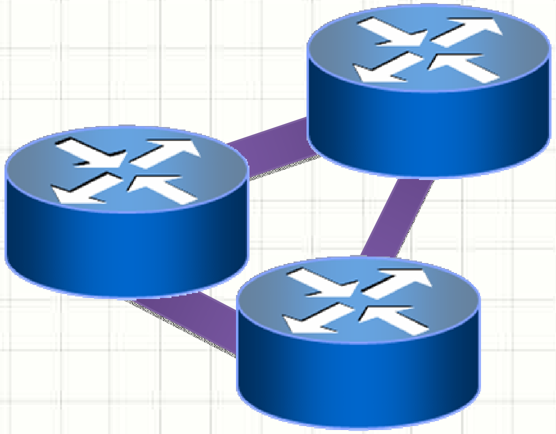


Virtual Private Network:

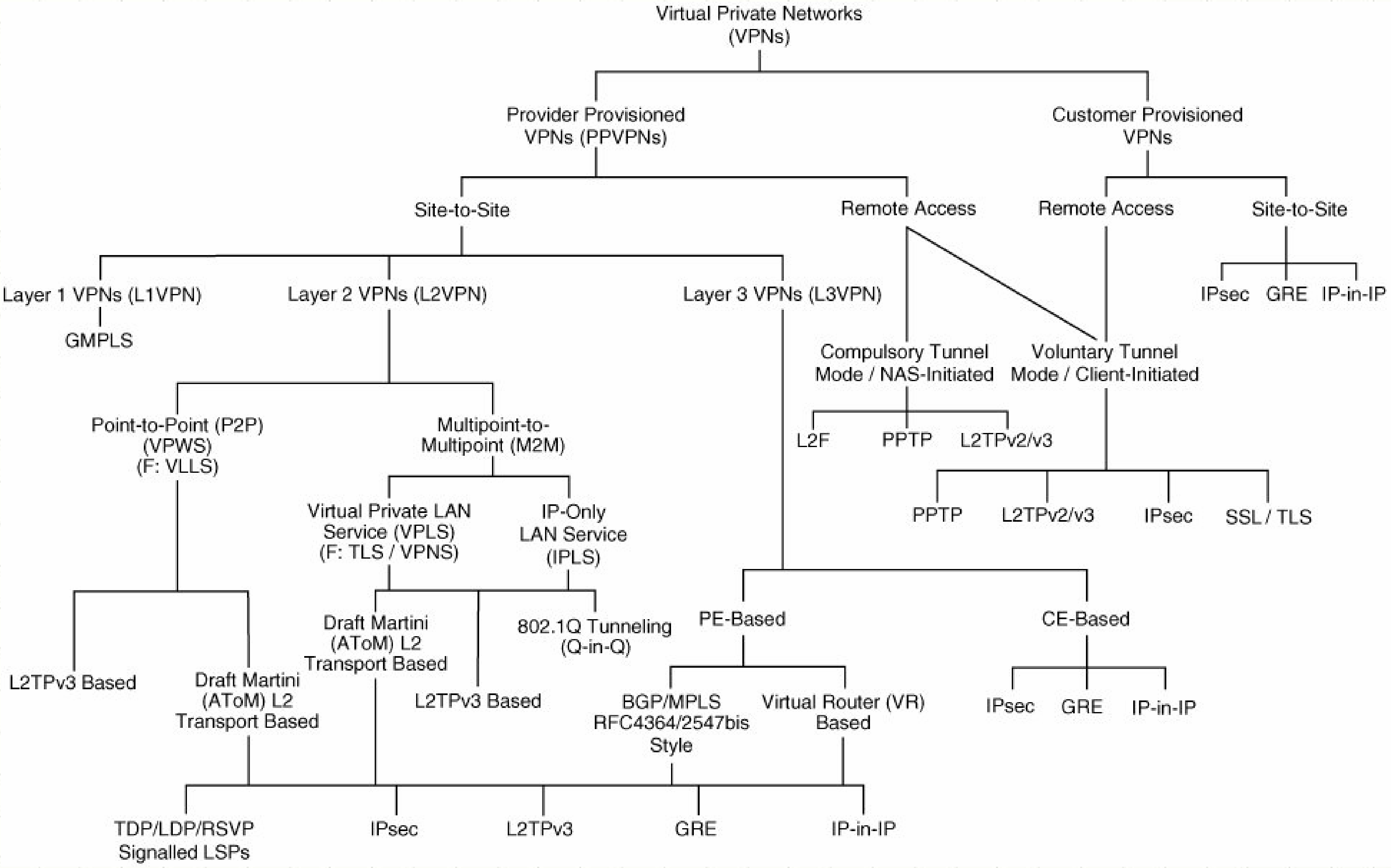
Layer 2 Solution

Giorgio Sadolfo
giorgiosadolfo@fastwebnet.it

What is virtual private network?

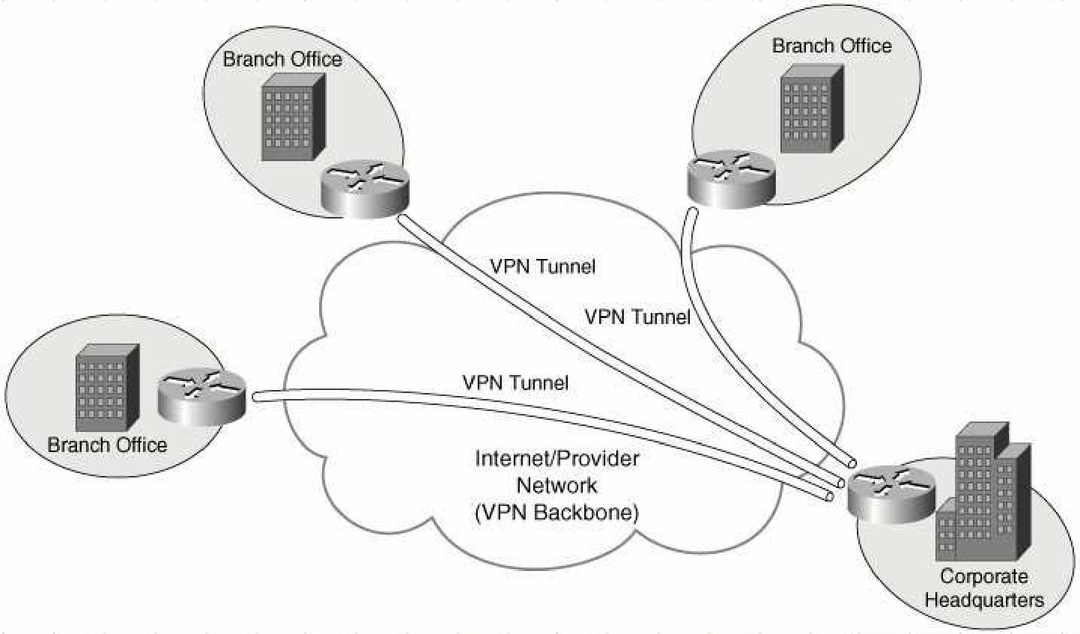
- A virtual private network (VPN) allows the provisioning of private network services for an organization or organizations over a public or shared infrastructure such as the Internet or service provider backbone network *(Cisco).*

Virtual Private Network: An Overview


Virtual Private Networks (VPNs)
Provider Provisioned VPNs (PPVPNs)
Customer Provisioned VPNs
Site-to-Site
Remote Access
Remote Access
Site-to-Site
Layer 1 VPNs (L1VPN)
Layer 2 VPNs (L2VPN)
Layer 3 VPNs (L3VPN)
IPsec
GRE
IP-in-IP
GMPLS
Compulsory Tunnel Mode / NAS-Initiated
Voluntary Tunnel Mode / Client-Initiated
L2F
PPTP
L2TPv2/v3
Point-to-Point (P2P) (VPWS) (F: VLLS)
Multipoint-to-Multipoint (M2M)
PPTP
L2TPv2/v3
IPsec
SSL / TLS
Virtual Private LAN Service (VPLS) (F: TLS / VPNS)
IP-Only LAN Service (IPLS)
PE-Based
CE-Based
Draft Martini (AToM) L2 Transport Based
802.1Q Tunneling (Q-in-Q)
L2TPv3 Based
Draft Martini (AToM) L2 Transport Based
L2TPv3 Based
BGP/MPLS RFC4364/2547bis Style
Virtual Router (VR) Based
IPsec
GRE
IP-in-IP
TDP/LDP/RSVP Signalled LSPs
IPsec
L2TPv3
GRE
IP-in-IP

Type of virtual private network

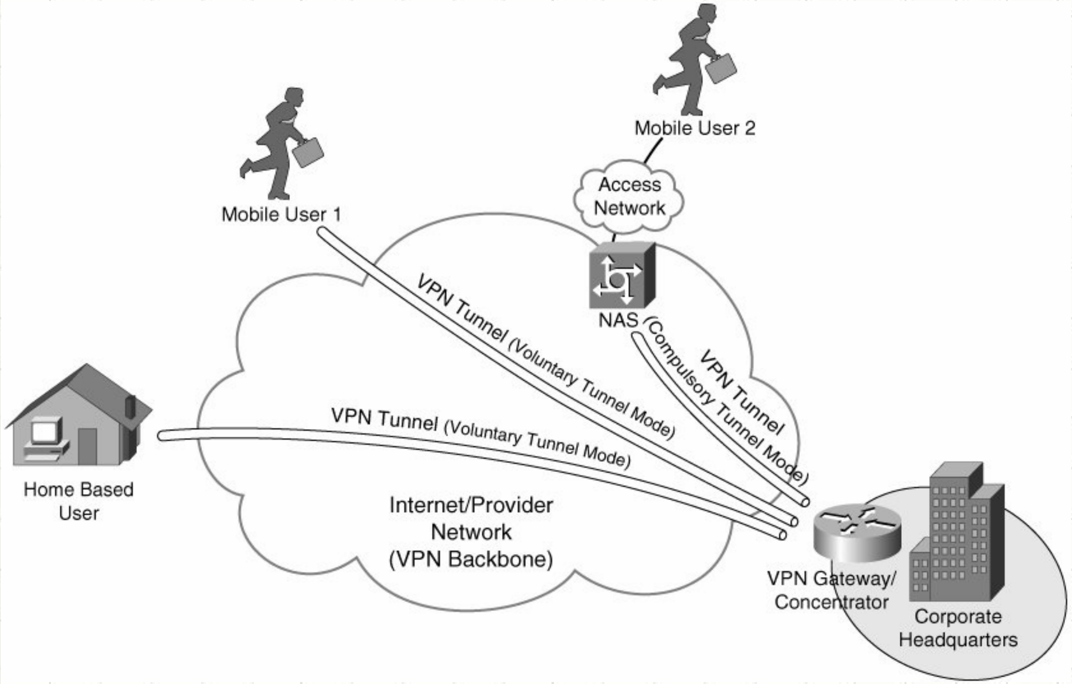
- SITE to SITE: Site-to-site VPNs provide an Internet-based WAN infrastructure to extend network resources to branch offices, home offices, and business partner sites.
  - Reliable and high-quality transport of complex, mission-critical traffic, such as voice and client server applications
  - Simplified provisioning and reduced operational tasks for network designs
  - Integrated advanced network intelligence and routing for a wide range of network designs



Type of virtual private network

- REMOTE ACCESS: Remote access VPNs extend almost any data, voice, or video application to the remote desktop, emulating the main office desktop. With this VPN, you can provide highly secure, customizable remote access to anyone, anytime, anywhere, with almost any device.

  - Create a remote user experience that emulates working on the main office desktop
  - Deliver VPN access safely and easily to a wide range of users and devices
  - Support a wide range of connectivity options, endpoints, and platforms to meet your dynamic remote access needs


Mobile User 2
Access Network
Mobile User 1
NAS
VPN Tunnel (Voluntary Tunnel Mode)
VPN Tunnel (Compulsory Tunnel Mode)
VPN Tunnel (Voluntary Tunnel Mode)
Home Based User
Internet/Provider Network (VPN Backbone)
VPN Gateway/ Concentrator
Corporate Headquarters

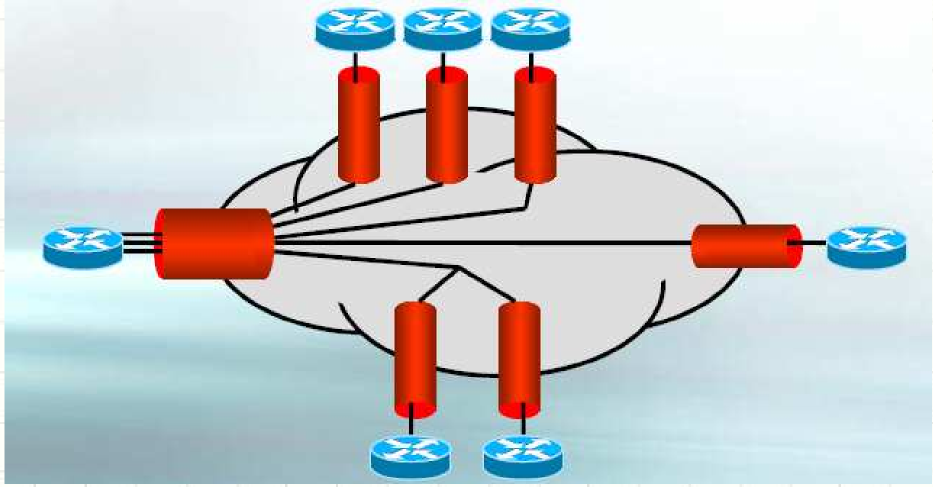
VPN Layer 2: Overview

- Layer 2 site-to-site VPNs (L2VPN) can be provisioned between switches, hosts, and routers and allow data link layer connectivity between separate sites.
- Communication between customer switches, hosts, and routers is based on Layer 2 addressing, and PE devices perform forwarding of customer data traffic based on incoming link and Layer 2 header information:
    - MAC address;
    - Frame Relay;
    - Data Link Connection Identifier [DLCI];
    - and so on.

Layer 2 VPN

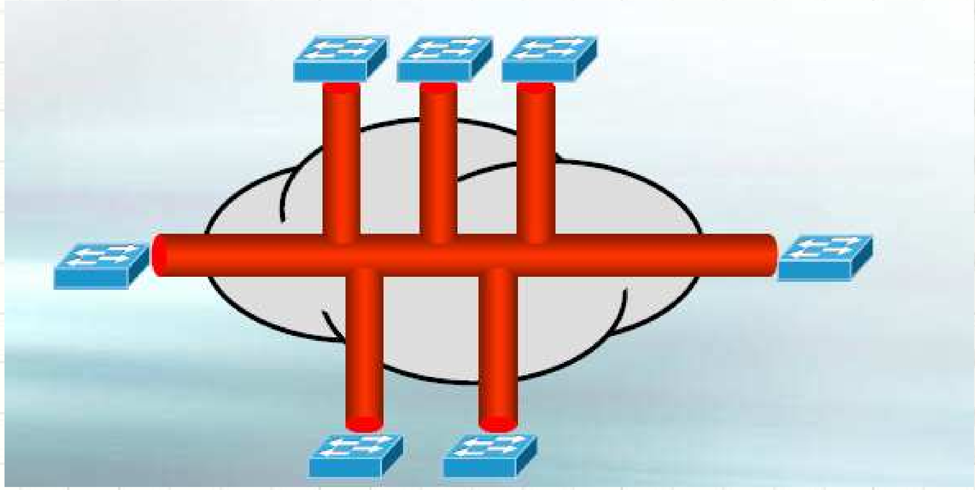
There are two categories of provider provisioned L2VPN:

•**Point-to-point (P2P) circuit-based VPNs** also known as Virtual Private Wire Service (VPWS) VPNs and are constructed using, for example, Draft Martini (MPLS) or L2TPv3 pseudowires (emulated circuits).



Layer 2 VPN

There are two categories of provider provisioned L2VPN:



- **Multipoint-to-multipoint (M2M) VPNs** M2M VPNs come in two varieties:
  - Virtual Private LAN Service (VPLS) VPNs
  - IP-Only LAN Service (IPLS) VPNs

Virtual Private LAN Service: VPLS

Virtual private LAN service (VPLS) is a way to provide Ethernet based multipoint to multipoint communication over IP/MPLS networks. It allows geographically dispersed sites to share an Ethernet broadcast domain by connecting sites through pseudo-wires. *(Wikipedia)*

•VPLS is also know as:

- *Trasparent LAN Service (TLS)*
- *E-LAN*

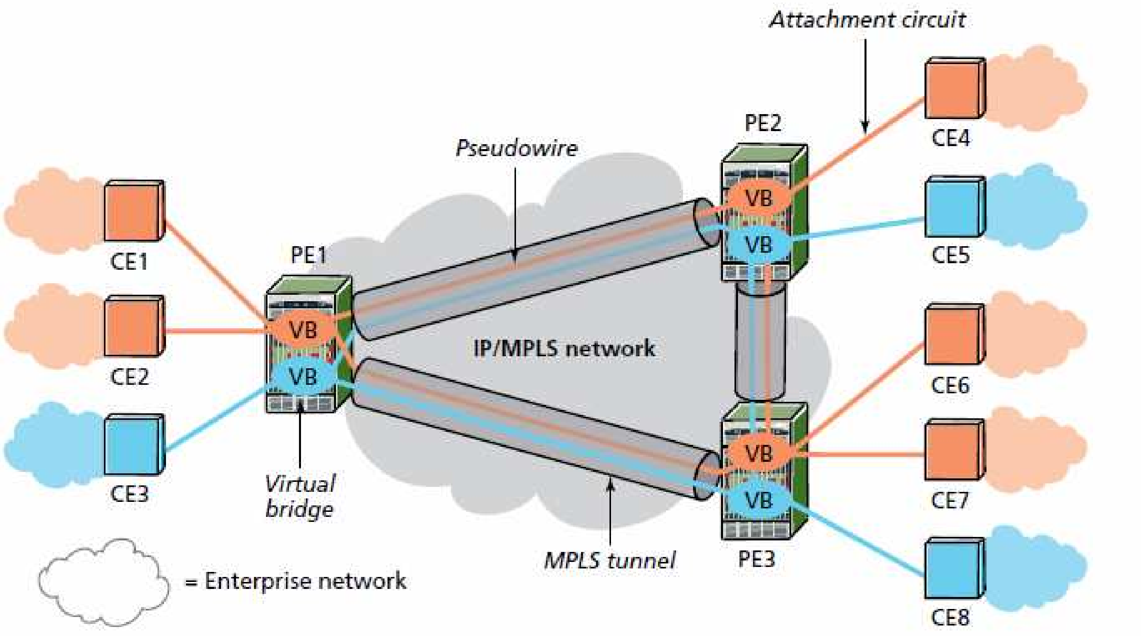
VPLS Actors

- The **CE** ***(Customer Edge)*** device is a router or switch located at the customer's premises; it can be owned and managed by the customer, or owned and managed by the service provider. It is connected to the PE through an Attachment Circuit (AC).
- The **PE** ***(Provider Edge)*** device is where all the VPN intelligence resides, where the VPLS originates and terminates, and where all the necessary tunnels are set up to connect to all the other PEs. As VPLS is an Ethernet layer 2 service, the PE must be capable of Media Access Control (MAC) learning, bridging and replication on a per-VPLS basis.
- The **IP/MPLS core network** interconnects the PEs; it does not really participate in the VPN functionality. Traffic is simply switched based on the MPLS labels.

VPLS: Setting Up

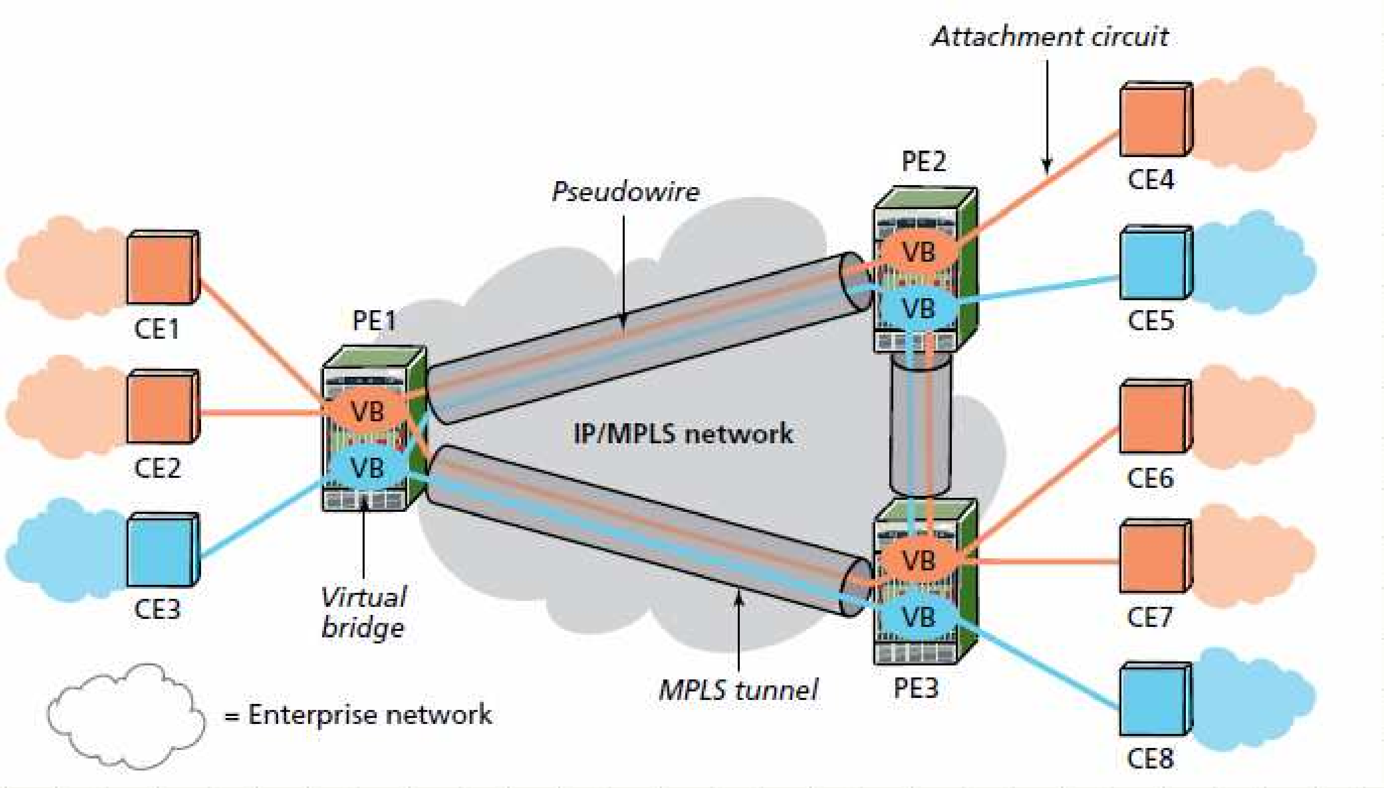
The basis of any multipoint VPN service (IP VPN or VPLS) is the full mesh of MPLS tunnels (Label Switched Paths [LSPs], also called outer tunnels.

- •Label Distribuition Protocol LDP
- •Resource Reservation Protocol – Traffic Engineering (RSVP-TE)



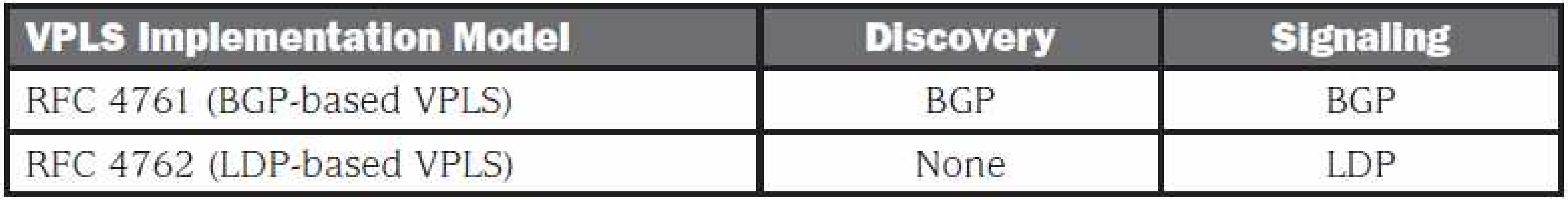
VPLS: Setting Up

For every VPLS instance, a full mesh of inner tunnels (PWs) is created between all the PEs that participate in the VPLS instance



VPLS: Implementation type

- **Auto-Discovery:** What method is used that enables multiple provider edge routers (PE) participating in a VPLS domain to find each other?
- **Signaling:** What protocol is used to set up MPLS tunnels and distribute labels between PEs for packet demultiplexing purpose?



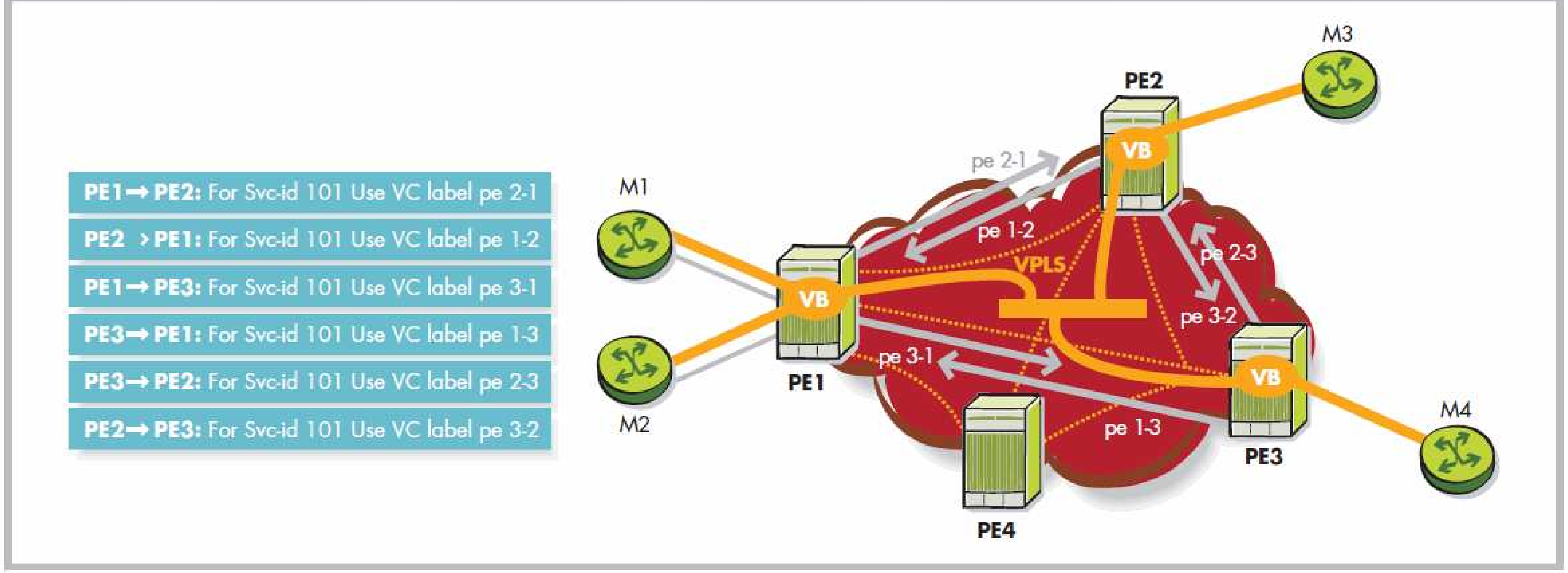
VPLS Implementation Model	Discovery	Signaling
RFC 4761 (BGP-based VPLS)	BGP	BGP
RFC 4762 (LDP-based VPLS)	None	LDP

How does VPLS work?

Creating the pseudo wires:

Three PWs need to be created, each consisting of a pair of unidirectional LSPs or virtual connections. For VC-label signaling between PEs, each PE initiates a targeted LDP session to the peer PE and communicates to the peer PE what VC label to use when sending packets for the considered VPLS. The specific VPLS instance is identified in the signaling exchange using a service identifier.

Fig. 2 Pseudo wire signaling



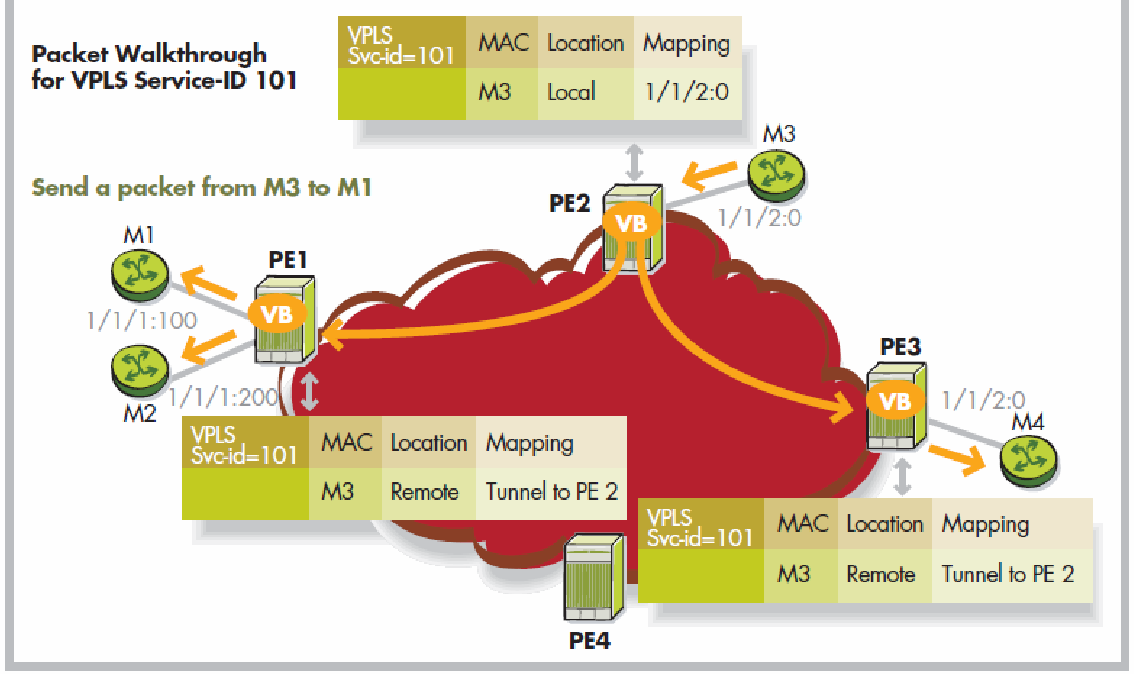
- **PE1→PE2:** For Svc-id 101 Use VC label pe 2-1
- **PE2 >PE1:** For Svc-id 101 Use VC label pe 1-2
- **PE1→PE3:** For Svc-id 101 Use VC label pe 3-1
- **PE3→PE1:** For Svc-id 101 Use VC label pe 1-3
- **PE3→PE2:** For Svc-id 101 Use VC label pe 2-3
- **PE2→PE3:** For Svc-id 101 Use VC label pe 3-2

How does VPLS work?

MAC learning and packet forwarding:

- PE2 receive a packet from M3 but it doesn't know the destination of M1: flood the packet;
- PE1 learns from VC label pe2-1 that M3 is behind PE2it stores this information in the FIB for Svc-id 101*(PE3 does the same)*;
- PE1 strips off label pe2-1, does not know the destination M1 and floods the packet on ports 1/1/1:100 and 1/1/1:200; PE1 does not flood the packet to PE3 because of the split horizon rule;
- M1 receives the packet.

Fig. 3 VPLS learning



Packet Walkthrough for VPLS Service-ID 101

Send a packet from M3 to M1

VPLS Svc-id=101	MAC	Location	Mapping
	M3	Local	1/1/2:0

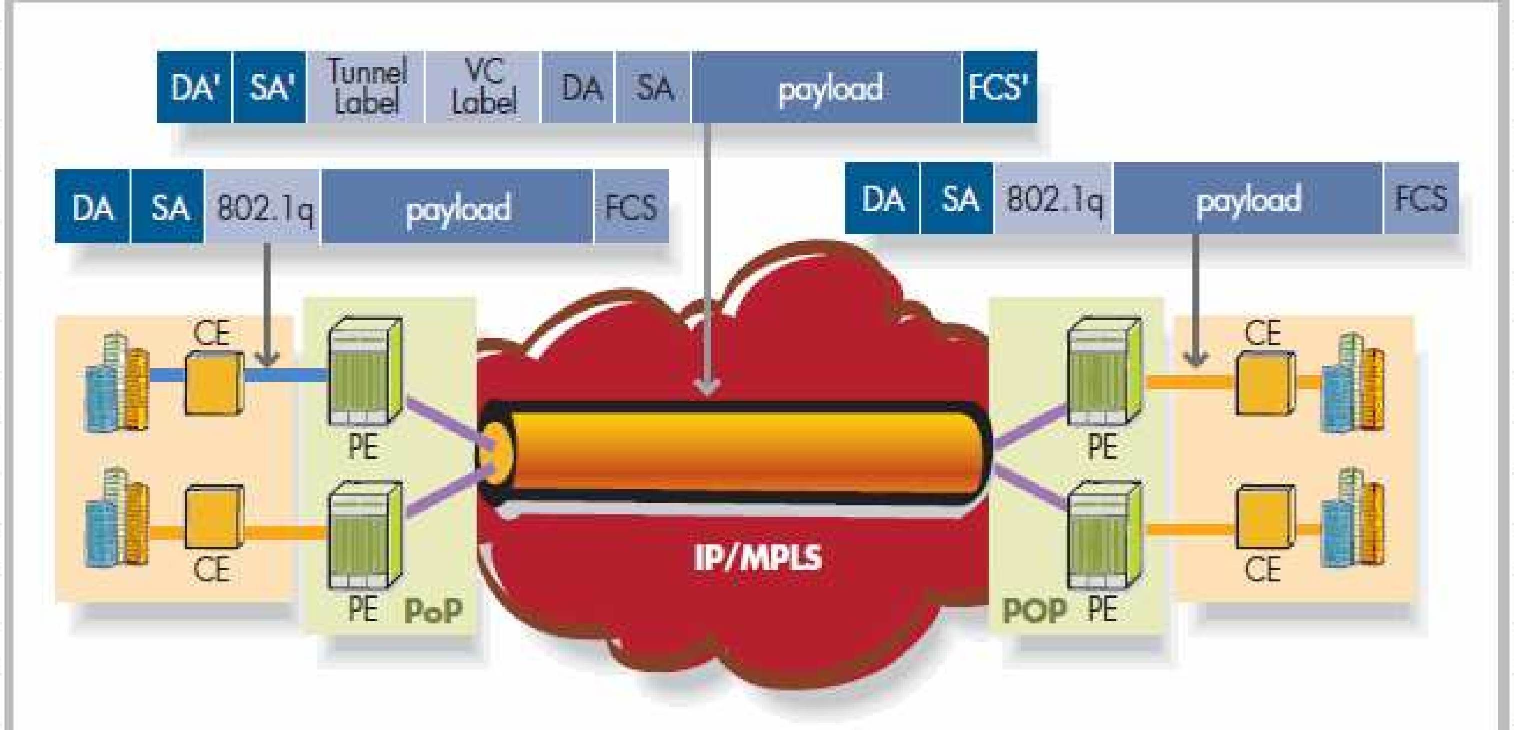
VPLS Svc-id=101	MAC	Location	Mapping
	M3	Remote	Tunnel to PE 2

VPLS Svc-id=101	MAC	Location	Mapping
	M3	Remote	Tunnel to PE 2

How does VPLS work?

The Packet Format:

Fig. 4 VPLS packet format



DA: Destination Address **FCS:** Frame Check Sequence **SA:** Source Address

VPLS: Test Bed

VPLS step by step:

1. Setting up PE’s loopback
2. Setting up IP/MPLS provider backbone
   - Enable BGP (or LDP)
   - Enable RSVP
   - Enable OSPF
3. Setting up the VPLS istance

VPLS: Setting up the PE

ROUTER-ID e AS-NUMBER

```
•Set routing-options router-id 10.0.0.1
•Set routing-options autonomous-system 50
```

Loopback

```
•Set interfaces lo0 unit 0 family inet address 127.0.0.1/32
•Set interfaces lo0 unit 0 family inet address 10.0.0.1/32 primary
```

VPLS: IP/MPLS backbone

Interface inside the provider network

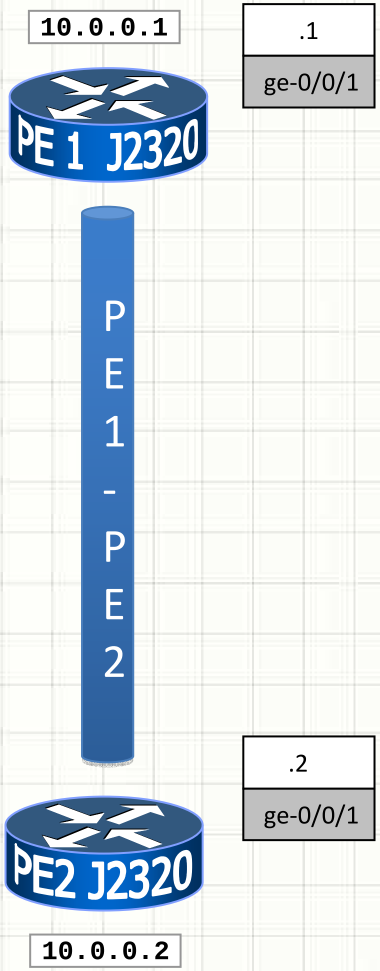
```
•Set interfaces ge-0/0/1 unit 0 family inet address 40.0.0.1/32
•Set interfaces ge-0/0/1 unit 0 family mpls
```

MPLS and TUNNEL

```
•Set protocols mpls interface ge-0/0/1
•Set protocols mpls interface lo0.0
•Set protocols mpls label-switched-path PE1-PE2 to 10.0.0.2
```

RSVP

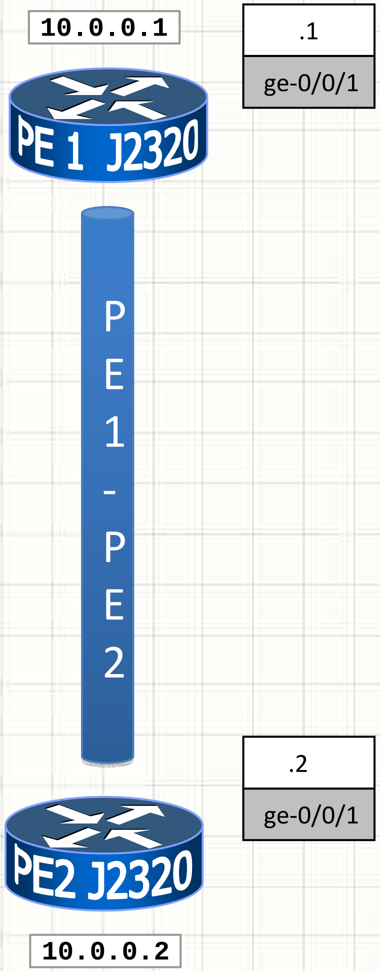
```
•Set protocols rsvp interface ge-0/0/1
•Set protocols rsvp interface lo0.0
```



VPLS: IP/MPLS backbone

BGP

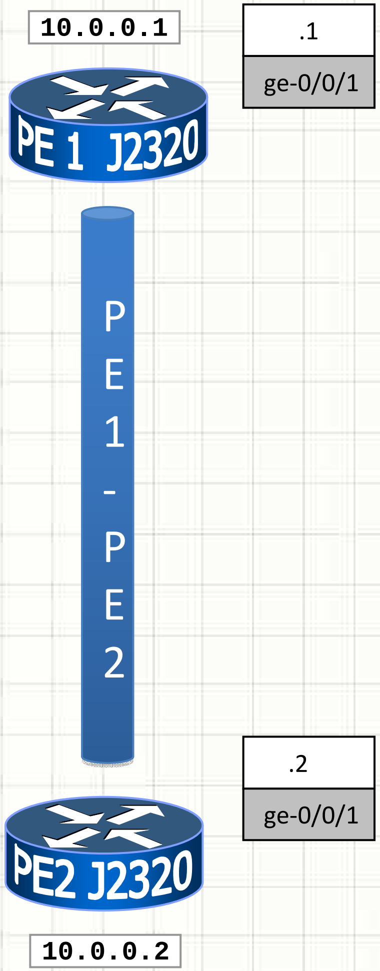
- Set protocols bgp group IBGP type internal local-address 10.0.0.1 neighbor 10.0.0.2
- Set protocols bgp group IBGP family l2vpn signaling
  - ***Enable the signaling***
- Set protocols bgp local-as 50
  - ***Enable MP-BGP flow***



VPLS: IP/MPLS backbone

OSPF

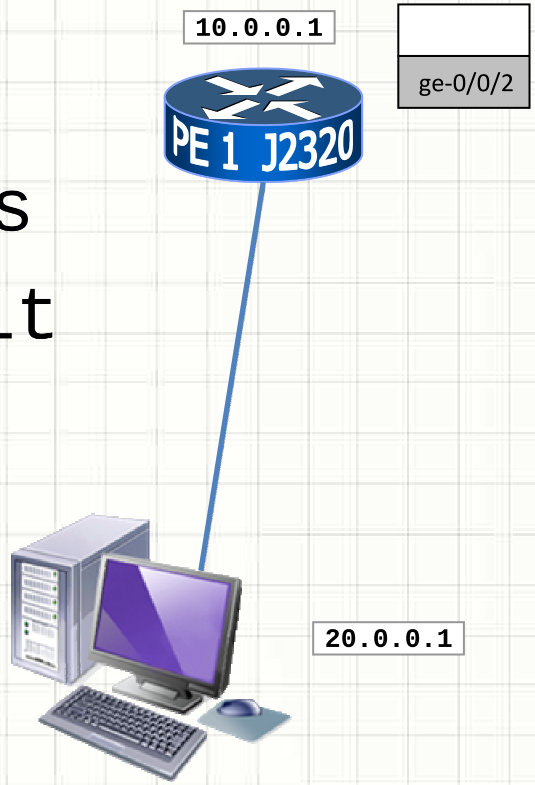
- Set protocols ospf area 0.0.0.0 interface ge-0/0/1
- Set protocols ospf area 0.0.0.0 interface lo0.0
- Set protocols ospf traffic-engineering



VPLS: IP/MPLS backbone

PE-CE interface

- Set interface ge-0/0/2 encapsulation ethernet-vpls
- Set interface ge-0/0/2 unit 0 family vpls

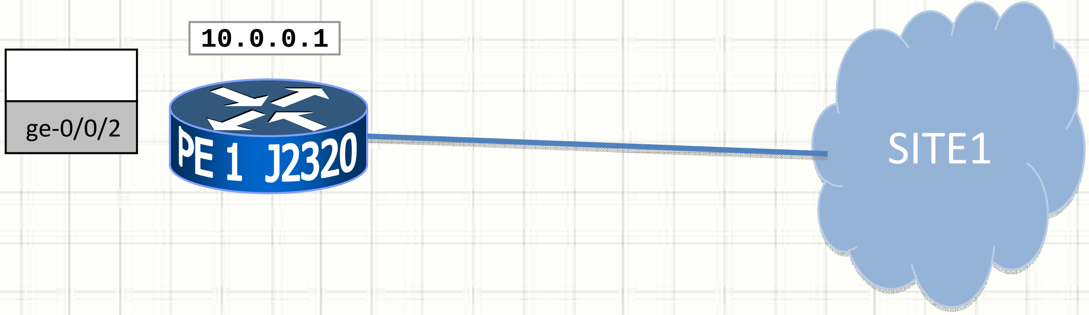


ETHERNET-VPLS: Directly connect with ethernet cable
VLAN-TAGGING: trunk Q-in-Q between CE and PE

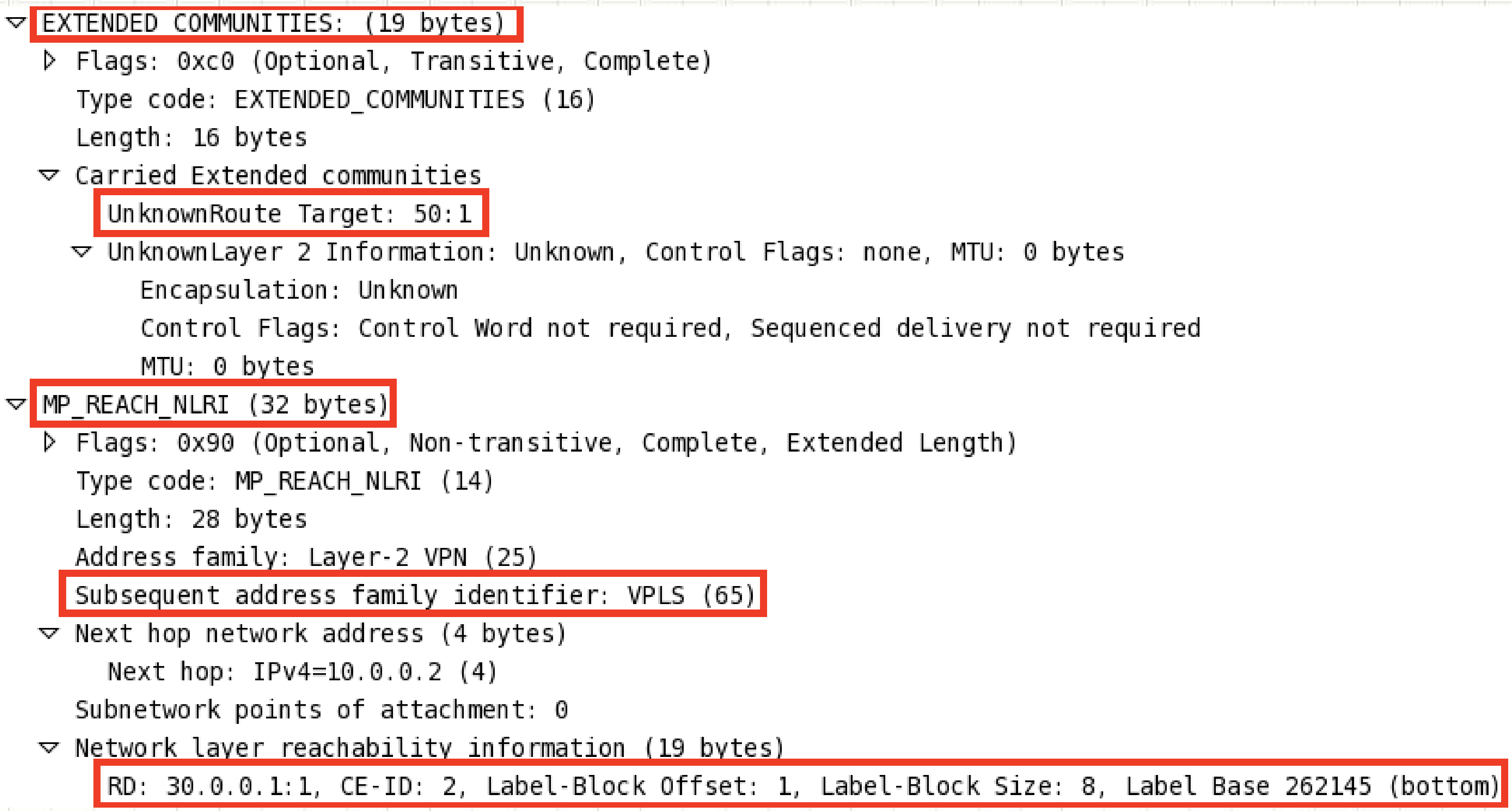
VPLS: Define an instance

VPLS Instance

```
•Set routing-instance VPLS instance-type vpls
•Set routing-instance VPLS protocols vpls site-range 5 site SITO1 site-identifier 1
•Set routing-instance VPLS protocols vpls no-tunnel-services
•Set routing-instance VPLS route-distinguisher 30.0.0.1:1
•Set routing-instance VPLS vrf-target target:50:1
•Set routing-instance VPLS instance-type vpls interface ge-0/0/2
```

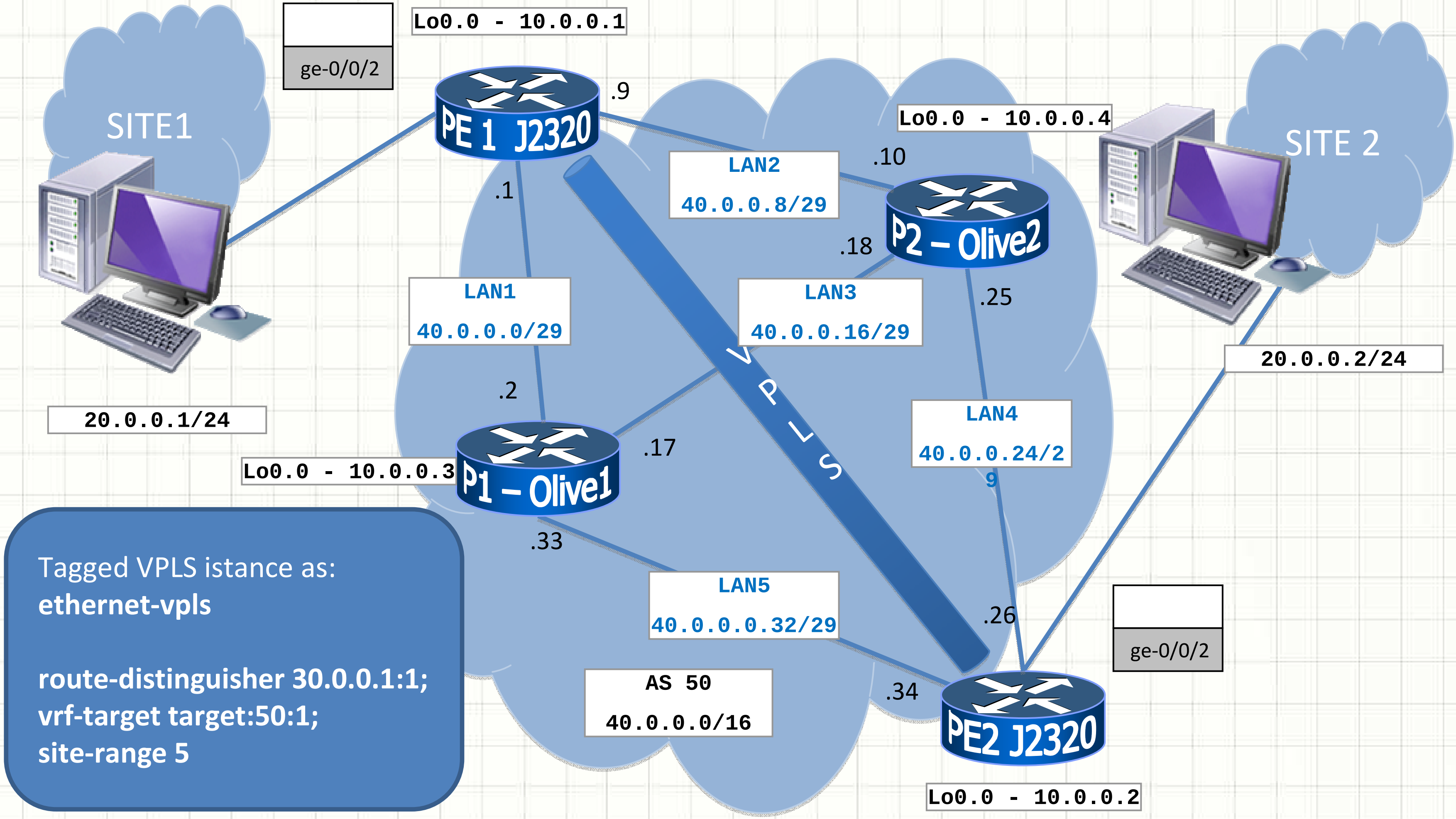


VPLS: IP/MPLS backbone



```
▽ EXTENDED_COMMUNITIES: (19 bytes)
  ▷ Flags: 0xc0 (Optional, Transitive, Complete)
    Type code: EXTENDED_COMMUNITIES (16)
    Length: 16 bytes
  ▽ Carried Extended communities
      UnknownRoute Target: 50:1
    ▽ UnknownLayer 2 Information: Unknown, Control Flags: none, MTU: 0 bytes
        Encapsulation: Unknown
        Control Flags: Control Word not required, Sequenced delivery not required
        MTU: 0 bytes
▽ MP_REACH_NLRI (32 bytes)
  ▷ Flags: 0x90 (Optional, Non-transitive, Complete, Extended Length)
    Type code: MP_REACH_NLRI (14)
    Length: 28 bytes
    Address family: Layer-2 VPN (25)
    Subsequent address family identifier: VPLS (65)
  ▽ Next hop network address (4 bytes)
      Next hop: IPv4=10.0.0.2 (4)
    Subnetwork points of attachment: 0
  ▽ Network layer reachability information (19 bytes)
      RD: 30.0.0.1:1, CE-ID: 2, Label-Block Offset: 1, Label-Block Size: 8, Label Base 262145 (bottom)
```

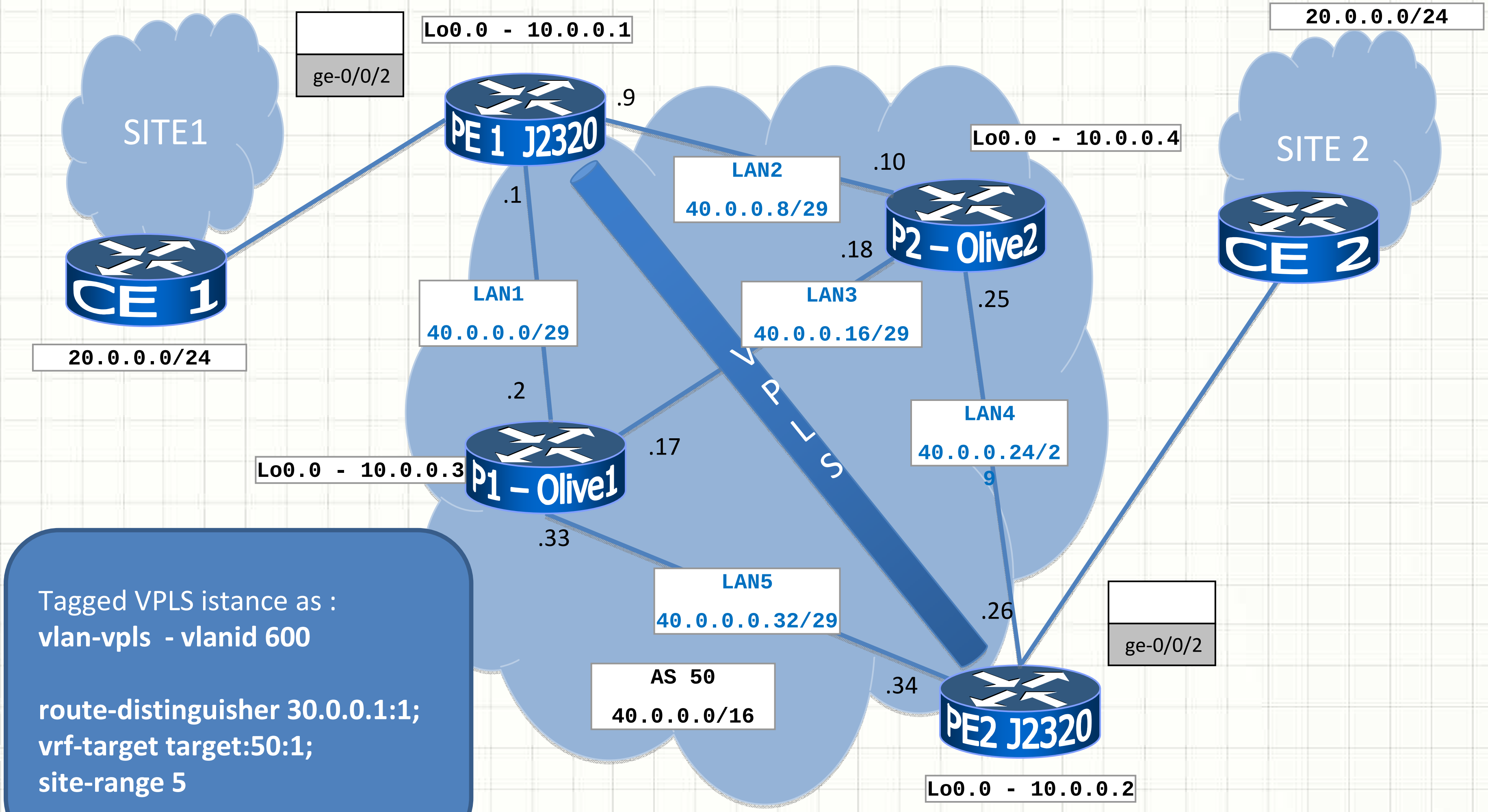
VPLS: 1 Scenario



Tagged VPLS istance as:
ethernet-vpls

route-distinguisher 30.0.0.1:1;
vrf-target target:50:1;
site-range 5

VPLS: 2^ Scenario



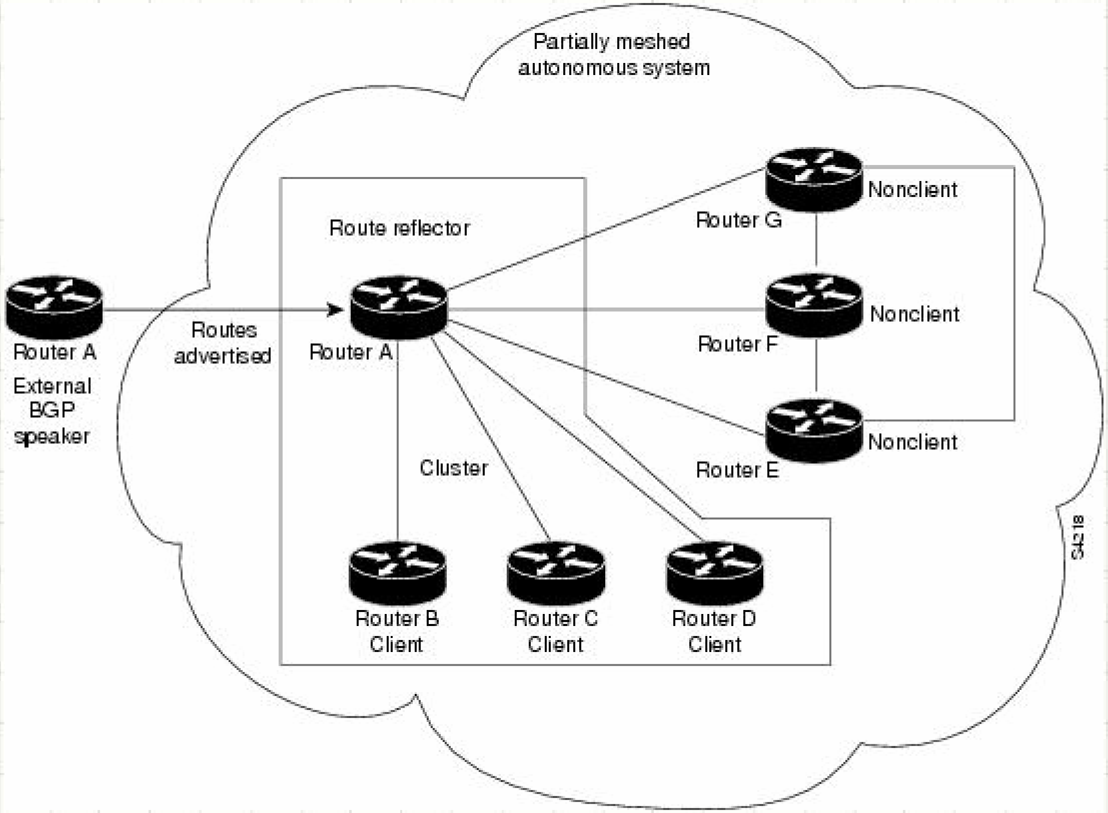
Tagged VPLS istance as :
vlan-vpls - vlanid 600

route-distinguisher 30.0.0.1:1;
vrf-target target:50:1;
site-range 5

H-VPLS: Hierarchical VPLS

VPLS BGP based:

- Route reflector solution

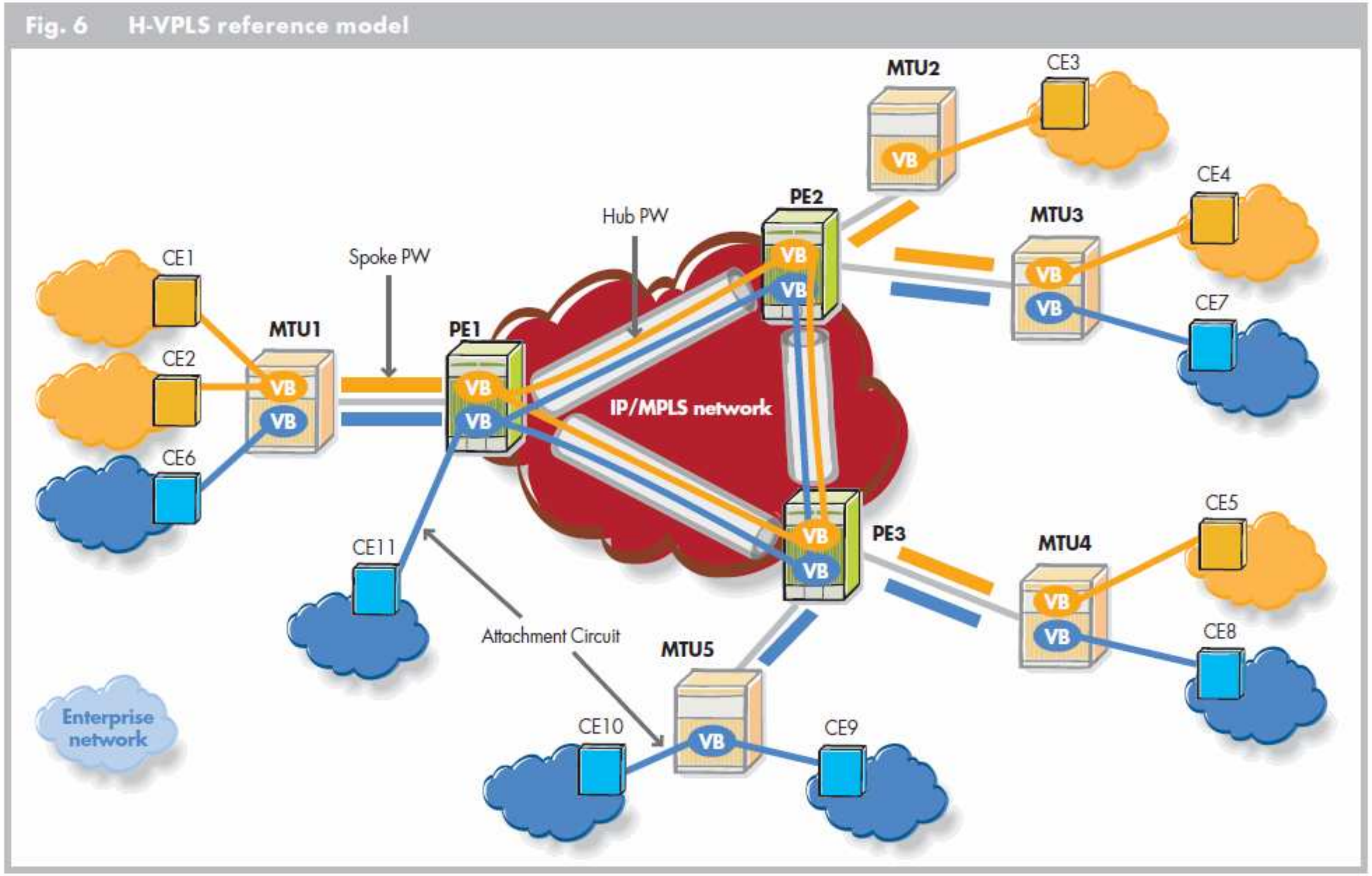


H-VPLS: Hierarchical VPLS

VPLS LDP based:

- Hub-Spoken solution

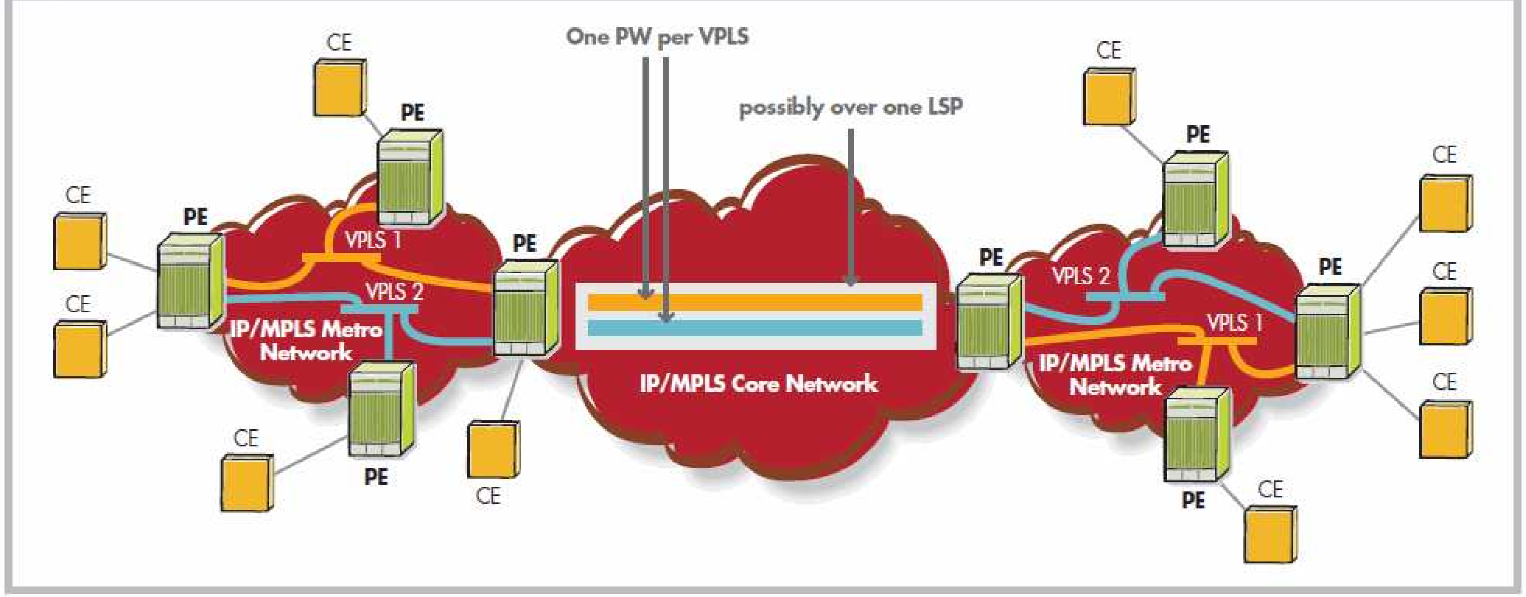
Fig. 6 H-VPLS reference model



H-VPLS: Hierarchical VPLS

H-VPLS enables VPLS to span multiple metro networks. A spoke connection is used to connect each VPLS between the two metros. In its simplest form, this could be a single tunnel LSP. A set of ingress and egress PW labels is exchanged between the border PE devices to create a PW for each VPLS instance to be transported over this LSP.

Fig. 7 H-VPLS used as an inter-metro service



References

- RFC 4761, *Virtual Private LAN Service (VPLS) Using BGP for Auto-Discovery and Signaling*, Jannuary 2007;
- RFC 4762, *Virtual Private LAN Service (VPLS) Using Label Distribution Protocol (LDP) Signaling*, Jannuary 2007;
- White Paper, *VPLS Technical Tutorial*, Alacatel-Lucent, Jannuary 2009;
- **Wei Luo**, *Layer 2 VPN Architectures*, Cisco Press, March 2005;
- **Luc De Ghein**, *MPLS Foundamentals*, Cisco Press, November 2006;
- **Mark Lewis**, *Comparing, Designing, and Deploying VPNs*, Cisco Press, March 2006;
- **Zhuo (Frank) Xu**, *Designing and Implementing IP/MPLS-Based Ethernet Layer 2 VPN Services,* Alcatel - Lucent SRA, Jannuary 2010;