Interconnecting Geographically Dispersed Data Centers Using VPLS

Design and System Assurance Guide

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Preface

Overview

This document provides design guidance, configuration examples and Cisco recommended best practices for interconnecting geographically dispersed data centers and implementing Layer 2 connectivity across Layer 3 network infrastructure using VPLS.

Audience

This document is intended for customers and system engineers who are designing solutions or looking for design guidance with interconnecting data centers ensuring high availability Layer 2 connectivity and STP isolation. In addition, these solutions apply to large-scale Layer 2 extension.

Organization

This manual is organized as follows:

Chapter 1, “Executive Summary”	Provides an overview of design considerations and the Cisco Validated Design (CVD) program
Chapter 2, “Data Center Interconnect: Legacy Deployment Models and Problems Associated with Extended L2 Networks”	Provides an overview of legacy models for interconnecting data centers and of the problems that are associated with extending L2 networks
Chapter 3, “VPLS Overview and Solutions Portfolio”	Provides an overview of VPLS and of VPLS-based solutions that have been validated under the CVD program
Chapter 4, “Data Center Multitier Model and Testbed Topology”	Describes the Cisco-recommended data center multitier model and the testbed that was used to validate VPLS-based data center interconnect solutions
Chapter 5, “DCI Solution using Cisco 7600 Routers for MST-Based Data Centers (Option 1a)”	Describes the MST in pseudowire solution for data center interconnect

Chapter 6, "Scalable H-VPLS DCI Solution using Cisco 7600 Routers (Option 5c)"	Describes the scalable H-VPLS with MEC and VLAN load balancing solution for data center interconnect
Chapter 7, "VPLSoGRE DCI Solution using Cisco Catalyst 6500 (VPLSoGRE Option 4a)"	Describes the VPLSoGRE using Cisco Catalyst 6500 solution for data center interconnect

Obtaining Documentation, Obtaining Support, and Security Guidelines

For information about obtaining documentation, submitting a service request, and gathering additional information, see the monthly *What's New in Cisco Product Documentation*, which also lists all new and revised Cisco technical documentation, at:

http://www.cisco.com/en/US/docs/general/whatsnew/whatsnew.html

Subscribe to the *What's New in Cisco Product Documentation* as a Really Simple Syndication (RSS) feed and set content to be delivered directly to your desktop using a reader application. The RSS feeds are a free service and Cisco currently supports RSS version 2.0.

CHAPTER 1

Executive Summary

Various data center requirements have resulted in an expansion of Layer 2 domains, thus increasing Spanning Tree domain at the network level. Considering the fact that the Spanning Tree Protocol was developed to handle a small network diameter, the enterprise network needs to meet the required Layer 2 connectivity challenges to ensure high availability between geographically dispersed data centers. Exponential growth in data center resources and security requirements are driving the requirement to connect multiple data centers over larger distances. As a result, customers are facing additional challenges such as maintaining the high availability of applications and dealing with complex multi-site interconnections.

This document covers three VPLS-based solutions that provide a high-speed, low-latency network and Spanning Tree Protocol isolation between data centers. This document encompasses issues related with large Layer 2 bridging domains and provides guidance for extending VLANs over Layer 3 network using VPLS technology.

Extensive manual testing was conducted in a large scale customer representative network. VPLS-based solutions were validated with a wide range of system test types, including system integration, fault and error handling, and redundancy to ensure successful customer deployments. An important part of the testing was end-to-end verification of unicast and multicast, unidirectional traffic. Voice using components of Cisco Unified Communication solution was also implemented and verified.

This document provides information about a subset of options that are covered in the Cisco Press book titled *Interconnecting Data Centers Using VPLS* (ISBN 9781587059926), which is available from major booksellers or on line from Safari Books Online at http://my.safaribooksonline.com/9781587059988.

Cisco Validated Design Program

The Cisco Validated Design (CVD) Program consists of systems and solutions that are designed, tested, and documented to facilitate faster, more reliable and more predictable customer deployments. These designs incorporate a wide range of technologies and products into a broad portfolio of solutions that meet the needs of our customers. There are two levels of designs in the program: Cisco Validated Design and CVD System Assurance.

Cisco Validated Design

Cisco Validated Designs are systems or solutions that have been validated through architectural review and proof-of concept testing in a Cisco lab. Cisco Validated Design provides guidance for deploying new technologies or in applying enhancements to existing infrastructure.

CVD System Assurance

Cisco Validated Design System Assurance is a program that identifies systems that have undergone architectural and customer relevant testing. Designs at this level have met the requirements of a CVD design as well as being certified to a baseline level of quality that is maintained through ongoing testing and automated regression for a common design and configuration. Certified designs are architectural best practices that have been reviewed and updated with appropriate customer feedback and can be used in pre and post-sales opportunities. Certified designs are supported with forward looking CVD roadmaps and system test programs that provide a mechanism to promote new technology and design adoption. CVD Certified Designs advance Cisco System's competitive edge and maximize our customers' return on investment while ensuring operational impact is minimized.

A CVD certified design is a highly validated and customized solution that meets the following criteria:

- Reviewed and updated for general deployment
- Achieves the highest levels of consistency and coverage within the Cisco Validated Design program
- Solution requirements successfully tested and documented with evidence to function as detailed within a specific design in a scaled, customer representative environment
- Zero observable operation impacting defects within the given test parameters, that is, no defects that have not been resolved either outright or through software change, redesign, or workaround (refer to test plan for specific details)
- A detailed record of the testing conducted is generally available to customers and field teams, which provides:
  - Design baseline that provides a foundational list of test coverage to accelerate a customer deployment
  - Software baseline recommendations that are supported by successful testing completion and product roadmap alignment
  - Detailed record of the associated test activity that includes configurations, traffic profiles, and expected results as compared to actual testing results

For more information about the Cisco CVD program, refer to:

http://cisco.com/en/US/netsol/ns741/networking_solutions_program_home.html

CHAPTER 2

Data Center Interconnect: Legacy Deployment Models and Problems Associated with Extended L2 Networks

This chapter provides an overview of legacy models for interconnecting data centers and of the problems that are associated with extending L2 networks. It includes these topics:

Legacy Deployment Models for Data Center Interconnect

Several transport technologies are available for interconnecting the data centers, each of which provide various features and allow different distances, depending on factors such as the power budget of the optics, the lambda used for transmission, the type of fiber, and so forth.

Consider the features of the LAN and SAN switches that provide higher availability for the data center interconnect before considering some of the available technologies. The convergence time required for the application also is important and should be evaluated.

The following list describes common transport options:

- Dark Fiber—Dark fiber is a viable method for extending VLANs over data center or campus distances. The maximum attainable distance is a function of the optical characteristics (transmit power and receive sensitivity) of the LED or laser that resides in a Small Form-Factor Pluggable (SFP) or Gigabit Interface Converter (GBIC) transponder, combined with the number of fiber joins, and the attenuation of the fiber.
- Coarse Wavelength Division Multiplexing (CWDM)—CWDM offers a simple solution to carry up to eight channels (1 Gbps or 2 Gbps) on the same fiber. These channels can carry Ethernet or fiber channel. CWDM does not offer protected lambdas, but client protection allows rerouting of the traffic on the functioning links when a failure occurs. CWDM lambdas can be added and dropped, allowing the creation of hub-and-spoke, ring, and meshed topologies. The maximum achievable distance is approximately 100 km with a point-to-point physical topology and approximately 40 km with a physical ring topology.
- Dense Wavelength Division Multiplexing (DWDM)—DWDM enables up to 32 channels (lambdas). Each of these channels can operate at up to 10 Gbps. DWDM networks can be designed either as multiplexing networks that are similar to CWDM or with a variety of protection schemes to guard

against failures in the fiber plant. DWDM also offers more protection mechanisms (splitter protection and Y-cable protection), and the possibility to amplify the channels to reach greater distances.

Note For details about data center transport technologies, refer to the "Data Center Transport Technologies" chapter in *Data Center High Availability Clusters Design Guid*e, which is available at: http://www.cisco.com/en/US/docs/solutions/Enterprise/Data_Center/HA_Clusters/HA_Clusters.html

In nearly all of these deployment models, costs associated with deploying and maintaining a dedicated optical network is one of the biggest concerns. Also, there is no Spanning Tree Protocol isolation. Depending on the nature of the problem, issues in one data center will affect other data centers. Another disadvantage is the lack of load balancing across redundant paths due to blocked links in the core network.

Problems Associated with Extended Layer 2 Networks

It is common practice to add redundancy to interconnect between two data centers to avoid split-subnet scenarios and interruption of the communication between servers. The split-subnet is not necessarily a problem if the routing metric makes one site preferred over the other. Also, if the servers at each site are part of a cluster and the communication is lost, mechanisms such as the quorum disk avoid a split-brain condition.

Adding redundancy to an extended Ethernet network typically means relying on spanning tree to keep the topology free from loops. STP domains should be reduced as much as possible and limited within the data center. Cisco does not recommend deploying the legacy 802.1d because of its old timer-based mechanisms that make the recovery time too slow for most applications including typical clustering software. The solutions that this document describes provide layer 2 extension in a redundant fashion with STP isolation between data centers.

Problems that are associated with an extended Layer 2 network include:

- Spanning Tree Protocol (STP) operates at Layer 2. Its primary function is to prevent loops that redundant links create in bridge networks.

  Aggressive values of STP timers can lead to an unstable topology. In these cases, loss of BPDUs can cause a loop to appear.

  For understanding and tuning STP timers and the rules to tune them when absolutely necessary, refer to the following URL:

  http://www.cisco.com/en/US/tech/tk389/tk621/technologies_tech_note09186a0080094954.shtml

- Network stability can be compromised as a result of slow response to network failures. Even new STP developments, such as RSTP, are not built to accommodate frequent link flapping conditions, high error rates, unidirectional failures or non report of loss-of-signal. These typical and frequent behaviors of long and medium distance links could lead to STP slow convergence or even instability.
- The number one reason for multi-site data centers is disaster recovery. However, as data centers typically require Layer 2 connectivity, failure in one data center can affect other data centers which could potentially lead to a black-out of all data centers at the same time.

- A broadcast storm propagates to every data center which if uncontrolled may result in network wide outage. Broadcast storms may be directly related to STP. A misconfigured Flexlink at the access layer can generate a broadcast storm and disrupt remote data centers. Therefore, even with STP isolation between the data centers, broadcast storm issues can disrupt the entire Layer2 domain. VPLS does not natively address this risk, so storm control mechanisms must be deployed.
- Unable to load balance traffic across redundant paths due to blocked links in the core network.

CHAPTER 3

VPLS Overview and Solutions Portfolio

This chapter provides an overview of VPLS and of VPLS-based solutions that have been validated under the CVD program. It includes these topics:

This chapter includes these topics:

VPLS Overview

Virtual Private LAN Service (VPLS) is an architecture that provides multipoint Ethernet LAN services, often referred to as Transparent LAN Services (TLS) across geographically dispersed locations using MPLS as transport.

VPLS is often used by service providers to provide Ethernet Multipoint Services (EMS) and is also being adopted by Enterprises on a self-managed MPLS-based metropolitan area network (MAN) to provide high-speed any-to-any forwarding at Layer 2 without the need to rely on spanning tree to keep the physical topology loop free. The MPLS core uses a full mesh of pseudowires and split-horizon to avoid loops.

To provide multipoint Ethernet capability, IETF VPLS drafts describe the concept of linking virtual Ethernet bridges using MPLS pseudowires. At a basic level, VPLS can be defined as a group of Virtual Switch Instances (VSIs) that are interconnected using EoMPLS circuits in a full mesh topology to form a single, logical bridge. In concept, a VSI is similar to the bridging function found in IEEE 802.1q bridges in that a frame is switched based upon the destination MAC and membership in a Layer 2 VPN (a virtual LAN or VLAN). VPLS forwards Ethernet frames at Layer 2, dynamically learns source MAC address to port associations, and frames are forwarded based upon the destination MAC address. If the destination address is unknown, or is a broadcast or multicast address, the frame is flooded to all ports associated with the virtual bridge. Therefore in operation, VPLS offers the same connectivity experienced if a device were attached to an Ethernet switch by linking virtual switch instances (VSIs) using MPLS pseudowires to form an “emulated” Ethernet switch.

Compared to traditional LAN switching technologies, VPLS is also more flexible in its geographic scaling, so that Customer Edge (CE) sites may be within the same metropolitan domain, or may be geographically dispersed on a regional or national basis. The increasing availability of Ethernet-based multipoint service architectures from service providers, for both L2 VPN and L3 VPN services, is resulting in a growing number of enterprises transitioning their WANs to these multipoint services and VPLS is playing an increasingly important role in this transition.

Note When MPLS as used as the tunneling protocol, the largest frame increases by 8 or more bytes. Other tunneling protocols may have larger headers and may require larger MTU values.

Fragmentation within MPLS network is not allowed. Therefore, it is extremely important to configure MTU appropriately so as to not drop traffic in the core or the service provider network.

VPLS-Based Solutions

The best way to ensure loop free global topology is to ensure that each data center connects to the VPLS device through only one active link at a time. Depending on the protocol used to ensure this global loop free topology, the following main models have emerged:

- Multi-Instance Spanning-Tree (MST) protocol.
- Active/Standby Inter-Chassis Communication using EEM semaphore in the absence of Inter-Chassis Communication Protocol (ICCP).

The solutions that are described in the following sections were validated with MPLS enabled in the core network using Cisco 7600 routers as VPLS nodes. Options 2 and 4a also were validated with an IP core network that used VPLSoGRE and that used Cisco Catalyst 6500 devices as VPLS nodes.

N-PE Using MST for Access to VPLS

In N-PE using MST for access to VPLS model, both N-PEs participate in spanning tree protocol local to the data center. Two links, one from each N-PE device connect the data center to the MPLS-enabled core network. One of these links is in forwarding mode and is in blocking mode. Which link is in which mode depends on the placement of the MST root bridge.

The MST-based solutions are:

- MST Option 1a—MST in pseudowire. This IOS-integrated feature can be a viable option if all Layer 2 switches within the data center run MST. Cisco 7600 series platforms with Cisco IOS release 12.2(33)SRC or later offer this feature.

  In this solution, an EoMPLS pseudowire relays MST BPDUs between the primary and backup N-PEs. Because both N-PEs participate in local STP, one of the N-PE-to-Agg-PE links is in forwarding state and the second link is either in blocking or down state. This solution is also known as MST in N-PE using Layer 2 forward protocol.
- MST Option 1b—Isolated MST in N-PE. Consider this solution even in situations in which all Layer 2 switches within the data center do not run the MST protocol. In this solution, MST provides VPLS access control. The N-PEs may enable RSTP / MST interoperability, and run MST only on an Etherchannel that connects the primary and backup N-PE.

N-PE using ICCP Emulation for Access to VPLS

The N-PE using ICCP emulation for access to VPLS model (also known as *N-PE using semaphore concept for active/standby access to VPLS core*) relies on local synchronization of the active/standby state on the primary and backup N-PEs to ensure backup and recovery.

In this solution, EEM tracks the reachability of the B-semaphore on the primary N-PE and the P-semaphore on the backup N-PE. If the backup N-PE cannot reach the P-semaphore, the backup N-PE enables its PWs by using an EEM script.

The EEM semaphore concept and scripts are identical regardless of the various EEM-based options. However, depending on the data center design, there are several options for performing MAC-address flushing. These options are:

- EEM option 2—VPLS

  An N-PE device participates in local STP. EEM manages VPLS pseudowire redundancy and local STP controls the edge links.

- EEM option 3—H-VPLS

  An N-PE device participates in the local STP and uses QinQ to scale VPLS. A control-plane link on the N-PE participates in local STP. EEM manages the data-plane links and VPLS pseudowire redundancy.

- EEM option 4a—Multi-domains H-VPLS

  An N-PE device does not participate in the local STP and uses H-VPLS. This option requires an EEM script on aggregation switches to adapt to topology changes and flush MAC-addresses. EEM also controls the data-plane links and VPLS pseudowire redundancy.

- EEM option 4b—Multi-domains H-VPLS with dedicated U-PE

  An N-PE does not participating in the local STP and uses H-VPLS. A U-PE switch exists between the N-PE and the data center to perform MAC-flushing. Due to the insertion of a U-PE switch, there is no affect to the distribution device. EEM scripts are required on the intermediate U-PE switch instead of the aggregation switches as in option 4a.

- EEM option 5a—Multi-domains H-VPLS with MEC

  An N-PE connects to the data center via MEC toward the VSS or a Nexus 7000 vPC system. EEM manages VPLS pseudowire redundancy and Link Aggregation Control Protocol (LACP) controls the MEC at the edge.

- EEM option 5b—Multi-domains H-VPLS with MEC and VLAN load-balancing

  N-PE connects to the data center via MEC toward the VSS or a Nexus 7000 vPC system. EEM manages VPLS pseudowire redundancy and load balanced LACP controls the MEC at the edge. Aggregation switches require EEM scripts for MAC-address flushing.

- EEM option 5c—Multi-domains H-VPLS with MEC and VLAN load-balancing

  Pseudowires on primary and backup N-PEs are in UP/UP state. This design enables faster convergence time because the backup pseudowire always is up and ready for use.

Note This document covers only options 1a, 5c, and VPLSoGRE 4a. For detailed information about other options, theory of operations, configuration guidelines, additional design considerations, complementary features such MPLS TE and FRR, and an author's view of the future of data center interconnect, see the Cisco Press book titled *Interconnecting Data Centers Using VPLS* (ISBN 9781587059926), which is available from major booksellers or on line from Safari Books Online at http://my.safaribooksonline.com/9781587059988.

VPLS-Based Solutions Portfolio

Table 3-1 provides an overview of the VPLS-based solutions.

Table 3-1 VPLS-Based Solutions Portfolio

Type	MST		EEM / Semaphore					
Option	**1a**	**1b**	**2**	**3**	**4a**	**4b**	**5a**	**5b and 5c**
Description	MST in pseudowire	Isolated MST	VPLS	H-VPLS	Multi-domains H-VPLS	Multi-domains H-VPLS with dedicated U-PE	Multi-domains H-VPLS with MEC	Multi-domains H-VPLS with MEC and VLAN load balancing
Domain	Enterprise	Enterprise	Enterprise	Enterprise	Multi-tenants (ASP/ enterprise)	Multi-tenants (ASP/ enterprise)	Multi-tenants (ASP/ enterprise)	Multi-tenants (ASP/ enterprise)
DC STP type	Only MST (one instance)	RSTP	RSTP/ MST	RSTP/ MST	Any	RSTP/ MST	Any	Any
Solution complexity	Low	Low	Average	Medium	Medium	High	Average	Medium
Ease of implemen-tation	Straight-forward (native)	Average	Average	Medium	Medium	High	Average	Medium
Scalability	Medium (hundreds of VLANs) One dynamic VFI per VLAN	Low (5 to 30 VLANs) One static VFI per VLAN	Low (5 to 30 VLANs) One static VFI per VLAN	Medium (max 1,000 VLANs) One VFI per QinQ	High (any number of VLANs) One semaphore/script per access-block	High (any number of VLANs) One semaphore/ script per access-block	Very high (any number of VLANs) One semaphore/ script per N-PE	High (any number of VLANs) One semaphore/script per access-block
Local VLAN overlapping	No	No	No	No	Yes	Yes (at N-PE level)	Yes	Yes
Intrusive on DC	Medium (N-PE participate to local MST)	High (N-PE is root bridge of DC for cross connected VLANs)	Medium (N-PE participate to local STP	Medium (N-PE participate to local STP)	Low (requires a simple script into distribu-tion)	None	None	Low (requires a simple script into distribution)

Table 3-1 VPLS-Based Solutions Portfolio (continued)

Type	MST		EEM / Semaphore					
Option	**1a**	**1b**	**2**	**3**	**4a**	**4b**	**5a**	**5b and 5c**
IOS native	Yes 12.2(33)SR C1 or later IOS release	Partially (requires small additional scripts)	Requires EEM scripts in N-PE	Requires EEM scripts in N-PE	Requires EEM scripts in N-PE and in distribu-tion switches	Requires EEM scripts in N-PE and in U-PE	Requires EEM scripts in N-PE	Requires EEM scripts in N-PE and in distribu-tion switches
N-PE platform	Cisco 7600	Cisco 7600	Cisco 7600 (Cisco Catalyst 6500 for VPLSoGRE)	Cisco 7600	Cisco 7600 (Cisco Catalyst 6500 for VPLSoGRE)	Cisco 7600	Cisco 7600	Cisco 7600
Requires additional control-plane links	No	No	No	Yes (TCN link to distribution and inter N-PE B-link)	Yes (E-link to trigger distribution script)	Yes (only between U-PE and N-PE, not toward distribution)	No	Yes (E-link to trigger distribution script)

Note VPLSoGRE with IP core—Options 2 and 4a were validated using Cisco Catalyst 6500 devices as VPLS nodes.

CHAPTER 4

Data Center Multitier Model and Testbed Topology

This chapter describes the Cisco-recommended data center multitier model the testbed that was used to validate VPLS-based data center interconnect solutions. It includes these topics:

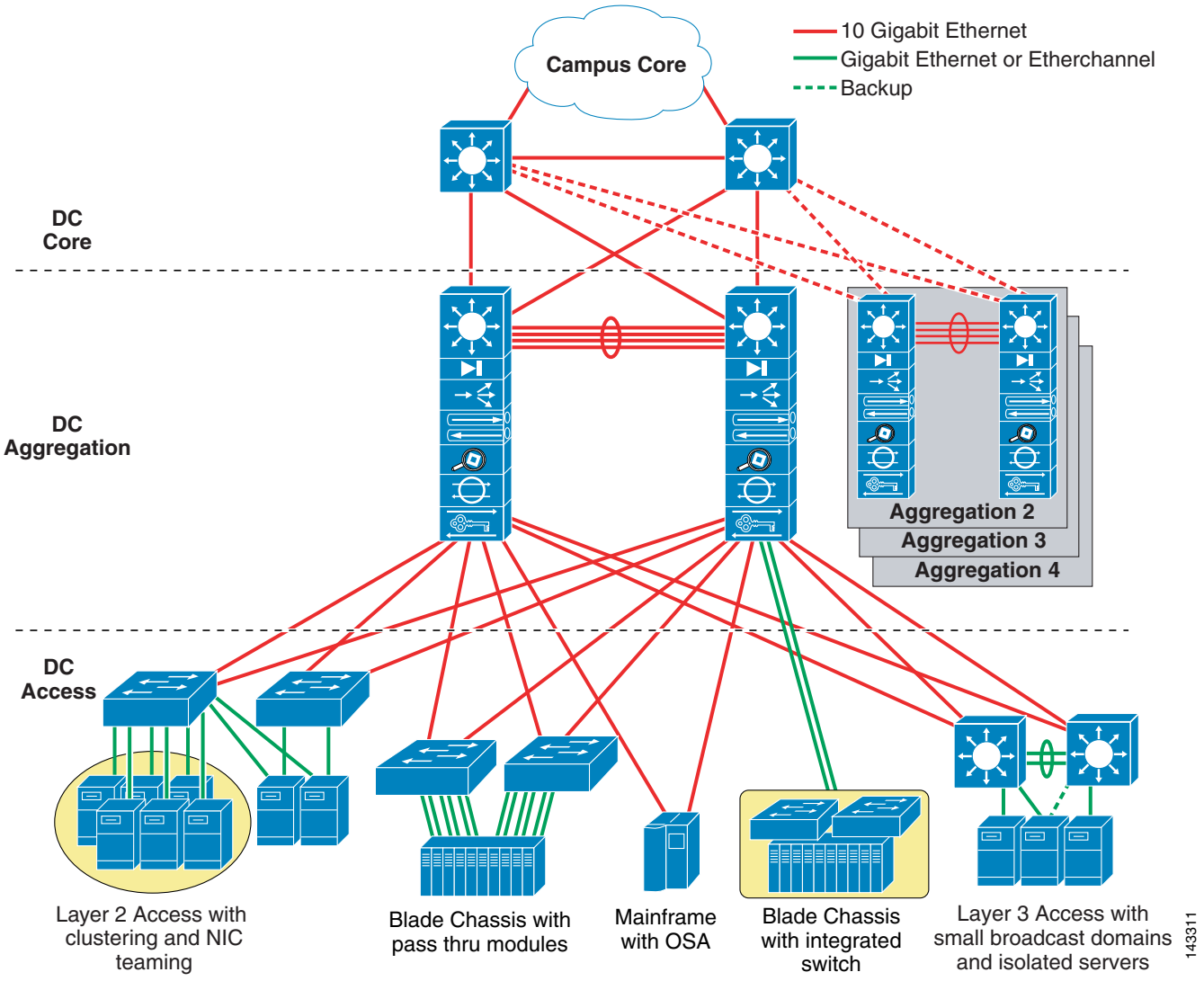
Data Center Multitier Model

A data center is home to the computational power, storage, and applications that support an enterprise business. The data center infrastructure is central to the IT architecture, from which all content is sourced or passes through. It is critical to properly plan the data center infrastructure design, and to carefully consider performance, resiliency, and scalability.

Data center design should also address flexibility to enable quickly deploying and supporting new services. Designing a flexible architecture that efficiently supports new applications can provide a significant competitive advantage. Such a design requires solid initial planning and thoughtful consideration of port density, access layer uplink bandwidth, true server capacity, oversubscription, and various other factor

The data center network design is based on a proven layered approach, which has been tested and improved over several years in some of the largest data center implementations. The layered approach provides the basic foundation of a data center design that improves scalability, performance, flexibility, resiliency, and maintenance. Figure 4-1 shows the basic layered design.

Figure 4-1 Data Center Multi-Tier Model Topology



The data center includes the following layers:

- Core layer—Provides the high-speed packet switching backplane for all flows that pass in to and out of the data center. The core layer provides connectivity to multiple aggregation modules and provides a resilient Layer 3 routed fabric with no single point of failure. The core layer runs an interior routing protocol, such as OSPF or EIGRP, and load balances traffic between the campus core and aggregation layers by using Cisco Express Forwarding based hashing algorithms.
- Aggregation layer—Provides important functions, such as service module integration, Layer 2 domain definitions, spanning tree processing, and default gateway redundancy. Server-to-server multi-tier traffic flows through the aggregation layer and can use services such as firewall and server load balancing to optimize and secure applications. The smaller icons within the aggregation layer switch in Figure 4-1 represent the integrated service modules. These modules provide services, such as content switching, firewall, SSL offload, intrusion detection, network analysis, and more.
- Access layer—This layer is where the servers physically attach to the network. The server components consist of 1 RU servers, blade servers with integral switches, blade servers with pass-through cabling, clustered servers, and mainframes with OSA adapters. The access layer

network infrastructure consists of modular switches, fixed configuration 1 RU or 2 RU switches, and integral blade server switches. Switches provide both Layer 2 and Layer 3 topologies, fulfilling the various servers' broadcast domain or administrative requirements.

Some access switches, known as Unified Fabric, support DCE/FCoE for unified I/O transport to attach to CNA-based servers and to unified computing systems. These emerging technologies are restricted to server access and cannot currently be extended via VPLS. For an overview of unified computing, refer to the following URL:

http://www.cisco.com/en/US/solutions/collateral/ns340/ns517/ns224/ns944/white_paper_c11-522754.html

For detailed information about each of the three layers of the data center design and their functions, refer to *Cisco Data Center Infrastructure 2.5 Design Guide* at the following URL:

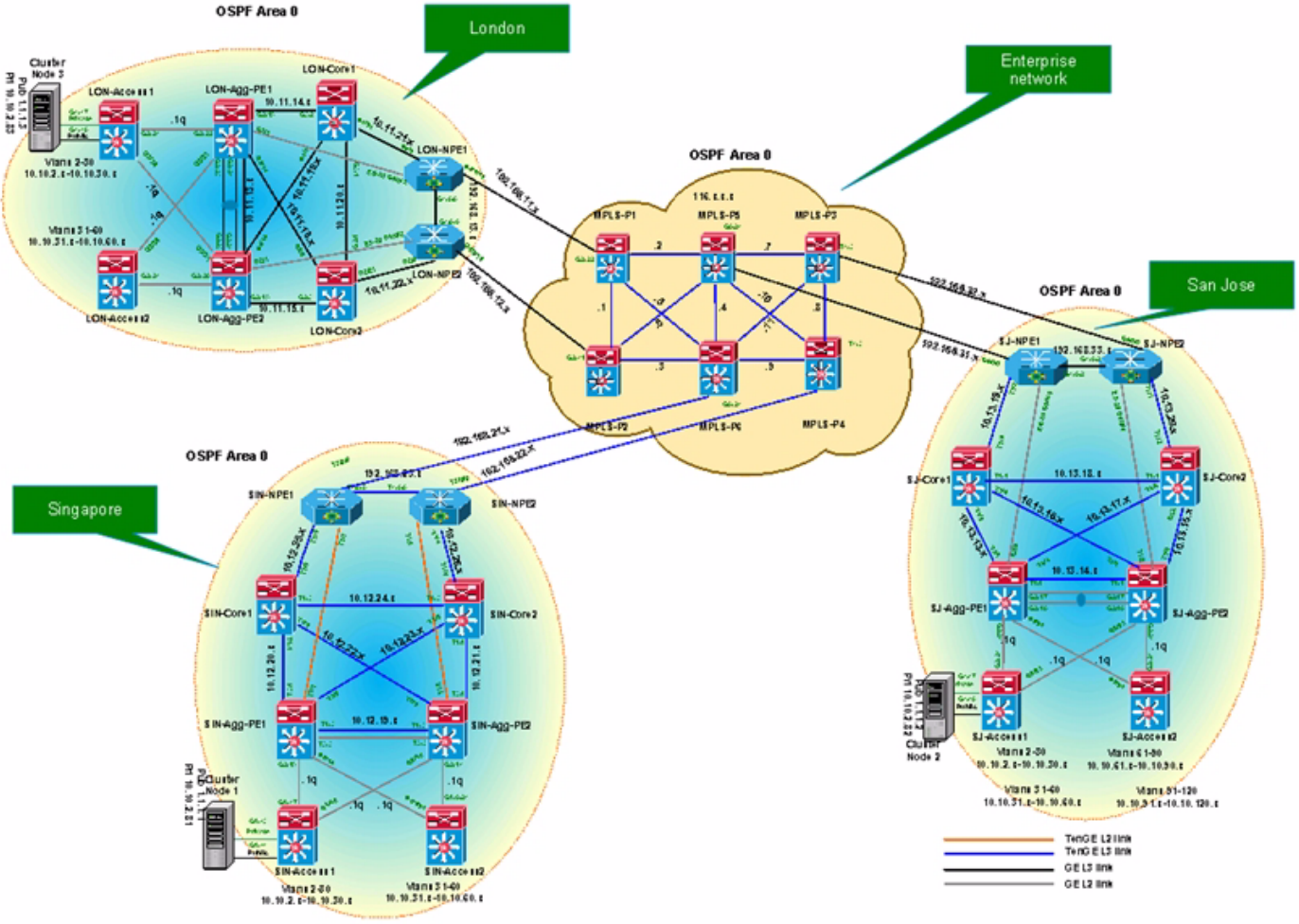
http://www.cisco.com/application/pdf/en/us/guest/netsol/ns107/c649/ccmigration_09186a008073377d.pdf

Testbed Details

Design validation network consists of data centers interconnected via the enterprise core network. Each data center is built based on the data center multi-tier design that is described the "Data Center Multitier Model" section on page 4-1.

Figure 4-2 illustrates interconnected data centers. Dual N-PE routers have been added in addition to core, aggregation, and access layers in each data center.

Figure 4-2 Data Center Interconnect Testbed Topology



Microsoft server cluster is implemented via 3 servers located within each data center. Two VLANs were provisioned for connectivity to public and private networks. These VLANs were then extended across data centers via pseudowire schemes as described in the solution section.

End-to-end service validation was performed by using traffic tools to generate IP unicast, multicast, and simulated voice traffic on the network. Health checks were performed before and after each test. These checks included memory and CPU utilization, tracebacks, memory alignment errors, deviations in number of routes and mroutes, interface errors, line card status and syslog messages.

Note Figure 4-2 refers to London, San Jose, and Singapore data centers. These names were selected to reflect remote locations or represent geographically dispersed locations and are not meant to imply the actual distances between these locations. The data centers were collocated in a lab with back-to-back fiber connections.

Hardware and Software Device Information

Table 4-1 provides information about the hardware and software that was used during testing.

Table 4-1 Hardware and Software Device Information

Hardware Platform	Role	DRAM	Software Version	Line Cards / Interfaces
Cisco 7600 RSP720-3CXL-GE	N-PE	RP—2GB SP—2GB	12.2(33)SRC1	WS-X6724-SFP 7600-ES20-GE3C WS-X6704-10GE
Catalyst 6500 Sup720-3BXL	N-PE[1]	RP—1GB SP—1GB	12.2(33)SXH1	WS-X6724-SFP WS-X6704-10GE
Catalyst 6500 Sup720-3BXL	DC core	RP—1GB SP—1GB	12.2(33)SXH 1	WS-X6724-SFP WS-X6704-10GE
Catalyst 6500 Sup720-3BXL VS-S720-10G	DC aggregation	RP—1GB SP—1GB	12.2(33)SXH 1 12.2(33)SXH2a (for VSS)	WS-X6704-10GE WS-X6724-SFP ACE20-MOD-K9
Catalyst 6500 Sup720-3BXL	DC access	RP—1GB SP - 1GB	12.2(33)SXH1	WS-X6724-SFP
Catalyst 4948	DC access	256 MB	12.2(40)SG	WS-X4548-GB-RJ45
Catalyst 3750G	DC access	256 MB	12.2(37)SE	WS-C3750-24P WS-C3750E-24

1. Cisco Catalyst 6500 platforms were used as N-PEs in VPLSoGRE solutions.

Convergence Tests

The purpose of these tests is to measure convergence times for voice, unicast, and multicast traffic during various link and node failures. In this test suite, convergence is measured from the data source to the receiver (end-to-end network convergence). During convergence, packet loss is determined for each individual flow. For example, packet rate of 1000 pps corresponds to 1 millisecond (ms) convergence time for each packet dropped.

Traffic Flow

Even though three data centers are used in all the designs documented in this guide, only two data centers, namely London and San Jose were used for convergence tests. Unidirectional traffic flows were provisioned across two data centers.

For each traffic type, i.e. unicast, multicast and voice:

- 58 unidirectional flows from London to San Jose
- 60 unidirectional flows from San Jose to London

Convergence tests were performed with all the three traffic types enabled simultaneously. Thus the total number of unidirectional traffic flows from London to San Jose were 174 and from San Jose to London were 180.

Traffic Rate

Voice:

- Codec type—G711A
- Packet size—28 bytes
- Forwarding rate—50 pps; 1 packet every 20msec
- London to San Jose—2900 pps or 2.97 mbps
- San Jose to London—3000 pps or 3.07 mbps

Unicast:

- Packet size—128 bytes
- Forwarding rate—1000 pps
- London to San Jose—58000 pps or 59.39 mbps
- San Jose to London—60000 pps or 61.44 mbps

Multicast:

- 120 multicast groups with one source and one receiver per group
- Packet size—128 bytes
- Forwarding rate—100 pps
- London to San Jose—5800 pps or 5.93 mbps
- San Jose to London—6000 pps or 6.14 mbps

The above traffic profile was used in validating all the solutions documented in this design and assurance guide.

Traffic Profile

Table 4-2 lists the traffic flows from the London to San Jose and from the San Jose to London data centers.

Table 4-2 Traffic Flows

Voice Stream No.	Ixia Source Port	Ixia Dest Port	Source Switch Port	Dest Switch Port	Source VLAN	Source IP	Destination VLAN		Destination IP	Traffic Rate	Frame Size
Intra-VLAN 4-61 London -> San Jose											
1	3/1	3/3	lon-a1 g4/17	sj-a1 g4/17	4	10.10.4.71	4	x	10.10.4.72	50 pps	128 bytes
…	…	…	…	…	…	…	…	x	…	…	…
58	3/1	3/3	lon-a1 g4/17	sj-a1 g4/17	61	10.10.61.71	61	x	10.10.61.72	50 pps	128 bytes
1	3/1	3/3	lon-a1 g4/17	sj-a1 g4/17	4	10.10.4.61	4	239.254.4.4	10.10.4.62	100 pps	128 bytes
…	…	…	…	…	…	…	…	…	…	…	…
58	3/1	3/3	lon-a1 g4/17	sj-a1 g4/17	61	10.10.61.61	61	239.254.4.61	10.10.61.62	100 pps	128 bytes

Table 4-2 Traffic Flows (continued)

Voice Stream No.	Ixia Source Port	Ixia Dest Port	Source Switch Port	Dest Switch Port	Source VLAN	Source IP	Destination VLAN		Destination IP	Traffic Rate	Frame Size
1	3/1	3/3	lon-a1 g4/17	sj-a1 g4/17	4	10.10.4.51	4	x	10.10.4.52	1000pps	128 bytes
…	…	…	…	…	…	…	…	x	…	…	…
58	3/1	3/3	lon-a1 g4/17	sj-a1 g4/17	61	10.10.4.51	61	x	10.10.61.52	1000 pps	128 bytes
Intra-VLAN 201-260 San Jose--> London											
1	3/4	3/2	sj-a2 g2/17	lon-a2 g2/17	201	10.30.1.72	201	x	10.30.1.71	50pps	128 bytes
…	…	…	…	…	…	…	…	x	…	…	…
60	3/4	3/2	sj-a2 g2/17	lon-a2 g2/17	260	10.30.60.72	260	x	10.30.60.71	50pps	128 bytes
1	3/4	3/2	sj-a2 g2/17	lon-a2 g2/17	201	10.30.1.62	201	239.254.4.62	10.30.1.61	100pps	128 bytes
…	…	…	…	…	…	…	…	…	…	…	…
60	3/4	3/2	sj-a2 g2/17	lon-a2 g2/17	260	10.30.60.62	260	239.254.4.121	10.30.60.61	100pps	128 bytes

Cluster Server Tests

The purpose of these tests is to measure cluster server convergence times between data centers for various link and node failures.

CHAPTER 5

DCI Solution using Cisco 7600 Routers for MST-Based Data Centers (Option 1a)

MST in N-PE, also known as MST in pseudowire using Layer 2 forwarding protocol, is available on Cisco 7600 platforms running Cisco IOS Software Release 12.2(33)SRC or later. The key aspect of this feature is the capability to create a pseudowire tunnel to carry only the MST Bridge Protocol Data Units (BPDUs) between the primary and backup N-PE within the data center through the Multiprotocol Label Switching (MPLS) cloud. This special pseudowire is not blocked by STP nor used to forward any data packets. However, this feature requires that the access network be designed so that one of the N-PEs is always the root of MST.

This solution that this chapter describes is MST in pseudowire, MST option 1a. This chapter includes these topics:

Overview

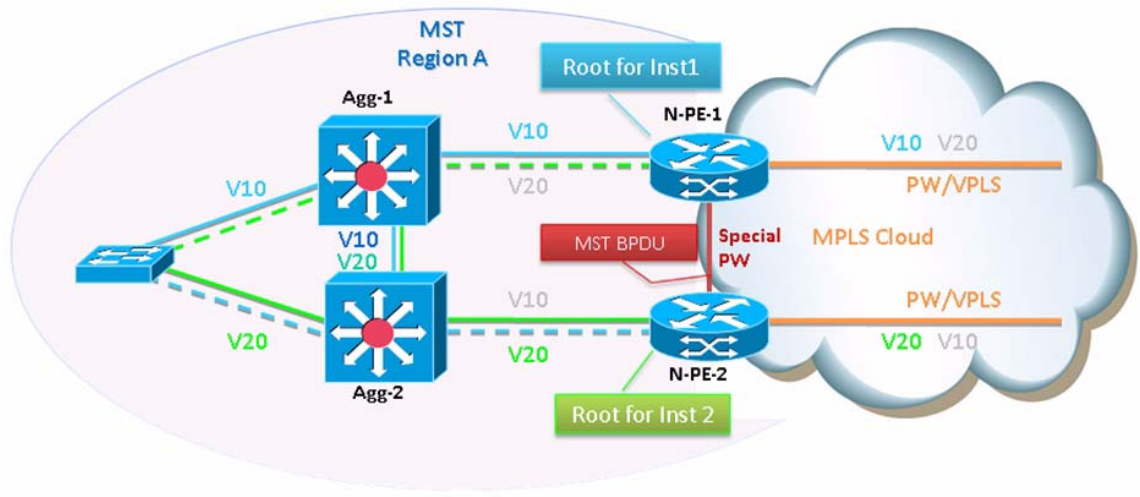
In this solution, each data center is a separate MST region and STP between data centers is isolated via the VPLS core. MST instance 1 and 2 are created and all odd VLANs are assigned to MST instance 1 and all even VLANs to MST instance 2. In addition, MST instance priority on both N-PEs in the data center is configured so that N-PE1 becomes the root bridge for MST instance 1 and N-PE2 becomes the root bridge for MST instance 2.

Note In MST, only one BPDU is sent for all MST instances configured on the switch. This single BPDU carries all mappings between MST instances and the member VLANs.

You must configure multiple MST instances because, in MST, the STP cost can be applied only on a per MST instance basis and not on a per VLAN basis as with Rapid Per VLAN STP (RPVSTP). Configuration of the appropriate STP cost per MST instance ensures that certain VLANs are blocked on the dot1q trunk between the N-PE and the aggregation switch and the inter-aggregation dot1q trunk is always forwarding all VLANs, thus avoiding a loop in the topology and providing a mechanism to load balance VLANs between the two N-PE/Aggregation trunk links.

Figure 5-1 shows N-PE1 and N-PE2 are configured as the MST root bridges for instance 1 and 2, respectively, and VLANs are assigned to these MST instances. For example, VLAN 10 (V10) is mapped to MST instance 1 and VLAN 20 (V20) is mapped to instance 2.

Figure 5-1 VPLS with N-PE Redundancy Using MST in N-PE



In this solution, every N-PE is configured as the root bridge and backup root bridge for each MSTP instance. This configuration requires that the root and backup root bridge be moved from the aggregation to the WAN edge layer. In addition, STP mode MST also might have to be configured on all Layer 2 switches that are not running MST.

In a standard MST deployment, multiple MST regions are interconnected by using the regular RSPT protocol (not the Cisco RSTP implementation), in which all VLANs are mapped to one STP instance. With regular MST, STP domains for all MST instances can be isolated, except for MST instance zero, which exists everywhere. Therefore, any topology changes in MST instance 0 are propagated to all switches.

MST in N-PE is implemented to control the forwarding state of STP instances while STP is isolated between regions. This approach prevents propagation of STP notifications and topology changes.

Configuring MST in pseudowire is a two-step process:

1. Define the special pseudowire using the forward permit l2protocol all command:

```
l2 vfi vfi_name manual
 vpn id vpn_id
 forward permit l2protocol all
 neighbor IP address of peer N-PE encapsulation mpls
!
end
```

2. Connect this pseudowire to the native VLAN (usually VLAN 1) to carry the untagged MST BPDUs:

```
interface vlan 1
 xconnect vfi vfi_name
!
end
```

The following modules support the configuration of an Ethernet over MPLS (EoMPLS) pseudowire tunnel to carry MSTP BPDUs:

- SIP-400

- SIP-600
- ES-20

Configuration Summary

In this solution, all pseudowires on N-PE1 and N-PE2 routers are active. Blocking of VLANs (loop avoidance) is performed on the links between the N-PEs and aggregation switches via STP cost associated with multiple MST instances.

The following provides snippets of configuration from N-PE and aggregation devices and output from various show commands.

1. Determine the existing STP root bridge priority for all VLANs that are required to be extended across data centers.

```
lon-n-pe1#sh spanning-tree vlan 7

MST0
  Spanning tree enabled protocol mstp
  Root ID    Priority    8192
             Address     001d.7198.8fc0
             Cost        0
             Port        3329 (Port-channel1)
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID  Priority    16384  (priority 16384 sys-id-ext 0)
             Address     001d.7198.9500
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec

Interface           Role Sts Cost      Prio.Nbr Type
------------------- ---- --- --------- -------- --------------------------------
Gi2/1               Desg FWD 20000     128.257  P2p Bound(PVST)

lon-n-pe1#
```

2. Configure STP mode MST on N-PE1. Configure N-PE1 as the root bridge for MST instance 0 and 1 by reducing the bridge priority to a value lower than the value found in step 1. Similarly, configure N-PE2 as the root bridge for MST instance 2. Assign all odd VLANs to MST instance 1 and all even VLANs to MST instance 2. Lower the priority for MST instances 0-2 such that N-PE1 becomes the backup root bridge for all the even VLANs and N-PE2, the backup root bridge for all odd VLANs:

N-PE1 Configuration	N-PE2 Configuration
spanning-tree mode mst ! spanning-tree mst configuration name lon-datacenter revision 10 instance 1 vlan 1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, 23, 25, 27, 29 ... instance 2 vlan 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30 ... ! spanning-tree mst 0-1 priority 8192 spanning-tree mst 2 priority 16384 ! vlan 2-61,201-260	spanning-tree mode mst ! spanning-tree mst configuration name lon-datacenter revision 10 instance 1 vlan 1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, 23, 25, 27, 29 ... instance 2 vlan 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30 ... ! spanning-tree mst 0-1 priority 16384 spanning-tree mst 2 priority 8192 ! vlan 2-61,201-260

3. Verify MST configuration on the both the N-PEs.

```
N-PE1 ConfigurationN-PE2 Configuration
spanning-tree mode mst
!
spanning-tree mst configuration
name lon-datacenter
revision 10
instance 1 vlan 1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, 23, 25, 27, 29 ...
instance 2 vlan 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30 ...
!
spanning-tree mst 0-1 priority 8192
spanning-tree mst 2 priority 16384
!
vlan 2-61,201-260
spanning-tree mode mst
!
spanning-tree mst configuration
name lon-datacenter
revision 10
instance 1 vlan 1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, 23, 25, 27, 29 ...
instance 2 vlan 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30 ...
!
spanning-tree mst 0-1 priority 16384
spanning-tree mst 2 priority 8192
!
vlan 2-61,201-260
Step 3.Verify MST configuration on the both the N-PEs.
! On N-PE1:
lon-n-pe1#show spanning-tree mst detail

##### MST0    vlans mapped:   62-200,261-300,302,304-4094
Bridge        address 001d.7198.9500  priority      8192  (8192 sysid 0)
Root          this switch for the CIST
Operational   hello time 2 , forward delay 15, max age 20, txholdcount 6
Configured    hello time 2 , forward delay 15, max age 20, max hops    20

GigabitEthernet2/1 of MST0 is designated forwarding
Port info             port id        128.257  priority    128  cost       20000
Designated root       address 001d.7198.9500  priority   8192  cost           0
Design. regional root address 001d.7198.9500  priority   8192  cost           0
Designated bridge     address 001d.7198.9500  priority   8192  port id  128.257
Timers: message expires in 0 sec, forward delay 0, forward transitions 1
Bpdus sent 11083, received 4

BRIDGE4/132 of MST0 is designated forwarding
Port info             port id        128.900  priority    128  cost         200
Designated root       address 001d.7198.9500  priority   8192  cost           0
Design. regional root address 001d.7198.9500  priority   8192  cost           0
Designated bridge     address 001d.7198.9500  priority   8192  port id  128.900
Timers: message expires in 0 sec, forward delay 0, forward transitions 23
Bpdus sent 30369, received 18330

BRIDGE4/196 of MST0 is designated forwarding
Port info             port id        128.964  priority    128  cost         200
Designated root       address 001d.7198.9500  priority   8192  cost           0
Design. regional root address 001d.7198.9500  priority   8192  cost           0
Designated bridge     address 001d.7198.9500  priority   8192  port id  128.964
Timers: message expires in 0 sec, forward delay 0, forward transitions 24
Bpdus sent 30416, received 11409

##### MST1    vlans mapped:   1,3,5,7,9,11,13,15,17,19,21,23,25,27,29
                             31,33,35,37,39,41,43,45,47,49,51,53,55,57
                             59,61,201,203,205,207,209,211,213,215,217
```

```
                              219,221,223,225,227,229,231,233,235,237
                              239,241,243,245,247,249,251,253,255,257
                              259,301,303
Bridge        address 001d.7198.9500  priority      8193  (8192 sysid 1)
Root          this switch for MST1

GigabitEthernet2/1 of MST1 is designated forwarding
Port info             port id        128.257  priority    128  cost       20000
Designated root       address 001d.7198.9500  priority   8193  cost           0
Designated bridge     address 001d.7198.9500  priority   8193  port id  128.257
Timers: message expires in 0 sec, forward delay 0, forward transitions 1
Bpdus (MRecords) sent 11083, received 4

BRIDGE4/132 of MST1 is designated forwarding
Port info             port id        128.900  priority    128  cost         200
Designated root       address 001d.7198.9500  priority   8193  cost           0
Designated bridge     address 001d.7198.9500  priority   8193  port id  128.900
Timers: message expires in 0 sec, forward delay 0, forward transitions 23
Bpdus (MRecords) sent 30369, received 18329

BRIDGE4/196 of MST1 is designated forwarding
Port info             port id        128.964  priority    128  cost         200
Designated root       address 001d.7198.9500  priority   8193  cost           0
Designated bridge     address 001d.7198.9500  priority   8193  port id  128.964
Timers: message expires in 0 sec, forward delay 0, forward transitions 24
Bpdus (MRecords) sent 30416, received 11408

##### MST2    vlans mapped:   2,4,6,8,10,12,14,16,18,20,22,24,26,28,30
                              32,34,36,38,40,42,44,46,48,50,52,54,56,58
                              60,202,204,206,208,210,212,214,216,218,220
                              222,224,226,228,230,232,234,236,238,240
                              242,244,246,248,250,252,254,256,258,260
Bridge        address 001d.7198.9500  priority      16386 (16384 sysid 2)
Root          address 001d.7198.8fc0  priority      8194  (8192 sysid 2)
            port    BR4/132         cost      200                  rem hops 19

GigabitEthernet2/1 of MST2 is designated forwarding
Port info             port id        128.257  priority    128  cost       20000
Designated root       address 001d.7198.8fc0  priority   8194  cost         200
Designated bridge     address 001d.7198.9500  priority  16386  port id  128.257
Timers: message expires in 0 sec, forward delay 0, forward transitions 1
Bpdus (MRecords) sent 11083, received 4

BRIDGE4/132 of MST2 is root forwarding
Port info             port id        128.900  priority    128  cost         200
Designated root       address 001d.7198.8fc0  priority   8194  cost           0
Designated bridge     address 001d.7198.8fc0  priority   8194  port id  128.900
Timers: message expires in 4 sec, forward delay 0, forward transitions 22
Bpdus (MRecords) sent 30369, received 18329

BRIDGE4/196 of MST2 is designated forwarding
Port info             port id        128.964  priority    128  cost         200
Designated root       address 001d.7198.8fc0  priority   8194  cost         200
Designated bridge     address 001d.7198.9500  priority  16386  port id  128.964
Timers: message expires in 0 sec, forward delay 0, forward transitions 24
Bpdus (MRecords) sent 30416, received 11408

lon-n-pe1#
lon-n-pe1#show running-config interface gig 2/1
Building configuration...

Current configuration : 384 bytes
!
interface GigabitEthernet2/1
```

```
 description L2 to Agg-1
 switchport
 switchport trunk encapsulation dot1q
 switchport trunk allowed vlan 1-61,201-260
 switchport mode trunk
 switchport nonegotiate
 mtu 9216
 logging event link-status
 logging event spanning-tree status
 storm-control broadcast level 5.00
 storm-control multicast level 5.00
 spanning-tree portfast trunk
 spanning-tree link-type point-to-point
end
lon-n-pe1#show spanning-tree vlan 7

MST1
  Spanning tree enabled protocol mstp
  Root ID    Priority    8193
             Address     001d.7198.9500
             This bridge is the root
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID  Priority    8193   (priority 8192 sys-id-ext 1)
             Address     001d.7198.9500
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec

Interface           Role Sts Cost      Prio.Nbr Type
------------------- ---- --- --------- -------- --------------------------------
Gi2/1               Desg FWD 20000     128.257  P2p
BR4/132             Desg FWD 200       128.900  P2p
BR4/196             Desg FWD 200       128.964  P2p

lon-n-pe1#
```

```
! On N-PE2:
lon-n-pe2#show spanning-tree mst detail

##### MST0    vlans mapped:   62-200,261-300,302,304-4094
Bridge        address 001d.7198.8fc0  priority      16384 (16384 sysid 0)
Root          address 001d.7198.9500  priority      8192  (8192 sysid 0)
              port    BR4/132         path cost     0
Regional Root address 001d.7198.9500  priority      8192  (8192 sysid 0)
                                      internal cost 200       rem hops 19
Operational   hello time 2 , forward delay 15, max age 20, txholdcount 6
Configured    hello time 2 , forward delay 15, max age 20, max hops    20

GigabitEthernet2/2 of MST0 is designated forwarding
Port info             port id        128.258  priority    128  cost       20000
Designated root       address 001d.7198.9500  priority   8192  cost           0
Design. regional root address 001d.7198.9500  priority   8192  cost         200
Designated bridge     address 001d.7198.8fc0  priority  16384  port id  128.258
Timers: message expires in 0 sec, forward delay 0, forward transitions 4
Bpdus sent 11707, received 49

BRIDGE4/132 of MST0 is root forwarding
Port info             port id        128.900  priority    128  cost         200
Designated root       address 001d.7198.9500  priority   8192  cost           0
Design. regional root address 001d.7198.9500  priority   8192  cost           0
Designated bridge     address 001d.7198.9500  priority   8192  port id  128.900
Timers: message expires in 5 sec, forward delay 0, forward transitions 32
Bpdus sent 31817, received 19251
```

```
BRIDGE4/196 of MST0 is designated forwarding
Port info             port id        128.964  priority    128  cost         200
Designated root       address 001d.7198.9500  priority   8192  cost           0
Design. regional root address 001d.7198.9500  priority   8192  cost         200
Designated bridge     address 001d.7198.8fc0  priority  16384  port id  128.964
Timers: message expires in 0 sec, forward delay 0, forward transitions 45
Bpdus sent 31868, received 11415

##### MST1    vlans mapped:   1,3,5,7,9,11,13,15,17,19,21,23,25,27,29
                              31,33,35,37,39,41,43,45,47,49,51,53,55,57
                              59,61,201,203,205,207,209,211,213,215,217
                              219,221,223,225,227,229,231,233,235,237
                              239,241,243,245,247,249,251,253,255,257
                              259,301,303
Bridge        address 001d.7198.8fc0  priority      16385 (16384 sysid 1)
Root          address 001d.7198.9500  priority      8193  (8192 sysid 1)
            port    BR4/132         cost      200                  rem hops 19

GigabitEthernet2/2 of MST1 is designated forwarding
Port info             port id        128.258  priority    128  cost       20000
Designated root       address 001d.7198.9500  priority   8193  cost         200
Designated bridge     address 001d.7198.8fc0  priority  16385  port id  128.258
Timers: message expires in 0 sec, forward delay 0, forward transitions 4
Bpdus (MRecords) sent 11707, received 45

BRIDGE4/132 of MST1 is root forwarding
Port info             port id        128.900  priority    128  cost         200
Designated root       address 001d.7198.9500  priority   8193  cost           0
Designated bridge     address 001d.7198.9500  priority   8193  port id  128.900
Timers: message expires in 5 sec, forward delay 0, forward transitions 23
Bpdus (MRecords) sent 31817, received 19251

BRIDGE4/196 of MST1 is designated forwarding
Port info             port id        128.964  priority    128  cost         200
Designated root       address 001d.7198.9500  priority   8193  cost         200
Designated bridge     address 001d.7198.8fc0  priority  16385  port id  128.964
Timers: message expires in 0 sec, forward delay 0, forward transitions 35
Bpdus (MRecords) sent 31868, received 11415

##### MST2    vlans mapped:   2,4,6,8,10,12,14,16,18,20,22,24,26,28,30
                              32,34,36,38,40,42,44,46,48,50,52,54,56,58
                              60,202,204,206,208,210,212,214,216,218,220
                              222,224,226,228,230,232,234,236,238,240
                              242,244,246,248,250,252,254,256,258,260
Bridge        address 001d.7198.8fc0  priority      8194  (8192 sysid 2)
Root          this switch for MST2

GigabitEthernet2/2 of MST2 is designated forwarding
Port info             port id        128.258  priority    128  cost       20000
Designated root       address 001d.7198.8fc0  priority   8194  cost           0
Designated bridge     address 001d.7198.8fc0  priority   8194  port id  128.258
Timers: message expires in 0 sec, forward delay 0, forward transitions 4
Bpdus (MRecords) sent 11707, received 45

BRIDGE4/132 of MST2 is designated forwarding
Port info             port id        128.900  priority    128  cost         200
Designated root       address 001d.7198.8fc0  priority   8194  cost           0
Designated bridge     address 001d.7198.8fc0  priority   8194  port id  128.900
Timers: message expires in 0 sec, forward delay 0, forward transitions 32
Bpdus (MRecords) sent 31817, received 19251

BRIDGE4/196 of MST2 is designated forwarding
Port info             port id        128.964  priority    128  cost         200
```

```
Designated root       address 001d.7198.8fc0  priority   8194  cost           0
Designated bridge     address 001d.7198.8fc0  priority   8194  port id  128.964
Timers: message expires in 0 sec, forward delay 0, forward transitions 44
Bpdus (MRecords) sent 31868, received 11415

lon-n-pe2#
lon-n-pe2#show running-config interface gig 2/2
Building configuration...

Current configuration : 374 bytes
!
interface GigabitEthernet2/2
 description L2 to Agg-2
 switchport
 switchport trunk encapsulation dot1q
 switchport trunk allowed vlan 1-61,201-260
 switchport mode trunk
 switchport nonegotiate
 mtu 9216
 load-interval 30
 storm-control broadcast level 5.00
 storm-control multicast level 5.00
 spanning-tree portfast trunk
 spanning-tree link-type point-to-point
end
lon-n-pe2#show spanning-tree vlan 7

MST1
  Spanning tree enabled protocol mstp
  Root ID    Priority    8193
             Address     001d.7198.9500
             Cost        200
             Port        900 (BRIDGE4/132)
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID  Priority    16385  (priority 16384 sys-id-ext 1)
             Address     001d.7198.8fc0
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec

Interface           Role Sts Cost      Prio.Nbr Type
------------------- ---- --- --------- -------- --------------------------------
Gi2/2               Desg FWD 20000     128.258  P2p
BR4/132             Root FWD 200       128.900  P2p
BR4/196             Desg FWD 200       128.964  P2p

lon-n-pe2#
```

4. Ensure that all Layer 2 switches in the local data center are running MST. If they are not, configure spanning tree mode MST and allocate all odd VLANs to MST instance 1 and all even VLANs to MST instance 2 on all the Agg PEs and access switches:

```
! On Agg-1 , Agg-2, Access-1, and Access-2:
spanning-tree mode mst
!
spanning-tree mst configuration
name lon-datacenter
revision 10
instance 1 vlan 1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, 23, 25, 27, 29 ..
instance 2 vlan 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30 ..
!
vlan 2-61,201-260
```

5. On the link between both N-PEs and aggregation switches, configure the following:

- Increase the STP cost on the aggregation switch link connected to N-PE such that all odd VLANs in MST instance 1 forward via Agg-1 to N-PE1 and all even VLANs in MST instance 2 forward through Agg-2 and N-PE2 link. Configure a higher cost on the aggregation switch link connected to N-PE so that regardless of the bandwidth of the inter-aggregation switch link, the inter-aggregation switch link always is in forwarding mode for all VLANs.
- As per the N-PE to Agg switch interface configuration that follows, STP cost for MST instance 1 on Agg1 has been set to 1000 and the STP cost for MST instance 2 is 1500. On Agg-2, the STP cost of 1000 has been configured for MST instance 2 and 1500 for MST instance 1.
- STP point-to-point link.
- Storm control (broadcast and multicast) on the N-PE side of the link. For related information about storm control, refer to the following URL:

  http://www.cisco.com/en/US/docs/routers/7600/ios/12.1E/configuration/guide/storm.html

Note In the configurations that this document shows, the storm control level for broadcast and multicast traffic was set to 5. However, Cisco does not recommend a specific value. Some required protocols such as Address Resolution Protocol (ARP) and Dynamic Host Configuration Protocol (DHCP) use broadcasts. Consider your applications and specific traffic patterns to determine the optimal value for threshold guidelines.

Agg-1 Configuration	Agg-2 Configuration
interface GigabitEthernet2/19 description L2 connection to lon-n-pe1 switchport switchport trunk encapsulation dot1q switchport trunk allowed vlan 1-61,201-260 switchport mode trunk switchport nonegotiate mtu 9216 logging event link-status logging event spanning-tree status spanning-tree link-type point-to-point spanning-tree mst 0-1 cost 1000 spanning-tree mst 2 cost 1500	interface GigabitEthernet2/18 description L2 connection to lon-n-pe2 switchport switchport trunk encapsulation dot1q switchport trunk allowed vlan 1-61,201-260 switchport mode trunk switchport nonegotiate mtu 9216 logging event link-status logging event spanning-tree status spanning-tree link-type point-to-point spanning-tree mst 2 cost 1000 spanning-tree mst 0-1 cost 1500

6. Verify the STP configuration on both of the aggregation switches and confirm that the inter Agg switch link forwards all VLANs:

```
! On Agg-1:
lon-agg-1#show spanning-tree interface Port-channel 1

Mst Instance        Role Sts Cost      Prio.Nbr Type
------------------- ---- --- --------- -------- --------------------------------
MST0                Desg FWD 1         128.1665 P2p
MST1                Desg FWD 1         128.1665 P2p
MST2                Root FWD 1         128.1665 P2p
lon-agg-1#show spanning-tree vlan7

MST1
  Spanning tree enabled protocol mstp
  Root ID    Priority    8193
             Address     001d.7198.9500
             Cost        1000
```

```
            Port        147 (GigabitEthernet2/19)
            Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID  Priority    32769  (priority 32768 sys-id-ext 1)
             Address     001c.b126.d000
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec

Interface           Role Sts Cost      Prio.Nbr Type
------------------- ---- --- --------- -------- --------------------------------
Gi2/19              Root FWD 1000      128.147  P2p
Gi2/22              Desg FWD 20000     128.150  P2p
Po1                 Desg FWD 1         128.1665 P2p
```

```
! On Agg-2:
lon-agg-2#show spanning-tree interface Port-channel 1

Mst Instance        Role Sts Cost      Prio.Nbr Type
------------------- ---- --- --------- -------- --------------------------------
MST0                Root FWD 1         128.1665 P2p
MST1                Root FWD 1         128.1665 P2p
MST2                Desg FWD 1         128.1665 P2p


lon-agg-2#show spanning-tree vlan 7

MST1
  Spanning tree enabled protocol mstp
  Root ID    Priority    8193
             Address     001d.7198.9500
             Cost        1001
             Port        1665 (Port-channel1)
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID  Priority    32769  (priority 32768 sys-id-ext 1)
             Address     001c.b144.4c00
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec

Interface           Role Sts Cost      Prio.Nbr Type
------------------- ---- --- --------- -------- --------------------------------
Gi2/18              Altn BLK 1500      128.146  P2p
Gi2/21              Desg FWD 20000     128.149  P2p
Po1                 Root FWD 1         128.1665 P2p
```

From the output of show spanning-tree vlan 7, you can see that spanning tree blocks odd VLANs on the link between N-PE2 and Agg-2. Also, all VLANs are in forwarding state on the inter-aggregation switch link. This configuration provides per-MST instance VLAN load balancing and avoids Layer 2 loop.

7. Configure OSPF on the N-PE routers:

```
router ospf 1
 router-id 11.11.11.11
 log-adjacency-changes
 auto-cost reference-bandwidth 10000
 area 0 authentication message-digest
 timers throttle spf 100 100 5000
 timers throttle lsa 100 100 5000
 timers lsa arrival 80
 ...
 distribute-list 1 in GigabitEthernet2/6
 bfd all-interfaces
 mpls ldp sync
!
```

```
lon-n-pe1#show ip ospf 1

Routing Process "ospf 1" with ID 11.11.11.11
 Start time: 00:00:50.580, Time elapsed: 06:14:40.996
 Supports only single TOS(TOS0) routes
 Supports opaque LSA
 Supports Link-local Signaling (LLS)
 Supports area transit capability
 Event-log enabled, Maximum number of events: 1000, Mode: cyclic
 Router is not originating router-LSAs with maximum metric
 Initial SPF schedule delay 100 msecs
 Minimum hold time between two consecutive SPFs 100 msecs
 Maximum wait time between two consecutive SPFs 5000 msecs
 Incremental-SPF disabled
 Initial LSA throttle delay 100 msecs
 Minimum hold time for LSA throttle 100 msecs
 Maximum wait time for LSA throttle 5000 msecs
 Minimum LSA arrival 80 msecs
 LSA group pacing timer 240 secs
 Interface flood pacing timer 33 msecs
 Retransmission pacing timer 66 msecs
 Number of external LSA 1. Checksum Sum 0x00D71C
 Number of opaque AS LSA 0. Checksum Sum 0x000000
 Number of DCbitless external and opaque AS LSA 0
 Number of DoNotAge external and opaque AS LSA 0
 Number of areas in this router is 1. 1 normal 0 stub 0 nssa
 Number of areas transit capable is 0
 External flood list length 0
 IETF NSF helper support enabled
 Cisco NSF helper support enabled
 BFD is enabled
 Reference bandwidth unit is 10000 mbps
    Area BACKBONE(0)
        Number of interfaces in this area is 6 (2 loopback)
        Area has message digest authentication
        SPF algorithm last executed 00:55:35.412 ago
        SPF algorithm executed 68 times
        Area ranges are
        Number of LSA 22. Checksum Sum 0x099D4E
        Number of opaque link LSA 0. Checksum Sum 0x000000
        Number of DCbitless LSA 0
        Number of indication LSA 0
        Number of DoNotAge LSA 0
        Flood list length 0

lon-n-pe1#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
116.5.200.77      0   FULL/  -        00:00:39    192.168.11.7
GigabitEthernet4/0/19
12.12.12.12       0   FULL/  -        00:00:37    192.168.13.6    GigabitEthernet4/0/0
13.13.13.13       0   FULL/  -        00:00:35    10.11.21.3      GigabitEthernet2/6

lon-n-pe1#show cdp neighbors

Capability Codes: R - Router, T - Trans Bridge, B - Source Route Bridge
                  S - Switch, H - Host, I - IGMP, r - Repeater, P - Phone

Device ID        Local Intrfce     Holdtme    Capability  Platform  Port ID
lon-n-pe2        Gig 4/0/0         150          R S I     CISCO7604 Gig 4/0/0
lon-agg-1        Gig 2/1           144          R S I     WS-C6509- Gig 2/19
lon-core1        Gig 2/6           151          R S I     WS-C6506  Gig 3/21
mpls-p1          Gig 4/0/19        149          R S I     WS-C6506  Gig 2/22
```

8. Configure MPLS, VFI and SVI with l2transport show commands on N-PEs is shown below. MST in pseudowire is implemented with a separate VFI-bpdu-pw. Redundancy in the VPLS domain relies on an MPLS mechanism. Each N-PE will have an alternate MPLS path, or an EEM policy can be used at each N-PE to shut down its link to the local Agg switch when the VPLS link is down.

```
! On N-PE1:
lon-n-pe1#
!
...
mpls ldp neighbor 10.76.70.12 targeted ldp
mpls ldp neighbor 10.76.70.21 targeted ldp
mpls ldp neighbor 10.76.70.22 targeted ldp
mpls ldp neighbor 10.76.70.31 targeted ldp
mpls ldp neighbor 10.76.70.32 targeted ldp
mpls ldp tcp pak-priority
mpls ldp session protection
no mpls ldp advertise-labels
mpls ldp advertise-labels for 76
mpls label protocol ldp
!
xconnect logging pseudowire status
!
access-list 76 permit 10.76.0.0 0.0.255.255
! VFI for MST in PW
l2 vfi bpdu-pw manual
 vpn id 1
 forward permit l2protocol all
 neighbor 10.76.100.12 encapsulation mpls
! VFI for VLAN 7
l2 vfi lon-pe1-7 manual
 vpn id 7
 neighbor 10.76.100.32 encapsulation mpls
 neighbor 10.76.100.31 encapsulation mpls
 neighbor 10.76.100.22 encapsulation mpls
 neighbor 10.76.100.21 encapsulation mpls
!
!
interface Vlan7
 mtu 9216
 no ip address
 xconnect vfi lon-pe1-7
!
lon-n-pe1#show mpls l2transport vc

Local intf     Local circuit              Dest address    VC ID      Status
-------------  -------------------------- --------------- ---------- ----------
VFI bpdu-pw    VFI                        10.76.100.11    1          UP
VFI lon-pe2-7  VFI                        10.76.100.21    7          UP
VFI lon-pe2-7  VFI                        10.76.100.22    7          UP
VFI lon-pe2-7  VFI                        10.76.100.31    7          UP
VFI lon-pe2-7  VFI                        10.76.100.32    7          UP

Lon-n-pe1#
lon-n-pe1#show running-config interface gig 4/0/19
!
interface GigabitEthernet4/0/19
 description L3 connection to MPLS P router
 dampening
 mtu 9216
 ip address 192.168.11.5 255.255.255.0
 ip ospf message-digest-key 1 md5 lab
 ip ospf network point-to-point
```

```
 load-interval 30
 carrier-delay msec 0
 mls qos trust dscp
 mpls ip
 bfd interval 100 min_rx 100 multiplier 3
end
```

```
! On N-PE2:
lon-n-pe2#
! VFI for MST in PW
l2 vfi bpdu-pw manual
 vpn id 1
 forward permit l2protocol all
 neighbor 10.76.100.11 encapsulation mpls  << lon-n-pe1
!
l2 vfi lon-pe2-7 manual
 vpn id 7
 neighbor 10.76.100.32 encapsulation mpls  << sj-n-pe2
 neighbor 10.76.100.31 encapsulation mpls  << sj-n-pe1
 neighbor 10.76.100.22 encapsulation mpls  << sin-n-pe2
 neighbor 10.76.100.21 encapsulation mpls  << sin-n-pe1
!
!
interface Vlan7
 mtu 9216
 no ip address
 xconnect vfi lon-pe2-7
!
lon-n-pe2#show mpls l2transport vc

Local intf     Local circuit              Dest address    VC ID      Status
-------------  -------------------------- --------------- ---------- ----------VFI
bpdu-pw    VFI                         10.76.100.11    1          UP
VFI lon-pe2-7  VFI                         10.76.100.21    7          UP
VFI lon-pe2-7  VFI                         10.76.100.22    7          UP
VFI lon-pe2-7  VFI                         10.76.100.31    7          UP
VFI lon-pe2-7  VFI                         10.76.100.32    7          UP
Lon-n-pe2#
```

9. EEM configuration and show commands.

```
lon-n-pe1#
!
process-max-time 50
!
track 20 interface GigabitEthernet4/0/0 line-protocol
!
track 21 interface GigabitEthernet4/0/19 line-protocol
!
track 25 list boolean or
 object 20
 object 21
 delay up 90

lon-n-pe1#show running-config | begin event manager
event manager applet DOWN_Gig2/1
 event track 25 state down
 action 1.0 cli command "enable"
 action 2.0 cli command "config t"
 action 3.0 cli command "int Gig 2/1 "
 action 4.0 cli command "shut"
 action 5.0 syslog msg "EEM has shut Gig 2/1 "
```

```
event manager applet UP_Gig2/1
 event track 25 state up
 action 1.0 cli command "enable"
 action 2.0 cli command "config t"
 action 3.0 cli command "int Gig2/1"
 action 4.0 cli command "no shut"
 action 5.0 syslog msg "EEM has unshut Gig2/1"
event manager applet DOWN_GIG2/1-boot
 event timer cron name "_EEMinternalname6" cron-entry "@reboot"
 action 1.0 cli command "enable"
 action 2.0 cli command "config t"
 action 3.0 cli command "interface Gig 2/1 "
 action 4.0 cli command "shutdown"
 action 5.0 syslog msg "EEM has shut Gig 2/1 "
!
end
```

Pertaining to the bolded line of output: When an N-PE router reloads, power to the LAN modules is enabled before the WAN modules power on. In this situation, LAN interfaces are enabled before interfaces on the WAN modules become active. After the LAN interfaces become active, spanning tree converges and puts the interface between N-PE and aggregation switch in forwarding mode. Therefore, traffic is black-holed because the WAN interfaces might still be in down state or the path to the core network might not be available via the N-PE that was reloaded. An EEM reboot applet ensures that the LAN interfaces are in shut state until the WAN interfaces configured in track command become active after the router initializes completely.

Convergence Tests

The traffic profile that is outlined in the "Traffic Profile" section on page 4-6 was used to determine end-to-end convergence for unidirectional voice, unicast, and multicast traffic. Links and nodes were failed to simulate network failures.

Table 5-1 shows results of various nodes and links failures. Convergence numbers (Max and Min) are in seconds.

Table 5-1 Convergence Numbers for DCI Solution using Cisco 7600 Routers for MST-Based Data Centers (MST Option 1a)

				Traffic Direction			
				LON -> SJ		SJ -> LON	
Failure Type	**Action**	**VLAN**	**Traffic Type**	**Max**	**Min**	**Max**	**Min**
Node Failure							
Reload N-PE1	Reload	Odd VLAN[1]	Voice	3.92	3.84	3.78	3.76
			Unicast	3.91	3.87	3.77	3.75
			Multicast	6.37	4.06	6.61	3.93
		Even VLAN	Voice	0.14	0.12	0.00	0.00
			Unicast	0.14	0.14	0.00	0.00
			Multicast	0.15	0.13	0.00	0.00
	Restore	Odd VLAN	Voice	0.44	0.02	0.73	0.73
			Unicast	0.43	0.16	0.71	0.18
			Multicast	8.43	0.92	5.47	2.45
		Even VLAN	Voice	0.00	0.73	0.02	0.02
			Unicast	0.00	0.00	0.00	0.00
			Multicast	0.00	0.00	0.00	0.00
Reload N-PE2	Reload	Odd VLAN	Voice	0.02	0.02	0.02	0.02
			Unicast	0.00	0.00	0.00	0.00
			Multicast	0.01	0.00	0.02	0.02
		Even VLAN[1]	Voice	3.76	3.66	3.76	3.74
			Unicast	3.73	3.68	3.74	3.72
			Multicast	6.30	4.18	6.00	3.84
	Restore	Odd VLAN	Voice	0.02	0.02	0.02	0.02
			Unicast	0.00	0.00	0.00	0.00
			Multicast	0.10	0.00	0.03	0.02
		Even VLAN	Voice	1.18	0.62	1.34	1.28
			Unicast	1.15	0.62	1.32	0.72
			Multicast	4.68	0.97	6.04	0.96

Table 5-1 Convergence Numbers for DCI Solution using Cisco 7600 Routers for MST-Based Data Centers (MST Option 1a) (continued)

				Traffic Direction			
				LON -> SJ		SJ -> LON	
Failure Type	**Action**	**VLAN**	**Traffic Type**	**Max**	**Min**	**Max**	**Min**
Reload Agg-1	Reload	Odd VLAN	Voice	0.50	0.02	0.50	0.50
			Unicast	0.47	0.47	0.48	0.48
			Multicast	4.59	2.49	1.21	0.67
		Even VLAN	Voice	0.02	0.02	0.02	0.02
			Unicast	0.00	0.00	0.00	0.00
			Multicast	0.03	0.01	0.03	0.01
	Restore	Odd VLAN	Voice	0.06	0.02	0.04	0.04
			Unicast	0.03	0.02	0.00	0.00
			Multicast	2.89	0.76	2.00	0.02
		Even VLAN	Voice	0.02	0.02	0.04	0.04
			Unicast	0.00	0.00	0.00	0.00
			Multicast	0.01	0.00	0.02	0.02
Reload Agg-2	Reload	Odd VLAN	Voice	0.46	0.00	0.00	0.00
			Unicast	0.00	0.00	0.00	0.00
			Multicast	0.00	0.00	0.00	0.00
		Even VLAN	Voice	0.48	0.46	0.46	0.46
			Unicast	0.47	0.46	0.46	0.46
			Multicast	4.53	1.76	7.06	0.79
	Restore	Odd VLAN	Voice	0.02	0.00	0.02	0.02
			Unicast	0.00	0.00	0.00	0.00
			Multicast	0.00	0.00	0.01	0.01
		Even VLAN	Voice	0.06	0.02	0.02	0.02
			Unicast	0.04	0.04	0.01	0.01
			Multicast	1.74	0.28	1.07	0.02

Table 5-1 Convergence Numbers for DCI Solution using Cisco 7600 Routers for MST-Based Data Centers (MST Option 1a) (continued)

				Traffic Direction			
				LON -> SJ		SJ -> LON	
Failure Type	**Action**	**VLAN**	**Traffic Type**	**Max**	**Min**	**Max**	**Min**
Link Failure							
Fail L2 link between N-PE1 and Agg-1	Shut	Odd VLAN	Voice	0.90	0.87	0.30	0.24
			Unicast	0.89	0.89	0.30	0.23
			Multicast	5.55	0.97	2.60	0.56
		Even VLAN	Voice	0.00	0.24	0.00	0.00
			Unicast	0.00	0.00	0.00	0.00
			Multicast	0.01	0.00	0.02	0.01
	No shut	Odd VLAN	Voice	0.28	0.02	0.36	0.26
			Unicast	0.29	0.20	0.33	0.18
			Multicast	4.29	0.46	3.32	0.28
		Even VLAN	Voice	0.02	0.02	0.02	0.02
			Unicast	0.00	0.00	0.00	0.00
			Multicast	0.01	0.00	0.00	0.00
Fail L2 link between N-PE2 and Agg-2	Shut	Odd VLAN	Voice	0.58	0.00	0.02	0.02
			Unicast	0.00	0.00	0.00	0.00
			Multicast	0.02	0.00	0.01	0.01
		Even VLAN	Voice	0.62	0.58	0.60	0.58
			Unicast	0.59	0.57	0.58	0.56
			Multicast	5.75	2.26	5.94	2.25
	No shut	Odd VLAN	Voice	0.02	0.02	0.00	0.00
			Unicast	0.00	0.00	0.00	0.00
			Multicast	0.01	0.00	0.01	0.01
		Even VLAN	Voice	0.64	0.40	0.72	0.72
			Unicast	0.63	0.41	0.71	0.63
			Multicast	6.86	1.52	2.74	1.03

Table 5-1 Convergence Numbers for DCI Solution using Cisco 7600 Routers for MST-Based Data Centers (MST Option 1a) (continued)

				Traffic Direction			
				LON -> SJ		SJ -> LON	
Failure Type	**Action**	**VLAN**	**Traffic Type**	**Max**	**Min**	**Max**	**Min**
Fail L2 link between Agg-1 and Agg-2	Shut	Odd VLAN	Voice	0.00	0.00	0.00	0.00
			Unicast	0.00	0.00	0.00	0.00
			Multicast	0.01	0.00	0.00	0.00
		Even VLAN	Voice	0.00	0.00	0.00	0.00
			Unicast	0.00	0.00	0.00	0.00
			Multicast	0.01	0.00	0.01	0.01
	No shut	Odd VLAN	Voice	0.00	0.00	0.00	0.00
			Unicast	0.00	0.00	0.00	0.00
			Multicast	0.01	0.00	0.00	0.00
		Even VLAN	Voice	0.00	0.00	0.00	0.00
			Unicast	0.00	0.00	0.00	0.00
			Multicast	0.01	0.00	0.01	0.01
Fail Wan link facing core on N-PE1	Shut	Odd VLAN	Voice	0.56	0.04	0.54	0.46
			Unicast	0.53	0.51	0.51	0.43
			Multicast	2.48	1.37	0.52	0.44
		Even VLAN	Voice	0.02	0.02	0.04	0.04
			Unicast	0.00	0.00	0.00	0.00
			Multicast	0.01	0.00	0.01	0.01
	No shut	Odd VLAN	Voice	0.02	0.02	0.02	0.02
			Unicast	0.00	0.00	0.00	0.00
			Multicast	3.60	0.17	0.02	0.02
		Even VLAN	Voice	0.02	0.02	0.02	0.02
			Unicast	0.00	0.00	0.00	0.00
			Multicast	0.01	0.00	0.02	0.02

Table 5-1 Convergence Numbers for DCI Solution using Cisco 7600 Routers for MST-Based Data Centers (MST Option 1a) (continued)

				Traffic Direction			
				LON -> SJ		SJ -> LON	
Failure Type	**Action**	**VLAN**	**Traffic Type**	**Max**	**Min**	**Max**	**Min**
Fail Wan link facing core on N-PE2	Shut	Odd VLAN	Voice	0.06	0.02	0.02	0.02
			Unicast	0.01	0.01	0.01	0.00
			Multicast	0.02	0.00	0.01	0.01
		Even VLAN	Voice	0.62	0.56	0.54	0.50
			Unicast	0.61	0.56	0.54	0.27
			Multicast	3.44	0.61	0.54	0.27
	No shut	Odd VLAN	Voice	0.02	0.02	0.04	0.04
			Unicast	0.01	0.00	0.00	0.00
			Multicast	0.02	0.00	0.01	0.01
		Even VLAN	Voice	0.02	0.02	0.12	0.10
			Unicast	0.00	0.00	0.06	0.06
			Multicast	3.12	0.14	0.07	0.07
Fail both WAN links on N-PE1	Shut	Odd VLAN[1]	Voice	3.88	0.04	3.98	3.98
			Unicast	3.86	3.85	3.99	3.99
			Multicast	6.54	4.81	7.42	4.28
		Even VLAN	Voice	0.02	0.02	0.04	0.04
			Unicast	0.02	0.02	0.01	0.01
			Multicast	0.01	0.00	0.02	0.02
	No shut	Odd VLAN	Voice	0.26	0.06	0.54	0.54
			Unicast	0.26	0.06	0.54	0.26
			Multicast	4.25	0.35	4.51	0.58
		Even VLAN	Voice	0.54	0.00	0.00	0.00
			Unicast	0.00	0.00	0.00	0.00
			Multicast	0.01	0.00	0.00	0.00

Table 5-1 Convergence Numbers for DCI Solution using Cisco 7600 Routers for MST-Based Data Centers (MST Option 1a) (continued)

				Traffic Direction			
				LON -> SJ		SJ -> LON	
Failure Type	**Action**	**VLAN**	**Traffic Type**	**Max**	**Min**	**Max**	**Min**
Fail both WAN links on N-PE2	Shut	Odd VLAN	Voice	0.02	0.02	0.04	0.02
			Unicast	0.00	0.00	0.00	0.00
			Multicast	0.01	0.00	0.00	0.00
		Even VLAN[1]	Voice	2.86	2.82	2.86	2.86
			Unicast	2.84	2.84	2.84	2.84
			Multicast	2.85	2.84	4.76	4.56
	No shut	Odd VLAN	Voice	0.06	0.02	0.02	0.02
			Unicast	0.01	0.00	0.00	0.00
			Multicast	0.02	0.01	0.00	0.00
		Even VLAN	Voice	0.43	0.08	0.50	0.46
			Unicast	0.44	0.10	0.48	0.12
			Multicast	5.28	0.86	2.62	0.85
Clear entire routing table on both N-PEs	Clear	Odd VLAN	Voice	0.02	0.02	0.00	0.00
			Unicast	0.00	0.00	0.00	0.00
			Multicast	0.00	0.00	0.01	0.01
		Even VLAN	Voice	0.00	0.00	0.00	0.00
			Unicast	0.00	0.00	0.00	0.00
			Multicast	0.01	0.00	0.01	0.01
Clear entire dynamic MAC address table on both N-PEs	Clear	Odd VLAN	Voice	0.00	0.00	0.00	0.00
			Unicast	0.00	0.00	0.00	0.00
			Multicast	0.01	0.00	0.00	0.00
		Even VLAN	Voice	0.00	0.00	0.00	0.00
			Unicast	0.00	0.00	0.00	0.00
			Multicast	0.01	0.00	0.01	0.01

Table 5-1 Convergence Numbers for DCI Solution using Cisco 7600 Routers for MST-Based Data Centers (MST Option 1a) (continued)

				Traffic Direction			
				LON -> SJ		SJ -> LON	
Failure Type	**Action**	**VLAN**	**Traffic Type**	**Max**	**Min**	**Max**	**Min**
Fail L3 links between N-PEs	Shut	Odd VLAN	Voice	0.00	0.00	0.00	0.00
			Unicast	0.00	0.00	0.00	0.00
			Multicast	0.01	0.00	0.00	0.00
		Even VLAN	Voice	0.00	0.00	0.00	0.00
			Unicast	0.00	0.00	0.00	0.00
			Multicast	0.01	0.00	0.01	0.01
	No shut	Odd VLAN	Voice	0.00	0.00	0.00	0.00
			Unicast	0.00	0.00	0.00	0.00
			Multicast	0.01	0.00	0.01	0.00
		Even VLAN	Voice	0.00	0.00	0.00	0.00
			Unicast	0.00	0.00	0.00	0.00
			Multicast	0.01	0.00	0.01	0.01

1. If the EoMPLS pseudowire carrying MST BPDUs between the N-PEs fails, MST convergence within the local data center takes longer due to the delay in propagation of topology change notification. Cisco defect number CSCsk85658 documents this issue.

Cluster Server Tests

Event logs are captured from event viewer of Microsoft cluster server. The logs are in the reverse order showing the last event, first. It is best to view the timestamps when analyzing these logs.

Table 5-2 shows the event logs from the event viewer of Microsoft cluster server.

Table 5-2 Event Logs for DCI Solution using Cisco 7600 Routers for MST-Based Data Centers (MST Option 1a)

Test Case	Time (Seconds)	Event Logs with Timestamps from Microsoft Server			
Power Off Both N-PEs	123	12/16/2008	3:47:48 PM	CAMP3-SERVER2	The Cluster Service brought the Resource Group “ClusterGroup” online.
		12/16/2008	3:46:09 PM	CAMP3-SERVER2	The Cluster Service is attempting to bring online the Resource Group “Cluster Group.”
		12/16/2008	3:46:09 PM	CAMP3-SERVER2	Cluster node CAMP3-SERVER3 was removed from the active server cluster membership. Cluster service may have been stopped on the node, the node may have failed, or the node may have lost communication with the other active server cluster nodes.
		12/16/2008	3:45:47 PM	CAMP3-SERVER2	The node lost communication with cluster node “CAMP3-SERVER3” on network “public.”
		12/16/2008	3:45:45 PM	CAMP3-SERVER2	The node lost communication with cluster node “CAMP3-SERVER3” on network “private(1).”
Power Off Access Switch	120	12/16/2008	6:24:19 PM	CAMP3-SERVER2	The Cluster Service brought the Resource Group “Cluster Group” online.
		12/16/2008	6:22:49 PM	CAMP3-SERVER2	The Cluster Service is attempting to bring online the Resource Group “Cluster Group.”
		12/16/2008	6:22:49 PM	CAMP3-SERVER2	Cluster node CAMP3-SERVER3 was removed from the active server cluster membership. Cluster service may have been stopped on the node, the node may have failed, or the node may have lost communication with the other active server cluster nodes.
		12/16/2008	6:22:27 PM	CAMP3-SERVER2	The node lost communication with cluster node “CAMP3-SERVER3' on network “private(1).”
		12/16/2008	6:22:27 PM	CAMP3-SERVER2	The node lost communication with cluster node “CAMP3-SERVER3” on network “public.”
		12/16/2008	6:22:19 PM	CAMP3-SERVER1	The node lost communication with cluster node “CAMP3-SERVER3' on network “private(1).”
		12/16/2008	6:22:19 PM	CAMP3-SERVER1	The node lost communication with cluster node “CAMP3-SERVER3” on network “public.”

Table 5-2 Event Logs for DCI Solution using Cisco 7600 Routers for MST-Based Data Centers (MST Option 1a) (continued)

Test Case	Time (Seconds)	Event Logs with Timestamps from Microsoft Server			
Power Off Active Node	125	12/16/2008	5:54:19 PM	CAMP3-SERVER2	The Cluster Service brought the Resource Group "Cluster Group" online.
		12/16/2008	5:52:44 PM	CAMP3-SERVER2	The Cluster Service is attempting to bring online the Resource Group "ClusterGroup."
		12/16/2008	5:52:44 PM	CAMP3-SERVER2	Cluster node CAMP3-SERVER3 was removed from the active server cluster membership. Cluster service may have been stopped on the node, the node may have failed, or the node may have lost communication with the other active server cluster nodes.
		12/16/2008	5:52:22 PM	CAMP3-SERVER2	The node lost communication with cluster node "CAMP3-SERVER3" on network "private(1)."
		12/16/2008	5:52:22 PM	CAMP3-SERVER2	The node lost communication with cluster node "CAMP3-SERVER3" on network "public."
		12/16/2008	5:52:14 PM	CAMP3-SERVER1	The node lost communication with cluster node "CAMP3-SERVER3" on network "private(1)."
		12/16/2008	5:52:14 PM	CAMP3-SERVER1	The node lost communication with cluster node "CAMP3-SERVER3" on network "public."
Private VLAN NPE reload	6	12/16/2008	5:35:23 PM	CAMP3-SERVER2	Cluster network "private(1)" is operational (up). All available server cluster nodes attached to the network can communicate using it.
		12/16/2008	5:35:20 PM	CAMP3-SERVER3	The node (re)established communication with cluster node "CAMP3-SERVER2" on network "private(1)."
		12/16/2008	5:35:20 PM	CAMP3-SERVER3	The node (re)established communication with cluster node "CAMP3-SERVER1" on network "private(1)."
		12/16/2008	5:35:14 PM	CAMP3-SERVER3	The node lost communication with cluster node "CAMP3-SERVER2" on network "private(1)."
		12/16/2008	5:35:14 PM	CAMP3-SERVER3	The node lost communication with cluster node "CAMP3-SERVER1" on network "private(1)."

Table 5-2 Event Logs for DCI Solution using Cisco 7600 Routers for MST-Based Data Centers (MST Option 1a) (continued)

Test Case	Time (Seconds)	Event Logs with Timestamps from Microsoft Server			
Unplug Active Server	125	12/16/2008	5:54:19 PM	CAMP3-SERVER2	The Cluster Service brought the Resource Group “Cluster Group” online.
		12/16/2008	5:52:44 PM	CAMP3-SERVER2	The Cluster Service is attempting to bring online the Resource Group “Cluster Group.”
		12/16/2008	5:52:44 PM	CAMP3-SERVER2	Cluster node CAMP3-SERVER3 was removed from the active server cluster membership. Cluster service might have been stopped on the node, the node might have failed, or the node might have lost communication with the other active server cluster nodes.
		12/16/2008	5:52:22 PM	CAMP3-SERVER2	The node lost communication with cluster node “CAMP3-SERVER3” on network “public.”
		12/16/2008	5:52:14 PM	CAMP3-SERVER1	The node lost communication with cluster node “CAMP3-SERVER3” on network “public.”
Establish L2 Connectivity	No Convergence	12/16/2008	6:36:03 PM	CAMP3-SERVER2	The Cluster Service service entered the running state.
		12/16/2008	6:36:02 PM	CAMP3-SERVER2	Cluster service successfully joined the server cluster CLUSTER-MNS.
		12/16/2008	6:35:44 PM	CAMP3-SERVER2	The node (re)established communication with cluster node “CAMP3-SERVER3” on network “public.”
		12/16/2008	6:35:44 PM	CAMP3-SERVER2	The node (re)established communication with cluster node “CAMP3-SERVER3” on network “private(1).”
		12/16/2008	6:35:43 PM	CAMP3-SERVER2	The node (re)established communication with cluster node “CAMP3-SERVER1” on network “public.”
		12/16/2008	6:35:43 PM	CAMP3-SERVER2	The node (re)established communication with cluster node “CAMP3-SERVER1” on network “private(1).”
		12/16/2008	6:35:35 PM	CAMP3-SERVER2	The Cluster Service service was successfully sent a start control.

CHAPTER 6

Scalable H-VPLS DCI Solution using Cisco 7600 Routers (Option 5c)

The MST solution that Chapter 5, "DCI Solution using Cisco 7600 Routers for MST-Based Data Centers (Option 1a)" describes, spanning tree provides redundant access to VPLS nodes to manage the states of links that connect aggregation switches to VPLS nodes (N-PEs). The solution that this chapter describes is scalable H-VPLS with MEC and VLAN load balancing, EEM option 5c, which provides high availability for link and node failures by using MEC technology to connect data center aggregation. It also provides scalability based on 802.1q in 802.1q (QinQ) technology and supports multiple edge domain with overlapping VLANs.

This solution does not require modification of the local data center STP design. The pseudowires on the backup N-PE are always in UP state, which accelerates the activation of a backup path if a primary path fails. This solution requires the aggregation device to support MEC via VSS on Cisco Catalyst 6500 platforms or vPC on Cisco Nexus 7000 platforms.

In the absence of Inter Chassis Communication Protocol (ICCP), VPLS node state synchronization is achieved by a set of validated scripts that are executed in IOS by the Embedded Event Manager (EEM). EEM scripts provide synchronization of VPLS nodes by using a semaphore concept.

As discussed in Chapter 3, "VPLS Overview and Solutions Portfolio," there are several EEM semaphore based solutions that provide N-PE redundancy. These solutions can easily be adapted for data centers with a wide variety of data center formats and various types of connectivity to aggregations switches.

This chapter includes these topics:

Introduction to Semaphores

Semaphores are event indicators that actively monitor the states of the primary and backup VPLS nodes. Primary semaphore (P-semaphore) and backup semaphore (B-semaphore) are dedicated loopback interfaces on an N-PE. EEM tracks the reachability of the B-semaphore on the primary N-PE and the reachability of the P-semaphore on the backup N-PE. Primary and backup N-PE states are synchronized via the advertisement of IP addresses of these loopback interfaces by the core IGP.

In each of the EEM based designs, semaphores play a major role in synchronizing the states between primary and backup N-PE to achieve redundancy at the chassis level. They facilitate a dual handshake mechanism between both N-PEs in the data center and ensure that the backup path activates only if the primary path fails, thus preventing an active-active state that would lead to a bridging loop. As long as the P-semaphore is active and is reachable by the backup node, the backup or the standby PW is in shut state. Therefore, there is only one PW active at any given time, which prevents layer 2 loops in the global topology.

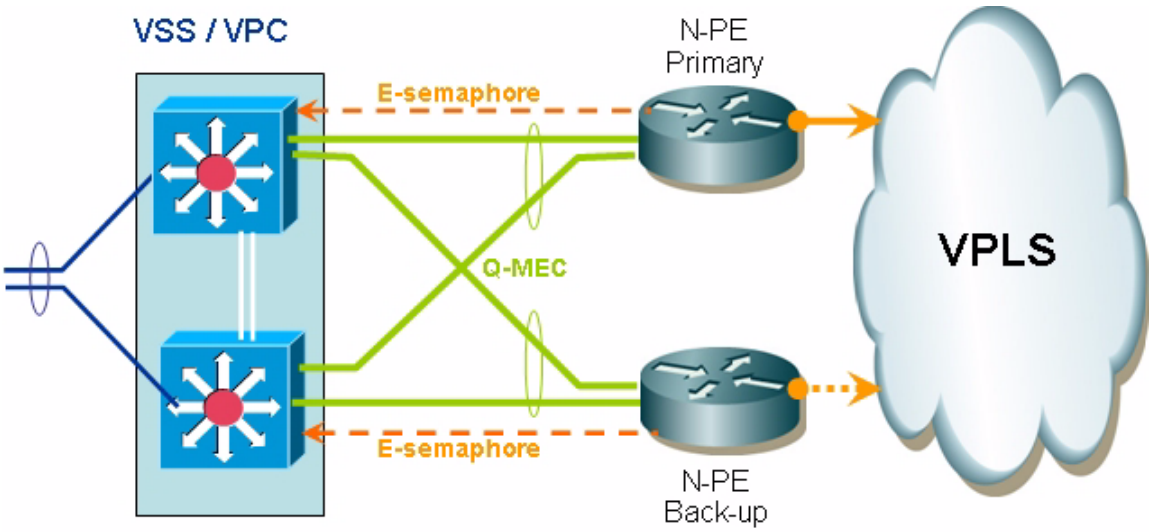
Overview

In this scalable H-VPLS DCI solution, MEC (VSS or Nexus vPC) in the aggregation layer is connected by using one EtherChannel toward each N-PE. This EEM based solution allows PWs on backup N-PEs also to be in UP state. This solution accelerates the activation of the backup path if the primary path fails. The backup PW is in UP state, but does not forward traffic. An EEM script ensures that one service instance within an EtherChannel is cross-connected toward only one multipoint VFI at any time, thus avoiding a loop in the topology.

As with all the EEM based deployment models, the PW topology is based on the split-horizon concept. All primary N-PE routers are fully meshed with the remote primary and backup N-PE routers. The backup N-PE routers have only pseudowires toward the remote primary N-PEs; there are no pseudowires configured between the backup N-PE routers.

Figure 6-1 illustrates H-VPLS with MEC using VSS/vPC in aggregation.

Figure 6-1 H-VPLS with VSS/vPC and MEC



The pseudowires on the primary and backup N-PEs are always in UP state and service instance is ATTACHED/DETACHED from the bridge-domain on the backup N-PE. The concept is to forward edge traffic to a null QinQ VLAN until the backup path needs to be activated, thus avoiding a Layer 2 loop in the global topology. If the primary path fails, EEM maps the edge traffic to a QinQ VLAN that is connected to VFI. A dummy edge-VLAN, for example 998, is configured solely to keep the VFI in UP state and to prevent the autostate function from automatically shutting down the VFI. In normal mode, which is under no failure condition, VLANs are associated with a null bridge-domain on the QinQ link that connects the backup N-PE to the aggregation switch.

Selective QinQ is configured on the N-PE side of the link connection to aggregation. This configuration allows the creation of several service instances to groom edge-VLAN. Each service instance is associated with a bridge-domain that is cross-connected to a VFI . The VFI uses a pseudowire to connect over the core toward the remote nodes. See the "Configuration Summary" section on page 6-3 for detailed information.

N-PE Routers: Hardware and Software

Table 6-2 shows the hardware and software required for N-PE nodes. Cisco 7600 routers were used as N-PEs for all the MST and EEM-based solutions that this document describes. In this solution, selective QinQ with two EVCs were configured using ES-20 modules facing the aggregation. Also, the aggregation switches must support EEM script which can be triggered on a specific syslog message or on the link state.

Table 6-1 Hardware and Software for N-PE Nodes

Hardware/Software	Cisco 7600 Router
Facing core	Interfaces on SIP or ES modules are required for connectivity toward VPLS core
Facing edge	ES module due to selective QinQ requirement in this solution
E-link	Interface on any WS-X67xx LAN or ES module; does not carry any traffic
Software	Cisco IOS version 12.2(33)SRC1

In addition, Enhanced Object Tracking is required to perform route watch of peer node semaphore.

Aggregation devices must support Multi-chassis EtherChannel (MEC) that allows EtherChannel to span two physical devices. This approach takes advantage of of VSS (Virtual Switching System) technology on Cisco Catalyst 6500 devices and Virtual Port Channel (vPC) on Cisco Nexus 7000 devices.

Configuration Summary

The following configuration from N-PE1 and N-PE2 routers highlight the framework of the UP/UP pseudowire solution.

On N-PE1:

```
vlan 2-61,201-260,998-999
!
vlan 3001
 name H-VPLS_Primary_core_VLAN
!
vlan 3004
 name H-VPLS_Backup_core_VLAN
!
l2 vfi VFI-Even manual
 vpn id 3002
 neighbor 10.76.90.22 encapsulation mpls
 neighbor 10.76.90.32 encapsulation mpls
!
l2 vfi VFI-Odd manual
 vpn id 3001
```

```
 neighbor 10.76.91.32 encapsulation mpls
 neighbor 10.76.91.31 encapsulation mpls
 neighbor 10.76.91.21 encapsulation mpls
 neighbor 10.76.91.22 encapsulation mpls
!
interface Vlan3001
 description Primary Core QinQ VLAN - used to transport Odd edge VLAN
 mtu 9216
 no ip address
 xconnect vfi VFI-Odd
!
interface Vlan3004
 description Backup Core QinQ VLAN - used to transport Even edge VLAN
 mtu 9216
 no ip address
 xconnect vfi VFI-Even

interface Port-channel31
 description used for QinQ ES20 card facing Aggregation (Multi-Etherchannel toward VSS)
 mtu 9216
 ip arp inspection limit none
 no ip address
 logging event bundle-status
 load-interval 30
 mls qos trust dscp
 spanning-tree portfast trunk
 service instance 998 ethernet
  description Dummy to hold Vlan 3004 up
  encapsulation dot1q 998
  bridge-domain 3004
 !
 service instance 999 ethernet
  description Dummy to hold Vlan 3001 up
  encapsulation dot1q 999
  bridge-domain 3001
 !
 service instance 3001 ethernet
  encapsulation dot1q
1,3,5,7,9,11,13,15,17,19,21,23,25,27,29,31,33,35,37,39,41,43,45,47,49,51,53,55,57,59,61,20
1,203,205,207,209,211,213,215,217,219,221,223,225,227,229,231,233,235,237,239,241,243,245,
247,249,251,253,255,257,259
  bridge-domain 3001
 !
 service instance 3004 ethernet
  encapsulation dot1q
2,4,6,8,10,12,14,16,18,20,22,24,26,28,30,32,34,36,38,40,42,44,46,48,50,52,54,56,58,60,202,
204,206,208,210,212,214,216,218,220,222,224,226,228,230,232,234,236,238,240,242,244,246,24
8,250,252,254,256,258,260
  bridge-domain 998

lon-n-pe1#sh cdp neigh
Capability Codes: R - Router, T - Trans Bridge, B - Source Route Bridge
                  S - Switch, H - Host, I - IGMP, r - Repeater, P - Phone

Device ID        Local Intrfce     Holdtme    Capability  Platform  Port ID
campus3-223sw8   Gig 1/2           156           S I      WS-C2950T Fas 0/2
lon-n-pe2        Ten 4/0/0         127         R S I      CISCO7604 Ten 4/0/0
lon-agg-1        Ten 2/0/1         135         R S I      WS-C6509- Ten 2/7/12
lon-agg-1        Ten 3/1           179         R S I      WS-C6509- Ten 1/7/6
lon-agg-1        Ten 2/0/0         138         R S I      WS-C6509- Ten 1/7/11
CRS1-mpls-p1     Ten 4/0/1         147           R        CRS-1     TenGigE0/0/0/0
lon-core1        Ten 3/2           161         R S I      WS-C6506  Ten 1/2
lon-n-pe1#
```

```
lon-n-pe1#sh mpls l2transport vc

Local intf     Local circuit              Dest address    VC ID      Status
-------------  -------------------------- --------------- ---------- ----------
VFI VFI-Odd    VFI                        10.76.70.21     3001       UP
VFI VFI-Odd    VFI                        10.76.70.22     3001       UP
VFI VFI-Even   VFI                        10.76.70.22     3002       UP
VFI VFI-Odd    VFI                        10.76.70.31     3001       UP
VFI VFI-Odd    VFI                        10.76.70.32     3001       UP
VFI VFI-Even   VFI                        10.76.70.32     3002       UP
lon-n-pe1#
```

On N-PE2:

```
vlan 2-61,201-260,998-999
!
vlan 3002
 name H-VPLS_Primary_core_VLAN
!
vlan 3003
 name H-VPLS_Backup_core_VLAN
!
l2 vfi VFI-Even manual
 vpn id 3002
 neighbor 10.76.90.21 encapsulation mpls
 neighbor 10.76.90.22 encapsulation mpls
 neighbor 10.76.90.31 encapsulation mpls
 neighbor 10.76.90.32 encapsulation mpls
!
l2 vfi VFI-Odd manual
 vpn id 3001
 neighbor 10.76.91.21 encapsulation mpls
 neighbor 10.76.91.31 encapsulation mpls
!
interface Vlan3002
 description Primary Core QinQ VLAN - used to transport Even edge VLAN
 mtu 9216
 no ip address
 xconnect vfi VFI-Even
!
interface Vlan3003
 description Backup Core QinQ VLAN - used to transport Odd edge VLAN
 mtu 9216
 no ip address
 xconnect vfi VFI-Odd

interface Port-channel32
 description used for QinQ ES20 card facing Aggregation (Multi-Etherchannel toward VSS)
 mtu 9216
 ip arp inspection limit none
 no ip address
 logging event link-status
 load-interval 30
 mls qos trust dscp
 spanning-tree portfast trunk
 service instance 998 ethernet
  description Dummy to hold Vlan 3002 up
  encapsulation dot1q 998
  bridge-domain 3002
 !
 service instance 999 ethernet
  description Dummy to hold Vlan 3003 up
  encapsulation dot1q 999
  bridge-domain 3003
```

```
 !
 service instance 3002 ethernet
  encapsulation dot1q
2,4,6,8,10,12,14,16,18,20,22,24,26,28,30,32,34,36,38,40,42,44,46,48,50,52,54,56,58,60,202,
204,206,208,210,212,214,216,218,220,222,224,226,228,230,232,234,236,238,240,242,244,246,24
8,250,252,254,256,258,260
  bridge-domain 3002
 !
 service instance 3003 ethernet
  encapsulation dot1q
1,3,5,7,9,11,13,15,17,19,21,23,25,27,29,31,33,35,37,39,41,43,45,47,49,51,53,55,57,59,61,20
1,203,205,207,209,211,213,215,217,219,221,223,225,227,229,231,233,235,237,239,241,243,245,
247,249,251,253,255,257,259
  bridge-domain 999
```

EEM scripts on the N-PE router alternatively position the even VLANs in non-forwarding bridge-domain 998 and the forwarding bridge-domain 3004:

```
! On N-PE1:
process-max-time 50
!
track timer ip route 1
!
track 10 ip route 10.76.80.12 255.255.255.255 reachability
 delay up 100
!
track 11 ip route 10.76.81.12 255.255.255.255 reachability
!
track 20 interface Port-channel31 line-protocol
!
track 25 list boolean or
 object 110
 object 112
 delay up 40
!
track 40 ip route 10.76.81.32 255.255.255.255 reachability
!
track 110 interface TenGigabitEthernet4/0/1 line-protocol
 delay down 5 up 60
!
track 112 interface TenGigabitEthernet4/0/0 line-protocol
!
event manager applet VPLS_EVEN-VLAN_P_semaphore-is-down
 event track 10 state down
 action 1.0 cli command "enable"
 action 2.0 cli command "conf t"
 action 3.0 cli command "interface port-channel 31"
 action 3.1 cli command "service instance 3004 ethernet"
 action 3.2 cli command "bridge-domain 3004"
 action 4.0 cli command "int lo80"
 action 4.1 cli command "no shut"
 action 9.0 syslog msg "Backup PW is active"
event manager applet VPLS_EVEN-VLAN_P_semaphore-is-up
 event track 10 state up
 action 1.0 cli command "enable"
 action 2.0 cli command "conf t"
 action 3.0 cli command "interface port-channel 31"
 action 3.1 cli command "service instance 3004 ethernet"
 action 3.2 cli command "bridge-domain 998"
 action 4.0 cli command "int lo80"
 action 4.1 cli command "shutdown"
 action 5.0 cli command "int Te3/1"
 action 5.1 cli command "shut"
 action 5.2 cli command "no shut"
```

```
 action 9.0 syslog msg "Backup PW is shutdown"
event manager applet VPLS_ODD-VLAN_B_semaphore-is-up
 event track 11 state up
 action 1.0 cli command "enable"
 action 2.0 cli command "conf t"
 action 4.0 cli command "interface port-channel 31"
 action 4.1 cli command "service instance 3001 ethernet"
 action 4.2 cli command "bridge-domain 999"
 action 9.0 syslog msg "Backup N-PE is Active, Force Primary in Standby"
event manager applet VPLS_ODD-VLAN_B_semaphore-is-down
 event track 11 state down
 action 1.0 cli command "enable"
 action 2.0 cli command "conf t"
 action 4.0 cli command "interface port-channel 31"
 action 4.1 cli command "service instance 3001 ethernet"
 action 4.2 cli command "bridge-domain 3001"
 action 9.0 syslog msg "Backup N-PE has become Standby, Primary runs Active"
event manager applet Track_Aggregation_link_failure
 event track 20 state down
 action 1.0 cli command "enable"
 action 2.0 cli command "conf t"
 action 3.0 cli command "int lo81"
 action 3.1 cli command "shutdown"
 action 4.0 cli command "interface port-channel 31"
 action 4.1 cli command "service instance 3001 ethernet"
 action 4.2 cli command "bridge-domain 999"
 action 9.0 syslog msg "Aggregation link is failing, Force Primary in Standby"
event manager applet Track_Aggregation_link_recovery
 event track 20 state up
 action 1.0 cli command "enable"
 action 2.0 cli command "conf t"
 action 4.0 cli command "int lo81"
 action 4.1 cli command "no shutdown"
 action 9.0 syslog msg "Aggregation link as recover, Primary requests to become active"
event manager applet Backup-node_ready
 event track 110 state up
 action 1.0 cli command "enable"
 action 2.0 cli command "conf t"
 action 3.0 cli command "track 10 ip route 10.76.80.12 255.255.255.255 reachability"
 action 3.1 cli command "delay up 100"
 action 9.0 syslog msg "Backup node is operational"
event manager applet Backup-node_not_ready
 event track 110 state down
 action 1.0 cli command "enable"
 action 4.0 cli command "configure t"
 action 5.0 cli command "no track 10"
 action 5.1 cli command "interface port-channel 31"
 action 5.2 cli command "service instance 3004 ethernet"
 action 5.3 cli command "bridge-domain 998"
 action 5.4 cli command "int lo80"
 action 5.5 cli command "shutdown"
 action 9.0 syslog msg "Backup node not operational"
event manager applet MPLS_Interfaces_Down
 event track 25 state down
 action 1.0 cli command "enable"
 action 2.0 cli command "config t"
 action 4.0 cli command "interface port-channel 31"
 action 4.1 cli command "shut"
 action 9.0 syslog msg "Both MPLS Interfaces are down. Shutting down ES20 link"
event manager applet MPLS_Either_Interface_up
 event track 25 state up
 action 1.0 cli command "enable"
 action 2.0 cli command "config t"
 action 3.0 cli command "interface port-channel 31"
```

```
 action 4.0 cli command "no shut"
 action 9.0 syslog msg "One MPLS Int is up. Unshutting ES20 link"
event manager applet SJ-Odd-VLAN_B-Semaphor-up
 event track 40 state up
 action 1.0 cli command "enable"
 action 2.0 cli command "clear mac-address-table dynamic"
event manager applet SJ-Odd-VLAN_B-Semaphor-down
 event track 40 state down
 action 1.0 cli command "enable"
 action 2.0 cli command "clear mac-address-table dynamic"
!
```

Convergence Tests

The traffic profile outlined in the "Traffic Profile" section on page 4-6 was used to determine end-to-end convergence for unidirectional voice, unicast, and multicast traffic. Links and nodes were failed to simulate network failures.

Table 6-2 shows results of various node and link failures. Convergence numbers (max and min) are in seconds.

Table 6-2 Convergence Numbers for Link and Node Failures for Scalable H-VPLS DCI Solution using Cisco 7600 Routers (EEM Option 5c)

				Traffic Direction			
				LON -> SJ		SJ -> LON	
Failure Type	Action	VLAN	Traffic Type	Max	Min	Max	Min
Node Failure							
Reload Agg-1	Reload	Odd VLAN	Voice	0.04	0.02	0.02	0.02
			Unicast	0.01	0.00	0.00	0.00
			Multicast	0.44	0.01	0.01	0.01
		Even VLAN	Voice	0.02	0.02	0.02	0.02
			Unicast	0.00	0.00	0.00	0.00
			Multicast	0.43	0.42	0.01	0.01
	Restore	Odd VLAN	Voice	0.26	0.24	0.00	0.00
			Unicast	0.24	0.24	0.00	0.00
			Multicast	0.25	0.00	0.64	0.00
		Even VLAN	Voice	0.24	0.24	0.00	0.00
			Unicast	0.24	0.24	0.00	0.00
			Multicast	0.25	0.00	0.14	0.00

Table 6-2 Convergence Numbers for Link and Node Failures for Scalable H-VPLS DCI Solution using Cisco 7600 Routers (EEM Option 5c) (continued)

				Traffic Direction			
				LON -> SJ		SJ -> LON	
Failure Type	Action	VLAN	Traffic Type	Max	Min	Max	Min
Reload Agg-2	Reload	Odd VLAN	Voice	0.02	0.02	0.02	0.02
			Unicast	0.00	0.00	0.02	0.02
			Multicast	0.21	0.02	0.08	0.03
		Even VLAN	Voice	0.00	0.02	0.00	0.00
			Unicast	0.00	0.00	0.02	0.02
			Multicast	0.22	0.01	0.07	0.02
	Restore	Odd VLAN	Voice	0.06	0.02	0.02	0.02
			Unicast	0.03	0.03	0.02	0.02
			Multicast	0.22	0.02	0.07	0.02
		Even VLAN	Voice	0.04	0.02	0.00	0.00
			Unicast	0.01	0.01	0.02	0.02
			Multicast	0.22	0.01	0.06	0.01
Agg Forced Switchover	Reload	Odd VLAN	Voice	0.02	0.02	0.02	0.02
			Unicast	0.00	0.00	0.02	0.02
			Multicast	0.48	0.38	0.13	0.02
		Even VLAN	Voice	0.02	0.02	0.04	0.04
			Unicast	0.00	0.00	0.03	0.03
			Multicast	0.40	0.01	0.15	0.04
	Restore	Odd VLAN	Voice	0.12	0.02	0.02	0.02
			Unicast	0.09	0.09	0.00	0.00
			Multicast	0.10	0.00	0.00	0.00
		Even VLAN	Voice	0.14	0.08	0.02	0.02
			Unicast	0.09	0.09	0.00	0.00
			Multicast	0.54	0.00	0.00	0.00

Table 6-2 Convergence Numbers for Link and Node Failures for Scalable H-VPLS DCI Solution using Cisco 7600 Routers (EEM Option 5c) (continued)

				Traffic Direction			
				LON -> SJ		SJ -> LON	
Failure Type	Action	VLAN	Traffic Type	Max	Min	Max	Min
Reload N-PE1	Reload	Odd VLAN	Voice	0.98	0.02	1.00	1.00
			Unicast	0.97	0.96	0.99	0.99
			Multicast	0.98	0.96	0.99	0.99
		Even VLAN	Voice	0.02	0.02	0.02	0.02
			Unicast	0.00	0.00	0.00	0.00
			Multicast	0.00	0.00	0.01	0.01
	Restore	Odd VLAN	Voice	1.25	1.20	1.20	1.20
			Unicast	1.22	1.21	1.21	1.21
			Multicast	2.44	1.26	1.22	1.22
		Even VLAN	Voice	0.02	0.02	0.00	0.00
			Unicast	0.00	0.00	0.00	0.00
			Multicast	0.02	0.00	0.01	0.01
Reload N-PE2	Reload	Odd VLAN	Voice	0.04	0.02	0.00	0.00
			Unicast	0.02	0.01	0.00	0.00
			Multicast	0.04	0.00	0.00	0.00
		Even VLAN	Voice	0.52	0.48	0.52	0.52
			Unicast	0.50	0.50	0.52	0.52
			Multicast	2.59	0.53	0.52	0.52
	Restore	Odd VLAN	Voice	0.14	0.02	0.02	0.02
			Unicast	0.08	0.05	0.00	0.00
			Multicast	0.12	0.02	0.00	0.00
		Even VLAN	Voice	0.42	0.38	0.42	0.42
			Unicast	0.40	0.39	0.40	0.40
			Multicast	2.17	0.46	0.39	0.39

Table 6-2 Convergence Numbers for Link and Node Failures for Scalable H-VPLS DCI Solution using Cisco 7600 Routers (EEM Option 5c) (continued)

Failure Type	Action	VLAN	Traffic Type	Traffic Direction			
				LON -> SJ		SJ -> LON	
				Max	Min	Max	Min
Link Failure							
Fail VSL Control Link	Shut	Odd VLAN	Voice	0.04	0.02	0.02	0.02
			Unicast	0.01	0.01	0.00	0.00
			Multicast	0.03	0.00	0.00	0.00
		Even VLAN	Voice	0.00	0.02	0.02	0.02
			Unicast	0.00	0.00	0.00	0.00
			Multicast	0.00	0.00	0.00	0.00
	No shut	Odd VLAN	Voice	0.02	0.00	0.00	0.00
			Unicast	0.00	0.00	0.00	0.00
			Multicast	0.01	0.00	0.00	0.00
		Even VLAN	Voice	0.02	0.00	0.00	0.00
			Unicast	0.00	0.00	0.00	0.00
			Multicast	0.02	0.00	0.00	0.00
Fail VSL	Shut	Odd VLAN	Voice	0.04	0.02	0.02	0.02
			Unicast	0.01	0.01	0.00	0.00
			Multicast	0.03	0.00	0.00	0.00
		Even VLAN	Voice	0.00	0.02	0.02	0.02
			Unicast	0.00	0.00	0.00	0.00
			Multicast	0.00	0.00	0.00	0.00
	No shut	Odd VLAN	Voice	0.02	0.00	0.00	0.00
			Unicast	0.00	0.00	0.00	0.00
			Multicast	0.01	0.00	0.00	0.00
		Even VLAN	Voice	0.02	0.00	0.00	0.00
			Unicast	0.00	0.00	0.00	0.00
			Multicast	0.02	0.00	0.00	0.00

Table 6-2 Convergence Numbers for Link and Node Failures for Scalable H-VPLS DCI Solution using Cisco 7600 Routers (EEM Option 5c) (continued)

				Traffic Direction			
				LON -> SJ		SJ -> LON	
Failure Type	Action	VLAN	Traffic Type	Max	Min	Max	Min
Fail Link between N-PE1 and Agg-1	Shut	Odd VLAN	Voice	0.44	0.26	0.00	0.00
			Unicast	0.37	0.27	0.00	0.00
			Multicast	0.41	0.01	0.00	0.00
		Even VLAN	Voice	0.02	0.00	0.00	0.00
			Unicast	0.00	0.00	0.00	0.00
			Multicast	0.00	0.00	0.00	0.00
	No shut	Odd VLAN	Voice	0.24	0.06	0.00	0.00
			Unicast	0.17	0.07	0.00	0.00
			Multicast	0.26	0.01	0.01	0.01
		Even VLAN	Voice	0.02	0.00	0.00	0.00
			Unicast	0.00	0.00	0.00	0.00
			Multicast	0.00	0.00	0.01	0.01
Fail Link between N-PE1 and Agg-2	Shut	Odd VLAN	Voice	0.02	0.02	0.10	0.10
			Unicast	0.01	0.00	0.09	0.09
			Multicast	0.37	0.00	0.09	0.09
		Even VLAN	Voice	0.02	0.02	0.02	0.02
			Unicast	0.00	0.00	0.00	0.00
			Multicast	0.01	0.00	0.02	0.00
	No shut	Odd VLAN	Voice	0.04	0.00	0.02	0.02
			Unicast	0.01	0.01	0.00	0.00
			Multicast	0.03	0.01	0.01	0.01
		Even VLAN	Voice	0.00	0.02	0.00	0.00
			Unicast	0.00	0.00	0.00	0.00
			Multicast	0.01	0.00	0.00	0.00

Table 6-2 Convergence Numbers for Link and Node Failures for Scalable H-VPLS DCI Solution using Cisco 7600 Routers (EEM Option 5c) (continued)

				Traffic Direction			
				LON -> SJ		SJ -> LON	
Failure Type	Action	VLAN	Traffic Type	Max	Min	Max	Min
Fail Link between N-PE2 and Agg-1	Shut	Odd VLAN	Voice	0.04	0.02	0.02	0.02
			Unicast	0.01	0.01	0.00	0.00
			Multicast	0.02	0.00	0.01	0.01
		Even VLAN	Voice	0.44	0.26	0.02	0.02
			Unicast	0.38	0.28	0.00	0.00
			Multicast	0.38	0.00	0.01	0.01
	No shut	Odd VLAN	Voice	0.02	0.02	0.00	0.00
			Unicast	0.01	0.00	0.00	0.00
			Multicast	0.02	0.01	0.01	0.01
		Even VLAN	Voice	0.38	0.06	0.00	0.00
			Unicast	0.28	0.06	0.00	0.00
			Multicast	0.36	0.00	0.01	0.01
Fail Link between Access1 and Agg-1	Shut	Odd VLAN	Voice	0.02	0.02	0.00	0.00
			Unicast	0.01	0.00	0.00	0.00
			Multicast	0.01	0.00	0.01	0.01
		Even VLAN	Voice	0.02	0.00	0.10	0.10
			Unicast	0.00	0.00	0.09	0.09
			Multicast	0.59	0.50	0.10	0.10
	No shut	Odd VLAN	Voice	0.02	0.02	0.00	0.00
			Unicast	0.00	0.00	0.00	0.00
			Multicast	0.02	0.01	0.01	0.01
		Even VLAN	Voice	0.02	0.00	0.00	0.00
			Unicast	0.00	0.00	0.00	0.00
			Multicast	0.02	0.01	0.01	0.01

Table 6-2 Convergence Numbers for Link and Node Failures for Scalable H-VPLS DCI Solution using Cisco 7600 Routers (EEM Option 5c) (continued)

				Traffic Direction			
				LON -> SJ		SJ -> LON	
Failure Type	Action	VLAN	Traffic Type	Max	Min	Max	Min
Fail Link between Access1 and Agg-2	Shut	Odd VLAN	Voice	0.04	0.02	0.02	0.02
			Unicast	0.01	0.00	0.00	0.00
			Multicast	0.02	0.00	0.01	0.01
		Even VLAN	Voice	0.02	0.02	0.02	0.02
			Unicast	0.01	0.00	0.00	0.00
			Multicast	0.02	0.00	0.01	0.01
	No shut	Odd VLAN	Voice	0.04	0.02	0.02	0.02
			Unicast	0.02	0.02	0.00	0.00
			Multicast	0.03	0.01	0.01	0.01
		Even VLAN	Voice	0.04	0.02	0.02	0.02
			Unicast	0.02	0.02	0.00	0.00
			Multicast	0.02	0.00	0.01	0.01
Fail Link between Access2 and Agg-1	Shut	Odd VLAN	Voice	0.10	0.02	0.00	0.00
			Unicast	0.03	0.01	0.00	0.00
			Multicast	0.06	0.00	0.01	0.00
		Even VLAN	Voice	0.02	0.00	0.00	0.00
			Unicast	0.00	0.00	0.00	0.00
			Multicast	0.03	0.01	0.01	0.00
	No shut	Odd VLAN	Voice	0.04	0.02	0.02	0.02
			Unicast	0.01	0.01	0.00	0.00
			Multicast	0.02	0.00	0.01	0.01
		Even VLAN	Voice	0.02	0.02	0.02	0.02
			Unicast	0.01	0.01	0.00	0.00
			Multicast	0.01	0.00	0.01	0.01

Table 6-2 Convergence Numbers for Link and Node Failures for Scalable H-VPLS DCI Solution using Cisco 7600 Routers (EEM Option 5c) (continued)

Failure Type	Action	VLAN	Traffic Type	Traffic Direction			
				LON -> SJ		SJ -> LON	
				Max	Min	Max	Min
Fail Link between Access2 and Agg-2	Shut	Odd VLAN	Voice	0.02	0.02	0.58	0.44
			Unicast	0.00	0.00	0.53	0.44
			Multicast	0.01	0.00	0.54	0.39
		Even VLAN	Voice	0.02	0.02	0.00	0.00
			Unicast	0.00	0.00	0.00	0.00
			Multicast	0.01	0.00	0.01	0.01
	No shut	Odd VLAN	Voice	0.00	0.02	0.28	0.06
			Unicast	0.00	0.00	0.18	0.02
			Multicast	0.01	0.00	0.29	0.03
		Even VLAN	Voice	0.02	0.02	0.02	0.02
			Unicast	0.00	0.00	0.00	0.00
			Multicast	0.01	0.00	0.00	0.00
Fail WAN link facing core on N-PE1	Shut	Odd VLAN	Voice	0.16	0.02	0.02	0.02
			Unicast	0.06	0.04	0.00	0.00
			Multicast	0.10	0.01	0.03	0.01
		Even VLAN	Voice	0.02	0.02	0.42	0.42
			Unicast	0.00	0.00	0.41	0.41
			Multicast	0.02	0.00	0.42	0.35
	No shut	Odd VLAN	Voice	0.02	0.02	0.02	0.02
			Unicast	0.00	0.00	0.00	0.00
			Multicast	0.01	0.01	0.00	0.00
		Even VLAN	Voice	0.02	0.02	0.00	0.00
			Unicast	0.00	0.00	0.02	0.02
			Multicast	0.01	0.00	0.03	0.01

Table 6-2 Convergence Numbers for Link and Node Failures for Scalable H-VPLS DCI Solution using Cisco 7600 Routers (EEM Option 5c) (continued)

				Traffic Direction			
				LON -> SJ		SJ -> LON	
Failure Type	Action	VLAN	Traffic Type	Max	Min	Max	Min
Fail WAN link facing core on N-PE2	Shut	Odd VLAN	Voice	0.24	0.20	0.06	0.06
			Unicast	0.21	0.21	0.06	0.05
			Multicast	0.23	0.20	0.06	0.06
		Even VLAN	Voice	0.02	0.02	0.00	0.00
			Unicast	0.00	0.00	0.00	0.00
			Multicast	0.00	0.00	0.00	0.00
	No shut	Odd VLAN	Voice	0.04	0.02	0.02	0.02
			Unicast	0.03	0.03	0.00	0.00
			Multicast	0.04	0.02	0.01	0.01
		Even VLAN	Voice	0.02	0.02	0.02	0.02
			Unicast	0.00	0.00	0.00	0.00
			Multicast	0.01	0.00	0.01	0.01
Fail both WAN links on N-PE1	Shut	Odd VLAN	Voice	0.02	0.02	0.00	0.00
			Unicast	0.00	0.00	0.00	0.00
			Multicast	0.01	0.00	0.01	0.01
		Even VLAN	Voice	0.26	0.24	0.02	0.02
			Unicast	0.25	0.25	0.02	0.02
			Multicast	0.26	0.25	0.03	0.03
	No shut	Odd VLAN	Voice	0.02	0.02	0.02	0.02
			Unicast	0.00	0.00	0.00	0.00
			Multicast	0.01	0.00	0.00	0.00
		Even VLAN	Voice	0.02	0.02	0.02	0.02
			Unicast	0.01	0.01	0.00	0.00
			Multicast	0.01	0.00	0.00	0.00

Table 6-2 Convergence Numbers for Link and Node Failures for Scalable H-VPLS DCI Solution using Cisco 7600 Routers (EEM Option 5c) (continued)

				Traffic Direction			
				LON -> SJ		SJ -> LON	
Failure Type	Action	VLAN	Traffic Type	Max	Min	Max	Min
Fail both WAN links on N-PE2	Shut	Odd VLAN	Voice	0.54	0.02	0.46	0.46
			Unicast	0.51	0.51	0.44	0.44
			Multicast	2.23	0.66	0.45	0.45
		Even VLAN	Voice	0.02	0.02	0.02	0.02
			Unicast	0.00	0.00	0.00	0.00
			Multicast	0.01	0.00	0.01	0.01
	No shut	Odd VLAN	Voice	1.36	1.31	1.32	1.32
			Unicast	1.33	1.32	1.32	1.32
			Multicast	2.44	1.92	1.33	1.33
		Even VLAN	Voice	0.02	0.02	0.00	0.00
			Unicast	0.00	0.00	0.00	0.00
			Multicast	0.01	0.00	0.01	0.01
Clear dynamic MAC address table on aggregation switches	Clear	Odd VLAN	Voice	0.06	0.02	0.02	0.02
			Unicast	0.01	0.01	0.00	0.00
			Multicast	0.04	0.00	0.00	0.00
		Even VLAN	Voice	0.71	0.67	0.54	0.54
			Unicast	0.69	0.69	0.53	0.53
			Multicast	2.50	1.09	0.54	0.52
Clear IP routing table on both N-PEs	Clear	Odd VLAN	Voice	0.04	0.02	0.00	0.00
			Unicast	0.02	0.01	0.00	0.00
			Multicast	0.05	0.01	0.00	0.00
		Even VLAN	Voice	0.74	0.70	0.72	0.72
			Unicast	0.71	0.71	0.71	0.71
			Multicast	2.05	0.81	0.71	0.71
Clear dynamic MAC address table on both N-PEs	Clear	Odd VLAN	Voice	0.02	0.00	0.00	0.00
			Unicast	0.00	0.00	0.00	0.00
			Multicast	0.01	0.00	0.00	0.00
		Even VLAN	Voice	0.02	0.00	0.00	0.00
			Unicast	0.00	0.00	0.00	0.00
			Multicast	0.02	0.00	0.00	0.00

CHAPTER 7

VPLSoGRE DCI Solution using Cisco Catalyst 6500 (VPLSoGRE Option 4a)

Typically, EoMPLS and VPLS technologies have required MPLS switching core for Layer 2 extension over long distances. When the core network is not dedicated for L2VPN extension, migrating an existing IP core to MPLS can be complex. Also, MPLS and its related technologies require expertise for deployment and maintenance. To ease the adoption of Layer 2 extension, Cisco Systems offers solutions to encapsulate EoMPLS or VPLS traffic over GRE tunnels. These solutions allow transporting all Layer 2 traffic across data centers over the existing IP core. EoMPLS / VPLS over GRE also is known as Any Transport over MPLS over GRE (AToMoGRE) or Layer 2 Virtual Private Network over Generic Routing Encapsulation (L2VPNoGRE).

GRE-based deployment models focus on using L2VPN over an IP core network, which eliminates MPLS switching in the core. These deployment models provide Layer 2 extension over a WAN and take advantage of Layer 3 fast convergence and EEM to interconnect geographically dispersed data centers.

Cisco Catalyst 6500 series switches with a SIP-400 module running Cisco IOS Software Release 12.2(33)SXI or later support multipoint bridging using VPLSoGRE over an IP network with STP isolation.

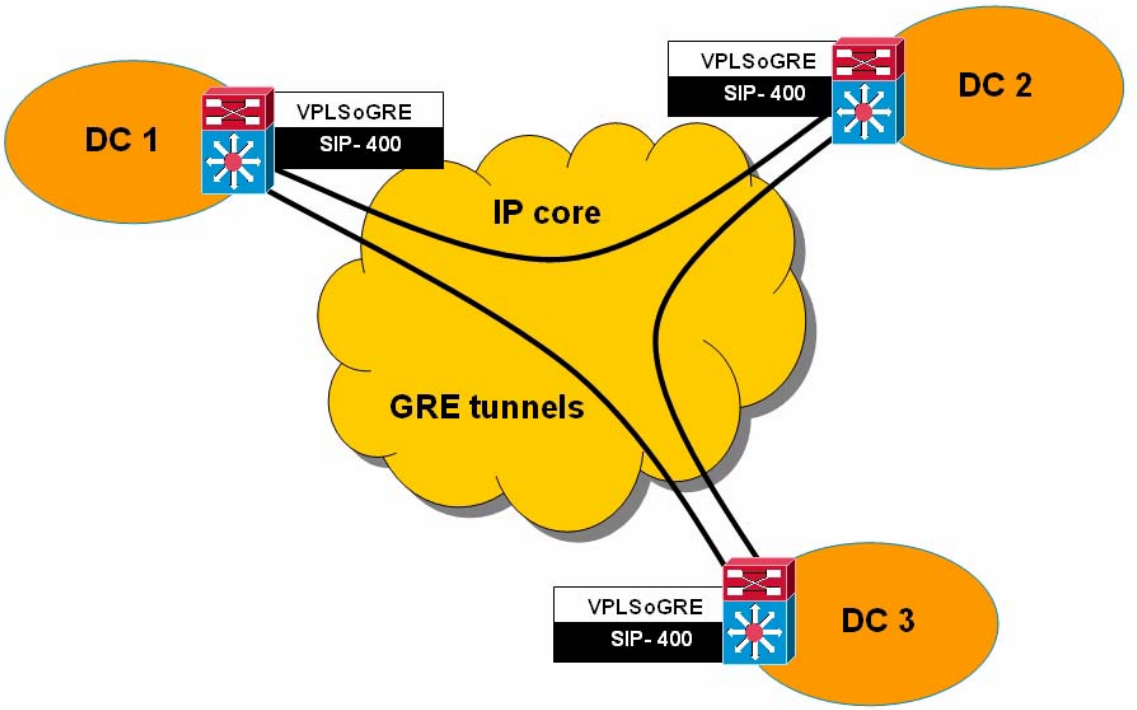
This chapter includes these topics:

Overview

In VPLSoGRE, IP GRE tunnels are established between the core routers within each data center. MPLS LDP sessions are established through these GRE tunnels, which provide MPLS connectivity. MPLS connectivity over GRE tunnels is known as MPLSoGRE. VPLS virtual circuits are then established over MPLSoGRE tunnels, which provide multipoint connectivity over an IP network.

Figure 7-1 shows VPLS connectivity across an IP network.

Figure 7-1 VPLSoGRE using Cisco Catalyst 6500



Configuration Summary

This section describes the key configuration differences between VPLSoGRE and EEM option 5c.

- Create GRE tunnels between N-PEs and enable MPLS on these GRE tunnels. Ensure that the tunnel destination is reachable via a Gigabit Ethernet interface on the SIP-400 module. The following shows the configuration for N-PE1:

```
lon-n-pe1-cat6500#
!
interface Loopback1
 description tunnel source for VPLSoGRE
 ip address 99.1.1.11 255.255.255.255
!
interface Loopback2
 description tunnel source for VPLSoGRE
 ip address 99.1.1.13 255.255.255.255
!
interface Loopback3
 description tunnel source for VPLSoGRE
 ip address 99.1.1.15 255.255.255.255
!
interface Loopback4
 description tunnel source for VPLSoGRE
 ip address 99.1.1.17 255.255.255.255
!
interface Tunnel1121
 description to sin-n-pe1 Tunnel2111
 ip address 200.1.1.1 255.255.255.252
 ip ospf network point-to-point
```

```
 mpls ip
 tunnel source 99.1.1.15
 tunnel destination 99.1.1.21
!
interface Tunnel1122
 description to sin-n-pe2 tunn2211
 ip address 200.1.2.1 255.255.255.252
 ip ospf network point-to-point
 mpls ip
 tunnel source 99.1.1.17
 tunnel destination 99.1.1.22
!
interface Tunnel1131
 description to sj-n-pe1 Tunnel3111
 ip address 200.1.3.1 255.255.255.252
 ip ospf network point-to-point
 mpls ip
 tunnel source 99.1.1.11
 tunnel destination 99.1.1.31
!
interface Tunnel1132
 description to sj-n-pe2 Tunnel3211
 ip address 200.1.4.1 255.255.255.252
 ip ospf network point-to-point
 mpls ip
 tunnel source 99.1.1.13
 tunnel destination 99.1.1.32
```

- MPLS LDP neighbors should be reachable via GRE tunnels. Configure static routes to reach the LDP neighbors via the tunnels configured in step 1. The following shows the configuration for N-PE1:

```
lon-n-pe1-cat6500#
!
! Tunnels for LDP peering with N-PEs in remote data centers
ip route 10.76.70.21 255.255.255.255 Tunnel1121
ip route 10.76.70.22 255.255.255.255 Tunnel1122
ip route 10.76.70.31 255.255.255.255 Tunnel1131
ip route 10.76.70.32 255.255.255.255 Tunnel1132
!
! Tunnels to enable backup PWs for even VLANs to N-PE2's in remote data centers
ip route 10.76.90.22 255.255.255.255 Tunnel1122
ip route 10.76.90.32 255.255.255.255 Tunnel1132
!
! Tunnels to enable primary PWs for odd VLANs on N-PE1's in remote data centers
ip route 10.76.91.21 255.255.255.255 Tunnel1121
ip route 10.76.91.31 255.255.255.255 Tunnel1131
!
! Tunnels to enable backup PWs for odd VLANs on N-PE2's in remote data centers
ip route 10.76.91.22 255.255.255.255 Tunnel1122
ip route 10.76.91.32 255.255.255.255 Tunnel1132
```

- Verify that OSPF neighbors and LDP peers are established via these GRE tunnels:

```
lon-n-pe1-cat6500#sh ip route 99.1.1.31

Routing entry for 99.1.1.31/32
  Known via "ospf 1", distance 110, metric 14, type intra area
  Last update from 192.168.41.12 on GigabitEthernet3/0/0, 00:05:18 ago
  Routing Descriptor Blocks:
  * 192.168.41.12, from 31.31.31.31, 00:05:18 ago, via GigabitEthernet3/0/0
      Route metric is 14, traffic share count is 1

lon-n-pe1-cat6500#show ip route 10.76.70.31
```

```
Routing entry for 10.76.70.31/32
  Known via "static", distance 1, metric 0 (connected)
  Routing Descriptor Blocks:
  * directly connected, via Tunnel1131
      Route metric is 0, traffic share count is 1

lon-n-pe1-cat6500#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
99.1.1.38         0   FULL/  -        00:00:33    200.1.4.2       Tunnel1132
99.1.1.37         0   FULL/  -        00:00:33    200.1.3.2       Tunnel1131
99.1.1.28         0   FULL/  -        00:00:32    200.1.2.2       Tunnel1122
99.1.1.27         0   FULL/  -        00:00:33    200.1.1.2       Tunnel1121
116.5.200.77      0   FULL/  -        00:00:37    192.168.41.12   GigabitEthernet3/0/0
12.12.12.12       0   FULL/  -        00:00:39    192.168.13.2    GigabitEthernet3/0/1
13.13.13.13       0   FULL/  -        00:00:33    10.11.11.2      GigabitEthernet2/8

lon-n-pe1-cat6500#show cdp neighbors
Capability Codes: R - Router, T - Trans Bridge, B - Source Route Bridge
                  S - Switch, H - Host, I - IGMP, r - Repeater, P - Phone

Device ID        Local Intrfce     Holdtme    Capability  Platform  Port ID
lon-agg-1        Gig 2/7           179             R S I  WS-C6509- Gig 2/3
lon-core1        Gig 2/8           159             R S I  WS-C6506  Gig 3/8
mpls-p1          Gig 3/0/0         140             R S I  WS-C6506  Gig 5/1
lon-n-pe2-cat6500
                 Gig 3/0/1         155             R S I  WS-C6506- Gig 3/0/1
lon-n-pe2-cat6500
                 Gig 2/2           146             R S I  WS-C6506- Gig 2/2
lon-n-pe2-cat6500
                 Gig 2/1           133             R S I  WS-C6506- Gig 2/1

lon-n-pe1-cat6500#
```

- For one VFI per group of VLANs to be transported across data centers, create QinQ VLANs on both N-PEs. Configure QinQ using dot1q-tunnel on the Q-links between N-PEs and aggregation switches.

Note The Cisco Catalyst 6500 does not support selective QinQ. Two physical links were provisioned between N-PEs and aggregation switches to load-balance traffic between odd and even VLANs.

On N-PE1

```
vlan 4001
name H-VPLS_Primary_core_VLAN_for_odd_vlans
vlan 4004
name H-VPLS_Backup_core_VLAN_for_even_vlans
!
interface GigabitEthernet2/5
 description QinQ link for Odd Vlans -
connected to LON-Agg-1
 switchport
 switchport access vlan 4001
 switchport trunk allowed vlan 1,3,5,7,9,11
..
 switchport mode dot1q-tunnel
 mtu 9216
 spanning-tree bpdufilter enable
!
interface GigabitEthernet2/6
 description QonQ link for Even Vlans
-connected to LON-Agg-1
 switchport
 switchport access vlan 4004
 switchport trunk allowed vlan
2,4,6,8,10,12 ..
 switchport mode dot1q-tunnel
 mtu 9216
 spanning-tree bpdufilter enable
!
end
```

On N-PE2

```
vlan 4004
name
H-VPLS_Primary_core_VLAN_for_even_vlans
vlan 4001
name H-VPLS_Backup_core_VLAN_for_odd_vlans
!
interface GigabitEthernet2/5
 description QinQ link for Even Vlans
connected to LON-Agg-2
 switchport
 switchport access vlan 4004
 switchport trunk allowed vlan 2,4,6,8,10
..
 switchport mode dot1q-tunnel
 mtu 9216
 spanning-tree bpdufilter enable
!
interface GigabitEthernet2/6
 description QinQ link for Odd Vlans
connected to LON-Agg-2.
 switchport
 switchport access vlan 4001
 switchport trunk allowed vlan 1,3,5,7,9,11
..
 switchport mode dot1q-tunnel
 mtu 9216
 spanning-tree bpdufilter enable
!
end
```

On Agg-1

```
interface GigabitEthernet2/2
 description Odd-Vlans QinQ Link to
lon-n-pe1-cat6500 g2/5
 switchport
 switchport trunk encapsulation dot1q
 switchport trunk allowed vlan 1,3,5,7,9,11
..
 switchport mode trunk
 mtu 9216
 spanning-tree portfast trunk
 spanning-tree bpdufilter enable
!
interface GigabitEthernet2/4
 description Even Vlans QinQ link to
lon-n-pe1-cat6500 g2/6
 switchport
 switchport trunk encapsulation dot1q
 switchport trunk allowed vlan
2,4,6,8,10,12 ..
 switchport mode trunk
 mtu 9216
 spanning-tree portfast trunk
 spanning-tree bpdufilter enable
end
```

On Agg-2

```
interface GigabitEthernet2/2
 description Even-Vlans QinQ Link to
lon-n-pe2-cat6500 gi2/5
 switchport
 switchport trunk encapsulation dot1q
 switchport trunk allowed vlan
2,4,6,8,10,12 ..
 switchport mode trunk
 mtu 9216
 spanning-tree portfast trunk
 spanning-tree bpdufilter enable
!
interface GigabitEthernet2/4
 description Odd-Vlans QiQ Link to
lon-n-pe2-cat6500 g2/6
 switchport
 switchport trunk encapsulation dot1q
 switchport trunk allowed vlan 1,3,5,7,9,11
..
 switchport mode trunk
 mtu 9216
 spanning-tree portfast trunk
 spanning-tree bpdufilter enable
end
```

Create one VFI per QinQ VLAN to be connected to other data centers and create one switched virtual interface (SVI) per QinQ VLAN as shown here for N-PE1 and N-PE2:

On N-PE1

```
lon-n-pe1-cat6500#
!
l2 vfi VFI-4001 manual
 vpn id 4001
 neighbor 10.76.91.31 encapsulation mpls
 neighbor 10.76.91.22 encapsulation mpls
 neighbor 10.76.91.21 encapsulation mpls
 neighbor 10.76.91.32 encapsulation mpls
!
l2 vfi VFI-4004 manual
 vpn id 4004
 neighbor 10.76.90.22 encapsulation mpls
 neighbor 10.76.90.32 encapsulation mpls

lon-n-pe1-cat6500#
...
!
mpls ldp neighbor 10.76.70.12 targeted ldp
mpls ldp neighbor 10.76.70.21 targeted ldp
mpls ldp neighbor 10.76.70.22 targeted ldp
mpls ldp neighbor 10.76.70.31 targeted ldp
mpls ldp neighbor 10.76.70.32 targeted ldp
mpls ldp tcp pak-priority
mpls ldp session protection
no mpls ldp advertise-labels
mpls ldp advertise-labels for 76
mpls label protocol ldp
xconnect logging pseudowire status
!
access-list 76 permit 10.76.0.0 0.0.255.255
!
lon-n-pe1-cat6500#

lon-n-pe1-cat6500#
!
interface Vlan4001
 description Primary Core QinQ VLAN - used to transport Odd edge VLAN
 mtu 9216
 no ip address
 xconnect vfi VFI-4001
!
interface Vlan4004
 description Backup Core QinQ VLAN - used to transport Even edge VLAN
 mtu 9216
 no ip address
 xconnect vfi VFI-4004

lon-n-pe1-cat6500#show mpls l2 vc

Local intf     Local circuit              Dest address    VC ID      Status
-------------  -------------------------- --------------- ---------- ----------
VFI VFI-4004   VFI                        10.76.90.22     4004       DOWN
VFI VFI-4004   VFI                        10.76.90.32     4004       DOWN
VFI VFI-4001   VFI                        10.76.91.21     4001       UP
VFI VFI-4001   VFI                        10.76.91.22     4001       DOWN
VFI VFI-4001   VFI                        10.76.91.31     4001       UP
VFI VFI-4001   VFI                        10.76.91.32     4001       DOWN

lon-n-pe1-cat6500#
```

On N-PE2

```
lon-n-pe2-cat6500#
!
l2 vfi VFI-4001 manual
 vpn id 4001
 neighbor 10.76.91.31 encapsulation mpls
 neighbor 10.76.91.21 encapsulation mpls
!
l2 vfi VFI-4004 manual
 vpn id 4004
 neighbor 10.76.90.22 encapsulation mpls
 neighbor 10.76.90.21 encapsulation mpls
 neighbor 10.76.90.32 encapsulation mpls
 neighbor 10.76.90.31 encapsulation mpls

lon-n-pe2-cat6500#
...
!
mpls ldp neighbor 10.76.70.11 targeted ldp
mpls ldp neighbor 10.76.70.21 targeted ldp
mpls ldp neighbor 10.76.70.22 targeted ldp
mpls ldp neighbor 10.76.70.31 targeted ldp
mpls ldp neighbor 10.76.70.32 targeted ldp
mpls ldp tcp pak-priority
mpls ldp session protection
no mpls ldp advertise-labels
mpls ldp advertise-labels for 76
mpls label protocol ldp
xconnect logging pseudowire status
!
access-list 76 permit 10.76.0.0 0.0.255.255
!
lon-n-pe2-cat6500#

lon-n-pe2-cat6500#
!
interface Vlan4004
 description Primary Core QinQ VLAN - used to transport Even edge VLAN
 mtu 9216
 no ip address
 xconnect vfi VFI-4004
!
interface Vlan4001
description Backup Core QinQ VLAN - used to transport odd edge VLAN
mtu 9216
 no ip address
 xconnect vfi VFI-4001

lon-n-pe2-cat6500#show mpls l2 vc

Local intf     Local circuit              Dest address    VC ID      Status
-------------  -------------------------- --------------- ---------- ----------
VFI VFI-4004   VFI                        10.76.90.21     4004       DOWN
VFI VFI-4004   VFI                        10.76.90.22     4004       UP
VFI VFI-4004   VFI                        10.76.90.31     4004       DOWN
VFI VFI-4004   VFI                        10.76.90.32     4004       UP
VFI VFI-4001   VFI                        10.76.91.21     4001       DOWN
VFI VFI-4001   VFI                        10.76.91.31     4001       DOWN

lon-n-pe2-cat6500#
```

Convergence Tests

The traffic profile outlined in the "Traffic Profile" section on page 4-6 was used to determine end-to-end convergence for unidirectional voice, unicast, and multicast traffic. Links and nodes were failed to simulate network failures.

Table 7-1 shows results of various node and link failures for the VPLSoGRE with N-PE redundancy using EEM semaphore solution. Convergence numbers (max and min) are in seconds

Table 7-1 Convergence Numbers for VPLSoGRE DCI Solution using Cisco Catalyst 6500

				Traffic Direction			
				LON -> SJ		SJ -> LON	
Failure Type	**Action**	**VLAN**	**Traffic Type**	**Max**	**Min**	**Max**	**Min**
Reload N-PE1	Reload	Odd VLAN	Voice	2.46	0.02	2.62	2.62
			Unicast	2.43	2.43	2.62	2.62
		Even VLAN	Voice	0.02	0.02	0.02	0.02
			Unicast	0.00	0.00	0.00	0.00
	Restore	Odd VLAN	Voice	0.90	0.88	0.88	0.88
			Unicast	0.89	0.89	0.87	0.87
		Even VLAN	Voice	0.00	0.00	0.00	0.00
			Unicast	0.00	0.00	0.00	0.00
Reload N-PE2	Reload	Odd VLAN	Voice	0.02	0.00	0.02	0.02
			Unicast	0.00	0.00	0.00	0.00
		Even VLAN	Voice	1.40	1.38	1.36	1.36
			Unicast	1.38	1.38	1.36	1.36
	Restore	Odd VLAN	Voice	0.02	0.02	0.02	0.02
			Unicast	0.00	0.00	0.00	0.00
		Even VLAN	Voice	0.58	0.56	0.55	0.55
			Unicast	0.57	0.57	0.55	0.55
Reload Agg-1	Reload	Odd VLAN	Voice	5.56	5.54	3.58	3.58
			Unicast	5.55	5.55	3.58	3.58
		Even VLAN	Voice	0.02	0.02	0.00	0.00
			Unicast	0.06	0.00	0.05	0.01
	Restore	Odd VLAN	Voice	0.62	0.02	0.86	0.64
			Unicast	0.61	0.61	0.86	0.64
		Even VLAN	Voice	0.00	0.00	0.00	0.00
			Unicast	0.00	0.00	0.00	0.00

Table 7-1 Convergence Numbers for VPLSoGRE DCI Solution using Cisco Catalyst 6500 (continued)

				Traffic Direction			
				LON -> SJ		SJ -> LON	
Failure Type	**Action**	**VLAN**	**Traffic Type**	**Max**	**Min**	**Max**	**Min**
Reload Agg-2	Reload	Odd VLAN	Voice	0.02	0.02	0.00	0.00
			Unicast	0.00	0.00	0.00	0.00
		Even VLAN	Voice	2.14	2.12	2.12	2.12
			Unicast	2.13	2.13	2.13	2.13
	Restore	Odd VLAN	Voice	0.00	0.00	0.00	0.00
			Unicast	0.00	0.00	0.00	0.00
		Even VLAN	Voice	1.18	1.10	1.50	1.50
			Unicast	1.17	1.12	1.50	1.12
Fail L2 link between N-PE1 and Agg-1	Shut	Odd VLAN	Voice	2.68	2.65	2.64	2.62
			Unicast	2.68	2.68	2.64	2.61
		Even VLAN	Voice	0.02	0.02	0.00	0.00
			Unicast	0.00	0.00	0.00	0.00
	No shut	Odd VLAN	Voice	1.44	1.44	1.44	1.44
			Unicast	1.44	1.44	1.42	1.42
		Even VLAN	Voice	0.02	0.02	0.02	0.02
			Unicast	0.00	0.00	0.00	0.00
Fail L2 link between N-PE2 and Agg-2	Shut	Odd VLAN	Voice	0.00	0.00	0.02	0.02
			Unicast	0.00	0.00	0.00	0.00
		Even VLAN	Voice	2.26	2.24	2.30	2.30
			Unicast	2.26	2.26	2.28	2.27
	No shut	Odd VLAN	Voice	0.02	0.02	0.02	0.02
			Unicast	0.00	0.00	0.00	0.00
		Even VLAN	Voice	1.10	1.08	1.10	1.10
			Unicast	1.09	1.09	1.07	1.07
Fail L2 link between Agg-1 and Agg-2	Shut	Odd VLAN	Voice	0.02	0.02	0.02	0.02
			Unicast	0.00	0.00	0.00	0.00
		Even VLAN	Voice	0.02	0.02	0.02	0.02
			Unicast	0.00	0.00	0.00	0.00
	No shut	Odd VLAN	Voice	0.02	0.02	0.00	0.00
			Unicast	0.00	0.00	0.00	0.00
		Even VLAN	Voice	0.02	0.00	0.00	0.00
			Unicast	0.00	0.00	0.00	0.00

Table 7-1 Convergence Numbers for VPLSoGRE DCI Solution using Cisco Catalyst 6500 (continued)

				Traffic Direction			
				LON -> SJ		SJ -> LON	
Failure Type	**Action**	**VLAN**	**Traffic Type**	**Max**	**Min**	**Max**	**Min**
Fail WAN link facing core on N-PE1	Shut	Odd VLAN	Voice	1.18	1.14	0.00	0.00
			Unicast	1.16	1.16	0.00	0.00
		Even VLAN	Voice	0.00	0.00	0.00	0.00
			Unicast	0.00	0.00	0.00	0.00
	No shut	Odd VLAN	Voice	0.00	0.00	0.00	0.00
			Unicast	0.00	0.00	0.00	0.00
		Even VLAN	Voice	0.02	0.00	0.00	0.00
			Unicast	0.00	0.00	0.00	0.00
Fail WAN link facing core on N-PE2	Shut	Odd VLAN	Voice	0.00	0.00	0.00	0.00
			Unicast	0.03	0.00	0.00	0.00
		Even VLAN	Voice	1.02	1.00	0.00	0.00
			Unicast	1.00	1.00	0.00	0.00
	No shut	Odd VLAN	Voice	0.00	0.00	0.02	0.02
			Unicast	0.00	0.00	0.00	0.00
		Even VLAN	Voice	0.02	0.02	0.02	0.02
			Unicast	0.00	0.00	0.00	0.00
Fail both WAN links on N-PE1	Shut	Odd VLAN	Voice	1.76	1.74	1.84	1.84
			Unicast	1.74	1.74	1.80	1.80
		Even VLAN	Voice	0.02	0.02	0.04	0.04
			Unicast	0.00	0.00	0.00	0.00
	No shut	Odd VLAN	Voice	0.50	0.48	0.52	0.52
			Unicast	0.48	0.47	0.48	0.47
		Even VLAN	Voice	0.02	0.02	0.04	0.04
			Unicast	0.00	0.00	0.00	0.00
Fail both WAN links on N-PE2	Shut	Odd VLAN	Voice	0.02	0.02	0.04	0.04
			Unicast	0.00	0.00	0.00	0.00
		Even VLAN	Voice	1.39	1.36	1.64	1.64
			Unicast	1.37	1.37	1.60	1.60
	No shut	Odd VLAN	Voice	0.02	0.02	0.02	0.02
			Unicast	0.00	0.00	0.00	0.00
		Even VLAN	Voice	0.40	0.36	0.42	0.42
			Unicast	0.38	0.38	0.41	0.41

Table 7-1 Convergence Numbers for VPLSoGRE DCI Solution using Cisco Catalyst 6500 (continued)

				Traffic Direction			
				LON -> SJ		SJ -> LON	
Failure Type	**Action**	**VLAN**	**Traffic Type**	**Max**	**Min**	**Max**	**Min**
Clear entire routing table on both N-PEs	Clear	Odd VLAN	Voice	5.02	4.98	4.98	4.98
			Unicast	4.99	4.98	4.96	4.96
		Even VLAN	Voice	0.02	0.02	0.02	0.02
			Unicast	0.00	0.00	0.00	0.00
Clear dynamic MAC address table on both N-PEs	Clear	Odd VLAN	Voice	0.02	0.02	0.00	0.00
			Unicast	0.00	0.00	0.00	0.00
		Even VLAN	Voice	0.00	0.00	0.00	0.00
			Unicast	0.00	0.00	0.00	0.00

Cluster Server Tests

Table 7-2 shows event logs from the event viewer of Microsoft cluster server. Event logs were captured from the event viewer of Microsoft cluster server. The logs are in the reverse order, showing the last event, first. It is best to view the timestamps while analyzing these logs.

Table 10-2Event Logs for the VPLSoGRE with N-PE Redundancy Using EEM Semaphore Solution

Table 7-2 Event Logs for VPLSoGRE DCI Solution using Cisco Catalyst 6500

Test Case	Time (Seconds)	Event Logs with Timestamps from Microsoft Server			
Establish L2 Connectivity between Microsoft Server Nodes	No Convergence	1/12/2009	12:44:21 PM	CAMP3-SERVER3	Cluster service successfully joined the server cluster CLUSTER-MNS
		1/12/2009	12:44:13 PM	CAMP3-SERVER2	The interface for cluster node 'CAMP3-SERVER3' on network 'private (1)' is operational (up). The node can communicate with all other available cluster nodes on the network.
		1/12/2009	12:44:12 PM	CAMP3-SERVER2	The interface for cluster node 'CAMP3-SERVER3' on network 'public' is operational (up). The node can communicate with all other available cluster nodes on the network.
		1/12/2009	12:44:11 PM	CAMP3-SERVER3	The node (re)established communication with cluster node 'CAMP3-SERVER1' on network 'public'
		1/12/2009	12:44:11 PM	CAMP3-SERVER3	The node (re)established communication with cluster node 'CAMP3-SERVER1' on network 'private (1)'.
		1/12/2009	12:44:11 PM	CAMP3-SERVER3	The node (re)established communication with cluster node 'CAMP3-SERVER2' on network 'public'
		1/12/2009	12:44:11 PM	CAMP3-SERVER3	The node (re)established communication with cluster node 'CAMP3-SERVER2' on network 'private(1)'
		1/12/2009	12:44:10 PM	CAMP3-SERVER2	The node (re)established communication with cluster node 'CAMP3-SERVER3' on network 'private (1)'.
		1/12/2009	12:44:10 PM	CAMP3-SERVER2	The node (re)established communication with cluster node 'CAMP3-SERVER3' on network 'public'.
		1/12/2009	12:44:10 PM	CAMP3-SERVER1	The node (re)established communication with cluster node 'CAMP3-SERVER3' on network 'public'.
		1/12/2009	12:44:10 PM	CAMP3-SERVER1	The node (re)established communication with cluster node 'CAMP3-SERVER3' on network 'private (1)'.

Table 7-2 Event Logs for VPLSoGRE DCI Solution using Cisco Catalyst 6500 (continued)

Test Case	Time (Seconds)	Event Logs with Timestamps from Microsoft Server			
Shut Down Both N-PEs in a Data Center	119	1/8/2009	5:34:00 PM	CAMP3-SERVER2	The Cluster Service brought the Resource Group "ClusterGroup" online.
		1/8/2009	5:32:25 PM	CAMP3-SERVER2	The Cluster Service is attempting to bring online the Resource Group "ClusterGroup."
		1/8/2009	5:32:25 PM	CAMP3-SERVER2	Cluster node CAMP3-SERVER3 was removed from the active server cluster membership. Cluster service may have been stopped on the node, the node may have failed, or the node may have lost communication with the other active server cluster nodes.
		1/8/2009	5:32:01 PM	CAMP3-SERVER1	The node lost communication with cluster node "CAMP3-SERVER3" on network "private(1)."
		1/8/2009	5:32:01 PM	CAMP3-SERVER1	The node lost communication with cluster node "CAMP3-SERVER3" on network "public."
Power Off Access Switch	160	1/8/2009	5:04:07 PM	CAMP3-SERVER2	The Cluster Service brought the Resource Group "ClusterGroup" online.
		1/8/2009	5:01:50 PM	CAMP3-SERVER2	The Cluster Service is attempting to bring online the Resource Group "ClusterGroup."
		1/8/2009	5:01:50 PM	CAMP3-SERVER2	Cluster node CAMP3-SERVER3 was removed from the active server cluster membership. Cluster service may have been stopped on the node, the node may have failed, or the node may have lost communication with the other active server cluster nodes.
		1/8/2009	5:01:28 PM	CAMP3-SERVER2	The node lost communication with cluster node "CAMP3-SERVER3" on network "public."
		1/8/2009	5:01:29 PM	CAMP3-SERVER2	The node lost communication with cluster node "CAMP3-SERVER3" on network "private(1)."
		1/8/2009	5:01:27 PM	CAMP3-SERVER1	The node lost communication with cluster node "CAMP3-SERVER3" on network "public."
		1/8/2009	5:01:28 PM	CAMP3-SERVER1	The node lost communication with cluster node "CAMP3-SERVER3" on network "private (1)."

Table 7-2 Event Logs for VPLSoGRE DCI Solution using Cisco Catalyst 6500 (continued)

Test Case	Time (Seconds)	Event Logs with Timestamps from Microsoft Server			
Shut Down Active Node	103	1/8/2009	6:25:40 PM	CAMP3-SERVER2	The Cluster Service brought the Resource Group “ClusterGroup” online.
		1/8/2009	6:24:36 PM	CAMP3-SERVER3	Cluster service is attempting to failover the Cluster Resource Group “ClusterGroup” from node CAMP3-SERVER3 to node CAMP3-SERVER2.
		1/8/2009	6:24:17 PM	CAMP3-SERVER2	The Cluster Service is attempting to bring online the Resource Group “ClusterGroup.”
		1/8/2009	6:23:56 PM	CAMP3-SERVER2	The node lost communication with cluster node “CAMP3-SERVER3” on network “public.”
		1/8/2009	6:23:57 PM	CAMP3-SERVER1	The node lost communication with cluster node “CAMP3-SERVER3” on network “public.”
Private VLAN NPE Reload	4	1/8/2009	5:51:27 PM	CAMP3-SERVER3	The node (re)established communication with cluster node “CAMP3-SERVER1” on network “private(1).”
		1/8/2009	5:51:27 PM	CAMP3-SERVER1	The node (re)established communication with cluster node “CAMP3-SERVER3” on network “private(1).”
		1/8/2009	5:51:27 PM	CAMP3-SERVER2	The node (re)established communication with cluster node “CAMP3-SERVER3” on network “private(1).”
		1/8/2009	5:51:26 PM	CAMP3-SERVER3	The node (re)established communication with cluster node “CAMP3-SERVER2” on network “private(1).”
		1/8/2009	5:51:24 PM	CAMP3-SERVER3	The node lost communication with cluster node “CAMP3-SERVER1” on network “private(1).”
		1/8/2009	5:51:24 PM	CAMP3-SERVER3	The node lost communication with cluster node “CAMP3-SERVER2” on network “private(1).”
		1/8/2009	5:51:24 PM	CAMP3-SERVER1	The node lost communication with cluster node “CAMP3-SERVER3” on network “private(1).”
		1/8/2009	5:51:23 PM	CAMP3-SERVER2	The node lost communication with cluster node “CAMP3-SERVER3” on network '“private(1).”

Table 7-2 Event Logs for VPLSoGRE DCI Solution using Cisco Catalyst 6500 (continued)

Test Case	Time (Seconds)	Event Logs with Timestamps from Microsoft Server			
Unplug Active Server	104	1/8/2009	6:25:40 PM	CAMP3-SERVER2	The Cluster Service brought the Resource Group "ClusterGroup" online.
		1/8/2009	6:24:36 PM	CAMP3-SERVER2	Cluster service is attempting to failover the Cluster Resource Group "ClusterGroup" from node CAMP3-SERVER3 to node CAMP3-SERVER2.
		1/8/2009	6:24:17 PM	CAMP3-SERVER2	The Cluster Service is attempting to bring online the Resource Group "ClusterGroup."
		1/8/2009	6:24:05 PM	CAMP3-SERVER2	The interface for cluster node "CAMP3-SERVER3" on network "public" failed. If the condition persists, check the cable connecting the node to the network. Next, check for hardware or software errors in node's network adapter. Finally, check for failures in any network components to which the node is connected such as hubs, switches, or bridges.
		1/8/2009	6:23:56 PM	CAMP3-SERVER2	The node lost communication with cluster node "CAMP3-SERVER3" on network "public."