Cisco IOS® MPLS
Virtual Private LAN Service (VPLS)
Technical Deployment Overview

Enabling Innovative Services
Agenda

• Introduction
• VPLS Technical Overview
• VPLS Architectures
• Deployment Scenarios
• Summary
Introduction
Metro Ethernet: Emerging Multiservice Access Opportunity

- Videoconferencing
- Hosted Telephony
- Business Continuance
- Unified Messaging
- Directory Services
- Mobile Access
- Secure E-Mail
- Web Hosting
- Storage Hosting

SP Metro Ethernet Network

- Residential CPE
- Remote Office 1
- Remote Office 2
- Ethernet-Connected Branch
- Remote Worker
- Subscriber
- Regional Headquarters
- Multitenant Unit (MTU) Basement Access Device

100 Mbps Ethernet

- Ethernet, SONET/SDH, RPR, DWDM/CWDM, MPLS/IP

Internet

PSTN

Web Hosting

Directory Services

Hosted Telephony

Business Continuance

Unified Messaging

Secure E-Mail

Web Hosting

Directory Services

Hosted Telephony

Business Continuance

Unified Messaging
Metro Ethernet: Business Drivers*

Service Provider
- Revenue Growth
  - New, Differentiated Services
  - Expanded Enterprise Penetration
- Cost Efficiencies
  - Network Convergence
  - Flexible Bandwidth Provisioning
  - Best Value for Increased Bandwidth

Enterprise
- Business Demands
  - Increased Productivity
  - Peer-to-Peer Applications
- Service Expectations
  - Scalable Bandwidth (from 1Mbps to 1Gbps)
  - Customized Services
  - Multipoint Connectivity
  - Operational Simplicity

The Ethernet Advantage

- Connectionless, IP aware-operation
- Distributed intelligence
- Inexpensive, scalable bandwidth options
- L2 VPNs
  - Point-to-point
  - Multipoint
- L3 VPNs
  - High speed transport enables innovative services and applications
    - Storage, IP video conferencing
- Value added services
  - IP Telephony
  - IP video conferencing
  - High speed, Business class Internet
  - Managed Security
  - Managed Storage
• Delivers Ethernet-based multipoint L2 VPN service
• Enhances L2 VPN scalability (geographic sites & no. of customers)
• Leverages existing SP MPLS Core
• Supports operational speeds of GB to 10 GB
• On track for IETF standardization: Draft Lasserre-Kompella
• Uses familiar Ethernet user network interface
VPLS Technical Overview
Virtual Private LAN Services (VPLS)

- VPLS defines an architecture that delivers Ethernet Multipoint Services (EMS) over an MPLS network.
- VPLS operation emulates an IEEE Ethernet bridge.
- Two VPLS drafts in existence:
  - Draft-ietf-l2vpn-vpls-ldp-01
  - Draft-ietf-l2vpn-vpls-bgp-01
  - Cisco’s Implementation

**VPLS & H-VPLS**

- **VPLS**
  - Direct Attachment
    - Single Flat Hierarchy
    - MPLS to the Edge

- **H-VPLS**
  - Two Tier Hierarchy
  - MPLS or Ethernet Edge
  - MPLS Core

**Diagram:**
- U-PE
- N-PE
- PE-POP
- PE-rs
- MTU-s
- PW
- GE
- Ethernet Edge
- Point-to-Point or Ring
- MPLS Core
- MPLS Edge

Network Diagrams showing connectivity and components.
VPLS Components

Legend
- CE - Customer Edge Device
- n-PE - network facing-Provider Edge
- VSI - Virtual Switch Instance
- PW - Pseudo-Wire
- Tunnel LSP - Tunnel Label Switch Path that provides PW transport

Directed LDP session between participating PEs
Full Mesh of PWs between VSIs
VPN & VPLS Desirable Characteristics

- Auto-discovery of VPN membership
  Reduces VPN configuration and errors associated with configuration

- Signaling of connections between PE devices associated with a VPN

- Forwarding of frames
  AToM uses Interface based forwarding
  VPLS uses IEEE 802.1q Ethernet Bridging techniques

- Loop prevention
  MPLS Core will use a full mesh of PWs and “split-horizon” forwarding
  H-VPLS edge domain may use IEEE 802.1s Spanning Tree, RPR, or SONET Protection
Cisco VPLS Building Blocks

A Comprehensive Solution: Robust, Flexible, Scalable, Manageable
VPLS Auto-discovery & Signaling

- Draft-ietf-l2vpn-vpls-ldp-01 does not mandate an auto-discovery protocol
  Can be BGP, Radius, DNS, AD based
- Draft-ietf-l2vpn-vpls-ldp-01 describes using Targeted LDP for Label exchange and PW signaling
  PWs signal other information such as Attachment Circuit State, Sequencing information, etc
  Cisco IOS supports Targeted LDP for AToM and Virtual Private LAN Services
VPLS: Layer 2 Forwarding Instance Requirements

Flooding / Forwarding:
• MAC table instances per customer and per customer VLAN (L2-VRF idea) for each PE
• VSI will participate in learning, forwarding process
• Uses Ethernet VC-Type defined in pwe3-control-protocol-xx

Address Learning / Aging:
• Self Learn Source MAC to port associations
• Refresh MAC timers with incoming frames
• New additional MAC TLV to LDP

Loop Prevention:
• Create partial or full-mesh of EoMPLS VCs per VPLS
• Use “split horizon” concepts to prevent loops
• Announce EoMPLS VPLS VC tunnels
VPLS Overview: Flooding & Forwarding

- Flooding (Broadcast, Multicast, Unknown Unicast)
- Dynamic learning of MAC addresses on PHY and VCs
- Forwarding
  - Physical port
  - Virtual circuit
VPLS Overview: MAC Address Learning

- Broadcast, Multicast, and unknown Unicast are learned via the received label associations
- Two LSPs associated with an VC (Tx & Rx)
- If inbound or outbound LSP is down, then the entire circuit is considered down
VPLS Overview: MAC Address Withdrawal

- Primary link failure triggers notification message
- PE removes any locally learned MAC addresses and sends LDP address withdrawal (RFC3036) to remote PEs in VPLS
- New MAC TLV is used
VPLS Overview:
Data Forwarding in Ethernet Edge H-VPLS

Topology 2: L2VPN, Ethernet Virtual Circuit Service (Distributed PE)

- Customer frames / VLANs are forwarded only
- Service delimiters are local to PE
  - .1q tags, VC-labels, RFC1483, etc.
- Allows for hierarchical design options
VPLS Overview: VPLS Loop Prevention

- LDP between VPLS members
- EoMPLS PW to each peer

- Each PE has a P2MP view of all other PEs it sees itself as a root bridge, split horizon loop protection
- Full mesh topology obviates STP requirements in the service provider network
- Customer STP is transparent to the SP / customer BPDUs are forwarded transparently
- Traffic received from the network will not be forwarded back to the network
VPLS Overview: VPLS Learning

- **Unqualified**
  - Single port assigned for all customer VLANs
  - Single broadcast domain for all customer VLANs
  - Single MAC address space (no overlap!)

- **Qualified**
  - Each VLAN has its own VPLS instance
  - A VLAN has its own broadcast space and MAC address space
  - Customer MAC addresses MAY overlap
  - One FIB per customer VLAN
  - Broadcast domain limited to VLAN scope
VPLS Architectures
VPLS & H-VPLS

- **VPLS**
  
  Single Flat Hierarchy
  
  MPLS to the Edge

- **H-VPLS**
  
  Two Tier Hierarchy
  
  MPLS or Ethernet Edge
  
  MPLS Core
VPLS Overview:
Illustrated – Direct Attachment (Flat)

MAC 1 103 / 301
Address            Tx / Rx
MAC 2 203 / 302
MAC 3 E0/1

MAC 1 102 / 201
Address            Tx / Rx
MAC 2 E1/1
MAC 3 303 / 203

PE1, VCID 100
Address            Tx / Rx
MAC 1 E0/0
MAC 2 201 / 102
MAC 3 301 / 103

CE1
PE1

CE2
MAC 2

PE2

PE3

CE3
MAC 3

MAC 1

MPLS Network

- Port or P-VLAN based membership in the VSI in PEs
- All packet replication occurs on PEs
Create a L2 VFI with a full mesh of participating VPLS PE nodes

VPLS: Configuration Example
PE → PE

1.1.1.1 / 32 PE-1

PE-1

PE-2 2.2.2.2 / 32

PE-3 3.3.3.3 / 32

MPLS Network

I2 vfi PE1-VPLS-A manual
vpn id 100
neighbor 2.2.2.2 encapsulation mpls
neighbor 3.3.3.3 encapsulation mpls
!
Interface loopback 0
ip address 1.1.1.1 255.255.255.255

I2 vfi PE3-VPLS-A manual
vpn id 100
neighbor 1.1.1.1 encapsulation mpls
neighbor 2.2.2.2 encapsulation mpls
!
Interface loopback 0
ip address 3.3.3.3 255.255.255.255
VPLS: Configuration Example

**PE → CE**

**PE-1**
- Interface fastethernet0/0
  - switchport
  - switchport mode dot1qtunnel
  - switchport access vlan 100

**CE1**
- Interface fastethernet0/0
  - switchport
  - switchport mode dot1qtunnel
  - switchport access vlan 100
  - xconnect vfi PE1-VPLS-A

**PE-2**
- Interface fastethernet0/0
  - switchport
  - switchport mode dot1qtunnel
  - switchport access vlan 100

**CE1**
- Interface fastethernet0/0
  - switchport
  - switchport mode dot1qtunnel
  - switchport access vlan 100
  - xconnect vfi PE2-VPLS-A

**PE-3**
- Interface fastethernet0/1
  - switchport
  - switchport mode dot1qtunnel
  - switchport access vlan 100

**CE1**
- Interface fastethernet0/1
  - switchport
  - switchport mode dot1qtunnel
  - switchport access vlan 100
  - xconnect vfi PE3-VPLS-A

**MPLS Network**

- VLAN 100
  - State active
### VPLS: Sample Output

#### VPLS1#show mpls l2 vc

<table>
<thead>
<tr>
<th>Local intf</th>
<th>Local circuit</th>
<th>Dest address</th>
<th>VC ID</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vi1</td>
<td>VFI</td>
<td>22.22.22.22</td>
<td>100</td>
<td>DOWN</td>
</tr>
<tr>
<td>Vi1</td>
<td>VFI</td>
<td>22.22.22.22</td>
<td>200</td>
<td>UP</td>
</tr>
<tr>
<td>Vi1</td>
<td>VFI</td>
<td>33.33.33.33</td>
<td>100</td>
<td>UP</td>
</tr>
<tr>
<td>Vi1</td>
<td>VFI</td>
<td>44.44.44.44</td>
<td>100</td>
<td>UP</td>
</tr>
<tr>
<td>Vi1</td>
<td>VFI</td>
<td>44.44.44.44</td>
<td>200</td>
<td>UP</td>
</tr>
</tbody>
</table>

#### PE-1#show vfi PE1-VPLS-A

**WORD VFI name**

**PE-1#show vfi PE1-VPLS-A**

VFI name: VPLSA, state: up

Local attachment circuits: Vlan100

Neighbors connected via pseudowires: 2.2.2.2 3.3.3.3
VPLS: Sample Output (Cont)

VPLS1#show mpls l2transport vc vcid 200 detail
Local interface: Vi1 up, line protocol up, VFI
Destination address: 22.22.22.22, VC ID: 200, VC status: up
  Tunnel label: imp-null, next hop point2point
  Output interface: PO2/1, imposed label stack {16}
  MPLS VC labels: local 18, remote 16
  Group ID: local 200, remote 200
  MTU: local 1500, remote 1500
  Remote interface description:
  Sequencing: receive disabled, send disabled
  VC statistics:
    packet totals: receive 0, send 0
    byte totals: receive 0, send 0
    packet drops: receive 0, send 0
  .....cont...for all VPLS PWs sharing a common VC ID

Use common AToM “show” commands
VPLS Architecture: Characteristics - Direct Attachment (Flat)

Overview:
- Okay for small customer implementations
- Simple provisioning
- Full mesh of directed LDP sessions required between participating PEs
- VLAN and Port level support (no QinQ)

Drawbacks:
- No hierarchical scalability
- Scaling issues:
  - PE packet replication
  - Full mesh causes classic - $N^2 / 2$ concerns
VPLS & H-VPLS

- **VPLS**
  - Single Flat Hierarchy
  - MPLS to the Edge

- **H-VPLS**
  - Two Tier Hierarchy
  - MPLS or Ethernet Edge
  - MPLS Core
VPLS Architecture: Architecture – Ethernet Edge H-VPLS

VPLS functioning between participating PEs

Dot1q Tunneling

Customer applied VLAN Tags for WG isolation (CE-VLAN)

Customer applied VLAN Tags for Customer isolation (PE-VLAN)

Layer 2 framing:

- 802.3
- .1Q
- QinQ
- Full Mesh LDP

Data

Ether Type

SA

DA

102

Ether Type

SA

DA

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VPLS Architecture: Architecture – Ethernet Edge H-VPLS

3550s

CE1

CE2a

CE2b

u-PE

802.3 .1Q

QinQ

Full Mesh LDP

7600s

n-PE

CE4

SP applied VLAN Tags for Customer isolation (PE-VLAN)

Customer applied VLAN Tags for WG isolation (CE-VLAN)

VPLS functioning between participating PEs

Data 401 Ether Type SA DA 25 47
VPLS Architecture: Architecture – MPLS Edge H-VPLS

Architecture – MPLS Edge H-VPLS

MPLS Network

CE1

Full Mesh LDP

AToM or L2TPv3

L2VPN Router

PSN

7600s

PE-PoP

PE-PoP

CE4

CE2a

CE2b

Customer applied VLAN Tags for WG isolation (CE-VLAN)

SP applied VC-Label & Tunnel LSP Label

VPLS functioning between participating PEs

Data 401 Ether Type 0x0 1000 SA 33 DA
VPLS Architecture: Architecture – MPLS Edge H-VPLS

- CE1
- CE2a
- CE2b
- CE4
- u-PE
- n-PE
- 802.3
- 7600s
- L2VPN Router
- AToM or L2TPv3
- Full Mesh LDP
- PSN

Customer applied VLAN Tags for WG isolation (CE-VLAN)

Data 401 Ether Type SA DA 25 47

PAW – VC & Tunnel labels are imposed

VPLS functioning between participating PEs

AToM or L2TPv3 Header is now removed.
VPLS Architecture: Characteristics – H-VPLS

Benefits:
- Best for larger scale deployment
- Reduction in packet replication and signaling overhead on PEs
- Full mesh for core tier (Hub) only
- Attachment VCs “virtual switch ports” effected through Layer 2 tunneling mechanisms (AToM, L2TPv3, QinQ)
- Expansion affects new nodes only (no re-configuring existing PEs)

Drawbacks:
- More complicated provisioning
- MPLS Edge H-VPLS requires MPLS to u-PE
  - Complex operational support
  - Complex network design
  - Expensive Hardware support
VPLS Deployment Scenarios
VPLS Deployment: SMB Connectivity

- New Layer 2 multipoint service offering
- Enterprise maintains routing and administrative autonomy
- Layer 3 protocol independence
- Full mesh between customer sites
VPLS Deployment: Layer 2 Multipoint Transit Provider

- SP-As PEs appear back to back and packets are forwarded
- No LDP or Route exchange with transit provider
- Provides optimal traffic path to carrier’s PE
Summary
Phase I – Architecture Support

Service Definitions Supported

Topology 1: L2VPN, Transparent LAN Service (Non-distributed PE)

Topology 2: L2VPN, Ethernet Virtual Circuit Service (Distributed PE)
• IETF VPLS is a part of an overall Ethernet solution
  IEEE 802.1ad Provider Bridges
  ITU SG12 Ethernet OAM – L2TRACE & L2PING
  MEF Ethernet E-LMI, E-UNI and Ethernet Service Definitions
Cisco VPLS Summary

- Fills L2 multipoint VPN gap between customer requirements and existing L2VPN point-to-point technologies
- Expands the service portfolio for existing MPLS networks
- Has wide-industry support for LDP-based VPLS implementations & wide coordination between Ethernet focused standards bodies (IETF, IEEE, MEF, ITU)
- Cisco is actively driving development of standards and liaising between Forum’s to ensure the rapid development of standards and interoperable solutions
World-Class Customer Support

- **2,000** Technical Support Professionals
- **1,600+** Support Engineers* (400 CCIEs) on 24x7
- **630+** Depots and **10,000** Field Engineers in **120** countries*
- **85,000+** Assisted cases/ month
- **321,000** Customer issues resolved/month
- **75%** TAC Web resolved: of **25%** assisted, **64%** were web-initiated
- **98%** Material availability
- **92%** Orders submitted online, **55%** “no touch”
- **60%** Change orders submitted online

* Internal & Outsource Partners

Customer Advocacy Mission

Accelerate customer success with Cisco through innovative services and world-class people, partners, process, and tools.
Cisco leads in the MPLS Market

<table>
<thead>
<tr>
<th>Americas</th>
<th>EMEA</th>
<th>AsiaPac/Japan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Some 200 Customers (MPLS Core &amp; L2/L3 Edge)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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- AT&T
- MCI
- Bellsouth
- Bell Nexxia
- PROTEL
- FirstCom Colombia
- Global Crossing
- Telus
- Level(3) Communications
- Telemar
- SaskTel
- ELMEX
- Ignite
- BT
- MediaWays
- Telenor
- Korea Telecom
- NTT Communications
- Telestraw
- KDDI
- Swisscom
- Telefonica
- Equant
- FastWeb
- CableCom
- SingTel
- SingTel
- China Unicom
- TELUS
- TeliaSonera
- Topnet
- MobilCom Business
- Equant
- Optus
- Saudi Telecom
- Telecom Italia
- Japan Telecom
Enabling Innovative Services

- Smarter: The foundation for more services and more revenues
- Faster: A flexible QoS framework to enable migration to a converged infrastructure
- Lasting: Extensibility to different transports with standards-based open architecture for investment protection

Cisco IOS MPLS