Designing SAN Using Cisco MDS 9000 Series Fabric Switches

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Summary

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What You Will Learn

In this document you will learn the options available to design a robust, flexible, and high-performance storage area network (SAN) built using the Cisco® MDS 9000 Series fabric switches. This document also covers best practices to increase scalability and operational simplicity. Key software enhancements to provision and manage your SAN are also discussed.

Scope

The focus of this document is on the Cisco MDS 9148S 16G Multilayer Fabric Switch and the Cisco MDS 9396S 16G Multilayer Fabric Switch, as shown in Figure 1.

Figure 1. Cisco MDS 9148S and 9396S Fabric Switches

The principles described here apply to director-class platforms as well. Detailed design information for the director-class platforms is available in the Large SAN Design Best Practices Using Cisco MDS 9700 and MDS 9500 Multilayer Directors white paper.

SAN Designs Based on Fabric Switches

The purpose of a SAN is to provide connectivity between end devices (servers and storage arrays). To increase high availability, two paths are maintained between same pair of servers and storage arrays. Servers are installed with (at least) dual port host bus adapters (HBA) which are connected to ports on two different controllers on storage arrays. The dual path connectivity between servers and storage arrays is provided by two distinct SANs built using one or more switches. These dual networks are commonly known as SAN-A and SAN-B. Both SANs are designed to be identical. This document shows only a single SAN in the network diagrams for the sake of simplicity.

SAN design depends on the number of end devices connected to a fabric. The subsections that follow elaborate on the options available to build a SAN using Cisco MDS fabric switches.

Single-Switch Solutions

The MDS 9148S and MDS 9396S can be used to connect 48 or 96 end devices, respectively. Solutions built using a single switch are simple to design, install, manage, and operate.

Solutions with up to 48 End Devices

Up to 12 end devices can be connected using the 12-port base license on the MDS 9148S. Up to 48 end devices can be connected to the MDS 9148S using 12-port incremental port-on-demand licenses. The finer granularity of the 12-port incremental port-on-demand license helps to increase the return on your investment. For example, if the plan is to connect 10 end devices this year and 10 end devices next year, you can procure the MDS 9148S with the 12-port base license now and install a 12-port increment port-on-demand license next year (Figure 2).
Installing a license on a Cisco MDS 9000 Series switch is a nondisruptive process. For more information on licensing, please refer to the Cisco MDS 9000 Family NX-OS Licensing Guide.

Solutions with up to 96 End Devices

Up to 48 end devices can be connected using the 48-port base license on the MDS 9396S. Up to 96 end devices can be connected to the MDS 9396S using 12-port incremental port-on-demand licenses. The finer granularity of the 12-port incremental port-on-demand license helps to increase the return on your investment. For example, if the plan is to connect 40 end devices this year and 30 end devices next year, you can procure the MDS 9396S with the 48-port base license now and install two 12-port incremental port-on-demand licenses next year (Figure 3).

Figure 3. Flexible Licensing on MDS 9396S for up to 96 Ports

Multiswitch Solutions

A fabric built using multiple switches can be used to provide connectivity among more than 96 end devices. You should carefully analyze application throughput requirements and traffic patterns to make decisions regarding topology, network oversubscription, number of inter-switch links (ISLs), level of high availability, and switch model.

Consider the network shown in Figure 4. Two MDS 9396S switches are used to provide connectivity among 144 end devices. Twenty-four ports on each MDS 9396S are used for ISL connectivity. Assuming that all links are at 16G Fibre Channel, the network shown has an oversubscription ratio of 3:1 between the two switches. The network can be further optimized by increasing traffic localization.
Fabric Switches at the Server Edge in a Large-Scale Edge-Core or Edge-Core-Edge Design
Cisco MDS fabric switches can be used at the server edge in large-scale edge-core or edge-core-edge designs. Server-edge switches can be installed at the top of a rack (TOR). TOR switches can be connected to Cisco MDS 9700 Series Multilayer Directors installed at the end of a row (EOR). The number, model, and port count of switches are derived from the number of servers installed per rack and the traffic profile. The MDS 9396S can increase consolidation by acting as a shared TOR switch between multiple racks. A reduced number of TOR switches leads to reduced management overhead and reduced real estate, power, cooling, and cabling requirements, leading to lower operating expenses (OpEx).

The MDS 9148S and MDS 9396S can be configured in N-Port Virtualization (NPV) mode with MDS 9700 Series directors acting as the N-Port Identifier Virtualization (NPIV) parents (Figure 5). Servers should maintain dual paths to reach storage arrays. The design shown in Figure 5 should be replicated in dual networks (SAN A and SAN B). Switches in NPV mode do not consume a Fibre Channel domain ID or join a fabric. Multiple end devices connected to a switch in NPV mode can log in to a fabric using the same port on the parent NPIV switch. The NPV and NPIV model simplifies management and increases scalability, especially in large networks. NPV and NPIV functionality is included in the base license.
Native Fibre Channel SAN Extension

The MDS 9396S can be used for replication and backup services over long-distance native Fibre Channel links (Figure 6). By default, all ports on the MDS 9396S have 500 buffer-to-buffer (B2B) credits. This quantity is enough for a 62-km Fibre Channel link, assuming full-size frames of 2112 bytes. The number of B2B credits can be increased up to 4095 per port using enterprise licenses. This quantity is enough for a 510-km Fibre Channel link, assuming full-size frames of 2112 bytes.

Table 1 lists the number of B2B credits required per kilometer of ISL at different speeds and frame sizes. Note that one B2B credit is needed per frame irrespective of the frame size. Also, scope should be left for a longer end-to-end path in the optical WAN/MAN infrastructure and with small frame sizes.
Table 1. Per-Kilometer B2B Credit Requirements at Different Speeds and Frame Sizes

<table>
<thead>
<tr>
<th>Frame Size</th>
<th>1 Gbps</th>
<th>2 Gbps</th>
<th>4 Gbps</th>
<th>8 Gbps</th>
<th>10 Gbps</th>
<th>16 Gbps</th>
</tr>
</thead>
<tbody>
<tr>
<td>512 bytes</td>
<td>2 B2B per km</td>
<td>4 B2B per km</td>
<td>8 B2B per km</td>
<td>16 B2B per km</td>
<td>24 B2B per km</td>
<td>32 B2B per km</td>
</tr>
<tr>
<td>1024 bytes</td>
<td>1 B2B per km</td>
<td>2 B2B per km</td>
<td>4 B2B per km</td>
<td>8 B2B per km</td>
<td>12 B2B per km</td>
<td>16 B2B per km</td>
</tr>
<tr>
<td>2112 bytes</td>
<td>0.5 B2B per km</td>
<td>1 B2B per km</td>
<td>2 B2B per km</td>
<td>4 B2B per km</td>
<td>6 B2B per km</td>
<td>8 B2B per km</td>
</tr>
</tbody>
</table>

This use case assumes the existence of an optical infrastructure between two data centers. The Cisco MDS 9000 Series switches support a wide range of optical transceivers. More details are available in the Cisco MDS 9000 Family Pluggable Transceivers data sheet.

Best Practices for SAN Design Using Cisco MDS 9000 Series Fabric Switches

The following best practices should be used while designing and operating a SAN using Cisco MDS 9000 Series fabric switches.

Increase Traffic Localization

Servers and storage arrays in the same zone should be connected to the same switch in a two-switch network (Figure 7). This approach increases traffic localization and decreases traffic flow on the ISL. Traffic localization brings the following benefits.

1. Data traffic between servers and storage arrays is subjected to single-hop switching, leading to optimized performance.
2. Reduced traffic between switches means fewer ports are required for ISL connectivity. These available ports can be used to connect more end devices.
3. Traffic localization also brings fault isolation. Failure of cables or SFP between the switches causes no impact on data traffic. Also, local traffic is not subjected to Fibre Channel control plane mechanisms (such as Fabric Shortest Path First [F SPF] to calculate the next hop).
4. Traffic localization simplifies management, monitoring, and troubleshooting.

Figure 7. Connect Devices in the Same Zone to the Same Switch for Increased Traffic Localization
Use Port-Channels
A port-channel is a logical interface with multiple physical ports as members. ISLs between switches should be aggregated into port-channels. In case of failure of a single physical port, data traffic automatically fails over to other ports in the same port-channel. A single physical link failure does not trigger Fibre Channel control plane (FSPF) recalculations. Port-channels bring resiliency and stability to your SAN.

Cisco MDS 9000 Series switches do not require any special license to use port-channels. Port-channel members can reside anywhere on a switch. A single port-channel interface on the Cisco MDS switches can have up to 16 physical ports. We recommend the following guidelines for the position of port-channel member ports to increase scale and resilience.

Port-Channel Members on the MDS 9148S
Port-channel members should be uniformly distributed among ports 1 through 16, 17 through 32, and 33 through 48 on the MDS 9148S. Within these three sets of 16 ports, port-channel members should further be uniformly distributed among port-groups. A port-group on the MDS 9148S consists of four consecutive ports. For example, ports 1 through 4 are in port-group 1, ports 5 through 8 are in port-group 2, and so on. Using this two-level recommendation (Figure 8), a port-channel with three members should use ports 1, 17, and 33 (or any other ports as long as there is one from each set of ports mentioned above). A port-channel with four members should use ports 1, 17, 33, and 5 (from port-group 2 within the set of ports 1 through 16). A port-channel with 5 members should use ports 1, 17, 33, 5 (from port-group 2 within the set of ports 1 through 16), and 21 (from port-group 6 within the set of ports 17 through 32). Port-channels with more members should be distributed by extrapolating this approach.

Figure 8. Recommendation for Positions of Members of a Port-Channel on the MDS 9148S

Port-Channel Members on the MDS 9396S
On the MDS 9396S, port-channel members should be uniformly distributed among ports 1 through 8, 9 through 16, 17 through 24, and so on. Within these 12 sets of 8 ports, port-channel members should further be uniformly distributed among port-groups. A port-group on the MDS 9396S consists of four consecutive ports. For example, ports 1 through 4 are in port-group 1, ports 5 through 8 are in port-group 2, and so on. Using this two-level
recommendation (Figure 9), a port-channel with three members should use ports 1, 9, and 17. A port-channel with 12 members should use ports 1, 9, 17, 25, 33, 41, 49, 57, 65, 73, 81, and 89. A port-channel with 13 members should use ports 1, 9, 17, 25, 33, 41, 49, 57, 65, 73, 81, 89, and 5 (from port-group 2 within the set of ports 1 through 8). Port-channels with more members should be distributed by extrapolating this approach.

**Figure 9.** Recommendation for Positions of Members of a Port-Channel on the MDS 9396S

The licensing model for the Cisco MDS 9000 Series switches provides flexibility to choose the port number as long as the total number of activated ports is within the licensed limit. With the 12-port base license on the MDS 9148S, you can activate any 12 ports. The activated ports need not be consecutive or the first 12 ports. As per the above recommendation, you should activate ports 1, 5, 9, 13, 17, 21, 25, 29, 33, 37, 41, and 45 with this base license. Similarly, with the 48-port base license on the MDS 9396S, you can activate any 48 ports. As per the recommendation above, you should activate ports 1, 3, 5, 7, and so on with this base license. Ports can be activated or deactivated using the Cisco NX-OS command port-license acquire. More information is available in the [Cisco MDS 9000 Family NX-OS Licensing Guide](#). Please also consider your cable plant and future expansion plans when deciding which ports to activate.

**Zoning**

1. **We do not recommend using a default zone (permit all) for your production traffic.**
2. **Device aliases:** We recommend using device aliases for all port worldwide names (pWWNs) in your fabric. Device aliases provide user-friendly and human-readable names to pWWNs to simplify zoning operations.
3. **Enhanced zoning:** Enhanced zoning should be enabled on all switches. When you begin a zoning change, the switch creates a session to lock the entire fabric to implement the change. The lock is released after the zoning change is committed. This helps maintain zoning database consistency between switches in the same fabric.
4. We recommend configuring only one initiator and one target per zone member. Configuring the same initiator to multiple targets is acceptable for small networks (one or two switches). Configuring multiple initiators to multiple targets is not recommended.

5. **Smart zoning:** We recommend configuring a single initiator to a single target zone. However, this approach requires SAN administrators to spend a great deal of time in configuration and management. Using smart zoning, you can create smart zones in which all initiators and targets are in the same zone. Cisco MDS 9000 Series switches internally create single initiator to single target zones based on your configuration in smart zones. Using smart zoning, you get operational simplicity with optimized resources.

6. Remove configuration of unused zones from your active zone set to free up resources.

7. Names of zones, zone sets, and device aliases should be descriptive and convey the meaning in a crisp format. We recommend using any standard naming convention to maintain consistency and shorter length.

**Provisioning and Managing a Cisco MDS 9000 Series Switch**

Cisco MDS 9000 Series switches have multiple mechanisms for zero-touch provisioning and simplified management. Features such as USB-based plug-and-play and network-based power-on automatic provisioning (POAP) enable you to go live in minutes by automating the initial provisioning. You get consistent, reliable switch configuration without any potential human errors. The time required to provision remains within minutes, be it a single switch or hundreds of switches. The subsections that follow elaborate on the options available to provision and manage Cisco MDS 9000 Series switches.

**Cisco NX-OS**

Cisco NX-OS running on Cisco MDS 9000 Series switches offers an industry-leading command-line interface (CLI) for provisioning and management. A serial cable connected to the console port on a new, factory-shipped Cisco MDS switch provides you access to the NX-OS CLI. You can perform basic tasks like configuring the switch name, management IP address, gateway, etc. Once the switch has an IP address, it can be connected to your management network via the management port. You can then continue using the console connection or access the switch over Secure Shell (SSH). Intuitive NX-OS commands can be used to configure port modes, device aliases, zonings, etc. More information is available in the **Cisco MDS 9000 NX-OS configuration guides**.

**Device Manager**

Device Manager is a built-in graphical user interface (GUI) that you can use to configure, monitor, and manage a single Cisco MDS 9000 Series switch. It is an intuitive, web-based application (Figure 10). You first use a serial console connection to configure the IP address on the management interface of the switch. Once the switch is connected and accessible over the management network, you can load Device Manager by entering the switch’s IP address in your favorite web browser. You are presented with a GUI that can be used for configuring interfaces, monitoring interface counters, monitoring switch health, configuring zoning, setting automated alarms, etc.
USB-Based Plug-and-Play Switch Provisioning
Cisco MDS 9000 Series switches have USB ports that can be used to provision a new switch in addition to storing logs, software images, etc. When a Cisco MDS 9000 Series switch boots with no configuration, it looks for a USB storage device connected to USB port 1 on the switch. The USB device can contain a provisioning script, configuration files, and software images. The switch automatically loads the supplied configuration and upgrades to the new software version. Multiple switches can be configured by using the same USB storage device. The provisioning script can be modified to look for configuration files that have the switch serial number in the configuration file name. A Cisco MDS switch provisions itself using a configuration file with its own serial number in the file name without interfering with other files on the same USB device (Figure 11). Once a switch is provisioned and accessible from the management network, it can be further managed for day-to-day operations using Secure Shell (SSH) on NX-OS, Device Manager, or Cisco Data Center Network Manager (DCNM).

Following are the benefits of USB based plug-and-play switch provisioning.

1. **Go live in minutes**: Configuration files can be made ready before the arrival of MDS switches at your facility. Cisco NX-OS configuration files can be customized in any test editor of your choice. In summary, you create
the configuration file for a switch before its arrival. USB plug-and-play then loads the configuration onto the switch within minutes after the switch is physically installed and powered up.

2. **Remote management:** As a SAN administrator, you do not have to be physically present in the data center for the initial provisioning of Cisco MDS switches (such as IP address assignment). You can copy configuration files to a USB storage device and request the facilities team to plug this device into the USB ports of new switches after the switches are powered up. Minutes later, you can manage the switches from a remote location using their management IP address.

3. **Reduced dependency on serial cables or laptops:** Traditionally, switches need to be connected via serial console connections for initial configuration. Using USB plug-and-play, you do not have to wait for serial console cables to provision your switches.

4. **Fewer human errors:** If you provision new switches frequently with a similar basic configuration, you can make your task error-free by using the same tested and verified basic configuration every time after making small relevant changes to it.

The provisioning script can be downloaded in the same way that you download NX-OS software images from [http://www.cisco.com](http://www.cisco.com). The USB plug-and-play feature is included in the base license. More details are available in the [Cisco MDS 9000 Family NX-OS Fundamentals Configuration Guide](http://www.cisco.com).

**Network-Based Power-on Automatic Provisioning (POAP)**

The time required to provision a new switch using the manual approach increases linearly as the number of switches increases. Network-based POAP is an ideal solution for larger networks, whether you are provisioning hundreds of switches now or provisioning new switches every few months. Cisco MDS 9000 Series switches have intelligence to locate a Dynamic Host Configuration Protocol (DHCP) server on your management network and request an IP address (Figure 12). The DHCP server assigns an IP address and also sends information about the network gateway, DNS server, Trivial File Transfer Protocol (TFTP) server, etc. using various DHCP options. The switch downloads a provisioning script from the TFTP server and further downloads the configuration file and software images as guided by the provisioning script. You can maintain a central repository of configuration files and software images at a central secure server. A simple base configuration template can be reused for new switches with minor customization.

Note that USB-based plug-and-play takes precedence over network-based POAP. If you want your new switches to be provisioned via USB, plug in a USB device with the required files. If you want to use network-based POAP, do not plug a USB device into the USB port, or at least do not keep the required files on the USB device. If you wish to use the traditional approach of provisioning new switches using a serial console connection, do not plug in a USB device and do not allow your DHCP server (if you have one) to assign an IP address to new switches. You can manually interrupt the automated provisioning (USB or network based) after connecting to the switch using a serial console cable.
Network-based POAP has the following additional benefits over USB-based plug-and-play.

1. **Zero-touch provisioning:** Network-based POAP gets activated as soon as Cisco MDS switches are powered up and the management port is connected to the network. Interaction with the DHCP, TFTP, and file servers is fully automated. This approach removes the single touch to plug in a USB storage device required for the USB-based plug-and-play approach. Network-based POAP is zero-touch provisioning.

2. **Go live in minutes, even for hundreds of switches:** With network-based POAP, the time required to provision new switches does not increase as the number of switches increases. This is an advantage for large networks.

The provisioning script can be downloaded in the same way that you download NX-OS software images from http://www.cisco.com. The network-based POAP feature is included in the base license. More details are available in the [Cisco MDS 9000 Family NX-OS Fundamentals Configuration Guide](#).

**Note:** USB-based plug-and-play and network-based POAP are aimed at provisioning new, factory-shipped switches. These features get activated only if an MDS switch boots without any configuration (blank startup-config). Once an MDS switch is configured and the configuration is saved, the switch will not invoke USB-based plug-and-play, even if a USB storage device with the required files is plugged into the switch. Similarly, once an MDS switch is configured and the configuration is saved, the switch will not invoke network-based POAP, nor it will try to seek an IP address from any DHCP server on the management network. An MDS switch loads the saved configuration after a reboot if it was configured and the configuration was saved. To invoke these features on an already configured switch, erase the saved configuration before reboot.

**Cisco Data Center Network Manager (DCNM)**
Cisco DCNM is an intuitive, web-based application for management of your SAN built using Cisco MDS 9000 Series switches (Figure 10). Additionally, DCNM delivers management for Cisco Nexus® 5000, 6000, 7000, and 9000 Series Switches in Cisco NX-OS mode. For storage networks, DCNM provides single-pane-of-glass visibility into all aspects of the network as well as the compute and storage infrastructure.

You can use Cisco DCNM with a single Cisco MDS switch or a very large network of hundreds of switches.
Cisco DCNM offers powerful configuration capabilities for tuning a fabric after it is operational and setting up zones, network security, and VSANs. Wizards are provided to accelerate configuration and eliminate errors in configuring zones, port-channels, and access control lists (ACLs) and to perform software updates. Network wide historical performance monitoring and analysis are provided. Throughput on all host and storage device connections and ISLs and between specific Fibre Channel sources and destinations (flows) can be monitored. Long-term performance statistics are maintained for trend analysis.

![Cisco Data Center Network Manager 10](image)

Figure 13. Cisco Data Center Network Manager 10

More details on Cisco DCNM are available in the [DCNM support documentation and software](#).

**Summary**

Cisco MDS 9000 Series fabric switches (the MDS 9396S and MDS 9148S) are flexible, affordable, and simple to operate. New enhancements such as USB based plug-and-play and network-based POAP simplify the provisioning of your infrastructure. You can make your new switches go live within minutes with consistency, reliability, and fewer potential human errors. Day-to-day operations can be managed using web-based Device Manager or Cisco DCNM. Overall, Cisco MDS 9000 Series fabric switches bring unique advantages to your SAN to support business requirements.

**More Information**

- [Cisco MDS 9148S 16G Multilayer Fabric Switch Data Sheet](#)
- [Cisco MDS 9396S 16G Multilayer Fabric Switch Data Sheet](#)
- [Five Reasons to Choose Cisco MDS 9000 Family Fabric Switches](#) (white paper)
- [Quick and Simple Setup of MDS Fabric Switches with MDS Device Manager](#) (YouTube video)
- [Cisco MDS 9000 NX-OS documentation](#) (configuration guides and command references)
DCNM support documentation and software (configuration guides and command references)

Cisco MDS 9000 Family NX-OS licensing guide

How to buy