

# L2 VPNs

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- Topics:
  - **L2VPN Introduction**
  - L2VPN Models
  - Quality of Service
  - L2VPN End-to-End Connectivity
  - IETF Drafts

# What is L2VPN?

- L2VPN provides end-to-end layer 2 connection to an office in Kyoto to an office in San Jose over a SP's MPLS core
  - It can be Ethernet, Frame Relay, ATM, HDLC, PPP, etc ...
  - It is for **layer 2 connectivity only**, layer 3 is transparent to MPLS core. Layer 3 can be ATM, IPv4, IPv6, etc ... and no routing is involved with MPLS core
  - It is deployed over MPLS core but IP core (L2TPv3) deployments exist

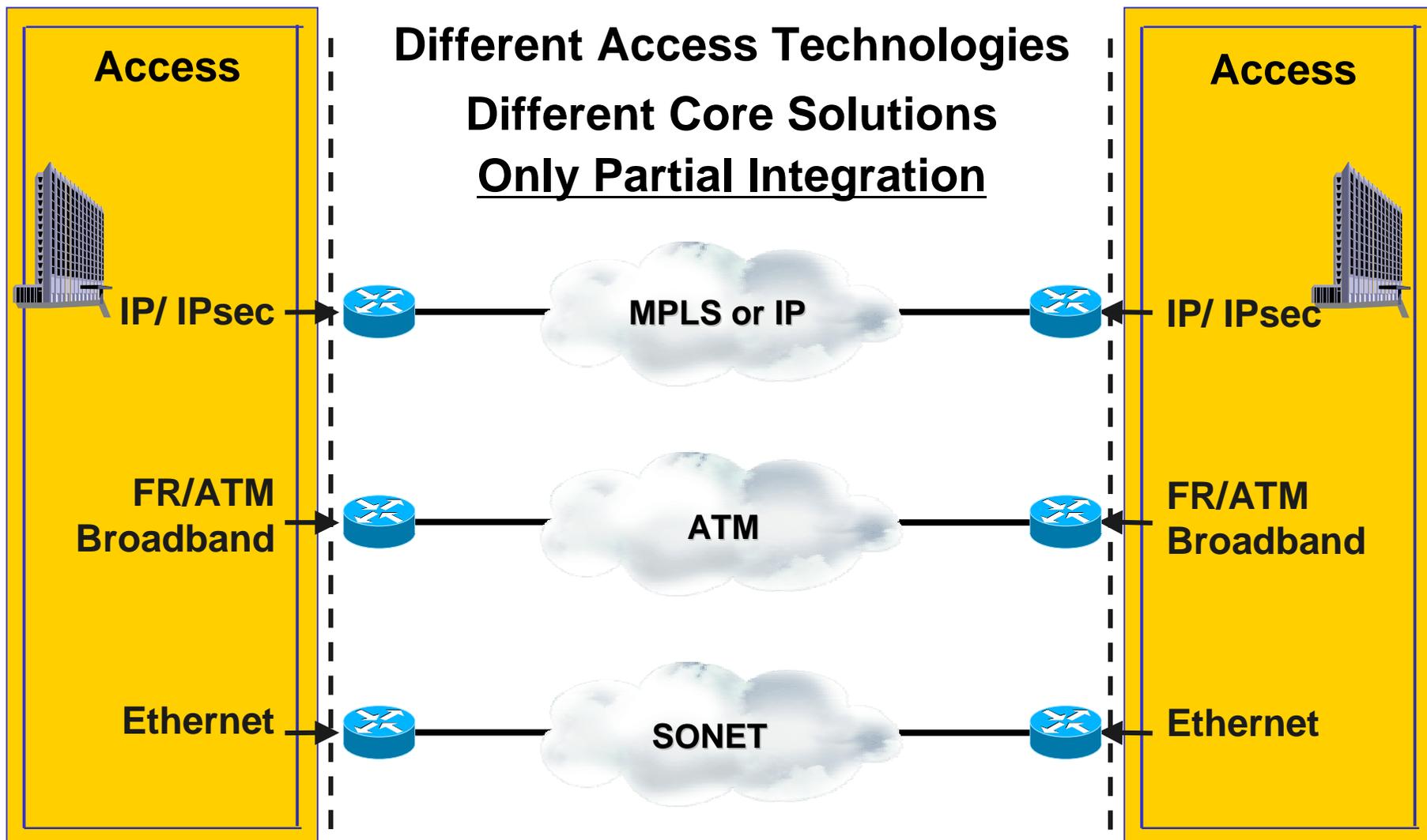


# Why is L2VPN needed?

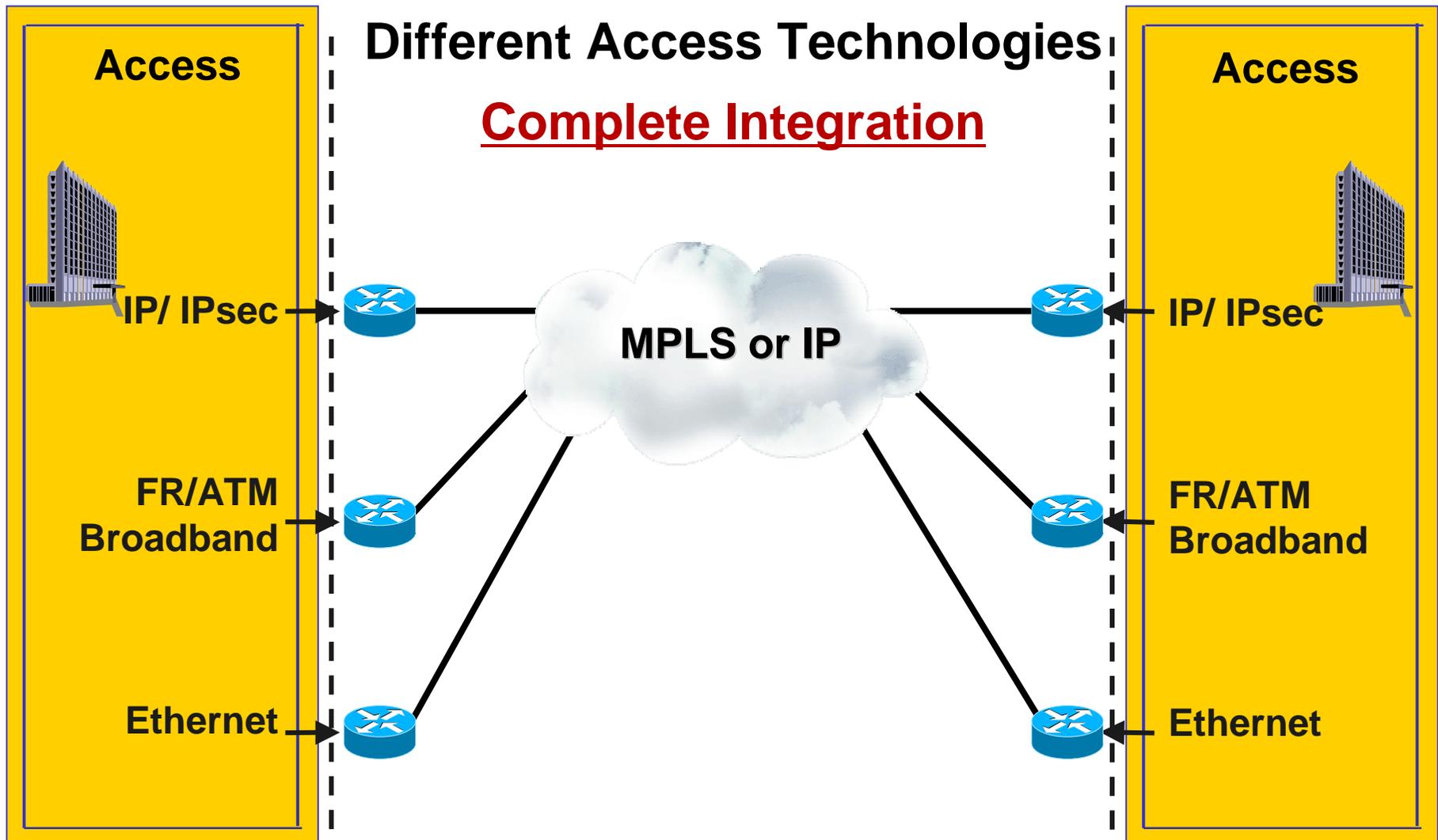
- Allows SP to have a **single infrastructure** for both IP and legacy services
  - Migrate legacy ATM and Frame Relay services to MPLS/IP core without interruption to existing services
  - Provisioning new L2VPN services is **incremental (not from scratch)** in existing MPLS/IP core
  - **Capital and Operational savings** of converged IP/MPLS network
- SP provides new **point-2-point** or **point-2-multipoint** services
  - Customer can have their own routing, qos policies, security mechanisms, etc  
...
- Based on IETF drafts that promote open architecture and vendor interoperability

# VPN Deployments Today

## *Technology & VPN Diversity*



# Consolidated Core supports ...



# Layer 3 and Layer 2 VPN Characteristics

## LAYER 3 VPNS

- SP devices forward customer packets based on **Layer 3 information** (e.g. IP addresses)
- SP is involved in customer IP routing
- Support for **any access** or backbone technology
- **IP** specific
- **Foundation for L4–7 services!**
- Example: RFC 2547bis VPNs (L3 MPLS-VPN)

## LAYER 2 VPNS

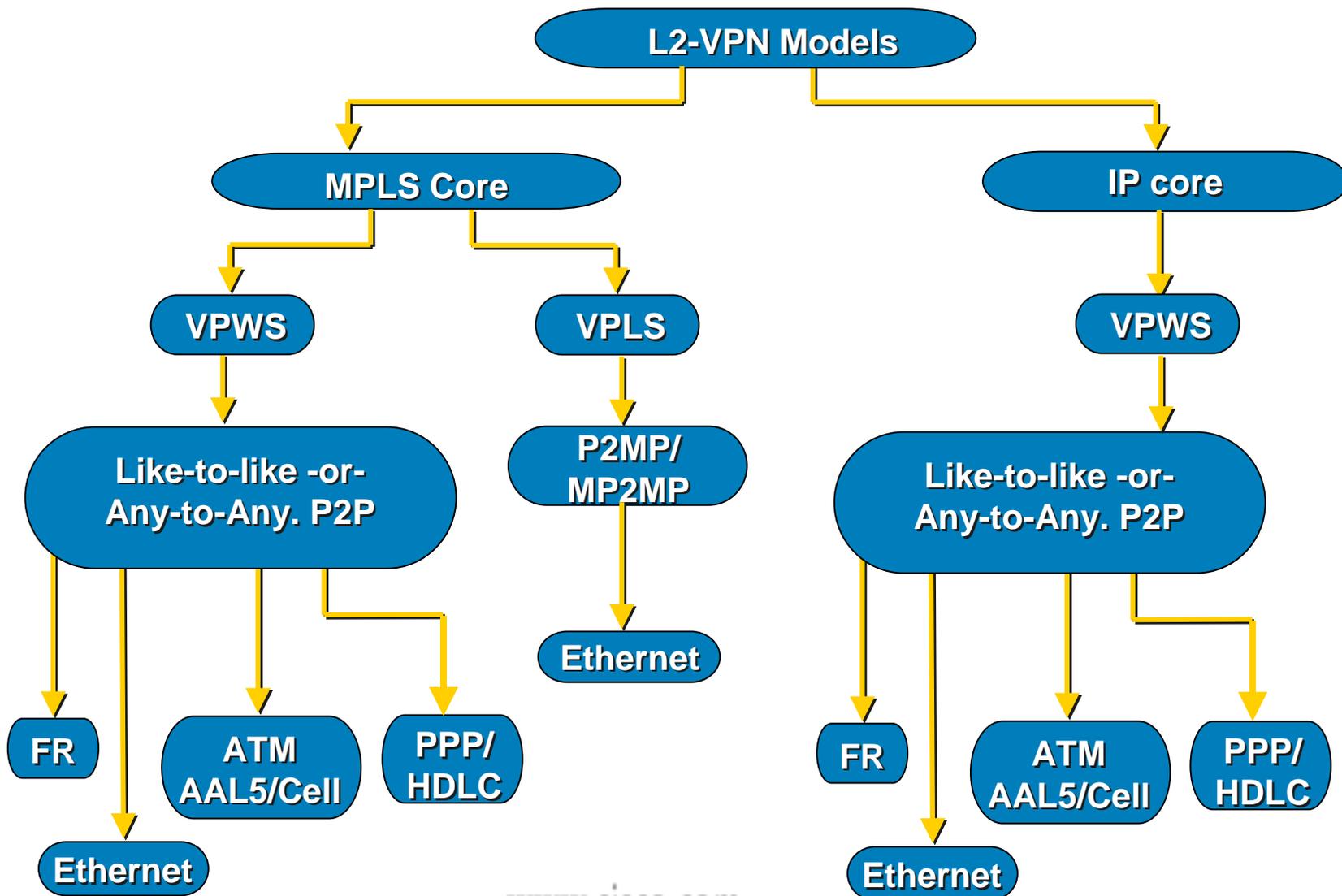
- SP devices forward customer frames based on **Layer 2 information** (e.g. DLCI, VPI/VCI, MAC, VLAN ID)
- Enterprise stays in **control** of L3 policies (Routing, QoS)
- No SP involvement in customer IP routing
- **Multiprotocol** support
- Example: FR—ATM—Ethernet

The Choice of L2VPN over L3VPN Will Depend on **How Much Control** the Enterprise Wants to Retain.  
L2 VPN Services Are **Complementary** to L3 VPN Services

# Agenda

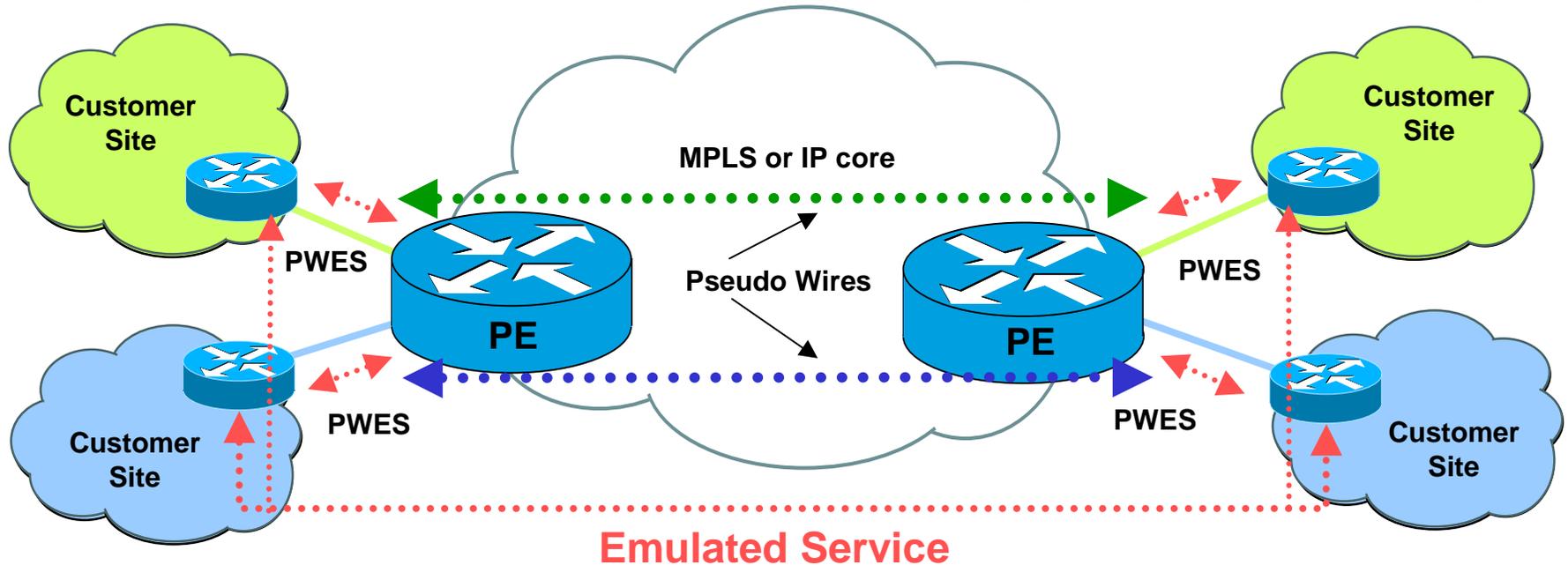
- Topics:
  - L2VPN Introduction
  - **L2VPN Models**
  - Quality of Service
  - Tunnel Stitching
  - IETF drafts
  - Summary

# L2VPN Models



# Pseudo Wire Reference Model

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**A pseudo-wire (PW) is a connection between two provider edge (PE) devices which connects two pseudo-wire end-services (PWESs)**

## Emulated Services:

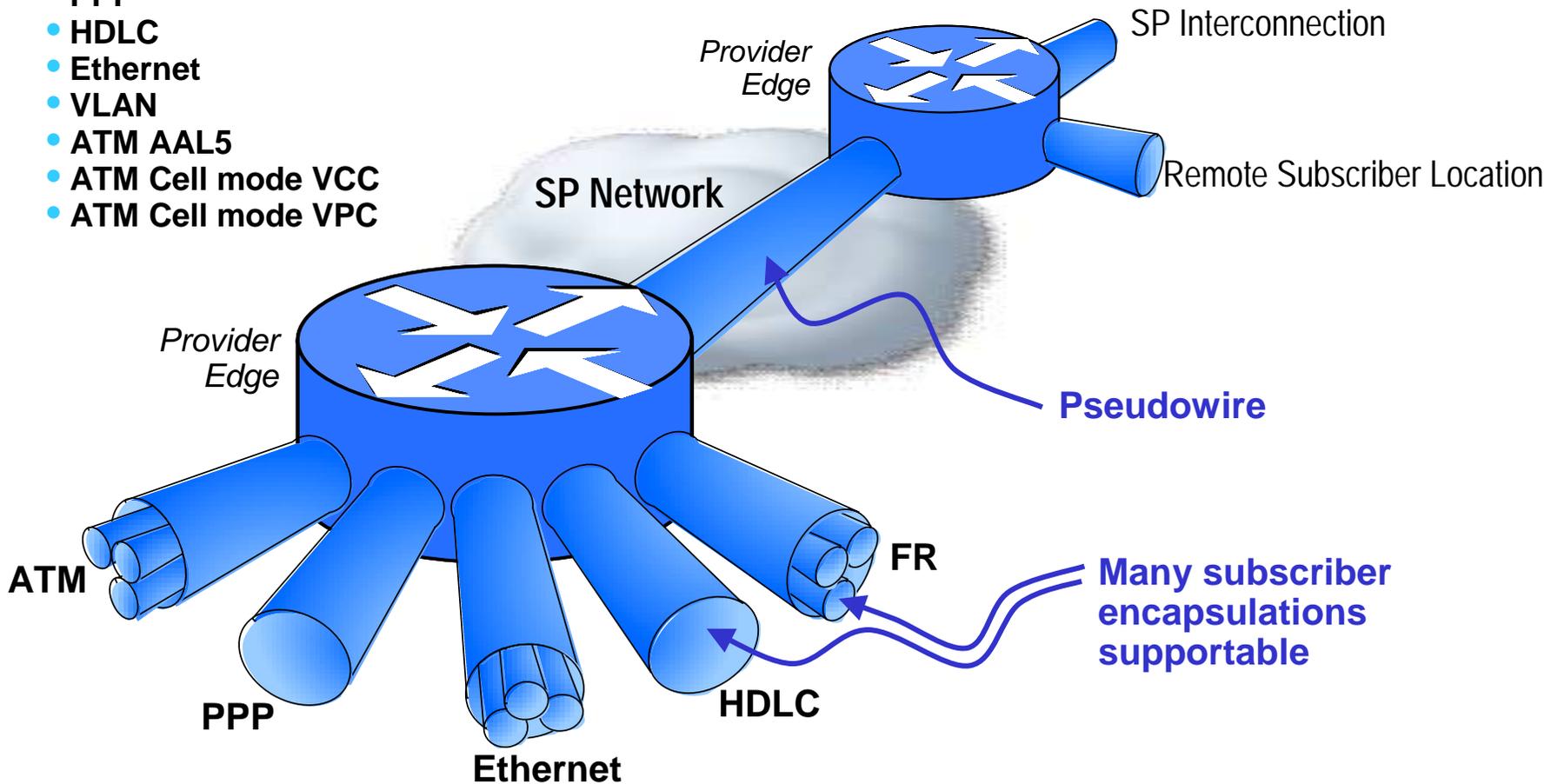
- Ethernet
- 802.1Q (VLAN)
- ATM VC or VP
- HDLC
- PPP
- Frame Relay VC

# VPWS Pseudo Wire – Basic Building Blocks

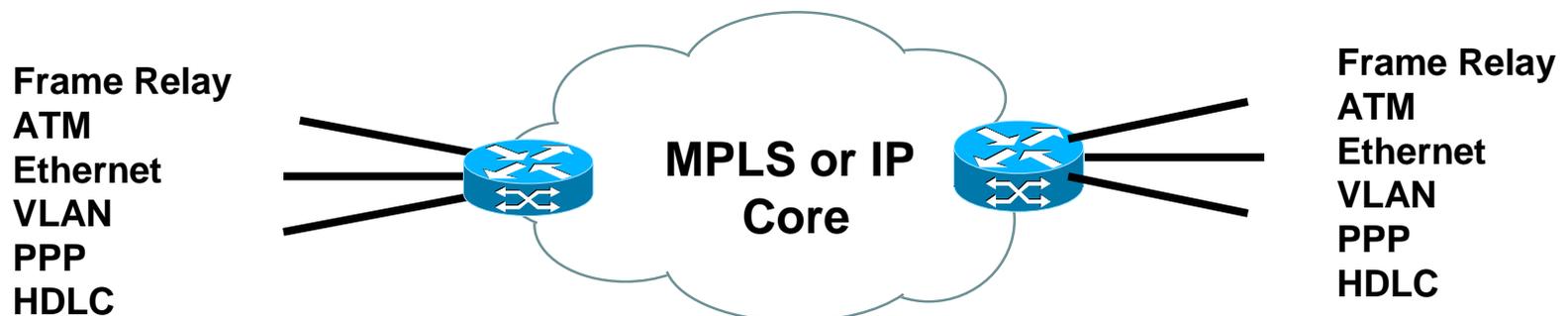
- 'Emulated Circuits' use 3 layers of encapsulation
  - **Tunnel Header**
    - to get PDU from ingress to egress PE; could be an MPLS label, GRE tunnel, L2TP tunnel
  - **Demultiplexer field**
    - to identify individual circuits within a tunnel; could be an MPLS label or GRE key
  - **Emulated VC encapsulation**
    - information on enclosed Layer-2 PDU; implemented as a 32-bit control word
- **L2 PDU data**

# VPWS - Encapsulations

- Pseudo wire encapsulations include:
  - Frame Relay
  - PPP
  - HDLC
  - Ethernet
  - VLAN
  - ATM AAL5
  - ATM Cell mode VCC
  - ATM Cell mode VPC

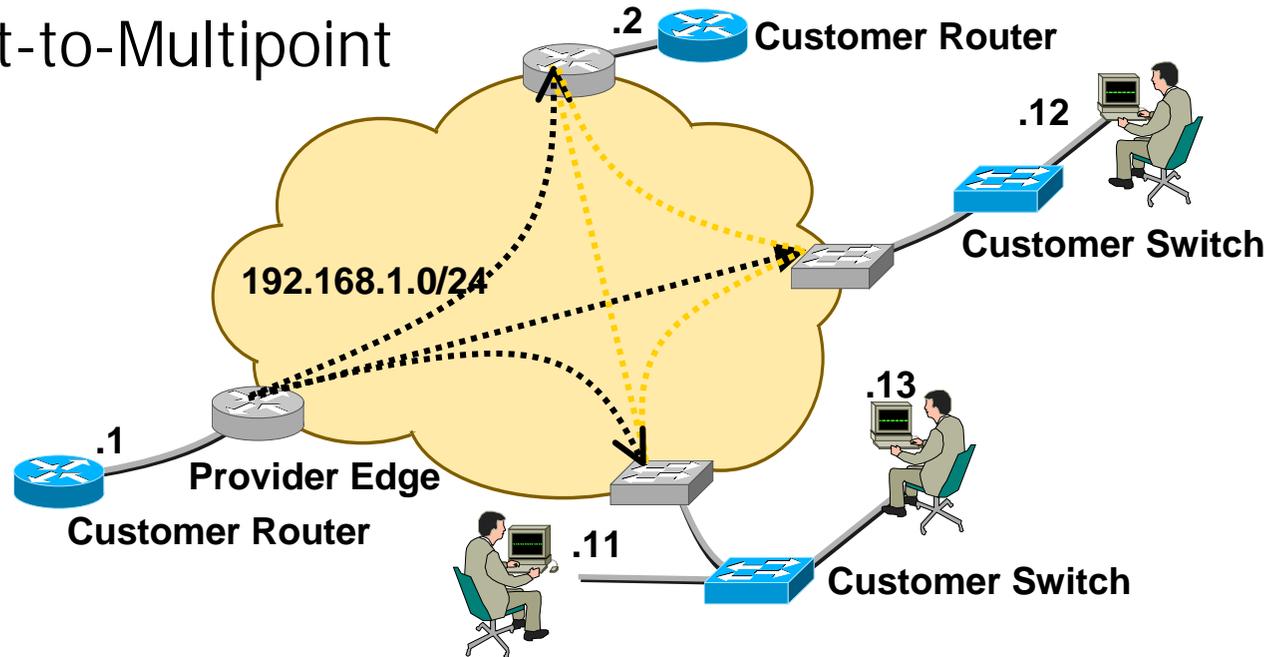


- **Like-to-Like Transport Connectivity:**
  - Pseudo Wire end-points of the **same** attachment circuit type
- **Any-to-Any Transport Connectivity:**
  - Pseudo Wire end-points of **disparate** attachment circuit type



# VPLS – Virtual Private LAN Services

## Point-to-Multipoint



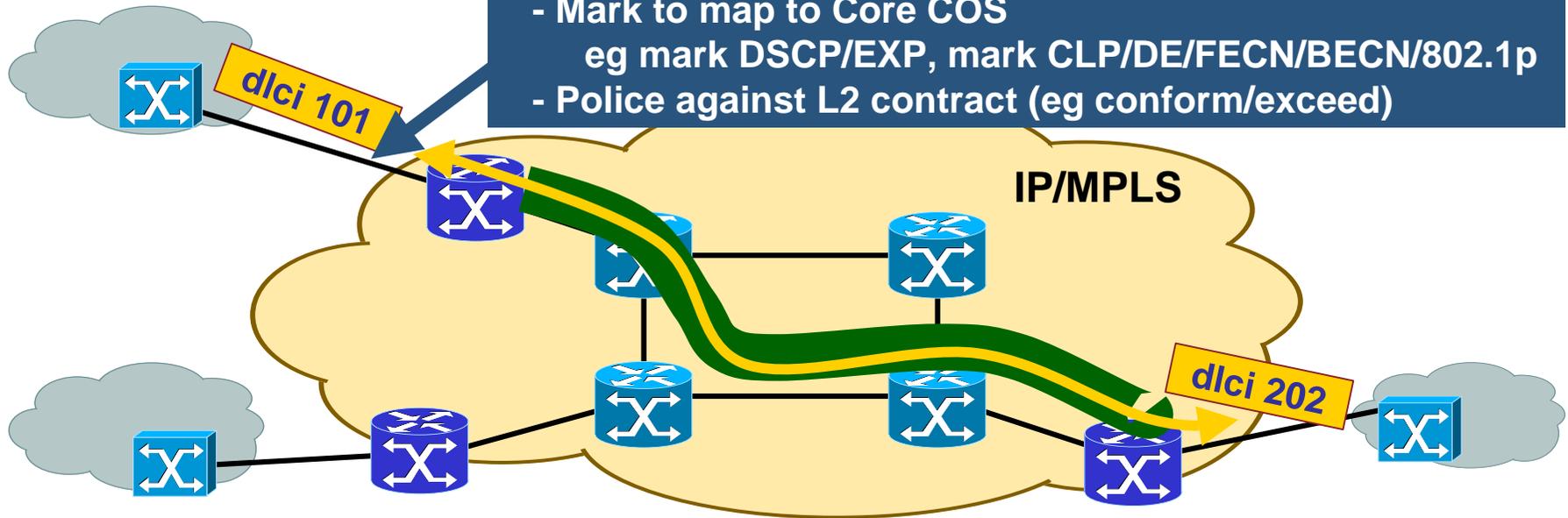
- Single bridge domain (1 VLAN)
- Single subnet
- Single SLA
- Single protection attributes
- Single availability attributes
- Mac-address learning and forwarding

- Topics:
  - L2VPN Introduction
  - L2VPN Models
  - **Quality of Service**
  - L2VPN End-to-End Connectivity
  - IETF Drafts

# VPWS Edge QoS: Ingress Edge

## Ingress Edge QoS Mechanisms:

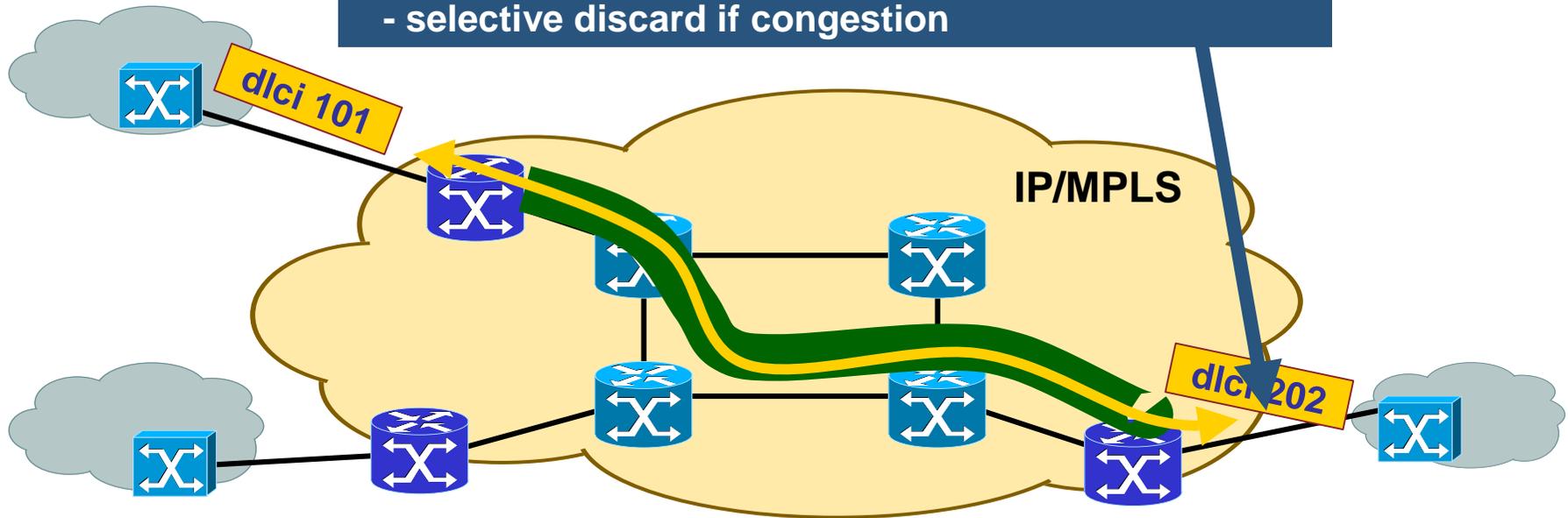
- Classify traffic
  - eg which L2 circuit (DLCI, PVC, VLAN)
  - eg L2 QoS marking (CLP/DE, 802.1p COS)
- Mark to map to Core COS
  - eg mark DSCP/EXP, mark CLP/DE/FECN/BECN/802.1p
- Police against L2 contract (eg conform/exceed)



# VPWS Edge QoS: Egress Edge

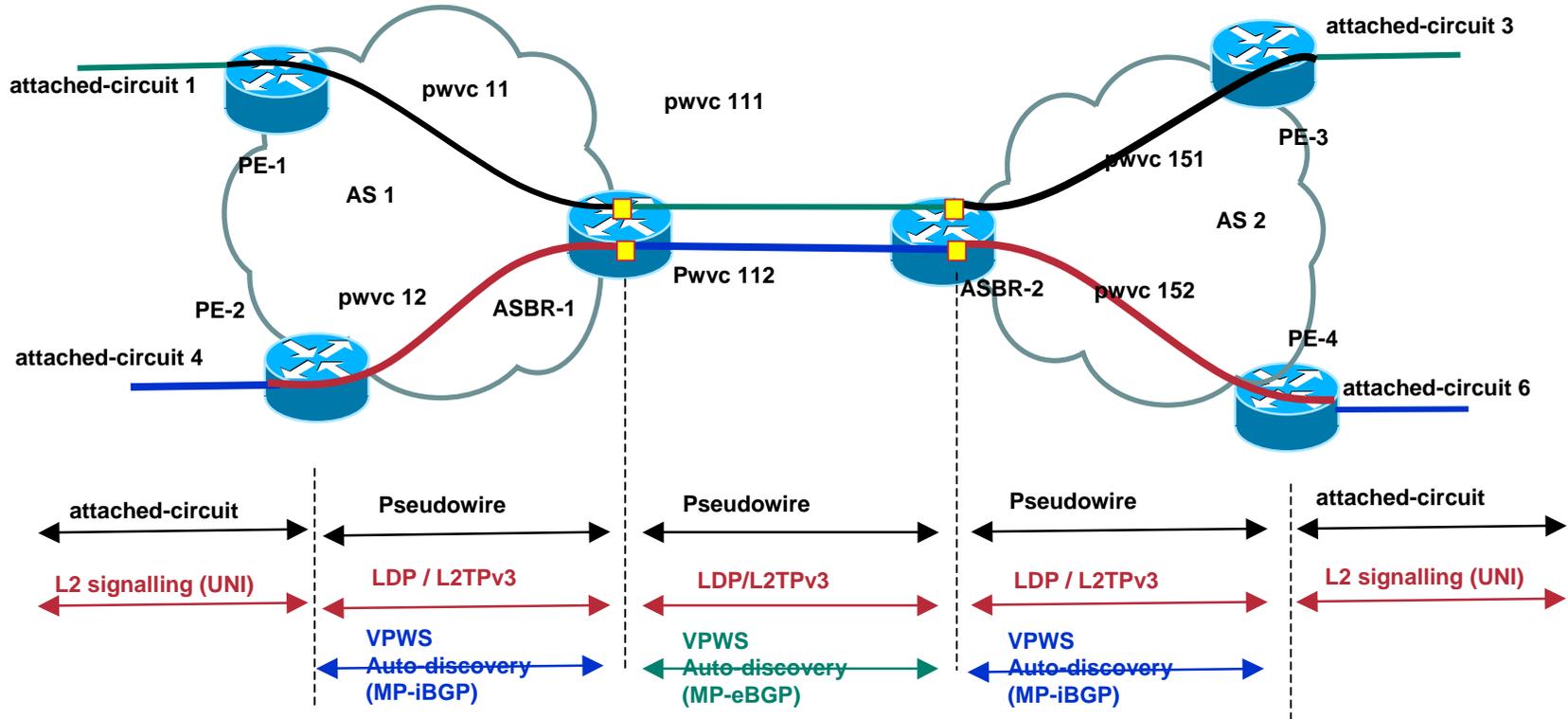
## Egress Edge QoS Mechanisms:

- Classify traffic
- Schedule on egress interface (possibly based on popped EXP values)
- selective discard if congestion



- Topics:
  - L2VPN Introduction
  - L2VPN Models
  - Quality of Service
  - **L2VPN End-to-End Connectivity**
  - IETF Drafts

# L2VPN End to End Connectivity



## Pseudo Wire Stitching Model

# IETF Drafts

- [1] RFC 3031 - Multiprotocol Label Switching Architecture
- [2] RFC 3036 - LDP Specification
- [3] RFC 2547 - BGP/MPLS VPNs
- [4] RFC 3107 - Carrying Label Information in BGP-4
- [5] draft-martini-l2circuit-encap-mpls-06.txt
- [6] draft-martini-l2circuit-trans-mpls-13.txt
- [7] draft-ietf-l2vpn-signaling-01.txt
- [8] draft-sajassi-l2vpn-interworking-01.txt
- [9] draft-shah-l2vpn-arp-mediation-03.txt
- [10] Pseudowire Setup and Maintenance using LDP- draft-ietf-pwe3-control-protocol-14.txt
- [11] Service Provider requirements for PWs- draft-willis-pwe3-requirements-00.txt
- [12] PWE3 Architecture- draft-ietf-pwe3-arch-07.txt
- [13] Encapsulation Methods for Transport of Ethernet Frames Over IP/MPLS Networks- draft-ietf-pwe3-ethernet-encap-08.txt
- [14] Pseudo Wire Switching-draft-martini-pwe3-pw-switching-01.txt
- [15] Frame Relay over Pseudo-Wires- draft-ietf-pwe3-frame-relay-03.txt
- [16] PWE3 Control Word- draft-bryant-mcpherson-pwe3-cw-00.txt
- [17] Encapsulation Methods for Transport of ATM Over MPLS Networks- draft-ietf-pwe3-atm-encap-07.txt
- [18] PWE3 ATM Transparent Cell Transport Service- draft-ietf-pwe3-cell-transport-01.txt
- [19] Pseudo Wire (PW) Management Information Base- draft-ietf-pwe3-pw-mib-05.txt

# Summary

- L2VPN provides transport of Layer-2 PDUs across an MPLS/IP backbone
- VPWS is a point-to-point L2VPN
  - It allows Like-to-Like and Any-to-Any transport connectivity
- VPLS is a point-to-multipoint L2VPN
- L2VPN QoS has capabilities to maintain strict SLA requirements comparable to L2 switches

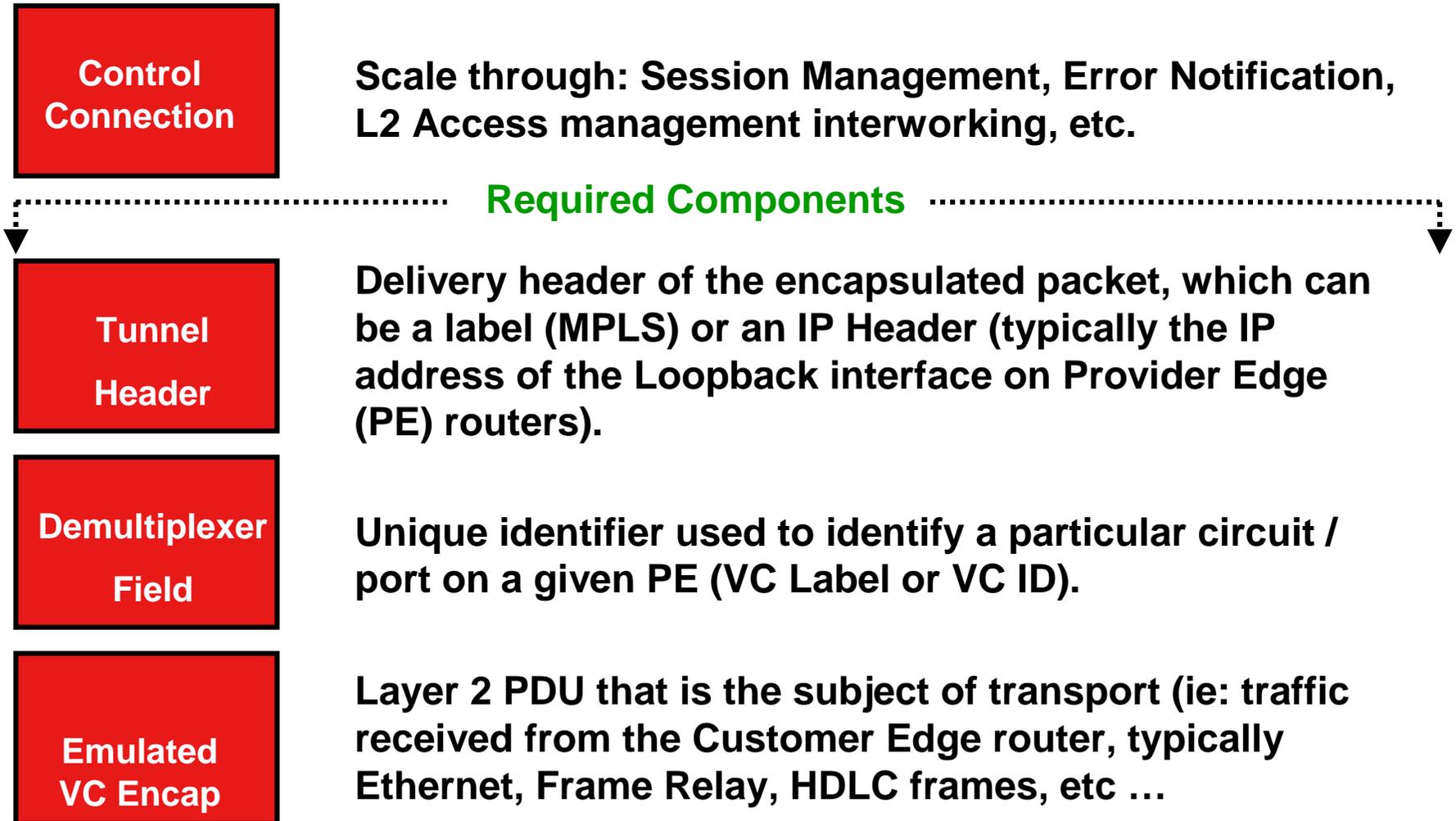
# Open Discussion

## Question & Answer

# Backup slides

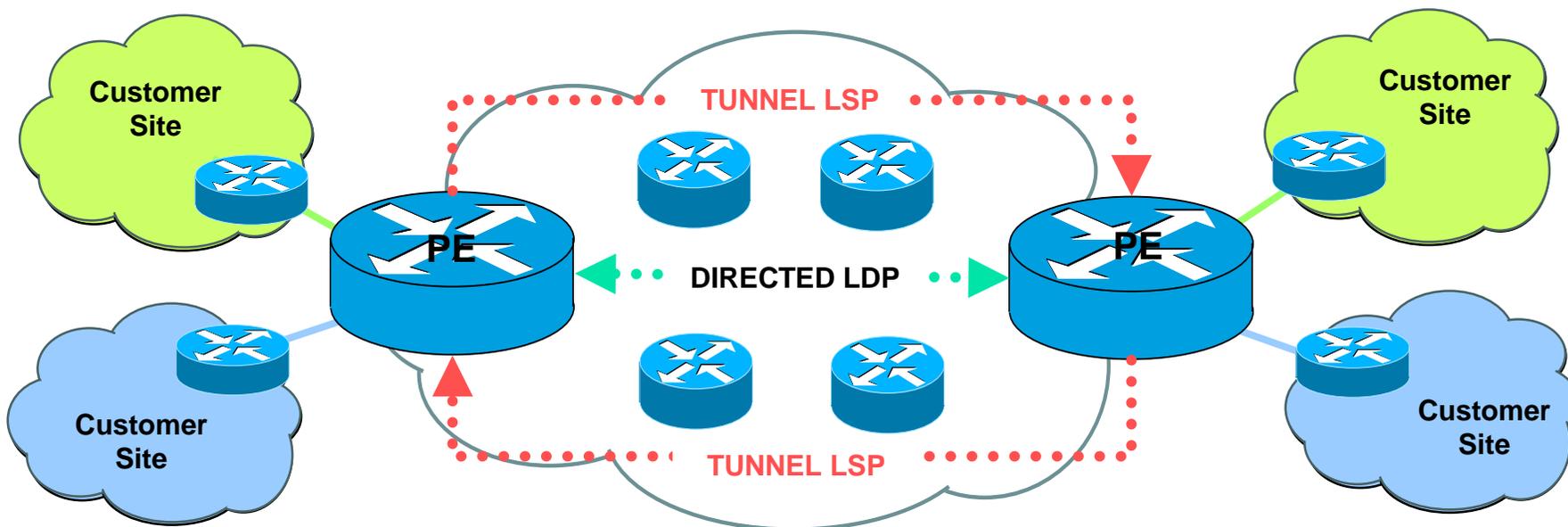
- Pseudo wire emulation edge to edge (PWE3)
  - A mechanism that emulates the essential attributes of a service (such as a T1 leased line or FR) over a PSN
- Packet switched network (PSN)
  - Within the context of PWE3, this is a network using IP or MPLS as the mechanism for packet forwarding
- Attachment circuit (AC)
  - Physical or VC attaching a CE to a PE.
- One PW connects two ACs
  - Creates VCs between two CEs
- Packet switching tunnel
  - A tunnel across a PSN inside which one or more PW can be carried

# VPWS Pseudo Wire – Basic Building Blocks



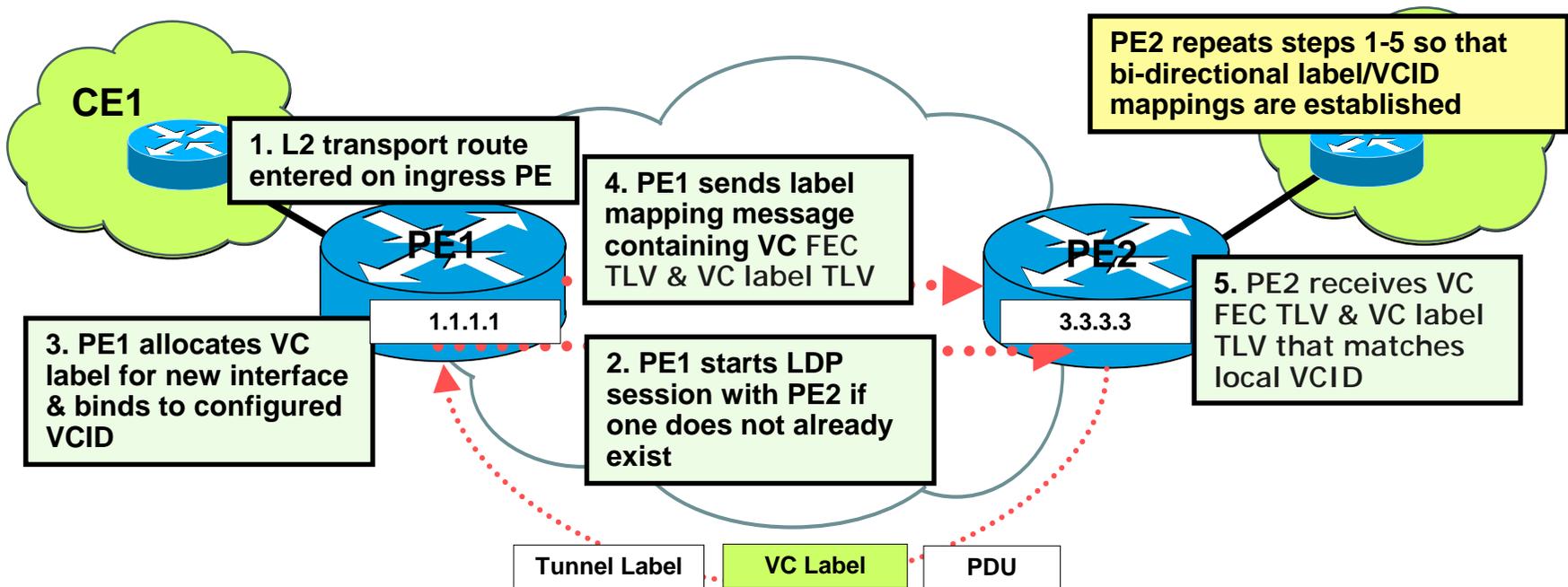
**“Connectivity between PEs assumed; verified through ICMP or LSP ping.”**

# VPWS – Label Distribution



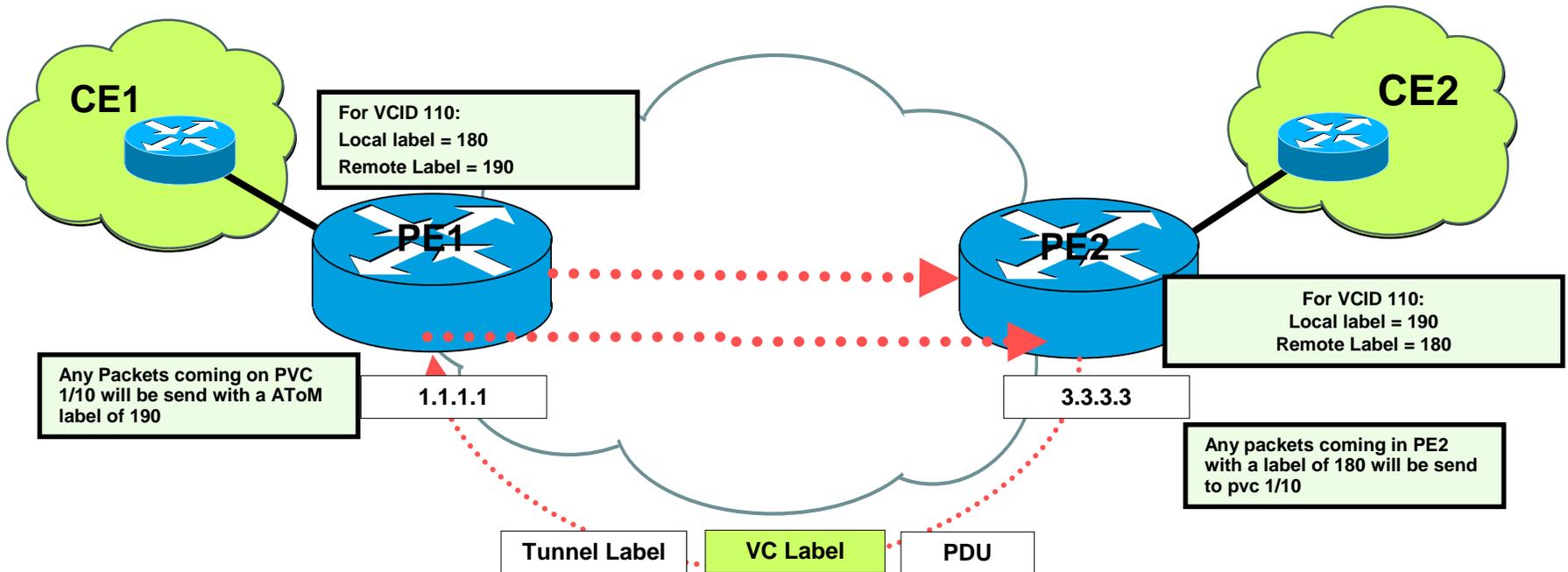
- Tunnel LSPs between PE routers
  - to transport PW PDU from PE to PE using **tunnel labels**
- MPLS core: Directed LDP session between PE routers
- IP core: L2TP control channel between PE routers
  - to exchange VC info, such as **VC labels** and **control word**

# VPWS – Label Mapping Exchange



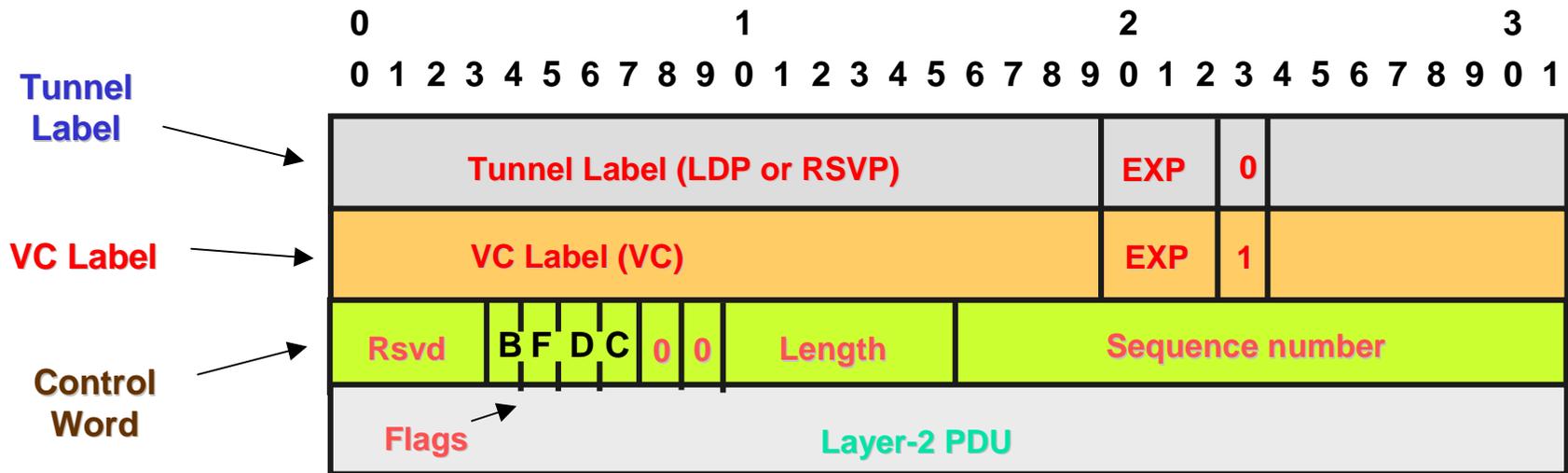
## Bi-directional Label/VCID mapping exchange

# VPWS – After Label Mapping Exchange



**Bi-directional Label/VCID mapping exchange**

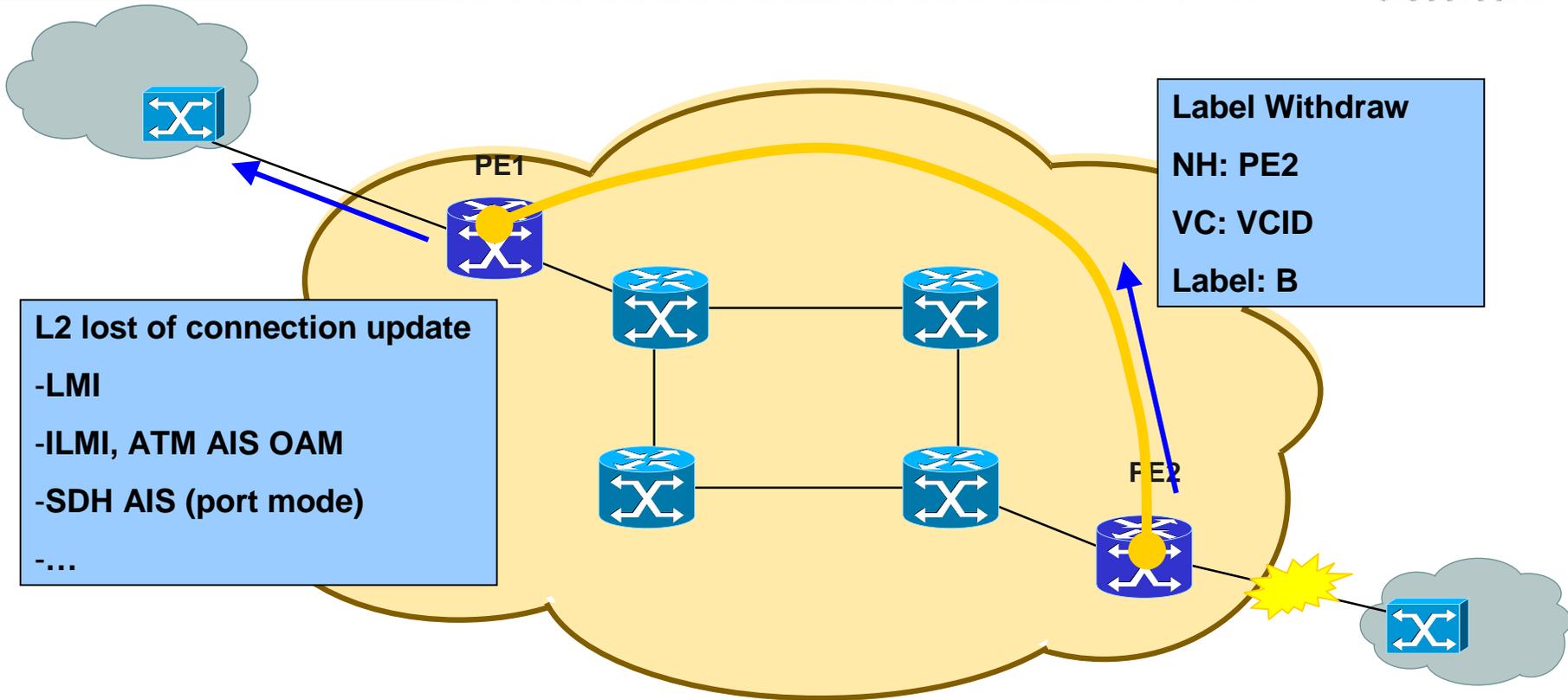
# VPWS – Generic Packet Format



- When transporting layer 2 protocol over an IP or MPLS backbone:
  - Sequence number of the packets needs to be preserved
  - Control bits carried in layer 2 frame may need to be transported
  - Small packets are padded if the minimum MTU of media > actual packet size

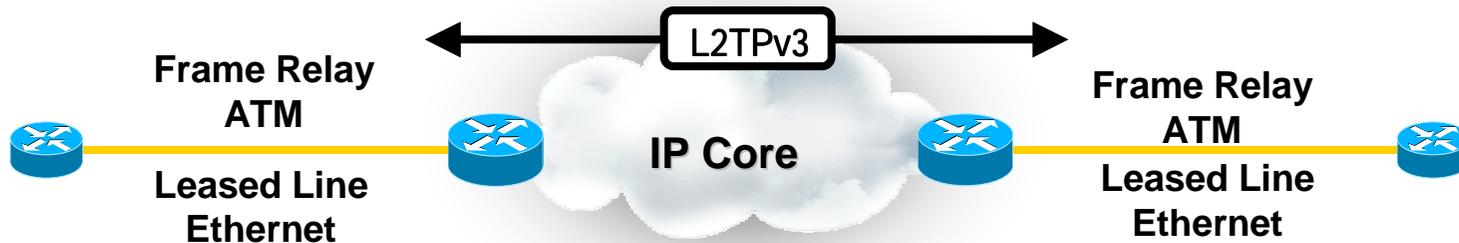
| Control Word |          |
|--------------|----------|
| Encap.       | Required |
| CR           | No       |
| AAL5         | Yes      |
| Eth          | No       |
| FR           | Yes      |
| HDLC         | No       |
| PPP          | No       |

# L2VPN: Lost of connectivity and Label Withdraw



# Layer 2 Tunneling Protocol version 3

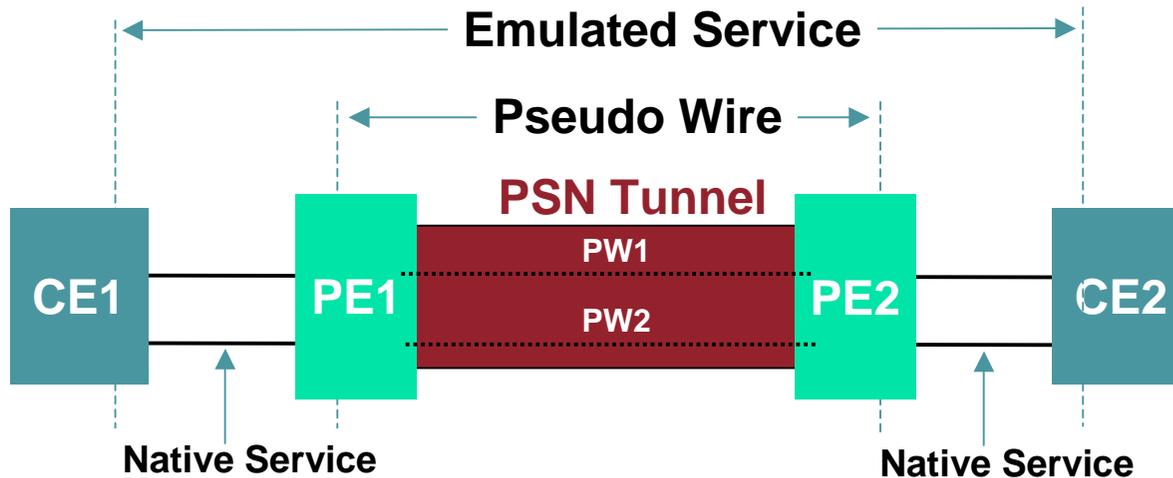
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- L2TPv3 for customers that prefer a **native IP** network
- Provides ability to **transport layer 2** traffic across IP packet-based core networks
- A **standards track** open architecture allows extensibility to many transport types
- Configuration on the **edge routers (PEs)** only!

# Virtual Circuit Connection Verification (VCCV)

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- Multiple PSN Tunnel Types
  - MPLS, IPSEC, L2TP, GRE, ...
- Motivation
  - One tunnel can serve many pseudo-wires.
  - MPLS LSP ping is sufficient to monitor the PSN tunnel (PE-PE connectivity), but not VCs inside

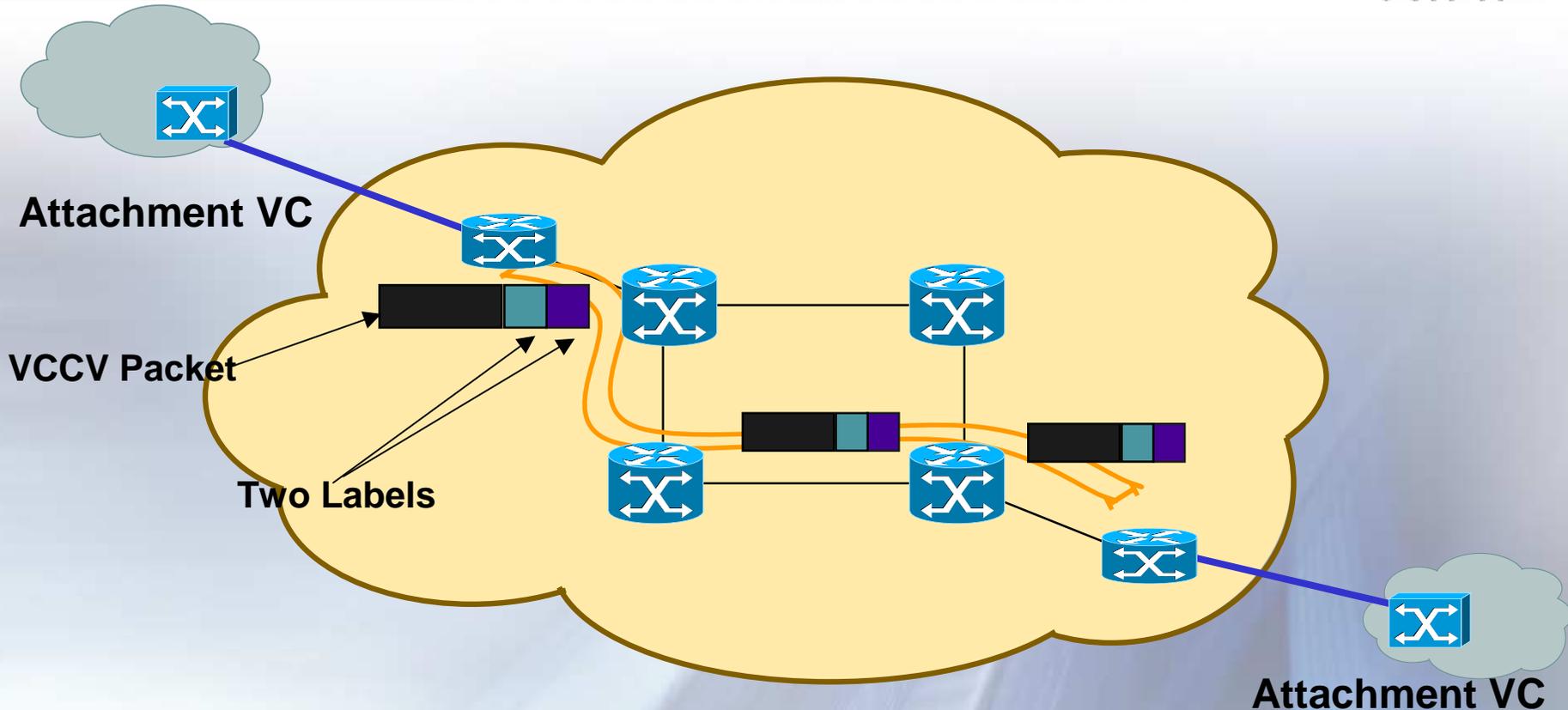
# VCCV Overview

- Mechanism for connectivity verification of PW
- Really a control channel
- Features
  - Works over MPLS or IP networks
  - In-band CV via control word flag or out-of-band option by inserting router alert label between tunnel and PW labels
  - Works with BFD, ICMP Ping and/or LSP ping
- VCCV results may drive OAM/LMI injection on corresponding AC(s)
- <http://www.ietf.org/internet-drafts/draft-ietf-pwe3-vccv-02.txt>

# PWE3 OAM Example

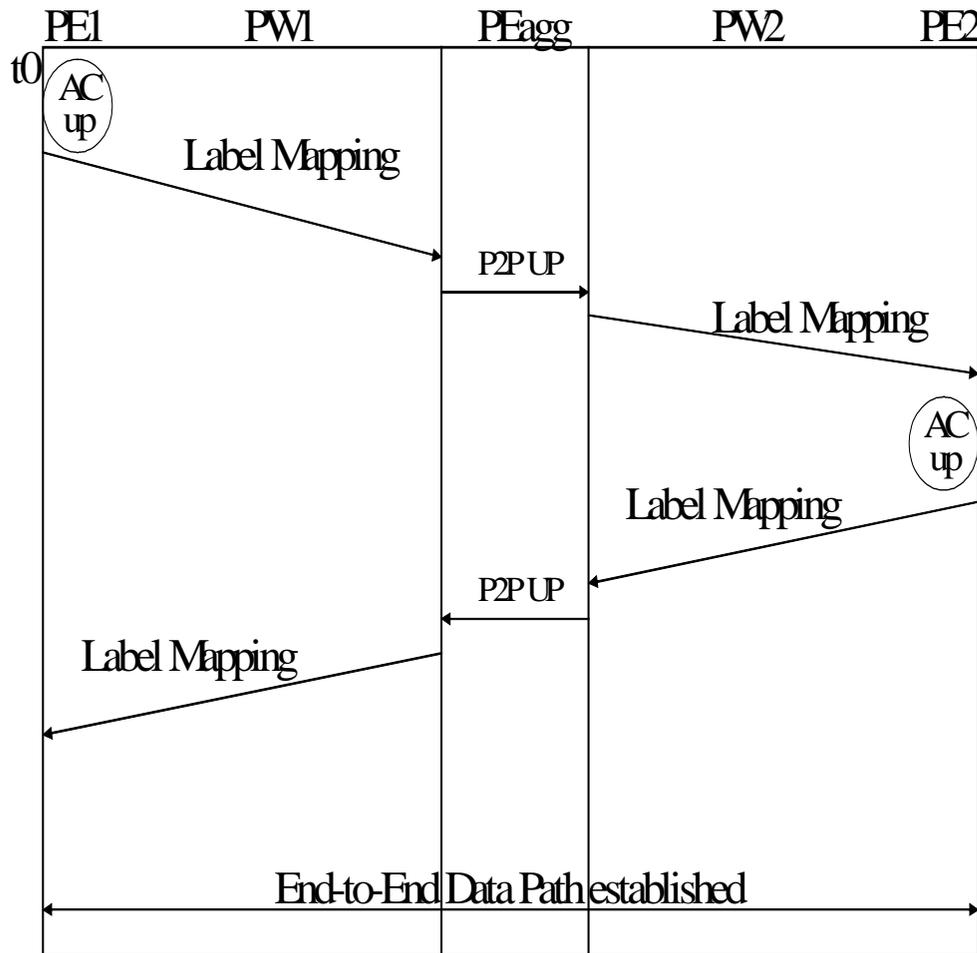
## *Connection Verification*

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- Verify/Trace Path of LSP Tunnels between PEs.
- Verify/Trace Emulated services (e.g. ATM, FR) mapped to Attachment VCs
- Trace/Verify packets must take same path as data packets.

# L2VPN: MPLS to MPLS Tunnel Stitching Protocol Setup



- At the pseudo wire stitch point ASBR2 will send VC **label X** to ASBR1
- ASBR1 will swap its VC label with **label X**
- Point-to-point session is up
- End to end data path is established

# Some Currently Defined VC-Types

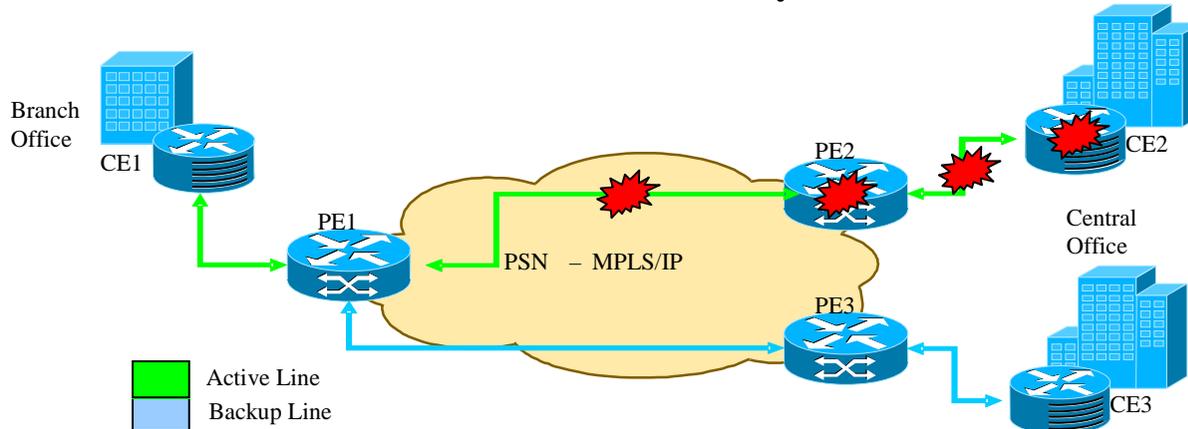
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| <u>PW type</u> | <u>Description</u>  |                             |
|----------------|---|-----------------------------|
| 0x0001         | Frame Relay DLCI  | <i>! Frame Relay</i>        |
| 0x0002         | ATM AAL5 SDU VCC transport                                  | <i>! ATM AAL5 SDU</i>       |
| 0x0003         | ATM transparent cell transport                              | <i>! ATM Cell Port Mode</i> |
| 0x0004         | Ethernet Tagged Mode  | <i>! Ethernet VLAN</i>      |
| 0x0005         | Ethernet  | <i>! Ethernet</i>           |
| 0x0006         | HDLc  | <i>! HDLC</i>               |
| 0x0007         | PPP   | <i>! PPP</i>                |
| 0x0008         | SONET/SDH Circuit Emulation Service Over MPLS (CEM) [Notel] |                             |
| 0x0009         | ATM n-to-one VCC cell transport                             | <i>! ATM Cell VC Mode</i>   |
| 0x000A         | ATM n-to-one VPC cell transport                             | <i>! ATM Cell VP Mode</i>   |
| 0x000B         | IP Layer2 Transport   | <i>! Interworking IP</i>    |
| 0x000C         | ATM one-to-one VCC Cell Mode                                |                             |
| 0x000D         | ATM one-to-one VPC Cell Mode                                |                             |
| 0x000E         | ATM AAL5 PDU VCC transport                                  |                             |
| 0x000F         | Frame-Relay Port mode                                       |                             |
| 0x0010         | SONET/SDH Circuit Emulation over Packet (CEP)               |                             |
| 0x0011         | Structure-agnostic E1 over Packet (SAToP)                   |                             |
| 0x0012         | Structure-agnostic T1 (DS1) over Packet (SAToP)             |                             |
| 0x0013         | Structure-agnostic E3 over Packet (SAToP)                   |                             |
| 0x0014         | Structure-agnostic T3 (DS3) over Packet (SAToP)             |                             |
| 0x0015         | CESoPSN basic mode  |                             |
| 0x0016         | TDMoIP basic mode   |                             |
| 0x0017         | CESoPSN TDM with CAS  |                             |
| 0x0018         | TDMoIP TDM with CAS   |                             |

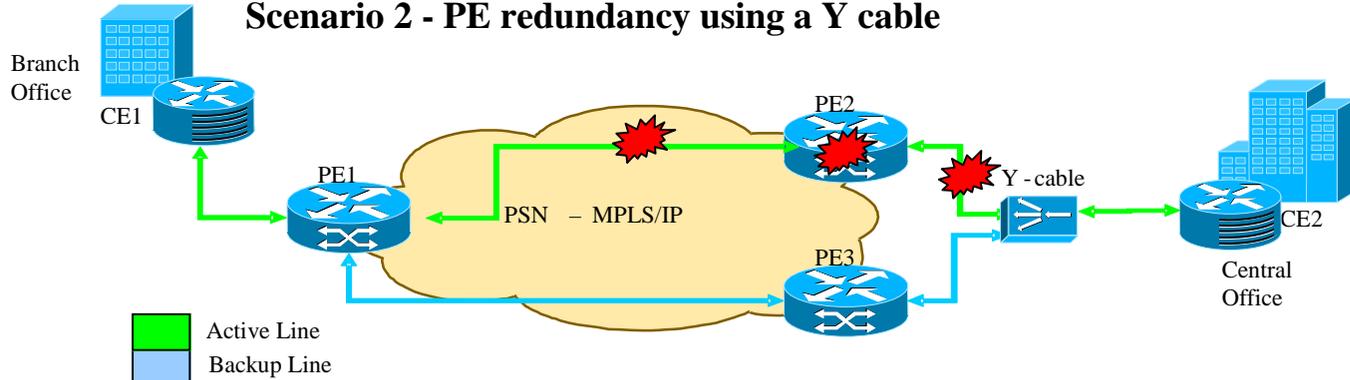
**Note 1: This PW Type Is Grandfathered for a Historical Protocol; the Recommended Standards-Track Protocol to Use Is CEP (PW Type 0x0010)**

# L2VPN Redundancy Scenarios

## Scenario 1 - PE and CE redundancy at central site

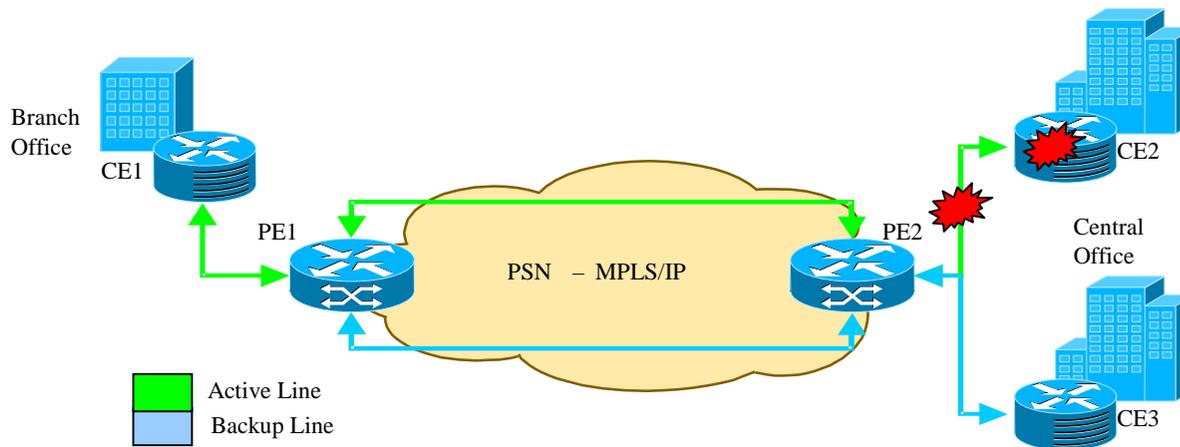


## Scenario 2 - PE redundancy using a Y cable

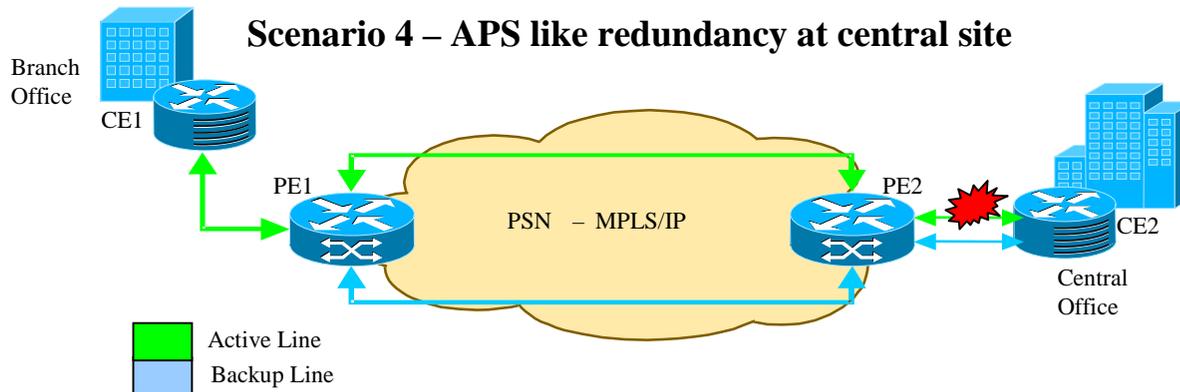


# L2VPN Redundancy Scenarios

## Scenario 3 - Circuit redundancy at central site



## Scenario 4 - APS like redundancy at central site



# L2VPN End to End Redundant Solution

- By combining L2VPN stitching and redundancy SPs can:
  - Offer end to end L2VPN services across multiple BGP domains
  - Protect primary end to end L2VPN path with a backup path
  - Apply security profiles when L2VPN path enters an un-trusted domain
  - Apply QoS policing and shaping to maintain SLAs

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