

NETWORKING BEST PRACTICES

FOR VMWARE® vSPHERE 4 ON DELL™
POWEREDGE™ BLADE SERVERS

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1 Introduction

This whitepaper provides an overview of the networking architecture for VMware® vSphere 4 on Dell™ PowerEdge blade servers. It provides best practices for deploying and configuring your network in the VMware environment. References to other guides for step by step instructions are provided. The intended audiences for this whitepaper are systems administrators who want to deploy VMware virtualization on Dell PowerEdge blade servers and iSCSI storage.

The network architecture discussed in this white paper primarily focuses on iSCSI SAN. Best practices for Fibre Channel SAN are not covered in this document.

2 Overview

The PowerEdge M1000e is a high density and energy efficient blade chassis. It supports up to sixteen half height blade servers or eight full height blade servers and three layers of I/O fabric (A, B and C), which you can select between combinations of Ethernet, InfiniBand, and Fibre Channel modules. You can install up to six hot-swappable I/O modules in the enclosure, including Fibre Channel switch I/O modules, Fibre Channel pass-through I/O modules, InfiniBand switch I/O modules, Ethernet switch I/O modules, and Ethernet pass-through module I/O modules.

The integrated Chassis Management Controller also enables easy management of I/O Modules through a single secure interface.

2.1 Fabrics

The PowerEdge M1000e system consists of three I/O fabrics: Fabric A, B and C. Each fabric is comprised of two I/O modules. The modules are A1, A2, B1, B2, C1 and C2.

The following figure illustrates the different I/O modules supported by the chassis.



Figure 1: Blade Fabric Layout

- **Fabric A** is a redundant 1Gb Ethernet fabric that supports I/O module slots A1 and A2. The integrated Ethernet controllers in each blade dictate Fabric A as an Ethernet-only fabric.
- **Fabric B** is a 1 to 10 Gb/sec dual port, redundant fabric that supports I/O module slots B1 and B2. Fabric B currently supports 1/10Gb Ethernet, InfiniBand, and Fibre Channel modules. To communicate with an I/O

module in the Fabric B slots, a blade must have at least one matching mezzanine card installed in a Fabric B mezzanine card location.

- **Fabric C** is a 1 to 10 Gb/sec dual port, redundant fabric that supports I/O module slots C1 and C2. Fabric C currently supports 1 or 10 Gb Ethernet, Infiniband, and Fibre Channel modules. To communicate with an I/O module in the Fabric C slots, a blade must have at least one matching mezzanine card installed in a Fabric C mezzanine card location.

2.2 I/O Modules

This subsection lists the I/O modules that the PowerEdge M1000e chassis supports. New I/O modules may have been released after this document is published. For the latest information and detailed specification refer to www.dell.com

- **PowerConnect M6220 Ethernet Switch:** This Includes 16 internal server 1Gb Ethernet ports, 4 fixed copper 10/100/1000Mb Ethernet uplinks plus two of the following optional modules:
 - 48Gb (full duplex) Stacking module
 - 2 x 10Gb Optical (XFP-SR/LR) uplinks
 - 2 x 10Gb copper CX4 uplinks.

The Standard Features include:

- Layer 3 routing (OSPF, RIP, VRRP)
 - Layer 2/3 QoS
- **PowerConnect M8024 Ethernet Switch (10Gb Module):** This includes 16 internal server 1/10Gb Ethernet ports, up to 8 external 10GbE ports via up to 2 selectable uplinks modules, 4-port SFP plus 1 10GbE module and 3-port CX-4 10GbE copper module.

The Standard Features include:

- Layer 3 routing (OSPF, RIP, VRRP)
 - Layer 2/3 QoS
- **Cisco® Catalyst Blade Switch M 3032:** This includes 16 internal server 1Gb Ethernet ports, 4 fixed copper 10/100/1000Mb Ethernet uplinks plus 2 optional module bays which can support either 2 x 1Gb copper or optical SFPs.

The Standard features include:

- Base Layer 3 routing (static routes, RIP)
 - L2/3 QoS
- **Cisco Catalyst Blade Switch M 3130G:** This includes 16 internal server 1Gb Ethernet ports, 4 fixed copper 10/100/1000Mb Ethernet uplinks plus 2 optional module bays which can support either 2 x 1Gb copper or optical SFPs.

The Standard Features include:

- Base Layer 3 routing (static routes, RIP)
 - L2/3 QoS
 - Virtual Blade Switch Technology provides a high bandwidth interconnection between 8 CBS 3130 switches. You can configure and manage the switches as 1 logical switch. This radically simplifies management, allows server to server traffic to stay within the VBS domain as against congesting the core network, and can significantly help consolidate external cabling.
 - Optional software license key upgrades to IP Services (Advanced L3 protocol support) and Advanced IP Services (IPv6)
- **Cisco Catalyst Blade Switch M 3130X (supports 10G modules):** This includes 16 internal server 1Gb Ethernet ports, 4 fixed copper 10/100/1000Mb Ethernet uplinks, 2 stacking ports, and support for 2 X2 modules which can be configured with up to four SFP ports, or two 10Gig CX4 or SR/LRM uplinks.

The Standard Features include:

- Base Layer 3 routing (static routes, RIP)

- L2/3 QoS
- Virtual Blade Switch Technology provides a high bandwidth interconnect between up to 8 CBS 3130 switches enabling them to be configured and managed as 1 logical switch. This radically simplifies management, allows server-server traffic to stay within the VBS domain vs. congesting the core network, and can help significantly consolidate external cabling.
- Optional software license key upgrades to IP Services (Advanced L3 protocol support) and Advanced IP Services (IPv6)
- **Dell Ethernet Pass-Through Module:** This supports 16 x 10/100/1000Mb copper RJ45 connections. This is the only Ethernet Pass-through module in the market that supports the full range of 10/100/1000Mb operation.

Note: PowerEdge M1000e also supports additional I/O modules - Brocade M5424 SAN I/O Module , Brocade M4424 SAN I/O Module, 4Gb Fibre Channel Pass-through Module and Infiniband.

For more information on the fabrics, I/O modules, mezzanine cards, mapping between mezzanine cards and I/O modules refer to *Hardware Owner's Manual* of your blade server model under section *About Your System* at <http://support.dell.com>.

2.3 Mapping between Blade Server and I/O Modules in Chassis

This section describes how the onboard network adapter and add-in mezzanine cards map to the I/O modules in the chassis.

Each half height blade has a dual port onboard network adapter and two optional dual port mezzanine I/O cards. One mezzanine I/O card is for Fabric B and one mezzanine I/O card for Fabric C.

The following figure illustrates how these adapters are connected to the I/O modules in the chassis.

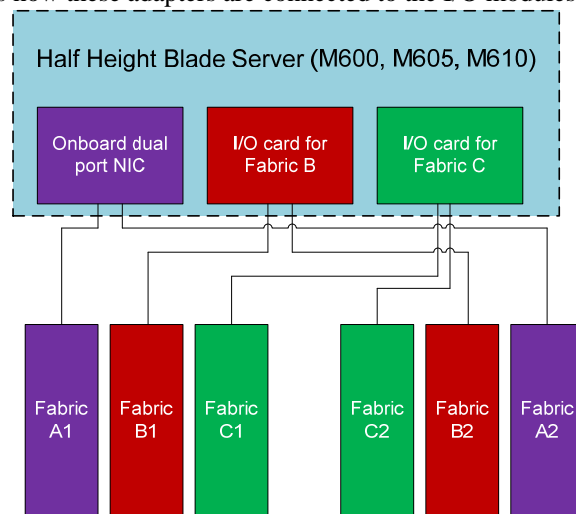


Figure 2: Adapter and I/O Modules connection in Chassis for Half Height Blades

Each full height blade has two dual port onboard network adapter and four optional dual port I/O mezzanine cards. Two I/O mezzanine cards are for Fabric B and two I/O mezzanine cards are for Fabric C. The following figure illustrates how the network adapters on a full height blade are connected to the I/O modules.

The following figure illustrates how the network adapters on a full height blade are connected to the I/O modules.

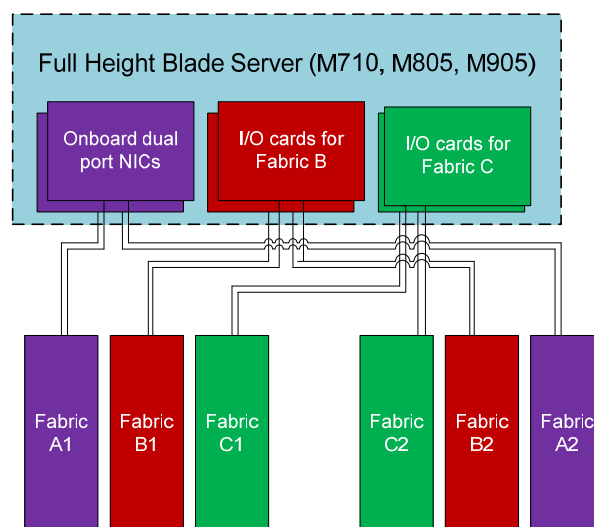


Figure 3: Adapter and I/O Modules connection in Chassis for Full Height Blades

For more information on port mapping, see the *Hardware Owner's Manual* for your blade server model at <http://support.dell.com>.

2.4 Mapping between ESX Physical Adapter Enumeration and I/O Modules

The following table shows how the ESX/ESXi 4.0 servers enumerate the physical adapters and the I/O modules they connect to. This enumeration only applies to blade servers that have all their I/O mezzanine cards populated with dual port network adapters. For servers that are not fully populated, the order should not change.

Table 1: ESX/ESXi Physical Adapter Enumeration

ESX and ESXi Network Adapter enumeration	Full Height Blade Connection (M710, M805, M905)	Half Height Blade Connection (M600, M605, M610)
vmnic0	I/O Module A1 (port n)	I/O Module A1(port n)
vmnic1	I/O Module A2 (port n)	I/O Module A2(port n)
vmnic2	I/O Module A1 (port $n+8$)	I/O Module B1(port n)
vmnic3	I/O Module A2 (port $n+8$)	I/O Module B2(port n)
vmnic4	I/O Module C1 (port n)	I/O Module C1(port n)
vmnic5	I/O Module C2 (port n)	I/O Module C2(port n)
vmnic6	I/O Module B1 (port n)	N/A
vmnic7	I/O Module B2 (port n)	N/A
vmnic8	I/O Module C1 (port $n+8$)	N/A
vmnic9	I/O Module C2 (port $n+8$)	N/A
vmnic10	I/O Module B1 (port $n+8$)	N/A
vmnic11	I/O Module B2 (port $n+8$)	N/A

In the above table, *port n* refers to the port in the I/O modules to which the physical adapter connects, where n represents the slot in which the blade is installed. For example, *vmnic0* of a PowerEdge M710 blade in slot 3 is connected to I/O module A1 at port 3. *vmnic3* for the same server connects to I/O module A2 at port 11.

3 Network Architecture

Network traffic can be divided into two primary types - Local Area Network (LAN) and iSCSI Storage Area Network (SAN). LAN consists of traffic from virtual machines, ESX/ESXi management (service console for ESX), and VMotion. iSCSI SAN consists of iSCSI storage network traffic. You can replace the iSCSI network with the Fibre Channel SAN by replacing the network adapters with the Fibre Channel and network switches with Fibre Channel switches. This section discusses the best practices for the iSCSI SAN only.

3.1 Design Principles

The following design principles are used to develop the network architecture:

- **Redundancy:** Both LAN and iSCSI SAN have redundant I/O modules. Redundancy of the network adapters is achieved through NIC teaming at the virtual switch.
- **Simplified management through stacking:** You can combine switches servicing the same traffic type into logical fabrics using the high-speed stacking ports on the switches.
- **iSCSI SAN physical isolation:** You should physically separate the iSCSI SAN network from the LAN network. Typically iSCSI traffic is network intensive and may consume disproportionate share of the switch resources if sharing a switch with LAN traffic.
- **Logical isolation of VMotion using VLAN:** VMotion traffic is unencrypted. It is important to logically isolate the VMotion traffic using VLANs.
- **Optimal performance:** Load balancing is used to achieve the highest throughput possible

3.2 Recommended Configurations

Based on the bandwidth requirements of LAN and iSCSI SAN, there are different ways to configure the I/O modules. The different configurations are listed in the table below. They meet the design principles listed above.

Table 2: Bandwidth Configurations for LAN and iSCSI SAN

	Minimum Configuration	High LAN Bandwidth	Balanced	High iSCSI Bandwidth	Isolated Fabric
I/O Module A1	LAN	LAN	LAN	LAN	LAN
I/O Module B1	iSCSI SAN	iSCSI SAN	iSCSI SAN	iSCSI SAN	iSCSI SAN
I/O Module C1	Blank	LAN	LAN	iSCSI SAN	Isolated Fabric
I/O Module C2	Blank	LAN	iSCSI SAN	iSCSI SAN	Isolated Fabric
I/O Module B2	iSCSI SAN	iSCSI SAN	iSCSI SAN	iSCSI SAN	iSCSI SAN
I/O Module A2	LAN	LAN	LAN	LAN	LAN

- **Minimum Configuration:** This is the simplest configuration and has the minimum number of I/O modules. Two I/O modules are dedicated for LAN and two for iSCSI SAN. Two modules are left blank and you can populate them at any time to meet any growing bandwidth demands.
- **High LAN Bandwidth:** In this configuration four I/O modules are dedicated to the LAN and two I/O modules dedicated to the iSCSI SAN. This configuration is useful for environments which have high LAN bandwidth requirements. Requirements of most environments can be met with this configuration. The rest of this whitepaper uses this configuration to further illustrate best practices. You can easily apply the best practices to other configurations.
- **Balanced:** In this configuration three I/O modules are dedicated to both LAN and iSCSI SAN. Both fabrics have an equal amount of bandwidth allocated. This configuration is useful for environments which have high back end SAN requirements such as database environments.

- **High iSCSI SAN Bandwidth:** In this configuration two I/O modules are dedicated to the LAN and four I/O modules are dedicated to the iSCSI SAN. This configuration is useful for environments which have high back end SAN requirements such as database environments and low LAN bandwidth requirements.
- **Isolated Fabric:** Certain environments require physically isolated network of certain class of virtual machines (such as credit card transactions). To accommodate those virtual machines, we can dedicate two redundant I/O modules. The two additional switches are stacked together to form a third fault-tolerant logical fabric.

The following sections describe the best practices to configure the LAN and iSCSI SAN network. The *high LAN bandwidth* configuration is used as an example for illustrations.

3.3 Local Area Network (LAN)

The LAN traffic includes the traffic generated from Virtual Machines, ESX Management, and VMotion. This section provides the best practices for LAN configuration, traffic isolation using VLANs, load balancing, and external connectivity using uplinks. See figures 4 and 5 below. Based on [Table 2](#), the four I/O modules are dedicated to the LAN.

All the I/O Modules are stacked together to create a single Virtual Blade Switch to further simplify the deployment, management, and increase the load balancing capabilities of the solution. The virtual switch, vSwitch0, is connected to the Virtual Blade Switch using the physical adapters.



Figure 4: Virtual Switch connections for LAN on Half Height Blade Servers

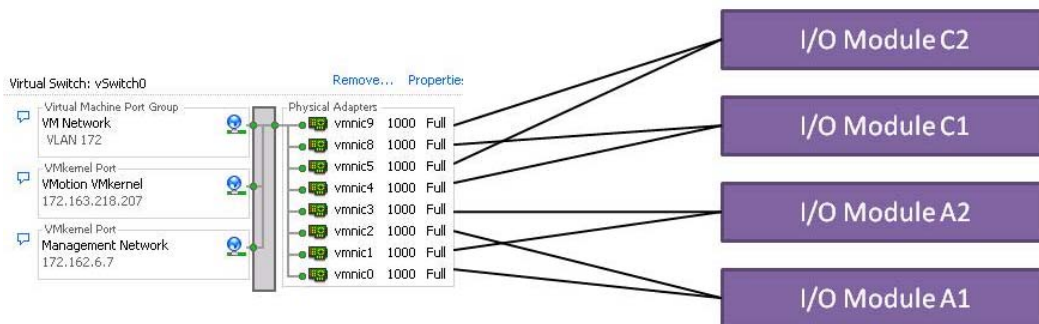


Figure 5: Virtual Switch connections for LAN on Full Height Blade Servers

3.3.1 Traffic Isolation using VLANs

Using VLANs, we achieve traffic isolation between various traffic types, including the VMotion traffic. The four network adapters provide sufficient bandwidth for all the traffic types.

The traffic on the LAN network is separated into three VLANs, one VLAN each for management, VMotion, and virtual machine traffic. Network traffic is tagged with respective VLAN ID for each traffic type in the virtual switch. This is achieved through the Virtual Switch Tagging (VST) mode. In this mode, a VLAN is assigned to each of the three port groups. The virtual switch port group tags all outbound frames and removes tags for all inbound frames.

For example (on ESX 4.0):

- Service Console (VLAN 162)
- vMotion (VLAN 163)
- General Virtual Machine Traffic (VLAN 172)
- Special Virtual Machine Traffic #1 (VLAN 173)
- Special Virtual Machine Traffic #2 (VLAN 174)

Trunking must be used so that all the VLANs can share the same physical connection, and the configuration of the physical switch must match the configuration of the virtual switch. To achieve this, all the internal ports in the Cisco I/O modules should be configured to be in the trunk mode.

3.3.2 Load Balancing & Failover

The virtual switch provides fault-tolerance and load balancing by allowing multiple physical Network Identification Cards (NICs) to be connected to a single switch. The stacking link between the I/O Modules (used for LAN) creates a single virtual switch which provides failover and load-balancing between the physical NICs connected to different I/O Modules.

VMware virtual switch provides three options to configure load balancing:

- **Route based on the originating virtual switch port ID (default configuration):** Here a physical adapter is selected for transmit based on the hash of the virtual port. This means that a given virtual network adapter will use only one physical adapter at any given time to transmit network packets. Packets are received on the same physical adapter.
- **Route based on source MAC hash:** Here a physical adapter is selected for transmit based on the hash on the source MAC address. This means that a given virtual network adapter will use only one physical adapter at any given time to transmit network packets. Packets are received on the same physical adapter.
- **Route based on IP hash:** Here the physical adapter is selected for transmit based on the hash on the source and destination IP address. Because you may select different adapters based on the destination IP, you need to configure both the virtual switches and the physical switches to support this method. The physical switch combines the connections to multiple NICs into a single logical connection using EtherChannel, and the load balancing algorithm selected for the switch will then determine which physical adapter receives the packets.

Note: The virtual switch and the physical switch hashing algorithms work independent of each other.

If connectivity to a physical network adapter is lost, then any virtual network adaptor that is currently using that physical channel will fail-over to a different physical adapter, and the physical switch will learn that the MAC address has moved to a different channel.

3.3.3 External Connectivity

There are multiple options for connecting the blade chassis to an existing LAN.

- You can use the pass-through module to connect each blade server directly into an existing network. This is the simplest solution to connect to an existing infrastructure, but it requires many cables.
- When using switch modules, each Ethernet switch has four built-in 1 Gb uplink ports, and there are various options for adding additional 1Gb and 10Gb Ethernet ports. The configuration of these uplink ports may need to be changed to match the existing infrastructure. When using multiple Ethernet ports, you should

join them together into a single EtherChannel, and distribute them evenly across all the physical switches in a stack of switches to provide redundancy.

- You can also connect multiple blade chassis together. If the total number of front-end switches is less than 8 for Cisco, or 12 for Dell PowerConnect, then you can stack all the switches together into a single Virtual Blade Switch.
- Multiple Virtual Blade Switches could be daisy-chained together by creating two EtherChannels.

3.4 iSCSI Storage Area Network (SAN)

The iSCSI SAN traffic includes the traffic generated between the ESX Servers and Storage Arrays. This section provides the best practices to configure iSCSI SAN including storage connectivity, load balancing, and external connectivity using uplinks.

The following figure illustrates the virtual switch configuration with port groups and how the virtual switch is connected to the physical network adapters and in turn to the I/O modules.

Figure 5 is based on ESX. If ESXi is used, you need not configure the service console port group for iSCSI.



Figure 6: Virtual Switch for SAN on Half Height Blade Servers

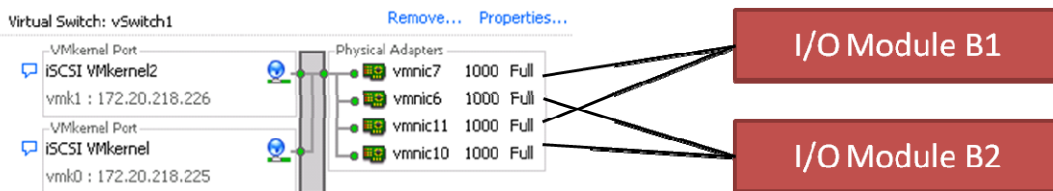


Figure 7: Virtual Switch for SAN on Full Height Blade Servers

3.4.1 Load Balancing

Multipathing is a technique that allows more than one physical path to be used to transfer data between a host and an external storage device. In version 4.0 of ESXi, VMware provides the VMware Native Multipathing Plugin. This plugin supports three Path Selection Plugins; Most Recently Used (MRU), Fixed, and Round Robin (RR). For a detailed discussion of iSCSI connections, see the VMware ESX/ESXi 4.0 “iSCSI SAN Configuration Guide”. In order to have multiple paths, you must create multiple VMkernel Ports for iSCSI. Figure 8 below shows two iSCSI VMkernel ports and multiple paths to storage. Each VMkernel port is associated with a dedicated physical NIC.

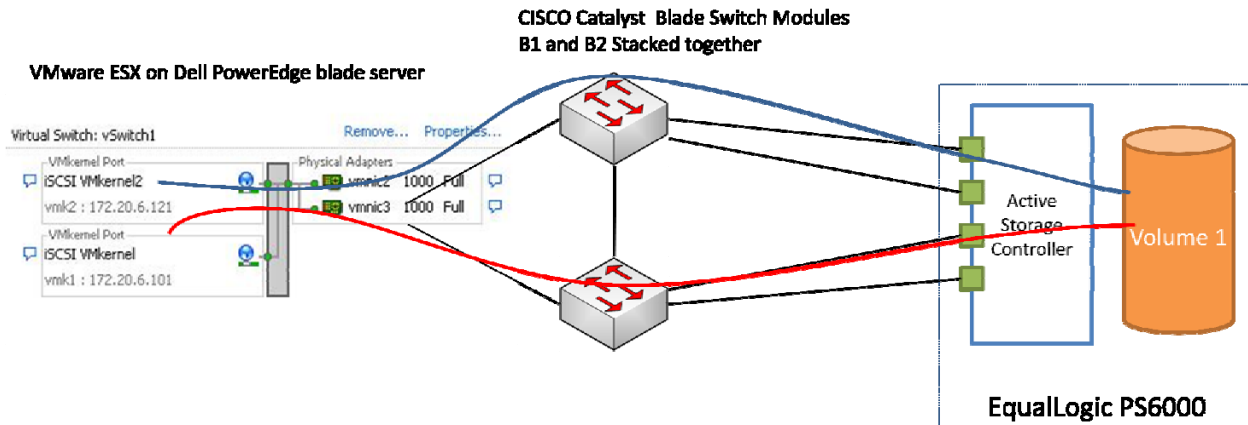


Figure 8: Multipathing using Round Robin

3.4.2 Storage Array Networking Recommendations

These recommendations are specific to the Dell EqualLogic storage arrays; however most of these recommendations will apply to all iSCSI storage arrays. Check the documentation for your specific array. No special network switch configurations are necessary for the Dell EqualLogic SAN to automatically distribute iSCSI connections between the available network interfaces in each controller, or to automatically distribute volumes between different storage devices in the storage pool.

EqualLogic has specific recommendations for connecting PS Series arrays to a network. We have highlighted some of the important recommendations. For more information, see the *Dell EqualLogic PS Quick Start Guide* at <https://www.equallogic.com/support/> (Account registration may be required).

- Do not use Spanning-Tree (STP) on switch ports that connect end nodes (iSCSI initiators or array network interfaces). However, if you want to use STP or Rapid STP (preferable to STP), you should enable the port settings available on some switches that let the port immediately transition into the STP forwarding state upon link up (PortFast). This functionality can reduce network interruptions that occur when devices restart and should only be enabled on switch ports that connect end nodes.

Note: The use of Spanning-Tree for a single-cable connection between switches is encouraged, as is the use of trunking for multi-cable connections between switches.

- Enable Flow Control on each switch port and NIC that handles iSCSI traffic. PS Series arrays will correctly respond to Flow Control.
- Disable unicast storm control on each switch that handles iSCSI traffic if the switch provides this feature. However, the use of broadcast and multicast storm control is encouraged on switches.
- Enable Jumbo Frames on all the physical network switches.
- Create Jumbo Frames enabled virtual switches and VMkernel interfaces.

3.4.3 Storage Array Connection Recommendations

This section will cover some general recommendations on connecting a storage array to the Dell blade chassis. The examples below use a Dell EqualLogic PS 6000XV as a reference array but the recommendations can be applied to most available iSCSI arrays.

- If directly connecting the Ethernet I/O modules to the storage array, make sure the I/O modules have enough available physical ports to accommodate all the active-active or active-passive connections from the array. For example, using two CISCO 3130G I/O Modules (8 external ports each, 16 total) you can

connect to a maximum of two EqualLogic PS 6000 (8 ports each, 16 total). You can increase the number of directly connected arrays by stacking additional I/O modules.

- For direct connections, in order to expand the configuration to include multiple chassis you should use stacking connectors to link I/O modules between the chassis. Dell PowerConnect I/O modules allow a maximum of 12 I/O modules and CISCO I/O modules allow a maximum eight I/O modules in a stacked configuration.
- In order to expand beyond the limits of the stacking connectors, or the number of ports available for direct connection to the storage arrays, external switches are recommended.
 - When using external switches, stack the switches directly connected to the arrays to allow for inter-array communication.
 - If both the internal I/O modules and the external switches are stacked, then only a single Port-Channel connection could be active between the two virtual switches. Instead, to allow for more bandwidth, the internal I/O modules should not be stacked, and each I/O module should have a separate Port-Channel for connection to the external virtual switch. (See figure 9)
- When setting up a scalable configuration it is important to consider the total amount of bandwidth between the chassis and the external switches, and between the external switches and the storage arrays. If higher bandwidth is required between the internal I/O modules and the external switches, consider using 10 Gb uplinks between the internal I/O modules, and the external switches. See figure 10. Each switch in the example can have up to two 10 Gb modules for CISCO switches, or four 10Gb modules for Dell PowerConnect

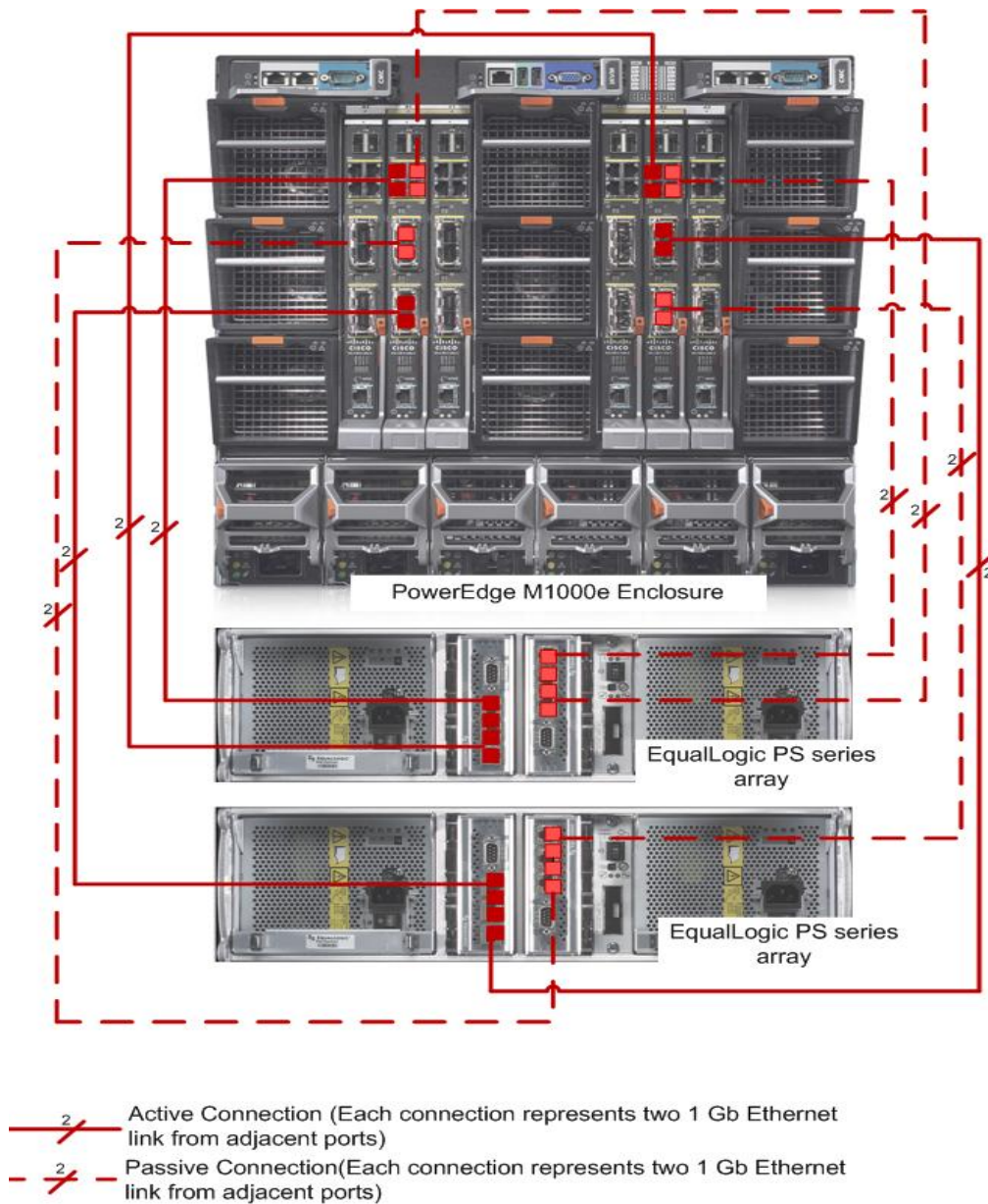


Figure 9: Directly connecting Storage Array to the I/O Modules

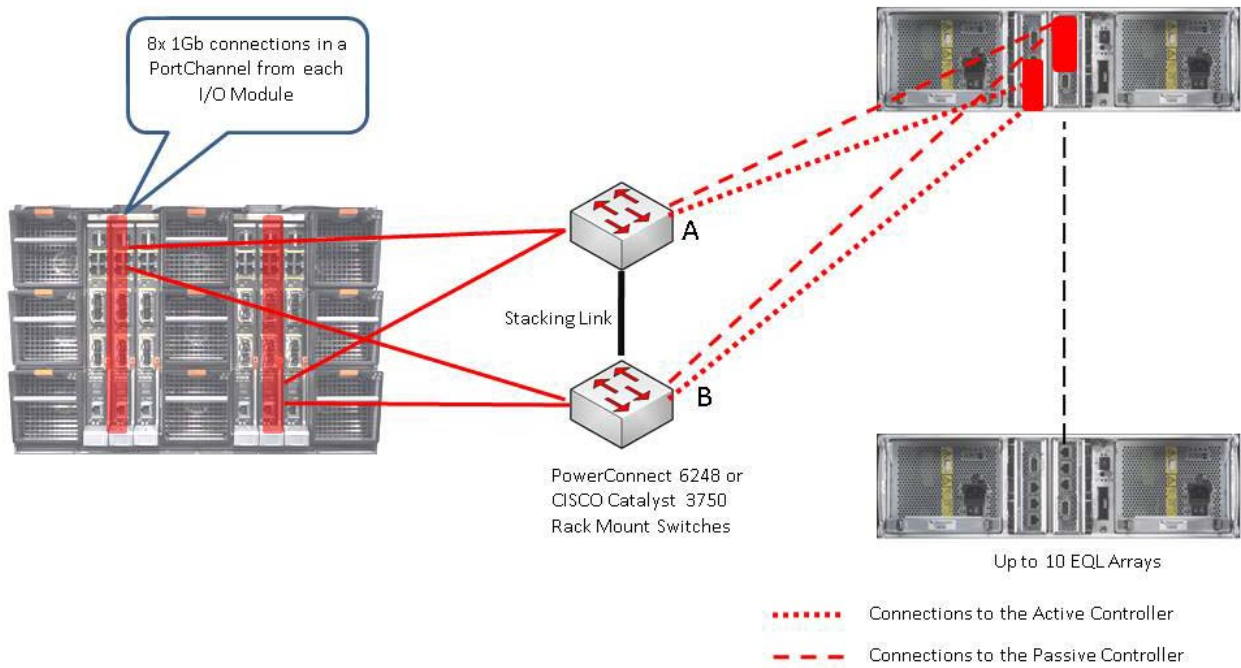


Figure 10: Scalable storage configuration using 48 port external switches

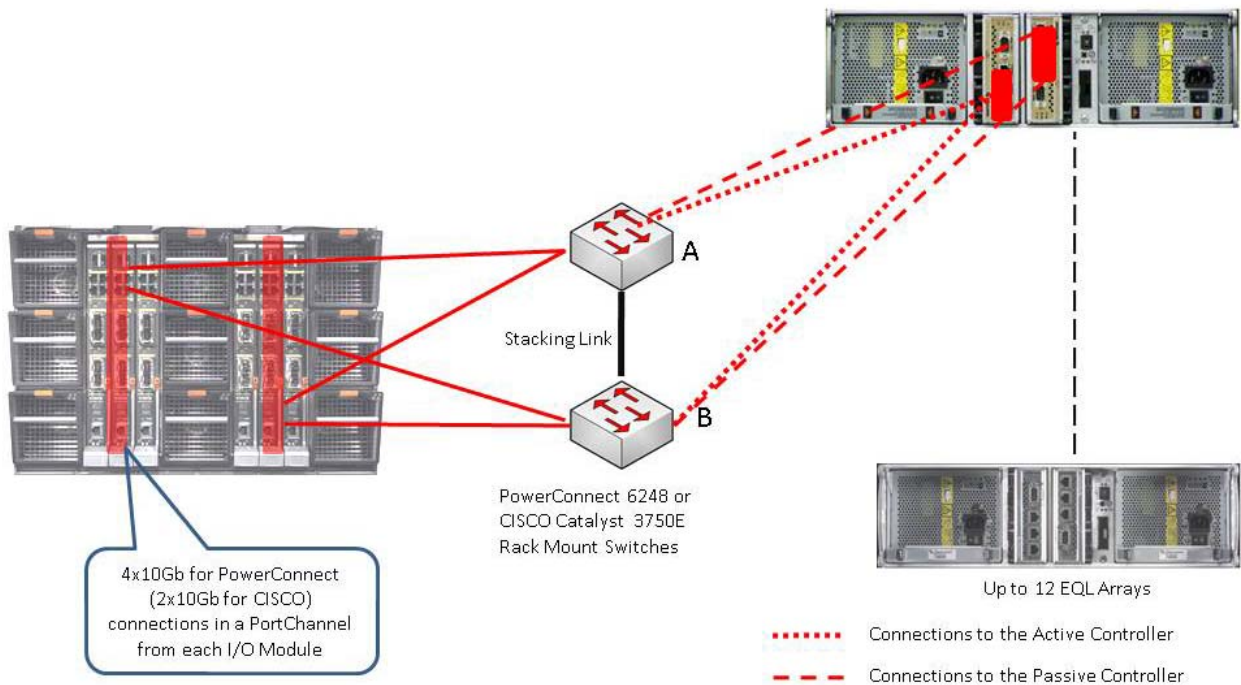


Figure 11: Scalable storage configuration using 48 port external switches and 10 Gigabit Links

4 References

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http://virtualgeek.typepad.com/virtual_geek/2009/01/a-multivendor-post-to-help-our-mutual-iscsi-customers-using-vmware.html

Integrating Blade Solutions with EqualLogic SANs

http://www.dell.com/downloads/global/partnerdirect/apj/Integrating_Blades_to_EqualLogic_SAN.pdf

Cisco Products

http://www.cisco.com/en/US/products/ps6746/Products_Sub_Category_Home.html

Cisco 3130 Product Page

<http://www.cisco.com/en/US/products/ps8764/index.html>

VMware Infrastructure 3 in a Cisco Network Environment

http://www.cisco.com/en/US/docs/solutions/Enterprise/Data_Center/vmware/VMware.html

Cisco Catalyst 3750 and 2970 Switches: Using Switches with a PS Series Group

<http://www.equallogic.com/resourcecenter/assetview.aspx?id=5269>