1	e0a	e0a	
Cluster net-f8040-34-01_clus2	e0b	e0b	
Cluster net-f8040-34-01_clus3	e0c	e0c	
Cluster net-f8040-34-01_clus4	e0d	e0d	
net-f8040-34			
cluster_mgmt	e0M	e0M	
net-f8040-34			
m	e0e	e0i	
net-f8040-34			
net-f8040-34-01_mgmt1	e0M	e0M	

7 entries were displayed.

```

net-f8040-34::> ucadmin modify local 0e fc

```

```

Warning: Mode on adapter 0e and also adapter 0f will be changed
to fc.
Do you want to continue? {y|n}: y

```

Any changes will take effect after rebooting the system. Use the "system node reboot" command to reboot.

```
net-f8040-34::> reboot local
(system node reboot)
```

```
Warning: Are you sure you want to reboot node "net-f8040-34-01"?
{y|n}: y
```

5. Verify that you have the correct SFP+ installed:

```
network fcp adapter show -instance -node -adapter
```

For CNA, you should use a 10Gb Ethernet SFP. For FC, you should either use an 8 Gb SFP or a 16 Gb SFP, before changing the configuration on the node.

= Change the CNA/UTA2 target adapter optical modules

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You should change the optical modules on the unified target adapter (CNA/UTA2) to support the personality mode you have selected for the adapter.

Steps

1. Verify the current SFP+ used in the card. Then, replace the current SFP+ with the appropriate SFP+ for the preferred personality (FC or CNA).
2. Remove the current optical modules from the X1143A-R6 adapter.
3. Insert the correct modules for your preferred personality mode (FC or CNA) optics.
4. Verify that you have the correct SFP+ installed:

```
network fcp adapter show -instance -node -adapter
```

Supported SFP+ modules and Cisco-branded Copper (Twinax) cables are listed in the *Hardware Universe*.

Related information

[NetApp Hardware Universe](#)

= Supported port configurations for X1143A-R6 adapters

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

The FC target mode is the default configuration for X1143A-R6 adapter ports. However, ports on this adapter can be configured as either 10-Gb Ethernet and FCoE ports or as 16-Gb FC ports.

When configured for Ethernet and FCoE, X1143A-R6 adapters support concurrent NIC and FCoE target

traffic on the same 10-GBE port. When configured for FC, each two-port pair that shares the same ASIC can be individually configured for FC target or FC initiator mode. This means that a single X1143A-R6 adapter can support FC target mode on one two-port pair and FC initiator mode on another two-port pair.

Related information

[NetApp Hardware Universe](#)

SAN configuration

= Configure the ports

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

To configure the unified target adapter (X1143A-R6), you must configure the two adjacent ports on the same chip in the same personality mode.

Steps

1. Configure the ports as needed for Fibre Channel (FC) or Converged Network Adapter (CNA) using the `system node hardware unified-connect modify` command.
2. Attach the appropriate cables for FC or 10 Gb Ethernet.
3. Verify that you have the correct SFP+ installed:

```
network fcp adapter show -instance -node -adapter
```

For CNA, you should use a 10Gb Ethernet SFP. For FC, you should either use an 8 Gb SFP or a 16 Gb SFP, based on the FC fabric being connected to.

= Prevent loss of connectivity when using the X1133A-R6 adapter

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You can prevent loss of connectivity during a port failure by configuring your system with redundant paths to separate X1133A-R6 HBAs.

The X1133A-R6 HBA is a 4-port, 16 Gb FC adapter consisting of two 2-port pairs. The X1133A-R6 adapter can be configured as target mode or initiator mode. Each 2-port pair is supported by a single ASIC (for example, Port 1 and Port 2 on ASIC 1 and Port 3 and Port 4 on ASIC 2). Both ports on a single ASIC must be configured to operate in the same mode, either target mode or initiator mode. If an error occurs with the ASIC supporting a pair, both ports in the pair go offline.

To prevent this loss of connectivity, you configure your system with redundant paths to separate X1133A-R6 HBAs, or with redundant paths to ports supported by different ASICs on the HBA.

= Manage LIFs for all SAN protocols

= Manage LIFs for all SAN protocols

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

LIFs are connected to the SAN hosts. They can be removed from port sets, moved to different nodes within a storage virtual machine (SVM), and deleted.

Related information

[Network management](#)

= Configure an NVMe LIF

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

Certain requirements must be met when configuring NVMe LIFs.

What you'll need

NVMe must be supported by the FC adapter on which you create the LIF. Supported adapters are listed in the *Hardware Universe*.

[NetApp Hardware Universe](#)

About this task

The following rules apply when creating an NVMe LIF:

- NVMe can be the only data protocol on data LIFs.
- You should configure one management LIF for every SVM that supports SAN.
- For ONTAP 9.5 and later:
 - You can only configure two NVMe LIFs per node on a maximum of four nodes.
 - You must configure an NVMe LIF on the node containing the namespace and on node's HA partner.
- For ONTAP 9.4 only:
 - NVMe LIFs and namespaces must be hosted on the same node.
 - Only one NVMe data LIF can be configured per SVM.

Steps

1. Create the LIF:

```
network interface create -vserver SVM_name -lif LIF_name -role LIF_role
-data-protocol fc-nvme -home-node home_node -home-port
home_port
```

2. Verify that the LIF was created:

```
network interface show -vserver SVM_name
```

= What to know before moving a SAN LIF

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You only need to perform a LIF movement if you are changing the contents of your cluster, for example, adding nodes to the cluster or deleting nodes from the cluster. If you perform a LIF movement, you do not have to re-zone your FC fabric or create new iSCSI sessions between the attached hosts of your cluster and the new target interface.

You cannot move a SAN LIF using the `network interface move` command. SAN LIF movement must be performed by taking the LIF offline, moving the LIF to a different home node or port, and then bringing it back online in its new location. Asymmetric Logical Unit Access (ALUA) provides redundant paths and automatic path selection as part of any ONTAP SAN solution. Therefore, there is no I/O interruption when the LIF is taken offline for the movement. The host simply retries and then moves I/O to another LIF.

Using LIF movement, you can nondisruptively do the following:

- Replace one HA pair of a cluster with an upgraded HA pair in a way that is transparent to hosts accessing LUN data
- Upgrade a target interface card
- Shift the resources of a storage virtual machine (SVM) from one set of nodes in a cluster to another set of nodes in the cluster

= Remove a SAN LIF from a port set

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

If the LIF you want to delete or move is in a port set, you must remove the LIF from the port set before you can delete or move the LIF.

About this task

You need to do Step 1 in the following procedure only if one LIF is in the port set. You cannot remove the last LIF in a port set if the port set is bound to an initiator group. Otherwise, you can start with Step 2 if multiple LIFs are in the port set.

Steps

1. If only one LIF is in the port set, use the `lun igroup unbind` command to unbind the port set from the initiator group.

When you unbind an initiator group from a port set, all of the initiators in the initiator group have access to all target LUNs mapped to the initiator group on all network interfaces.

+

```
cluster1::>lun igroup unbind -vserver vs1 -igroup ig1
```

1. Use the `lun portset remove` command to remove the LIF from the port set.

```
cluster1::> port set remove -vserver vs1 -portset ps1 -port-name lif1
```

= Move a SAN LIF

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

If a node needs to be taken offline, you can move a SAN LIF to preserve its configuration information, such as its WWPN, and avoid rezoning the switch fabric. Because a SAN LIF must be taken offline before it is moved, host traffic must rely on host multipathing software to provide nondisruptive access to the LUN. You can move SAN LIFs to any node in a cluster, but you cannot move the SAN LIFs between storage virtual machines (SVMs).

What you'll need

If the LIF is a member of a port set, the LIF must have been removed from the port set before the LIF can be moved to a different node.

About this task

The destination node and physical port for a LIF that you want to move must be on the same FC fabric or Ethernet network. If you move a LIF to a different fabric that has not been properly zoned, or if you move a LIF to an Ethernet network that does not have connectivity between iSCSI initiator and target, the LUN will be inaccessible when you bring it back online.

Steps

1. View the administrative and operational status of the LIF:

```
network interface show -vserver vs1 -lif lif1
```

2. Change the status of the LIF to down (offline):

```
network interface modify -vserver vs1 -lif lif1 -status-admin down
```

3. Assign the LIF a new node and port:

```
network interface modify -vserver vs1 -lif lif1 -home-node node1 -home-port port1
```

4. Change the status of the LIF to up (online):

```
network interface modify -vserver vs1 -lif lif1 -status-admin up
```

5. Verify your changes:


```
network interface show -vserver vs1
```

= Delete a LIF in a SAN environment

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

Before you delete a LIF, you should ensure that the host connected to the LIF can access the LUNs through another path.


What you'll need

If the LIF you want to delete is a member of a port set, you must first remove the LIF from the port set before you can delete the LIF.

System Manager

Delete a LIF with ONTAP System Manager (9.7 and later).

Steps

1. In System Manager, click **Network > Overview**, and then select **Network Interfaces**.
2. Select the storage VM from which you want to delete the LIF.
3. Click  and select **Delete**.

CLI

Delete a LIF with the ONTAP CLI.

Steps

1. Verify the name of the LIF and current port to be deleted:

```
network interface show -vserver vs1
```

2. Delete the LIF:

```
network interface delete
```

```
network interface delete -vserver vs1 -lif lif1
```

3. Verify that you deleted the LIF:

```
network interface show
```

```
network interface show -vserver vs1
```

Logical Vserver	Status Interface	Network Admin/Oper	Address/Mask	Current Node	Current Port	Is Home
vs1						
	lif2	up/up	192.168.2.72/24	node-01	e0b	true
	lif3	up/up	192.168.2.73/24	node-01	e0b	true

= SAN LIF requirements for adding nodes to a cluster

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You need to be aware of certain considerations when adding nodes to a cluster.

- You must create LIFs on the new nodes as appropriate before you create LUNs on those new nodes.
- You must discover those LIFs from the hosts as dictated by the host stack and protocol.
- You must create LIFs on the new nodes so that the LUN and volume movements are possible without using the cluster interconnect network.

= Configure iSCSI LIFs to return FQDN to host iSCSI SendTargets Discovery Operation

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

Beginning with ONTAP 9, iSCSI LIFs can be configured to return a Fully Qualified Domain Name (FQDN) when a host OS sends an iSCSI SendTargets Discovery Operation. Returning a FQDN is useful when there is a Network Address Translation (NAT) device between the host OS and the storage service.

About this task

IP addresses on one side of the NAT device are meaningless on the other side, but FQDNs can have meaning on both sides.

The FQDN value interoperability limit is 128 characters on all host OS.

Steps

1. Change the privilege setting to advanced:

```
set -privilege advanced
```

2. Configure iSCSI LIFs to return FQDN:

```
vserver iscsi interface modify -vserver SVM_name -lif iscsi_LIF_name -sendtargets_fqdn FQDN
```

In the following example, the iSCSI LIFs are configured to return storagehost-005.example.com as the FQDN.

```
vserver iscsi interface modify -vserver vs1 -lif vs1_iscsi1 -sendtargets -fqdn storagehost-005.example.com
```

3. Verify that sendtargets is the FQDN:

```
vserver iscsi interface show -vserver SVM_name -fields sendtargets-fqdn
```

In this example, storagehost-005.example.com is displayed in the sendtargets-fqdn output field.

```
cluster::vserver*> vserver iscsi interface show -vserver vs1 -fields
sendtargets-fqdn
vserver lif          sendtargets-fqdn
-----
vs1      vs1_iscsi1  storagehost-005.example.com
vs1      vs1_iscsi2  storagehost-006.example.com
```

Related information

[ONTAP 9 Commands](#)

= Recommended volume and file or LUN configuration combinations

= Recommended volume and file or LUN configuration combinations overview

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

There are specific combinations of FlexVol volume and file or LUN configurations you can use, depending on your application and administration requirements. Understanding the benefits and costs of these combinations can help you determine the right volume and LUN configuration combination for your environment.

The following volume and LUN configuration combinations are recommended:

- Space-reserved files or LUNs with thick volume provisioning
- Non-space-reserved files or LUNs with thin volume provisioning

- Space-reserved files or LUNs with semi-thick volume provisioning

You can use SCSI thin provisioning on your LUNs in conjunction with any of these configuration combinations.

== Space-reserved files or LUNs with thick volume provisioning

Benefits:

- All write operations within space-reserved files are guaranteed; they will not fail due to insufficient space.
- There are no restrictions on storage efficiency and data protection technologies on the volume.

Costs and limitations:

- Enough space must be set aside from the aggregate up front to support the thickly provisioned volume.
- Space equal to twice the size of the LUN is allocated from the volume at LUN creation time.

== Non-space-reserved files or LUNs with thin volume provisioning

Benefits:

- There are no restrictions on storage efficiency and data protection technologies on the volume.
- Space is allocated only as it is used.

Costs and restrictions:

- Write operations are not guaranteed; they can fail if the volume runs out of free space.
- You must manage the free space in the aggregate effectively to prevent the aggregate from running out of free space.

== Space-reserved files or LUNs with semi-thick volume provisioning

Benefits:

Less space is reserved up front than for thick volume provisioning, and a best-effort write guarantee is still provided.

Costs and restrictions:

- Write operations can fail with this option.

You can mitigate this risk by properly balancing free space in the volume against data volatility.

- You cannot rely on retention of data protection objects such as Snapshot copies and FlexClone files and LUNs.
- You cannot use ONTAP block-sharing storage efficiency capabilities that cannot be automatically deleted, including deduplication, compression, and ODX/Copy Offload.

= Determine the correct volume and LUN configuration combination for your environment

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

Answering a few basic questions about your environment can help you determine the best FlexVol volume and LUN configuration for your environment.

About this task

You can optimize your LUN and volume configurations for maximum storage utilization or for the security of write guarantees. Based on your requirements for storage utilization and your ability to monitor and replenish free space quickly, you must determine the FlexVol volume and LUN volumes appropriate for your installation.

You do not need a separate volume for each LUN.

Step

1. Use the following decision tree to determine the best volume and LUN configuration combination for your environment:



= Calculate rate of data growth for LUNs

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You need to know the rate at which your LUN data is growing over time to determine whether you should use space-reserved LUNs or non-space-reserved LUNs.

About this task

If you have a consistently high rate of data growth, then space-reserved LUNs might be a better option for you. If you have a low rate of data growth, then you should consider non-space-reserved LUNs.

You can use tools such as OnCommand Insight to calculate your rate of data growth or you can calculate it manually. The following steps are for manual calculation.

Steps

1. Set up a space-reserved LUN.
2. Monitor the data on the LUN for a set period of time, such as one week.

Make sure that your monitoring period is long enough to form a representative sample of regularly occurring increases in data growth. For instance, you might consistently have a large amount of data growth at the end of each month.

3. Each day, record in GB how much your data grows.

4. At the end of your monitoring period, add the totals for each day together, and then divide by the number of days in your monitoring period.

This calculation yields your average rate of growth.

Example

In this example, you need a 200 GB LUN. You decide to monitor the LUN for a week and record the following daily data changes:

- Sunday: 20 GB
- Monday: 18 GB
- Tuesday: 17 GB
- Wednesday: 20 GB
- Thursday: 20 GB
- Friday: 23 GB
- Saturday: 22 GB

In this example, your rate of growth is $(20+18+17+20+20+23+22) / 7 = 20$ GB per day.

= Configuration settings for space-reserved files or LUNs with thick-provisioned volumes

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

This FlexVol volume and file or LUN configuration combination provides the ability to use storage efficiency technologies and does not require you to actively monitor your free space, because sufficient space is allocated up front.

The following settings are required to configure a space-reserved file or LUN in a volume using thick provisioning:

Volume setting	Value
Guarantee	Volume
Fractional reserve	100
Snapshot reserve	Any
Snapshot autodelete	Optional
Autogrow	Optional; if enabled, aggregate free space must be actively monitored.

File or LUN setting	Value
Space reservation	Enabled

= Configuration settings for non-space-reserved files or LUNs with thin-provisioned volumes

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

This FlexVol volume and file or LUN configuration combination requires the smallest amount of storage to be allocated up front, but requires active free space management to prevent errors due to lack of space.

The following settings are required to configure a non-space-reserved files or LUN in a thin-provisioned volume:

Volume setting	Value
Guarantee	None
Fractional reserve	0
Snapshot reserve	Any
Snapshot autodelete	Optional
Autogrow	Optional

File or LUN setting	Value
Space reservation	Disabled

== Additional considerations

When the volume or aggregate runs out of space, write operations to the file or LUN can fail.

If you do not want to actively monitor free space for both the volume and the aggregate, you should enable Autogrow for the volume and set the maximum size for the volume to the size of the aggregate. In this configuration, you must monitor aggregate free space actively, but you do not need to monitor the free space in the volume.

= Configuration settings for space-reserved files or LUNs with semi-thick volume provisioning

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

This FlexVol volume and file or LUN configuration combination requires less storage to be allocated up front than the fully provisioned combination, but places restrictions on the efficiency technologies you can use for the volume. Overwrites are fulfilled on a best-effort basis for this configuration combination.

The following settings are required to configure a space-reserved LUN in a volume using semi-thick provisioning:

Volume setting	Value
Guarantee	Volume
Fractional reserve	0
Snapshot reserve	0
Snapshot autodelete	On, with a commitment level of destroy, a destroy list that includes all objects, the trigger set to volume, and all FlexClone LUNs and FlexClone files enabled for automatic deletion.
Autogrow	Optional; if enabled, aggregate free space must be actively monitored.

File or LUN setting	Value
Space reservation	Enabled

== Technology restrictions

You cannot use the following volume storage efficiency technologies for this configuration combination:

- Compression
- Deduplication
- ODX and FlexClone Copy Offload
- FlexClone LUNs and FlexClone files not marked for automatic deletion (active clones)
- FlexClone subfiles
- ODX/Copy Offload

== Additional considerations

The following facts must be considered when employing this configuration combination:

- When the volume that supports that LUN runs low on space, protection data (FlexClone LUNs and files, Snapshot copies) is destroyed.
- Write operations can time out and fail when the volume runs out of free space.

Compression is enabled by default for AFF platforms. You must explicitly disable compression for any volume for which you want to use semi-thick provisioning on an AFF platform.

= Data protection methods in SAN environments

= Data protection methods in SAN environments overview

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You can protect your data by making copies of it so that it is available for restoration in the event of accidental deletion, application crashes, data corruption, or disaster. Depending on your data protection and backup needs, ONTAP offers a variety of methods that enable you to protect your data.

== SnapMirror Business Continuity (SM-BC)

Beginning with general availability in ONTAP 9.9.1, provides Zero Recovery Time Objective (Zero RTO) or Transparent Application Failover (TAF) to enable automatic failover of business-critical applications in SAN environments. SM-BC requires the installation of ONTAP Mediator 1.2 in a configuration with either two AFF clusters or two All SAN Array (ASA) clusters.

[NetApp Documentation: SnapMirror Business Continuity](#)

== Snapshot copy

Enables you to manually or automatically create, schedule, and maintain multiple backups of your LUNs. Snapshot copies use only a minimal amount of additional volume space and do not have a performance cost. If your LUN data is accidentally modified or deleted, that data can easily and quickly be restored from one of the latest Snapshot copies.

== FlexClone LUNs (FlexClone license required)

Provides point-in-time, writable copies of another LUN in an active volume or in a Snapshot copy. A clone and its parent can be modified independently without affecting each other.

== SnapRestore (license required)

Enables you to perform fast, space-efficient, on-request data recovery from Snapshot copies on an entire volume. You can use SnapRestore to restore a LUN to an earlier preserved state without rebooting the storage system.

== Data protection mirror copies (SnapMirror license required)

Provides asynchronous disaster recovery by enabling you to periodically create Snapshot copies of data on your volume; copy those Snapshot copies over a local or wide area network to a partner volume, usually on another cluster; and retain those Snapshot copies. The mirror copy on the partner volume provides quick availability and restoration of data from the time of the last Snapshot copy, if the data on the source volume is corrupted or lost.

== SnapVault backups (SnapMirror license required)

Provides storage efficient and long-term retention of backups. SnapVault relationships enable you to back up selected Snapshot copies of volumes to a destination volume and retain the backups.

If you conduct tape backups and archival operations, you can perform them on the data that is already backed up on the SnapVault secondary volume.

== SnapDrive for Windows or UNIX (SnapDrive license required)

Configures access to LUNs, manages LUNs, and manages storage system Snapshot copies directly from a Windows or UNIX hosts.

== Native tape backup and recovery

Support for most existing tape drives are included in ONTAP, as well as a method for tape vendors to dynamically add support for new devices. ONTAP also supports the Remote Magnetic Tape (RMT) protocol, enabling backup and recovery to any capable system.

Related information

[NetApp Documentation: SnapDrive for UNIX](#)

[NetApp Documentation: SnapDrive for Windows \(current releases\)](#)

Data protection using tape backup

= Effect of moving or copying a LUN on Snapshot copies

= Effect of moving or copying a LUN on Snapshot copies overview

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

Snapshot copies are created at the volume level. If you copy or move a LUN to a different volume, the Snapshot copy policy of the destination volume is applied to the copied or moved volume. If Snapshot copies are not established for the destination volume, Snapshot copies will not be created of the moved or copied LUN.

= Restore a single LUN from a Snapshot copy

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You can restore a single LUN from a Snapshot copy without restoring the entire volume that contains the single LUN. You can restore the LUN in place or to a new path in the volume. The operation restores only the single LUN without impacting other files or LUNs in the volume. You can also restore files with streams.

What you'll need

- You must have enough space on your volume to complete the restore operation:
 - If you are restoring a space-reserved LUN where the fractional reserve is 0%, you require one times the size of the restored LUN.
 - If you are restoring a space-reserved LUN where the fractional reserve is 100%, you require two times the size of the restored LUN.
 - If you are restoring a non-space-reserved LUN, you only require the actual space used for the restored LUN.
- A Snapshot copy of the destination LUN must have been created.

If the restore operation fails, the destination LUN might be truncated. In such cases, you can use the Snapshot copy to prevent data loss.

- A Snapshot copy of the source LUN must have been created.

In rare cases, the LUN restore can fail, leaving the source LUN unusable. If this occurs, you can use the Snapshot copy to return the LUN to the state just before the restore attempt.

- The destination LUN and source LUN must have the same OS type.

If your destination LUN has a different OS type from your source LUN, your host can lose data access to the destination LUN after the restore operation.

Steps

1. From the host, stop all host access to the LUN.
2. Unmount the LUN on its host so that the host cannot access the LUN.
3. Unmap the LUN:

```
lun mapping delete -vserver vservice_name -volume volume_name -lun lun_name
-igroup igroup_name
```

4. Determine the Snapshot copy you want to restore your LUN to:

```
volume snapshot show -vserver vservice_name -volume volume_name
```

5. Create a Snapshot copy of the LUN prior to restoring the LUN:

```
volume snapshot create -vserver vservice_name -volume volume_name -snapshot
snapshot_name
```

6. Restore the specified LUN in a volume:

```
volume snapshot restore-file -vserver vservice_name -volume volume_name
-snapshot snapshot_name -path lun_path
```

7. Follow the steps on the screen.
8. If necessary, bring the LUN online:

```
lun modify -vserver vservice_name -path lun_path -state online
```

9. If necessary, remap the LUN:

```
lun mapping create -vserver vservice_name -volume volume_name -lun lun_name
-igroup igroup_name
```

10. From the host, remount the LUN.
11. From the host, restart access to the LUN.

= Restore all LUNs in a volume from a Snapshot copy

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You can use `volume snapshot restore` command to restore all the LUNs in a specified volume from a Snapshot copy.

Steps

1. From the host, stop all host access to the LUNs.

Using SnapRestore without stopping all host access to LUNs in the volume can cause data corruption and system errors.

2. Unmount the LUNs on that host so that the host cannot access the LUNs.
3. Unmap your LUNs:

```
lun mapping delete -vserver vserver_name -volume volume_name -lun lun_name  
-igroup igroup_name
```

4. Determine the Snapshot copy to which you want to restore your volume:

```
volume snapshot show -vserver vserver_name -volume volume_name
```

5. Change your privilege setting to advanced:

```
set -privilege advanced
```

6. Restore your data:

```
volume snapshot restore -vserver vserver_name -volume volume_name -snapshot  
snapshot_name
```

7. Follow the instructions on the screen.

8. Remap your LUNs:

```
lun mapping create -vserver vserver_name -volume volume_name -lun lun_name  
-igroup igroup_name
```

9. Verify that your LUNs are online:

```
lun show -vserver vserver_name -path lun_path -fields state
```

10. If your LUNs are not online, bring them online:

```
lun modify -vserver vserver_name -path lun_path -state online
```

11. Change your privilege setting to admin:

```
set -privilege admin
```

12. From the host, remount your LUNs.

13. From the host, restart access to your LUNs.

= Delete one or more existing Snapshot copies from a volume

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You can manually delete one or more existing Snapshot copies from the volume. You might want to do this if you need more space on your volume.

Steps

1. Use the `volume snapshot show` command to verify which Snapshot copies you want to delete.

```
cluster::> volume snapshot show -vserver vs3 -volume vol3
```

Vserver	Volume	Snapshot	Size	---Blocks---	
				Total%	Used%
-----	-----	-----	-----	-----	-----
vs3	vol3				
		snap1.2013-05-01_0015	100KB	0%	38%
		snap1.2013-05-08_0015	76KB	0%	32%
		snap2.2013-05-09_0010	76KB	0%	32%
		snap2.2013-05-10_0010	76KB	0%	32%
		snap3.2013-05-10_1005	72KB	0%	31%
		snap3.2013-05-10_1105	72KB	0%	31%
		snap3.2013-05-10_1205	72KB	0%	31%
		snap3.2013-05-10_1305	72KB	0%	31%
		snap3.2013-05-10_1405	72KB	0%	31%
		snap3.2013-05-10_1505	72KB	0%	31%

10 entries were displayed.

2. Use the `volume snapshot delete` command to delete Snapshot copies.

If you want to...	Enter this command...
Delete a single Snapshot copy	<code>volume snapshot delete -vserver <i>svm_name</i> -volume <i>vol_name</i> -snapshot <i>snapshot_name</i></code>
Delete multiple Snapshot copies	<code>volume snapshot delete -vserver <i>svm_name</i> -volume <i>vol_name</i> -snapshot <i>snapshot_name1</i>[, <i>snapshot_name2</i>,...]</code>
Delete all Snapshot copies	<code>volume snapshot delete -vserver <i>svm_name</i> -volume <i>vol_name</i> -snapshot *</code>

The following example deletes all Snapshot copies on the volume vol3.

```
cluster::> volume snapshot delete -vserver vs3 -volume vol3 *

10 entries were acted on.
```

= Use FlexClone LUNs to protect your data

= Use FlexClone LUNs to protect your data overview

```
:icons: font
:relative_path: ./san-admin/
:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/
```

A FlexClone LUN is a point-in-time, writeable copy of another LUN in an active volume or in a Snapshot copy. The clone and its parent can be modified independently without affecting each other.

A FlexClone LUN shares space initially with its parent LUN. By default, the FlexClone LUN inherits the space-reserved attribute of the parent LUN. For example, if the parent LUN is non-space-reserved, the FlexClone LUN is also non-space-reserved by default. However, you can create a non-space-reserved FlexClone LUN from a parent that is a space-reserved LUN.

When you clone a LUN, block sharing occurs in the background and you cannot create a volume Snapshot copy until the block sharing is finished.

You must configure the volume to enable the FlexClone LUN automatic deletion function with the `volume snapshot autodelete modify` command. Otherwise, if you want FlexClone LUNs to be deleted automatically but the volume is not configured for FlexClone auto delete, none of the FlexClone LUNs are deleted.

When you create a FlexClone LUN, the FlexClone LUN automatic deletion function is disabled by default. You must manually enable it on every FlexClone LUN before that FlexClone LUN can be automatically deleted. If you are using semi-thick volume provisioning and you want the “best effort” write guarantee provided by this option, you must make *all* FlexClone LUNs available for automatic deletion.

When you create a FlexClone LUN from a Snapshot copy, the LUN is automatically split from the Snapshot copy by using a space-efficient background process so that the LUN does not continue to depend on the Snapshot copy or consume any additional space. If this background split has not been completed and this Snapshot copy is automatically deleted, that FlexClone LUN is deleted even if you have disabled the FlexClone auto delete function for that FlexClone LUN. After the background split is complete, the FlexClone LUN is not deleted even if that Snapshot copy is deleted.

Related information

[Logical storage management](#)

= Reasons for using FlexClone LUNs

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You can use FlexClone LUNs to create multiple read/write copies of a LUN.

You might want to do this for the following reasons:

- You need to create a temporary copy of a LUN for testing purposes.
- You need to make a copy of your data available to additional users without giving them access to the production data.
- You want to create a clone of a database for manipulation and projection operations, while preserving the original data in an unaltered form.
- You want to access a specific subset of a LUN's data (a specific logical volume or file system in a volume group, or a specific file or set of files in a file system) and copy it to the original LUN, without restoring the rest of the data in the original LUN. This works on operating systems that support mounting a LUN and a clone of the LUN at the same time. SnapDrive for UNIX supports this with the `snap connect` command.
- You need multiple SAN boot hosts with the same operating system.

= How a FlexVol volume can reclaim free space with autodelete setting

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You can enable the autodelete setting of a FlexVol volume to automatically delete FlexClone files and FlexClone LUNs. By enabling autodelete, you can reclaim a target amount of free space in the volume when a volume is nearly full.

You can configure a volume to automatically start deleting FlexClone files and FlexClone LUNs when the free space in the volume decreases below a particular threshold value, and automatically stop deleting clones when a target amount of free space in the volume is reclaimed. Although, you cannot specify the threshold value that starts the automatic deletion of clones, you can specify whether a clone is eligible for deletion, and you can specify the target amount of free space for a volume.

A volume automatically deletes FlexClone files and FlexClone LUNs when the free space in the volume decreases below a particular threshold and when *both* of the following requirements are met:

- The autodelete capability is enabled for the volume that contains the FlexClone files and FlexClone LUNs.

You can enable the autodelete capability for a FlexVol volume by using the `volume snapshot autodelete modify` command. You must set the `-trigger` parameter to `volume` or `snap_reserve` for a volume to automatically delete FlexClone files and FlexClone LUNs.

- The autodelete capability is enabled for the FlexClone files and FlexClone LUNs.

You can enable autodelete for a FlexClone file or FlexClone LUN by using the `file clone create` command with the `-autodelete` parameter. As a result, you can preserve certain FlexClone files and FlexClone LUNs by disabling autodelete for the clones and ensuring that other volume settings do not override the clone setting.

= Configure a FlexVol volume to automatically delete FlexClone files and FlexClone LUNs

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You can enable a FlexVol volume to automatically delete FlexClone files and FlexClone LUNs with autodelete enabled when the free space in the volume decreases below a particular threshold.

What you'll need

- The FlexVol volume must contain FlexClone files and FlexClone LUNs and be online.
- The FlexVol volume must not be a read-only volume.

Steps

1. Enable automatic deletion of FlexClone files and FlexClone LUNs in the FlexVol volume by using the `volume snapshot autodelete modify` command.
 - For the `-trigger` parameter, you can specify `volume` or `snap_reserve`.
 - For the `-destroy-list` parameter, you must always specify `lun_clone`, `file_clone` regardless of whether you want to delete only one type of clone.

The following example shows how you can enable volume `vol1` to trigger the automatic deletion of FlexClone files and FlexClone LUNs for space reclamation until 25% of the volume consists of free space:

```
cluster1::> volume snapshot autodelete modify -vserver vs1
-volume vol1 -enabled true -commitment disrupt -trigger volume
-target-free-space 25 -destroy-list lun_clone,file_clone

Volume modify successful on volume:vol1
```

While enabling FlexVol volumes for automatic deletion, if you set the value of the `-commitment` parameter to `destroy`, all the FlexClone files and FlexClone LUNs with the `-autodelete` parameter set to `true` might be deleted when the free space in the volume decreases below the specified threshold value. However, FlexClone files and FlexClone LUNs with the `-autodelete` parameter set to `false` will not be deleted.

1. Verify that automatic deletion of FlexClone files and FlexClone LUNs is enabled in the FlexVol volume by using the `volume snapshot autodelete show` command.

The following example shows that volume `vol1` is enabled for automatic deletion of FlexClone files and FlexClone LUNs:

```
cluster1::> volume snapshot autodelete show -vserver vs1 -volume
vol1

Vserver Name: vs1
Volume Name: vol1
Enabled: true
Commitment: disrupt
Defer Delete: user_created
Delete Order: oldest_first
Defer Delete Prefix: (not specified)*
Target Free Space: 25%
Trigger: volume
Destroy List: lun_clone,file_clone
Is Constituent Volume: false
```

2. Ensure that autodelete is enabled for the FlexClone files and FlexClone LUNs in the volume that you want to delete by performing the following steps:

- a. Enable automatic deletion of a particular FlexClone file or FlexClone LUN by using the `volume file clone autodelete` command.

You can force a specific FlexClone file or FlexClone LUN to be automatically deleted by using the `volume file clone autodelete` command with the `-force` parameter.

The following example shows that automatic deletion of the FlexClone LUN `lun1_clone` contained in volume `vol1` is enabled:

```
cluster1::> volume file clone autodelete -vserver vs1 -clone-path
/vol/vol1/lun1_clone -enabled true
```

You can enable autodelete when you create FlexClone files and FlexClone LUNs.

- b. Verify that the FlexClone file or FlexClone LUN is enabled for automatic deletion by using the `volume file clone show-autodelete` command.

The following example shows that the FlexClone LUN `lun1_clone` is enabled for automatic deletion:

```
cluster1::> volume file clone show-autodelete -vserver vs1 -clone
-path vol/vol1/lun1_clone

Vserver Name: vs1
Clone

Path: vol/vol1/lun1_clone

**Autodelete Enabled: true**
```

For more information about using the commands, see the respective man pages.

= Clone LUNs from an active volume

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You can create copies of your LUNs by cloning the LUNs in the active volume. These FlexClone LUNs are readable and writeable copies of the original LUNs in the active volume.

What you'll need

A FlexClone license must be installed.

About this task

A space-reserved FlexClone LUN requires as much space as the space-reserved parent LUN. If the FlexClone LUN is not space-reserved, you must ensure that the volume has enough space to accommodate changes to the FlexClone LUN.

Steps

1. You must have verified that the LUNs are not mapped to an igroup or are written to before making the clone.
2. Use the `lun show` command to verify that the LUN exists.

```
lun show -vserver vs1
```

Vserver	Path	State	Mapped	Type	Size
vs1	/vol/vol1/lun1	online	unmapped	windows	47.07MB

3. Use the `volume file clone create` command to create the FlexClone LUN.

```
volume file clone create -vserver vs1 -volume vol1 -source-path lun1
-destination-path/lun1_clone
```

If you need the FlexClone LUN to be available for automatic deletion, you include `-autodelete true`. If you are creating this FlexClone LUN in a volume using semi-thick provisioning, you must

enable automatic deletion for all FlexClone LUNs.

4. Use the `lun show` command to verify that you created a LUN.

```
lun show -vserver vs1
```

Vserver	Path	State	Mapped	Type	Size
vs1	/vol/volX/lun1	online	unmapped	windows	47.07MB
vs1	/vol/volX/lun1_clone	online	unmapped	windows	47.07MB

= Create FlexClone LUNs from a Snapshot copy in a volume

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You can use a Snapshot copy in your volume to create FlexClone copies of your LUNs. FlexClone copies of LUNs are both readable and writeable.

What you'll need

A FlexClone license must be installed.

About this task

The FlexClone LUN inherits the space reservations attribute of the parent LUN. A space-reserved FlexClone LUN requires as much space as the space-reserved parent LUN. If the FlexClone LUN is not space-reserved, the volume must have enough space to accommodate changes to the clone.

Steps

1. Verify that the LUN is not mapped or being written to.
2. Create a Snapshot copy of the volume that contains the LUNs:

```
volume snapshot create -vserver vs1 -volume volume_name -snapshot snapshot_name
```

You must create a Snapshot copy (the backing Snapshot copy) of the LUN you want to clone.

3. Create the FlexClone LUN from the Snapshot copy:

```
file clone create -vserver vs1 -volume volume_name -source-path source_path -snapshot-name snapshot_name -destination-path destination_path
```

If you need the FlexClone LUN to be available for automatic deletion, you include `-autodelete true`. If you are creating this FlexClone LUN in a volume using semi-thick provisioning, you must enable automatic deletion for all FlexClone LUNs.

4. Verify that the FlexClone LUN is correct:

```
lun show -vserver vs1
```

Vserver	Path	State	Mapped	Type	Size
-----	-----	-----	-----	-----	-----
vs1	/vol/vol1/lun1_clone	online	unmapped	windows	47.07MB
vs1	/vol/vol1/lun1_snap_clone	online	unmapped	windows	47.07MB

= Prevent a specific FlexClone file or FlexClone LUN from being automatically deleted

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

If you configure a FlexVol volume to automatically delete FlexClone files and FlexClone LUNs, any clone that fits the criteria you specify might be deleted. If you have specific FlexClone files or FlexClone LUNs that you want to preserve, you can exclude them from the automatic FlexClone deletion process.

What you'll need

A FlexClone license must be installed.

About this task

When you create a FlexClone file or FlexClone LUN, by default the autodelete setting for the clone is disabled. FlexClone files and FlexClone LUNs with autodelete disabled are preserved when you configure a FlexVol volume to automatically delete clones to reclaim space on the volume.

If you set the `commitment` level on the volume to `try` or `disrupt`, you can individually preserve specific FlexClone files or FlexClone LUNs by disabling autodelete for those clones. However, if you set the `commitment` level on the volume to `destroy` and the `destroy` lists include `lun_clone`, `file_clone`, the volume setting overrides the clone setting, and all FlexClone files and FlexClone LUNs can be deleted regardless of the autodelete setting for the clones.

Steps

1. Prevent a specific FlexClone file or FlexClone LUN from being automatically deleted by using the `volume file clone autodelete` command.

The following example shows how you can disable autodelete for FlexClone LUN `lun1_clone` contained in `vol1`:

```
cluster1::> volume file clone autodelete -vserver vs1 -volume vol1  
-clone-path lun1_clone -enable false
```

A FlexClone file or FlexClone LUN with autodelete disabled cannot be deleted automatically to reclaim space on the volume.

2. Verify that autodelete is disabled for the FlexClone file or FlexClone LUN by using the `volume file clone show-autodelete` command.

The following example shows that autodelete is false for the FlexClone LUN `lun1_clone`:

```
cluster1::> volume file clone show-autodelete -vserver vs1 -clone  
-path vol/vol1/lun1_clone
```

	Vserver
Name:	vs1
	Clone
Path:	vol/vol1/lun1_clone
Autodelete Enabled:	false

= Configure and use SnapVault backups in a SAN environment

= Configure and use SnapVault backups in a SAN environment overview

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

SnapVault configuration and use in a SAN environment is very similar to configuration and use in a NAS environment, but restoring LUNs in a SAN environment requires some special procedures.

SnapVault backups contain a set of read-only copies of a source volume. In a SAN environment you always back up entire volumes to the SnapVault secondary volume, not individual LUNs.

The procedure for creating and initializing the SnapVault relationship between a primary volume containing LUNs and a secondary volume acting as a SnapVault backup is identical to the procedure used with FlexVol volumes used for file protocols. This procedure is described in detail in [Data Protection](#).

It is important to ensure that LUNs being backed up are in a consistent state before the Snapshot copies are created and copied to the SnapVault secondary volume. Automating the Snapshot copy creation with

SnapCenter ensures that backed up LUNs are complete and usable by the original application.

There are three basic choices for restoring LUNs from a SnapVault secondary volume:

- You can map a LUN directly from the SnapVault secondary volume and connect a host to the LUN to access the contents of the LUN.

The LUN is read-only and you can map only from the most recent Snapshot copy in the SnapVault backup. Persistent reservations and other LUN metadata are lost. If desired, you can use a copy program on the host to copy the LUN contents back to the original LUN if it is still accessible.

The LUN has a different serial number from the source LUN.

- You can clone any Snapshot copy in the SnapVault secondary volume to a new read-write volume.

You can then map any of the LUNs in the volume and connect a host to the LUN to access the contents of the LUN. If desired, you can use a copy program on the host to copy the LUN contents back to the original LUN if it is still accessible.

- You can restore the entire volume containing the LUN from any Snapshot copy in the SnapVault secondary volume.

Restoring the entire volume replaces all of the LUNs, and any files, in the volume. Any new LUNs created since the Snapshot copy was created are lost.

The LUNs retain their mapping, serial numbers, UUIDs, and persistent reservations.

= Access a read-only LUN copy from a SnapVault backup

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You can access a read-only copy of a LUN from the latest Snapshot copy in a SnapVault backup. The LUN ID, path, and serial number are different from the source LUN and must first be mapped. Persistent reservations, LUN mappings, and igroups are not replicated to the SnapVault secondary volume.

What you'll need

- The SnapVault relationship must be initialized and the latest Snapshot copy in the SnapVault secondary volume must contain the desired LUN.
- The storage virtual machine (SVM) containing the SnapVault backup must have one or more LIFs with the desired SAN protocol accessible from the host used to access the LUN copy.
- If you plan to access LUN copies directly from the SnapVault secondary volume, you must create your igroups on the SnapVault SVM in advance.

You can access a LUN directly from the SnapVault secondary volume without having to first restore or clone the volume containing the LUN.

About this task

If a new Snapshot copy is added to the SnapVault secondary volume while you have a LUN mapped from a previous Snapshot copy, the contents of the mapped LUN changes. The LUN is still mapped with the same identifiers, but the data is taken from the new Snapshot copy. If the LUN size changes, some hosts

automatically detect the size change; Windows hosts require a disk rescan to pick up any size change.

Steps

1. Run the `lun show` command to list the available LUNs in the SnapVault secondary volume.

In this example, you can see both the original LUNs in the primary volume `srcvolA` and the copies in the SnapVault secondary volume `dstvolB`:

```
cluster::> lun show
```

Vserver	Path	State	Mapped	Type	Size
-----	-----	-----	-----	-----	-----
vserverA	/vol/srcvolA/lun_A	online	mapped	windows	300.0GB
vserverA	/vol/srcvolA/lun_B	online	mapped	windows	300.0GB
vserverA	/vol/srcvolA/lun_C	online	mapped	windows	300.0GB
vserverB	/vol/dstvolB/lun_A	online	unmapped	windows	300.0GB
vserverB	/vol/dstvolB/lun_B	online	unmapped	windows	300.0GB
vserverB	/vol/dstvolB/lun_C	online	unmapped	windows	300.0GB

6 entries were displayed.

2. If the `igroup` for the desired host does not already exist on the SVM containing the SnapVault secondary volume, run the `igroup create` command to create an `igroup`.

This command creates an `igroup` for a Windows host that uses the iSCSI protocol:

```
cluster::> igroup create -vserver vserverB -igroup temp_igroup
               -protocol iscsi -ostype windows
               -initiator iqn.1991-05.com.microsoft:hostA
```

3. Run the `lun mapping create` command to map the desired LUN copy to the `igroup`.

```
cluster::> lun mapping create -vserver vserverB -path
/vol/dstvolB/lun_A
               -igroup temp_igroup
```

4. Connect the host to the LUN and access the contents of the LUN as desired.

= Restore a single LUN from a SnapVault backup

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You can restore a single LUN to a new location or to the original location. You can restore from any Snapshot copy in the SnapVault secondary volume. To restore the LUN to the original location, you first restore it to a new location and then copy it.

What you'll need

- The SnapVault relationship must be initialized and the SnapVault secondary volume must contain an appropriate Snapshot copy to restore.
- The storage virtual machine (SVM) containing the SnapVault secondary volume must have one or more LIFs with the desired SAN protocol that are accessible from the host used to access the LUN copy.
- The igroups must already exist on the SnapVault SVM.

About this task

The process includes creating a read-write volume clone from a Snapshot copy in the SnapVault secondary volume. You can use the LUN directly from the clone, or you can optionally copy the LUN contents back to the original LUN location.

The LUN in the clone has a different path and serial number from the original LUN. Persistent reservations are not retained.

Steps

1. Run the `snapmirror show` command to verify the secondary volume that contains the SnapVault backup.

```
cluster::> snapmirror show
```

Source Path	Type	Dest Path	Mirror State	Relation Status	Total Progress	Healthy	Last Updated
vserverA:srcvolA	XDP	vserverB:dstvolB	Snapmirrored	Idle	-	true	-

2. Run the `volume snapshot show` command to identify the Snapshot copy that you want to restore the LUN from.

```
cluster::> volume snapshot show
```

Vserver	Volume	Snapshot	State	Size	Total%	Used%
vserverB	dstvolB	snap2.2013-02-10_0010	valid	124KB	0%	0%
		snap1.2013-02-10_0015	valid	112KB	0%	0%
		snap2.2013-02-11_0010	valid	164KB	0%	0%

3. Run the `volume clone create` command to create a read-write clone from the desired Snapshot copy.

The volume clone is created in the same aggregate as the SnapVault backup. There must be enough space in the aggregate to store the clone.

```
cluster::> volume clone create -vserver vserverB
        -flexclone dstvolB_clone -type RW -parent-volume dstvolB
        -parent-snapshot daily.2013-02-10_0010
[Job 108] Job succeeded: Successful
```

4. Run the `lun show` command to list the LUNs in the volume clone.

```
cluster::> lun show -vserver vserverB -volume dstvolB_clone
```

Vserver	Path	State	Mapped	Type
vserverB	/vol/dstvolB_clone/lun_A	online	unmapped	windows
vserverB	/vol/dstvolB_clone/lun_B	online	unmapped	windows
vserverB	/vol/dstvolB_clone/lun_C	online	unmapped	windows

3 entries were displayed.

5. If the igroup for the desired host does not already exist on the SVM containing the SnapVault backup, run the `igroup create` command to create an igroup.

This example creates an igroup for a Windows host that uses the iSCSI protocol:

```
cluster::> igroup create -vserver vserverB -igroup temp_igroup
        -protocol iscsi -ostype windows
        -initiator iqn.1991-05.com.microsoft:hostA
```

6. Run the `lun mapping create` command to map the desired LUN copy to the igroup.

```
cluster::> lun mapping create -vserver vserverB
        -path /vol/dstvolB_clone/lun_C -igroup temp_igroup
```

7. Connect the host to the LUN and access the contents of the LUN, as desired.

The LUN is read-write and can be used in place of the original LUN. Because the LUN serial number is different, the host interprets it as a different LUN from the original.

8. Use a copy program on the host to copy the LUN contents back to the original LUN.

= Restore all LUNs in a volume from a SnapVault backup

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

If one or more LUNs in a volume need to be restored from a SnapVault backup, you can restore the entire volume. Restoring the volume affects all LUNs in the volume.

What you'll need

The SnapVault relationship must be initialized and the SnapVault secondary volume must contain an appropriate Snapshot copy to restore.

About this task

Restoring an entire volume returns the volume to the state it was in when the Snapshot copy was made. If a LUN was added to the volume after the Snapshot copy, that LUN is removed during the restore process.

After restoring the volume, the LUNs remain mapped to the igroups they were mapped to just before the restore. The LUN mapping might be different from the mapping at the time of the Snapshot copy. Persistent reservations on the LUNs from host clusters are retained.

Steps

1. Stop I/O to all LUNs in the volume.
2. Run the `snapmirror show` command to verify the secondary volume that contains the SnapVault secondary volume.

```
cluster::> snapmirror show
```

Source Path	Type	Dest Path	Mirror State	Relation Status	Total Progress	Healthy	Last Updated
vserverA:srcvolA							
	XDP	vserverB:dstvolB					
			Snapmirrored				
				Idle	-	true	-

3. Run the `volume snapshot show` command to identify the Snapshot copy that you want to restore from.

```
cluster::> volume snapshot show
```

Vserver	Volume	Snapshot	State	Size	Total%	Used%
vserverB						
	dstvolB					
		snap2.2013-02-10_0010	valid	124KB	0%	0%
		snap1.2013-02-10_0015	valid	112KB	0%	0%
		snap2.2013-02-11_0010	valid	164KB	0%	0%

4. Run the `snapmirror restore` command and specify the `-source-snapshot` option to specify the Snapshot copy to use.

The destination you specify for the restore is the original volume you are restoring to.

```
cluster::> snapmirror restore -destination-path vserverA:srcvolA  
-source-path vserverB:dstvolB -source-snapshot daily.2013-02-  
10_0010
```

```
Warning: All data newer than Snapshot copy hourly.2013-02-11_1205 on  
volume vserverA:src_volA will be deleted.
```

```
Do you want to continue? {y|n}: y
```

```
[Job 98] Job is queued: snapmirror restore from source  
"vserverB:dstvolB" for the snapshot daily.2013-02-10_0010.
```

5. If you are sharing LUNs across a host cluster, restore the persistent reservations on the LUNs from the affected hosts.

== Restoring a volume from a SnapVault backup

In the following example, the LUN named lun_D was added to the volume after the Snapshot copy was created. After restoring the entire volume from the Snapshot copy, lun_D no longer appears.

In the `lun show` command output, you can see the LUNs in the primary volume srcvolA and the read-only copies of those LUNs in the SnapVault secondary volume dstvolB. There is no copy of lun_D in the SnapVault backup.

```
cluster::> lun show
```

Vserver	Path	State	Mapped	Type	Size
vserverA	/vol/srcvolA/lun_A	online	mapped	windows	300.0GB
vserverA	/vol/srcvolA/lun_B	online	mapped	windows	300.0GB
vserverA	/vol/srcvolA/lun_C	online	mapped	windows	300.0GB
vserverA	/vol/srcvolA/lun_D	online	mapped	windows	250.0GB
vserverB	/vol/dstvolB/lun_A	online	unmapped	windows	300.0GB
vserverB	/vol/dstvolB/lun_B	online	unmapped	windows	300.0GB
vserverB	/vol/dstvolB/lun_C	online	unmapped	windows	300.0GB

7 entries were displayed.

```
cluster::>snapmirror restore -destination-path vserverA:srcvolA
        -source-path vserverB:dstvolB
        -source-snapshot daily.2013-02-10_0010
```

Warning: All data newer than Snapshot copy hourly.2013-02-11_1205
on volume vserverA:src_volA will be deleted.

Do you want to continue? {y|n}: y

[Job 98] Job is queued: snapmirror restore from source
"vserverB:dstvolB" for the snapshot daily.2013-02-10_0010.

```
cluster::> lun show
```

Vserver	Path	State	Mapped	Type	Size
vserverA	/vol/srcvolA/lun_A	online	mapped	windows	300.0GB
vserverA	/vol/srcvolA/lun_B	online	mapped	windows	300.0GB
vserverA	/vol/srcvolA/lun_C	online	mapped	windows	300.0GB
vserverB	/vol/dstvolB/lun_A	online	unmapped	windows	300.0GB
vserverB	/vol/dstvolB/lun_B	online	unmapped	windows	300.0GB
vserverB	/vol/dstvolB/lun_C	online	unmapped	windows	300.0GB

6 entries were displayed.

After the volume is restored from the SnapVault secondary volume, the source volume no longer contains lun_D. You do not need to remap the LUNs in the source volume after the restore because they are still mapped.

= How you can connect a host backup system to the primary storage system

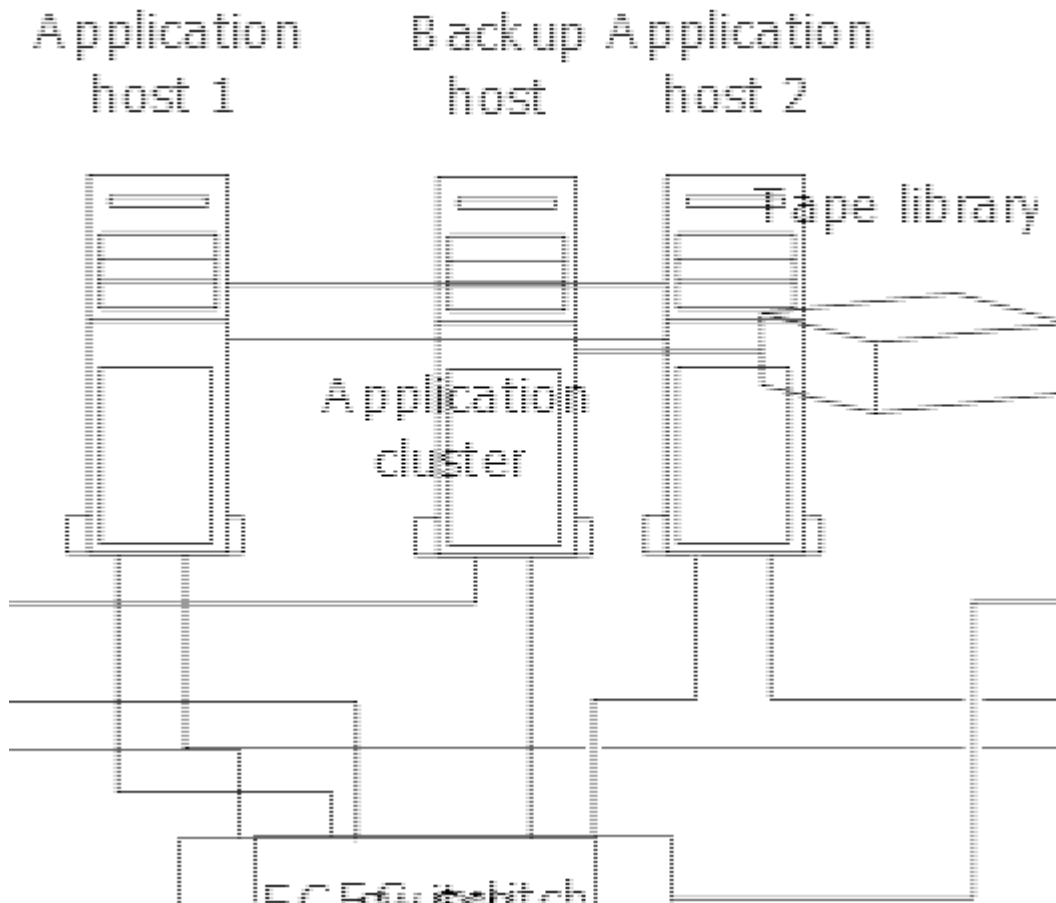
:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You can back up SAN systems to tape through a separate backup host to avoid performance degradation on the application host.

It is imperative that you keep SAN and NAS data separated for backup purposes. The figure below shows the recommended physical configuration for a host backup system to the primary storage system. You must configure volumes as SAN-only. LUNs can be confined to a single volume or the LUNs can be spread across multiple volumes or storage systems.



Volumes on a host can consist of a single LUN mapped from the storage system or multiple LUNs using a volume manager, such as VxVM on HP-UX systems.

= Back up a LUN through a host backup system

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You can use a cloned LUN from a Snapshot copy as source data for the host backup system.

What you'll need

A production LUN must exist and be mapped to an igroup that includes the WWPN or initiator node name of the application server. The LUN must also be formatted and accessible to the host

Steps

1. Save the contents of the host file system buffers to disk.

You can use the command provided by your host operating system, or you can use SnapDrive for Windows or SnapDrive for UNIX. You can also opt to make this step part of your SAN backup pre-processing script.

2. Use the `volume snapshot create` command to create a Snapshot copy of the production LUN.

```
volume snapshot create -vserver vs0 -volume vol3 -snapshot vol3_snapshot  
-comment "Single snapshot" -foreground false
```

3. Use the `volume file clone create` command to create a clone of the production LUN.

```
volume file clone create -vserver vs3 -volume vol3 -source-path lun1  
-snapshot-name snap_vol3 -destination-path lun1_backup
```

4. Use the `lun igroup create` command to create an igroup that includes the WWPN of the backup server.

```
lun igroup create -vserver vs3 -igroup igroup3 -protocol fc -ostype windows  
-initiator 10:00:00:00:c9:73:5b:91
```

5. Use the `lun mapping create` command to map the LUN clone you created in Step 3 to the backup host.

```
lun mapping create -vserver vs3 -volume vol3 -lun lun1_backup -igroup  
igroup3
```

You can opt to make this step part of your SAN backup application's post-processing script.

6. From the host, discover the new LUN and make the file system available to the host.

You can opt to make this step part of your SAN backup application's post-processing script.

7. Back up the data in the LUN clone from the backup host to tape by using your SAN backup application.

8. Use the `lun modify` command to take the LUN clone offline.

```
lun modify -vserver vs3 -path /vol/vol3/lun1_backup -state offline
```

9. Use the `lun delete` to remove the LUN clone.

```
lun delete -vserver vs3 -volume vol3 -lun lun1_backup
```

10. Use the `volume snapshot delete` command to remove the Snapshot copy.

```
volume snapshot delete -vserver vs3 -volume vol3 -snapshot vol3_snapshot
```

= SAN configurations in a MetroCluster environment

= SAN configurations in a MetroCluster environment

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You must be aware of certain considerations when using SAN configurations in a MetroCluster environment.

- MetroCluster configurations do not support front-end FC fabric “routed” vSAN configurations.
- Beginning with ONTAP 9.12.1, four-node MetroCluster IP configurations are supported on NVMe/FC. MetroCluster configurations are not supported for NVMe prior to ONTAP 9.12.1.
- Other SAN protocols such as iSCSI, FC, and FCoE are supported on MetroCluster configurations.
- When using SAN client configurations, you must check whether any special considerations for MetroCluster configurations are included in the notes that are provided in the [NetApp Interoperability Matrix Tool](#) (IMT).
- Operating systems and applications must provide an I/O resiliency of 120 seconds to support MetroCluster automatic unplanned switchover and Tiebreaker or Mediator-initiated switchover.
- The MetroCluster is using the same WWPNs on both sides of the front-end SAN.

Related information

[Understanding MetroCluster data protection and disaster recovery](#)

For further MetroCluster-specific host information, refer to the following NetApp Knowledge Base articles:

[What are AIX Host support considerations in a MetroCluster configuration?](#)

[Solaris host support considerations in a MetroCluster configuration](#)

= Prevent port overlap between switchover and switchback

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

In a SAN environment, you can configure the front-end switches to avoid overlap when the old port goes offline and the new port comes online.

During switchover, the FC port on the surviving site might log in to the fabric before the fabric has detected that the FC port on the disaster site is offline and has removed this port from the name and directory services.

If the FC port on the disaster is not yet removed, the fabric login attempt of the FC port at the surviving site might be rejected due to a duplicate WWPN. This behavior of the FC switches can be changed to honor the login of the previous device and not the existing one. You should verify the effects of this behavior on other fabric devices. Contact the switch vendor for more information.

Choose the correct procedure according to your switch type.

Cisco switch

1. Connect to the switch and log in.
2. Enter configuration mode:

```
switch# config t
switch(config)#
```

3. Overwrite the first device entry in the name server database with the new device:


```
switch(config)# no fcns reject-duplicate-pwvn vsan 1
```

4. In switches that are running NX-OS 8.x, confirm that the flogi quiesce timeout is set to zero:

a. Display the quiesce timerval:

```
switch(config)# show flogi interval info \ i quiesce
```

```
Stats:  fs flogi quiesce timerval:  0
```

b. If the output in the previous step does not indicate that the timerval is zero, then set it to zero:

```
switch(config)# flogi scale enable
```

```
switch(config)$ flogi quiesce timeout 0
```

Brocade switch

1. Connect to the switch and log in.
2. Enter the switchDisable command.
3. Enter the configure command, and press *y* at the prompt.

```
F-Port login parameters (yes, y, no, n): [no] y
```

4. Choose setting 1:

```
- 0: First login take precedence over the second login (default)
- 1: Second login overrides first login.
- 2: the port type determines the behavior
Enforce FLOGI/FDISC login: (0..2) [0] 1
```

5. Respond to the remaining prompts, or press **Ctrl + D**.
6. Enter the switchEnable command.

Related information

[Performing switchover for tests or maintenance](#)

= SAN concepts

= About SAN host provisioning

= SAN provisioning with iSCSI

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

In SAN environments, storage systems are targets that have storage target devices. For iSCSI and FC, the storage target devices are referred to as LUNs (logical units). For Non-Volatile Memory Express (NVMe) over Fibre Channel, the storage target devices are referred to as namespaces.

You configure storage by creating LUNs for iSCSI and FC or by creating namespaces for NVMe. The LUNs or namespaces are then accessed by hosts using Internet Small Computer Systems Interface (iSCSI) or Fibre Channel (FC) protocol networks.

To connect to iSCSI networks, hosts can use standard Ethernet network adapters (NICs), TCP offload engine (TOE) cards with software initiators, converged network adapters (CNAs), or dedicated iSCSI host bus adapters (HBAs).

To connect to FC networks, hosts require FC HBAs or CNAs.

Supported FC protocols include:

- FC
- FCoE
- NVMe

== iSCSI target node network connections and names

iSCSI target nodes can connect to the network in several ways:

- Over Ethernet interfaces using software that is integrated into ONTAP.
- Over multiple system interfaces, with an interface used for iSCSI that can also transmit traffic for other protocols, such as SMB and NFS.
- Using a unified target adapter (UTA) or a converged network adapter (CNA).

Every iSCSI node must have a node name.

The two formats, or type designators, for iSCSI node names are *iqn* and *eui*. The SVM iSCSI target always uses the iqn-type designator. The initiator can use either the iqn-type or eui-type designator.

== Storage system node name

Each SVM running iSCSI has a default node name based on a reverse domain name and a unique encoding number.

The node name is displayed in the following format:

iqn.1992-08.com.netapp:sn.*unique-encoding-number*

The following example shows the default node name for a storage system with a unique encoding number:

iqn.1992-08.com.netapp:sn.812921059e6c11e097b3123478563412:vs.6

== TCP port for iSCSI

The iSCSI protocol is configured in ONTAP to use TCP port number 3260.

ONTAP does not support changing the port number for iSCSI. Port number 3260 is registered as part of the iSCSI specification and cannot be used by any other application or service.

Related information

[NetApp Documentation: ONTAP SAN Host Configuration](#)

= iSCSI service management

= iSCSI service management

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You can manage the availability of the iSCSI service on the iSCSI logical interfaces of the storage virtual machine (SVM) by using the `vserver iscsi interface enable` or `vserver iscsi interface disable` commands.

By default, the iSCSI service is enabled on all iSCSI logical interfaces.

== How iSCSI is implemented on the host

iSCSI can be implemented on the host using hardware or software.

You can implement iSCSI in one of the following ways:

- Using Initiator software that uses the host's standard Ethernet interfaces.
- Through an iSCSI host bus adapter (HBA): An iSCSI HBA appears to the host operating system as a SCSI disk adapter with local disks.
- Using a TCP Offload Engine (TOE) adapter that offloads TCP/IP processing.

The iSCSI protocol processing is still performed by host software.

= How iSCSI authentication works

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

During the initial stage of an iSCSI session, the initiator sends a login request to the storage system to begin an iSCSI session. The storage system then either permits or

denies the login request, or determine that a login is not required.

iSCSI authentication methods are:

- Challenge Handshake Authentication Protocol (CHAP)—The initiator logs in using a CHAP user name and password.

You can specify a CHAP password or generate a hexadecimal secret password. There are two types of CHAP user names and passwords:

- Inbound—The storage system authenticates the initiator.

Inbound settings are required if you are using CHAP authentication.

- Outbound—This is an optional setting to enable the initiator to authenticate the storage system.

You can use outbound settings only if you define an inbound user name and password on the storage system.

- deny—The initiator is denied access to the storage system.
- none—The storage system does not require authentication for the initiator.

You can define the list of initiators and their authentication methods. You can also define a default authentication method that applies to initiators that are not on this list.

Related information

[Windows Multipathing Options with Data ONTAP: Fibre Channel and iSCSI](#)

= iSCSI initiator security management

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

ONTAP provides a number of features for managing security for iSCSI initiators. You can define a list of iSCSI initiators and the authentication method for each, display the initiators and their associated authentication methods in the authentication list, add and remove initiators from the authentication list, and define the default iSCSI initiator authentication method for initiators not in the list.

= iSCSI endpoint isolation

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

Beginning with ONTAP 9.1 existing iSCSI security commands were enhanced to accept an IP address range, or multiple IP addresses.

All iSCSI initiators must provide origination IP addresses when establishing a session or connection with a target. This new functionality prevents an initiator from logging into the cluster if the origination IP address is unsupported or unknown, providing a unique identification scheme. Any initiator originating from an unsupported or unknown IP address will have their login rejected at the iSCSI session layer, preventing the initiator from accessing any LUN or volume within the cluster.

Implement this new functionality with two new commands to help manage pre-existing entries.

== Add initiator address range

Improve iSCSI initiator security management by adding an IP address range, or multiple IP addresses with the `vserver iscsi security add-initiator-address-range` command.

```
cluster1::> vserver iscsi security add-initiator-address-range
```

== Remove initiator address range

Remove an IP address range, or multiple IP addresses, with the `vserver iscsi security remove-initiator-address-range` command.

```
cluster1::> vserver iscsi security remove-initiator-address-range
```

= What CHAP authentication is

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

The Challenge Handshake Authentication Protocol (CHAP) enables authenticated communication between iSCSI initiators and targets. When you use CHAP authentication, you define CHAP user names and passwords on both the initiator and the storage system.

During the initial stage of an iSCSI session, the initiator sends a login request to the storage system to begin the session. The login request includes the initiator's CHAP user name and CHAP algorithm. The storage system responds with a CHAP challenge. The initiator provides a CHAP response. The storage system verifies the response and authenticates the initiator. The CHAP password is used to compute the response.

== Guidelines for using CHAP authentication

You should follow certain guidelines when using CHAP authentication.

- If you define an inbound user name and password on the storage system, you must use the same user name and password for outbound CHAP settings on the initiator. If you also define an outbound user name and password on the storage system to enable bidirectional authentication, you must use the same user name and password for inbound CHAP settings on the initiator.
- You cannot use the same user name and password for inbound and outbound settings on the storage system.
- CHAP user names can be 1 to 128 bytes.

A null user name is not allowed.

- CHAP passwords (secrets) can be 1 to 512 bytes.

Passwords can be hexadecimal values or strings. For hexadecimal values, you should enter the value with a prefix of "0x" or "0X". A null password is not allowed.

ONTAP allows the use of special characters, non-English letters, numbers and spaces for CHAP passwords

(secrets). However, this is subject to host restrictions. If any of these are not allowed by your specific host, they cannot be used.

For example, the Microsoft iSCSI software initiator requires both the initiator and target CHAP passwords to be at least 12 bytes if IPsec encryption is not being used. The maximum password length is 16 bytes regardless of whether IPsec is used.

For additional restrictions, you should see the initiator's documentation.

= How using iSCSI interface access lists to limit initiator interfaces can increase performance and security

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

iSCSI interface access lists can be used to limit the number of LIFs in an SVM that an initiator can access, thereby increasing performance and security.

When an initiator begins a discovery session using an iSCSI `SendTargets` command, it receives the IP addresses associated with the LIF (network interface) that is in the access list. By default, all initiators have access to all iSCSI LIFs in the SVM. You can use the access list to restrict the number of LIFs in an SVM that an initiator has access to.

= iSNS server registration requirement

= What iSNS is

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

The Internet Storage Name Service (iSNS) is a protocol that enables automated discovery and management of iSCSI devices on a TCP/IP storage network. An iSNS server maintains information about active iSCSI devices on the network, including their IP addresses, iSCSI node names IQN's, and portal groups.

You can obtain an iSNS server from a third-party vendor. If you have an iSNS server on your network configured and enabled for use by the initiator and target, you can use the management LIF for a storage virtual machine (SVM) to register all the iSCSI LIFs for that SVM on the iSNS server. After the registration is complete, the iSCSI initiator can query the iSNS server to discover all the LIFs for that particular SVM.

If you decide to use an iSNS service, you must ensure that your storage virtual machines (SVMs) are properly registered with an Internet Storage Name Service (iSNS) server.

If you do not have an iSNS server on your network, you must manually configure each target to be visible to the host.

== What an iSNS server does

An iSNS server uses the Internet Storage Name Service (iSNS) protocol to maintain information about active iSCSI devices on the network, including their IP addresses, iSCSI node names (IQNs), and portal groups.

The iSNS protocol enables automated discovery and management of iSCSI devices on an IP storage network. An iSCSI initiator can query the iSNS server to discover iSCSI target devices.

NetApp does not supply or resell iSNS servers. You can obtain these servers from a vendor supported by NetApp.

= How SVMs interact with an iSNS server

:icons: font

:relative_path: ./san-admin/

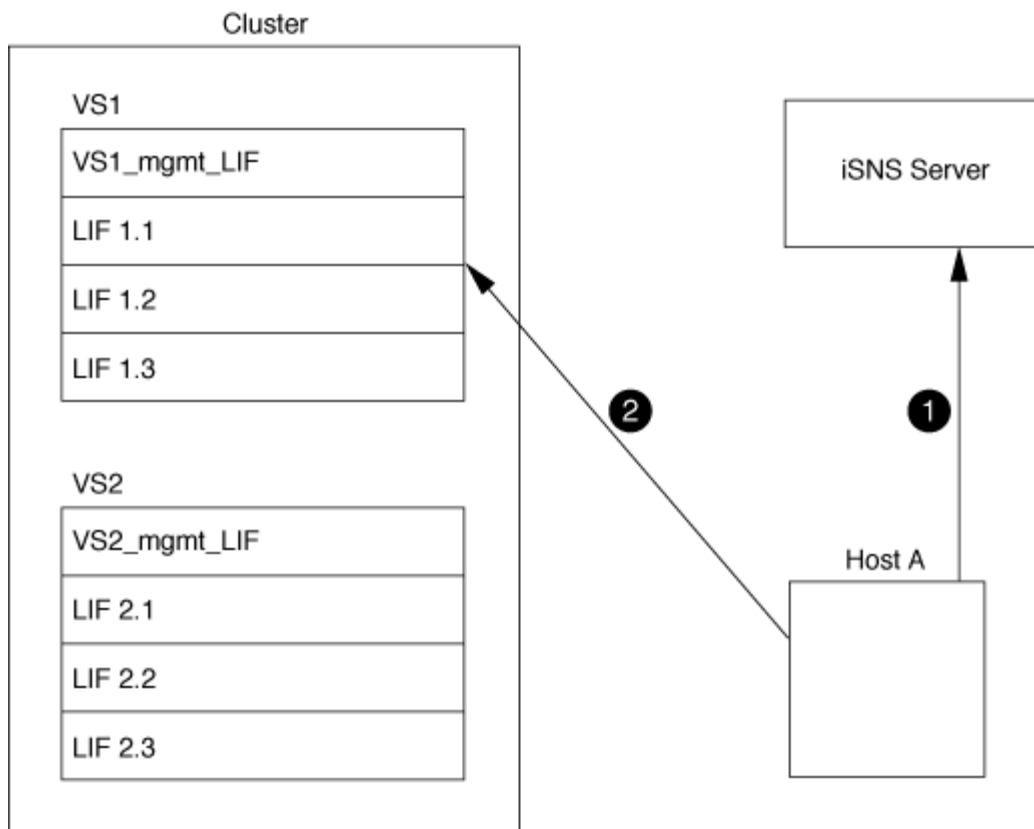
:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

The iSNS server communicates with each storage virtual machine (SVM) through the SVM management LIF. The management LIF registers all iSCSI target node name, alias, and portal information with the iSNS service for a specific SVM.

In the following example, SVM VS1 uses the SVM management LIF vs1_mgmt_lif to register with the iSNS server. During iSNS registration, an SVM sends all the iSCSI LIFs through the SVM management LIF to the iSNS Server. After the iSNS registration is complete, the iSNS server has a list of all the LIFs serving iSCSI in VS1. If a cluster contains multiple SVMs, each SVM must register individually with the iSNS server to use the iSNS service.



In the next example, after the iSNS server completes the registration with the target, Host A can discover all the LIFs for VS1 through the iSNS server as indicated in step 1. After Host A completes the discovery of the LIFs for VS1, Host A can establish a connection with any of the LIFs in VS1 as shown in step 2. Host A is not aware of any of the LIFs in VS2 until the management LIF VS2_mgmt_LIF for VS2 registers with the iSNS server.



However, if you define the interface access lists, the host can only use the defined LIFs in the interface access list to access the target.

After iSNS is initially configured, ONTAP automatically updates the iSNS server when the SVM configuration settings change.

A delay of a few minutes can occur between the time you make the configuration changes and when ONTAP sends the update to the iSNS server. Force an immediate update of the iSNS information on the iSNS server: `vserver iscsi isns update`

= Commands for managing iSNS

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

ONTAP provides commands to manage your iSNS service.

If you want to...	Use this command...
Configure an iSNS service	<code>vserver iscsi isns create</code>
Start an iSNS service	<code>vserver iscsi isns start</code>
Modify an iSNS service	<code>vserver iscsi isns modify</code>
Display iSNS service configuration	<code>vserver iscsi isns show</code>

If you want to...	Use this command...
Force an update of registered iSNS information	<code>vserver iscsi isns update</code>
Stop an iSNS service	<code>vserver iscsi isns stop</code>
Remove an iSNS service	<code>vserver iscsi isns delete</code>
View the man page for a command	<code>man <i>command name</i></code>

See the man page for each command for more information.

= SAN provisioning with FC

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You should be aware of the important concepts that are required to understand how ONTAP implements an FC SAN.

== How FC target nodes connect to the network

Storage systems and hosts have adapters so that they can be connected to FC switches with cables.

When a node is connected to the FC SAN, each SVM registers the World Wide Port Name (WWPN) of its LIF with the switch Fabric Name Service. The WWNN of the SVM and the WWPN of each LIF is automatically assigned by ONTAP..

Direct-connection to nodes from hosts with FC is not supported, NPIV is required and this requires a switch to be used. With iSCSI sessions, communication works with connections that are either network routed or direct-connect. However, both of these methods are supported with ONTAP.

== How FC nodes are identified

Each SVM configured with FC is identified by a worldwide node name (WWNN).

== How WWPNs are used

WWPNs identify each LIF in an SVM configured to support FC. These LIFs utilize the physical FC ports in each node in the cluster, which can be FC target cards, UTA or UTA2 configured as FC or FCoE in the nodes.

- Creating an initiator group

The WWPNs of the host's HBAs are used to create an initiator group (igroup). An igroup is used to control host access to specific LUNs. You can create an igroup by specifying a collection of WWPNs of initiators in an FC network. When you map a LUN on a storage system to an igroup, you can grant all the initiators in that group access to that LUN. If a host's WWPN is not in an igroup that is mapped to a LUN, that host does not have access to the LUN. This means that the LUNs do not appear as disks on that host.

You can also create port sets to make a LUN visible only on specific target ports. A port set consists of a group of FC target ports. You can bind an igroup to a port set. Any host in the igroup can access the LUNs only by connecting to the target ports in the port set.

- Uniquely identifying FC LIFs

WWPNs uniquely identify each FC logical interface. The host operating system uses the combination of the WWNN and WWPN to identify SVMs and FC LIFs. Some operating systems require persistent binding to ensure that the LUN appears at the same target ID on the host.

== How worldwide name assignments work

Worldwide names are created sequentially in ONTAP. However, because of the way ONTAP assigns them, they might appear to be assigned in a non-sequential order.

Each adapter has a pre-configured WWPN and WWNN, but ONTAP does not use these pre-configured values. Instead, ONTAP assigns its own WWPNS or WWNNs, based on the MAC addresses of the onboard Ethernet ports.

The worldwide names might appear to be non-sequential when assigned for the following reasons:

- Worldwide names are assigned across all the nodes and storage virtual machines (SVMs) in the cluster.
- Freed worldwide names are recycled and added back to the pool of available names.

== How FC switches are identified

Fibre Channel switches have one worldwide node name (WWNN) for the device itself, and one worldwide port name (WWPN) for each of its ports.

For example, the following diagram shows how the WWPNS are assigned to each of the ports on a 16-port Brocade switch. For details about how the ports are numbered for a particular switch, see the vendor-supplied documentation for that switch.



Port **0**, WWPN 20:**00**:00:60:69:51:06:b4

Port **1**, WWPN 20:**01**:00:60:69:51:06:b4

Port **14**, WWPN 20:**0e**:00:60:69:51:06:b4

Port **15**, WWPN 20:**0f**:00:60:69:51:06:b4

= SAN provisioning with NVMe

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

Beginning with ONTAP 9.4, NVMe/FC is supported in SAN environment. NVMe/FC enables storage administrators to provision namespaces and subsystems and then map the namespaces to subsystems, similar to the way LUNs are provisioned and mapped to igroups for FC and iSCSI.

An NVMe namespace is a quantity of non-volatile memory that can be formatted into logical blocks. Namespaces are the equivalent of LUNs for FC and iSCSI protocols, and an NVMe subsystem is analogous to an igroup. An NVMe subsystem can be associated with initiators so that namespaces within the subsystem can be accessed by the associated initiators.

Although analogous in function, NVMe namespaces do not support all features supported by LUNs.

Beginning with ONTAP 9.5 a license is required to support host-facing data access with NVMe. If NVMe is enabled in ONTAP 9.4, a 90 day grace period is given to acquire the license after upgrading to ONTAP 9.5. You can enable the license using the following command:

```
system license add -license-code NVMe_license_key
```

Related information

[NetApp Technical Report 4684: Implementing and Configuring Modern SANs with NVMe/FC](#)

= About SAN volumes

= About SAN volumes overview

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

ONTAP provides three basic volume provisioning options: thick provisioning, thin provisioning, and semi-thick provisioning. Each option uses different ways to manage the volume space and the space requirements for ONTAP block sharing technologies. Understanding how the options work enables you to choose the best option for your environment.

Putting SAN LUNs and NAS shares in the same FlexVol volume is not recommended. You should provision separate FlexVol volumes specifically for your SAN LUNs and you should provision separate FlexVol volumes specifically to your NAS shares. This simplifies management and replication deployments and parallels the way FlexVol volumes are supported in Active IQ Unified Manager (formerly OnCommand Unified Manager).

== Thin provisioning for volumes

When a thinly provisioned volume is created, ONTAP does not reserve any extra space when the volume is created. As data is written to the volume, the volume requests the storage it needs from the aggregate to accommodate the write operation. Using thin-provisioned volumes enables you to overcommit your aggregate, which introduces the possibility of the volume not being able to secure the space it needs when the aggregate runs out of free space.

You create a thin-provisioned FlexVol volume by setting its `-space-guarantee` option to `none`.

== Thick provisioning for volumes

When a thick-provisioned volume is created, ONTAP sets aside enough storage from the aggregate to ensure that any block in the volume can be written to at any time. When you configure a volume to use thick provisioning, you can employ any of the ONTAP storage efficiency capabilities, such as compression and deduplication, to offset the larger upfront storage requirements.

You create a thick-provisioned FlexVol volume by setting its `-space-slo` (service level objective) option to `thick`.

== Semi-thick provisioning for volumes

When a volume using semi-thick provisioning is created, ONTAP sets aside storage space from the aggregate to account for the volume size. If the volume is running out of free space because blocks are in use by block-sharing technologies, ONTAP makes an effort to delete protection data objects (Snapshot copies and FlexClone files and LUNs) to free up the space they are holding. As long as ONTAP can delete the protection data objects fast enough to keep pace with the space required for overwrites, the write operations continue to succeed. This is called a “best effort” write guarantee.

Note: The following functionality is not supported on volumes that use semi-thick provisioning:

- storage efficiency technologies such as deduplication, compression, and compaction
- Microsoft Offloaded Data Transfer (ODX)

You create a semi-thick-provisioned FlexVol volume by setting its `-space-slo` (service level objective) option to `semi-thick`.

== Use with space-reserved files and LUNs

A space-reserved file or LUN is one for which storage is allocated when it is created. Historically, NetApp has used the term “thin-provisioned LUN” to mean a LUN for which space reservation is disabled (a non-space-reserved LUN).

Note: Non-space-reserved files are not generally referred to as “thin-provisioned files”.

The following table summarizes the major differences in how the three volume provisioning options can be used with space-reserved files and LUNs:

Volume provisioning	LUN/file space reservation	Overwrites	Protection data ²	Storage efficiency ³
Thick	Supported	Guaranteed ¹	Guaranteed	Supported

Volume provisioning	LUN/file space reservation	Overwrites	Protection data ²	Storage efficiency ³
Thin	No effect	None	Guaranteed	Supported
Semi-thick	Supported	Best effort ¹	Best effort	Not supported

Notes

1. The ability to guarantee overwrites or provide a best-effort overwrite assurance requires that space reservation is enabled on the LUN or file.
2. Protection data includes Snapshot copies, and FlexClone files and LUNs marked for automatic deletion (backup clones).
3. Storage efficiency includes deduplication, compression, any FlexClone files and LUNs not marked for automatic deletion (active clones), and FlexClone subfiles (used for Copy Offload).

== Support for SCSI thin-provisioned LUNs

ONTAP supports T10 SCSI thin-provisioned LUNs as well as NetApp thin-provisioned LUNs. T10 SCSI thin provisioning enables host applications to support SCSI features including LUN space reclamation and LUN space monitoring capabilities for blocks environments. T10 SCSI thin provisioning must be supported by your SCSI host software.

You use the `ONTAP space-allocation` setting to enable/disable support for the T10 thin provisioning on a LUN. You use the `ONTAP space-allocation enable` setting to enable T10 SCSI thin provisioning on a LUN.

The `[-space-allocation {enabled|disabled}]` command in the ONTAP Command Reference Manual has more information to enable/disable support for the T10 thin provisioning and to enable T10 SCSI thin provisioning on a LUN.

ONTAP 9 commands

= Configure volume provisioning options

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You can configure a volume for thin provisioning, thick provisioning, or semi-thick provisioning.

About this task

Setting the `-space-slo` option to `thick` ensures the following:

- The entire volume is preallocated in the aggregate. You cannot use the `volume create` or `volume modify` command to configure the volume's `-space-guarantee` option.
- 100% of the space required for overwrites is reserved. You cannot use the `volume modify` command to configure the volume's `-fractional-reserve` option

Setting the `-space-slo` option to `semi-thick` ensures the following:

- The entire volume is preallocated in the aggregate. You cannot use the `volume create` or `volume modify` command to configure the volume's `-space-guarantee` option.
- No space is reserved for overwrites. You can use the `volume modify` command to configure the volume's `-fractional-reserve` option.
- Automatic deletion of Snapshot copies is enabled.

Step

1. Configure volume provisioning options:

```
volume create -vserver vserver_name -volume volume_name -aggregate
aggregate_name -space-slo none|thick|semi-thick -space-guarantee
none|volume
```

The `-space-guarantee` option defaults to `none` for AFF systems and for non-AFF DP volumes. Otherwise, it defaults to `volume`. For existing FlexVol volumes, use the `volume modify` command to configure provisioning options.

The following command configures vol1 on SVM vs1 for thin provisioning:

```
cluster1::> volume create -vserver vs1 -volume vol1 -space-guarantee
none
```

The following command configures vol1 on SVM vs1 for thick provisioning:

```
cluster1::> volume create -vserver vs1 -volume vol1 -space-slo thick
```

The following command configures vol1 on SVM vs1 for semi-thick provisioning:

```
cluster1::> volume create -vserver vs1 -volume vol1 -space-slo semi-
thick
```

= SAN volume configuration options

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You must set various options on the volume containing your LUN. The way you set the volume options determines the amount of space available to LUNs in the volume.

== Autogrow

You can enable or disable Autogrow. If you enable it, autogrow allows ONTAP to automatically increase the size of the volume up to a maximum size that you predetermine. There must be space available in the containing aggregate to support the automatic growth of the volume. Therefore, if you enable autogrow, you must monitor the free space in the containing aggregate and add more when needed.

Autogrow cannot be triggered to support Snapshot creation. If you attempt to create a Snapshot copy and there is insufficient space on the volume, the Snapshot creation fails, even with autogrow enabled.

If autogrow is disabled, the size of your volume will remain the same.

== Autoshrink

You can enable or disable Autoshrink. If you enable it, autoshrink allows ONTAP to automatically decrease the overall size of a volume when the amount of space consumed in the volume decreases a predetermined threshold. This increases storage efficiency by triggering volumes to automatically release unused free space.

== Snapshot autodelete

Snapshot autodelete automatically deletes Snapshot copies when one of the following occurs:

- The volume is nearly full.
- The Snapshot reserve space is nearly full.
- The overwrite reserve space is full.

You can configure Snapshot autodelete to delete Snapshot copies from oldest to newest or from newest to oldest. Snapshot autodelete does not delete Snapshot copies that are linked to Snapshot copies in cloned volumes or LUNs.

If your volume needs additional space and you have enabled both autogrow and Snapshot autodelete, by default, ONTAP attempts to acquire the needed space by triggering autogrow first. If enough space is not acquired through autogrow, then Snapshot autodelete is triggered.

== Snapshot reserve

Snapshot reserve defines the amount of space in the volume reserved for Snapshot copies. Space allocated to Snapshot reserve cannot be used for any other purpose. If all of the space allocated for Snapshot reserve is used, then Snapshot copies begin to consume additional space on the volume.

= Requirement for moving volumes in SAN environments

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

Before you move a volume that contains LUNs or namespaces, you must meet certain requirements.

- For volumes containing one or more LUNs, you should have a minimum of two paths per LUN (LIFs) connecting to each node in the cluster.

This eliminates single points of failure and enables the system to survive component failures.

- For volumes containing namespaces, the cluster must be running ONTAP 9.6 or later.

Volume move is not supported for NVMe configurations running ONTAP 9.5.

= Considerations for setting fractional reserve

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

Fractional reserve, also called *LUN overwrite reserve*, enables you to turn off overwrite reserve for space-reserved LUNs and files in a FlexVol volume. This can help you maximize your storage utilization, but if your environment is negatively affected by write operations failing due to lack of space, you must understand the requirements that this configuration imposes.

The fractional reserve setting is expressed as a percentage; the only valid values are 0 and 100 percent. The fractional reserve setting is an attribute of the volume.

Setting fractional reserve to 0 increases your storage utilization. However, an application accessing data residing in the volume could experience a data outage if the volume is out of free space, even with the volume guarantee set to `volume`. With proper volume configuration and use, however, you can minimize the chance of writes failing. ONTAP provides a “best effort” write guarantee for volumes with fractional reserve set to 0 when *all* of the following requirements are met:

- Deduplication is not in use
- Compression is not in use
- FlexClone sub-files are not in use
- All FlexClone files and FlexClone LUNs are enabled for automatic deletion

This is not the default setting. You must explicitly enable automatic deletion, either at creation time or by modifying the FlexClone file or FlexClone LUN after it is created.

- ODX and FlexClone copy offload are not in use
- Volume guarantee is set to `volume`
- File or LUN space reservation is `enabled`
- Volume Snapshot reserve is set to 0
- Volume Snapshot copy automatic deletion is enabled with a commitment level of `destroy`, a destroy list of `lun_clone, vol_clone, cifs_share, file_clone, sfsr`, and a trigger of `volume`

This setting also ensures that FlexClone files and FlexClone LUNs are deleted when necessary.

Note that if your rate of change is high, in rare cases the Snapshot copy automatic deletion could fall behind, resulting in the volume running out of space, even with all of the above required configuration settings in use.

In addition, you can optionally use the volume autogrow capability to decrease the likelihood of volume Snapshot copies needing to be deleted automatically. If you enable the autogrow capability, you must monitor the free space in the associated aggregate. If the aggregate becomes full enough that the volume is prevented from growing, more Snapshot copies will probably be deleted as the free space in the volume is depleted.

If you cannot meet all of the above configuration requirements and you need to ensure that the volume does not run out of space, you must set the volume’s fractional reserve setting to 100. This requires more free space up front, but guarantees that data modification operations will succeed even when the technologies listed above are in use.

The default value and allowed values for the fractional reserve setting depend on the guarantee of the volume:

Volume guarantee	Default fractional reserve	Allowed values
Volume	100	0, 100
None	0	0, 100

= About host-side space management

= Host-side space management overview

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

In a thinly provisioned environment, host side space management completes the process of managing space from the storage system that has been freed in the host file system.

A host file system contains metadata to keep track of which blocks are available to store new data and which blocks contain valid data that must not be overwritten. This metadata is stored within the LUN. When a file is deleted in the host file system, the file system metadata is updated to mark that file's blocks as free space. Total file system free space is then recalculated to include the newly freed blocks. To the storage system, these metadata updates appear no different from any other writes being performed by the host. Therefore, the storage system is unaware that any deletions have occurred.

This creates a discrepancy between the amount of free space reported by the host and the amount of free space reported by the underlying storage system. For example, suppose you have a newly provisioned 200-GB LUN assigned to your host by your storage system. Both the host and the storage system report 200 GB of free space. Your host then writes 100 GB of data. At this point, both the host and storage system report 100 GB of used space and 100 GB of unused space.

Then you delete 50 GB of data from your host. At this point, your host will report 50 GB of used space and 150 GB of unused space. However, your storage system will report 100 GB of used space and 100 GB of unused space.

Host-side space management uses various methods to reconcile the space differential between the host and the storage system.

= Automatic host-side space management with SCSI thinly provisioned LUNs

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

If your host supports SCSI thin provisioning, you can enable the `space-allocation` option in ONTAP to turn on automatic host-side space management.

Enabling SCSI thin provisioning enables you to do the following.

- Automatic host-side space management

When data is deleted on a host that supports SCSI thin provisioning, host-side space management identifies the blocks of deleted data on the host file system and automatically issues one or more SCSI UNMAP commands to free corresponding blocks on the storage system.

- Notify the host when a LUN runs out of space while keeping the LUN online

On hosts that do not support SCSI thin provisioning, when the volume containing LUN runs out of space and cannot automatically grow, ONTAP takes the LUN offline. However, on hosts that support SCSI thin provisioning, ONTAP does not take the LUN offline when it runs out of space. The LUN remains online in read-only mode and the host is notified that the LUN can no longer accept writes.

Related information

[ONTAP SAN host configuration](#)

= Enable space allocation for SCSI thinly provisioned LUNs

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

If you set the `space-allocation` option to `enabled`, ONTAP notifies the host when the volume has run out of space and the LUN in the volume cannot accept writes. This option also enables ONTAP to reclaim space automatically when your host deletes data.

About this task

The `space-allocation` option is set to `disabled` by default, and you must take the LUN offline to enable space allocation. After you enable space allocation, you must perform discovery on the host before the host will recognize that space allocation has been enabled.

Steps

1. Take the LUN offline.

```
lun modify -vserver vservice_name -volume volume_name -lun lun_name -state offline
```

2. Set the `-space-allocation` parameter to `enabled`:

```
lun modify -vserver vservice_name -volume volume_name -lun lun_name -space-allocation enabled
```

3. Verify that space allocation is enabled:

```
lun show -vserver vservice_name -volume volume_name -lun lun_name -fields space-allocation
```

4. Bring the LUN online:

```
lun modify -vserver vservice_name -volume volume_name -lun lun_name -state online
```

5. On the host, rescan all disks to ensure that the change to the `-space-allocation` option is correctly discovered.

= Host support for SCSI thin provisioning

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

To leverage the benefits of SCSI thin provisioning, it must be supported by your host. SCSI thin provisioning uses the Logical Block Provisioning feature as defined in the SCSI SBC-3 standard. Only hosts that support this standard can use SCSI thin provisioning in ONTAP.

The following hosts currently support SCSI thin provisioning when you enable space allocation:

- VMware ESX 5.0 and later
- Red Hat Enterprise Linux 6.2 and later
- Citrix XenServer 6.5 and later
- Microsoft Windows 2012
- Microsoft Windows 2016

When you enable the space allocation functionality in ONTAP, you turn on the following SCSI thin provisioning features:

- Unmapping and reporting space usage for space reclamation
- Reporting resource exhaustion errors

= Simplified host management with SnapCenter

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You can use SnapCenter software to simplify some of the management and data protection tasks associated with iSCSI and FC storage. SnapCenter is an optional management package for Windows and UNIX hosts.

You can use SnapCenter Software to easily create virtual disks from pools of storage that can be distributed among several storage systems and to automate storage provisioning tasks and simplify the process of creating Snapshot copies and clones from Snapshot copies consistent with host data.

See NetApp product documentation for more information on [SnapCenter](#).

= About igroups

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

Initiator groups (igroups) are tables of FC protocol host WWPNs or iSCSI host node names. You can define igroups and map them to LUNs to control which initiators have access to LUNs.

Typically, you want all of the host's initiator ports or software initiators to have access to a LUN. If you are using multipathing software or have clustered hosts, each initiator port or software initiator of each

clustered host needs redundant paths to the same LUN.

You can create igroups that specify which initiators have access to the LUNs either before or after you create LUNs, but you must create igroups before you can map a LUN to an igroup.

Initiator groups can have multiple initiators, and multiple igroups can have the same initiator. However, you cannot map a LUN to multiple igroups that have the same initiator. An initiator cannot be a member of igroups of differing otypes.

= Example of how igroups give LUN access

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You can create multiple igroups to define which LUNs are available to your hosts. For example, if you have a host cluster, you can use igroups to ensure that specific LUNs are visible to only one host in the cluster or to all of the hosts in the cluster.

The following table illustrates how four igroups give access to the LUNs for four different hosts that are accessing the storage system. The clustered hosts (Host3 and Host4) are both members of the same igroup (group3) and can access the LUNs mapped to this igroup. The igroup named group4 contains the WWPNs of Host4 to store local information that is not intended to be seen by its partner.

Hosts with HBA WWPNs, IQNs, or EUIs	igroups	WWPNs, IQNs, EUIs added to igroups	LUNs mapped to igroups
Host1, single-path (iSCSI software initiator) iqn.1991- 05.com.microsoft:host1	group1	iqn.1991- 05.com.microsoft:host1	/vol/vol2/lun1
Host2, multipath (two HBAs) 10:00:00:00:c9:2b:6b:3c 10:00:00:00:c9:2b:02:3c	group2	10:00:00:00:c9:2b:6b:3c 10:00:00:00:c9:2b:02:3c	/vol/vol2/lun2
Host3, multipath, clustered with host 4 10:00:00:00:c9:2b:32:1b 10:00:00:00:c9:2b:41:02	group3	10:00:00:00:c9:2b:32:1b 10:00:00:00:c9:2b:41:02 10:00:00:00:c9:2b:51:2c 10:00:00:00:c9:2b:47:a2	/vol/vol2/qtrees1/l un3

Hosts with HBA WWPNs, IQNs, or EUIs	igroups	WWPNs, IQNs, EUIs added to igroups	LUNs mapped to igroups
Host4, multipath, clustered (not visible to Host3) 10:00:00:00:c9:2b:51:2c 10:00:00:00:c9:2b:47:a2	group4	10:00:00:00:c9:2b:51:2c 10:00:00:00:c9:2b:47:a2	/vol/vol2/qtrees2/1un4 /vol/vol2/qtrees1/1un5

= Specify initiator WWPNs and iSCSI node names for an igroup

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You can specify the iSCSI node names and WWPNs of the initiators when you create an igroup or you can add them later. If you choose to specify the initiator iSCSI node names and WWPNs when you create the LUN, they can be removed later, if needed.

Follow the instructions in your Host Utilities documentation to obtain WWPNs and to find the iSCSI node names associated with a specific host. For hosts running ESX software, use Virtual Storage Console.

= Storage virtualization with VMware and Microsoft copy offload

= Storage virtualization with VMware and Microsoft copy offload overview

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

VMware and Microsoft support copy offload operations to increase performance and network throughput. You must configure your system to meet the requirements of the VMware and Windows operating system environments to use their respective copy offload functions.

When using VMware and Microsoft copy offload in virtualized environments, your LUNs must be aligned. Unaligned LUNs can degrade performance.

== Advantages of using a virtualized SAN environment

Creating a virtualized environment by using storage virtual machines (SVMs) and LIFs enables you to expand your SAN environment to all of the nodes in your cluster.

- Distributed management

You can log in to any node in the SVM to administer all of the nodes in a cluster.

- Increased data access

With MPIO and ALUA, you have access to your data through any active iSCSI or FC LIFs for the SVM.

- Controlled LUN access

If you use SLM and portsets, you can limit which LIFs an initiator can use to access LUNs.

= How LUN access works in a virtualized environment

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

In a virtualized environment, LIFs enable hosts (clients) to access LUNs through optimized and unoptimized paths.

A LIF is a logical interface that connects the SVM to a physical port. Although multiple SVMs can have multiple LIFs on the same port, a LIF belongs to one SVM. You can access LUNs through the SVMs LIFs.

Example of LUN access with a single SVM in a cluster

In the following example, Host 1 connects to LIF1.1 and LIF1.2 in SVM-1 to access LUN1. LIF1.1 uses the physical port node1:0c and LIF1.2 uses the node2:0c. LIF1.1 and LIF1.2 belongs only to SVM-1. If a new LUN is created on node 1 or node 2, for SVM-1, then it can use these same LIFs. If a new SVM is created, then new LIFs can be created using physical ports 0c or 0d on both the nodes.



Example of LUN access with multiple SVMs in a cluster

A physical port can support multiple LIFs serving different SVMs. Because LIFs are associated with a particular SVM, the cluster nodes can send the incoming data traffic to the correct SVM. In the following example, each node from 1 through 4 has a LIF for SVM-2 using the physical port 0c on each node. Host 1 connects to LIF1.1 and LIF1.2 in SVM-1 to access LUN1. Host 2 connects to LIF2-1 and LIF2-2 in SVM-2 to access LUN2. Both SVMs are sharing the physical port 0c on the nodes 1 and 2. SVM-2 has additional LIFs that Host 2 is using to access LUNs 3 and 4. These LIFs are using physical port 0c on nodes 3 and 4. Multiple SVMs can share the physical ports on the nodes.



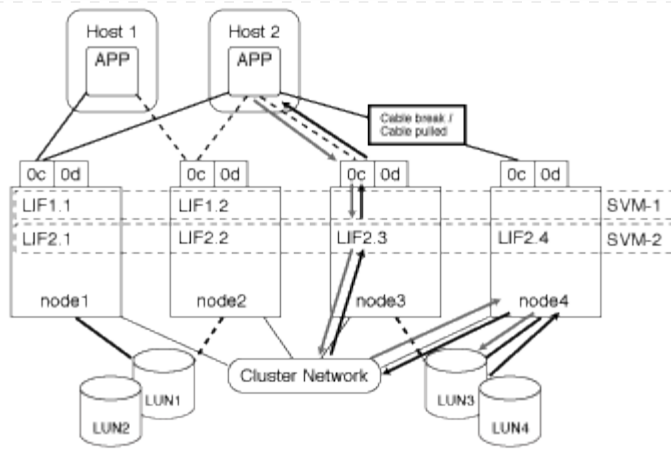
Example of an active or optimized path to a LUN from a host system

In an active or optimized path, the data traffic does not travel over the cluster network; it travels the most direct route to the LUN. The active or optimized path to LUN1 is through LIF1.1 in node1, using physical port 0c. Host 2 has two active or optimized paths, one path to node1, LIF2.1, which is sharing physical port 0c and the other path to node4, LIF2.4, which is using physical port 0c.



Example of an active or unoptimized path (indirect) path to a LUN from a host system

In an active or unoptimized path (indirect) path, the data traffic travels over the cluster network. This issue occurs only if all the active or optimized paths from a host are unavailable to handle traffic. If the path from Host 2 to SVM-2 LIF2.4 is lost, then access to LUN3 and LUN4 traverses the cluster network. Access from Host 2 uses LIF2.3 on node3. Then the traffic enters the cluster network switch and backs up to node4 for access to the LUN3 and LUN4. It will then traverse back over the cluster network switch and then back out through LIF2.3 to Host 2. This active or unoptimized path is used until the path to LIF2.4 is restored or a new LIF is established for SVM-2 on another physical port on node 4.



= Considerations for LIFs in cluster SAN environments

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You must be aware of certain LIF considerations in a SAN environment.

- Initiators must use Multipath I/O (MPIO) and asymmetric logical unit access (ALUA) for failover capability for clusters in a SAN iSCSI or FC environment because SAN does not support automatic failover for LIFs.
- At least one SAN LIF of the appropriate protocol must be configured on each node that hosts a mapped LUN and the node's HA partner.

You can configure two LIFs per node, one for each fabric being used with FC and to separate Ethernet networks for iSCSI.

- Some options are not applicable for iSCSI or FC.

For example, you cannot use IP addresses with FC.

= Improve VMware VAAI performance for ESX hosts

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

ONTAP supports certain VMware vStorage APIs for Array Integration (VAAI) features when the ESX host is running ESX 4.1 or later. These features help offload operations from the ESX host to the storage system and increase the network throughput. The ESX host enables the features automatically in the correct environment.

The VAAI feature supports the following SCSI commands:

- EXTENDED_COPY

This feature enables the host to initiate the transfer of data between the LUNs or within a LUN without involving the host in the data transfer. This results in saving ESX CPU cycles and increasing the network throughput. The extended copy feature, also known as "copy offload," is used in scenarios

such as cloning a virtual machine. When invoked by the ESX host, the copy offload feature copies the data within the storage system rather than going through the host network. Copy offload transfers data in the following ways:

- Within a LUN
- Between LUNs within a volume
- Between LUNs on different volumes within a storage virtual machine (SVM)
- Between LUNs on different SVMs within a cluster

If this feature cannot be invoked, the ESX host automatically uses the standard READ and WRITE commands for the copy operation.

- `WRITE_SAME`

This feature offloads the work of writing a repeated pattern, such as all zeros, to a storage array. The ESX host uses this feature in operations such as zero-filling a file.

- `COMPARE_AND_WRITE`

This feature bypasses certain file access concurrency limits, which speeds up operations such as booting up virtual machines.

== Requirements for using the VAAI environment

The VAAI features are part of the ESX operating system and are automatically invoked by the ESX host when you have set up the correct environment.

The environment requirements are as follows:

- The ESX host must be running ESX 4.1 or later.
- The NetApp storage system that is hosting the VMware datastore must be running ONTAP.
- (Copy offload only) The source and the destination of the VMware copy operation must be hosted on the same storage system within the same cluster.

The copy offload feature currently does not support copying data between VMware datastores that are hosted on different storage systems.

== Determine if VAAI features are supported by ESX

To confirm whether the ESX operating system supports the VAAI features, you can check the vSphere Client or use any other means of accessing the host. ONTAP supports the SCSI commands by default.

You can check your ESX host advanced settings to determine whether VAAI features are enabled. The table indicates which SCSI commands correspond to ESX control names.

SCSI command	ESX control name (VAAI feature)
EXTENDED_COPY	HardwareAcceleratedMove
WRITE_SAME	HardwareAcceleratedInit
COMPARE_AND_WRITE	HardwareAcceleratedLocking

= Microsoft Offloaded Data Transfer (ODX)

= Microsoft Offloaded Data Transfer (ODX) overview

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

Microsoft Offloaded Data Transfer (ODX), also known as *copy offload*, enables direct data transfers within a storage device or between compatible storage devices without transferring the data through the host computer.

ONTAP supports ODX for both the SMB and SAN protocols.

In non-ODX file transfers, the data is read from the source and is transferred across the network to the host. The host transfers the data back over the network to the destination. In ODX file transfer, the data is copied directly from the source to the destination without passing through the host.

Because ODX offloaded copies are performed directly between the source and destination, significant performance benefits are realized, including faster copy time, reduced utilization of CPU and memory on the client, and reduced network I/O bandwidth utilization.

For SAN environments, ODX is only available when it is supported by both the host and the storage system. Client computers that support ODX and have ODX enabled automatically and transparently use offloaded file transfer when moving or copying files. ODX is used regardless of whether you drag-and-drop files through Windows Explorer or use command-line file copy commands, or whether a client application initiates file copy requests.

= Requirements for using ODX

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

If you plan to use ODX for copy offloads, you need to be familiar with volume support considerations, system requirements, and software capability requirements.

To use ODX, your system must have the following:

- ONTAP

ODX is automatically enabled in supported versions of ONTAP.

- Minimum source volume of 2 GB

For optimal performance, the source volume should be greater than 260 GB.

- Deduplication

ODX uses deduplication as part of the copy process. If you do not want deduplication on your SVM, you should disable ODX on that SVM.

- ODX support on the Windows client

ODX is supported in Windows Server 2012 or later and in Windows 8 or later. The Interoperability Matrix contains the latest information about supported Windows clients.

[NetApp Interoperability Matrix Tool](#)

- Copy application support for ODX

The application that performs the data transfer must support ODX. Application operations that support ODX include the following:

- Hyper-V management operations, such as creating and converting virtual hard disks (VHDs), managing Snapshot copies, and copying files between virtual machines
- Windows Explorer operations
- Windows PowerShell copy commands
- Windows command prompt copy commands

The Microsoft TechNet Library contains more information about supported ODX applications on Windows servers and clients.

- If you use compressed volumes, the compression group size must be 8K.

32K compression group size is not supported.

ODX does not work with the following volume types:

- Source volumes with capacities of less than 2 GB
- Read-only volumes
- [FlexCache volumes](#)
- [Semi-thick provisioned volumes](#)

= Use cases for ODX

:icons: font

:relative_path: ./san-admin/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You should be aware of the use cases for using ODX on SVMs so that you can

determine under what circumstances ODX provides you with performance benefits.

Windows servers and clients that support ODX use copy offload as the default way of copying data across remote servers. If the Windows server or client does not support ODX or the ODX copy offload fails at any point, the copy or move operation falls back to traditional reads and writes for the copy or move operation.

The following use cases support using ODX copies and moves:

- Intra-volume

The source and destination files or LUNs are within the same volume.

- Inter-volume, same node, same SVM

The source and destination files or LUNs are on different volumes that are located on the same node. The data is owned by the same SVM.

- Inter-volume, different nodes, same SVM

The source and destination files or LUNs are on different volumes that are located on different nodes. The data is owned by the same SVM.

- Inter-SVM, same node

The source and destination file or LUNs are on different volumes that are located on the same node. The data is owned by different SVMs.

- Inter-SVM, different nodes

The source and destination file or LUNs are on different volumes that are located on different nodes. The data is owned by different SVMs.

- Inter-cluster

The source and destination LUNs are on different volumes that are located on different nodes across clusters. This is only supported for SAN and does not work for SMB.

There are some additional special use cases:

- With the ONTAP ODX implementation, you can use ODX to copy files between SMB shares and FC or iSCSI attached virtual drives.

You can use Windows Explorer, the Windows CLI or PowerShell, Hyper-V, or other applications that support ODX to copy or move files seamlessly using ODX copy offload between SMB shares and connected LUNs, provided that the SMB shares and LUNs are on the same cluster.

- Hyper-V provides some additional use cases for ODX copy offload:

- You can use ODX copy offload pass-through with Hyper-V to copy data within or across virtual hard disk (VHD) files or to copy data between mapped SMB shares and connected iSCSI LUNs within the same cluster.

This allows copies from guest operating systems to pass through to the underlying storage.

- When creating fixed-sized VHDs, ODX is used for initializing the disk with zeros, using a well-known zeroed token.

- ODX copy offload is used for virtual machine storage migration if the source and destination storage is on the same cluster.

To take advantage of the use cases for ODX copy offload pass-through with Hyper-V, the guest operating system must support ODX and the guest operating system's disks must be SCSI disks backed by storage (either SMB or SAN) that supports ODX. IDE disks on the guest operating system do not support ODX pass-through.

== Special system file requirements

You can delete ODX files found in qtrees. You must not remove or modify any other ODX system files unless you are told by technical support to do so.

When using the ODX feature, there are ODX system files that exist in every volume of the system. These files enable point-in-time representation of data used during the ODX transfer. The following system files are in the root level of each volume that contains LUNs or files to which data was offloaded:

- `.copy-offload` (a hidden directory)
- `.tokens` (file under the hidden `.copy-offload` directory)

You can use the `copy-offload delete-tokens -path dir_path -node node_name` command to delete a qtree containing an ODX file.

= SAN configuration reference

= SAN configuration reference

:icons: font

:relative_path: ./san-config/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

The following sections describe supported FC-NVMe, FC, iSCSI, and FCoE topologies for connecting host computers to nodes, and list supported limits for SAN components.

You should use this information in conjunction with basic SAN configuration documentation:

- [SAN administration overview](#)

= Considerations for iSCSI configurations

= Considerations for iSCSI configurations overview

:icons: font

:relative_path: ./san-config/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You should consider several things when setting up your iSCSI configuration.

- You can set up your iSCSI configuration with single nodes or with HA pairs.

Direct connect or the use of Ethernet switches is supported for connectivity. You must create LIFs for both types of connectivity

- You should configure one management LIF for every storage virtual machine (SVM) supporting SAN.
- Selective LUN mapping (SLM) limits the paths that are being utilized in accessing the LUNs owned by an HA pair.

This is the default behavior for LUNs created with ONTAP releases.

- HA pairs are defined as the reporting nodes for the Active/Optimized and the Active/Unoptimized paths that will be used by the host in accessing the LUNs through ALUA.

- It is recommended that all SVMs in iSCSI configurations have a minimum of two LIF's per node in separate Ethernet networks for redundancy and MPIO across multiple paths.
- You need to create one or more iSCSI paths from each node in an HA pair, using logical interfaces (LIFs) to allow access to LUNs that are serviced by the HA pair.

If a node fails, LIFs do not migrate or assume the IP addresses of the failed partner node. Instead, the MPIO software, using ALUA on the host, is responsible for selecting the appropriate paths for LUN access through LIFs.

- VLANs offer specific benefits, such as increased security and improved network reliability that you might want to leverage in iSCSI.

= Ways to configure iSCSI SAN hosts with single nodes

:icons: font

:relative_path: ./san-config/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You can configure the iSCSI SAN hosts to connect directly to a single node or by using either one or multiple IP switches. You should determine whether you want a single-switch configuration that is not completely redundant or a multi-switch configuration that is completely redundant.

You can configure iSCSI SAN hosts in a direct-attached, single-switch, or multi-switch environment. If there are multiple hosts connecting to the node, each host can be configured with a different operating system. For single and multi-network configurations, the node can have multiple iSCSI connections to the switch, but multipathing software that supports ALUA is required.

If there are multiple paths from the host to the controller, then ALUA must be enabled on the host.

== Direct-attached single-node configurations

In direct-attached configurations, one or more hosts are directly connected to the node.



== Single-network single-node configurations

In single-network single-node configurations, one switch connects a single node to one or more hosts. Because there is a single switch, this configuration is not fully redundant.



== Multi-network single-node configurations

In multi-network single-node configurations, two or more switches connect a single node to one or more hosts. Because there are multiple switches, this configuration is fully redundant.



= Ways to configure iSCSI SAN hosts with HA pairs

:icons: font

:relative_path: ./san-config/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You can configure the iSCSI SAN hosts to connect to dual-node or multi-node configurations by using either one or multiple IP switches. You should determine whether you want a single-switch configuration that is not completely redundant or a multi-switch configuration that is completely redundant.

You can configure iSCSI SAN hosts with single controllers and HA pairs on direct-attached, single-network, or multi-network environments. HA pairs can have multiple iSCSI connections to each switch, but multipathing software that supports ALUA is required on each host. If there are multiple hosts, you can configure each host with a different operating system by checking the NetApp Interoperability Matrix Tool.

NetApp Interoperability Matrix Tool

== Direct-attachment

In a direct-attached configuration, one or more hosts are directly connected to the controllers.



== Single-network HA pairs

In single-network HA pair configurations, one switch connects the HA pair to one or more hosts. Because there is a single switch, this configuration is not fully redundant.



== Multi-network HA pairs

In multi-network HA pair configurations, two or more switches connect the HA pair to one or more hosts. Because there are multiple switches, this configuration is fully redundant.



= Benefits of using VLANs in iSCSI configurations

:icons: font
:relative_path: ./san-config/
:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

A VLAN consists of a group of switch ports grouped together into a broadcast domain. A VLAN can be on a single switch or it can span multiple switch chassis. Static and dynamic VLANs enable you to increase security, isolate problems, and limit available paths within your IP network infrastructure.

When you implement VLANs in large IP network infrastructures, you derive the following benefits:

- Increased security.

VLANs enable you to leverage existing infrastructure while still providing enhanced security because they limit access between different nodes of an Ethernet network or an IP SAN.

- Improved Ethernet network and IP SAN reliability by isolating problems.
- Reduction of problem resolution time by limiting the problem space.
- Reduction of the number of available paths to a particular iSCSI target port.
- Reduction of the maximum number of paths used by a host.

Having too many paths slows reconnect times. If a host does not have a multipathing solution, you can use VLANs to allow only one path.

== Dynamic VLANs

Dynamic VLANs are MAC address-based. You can define a VLAN by specifying the MAC address of the members you want to include.

Dynamic VLANs provide flexibility and do not require mapping to the physical ports where the device is physically connected to the switch. You can move a cable from one port to another without reconfiguring the VLAN.

== Static VLANs

Static VLANs are port-based. The switch and switch port are used to define the VLAN and its members.

Static VLANs offer improved security because it is not possible to breach VLANs using media access control (MAC) spoofing. However, if someone has physical access to the switch, replacing a cable and reconfiguring the network address can allow access.

In some environments, it is easier to create and manage static VLANs than dynamic VLANs. This is because static VLANs require only the switch and port identifier to be specified, instead of the 48-bit MAC address. In addition, you can label switch port ranges with the VLAN identifier.

= Considerations for FC-NVMe configurations

:icons: font
:relative_path: ./san-config/
:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

Beginning with ONTAP 9.4, the non-volatile memory express (NVMe) protocol is available for SAN environments. FC-NVMe allows you to run NVMe over an existing

FC network with an AFF system. FC-NVMe uses the same physical setup and zoning practice as traditional FC networks but allows for greater bandwidth, increased IOPs and reduced latency than FC-SCSI.

Supported configurations:

- NVMe is supported on AFF platforms that have 32G FC ports.
- You can set up your FC-NVMe configuration with single nodes or HA pairs using a single fabric or multifabric.
- NVMe is supported on 4-node clusters or smaller.
- NVMe can be the only data protocol on the storage virtual machine (SVM).
- Up to 8 NVMe SVMs are supported per cluster.
- FC-NVMe can be the only data protocol on data LIFs.
- LUNs and namespaces cannot be mixed on the same volume.
- You should configure one management LIF for every SVM supporting SAN.
- The use of heterogeneous FC switch fabrics is not supported, except in the case of embedded blade switches.

Specific exceptions are listed on the [NetApp Interoperability Matrix Tool](#).

- Cascade, partial mesh, full mesh, core-edge, and director fabrics are all industry-standard methods of connecting FC switches to a fabric, and all are supported.

A fabric can consist of one or multiple switches, and the storage controllers can be connected to multiple switches.

Functionality enhancements:

This functionality is supported...	Starting with...
volume move with mapped namespaces	ONTAP 9.6
Namespaces support 512 byte blocks and 4096 byte blocks. 4096 is the default value. 512 should only be used if the host operating system does not support 4096 byte blocks.	ONTAP 9.6
Multipath HA pair failover/giveback	ONTAP 9.5

The following applies only to nodes running ONTAP 9.4:

- NVMe LIFs and namespaces must be hosted on the same node.
- The NVMe service must be created before the NVMe LIF is created.

The following ONTAP features are not supported by NVMe configurations:

- NVMe namespace move
- NVMe namespaces (Copy on Demand)

- Creating namespaces on a volume transitioned from Data ONTAP operating in 7-mode.
- Sync
- Virtual Storage Console

See the [NetApp Hardware Universe](#) for a complete list of NVMe limits.

Related information

[How to configure and Connect SUSE Enterprise Linux to ONTAP NVMe/FC namespaces](#)

[Licensing information for NVMe protocol on ONTAP](#)

[NetApp Technical Report 4684: Implementing and Configuring Modern SANs with NVMe/FC](#)

= Considerations for FC configurations

= Considerations for FC configurations overview

:icons: font

:relative_path: ./san-config/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You should be aware of several things when setting up your FC configuration.

- You can set up your FC configuration with single nodes or HA pairs using a single fabric or multifabric.
- You should configure two FC data LIFs per node.

This creates redundancy and protects against loss of data access.

- You should configure one management LIF for every storage virtual machine (SVM) supporting SAN.
- Multiple hosts, using different operating systems, such as Windows, Linux, or UNIX, can access the storage solution at the same time.

Hosts require that a supported multipathing solution be installed and configured. Supported operating systems and multipathing solutions can be verified on the Interoperability Matrix.

- ONTAP supports single, dual, or multiple node solutions that are connected to multiple physically independent storage fabrics; a minimum of two are recommended for SAN solutions.

This provides redundancy at the fabric and storage system layers. Redundancy is particularly important because these layers typically support many hosts.

- The use of heterogeneous FC switch fabrics is not supported, except in the case of embedded blade switches.

Specific exceptions are listed on the Interoperability Matrix.

- Cascade, partial mesh, full mesh, core-edge, and director fabrics are all industry-standard methods of connecting FC switches to a fabric, and all are supported.

A fabric can consist of one or multiple switches, and the storage controllers can be connected to multiple switches.

Related information

= Ways to configure FC and FC-NVMe SAN hosts with single nodes

:icons: font

:relative_path: ./san-config/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

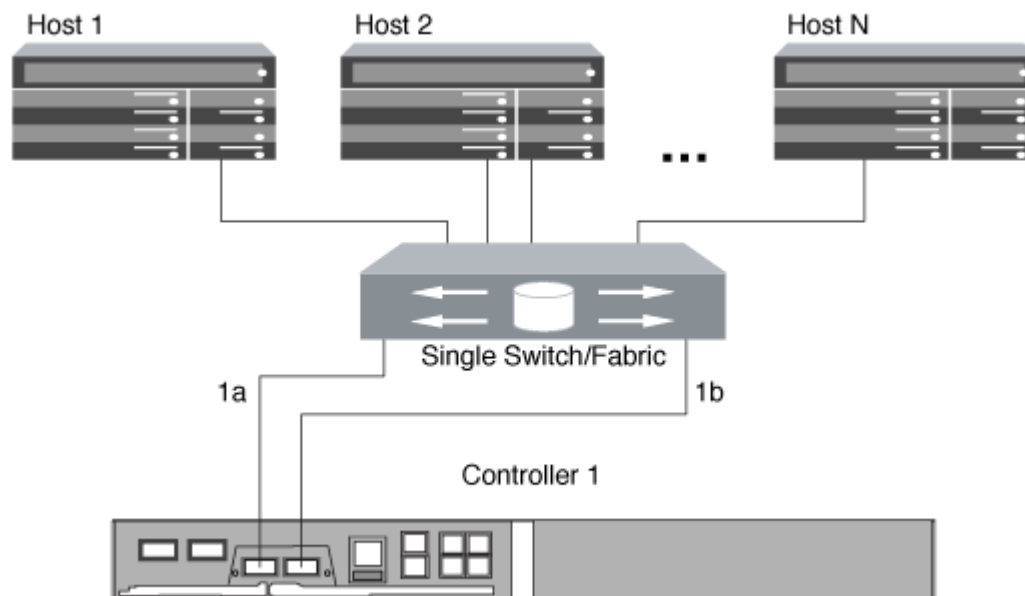
You can configure FC and FC-NVMe SAN hosts with single nodes through one or more fabrics. N-Port ID Virtualization (NPIV) is required and must be enabled on all FC switches in the fabric. You cannot directly attach FC or FC-NMVE SAN hosts to single nodes without using an FC switch.

You can configure FC or FC-NVMe SAN hosts with single nodes through a single fabric or multifabrics. The FC target ports (0a, 0c, 0b, 0d) in the illustrations are examples. The actual port numbers vary depending on the model of your storage node and whether you are using expansion adapters.

== Single-fabric single-node configurations

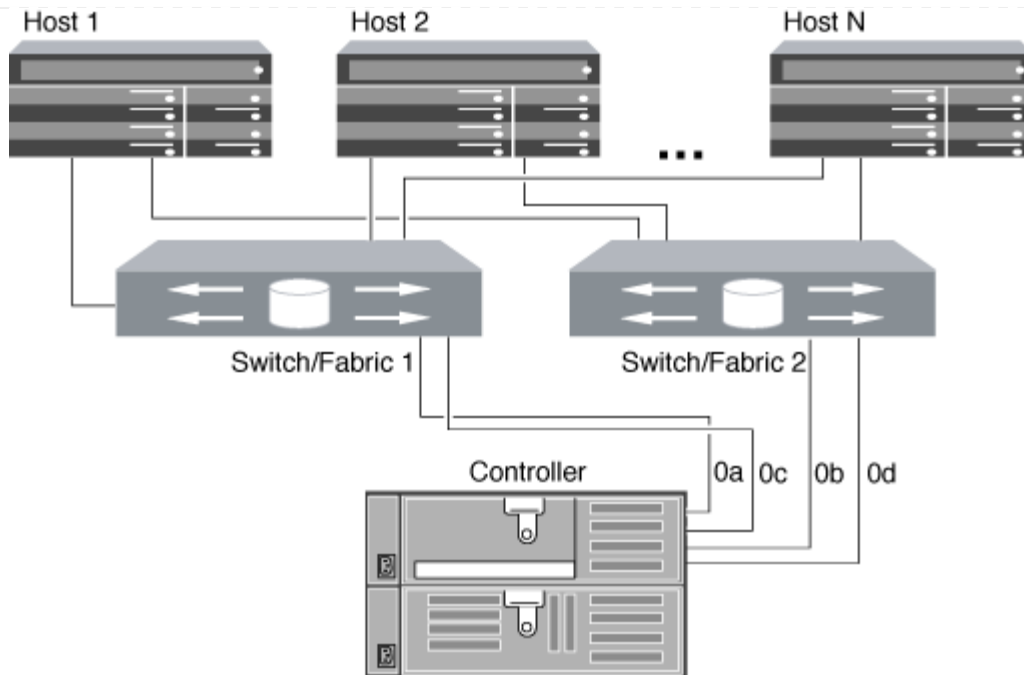
In single-fabric single-node configurations, there is one switch connecting a single node to one or more hosts. Because there is a single switch, this configuration is not fully redundant. All hardware platforms that support FC and FC-NVMe support single-fabric single-node configurations. However, the FAS2240 platform requires the X1150A-R6 expansion adapter to support a single-fabric single-node configuration.

The following figure shows a FAS2240 single-fabric single-node configuration. It shows the storage controllers side by side, which is how they are mounted in the FAS2240-2. For the FAS2240-4, the controllers are mounted one above the other. There is no difference in the SAN configuration for the two models.



== Multifabric single-node configurations

In multifabric single-node configurations, there are two or more switches connecting a single node to one or more hosts. For simplicity, the following figure shows a multifabric single-node configuration with only two fabrics, but you can have two or more fabrics in any multifabric configuration. In this figure, the storage controller is mounted in the top chassis and the bottom chassis can be empty or can have an IOMX module, as it does in this example.



Related information

[NetApp Technical Report 4684: Implementing and Configuring Modern SANs with NVMe/FC](#)

= Ways to configure FC & FC-NVMe SAN hosts with HA pairs

:icons: font

:relative_path: ./san-config/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You can configure FC and FC-NVMe SAN hosts to connect to HA pairs through one or more fabrics. You cannot directly attach FC or FC-NVMe SAN hosts to HA pairs without using a switch.

You can configure FC and FC-NVMe SAN hosts with single fabric HA pairs or with multifabric HA pairs. The FC target port numbers (0a, 0c, 0d, 1a, 1b) in the illustrations are examples. The actual port numbers vary depending on the model of your storage node and whether you are using expansion adapters.

== Single-fabric HA pairs

In single-fabric HA pair configurations, there is one fabric connecting both controllers in the HA pair to one or more hosts. Because the hosts and controllers are connected through a single switch, single-fabric HA pairs are not fully redundant.

All platforms that support FC configurations support single-fabric HA pair configurations, except the FAS2240 platform. The FAS2240 platform only supports single-fabric single-node configurations.



== Multifabric HA pairs

In multifabric HA pairs, there are two or more switches connecting HA pairs to one or more hosts. For simplicity, the following multifabric HA pair figure shows only two fabrics, but you can have two or more fabrics in any multifabric configuration:



= FC switch configuration best practices

:icons: font

:relative_path: ./san-config/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

For best performance, you should consider certain best practices when configuring your FC switch.

A fixed link speed setting is the best practice for FC switch configurations, especially for large fabrics because it provides the best performance for fabric rebuilds and can significantly save time. Although autonegotiation provides the greatest flexibility, FC switch configuration does not always perform as expected, and it adds time to the overall fabric-build sequence.

All of the switches that are connected to the fabric must support N_Port ID virtualization (NPIV) and must have NPIV enabled. ONTAP uses NPIV to present FC targets to a fabric.

For details about which environments are supported, see the [NetApp Interoperability Matrix Tool](#).

For FC and iSCSI best practices, see [Best Practices for Scalable SAN - ONTAP 9](#).

= Supported number of FC hop counts

:icons: font

:relative_path: ./san-config/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

The maximum supported FC hop count between a host and storage system depends on the switch supplier and storage system support for FC configurations.

The hop count is defined as the number of switches in the path between the initiator (host) and target (storage system). Cisco also refers to this value as the *diameter of the SAN fabric*.

Switch supplier	Supported hop count
Brocade	7 for FC5 for FCoE
Cisco	7 for FCUp to 3 of the switches can be FCoE switches.

Related information

[NetApp Downloads: Brocade Scalability Matrix Documents](#)

[NetApp Downloads: Cisco Scalability Matrix Documents](#)

= FC target port supported speeds

:icons: font

:relative_path: ./san-config/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

FC target ports can be configured to run at different speeds. You should set the target port speed to match the speed of the device to which it connects. All target ports used by a given host should be set to the same speed.

FC target ports can be used for FC-NVMe configurations in the exact same way they are used for FC configurations.

You should set the target port speed to match the speed of the device to which it connects instead of using autonegotiation. A port that is set to autonegotiation can take longer to reconnect after a takeover/giveback or other interruption.

You can configure onboard ports and expansion adapters to run at the following speeds. Each controller and expansion adapter port can be configured individually for different speeds as needed.

4 Gb ports	8 Gb ports	16 Gb ports	32 Gb ports
<ul style="list-style-type: none">• 4 Gb• 2 Gb• 1 Gb	<ul style="list-style-type: none">• 8 Gb• 4 Gb• 2 Gb	<ul style="list-style-type: none">• 16 Gb• 8 Gb• 4 Gb	<ul style="list-style-type: none">• 32 Gb• 16 Gb• 8 Gb

UTA2 ports can use an 8 Gb SFP+ adapter to support 8, 4, and 2 Gb speeds, if required.

= FC Target port configuration recommendations

:icons: font

:relative_path: ./san-config/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

For best performance and highest availability, you should use the recommended FC target port configuration.

The following table shows the preferred port usage order for onboard FC and FC-NVMe target ports. For expansion adapters, the FC ports should be spread so that they do not use the same ASIC for connectivity. The preferred slot order is listed in [NetApp Hardware Universe](#) for the version of ONTAP software used by your controller.

FC-NVMe is supported on the following models:

- AFF A300

The AFF A300 onboard ports do not support FC-NVMe.

- AFF A700
- AFF A700s
- AFF A800

The FAS22xx and FAS2520 systems do not have onboard FC ports and do not support add-on adapters.

Controller	Port pairs with shared ASIC	Number of target ports: Preferred ports
FAS9000, AFF A700, AFF A700s and AFF A800	None	All data ports are on expansion adapters. See NetApp Hardware Universe for more information.
8080, 8060 and 8040	0e+0f 0g+0h	1: 0e 2: 0e, 0g 3: 0e, 0g, 0h 4: 0e, 0g, 0f, 0h
FAS8200 and AFF A300	0g+0h	1: 0g 2: 0g, 0h
8020	0c+0d	1: 0c 2: 0c, 0d
62xx	0a+0b 0c+0d	1: 0a 2: 0a, 0c 3: 0a, 0c, 0b 4: 0a, 0c, 0b, 0d
32xx	0c+0d	1: 0c 2: 0c, 0d
FAS2554, FAS2552, FAS2600 series, FAS2720, FAS2750, AFF A200 and AFF A220	0c+0d 0e+0f	1: 0c 2: 0c, 0e 3: 0c, 0e, 0d 4: 0c, 0e, 0d, 0f

= Manage systems with FC adapters

= Managing systems with FC adapters overview

:icons: font

:relative_path: ./san-config/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

Commands are available to manage onboard FC adapters and FC adapter cards.

These commands can be used to configure the adapter mode, display adapter information, and change the speed.

Most storage systems have onboard FC adapters that can be configured as initiators or targets. You can also use FC adapter cards configured as initiators or targets. Initiators connect to back-end disk shelves, and possibly foreign storage arrays (FlexArray). Targets connect only to FC switches. Both the FC target HBA ports and the switch port speed should be set to the same value and should not be set to auto.

= Commands for managing FC adapters

:icons: font

:relative_path: ./san-config/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You can use FC commands to manage FC target adapters, FC initiator adapters, and onboard FC adapters for your storage controller. The same commands are used to manage FC adapters for the FC protocol and the FC-NVMe protocol.

FC initiator adapter commands work only at the node level. You must use the `run -node node_name` command before you can use the FC initiator adapter commands.

== Commands for managing FC target adapters

If you want to...	Use this command...
Display FC adapter information on a node	<code>network fcp adapter show</code>
Modify FC target adapter parameters	<code>network fcp adapter modify</code>
Display FC protocol traffic information	<code>run -node node_name sysstat -f</code>
Display how long the FC protocol has been running	<code>run -node node_name uptime</code>
Display adapter configuration and status	<code>run -node node_name sysconfig -v adapter</code>
Verify which expansion cards are installed and whether there are any configuration errors	<code>run -node node_name sysconfig -ac</code>
View a man page for a command	<code>man command_name</code>

== Commands for managing FC initiator adapters

If you want to...	Use this command...
Display information for all initiators and their adapters in a node	<code>run -node node_name storage show adapter</code>

If you want to...	Use this command...
Display adapter configuration and status	<code>run -node <i>node_name</i> sysconfig -v <i>adapter</i></code>
Verify which expansion cards are installed and whether there are any configuration errors	<code>run -node <i>node_name</i> sysconfig -ac</code>

== Commands for managing onboard FC adapters

If you want to...	Use this command...
Display the status of the onboard FC ports	<code>system node hardware unified-connect show</code>

= Configure FC adapters for initiator mode

:icons: font

:relative_path: ./san-config/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You can configure individual FC ports of onboard adapters and certain FC adapter cards for initiator mode. Initiator mode is used to connect the ports to tape drives, tape libraries, or third-party storage with FlexArray Virtualization or Foreign LUN Import (FLI).

What you'll need

- LIFs on the adapter must be removed from any port sets of which they are members.
- All LIF's from every storage virtual machine (SVM) using the physical port to be modified must be migrated or destroyed before changing the personality of the physical port from target to initiator.

About this task

Each onboard FC port can be individually configured as an initiator or a target. Ports on certain FC adapters can also be individually configured as either a target port or an initiator port, just like the onboard FC ports. A list of adapters that can be configured for target mode is available in [NetApp Hardware Universe](#).

NVMe/FC does support initiator mode.

Steps

1. Remove all LIFs from the adapter:

```
network interface delete -vserver SVM_name -lif lif_name,lif_name
```

2. Take your adapter offline:

```
network fcp adapter modify -node node_name -adapter adapter_port -status  
-admin down
```

If the adapter does not go offline, you can also remove the cable from the appropriate adapter port on the system.

3. Change the adapter from target to initiator:

```
system hardware unified-connect modify -t initiator adapter_port
```

4. Reboot the node hosting the adapter you changed.
5. Verify that the FC ports are configured in the correct state for your configuration:

```
system hardware unified-connect show
```

6. Bring the adapter back online:

```
node run -node node_name storage enable adapter adapter_port
```

= Configure FC adapters for target mode

:icons: font

:relative_path: ./san-config/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You can configure individual FC ports of onboard adapters and certain FC adapter cards for target mode. Target mode is used to connect the ports to FC initiators.

About this task

Each onboard FC port can be individually configured as an initiator or a target. Ports on certain FC adapters can also be individually configured as either a target port or an initiator port, just like the onboard FC ports. A list of adapters that can be configured for target mode is available in the [NetApp Hardware Universe](#).

The same steps are used when configuring FC adapters for the FC protocol and the FC-NVMe protocol. However, only certain FC adapters support FC-NVMe. See the [NetApp Hardware Universe](#) for a list of adapters that support the FC-NVMe protocol.

Steps

1. Take the adapter offline:

```
node run -node node_name storage disable adapter adapter_name
```

If the adapter does not go offline, you can also remove the cable from the appropriate adapter port on the system.

2. Change the adapter from initiator to target:

```
system node hardware unified-connect modify -t target -node node_name  
adapter adapter_name
```

3. Reboot the node hosting the adapter you changed.

4. Verify that the target port has the correct configuration:

```
network fcp adapter show -node node_name
```

5. Bring your adapter online:

```
network fcp adapter modify -node node_name -adapter adapter_port -state up
```

= Display information about an FC target adapter

:icons: font

:relative_path: ./san-config/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You can use the `network fcp adapter show` command to display system configuration and adapter information for any FC adapter in the system.

Step

1. Display information about the FC adapter by using the `network fcp adapter show` command.

The output displays system configuration information and adapter information for each slot that is used.

```
network fcp adapter show -instance -node node1 -adapter 0a
```

= Change the FC adapter speed

:icons: font

:relative_path: ./san-config/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You should set your adapter target port speed to match the speed of the device to which it connects, instead of using autonegotiation. A port that is set to autonegotiation can take longer time to reconnect after a takeover/giveback or other interruption.

What you'll need

All LIFs that use this adapter as their home port must be offline.

About this task

Because this task encompasses all storage virtual machines (SVMs) and all LIFs in a cluster, you must use the `-home-port` and `-home-lif` parameters to limit the scope of this operation. If you do not use these parameters, the operation applies to all LIFs in the cluster, which might not be desirable.

Steps

1. Take all of the LIFs on this adapter offline:

```
network interface modify -vserver * -lif * { -home-node node1 -home-port 0c
} -status-admin down
```

2. Take the adapter offline:

```
network fcp adapter modify -node node1 -adapter 0c -state down
```

If the adapter does not go offline, you can also remove the cable from the appropriate adapter port on the system.

3. Determine the maximum speed for the port adapter:

```
fcp adapter show -instance
```

You cannot modify the adapter speed beyond the maximum speed.

4. Change the adapter speed:

```
network fcp adapter modify -node node1 -adapter 0c -speed 16
```

5. Bring the adapter online:

```
network fcp adapter modify -node node1 -adapter 0c -state up
```

6. Bring all of the LIFs on the adapter online:

```
network interface modify -vserver * -lif * { -home-node node1 -home-port 0c
} -status-admin up
```

= Supported FC ports

:icons: font

:relative_path: ./san-config/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

The number of onboard FC ports and CNA/UTA2 ports configured for FC varies based on the model of the controller. FC ports are also available through supported FC target expansion adapters or additional UTA2 cards configured with FC SFP+ adapters.

== Onboard FC, UTA, and UTA2 ports

- Onboard ports can be individually configured as either target or initiator FC ports.
- The number of onboard FC ports differs depending on controller model.

The [NetApp Hardware Universe](#) contains a complete list of onboard FC ports on each controller model.

- FC ports are only available on FAS2240 systems through the X1150A-R6 expansion adapter.

FAS2220 and FAS2520 systems do not support FC.

== Target expansion adapter FC ports

- Available target expansion adapters differ depending on controller model.

The [NetApp Hardware Universe](#) contains a complete list of target expansion adapters for each controller model.

- The ports on some FC expansion adapters are configured as initiators or targets at the factory and cannot be changed.

Others can be individually configured as either target or initiator FC ports, just like the onboard FC ports. A complete list is available in [NetApp Hardware Universe](#).

= Prevent loss of connectivity when using the X1133A-R6 adapter

:icons: font

:relative_path: ./san-config/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You can prevent loss of connectivity during a port failure by configuring your system with redundant paths to separate X1133A-R6 HBAs.

The X1133A-R6 HBA is a 4-port, 16 Gb FC adapter consisting of two 2-port pairs. The X1133A-R6 adapter can be configured as target mode or initiator mode. Each 2-port pair is supported by a single ASIC (for example, Port 1 and Port 2 on ASIC 1 and Port 3 and Port 4 on ASIC 2). Both ports on a single ASIC must be configured to operate in the same mode, either target mode or initiator mode. If an error occurs with the ASIC supporting a pair, both ports in the pair go offline.

To prevent this loss of connectivity, you configure your system with redundant paths to separate X1133A-R6 HBAs, or with redundant paths to ports supported by different ASICs on the HBA.

= Manage X1143A-R6 adapters

= Supported port configurations for X1143A-R6 adapters overview

:icons: font

:relative_path: ./san-config/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

By default the X1143A-R6 adapter is configured in FC target mode, but you can configure its ports as either 10 Gb Ethernet and FCoE (CNA) ports or as 16 Gb FC initiator or target ports. This requires different SFP+ adapters.

When configured for Ethernet and FCoE, X1143A-R6 adapters support concurrent NIC and FCoE target traffic on the same 10-GBE port. When configured for FC, each two-port pair that shares the same ASIC can be individually configured for FC target or FC initiator mode. This means that a single X1143A-R6 adapter can support FC target mode on one two-port pair and FC initiator mode on another two-port pair. Port pairs connected to the same ASIC must be configured in the same mode.

In FC mode, the X1143A-R6 adapter behaves just like any existing FC device with speeds up to 16 Gbps. In CNA mode, you can use the X1143A-R6 adapter for concurrent NIC and FCoE traffic sharing the same 10 GbE port. CNA mode only supports FC target mode for the FCoE function.

= Configure the ports

:icons: font

:relative_path: ./san-config/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

To configure the unified target adapter (X1143A-R6), you must configure the two adjacent ports on the same chip in the same personality mode.

Steps

1. Configure the ports as needed for Fibre Channel (FC) or Converged Network Adapter (CNA) using the `system node hardware unified-connect modify` command.
2. Attach the appropriate cables for FC or 10 Gb Ethernet.
3. Verify that you have the correct SFP+ installed:

```
network fcp adapter show -instance -node -adapter
```

For CNA, you should use a 10Gb Ethernet SFP. For FC, you should either use an 8 Gb SFP or a 16 Gb SFP, based on the FC fabric being connected to.

= Change the UTA2 port from CNA mode to FC mode

:icons: font

:relative_path: ./san-config/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You should change the UTA2 port from Converged Network Adapter (CNA) mode to Fibre Channel (FC) mode to support the FC initiator and FC target mode. You should change the personality from CNA mode to FC mode when you need to change the physical medium that connects the port to its network.

Steps

1. Take the adapter offline:

```
network fcp adapter modify -node node_name -adapter adapter_name -status  
-admin down
```

2. Change the port mode:

```
ucadmin modify -node node_name -adapter adapter_name -mode fcp
```

3. Reboot the node, and then bring the adapter online:

```
network fcp adapter modify -node node_name -adapter adapter_name -status  
-admin up
```

4. Notify your admin or VIF manager to delete or remove the port, as applicable:

- If the port is used as a home port of a LIF, is a member of an interface group (ifgrp), or hosts VLANs, then an admin should do the following:
 - i. Move the LIFs, remove the port from the ifgrp, or delete the VLANs, respectively.
 - ii. Manually delete the port by running the `network port delete` command.

If the `network port delete` command fails, the admin should address the errors, and then run the command again.

- If the port is not used as the home port of a LIF, is not a member of an ifgrp, and does not host

VLANs, then the VIF manager should remove the port from its records at the time of reboot.

If the VIF manager does not remove the port, then the admin must remove it manually after the reboot by using the `network port delete` command.

```
net-f8040-34::> network port show
```

```
Node: net-f8040-34-01
```

Health	Port	IPspace	Broadcast	Domain	Link	MTU	Admin/Oper	Speed (Mbps)
Status	-----	-----	-----	-----	-----	-----	-----	
...								
	e0i	Default	Default		down	1500	auto/10	-
	e0f	Default	Default		down	1500	auto/10	-
...								

```
net-f8040-34::> ucadmin show
```

Admin	Node	Adapter	Current Mode	Current Type	Pending Mode	Pending Type
Status	-----	-----	-----	-----	-----	-----
...						
	net-f8040-34-01	0e	cna	target	-	-
offline						
	net-f8040-34-01	0f	cna	target	-	-
offline						
...						

```
net-f8040-34::> network interface create -vs net-f8040-34 -lif m
-role
node-mgmt-home-node net-f8040-34-01 -home-port e0e -address 10.1.1.1
-netmask 255.255.255.0
```

```
net-f8040-34::> network interface show -fields home-port, curr-
port
```

vserver	lif	home-port	curr-port
Cluster	net-f8040-34-01_clus1	e0a	e0a
Cluster	net-f8040-34-01_clus2	e0b	e0b

```

Cluster net-f8040-34-01_clus3 e0c      e0c
Cluster net-f8040-34-01_clus4 e0d      e0d
net-f8040-34
      cluster_mgmt      e0M      e0M
net-f8040-34
      m      e0e      e0i
net-f8040-34
      net-f8040-34-01_mgmt1 e0M      e0M
7 entries were displayed.

```

```
net-f8040-34::> ucadmin modify local 0e fc
```

Warning: Mode on adapter 0e and also adapter 0f will be changed to fc.

```
Do you want to continue? {y|n}: y
```

Any changes will take effect after rebooting the system. Use the "system node reboot" command to reboot.

```
net-f8040-34::> reboot local
(system node reboot)
```

```
Warning: Are you sure you want to reboot node "net-f8040-34-01"?
{y|n}: y
```

5. Verify that you have the correct SFP+ installed:

```
network fcp adapter show -instance -node -adapter
```

For CNA, you should use a 10Gb Ethernet SFP. For FC, you should either use an 8 Gb SFP or a 16 Gb SFP, before changing the configuration on the node.

= Change the CNA/UTA2 target adapter optical modules

```
:icons: font
```

```
:relative_path: ./san-config/
```

```
:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/
```

You should change the optical modules on the unified target adapter (CNA/UTA2) to support the personality mode you have selected for the adapter.

Steps

1. Verify the current SFP+ used in the card. Then, replace the current SFP+ with the appropriate SFP+ for the preferred personality (FC or CNA).
2. Remove the current optical modules from the X1143A-R6 adapter.
3. Insert the correct modules for your preferred personality mode (FC or CNA) optics.
4. Verify that you have the correct SFP+ installed:

```
network fcp adapter show -instance -node -adapter
```

Supported SFP+ modules and Cisco-branded Copper (Twinax) cables are listed in the [NetApp Hardware Universe](#).

= View adapter settings

:icons: font

:relative_path: ./san-config/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

To view the settings for your unified target adapter (X1143A-R6), you must run the `system hardware unified-connect show` command to display all modules on your controller.

Steps

1. Boot your controller without the cables attached.
2. Run the `system hardware unified-connect show` command to see the port configuration and modules.
3. View the port information before configuring the CNA and ports.

= Ways to Configure FCoE

= Ways to Configure FCoE overview

:icons: font

:relative_path: ./san-config/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

FCoE can be configured in various ways using FCoE switches. Direct-attached configurations are not supported in FCoE.

All FCoE configurations are dual-fabric, fully redundant, and require host-side multipathing software. In all FCoE configurations, you can have multiple FCoE and FC switches in the path between the initiator and target, up to the maximum hop count limit. To connect switches to each other, the switches must run a firmware version that supports Ethernet ISLs. Each host in any FCoE configuration can be configured with a different operating system.

FCoE configurations require Ethernet switches that explicitly support FCoE features. FCoE configurations are validated through the same interoperability and quality assurance process as FC switches. Supported configurations are listed in the Interoperability Matrix. Some of the parameters included in these supported configurations are the switch model, the number of switches that can be deployed in a single fabric, and the supported switch firmware version.

The FC target expansion adapter port numbers in the illustrations are examples. The actual port numbers might vary, depending on the expansion slots in which the FCoE target expansion adapters are installed.

== FCoE initiator to FC target

Using FCoE initiators (CNAs), you can connect hosts to both controllers in an HA pair through FCoE switches to FC target ports. The FCoE switch must also have FC ports. The host FCoE initiator always connects to the FCoE switch. The FCoE switch can connect directly to the FC target or can connect to the FC target through FC switches.

The following illustration shows host CNAs connecting to an FCoE switch, and then to an FC switch before connecting to the HA pair:



== FCoE initiator to FCoE target

Using host FCoE initiators (CNAs), you can connect hosts to both controllers in an HA pair to FCoE target ports (also called UTAs or UTA2s) through FCoE switches.



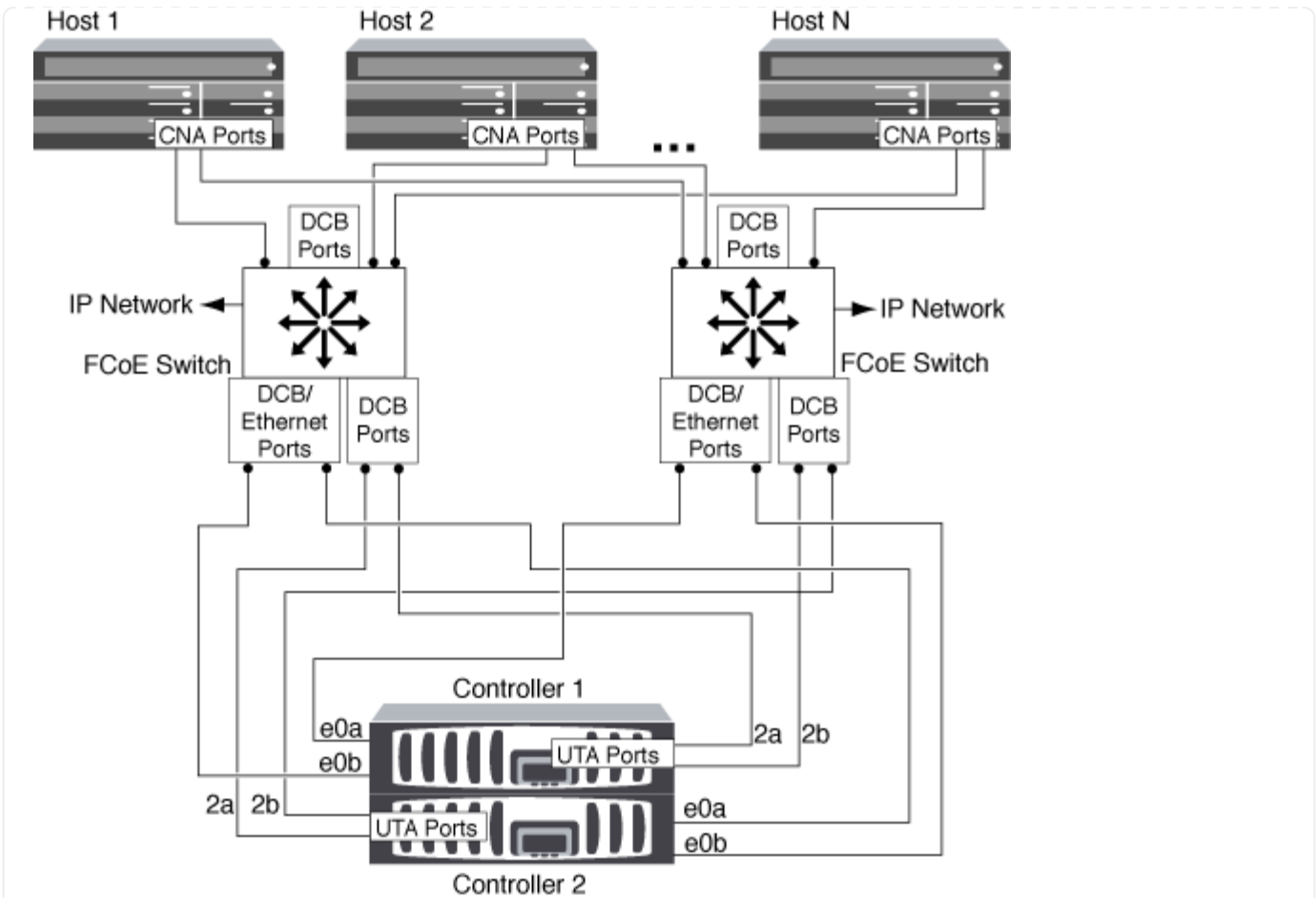
== FCoE initiator to FCoE and FC targets

Using host FCoE initiators (CNAs), you can connect hosts to both controllers in an HA pair to FCoE and FC target ports (also called UTAs or UTA2s) through FCoE switches.



== FCoE mixed with IP storage protocols

Using host FCoE initiators (CNAs), you can connect hosts to both controllers in an HA pair to FCoE target ports (also called UTAs or UTA2s) through FCoE switches. FCoE ports cannot use traditional link aggregation to a single switch. Cisco switches support a special type of link aggregation (Virtual Port Channel) that does support FCoE. A Virtual Port Channel aggregates individual links to two switches. You can also use Virtual Port Channels for other Ethernet traffic. Ports used for traffic other than FCoE, including NFS, SMB, iSCSI, and other Ethernet traffic, can use regular Ethernet ports on the FCoE switches.



= FCoE initiator and target combinations

:icons: font

:relative_path: ./san-config/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

Certain combinations of FCoE and traditional FC initiators and targets are supported.

== FCoE initiators

You can use FCoE initiators in host computers with both FCoE and traditional FC targets in storage controllers. The host FCoE initiator must connect to an FCoE DCB (data center bridging) switch; direct connection to a target is not supported.

The following table lists the supported combinations:

Initiator	Target	Supported?
FC	FC	Yes
FC	FCoE	Yes
FCoE	FC	Yes
FCoE	FCoE	Yes

== FCoE targets

You can mix FCoE target ports with 4-Gb, 8-Gb, or 16-Gb FC ports on the storage controller regardless of whether the FC ports are add-in target adapters or onboard ports. You can have both FCoE and FC target adapters in the same storage controller.

The rules for combining onboard and expansion FC ports still apply.

= FCoE supported hop count

:icons: font

:relative_path: ./san-config/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

The maximum supported Fibre Channel over Ethernet (FCoE) hop count between a host and storage system depends on the switch supplier and storage system support for FCoE configurations.

The hop count is defined as the number of switches in the path between the initiator (host) and target (storage system). Documentation from Cisco Systems also refers to this value as the *diameter of the SAN fabric*.

For FCoE, you can have FCoE switches connected to FC switches.

For end-to-end FCoE connections, the FCoE switches must be running a firmware version that supports Ethernet inter-switch links (ISLs).

The following table lists the maximum supported hop counts:

Switch supplier	Supported hop count
Brocade	7 for FC 5 for FCoE
Cisco	7 Up to 3 of the switches can be FCoE switches.

= Fibre Channel and FCoE zoning

= Fibre Channel and FCoE zoning overview

:icons: font

:relative_path: ./san-config/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

An FC, FC-NVMe or FCoE zone is a logical grouping of one or more ports within a fabric. For devices to be able see each other, connect, create sessions with one another, and communicate, both ports need to have a common zone membership. Single initiator zoning is recommended.

== Reasons for zoning

- Zoning reduces or eliminates *crosstalk* between initiator HBAs.

This occurs even in small environments and is one of the best arguments for implementing zoning. The logical fabric subsets created by zoning eliminate crosstalk problems.

- Zoning reduces the number of available paths to a particular FC, FC-NVMe, or FCoE port and reduces the number of paths between a host and a particular LUN that is visible.

For example, some host OS multipathing solutions have a limit on the number of paths they can manage. Zoning can reduce the number of paths that an OS multipathing driver sees. If a host does not have a multipathing solution installed, you need to verify that only one path to a LUN is visible by using either zoning in the fabric or a combination of Selective LUN Mapping (SLM) and portsets in the SVM.

- Zoning increases security by limiting access and connectivity to end-points that share a common zone.

Ports that have no zones in common cannot communicate with one another.

- Zoning improves SAN reliability by isolating problems that occur and helps to reduce problem resolution time by limiting the problem space.

== Recommendations for zoning

- You should implement zoning any time, if four or more hosts are connected to a SAN or if SLM is not implemented on the nodes to a SAN.
- Although World Wide Node Name zoning is possible with some switch vendors, World Wide Port Name zoning is required to properly define a specific port and to use NPIV effectively.
- You should limit the zone size while still maintaining manageability.

Multiple zones can overlap to limit size. Ideally, a zone is defined for each host or host cluster.

- You should use single-initiator zoning to eliminate crosstalk between initiator HBAs.

= World Wide Name-based zoning

:icons: font

:relative_path: ./san-config/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

Zoning based on World Wide Name (WWN) specifies the WWN of the members to be included within the zone. When zoning in ONTAP, you must use World Wide Port Name (WWPN) zoning.

WWPN zoning provides flexibility because access is not determined by where the device is physically connected to the fabric. You can move a cable from one port to another without reconfiguring zones.

For Fibre Channel paths to storage controllers running ONTAP, be sure the FC switches are zoned using the WWPNs of the target logical interfaces (LIFs), not the WWPNs of the physical ports on the node. For more information on LIFs, see the *ONTAP Network Management Guide*.

Network management

= Individual zones

:icons: font

:relative_path: ./san-config/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

In the recommended zoning configuration, there is one host initiator per zone. The zone consists of the host initiator port and one or more target LIFs on the storage nodes that are providing access to the LUNs up to the desired number of paths per target. This means that hosts accessing the same nodes cannot see each other's

ports, but each initiator can access any node.

You should add all LIF's from the storage virtual machine (SVM) into the zone with the host initiator. This allows you to move volumes or LUNs without editing your existing zones or creating new zones.

For Fibre Channel paths to nodes running ONTAP, be sure that the FC switches are zoned using the WWPNs of the target logical interfaces (LIFs), not the WWPNs of the physical ports on the node. The WWPNs of the physical ports start with "50" and the WWPNs of the LIFs start with "20".

= Single-fabric zoning

:icons: font

:relative_path: ./san-config/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

In a single-fabric configuration, you can still connect each host initiator to each storage node. Multipathing software is required on the host to manage multiple paths. Each host should have two initiators for multipathing to provide resiliency in the solution.

Each initiator should have a minimum of one LIF from each node that the initiator can access. The zoning should allow at least one path from the host initiator to the HA pair of nodes in the cluster to provide a path for LUN connectivity. This means that each initiator on the host might only have one target LIF per node in its zone configuration. If there is a requirement for multipathing to the same node or multiple nodes in the cluster, then each node will have multiple LIFs per node in its zone configuration. This enables the host to still access its LUNs if a node fails or a volume containing the LUN is moved to a different node. This also requires the reporting nodes to be set appropriately.

Single-fabric configurations are supported, but are not considered highly available. The failure of a single component can cause loss of access to data.

In the following figure, the host has two initiators and is running multipathing software. There are two zones:

The naming convention used in this figure is just a recommendation of one possible naming convention that you can choose to use for your ONTAP solution.

- Zone 1: HBA 0, LIF_1, and LIF_3
- Zone 2: HBA 1, LIF_2, and LIF_4

If the configuration included more nodes, the LIFs for the additional nodes would be included in these zones.



In this example, you could also have all four LIFs in each zone. In that case, the zones would be as follows:

- Zone 1: HBA 0, LIF_1, LIF_2, LIF_3, and LIF_4
- Zone 2: HBA 1, LIF_1, LIF_2, LIF_3, and LIF_4

The host operating system and multipathing software have to support the number of supported paths that are being used to access the LUNs on the nodes. To determine the number of paths used to access the LUNs on nodes, see the SAN configuration limits section.

Related information

[NetApp Hardware Universe](#)

= Dual-fabric HA pair zoning

:icons: font

:relative_path: ./san-config/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

In dual-fabric configurations, you can connect each host initiator to each cluster node. Each host initiator uses a different switch to access the cluster nodes. Multipathing software is required on the host to manage multiple paths.

Dual-fabric configurations are considered high availability because access to data is maintained if a single component fails.

In the following figure, the host has two initiators and is running multipathing software. There are two zones. SLM is configured so that all nodes are considered as reporting nodes.

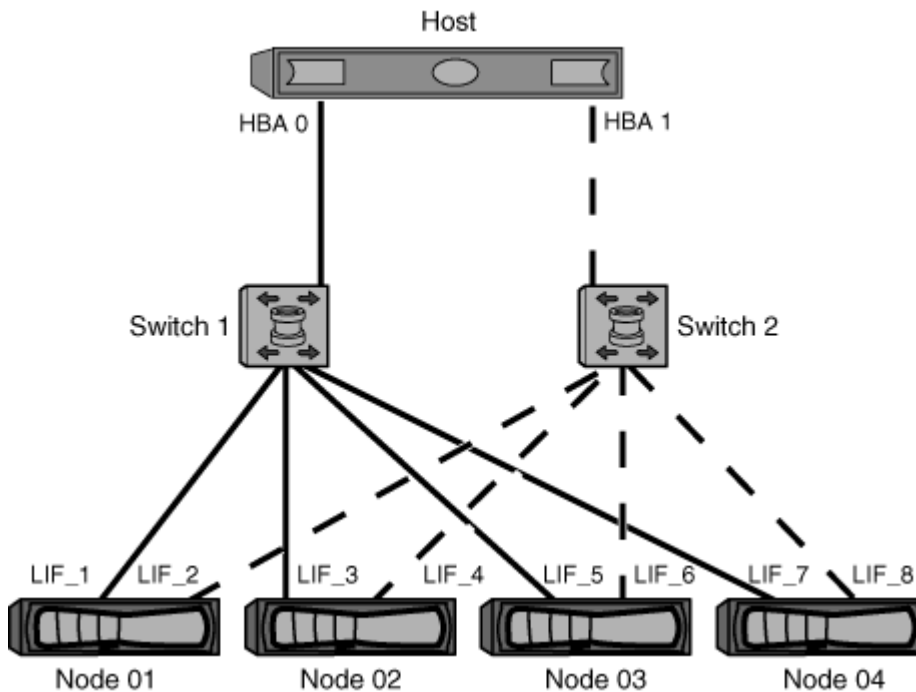
The naming convention used in this figure is just a recommendation of one possible naming convention that you can choose to use for your ONTAP solution.

- Zone 1: HBA 0, LIF_1, LIF_3, LIF_5, and LIF_7
- Zone 2: HBA 1, LIF_2, LIF_4, LIF_6, and LIF_8

Each host initiator is zoned through a different switch. Zone 1 is accessed through Switch 1. Zone 2 is accessed through Switch 2.

Each initiator can access a LIF on every node. This enables the host to still access its LUNs if a node fails. SVMs have access to all iSCSI and FC LIFs on every node in a clustered solution based on the setting for Selective LUN Map (SLM) and the reporting node configuration. You can use SLM, portsets, or FC switch zoning to reduce the number of paths from an SVM to the host and the number of paths from an SVM to a LUN.

If the configuration included more nodes, the LIFs for the additional nodes would be included in these zones.



The host operating system and multipathing software have to support the number of paths that is being used to access the LUNs on the nodes.

Related information

[NetApp Hardware Universe](#)

= Zoning restrictions for Cisco FC and FCoE switches

:icons: font

:relative_path: ./san-config/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

When using Cisco FC and FCoE switches, a single fabric zone must not contain more than one target LIF for the same physical port. If multiple LIFs on the same port are in the same zone, then the LIF ports might fail to recover from a connection loss.

Regular FC switches are used for the FC-NVMe protocol in the exact same way they are used for the FC protocol.

- Multiple LIFs for the FC and FCoE protocols, can share physical ports on a node as long as they are in different zones.
- FC-NVMe and FCoE cannot share the same physical port.
- FC and FC-NVMe can share the same 32 Gb physical port.
- Cisco FC and FCoE switches require each LIF on a given port to be in a separate zone from the other LIFs on that port.
- A single zone can have both FC and FCoE LIFs. A zone can contain a LIF from every target port in the cluster, but be careful to not exceed the host's path limits and verify the SLM configuration.
- LIFs on different physical ports can be in the same zone.
- Cisco switches require that LIFs be separated.

Though not required, separating LIFs is recommended for all switches

= Requirements for shared SAN configurations

:icons: font

:relative_path: ./san-config/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

Shared SAN configurations are defined as hosts that are attached to both ONTAP storage systems and other vendors' storage systems. Accessing ONTAP storage systems and other vendors' storage systems from a single host is supported as long as several requirements are met.

For all of the host operating systems, it is a best practice to use separate adapters to connect to each vendor's storage systems. Using separate adapters reduces the chances of conflicting drivers and settings. For connections to an ONTAP storage system, the adapter model, BIOS, firmware, and driver must be listed as supported in the NetApp Interoperability Matrix Tool.

You should set the required or recommended timeout values and other storage parameters for the host. You must always install the NetApp software or apply the NetApp settings last.

- For AIX, you should apply the values from the AIX Host Utilities version that is listed in the Interoperability Matrix Tool for your configuration.

- For ESX, you should apply host settings by using Virtual Storage Console for VMware vSphere.
- For HP-UX, you should use the HP-UX default storage settings.
- For Linux, you should apply the values from the Linux Host Utilities version that is listed in the Interoperability Matrix Tool for your configuration.
- For Solaris, you should apply the values from the Solaris Host Utilities version that is listed in the Interoperability Matrix Tool for your configuration.
- For Windows, you should install the Windows Host Utilities version that is listed in the Interoperability Matrix Tool for your configuration.

Related information

[NetApp Interoperability Matrix Tool](#)

= Host support for multipathing

= Host support for multipathing overview

:icons: font

:relative_path: ./san-config/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

ONTAP always uses Asymmetric Logical Unit Access (ALUA) for both FC and iSCSI paths. Be sure to use host configurations that support ALUA for FC and iSCSI protocols.

Beginning with ONTAP 9.5 multipath HA pair failover/giveback is supported for NVMe configurations using Asynchronous Namespace Access (ANA). In ONTAP 9.4, NVMe only supports one path from host to target. The application host needs to manage path failover to its high availability (HA) partner.

For information about which specific host configurations support ALUA or ANA, see the [NetApp Interoperability Matrix Tool](#) and [ONTAP SAN Host Configuration](#) for your host operating system.

= When host multipathing software is required

:icons: font

:relative_path: ./san-config/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

If there is more than one path from the storage virtual machine (SVM) logical interfaces (LIFs) to the fabric, multipathing software is required. Multipathing software is required on the host any time the host can access a LUN through more than one path.

The multipathing software presents a single disk to the operating system for all paths to a LUN. Without multipathing software, the operating system could treat each path as a separate disk, which can lead to data corruption.

Your solution is considered to have multiple paths if you have any of the following:

- A single initiator port in the host attaching to multiple SAN LIFs in the SVM
- Multiple initiator ports attaching to a single SAN LIF in the SVM
- Multiple initiator ports attaching to multiple SAN LIFs in the SVM

In single-fabric single-node configurations, multipathing software is not required if you only have a single path from the host to the node.

Multipathing software is recommended in HA configurations. In addition to Selective LUN Map, using FC switch zoning or portsets to limit the paths used to access LUNs is recommended.

Multipathing software is also known as MPIO (multipath I/O) software.

= Recommended number of paths from host to nodes in cluster

:icons: font

:relative_path: ./san-config/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You should not exceed more than eight paths from your host to each node in your cluster, paying attention to the total number of paths that can be supported for the host OS and the multipathing used on the host.

You should have a minimum of two paths per LUN connecting to each reporting node through Selective LUN Map (SLM) being used by the storage virtual machine (SVM) in your cluster. This eliminates single points of failure and enables the system to survive component failures.

If you have four or more nodes in your cluster or more than four target ports being used by the SVMs in any of your nodes, you can use the following methods to limit the number of paths that can be used to access LUNs on your nodes so that you do not exceed the recommended maximum of eight paths.

- SLM

SLM reduces the number of paths from the host to LUN to only paths on the node owning the LUN and the owning node's HA partner. SLM is enabled by default.

- Portsets for iSCSI
- FC igroup mappings from your host
- FC switch zoning

Related information

[SAN administration](#)

= Configuration limits

= Determine the number of supported nodes for SAN configurations

:icons: font

:relative_path: ./san-config/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

The number of nodes per cluster supported by ONTAP varies depending on your version of ONTAP, the storage controller models in your cluster, and the protocol of your cluster nodes.

About this task

If any node in the cluster is configured for FC, FC-NVMe, FCoE, or iSCSI, that cluster is limited to the SAN node limits. Node limits based on the controllers in your cluster are listed in the *Hardware Universe*.

Steps

1. Go to [NetApp Hardware Universe](#).
2. Click **Platforms** in the upper left (next to the **Home** button) and select the platform type.
3. Select the check box next to your version of ONTAP.

A new column is displayed for you to choose your platforms.

4. Select the check boxes next to the platforms used in your solution.
5. Unselect the **Select All** check box in the **Choose Your Specifications** column.
6. Select the **Max Nodes per Cluster (NAS/SAN)** check box.
7. Click **Show Results**.

Related information

[NetApp Hardware Universe](#)

= Determine the number of supported hosts per cluster in FC and FC-NVMe configurations

:icons: font

:relative_path: ./san-config/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

The maximum number of SAN hosts that can be connected to a cluster varies greatly based upon your specific combination of multiple cluster attributes, such as the number of hosts connected to each cluster node, initiators per host, sessions per host, and nodes in the cluster.

About this task

For FC and FC-NVMe configurations, you should use the number of initiator-target nexuses (ITNs) in your system to determine whether you can add more hosts to your cluster.

An ITN represents one path from the host's initiator to the storage system's target. The maximum number of ITNs per node in FC and FC-NVMe configurations is 2,048. As long as you are below the maximum number of ITNs, you can continue to add hosts to your cluster.

To determine the number of ITNs used in your cluster, perform the following steps for each node in the cluster.

Steps

1. Identify all the LIFs on a given node.
2. Run the following command for every LIF on the node:

```
fcpx initiator show -fields wwpn, lif
```

The number of entries displayed at the bottom of the command output represents your number of ITNs for that LIF.

3. Record the number of ITNs displayed for each LIF.
4. Add the number of ITNs for each LIF on every node in your cluster.

This total represents the number of ITNs in your cluster.

= Determine the supported number of hosts in iSCSI configurations

:icons: font
:relative_path: ./san-config/
:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

The maximum number of SAN hosts that can be connected in iSCSI configurations varies greatly based on your specific combination of multiple cluster attributes, such as the number of hosts connected to each cluster node, initiators per host, logins per host, and nodes in the cluster.

About this task

The number of hosts that can be directly connected to a node or that can be connected through one or more switches depends on the number of available Ethernet ports. The number of available Ethernet ports is determined by the model of the controller and the number and type of adapters installed in the controller. The number of supported Ethernet ports for controllers and adapters is available in the *Hardware Universe*.

For all multi-node cluster configurations, you must determine the number of iSCSI sessions per node to know whether you can add more hosts to your cluster. As long as your cluster is below the maximum number of iSCSI sessions per node, you can continue to add hosts to your cluster. The maximum number of iSCSI sessions per node varies based on the types of controllers in your cluster.

Steps

1. Identify all of the target portal groups on the node.
2. Check the number of iSCSI sessions for every target portal group on the node:

```
iscsi session show -tpgroup tpgroup
```

The number of entries displayed at the bottom of the command output represents your number of iSCSI sessions for that target portal group.

3. Record the number of iSCSI sessions displayed for each target portal group.
4. Add the number of iSCSI sessions for each target portal group on the node.

The total represents the number of iSCSI sessions on your node.

= FC switch configuration limits

:icons: font
:relative_path: ./san-config/
:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

Fibre Channel switches have maximum configuration limits, including the number of logins supported per port, port group, blade, and switch. The switch vendors document their supported limits.

Each FC logical interface (LIF) logs into an FC switch port. The total number of logins from a single target on the node equals the number of LIFs plus one login for the underlying physical port. Do not exceed the switch vendor's configuration limits for logins or other configuration values. This also holds true for the initiators being used on the host side in virtualized environments with NPIV enabled. Do not exceed the switch vendor's configuration limits for logins for either the target or the initiators being used in the solution.

== Brocade switch limits

You can find the configuration limits for Brocade switches in the *Brocade Scalability Guidelines*.

== Cisco Systems switch limits

You can find the configuration limits for Cisco switches in the [Cisco Configuration Limits](#) guide for your version of Cisco switch software.

= Calculate queue depth overview

:icons: font

:relative_path: ./san-config/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You might need to tune your FC queue depth on the host to achieve the maximum values for ITNs per node and FC port fan-in. The maximum number of LUNs and the number of HBAs that can connect to an FC port are limited by the available queue depth on the FC target ports.

About this task

Queue depth is the number of I/O requests (SCSI commands) that can be queued at one time on a storage controller. Each I/O request from the host's initiator HBA to the storage controller's target adapter consumes a queue entry. Typically, a higher queue depth equates to better performance. However, if the storage controller's maximum queue depth is reached, that storage controller rejects incoming commands by returning a QFULL response to them. If a large number of hosts are accessing a storage controller, you should plan carefully to avoid QFULL conditions, which significantly degrade system performance and can lead to errors on some systems.

In a configuration with multiple initiators (hosts), all hosts should have similar queue depths. Because of the inequality in queue depth between hosts connected to the storage controller through the same target port, hosts with smaller queue depths are being deprived of access to resources by hosts with larger queue depths.

The following general recommendations can be made about "tuning" queue depths:

- For small to mid-size systems, use an HBA queue depth of 32.
- For large systems, use an HBA queue depth of 128.
- For exception cases or performance testing, use a queue depth of 256 to avoid possible queuing problems.
- All hosts should have the queue depths set to similar values to give equal access to all hosts.
- To avoid performance penalties or errors, the storage controller target FC port queue depth must not be exceeded.

Steps

1. Count the total number of FC initiators in all of the hosts that connect to one FC target port.
2. Multiply by 128.
 - If the result is less than 2,048, set the queue depth for all initiators to 128.
You have 15 hosts with one initiator connected to each of two target ports on the storage controller. $15 \times 128 = 1,920$. Because 1,920 is less than the total queue depth limit of 2,048, you can set the queue depth for all of your initiators to 128.

- If the result is greater than 2,048, go to step 3.
You have 30 hosts with one initiator connected to each of two target ports on the storage controller. $30 \times 128 = 3,840$. Because 3,840 is greater than the total queue depth limit of 2,048, you should choose one of the options under step 3 for remediation.

3. Choose one of the following options to add more hosts to the storage controller.

- Option 1:
 - i. Add more FC target ports.
 - ii. Redistribute your FC initiators.
 - iii. Repeat steps 1 and 2.

The desired queue depth of 3,840 exceeds the available queue depth per port. To remedy this, you can add a two-port FC target adapter to each controller, then rezone your FC switches so that 15 of your 30 hosts connect to one set of ports, and the remaining 15 hosts connect to a second set of ports. The queue depth per port is then reduced to $15 \times 128 = 1,920$.

- Option 2:
 - i. Designate each host as “large” or “small” based on its expected I/O need.
 - ii. Multiply the number of large initiators by 128.
 - iii. Multiply the number of small initiators by 32.
 - iv. Add the two results together.
 - v. If the result is less than 2,048, set the queue depth for large hosts to 128 and the queue depth for small hosts to 32.
 - vi. If the result is still greater than 2,048 per port, reduce the queue depth per initiator until the total queue depth is less than or equal to 2,048.

To estimate the queue depth needed to achieve a certain I/O per second throughput, use this formula:

Needed queue depth = (Number of I/O per second) × (Response time)

For example, if you need 40,000 I/O per second with a response time of 3 milliseconds, the needed queue depth = $40,000 \times (.003) = 120$.

The maximum number of hosts that you can connect to a target port is 64, if you decide to limit the queue depth to the basic recommendation of 32. However, if you decide to have a queue depth of 128, then you can have a maximum of 16 hosts connected to one target port. The larger the queue depth, the fewer hosts that a single target port can support. If your requirement is such that you cannot compromise on the queue depth, then you should get more target ports.

The desired queue depth of 3,840 exceeds the available queue depth per port. You have 10 “large” hosts that have high storage I/O needs, and 20 “small” hosts that have low I/O needs. Set the initiator queue depth on the large hosts to 128 and the initiator queue depth on the small hosts to 32.

Your resulting total queue depth is $(10 \times 128) + (20 \times 32) = 1,920$.

You can spread the available queue depth equally across each initiator.

Your resulting queue depth per initiator is $2,048 \div 30 = 68$.

= Set queue depths on SAN hosts

:icons: font

:relative_path: ./san-config/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

You might need to change the queue depths on your host to achieve the maximum values for ITNs per node and FC port fan-in.

== AIX hosts

You can change the queue depth on AIX hosts using the `chdev` command. Changes made using the `chdev` command persist across reboots.

Examples:

- To change the queue depth for the `hdisk7` device, use the following command:

```
chdev -l hdisk7 -a queue_depth=32
```

- To change the queue depth for the `fcs0` HBA, use the following command:

```
chdev -l fcs0 -a num_cmd_elems=128
```

The default value for `num_cmd_elems` is 200. The maximum value is 2,048.

It might be necessary to take the HBA offline to change `num_cmd_elems` and then bring it back online using the `rmdev -l fcs0 -R` and `makdev -l fcs0 -P` commands.

== HP-UX hosts

You can change the LUN or device queue depth on HP-UX hosts using the kernel parameter `scsi_max_qdepth`. You can change the HBA queue depth using the kernel parameter `max_fcp_reqs`.

- The default value for `scsi_max_qdepth` is 8. The maximum value is 255.

`scsi_max_qdepth` can be dynamically changed on a running system using the `-u` option on the `kmtune` command. The change will be effective for all devices on the system. For example, use the following command to increase the LUN queue depth to 64:

```
kmtune -u -s scsi_max_qdepth=64
```

It is possible to change queue depth for individual device files using the `scsictl` command. Changes using the `scsictl` command are not persistent across system reboots. To view and change the queue depth for a particular device file, execute the following command:

```
scsictl -a /dev/rdisk/c2t2d0
```

```
scsictl -m queue_depth=16 /dev/rdisk/c2t2d0
```

- The default value for `max_fcp_reqs` is 512. The maximum value is 1024.

The kernel must be rebuilt and the system must be rebooted for changes to `max_fcp_reqs` to take effect. To change the HBA queue depth to 256, for example, use the following command:

```
kmtune -u -s max_fcp_reqs=256
```

== Solaris hosts

You can set the LUN and HBA queue depth for your Solaris hosts.

- For LUN queue depth: The number of LUNs in use on a host multiplied by the per-LUN throttle (lun-queue-depth) must be less than or equal to the `tgt-queue-depth` value on the host.
- For queue depth in a Sun stack: The native drivers do not allow for per LUN or per target `max_throttle` settings at the HBA level. The recommended method for setting the `max_throttle` value for native drivers is on a per-device type (VID_PID) level in the `/kernel/drv/sd.conf` and `/kernel/drv/ssd.conf` files. The host utility sets this value to 64 for MPxIO configurations and 8 for Veritas DMP configurations.

Steps

1. # `cd/kernel/drv`
2. # `vi lpfc.conf`
3. Search for `/tft-queue (/tgt-queue)`

```
tgt-queue-depth=32
```

The default value is set to 32 at installation.

1. Set the desired value based on the configuration of your environment.
2. Save the file.
3. Reboot the host using the `sync; sync; sync; reboot -- -r` command.

== VMware hosts for a QLogic HBA

Use the `esxcfg-module` command to change the HBA timeout settings. Manually updating the `esx.conf` file is not recommended.

Steps

1. Log on to the service console as the root user.
2. Use the `#vmkload_mod -l` command to verify which QLogic HBA module is currently loaded.
3. For a single instance of a QLogic HBA, run the following command:

```
#esxcfg-module -s ql2xmaxqdepth=64 qla2300_707
```

This example uses `qla2300_707` module. Use the appropriate module based on the output of `vmkload_mod -l`.

1. Save your changes using the following command:

```
#!/usr/sbin/esxcfg-boot -b
```

2. Reboot the server using the following command:

```
#reboot
```

3. Confirm the changes using the following commands:

a. `#esxcfg-module -g qla2300_707`

b. `qla2300_707 enabled = 1 options = 'ql2xmaxqdepth=64'`

== VMware hosts for an Emulex HBA

Use the `esxcfg-module` command to change the HBA timeout settings. Manually updating the `esx.conf` file is not recommended.

Steps

1. Log on to the service console as the root user.
2. Use the `#vmkload_mod -l grep lpfc` command to verify which Emulex HBA is currently loaded.
3. For a single instance of an Emulex HBA, enter the following command:

```
#esxcfg-module -s lpfc0_lun_queue_depth=16 lpfcdd_7xx
```

Depending on the model of the HBA, the module can be either `lpfcdd_7xx` or `lpfcdd_732`. The above command

uses the `lpfcdd_7xx` module. You should use the appropriate module based on the outcome of `vmkload_mod -l`.

+

Running this command will set the LUN queue depth to 16 for the HBA represented by `lpfc0`.

1. For multiple instances of an Emulex HBA, run the following command:

```
a esxcfg-module -s "lpfc0_lun_queue_depth=16 lpfc1_lun_queue_depth=16"
lpfcdd_7xx
```

The LUN queue depth for `lpfc0` and the LUN queue depth for `lpfc1` is set to 16.

2. Enter the following command:

```
#esxcfg-boot -b
```

3. Reboot using `#reboot`.

== Windows hosts for an Emulex HBA

On Windows hosts, you can use the `LPUTILNT` utility to update the queue depth for Emulex HBAs.

Steps

1. Run the `LPUTILNT` utility located in the `C:\WINNT\system32` directory.
2. Select **Drive Parameters** from the menu on the right side.
3. Scroll down and double-click **QueueDepth**.

If you are setting **QueueDepth** greater than 150, the following Windows Registry value also need to be increased appropriately:

```
HKEY_LOCAL_MACHINE\System\CurrentControlSet\Services\lpxnds\Parameters\Device\NumberOfRequests
```

== Windows hosts for a Qlogic HBA

On Windows hosts, you can use the `and` and the `SANsurfer` HBA manager utility to update the queue depths for Qlogic HBAs.

Steps

1. Run the `SANsurfer` HBA manager utility.
2. Click on **HBA port > Settings**.
3. Click **Advanced HBA port settings** in the list box.
4. Update the `Execution Throttle` parameter.

== Linux hosts for Emulex HBA

You can update the queue depths of an Emulex HBA on a Linux host. To make the updates persistent across reboots, you must then create a new RAM disk image and reboot the host.

Steps

1. Identify the queue depth parameters to be modified:

```
modinfo lpfc|grep queue_depth
```

The list of queue depth parameters with their description is displayed. Depending on your operating system version, you can modify one or more of the following queue depth parameters:

- `lpfc_lun_queue_depth`: Maximum number of FC commands that can be queued to a specific LUN (uint)
- `lpfc_hba_queue_depth`: Maximum number of FC commands that can be queued to an lpfc HBA (uint)
- `lpfc_tgt_queue_depth`: Maximum number of FC commands that can be queued to a specific target port (uint)

The `lpfc_tgt_queue_depth` parameter is applicable only for Red Hat Enterprise Linux 7.x systems, SUSE Linux Enterprise Server 11 SP4 systems and 12.x systems.

2. Update the queue depths by adding the queue depth parameters to the `/etc/modprobe.conf` file for a Red Hat Enterprise Linux 5.x system and to the `/etc/modprobe.d/scsi.conf` file for a Red Hat Enterprise Linux 6.x or 7.x system, or a SUSE Linux Enterprise Server 11.x or 12.x system.

Depending on your operating system version, you can add one or more of the following commands:

- `options lpfc lpfc_hba_queue_depth=new_queue_depth`
- `options lpfc lpfc_lun_queue_depth=new_queue_depth`
- `options lpfc lpfc_tgt_queue_depth=new_queue_depth`

3. Create a new RAM disk image, and then reboot the host to make the updates persistent across reboots.

For more information, see the [System administration](#) for your version of Linux operating system.

4. Verify that the queue depth values are updated for each of the queue depth parameter that you have modified:

```
cat /sys/class/scsi_host/host_number/lpfc_lun_queue_depthcat
/sys/class/scsi_host/host_number/lpfc_tgt_queue_depthcat
/sys/class/scsi_host/host_number/lpfc_hba_queue_depth
```

```
root@localhost ~]#cat
/sys/class/scsi_host/host5/lpfc_lun_queue_depth
30
```

The current value of the queue depth is displayed.

== Linux hosts for QLogic HBA

You can update the device queue depth of a QLogic driver on a Linux host. To make the updates persistent across reboots, you must then create a new RAM disk image and reboot the host. You can use the QLogic HBA management GUI or command-line interface (CLI) to modify the QLogic HBA queue depth.

This task shows how to use the QLogic HBA CLI to modify the QLogic HBA queue depth

Steps

1. Identify the device queue depth parameter to be modified:

```
modinfo qla2xxx | grep ql2xmaxqdepth
```

You can modify only the `ql2xmaxqdepth` queue depth parameter, which denotes the maximum queue depth that can be set for each LUN. The default value is 64 for RHEL 7.5 and later. The default value is 32 for RHEL 7.4 and earlier.

```
root@localhost ~]# modinfo qla2xxx|grep ql2xmaxqdepth
parm:          ql2xmaxqdepth:Maximum queue depth to set for each LUN.
Default is 64. (int)
```

2. Update the device queue depth value:

- If you want to make the modifications persistent, perform the following steps:
 - i. Update the queue depths by adding the queue depth parameter to the `/etc/modprobe.conf` file for a Red Hat Enterprise Linux 5.x system and to the `/etc/modprobe.d/scsi.conf` file for a Red Hat Enterprise Linux 6.x or 7.x system, or a SUSE Linux Enterprise Server 11.x or 12.x system: `options qla2xxx ql2xmaxqdepth=new_queue_depth`
 - ii. Create a new RAM disk image, and then reboot the host to make the updates persistent across reboots.

For more information, see the [System administration](#) for your version of Linux operating system.

- If you want to modify the parameter only for the current session, run the following command:

```
echo new_queue_depth > /sys/module/qla2xxx/parameters/ql2xmaxqdepth
```

In the following example, the queue depth is set to 128.

```
echo 128 > /sys/module/qla2xxx/parameters/ql2xmaxqdepth
```

3. Verify that the queue depth values are updated:

```
cat /sys/module/qla2xxx/parameters/ql2xmaxqdepth
```

The current value of the queue depth is displayed.

4. Modify the QLogic HBA queue depth by updating the firmware parameter `Execution Throttle` from the QLogic HBA BIOS.

- a. Log in to the QLogic HBA management CLI:

```
/opt/QLogic_Corporation/QConvergeConsoleCLI/qauccli
```

- b. From the main menu, select the `Adapter Configuration` option.


```

[root@localhost ~]#
/opt/QLogic_Corporation/QConvergeConsoleCLI/qauccli
Using config file:
/opt/QLogic_Corporation/QConvergeConsoleCLI/qauccli.cfg
Installation directory:
/opt/QLogic_Corporation/QConvergeConsoleCLI
Working dir: /root

QConvergeConsole

          CLI - Version 2.2.0 (Build 15)

Main Menu

1:  Adapter Information
**2: Adapter Configuration**
3:  Adapter Updates
4:  Adapter Diagnostics
5:  Monitoring
6:  FabricCache CLI
7:  Refresh
8:  Help
9:  Exit

Please Enter Selection: 2

```

c. From the list of adapter configuration parameters, select the HBA Parameters option.

```

1:  Adapter Alias
2:  Adapter Port Alias
**3: HBA Parameters**
4:  Persistent Names (udev)
5:  Boot Devices Configuration
6:  Virtual Ports (NPIV)
7:  Target Link Speed (iidMA)
8:  Export (Save) Configuration
9:  Generate Reports
10: Personality
11: FEC
(p or 0: Previous Menu; m or 98: Main Menu; ex or 99: Quit)
Please Enter Selection: 3

```

d. From the list of HBA ports, select the required HBA port.

Fibre Channel Adapter Configuration

```
HBA Model QLE2562 SN: BFD1524C78510
  1: Port    1: WWPN: 21-00-00-24-FF-8D-98-E0 Online
  2: Port    2: WWPN: 21-00-00-24-FF-8D-98-E1 Online
HBA Model QLE2672 SN: RFE1241G81915
  3: Port    1: WWPN: 21-00-00-0E-1E-09-B7-62 Online
  4: Port    2: WWPN: 21-00-00-0E-1E-09-B7-63 Online
```

(p or 0: Previous Menu; m or 98: Main Menu; ex or 99: Quit)

Please Enter Selection: 1

The details of the HBA port are displayed.

- e. From the HBA Parameters menu, select the Display HBA Parameters option to view the current value of the Execution Throttle option.

The default value of the Execution Throttle option is 65535.

HBA Parameters Menu

```
=====
HBA          : 2 Port: 1
SN           : BFD1524C78510
HBA Model    : QLE2562
HBA Desc.    : QLE2562 PCI Express to 8Gb FC Dual Channel
FW Version   : 8.01.02
WWPN         : 21-00-00-24-FF-8D-98-E0
WWNN         : 20-00-00-24-FF-8D-98-E0
Link         : Online
=====
```

- 1: Display HBA Parameters
- 2: Configure HBA Parameters
- 3: Restore Defaults

(p or 0: Previous Menu; m or 98: Main Menu; x or 99: Quit)

Please Enter Selection: 1

HBA Instance 2: QLE2562 Port 1 WWPN 21-00-00-24-FF-8D-98-E0

PortID 03-07-00

Link: Online

```
-----
-----
Connection Options           : 2 - Loop Preferred, Otherwise
Point-to-Point
Data Rate                   : Auto
Frame Size                  : 2048
Hard Loop ID                : 0
Loop Reset Delay (seconds)  : 5
Enable Host HBA BIOS        : Enabled
Enable Hard Loop ID         : Disabled
Enable FC Tape Support      : Enabled
Operation Mode              : 0 - Interrupt for every I/O
completion
Interrupt Delay Timer (100us) : 0
**Execution Throttle        : 65535**
Login Retry Count           : 8
Port Down Retry Count       : 30
Enable LIP Full Login       : Enabled
Link Down Timeout (seconds) : 30
Enable Target Reset         : Enabled
LUNs Per Target             : 128
Out Of Order Frame Assembly : Disabled
Enable LR Ext. Credits      : Disabled
Enable Fabric Assigned WWN  : N/A
```

Press <Enter> to continue:

- f. Press **Enter** to continue.
- g. From the HBA Parameters menu, select the **Configure HBA Parameters** option to modify the HBA parameters.
- h. From the **Configure Parameters** menu, select the **Execute Throttle** option and update the value of this parameter.

Configure Parameters Menu

```
=====
HBA          : 2 Port: 1
SN           : BFD1524C78510
HBA Model    : QLE2562
HBA Desc.    : QLE2562 PCI Express to 8Gb FC Dual Channel
FW Version   : 8.01.02
WWPN         : 21-00-00-24-FF-8D-98-E0
WWNN         : 20-00-00-24-FF-8D-98-E0
Link         : Online
=====

1: Connection Options
2: Data Rate
3: Frame Size
4: Enable HBA Hard Loop ID
5: Hard Loop ID
6: Loop Reset Delay (seconds)
7: Enable BIOS
8: Enable Fibre Channel Tape Support
9: Operation Mode
10: Interrupt Delay Timer (100 microseconds)
11: Execution Throttle
12: Login Retry Count
13: Port Down Retry Count
14: Enable LIP Full Login
15: Link Down Timeout (seconds)
16: Enable Target Reset
17: LUNs per Target
18: Enable Receive Out Of Order Frame
19: Enable LR Ext. Credits
20: Commit Changes
21: Abort Changes

      (p or 0: Previous Menu; m or 98: Main Menu; x or 99:
Quit)

      Please Enter Selection: 11
Enter Execution Throttle [1-65535] [65535]: 65500
```

i. Press **Enter** to continue.

j. From the Configure Parameters menu, select the `Commit Changes` option to save the changes.

k. Exit the menu.

= Considerations for SAN configurations in a MetroCluster environment

:icons: font

:relative_path: ./san-config/

:imagesdir: /tmp/d20230404-16473-bmofzo/source/./san-admin/./media/

- MetroCluster configurations do not support front-end FC fabric “routed” vSAN configurations.
- Beginning with ONTAP 9.12.1, four-node MetroCluster IP configurations are supported on NVMe/FC. MetroCluster configurations are not supported for NVMe prior to ONTAP 9.12.1.
- Other SAN protocols such as iSCSI, FC, and FCoE are supported on MetroCluster configurations.
- When using SAN client configurations, you must check whether any special considerations for MetroCluster configurations are included in the notes that are provided in the [NetApp Interoperability Matrix Tool](#) (IMT).
- Operating systems and applications must provide an I/O resiliency of 120 seconds to support MetroCluster automatic unplanned switchover and Tiebreaker or Mediator-initiated switchover.
- The MetroCluster is using the same WWPNs on both sides of the front-end SAN.

Related information

[Understanding MetroCluster data protection and disaster recovery](#)

For further MetroCluster-specific host information, refer to the following NetApp Knowledge Base articles:

[What are AIX Host support considerations in a MetroCluster configuration?](#)

[Solaris host support considerations in a MetroCluster configuration](#)

Copyright information

Copyright © 2023 NetApp, Inc. All Rights Reserved. Printed in the U.S. No part of this document covered by copyright may be reproduced in any form or by any means—graphic, electronic, or mechanical, including photocopying, recording, taping, or storage in an electronic retrieval system—without prior written permission of the copyright owner.

Software derived from copyrighted NetApp material is subject to the following license and disclaimer:

THIS SOFTWARE IS PROVIDED BY NETAPP “AS IS” AND WITHOUT ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE, WHICH ARE HEREBY DISCLAIMED. IN NO EVENT SHALL NETAPP BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.

NetApp reserves the right to change any products described herein at any time, and without notice. NetApp assumes no responsibility or liability arising from the use of products described herein, except as expressly agreed to in writing by NetApp. The use or purchase of this product does not convey a license under any patent rights, trademark rights, or any other intellectual property rights of NetApp.

The product described in this manual may be protected by one or more U.S. patents, foreign patents, or pending applications.

LIMITED RIGHTS LEGEND: Use, duplication, or disclosure by the government is subject to restrictions as set forth in subparagraph (b)(3) of the Rights in Technical Data -Noncommercial Items at DFARS 252.227-7013 (FEB 2014) and FAR 52.227-19 (DEC 2007).

Data contained herein pertains to a commercial product and/or commercial service (as defined in FAR 2.101) and is proprietary to NetApp, Inc. All NetApp technical data and computer software provided under this Agreement is commercial in nature and developed solely at private expense. The U.S. Government has a non-exclusive, non-transferrable, nonsublicensable, worldwide, limited irrevocable license to use the Data only in connection with and in support of the U.S. Government contract under which the Data was delivered. Except as provided herein, the Data may not be used, disclosed, reproduced, modified, performed, or displayed without the prior written approval of NetApp, Inc. United States Government license rights for the Department of Defense are limited to those rights identified in DFARS clause 252.227-7015(b) (FEB 2014).

Trademark information

NETAPP, the NETAPP logo, and the marks listed at <http://www.netapp.com/TM> are trademarks of NetApp, Inc. Other company and product names may be trademarks of their respective owners.