

Booting VMware ESXi from FCoE

Abstract

FCoE is a network technology which transports Fibre Channel traffic over Ethernet network to make use of 10 Gbit speed and reduce the operational costs. This technical white paper gives an overview of FCoE, software and hardware requirements to boot VMware ESXi from an FCoE LUN. In this white paper, we focus on a hardware CNA initiator, a switch and a storage array to make it more specific, however majority of the flow would be same across storage arrays and initiators except the switch specific commands. This white paper also provides useful ESXi commands which provides the initiator with target details and the statistics of FCoE LUN.

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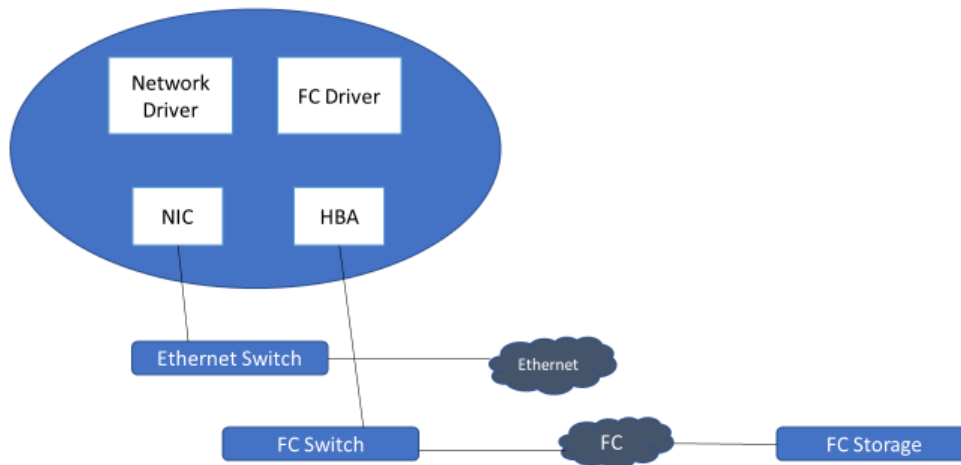
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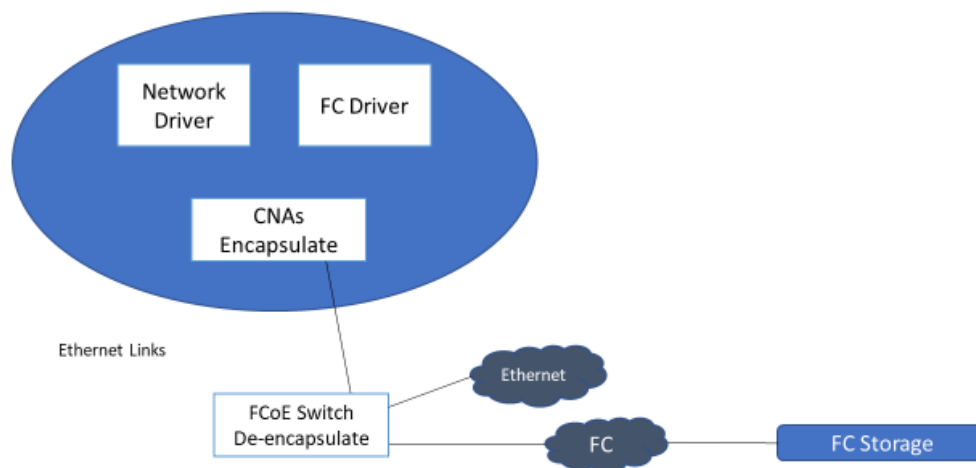
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Executive summary

Traditional SCSI was designed to transport Storage Area Network (SAN) traffic between devices in a fabric with shorter distance. Data transport was quick and reliable, but over a short distance. Ethernet was developed to overcome this problem by transporting data over long distances. But the dependency on transmission mechanics such as TCP and UDP brings in latency (especially during TCP retransmission).



FCoE combines the best of both worlds by transporting Fibre Channel SAN traffic encapsulated over Ethernet networks which also cuts down the overall capital and operational cost. With FCoE, the native FC protocol is preserved yet leveraging the use of SCSI directly over Ethernet unlike iSCSI which sends SCSI over TCP/IP which can introduce latency over the network.



VMware ESXi supports booting from FCoE capable network adapters in Dell EMC PowerEdge servers. When ESXi is installed from an FCoE LUN, the host requires a dedicated CNA with FCoE capabilities.

1 Introduction

This document is intended to help the user with configuring Dell EMC PowerEdge server and Dell EMC supported FCoE CNA adapter to boot from SAN.

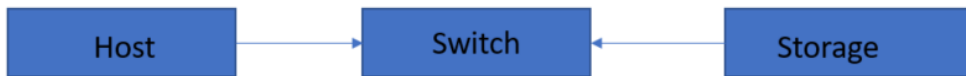
1.1 Audience and Scope

This whitepaper is intended for IT administrators planning to boot ESXi over FCoE LUN with DELL EMC PowerEdge servers utilizing Dell S5000 switch which offers converged network capabilities and Dell Compellent SC8000 storage center controller which provides failover capabilities and support datacenter requirements. The whitepaper covers switch and storage configurations to set up ESXi installation over FCoE LUN exposed to the fabric.

1.2 Hardware and Software Requirements

To boot VMware ESXi from an FCoE LUN, following components are required:

- A Converged network adapter (CNA)
For more information about Dell EMC supported FCoE CNAs, see [VMware Compatibility Guide](#).
- Ethernet link
- FCoE capable switch
- Storage array with FCoE IO card(s)



The CNA adapter can be based on hardware or software (capable of running FCoE software stack). Hardware FCoE adapters contain network and fibre channel functionalities on the same card. When the host is installed with the hardware FCoE adapter, the hosts can use both the CNA components. The networking components appear as a standard network adapter (vmnic), and the Fibre channel component appears as an FCoE adapter (vmhba) in the vSphere client.

A software based FCoE adapter uses software code to perform FCoE processing. The software adapter must be added before using the software based FCoE adapter as a NIC supporting partial FCoE offload. To add the software adapter, navigate to **Datacenter→Host→Configure→Storage Adapters→Add Software FCoE Adapter**. Select the appropriate **Physical network adapter** and **VLAN ID**, if any.

The Ethernet link must be an extension to existing Ethernet and provide similar lossless behavior like Fibre channel links, where frames are not lost during congestion, as FCoE enables FC over existing Ethernet. An FCoE switch is an L2 switch capable of transporting FCoE frames over Ethernet. This is also termed as data center bridging (DCB) switch supports both Ethernet and native FC traffic on its interfaces.

The FCoE capable switch has the capabilities to converge LAN and SAN traffic over a single 10GbE connection to optimize enterprise-scale data center for maximum flexibility and scalability.

The testbed setup used in the above example to explain the FCoE boot for VMware ESXi comprises of the following hardware:

- Dell EMC PowerEdge R630 server
- QLogic BCM57xxx series CNA adapter

- Dell S5000 Ethernet switch
- Dell Compellent SC8000 Storage Center Controller

For more information about the FCoE boot from SAN, BIOS, and UEFI perspective, see [VMware Knowledge Base Article 2148531](#). In this example testbed, we use QLogic BCM 57xxx series adapter which is an FCoE hardware offload capable CNA and it uses `qfle3f` driver module for storage adapter and `qfle3` driver module for network processing FCoE frames. For more information about the CNA adapter, see [VMware Compatibility Guide](#).

1.3 Storage configuration

To proceed with storage configuration, complete the following steps:

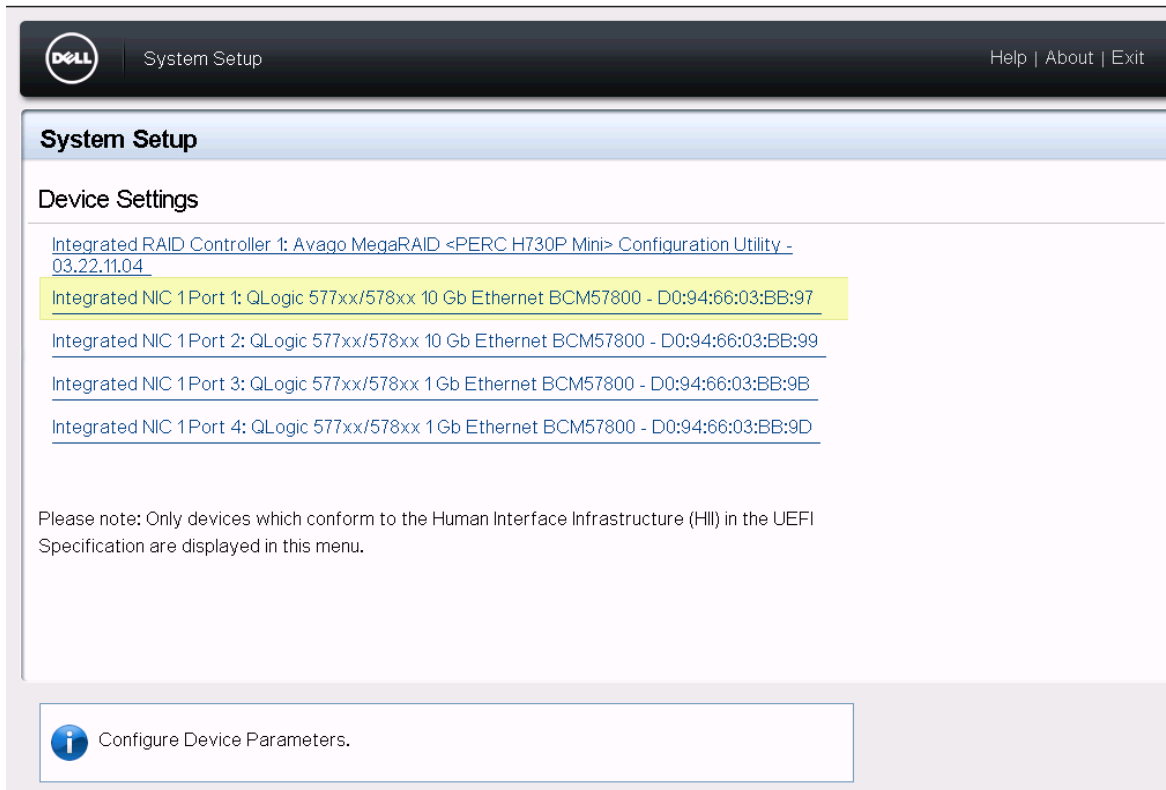
1. On the **Storage Center Login** page, enter your username and password, and then click **Login**.
2. Read the license agreement and on accepting, click **Accept**.
3. On the **Load license** page, browse and select the license file and then click **Load License**.
Note:
The serial number of the license file must match with the serial number of the controller.
The license submission must be completed successfully complete.
4. Click **Continue**.
The **Create Disk Folder** page appears.
Note: Use this to assign disks to a folder and to create a single pool of storage for volumes.
5. On the **Create Disk Folder** page, select the required disk folder, and then click **Continue**.
Note: By default, all the disks are selected.
6. If required, rename the default folder name.
7. To configure Disk Folder, click **Advanced**.
 - a. Configure Tier Redundancy for each Tier, by selecting **Single Redundant** or **Dual Redundant** from the drop-down menu.
 - b. From the **Datapage Size** drop-down menu, select the required Datapage size.
 - c. Select Prepare Disk Folder for redundant storage, and then click Continue.
8. Click **Create Now**, and then click **OK**.
9. On the **Add Controller** page, for Single-controller storage center, click **Continue Setup**.
 - a. For Dual- controller storage center, click **Add Controller** to add the second controller.
 - b. In **Controller ID**, enter the HSN value.
Note: If the HSN for Controller 2 is included in the license file, then the value in Controller ID is auto-populated, and the value cannot be changed. If the HSN for Controller 2 is not included in the license file, you must enter the HSN value.
 - c. Under the Ether 0 interface, enter the values in **IP Address**, **Net Mask**, and **Gateway**.
 - d. Under the Ether 1 interface, enter the values in **IP Address**, **Net Mask**, and **Gateway**.
 - e. In **Primary DNS Server**, enter the IP Address of the primary DNS server.
 - f. If there is a secondary DNS server, then you must enter the IP address in **Secondary DNS server**.
10. Click **Continue**.
11. Click **Join Now**.
12. On the **Time Settings** page, set the system time for the Storage Center, and then click **Continue**.

13. On the **System Setup** page, enter the system name and management IP address for the Storage Center, and then click **Continue**.
The wizard prompts you to enable or disable the read and write cache.
14. Select **Enable Read Cache** and **Enable Write Cache**, and then Click **Continue**.
15. **Configure SMTP** page, to enable alert message emails to be sent to users who have specified a recipient address in their contact properties. Click **Continue**.
16. Use the **Update setup** page to configure how Storage Center handles software updates. Click **Continue**.
17. On the **User Setup** page, specify session timeout and email addresses for the Admin account. Click **Continue**.
18. On the **Configure SMTP** page, enter the IP address or a domain name of the SMTP email server.
Note: To configure SMTP later, click **Skip SMTP Configuration**. SMTP settings can be configured later in the **System Manager**.
19. In the **Sender E-mail Address** field, enter the email address of the sender.
20. On the **Update Setup** page, select an update option from the drop-down menu, and then click **Continue**.
21. On the **User Setup** page, for **Session Timeout**, select the time from the drop-down menu.
22. In the **Email**, **Email 2**, and **Email 3** fields, enter email addresses to which the Storage Center has to send system alerts.
23. Click **Continue**.
24. On the **Configure IO Cards** page, enter the values in the **IP Address**, **Subnet Mask**, and **Gateway** fields.
25. Click **Continue**.
26. On the **Configure Ports** page, click **Configure Local Ports**.
The wizard lists the IO cards installed in the storage center (FC, iSCSi and SAS) along with the status of the port(s).
27. Configure **Purpose**, **Fault Domain** and **User Alias** (optional) based on your requirement.
 - a. For Single Controller Storage Center, by default, fault domain is created for each FC port.
 - b. For Dual-Controller Storage Center, create a fault domain for each pair of redundant FC ports.
28. Click **Continue**.
29. On the **Generate SSL Certificate** page, click **Import**.
30. Browse to the location of the public key (*.pem) file, and then select the file.
Note: If you do not have a certificate containing the Storage Center host name or IP address, generate a certificate by clicking **Generate Now**.
31. Click **Next**.
32. To import the certificate, click **Save**.

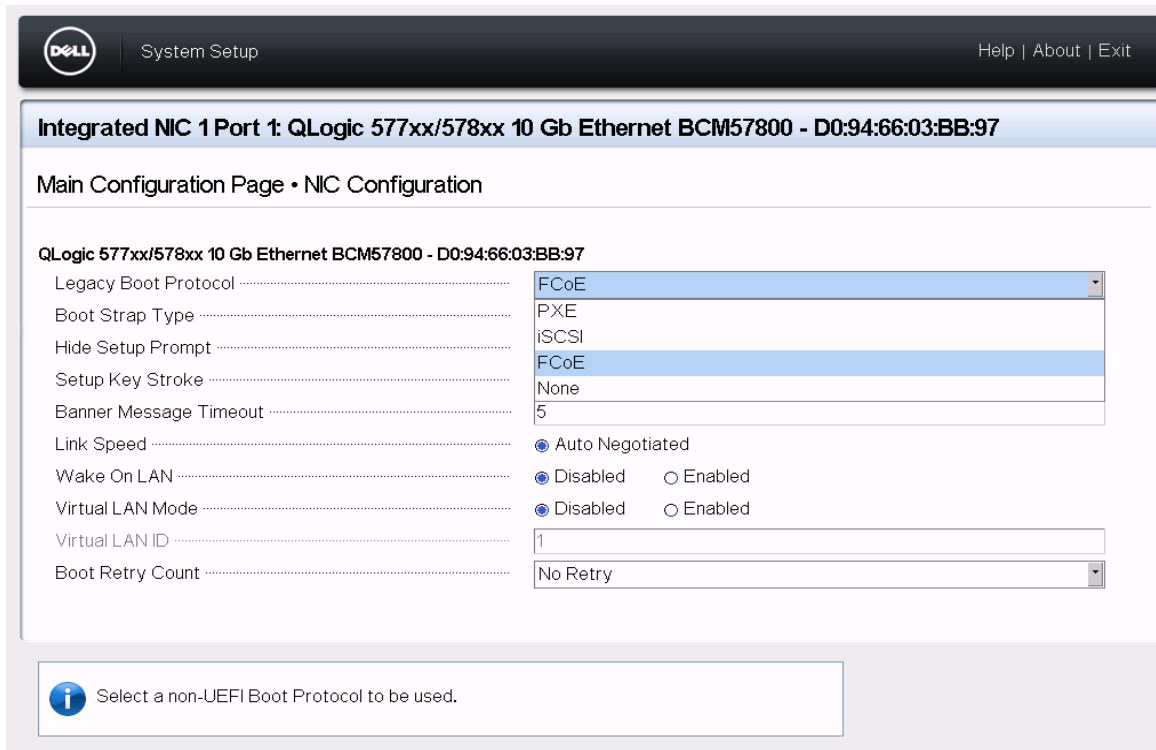
1.4 Enabling FCoE in PowerEdge servers

To enable FCoE, complete the following steps:

1. On a supported Dell EMC PowerEdge server, navigate to **Device Settings** in the BIOS setup, and then select the CNA adapter port that you want to boot.
2. To enable logical interfaces partitioned from a single interface, select **enable**.



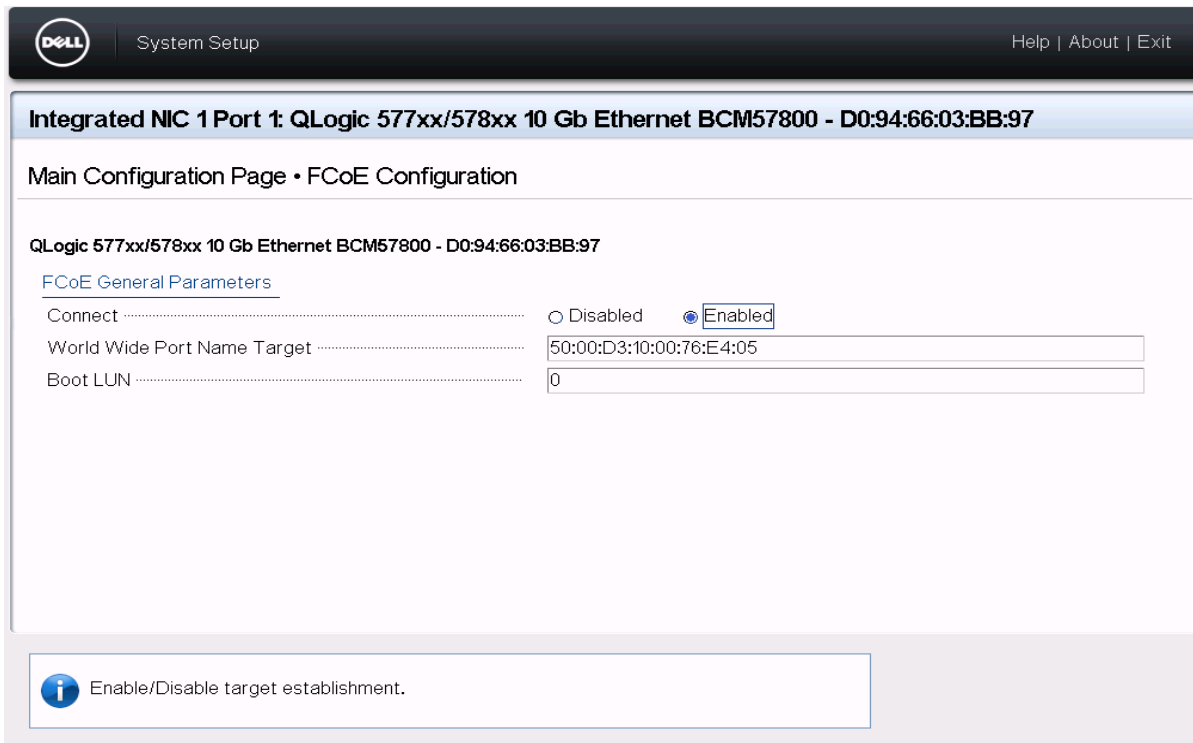
3. In the Main Configuration Page, select **NIC Configuration**.
4. From the Legacy Boot Protocol drop-down menu, select **FCoE**.



5. Select **FCoE Configuration**, and then click **FCoE General Parameters**.
6. To enable Boot to FCoE target, in FCoE General Parameters, select **Enabled**. Following are the options available in the FCoE General Parameters:
 - **Boot to FCoE Target:** Enable/Disable booting to FCoE target after logging in.
 - **Target as First HDD:** Target appears as a first Hard disk drive (HDD) in the system.
 - **Link Up Delay Time:** The time (in seconds) of the FCoE initiator that waits after an Ethernet link is established before sending any data over the network. By default, it is set to 0.
 - **LUN busy retry count:** The number of connections retries that the FCoE initiator attempts when the FCoE target LUN is busy. By default, it is set to 0.
 - **Fabric Discovery Retry Count:** The retry count for FCoE fabric discovery. By default, it is set to 4.



7. To enable Connect, select **Enable**, and then enter the World-Wide Port Name (WWPN) of the target device in the **World Wide Port Name Target** field and specify Boot LUN as required.



Note: To get the target WWPN (Controller Port), log in to the storage array and navigate to Hardware-Controllers-IO Ports-Fibre Channel.

Note: Boot LUN is the first FCoE storage target's LUN that is used by the FCoE initiator as the system boot device. LUN ID 0 is reserved for Boot LUNs.

8. The host or initiator WWPN is listed in the Main configuration page.

The screenshot shows the Dell System Setup BIOS configuration page for an Integrated NIC. The page title is "Integrated NIC 1 Port 1: QLogic 577xx/578xx 10 Gb Ethernet BCM57800 - D0:94:66:03:BB:97". The "Main Configuration Page" displays the following settings:

PCI Address	01:00:00
Link Status	Connected
MAC Address	D0:94:66:03:BB:97
Virtual MAC Address	D0:94:66:03:BB:97
iSCSI Offload MAC Address	D0:94:66:03:BB:98
Virtual iSCSI Offload MAC Address	D0:94:66:03:BB:98
FIP MAC Address	D0:94:66:03:BB:98
Virtual FIP MAC Address	D0:94:66:03:BB:98
World Wide Node Name	20:00:D0:94:66:03:BB:98
Virtual World Wide Node Name	20:00:D0:94:66:03:BB:98
World Wide Port Name	20:01:D0:94:66:03:BB:98
Virtual World Wide Port Name	20:01:D0:94:66:03:BB:98

After configuring the BIOS settings, the next step is to configure Zoning to control the Fibre channel ports that communicates with each other. This configuration prevents the zone from discovering unauthorized target devices and reduces traffic, which makes the Fibre channel network more reliable and stable.

Separate logical group of ports are configured to address the separate set of connectivity requirements. For example, zone A acts as server 1 to communicate with the storage system and zone B acts as server 2 to communicate with the storage system and so on.

The following are the types of zoning:

- **Soft zoning:** Soft zoning relies on the WWN of the node in the fabric. That means, a host WWN is placed in a zone without concerning about the ports they are connected in the FC switch.
- **Hard zoning:** Hard zoning is implemented in hardware. A physical switch port is placed for zone membership. This method physically blocks access to a zone from any devices which resides outside of the zone.

In the below example, Soft zoning is performed.

Note: The zoning configuration varies by switch vendor or model.

The below screenshot shows an active zone in a Dell S5000 Switch. The output shown is generated by executing `show fc zoneset active` command in the Switch command-line interface.

```

ZoneName                               ZoneMember
=====
FCOE
                                         *20:01:d0:94:66:03:bb:98
                                         *50:00:d3:10:00:76:e4:05

```

For more information, see the [PowerSwitch S5000](#) documents.

Following are the two ways to access the storage controller:

- Use a web browser with network access and connect to the eth0 IP address of the controller.
- [Download](#) Storage Manager Client (Windows/Linux) to manage and monitor Storage center (s).

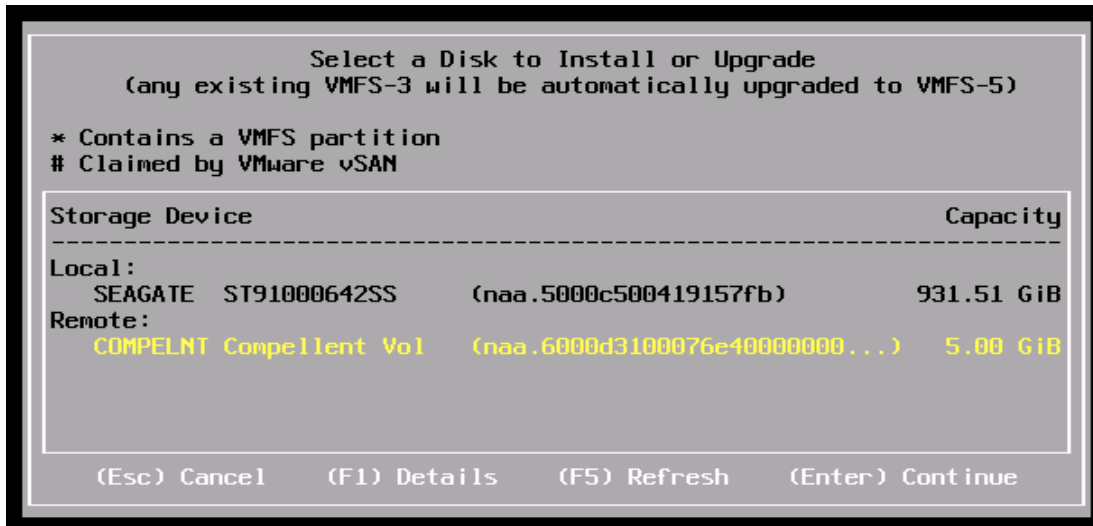
The following screenshot displays a volume mapped to an FCoE initiator in a Dell Compellent SC8000 storage array.

Volume	Connectivity	Volume Folder Path	Mapped Via	LUN Requested	LUN Used	Read Only
FCOE	Up	/	Server	N/A	1	No

Volume	Status	Transport	Server HBA	Controller Port	LUN	Read Only	Operational State
FCOE	Up	Fibre Channel	2001D0946603BB98	5000D3100076E405	1	No	Active/Optimized

For more information, see the [Dell Storage SC8000](#) documents.

Boot PowerEdge server with ESXi ISO build mounted. The configured FCoE LUN is listed as one of the storage devices as shown:



To get the device driver, firmware details, and additional information in the test setup, see [VMware Compatibility Guide](#).

2 ESXi FCoE commands

This section lists the commands used for FCoE.

2.1 FCoE capable CNA devices

The following screenshot captured with the command that lists the FCoE capable CNA devices:

```
[root@he-dhcp-100-98-13-204:~] esxcli fcoe adapter list
vmhba64
Source MAC: d0:94:66:03:bb:97
FCF MAC: 5c:f9:dd:ef:aa:83
VNPort MAC: 0e:fc:02:01:30:00
Physical NIC: vmnic0
User Priority: 3
VLAN id: 1002
VN2VN Mode Enabled: false
```

The following are list of commands and its description mentioned in the above screenshot:

- **vmhba64:** Name of the storage adapter. This refers to the physical adapter on the host.
- **Source MAC:** The unique hardware address i.e. physical address of the source node.
- **FCF MAC:** The unique address assigned by Fibre channel forwarder (FCF) during FLOGI (Fibre channel login) or FDISC (Fabric discovery) process.
- **VNPort MAC:** A MAC address that uniquely identifies a CNA port (VN_port in FCoE terminology)
- **Physical NIC:** A virtual machine network interface card, also a physical adapter on the ESXi host.
- **User Priority:** Priority to use for FCoE traffic.
- **VLAN id:** To identify VLAN.
- **VN2VN mode:** Allows FCoE network to work without any FCoE switches (or FCFs). The default setting is false.

2.2 LUN pathing information

The following screenshot captured with the commands to obtain LUN pathing information:

```
[root@he-dhcp-100-98-13-204:~] esxcli storage fcoe list
fcoe.2000d0946603bb98:2001d0946603bb98-fcoe.5000d3100076e401:5000d3100076e405-aaa.6000d3100076e400000000000000001a
  UID: fcoe.2000d0946603bb98:2001d0946603bb98-fcoe.5000d3100076e401:5000d3100076e405-aaa.6000d3100076e400000000000000001a
  Runtime Name: vmhba64:CO:TO:L0
  Device: naa.6000d3100076e4000000000000000001a
  Device Display Name: COMPELNT Fibre Channel Over Ethernet Disk (naa.6000d3100076e400000000000000001a)
  Adapter: vmhba64
  Channel: 0
  Target: 0
  LUN: 0
  Plugin: NMP
  State: active
  Transport: fcoe
  Adapter Identifier: fcoe.2000d0946603bb98:2001d0946603bb98
  Target Identifier: fcoe.5000d3100076e401:5000d3100076e405
  Adapter Transport Details: WWNN: 20:00:d0:94:66:03:bb:98 WWPN: 20:01:d0:94:66:03:bb:98 FCF MAC: 5c:f9:dd:ef:aa:8d VNPort MAC: 0e:fc:02:01:3a:00 VLAN ID: 1002 Underlying PNIC: vmnic0
  Target Transport Details: WWNN: 50:00:d3:10:00:76:e4:01 WWPN: 50:00:d3:10:00:76:e4:05
  Maximum IO Size: 262144

sas.544a842011db1000-sas.6014abf505e0fb5b-aaa.644a842011db10002514abf505e0fb5b
  UID: sas.544a842011db1000-sas.6014abf505e0fb5b-aaa.644a842011db10002514abf505e0fb5b
  Runtime Name: vmhba0:C2:TO:L0
  Device: naa.644a842011db10002514abf505e0fb5b
  Device Display Name: Local DELL Disk (naa.644a842011db10002514abf505e0fb5b)
  Adapter: vmhba0
  Channel: 2
  Target: 0
  LUN: 0
  Plugin: NMP
  State: active
  Transport: sas
  Adapter Identifier: sas.544a842011db1000
  Target Identifier: sas.6014abf505e0fb5b
  Adapter Transport Details: 544a842011db1000
  Target Transport Details: 6014abf505e0fb5b
  Maximum IO Size: 262144

sata.vmhba2-sata.0:5-mpx.vmhba2:CO:TS:L0
  UID: sata.vmhba2-sata.0:5-mpx.vmhba2:CO:TS:L0
  Runtime Name: vmhba2:CO:TS:L0
  Device: mpx.vmhba2:CO:TS:L0
  Device Display Name: Local HL-DT-ST CD-ROM (mpx.vmhba2:CO:TS:L0)
  Adapter: vmhba2
  Channel: 0
  Target: 5
  LUN: 0
  Plugin: NMP
  State: active
  Transport: sata
  Adapter Identifier: sata.vmhba2
  Target Identifier: sata.0:5
  Adapter Transport Details: Unavailable or path is unclaimed
  Target Transport Details: Unavailable or path is unclaimed
  Maximum IO Size: 33554432
[root@he-dhcp-100-98-13-204:~] █
```

2.3 FCoE adapter attributes

The following screenshot captured with the commands to list adapter attributes:

```
[root@he-dhcp-100-98-13-204:~] esxcli storage san fcoe list
  Adapter: vmhba64
  Port ID: 013A00
  Node Name: 20:00:d0:94:66:03:bb:98
  Port Name: 20:01:d0:94:66:03:bb:98
  Speed: 0 Gbps
  Port Type: NLPort
  Port State: ONLINE
  Controller MAC: d0:94:66:03:bb:98
  FCF MAC: 5c:f9:dd:ef:aa:8d
  VN Port MAC: 0e:fc:02:01:3a:00
  VLAN ID: 1002
  Vmnic Name: vmnic0
  Model Description: Broadcom NetXtreme II 57800 FCoE Driver
  Hardware Version:
  OptionROM Version:
  Firmware Version:
  Driver Name: qfle3f
  DriverVersion: 1.0.63.0
[root@he-dhcp-100-98-13-204:~] █
```

2.4 FCoE adapter statistics

The following screenshot captured with the command to obtain adapter statistics:

```
[root@he-dhcp-100-98-13-204:~] esxcli storage san fcoe stats get
Adapter: vmhba64
Tx Frames: 12388563
Rx Frames: 15172830
Error Frames: 0
Dumped Frames: 0
Link Failure Count: 0
Loss of Signal Count: 0
Invalid Tx Word Count: 0
Invalid CRC Count: 0
VLink Failure Count: 0
Miss Disc Adv Count: 0
Input Requests: 0
Output Requests: 0
Control Requests: 0
[root@he-dhcp-100-98-13-204:~] █
```


3 Logging into FCoE during system boot

The screenshot below shows the DCBX startup and initiator login to the target to enable OS boot from the FCoE LUN exposed over the network:

```

Copyright (C) 2017 QLogic Corporation
FCoE Boot v7.15.0

Starting DCBX process with interface (D0:94:66:03:BB:98) ... Succeeded
Discovering FC Fabric with interface (D0:94:66:03:BB:98) ... Succeeded

World Wide Node Name : 20:00:D0:94:66:03:BB:98
World Wide Port Name : 20:01:D0:94:66:03:BB:98
Fabric Name          : 10:00:5C:F9:DD:EF:AA:80
FCF MAC Address      : 5C:F9:DD:EF:AA:83
FP MAC Address       : 0E:FC:02:01:30:00
VLAN ID              : 1002

Fabric Login via interface (D0:94:66:03:BB:98) ... Succeeded
Login to target [5000D3100076E405:013600:LUN=000] ... Succeeded

FC Target Drive: COMPELNT Compellent Vol   (Rev: 0703)

Press <Ctrl-D> within 4s to stop booting from the target ... _

```

Data center bridging exchange (DCBX) is a protocol which is an extension to the Link layer discovery protocol (LLDP). DCBX cannot run if LLDP is disabled. DCBX enables the devices connected in a fabric to discover and exchange configuration information.

Note that the DCBX capabilities are supported by the FCoE capable switch.

In this case, DCBX exchanges FCoE information by default as the interface carries FCoE traffic.

During FC fabric discovery, The FC switch discover the WWPN of a device or host and assign a port address to the device. This port address is unique and routable over the network and valid only till the device (host or target) is logged on.

After the DCBX setup and FCF discovery, the initiator successfully logs in to the target, i.e. the FCoE disk is ready for read/write operations.

The following screenshot captured with the commands that lists the FCoE software packages installed after ESXi completes to boot to DCUI.

```
[root@he-dhcp-100-98-13-204:~] esxcli software vib list | grep -i fcoe
brcmfcoe          11.4.1078.5-11vmw.670.1.28.10302608  VMW    VMwareCertified  2019-07-01
net-fcoe          1.0.29.9.3-7vmw.670.0.0.8169922      VMW    VMwareCertified  2019-07-01
net-libfcoe-92    1.0.24.9.4-8vmw.670.0.0.8169922      VMW    VMwareCertified  2019-07-01
shim-libfcoe-9-2-1-0  6.7.0-0.0.8169922                    VMW    VMwareCertified  2019-07-01
shim-libfcoe-9-2-2-0  6.7.0-0.0.8169922                    VMW    VMwareCertified  2019-07-01
vmkfcoe          1.0.0.1-1vmw.670.1.28.10302608      VMW    VMwareCertified  2019-07-01
```

The following screenshot captured with the commands FCoE driver loaded after ESXi completes boot to DCUI:

```
[root@he-dhcp-100-98-13-204:~] esxcli system module list | grep -i qfle3f
qfle3f          true      true
[root@he-dhcp-100-98-13-204:~]
```

```
[root@he-dhcp-100-98-13-204:~] vmkload_mod -l | grep -i qfle3f
qfle3f          2        708
[root@he-dhcp-100-98-13-204:~]
```

```
[root@he-dhcp-100-98-13-204:~] esxcli system module get -m qfle3f
Module: qfle3f
Module File: /usr/lib/vmware/vmkmod/qfle3f
License: ThirdParty:QLogic_Proprietary
Version: 1.0.63.0-10EM.670.0.0.8169922
Build Type: release
Provided Namespaces:
Required Namespaces: com.vmware.vmkapi@v2_5_0_0
Containing VIB: qfle3f
VIB Acceptance Level: certified
```

4 Troubleshooting

Switches are located between the hosts and storage devices and have visibility to both sides of the storage network. When there is an issue in the fabric, observe if the issue persisting on the host or storage or the switch and then perform a detailed diagnosis.

Verify the following issues:

Host issues:

- Missing device(s)
- CNA firmware
- Incorrect device driver installation and device configuration
- Interrupted or damaged links between host and switch

Storage issues:

- Physical connectivity between switch and storage
- Incorrect storage configuration

Switch issues:

- Missing or interrupted links
- Damaged cables
- Incorrect switch and zoning configuration

5 Summary

This paper explains about configuring Dell EMC PowerEdge server, Dell S5000 switch and Dell Compellent SC8000 Storage Center to VMware ESXi from FCoE LUN exposed to SAN.

6 References

- [Booting ESXi with Software FCoE](#)