



# **RHEL**

## **ONTAP SAN Host Utilities**

NetApp  
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# RHEL

## RHEL 10

### Configure RHEL 10 for FCP and iSCSI with ONTAP storage

The Linux Host Utilities software provides management and diagnostic tools for Linux hosts that are connected to ONTAP storage. When you install the Linux Host Utilities on a Red Hat Enterprise Linux (RHEL) 10 host, you can use the Host Utilities to help you manage FCP and iSCSI protocol operations with ONTAP LUNs.



You don't need to manually configure Kernel-based Virtual Machine (KVM) settings because ONTAP LUNs are automatically mapped to the hypervisor.

#### Step 1: Optionally, enable SAN booting

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

##### Before you begin

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

##### Steps

1. [Create a SAN boot LUN and map it to the host.](#)
2. Enable SAN booting in the server BIOS for the ports to which the SAN boot LUN is mapped.

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

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

#### Step 2: Install the Linux Host Utilities

NetApp strongly recommends installing the Linux Host Utilities to support ONTAP LUN management and assist technical support with gathering configuration data.

[Install Linux Host Utilities 8.0.](#)



Installing the Linux Host Utilities doesn't change any host timeout settings on your Linux host.

#### Step 3: Confirm the multipath configuration for your host

You can use multipathing with RHEL 10 to manage ONTAP LUNs.

To ensure that multipathing is configured correctly for your host, verify that the `/etc/multipath.conf` file is defined and that you have the NetApp recommended settings configured for your ONTAP LUNs.

##### Steps

1. Verify that the `/etc/multipath.conf` file exists. If the file doesn't exist, create an empty, zero-byte file:

```
touch /etc/multipath.conf
```

2. The first time the `multipath.conf` file is created, you might need to enable and start the multipath services to load the recommended settings:

```
systemctl enable multipathd
```

```
systemctl start multipathd
```

3. Each time you boot the host, the empty `/etc/multipath.conf` zero-byte file automatically loads the NetApp recommended host multipath parameters as the default settings. You shouldn't need to make changes to the `/etc/multipath.conf` file for your host because the operating system is compiled with the multipath parameters that recognize and manage ONTAP LUNs correctly.

The following table shows the Linux OS native compiled multipath parameter settings for ONTAP LUNs.

#### Show parameter settings

Parameter	Setting
detect_prio	yes
dev_loss_tmo	"infinity"
failback	immediate
fast_io_fail_tmo	5
features	"2 pg_init_retries 50"
flush_on_last_del	"yes"
hardware_handler	"0"
no_path_retry	queue
path_checker	"tur"
path_grouping_policy	"group_by_prio"
path_selector	"service-time 0"
polling_interval	5
prio	"ontap"
product	LUN
retain_attached_hw_handler	yes
rr_weight	"uniform"
user_friendly_names	no
vendor	NETAPP

#### 4. Verify the parameter settings and path status for your ONTAP LUNs:

```
multipath -ll
```

The default multipath parameters support ASA, AFF, and FAS configurations. In these configurations, a single ONTAP LUN shouldn't require more than four paths. If there are more than four paths, it might cause issues with the paths during a storage failure.

The following example outputs show the correct parameter settings and path status for ONTAP LUNs in an ASA, AFF, or FAS configuration.

##### ASA configuration

An ASA configuration optimizes all paths to a given LUN, keeping them active. This improves performance by serving I/O operations through all paths at the same time.

```
# multipath -ll
3600a098038314e535a24584e4b496252 dm-32 NETAPP,LUN C-Mode
size=10G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
`-+- policy='service-time 0' prio=50 status=active
  |- 11:0:0:41 sdan 66:112 active ready running
  |- 11:0:1:41 sdcg 68:240 active ready running
  |- 14:0:2:41 sdfd 129:240 active ready running
  `-- 14:0:0:41 sddp 71:112 active ready running
```

##### AFF or FAS configuration

An AFF or FAS configuration should have two groups of paths with higher and lower priorities. Higher priority Active/Optimized paths are served by the controller where the aggregate is located. Lower priority paths are active but non-optimized because they are served by a different controller. Non-optimized paths are only used when optimized paths aren't available.

The following example displays the output for an ONTAP LUN with two Active/Optimized paths and two Active/Non-Optimized paths:

```
# multipath -ll
3600a0980383149764b5d567257516273 dm-0 NETAPP,LUN C-Mode
size=150G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
|-+- policy='service-time 0' prio=50 status=active
| |- 16:0:3:0 sdcg 69:64 active ready running
| `-- 10:0:0:0 sdb 8:16 active ready running
`-+- policy='service-time 0' prio=10 status=enabled
  |- 10:0:1:0 sdc 8:32 active ready running
  `-- 16:0:2:0 sdcf 69:48 active ready running
```

## Step 4: Optionally, exclude a device from multipathing

If required, you can exclude a device from multipathing by adding the WWID for the unwanted device to the "blacklist" stanza for the `multipath.conf` file.

### Steps

1. Determine the WWID:

```
/lib/udev/scsi_id -gud /dev/sda
```

"sda" is the local SCSI disk that you want to add to the blacklist.

An example WWID is 360030057024d0730239134810c0cb833.

2. Add the WWID to the "blacklist" stanza:

```
blacklist {
    wwid      360030057024d0730239134810c0cb833
    devnode   "^(ram|raw|loop|fd|md|dm-|sr|scd|st)[0-9]*"
    devnode   "^hd[a-z]"
    devnode   "^cciss.*"
}
```

## Step 5: Customize multipath parameters for ONTAP LUNs

If your host is connected to LUNs from other vendors and any of the multipath parameter settings are overridden, you need to correct them by adding stanzas later in the `multipath.conf` file that apply specifically to ONTAP LUNs. If you don't do this, the ONTAP LUNs might not work as expected.

Check your `/etc/multipath.conf` file, especially in the defaults section, for settings that might be overriding the [default settings for multipath parameters](#).



You shouldn't override the recommended parameter settings for ONTAP LUNs. These settings are required for optimal performance of your host configuration. Contact NetApp support, your OS vendor, or both for more information.

The following example shows how to correct an overridden default. In this example, the `multipath.conf` file defines values for `path_checker` and `no_path_retry` that aren't compatible with ONTAP LUNs, and you can't remove these parameters because ONTAP storage arrays are still attached to the host. Instead, you correct the values for `path_checker` and `no_path_retry` by adding a device stanza to the `multipath.conf` file that applies specifically to the ONTAP LUNs.

### Show example

```
defaults {
    path_checker      readsector0
    no_path_retry     fail
}

devices {
    device {
        vendor        "NETAPP"
        product        "LUN"
        no_path_retry  queue
        path_checker   tur
    }
}
```

### Step 6: Review the known issues

There are no known issues.

### What's next?

- [Learn about using the Linux Host Utilities tool.](#)
- Learn about ASM mirroring.

Automatic Storage Management (ASM) mirroring might require changes to the Linux multipath settings to allow ASM to recognize a problem and switch over to an alternate failure group. Most ASM configurations on ONTAP use external redundancy, which means that data protection is provided by the external array and ASM doesn't mirror data. Some sites use ASM with normal redundancy to provide two-way mirroring, normally across different sites. See [Oracle databases on ONTAP](#) for further information.

## RHEL 9

### Configure RHEL 9.6 for FCP and iSCSI with ONTAP storage

The Linux Host Utilities software provides management and diagnostic tools for Linux hosts that are connected to ONTAP storage. When you install the Linux Host Utilities on a Red Hat Enterprise Linux (RHEL) 9.6 host, you can use the Host Utilities to help you manage FCP and iSCSI protocol operations with ONTAP LUNs.



You don't need to manually configure Kernel-based Virtual Machine (KVM) settings because ONTAP LUNs are automatically mapped to the hypervisor.

## Step 1: Optionally, enable SAN booting

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

### Before you begin

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

### Steps

1. [Create a SAN boot LUN and map it to the host.](#)
2. Enable SAN booting in the server BIOS for the ports to which the SAN boot LUN is mapped.

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

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

## Step 2: Install the Linux Host Utilities

NetApp strongly recommends installing the Linux Host Utilities to support ONTAP LUN management and assist technical support with gathering configuration data.

[Install Linux Host Utilities 8.0.](#)



Installing the Linux Host Utilities doesn't change any host timeout settings on your Linux host.

## Step 3: Confirm the multipath configuration for your host

You can use multipathing with RHEL 9.6 to manage ONTAP LUNs.

To ensure that multipathing is configured correctly for your host, verify that the `/etc/multipath.conf` file is defined and that you have the NetApp recommended settings configured for your ONTAP LUNs.

### Steps

1. Verify that the `/etc/multipath.conf` file exists. If the file doesn't exist, create an empty, zero-byte file:

```
touch /etc/multipath.conf
```

2. The first time the `multipath.conf` file is created, you might need to enable and start the multipath services to load the recommended settings:

```
systemctl enable multipathd
```

```
systemctl start multipathd
```

3. Each time you boot the host, the empty `/etc/multipath.conf` zero-byte file automatically loads the NetApp recommended host multipath parameters as the default settings. You shouldn't need to make



changes to the `/etc/multipath.conf` file for your host because the operating system is compiled with the multipath parameters that recognize and manage ONTAP LUNs correctly.

The following table shows the Linux OS native compiled multipath parameter settings for ONTAP LUNs.

#### Show parameter settings

Parameter	Setting
detect_prio	yes
dev_loss_tmo	"infinity"
failback	immediate
fast_io_fail_tmo	5
features	"2 pg_init_retries 50"
flush_on_last_del	"yes"
hardware_handler	"0"
no_path_retry	queue
path_checker	"tur"
path_grouping_policy	"group_by_prio"
path_selector	"service-time 0"
polling_interval	5
prio	"ontap"
product	LUN
retain_attached_hw_handler	yes
rr_weight	"uniform"
user_friendly_names	no
vendor	NETAPP

4. Verify the parameter settings and path status for your ONTAP LUNs:

```
multipath -ll
```

The default multipath parameters support ASA, AFF, and FAS configurations. In these configurations, a single ONTAP LUN shouldn't require more than four paths. If there are more than four paths, it might cause issues with the paths during a storage failure.

The following example outputs show the correct parameter settings and path status for ONTAP LUNs in an ASA, AFF, or FAS configuration.

## ASA configuration

An ASA configuration optimizes all paths to a given LUN, keeping them active. This improves performance by serving I/O operations through all paths at the same time.

### Show example

```
multipath -ll
3600a098038314c4a433f577471797958 dm-2 NETAPP,LUN C-Mode
size=180G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
`-+- policy='service-time 0' prio=50 status=active
| - 14:0:0:0 sdc 8:32 active ready running
| - 17:0:0:0 sdas 66:192 active ready running
| - 14:0:3:0 sdar 66:176 active ready running
`- 17:0:3:0 sdch 69:80 active ready running
```

## AFF or FAS configuration

An AFF or FAS configuration should have two groups of paths with higher and lower priorities. Higher priority Active/Optimized paths are served by the controller where the aggregate is located. Lower priority paths are active but non-optimized because they are served by a different controller. Non-optimized paths are only used when optimized paths aren't available.

The following example displays the output for an ONTAP LUN with two Active/Optimized paths and two Active/Non-Optimized paths:

### Show example

```
multipath -ll
3600a0980383149764b5d567257516273 dm-0 NETAPP,LUN C-Mode
size=150G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
|+- policy='service-time 0' prio=50 status=active
| | - 16:0:3:0 sdcg 69:64 active ready running
| ` - 10:0:0:0 sdb 8:16 active ready running
`+- policy='service-time 0' prio=10 status=enabled
| - 10:0:1:0 sdc 8:32 active ready running
`- 16:0:2:0 sdcf 69:48 active ready running
```

## Step 4: Optionally, exclude a device from multipathing

If required, you can exclude a device from multipathing by adding the WWID for the unwanted device to the "blacklist" stanza for the `multipath.conf` file.

## Steps

1. Determine the WWID:

```
/lib/udev/scsi_id -gud /dev/sda
```

"sda" is the local SCSI disk that you want to add to the blacklist.

An example WWID is 360030057024d0730239134810c0cb833.

2. Add the WWID to the "blacklist" stanza:

```
blacklist {  
    wwid      360030057024d0730239134810c0cb833  
    devnode   "^(ram|raw|loop|fd|md|dm-|sr|scd|st)[0-9]*"  
    devnode   "^hd[a-z]"  
    devnode   "^cciss.*"  
}
```

## Step 5: Customize multipath parameters for ONTAP LUNs

If your host is connected to LUNs from other vendors and any of the multipath parameter settings are overridden, you need to correct them by adding stanzas later in the `multipath.conf` file that apply specifically to ONTAP LUNs. If you don't do this, the ONTAP LUNs might not work as expected.

Check your `/etc/multipath.conf` file, especially in the defaults section, for settings that might be overriding the [default settings for multipath parameters](#).



You shouldn't override the recommended parameter settings for ONTAP LUNs. These settings are required for optimal performance of your host configuration. Contact NetApp support, your OS vendor, or both for more information.

The following example shows how to correct an overridden default. In this example, the `multipath.conf` file defines values for `path_checker` and `no_path_retry` that aren't compatible with ONTAP LUNs, and you can't remove these parameters because ONTAP storage arrays are still attached to the host. Instead, you correct the values for `path_checker` and `no_path_retry` by adding a device stanza to the `multipath.conf` file that applies specifically to the ONTAP LUNs.

## Show example

```
defaults {
    path_checker      readsector0
    no_path_retry     fail
}

devices {
    device {
        vendor        "NETAPP"
        product        "LUN"
        no_path_retry  queue
        path_checker   tur
    }
}
```

### Step 6: Review the known issues

There are no known issues.

### What's next?

- [Learn about using the Linux Host Utilities tool.](#)
- Learn about ASM mirroring.

Automatic Storage Management (ASM) mirroring might require changes to the Linux multipath settings to allow ASM to recognize a problem and switch over to an alternate failure group. Most ASM configurations on ONTAP use external redundancy, which means that data protection is provided by the external array and ASM doesn't mirror data. Some sites use ASM with normal redundancy to provide two-way mirroring, normally across different sites. See [Oracle databases on ONTAP](#) for further information.

## Configure RHEL 9.5 for FCP and iSCSI with ONTAP storage

The Linux Host Utilities software provides management and diagnostic tools for Linux hosts that are connected to ONTAP storage. When you install the Linux Host Utilities on a Red Hat Enterprise Linux (RHEL) 9.5 host, you can use the Host Utilities to help you manage FCP and iSCSI protocol operations with ONTAP LUNs.



You don't need to manually configure Kernel-based Virtual Machine (KVM) settings because ONTAP LUNs are automatically mapped to the hypervisor.

### Step 1: Optionally, enable SAN booting

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

### Before you begin

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

### Steps

1. [Create a SAN boot LUN and map it to the host.](#)
2. Enable SAN booting in the server BIOS for the ports to which the SAN boot LUN is mapped.

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

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

## Step 2: Install the Linux Host Utilities

NetApp strongly recommends installing the Linux Host Utilities to support ONTAP LUN management and assist technical support with gathering configuration data.

[Install Linux Host Utilities 8.0.](#)



Installing the Linux Host Utilities doesn't change any host timeout settings on your Linux host.

## Step 3: Confirm the multipath configuration for your host

You can use multipathing with RHEL 9.5 to manage ONTAP LUNs.

To ensure that multipathing is configured correctly for your host, verify that the `/etc/multipath.conf` file is defined and that you have the NetApp recommended settings configured for your ONTAP LUNs.

### Steps

1. Verify that the `/etc/multipath.conf` file exists. If the file doesn't exist, create an empty, zero-byte file:

```
touch /etc/multipath.conf
```

2. The first time the `multipath.conf` file is created, you might need to enable and start the multipath services to load the recommended settings:

```
systemctl enable multipathd
```

```
systemctl start multipathd
```

3. Each time you boot the host, the empty `/etc/multipath.conf` zero-byte file automatically loads the NetApp recommended host multipath parameters as the default settings. You shouldn't need to make changes to the `/etc/multipath.conf` file for your host because the operating system is compiled with the multipath parameters that recognize and manage ONTAP LUNs correctly.

The following table shows the Linux OS native compiled multipath parameter settings for ONTAP LUNs.

### Show parameter settings

Parameter	Setting
detect_prio	yes
dev_loss_tmo	"infinity"
failback	immediate
fast_io_fail_tmo	5
features	"2 pg_init_retries 50"
flush_on_last_del	"yes"
hardware_handler	"0"
no_path_retry	queue
path_checker	"tur"
path_grouping_policy	"group_by_prio"
path_selector	"service-time 0"
polling_interval	5
prio	"ontap"
product	LUN
retain_attached_hw_handler	yes
rr_weight	"uniform"
user_friendly_names	no
vendor	NETAPP

#### 4. Verify the parameter settings and path status for your ONTAP LUNs:

```
multipath -ll
```

The default multipath parameters support ASA, AFF, and FAS configurations. In these configurations, a single ONTAP LUN shouldn't require more than four paths. If there are more than four paths, it might cause issues with the paths during a storage failure.

The following example outputs show the correct parameter settings and path status for ONTAP LUNs in an ASA, AFF, or FAS configuration.

## ASA configuration

An ASA configuration optimizes all paths to a given LUN, keeping them active. This improves performance by serving I/O operations through all paths at the same time.

### Show example

```
multipath -ll
3600a098038314c4a433f577471797958 dm-2 NETAPP,LUN C-Mode
size=180G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
`-+- policy='service-time 0' prio=50 status=active
| - 14:0:0:0 sdc 8:32 active ready running
| - 17:0:0:0 sdas 66:192 active ready running
| - 14:0:3:0 sdar 66:176 active ready running
`- 17:0:3:0 sdch 69:80 active ready running
```

## AFF or FAS configuration

An AFF or FAS configuration should have two groups of paths with higher and lower priorities. Higher priority Active/Optimized paths are served by the controller where the aggregate is located. Lower priority paths are active but non-optimized because they are served by a different controller. Non-optimized paths are only used when optimized paths aren't available.

The following example displays the output for an ONTAP LUN with two Active/Optimized paths and two Active/Non-Optimized paths:

### Show example

```
multipath -ll
3600a0980383149764b5d567257516273 dm-0 NETAPP,LUN C-Mode
size=150G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
| -+- policy='service-time 0' prio=50 status=active
| | - 16:0:3:0 sdcg 69:64 active ready running
| | ` - 10:0:0:0 sdb 8:16 active ready running
`-+- policy='service-time 0' prio=10 status=enabled
| - 10:0:1:0 sdc 8:32 active ready running
`- 16:0:2:0 sdcf 69:48 active ready running
```

## Step 4: Optionally, exclude a device from multipathing

If required, you can exclude a device from multipathing by adding the WWID for the unwanted device to the "blacklist" stanza for the `multipath.conf` file.

## Steps

1. Determine the WWID:

```
/lib/udev/scsi_id -gud /dev/sda
```

"sda" is the local SCSI disk that you want to add to the blacklist.

An example WWID is 360030057024d0730239134810c0cb833.

2. Add the WWID to the "blacklist" stanza:

```
blacklist {
    wwid      360030057024d0730239134810c0cb833
    devnode   "^(ram|raw|loop|fd|md|dm-|sr|scd|st)[0-9]*"
    devnode   "^hd[a-z]"
    devnode   "^cciss.*"
}
```

## Step 5: Customize multipath parameters for ONTAP LUNs

If your host is connected to LUNs from other vendors and any of the multipath parameter settings are overridden, you need to correct them by adding stanzas later in the `multipath.conf` file that apply specifically to ONTAP LUNs. If you don't do this, the ONTAP LUNs might not work as expected.

Check your `/etc/multipath.conf` file, especially in the defaults section, for settings that might be overriding the [default settings for multipath parameters](#).



You shouldn't override the recommended parameter settings for ONTAP LUNs. These settings are required for optimal performance of your host configuration. Contact NetApp support, your OS vendor, or both for more information.

The following example shows how to correct an overridden default. In this example, the `multipath.conf` file defines values for `path_checker` and `no_path_retry` that aren't compatible with ONTAP LUNs, and you can't remove these parameters because ONTAP storage arrays are still attached to the host. Instead, you correct the values for `path_checker` and `no_path_retry` by adding a device stanza to the `multipath.conf` file that applies specifically to the ONTAP LUNs.



## Show example

```
defaults {
    path_checker      readsector0
    no_path_retry     fail
}

devices {
    device {
        vendor        "NETAPP"
        product        "LUN"
        no_path_retry  queue
        path_checker   tur
    }
}
```

### Step 6: Review the known issues

There are no known issues.

### What's next?

- [Learn about using the Linux Host Utilities tool.](#)
- Learn about ASM mirroring.

Automatic Storage Management (ASM) mirroring might require changes to the Linux multipath settings to allow ASM to recognize a problem and switch over to an alternate failure group. Most ASM configurations on ONTAP use external redundancy, which means that data protection is provided by the external array and ASM doesn't mirror data. Some sites use ASM with normal redundancy to provide two-way mirroring, normally across different sites. See [Oracle databases on ONTAP](#) for further information.

## Configure RHEL 9.4 for FCP and iSCSI with ONTAP storage

The Linux Host Utilities software provides management and diagnostic tools for Linux hosts that are connected to ONTAP storage. When you install the Linux Host Utilities on a Red Hat Enterprise Linux (RHEL) 9.4 host, you can use the Host Utilities to help you manage FCP and iSCSI protocol operations with ONTAP LUNs.



You don't need to manually configure Kernel-based Virtual Machine (KVM) settings because ONTAP LUNs are automatically mapped to the hypervisor.

### Step 1: Optionally, enable SAN booting

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

### Before you begin

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

### Steps

1. [Create a SAN boot LUN and map it to the host.](#)
2. Enable SAN booting in the server BIOS for the ports to which the SAN boot LUN is mapped.

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

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

## Step 2: Install the Linux Host Utilities

NetApp strongly recommends installing the Linux Host Utilities to support ONTAP LUN management and assist technical support with gathering configuration data.

[Install Linux Host Utilities 8.0.](#)



Installing the Linux Host Utilities doesn't change any host timeout settings on your Linux host.

## Step 3: Confirm the multipath configuration for your host

You can use multipathing with RHEL 9.4 to manage ONTAP LUNs.

To ensure that multipathing is configured correctly for your host, verify that the `/etc/multipath.conf` file is defined and that you have the NetApp recommended settings configured for your ONTAP LUNs.

### Steps

1. Verify that the `/etc/multipath.conf` file exists. If the file doesn't exist, create an empty, zero-byte file:

```
touch /etc/multipath.conf
```

2. The first time the `multipath.conf` file is created, you might need to enable and start the multipath services to load the recommended settings:

```
systemctl enable multipathd
```

```
systemctl start multipathd
```

3. Each time you boot the host, the empty `/etc/multipath.conf` zero-byte file automatically loads the NetApp recommended host multipath parameters as the default settings. You shouldn't need to make changes to the `/etc/multipath.conf` file for your host because the operating system is compiled with the multipath parameters that recognize and manage ONTAP LUNs correctly.

The following table shows the Linux OS native compiled multipath parameter settings for ONTAP LUNs.

### Show parameter settings

Parameter	Setting
detect_prio	yes
dev_loss_tmo	"infinity"
failback	immediate
fast_io_fail_tmo	5
features	"2 pg_init_retries 50"
flush_on_last_del	"yes"
hardware_handler	"0"
no_path_retry	queue
path_checker	"tur"
path_grouping_policy	"group_by_prio"
path_selector	"service-time 0"
polling_interval	5
prio	"ontap"
product	LUN
retain_attached_hw_handler	yes
rr_weight	"uniform"
user_friendly_names	no
vendor	NETAPP

#### 4. Verify the parameter settings and path status for your ONTAP LUNs:

```
multipath -ll
```

The default multipath parameters support ASA, AFF, and FAS configurations. In these configurations, a single ONTAP LUN shouldn't require more than four paths. If there are more than four paths, it might cause issues with the paths during a storage failure.

The following example outputs show the correct parameter settings and path status for ONTAP LUNs in an ASA, AFF, or FAS configuration.

### ASA configuration

An ASA configuration optimizes all paths to a given LUN, keeping them active. This improves performance by serving I/O operations through all paths at the same time.

#### Show example

```
multipath -ll
3600a098038314c4a433f577471797958 dm-2 NETAPP,LUN C-Mode
size=180G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
`-+- policy='service-time 0' prio=50 status=active
| - 14:0:0:0 sdc 8:32 active ready running
| - 17:0:0:0 sdas 66:192 active ready running
| - 14:0:3:0 sdar 66:176 active ready running
`- 17:0:3:0 sdch 69:80 active ready running
```

### AFF or FAS configuration

An AFF or FAS configuration should have two groups of paths with higher and lower priorities. Higher priority Active/Optimized paths are served by the controller where the aggregate is located. Lower priority paths are active but non-optimized because they are served by a different controller. Non-optimized paths are only used when optimized paths aren't available.

The following example displays the output for an ONTAP LUN with two Active/Optimized paths and two Active/Non-Optimized paths:

#### Show example

```
multipath -ll
3600a0980383149764b5d567257516273 dm-0 NETAPP,LUN C-Mode
size=150G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
| -+- policy='service-time 0' prio=50 status=active
| | - 16:0:3:0 sdcg 69:64 active ready running
| | ` - 10:0:0:0 sdb 8:16 active ready running
`-+- policy='service-time 0' prio=10 status=enabled
| - 10:0:1:0 sdc 8:32 active ready running
`- 16:0:2:0 sdcf 69:48 active ready running
```

## Step 4: Optionally, exclude a device from multipathing

If required, you can exclude a device from multipathing by adding the WWID for the unwanted device to the "blacklist" stanza for the `multipath.conf` file.

## Steps

1. Determine the WWID:

```
/lib/udev/scsi_id -gud /dev/sda
```

"sda" is the local SCSI disk that you want to add to the blacklist.

An example WWID is 360030057024d0730239134810c0cb833.

2. Add the WWID to the "blacklist" stanza:

```
blacklist {
    wwid      360030057024d0730239134810c0cb833
    devnode   "^(ram|raw|loop|fd|md|dm-|sr|scd|st)[0-9]*"
    devnode   "^hd[a-z]"
    devnode   "^cciss.*"
}
```

## Step 5: Customize multipath parameters for ONTAP LUNs

If your host is connected to LUNs from other vendors and any of the multipath parameter settings are overridden, you need to correct them by adding stanzas later in the `multipath.conf` file that apply specifically to ONTAP LUNs. If you don't do this, the ONTAP LUNs might not work as expected.

Check your `/etc/multipath.conf` file, especially in the defaults section, for settings that might be overriding the [default settings for multipath parameters](#).



You shouldn't override the recommended parameter settings for ONTAP LUNs. These settings are required for optimal performance of your host configuration. Contact NetApp support, your OS vendor, or both for more information.

The following example shows how to correct an overridden default. In this example, the `multipath.conf` file defines values for `path_checker` and `no_path_retry` that aren't compatible with ONTAP LUNs, and you can't remove these parameters because ONTAP storage arrays are still attached to the host. Instead, you correct the values for `path_checker` and `no_path_retry` by adding a device stanza to the `multipath.conf` file that applies specifically to the ONTAP LUNs.

## Show example

```
defaults {
    path_checker      readsector0
    no_path_retry     fail
}

devices {
    device {
        vendor        "NETAPP"
        product        "LUN"
        no_path_retry  queue
        path_checker   tur
    }
}
```

### Step 6: Review the known issues

There are no known issues.

### What's next?

- [Learn about using the Linux Host Utilities tool.](#)
- Learn about ASM mirroring.

Automatic Storage Management (ASM) mirroring might require changes to the Linux multipath settings to allow ASM to recognize a problem and switch over to an alternate failure group. Most ASM configurations on ONTAP use external redundancy, which means that data protection is provided by the external array and ASM doesn't mirror data. Some sites use ASM with normal redundancy to provide two-way mirroring, normally across different sites. See [Oracle databases on ONTAP](#) for further information.

## Configure RHEL 9.3 for FCP and iSCSI with ONTAP storage

The Linux Host Utilities software provides management and diagnostic tools for Linux hosts that are connected to ONTAP storage. When you install the Linux Host Utilities on a Red Hat Enterprise Linux (RHEL) 9.3 host, you can use the Host Utilities to help you manage FCP and iSCSI protocol operations with ONTAP LUNs.



You don't need to manually configure Kernel-based Virtual Machine (KVM) settings because ONTAP LUNs are automatically mapped to the hypervisor.

### Step 1: Optionally, enable SAN booting

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

### Before you begin

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

### Steps

1. [Create a SAN boot LUN and map it to the host.](#)
2. Enable SAN booting in the server BIOS for the ports to which the SAN boot LUN is mapped.

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

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

## Step 2: Install the Linux Host Utilities

NetApp strongly recommends installing the Linux Host Utilities to support ONTAP LUN management and assist technical support with gathering configuration data.

[Install Linux Host Utilities 8.0.](#)



Installing the Linux Host Utilities doesn't change any host timeout settings on your Linux host.

## Step 3: Confirm the multipath configuration for your host

You can use multipathing with RHEL 9.3 to manage ONTAP LUNs.

To ensure that multipathing is configured correctly for your host, verify that the `/etc/multipath.conf` file is defined and that you have the NetApp recommended settings configured for your ONTAP LUNs.

### Steps

1. Verify that the `/etc/multipath.conf` file exists. If the file doesn't exist, create an empty, zero-byte file:

```
touch /etc/multipath.conf
```

2. The first time the `multipath.conf` file is created, you might need to enable and start the multipath services to load the recommended settings:

```
systemctl enable multipathd
```

```
systemctl start multipathd
```

3. Each time you boot the host, the empty `/etc/multipath.conf` zero-byte file automatically loads the NetApp recommended host multipath parameters as the default settings. You shouldn't need to make changes to the `/etc/multipath.conf` file for your host because the operating system is compiled with the multipath parameters that recognize and manage ONTAP LUNs correctly.

The following table shows the Linux OS native compiled multipath parameter settings for ONTAP LUNs.

## Show parameter settings

Parameter	Setting
detect_prio	yes
dev_loss_tmo	"infinity"
failback	immediate
fast_io_fail_tmo	5
features	"2 pg_init_retries 50"
flush_on_last_del	"yes"
hardware_handler	"0"
no_path_retry	queue
path_checker	"tur"
path_grouping_policy	"group_by_prio"
path_selector	"service-time 0"
polling_interval	5
prio	"ontap"
product	LUN
retain_attached_hw_handler	yes
rr_weight	"uniform"
user_friendly_names	no
vendor	NETAPP

### 4. Verify the parameter settings and path status for your ONTAP LUNs:

```
multipath -ll
```

The default multipath parameters support ASA, AFF, and FAS configurations. In these configurations, a single ONTAP LUN shouldn't require more than four paths. If there are more than four paths, it might cause issues with the paths during a storage failure.

The following example outputs show the correct parameter settings and path status for ONTAP LUNs in an ASA, AFF, or FAS configuration.



### ASA configuration

An ASA configuration optimizes all paths to a given LUN, keeping them active. This improves performance by serving I/O operations through all paths at the same time.

#### Show example

```
multipath -ll
3600a098038314c4a433f577471797958 dm-2 NETAPP,LUN C-Mode
size=180G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
`-+- policy='service-time 0' prio=50 status=active
| - 14:0:0:0 sdc 8:32 active ready running
| - 17:0:0:0 sdas 66:192 active ready running
| - 14:0:3:0 sdar 66:176 active ready running
`- 17:0:3:0 sdch 69:80 active ready running
```

### AFF or FAS configuration

An AFF or FAS configuration should have two groups of paths with higher and lower priorities. Higher priority Active/Optimized paths are served by the controller where the aggregate is located. Lower priority paths are active but non-optimized because they are served by a different controller. Non-optimized paths are only used when optimized paths aren't available.

The following example displays the output for an ONTAP LUN with two Active/Optimized paths and two Active/Non-Optimized paths:

#### Show example

```
multipath -ll
3600a0980383149764b5d567257516273 dm-0 NETAPP,LUN C-Mode
size=150G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
|+- policy='service-time 0' prio=50 status=active
| | - 16:0:3:0 sdcg 69:64 active ready running
| ` - 10:0:0:0 sdb 8:16 active ready running
`+- policy='service-time 0' prio=10 status=enabled
| - 10:0:1:0 sdc 8:32 active ready running
`- 16:0:2:0 sdcf 69:48 active ready running
```

### Step 4: Optionally, exclude a device from multipathing

If required, you can exclude a device from multipathing by adding the WWID for the unwanted device to the "blacklist" stanza for the `multipath.conf` file.

## Steps

1. Determine the WWID:

```
/lib/udev/scsi_id -gud /dev/sda
```

"sda" is the local SCSI disk that you want to add to the blacklist.

An example WWID is 360030057024d0730239134810c0cb833.

2. Add the WWID to the "blacklist" stanza:

```
blacklist {  
    wwid      360030057024d0730239134810c0cb833  
    devnode   "^(ram|raw|loop|fd|md|dm-|sr|scd|st)[0-9]*"  
    devnode   "^hd[a-z]"  
    devnode   "^cciss.*"  
}
```

## Step 5: Customize multipath parameters for ONTAP LUNs

If your host is connected to LUNs from other vendors and any of the multipath parameter settings are overridden, you need to correct them by adding stanzas later in the `multipath.conf` file that apply specifically to ONTAP LUNs. If you don't do this, the ONTAP LUNs might not work as expected.

Check your `/etc/multipath.conf` file, especially in the defaults section, for settings that might be overriding the [default settings for multipath parameters](#).



You shouldn't override the recommended parameter settings for ONTAP LUNs. These settings are required for optimal performance of your host configuration. Contact NetApp support, your OS vendor, or both for more information.

The following example shows how to correct an overridden default. In this example, the `multipath.conf` file defines values for `path_checker` and `no_path_retry` that aren't compatible with ONTAP LUNs, and you can't remove these parameters because ONTAP storage arrays are still attached to the host. Instead, you correct the values for `path_checker` and `no_path_retry` by adding a device stanza to the `multipath.conf` file that applies specifically to the ONTAP LUNs.

## Show example

```
defaults {
    path_checker      readsector0
    no_path_retry     fail
}

devices {
    device {
        vendor        "NETAPP"
        product        "LUN"
        no_path_retry  queue
        path_checker   tur
    }
}
```

## Step 6: Review the known issues

The RHEL 9.3 with ONTAP storage release has the following known issues:

NetApp Bug ID	Title	Description	JIRA ID
<a href="#">1508554</a>	NetApp Linux Host Utilities CLI requires additional library package dependencies to support Emulex host bus adapter (HBA) adapter discovery	In RHEL 9.x, the NetApp Linux SAN Host Utilities CLI <code>sanlun fcp show adapter -v</code> fails because the library package dependencies to support Emulex host bus adapter (HBA) discovery cannot be found.	Not applicable
<a href="#">1593771</a>	A Red Hat Enterprise Linux 9.3 QLogic SAN host encounters loss of partial multipaths during storage mobility operations	During the ONTAP storage controller takeover operation, half of the multipaths are expected to go down or switch to a failover mode and then recover to full path count during the giveback workflow. However, with a Red Hat Enterprise Linux (RHEL) 9.3 QLogic host, only partial multipaths are recovered after a storage failover giveback operation.	RHEL 17811

## What's next?

- [Learn about using the Linux Host Utilities tool.](#)
- Learn about ASM mirroring.

Automatic Storage Management (ASM) mirroring might require changes to the Linux multipath settings to allow ASM to recognize a problem and switch over to an alternate failure group. Most ASM configurations on ONTAP use external redundancy, which means that data protection is provided by the external array

and ASM doesn't mirror data. Some sites use ASM with normal redundancy to provide two-way mirroring, normally across different sites. See [Oracle databases on ONTAP](#) for further information.

## Configure RHEL 9.2 for FCP and iSCSI with ONTAP storage

The Linux Host Utilities software provides management and diagnostic tools for Linux hosts that are connected to ONTAP storage. When you install the Linux Host Utilities on a Red Hat Enterprise Linux (RHEL) 9.2 host, you can use the Host Utilities to help you manage FCP and iSCSI protocol operations with ONTAP LUNs.



You don't need to manually configure Kernel-based Virtual Machine (KVM) settings because ONTAP LUNs are automatically mapped to the hypervisor.

### Step 1: Optionally, enable SAN booting

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

#### Before you begin

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

#### Steps

1. [Create a SAN boot LUN and map it to the host.](#)
2. Enable SAN booting in the server BIOS for the ports to which the SAN boot LUN is mapped.

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

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

### Step 2: Install the Linux Host Utilities

NetApp strongly recommends installing the Linux Host Utilities to support ONTAP LUN management and assist technical support with gathering configuration data.

[Install Linux Host Utilities 8.0.](#)



Installing the Linux Host Utilities doesn't change any host timeout settings on your Linux host.

### Step 3: Confirm the multipath configuration for your host

You can use multipathing with RHEL 9.2 to manage ONTAP LUNs.

To ensure that multipathing is configured correctly for your host, verify that the `/etc/multipath.conf` file is defined and that you have the NetApp recommended settings configured for your ONTAP LUNs.

#### Steps

1. Verify that the `/etc/multipath.conf` file exists. If the file doesn't exist, create an empty, zero-byte file:

```
touch /etc/multipath.conf
```

2. The first time the `multipath.conf` file is created, you might need to enable and start the multipath services to load the recommended settings:

```
systemctl enable multipathd
```

```
systemctl start multipathd
```

3. Each time you boot the host, the empty `/etc/multipath.conf` zero-byte file automatically loads the NetApp recommended host multipath parameters as the default settings. You shouldn't need to make changes to the `/etc/multipath.conf` file for your host because the operating system is compiled with the multipath parameters that recognize and manage ONTAP LUNs correctly.

The following table shows the Linux OS native compiled multipath parameter settings for ONTAP LUNs.

#### Show parameter settings

Parameter	Setting
detect_prio	yes
dev_loss_tmo	"infinity"
failback	immediate
fast_io_fail_tmo	5
features	"2 pg_init_retries 50"
flush_on_last_del	"yes"
hardware_handler	"0"
no_path_retry	queue
path_checker	"tur"
path_grouping_policy	"group_by_prio"
path_selector	"service-time 0"
polling_interval	5
prio	"ontap"
product	LUN
retain_attached_hw_handler	yes
rr_weight	"uniform"
user_friendly_names	no
vendor	NETAPP

4. Verify the parameter settings and path status for your ONTAP LUNs:

```
multipath -ll
```

The default multipath parameters support ASA, AFF, and FAS configurations. In these configurations, a single ONTAP LUN shouldn't require more than four paths. If there are more than four paths, it might cause issues with the paths during a storage failure.

The following example outputs show the correct parameter settings and path status for ONTAP LUNs in an ASA, AFF, or FAS configuration.

## ASA configuration

An ASA configuration optimizes all paths to a given LUN, keeping them active. This improves performance by serving I/O operations through all paths at the same time.

### Show example

```
multipath -ll
3600a098038314c4a433f577471797958 dm-2 NETAPP,LUN C-Mode
size=180G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
`-+- policy='service-time 0' prio=50 status=active
| - 14:0:0:0 sdc 8:32 active ready running
| - 17:0:0:0 sdas 66:192 active ready running
| - 14:0:3:0 sdar 66:176 active ready running
`- 17:0:3:0 sdch 69:80 active ready running
```

## AFF or FAS configuration

An AFF or FAS configuration should have two groups of paths with higher and lower priorities. Higher priority Active/Optimized paths are served by the controller where the aggregate is located. Lower priority paths are active but non-optimized because they are served by a different controller. Non-optimized paths are only used when optimized paths aren't available.

The following example displays the output for an ONTAP LUN with two Active/Optimized paths and two Active/Non-Optimized paths:

### Show example

```
multipath -ll
3600a0980383149764b5d567257516273 dm-0 NETAPP,LUN C-Mode
size=150G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
|+- policy='service-time 0' prio=50 status=active
| | - 16:0:3:0 sdcg 69:64 active ready running
| ` - 10:0:0:0 sdb 8:16 active ready running
`+- policy='service-time 0' prio=10 status=enabled
| - 10:0:1:0 sdc 8:32 active ready running
`- 16:0:2:0 sdcf 69:48 active ready running
```

## Step 4: Optionally, exclude a device from multipathing

If required, you can exclude a device from multipathing by adding the WWID for the unwanted device to the "blacklist" stanza for the `multipath.conf` file.

## Steps

1. Determine the WWID:

```
/lib/udev/scsi_id -gud /dev/sda
```

"sda" is the local SCSI disk that you want to add to the blacklist.

An example WWID is 360030057024d0730239134810c0cb833.

2. Add the WWID to the "blacklist" stanza:

```
blacklist {  
    wwid      360030057024d0730239134810c0cb833  
    devnode   "^(ram|raw|loop|fd|md|dm-|sr|scd|st)[0-9]*"  
    devnode   "^hd[a-z]"  
    devnode   "^cciss.*"  
}
```

## Step 5: Customize multipath parameters for ONTAP LUNs

If your host is connected to LUNs from other vendors and any of the multipath parameter settings are overridden, you need to correct them by adding stanzas later in the `multipath.conf` file that apply specifically to ONTAP LUNs. If you don't do this, the ONTAP LUNs might not work as expected.

Check your `/etc/multipath.conf` file, especially in the defaults section, for settings that might be overriding the [default settings for multipath parameters](#).



You shouldn't override the recommended parameter settings for ONTAP LUNs. These settings are required for optimal performance of your host configuration. Contact NetApp support, your OS vendor, or both for more information.

The following example shows how to correct an overridden default. In this example, the `multipath.conf` file defines values for `path_checker` and `no_path_retry` that aren't compatible with ONTAP LUNs, and you can't remove these parameters because ONTAP storage arrays are still attached to the host. Instead, you correct the values for `path_checker` and `no_path_retry` by adding a device stanza to the `multipath.conf` file that applies specifically to the ONTAP LUNs.



## Show example

```
defaults {
    path_checker      readsector0
    no_path_retry     fail
}

devices {
    device {
        vendor        "NETAPP"
        product        "LUN"
        no_path_retry  queue
        path_checker   tur
    }
}
```

## Step 6: Review the known issues

The RHEL 9.2 with ONTAP storage release has the following known issue:

NetApp Bug ID	Title	Description
<a href="#">1508554</a>	NetApp Linux Host Utilities CLI requires additional library package dependencies to support Emulex HBA adapter discovery	In RHEL 9.2, the NetApp Linux SAN Host Utilities CLI <code>sanlun fcp show adapter -v</code> fails because the library package dependencies to support HBA discovery cannot be found.
<a href="#">1537359</a>	A Red Hat Linux 9.2 SAN booted host with Emulex HBA encounters stalled tasks leading to kernel disruption	During a storage failover giveback operation, a Red Hat Linux 9.2 SAN booted host with an Emulex host bus adapter (HBA) encounters stalled tasks leading to kernel disruption. The kernel disruption causes the operating system to reboot and if <code>kdump</code> is configured, it generates the <code>vmcore</code> file under the <code>/var/crash/</code> directory. The issue is being triaged with the <code>lpfc</code> driver but it cannot be reproduced consistently.

## What's next?

- [Learn about using the Linux Host Utilities tool.](#)
- Learn about ASM mirroring.

Automatic Storage Management (ASM) mirroring might require changes to the Linux multipath settings to allow ASM to recognize a problem and switch over to an alternate failure group. Most ASM configurations on ONTAP use external redundancy, which means that data protection is provided by the external array and ASM doesn't mirror data. Some sites use ASM with normal redundancy to provide two-way mirroring,

normally across different sites. See [Oracle databases on ONTAP](#) for further information.

## Configure RHEL 9.1 for FCP and iSCSI with ONTAP storage

The Linux Host Utilities software provides management and diagnostic tools for Linux hosts that are connected to ONTAP storage. When you install the Linux Host Utilities on a Red Hat Enterprise Linux (RHEL) 9.1 host, you can use the Host Utilities to help you manage FCP and iSCSI protocol operations with ONTAP LUNs.



You don't need to manually configure Kernel-based Virtual Machine (KVM) settings because ONTAP LUNs are automatically mapped to the hypervisor.

### Step 1: Optionally, enable SAN booting

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

#### Before you begin

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

#### Steps

1. [Create a SAN boot LUN and map it to the host.](#)
2. Enable SAN booting in the server BIOS for the ports to which the SAN boot LUN is mapped.

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

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

### Step 2: Install the Linux Host Utilities

NetApp strongly recommends installing the Linux Host Utilities to support ONTAP LUN management and assist technical support with gathering configuration data.

[Install Linux Host Utilities 8.0.](#)



Installing the Linux Host Utilities doesn't change any host timeout settings on your Linux host.

### Step 3: Confirm the multipath configuration for your host

You can use multipathing with RHEL 9.1 to manage ONTAP LUNs.

To ensure that multipathing is configured correctly for your host, verify that the `/etc/multipath.conf` file is defined and that you have the NetApp recommended settings configured for your ONTAP LUNs.

#### Steps

1. Verify that the `/etc/multipath.conf` file exists. If the file doesn't exist, create an empty, zero-byte file:

```
touch /etc/multipath.conf
```

2. The first time the `multipath.conf` file is created, you might need to enable and start the multipath services to load the recommended settings:

```
systemctl enable multipathd
```

```
systemctl start multipathd
```

3. Each time you boot the host, the empty `/etc/multipath.conf` zero-byte file automatically loads the NetApp recommended host multipath parameters as the default settings. You shouldn't need to make changes to the `/etc/multipath.conf` file for your host because the operating system is compiled with the multipath parameters that recognize and manage ONTAP LUNs correctly.

The following table shows the Linux OS native compiled multipath parameter settings for ONTAP LUNs.

#### Show parameter settings

Parameter	Setting
detect_prio	yes
dev_loss_tmo	"infinity"
failback	immediate
fast_io_fail_tmo	5
features	"2 pg_init_retries 50"
flush_on_last_del	"yes"
hardware_handler	"0"
no_path_retry	queue
path_checker	"tur"
path_grouping_policy	"group_by_prio"
path_selector	"service-time 0"
polling_interval	5
prio	"ontap"
product	LUN
retain_attached_hw_handler	yes
rr_weight	"uniform"
user_friendly_names	no
vendor	NETAPP

4. Verify the parameter settings and path status for your ONTAP LUNs:

```
multipath -ll
```

The default multipath parameters support ASA, AFF, and FAS configurations. In these configurations, a single ONTAP LUN shouldn't require more than four paths. If there are more than four paths, it might cause issues with the paths during a storage failure.

The following example outputs show the correct parameter settings and path status for ONTAP LUNs in an ASA, AFF, or FAS configuration.

## ASA configuration

An ASA configuration optimizes all paths to a given LUN, keeping them active. This improves performance by serving I/O operations through all paths at the same time.

### Show example

```
multipath -ll
3600a098038314c4a433f577471797958 dm-2 NETAPP,LUN C-Mode
size=180G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
`-+- policy='service-time 0' prio=50 status=active
| - 14:0:0:0 sdc 8:32 active ready running
| - 17:0:0:0 sdas 66:192 active ready running
| - 14:0:3:0 sdar 66:176 active ready running
`- 17:0:3:0 sdch 69:80 active ready running
```

## AFF or FAS configuration

An AFF or FAS configuration should have two groups of paths with higher and lower priorities. Higher priority Active/Optimized paths are served by the controller where the aggregate is located. Lower priority paths are active but non-optimized because they are served by a different controller. Non-optimized paths are only used when optimized paths aren't available.

The following example displays the output for an ONTAP LUN with two Active/Optimized paths and two Active/Non-Optimized paths:

### Show example

```
multipath -ll
3600a0980383149764b5d567257516273 dm-0 NETAPP,LUN C-Mode
size=150G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
|+- policy='service-time 0' prio=50 status=active
| | - 16:0:3:0 sdcg 69:64 active ready running
| ` - 10:0:0:0 sdb 8:16 active ready running
`+- policy='service-time 0' prio=10 status=enabled
| - 10:0:1:0 sdc 8:32 active ready running
`- 16:0:2:0 sdcf 69:48 active ready running
```

## Step 4: Optionally, exclude a device from multipathing

If required, you can exclude a device from multipathing by adding the WWID for the unwanted device to the "blacklist" stanza for the `multipath.conf` file.

## Steps

1. Determine the WWID:

```
/lib/udev/scsi_id -gud /dev/sda
```

"sda" is the local SCSI disk that you want to add to the blacklist.

An example WWID is 360030057024d0730239134810c0cb833.

2. Add the WWID to the "blacklist" stanza:

```
blacklist {
    wwid      360030057024d0730239134810c0cb833
    devnode   "^(ram|raw|loop|fd|md|dm-|sr|scd|st) [0-9] *"
    devnode   "^hd[a-z] *"
    devnode   "^cciss.*"
}
```

## Step 5: Customize multipath parameters for ONTAP LUNs

If your host is connected to LUNs from other vendors and any of the multipath parameter settings are overridden, you need to correct them by adding stanzas later in the `multipath.conf` file that apply specifically to ONTAP LUNs. If you don't do this, the ONTAP LUNs might not work as expected.

Check your `/etc/multipath.conf` file, especially in the defaults section, for settings that might be overriding the [default settings for multipath parameters](#).



You shouldn't override the recommended parameter settings for ONTAP LUNs. These settings are required for optimal performance of your host configuration. Contact NetApp support, your OS vendor, or both for more information.

The following example shows how to correct an overridden default. In this example, the `multipath.conf` file defines values for `path_checker` and `no_path_retry` that aren't compatible with ONTAP LUNs, and you can't remove these parameters because ONTAP storage arrays are still attached to the host. Instead, you correct the values for `path_checker` and `no_path_retry` by adding a device stanza to the `multipath.conf` file that applies specifically to the ONTAP LUNs.

## Show example

```
defaults {
    path_checker      readsector0
    no_path_retry     fail
}

devices {
    device {
        vendor        "NETAPP"
        product        "LUN"
        no_path_retry  queue
        path_checker   tur
    }
}
```

## Step 6: Review the known issues

The RHEL 9.1 with ONTAP storage release has the following known issue:

NetApp Bug ID	Title	Description
<a href="#">1508554</a>	NetApp Linux Host Utilities CLI requires additional library package dependencies to support Emulex HBA adapter discovery	In RHEL 9.1, the NetApp Linux SAN Host Utilities CLI <code>sanlun fcp show adapter -v</code> fails because the library package dependencies to support HBA discovery cannot be found.

## What's next?

- [Learn about using the Linux Host Utilities tool.](#)
- Learn about ASM mirroring.

Automatic Storage Management (ASM) mirroring might require changes to the Linux multipath settings to allow ASM to recognize a problem and switch over to an alternate failure group. Most ASM configurations on ONTAP use external redundancy, which means that data protection is provided by the external array and ASM doesn't mirror data. Some sites use ASM with normal redundancy to provide two-way mirroring, normally across different sites. See [Oracle databases on ONTAP](#) for further information.

## Configure RHEL 9.0 for FCP and iSCSI with ONTAP storage

The Linux Host Utilities software provides management and diagnostic tools for Linux hosts that are connected to ONTAP storage. When you install the Linux Host Utilities on a Red Hat Enterprise Linux (RHEL) 9.0 host, you can use the Host Utilities to help you manage FCP and iSCSI protocol operations with ONTAP LUNs.



You don't need to manually configure Kernel-based Virtual Machine (KVM) settings because ONTAP LUNs are automatically mapped to the hypervisor.

### Step 1: Optionally, enable SAN booting

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

#### Before you begin

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

#### Steps

1. [Create a SAN boot LUN and map it to the host.](#)
2. Enable SAN booting in the server BIOS for the ports to which the SAN boot LUN is mapped.

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

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

### Step 2: Install the Linux Host Utilities

NetApp strongly recommends installing the Linux Host Utilities to support ONTAP LUN management and assist technical support with gathering configuration data.

[Install Linux Host Utilities 8.0.](#)



Installing the Linux Host Utilities doesn't change any host timeout settings on your Linux host.

### Step 3: Confirm the multipath configuration for your host

You can use multipathing with RHEL 9.0 to manage ONTAP LUNs.

To ensure that multipathing is configured correctly for your host, verify that the `/etc/multipath.conf` file is defined and that you have the NetApp recommended settings configured for your ONTAP LUNs.

#### Steps

1. Verify that the `/etc/multipath.conf` file exists. If the file doesn't exist, create an empty, zero-byte file:

```
touch /etc/multipath.conf
```

2. The first time the `multipath.conf` file is created, you might need to enable and start the multipath services to load the recommended settings:

```
systemctl enable multipathd
```

```
systemctl start multipathd
```



- Each time you boot the host, the empty `/etc/multipath.conf` zero-byte file automatically loads the NetApp recommended host multipath parameters as the default settings. You shouldn't need to make changes to the `/etc/multipath.conf` file for your host because the operating system is compiled with the multipath parameters that recognize and manage ONTAP LUNs correctly.

The following table shows the Linux OS native compiled multipath parameter settings for ONTAP LUNs.

#### Show parameter settings

Parameter	Setting
<code>detect_prio</code>	<code>yes</code>
<code>dev_loss_tmo</code>	<code>"infinity"</code>
<code>failback</code>	<code>immediate</code>
<code>fast_io_fail_tmo</code>	<code>5</code>
<code>features</code>	<code>"2 pg_init_retries 50"</code>
<code>flush_on_last_del</code>	<code>"yes"</code>
<code>hardware_handler</code>	<code>"0"</code>
<code>no_path_retry</code>	<code>queue</code>
<code>path_checker</code>	<code>"tur"</code>
<code>path_grouping_policy</code>	<code>"group_by_prio"</code>
<code>path_selector</code>	<code>"service-time 0"</code>
<code>polling_interval</code>	<code>5</code>
<code>prio</code>	<code>"ontap"</code>
<code>product</code>	<code>LUN</code>
<code>retain_attached_hw_handler</code>	<code>yes</code>
<code>rr_weight</code>	<code>"uniform"</code>
<code>user_friendly_names</code>	<code>no</code>
<code>vendor</code>	<code>NETAPP</code>

- Verify the parameter settings and path status for your ONTAP LUNs:

```
multipath -ll
```

The default multipath parameters support ASA, AFF, and FAS configurations. In these configurations, a single ONTAP LUN shouldn't require more than four paths. If there are more than four paths, it might cause issues with the paths during a storage failure.

The following example outputs show the correct parameter settings and path status for ONTAP LUNs in an ASA, AFF, or FAS configuration.

## ASA configuration

An ASA configuration optimizes all paths to a given LUN, keeping them active. This improves performance by serving I/O operations through all paths at the same time.

### Show example

```
multipath -ll
3600a098038314c4a433f577471797958 dm-2 NETAPP,LUN C-Mode
size=180G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
`-+- policy='service-time 0' prio=50 status=active
| - 14:0:0:0 sdc 8:32 active ready running
| - 17:0:0:0 sdas 66:192 active ready running
| - 14:0:3:0 sdar 66:176 active ready running
`- 17:0:3:0 sdch 69:80 active ready running
```

## AFF or FAS configuration

An AFF or FAS configuration should have two groups of paths with higher and lower priorities. Higher priority Active/Optimized paths are served by the controller where the aggregate is located. Lower priority paths are active but non-optimized because they are served by a different controller. Non-optimized paths are only used when optimized paths aren't available.

The following example displays the output for an ONTAP LUN with two Active/Optimized paths and two Active/Non-Optimized paths:

### Show example

```
multipath -ll
3600a0980383149764b5d567257516273 dm-0 NETAPP,LUN C-Mode
size=150G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
| -+- policy='service-time 0' prio=50 status=active
| | - 16:0:3:0 sdcg 69:64 active ready running
| | ` - 10:0:0:0 sdb 8:16 active ready running
`-+- policy='service-time 0' prio=10 status=enabled
| - 10:0:1:0 sdc 8:32 active ready running
`- 16:0:2:0 sdcf 69:48 active ready running
```

## Step 4: Optionally, exclude a device from multipathing

If required, you can exclude a device from multipathing by adding the WWID for the unwanted device to the "blacklist" stanza for the `multipath.conf` file.

## Steps

1. Determine the WWID:

```
/lib/udev/scsi_id -gud /dev/sda
```

"sda" is the local SCSI disk that you want to add to the blacklist.

An example WWID is 360030057024d0730239134810c0cb833.

2. Add the WWID to the "blacklist" stanza:

```
blacklist {  
    wwid      360030057024d0730239134810c0cb833  
    devnode   "^(ram|raw|loop|fd|md|dm-|sr|scd|st)[0-9]*"  
    devnode   "^hd[a-z]"  
    devnode   "^cciss.*"  
}
```

## Step 5: Customize multipath parameters for ONTAP LUNs

If your host is connected to LUNs from other vendors and any of the multipath parameter settings are overridden, you need to correct them by adding stanzas later in the `multipath.conf` file that apply specifically to ONTAP LUNs. If you don't do this, the ONTAP LUNs might not work as expected.

Check your `/etc/multipath.conf` file, especially in the defaults section, for settings that might be overriding the [default settings for multipath parameters](#).



You shouldn't override the recommended parameter settings for ONTAP LUNs. These settings are required for optimal performance of your host configuration. Contact NetApp support, your OS vendor, or both for more information.

The following example shows how to correct an overridden default. In this example, the `multipath.conf` file defines values for `path_checker` and `no_path_retry` that aren't compatible with ONTAP LUNs, and you can't remove these parameters because ONTAP storage arrays are still attached to the host. Instead, you correct the values for `path_checker` and `no_path_retry` by adding a device stanza to the `multipath.conf` file that applies specifically to the ONTAP LUNs.

### Show example

```
defaults {
    path_checker      readsector0
    no_path_retry     fail
}

devices {
    device {
        vendor        "NETAPP"
        product        "LUN"
        no_path_retry  queue
        path_checker    tur
    }
}
```

### Step 6: Review the known issues

There are no known issues.

### What's next?

- [Learn about using the Linux Host Utilities tool.](#)
- Learn about ASM mirroring.

Automatic Storage Management (ASM) mirroring might require changes to the Linux multipath settings to allow ASM to recognize a problem and switch over to an alternate failure group. Most ASM configurations on ONTAP use external redundancy, which means that data protection is provided by the external array and ASM doesn't mirror data. Some sites use ASM with normal redundancy to provide two-way mirroring, normally across different sites. See [Oracle databases on ONTAP](#) for further information.

## RHEL 8

### Configure RHEL 8.10 for FCP and iSCSI with ONTAP storage

The Linux Host Utilities software provides management and diagnostic tools for Linux hosts that are connected to ONTAP storage. When you install the Linux Host Utilities on a Red Hat Enterprise Linux (RHEL) 8.10 host, you can use the Host Utilities to help you manage FCP and iSCSI protocol operations with ONTAP LUNs.



You don't need to manually configure Kernel-based Virtual Machine (KVM) settings because ONTAP LUNs are automatically mapped to the hypervisor.

## Step 1: Optionally, enable SAN booting

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

### Before you begin

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

### Steps

1. [Create a SAN boot LUN and map it to the host.](#)
2. Enable SAN booting in the server BIOS for the ports to which the SAN boot LUN is mapped.

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

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

## Step 2: Install the Linux Host Utilities

NetApp strongly recommends installing the Linux Host Utilities to support ONTAP LUN management and assist technical support with gathering configuration data.

[Install Linux Host Utilities 8.0.](#)



Installing the Linux Host Utilities doesn't change any host timeout settings on your Linux host.

## Step 3: Confirm the multipath configuration for your host

You can use multipathing with RHEL 8.10 to manage ONTAP LUNs.

To ensure that multipathing is configured correctly for your host, verify that the `/etc/multipath.conf` file is defined and that you have the NetApp recommended settings configured for your ONTAP LUNs.

### Steps

1. Verify that the `/etc/multipath.conf` file exists. If the file doesn't exist, create an empty, zero-byte file:

```
touch /etc/multipath.conf
```

2. The first time the `multipath.conf` file is created, you might need to enable and start the multipath services to load the recommended settings:

```
systemctl enable multipathd
```

```
systemctl start multipathd
```

3. Each time you boot the host, the empty `/etc/multipath.conf` zero-byte file automatically loads the NetApp recommended host multipath parameters as the default settings. You shouldn't need to make

changes to the `/etc/multipath.conf` file for your host because the operating system is compiled with the multipath parameters that recognize and manage ONTAP LUNs correctly.

The following table shows the Linux OS native compiled multipath parameter settings for ONTAP LUNs.

#### Show parameter settings

Parameter	Setting
detect_prio	yes
dev_loss_tmo	"infinity"
failback	immediate
fast_io_fail_tmo	5
features	"2 pg_init_retries 50"
flush_on_last_del	"yes"
hardware_handler	"0"
no_path_retry	queue
path_checker	"tur"
path_grouping_policy	"group_by_prio"
path_selector	"service-time 0"
polling_interval	5
prio	"ontap"
product	LUN
retain_attached_hw_handler	yes
rr_weight	"uniform"
user_friendly_names	no
vendor	NETAPP

4. Verify the parameter settings and path status for your ONTAP LUNs:

```
multipath -ll
```

The default multipath parameters support ASA, AFF, and FAS configurations. In these configurations, a single ONTAP LUN shouldn't require more than four paths. If there are more than four paths, it might cause issues with the paths during a storage failure.

The following example outputs show the correct parameter settings and path status for ONTAP LUNs in an ASA, AFF, or FAS configuration.

## ASA configuration

An ASA configuration optimizes all paths to a given LUN, keeping them active. This improves performance by serving I/O operations through all paths at the same time.

### Show example

```
multipath -ll
3600a098038314c4a433f577471797958 dm-2 NETAPP,LUN C-Mode
size=180G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
`-+- policy='service-time 0' prio=50 status=active
  |- 14:0:0:0 sdc 8:32 active ready running
  |- 17:0:0:0 sdas 66:192 active ready running
  |- 14:0:3:0 sdar 66:176 active ready running
  `-- 17:0:3:0 sdch 69:80 active ready running
```

## AFF or FAS configuration

An AFF or FAS configuration should have two groups of paths with higher and lower priorities. Higher priority Active/Optimized paths are served by the controller where the aggregate is located. Lower priority paths are active but non-optimized because they are served by a different controller. Non-optimized paths are only used when optimized paths aren't available.

The following example displays the output for an ONTAP LUN with two Active/Optimized paths and two Active/Non-Optimized paths:

### Show example

```
multipath -ll
3600a0980383149764b5d567257516273 dm-0 NETAPP,LUN C-Mode
size=150G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
|-+- policy='service-time 0' prio=50 status=active
| |- 16:0:3:0 sdcg 69:64 active ready running
| `-- 10:0:0:0 sdb 8:16 active ready running
`-+- policy='service-time 0' prio=10 status=enabled
  |- 10:0:1:0 sdc 8:32 active ready running
  `-- 16:0:2:0 sdcf 69:48 active ready running
```

## Step 4: Optionally, exclude a device from multipathing

If required, you can exclude a device from multipathing by adding the WWID for the unwanted device to the "blacklist" stanza for the `multipath.conf` file.

## Steps

1. Determine the WWID:

```
/lib/udev/scsi_id -gud /dev/sda
```

"sda" is the local SCSI disk that you want to add to the blacklist.

An example WWID is 360030057024d0730239134810c0cb833.

2. Add the WWID to the "blacklist" stanza:

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blacklist {
    wwid      360030057024d0730239134810c0cb833
    devnode   "^(ram|raw|loop|fd|md|dm-|sr|scd|st)[0-9]*"
    devnode   "^hd[a-z]"
    devnode   "^cciss.*"
}
```

## Step 5: Customize multipath parameters for ONTAP LUNs

If your host is connected to LUNs from other vendors and any of the multipath parameter settings are overridden, you need to correct them by adding stanzas later in the `multipath.conf` file that apply specifically to ONTAP LUNs. If you don't do this, the ONTAP LUNs might not work as expected.

Check your `/etc/multipath.conf` file, especially in the defaults section, for settings that might be overriding the [default settings for multipath parameters](#).



You shouldn't override the recommended parameter settings for ONTAP LUNs. These settings are required for optimal performance of your host configuration. Contact NetApp support, your OS vendor, or both for more information.

The following example shows how to correct an overridden default. In this example, the `multipath.conf` file defines values for `path_checker` and `no_path_retry` that aren't compatible with ONTAP LUNs, and you can't remove these parameters because ONTAP storage arrays are still attached to the host. Instead, you correct the values for `path_checker` and `no_path_retry` by adding a device stanza to the `multipath.conf` file that applies specifically to the ONTAP LUNs.



## Show example

```
defaults {
    path_checker      readsector0
    no_path_retry     fail
}

devices {
    device {
        vendor        "NETAPP"
        product        "LUN"
        no_path_retry  queue
        path_checker   tur
    }
}
```

### Step 6: Review the known issues

There are no known issues.

### What's next?

- [Learn about using the Linux Host Utilities tool.](#)
- Learn about ASM mirroring.

Automatic Storage Management (ASM) mirroring might require changes to the Linux multipath settings to allow ASM to recognize a problem and switch over to an alternate failure group. Most ASM configurations on ONTAP use external redundancy, which means that data protection is provided by the external array and ASM doesn't mirror data. Some sites use ASM with normal redundancy to provide two-way mirroring, normally across different sites. See [Oracle databases on ONTAP](#) for further information.

## Configure RHEL 8.9 for FCP and iSCSI with ONTAP storage

The Linux Host Utilities software provides management and diagnostic tools for Linux hosts that are connected to ONTAP storage. When you install the Linux Host Utilities on a Red Hat Enterprise Linux (RHEL) 8.9 host, you can use the Host Utilities to help you manage FCP and iSCSI protocol operations with ONTAP LUNs.



You don't need to manually configure Kernel-based Virtual Machine (KVM) settings because ONTAP LUNs are automatically mapped to the hypervisor.

### Step 1: Optionally, enable SAN booting

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

### Before you begin

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

### Steps

1. [Create a SAN boot LUN and map it to the host.](#)
2. Enable SAN booting in the server BIOS for the ports to which the SAN boot LUN is mapped.

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

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

## Step 2: Install the Linux Host Utilities

NetApp strongly recommends installing the Linux Host Utilities to support ONTAP LUN management and assist technical support with gathering configuration data.

[Install Linux Host Utilities 8.0.](#)



Installing the Linux Host Utilities doesn't change any host timeout settings on your Linux host.

## Step 3: Confirm the multipath configuration for your host

You can use multipathing with RHEL 8.9 to manage ONTAP LUNs.

To ensure that multipathing is configured correctly for your host, verify that the `/etc/multipath.conf` file is defined and that you have the NetApp recommended settings configured for your ONTAP LUNs.

### Steps

1. Verify that the `/etc/multipath.conf` file exists. If the file doesn't exist, create an empty, zero-byte file:

```
touch /etc/multipath.conf
```

2. The first time the `multipath.conf` file is created, you might need to enable and start the multipath services to load the recommended settings:

```
systemctl enable multipathd
```

```
systemctl start multipathd
```

3. Each time you boot the host, the empty `/etc/multipath.conf` zero-byte file automatically loads the NetApp recommended host multipath parameters as the default settings. You shouldn't need to make changes to the `/etc/multipath.conf` file for your host because the operating system is compiled with the multipath parameters that recognize and manage ONTAP LUNs correctly.

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hardware_handler	"0"
no_path_retry	queue
path_checker	"tur"
path_grouping_policy	"group_by_prio"
path_selector	"service-time 0"
polling_interval	5
prio	"ontap"
product	LUN
retain_attached_hw_handler	yes
rr_weight	"uniform"
user_friendly_names	no
vendor	NETAPP

#### 4. Verify the parameter settings and path status for your ONTAP LUNs:

```
multipath -ll
```

The default multipath parameters support ASA, AFF, and FAS configurations. In these configurations, a single ONTAP LUN shouldn't require more than four paths. If there are more than four paths, it might cause issues with the paths during a storage failure.

The following example outputs show the correct parameter settings and path status for ONTAP LUNs in an ASA, AFF, or FAS configuration.

## ASA configuration

An ASA configuration optimizes all paths to a given LUN, keeping them active. This improves performance by serving I/O operations through all paths at the same time.

### Show example

```
multipath -ll
3600a098038314c4a433f577471797958 dm-2 NETAPP,LUN C-Mode
size=180G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
`-+- policy='service-time 0' prio=50 status=active
| - 14:0:0:0 sdc 8:32 active ready running
| - 17:0:0:0 sdas 66:192 active ready running
| - 14:0:3:0 sdar 66:176 active ready running
`- 17:0:3:0 sdch 69:80 active ready running
```

## AFF or FAS configuration

An AFF or FAS configuration should have two groups of paths with higher and lower priorities. Higher priority Active/Optimized paths are served by the controller where the aggregate is located. Lower priority paths are active but non-optimized because they are served by a different controller. Non-optimized paths are only used when optimized paths aren't available.

The following example displays the output for an ONTAP LUN with two Active/Optimized paths and two Active/Non-Optimized paths:

### Show example

```
multipath -ll
3600a0980383149764b5d567257516273 dm-0 NETAPP,LUN C-Mode
size=150G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
|+- policy='service-time 0' prio=50 status=active
| | - 16:0:3:0 sdcg 69:64 active ready running
| ` - 10:0:0:0 sdb 8:16 active ready running
`+- policy='service-time 0' prio=10 status=enabled
| - 10:0:1:0 sdc 8:32 active ready running
`- 16:0:2:0 sdcf 69:48 active ready running
```

## Step 4: Optionally, exclude a device from multipathing

If required, you can exclude a device from multipathing by adding the WWID for the unwanted device to the "blacklist" stanza for the `multipath.conf` file.

## Steps

1. Determine the WWID:

```
/lib/udev/scsi_id -gud /dev/sda
```

"sda" is the local SCSI disk that you want to add to the blacklist.

An example WWID is 360030057024d0730239134810c0cb833.

2. Add the WWID to the "blacklist" stanza:

```
blacklist {
    wwid      360030057024d0730239134810c0cb833
    devnode   "^(ram|raw|loop|fd|md|dm-|sr|scd|st) [0-9] *"
    devnode   "^hd[a-z]"
    devnode   "^cciss.*"
}
```

## Step 5: Customize multipath parameters for ONTAP LUNs

If your host is connected to LUNs from other vendors and any of the multipath parameter settings are overridden, you need to correct them by adding stanzas later in the `multipath.conf` file that apply specifically to ONTAP LUNs. If you don't do this, the ONTAP LUNs might not work as expected.

Check your `/etc/multipath.conf` file, especially in the defaults section, for settings that might be overriding the [default settings for multipath parameters](#).



You shouldn't override the recommended parameter settings for ONTAP LUNs. These settings are required for optimal performance of your host configuration. Contact NetApp support, your OS vendor, or both for more information.

The following example shows how to correct an overridden default. In this example, the `multipath.conf` file defines values for `path_checker` and `no_path_retry` that aren't compatible with ONTAP LUNs, and you can't remove these parameters because ONTAP storage arrays are still attached to the host. Instead, you correct the values for `path_checker` and `no_path_retry` by adding a device stanza to the `multipath.conf` file that applies specifically to the ONTAP LUNs.

## Show example

```
defaults {
    path_checker      readsector0
    no_path_retry     fail
}

devices {
    device {
        vendor        "NETAPP"
        product        "LUN"
        no_path_retry  queue
        path_checker   tur
    }
}
```

### Step 6: Review the known issues

There are no known issues.

### What's next?

- [Learn about using the Linux Host Utilities tool.](#)
- Learn about ASM mirroring.

Automatic Storage Management (ASM) mirroring might require changes to the Linux multipath settings to allow ASM to recognize a problem and switch over to an alternate failure group. Most ASM configurations on ONTAP use external redundancy, which means that data protection is provided by the external array and ASM doesn't mirror data. Some sites use ASM with normal redundancy to provide two-way mirroring, normally across different sites. See [Oracle databases on ONTAP](#) for further information.

## Configure RHEL 8.8 for FCP and iSCSI with ONTAP storage

The Linux Host Utilities software provides management and diagnostic tools for Linux hosts that are connected to ONTAP storage. When you install the Linux Host Utilities on a Red Hat Enterprise Linux (RHEL) 8.8 host, you can use the Host Utilities to help you manage FCP and iSCSI protocol operations with ONTAP LUNs.



You don't need to manually configure Kernel-based Virtual Machine (KVM) settings because ONTAP LUNs are automatically mapped to the hypervisor.

### Step 1: Optionally, enable SAN booting

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

### Before you begin

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

### Steps

1. [Create a SAN boot LUN and map it to the host.](#)
2. Enable SAN booting in the server BIOS for the ports to which the SAN boot LUN is mapped.

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

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

## Step 2: Install the Linux Host Utilities

NetApp strongly recommends installing the Linux Host Utilities to support ONTAP LUN management and assist technical support with gathering configuration data.

[Install Linux Host Utilities 8.0.](#)



Installing the Linux Host Utilities doesn't change any host timeout settings on your Linux host.

## Step 3: Confirm the multipath configuration for your host

You can use multipathing with RHEL 8.8 to manage ONTAP LUNs.

To ensure that multipathing is configured correctly for your host, verify that the `/etc/multipath.conf` file is defined and that you have the NetApp recommended settings configured for your ONTAP LUNs.

### Steps

1. Verify that the `/etc/multipath.conf` file exists. If the file doesn't exist, create an empty, zero-byte file:

```
touch /etc/multipath.conf
```

2. The first time the `multipath.conf` file is created, you might need to enable and start the multipath services to load the recommended settings:

```
systemctl enable multipathd
```

```
systemctl start multipathd
```

3. Each time you boot the host, the empty `/etc/multipath.conf` zero-byte file automatically loads the NetApp recommended host multipath parameters as the default settings. You shouldn't need to make changes to the `/etc/multipath.conf` file for your host because the operating system is compiled with the multipath parameters that recognize and manage ONTAP LUNs correctly.

The following table shows the Linux OS native compiled multipath parameter settings for ONTAP LUNs.

## Show parameter settings

Parameter	Setting
detect_prio	yes
dev_loss_tmo	"infinity"
failback	immediate
fast_io_fail_tmo	5
features	"2 pg_init_retries 50"
flush_on_last_del	"yes"
hardware_handler	"0"
no_path_retry	queue
path_checker	"tur"
path_grouping_policy	"group_by_prio"
path_selector	"service-time 0"
polling_interval	5
prio	"ontap"
product	LUN
retain_attached_hw_handler	yes
rr_weight	"uniform"
user_friendly_names	no
vendor	NETAPP

### 4. Verify the parameter settings and path status for your ONTAP LUNs:

```
multipath -ll
```

The default multipath parameters support ASA, AFF, and FAS configurations. In these configurations, a single ONTAP LUN shouldn't require more than four paths. If there are more than four paths, it might cause issues with the paths during a storage failure.

The following example outputs show the correct parameter settings and path status for ONTAP LUNs in an ASA, AFF, or FAS configuration.



## ASA configuration

An ASA configuration optimizes all paths to a given LUN, keeping them active. This improves performance by serving I/O operations through all paths at the same time.

### Show example

```
multipath -ll
3600a098038314c4a433f577471797958 dm-2 NETAPP,LUN C-Mode
size=180G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
`-+- policy='service-time 0' prio=50 status=active
| - 14:0:0:0 sdc 8:32 active ready running
| - 17:0:0:0 sdas 66:192 active ready running
| - 14:0:3:0 sdar 66:176 active ready running
`- 17:0:3:0 sdch 69:80 active ready running
```

## AFF or FAS configuration

An AFF or FAS configuration should have two groups of paths with higher and lower priorities. Higher priority Active/Optimized paths are served by the controller where the aggregate is located. Lower priority paths are active but non-optimized because they are served by a different controller. Non-optimized paths are only used when optimized paths aren't available.

The following example displays the output for an ONTAP LUN with two Active/Optimized paths and two Active/Non-Optimized paths:

### Show example

```
multipath -ll
3600a0980383149764b5d567257516273 dm-0 NETAPP,LUN C-Mode
size=150G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
|+- policy='service-time 0' prio=50 status=active
| | - 16:0:3:0 sdcg 69:64 active ready running
| ` - 10:0:0:0 sdb 8:16 active ready running
`+- policy='service-time 0' prio=10 status=enabled
| - 10:0:1:0 sdc 8:32 active ready running
`- 16:0:2:0 sdcf 69:48 active ready running
```

## Step 4: Optionally, exclude a device from multipathing

If required, you can exclude a device from multipathing by adding the WWID for the unwanted device to the "blacklist" stanza for the `multipath.conf` file.

## Steps

1. Determine the WWID:

```
/lib/udev/scsi_id -gud /dev/sda
```

"sda" is the local SCSI disk that you want to add to the blacklist.

An example WWID is 360030057024d0730239134810c0cb833.

2. Add the WWID to the "blacklist" stanza:

```
blacklist {
    wwid      360030057024d0730239134810c0cb833
    devnode   "^(ram|raw|loop|fd|md|dm-|sr|scd|st)[0-9]*"
    devnode   "^hd[a-z]"
    devnode   "^cciss.*"
}
```

## Step 5: Customize multipath parameters for ONTAP LUNs

If your host is connected to LUNs from other vendors and any of the multipath parameter settings are overridden, you need to correct them by adding stanzas later in the `multipath.conf` file that apply specifically to ONTAP LUNs. If you don't do this, the ONTAP LUNs might not work as expected.

Check your `/etc/multipath.conf` file, especially in the defaults section, for settings that might be overriding the [default settings for multipath parameters](#).



You shouldn't override the recommended parameter settings for ONTAP LUNs. These settings are required for optimal performance of your host configuration. Contact NetApp support, your OS vendor, or both for more information.

The following example shows how to correct an overridden default. In this example, the `multipath.conf` file defines values for `path_checker` and `no_path_retry` that aren't compatible with ONTAP LUNs, and you can't remove these parameters because ONTAP storage arrays are still attached to the host. Instead, you correct the values for `path_checker` and `no_path_retry` by adding a device stanza to the `multipath.conf` file that applies specifically to the ONTAP LUNs.

## Show example

```
defaults {
    path_checker      readsector0
    no_path_retry     fail
}

devices {
    device {
        vendor        "NETAPP"
        product        "LUN"
        no_path_retry  queue
        path_checker   tur
    }
}
```

### Step 6: Review the known issues

There are no known issues.

### What's next?

- [Learn about using the Linux Host Utilities tool.](#)
- Learn about ASM mirroring.

Automatic Storage Management (ASM) mirroring might require changes to the Linux multipath settings to allow ASM to recognize a problem and switch over to an alternate failure group. Most ASM configurations on ONTAP use external redundancy, which means that data protection is provided by the external array and ASM doesn't mirror data. Some sites use ASM with normal redundancy to provide two-way mirroring, normally across different sites. See [Oracle databases on ONTAP](#) for further information.

## Configure RHEL 8.7 for FCP and iSCSI with ONTAP storage

The Linux Host Utilities software provides management and diagnostic tools for Linux hosts that are connected to ONTAP storage. When you install the Linux Host Utilities on a Red Hat Enterprise Linux (RHEL) 8.7 host, you can use the Host Utilities to help you manage FCP and iSCSI protocol operations with ONTAP LUNs.



You don't need to manually configure Kernel-based Virtual Machine (KVM) settings because ONTAP LUNs are automatically mapped to the hypervisor.

### Step 1: Optionally, enable SAN booting

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

### Before you begin

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

### Steps

1. [Create a SAN boot LUN and map it to the host.](#)
2. Enable SAN booting in the server BIOS for the ports to which the SAN boot LUN is mapped.

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

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

## Step 2: Install the Linux Host Utilities

NetApp strongly recommends installing the Linux Host Utilities to support ONTAP LUN management and assist technical support with gathering configuration data.

[Install Linux Host Utilities 8.0.](#)



Installing the Linux Host Utilities doesn't change any host timeout settings on your Linux host.

## Step 3: Confirm the multipath configuration for your host

You can use multipathing with RHEL 8.7 to manage ONTAP LUNs.

To ensure that multipathing is configured correctly for your host, verify that the `/etc/multipath.conf` file is defined and that you have the NetApp recommended settings configured for your ONTAP LUNs.

### Steps

1. Verify that the `/etc/multipath.conf` file exists. If the file doesn't exist, create an empty, zero-byte file:

```
touch /etc/multipath.conf
```

2. The first time the `multipath.conf` file is created, you might need to enable and start the multipath services to load the recommended settings:

```
systemctl enable multipathd
```

```
systemctl start multipathd
```

3. Each time you boot the host, the empty `/etc/multipath.conf` zero-byte file automatically loads the NetApp recommended host multipath parameters as the default settings. You shouldn't need to make changes to the `/etc/multipath.conf` file for your host because the operating system is compiled with the multipath parameters that recognize and manage ONTAP LUNs correctly.

The following table shows the Linux OS native compiled multipath parameter settings for ONTAP LUNs.

### Show parameter settings

Parameter	Setting
detect_prio	yes
dev_loss_tmo	"infinity"
failback	immediate
fast_io_fail_tmo	5
features	"2 pg_init_retries 50"
flush_on_last_del	"yes"
hardware_handler	"0"
no_path_retry	queue
path_checker	"tur"
path_grouping_policy	"group_by_prio"
path_selector	"service-time 0"
polling_interval	5
prio	"ontap"
product	LUN
retain_attached_hw_handler	yes
rr_weight	"uniform"
user_friendly_names	no
vendor	NETAPP

#### 4. Verify the parameter settings and path status for your ONTAP LUNs:

```
multipath -ll
```

The default multipath parameters support ASA, AFF, and FAS configurations. In these configurations, a single ONTAP LUN shouldn't require more than four paths. If there are more than four paths, it might cause issues with the paths during a storage failure.

The following example outputs show the correct parameter settings and path status for ONTAP LUNs in an ASA, AFF, or FAS configuration.

### ASA configuration

An ASA configuration optimizes all paths to a given LUN, keeping them active. This improves performance by serving I/O operations through all paths at the same time.

#### Show example

```
multipath -ll
3600a098038314c4a433f577471797958 dm-2 NETAPP,LUN C-Mode
size=180G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
`-+- policy='service-time 0' prio=50 status=active
  |- 14:0:0:0   sdc  8:32   active ready running
  |- 17:0:0:0   sdas 66:192 active ready running
  |- 14:0:3:0   sdar 66:176 active ready running
  `-- 17:0:3:0   sdch 69:80   active ready running
```

### AFF or FAS configuration

An AFF or FAS configuration should have two groups of paths with higher and lower priorities. Higher priority Active/Optimized paths are served by the controller where the aggregate is located. Lower priority paths are active but non-optimized because they are served by a different controller. Non-optimized paths are only used when optimized paths aren't available.

The following example displays the output for an ONTAP LUN with two Active/Optimized paths and two Active/Non-Optimized paths:

#### Show example

```
multipath -ll
3600a0980383149764b5d567257516273 dm-0 NETAPP,LUN C-Mode
size=150G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
|-+- policy='service-time 0' prio=50 status=active
| |- 16:0:3:0   sdcg 69:64   active ready running
| `-- 10:0:0:0   sdb  8:16    active ready running
`-+- policy='service-time 0' prio=10 status=enabled
  |- 10:0:1:0   sdc  8:32    active ready running
  `-- 16:0:2:0   sdcf 69:48   active ready running
```

## Step 4: Optionally, exclude a device from multipathing

If required, you can exclude a device from multipathing by adding the WWID for the unwanted device to the "blacklist" stanza for the `multipath.conf` file.

## Steps

1. Determine the WWID:

```
/lib/udev/scsi_id -gud /dev/sda
```

"sda" is the local SCSI disk that you want to add to the blacklist.

An example WWID is 360030057024d0730239134810c0cb833.

2. Add the WWID to the "blacklist" stanza:

```
blacklist {  
    wwid      360030057024d0730239134810c0cb833  
    devnode   "^(ram|raw|loop|fd|md|dm-|sr|scd|st) [0-9] *"  
    devnode   "^hd[a-z] "  
    devnode   "^cciss.*"  
}
```

## Step 5: Customize multipath parameters for ONTAP LUNs

If your host is connected to LUNs from other vendors and any of the multipath parameter settings are overridden, you need to correct them by adding stanzas later in the `multipath.conf` file that apply specifically to ONTAP LUNs. If you don't do this, the ONTAP LUNs might not work as expected.

Check your `/etc/multipath.conf` file, especially in the defaults section, for settings that might be overriding the [default settings for multipath parameters](#).



You shouldn't override the recommended parameter settings for ONTAP LUNs. These settings are required for optimal performance of your host configuration. Contact NetApp support, your OS vendor, or both for more information.

The following example shows how to correct an overridden default. In this example, the `multipath.conf` file defines values for `path_checker` and `no_path_retry` that aren't compatible with ONTAP LUNs, and you can't remove these parameters because ONTAP storage arrays are still attached to the host. Instead, you correct the values for `path_checker` and `no_path_retry` by adding a device stanza to the `multipath.conf` file that applies specifically to the ONTAP LUNs.

## Show example

```
defaults {
    path_checker      readsector0
    no_path_retry     fail
}

devices {
    device {
        vendor        "NETAPP"
        product        "LUN"
        no_path_retry  queue
        path_checker   tur
    }
}
```

### Step 6: Review the known issues

There are no known issues.

### What's next?

- [Learn about using the Linux Host Utilities tool.](#)
- Learn about ASM mirroring.

Automatic Storage Management (ASM) mirroring might require changes to the Linux multipath settings to allow ASM to recognize a problem and switch over to an alternate failure group. Most ASM configurations on ONTAP use external redundancy, which means that data protection is provided by the external array and ASM doesn't mirror data. Some sites use ASM with normal redundancy to provide two-way mirroring, normally across different sites. See [Oracle databases on ONTAP](#) for further information.

## Configure RHEL 8.6 for FCP and iSCSI with ONTAP storage

The Linux Host Utilities software provides management and diagnostic tools for Linux hosts that are connected to ONTAP storage. When you install the Linux Host Utilities on a Red Hat Enterprise Linux (RHEL) 8.6 host, you can use the Host Utilities to help you manage FCP and iSCSI protocol operations with ONTAP LUNs.



You don't need to manually configure Kernel-based Virtual Machine (KVM) settings because ONTAP LUNs are automatically mapped to the hypervisor.

### Step 1: Optionally, enable SAN booting

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

### Before you begin



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

### Steps

1. [Create a SAN boot LUN and map it to the host.](#)
2. Enable SAN booting in the server BIOS for the ports to which the SAN boot LUN is mapped.

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

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

## Step 2: Install the Linux Host Utilities

NetApp strongly recommends installing the Linux Host Utilities to support ONTAP LUN management and assist technical support with gathering configuration data.

[Install Linux Host Utilities 8.0.](#)



Installing the Linux Host Utilities doesn't change any host timeout settings on your Linux host.

## Step 3: Confirm the multipath configuration for your host

You can use multipathing with RHEL 8.6 to manage ONTAP LUNs.

To ensure that multipathing is configured correctly for your host, verify that the `/etc/multipath.conf` file is defined and that you have the NetApp recommended settings configured for your ONTAP LUNs.

### Steps

1. Verify that the `/etc/multipath.conf` file exists. If the file doesn't exist, create an empty, zero-byte file:

```
touch /etc/multipath.conf
```

2. The first time the `multipath.conf` file is created, you might need to enable and start the multipath services to load the recommended settings:

```
systemctl enable multipathd
```

```
systemctl start multipathd
```

3. Each time you boot the host, the empty `/etc/multipath.conf` zero-byte file automatically loads the NetApp recommended host multipath parameters as the default settings. You shouldn't need to make changes to the `/etc/multipath.conf` file for your host because the operating system is compiled with the multipath parameters that recognize and manage ONTAP LUNs correctly.

The following table shows the Linux OS native compiled multipath parameter settings for ONTAP LUNs.

#### Show parameter settings

Parameter	Setting
detect_prio	yes
dev_loss_tmo	"infinity"
failback	immediate
fast_io_fail_tmo	5
features	"2 pg_init_retries 50"
flush_on_last_del	"yes"
hardware_handler	"0"
no_path_retry	queue
path_checker	"tur"
path_grouping_policy	"group_by_prio"
path_selector	"service-time 0"
polling_interval	5
prio	"ontap"
product	LUN
retain_attached_hw_handler	yes
rr_weight	"uniform"
user_friendly_names	no
vendor	NETAPP

4. Verify the parameter settings and path status for your ONTAP LUNs:

```
multipath -ll
```

The default multipath parameters support ASA, AFF, and FAS configurations. In these configurations, a single ONTAP LUN shouldn't require more than four paths. If there are more than four paths, it might cause issues with the paths during a storage failure.

The following example outputs show the correct parameter settings and path status for ONTAP LUNs in an ASA, AFF, or FAS configuration.

## ASA configuration

An ASA configuration optimizes all paths to a given LUN, keeping them active. This improves performance by serving I/O operations through all paths at the same time.

### Show example

```
multipath -ll
3600a098038314c4a433f577471797958 dm-2 NETAPP,LUN C-Mode
size=180G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
`-+- policy='service-time 0' prio=50 status=active
  |- 14:0:0:0   sdc  8:32   active ready running
  |- 17:0:0:0   sdas 66:192 active ready running
  |- 14:0:3:0   sdar 66:176 active ready running
  `-- 17:0:3:0   sdch 69:80  active ready running
```

## AFF or FAS configuration

An AFF or FAS configuration should have two groups of paths with higher and lower priorities. Higher priority Active/Optimized paths are served by the controller where the aggregate is located. Lower priority paths are active but non-optimized because they are served by a different controller. Non-optimized paths are only used when optimized paths aren't available.

The following example displays the output for an ONTAP LUN with two Active/Optimized paths and two Active/Non-Optimized paths:

### Show example

```
multipath -ll
3600a0980383149764b5d567257516273 dm-0 NETAPP,LUN C-Mode
size=150G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
|-+- policy='service-time 0' prio=50 status=active
| |- 16:0:3:0   sdcg 69:64  active ready running
| `-- 10:0:0:0   sdb  8:16   active ready running
`-+- policy='service-time 0' prio=10 status=enabled
  |- 10:0:1:0   sdc  8:32   active ready running
  `-- 16:0:2:0   sdcf 69:48  active ready running
```

## Step 4: Optionally, exclude a device from multipathing

If required, you can exclude a device from multipathing by adding the WWID for the unwanted device to the "blacklist" stanza for the `multipath.conf` file.

## Steps

1. Determine the WWID:

```
/lib/udev/scsi_id -gud /dev/sda
```

"sda" is the local SCSI disk that you want to add to the blacklist.

An example WWID is 360030057024d0730239134810c0cb833.

2. Add the WWID to the "blacklist" stanza:

```
blacklist {
    wwid      360030057024d0730239134810c0cb833
    devnode   "^(ram|raw|loop|fd|md|dm-|sr|scd|st) [0-9] *"
    devnode   "^hd[a-z]"
    devnode   "^cciss.*"
}
```

## Step 5: Customize multipath parameters for ONTAP LUNs

If your host is connected to LUNs from other vendors and any of the multipath parameter settings are overridden, you need to correct them by adding stanzas later in the `multipath.conf` file that apply specifically to ONTAP LUNs. If you don't do this, the ONTAP LUNs might not work as expected.

Check your `/etc/multipath.conf` file, especially in the defaults section, for settings that might be overriding the [default settings for multipath parameters](#).



You shouldn't override the recommended parameter settings for ONTAP LUNs. These settings are required for optimal performance of your host configuration. Contact NetApp support, your OS vendor, or both for more information.

The following example shows how to correct an overridden default. In this example, the `multipath.conf` file defines values for `path_checker` and `no_path_retry` that aren't compatible with ONTAP LUNs, and you can't remove these parameters because ONTAP storage arrays are still attached to the host. Instead, you correct the values for `path_checker` and `no_path_retry` by adding a device stanza to the `multipath.conf` file that applies specifically to the ONTAP LUNs.

## Show example

```
defaults {
    path_checker      readsector0
    no_path_retry     fail
}

devices {
    device {
        vendor        "NETAPP"
        product        "LUN"
        no_path_retry  queue
        path_checker   tur
    }
}
```

### Step 6: Review the known issues

There are no known issues.

### What's next?

- [Learn about using the Linux Host Utilities tool.](#)
- Learn about ASM mirroring.

Automatic Storage Management (ASM) mirroring might require changes to the Linux multipath settings to allow ASM to recognize a problem and switch over to an alternate failure group. Most ASM configurations on ONTAP use external redundancy, which means that data protection is provided by the external array and ASM doesn't mirror data. Some sites use ASM with normal redundancy to provide two-way mirroring, normally across different sites. See [Oracle databases on ONTAP](#) for further information.

## Configure RHEL 8.5 for FCP and iSCSI with ONTAP storage

The Linux Host Utilities software provides management and diagnostic tools for Linux hosts that are connected to ONTAP storage. When you install the Linux Host Utilities on a Red Hat Enterprise Linux (RHEL) 8.5 host, you can use the Host Utilities to help you manage FCP and iSCSI protocol operations with ONTAP LUNs.



You don't need to manually configure Kernel-based Virtual Machine (KVM) settings because ONTAP LUNs are automatically mapped to the hypervisor.

### Step 1: Optionally, enable SAN booting

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

### Before you begin

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

### Steps

1. [Create a SAN boot LUN and map it to the host.](#)
2. Enable SAN booting in the server BIOS for the ports to which the SAN boot LUN is mapped.

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

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

## Step 2: Install the Linux Host Utilities

NetApp strongly recommends installing the Linux Host Utilities to support ONTAP LUN management and assist technical support with gathering configuration data.

[Install Linux Host Utilities 8.0.](#)



Installing the Linux Host Utilities doesn't change any host timeout settings on your Linux host.

## Step 3: Confirm the multipath configuration for your host

You can use multipathing with RHEL 8.5 to manage ONTAP LUNs.

To ensure that multipathing is configured correctly for your host, verify that the `/etc/multipath.conf` file is defined and that you have the NetApp recommended settings configured for your ONTAP LUNs.

### Steps

1. Verify that the `/etc/multipath.conf` file exists. If the file doesn't exist, create an empty, zero-byte file:

```
touch /etc/multipath.conf
```

2. The first time the `multipath.conf` file is created, you might need to enable and start the multipath services to load the recommended settings:

```
systemctl enable multipathd
```

```
systemctl start multipathd
```

3. Each time you boot the host, the empty `/etc/multipath.conf` zero-byte file automatically loads the NetApp recommended host multipath parameters as the default settings. You shouldn't need to make changes to the `/etc/multipath.conf` file for your host because the operating system is compiled with the multipath parameters that recognize and manage ONTAP LUNs correctly.

The following table shows the Linux OS native compiled multipath parameter settings for ONTAP LUNs.

### Show parameter settings

Parameter	Setting
detect_prio	yes
dev_loss_tmo	"infinity"
failback	immediate
fast_io_fail_tmo	5
features	"2 pg_init_retries 50"
flush_on_last_del	"yes"
hardware_handler	"0"
no_path_retry	queue
path_checker	"tur"
path_grouping_policy	"group_by_prio"
path_selector	"service-time 0"
polling_interval	5
prio	"ontap"
product	LUN
retain_attached_hw_handler	yes
rr_weight	"uniform"
user_friendly_names	no
vendor	NETAPP

#### 4. Verify the parameter settings and path status for your ONTAP LUNs:

```
multipath -ll
```

The default multipath parameters support ASA, AFF, and FAS configurations. In these configurations, a single ONTAP LUN shouldn't require more than four paths. If there are more than four paths, it might cause issues with the paths during a storage failure.

The following example outputs show the correct parameter settings and path status for ONTAP LUNs in an ASA, AFF, or FAS configuration.

## ASA configuration

An ASA configuration optimizes all paths to a given LUN, keeping them active. This improves performance by serving I/O operations through all paths at the same time.

### Show example

```
multipath -ll
3600a098038314c4a433f577471797958 dm-2 NETAPP,LUN C-Mode
size=180G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
`-+- policy='service-time 0' prio=50 status=active
  |- 14:0:0:0   sdc  8:32   active ready running
  |- 17:0:0:0   sdas 66:192 active ready running
  |- 14:0:3:0   sdar 66:176 active ready running
  `-- 17:0:3:0   sdch 69:80   active ready running
```

## AFF or FAS configuration

An AFF or FAS configuration should have two groups of paths with higher and lower priorities. Higher priority Active/Optimized paths are served by the controller where the aggregate is located. Lower priority paths are active but non-optimized because they are served by a different controller. Non-optimized paths are only used when optimized paths aren't available.

The following example displays the output for an ONTAP LUN with two Active/Optimized paths and two Active/Non-Optimized paths:

### Show example

```
multipath -ll
3600a0980383149764b5d567257516273 dm-0 NETAPP,LUN C-Mode
size=150G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
|-+- policy='service-time 0' prio=50 status=active
| |- 16:0:3:0   sdcg 69:64   active ready running
| `-- 10:0:0:0   sdb  8:16    active ready running
`-+- policy='service-time 0' prio=10 status=enabled
  |- 10:0:1:0   sdc  8:32    active ready running
  `-- 16:0:2:0   sdcf 69:48   active ready running
```

## Step 4: Optionally, exclude a device from multipathing

If required, you can exclude a device from multipathing by adding the WWID for the unwanted device to the "blacklist" stanza for the `multipath.conf` file.



## Steps

1. Determine the WWID:

```
/lib/udev/scsi_id -gud /dev/sda
```

"sda" is the local SCSI disk that you want to add to the blacklist.

An example WWID is 360030057024d0730239134810c0cb833.

2. Add the WWID to the "blacklist" stanza:

```
blacklist {  
    wwid      360030057024d0730239134810c0cb833  
    devnode   "^(ram|raw|loop|fd|md|dm-|sr|scd|st)[0-9]*"  
    devnode   "^hd[a-z]"  
    devnode   "^cciss.*"  
}
```

## Step 5: Customize multipath parameters for ONTAP LUNs

If your host is connected to LUNs from other vendors and any of the multipath parameter settings are overridden, you need to correct them by adding stanzas later in the `multipath.conf` file that apply specifically to ONTAP LUNs. If you don't do this, the ONTAP LUNs might not work as expected.

Check your `/etc/multipath.conf` file, especially in the defaults section, for settings that might be overriding the [default settings for multipath parameters](#).



You shouldn't override the recommended parameter settings for ONTAP LUNs. These settings are required for optimal performance of your host configuration. Contact NetApp support, your OS vendor, or both for more information.

The following example shows how to correct an overridden default. In this example, the `multipath.conf` file defines values for `path_checker` and `no_path_retry` that aren't compatible with ONTAP LUNs, and you can't remove these parameters because ONTAP storage arrays are still attached to the host. Instead, you correct the values for `path_checker` and `no_path_retry` by adding a device stanza to the `multipath.conf` file that applies specifically to the ONTAP LUNs.

## Show example

```
defaults {
    path_checker      readsector0
    no_path_retry     fail
}

devices {
    device {
        vendor        "NETAPP"
        product        "LUN"
        no_path_retry  queue
        path_checker   tur
    }
}
```

### Step 6: Review the known issues

There are no known issues.

### What's next?

- [Learn about using the Linux Host Utilities tool.](#)
- Learn about ASM mirroring.

Automatic Storage Management (ASM) mirroring might require changes to the Linux multipath settings to allow ASM to recognize a problem and switch over to an alternate failure group. Most ASM configurations on ONTAP use external redundancy, which means that data protection is provided by the external array and ASM doesn't mirror data. Some sites use ASM with normal redundancy to provide two-way mirroring, normally across different sites. See [Oracle databases on ONTAP](#) for further information.

## Configure RHEL 8.4 for FCP and iSCSI with ONTAP storage

The Linux Host Utilities software provides management and diagnostic tools for Linux hosts that are connected to ONTAP storage. When you install the Linux Host Utilities on a Red Hat Enterprise Linux (RHEL) 8.4 host, you can use the Host Utilities to help you manage FCP and iSCSI protocol operations with ONTAP LUNs.



You don't need to manually configure Kernel-based Virtual Machine (KVM) settings because ONTAP LUNs are automatically mapped to the hypervisor.

### Step 1: Optionally, enable SAN booting

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

### Before you begin

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

### Steps

1. [Create a SAN boot LUN and map it to the host.](#)
2. Enable SAN booting in the server BIOS for the ports to which the SAN boot LUN is mapped.

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

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

## Step 2: Install the Linux Host Utilities

NetApp strongly recommends installing the Linux Host Utilities to support ONTAP LUN management and assist technical support with gathering configuration data.

[Install Linux Host Utilities 8.0.](#)



Installing the Linux Host Utilities doesn't change any host timeout settings on your Linux host.

## Step 3: Confirm the multipath configuration for your host

You can use multipathing with RHEL 8.4 to manage ONTAP LUNs.

To ensure that multipathing is configured correctly for your host, verify that the `/etc/multipath.conf` file is defined and that you have the NetApp recommended settings configured for your ONTAP LUNs.

### Steps

1. Verify that the `/etc/multipath.conf` file exists. If the file doesn't exist, create an empty, zero-byte file:

```
touch /etc/multipath.conf
```

2. The first time the `multipath.conf` file is created, you might need to enable and start the multipath services to load the recommended settings:

```
systemctl enable multipathd
```

```
systemctl start multipathd
```

3. Each time you boot the host, the empty `/etc/multipath.conf` zero-byte file automatically loads the NetApp recommended host multipath parameters as the default settings. You shouldn't need to make changes to the `/etc/multipath.conf` file for your host because the operating system is compiled with the multipath parameters that recognize and manage ONTAP LUNs correctly.

The following table shows the Linux OS native compiled multipath parameter settings for ONTAP LUNs.

## Show parameter settings

Parameter	Setting
detect_prio	yes
dev_loss_tmo	"infinity"
failback	immediate
fast_io_fail_tmo	5
features	"2 pg_init_retries 50"
flush_on_last_del	"yes"
hardware_handler	"0"
no_path_retry	queue
path_checker	"tur"
path_grouping_policy	"group_by_prio"
path_selector	"service-time 0"
polling_interval	5
prio	"ontap"
product	LUN
retain_attached_hw_handler	yes
rr_weight	"uniform"
user_friendly_names	no
vendor	NETAPP

4. Verify the parameter settings and path status for your ONTAP LUNs:

```
multipath -ll
```

The default multipath parameters support ASA, AFF, and FAS configurations. In these configurations, a single ONTAP LUN shouldn't require more than four paths. If there are more than four paths, it might cause issues with the paths during a storage failure.

The following example outputs show the correct parameter settings and path status for ONTAP LUNs in an ASA, AFF, or FAS configuration.

## ASA configuration

An ASA configuration optimizes all paths to a given LUN, keeping them active. This improves performance by serving I/O operations through all paths at the same time.

### Show example

```
multipath -ll
3600a098038314c4a433f577471797958 dm-2 NETAPP,LUN C-Mode
size=180G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
`-+- policy='service-time 0' prio=50 status=active
| - 14:0:0:0 sdc 8:32 active ready running
| - 17:0:0:0 sdas 66:192 active ready running
| - 14:0:3:0 sdar 66:176 active ready running
`- 17:0:3:0 sdch 69:80 active ready running
```

## AFF or FAS configuration

An AFF or FAS configuration should have two groups of paths with higher and lower priorities. Higher priority Active/Optimized paths are served by the controller where the aggregate is located. Lower priority paths are active but non-optimized because they are served by a different controller. Non-optimized paths are only used when optimized paths aren't available.

The following example displays the output for an ONTAP LUN with two Active/Optimized paths and two Active/Non-Optimized paths:

### Show example

```
multipath -ll
3600a0980383149764b5d567257516273 dm-0 NETAPP,LUN C-Mode
size=150G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
|+- policy='service-time 0' prio=50 status=active
| | - 16:0:3:0 sdcg 69:64 active ready running
| ` - 10:0:0:0 sdb 8:16 active ready running
`+- policy='service-time 0' prio=10 status=enabled
| - 10:0:1:0 sdc 8:32 active ready running
`- 16:0:2:0 sdcf 69:48 active ready running
```

## Step 4: Optionally, exclude a device from multipathing

If required, you can exclude a device from multipathing by adding the WWID for the unwanted device to the "blacklist" stanza for the `multipath.conf` file.

## Steps

1. Determine the WWID:

```
/lib/udev/scsi_id -gud /dev/sda
```

"sda" is the local SCSI disk that you want to add to the blacklist.

An example WWID is 360030057024d0730239134810c0cb833.

2. Add the WWID to the "blacklist" stanza:

```
blacklist {  
    wwid      360030057024d0730239134810c0cb833  
    devnode   "^(ram|raw|loop|fd|md|dm-|sr|scd|st) [0-9] *"  
    devnode   "^hd[a-z] "  
    devnode   "^cciss.*"  
}
```

## Step 5: Customize multipath parameters for ONTAP LUNs

If your host is connected to LUNs from other vendors and any of the multipath parameter settings are overridden, you need to correct them by adding stanzas later in the `multipath.conf` file that apply specifically to ONTAP LUNs. If you don't do this, the ONTAP LUNs might not work as expected.

Check your `/etc/multipath.conf` file, especially in the defaults section, for settings that might be overriding the [default settings for multipath parameters](#).



You shouldn't override the recommended parameter settings for ONTAP LUNs. These settings are required for optimal performance of your host configuration. Contact NetApp support, your OS vendor, or both for more information.

The following example shows how to correct an overridden default. In this example, the `multipath.conf` file defines values for `path_checker` and `no_path_retry` that aren't compatible with ONTAP LUNs, and you can't remove these parameters because ONTAP storage arrays are still attached to the host. Instead, you correct the values for `path_checker` and `no_path_retry` by adding a device stanza to the `multipath.conf` file that applies specifically to the ONTAP LUNs.

## Show example

```
defaults {
    path_checker      readsector0
    no_path_retry     fail
}

devices {
    device {
        vendor        "NETAPP"
        product        "LUN"
        no_path_retry  queue
        path_checker   tur
    }
}
```

### Step 6: Review the known issues

There are no known issues.

### What's next?

- [Learn about using the Linux Host Utilities tool.](#)
- Learn about ASM mirroring.

Automatic Storage Management (ASM) mirroring might require changes to the Linux multipath settings to allow ASM to recognize a problem and switch over to an alternate failure group. Most ASM configurations on ONTAP use external redundancy, which means that data protection is provided by the external array and ASM doesn't mirror data. Some sites use ASM with normal redundancy to provide two-way mirroring, normally across different sites. See [Oracle databases on ONTAP](#) for further information.

## Configure RHEL 8.3 for FCP and iSCSI with ONTAP storage

The Linux Host Utilities software provides management and diagnostic tools for Linux hosts that are connected to ONTAP storage. When you install the Linux Host Utilities on a Red Hat Enterprise Linux (RHEL) 8.3 host, you can use the Host Utilities to help you manage FCP and iSCSI protocol operations with ONTAP LUNs.



You don't need to manually configure Kernel-based Virtual Machine (KVM) settings because ONTAP LUNs are automatically mapped to the hypervisor.

### Step 1: Optionally, enable SAN booting

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

### Before you begin

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

### Steps

1. [Create a SAN boot LUN and map it to the host.](#)
2. Enable SAN booting in the server BIOS for the ports to which the SAN boot LUN is mapped.

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

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

## Step 2: Install the Linux Host Utilities

NetApp strongly recommends installing the Linux Host Utilities to support ONTAP LUN management and assist technical support with gathering configuration data.

[Install Linux Host Utilities 8.0.](#)



Installing the Linux Host Utilities doesn't change any host timeout settings on your Linux host.

## Step 3: Confirm the multipath configuration for your host

You can use multipathing with RHEL 8.3 to manage ONTAP LUNs.

To ensure that multipathing is configured correctly for your host, verify that the `/etc/multipath.conf` file is defined and that you have the NetApp recommended settings configured for your ONTAP LUNs.

### Steps

1. Verify that the `/etc/multipath.conf` file exists. If the file doesn't exist, create an empty, zero-byte file:

```
touch /etc/multipath.conf
```

2. The first time the `multipath.conf` file is created, you might need to enable and start the multipath services to load the recommended settings:

```
systemctl enable multipathd
```

```
systemctl start multipathd
```

3. Each time you boot the host, the empty `/etc/multipath.conf` zero-byte file automatically loads the NetApp recommended host multipath parameters as the default settings. You shouldn't need to make changes to the `/etc/multipath.conf` file for your host because the operating system is compiled with the multipath parameters that recognize and manage ONTAP LUNs correctly.

The following table shows the Linux OS native compiled multipath parameter settings for ONTAP LUNs.



### Show parameter settings

Parameter	Setting
detect_prio	yes
dev_loss_tmo	"infinity"
failback	immediate
fast_io_fail_tmo	5
features	"2 pg_init_retries 50"
flush_on_last_del	"yes"
hardware_handler	"0"
no_path_retry	queue
path_checker	"tur"
path_grouping_policy	"group_by_prio"
path_selector	"service-time 0"
polling_interval	5
prio	"ontap"
product	LUN
retain_attached_hw_handler	yes
rr_weight	"uniform"
user_friendly_names	no
vendor	NETAPP

#### 4. Verify the parameter settings and path status for your ONTAP LUNs:

```
multipath -ll
```

The default multipath parameters support ASA, AFF, and FAS configurations. In these configurations, a single ONTAP LUN shouldn't require more than four paths. If there are more than four paths, it might cause issues with the paths during a storage failure.

The following example outputs show the correct parameter settings and path status for ONTAP LUNs in an ASA, AFF, or FAS configuration.

### ASA configuration

An ASA configuration optimizes all paths to a given LUN, keeping them active. This improves performance by serving I/O operations through all paths at the same time.

#### Show example

```
multipath -ll
3600a098038314c4a433f577471797958 dm-2 NETAPP,LUN C-Mode
size=180G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
`-+- policy='service-time 0' prio=50 status=active
| - 14:0:0:0 sdc 8:32 active ready running
| - 17:0:0:0 sdas 66:192 active ready running
| - 14:0:3:0 sdar 66:176 active ready running
`- 17:0:3:0 sdch 69:80 active ready running
```

### AFF or FAS configuration

An AFF or FAS configuration should have two groups of paths with higher and lower priorities. Higher priority Active/Optimized paths are served by the controller where the aggregate is located. Lower priority paths are active but non-optimized because they are served by a different controller. Non-optimized paths are only used when optimized paths aren't available.

The following example displays the output for an ONTAP LUN with two Active/Optimized paths and two Active/Non-Optimized paths:

#### Show example

```
multipath -ll
3600a0980383149764b5d567257516273 dm-0 NETAPP,LUN C-Mode
size=150G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
| -+- policy='service-time 0' prio=50 status=active
| | - 16:0:3:0 sdcg 69:64 active ready running
| | ` - 10:0:0:0 sdb 8:16 active ready running
`-+- policy='service-time 0' prio=10 status=enabled
| - 10:0:1:0 sdc 8:32 active ready running
`- 16:0:2:0 sdcf 69:48 active ready running
```

## Step 4: Optionally, exclude a device from multipathing

If required, you can exclude a device from multipathing by adding the WWID for the unwanted device to the "blacklist" stanza for the `multipath.conf` file.

## Steps

1. Determine the WWID:

```
/lib/udev/scsi_id -gud /dev/sda
```

"sda" is the local SCSI disk that you want to add to the blacklist.

An example WWID is 360030057024d0730239134810c0cb833.

2. Add the WWID to the "blacklist" stanza:

```
blacklist {
    wwid      360030057024d0730239134810c0cb833
    devnode   "^(ram|raw|loop|fd|md|dm-|sr|scd|st)[0-9]*"
    devnode   "^hd[a-z]"
    devnode   "^cciss.*"
}
```

## Step 5: Customize multipath parameters for ONTAP LUNs

If your host is connected to LUNs from other vendors and any of the multipath parameter settings are overridden, you need to correct them by adding stanzas later in the `multipath.conf` file that apply specifically to ONTAP LUNs. If you don't do this, the ONTAP LUNs might not work as expected.

Check your `/etc/multipath.conf` file, especially in the defaults section, for settings that might be overriding the [default settings for multipath parameters](#).



You shouldn't override the recommended parameter settings for ONTAP LUNs. These settings are required for optimal performance of your host configuration. Contact NetApp support, your OS vendor, or both for more information.

The following example shows how to correct an overridden default. In this example, the `multipath.conf` file defines values for `path_checker` and `no_path_retry` that aren't compatible with ONTAP LUNs, and you can't remove these parameters because ONTAP storage arrays are still attached to the host. Instead, you correct the values for `path_checker` and `no_path_retry` by adding a device stanza to the `multipath.conf` file that applies specifically to the ONTAP LUNs.

## Show example

```
defaults {
    path_checker      readsector0
    no_path_retry     fail
}

devices {
    device {
        vendor        "NETAPP"
        product       "LUN"
        no_path_retry  queue
        path_checker   tur
    }
}
```

### Step 6: Review the known issues

There are no known issues.

### What's next?

- [Learn about using the Linux Host Utilities tool.](#)
- Learn about ASM mirroring.

Automatic Storage Management (ASM) mirroring might require changes to the Linux multipath settings to allow ASM to recognize a problem and switch over to an alternate failure group. Most ASM configurations on ONTAP use external redundancy, which means that data protection is provided by the external array and ASM doesn't mirror data. Some sites use ASM with normal redundancy to provide two-way mirroring, normally across different sites. See [Oracle databases on ONTAP](#) for further information.

## Configure RHEL 8.2 for FCP and iSCSI with ONTAP storage

The Linux Host Utilities software provides management and diagnostic tools for Linux hosts that are connected to ONTAP storage. When you install the Linux Host Utilities on a Red Hat Enterprise Linux (RHEL) 8.2 host, you can use the Host Utilities to help you manage FCP and iSCSI protocol operations with ONTAP LUNs.



You don't need to manually configure Kernel-based Virtual Machine (KVM) settings because ONTAP LUNs are automatically mapped to the hypervisor.

### Step 1: Optionally, enable SAN booting

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

### Before you begin

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

### Steps

1. [Create a SAN boot LUN and map it to the host.](#)
2. Enable SAN booting in the server BIOS for the ports to which the SAN boot LUN is mapped.

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

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

## Step 2: Install the Linux Host Utilities

NetApp strongly recommends installing the Linux Host Utilities to support ONTAP LUN management and assist technical support with gathering configuration data.

[Install Linux Host Utilities 8.0.](#)



Installing the Linux Host Utilities doesn't change any host timeout settings on your Linux host.

## Step 3: Confirm the multipath configuration for your host

You can use multipathing with RHEL 8.2 to manage ONTAP LUNs.

To ensure that multipathing is configured correctly for your host, verify that the `/etc/multipath.conf` file is defined and that you have the NetApp recommended settings configured for your ONTAP LUNs.

### Steps

1. Verify that the `/etc/multipath.conf` file exists. If the file doesn't exist, create an empty, zero-byte file:

```
touch /etc/multipath.conf
```

2. The first time the `multipath.conf` file is created, you might need to enable and start the multipath services to load the recommended settings:

```
systemctl enable multipathd
```

```
systemctl start multipathd
```

3. Each time you boot the host, the empty `/etc/multipath.conf` zero-byte file automatically loads the NetApp recommended host multipath parameters as the default settings. You shouldn't need to make changes to the `/etc/multipath.conf` file for your host because the operating system is compiled with the multipath parameters that recognize and manage ONTAP LUNs correctly.

The following table shows the Linux OS native compiled multipath parameter settings for ONTAP LUNs.

## Show parameter settings

Parameter	Setting
detect_prio	yes
dev_loss_tmo	"infinity"
failback	immediate
fast_io_fail_tmo	5
features	"2 pg_init_retries 50"
flush_on_last_del	"yes"
hardware_handler	"0"
no_path_retry	queue
path_checker	"tur"
path_grouping_policy	"group_by_prio"
path_selector	"service-time 0"
polling_interval	5
prio	"ontap"
product	LUN
retain_attached_hw_handler	yes
rr_weight	"uniform"
user_friendly_names	no
vendor	NETAPP

### 4. Verify the parameter settings and path status for your ONTAP LUNs:

```
multipath -ll
```

The default multipath parameters support ASA, AFF, and FAS configurations. In these configurations, a single ONTAP LUN shouldn't require more than four paths. If there are more than four paths, it might cause issues with the paths during a storage failure.

The following example outputs show the correct parameter settings and path status for ONTAP LUNs in an ASA, AFF, or FAS configuration.

## ASA configuration

An ASA configuration optimizes all paths to a given LUN, keeping them active. This improves performance by serving I/O operations through all paths at the same time.

### Show example

```
multipath -ll
3600a098038314c4a433f577471797958 dm-2 NETAPP,LUN C-Mode
size=180G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
`-+- policy='service-time 0' prio=50 status=active
| - 14:0:0:0 sdc 8:32 active ready running
| - 17:0:0:0 sdas 66:192 active ready running
| - 14:0:3:0 sdar 66:176 active ready running
`- 17:0:3:0 sdch 69:80 active ready running
```

## AFF or FAS configuration

An AFF or FAS configuration should have two groups of paths with higher and lower priorities. Higher priority Active/Optimized paths are served by the controller where the aggregate is located. Lower priority paths are active but non-optimized because they are served by a different controller. Non-optimized paths are only used when optimized paths aren't available.

The following example displays the output for an ONTAP LUN with two Active/Optimized paths and two Active/Non-Optimized paths:

### Show example

```
multipath -ll
3600a0980383149764b5d567257516273 dm-0 NETAPP,LUN C-Mode
size=150G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
| -+- policy='service-time 0' prio=50 status=active
| | - 16:0:3:0 sdcg 69:64 active ready running
| | ` - 10:0:0:0 sdb 8:16 active ready running
`-+- policy='service-time 0' prio=10 status=enabled
| - 10:0:1:0 sdc 8:32 active ready running
`- 16:0:2:0 sdcf 69:48 active ready running
```

## Step 4: Optionally, exclude a device from multipathing

If required, you can exclude a device from multipathing by adding the WWID for the unwanted device to the "blacklist" stanza for the `multipath.conf` file.

## Steps

1. Determine the WWID:

```
/lib/udev/scsi_id -gud /dev/sda
```

"sda" is the local SCSI disk that you want to add to the blacklist.

An example WWID is 360030057024d0730239134810c0cb833.

2. Add the WWID to the "blacklist" stanza:

```
blacklist {
    wwid      360030057024d0730239134810c0cb833
    devnode   "^(ram|raw|loop|fd|md|dm-|sr|scd|st)[0-9]*"
    devnode   "^hd[a-z]"
    devnode   "^cciss.*"
}
```

## Step 5: Customize multipath parameters for ONTAP LUNs

If your host is connected to LUNs from other vendors and any of the multipath parameter settings are overridden, you need to correct them by adding stanzas later in the `multipath.conf` file that apply specifically to ONTAP LUNs. If you don't do this, the ONTAP LUNs might not work as expected.

Check your `/etc/multipath.conf` file, especially in the defaults section, for settings that might be overriding the [default settings for multipath parameters](#).



You shouldn't override the recommended parameter settings for ONTAP LUNs. These settings are required for optimal performance of your host configuration. Contact NetApp support, your OS vendor, or both for more information.

The following example shows how to correct an overridden default. In this example, the `multipath.conf` file defines values for `path_checker` and `no_path_retry` that aren't compatible with ONTAP LUNs, and you can't remove these parameters because ONTAP storage arrays are still attached to the host. Instead, you correct the values for `path_checker` and `no_path_retry` by adding a device stanza to the `multipath.conf` file that applies specifically to the ONTAP LUNs.



## Show example

```
defaults {
    path_checker      readsector0
    no_path_retry     fail
}

devices {
    device {
        vendor        "NETAPP"
        product        "LUN"
        no_path_retry  queue
        path_checker   tur
    }
}
```

### Step 6: Review the known issues

There are no known issues.

### What's next?

- [Learn about using the Linux Host Utilities tool.](#)
- Learn about ASM mirroring.

Automatic Storage Management (ASM) mirroring might require changes to the Linux multipath settings to allow ASM to recognize a problem and switch over to an alternate failure group. Most ASM configurations on ONTAP use external redundancy, which means that data protection is provided by the external array and ASM doesn't mirror data. Some sites use ASM with normal redundancy to provide two-way mirroring, normally across different sites. See [Oracle databases on ONTAP](#) for further information.

## Configure RHEL 8.1 for FCP and iSCSI with ONTAP storage

The Linux Host Utilities software provides management and diagnostic tools for Linux hosts that are connected to ONTAP storage. When you install the Linux Host Utilities on a Red Hat Enterprise Linux (RHEL) 8.1 host, you can use the Host Utilities to support managing FCP and iSCSI protocol operations with ONTAP LUNs.



You don't need to manually configure Kernel-based Virtual Machine (KVM) settings because ONTAP LUNs are automatically mapped to the hypervisor.

### Step 1: Optionally, enable SAN booting

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

### Before you begin

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

### Steps

1. [Create a SAN boot LUN and map it to the host.](#)
2. Enable SAN booting in the server BIOS for the ports to which the SAN boot LUN is mapped.

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

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

## Step 2: Install the Linux Host Utilities

NetApp strongly recommends installing the Linux Host Utilities to support ONTAP LUN management and assist technical support with gathering configuration data.

[Install Linux Host Utilities 8.0.](#)



Installing the Linux Host Utilities doesn't change any host timeout settings on your Linux host.

## Step 3: Confirm the multipath configuration for your host

You can use multipathing with RHEL 8.1 to manage ONTAP LUNs.

To ensure that multipathing is configured correctly for your host, verify that the `/etc/multipath.conf` file is defined and that you have the NetApp recommended settings configured for your ONTAP LUNs.

### Steps

1. Verify that the `/etc/multipath.conf` file exists. If the file doesn't exist, create an empty, zero-byte file:

```
touch /etc/multipath.conf
```

2. The first time the `multipath.conf` file is created, you might need to enable and start the multipath services to load the recommended settings:

```
systemctl enable multipathd
```

```
systemctl start multipathd
```

3. Each time you boot the host, the empty `/etc/multipath.conf` zero-byte file automatically loads the NetApp recommended host multipath parameters as the default settings. You shouldn't need to make changes to the `/etc/multipath.conf` file for your host because the operating system is compiled with the multipath parameters that recognize and manage ONTAP LUNs correctly.

The following table shows the Linux OS native compiled multipath parameter settings for ONTAP LUNs.

### Show parameter settings

Parameter	Setting
detect_prio	yes
dev_loss_tmo	"infinity"
failback	immediate
fast_io_fail_tmo	5
features	"2 pg_init_retries 50"
flush_on_last_del	"yes"
hardware_handler	"0"
no_path_retry	queue
path_checker	"tur"
path_grouping_policy	"group_by_prio"
path_selector	"service-time 0"
polling_interval	5
prio	"ontap"
product	LUN
retain_attached_hw_handler	yes
rr_weight	"uniform"
user_friendly_names	no
vendor	NETAPP

#### 4. Verify the parameter settings and path status for your ONTAP LUNs:

```
multipath -ll
```

The default multipath parameters support ASA, AFF, and FAS configurations. In these configurations, a single ONTAP LUN shouldn't require more than four paths. If there are more than four paths, it might cause issues with the paths during a storage failure.

The following example outputs show the correct parameter settings and path status for ONTAP LUNs in an ASA, AFF, or FAS configuration.

## ASA configuration

An ASA configuration optimizes all paths to a given LUN, keeping them active. This improves performance by serving I/O operations through all paths at the same time.

### Show example

```
multipath -ll
3600a098038314c4a433f577471797958 dm-2 NETAPP,LUN C-Mode
size=180G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
`-+- policy='service-time 0' prio=50 status=active
| - 14:0:0:0 sdc 8:32 active ready running
| - 17:0:0:0 sdas 66:192 active ready running
| - 14:0:3:0 sdar 66:176 active ready running
`- 17:0:3:0 sdch 69:80 active ready running
```

## AFF or FAS configuration

An AFF or FAS configuration should have two groups of paths with higher and lower priorities. Higher priority Active/Optimized paths are served by the controller where the aggregate is located. Lower priority paths are active but non-optimized because they are served by a different controller. Non-optimized paths are only used when optimized paths aren't available.

The following example displays the output for an ONTAP LUN with two Active/Optimized paths and two Active/Non-Optimized paths:

### Show example

```
multipath -ll
3600a0980383149764b5d567257516273 dm-0 NETAPP,LUN C-Mode
size=150G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
|+- policy='service-time 0' prio=50 status=active
| | - 16:0:3:0 sdcg 69:64 active ready running
| ` - 10:0:0:0 sdb 8:16 active ready running
`+- policy='service-time 0' prio=10 status=enabled
| - 10:0:1:0 sdc 8:32 active ready running
`- 16:0:2:0 sdcf 69:48 active ready running
```

## Step 4: Optionally, exclude a device from multipathing

If required, you can exclude a device from multipathing by adding the WWID for the unwanted device to the "blacklist" stanza for the `multipath.conf` file.

## Steps

1. Determine the WWID:

```
/lib/udev/scsi_id -gud /dev/sda
```

"sda" is the local SCSI disk that you want to add to the blacklist.

An example WWID is 360030057024d0730239134810c0cb833.

2. Add the WWID to the "blacklist" stanza:

```
blacklist {
    wwid      360030057024d0730239134810c0cb833
    devnode   "^(ram|raw|loop|fd|md|dm-|sr|scd|st)[0-9]*"
    devnode   "^hd[a-z]"
    devnode   "^cciss.*"
}
```

## Step 5: Customize multipath parameters for ONTAP LUNs

If your host is connected to LUNs from other vendors and any of the multipath parameter settings are overridden, you need to correct them by adding stanzas later in the `multipath.conf` file that apply specifically to ONTAP LUNs. If you don't do this, the ONTAP LUNs might not work as expected.

Check your `/etc/multipath.conf` file, especially in the defaults section, for settings that might be overriding the [default settings for multipath parameters](#).



You shouldn't override the recommended parameter settings for ONTAP LUNs. These settings are required for optimal performance of your host configuration. Contact NetApp support, your OS vendor, or both for more information.

The following example shows how to correct an overridden default. In this example, the `multipath.conf` file defines values for `path_checker` and `no_path_retry` that aren't compatible with ONTAP LUNs, and you can't remove these parameters because ONTAP storage arrays are still attached to the host. Instead, you correct the values for `path_checker` and `no_path_retry` by adding a device stanza to the `multipath.conf` file that applies specifically to the ONTAP LUNs.

## Show example

```
defaults {
    path_checker      readsector0
    no_path_retry     fail
}

devices {
    device {
        vendor        "NETAPP"
        product        "LUN"
        no_path_retry  queue
        path_checker   tur
    }
}
```

## Step 6: Review the known issues

The RHEL 8.1 with ONTAP storage release has the following known issues:

NetApp Bug ID	Title	Description
<a href="#">1275843</a>	Kernel disruption might occur on Red Hat Enterprise Linux 8.1 with QLogic QLE2672 16GB FC HBA during storage failover operation	Kernel disruption might occur during storage failover operations on the Red Hat Enterprise Linux 8.1 kernel with a QLogic QLE2672 Fibre Channel (FC) host bus adapter (HBA). The kernel disruption causes Red Hat Enterprise Linux 8.1 to reboot, leading to application disruption. If the kdump mechanism is enabled, the kernel disruption generates a vmcore file located in the /var/crash/ directory. You can check the vmcore file to determine the cause of the disruption. A storage failover with the QLogic QLE2672 HBA event affects the "kmem_cache_alloc+131" module. You can locate the event in the vmcore file by finding the following string: "[exception RIP: kmem_cache_alloc+131]" After the kernel disruption, reboot the Host OS and recover the operating system. Then restart the applications

NetApp Bug ID	Title	Description
<a href="#">1275838</a>	Kernel disruption occurs on Red Hat Enterprise Linux 8.1 with QLogic QLE2742 32GB FC HBA during storage failover operations	Kernel disruption occurs during storage failover operations on the Red Hat Enterprise Linux 8.1 kernel with a QLogic QLE2742 Fibre Channel (FC) host bus adapter (HBA). The kernel disruption causes Red Hat Enterprise Linux 8.1 to reboot, leading to application disruption. If the kdump mechanism is enabled, the kernel disruption generates a vmcore file located in the /var/crash/ directory. You can check the vmcore file to determine the cause of the disruption. A storage failover with the QLogic QLE2742 HBA event affects the "kmem_cache_alloc+131" module. You can locate the event in the vmcore file by finding the following string: "[exception RIP: kmem_cache_alloc+131]" After the kernel disruption, reboot the Host OS and recover the operating system. Then restart the applications.
<a href="#">1266250</a>	Login to multiple paths fails during the Red Hat Enterprise Linux 8.1 installation on iSCSI SAN LUN	You cannot login to multiple paths during the Red Hat Enterprise Linux 8.1 installation on iSCSI SAN LUN multipath devices. Installation is not possible on multipath iSCSI device and the multipath service is not enabled on the SAN boot device.

### What's next?

- [Learn about using the Linux Host Utilities tool.](#)
- Learn about ASM mirroring.

Automatic Storage Management (ASM) mirroring might require changes to the Linux multipath settings to allow ASM to recognize a problem and switch over to an alternate failure group. Most ASM configurations on ONTAP use external redundancy, which means that data protection is provided by the external array and ASM doesn't mirror data. Some sites use ASM with normal redundancy to provide two-way mirroring, normally across different sites. See [Oracle databases on ONTAP](#) for further information.

## Configure RHEL 8.0 for FCP and iSCSI with ONTAP storage

The Linux Host Utilities software provides management and diagnostic tools for Linux hosts that are connected to ONTAP storage. When you install the Linux Host Utilities on a Red Hat Enterprise Linux (RHEL) 8.0 host, you can use the Host Utilities to help you manage FCP and iSCSI protocol operations with ONTAP LUNs.



You don't need to manually configure Kernel-based Virtual Machine (KVM) settings because ONTAP LUNs are automatically mapped to the hypervisor.

### Step 1: Optionally, enable SAN booting

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

#### Before you begin

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

#### Steps

1. [Create a SAN boot LUN and map it to the host.](#)
2. Enable SAN booting in the server BIOS for the ports to which the SAN boot LUN is mapped.

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

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

### Step 2: Install the Linux Host Utilities

NetApp strongly recommends installing the Linux Host Utilities to support ONTAP LUN management and assist technical support with gathering configuration data.

[Install Linux Host Utilities 8.0.](#)



Installing the Linux Host Utilities doesn't change any host timeout settings on your Linux host.

### Step 3: Confirm the multipath configuration for your host

You can use multipathing with RHEL 8.0 to manage ONTAP LUNs.

To ensure that multipathing is configured correctly for your host, verify that the `/etc/multipath.conf` file is defined and that you have the NetApp recommended settings configured for your ONTAP LUNs.

#### Steps

1. Verify that the `/etc/multipath.conf` file exists. If the file doesn't exist, create an empty, zero-byte file:

```
touch /etc/multipath.conf
```

2. The first time the `multipath.conf` file is created, you might need to enable and start the multipath services to load the recommended settings:

```
systemctl enable multipathd
```

```
systemctl start multipathd
```



- Each time you boot the host, the empty `/etc/multipath.conf` zero-byte file automatically loads the NetApp recommended host multipath parameters as the default settings. You shouldn't need to make changes to the `/etc/multipath.conf` file for your host because the operating system is compiled with the multipath parameters that recognize and manage ONTAP LUNs correctly.

The following table shows the Linux OS native compiled multipath parameter settings for ONTAP LUNs.

#### Show parameter settings

Parameter	Setting
detect_prio	yes
dev_loss_tmo	"infinity"
failback	immediate
fast_io_fail_tmo	5
features	"2 pg_init_retries 50"
flush_on_last_del	"yes"
hardware_handler	"0"
no_path_retry	queue
path_checker	"tur"
path_grouping_policy	"group_by_prio"
path_selector	"service-time 0"
polling_interval	5
prio	"ontap"
product	LUN
retain_attached_hw_handler	yes
rr_weight	"uniform"
user_friendly_names	no
vendor	NETAPP

- Verify the parameter settings and path status for your ONTAP LUNs:

```
multipath -ll
```

The default multipath parameters support ASA, AFF, and FAS configurations. In these configurations, a single ONTAP LUN shouldn't require more than four paths. If there are more than four paths, it might cause issues with the paths during a storage failure.

The following example outputs show the correct parameter settings and path status for ONTAP LUNs in an ASA, AFF, or FAS configuration.

### ASA configuration

An ASA configuration optimizes all paths to a given LUN, keeping them active. This improves performance by serving I/O operations through all paths at the same time.

#### Show example

```
multipath -ll
3600a098038314c4a433f577471797958 dm-2 NETAPP,LUN C-Mode
size=180G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
`-+- policy='service-time 0' prio=50 status=active
| - 14:0:0:0 sdc 8:32 active ready running
| - 17:0:0:0 sdas 66:192 active ready running
| - 14:0:3:0 sdar 66:176 active ready running
`- 17:0:3:0 sdch 69:80 active ready running
```

### AFF or FAS configuration

An AFF or FAS configuration should have two groups of paths with higher and lower priorities. Higher priority Active/Optimized paths are served by the controller where the aggregate is located. Lower priority paths are active but non-optimized because they are served by a different controller. Non-optimized paths are only used when optimized paths aren't available.

The following example displays the output for an ONTAP LUN with two Active/Optimized paths and two Active/Non-Optimized paths:

#### Show example

```
multipath -ll
3600a0980383149764b5d567257516273 dm-0 NETAPP,LUN C-Mode
size=150G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
| -+- policy='service-time 0' prio=50 status=active
| | - 16:0:3:0 sdcg 69:64 active ready running
| | ` - 10:0:0:0 sdb 8:16 active ready running
`-+- policy='service-time 0' prio=10 status=enabled
| - 10:0:1:0 sdc 8:32 active ready running
`- 16:0:2:0 sdcf 69:48 active ready running
```

## Step 4: Optionally, exclude a device from multipathing

If required, you can exclude a device from multipathing by adding the WWID for the unwanted device to the "blacklist" stanza for the `multipath.conf` file.

## Steps

1. Determine the WWID:

```
/lib/udev/scsi_id -gud /dev/sda
```

"sda" is the local SCSI disk that you want to add to the blacklist.

An example WWID is 360030057024d0730239134810c0cb833.

2. Add the WWID to the "blacklist" stanza:

```
blacklist {
    wwid      360030057024d0730239134810c0cb833
    devnode   "^(ram|raw|loop|fd|md|dm-|sr|scd|st) [0-9] *"
    devnode   "^hd[a-z]"
    devnode   "^cciss.*"
}
```

## Step 5: Customize multipath parameters for ONTAP LUNs

If your host is connected to LUNs from other vendors and any of the multipath parameter settings are overridden, you need to correct them by adding stanzas later in the `multipath.conf` file that apply specifically to ONTAP LUNs. If you don't do this, the ONTAP LUNs might not work as expected.

Check your `/etc/multipath.conf` file, especially in the defaults section, for settings that might be overriding the [default settings for multipath parameters](#).



You shouldn't override the recommended parameter settings for ONTAP LUNs. These settings are required for optimal performance of your host configuration. Contact NetApp support, your OS vendor, or both for more information.

The following example shows how to correct an overridden default. In this example, the `multipath.conf` file defines values for `path_checker` and `no_path_retry` that aren't compatible with ONTAP LUNs, and you can't remove these parameters because ONTAP storage arrays are still attached to the host. Instead, you correct the values for `path_checker` and `no_path_retry` by adding a device stanza to the `multipath.conf` file that applies specifically to the ONTAP LUNs.

## Show example

```
defaults {
    path_checker      readsector0
    no_path_retry     fail
}

devices {
    device {
        vendor        "NETAPP"
        product        "LUN"
        no_path_retry  queue
        path_checker   tur
    }
}
```

## Step 6: Review the known issues

The RHEL 8.0 with ONTAP storage release has the following known issues:

NetApp Bug ID	Title	Description
<a href="#">1238719</a>	Kernel disruption on RHEL8 with QLogic QLE2672 16GB FC during storage failover operations	Kernel disruption might occur during storage failover operations on a Red Hat Enterprise Linux (RHEL) 8 kernel with a QLogic QLE2672 host bus adapter (HBA). The kernel disruption causes the operating system to reboot. The reboot causes application disruption and generates the vmcore file under the /var/crash/directory if kdump is configured. Use the vmcore file to identify the cause of the failure. In this case, the disruption is in the "kmem_cache_alloc+160" module. It is logged in the vmcore file with the following string: "[exception RIP: kmem_cache_alloc+160]". Reboot the host OS to recover the operating system and then restart the application.

NetApp Bug ID	Title	Description
<a href="#">1226783</a>	RHEL8 OS boots up to "emergency mode" when more than 204 SCSI devices are mapped on all Fibre Channel (FC) host bus adapters (HBA)	If a host is mapped with more than 204 SCSI devices during an operating systemreboot process, the RHEL8 OS fails to boot up to "normal mode" and enters "emergency mode". This results in most of the host services becoming unavailable.
<a href="#">1230882</a>	Creating a partition on an iSCSI multipath device during the RHEL8 installation is not feasible.	iSCSI SAN LUN multipath devices are not listed in disk selection during RHEL 8 installation. Consequently, the multipath service is not enabled on the SAN boot device.
<a href="#">1235998</a>	The "rescan-scsi-bus.sh -a" command does not scan more than 328 devices	If a Red Hat Enterprise Linux 8 host maps with more than 328 SCSI devices, the host OS command "rescan-scsi-bus.sh -a" only scans 328 devices. The host does not discover any remaining mapped devices.
<a href="#">1231087</a>	Remote ports transit to a blocked state on RHEL8 with Emulex LPe16002 16GB FC during storage failover operations	Remote ports transit to a blocked state on RHEL8 with Emulex LPe16002 16GB Fibre Channel (FC) during storage failover operations. When the storage node returns to an optimal state, the LIFs also come up and the remote port state should read "online". Occasionally, the remote port state might continue to read as "blocked" or "not present". This state can lead to a "failed faulty" path to LUNs at the multipath layer
<a href="#">1231098</a>	Remote ports transit to blocked state on RHEL8 with Emulex LPe32002 32GB FC during storage failover operations	Remote ports transit to a blocked state on RHEL8 with Emulex LPe32002 32GBFibre Channel (FC) during storage failover operations. When the storage node returns to an optimal state, the LIFs also come up and the remote port state should read "online". Occasionally, the remote port state might continue to read as "blocked" or "not present". This state can lead to a "failed faulty" path to LUNs at the multipath layer.

## What's next?

- [Learn about using the Linux Host Utilities tool.](#)
- Learn about ASM mirroring.

Automatic Storage Management (ASM) mirroring might require changes to the Linux multipath settings to allow ASM to recognize a problem and switch over to an alternate failure group. Most ASM configurations on ONTAP use external redundancy, which means that data protection is provided by the external array and ASM doesn't mirror data. Some sites use ASM with normal redundancy to provide two-way mirroring, normally across different sites. See [Oracle databases on ONTAP](#) for further information.

# RHEL 7

## Configure RHEL 7.9 for FCP and iSCSI with ONTAP storage

The Linux Host Utilities software provides management and diagnostic tools for Linux hosts that are connected to ONTAP storage. When you install the Linux Host Utilities on a Red Hat Enterprise Linux (RHEL) 7.9 host, you can use the Host Utilities to help you manage FCP and iSCSI protocol operations with ONTAP LUNs.



You don't need to manually configure Kernel-based Virtual Machine (KVM) settings because ONTAP LUNs are automatically mapped to the hypervisor.

### Step 1: Optionally, enable SAN booting

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

#### Before you begin

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

#### Steps

1. [Create a SAN boot LUN and map it to the host.](#)
2. Enable SAN booting in the server BIOS for the ports to which the SAN boot LUN is mapped.

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

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

### Step 2: Install the Linux Host Utilities

NetApp strongly recommends installing the Linux Host Utilities to support ONTAP LUN management and assist technical support with gathering configuration data.

[Install Linux Host Utilities 7.1.](#)



Installing the Linux Host Utilities doesn't change any host timeout settings on your Linux host.

### Step 3: Confirm the multipath configuration for your host

You can use multipathing with RHEL 7.9 to manage ONTAP LUNs.

To ensure that multipathing is configured correctly for your host, verify that the `/etc/multipath.conf` file is defined and that you have the NetApp recommended settings configured for your ONTAP LUNs.

#### Steps

1. Verify that the `/etc/multipath.conf` file exists:

```
ls /etc/multipath.conf
```

If the file doesn't exist, create an empty, zero-byte file:

```
touch /etc/multipath.conf
```

2. The first time the `multipath.conf` file is created, you might need to enable and start the multipath services to load the recommended settings:

```
systemctl enable multipathd
```

```
systemctl start multipathd
```

3. Each time you boot the host, the empty `/etc/multipath.conf` zero-byte file automatically loads the NetApp recommended host multipath parameters as the default settings. You shouldn't need to make changes to the `/etc/multipath.conf` file for your host because the host operating system is compiled with the multipath parameters that recognize and manage ONTAP LUNs correctly.

The following table shows the native Linux OS compiled multipath parameter settings for ONTAP LUNs.

## Show parameter settings

Parameter	Setting
detect_prio	yes
dev_loss_tmo	"infinity"
failback	immediate
fast_io_fail_tmo	5
features	"3 queue_if_no_path pg_init_retries 50"
flush_on_last_del	"yes"
hardware_handler	"0"
no_path_retry	queue
path_checker	"tur"
path_grouping_policy	"group_by_prio"
path_selector	"service-time 0"
polling_interval	5
prio	"ontap"
product	LUN.*
retain_attached_hw_handler	yes
rr_weight	"uniform"
user_friendly_names	no
vendor	NETAPP

### 4. Verify the parameter settings and path status for your ONTAP LUNs:

```
multipath -ll
```

The default multipath parameters support ASA, AFF, and FAS configurations. In these configurations, a single ONTAP LUN shouldn't require more than four paths. If there are more than four paths, it might cause issues with the paths during a storage failure.

The following example outputs show the correct parameter settings and path status for ONTAP LUNs in an ASA, AFF, or FAS configuration.



### ASA configuration

An ASA configuration optimizes all paths to a given LUN, keeping them active. This improves performance by serving I/O operations through all paths at the same time.

```
# multipath -ll
3600a09803831347657244e527766394e dm-5 NETAPP,LUN C-Mode
size=80G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
`-+- policy='service-time 0' prio=50 status=active
  |- 3:0:7:9      sdco 69:192  active ready running
  |- 3:0:8:9      sddi 71:0    active ready running
  |- 14:0:8:9     sdjq 65:320  active ready running
  `-- 14:0:7:9    sdiw 8:256   active ready running
```

### AFF or FAS configuration

An AFF or FAS configuration should have two groups of paths with higher and lower priorities. Higher priority Active/Optimized paths are served by the controller where the aggregate is located. Lower priority paths are active but non-optimized because they are served by a different controller. Non-optimized paths are only used when optimized paths aren't available.

The following example displays the output for an ONTAP LUN with two Active/Optimized paths and two Active/Non-Optimized paths:

```
# multipath -ll
3600a09803831347657244e527766394e dm-5 NETAPP,LUN C-Mode
size=80G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
|+- policy='service-time 0' prio=50 status=active
| |- 3:0:3:0      sdd  8:48    active ready running
| |- 3:0:4:0      sdx   65:112  active ready running
`-+- policy='service-time 0' prio=10 status=enabled
  |- 14:0:2:0     sdfk 130:96   active ready running
  `-- 14:0:5:0    sdgz 132:240  active ready running
```

### Step 4: Optionally, exclude a device from multipathing

If required, you can exclude a device from multipathing by adding the WWID for the unwanted device to the "blacklist" stanza for the `multipath.conf` file.

#### Steps

1. Determine the WWID:

```
/lib/udev/scsi_id -gud /dev/sda
```

"sda" is the local SCSI disk that you want to add to the blacklist.

An example WWID is 360030057024d0730239134810c0cb833.

2. Add the WWID to the "blacklist" stanza:

```
blacklist {
    wwid      360030057024d0730239134810c0cb833
    devnode   "^(ram|raw|loop|fd|md|dm-|sr|scd|st) [0-9] *"
    devnode   "^hd[a-z] *"
    devnode   "^cciss.*"
}
```

### Step 5: Customize multipath parameters for ONTAP LUNs

If your host is connected to LUNs from other vendors and any of the multipath parameter settings are overridden, you need to correct them by adding stanzas later in the `multipath.conf` file that apply specifically to ONTAP LUNs. If you don't do this, the ONTAP LUNs might not work as expected.

Check your `/etc/multipath.conf` file, especially in the defaults section, for settings that might be overriding the [default settings for multipath parameters](#).



You shouldn't override the recommended parameter settings for ONTAP LUNs. These settings are required for optimal performance of your host configuration. Contact NetApp support, your OS vendor, or both for more information.

The following example shows how to correct an overridden default. In this example, the `multipath.conf` file defines values for `path_checker` and `no_path_retry` that aren't compatible with ONTAP LUNs, and you can't remove these parameters because ONTAP storage arrays are still attached to the host. Instead, you correct the values for `path_checker` and `no_path_retry` by adding a device stanza to the `multipath.conf` file that applies specifically to the ONTAP LUNs.

## Show example

```
defaults {
    path_checker      readsector0
    no_path_retry     fail
}

devices {
    device {
        vendor        "NETAPP"
        product        "LUN"
        no_path_retry  queue
        path_checker   tur
    }
}
```

## Step 6: Review the known issues

The RHEL 7.9 with ONTAP storage release has the following known issue:

NetApp Bug ID	Title	Description
1440718	If you unmap or map a LUN without performing a SCSI rescan, it might lead to data corruption on the host.	When you set the 'disable_changed_wwids' multipath configuration parameter to YES, it disables access to the path device in the event of a WWID change. Multipath will disable access to the path device until the WWID of the path is restored to the WWID of the multipath device. To learn more, see <a href="#">NetApp Knowledge Base: The filesystem corruption on iSCSI LUN on the Oracle Linux 7</a> .

## What's next?

- [Learn about using the Linux Host Utilities tool](#).
- Learn about ASM mirroring.

Automatic Storage Management (ASM) mirroring might require changes to the Linux multipath settings to allow ASM to recognize a problem and switch over to an alternate failure group. Most ASM configurations on ONTAP use external redundancy, which means that data protection is provided by the external array and ASM doesn't mirror data. Some sites use ASM with normal redundancy to provide two-way mirroring, normally across different sites. See [Oracle databases on ONTAP](#) for further information.

## Configure RHEL 7.8 for FCP and iSCSI with ONTAP storage

The Linux Host Utilities software provides management and diagnostic tools for Linux hosts that are connected to ONTAP storage. When you install the Linux Host Utilities on a Red Hat Enterprise Linux (RHEL) 7.8 host, you can use the Host Utilities to help you manage FCP and iSCSI protocol operations with ONTAP LUNs.



You don't need to manually configure Kernel-based Virtual Machine (KVM) settings because ONTAP LUNs are automatically mapped to the hypervisor.

### Step 1: Optionally, enable SAN booting

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

#### Before you begin

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

#### Steps

1. [Create a SAN boot LUN and map it to the host.](#)
2. Enable SAN booting in the server BIOS for the ports to which the SAN boot LUN is mapped.

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

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

### Step 2: Install the Linux Host Utilities

NetApp strongly recommends installing the Linux Host Utilities to support ONTAP LUN management and assist technical support with gathering configuration data.

[Install Linux Host Utilities 7.1.](#)



Installing the Linux Host Utilities doesn't change any host timeout settings on your Linux host.

### Step 3: Confirm the multipath configuration for your host

You can use multipathing with RHEL 7.8 to manage ONTAP LUNs.

To ensure that multipathing is configured correctly for your host, verify that the `/etc/multipath.conf` file is defined and that you have the NetApp recommended settings configured for your ONTAP LUNs.

#### Steps

1. Verify that the `/etc/multipath.conf` file exists:

```
ls /etc/multipath.conf
```

If the file doesn't exist, create an empty, zero-byte file:

```
touch /etc/multipath.conf
```

2. The first time the `multipath.conf` file is created, you might need to enable and start the multipath services to load the recommended settings:

```
systemctl enable multipathd
```

```
systemctl start multipathd
```

3. Each time you boot the host, the empty `/etc/multipath.conf` zero-byte file automatically loads the NetApp recommended host multipath parameters as the default settings. You shouldn't need to make changes to the `/etc/multipath.conf` file for your host because the host operating system is compiled with the multipath parameters that recognize and manage ONTAP LUNs correctly.

The following table shows the native Linux OS compiled multipath parameter settings for ONTAP LUNs.

#### Show parameter settings

Parameter	Setting
detect_prio	yes
dev_loss_tmo	"infinity"
failback	immediate
fast_io_fail_tmo	5
features	"3 queue_if_no_path pg_init_retries 50"
flush_on_last_del	"yes"
hardware_handler	"0"
no_path_retry	queue
path_checker	"tur"
path_grouping_policy	"group_by_prio"
path_selector	"service-time 0"
polling_interval	5
prio	"ontap"
product	LUN.*
retain_attached_hw_handler	yes
rr_weight	"uniform"
user_friendly_names	no
vendor	NETAPP

#### 4. Verify the parameter settings and path status for your ONTAP LUNs:

```
multipath -ll
```

The default multipath parameters support ASA, AFF, and FAS configurations. In these configurations, a single ONTAP LUN shouldn't require more than four paths. If there are more than four paths, it might cause issues with the paths during a storage failure.

The following example outputs show the correct parameter settings and path status for ONTAP LUNs in an ASA, AFF, or FAS configuration.

##### ASA configuration

An ASA configuration optimizes all paths to a given LUN, keeping them active. This improves performance by serving I/O operations through all paths at the same time.

```
# multipath -ll
3600a09803831347657244e527766394e dm-5 NETAPP,LUN C-Mode
size=80G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
`-+- policy='service-time 0' prio=50 status=active
  |- 3:0:7:9      sdco 69:192  active ready running
  |- 3:0:8:9      sddi 71:0    active ready running
  |- 14:0:8:9     sdjq 65:320  active ready running
  `-- 14:0:7:9    sdiw 8:256   active ready running
```

##### AFF or FAS configuration

An AFF or FAS configuration should have two groups of paths with higher and lower priorities. Higher priority Active/Optimized paths are served by the controller where the aggregate is located. Lower priority paths are active but non-optimized because they are served by a different controller. Non-optimized paths are only used when optimized paths aren't available.

The following example displays the output for an ONTAP LUN with two Active/Optimized paths and two Active/Non-Optimized paths:

```
# multipath -ll
3600a09803831347657244e527766394e dm-5 NETAPP,LUN C-Mode
size=80G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
|+- policy='service-time 0' prio=50 status=active
| |- 3:0:3:0      sdd  8:48    active ready running
| |- 3:0:4:0      sdx  65:112  active ready running
`-+- policy='service-time 0' prio=10 status=enabled
  |- 14:0:2:0     sdfk 130:96  active ready running
  `-- 14:0:5:0    sdgz 132:240  active ready running
```

## Step 4: Optionally, exclude a device from multipathing

If required, you can exclude a device from multipathing by adding the WWID for the unwanted device to the "blacklist" stanza for the `multipath.conf` file.

### Steps

1. Determine the WWID:

```
/lib/udev/scsi_id -gud /dev/sda
```

"sda" is the local SCSI disk that you want to add to the blacklist.

An example WWID is 360030057024d0730239134810c0cb833.

2. Add the WWID to the "blacklist" stanza:

```
blacklist {
    wwid      360030057024d0730239134810c0cb833
    devnode   "^(ram|raw|loop|fd|md|dm-|sr|scd|st)[0-9]*"
    devnode   "^hd[a-z]"
    devnode   "^cciss.*"
}
```

## Step 5: Customize multipath parameters for ONTAP LUNs

If your host is connected to LUNs from other vendors and any of the multipath parameter settings are overridden, you need to correct them by adding stanzas later in the `multipath.conf` file that apply specifically to ONTAP LUNs. If you don't do this, the ONTAP LUNs might not work as expected.

Check your `/etc/multipath.conf` file, especially in the defaults section, for settings that might be overriding the [default settings for multipath parameters](#).



You shouldn't override the recommended parameter settings for ONTAP LUNs. These settings are required for optimal performance of your host configuration. Contact NetApp support, your OS vendor, or both for more information.

The following example shows how to correct an overridden default. In this example, the `multipath.conf` file defines values for `path_checker` and `no_path_retry` that aren't compatible with ONTAP LUNs, and you can't remove these parameters because ONTAP storage arrays are still attached to the host. Instead, you correct the values for `path_checker` and `no_path_retry` by adding a device stanza to the `multipath.conf` file that applies specifically to the ONTAP LUNs.

## Show example

```
defaults {
    path_checker      readsector0
    no_path_retry     fail
}

devices {
    device {
        vendor        "NETAPP"
        product        "LUN"
        no_path_retry  queue
        path_checker   tur
    }
}
```

## Step 6: Review the known issues

The RHEL 7.8 with ONTAP storage release has the following known issue:

NetApp Bug ID	Title	Description
1440718	If you unmap or map a LUN without performing a SCSI rescan, it might lead to data corruption on the host.	When you set the 'disable_changed_wwids' multipath configuration parameter to YES, it disables access to the path device in the event of a WWID change. Multipath will disable access to the path device until the WWID of the path is restored to the WWID of the multipath device. To learn more, see <a href="#">NetApp Knowledge Base: The filesystem corruption on iSCSI LUN on the Oracle Linux 7</a> .

## What's next?

- [Learn about using the Linux Host Utilities tool](#).
- Learn about ASM mirroring.

Automatic Storage Management (ASM) mirroring might require changes to the Linux multipath settings to allow ASM to recognize a problem and switch over to an alternate failure group. Most ASM configurations on ONTAP use external redundancy, which means that data protection is provided by the external array and ASM doesn't mirror data. Some sites use ASM with normal redundancy to provide two-way mirroring, normally across different sites. See [Oracle databases on ONTAP](#) for further information.



## Configure RHEL 7.7 for FCP and iSCSI with ONTAP storage

The Linux Host Utilities software provides management and diagnostic tools for Linux hosts that are connected to ONTAP storage. When you install the Linux Host Utilities on a Red Hat Enterprise Linux (RHEL) 7.7 host, you can use the Host Utilities to help you manage FCP and iSCSI protocol operations with ONTAP LUNs.



You don't need to manually configure Kernel-based Virtual Machine (KVM) settings because ONTAP LUNs are automatically mapped to the hypervisor.

### Step 1: Optionally, enable SAN booting

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

#### Before you begin

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

#### Steps

1. [Create a SAN boot LUN and map it to the host.](#)
2. Enable SAN booting in the server BIOS for the ports to which the SAN boot LUN is mapped.

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

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

### Step 2: Install the Linux Host Utilities

NetApp strongly recommends installing the Linux Host Utilities to support ONTAP LUN management and assist technical support with gathering configuration data.

[Install Linux Host Utilities 7.1.](#)



Installing the Linux Host Utilities doesn't change any host timeout settings on your Linux host.

### Step 3: Confirm the multipath configuration for your host

You can use multipathing with RHEL 7.7 to manage ONTAP LUNs.

To ensure that multipathing is configured correctly for your host, verify that the `/etc/multipath.conf` file is defined and that you have the NetApp recommended settings configured for your ONTAP LUNs.

#### Steps

1. Verify that the `/etc/multipath.conf` file exists:

```
ls /etc/multipath.conf
```

If the file doesn't exist, create an empty, zero-byte file:

```
touch /etc/multipath.conf
```

2. The first time the `multipath.conf` file is created, you might need to enable and start the multipath services to load the recommended settings:

```
systemctl enable multipathd
```

```
systemctl start multipathd
```

3. Each time you boot the host, the empty `/etc/multipath.conf` zero-byte file automatically loads the NetApp recommended host multipath parameters as the default settings. You shouldn't need to make changes to the `/etc/multipath.conf` file for your host because the host operating system is compiled with the multipath parameters that recognize and manage ONTAP LUNs correctly.

The following table shows the native Linux OS compiled multipath parameter settings for ONTAP LUNs.

#### Show parameter settings

Parameter	Setting
detect_prio	yes
dev_loss_tmo	"infinity"
failback	immediate
fast_io_fail_tmo	5
features	"3 queue_if_no_path pg_init_retries 50"
flush_on_last_del	"yes"
hardware_handler	"0"
no_path_retry	queue
path_checker	"tur"
path_grouping_policy	"group_by_prio"
path_selector	"service-time 0"
polling_interval	5
prio	"ontap"
product	LUN.*
retain_attached_hw_handler	yes
rr_weight	"uniform"
user_friendly_names	no
vendor	NETAPP

#### 4. Verify the parameter settings and path status for your ONTAP LUNs:

```
multipath -ll
```

The default multipath parameters support ASA, AFF, and FAS configurations. In these configurations, a single ONTAP LUN shouldn't require more than four paths. If there are more than four paths, it might cause issues with the paths during a storage failure.

The following example outputs show the correct parameter settings and path status for ONTAP LUNs in an ASA, AFF, or FAS configuration.

##### ASA configuration

An ASA configuration optimizes all paths to a given LUN, keeping them active. This improves performance by serving I/O operations through all paths at the same time.

```
# multipath -ll
3600a09803831347657244e527766394e dm-5 NETAPP,LUN C-Mode
size=80G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
`-+- policy='service-time 0' prio=50 status=active
| - 3:0:7:9      sdco 69:192  active ready running
| - 3:0:8:9      sddi 71:0    active ready running
| - 14:0:8:9     sdjq 65:320  active ready running
`- 14:0:7:9     sdiw 8:256   active ready running
```

##### AFF or FAS configuration

An AFF or FAS configuration should have two groups of paths with higher and lower priorities. Higher priority Active/Optimized paths are served by the controller where the aggregate is located. Lower priority paths are active but non-optimized because they are served by a different controller. Non-optimized paths are only used when optimized paths aren't available.

The following example displays the output for an ONTAP LUN with two Active/Optimized paths and two Active/Non-Optimized paths:

```
# multipath -ll
3600a09803831347657244e527766394e dm-5 NETAPP,LUN C-Mode
size=80G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
|+- policy='service-time 0' prio=50 status=active
| | - 3:0:3:0      sdd  8:48    active ready running
| | - 3:0:4:0      sdx  65:112  active ready running
`-+- policy='service-time 0' prio=10 status=enabled
   | - 14:0:2:0     sdfk 130:96  active ready running
   `- 14:0:5:0     sdgz 132:240  active ready running
```

## Step 4: Optionally, exclude a device from multipathing

If required, you can exclude a device from multipathing by adding the WWID for the unwanted device to the "blacklist" stanza for the `multipath.conf` file.

### Steps

1. Determine the WWID:

```
/lib/udev/scsi_id -gud /dev/sda
```

"sda" is the local SCSI disk that you want to add to the blacklist.

An example WWID is 360030057024d0730239134810c0cb833.

2. Add the WWID to the "blacklist" stanza:

```
blacklist {
    wwid      360030057024d0730239134810c0cb833
    devnode   "^(ram|raw|loop|fd|md|dm-|sr|scd|st)[0-9]*"
    devnode   "^hd[a-z]"
    devnode   "^cciss.*"
}
```

## Step 5: Customize multipath parameters for ONTAP LUNs

If your host is connected to LUNs from other vendors and any of the multipath parameter settings are overridden, you need to correct them by adding stanzas later in the `multipath.conf` file that apply specifically to ONTAP LUNs. If you don't do this, the ONTAP LUNs might not work as expected.

Check your `/etc/multipath.conf` file, especially in the defaults section, for settings that might be overriding the [default settings for multipath parameters](#).



You shouldn't override the recommended parameter settings for ONTAP LUNs. These settings are required for optimal performance of your host configuration. Contact NetApp support, your OS vendor, or both for more information.

The following example shows how to correct an overridden default. In this example, the `multipath.conf` file defines values for `path_checker` and `no_path_retry` that aren't compatible with ONTAP LUNs, and you can't remove these parameters because ONTAP storage arrays are still attached to the host. Instead, you correct the values for `path_checker` and `no_path_retry` by adding a device stanza to the `multipath.conf` file that applies specifically to the ONTAP LUNs.

## Show example

```
defaults {
    path_checker      readsector0
    no_path_retry     fail
}

devices {
    device {
        vendor        "NETAPP"
        product        "LUN"
        no_path_retry  queue
        path_checker   tur
    }
}
```

## Step 6: Review the known issues

The RHEL 7.7 with ONTAP storage release has the following known issues:

NetApp Bug ID	Title	Description
1440718	If you unmap or map a LUN without performing a SCSI rescan, it might lead to data corruption on the host.	When you set the 'disable_changed_wwids' multipath configuration parameter to YES, it disables access to the path device in the event of a WWID change. Multipath will disable access to the path device until the WWID of the path is restored to the WWID of the multipath device. To learn more, see <a href="#">NetApp Knowledge Base: The filesystem corruption on iSCSI LUN on the Oracle Linux 7</a> .
<a href="#">1258856</a>	Remote ports transit to a blocked state on RHEL7U7 with Emulex LPe16002 16GB FC during storage failover operations	Remote ports might transit to a blocked state on a RHEL 7.7 host with a LPe16002 16GB FC adapter during storage failover operations. When the storage node returns to an optimal state, the LIFs also come up and the remote port state should read "online". Occasionally, the remote port state might continue to read as "blocked" or "not present". This state can lead to a "failed faulty" path to LUNs at the multipath layer.

NetApp Bug ID	Title	Description
<a href="#">1261474</a>	Remote ports transit to blocked state on RHEL7U7 with Emulex LPe32002 32GB FC	Remote ports might transit to a blocked state on a RHEL 7.7 host with LPe32002 32GB FC adapter during storage failover operations. When the storage node returns to an optimal state, the LIFs also come up and the remote port state should read "online". Occasionally, the remote port state might continue to read as "blocked" or "not present". This state can lead to a "failed faulty" path to LUNs at the multipath layer.

### What's next?

- [Learn about using the Linux Host Utilities tool.](#)
- Learn about ASM mirroring.

Automatic Storage Management (ASM) mirroring might require changes to the Linux multipath settings to allow ASM to recognize a problem and switch over to an alternate failure group. Most ASM configurations on ONTAP use external redundancy, which means that data protection is provided by the external array and ASM doesn't mirror data. Some sites use ASM with normal redundancy to provide two-way mirroring, normally across different sites. See [Oracle databases on ONTAP](#) for further information.

## Configure RHEL 7.6 for FCP and iSCSI with ONTAP storage

The Linux Host Utilities software provides management and diagnostic tools for Linux hosts that are connected to ONTAP storage. When you install the Linux Host Utilities on a Red Hat Enterprise Linux (RHEL) 7.6 host, you can use the Host Utilities to help you manage FCP and iSCSI protocol operations with ONTAP LUNs.



You don't need to manually configure Kernel-based Virtual Machine (KVM) settings because ONTAP LUNs are automatically mapped to the hypervisor.

### Step 1: Optionally, enable SAN booting

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

#### Before you begin

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

#### Steps

1. [Create a SAN boot LUN and map it to the host.](#)
2. Enable SAN booting in the server BIOS for the ports to which the SAN boot LUN is mapped.

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

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

## Step 2: Install the Linux Host Utilities

NetApp strongly recommends installing the Linux Host Utilities to support ONTAP LUN management and assist technical support with gathering configuration data.

[Install Linux Host Utilities 7.1.](#)



Installing the Linux Host Utilities doesn't change any host timeout settings on your Linux host.

## Step 3: Confirm the multipath configuration for your host

You can use multipathing with RHEL 7.6 to manage ONTAP LUNs.

To ensure that multipathing is configured correctly for your host, verify that the `/etc/multipath.conf` file is defined and that you have the NetApp recommended settings configured for your ONTAP LUNs.

### Steps

1. Verify that the `/etc/multipath.conf` file exists:

```
ls /etc/multipath.conf
```

If the file doesn't exist, create an empty, zero-byte file:

```
touch /etc/multipath.conf
```

2. The first time the `multipath.conf` file is created, you might need to enable and start the multipath services to load the recommended settings:

```
systemctl enable multipathd
```

```
systemctl start multipathd
```

3. Each time you boot the host, the empty `/etc/multipath.conf` zero-byte file automatically loads the NetApp recommended host multipath parameters as the default settings. You shouldn't need to make changes to the `/etc/multipath.conf` file for your host because the host operating system is compiled with the multipath parameters that recognize and manage ONTAP LUNs correctly.

The following table shows the native Linux OS compiled multipath parameter settings for ONTAP LUNs.

## Show parameter settings

Parameter	Setting
detect_prio	yes
dev_loss_tmo	"infinity"
failback	immediate
fast_io_fail_tmo	5
features	"3 queue_if_no_path pg_init_retries 50"
flush_on_last_del	"yes"
hardware_handler	"0"
no_path_retry	queue
path_checker	"tur"
path_grouping_policy	"group_by_prio"
path_selector	"service-time 0"
polling_interval	5
prio	"ontap"
product	LUN.*
retain_attached_hw_handler	yes
rr_weight	"uniform"
user_friendly_names	no
vendor	NETAPP

### 4. Verify the parameter settings and path status for your ONTAP LUNs:

```
multipath -ll
```

The default multipath parameters support ASA, AFF, and FAS configurations. In these configurations, a single ONTAP LUN shouldn't require more than four paths. If there are more than four paths, it might cause issues with the paths during a storage failure.

The following example outputs show the correct parameter settings and path status for ONTAP LUNs in an ASA, AFF, or FAS configuration.



### ASA configuration

An ASA configuration optimizes all paths to a given LUN, keeping them active. This improves performance by serving I/O operations through all paths at the same time.

```
# multipath -ll
3600a09803831347657244e527766394e dm-5 NETAPP,LUN C-Mode
size=80G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
`-+- policy='service-time 0' prio=50 status=active
  |- 3:0:7:9      sdco 69:192  active ready running
  |- 3:0:8:9      sddi 71:0    active ready running
  |- 14:0:8:9     sdjq 65:320  active ready running
  `-- 14:0:7:9    sdiw 8:256   active ready running
```

### AFF or FAS configuration

An AFF or FAS configuration should have two groups of paths with higher and lower priorities. Higher priority Active/Optimized paths are served by the controller where the aggregate is located. Lower priority paths are active but non-optimized because they are served by a different controller. Non-optimized paths are only used when optimized paths aren't available.

The following example displays the output for an ONTAP LUN with two Active/Optimized paths and two Active/Non-Optimized paths:

```
# multipath -ll
3600a09803831347657244e527766394e dm-5 NETAPP,LUN C-Mode
size=80G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
|+- policy='service-time 0' prio=50 status=active
| |- 3:0:3:0      sdd  8:48    active ready running
| |- 3:0:4:0      sdx   65:112  active ready running
`-+- policy='service-time 0' prio=10 status=enabled
  |- 14:0:2:0     sdfk 130:96   active ready running
  `-- 14:0:5:0    sdgz 132:240  active ready running
```

### Step 4: Optionally, exclude a device from multipathing

If required, you can exclude a device from multipathing by adding the WWID for the unwanted device to the "blacklist" stanza for the `multipath.conf` file.

#### Steps

1. Determine the WWID:

```
/lib/udev/scsi_id -gud /dev/sda
```

"sda" is the local SCSI disk that you want to add to the blacklist.

An example WWID is 360030057024d0730239134810c0cb833.

2. Add the WWID to the "blacklist" stanza:

```
blacklist {
    wwid      360030057024d0730239134810c0cb833
    devnode   "^(ram|raw|loop|fd|md|dm-|sr|scd|st) [0-9] *"
    devnode   "^hd[a-z] *"
    devnode   "^cciss.*"
}
```

### Step 5: Customize multipath parameters for ONTAP LUNs

If your host is connected to LUNs from other vendors and any of the multipath parameter settings are overridden, you need to correct them by adding stanzas later in the `multipath.conf` file that apply specifically to ONTAP LUNs. If you don't do this, the ONTAP LUNs might not work as expected.

Check your `/etc/multipath.conf` file, especially in the defaults section, for settings that might be overriding the [default settings for multipath parameters](#).



You shouldn't override the recommended parameter settings for ONTAP LUNs. These settings are required for optimal performance of your host configuration. Contact NetApp support, your OS vendor, or both for more information.

The following example shows how to correct an overridden default. In this example, the `multipath.conf` file defines values for `path_checker` and `no_path_retry` that aren't compatible with ONTAP LUNs, and you can't remove these parameters because ONTAP storage arrays are still attached to the host. Instead, you correct the values for `path_checker` and `no_path_retry` by adding a device stanza to the `multipath.conf` file that applies specifically to the ONTAP LUNs.

## Show example

```
defaults {
    path_checker      readsector0
    no_path_retry     fail
}

devices {
    device {
        vendor        "NETAPP"
        product        "LUN"
        no_path_retry  queue
        path_checker    tur
    }
}
```

## Step 6: Review the known issues

The RHEL 7.6 with ONTAP storage release has the following known issues:

NetApp Bug ID	Title	Description
1440718	If you unmap or map a LUN without performing a SCSI rescan, it might lead to data corruption on the host.	When you set the 'disable_changed_wwids' multipath configuration parameter to YES, it disables access to the path device in the event of a WWID change. Multipath will disable access to the path device until the WWID of the path is restored to the WWID of the multipath device. To learn more, see <a href="#">NetApp Knowledge Base: The filesystem corruption on iSCSI LUN on the Oracle Linux 7</a> .
<a href="#">1186754</a>	Remote ports status on RHEL7U6 with QLogic QLE2742 host might be in blocked during host discovery	During host discovery, FC remote port status on RHEL7U6 host with a QLogic QLE2742 adapter might enter a blocked state. These blocked remote ports might result in the paths to LUNs becoming unavailable. During storage failover, the path redundancy might be reduced and result in I/O outage. You can check the remote port status by entering the following command:# cat /sys/class/fc_remote_ports/rport-*/port_state

NetApp Bug ID	Title	Description
<a href="#">1190698</a>	Remote port status on RHEL7U6 with QLogic QLE2672 host might be in blocked during storage failover operations	FC remote ports might be blocked on Red Hat Enterprise Linux (RHEL) 7U6 with the QLogic QLE2672 host during storage failover operations. Because the logical interfaces go down when a storage node is down, the remote ports set the storage node status to blocked. When the storage node returns to its optimal state, the logical interfaces also come up and the remote ports should be online. However, the remote ports might still be blocked. This blocked state registers as failed faulty to LUNS at the multipath layer. You can verify the remote ports state with the following command: <code># cat /sys/class/fc_remote_ports/rport-*/port_state</code>

### What's next?

- [Learn about using the Linux Host Utilities tool.](#)
- Learn about ASM mirroring.

Automatic Storage Management (ASM) mirroring might require changes to the Linux multipath settings to allow ASM to recognize a problem and switch over to an alternate failure group. Most ASM configurations on ONTAP use external redundancy, which means that data protection is provided by the external array and ASM doesn't mirror data. Some sites use ASM with normal redundancy to provide two-way mirroring, normally across different sites. See [Oracle databases on ONTAP](#) for further information.

## Configure RHEL 7.5 for FCP and iSCSI with ONTAP storage

The Linux Host Utilities software provides management and diagnostic tools for Linux hosts that are connected to ONTAP storage. When you install the Linux Host Utilities on a Red Hat Enterprise Linux (RHEL) 7.5 host, you can use the Host Utilities to help you manage FCP and iSCSI protocol operations with ONTAP LUNs.



You don't need to manually configure Kernel-based Virtual Machine (KVM) settings because ONTAP LUNs are automatically mapped to the hypervisor.

### Step 1: Optionally, enable SAN booting

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

#### Before you begin

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

## Steps

1. [Create a SAN boot LUN and map it to the host.](#)
2. Enable SAN booting in the server BIOS for the ports to which the SAN boot LUN is mapped.

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

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

## Step 2: Install the Linux Host Utilities

NetApp strongly recommends installing the Linux Host Utilities to support ONTAP LUN management and assist technical support with gathering configuration data.

[Install Linux Host Utilities 7.1.](#)



Installing the Linux Host Utilities doesn't change any host timeout settings on your Linux host.

## Step 3: Confirm the multipath configuration for your host

You can use multipathing with RHEL 7.5 to manage ONTAP LUNs.

To ensure that multipathing is configured correctly for your host, verify that the `/etc/multipath.conf` file is defined and that you have the NetApp recommended settings configured for your ONTAP LUNs.

## Steps

1. Verify that the `/etc/multipath.conf` file exists:

```
ls /etc/multipath.conf
```

If the file doesn't exist, create an empty, zero-byte file:

```
touch /etc/multipath.conf
```

2. The first time the `multipath.conf` file is created, you might need to enable and start the multipath services to load the recommended settings:

```
systemctl enable multipathd
```

```
systemctl start multipathd
```

3. Each time you boot the host, the empty `/etc/multipath.conf` zero-byte file automatically loads the NetApp recommended host multipath parameters as the default settings. You shouldn't need to make changes to the `/etc/multipath.conf` file for your host because the host operating system is compiled with the multipath parameters that recognize and manage ONTAP LUNs correctly.

The following table shows the native Linux OS compiled multipath parameter settings for ONTAP LUNs.

Show parameter settings

Parameter	Setting
detect_prio	yes
dev_loss_tmo	"infinity"
failback	immediate
fast_io_fail_tmo	5
features	"3 queue_if_no_path pg_init_retries 50"
flush_on_last_del	"yes"
hardware_handler	"0"
no_path_retry	queue
path_checker	"tur"
path_grouping_policy	"group_by_prio"
path_selector	"service-time 0"
polling_interval	5
prio	"ontap"
product	LUN.*
retain_attached_hw_handler	yes
rr_weight	"uniform"
user_friendly_names	no
vendor	NETAPP

4. Verify the parameter settings and path status for your ONTAP LUNs:

```
multipath -ll
```

The default multipath parameters support ASA, AFF, and FAS configurations. In these configurations, a single ONTAP LUN shouldn't require more than four paths. If there are more than four paths, it might cause issues with the paths during a storage failure.

The following example outputs show the correct parameter settings and path status for ONTAP LUNs in an ASA, AFF, or FAS configuration.

### ASA configuration

An ASA configuration optimizes all paths to a given LUN, keeping them active. This improves performance by serving I/O operations through all paths at the same time.

```
# multipath -ll
3600a09803831347657244e527766394e dm-5 NETAPP,LUN C-Mode
size=80G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
`-+- policy='service-time 0' prio=50 status=active
  |- 3:0:7:9      sdco 69:192  active ready running
  |- 3:0:8:9      sddi 71:0    active ready running
  |- 14:0:8:9     sdjq 65:320  active ready running
  `- 14:0:7:9     sdiw 8:256   active ready running
```

### AFF or FAS configuration

An AFF or FAS configuration should have two groups of paths with higher and lower priorities. Higher priority Active/Optimized paths are served by the controller where the aggregate is located. Lower priority paths are active but non-optimized because they are served by a different controller. Non-optimized paths are only used when optimized paths aren't available.

The following example displays the output for an ONTAP LUN with two Active/Optimized paths and two Active/Non-Optimized paths:

```
# multipath -ll
3600a09803831347657244e527766394e dm-5 NETAPP,LUN C-Mode
size=80G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
|-+- policy='service-time 0' prio=50 status=active
| |- 3:0:3:0      sdd  8:48    active ready running
| |- 3:0:4:0      sdx  65:112  active ready running
`-+- policy='service-time 0' prio=10 status=enabled
  |- 14:0:2:0     sdfk 130:96  active ready running
  `- 14:0:5:0     sdgz 132:240  active ready running
```

### Step 4: Optionally, exclude a device from multipathing

If required, you can exclude a device from multipathing by adding the WWID for the unwanted device to the "blacklist" stanza for the `multipath.conf` file.

#### Steps

1. Determine the WWID:

```
/lib/udev/scsi_id -gud /dev/sda
```

"sda" is the local SCSI disk that you want to add to the blacklist.

An example WWID is 360030057024d0730239134810c0cb833.

2. Add the WWID to the "blacklist" stanza:

```
blacklist {
    wwid      360030057024d0730239134810c0cb833
    devnode   "^(ram|raw|loop|fd|md|dm-|sr|scd|st) [0-9] *"
    devnode   "^hd[a-z] *"
    devnode   "^cciss.*"
}
```

### Step 5: Customize multipath parameters for ONTAP LUNs

If your host is connected to LUNs from other vendors and any of the multipath parameter settings are overridden, you need to correct them by adding stanzas later in the `multipath.conf` file that apply specifically to ONTAP LUNs. If you don't do this, the ONTAP LUNs might not work as expected.

Check your `/etc/multipath.conf` file, especially in the defaults section, for settings that might be overriding the [default settings for multipath parameters](#).



You shouldn't override the recommended parameter settings for ONTAP LUNs. These settings are required for optimal performance of your host configuration. Contact NetApp support, your OS vendor, or both for more information.

The following example shows how to correct an overridden default. In this example, the `multipath.conf` file defines values for `path_checker` and `no_path_retry` that aren't compatible with ONTAP LUNs, and you can't remove these parameters because ONTAP storage arrays are still attached to the host. Instead, you correct the values for `path_checker` and `no_path_retry` by adding a device stanza to the `multipath.conf` file that applies specifically to the ONTAP LUNs.



### Show example

```
defaults {
    path_checker      readsector0
    no_path_retry     fail
}

devices {
    device {
        vendor        "NETAPP"
        product        "LUN"
        no_path_retry  queue
        path_checker    tur
    }
}
```

### Step 6: Review the known issues

The RHEL 7.5 with ONTAP storage release has the following known issues:

NetApp Bug ID	Title	Description
1440718	If you unmap or map a LUN without performing a SCSI rescan, it might lead to data corruption on the host.	When you set the 'disable_changed_wwids' multipath configuration parameter to YES, it disables access to the path device in the event of a WWID change. Multipath will disable access to the path device until the WWID of the path is restored to the WWID of the multipath device. To learn more, see <a href="#">NetApp Knowledge Base: The filesystem corruption on iSCSI LUN on the Oracle Linux 7</a> .

NetApp Bug ID	Title	Description
<a href="#">1139053</a>	Kernel disruption occurs on RHEL7.5 with QLogic QLE2672 16GB FC during storage failover operations	During storage failover operations on the RHEL7U5 kernel with QLogic QLE2672 16GB fibre channel host bus adapter, the kernel disruption occurs due to a panic in the kernel. The kernel panic causes RHEL 7.5 to reboot, which leads to an application disruption. The kernel panic generates the vmcore file under the /var/crash/directory if kdump is configured. The vmcore file is used to understand the cause of the failure. In this case, the panic was observed in the "get_next_timer_interrupt+440" module which is logged in the vmcore file with the following string: "[exception RIP: get_next_timer_interrupt+440]" After the kernel disruption, you can recover the operating system by rebooting the host operating system and restarting the application as required.
<a href="#">1138536</a>	Kernel disruption occurs on RHEL7U5 with QLogic QLE2742 32GB FC during storage failover operations	During storage failover operations on the Red Hat Enterprise Linux (RHEL) RHEL7U5 kernel with QLogic QLE2742 HBA, kernel disruption occurs due to a panic in the kernel. The kernel panic leads to a reboot of the operating system, causing an application disruption. The kernel panic generates the vmcore file under the /var/crash/ directory if kdump is configured. When the kernel panics, you can use the vmcore file to investigate the reason for the failure. The following example shows a panic in the bget_next_timer_interrupt+440b module. The panic is logged in the vmcore file with the following string: "[exception RIP: get_next_timer_interrupt+440]" You can recover the operating system by rebooting the host OS and restarting the application as required.

NetApp Bug ID	Title	Description
<a href="#">1148090</a>	Kernel disruption occurs on RHEL 7.5 with QLogic QLE2742 32GB FC HBA during storage failover operations	<p>During storage failover operations on the Red Hat Enterprise Linux (RHEL) 7.5 kernel with a QLogic QLE2742 Fibre Channel (FC) host bus adapter (HBA), a kernel disruption occurs due to a panic in the kernel. The kernel panic causes RHEL 7.5 to reboot, which leads to an application disruption. If the kdump mechanism is enabled, the kernel panic generates a vmcore file located in the /var/crash/ directory. You can analyze the vmcore file to determine the cause of the panic. In this instance, when storage failover with the QLogic QLE2742 HBA event occurs, the "native_queued_spin_lock_slowpath+464" module is affected. You can locate the event in the vmcore file by finding the following string: "[exception RIP: native_queued_spin_lock_slowpath+464]" After the kernel disruption, you can reboot the Host OS and recover the operating system, and then you can restart the applications as required.</p>

NetApp Bug ID	Title	Description
<a href="#">1146898</a>	Kernel disruption occurs on RHEL 7.5 with Emulex HBAs during storage failover operations	During storage failover operations on a Red Hat Enterprise Linux (RHEL) 7.5 system with Emulex LPe32002-M2 32-GB FC host bus adapters (HBAs), a disruption in the kernel occurs. The kernel disruption causes a reboot of the operating system, which in turn causes an application disruption. If you configure kdump, the kernel disruption generates the vmcore file under the /var/crash/ directory. You can use the vmcore file to determine the cause of the failure. In the following example, you can see the disruption in the "lpfc_hba_clean_txcmplq+368" module. This disruption is logged in the vmcore file with the following string: "[exception RIP: lpfc_hba_clean_txcmplq+368]" After the kernel disruption, reboot the host OS to recover the operating system. Restart the application as required.

### What's next?

- [Learn about using the Linux Host Utilities tool.](#)
- Learn about ASM mirroring.

Automatic Storage Management (ASM) mirroring might require changes to the Linux multipath settings to allow ASM to recognize a problem and switch over to an alternate failure group. Most ASM configurations on ONTAP use external redundancy, which means that data protection is provided by the external array and ASM doesn't mirror data. Some sites use ASM with normal redundancy to provide two-way mirroring, normally across different sites. See [Oracle databases on ONTAP](#) for further information.

## Configure RHEL 7.4 for FCP and iSCSI with ONTAP storage

The Linux Host Utilities software provides management and diagnostic tools for Linux hosts that are connected to ONTAP storage. When you install the Linux Host Utilities on a Red Hat Enterprise Linux (RHEL) 7.4 host, you can use the Host Utilities to help you manage FCP and iSCSI protocol operations with ONTAP LUNs.



You don't need to manually configure Kernel-based Virtual Machine (KVM) settings because ONTAP LUNs are automatically mapped to the hypervisor.

## Step 1: Optionally, enable SAN booting

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

### Before you begin

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

### Steps

1. [Create a SAN boot LUN and map it to the host.](#)
2. Enable SAN booting in the server BIOS for the ports to which the SAN boot LUN is mapped.

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

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

## Step 2: Install the Linux Host Utilities

NetApp strongly recommends installing the Linux Host Utilities to support ONTAP LUN management and assist technical support with gathering configuration data.

[Install Linux Host Utilities 7.1.](#)



Installing the Linux Host Utilities doesn't change any host timeout settings on your Linux host.

## Step 3: Confirm the multipath configuration for your host

You can use multipathing with RHEL 7.4 to manage ONTAP LUNs.

To ensure that multipathing is configured correctly for your host, verify that the `/etc/multipath.conf` file is defined and that you have the NetApp recommended settings configured for your ONTAP LUNs.

### Steps

1. Verify that the `/etc/multipath.conf` file exists:

```
ls /etc/multipath.conf
```

If the file doesn't exist, create an empty, zero-byte file:

```
touch /etc/multipath.conf
```

2. The first time the `multipath.conf` file is created, you might need to enable and start the multipath services to load the recommended settings:

```
systemctl enable multipathd
```

```
systemctl start multipathd
```

- Each time you boot the host, the empty `/etc/multipath.conf` zero-byte file automatically loads the NetApp recommended host multipath parameters as the default settings. You shouldn't need to make changes to the `/etc/multipath.conf` file for your host because the host operating system is compiled with the multipath parameters that recognize and manage ONTAP LUNs correctly.

The following table shows the native Linux OS compiled multipath parameter settings for ONTAP LUNs.

#### Show parameter settings

Parameter	Setting
detect_prio	yes
dev_loss_tmo	"infinity"
failback	immediate
fast_io_fail_tmo	5
features	"3 queue_if_no_path pg_init_retries 50"
flush_on_last_del	"yes"
hardware_handler	"0"
no_path_retry	queue
path_checker	"tur"
path_grouping_policy	"group_by_prio"
path_selector	"service-time 0"
polling_interval	5
prio	"ontap"
product	LUN.*
retain_attached_hw_handler	yes
rr_weight	"uniform"
user_friendly_names	no
vendor	NETAPP

- Verify the parameter settings and path status for your ONTAP LUNs:

```
multipath -ll
```

The default multipath parameters support ASA, AFF, and FAS configurations. In these configurations, a single ONTAP LUN shouldn't require more than four paths. If there are more than four paths, it might cause issues with the paths during a storage failure.

The following example outputs show the correct parameter settings and path status for ONTAP LUNs in an ASA, AFF, or FAS configuration.

### ASA configuration

An ASA configuration optimizes all paths to a given LUN, keeping them active. This improves performance by serving I/O operations through all paths at the same time.

```
# multipath -ll
3600a09803831347657244e527766394e dm-5 NETAPP,LUN C-Mode
size=80G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
`-+- policy='service-time 0' prio=50 status=active
  |- 3:0:7:9      sdco 69:192  active ready running
  |- 3:0:8:9      sddi 71:0    active ready running
  |- 14:0:8:9     sdjq 65:320  active ready running
  `-- 14:0:7:9    sdiw 8:256   active ready running
```

### AFF or FAS configuration

An AFF or FAS configuration should have two groups of paths with higher and lower priorities. Higher priority Active/Optimized paths are served by the controller where the aggregate is located. Lower priority paths are active but non-optimized because they are served by a different controller. Non-optimized paths are only used when optimized paths aren't available.

The following example displays the output for an ONTAP LUN with two Active/Optimized paths and two Active/Non-Optimized paths:

```
# multipath -ll
3600a09803831347657244e527766394e dm-5 NETAPP,LUN C-Mode
size=80G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
|-+- policy='service-time 0' prio=50 status=active
| |- 3:0:3:0      sdd  8:48    active ready running
| |- 3:0:4:0      sdx   65:112  active ready running
`-+- policy='service-time 0' prio=10 status=enabled
  |- 14:0:2:0     sdfk 130:96   active ready running
  `-- 14:0:5:0    sdgz 132:240  active ready running
```

## Step 4: Optionally, exclude a device from multipathing

If required, you can exclude a device from multipathing by adding the WWID for the unwanted device to the "blacklist" stanza for the `multipath.conf` file.

### Steps

1. Determine the WWID:

```
/lib/udev/scsi_id -gud /dev/sda
```

"sda" is the local SCSI disk that you want to add to the blacklist.

An example WWID is 360030057024d0730239134810c0cb833.

2. Add the WWID to the "blacklist" stanza:

```
blacklist {  
    wwid      360030057024d0730239134810c0cb833  
    devnode   "^(ram|raw|loop|fd|md|dm-|sr|scd|st)[0-9]*"  
    devnode   "^hd[a-z]"  
    devnode   "^cciss.*"  
}
```

### Step 5: Customize multipath parameters for ONTAP LUNs

If your host is connected to LUNs from other vendors and any of the multipath parameter settings are overridden, you need to correct them by adding stanzas later in the `multipath.conf` file that apply specifically to ONTAP LUNs. If you don't do this, the ONTAP LUNs might not work as expected.

Check your `/etc/multipath.conf` file, especially in the defaults section, for settings that might be overriding the [default settings for multipath parameters](#).



You shouldn't override the recommended parameter settings for ONTAP LUNs. These settings are required for optimal performance of your host configuration. Contact NetApp support, your OS vendor, or both for more information.

The following example shows how to correct an overridden default. In this example, the `multipath.conf` file defines values for `path_checker` and `no_path_retry` that aren't compatible with ONTAP LUNs, and you can't remove these parameters because ONTAP storage arrays are still attached to the host. Instead, you correct the values for `path_checker` and `no_path_retry` by adding a device stanza to the `multipath.conf` file that applies specifically to the ONTAP LUNs.



## Show example

```
defaults {
    path_checker      readsector0
    no_path_retry     fail
}

devices {
    device {
        vendor        "NETAPP"
        product        "LUN"
        no_path_retry  queue
        path_checker   tur
    }
}
```

## Step 6: Review the known issues

The RHEL 7.4 with ONTAP storage release has the following known issue:

NetApp Bug ID	Title	Description
1440718	If you unmap or map a LUN without performing a SCSI rescan, it might lead to data corruption on the host.	When you set the 'disable_changed_wwids' multipath configuration parameter to YES, it disables access to the path device in the event of a WWID change. Multipath will disable access to the path device until the WWID of the path is restored to the WWID of the multipath device. To learn more, see <a href="#">NetApp Knowledge Base: The filesystem corruption on iSCSI LUN on the Oracle Linux 7</a> .

## What's next?

- [Learn about using the Linux Host Utilities tool](#).
- Learn about ASM mirroring.

Automatic Storage Management (ASM) mirroring might require changes to the Linux multipath settings to allow ASM to recognize a problem and switch over to an alternate failure group. Most ASM configurations on ONTAP use external redundancy, which means that data protection is provided by the external array and ASM doesn't mirror data. Some sites use ASM with normal redundancy to provide two-way mirroring, normally across different sites. See [Oracle databases on ONTAP](#) for further information.

## Configure RHEL 7.3 for FCP and iSCSI with ONTAP storage

The Linux Host Utilities software provides management and diagnostic tools for Linux hosts that are connected to ONTAP storage. When you install the Linux Host Utilities on a Red Hat Enterprise Linux (RHEL) 7.3 host, you can use the Host Utilities to help you manage FCP and iSCSI protocol operations with ONTAP LUNs.



You don't need to manually configure Kernel-based Virtual Machine (KVM) settings because ONTAP LUNs are automatically mapped to the hypervisor.

### Step 1: Optionally, enable SAN booting

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

#### Before you begin

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

#### Steps

1. [Create a SAN boot LUN and map it to the host.](#)
2. Enable SAN booting in the server BIOS for the ports to which the SAN boot LUN is mapped.

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

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

### Step 2: Install the Linux Host Utilities

NetApp strongly recommends installing the Linux Host Utilities to support ONTAP LUN management and assist technical support with gathering configuration data.

[Install Linux Host Utilities 7.1.](#)



Installing the Linux Host Utilities doesn't change any host timeout settings on your Linux host.

### Step 3: Confirm the multipath configuration for your host

You can use multipathing with RHEL 7.3 to manage ONTAP LUNs.

To ensure that multipathing is configured correctly for your host, verify that the `/etc/multipath.conf` file is defined and that you have the NetApp recommended settings configured for your ONTAP LUNs.

#### Steps

1. Verify that the `/etc/multipath.conf` file exists:

```
ls /etc/multipath.conf
```

If the file doesn't exist, create an empty, zero-byte file:

```
touch /etc/multipath.conf
```

2. The first time the `multipath.conf` file is created, you might need to enable and start the multipath services to load the recommended settings:

```
systemctl enable multipathd
```

```
systemctl start multipathd
```

3. Each time you boot the host, the empty `/etc/multipath.conf` zero-byte file automatically loads the NetApp recommended host multipath parameters as the default settings. You shouldn't need to make changes to the `/etc/multipath.conf` file for your host because the host operating system is compiled with the multipath parameters that recognize and manage ONTAP LUNs correctly.

The following table shows the native Linux OS compiled multipath parameter settings for ONTAP LUNs.

#### Show parameter settings

Parameter	Setting
detect_prio	yes
dev_loss_tmo	"infinity"
failback	immediate
fast_io_fail_tmo	5
features	"3 queue_if_no_path pg_init_retries 50"
flush_on_last_del	"yes"
hardware_handler	"0"
no_path_retry	queue
path_checker	"tur"
path_grouping_policy	"group_by_prio"
path_selector	"service-time 0"
polling_interval	5
prio	"ontap"
product	LUN.*
retain_attached_hw_handler	yes
rr_weight	"uniform"
user_friendly_names	no
vendor	NETAPP

#### 4. Verify the parameter settings and path status for your ONTAP LUNs:

```
multipath -ll
```

The default multipath parameters support ASA, AFF, and FAS configurations. In these configurations, a single ONTAP LUN shouldn't require more than four paths. If there are more than four paths, it might cause issues with the paths during a storage failure.

The following example outputs show the correct parameter settings and path status for ONTAP LUNs in an ASA, AFF, or FAS configuration.

##### ASA configuration

An ASA configuration optimizes all paths to a given LUN, keeping them active. This improves performance by serving I/O operations through all paths at the same time.

```
# multipath -ll
3600a09803831347657244e527766394e dm-5 NETAPP,LUN C-Mode
size=80G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
`-+- policy='service-time 0' prio=50 status=active
  |- 3:0:7:9      sdco 69:192  active ready running
  |- 3:0:8:9      sddi 71:0    active ready running
  |- 14:0:8:9     sdjq 65:320  active ready running
  `-- 14:0:7:9    sdiw 8:256   active ready running
```

##### AFF or FAS configuration

An AFF or FAS configuration should have two groups of paths with higher and lower priorities. Higher priority Active/Optimized paths are served by the controller where the aggregate is located. Lower priority paths are active but non-optimized because they are served by a different controller. Non-optimized paths are only used when optimized paths aren't available.

The following example displays the output for an ONTAP LUN with two Active/Optimized paths and two Active/Non-Optimized paths:

```
# multipath -ll
3600a09803831347657244e527766394e dm-5 NETAPP,LUN C-Mode
size=80G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
|+- policy='service-time 0' prio=50 status=active
| |- 3:0:3:0      sdd  8:48    active ready running
| |- 3:0:4:0      sdx   65:112  active ready running
`-+- policy='service-time 0' prio=10 status=enabled
  |- 14:0:2:0     sdfk 130:96   active ready running
  `-- 14:0:5:0    sdgz 132:240  active ready running
```

## Step 4: Optionally, exclude a device from multipathing

If required, you can exclude a device from multipathing by adding the WWID for the unwanted device to the "blacklist" stanza for the `multipath.conf` file.

### Steps

1. Determine the WWID:

```
/lib/udev/scsi_id -gud /dev/sda
```

"sda" is the local SCSI disk that you want to add to the blacklist.

An example WWID is 360030057024d0730239134810c0cb833.

2. Add the WWID to the "blacklist" stanza:

```
blacklist {
    wwid      360030057024d0730239134810c0cb833
    devnode   "^(ram|raw|loop|fd|md|dm-|sr|scd|st)[0-9]*"
    devnode   "^hd[a-z]"
    devnode   "^cciss.*"
}
```

## Step 5: Customize multipath parameters for ONTAP LUNs

If your host is connected to LUNs from other vendors and any of the multipath parameter settings are overridden, you need to correct them by adding stanzas later in the `multipath.conf` file that apply specifically to ONTAP LUNs. If you don't do this, the ONTAP LUNs might not work as expected.

Check your `/etc/multipath.conf` file, especially in the defaults section, for settings that might be overriding the [default settings for multipath parameters](#).



You shouldn't override the recommended parameter settings for ONTAP LUNs. These settings are required for optimal performance of your host configuration. Contact NetApp support, your OS vendor, or both for more information.

The following example shows how to correct an overridden default. In this example, the `multipath.conf` file defines values for `path_checker` and `no_path_retry` that aren't compatible with ONTAP LUNs, and you can't remove these parameters because ONTAP storage arrays are still attached to the host. Instead, you correct the values for `path_checker` and `no_path_retry` by adding a device stanza to the `multipath.conf` file that applies specifically to the ONTAP LUNs.

## Show example

```
defaults {
    path_checker      readsector0
    no_path_retry     fail
}

devices {
    device {
        vendor        "NETAPP"
        product        "LUN"
        no_path_retry  queue
        path_checker   tur
    }
}
```

### Step 6: Review the known issues

There are no known issues.

### What's next?

- [Learn about using the Linux Host Utilities tool.](#)
- Learn about ASM mirroring.

Automatic Storage Management (ASM) mirroring might require changes to the Linux multipath settings to allow ASM to recognize a problem and switch over to an alternate failure group. Most ASM configurations on ONTAP use external redundancy, which means that data protection is provided by the external array and ASM doesn't mirror data. Some sites use ASM with normal redundancy to provide two-way mirroring, normally across different sites. See [Oracle databases on ONTAP](#) for further information.

## Configure RHEL 7.2 for FCP and iSCSI with ONTAP storage

The Linux Host Utilities software provides management and diagnostic tools for Linux hosts that are connected to ONTAP storage. When you install the Linux Host Utilities on a Red Hat Enterprise Linux (RHEL) 7.2 host, you can use the Host Utilities to help you manage FCP and iSCSI protocol operations with ONTAP LUNs.



You don't need to manually configure Kernel-based Virtual Machine (KVM) settings because ONTAP LUNs are automatically mapped to the hypervisor.

### Step 1: Optionally, enable SAN booting

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

### Before you begin

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

### Steps

1. [Create a SAN boot LUN and map it to the host.](#)
2. Enable SAN booting in the server BIOS for the ports to which the SAN boot LUN is mapped.

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

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

## Step 2: Install the Linux Host Utilities

NetApp strongly recommends installing the Linux Host Utilities to support ONTAP LUN management and assist technical support with gathering configuration data.

[Install Linux Host Utilities 7.1.](#)



Installing the Linux Host Utilities doesn't change any host timeout settings on your Linux host.

## Step 3: Confirm the multipath configuration for your host

You can use multipathing with RHEL 7.2 to manage ONTAP LUNs.

To ensure that multipathing is configured correctly for your host, verify that the `/etc/multipath.conf` file is defined and that you have the NetApp recommended settings configured for your ONTAP LUNs.

### Steps

1. Verify that the `/etc/multipath.conf` file exists:

```
ls /etc/multipath.conf
```

If the file doesn't exist, create an empty, zero-byte file:

```
touch /etc/multipath.conf
```

2. The first time the `multipath.conf` file is created, you might need to enable and start the multipath services to load the recommended settings:

```
systemctl enable multipathd
```

```
systemctl start multipathd
```

3. Each time you boot the host, the empty `/etc/multipath.conf` zero-byte file automatically loads the NetApp recommended host multipath parameters as the default settings. You shouldn't need to make

changes to the `/etc/multipath.conf` file for your host because the host operating system is compiled with the multipath parameters that recognize and manage ONTAP LUNs correctly.

The following table shows the native Linux OS compiled multipath parameter settings for ONTAP LUNs.

#### Show parameter settings

Parameter	Setting
detect_prio	yes
dev_loss_tmo	"infinity"
failback	immediate
fast_io_fail_tmo	5
features	"3 queue_if_no_path pg_init_retries 50"
flush_on_last_del	"yes"
hardware_handler	"0"
no_path_retry	queue
path_checker	"tur"
path_grouping_policy	"group_by_prio"
path_selector	"service-time 0"
polling_interval	5
prio	"ontap"
product	LUN.*
retain_attached_hw_handler	yes
rr_weight	"uniform"
user_friendly_names	no
vendor	NETAPP

4. Verify the parameter settings and path status for your ONTAP LUNs:

```
multipath -ll
```

The default multipath parameters support ASA, AFF, and FAS configurations. In these configurations, a single ONTAP LUN shouldn't require more than four paths. If there are more than four paths, it might cause issues with the paths during a storage failure.

The following example outputs show the correct parameter settings and path status for ONTAP LUNs in an ASA, AFF, or FAS configuration.



## ASA configuration

An ASA configuration optimizes all paths to a given LUN, keeping them active. This improves performance by serving I/O operations through all paths at the same time.

```
# multipath -ll
3600a09803831347657244e527766394e dm-5 NETAPP,LUN C-Mode
size=80G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
`-+- policy='service-time 0' prio=50 status=active
  |- 3:0:7:9      sdco 69:192  active ready running
  |- 3:0:8:9      sddi 71:0    active ready running
  |- 14:0:8:9     sdjq 65:320  active ready running
  `- 14:0:7:9     sdiw 8:256   active ready running
```

## AFF or FAS configuration

An AFF or FAS configuration should have two groups of paths with higher and lower priorities. Higher priority Active/Optimized paths are served by the controller where the aggregate is located. Lower priority paths are active but non-optimized because they are served by a different controller. Non-optimized paths are only used when optimized paths aren't available.

The following example displays the output for an ONTAP LUN with two Active/Optimized paths and two Active/Non-Optimized paths:

```
# multipath -ll
3600a09803831347657244e527766394e dm-5 NETAPP,LUN C-Mode
size=80G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
|-+- policy='service-time 0' prio=50 status=active
| |- 3:0:3:0      sdd  8:48    active ready running
| |- 3:0:4:0      sdx   65:112  active ready running
`-+- policy='service-time 0' prio=10 status=enabled
  |- 14:0:2:0     sdfk 130:96   active ready running
  `- 14:0:5:0     sdgz 132:240  active ready running
```

## Step 4: Optionally, exclude a device from multipathing

If required, you can exclude a device from multipathing by adding the WWID for the unwanted device to the "blacklist" stanza for the `multipath.conf` file.

### Steps

1. Determine the WWID:

```
/lib/udev/scsi_id -gud /dev/sda
```

"sda" is the local SCSI disk that you want to add to the blacklist.

An example WWID is 360030057024d0730239134810c0cb833.

2. Add the WWID to the "blacklist" stanza:

```
blacklist {
    wwid      360030057024d0730239134810c0cb833
    devnode   "^(ram|raw|loop|fd|md|dm-|sr|scd|st) [0-9] *"
    devnode   "^hd[a-z] *"
    devnode   "^cciss.*"
}
```

### Step 5: Customize multipath parameters for ONTAP LUNs

If your host is connected to LUNs from other vendors and any of the multipath parameter settings are overridden, you need to correct them by adding stanzas later in the `multipath.conf` file that apply specifically to ONTAP LUNs. If you don't do this, the ONTAP LUNs might not work as expected.

Check your `/etc/multipath.conf` file, especially in the defaults section, for settings that might be overriding the [default settings for multipath parameters](#).



You shouldn't override the recommended parameter settings for ONTAP LUNs. These settings are required for optimal performance of your host configuration. Contact NetApp support, your OS vendor, or both for more information.

The following example shows how to correct an overridden default. In this example, the `multipath.conf` file defines values for `path_checker` and `no_path_retry` that aren't compatible with ONTAP LUNs, and you can't remove these parameters because ONTAP storage arrays are still attached to the host. Instead, you correct the values for `path_checker` and `no_path_retry` by adding a device stanza to the `multipath.conf` file that applies specifically to the ONTAP LUNs.

## Show example

```
defaults {
    path_checker      readsector0
    no_path_retry     fail
}

devices {
    device {
        vendor        "NETAPP"
        product        "LUN"
        no_path_retry  queue
        path_checker   tur
    }
}
```

### Step 6: Review the known issues

There are no known issues.

### What's next?

- [Learn about using the Linux Host Utilities tool.](#)
- Learn about ASM mirroring.

Automatic Storage Management (ASM) mirroring might require changes to the Linux multipath settings to allow ASM to recognize a problem and switch over to an alternate failure group. Most ASM configurations on ONTAP use external redundancy, which means that data protection is provided by the external array and ASM doesn't mirror data. Some sites use ASM with normal redundancy to provide two-way mirroring, normally across different sites. See [Oracle databases on ONTAP](#) for further information.

## Configure RHEL 7.1 for FCP and iSCSI with ONTAP storage

The Linux Host Utilities software provides management and diagnostic tools for Linux hosts that are connected to ONTAP storage. When you install the Linux Host Utilities on a Red Hat Enterprise Linux (RHEL) 7.1 host, you can use the Host Utilities to help you manage FCP and iSCSI protocol operations with ONTAP LUNs.



You don't need to manually configure Kernel-based Virtual Machine (KVM) settings because ONTAP LUNs are automatically mapped to the hypervisor.

### Step 1: Optionally, enable SAN booting

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

### Before you begin

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

### Steps

1. [Create a SAN boot LUN and map it to the host.](#)
2. Enable SAN booting in the server BIOS for the ports to which the SAN boot LUN is mapped.

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

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

## Step 2: Install the Linux Host Utilities

NetApp strongly recommends installing the Linux Host Utilities to support ONTAP LUN management and assist technical support with gathering configuration data.

[Install Linux Host Utilities 7.1.](#)



Installing the Linux Host Utilities doesn't change any host timeout settings on your Linux host.

## Step 3: Confirm the multipath configuration for your host

You can use multipathing with RHEL 7.1 to manage ONTAP LUNs.

To ensure that multipathing is configured correctly for your host, verify that the `/etc/multipath.conf` file is defined and that you have the NetApp recommended settings configured for your ONTAP LUNs.

### Steps

1. Verify that the `/etc/multipath.conf` file exists:

```
ls /etc/multipath.conf
```

If the file doesn't exist, create an empty, zero-byte file:

```
touch /etc/multipath.conf
```

2. The first time the `multipath.conf` file is created, you might need to enable and start the multipath services to load the recommended settings:

```
systemctl enable multipathd
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3. Each time you boot the host, the empty `/etc/multipath.conf` zero-byte file automatically loads the NetApp recommended host multipath parameters as the default settings. You shouldn't need to make

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flush_on_last_del	"yes"
hardware_handler	"0"
no_path_retry	queue
path_checker	"tur"
path_grouping_policy	"group_by_prio"
path_selector	"service-time 0"
polling_interval	5
prio	"ontap"
product	LUN.*
retain_attached_hw_handler	yes
rr_weight	"uniform"
user_friendly_names	no
vendor	NETAPP

4. Verify the parameter settings and path status for your ONTAP LUNs:

```
multipath -ll
```

The default multipath parameters support ASA, AFF, and FAS configurations. In these configurations, a single ONTAP LUN shouldn't require more than four paths. If there are more than four paths, it might cause issues with the paths during a storage failure.

The following example outputs show the correct parameter settings and path status for ONTAP LUNs in an ASA, AFF, or FAS configuration.

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```
# multipath -ll
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size=80G features='3 queue_if_no_path pg_init_retries 50'
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`-+- policy='service-time 0' prio=50 status=active
  |- 3:0:7:9      sdco 69:192  active ready running
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  |- 14:0:8:9     sdjq 65:320  active ready running
  `-- 14:0:7:9    sdiw 8:256   active ready running
```

## AFF or FAS configuration

An AFF or FAS configuration should have two groups of paths with higher and lower priorities. Higher priority Active/Optimized paths are served by the controller where the aggregate is located. Lower priority paths are active but non-optimized because they are served by a different controller. Non-optimized paths are only used when optimized paths aren't available.

The following example displays the output for an ONTAP LUN with two Active/Optimized paths and two Active/Non-Optimized paths:

```
# multipath -ll
3600a09803831347657244e527766394e dm-5 NETAPP,LUN C-Mode
size=80G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
|-+- policy='service-time 0' prio=50 status=active
| |- 3:0:3:0      sdd  8:48    active ready running
| |- 3:0:4:0      sdx   65:112  active ready running
`-+- policy='service-time 0' prio=10 status=enabled
  |- 14:0:2:0     sdfk 130:96   active ready running
  `-- 14:0:5:0    sdgz 132:240  active ready running
```

## Step 4: Optionally, exclude a device from multipathing

If required, you can exclude a device from multipathing by adding the WWID for the unwanted device to the "blacklist" stanza for the `multipath.conf` file.

### Steps

1. Determine the WWID:

```
/lib/udev/scsi_id -gud /dev/sda
```

"sda" is the local SCSI disk that you want to add to the blacklist.

An example WWID is 360030057024d0730239134810c0cb833.

2. Add the WWID to the "blacklist" stanza:

```
blacklist {
    wwid      360030057024d0730239134810c0cb833
    devnode   "^(ram|raw|loop|fd|md|dm-|sr|scd|st) [0-9] *"
    devnode   "^hd[a-z] *"
    devnode   "^cciss.*"
}
```

### Step 5: Customize multipath parameters for ONTAP LUNs

If your host is connected to LUNs from other vendors and any of the multipath parameter settings are overridden, you need to correct them by adding stanzas later in the `multipath.conf` file that apply specifically to ONTAP LUNs. If you don't do this, the ONTAP LUNs might not work as expected.

Check your `/etc/multipath.conf` file, especially in the defaults section, for settings that might be overriding the [default settings for multipath parameters](#).



You shouldn't override the recommended parameter settings for ONTAP LUNs. These settings are required for optimal performance of your host configuration. Contact NetApp support, your OS vendor, or both for more information.

The following example shows how to correct an overridden default. In this example, the `multipath.conf` file defines values for `path_checker` and `no_path_retry` that aren't compatible with ONTAP LUNs, and you can't remove these parameters because ONTAP storage arrays are still attached to the host. Instead, you correct the values for `path_checker` and `no_path_retry` by adding a device stanza to the `multipath.conf` file that applies specifically to the ONTAP LUNs.

## Show example

```
defaults {
    path_checker      readsector0
    no_path_retry     fail
}

devices {
    device {
        vendor        "NETAPP"
        product        "LUN"
        no_path_retry  queue
        path_checker   tur
    }
}
```

## Step 6: Review the known issues

The RHEL 7.1 with ONTAP storage release has the following known issues:

NetApp Bug ID	Title	Description
<a href="#">799323</a>	Emulex FCoE (OCe10102-FX-D) host hang or path failures observed during I/O with storage failover operations	You might observe a host hang or path failures on Emulex 10G FCoE host (OCe10102-FX-D) during I/O with storage failover operations. In such scenarios, you might see the following message: "driver's buffer pool is empty, IO busied and SCSI Layer I/O Abort Request Status"
<a href="#">836875</a>	IP addresses are not always assigned during the boot of a RHEL 7.0 OS installed on an iSCSI multipath'd LUN	When you install the root(/) on a iSCSI multipath'd LUN, the IP address for the Ethernet interfaces are specified in the kernel command line so that the IP addresses are assigned before the iSCSI service starts. However, dracut cannot assign IP addresses to all the Ethernet ports during the boot, before the iSCSI service starts. This causes the iSCSI login to fail on interfaces without IP addresses. You will see the iSCSI service attempt to login numerous times, which will cause a delay in the OS boot time.



## What's next?

- [Learn about using the Linux Host Utilities tool.](#)
- Learn about ASM mirroring.

Automatic Storage Management (ASM) mirroring might require changes to the Linux multipath settings to allow ASM to recognize a problem and switch over to an alternate failure group. Most ASM configurations on ONTAP use external redundancy, which means that data protection is provided by the external array and ASM doesn't mirror data. Some sites use ASM with normal redundancy to provide two-way mirroring, normally across different sites. See [Oracle databases on ONTAP](#) for further information.

## Configure RHEL 7.0 for FCP and iSCSI with ONTAP storage

The Linux Host Utilities software provides management and diagnostic tools for Linux hosts that are connected to ONTAP storage. When you install the Linux Host Utilities on a Red Hat Enterprise Linux (RHEL) 7.0 host, you can use the Host Utilities to help you manage FCP and iSCSI protocol operations with ONTAP LUNs.



You don't need to manually configure Kernel-based Virtual Machine (KVM) settings because ONTAP LUNs are automatically mapped to the hypervisor.

### Step 1: Optionally, enable SAN booting

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

#### Before you begin

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

#### Steps

1. [Create a SAN boot LUN and map it to the host.](#)
2. Enable SAN booting in the server BIOS for the ports to which the SAN boot LUN is mapped.

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

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

### Step 2: Install the Linux Host Utilities

NetApp strongly recommends installing the Linux Host Utilities to support ONTAP LUN management and assist technical support with gathering configuration data.

[Install Linux Host Utilities 7.1.](#)



Installing the Linux Host Utilities doesn't change any host timeout settings on your Linux host.

### Step 3: Confirm the multipath configuration for your host

You can use multipathing with RHEL 7.0 to manage ONTAP LUNs.

To ensure that multipathing is configured correctly for your host, verify that the `/etc/multipath.conf` file is defined and that you have the NetApp recommended settings configured for your ONTAP LUNs.

### Steps

1. Verify that the `/etc/multipath.conf` file exists:

```
ls /etc/multipath.conf
```

If the file doesn't exist, create an empty, zero-byte file:

```
touch /etc/multipath.conf
```

2. The first time the `multipath.conf` file is created, you might need to enable and start the multipath services to load the recommended settings:

```
systemctl enable multipathd
```

```
systemctl start multipathd
```

3. Each time you boot the host, the empty `/etc/multipath.conf` zero-byte file automatically loads the NetApp recommended host multipath parameters as the default settings. You shouldn't need to make changes to the `/etc/multipath.conf` file for your host because the host operating system is compiled with the multipath parameters that recognize and manage ONTAP LUNs correctly.

The following table shows the native Linux OS compiled multipath parameter settings for ONTAP LUNs.

## Show parameter settings

Parameter	Setting
detect_prio	yes
dev_loss_tmo	"infinity"
failback	immediate
fast_io_fail_tmo	5
features	"3 queue_if_no_path pg_init_retries 50"
flush_on_last_del	"yes"
hardware_handler	"0"
no_path_retry	queue
path_checker	"tur"
path_grouping_policy	"group_by_prio"
path_selector	"service-time 0"
polling_interval	5
prio	"ontap"
product	LUN.*
retain_attached_hw_handler	yes
rr_weight	"uniform"
user_friendly_names	no
vendor	NETAPP

### 4. Verify the parameter settings and path status for your ONTAP LUNs:

```
multipath -ll
```

The default multipath parameters support ASA, AFF, and FAS configurations. In these configurations, a single ONTAP LUN shouldn't require more than four paths. If there are more than four paths, it might cause issues with the paths during a storage failure.

The following example outputs show the correct parameter settings and path status for ONTAP LUNs in an ASA, AFF, or FAS configuration.

## ASA configuration

An ASA configuration optimizes all paths to a given LUN, keeping them active. This improves performance by serving I/O operations through all paths at the same time.

```
# multipath -ll
3600a09803831347657244e527766394e dm-5 NETAPP,LUN C-Mode
size=80G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
`-+- policy='service-time 0' prio=50 status=active
  |- 3:0:7:9      sdco 69:192  active ready running
  |- 3:0:8:9      sddi 71:0    active ready running
  |- 14:0:8:9     sdjq 65:320  active ready running
  `-- 14:0:7:9    sdiw 8:256   active ready running
```

## AFF or FAS configuration

An AFF or FAS configuration should have two groups of paths with higher and lower priorities. Higher priority Active/Optimized paths are served by the controller where the aggregate is located. Lower priority paths are active but non-optimized because they are served by a different controller. Non-optimized paths are only used when optimized paths aren't available.

The following example displays the output for an ONTAP LUN with two Active/Optimized paths and two Active/Non-Optimized paths:

```
# multipath -ll
3600a09803831347657244e527766394e dm-5 NETAPP,LUN C-Mode
size=80G features='3 queue_if_no_path pg_init_retries 50'
hwhandler='1 alua' wp=rw
|-+- policy='service-time 0' prio=50 status=active
| |- 3:0:3:0      sdd  8:48    active ready running
| |- 3:0:4:0      sdx   65:112  active ready running
`-+- policy='service-time 0' prio=10 status=enabled
  |- 14:0:2:0     sdfk 130:96   active ready running
  `-- 14:0:5:0    sdgz 132:240  active ready running
```

## Step 4: Optionally, exclude a device from multipathing

If required, you can exclude a device from multipathing by adding the WWID for the unwanted device to the "blacklist" stanza for the `multipath.conf` file.

### Steps

1. Determine the WWID:

```
/lib/udev/scsi_id -gud /dev/sda
```

"sda" is the local SCSI disk that you want to add to the blacklist.

An example WWID is 360030057024d0730239134810c0cb833.

2. Add the WWID to the "blacklist" stanza:

```
blacklist {
    wwid      360030057024d0730239134810c0cb833
    devnode   "^(ram|raw|loop|fd|md|dm-|sr|scd|st) [0-9] *"
    devnode   "^hd[a-z] *"
    devnode   "^cciss.*"
}
```

### Step 5: Customize multipath parameters for ONTAP LUNs

If your host is connected to LUNs from other vendors and any of the multipath parameter settings are overridden, you need to correct them by adding stanzas later in the `multipath.conf` file that apply specifically to ONTAP LUNs. If you don't do this, the ONTAP LUNs might not work as expected.

Check your `/etc/multipath.conf` file, especially in the defaults section, for settings that might be overriding the [default settings for multipath parameters](#).



You shouldn't override the recommended parameter settings for ONTAP LUNs. These settings are required for optimal performance of your host configuration. Contact NetApp support, your OS vendor, or both for more information.

The following example shows how to correct an overridden default. In this example, the `multipath.conf` file defines values for `path_checker` and `no_path_retry` that aren't compatible with ONTAP LUNs, and you can't remove these parameters because ONTAP storage arrays are still attached to the host. Instead, you correct the values for `path_checker` and `no_path_retry` by adding a device stanza to the `multipath.conf` file that applies specifically to the ONTAP LUNs.

## Show example

```
defaults {
  path_checker      readsector0
  no_path_retry     fail
}

devices {
  device {
    vendor          "NETAPP"
    product         "LUN"
    no_path_retry   queue
    path_checker    tur
  }
}
```

## Step 6: Review the known issues

The RHEL 7.0 with ONTAP storage release has the following known issues:

NetApp Bug ID	Title	Description
<a href="#">844417</a>	Emulex 16G FC (LPe16002B-M6) host crashes during I/O with storage failover operations	You might observe a 16G FC Emulex (LPe16002B-M6) host crash during I/O with storage failover operations.
<a href="#">811587</a>	Emulex 16G FC (LPe16002B-M6) host crashes during I/O with storage failover operations	You might observe a 16G FC Emulex (LPe16002B-M6) host crash during I/O with storage failover operations.
<a href="#">803071</a>	Emulex 16G FC (LPe16002B-M6) host crashes during I/O with storage failover operations	You might observe a 16G FC Emulex (LPe16002B-M6) host crash during I/O with storage failover operations.
<a href="#">820163</a>	QLogic host hang or path failures observed during I/O with storage failover operations	You might observe a host hang or path failures on QLogic host during I/O with storage failover operations. In such scenarios, you might see the following message: "Mailbox cmd timeout occurred, cmd=0x54, mb[0]=0x54 and Firmware dump saved to temp buffer" messages which leads to host hung/path failure.

NetApp Bug ID	Title	Description
<a href="#">799323</a>	Emulex FCoE (OCe10102-FX-D) host hang or path failures observed during I/O with storage failover operations	You might observe a host hang or path failures on Emulex 10G FCoE host (OCe10102-FX-D) during I/O with storage failover operations. In such scenarios, you might see the following message: "driver's buffer pool is empty, IO busied and SCSI Layer I/O Abort Request Status" messages which leads to host hung/path failures.
<a href="#">849212</a>	Emulex 16G FC (LPe16002B-M6) host hang or path failures are observed during I/O with storage failover operations	You might observe a host hang or path failures on Emulex 16G FC (LPe16002B-M6) host during I/O with storage failover operations. In such scenarios, you might see the following message: "RSCN timeout Data and iotag x1301 is out of range: max iotag" messages which leads to host hung/path failures.
<a href="#">836800</a>	Anaconda displays an iSCSI login failure message although logins are successful during RHEL 7.0 OS installation	When you install the root(/) on a iSCSI multipath'd LUN, the IP address for the Ethernet interfaces are specified in the kernel command line so that the IP addresses are assigned before the iSCSI service starts. However, dracut cannot assign IP addresses to all the Ethernet ports during the boot, before the iSCSI service starts. This causes the iSCSI login to fail on interfaces without IP addresses. You will see the iSCSI service attempt to login numerous times, which will cause a delay in the OS boot time.
<a href="#">836875</a>	IP addresses are not always assigned during the boot of a RHEL 7.0 OS installed on an iSCSI multipath'd LUN	When you are installing RHEL 7.0, the anaconda installation screen displays that iSCSI login to multiple target IPs have failed though the iSCSI logins are successful. Anaconda displays following error message: "Node Login Failed" You will observe this error only when you select multiple target IPs for iSCSI login. You can continue the OS installation by clicking the "ok" button. This bug does not hamper either the iSCSI or the RHEL 7.0 OS installation.

NetApp Bug ID	Title	Description
<a href="#">836657</a>	Anaconda does not add bootdev argument in kernel cmd line to set IP address for RHEL 7.0 OS installed on iSCSI multipath'd LUN	Anaconda does not add a bootdev argument in the kernel command line where you set the IPv4 address during the RHEL 7.0 OS installation on an iSCSI multipath'd LUN. This prevents assigning of IP addresses to any of the Ethernet interfaces that were configured to establish iSCSI sessions with the storage subsystem during the RHEL 7.0 boot. Since iSCSI sessions are not established, the root LUN is not discovered when the OS boots and hence the OS boot fails.

### What's next?

- [Learn about using the Linux Host Utilities tool.](#)
- Learn about ASM mirroring.

Automatic Storage Management (ASM) mirroring might require changes to the Linux multipath settings to allow ASM to recognize a problem and switch over to an alternate failure group. Most ASM configurations on ONTAP use external redundancy, which means that data protection is provided by the external array and ASM doesn't mirror data. Some sites use ASM with normal redundancy to provide two-way mirroring, normally across different sites. See [Oracle databases on ONTAP](#) for further information.

## RHEL 6

### Use Red Hat Enterprise Linux 6.10 with ONTAP

You can use the ONTAP SAN host configuration settings to configure Red Hat Enterprise Linux 6.10 with ONTAP as the target.

#### Install the Linux Host Utilities

The NetApp Linux Host Utilities software package is available on the [NetApp Support Site](#) in a 32-bit and 64-bit .rpm file. If you don't know which file is right for your configuration, use the [Interoperability Matrix Tool](#) to verify which one you need.

NetApp strongly recommends installing the Linux Host Utilities, but it's not mandatory. The utilities don't change any settings on your Linux host. The utilities improve management and assist NetApp customer support in gathering information about your configuration.

If you have Linux Host Utilities currently installed, you should either upgrade it to the latest version, or remove it and follow these steps to install the latest version.

#### Steps

1. Download the 32-bit or 64-bit Linux Host Utilities software package from the [NetApp Support Site](#) to your host.



## 2. Install the software package:

```
rpm -ivh netapp_linux_unified_host_utilities-7-1.x86_64
```



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

### SAN Toolkit

The toolkit is installed automatically when you install the NetApp Host Utilities package. This kit provides the `sanlun` utility, which helps you manage LUNs and HBAs. The `sanlun` command returns information about the LUNs mapped to your host, multipathing, and information necessary to create initiator groups.

#### Example

In the following example, the `sanlun lun show` command returns LUN information.

```
# sanlun lun show all
```

Example output:

```
controller(7mode/E-Series)/          device      host          lun
vserver(cDOT/FlashRay)  lun-pathname filename  adapter  protocol  size
Product
-----
-----
data_vserver            /vol/vol1/lun1  /dev/sdb    host16    FCP
120.0g  cDOT
data_vserver            /vol/vol1/lun1  /dev/sdc    host15    FCP
120.0g  cDOT
data_vserver            /vol/vol2/lun2  /dev/sdd    host16    FCP
120.0g  cDOT
data_vserver            /vol/vol2/lun2  /dev/sde    host15    FCP
120.0g  cDOT
```

### SAN Booting

#### Before you begin

If you decide to use SAN booting, it must be supported by your configuration. You can use the [Interoperability Matrix Tool](#) to verify that your OS, HBA, HBA firmware and the HBA boot BIOS, and ONTAP version are supported.

#### Steps

1. Map the SAN boot LUN to the host.
2. Verify that multiple paths are available.



Multiple paths become available after the host OS is up and running on the paths.

3. Enable SAN booting in the server BIOS for the ports to which the SAN boot LUN is mapped.

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

4. Reboot the host to verify that the boot was successful.

## Multipathing

For Red Hat Enterprise Linux (RHEL) 6.10 the `/etc/multipath.conf` file must exist, but you do not need to make specific changes to the file. RHEL 6.10 is compiled with all settings required to recognize and correctly manage ONTAP LUNs.

To Enable ALUA Handler, perform the following steps:

### Steps

1. Create a backup of the `initrd-image`.
2. Append the following parameter value to the kernel for ALUA and non-ALUA to work:  
`rdloaddriver=scsi_dh_alua`

### Example

```
kernel /vmlinuz-2.6.32-358.6.1.el6.x86_64 ro root=/dev/mapper/  
vg_ibmx355021082-lv_root rd_NO_LUKS rd_LVM_LV=vg_ibmx355021082/ lv_root  
LANG=en_US.UTF-8 rd_LVM_LV=vg_ibmx355021082/lv_swap rd_NO_MD  
SYSFONT=latarcyrheb-sun16 crashkernel=auto KEYBOARDTYPE=pc KEYTABLE=us  
rd_NO_DM rhgb quiet rdloaddriver=scsi_dh_alua
```

3. Use the `mkinitrd` command to recreate the `initrd-image`.  
RHEL 6x and later versions use either:  
The command: `mkinitrd -f /boot/ initrd-"uname -r".img uname -r`  
Or  
The command: `dracut -f`
4. Reboot the host.
5. Verify the output of the `cat /proc/cmdline` command to ensure that the setting is complete.

You can use the `multipath -ll` command to verify the settings for your ONTAP LUNs.

The following sections provide example multipath outputs for a LUN mapped to ASA and non-ASA personas.

### All SAN Array configurations

All SAN Array (ASA) configurations optimize all paths to a given LUN, keeping them active. This improves performance by serving I/O operations through all paths at the same time.

### Example

The following example displays the correct output for an ONTAP LUN.

```
# multipath -ll
3600a0980383034466b2b4a3775474859 dm-3 NETAPP,LUN C-Mode
size=20G features='4 queue_if_no_path pg_init_retries 50
retain_attached_hw_handle' hwhandler='1 alua' wp=rw
|+- policy='round-robin 0' prio=50 status=active
|- 1:0:8:1 sdb 8:16 active ready running
|- 2:0:8:1 sdd 8:48 active ready running
|- 1:0:9:1 sdc 8:32 active ready running
|- 2:0:9:1 sde 8:64 active ready running
```



A single LUN shouldn't require more than four paths. Having more than four paths might cause path issues during storage failures.

### Non-ASA configurations

For non-ASA configurations, there should be two groups of paths with different priorities. The paths with higher priorities are Active/Optimized. This means they are serviced by the controller where the aggregate is located. The paths with lower priorities are active but non-optimized because they are served from a different controller. The non-optimized paths are only used when optimized paths are not available.

### Example

The following example displays the correct output for an ONTAP LUN with two Active/Optimized paths and two Active/Non-Optimized paths.

```
# multipath -ll
3600a0980383034466b2b4a3775474859 dm-3 NETAPP,LUN C-Mode
size=20G features='4 queue_if_no_path pg_init_retries 50
retain_attached_hw_handle' hwhandler='1 alua' wp=rw
|+- policy='round-robin 0' prio=50 status=active
| |- 1:0:8:1 sdb 8:16 active ready running
| `-- 2:0:8:1 sdd 8:48 active ready running
`+- policy='round-robin 0' prio=10 status=enabled
  |- 1:0:9:1 sdc 8:32 active ready running
  `-- 2:0:9:1 sde 8:64 active ready running
```



A single LUN shouldn't require more than four paths. Having more than four paths might cause path issues during storage failures.

### Recommended Settings

The RHEL 6.10 OS is compiled to recognize ONTAP LUNs and automatically set all configuration parameters correctly for both ASA and non-ASA configuration.

The `multipath.conf` file must exist for the multipath daemon to start. If this file doesn't exist, you can create an empty, zero-byte file by using the `touch /etc/multipath.conf` command.

The first time you create the `multipath.conf` file, you might need to enable and start the multipath services by using the following commands:

```
chkconfig multipathd on
/etc/init.d/multipathd start
```

You don't need to add anything directly to the `multipath.conf` file unless you have devices that you don't want multipath to manage or you have existing settings that override defaults. To exclude unwanted devices, add the following syntax to the `multipath.conf` file, replacing `<DevId>` with the worldwide identifier (WWID) string of the device you want to exclude:

```
blacklist {
    wwid <DevId>
    devnode "^(ram|raw|loop|fd|md|dm-|sr|scd|st) [0-9]*"
    devnode "^hd[a-z]"
    devnode "^cciss.*"
}
```

The following example determines the WWID of a device and adds it to the `multipath.conf` file.

### Steps

1. Determine the WWID:

```
/lib/udev/scsi_id -gud /dev/sda
```

```
3600a098038314c4a433f5774717a3046
```

`sda` is the local SCSI disk that you want to add to the blacklist.

2. Add the WWID to the blacklist stanza in `/etc/multipath.conf`:

```
blacklist {
    wwid 3600a098038314c4a433f5774717a3046
    devnode "^(ram|raw|loop|fd|md|dm-|sr|scd|st) [0-9]*"
    devnode "^hd[a-z]"
    devnode "^cciss.*"
}
```

Always check your `/etc/multipath.conf` file, especially in the defaults section, for legacy settings that might be overriding default settings.

The following table demonstrates the critical `multipathd` parameters for ONTAP LUNs and the required

values. If a host is connected to LUNs from other vendors and any of these parameters are overridden, they must be corrected by later stanzas in the `multipath.conf` file that apply specifically to ONTAP LUNs. Without this correction, the ONTAP LUNs might not work as expected. You should only override these defaults in consultation with NetApp, the OS vendor, or both, and only when the impact is fully understood.

Parameter	Setting
<code>detect_prio</code>	<code>yes</code>
<code>dev_loss_tmo</code>	<code>"infinity"</code>
<code>failback</code>	<code>immediate</code>
<code>fast_io_fail_tmo</code>	<code>5</code>
<code>features</code>	<code>"3 queue_if_no_path pg_init_retries 50"</code>
<code>flush_on_last_del</code>	<code>"yes"</code>
<code>hardware_handler</code>	<code>"0"</code>
<code>no_path_retry</code>	<code>queue</code>
<code>path_checker</code>	<code>"tur"</code>
<code>path_grouping_policy</code>	<code>"group_by_prio"</code>
<code>path_selector</code>	<code>"round-robin 0"</code>
<code>polling_interval</code>	<code>5</code>
<code>prio</code>	<code>"ontap"</code>
<code>product</code>	<code>LUN.*</code>
<code>retain_attached_hw_handler</code>	<code>yes</code>
<code>rr_weight</code>	<code>"uniform"</code>
<code>user_friendly_names</code>	<code>no</code>
<code>vendor</code>	<code>NETAPP</code>

### Example

The following example shows how to correct an overridden default. In this case, the `multipath.conf` file defines values for `path_checker` and `no_path_retry` that are not compatible with ONTAP LUNs. If they cannot be removed because of other SAN arrays still attached to the host, these parameters can be corrected specifically for ONTAP LUNs with a device stanza.

```

defaults {
    path_checker      readsector0
    no_path_retry     fail
}

devices {
    device {
        vendor        "NETAPP  "
        product        "LUN.*"
        no_path_retry  queue
        path_checker   tur
    }
}

```

## Configure KVM settings

You don't need to configure settings for a Kernel-based Virtual Machine because the LUN is mapped to the hypervisor.

## ASM mirroring

Automatic Storage Management (ASM) mirroring might require changes to the Linux multipath settings to allow ASM to recognize a problem and switch over to an alternate failure group. Most ASM configurations on ONTAP use external redundancy, which means that data protection is provided by the external array and ASM doesn't mirror data. Some sites use ASM with normal redundancy to provide two-way mirroring, normally across different sites. See [Oracle databases on ONTAP](#) for further information.

## Known issues

There are no known issues for the RHEL 6.10 with ONTAP release.

## Use Red Hat Enterprise Linux 6.9 with ONTAP

You can use the ONTAP SAN host configuration settings to configure Red Hat Enterprise Linux 6.9 with ONTAP as the target.

## Install the Linux Host Utilities

The NetApp Linux Host Utilities software package is available on the [NetApp Support Site](#) in a 32-bit and 64-bit .rpm file. If you don't know which file is right for your configuration, use the [Interoperability Matrix Tool](#) to verify which one you need.

NetApp strongly recommends installing the Linux Host Utilities, but it's not mandatory. The utilities don't change any settings on your Linux host. The utilities improve management and assist NetApp customer support in gathering information about your configuration.

If you have Linux Host Utilities currently installed, you should either upgrade it to the latest version, or remove it and follow these steps to install the latest version.

## Steps

1. Download the 32-bit or 64-bit Linux Host Utilities software package from the [NetApp Support Site](#) to your host.
2. Install the software package:

```
rpm -ivh netapp_linux_unified_host_utilities-7-1.x86_64
```



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

## SAN Toolkit

The toolkit is installed automatically when you install the NetApp Host Utilities package. This kit provides the `sanlun` utility, which helps you manage LUNs and HBAs. The `sanlun` command returns information about the LUNs mapped to your host, multipathing, and information necessary to create initiator groups.

### Example

In the following example, the `sanlun lun show` command returns LUN information.

```
# sanlun lun show all
```

Example output:

```
controller(7mode/E-Series)/          device      host          lun
vserver(cDOT/FlashRay)  lun-pathname filename  adapter  protocol  size
Product
-----
-----
data_vserver            /vol/vol1/lun1  /dev/sdb      host16    FCP
120.0g  cDOT
data_vserver            /vol/vol1/lun1  /dev/sdc      host15    FCP
120.0g  cDOT
data_vserver            /vol/vol2/lun2  /dev/sdd      host16    FCP
120.0g  cDOT
data_vserver            /vol/vol2/lun2  /dev/sde      host15    FCP
120.0g  cDOT
```

## SAN Booting

### Before you begin

If you decide to use SAN booting, it must be supported by your configuration. You can use the [Interoperability Matrix Tool](#) to verify that your OS, HBA, HBA firmware and the HBA boot BIOS, and ONTAP version are supported.

### Steps

1. Map the SAN boot LUN to the host.

2. Verify that multiple paths are available.



Multiple paths become available after the host OS is up and running on the paths.

3. Enable SAN booting in the server BIOS for the ports to which the SAN boot LUN is mapped.

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

4. Reboot the host to verify that the boot was successful.

## Multipathing

For Red Hat Enterprise Linux (RHEL) 6.9 the `/etc/multipath.conf` file must exist, but you do not need to make specific changes to the file. RHEL 6.9 is compiled with all settings required to recognize and correctly manage ONTAP LUNs.

To Enable ALUA Handler, perform the following steps:

### Steps

1. Create a backup of the `initrd-image`.
2. Append the following parameter value to the kernel for ALUA and non-ALUA to work:

```
rdloaddriver=scsi_dh_alua
```

### Example

```
kernel /vmlinuz-2.6.32-358.6.1.el6.x86_64 ro root=/dev/mapper/  
vg_ibmx355021082-lv_root rd_NO_LUKS rd_LVM_LV=vg_ibmx355021082/ lv_root  
LANG=en_US.UTF-8 rd_LVM_LV=vg_ibmx355021082/lv_swap rd_NO_MD  
SYSFONT=latacyrheb-sun16 crashkernel=auto KEYBOARDTYPE=pc KEYTABLE=us  
rd_NO_DM rhgb quiet rdloaddriver=scsi_dh_alua
```

3. Use the `mkinitrd` command to recreate the `initrd-image`.  
RHEL 6x and later versions use either:  
The command: `mkinitrd -f /boot/ initrd-"uname -r".img uname -r`  
Or  
The command: `dracut -f`
4. Reboot the host.
5. Verify the output of the `cat /proc/cmdline` command to ensure that the setting is complete.

You can use the `multipath -ll` command to verify the settings for your ONTAP LUNs.

The following sections provide example multipath outputs for a LUN mapped to ASA and non-ASA personas.

### All SAN Array configurations

All SAN Array (ASA) configurations optimize all paths to a given LUN, keeping them active. This improves performance by serving I/O operations through all paths at the same time.

### Example

The following example displays the correct output for an ONTAP LUN.



```
# multipath -ll
3600a0980383034466b2b4a3775474859 dm-3 NETAPP,LUN C-Mode
size=20G features='4 queue_if_no_path pg_init_retries 50
retain_attached_hw_handle' hwhandler='1 alua' wp=rw
|+- policy='round-robin 0' prio=50 status=active
|- 1:0:8:1 sdb 8:16 active ready running
|- 2:0:8:1 sdd 8:48 active ready running
|- 1:0:9:1 sdc 8:32 active ready running
|- 2:0:9:1 sde 8:64 active ready running
```



A single LUN shouldn't require more than four paths. Having more than four paths might cause path issues during storage failures.

### Non-ASA configurations

For non-ASA configurations, there should be two groups of paths with different priorities. The paths with higher priorities are Active/Optimized. This means they are serviced by the controller where the aggregate is located. The paths with lower priorities are active but non-optimized because they are served from a different controller. The non-optimized paths are only used when optimized paths are not available.

### Example

The following example displays the correct output for an ONTAP LUN with two Active/Optimized paths and two Active/Non-Optimized paths.

```
# multipath -ll
3600a0980383034466b2b4a3775474859 dm-3 NETAPP,LUN C-Mode
size=20G features='4 queue_if_no_path pg_init_retries 50
retain_attached_hw_handle' hwhandler='1 alua' wp=rw
|+- policy='round-robin 0' prio=50 status=active
| |- 1:0:8:1 sdb 8:16 active ready running
| `-- 2:0:8:1 sdd 8:48 active ready running
`+- policy='round-robin 0' prio=10 status=enabled
  |- 1:0:9:1 sdc 8:32 active ready running
  `-- 2:0:9:1 sde 8:64 active ready running
```



A single LUN shouldn't require more than four paths. Having more than four paths might cause path issues during storage failures.

### Recommended Settings

The RHEL 6.9 OS is compiled to recognize ONTAP LUNs and automatically set all configuration parameters correctly for both ASA and non-ASA configuration.

The `multipath.conf` file must exist for the multipath daemon to start. If this file doesn't exist, you can create an empty, zero-byte file by using the `touch /etc/multipath.conf` command.

The first time you create the `multipath.conf` file, you might need to enable and start the multipath services by using the following commands:

```
chkconfig multipathd on
/etc/init.d/multipathd start
```

You don't need to add anything directly to the `multipath.conf` file unless you have devices that you don't want multipath to manage or you have existing settings that override defaults. To exclude unwanted devices, add the following syntax to the `multipath.conf` file, replacing `<DevId>` with the worldwide identifier (WWID) string of the device you want to exclude:

```
blacklist {
    wwid <DevId>
    devnode "^(ram|raw|loop|fd|md|dm-|sr|scd|st) [0-9]*"
    devnode "^hd[a-z]"
    devnode "^cciss.*"
}
```

The following example determines the WWID of a device and adds it to the `multipath.conf` file.

### Steps

1. Determine the WWID:

```
/lib/udev/scsi_id -gud /dev/sda
```

```
3600a098038314c4a433f5774717a3046
```

`sda` is the local SCSI disk that you want to add to the blacklist.

2. Add the WWID to the blacklist stanza in `/etc/multipath.conf`:

```
blacklist {
    wwid 3600a098038314c4a433f5774717a3046
    devnode "^(ram|raw|loop|fd|md|dm-|sr|scd|st) [0-9]*"
    devnode "^hd[a-z]"
    devnode "^cciss.*"
}
```

Always check your `/etc/multipath.conf` file, especially in the defaults section, for legacy settings that might be overriding default settings.

The following table demonstrates the critical `multipathd` parameters for ONTAP LUNs and the required

values. If a host is connected to LUNs from other vendors and any of these parameters are overridden, they must be corrected by later stanzas in the `multipath.conf` file that apply specifically to ONTAP LUNs. Without this correction, the ONTAP LUNs might not work as expected. You should only override these defaults in consultation with NetApp, the OS vendor, or both, and only when the impact is fully understood.

Parameter	Setting
<code>detect_prio</code>	<code>yes</code>
<code>dev_loss_tmo</code>	<code>"infinity"</code>
<code>failback</code>	<code>immediate</code>
<code>fast_io_fail_tmo</code>	<code>5</code>
<code>features</code>	<code>"3 queue_if_no_path pg_init_retries 50"</code>
<code>flush_on_last_del</code>	<code>"yes"</code>
<code>hardware_handler</code>	<code>"0"</code>
<code>no_path_retry</code>	<code>queue</code>
<code>path_checker</code>	<code>"tur"</code>
<code>path_grouping_policy</code>	<code>"group_by_prio"</code>
<code>path_selector</code>	<code>"round-robin 0"</code>
<code>polling_interval</code>	<code>5</code>
<code>prio</code>	<code>"ontap"</code>
<code>product</code>	<code>LUN.*</code>
<code>retain_attached_hw_handler</code>	<code>yes</code>
<code>rr_weight</code>	<code>"uniform"</code>
<code>user_friendly_names</code>	<code>no</code>
<code>vendor</code>	<code>NETAPP</code>

### Example

The following example shows how to correct an overridden default. In this case, the `multipath.conf` file defines values for `path_checker` and `no_path_retry` that are not compatible with ONTAP LUNs. If they cannot be removed because of other SAN arrays still attached to the host, these parameters can be corrected specifically for ONTAP LUNs with a device stanza.

```

defaults {
    path_checker      readsector0
    no_path_retry     fail
}

devices {
    device {
        vendor        "NETAPP  "
        product        "LUN.*"
        no_path_retry  queue
        path_checker    tur
    }
}

```

## Configure KVM settings

You don't need to configure settings for a Kernel-based Virtual Machine because the LUN is mapped to the hypervisor.

## ASM mirroring

Automatic Storage Management (ASM) mirroring might require changes to the Linux multipath settings to allow ASM to recognize a problem and switch over to an alternate failure group. Most ASM configurations on ONTAP use external redundancy, which means that data protection is provided by the external array and ASM doesn't mirror data. Some sites use ASM with normal redundancy to provide two-way mirroring, normally across different sites. See [Oracle databases on ONTAP](#) for further information.

## Known issues

The RHEL 6.9 with ONTAP release has the following known issues:

NetApp Bug ID	Title	Description
<a href="#">1067272</a>	Remote port status on EMULEX LPe32002 host might be in 'Blocked' state during storage failover operations	During storage failover operations, certain remote port status on RHEL 6.9 host with LPe32002 adapter might get into 'Blocked' state. Because the logical interfaces go down when a storage node is down, the remote port sets the storage node status to "Blocked" state. However, when the storage node comes back to optimal state, the logical interfaces also comes up and the remote port state is expected to be 'Online'. But, on certain occasion the remote port continues to be in 'Blocked' state. This state manifests as 'failed faulty' to LUNS at multipath layer.

NetApp Bug ID	Title	Description
<a href="#">1076584</a>	Firmware dumps occur on Red Hat Enterprise Linux 6.9 QLogic QE8362 HBA during storage failover operations	Firmware dumps can occur during storage failover operations on Red Hat Enterprise Linux (RHEL) 6.9 hosts with QLogic QLE8362 host bus adapters (HBA), firmware dumps are observed occasionally. The firmware dumps might manifest as an I/O outage on the host that can last as long as 1200 seconds. After the adapter completes dumping the firmware cores, the I/O operation resumes normally. No further recovery procedure is required on the host. To indicate the firmware dump, the following message is displayed in /var/log/message file: kernel: qla2xxx [0000:0c:00.3]-d001:3: Firmware dump saved to temp buffer (3/ffffc90018b01000), dump status flags (0x3f)

## Use Red Hat Enterprise Linux 6.8 with ONTAP

You can use the ONTAP SAN host configuration settings to configure Red Hat Enterprise Linux 6.8 with ONTAP as the target.

### Install the Linux Host Utilities

The NetApp Linux Host Utilities software package is available on the [NetApp Support Site](#) in a 32-bit and 64-bit .rpm file. If you don't know which file is right for your configuration, use the [Interoperability Matrix Tool](#) to verify which one you need.

NetApp strongly recommends installing the Linux Host Utilities, but it's not mandatory. The utilities don't change any settings on your Linux host. The utilities improve management and assist NetApp customer support in gathering information about your configuration.

If you have Linux Host Utilities currently installed, you should either upgrade it to the latest version, or remove it and follow these steps to install the latest version.

### Steps

1. Download the 32-bit or 64-bit Linux Host Utilities software package from the [NetApp Support Site](#) to your host.
2. Install the software package:

```
rpm -ivh netapp_linux_unified_host_utilities-7-1.x86_64
```



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

## SAN Toolkit

The toolkit is installed automatically when you install the NetApp Host Utilities package. This kit provides the `sanlun` utility, which helps you manage LUNs and HBAs. The `sanlun` command returns information about the LUNs mapped to your host, multipathing, and information necessary to create initiator groups.

### Example

In the following example, the `sanlun lun show` command returns LUN information.

```
# sanlun lun show all
```

Example output:

```
controller(7mode/E-Series)/          device      host          lun
vserver(cDOT/FlashRay)  lun-pathname filename  adapter  protocol  size
Product
-----
-----
data_vserver            /vol/vol1/lun1  /dev/sdb  host16    FCP
120.0g  cDOT
data_vserver            /vol/vol1/lun1  /dev/sdc  host15    FCP
120.0g  cDOT
data_vserver            /vol/vol2/lun2  /dev/sdd  host16    FCP
120.0g  cDOT
data_vserver            /vol/vol2/lun2  /dev/sde  host15    FCP
120.0g  cDOT
```

## SAN Booting

### Before you begin

If you decide to use SAN booting, it must be supported by your configuration. You can use the [Interoperability Matrix Tool](#) to verify that your OS, HBA, HBA firmware and the HBA boot BIOS, and ONTAP version are supported.

### Steps

1. Map the SAN boot LUN to the host.
2. Verify that multiple paths are available.



Multiple paths become available after the host OS is up and running on the paths.

3. Enable SAN booting in the server BIOS for the ports to which the SAN boot LUN is mapped.

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

4. Reboot the host to verify that the boot was successful.

## Multipathing

For Red Hat Enterprise Linux (RHEL) 6.8 the `/etc/multipath.conf` file must exist, but you do not need to make specific changes to the file. RHEL 6.8 is compiled with all settings required to recognize and correctly manage ONTAP LUNs.

To Enable ALUA Handler, perform the following steps:

### Steps

1. Create a backup of the initrd-image.
2. Append the following parameter value to the kernel for ALUA and non-ALUA to work:  
`rdloaddriver=scsi_dh_alua`

### Example

```
kernel /vmlinuz-2.6.32-358.6.1.el6.x86_64 ro root=/dev/mapper/  
vg_ibmx355021082-lv_root rd_NO_LUKS rd_LVM_LV=vg_ibmx355021082/ lv_root  
LANG=en_US.UTF-8 rd_LVM_LV=vg_ibmx355021082/lv_swap rd_NO_MD  
SYSFONT=latarcyrheb-sun16 crashkernel=auto KEYBOARDTYPE=pc KEYTABLE=us  
rd_NO_DM rhgb quiet rdloaddriver=scsi_dh_alua
```

3. Use the `mkinitrd` command to recreate the initrd-image.  
RHEL 6x and later versions use either:  
The command: `mkinitrd -f /boot/ initrd-"uname -r".img uname -r`  
Or  
The command: `dracut -f`
4. Reboot the host.
5. Verify the output of the `cat /proc/cmdline` command to ensure that the setting is complete.

You can use the `multipath -ll` command to verify the settings for your ONTAP LUNs.

The following sections provide example multipath outputs for a LUN mapped to ASA and non-ASA personas.

### All SAN Array configurations

All SAN Array (ASA) configurations optimize all paths to a given LUN, keeping them active. This improves performance by serving I/O operations through all paths at the same time.

### Example

The following example displays the correct output for an ONTAP LUN.

```
# multipath -ll
3600a0980383034466b2b4a3775474859 dm-3 NETAPP,LUN C-Mode
size=20G features='4 queue_if_no_path pg_init_retries 50
retain_attached_hw_handle' hwhandler='1 alua' wp=rw
|+- policy='round-robin 0' prio=50 status=active
|- 1:0:8:1 sdb 8:16 active ready running
|- 2:0:8:1 sdd 8:48 active ready running
|- 1:0:9:1 sdc 8:32 active ready running
|- 2:0:9:1 sde 8:64 active ready running
```



A single LUN shouldn't require more than four paths. Having more than four paths might cause path issues during storage failures.

### Non-ASA configurations

For non-ASA configurations, there should be two groups of paths with different priorities. The paths with higher priorities are Active/Optimized. This means they are serviced by the controller where the aggregate is located. The paths with lower priorities are active but non-optimized because they are served from a different controller. The non-optimized paths are only used when optimized paths are not available.

### Example

The following example displays the correct output for an ONTAP LUN with two Active/Optimized paths and two Active/Non-Optimized paths.

```
# multipath -ll
3600a0980383034466b2b4a3775474859 dm-3 NETAPP,LUN C-Mode
size=20G features='4 queue_if_no_path pg_init_retries 50
retain_attached_hw_handle' hwhandler='1 alua' wp=rw
|+- policy='round-robin 0' prio=50 status=active
| |- 1:0:8:1 sdb 8:16 active ready running
| `-- 2:0:8:1 sdd 8:48 active ready running
`+- policy='round-robin 0' prio=10 status=enabled
  |- 1:0:9:1 sdc 8:32 active ready running
  `-- 2:0:9:1 sde 8:64 active ready running
```



A single LUN shouldn't require more than four paths. Having more than four paths might cause path issues during storage failures.

### Recommended Settings

The RHEL 6.8 OS is compiled to recognize ONTAP LUNs and automatically set all configuration parameters correctly for both ASA and non-ASA configuration.

The `multipath.conf` file must exist for the multipath daemon to start. If this file doesn't exist, you can create an empty, zero-byte file by using the `touch /etc/multipath.conf` command.



The first time you create the `multipath.conf` file, you might need to enable and start the multipath services by using the following commands:

```
chkconfig multipathd on
/etc/init.d/multipathd start
```

You don't need to add anything directly to the `multipath.conf` file unless you have devices that you don't want multipath to manage or you have existing settings that override defaults. To exclude unwanted devices, add the following syntax to the `multipath.conf` file, replacing `<DevId>` with the worldwide identifier (WWID) string of the device you want to exclude:

```
blacklist {
    wwid <DevId>
    devnode "^(ram|raw|loop|fd|md|dm-|sr|scd|st) [0-9]*"
    devnode "^hd[a-z]"
    devnode "^cciss.*"
}
```

The following example determines the WWID of a device and adds it to the `multipath.conf` file.

### Steps

1. Determine the WWID:

```
/lib/udev/scsi_id -gud /dev/sda
```

```
3600a098038314c4a433f5774717a3046
```

`sda` is the local SCSI disk that you want to add to the blacklist.

2. Add the WWID to the blacklist stanza in `/etc/multipath.conf`:

```
blacklist {
    wwid 3600a098038314c4a433f5774717a3046
    devnode "^(ram|raw|loop|fd|md|dm-|sr|scd|st) [0-9]*"
    devnode "^hd[a-z]"
    devnode "^cciss.*"
}
```

Always check your `/etc/multipath.conf` file, especially in the defaults section, for legacy settings that might be overriding default settings.

The following table demonstrates the critical `multipathd` parameters for ONTAP LUNs and the required

values. If a host is connected to LUNs from other vendors and any of these parameters are overridden, they must be corrected by later stanzas in the `multipath.conf` file that apply specifically to ONTAP LUNs. Without this correction, the ONTAP LUNs might not work as expected. You should only override these defaults in consultation with NetApp, the OS vendor, or both, and only when the impact is fully understood.

Parameter	Setting
<code>detect_prio</code>	<code>yes</code>
<code>dev_loss_tmo</code>	<code>"infinity"</code>
<code>failback</code>	<code>immediate</code>
<code>fast_io_fail_tmo</code>	<code>5</code>
<code>features</code>	<code>"3 queue_if_no_path pg_init_retries 50"</code>
<code>flush_on_last_del</code>	<code>"yes"</code>
<code>hardware_handler</code>	<code>"0"</code>
<code>no_path_retry</code>	<code>queue</code>
<code>path_checker</code>	<code>"tur"</code>
<code>path_grouping_policy</code>	<code>"group_by_prio"</code>
<code>path_selector</code>	<code>"round-robin 0"</code>
<code>polling_interval</code>	<code>5</code>
<code>prio</code>	<code>"ontap"</code>
<code>product</code>	<code>LUN.*</code>
<code>retain_attached_hw_handler</code>	<code>yes</code>
<code>rr_weight</code>	<code>"uniform"</code>
<code>user_friendly_names</code>	<code>no</code>
<code>vendor</code>	<code>NETAPP</code>

### Example

The following example shows how to correct an overridden default. In this case, the `multipath.conf` file defines values for `path_checker` and `no_path_retry` that are not compatible with ONTAP LUNs. If they cannot be removed because of other SAN arrays still attached to the host, these parameters can be corrected specifically for ONTAP LUNs with a device stanza.

```

defaults {
    path_checker      readsector0
    no_path_retry     fail
}

devices {
    device {
        vendor        "NETAPP  "
        product        "LUN.*"
        no_path_retry  queue
        path_checker    tur
    }
}

```

## Configure KVM settings

You don't need to configure settings for a Kernel-based Virtual Machine because the LUN is mapped to the hypervisor.

## ASM mirroring

Automatic Storage Management (ASM) mirroring might require changes to the Linux multipath settings to allow ASM to recognize a problem and switch over to an alternate failure group. Most ASM configurations on ONTAP use external redundancy, which means that data protection is provided by the external array and ASM doesn't mirror data. Some sites use ASM with normal redundancy to provide two-way mirroring, normally across different sites. See [Oracle databases on ONTAP](#) for further information.

## Known issues

There are no known issues for the RHEL 6.8 with ONTAP release.

## Use Red Hat Enterprise Linux 6.7 with ONTAP

You can use the ONTAP SAN host configuration settings to configure Red Hat Enterprise Linux 6.7 with ONTAP as the target.

## Install the Linux Host Utilities

The NetApp Linux Host Utilities software package is available on the [NetApp Support Site](#) in a 32-bit and 64-bit .rpm file. If you don't know which file is right for your configuration, use the [Interoperability Matrix Tool](#) to verify which one you need.

NetApp strongly recommends installing the Linux Host Utilities, but it's not mandatory. The utilities don't change any settings on your Linux host. The utilities improve management and assist NetApp customer support in gathering information about your configuration.

If you have Linux Host Utilities currently installed, you should either upgrade it to the latest version, or remove it and follow these steps to install the latest version.

## Steps

1. Download the 32-bit or 64-bit Linux Host Utilities software package from the [NetApp Support Site](#) to your host.
2. Install the software package:

```
rpm -ivh netapp_linux_unified_host_utilities-7-1.x86_64
```



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

## SAN Toolkit

The toolkit is installed automatically when you install the NetApp Host Utilities package. This kit provides the `sanlun` utility, which helps you manage LUNs and HBAs. The `sanlun` command returns information about the LUNs mapped to your host, multipathing, and information necessary to create initiator groups.

### Example

In the following example, the `sanlun lun show` command returns LUN information.

```
# sanlun lun show all
```

Example output:

```
controller(7mode/E-Series)/          device      host          lun
vserver(cDOT/FlashRay)   lun-pathname filename  adapter  protocol  size
Product
-----
-----
data_vserver              /vol/vol1/lun1  /dev/sdb    host16    FCP
120.0g  cDOT
data_vserver              /vol/vol1/lun1  /dev/sdc    host15    FCP
120.0g  cDOT
data_vserver              /vol/vol2/lun2  /dev/sdd    host16    FCP
120.0g  cDOT
data_vserver              /vol/vol2/lun2  /dev/sde    host15    FCP
120.0g  cDOT
```

## SAN Booting

### Before you begin

If you decide to use SAN booting, it must be supported by your configuration. You can use the [Interoperability Matrix Tool](#) to verify that your OS, HBA, HBA firmware and the HBA boot BIOS, and ONTAP version are supported.

### Steps

1. Map the SAN boot LUN to the host.

2. Verify that multiple paths are available.



Multiple paths become available after the host OS is up and running on the paths.

3. Enable SAN booting in the server BIOS for the ports to which the SAN boot LUN is mapped.

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

4. Reboot the host to verify that the boot was successful.

## Multipathing

For Red Hat Enterprise Linux (RHEL) 6.7 the `/etc/multipath.conf` file must exist, but you do not need to make specific changes to the file. RHEL 6.7 is compiled with all settings required to recognize and correctly manage ONTAP LUNs.

To Enable ALUA Handler, perform the following steps:

### Steps

1. Create a backup of the `initrd-image`.
2. Append the following parameter value to the kernel for ALUA and non-ALUA to work:

```
rdloaddriver=scsi_dh_alua
```

### Example

```
kernel /vmlinuz-2.6.32-358.6.1.el6.x86_64 ro root=/dev/mapper/
vg_ibmx355021082-lv_root rd_NO_LUKS rd_LVM_LV=vg_ibmx355021082/ lv_root
LANG=en_US.UTF-8 rd_LVM_LV=vg_ibmx355021082/lv_swap rd_NO_MD
SYSFONT=latacyrheb-sun16 crashkernel=auto KEYBOARDTYPE=pc KEYTABLE=us
rd_NO_DM rhgb quiet rdloaddriver=scsi_dh_alua
```

3. Use the `mkinitrd` command to recreate the `initrd-image`.  
RHEL 6x and later versions use either:  
The command: `mkinitrd -f /boot/ initrd-"uname -r".img uname -r`  
Or  
The command: `dracut -f`
4. Reboot the host.
5. Verify the output of the `cat /proc/cmdline` command to ensure that the setting is complete.

You can use the `multipath -ll` command to verify the settings for your ONTAP LUNs.

The following sections provide example multipath outputs for a LUN mapped to ASA and non-ASA personas.

### All SAN Array configurations

All SAN Array (ASA) configurations optimize all paths to a given LUN, keeping them active. This improves performance by serving I/O operations through all paths at the same time.

### Example

The following example displays the correct output for an ONTAP LUN.

```
# multipath -ll
3600a0980383034466b2b4a3775474859 dm-3 NETAPP,LUN C-Mode
size=20G features='4 queue_if_no_path pg_init_retries 50
retain_attached_hw_handle' hwhandler='1 alua' wp=rw
|+- policy='round-robin 0' prio=50 status=active
|- 1:0:8:1 sdb 8:16 active ready running
|- 2:0:8:1 sdd 8:48 active ready running
|- 1:0:9:1 sdc 8:32 active ready running
|- 2:0:9:1 sde 8:64 active ready running
```



A single LUN shouldn't require more than four paths. Having more than four paths might cause path issues during storage failures.

### Non-ASA configurations

For non-ASA configurations, there should be two groups of paths with different priorities. The paths with higher priorities are Active/Optimized. This means they are serviced by the controller where the aggregate is located. The paths with lower priorities are active but non-optimized because they are served from a different controller. The non-optimized paths are only used when optimized paths are not available.

### Example

The following example displays the correct output for an ONTAP LUN with two Active/Optimized paths and two Active/Non-Optimized paths.

```
# multipath -ll
3600a0980383034466b2b4a3775474859 dm-3 NETAPP,LUN C-Mode
size=20G features='4 queue_if_no_path pg_init_retries 50
retain_attached_hw_handle' hwhandler='1 alua' wp=rw
|+- policy='round-robin 0' prio=50 status=active
| |- 1:0:8:1 sdb 8:16 active ready running
| `-- 2:0:8:1 sdd 8:48 active ready running
`+- policy='round-robin 0' prio=10 status=enabled
  |- 1:0:9:1 sdc 8:32 active ready running
  `-- 2:0:9:1 sde 8:64 active ready running
```



A single LUN shouldn't require more than four paths. Having more than four paths might cause path issues during storage failures.

### Recommended Settings

The RHEL 6.7 OS is compiled to recognize ONTAP LUNs and automatically set all configuration parameters correctly for both ASA and non-ASA configuration.

The `multipath.conf` file must exist for the multipath daemon to start. If this file doesn't exist, you can create an empty, zero-byte file by using the `touch /etc/multipath.conf` command.

The first time you create the `multipath.conf` file, you might need to enable and start the multipath services by using the following commands:

```
chkconfig multipathd on
/etc/init.d/multipathd start
```

You don't need to add anything directly to the `multipath.conf` file unless you have devices that you don't want multipath to manage or you have existing settings that override defaults. To exclude unwanted devices, add the following syntax to the `multipath.conf` file, replacing `<DevId>` with the worldwide identifier (WWID) string of the device you want to exclude:

```
blacklist {
    wwid <DevId>
    devnode "^(ram|raw|loop|fd|md|dm-|sr|scd|st) [0-9]*"
    devnode "^hd[a-z]"
    devnode "^cciss.*"
}
```

The following example determines the WWID of a device and adds it to the `multipath.conf` file.

### Steps

1. Determine the WWID:

```
/lib/udev/scsi_id -gud /dev/sda
```

```
3600a098038314c4a433f5774717a3046
```

`sda` is the local SCSI disk that you want to add to the blacklist.

2. Add the WWID to the blacklist stanza in `/etc/multipath.conf`:

```
blacklist {
    wwid 3600a098038314c4a433f5774717a3046
    devnode "^(ram|raw|loop|fd|md|dm-|sr|scd|st) [0-9]*"
    devnode "^hd[a-z]"
    devnode "^cciss.*"
}
```

Always check your `/etc/multipath.conf` file, especially in the defaults section, for legacy settings that might be overriding default settings.

The following table demonstrates the critical `multipathd` parameters for ONTAP LUNs and the required

values. If a host is connected to LUNs from other vendors and any of these parameters are overridden, they must be corrected by later stanzas in the `multipath.conf` file that apply specifically to ONTAP LUNs. Without this correction, the ONTAP LUNs might not work as expected. You should only override these defaults in consultation with NetApp, the OS vendor, or both, and only when the impact is fully understood.

Parameter	Setting
<code>detect_prio</code>	<code>yes</code>
<code>dev_loss_tmo</code>	<code>"infinity"</code>
<code>failback</code>	<code>immediate</code>
<code>fast_io_fail_tmo</code>	<code>5</code>
<code>features</code>	<code>"3 queue_if_no_path pg_init_retries 50"</code>
<code>flush_on_last_del</code>	<code>"yes"</code>
<code>hardware_handler</code>	<code>"0"</code>
<code>no_path_retry</code>	<code>queue</code>
<code>path_checker</code>	<code>"tur"</code>
<code>path_grouping_policy</code>	<code>"group_by_prio"</code>
<code>path_selector</code>	<code>"round-robin 0"</code>
<code>polling_interval</code>	<code>5</code>
<code>prio</code>	<code>"ontap"</code>
<code>product</code>	<code>LUN.*</code>
<code>retain_attached_hw_handler</code>	<code>yes</code>
<code>rr_weight</code>	<code>"uniform"</code>
<code>user_friendly_names</code>	<code>no</code>
<code>vendor</code>	<code>NETAPP</code>

### Example

The following example shows how to correct an overridden default. In this case, the `multipath.conf` file defines values for `path_checker` and `no_path_retry` that are not compatible with ONTAP LUNs. If they cannot be removed because of other SAN arrays still attached to the host, these parameters can be corrected specifically for ONTAP LUNs with a device stanza.



```

defaults {
    path_checker      readsector0
    no_path_retry     fail
}

devices {
    device {
        vendor        "NETAPP  "
        product        "LUN.*"
        no_path_retry  queue
        path_checker    tur
    }
}

```

## Configure KVM settings

You don't need to configure settings for a Kernel-based Virtual Machine because the LUN is mapped to the hypervisor.

## ASM mirroring

Automatic Storage Management (ASM) mirroring might require changes to the Linux multipath settings to allow ASM to recognize a problem and switch over to an alternate failure group. Most ASM configurations on ONTAP use external redundancy, which means that data protection is provided by the external array and ASM doesn't mirror data. Some sites use ASM with normal redundancy to provide two-way mirroring, normally across different sites. See [Oracle databases on ONTAP](#) for further information.

## Known issues

There are no known issues for the RHEL 6.7 with ONTAP release.

## Use Red Hat Enterprise Linux 6.6 with ONTAP

You can use the ONTAP SAN host configuration settings to configure Red Hat Enterprise Linux 6.6 with ONTAP as the target.

## Install the Linux Host Utilities

The NetApp Linux Host Utilities software package is available on the [NetApp Support Site](#) in a 32-bit and 64-bit .rpm file. If you don't know which file is right for your configuration, use the [Interoperability Matrix Tool](#) to verify which one you need.

NetApp strongly recommends installing the Linux Host Utilities, but it's not mandatory. The utilities don't change any settings on your Linux host. The utilities improve management and assist NetApp customer support in gathering information about your configuration.

If you have Linux Host Utilities currently installed, you should either upgrade it to the latest version, or remove it and follow these steps to install the latest version.

## Steps

1. Download the 32-bit or 64-bit Linux Host Utilities software package from the [NetApp Support Site](#) to your host.
2. Install the software package:

```
rpm -ivh netapp_linux_unified_host_utilities-7-1.x86_64
```



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

## SAN Toolkit

The toolkit is installed automatically when you install the NetApp Host Utilities package. This kit provides the `sanlun` utility, which helps you manage LUNs and HBAs. The `sanlun` command returns information about the LUNs mapped to your host, multipathing, and information necessary to create initiator groups.

### Example

In the following example, the `sanlun lun show` command returns LUN information.

```
# sanlun lun show all
```

Example output:

```
controller(7mode/E-Series)/          device      host          lun
vserver(cDOT/FlashRay)   lun-pathname filename  adapter  protocol  size
Product
-----
-----
data_vserver              /vol/vol1/lun1  /dev/sdb    host16    FCP
120.0g  cDOT
data_vserver              /vol/vol1/lun1  /dev/sdc    host15    FCP
120.0g  cDOT
data_vserver              /vol/vol2/lun2  /dev/sdd    host16    FCP
120.0g  cDOT
data_vserver              /vol/vol2/lun2  /dev/sde    host15    FCP
120.0g  cDOT
```

## SAN Booting

### Before you begin

If you decide to use SAN booting, it must be supported by your configuration. You can use the [Interoperability Matrix Tool](#) to verify that your OS, HBA, HBA firmware and the HBA boot BIOS, and ONTAP version are supported.

### Steps

1. Map the SAN boot LUN to the host.

2. Verify that multiple paths are available.



Multiple paths become available after the host OS is up and running on the paths.

3. Enable SAN booting in the server BIOS for the ports to which the SAN boot LUN is mapped.

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

4. Reboot the host to verify that the boot was successful.

## Multipathing

For Red Hat Enterprise Linux (RHEL) 6.6 the `/etc/multipath.conf` file must exist, but you do not need to make specific changes to the file. RHEL 6.6 is compiled with all settings required to recognize and correctly manage ONTAP LUNs.

To Enable ALUA Handler, perform the following steps:

### Steps

1. Create a backup of the `initrd-image`.
2. Append the following parameter value to the kernel for ALUA and non-ALUA to work:

```
rdloaddriver=scsi_dh_alua
```

### Example

```
kernel /vmlinuz-2.6.32-358.6.1.el6.x86_64 ro root=/dev/mapper/
vg_ibmx355021082-lv_root rd_NO_LUKS rd_LVM_LV=vg_ibmx355021082/ lv_root
LANG=en_US.UTF-8 rd_LVM_LV=vg_ibmx355021082/lv_swap rd_NO_MD
SYSFONT=latacyrheb-sun16 crashkernel=auto KEYBOARDTYPE=pc KEYTABLE=us
rd_NO_DM rhgb quiet rdloaddriver=scsi_dh_alua
```

3. Use the `mkinitrd` command to recreate the `initrd-image`.  
RHEL 6x and later versions use either:  
The command: `mkinitrd -f /boot/ initrd-"uname -r".img uname -r`  
Or  
The command: `dracut -f`
4. Reboot the host.
5. Verify the output of the `cat /proc/cmdline` command to ensure that the setting is complete.

You can use the `multipath -ll` command to verify the settings for your ONTAP LUNs.

The following sections provide example multipath outputs for a LUN mapped to ASA and non-ASA personas.

### All SAN Array configurations

All SAN Array (ASA) configurations optimize all paths to a given LUN, keeping them active. This improves performance by serving I/O operations through all paths at the same time.

### Example

The following example displays the correct output for an ONTAP LUN.

```
# multipath -ll
3600a0980383034466b2b4a3775474859 dm-3 NETAPP,LUN C-Mode
size=20G features='4 queue_if_no_path pg_init_retries 50
retain_attached_hw_handle' hwhandler='1 alua' wp=rw
|+- policy='round-robin 0' prio=50 status=active
|- 1:0:8:1 sdb 8:16 active ready running
|- 2:0:8:1 sdd 8:48 active ready running
|- 1:0:9:1 sdc 8:32 active ready running
|- 2:0:9:1 sde 8:64 active ready running
```



A single LUN shouldn't require more than four paths. Having more than four paths might cause path issues during storage failures.

### Non-ASA configurations

For non-ASA configurations, there should be two groups of paths with different priorities. The paths with higher priorities are Active/Optimized. This means they are serviced by the controller where the aggregate is located. The paths with lower priorities are active but non-optimized because they are served from a different controller. The non-optimized paths are only used when optimized paths are not available.

### Example

The following example displays the correct output for an ONTAP LUN with two Active/Optimized paths and two Active/Non-Optimized paths.

```
# multipath -ll
3600a0980383034466b2b4a3775474859 dm-3 NETAPP,LUN C-Mode
size=20G features='4 queue_if_no_path pg_init_retries 50
retain_attached_hw_handle' hwhandler='1 alua' wp=rw
|+- policy='round-robin 0' prio=50 status=active
| |- 1:0:8:1 sdb 8:16 active ready running
| `-- 2:0:8:1 sdd 8:48 active ready running
`+- policy='round-robin 0' prio=10 status=enabled
  |- 1:0:9:1 sdc 8:32 active ready running
  `-- 2:0:9:1 sde 8:64 active ready running
```



A single LUN shouldn't require more than four paths. Having more than four paths might cause path issues during storage failures.

### Recommended Settings

The RHEL 6.6 OS is compiled to recognize ONTAP LUNs and automatically set all configuration parameters correctly for both ASA and non-ASA configuration.

The `multipath.conf` file must exist for the multipath daemon to start. If this file doesn't exist, you can create an empty, zero-byte file by using the `touch /etc/multipath.conf` command.

The first time you create the `multipath.conf` file, you might need to enable and start the multipath services by using the following commands:

```
chkconfig multipathd on
/etc/init.d/multipathd start
```

You don't need to add anything directly to the `multipath.conf` file unless you have devices that you don't want multipath to manage or you have existing settings that override defaults. To exclude unwanted devices, add the following syntax to the `multipath.conf` file, replacing `<DevId>` with the worldwide identifier (WWID) string of the device you want to exclude:

```
blacklist {
    wwid <DevId>
    devnode "^(ram|raw|loop|fd|md|dm-|sr|scd|st) [0-9] *"
    devnode "^hd[a-z] *"
    devnode "^cciss.*"
}
```

The following example determines the WWID of a device and adds it to the `multipath.conf` file.

### Steps

1. Determine the WWID:

```
/lib/udev/scsi_id -gud /dev/sda
```

```
3600a098038314c4a433f5774717a3046
```

`sda` is the local SCSI disk that you want to add to the blacklist.

2. Add the WWID to the blacklist stanza in `/etc/multipath.conf`:

```
blacklist {
    wwid 3600a098038314c4a433f5774717a3046
    devnode "^(ram|raw|loop|fd|md|dm-|sr|scd|st) [0-9] *"
    devnode "^hd[a-z] *"
    devnode "^cciss.*"
}
```

Always check your `/etc/multipath.conf` file, especially in the defaults section, for legacy settings that might be overriding default settings.

The following table demonstrates the critical `multipathd` parameters for ONTAP LUNs and the required

values. If a host is connected to LUNs from other vendors and any of these parameters are overridden, they must be corrected by later stanzas in the `multipath.conf` file that apply specifically to ONTAP LUNs. Without this correction, the ONTAP LUNs might not work as expected. You should only override these defaults in consultation with NetApp, the OS vendor, or both, and only when the impact is fully understood.

Parameter	Setting
<code>detect_prio</code>	<code>yes</code>
<code>dev_loss_tmo</code>	<code>"infinity"</code>
<code>failback</code>	<code>immediate</code>
<code>fast_io_fail_tmo</code>	<code>5</code>
<code>features</code>	<code>"3 queue_if_no_path pg_init_retries 50"</code>
<code>flush_on_last_del</code>	<code>"yes"</code>
<code>hardware_handler</code>	<code>"0"</code>
<code>no_path_retry</code>	<code>queue</code>
<code>path_checker</code>	<code>"tur"</code>
<code>path_grouping_policy</code>	<code>"group_by_prio"</code>
<code>path_selector</code>	<code>"round-robin 0"</code>
<code>polling_interval</code>	<code>5</code>
<code>prio</code>	<code>"ontap"</code>
<code>product</code>	<code>LUN.*</code>
<code>retain_attached_hw_handler</code>	<code>yes</code>
<code>rr_weight</code>	<code>"uniform"</code>
<code>user_friendly_names</code>	<code>no</code>
<code>vendor</code>	<code>NETAPP</code>

### Example

The following example shows how to correct an overridden default. In this case, the `multipath.conf` file defines values for `path_checker` and `no_path_retry` that are not compatible with ONTAP LUNs. If they cannot be removed because of other SAN arrays still attached to the host, these parameters can be corrected specifically for ONTAP LUNs with a device stanza.

```

defaults {
    path_checker      readsector0
    no_path_retry     fail
}

devices {
    device {
        vendor        "NETAPP  "
        product        "LUN.*"
        no_path_retry  queue
        path_checker   tur
    }
}

```

## Configure KVM settings

You don't need to configure settings for a Kernel-based Virtual Machine because the LUN is mapped to the hypervisor.

## ASM mirroring

Automatic Storage Management (ASM) mirroring might require changes to the Linux multipath settings to allow ASM to recognize a problem and switch over to an alternate failure group. Most ASM configurations on ONTAP use external redundancy, which means that data protection is provided by the external array and ASM doesn't mirror data. Some sites use ASM with normal redundancy to provide two-way mirroring, normally across different sites. See [Oracle databases on ONTAP](#) for further information.

## Known issues

The RHEL 6.6 with ONTAP release has the following known issues:

NetApp Bug ID	Title	Description
<a href="#">863878</a>	Kernel crash occurs with RHEL 6U6 host during storage failures	You might observe kernel crash on RHEL 6U6 host during storage/fabric.
<a href="#">1076584</a>	I/O stall up to 300 sec seen with QLogic 16G FC (QLE2672) host during storage failures in RHEL 6U4	You might observe an I/O stall up to 300 sec on QLogic 16G FC (QLE2672) host during storage/fabric failures.

NetApp Bug ID	Title	Description
<a href="#">795684</a>	RHEL6 U5 multipathd incorrectly group multipath maps during MoD and storage failover fault operations	You might observe an incorrect path grouping on LUNs during LUN move on demand operation along with storage faults. During LUN move operation multipath path priorities will change and multipath is unable to reloads the device table due to device failure caused by storage fault. This leads to incorrect path grouping.

## Use Red Hat Enterprise Linux 6.5 with ONTAP

You can use the ONTAP SAN host configuration settings to configure Red Hat Enterprise Linux 6.5 with ONTAP as the target.

### Install the Linux Host Utilities

The NetApp Linux Host Utilities software package is available on the [NetApp Support Site](#) in a 32-bit and 64-bit .rpm file. If you don't know which file is right for your configuration, use the [Interoperability Matrix Tool](#) to verify which one you need.

NetApp strongly recommends installing the Linux Host Utilities, but it's not mandatory. The utilities don't change any settings on your Linux host. The utilities improve management and assist NetApp customer support in gathering information about your configuration.

If you have Linux Host Utilities currently installed, you should either upgrade it to the latest version, or remove it and follow these steps to install the latest version.

### Steps

1. Download the 32-bit or 64-bit Linux Host Utilities software package from the [NetApp Support Site](#) to your host.
2. Install the software package:

```
rpm -ivh netapp_linux_unified_host_utilities-7-1.x86_64
```



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

### SAN Toolkit

The toolkit is installed automatically when you install the NetApp Host Utilities package. This kit provides the `sanlun` utility, which helps you manage LUNs and HBAs. The `sanlun` command returns information about the LUNs mapped to your host, multipathing, and information necessary to create initiator groups.

### Example

In the following example, the `sanlun lun show` command returns LUN information.



```
# sanlun lun show all
```

Example output:

```
controller(7mode/E-Series)/      device      host      lun
vserver(cDOT/FlashRay)  lun-pathname filename  adapter  protocol  size
Product
-----
-----
data_vserver            /vol/vol1/lun1  /dev/sdb  host16    FCP
120.0g  cDOT
data_vserver            /vol/vol1/lun1  /dev/sdc  host15    FCP
120.0g  cDOT
data_vserver            /vol/vol2/lun2  /dev/sdd  host16    FCP
120.0g  cDOT
data_vserver            /vol/vol2/lun2  /dev/sde  host15    FCP
120.0g  cDOT
```

## SAN Booting

### Before you begin

If you decide to use SAN booting, it must be supported by your configuration. You can use the [Interoperability Matrix Tool](#) to verify that your OS, HBA, HBA firmware and the HBA boot BIOS, and ONTAP version are supported.

### Steps

1. Map the SAN boot LUN to the host.
2. Verify that multiple paths are available.



Multiple paths become available after the host OS is up and running on the paths.

3. Enable SAN booting in the server BIOS for the ports to which the SAN boot LUN is mapped.

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

4. Reboot the host to verify that the boot was successful.

## Multipathing

For Red Hat Enterprise Linux (RHEL) 6.5 the `/etc/multipath.conf` file must exist, but you do not need to make specific changes to the file. RHEL 6.5 is compiled with all settings required to recognize and correctly manage ONTAP LUNs.

To Enable ALUA Handler, perform the following steps:

### Steps

1. Create a backup of the `initrd`-image.

2. Append the following parameter value to the kernel for ALUA and non-ALUA to work:

`rdloaddriver=scsi_dh_alua`

#### Example

```
kernel /vmlinuz-2.6.32-358.6.1.el6.x86_64 ro root=/dev/mapper/  
vg_ibmx355021082-lv_root rd_NO_LUKS rd_LVM_LV=vg_ibmx355021082/ lv_root  
LANG=en_US.UTF-8 rd_LVM_LV=vg_ibmx355021082/lv_swap rd_NO_MD  
SYSFONT=latarcyrheb-sun16 crashkernel=auto KEYBOARDTYPE=pc KEYTABLE=us  
rd_NO_DM rhgb quiet rdloaddriver=scsi_dh_alua
```

3. Use the `mkinitrd` command to recreate the `initrd`-image.

RHEL 6x and later versions use either:

The command: `mkinitrd -f /boot/ initrd-"uname -r".img uname -r`

Or

The command: `dracut -f`

4. Reboot the host.
5. Verify the output of the `cat /proc/cmdline` command to ensure that the setting is complete.

You can use the `multipath -ll` command to verify the settings for your ONTAP LUNs.

The following sections provide example multipath outputs for a LUN mapped to ASA and non-ASA personas.

#### All SAN Array configurations

All SAN Array (ASA) configurations optimize all paths to a given LUN, keeping them active. This improves performance by serving I/O operations through all paths at the same time.

#### Example

The following example displays the correct output for an ONTAP LUN.

```
# multipath -ll  
3600a0980383034466b2b4a3775474859 dm-3 NETAPP,LUN C-Mode  
size=20G features='4 queue_if_no_path pg_init_retries 50  
retain_attached_hw_handle' hwhandler='1 alua' wp=rw  
|-+- policy='round-robin 0' prio=50 status=active  
|- 1:0:8:1 sdb 8:16 active ready running  
|- 2:0:8:1 sdd 8:48 active ready running  
|- 1:0:9:1 sdc 8:32 active ready running  
|- 2:0:9:1 sde 8:64 active ready running
```



A single LUN shouldn't require more than four paths. Having more than four paths might cause path issues during storage failures.

#### Non-ASA configurations

For non-ASA configurations, there should be two groups of paths with different priorities. The paths with higher

priorities are Active/Optimized. This means they are serviced by the controller where the aggregate is located. The paths with lower priorities are active but non-optimized because they are served from a different controller. The non-optimized paths are only used when optimized paths are not available.

### Example

The following example displays the correct output for an ONTAP LUN with two Active/Optimized paths and two Active/Non-Optimized paths.

```
# multipath -ll
3600a0980383034466b2b4a3775474859 dm-3 NETAPP,LUN C-Mode
size=20G features='4 queue_if_no_path pg_init_retries 50
retain_attached_hw_handle' hwhandler='1 alua' wp=rw
|-+- policy='round-robin 0' prio=50 status=active
|  |- 1:0:8:1   sdb 8:16 active ready running
|  `-- 2:0:8:1   sdd 8:48 active ready running
`--+- policy='round-robin 0' prio=10 status=enabled
    |- 1:0:9:1   sdc 8:32 active ready running
    `-- 2:0:9:1   sde 8:64 active ready running
```



A single LUN shouldn't require more than four paths. Having more than four paths might cause path issues during storage failures.

### Recommended Settings

The RHEL 6.5 OS is compiled to recognize ONTAP LUNs and automatically set all configuration parameters correctly for both ASA and non-ASA configuration.

The `multipath.conf` file must exist for the multipath daemon to start. If this file doesn't exist, you can create an empty, zero-byte file by using the `touch /etc/multipath.conf` command.

The first time you create the `multipath.conf` file, you might need to enable and start the multipath services by using the following commands:

```
chkconfig multipathd on
/etc/init.d/multipathd start
```

You don't need to add anything directly to the `multipath.conf` file unless you have devices that you don't want multipath to manage or you have existing settings that override defaults. To exclude unwanted devices, add the following syntax to the `multipath.conf` file, replacing `<DevId>` with the worldwide identifier (WWID) string of the device you want to exclude:

```

blacklist {
    wwid <DevId>
    devnode "^(ram|raw|loop|fd|md|dm-|sr|scd|st) [0-9] *"
    devnode "^hd[a-z]"
    devnode "^cciss.*"
}

```

The following example determines the WWID of a device and adds it to the `multipath.conf` file.

### Steps

1. Determine the WWID:

```
/lib/udev/scsi_id -gud /dev/sda
```

```
3600a098038314c4a433f5774717a3046
```

`sda` is the local SCSI disk that you want to add to the blacklist.

2. Add the WWID to the blacklist stanza in `/etc/multipath.conf`:

```

blacklist {
    wwid    3600a098038314c4a433f5774717a3046
    devnode "^(ram|raw|loop|fd|md|dm-|sr|scd|st) [0-9] *"
    devnode "^hd[a-z]"
    devnode "^cciss.*"
}

```

Always check your `/etc/multipath.conf` file, especially in the defaults section, for legacy settings that might be overriding default settings.

The following table demonstrates the critical `multipathd` parameters for ONTAP LUNs and the required values. If a host is connected to LUNs from other vendors and any of these parameters are overridden, they must be corrected by later stanzas in the `multipath.conf` file that apply specifically to ONTAP LUNs. Without this correction, the ONTAP LUNs might not work as expected. You should only override these defaults in consultation with NetApp, the OS vendor, or both, and only when the impact is fully understood.

Parameter	Setting
<code>detect_prio</code>	yes
<code>dev_loss_tmo</code>	"infinity"
<code>failback</code>	immediate
<code>fast_io_fail_tmo</code>	5

Parameter	Setting
features	"3 queue_if_no_path pg_init_retries 50"
flush_on_last_del	"yes"
hardware_handler	"0"
no_path_retry	queue
path_checker	"tur"
path_grouping_policy	"group_by_prio"
path_selector	"round-robin 0"
polling_interval	5
prio	"ontap"
product	LUN.*
retain_attached_hw_handler	yes
rr_weight	"uniform"
user_friendly_names	no
vendor	NETAPP

### Example

The following example shows how to correct an overridden default. In this case, the `multipath.conf` file defines values for `path_checker` and `no_path_retry` that are not compatible with ONTAP LUNs. If they cannot be removed because of other SAN arrays still attached to the host, these parameters can be corrected specifically for ONTAP LUNs with a device stanza.

```
defaults {
    path_checker      readsector0
    no_path_retry     fail
}

devices {
    device {
        vendor        "NETAPP  "
        product        "LUN.*"
        no_path_retry  queue
        path_checker    tur
    }
}
```

### Configure KVM settings

You don't need to configure settings for a Kernel-based Virtual Machine because the LUN is mapped to the hypervisor.

## ASM mirroring

Automatic Storage Management (ASM) mirroring might require changes to the Linux multipath settings to allow ASM to recognize a problem and switch over to an alternate failure group. Most ASM configurations on ONTAP use external redundancy, which means that data protection is provided by the external array and ASM doesn't mirror data. Some sites use ASM with normal redundancy to provide two-way mirroring, normally across different sites. See [Oracle databases on ONTAP](#) for further information.

## Known issues

The RHEL 6.5 with ONTAP release has the following known issues:

NetApp Bug ID	Title	Description
<a href="#">760515</a>	Path failures or host hangs were observed in RHEL 6.5 8G QLogic FC SAN host during storage failover operations	Path failures or host hangs were observed in RHEL 6.5 8G QLogic FC SAN host during storage failover operations.
<a href="#">758271</a>	bnx2 firmware fails to load when booting with custom initrd (dracut -f)	Broadcom NetXtreme II Gigabit controller ports will not ping due to bnx2 firmware fails to load during boot with custom initrd.
<a href="#">799394</a>	RHEL 6U5: Emulex 16G FC (LPe16002B-M6) host crash is seen during I/O with storage failover operations	16G FC Emulex (LPe16002B-M6) host crash is seen during I/O with storage failover operations.
<a href="#">786571</a>	QLogic FCoE host hangs/path failures observed in RHEL 6.5 during I/O with storage failover operations	QLogic FCoE (QLE8242) host hangs/path failures are observed in RHEL 6.5 during I/O with storage failover operations. In such scenarios, you might see the following message: "Mailbox cmd timeout occurred, cmd=0x54, mb[0]=0x54. Scheduling ISP abort" messages which leads to host hung/path failures.
<a href="#">801580</a>	QLogic 16G FC host hangs or path failures observed in RHEL 6.5 during I/O with storage failover operations	The I/O delays of more than 600 seconds are observed with QLogic 16G FC host (QLE2672) during storage failover operations. In such scenarios, the following message is displayed: "Failed mbx[0]=54, mb[1]=0, mb[2]=76b9, mb[3]=5200, cmd=54"

## Use Red Hat Enterprise Linux 6.4 with ONTAP

You can use the ONTAP SAN host configuration settings to configure Red Hat Enterprise Linux 6.4 with ONTAP as the target.

## Install the Linux Host Utilities

The NetApp Linux Host Utilities software package is available on the [NetApp Support Site](#) in a 32-bit and 64-bit .rpm file. If you don't know which file is right for your configuration, use the [Interoperability Matrix Tool](#) to verify which one you need.

NetApp strongly recommends installing the Linux Host Utilities, but it's not mandatory. The utilities don't change any settings on your Linux host. The utilities improve management and assist NetApp customer support in gathering information about your configuration.

If you have Linux Host Utilities currently installed, you should either upgrade it to the latest version, or remove it and follow these steps to install the latest version.

### Steps

1. Download the 32-bit or 64-bit Linux Host Utilities software package from the [NetApp Support Site](#) to your host.
2. Install the software package:

```
rpm -ivh netapp_linux_unified_host_utilities-7-1.x86_64
```



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

### SAN Toolkit

The toolkit is installed automatically when you install the NetApp Host Utilities package. This kit provides the `sanlun` utility, which helps you manage LUNs and HBAs. The `sanlun` command returns information about the LUNs mapped to your host, multipathing, and information necessary to create initiator groups.

### Example

In the following example, the `sanlun lun show` command returns LUN information.

```
# sanlun lun show all
```

Example output:

controller (7mode/E-Series) / vserver (cDOT/FlashRay) Product	lun-pathname	device filename	host adapter	protocol	lun size
-----					
data_vserver 120.0g cDOT	/vol/vol1/lun1	/dev/sdb	host16	FCP	
data_vserver 120.0g cDOT	/vol/vol1/lun1	/dev/sdc	host15	FCP	
data_vserver 120.0g cDOT	/vol/vol2/lun2	/dev/sdd	host16	FCP	
data_vserver 120.0g cDOT	/vol/vol2/lun2	/dev/sde	host15	FCP	

## SAN Booting

### Before you begin

If you decide to use SAN booting, it must be supported by your configuration. You can use the [Interoperability Matrix Tool](#) to verify that your OS, HBA, HBA firmware and the HBA boot BIOS, and ONTAP version are supported.

### Steps

1. Map the SAN boot LUN to the host.
2. Verify that multiple paths are available.



Multiple paths become available after the host OS is up and running on the paths.

3. Enable SAN booting in the server BIOS for the ports to which the SAN boot LUN is mapped.

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

4. Reboot the host to verify that the boot was successful.

## Multipathing

For Red Hat Enterprise Linux (RHEL) 6.4 the `/etc/multipath.conf` file must exist, but you do not need to make specific changes to the file. RHEL 6.4 is compiled with all settings required to recognize and correctly manage ONTAP LUNs.

To Enable ALUA Handler, perform the following steps:

### Steps

1. Create a backup of the `initrd`-image.
2. Append the following parameter value to the kernel for ALUA and non-ALUA to work:  
`rdloadddriver=scsi_dh_alua`



## Example

```
kernel /vmlinuz-2.6.32-358.6.1.el6.x86_64 ro root=/dev/mapper/  
vg_ibmx355021082-lv_root rd_NO_LUKS rd_LVM_LV=vg_ibmx355021082/ lv_root  
LANG=en_US.UTF-8 rd_LVM_LV=vg_ibmx355021082/lv_swap rd_NO_MD  
SYSFONT=latarcyrheb-sun16 crashkernel=auto KEYBOARDTYPE=pc KEYTABLE=us  
rd_NO_DM rhgb quiet rdloaddriver=scsi_dh_alua
```

3. Use the `mkinitrd` command to recreate the `initrd`-image.  
RHEL 6x and later versions use either:  
The command: `mkinitrd -f /boot/ initrd-"uname -r".img uname -r`  
Or  
The command: `dracut -f`
4. Reboot the host.
5. Verify the output of the `cat /proc/cmdline` command to ensure that the setting is complete.

You can use the `multipath -ll` command to verify the settings for your ONTAP LUNs.

The following sections provide example multipath outputs for a LUN mapped to ASA and non-ASA personas.

### All SAN Array configurations

All SAN Array (ASA) configurations optimize all paths to a given LUN, keeping them active. This improves performance by serving I/O operations through all paths at the same time.

## Example

The following example displays the correct output for an ONTAP LUN.

```
# multipath -ll  
3600a0980383034466b2b4a3775474859 dm-3 NETAPP,LUN C-Mode  
size=20G features='4 queue_if_no_path pg_init_retries 50  
retain_attached_hw_handle' hwhandler='1 alua' wp=rw  
|-+- policy='round-robin 0' prio=50 status=active  
|- 1:0:8:1 sdb 8:16 active ready running  
|- 2:0:8:1 sdd 8:48 active ready running  
|- 1:0:9:1 sdc 8:32 active ready running  
|- 2:0:9:1 sde 8:64 active ready running
```



A single LUN shouldn't require more than four paths. Having more than four paths might cause path issues during storage failures.

### Non-ASA configurations

For non-ASA configurations, there should be two groups of paths with different priorities. The paths with higher priorities are Active/Optimized. This means they are serviced by the controller where the aggregate is located. The paths with lower priorities are active but non-optimized because they are served from a different controller. The non-optimized paths are only used when optimized paths are not available.

## Example

The following example displays the correct output for an ONTAP LUN with two Active/Optimized paths and two Active/Non-Optimized paths.

```
# multipath -ll
3600a0980383034466b2b4a3775474859 dm-3 NETAPP,LUN C-Mode
size=20G features='4 queue_if_no_path pg_init_retries 50
retain_attached_hw_handle' hwhandler='1 alua' wp=rw
|-+- policy='round-robin 0' prio=50 status=active
|  |- 1:0:8:1   sdb 8:16 active ready running
|  `-- 2:0:8:1   sdd 8:48 active ready running
`--+- policy='round-robin 0' prio=10 status=enabled
    |- 1:0:9:1   sdc 8:32 active ready running
    `-- 2:0:9:1   sde 8:64 active ready running
```



A single LUN shouldn't require more than four paths. Having more than four paths might cause path issues during storage failures.

## Recommended Settings

The RHEL 6.4 OS is compiled to recognize ONTAP LUNs and automatically set all configuration parameters correctly for both ASA and non-ASA configuration.

The `multipath.conf` file must exist for the multipath daemon to start. If this file doesn't exist, you can create an empty, zero-byte file by using the `touch /etc/multipath.conf` command.

The first time you create the `multipath.conf` file, you might need to enable and start the multipath services by using the following commands:

```
chkconfig multipathd on
/etc/init.d/multipathd start
```

You don't need to add anything directly to the `multipath.conf` file unless you have devices that you don't want multipath to manage or you have existing settings that override defaults. To exclude unwanted devices, add the following syntax to the `multipath.conf` file, replacing `<DevId>` with the worldwide identifier (WWID) string of the device you want to exclude:

```
blacklist {
    wwid <DevId>
    devnode "^(ram|raw|loop|fd|md|dm-|sr|scd|st)[0-9]*"
    devnode "^hd[a-z]"
    devnode "^cciss.*"
}
```

The following example determines the WWID of a device and adds it to the `multipath.conf` file.

## Steps

1. Determine the WWID:

```
/lib/udev/scsi_id -gud /dev/sda
```

```
3600a098038314c4a433f5774717a3046
```

sda is the local SCSI disk that you want to add to the blacklist.

2. Add the WWID to the blacklist stanza in `/etc/multipath.conf`:

```
blacklist {
    wwid      3600a098038314c4a433f5774717a3046
    devnode   "^(ram|raw|loop|fd|md|dm-|sr|scd|st) [0-9] *"
    devnode   "^hd[a-z] *"
    devnode   "^cciss.*"
}
```

Always check your `/etc/multipath.conf` file, especially in the defaults section, for legacy settings that might be overriding default settings.

The following table demonstrates the critical `multipathd` parameters for ONTAP LUNs and the required values. If a host is connected to LUNs from other vendors and any of these parameters are overridden, they must be corrected by later stanzas in the `multipath.conf` file that apply specifically to ONTAP LUNs. Without this correction, the ONTAP LUNs might not work as expected. You should only override these defaults in consultation with NetApp, the OS vendor, or both, and only when the impact is fully understood.

Parameter	Setting
detect_prio	yes
dev_loss_tmo	"infinity"
failback	immediate
fast_io_fail_tmo	5
features	"3 queue_if_no_path pg_init_retries 50"
flush_on_last_del	"yes"
hardware_handler	"0"
no_path_retry	queue
path_checker	"tur"
path_grouping_policy	"group_by_prio"
path_selector	"round-robin 0"

Parameter	Setting
polling_interval	5
prio	"ontap"
product	LUN.*
retain_attached_hw_handler	yes
rr_weight	"uniform"
user_friendly_names	no
vendor	NETAPP

### Example

The following example shows how to correct an overridden default. In this case, the `multipath.conf` file defines values for `path_checker` and `no_path_retry` that are not compatible with ONTAP LUNs. If they cannot be removed because of other SAN arrays still attached to the host, these parameters can be corrected specifically for ONTAP LUNs with a device stanza.

```
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    path_checker      readsector0
    no_path_retry     fail
}

devices {
    device {
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        no_path_retry  queue
        path_checker    tur
    }
}
```

### Configure KVM settings

You don't need to configure settings for a Kernel-based Virtual Machine because the LUN is mapped to the hypervisor.

### ASM mirroring

Automatic Storage Management (ASM) mirroring might require changes to the Linux multipath settings to allow ASM to recognize a problem and switch over to an alternate failure group. Most ASM configurations on ONTAP use external redundancy, which means that data protection is provided by the external array and ASM doesn't mirror data. Some sites use ASM with normal redundancy to provide two-way mirroring, normally across different sites. See [Oracle databases on ONTAP](#) for further information.

### Known issues

The RHEL 6.4 with ONTAP release has the following known issues:

NetApp Bug ID	Title	Description
<a href="#">673009</a>	Creating ext4 file system on LV striped across 15 or more discard-enabled, thinly provisioned multipath devices triggers "request botched" kernel errors	"Request botched" kernel errors have been seen when users attempt to create an ext4 file system on discard-enabled, thinly provisioned multipath devices. As a result, creating the ext4 file system might take longer to complete and occasional disruption occurs. This issue has occurred only when users attempt to create the ext4 file system on a LV striped across 15 or more discard-enabled multipath devices on systems running Red Hat Enterprise Linux 6.x and Data ONTAP 8.1.3 and later operating in 7-Mode. The issue happens because the kernel erroneously attempts to merge discard requests, which is not supported on Red Hat Enterprise Linux 6.x at this time. When this issue occurs, multiple instances of the following message are written to syslog (/var/log/messages): kernel: blk: request botched. As a result, file system creation might take longer time to complete than expected.

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