WELCOME

APRICOT 2012

MPLS WORKSHOP – L2VPN

Alastair Johnson alastair.johnson@alcatel-lucent.com

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MPLS WORKSHOP
L2VPN

1. Introduction to L2VPN
   a. Background to VPNs
   b. Why L2VPNs
   c. Types of L2VPNs
2. Technology introduction
3. L2VPN – Ethernet Pseudowire (VLL, EPIPE)
4. L2VPN – Ethernet Virtual Private LAN Service (VPLS)
5. Advanced topics
6. Summary

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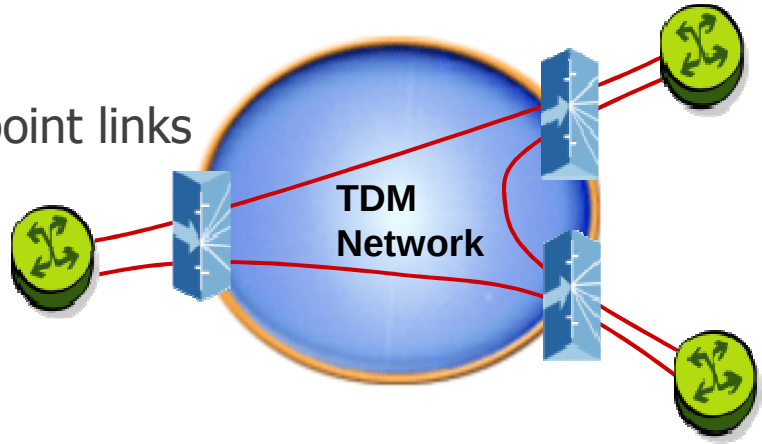
INTRODUCTION TO L2VPN

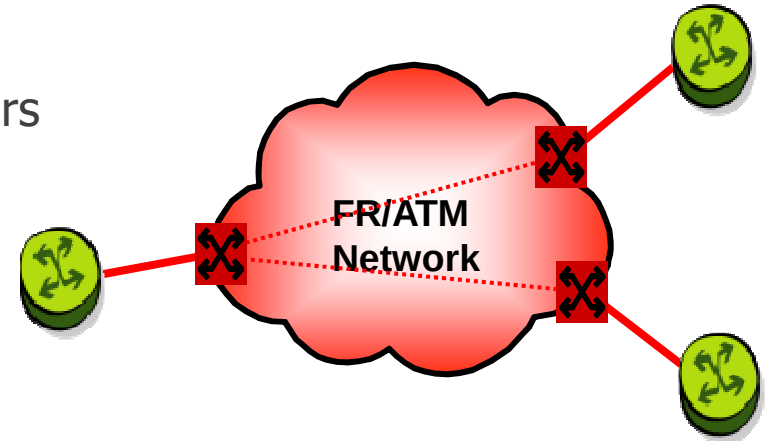
BACKGROUND TO VPNs

EXISTING SERVICE PORTFOLIO

- **Leased lines**
  - Customers subscribe to 'dedicated' point-to-point links
  - Cost prohibitive for customers

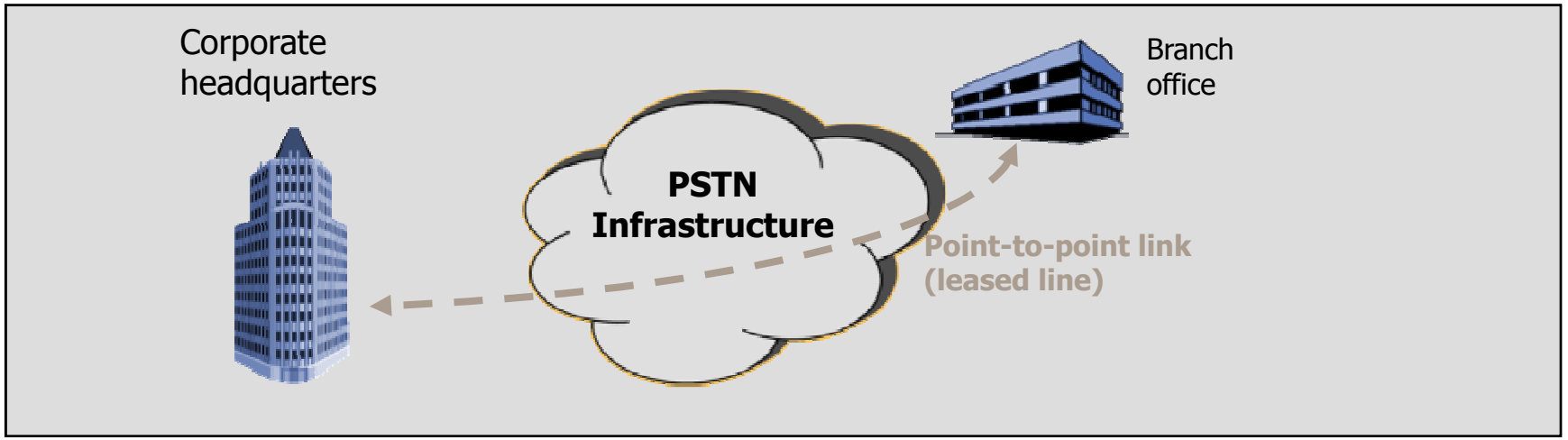


- **Frame Relay and ATM services**
  - Customers subscribe to point-to-point links to construct Hub and Spoke, Mesh or a Hybrid topology
  - Offered over a shared infrastructure that offers multiplexing advantages
  - Cheaper alternative to Leased line



THE ORIGIN OF PRIVATE NETWORKS

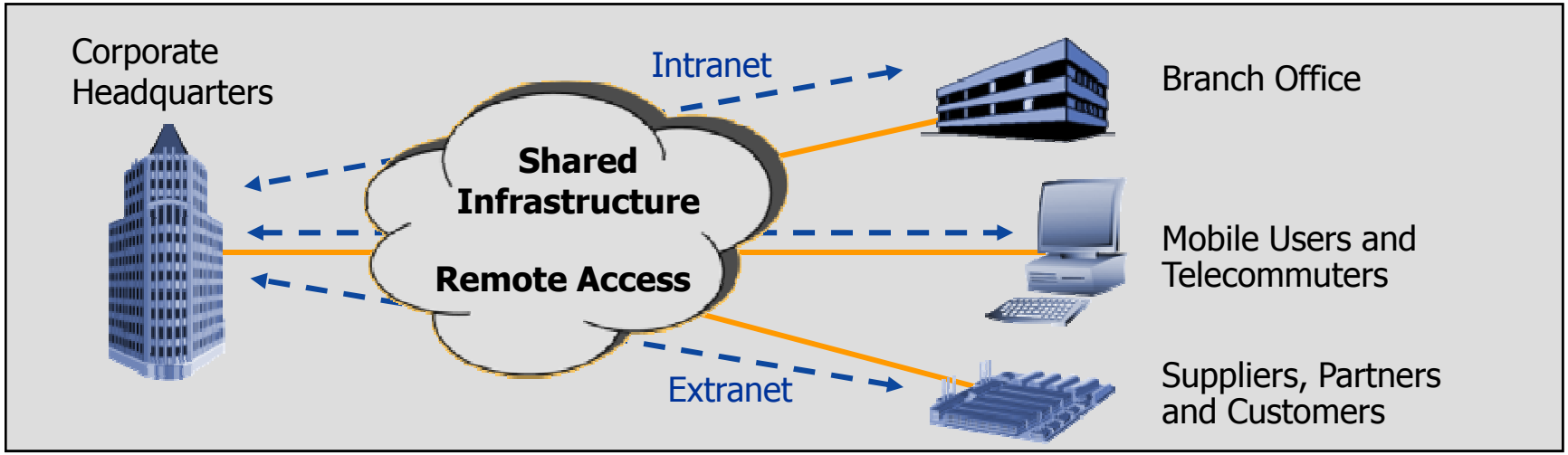
THE CORPORATE MODEL STARTED IN THE 80S



- **Large corporations having separate private networks**
  - Connected by means of leased lines for transmission throughout the PSTN-infrastructure
  - Voice focused, some data services (including packet switched, e.g. X.25)
- **Existing backbone wholesale solution but with limited opportunities for data core providers**
  - Transmission only
- **Point-to-Point links cannot address source mobility**

THE CURRENT IMPLEMENTATION OF VPNs

THE CORPORATE MODEL STARTED IN THE 90S



- **"A private network constructed over a shared infrastructure"**
  - Intranet
  - Extranet
  - Remote access
- **Opportunity for data core providers beyond transmission :**
  - Winning back corporate customers
  - high growth application area's such as e-commerce, Intranet, extranet, remote access provision
  - addressing source mobility

WHAT IS A VIRTUAL PRIVATE NETWORK (VPN)?

- VPNs emulate a private network over a shared Service Provider network
  - Interconnection of multiple private, geographically dispersed enterprise networks over a service provider network
  - Sharing service provider resources

- Virtual
  - No correspondent physical network
  - An emulated infrastructure utilizing underlying public network or networks

- Private
  - Access is restricted only to a defined set of entities

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INTRODUCTION TO L2VPN

WHY L2VPN

WHY L2VPN

- Expanded service offerings by a service provider
- Offering of VPNs at a lower layer than IP
  - Because customers may not want service providers involved in IP routing
  - Transport of services which are not IP based
  - Services where IP routing is not required
- Consolidation of networks in a service provider domain
  - Consolidate ATM, Frame-Relay, Metro Ethernet, IPVPN onto a single IP core
  - Optimize our core network capacities
  - Remove legacy technologies and platforms from our network
- Service provider simplicity
  - No need to scale L3VPNs to thousands or millions of routes
  - Customers responsible for own routing – we only switch

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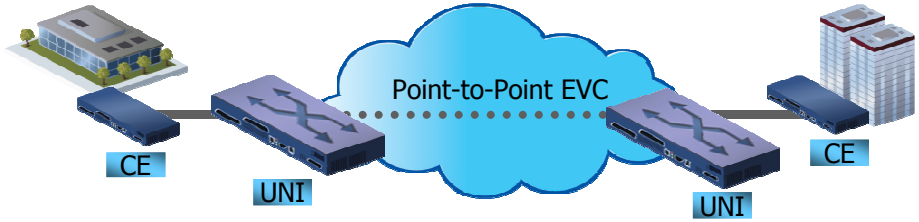
INTRODUCTION TO L2VPN

TYPES OF L2VPN

TYPES OF L2VPN

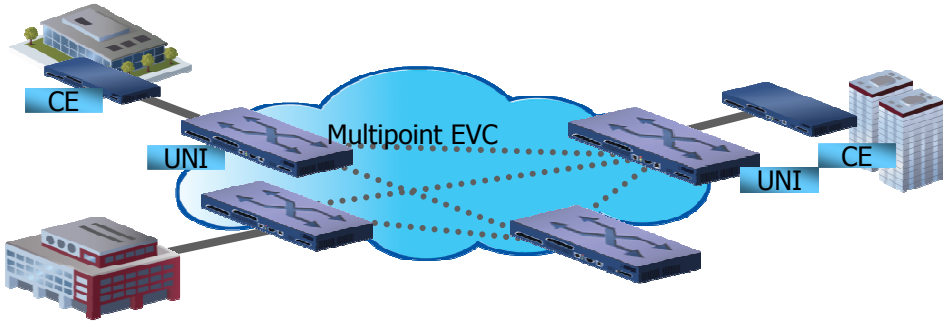
METRO ETHERNET FORUM SERVICE TYPES

E-LINE



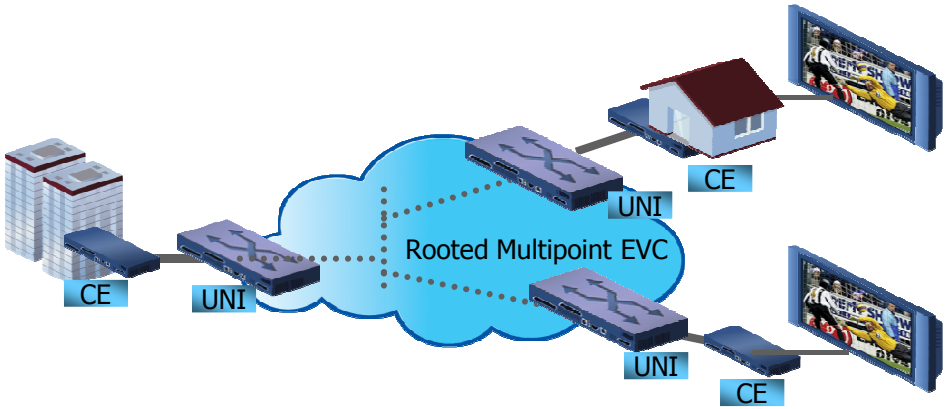
Point to Point
Service Type used to create
- Ethernet Private Lines
- Virtual Private Lines
- Ethernet Internet Access

E-LAN



Multi-Point to Multi-Point
Service Type used to create
- Multipoint Layer 2 VPNs
- Transparent LAN Service

E-TREE



Point to Multi-Point
- Efficient use of Service Provider ports
- Foundation for Multicast networks e.g. IPTV

TYPES OF L2VPN
OTHER TYPES OF VPN

- Layer 2 Transport focused
  - ATM
    Transport of ATM services over an IP/MPLS pseudowire, allowing the transport of legacy services and interfaces, or the optimization of your core networks for bandwidth
  - Frame Relay
    Transport of Frame Relay services over an IP/MPLS pseudowire, allowing the transport of legacy services and interfaces, or the optimization of your core networks for bandwidth
  - Circuit Emulation (TDM)
    Transport of TDM interfaces (T1/E1/DS3/etc) over an IP/MPLS pseudowire, allowing the transport of legacy services and interfaces – but not really an optimization of core network bandwidth
  - IP
    Interworking of discrete technologies (e.g. FR and Ethernet) at the IP layer, allowing separate interfaces to be interworked at the IP layer

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TECHNOLOGY INTRODUCTION

THE PSEUDOWIRE REFERENCE MODEL

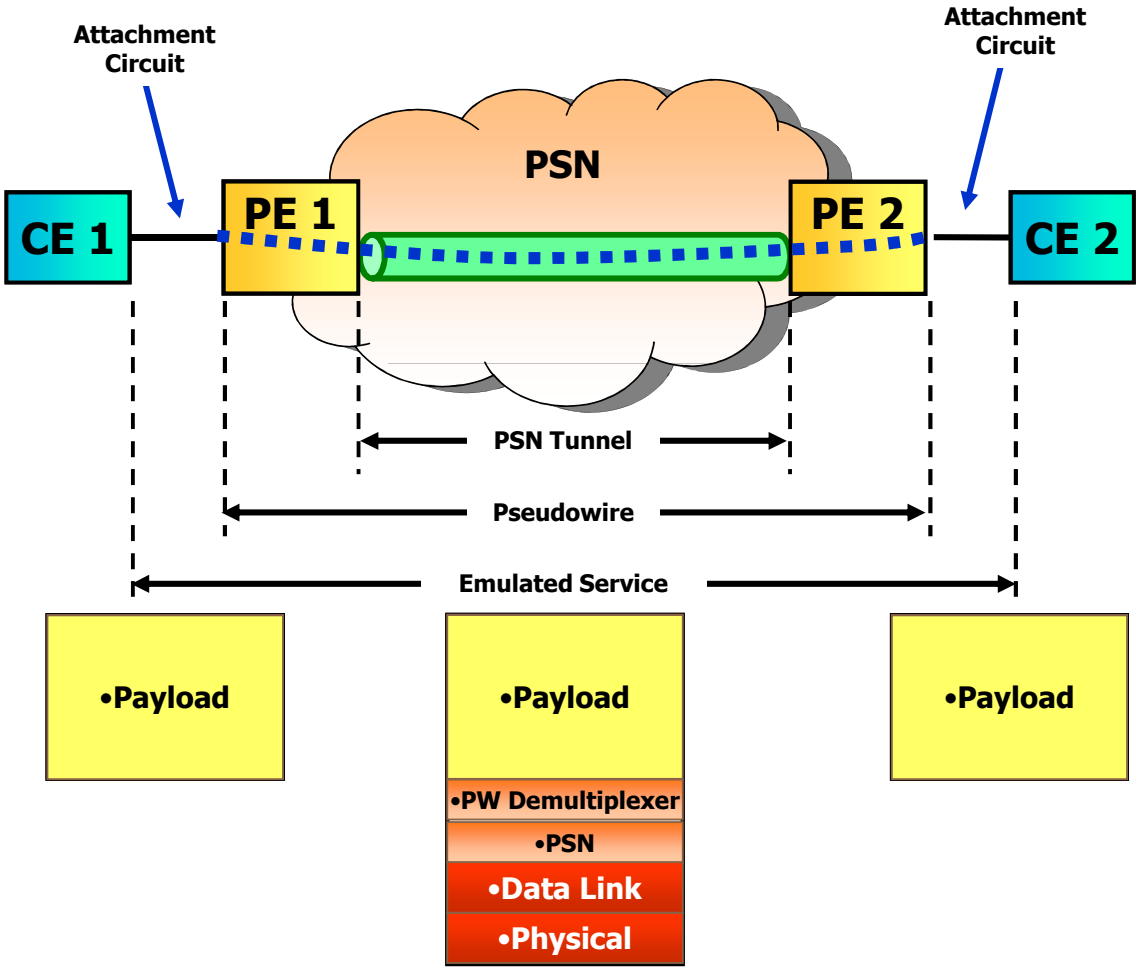
Pseudowires, Pwires, PWs, PWEs, or PWE3s:

- Key enabling technology for delivering Ethernet services over MPLS
- Specified by the **pwe3** working group of the IETF
- Originally designed for Ethernet over MPLS (EoMPLS) – initially called Martini tunnels
- Now extended to many other services – ATM, FR, Ethernet, TDM
- Encapsulates and transports service-specific PDUs/Frames across a Packet Switched Network (PSN) tunnel
- The use of pseudowires for the emulation of point-to-point services is referred to as Virtual Private Wire Service (VPWS)
- IETF definition (RFC3985):

  "...a mechanism that emulates the essential attributes of a telecommunications service (such as a T1 leased line or Frame Relay) over a PSN. PWE3 is intended to provide only the minimum necessary functionality to emulate the wire with the required degree of faithfulness for the given service definition."

PWE3 REFERENCE MODEL

- Generic PWE3 Architectural Reference Model:

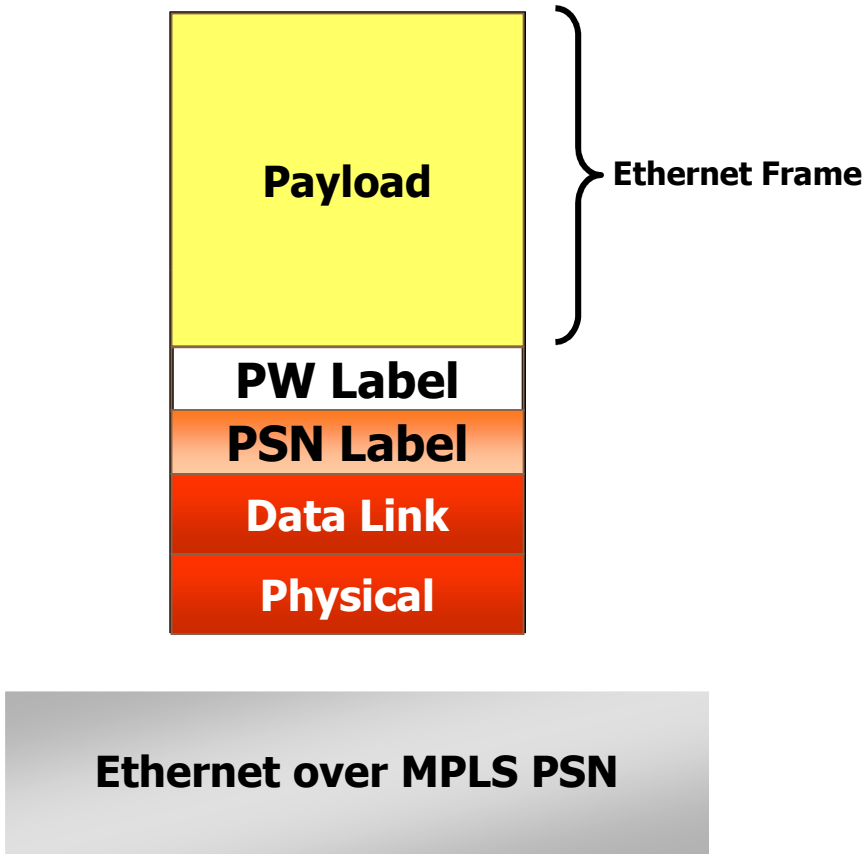


PWE3 TERMINOLOGY

- Attachment circuit (AC)
  - The physical or virtual circuit attaching a CE to a PE
- Customer Edge (CE)
  - A device where one end of a service originates and/or terminates
- Forwarder (FWRD)
  - A PE subsystem that selects the PW to use in order to transmit a payload received on an AC
- Packet Switched Network (PSN)
  - Within the context of PWE3, this is a network using IP or MPLS as the mechanism for packet forwarding
- Provider Edge (PE)
  - A device that provides PWE3 to a CE
- Pseudo Wire (PW)
  - A mechanism that carries the essential elements of an emulated service from one PE to one or more other PEs over a PSN
- PSN Tunnel
  - A tunnel across a PSN, inside which one or more PWs can be carried
- PW Demultiplexer
  - Data-plane method of identifying a PW terminating at a PE

PSEUDOWIRE PROTOCOL LAYERING

- The PW demultiplexing layer provides the ability to deliver multiple PWs over a single PSN tunnel

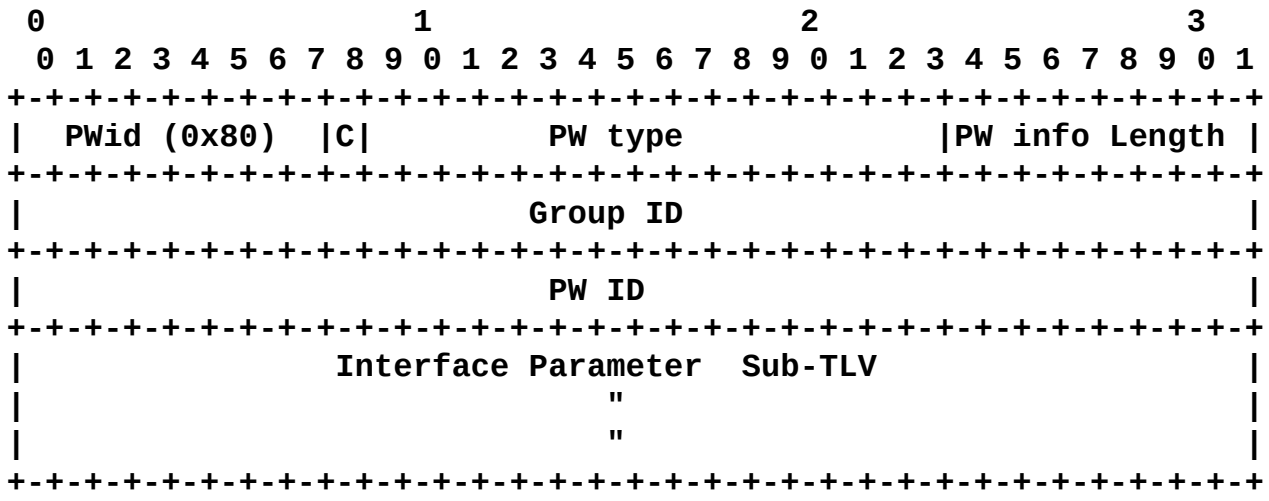


ETHERNET VIRTUAL PRIVATE WIRE SERVICE
SETUP AND MAINTENANCE

- Signalling specified in RFC4447 – "Pseudowire Setup and Maintenance Using the Label Distribution Protocol (LDP)"
- The MPLS Label Distribution Protocol, LDP [RFC5036], is used for setting up and maintaining the pseudowires
  - PW label bindings are distributed using the LDP downstream unsolicited mode
  - PEs establish an LDP session using the LDP Extended Discovery mechanism a.k.a Targeted LDP or tLDP
- The PSN tunnels are established and maintained separately by using any of the following:
  - The Label Distribution Protocol (LDP)
  - The Resource Reservation Protocol with Traffic Engineering (RSVP-TE)
  - Static labels

ETHERNET VIRTUAL PRIVATE WIRE SERVICE
SETUP AND MAINTENANCE

- LDP distributes FEC to label mappings using the PWid FEC Element (popularly known as FEC Type 128)
- Both pseudowire endpoints have to be provisioned with the same 32-bit identifier for the pseudowire to allow them to obtain a common understanding of which service a given pseudowire belongs to.

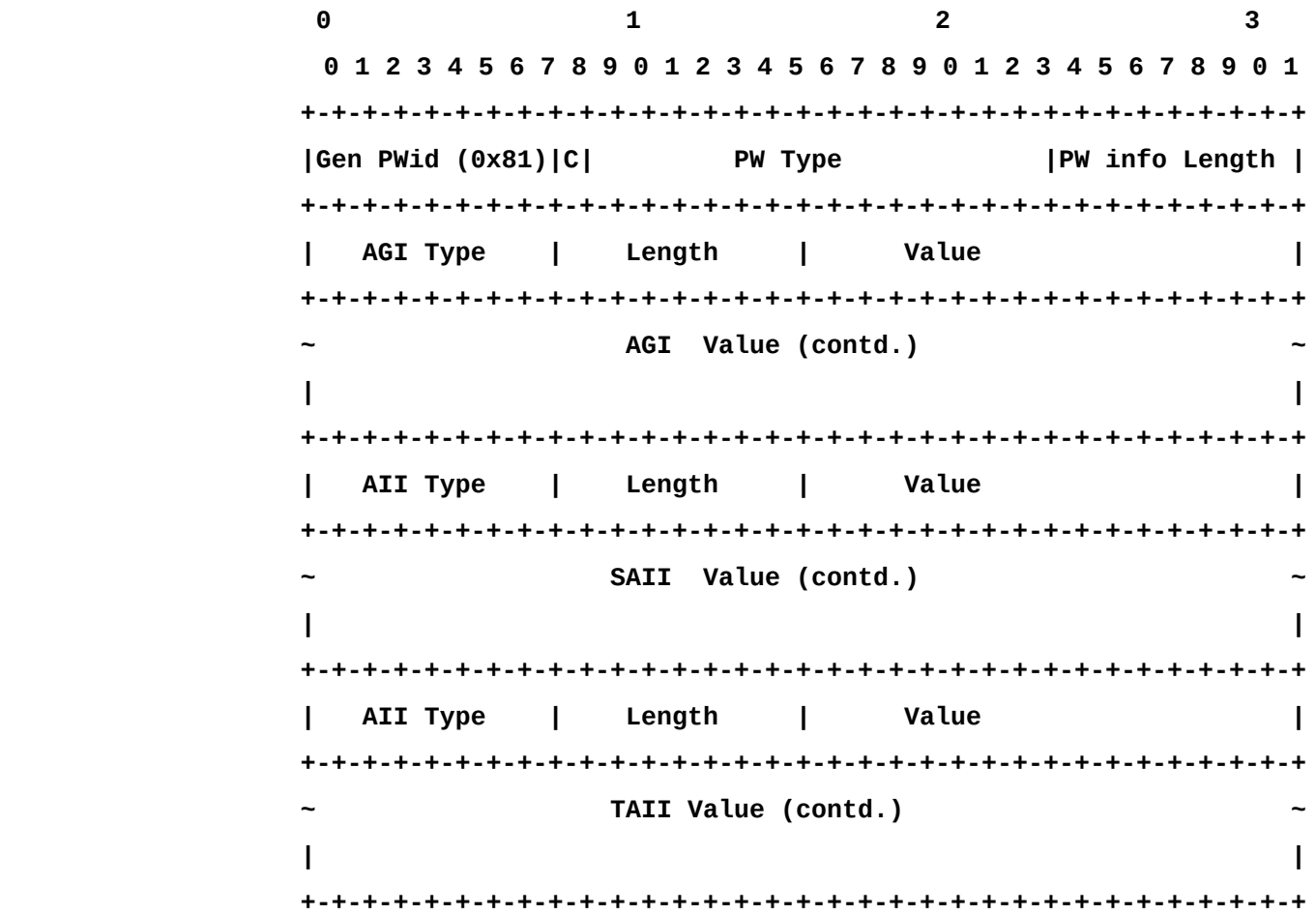


ETHERNET VIRTUAL PRIVATE WIRE SERVICE
SETUP AND MAINTENANCE

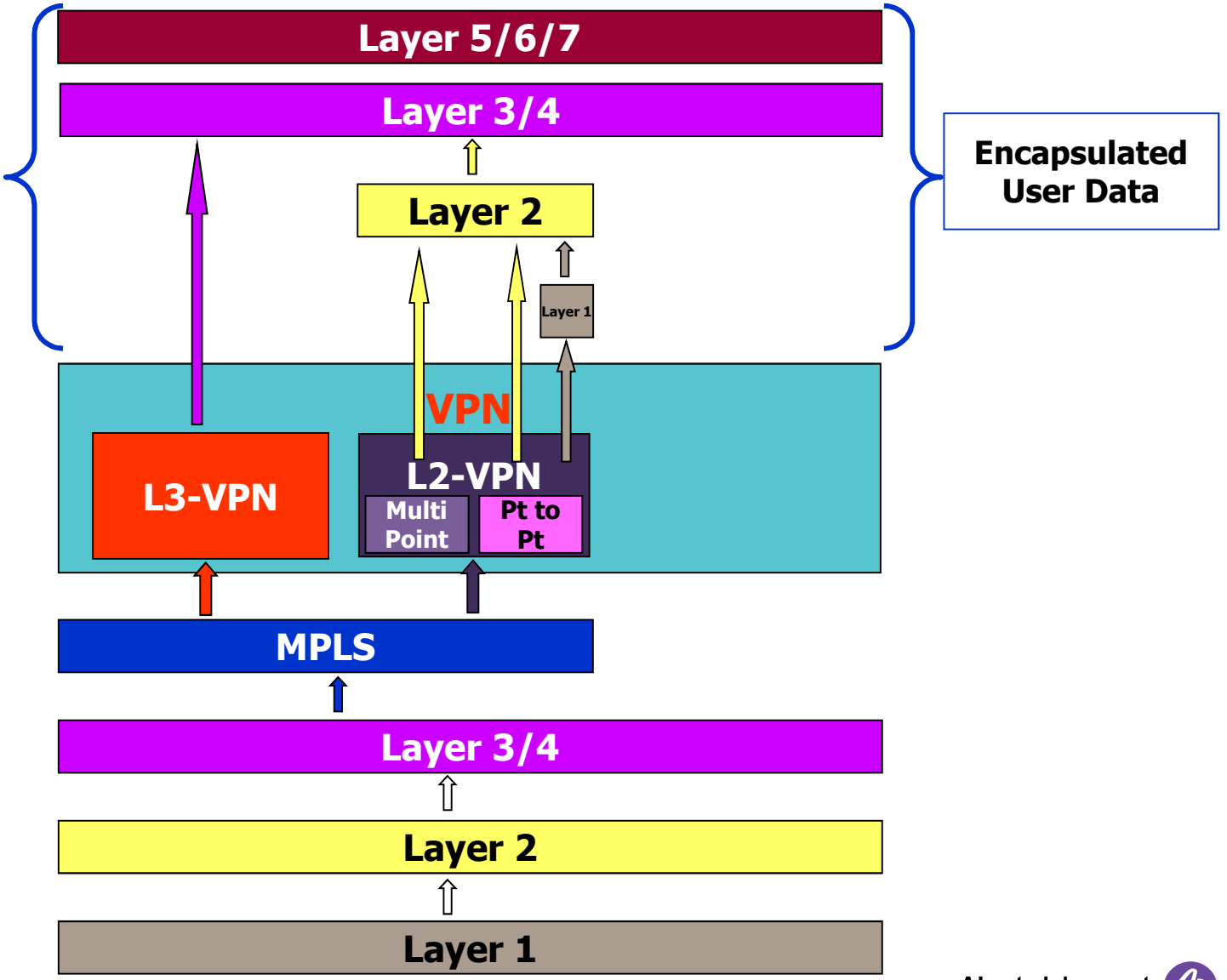
- A new TLV, the Generalized PWid FEC Element (popularly known as FEC Type 129) has also been developed but is not widely deployed as yet
- The Generalized PWid FEC element requires that the PW endpoints be uniquely identified; the PW itself is identified as a pair of endpoints. In addition, the endpoint identifiers are structured to support applications where the identity of the remote endpoints needs to be auto-discovered rather than statically configured.

ETHERNET VIRTUAL PRIVATE WIRE SERVICE
SETUP AND MAINTENANCE

- The Generalized PWid FEC Element (popularly known as FEC Type 129)

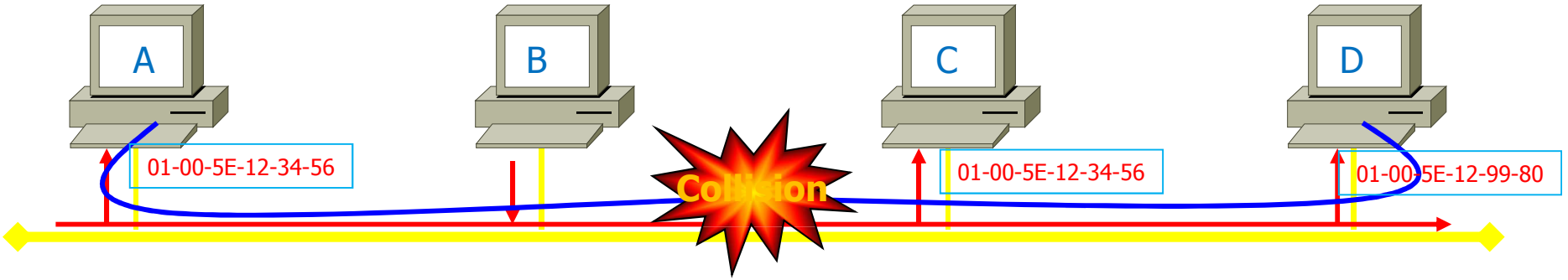


MPLS BASED VPN BUILDING BLOCKS



ETHERNET – BASIC : QUICK REFRESHER…

- A device is defined by its Media Access Control (MAC) address (6 bytes long: 00-dd-01-1e-ba-37).
- The MAC address must be unique
- The device MAC address usually don't change (often burned-in at manufacturing)
- Special MAC: **Broadcast:** → "ff-ff-ff-ff-ff-ff" **Multicast:** "01-00-5E-xx-xx-xx" (IGMP)



Device	Layer 2
A	MAC-A
B	MAC-B
C	MAC-C
D	MAC-D

A device listens to :

1. **Unicast** with its MAC (Dst: MAC-D)
2. **Broadcast** Packet (Dst: ff-ff-ff-ff-ff-ff)
3. **Multicast** where it is registered (Dst: 01-00-5E-12-34-56)

- Only **one device can speak** at a time on a segment
- If more than one device speak at the same time → **Collision**
- When a collision happens, information are **discarded** and need to be **resend** using a various delay mechanism – CSMA/CD

STANDARDS – PWE3

Standard	Title	Standard	Title
RFC3916	Requirements for PWE3 Edge-to-Edge	draft-ietf-pwe3-oam-msg-map	Pseudowire OAM Message Mapping
RFC3985	PWE3 Edge-to-Edge	draft-ietf-l2vpn-arp-mediation	ARP Mediation for IP Interworking of Layer 2 VPNs
RFC4385	PWE3 Control Words	RFC6073	Segmented pseudowires
RFC4717	Encapsulation Methods for ATM Transport over MPLS	draft-ietf-pwe3-dynamic-ms-pw	Dynamic placement of multisegment pseudowires
RFC4816	PWE3 ATM Transparent Cell Transport Service	draft-ietf-pwe3-redundancy-bit	Pseudowire preferential forwarding status bit definition
RFC4448	Encapsulation Methods for Transport of Ethernet over MPLS	draft-ietf-pwe3-redundancy	Pseudowire redundancy
RFC4619	Encapsulation Methods for Transport of Frame-Relay over MPLS		
RFC4446	IANA Allocations for PWE3		
RFC4447	Pseudowire setup and maintenance using LDP		
RFC5085	Pseudowire Virtual Circuit Connectivity Verification		
RFC5659	An architecture for multi-segment pseudowire emulation edge-to-edge		
draft-ietf-l2vpn-vpws-iw-oam	OAM Procedures for VPWS Interworking		

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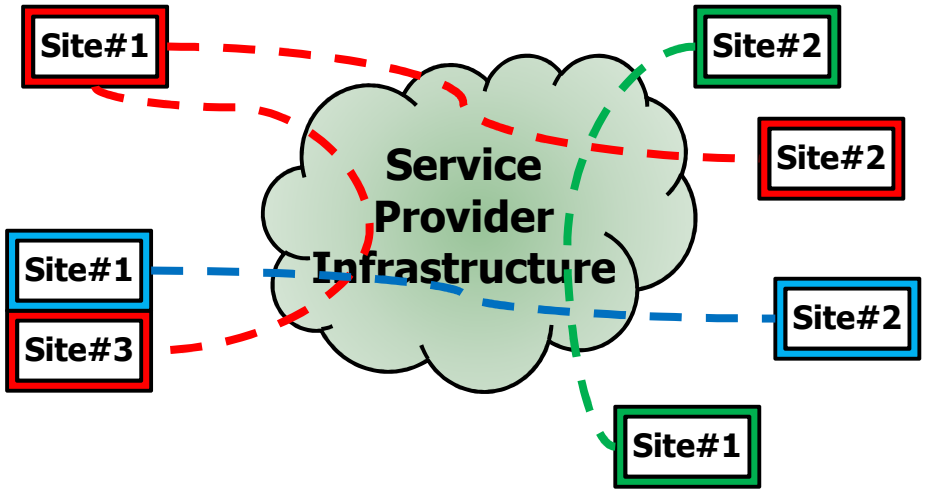
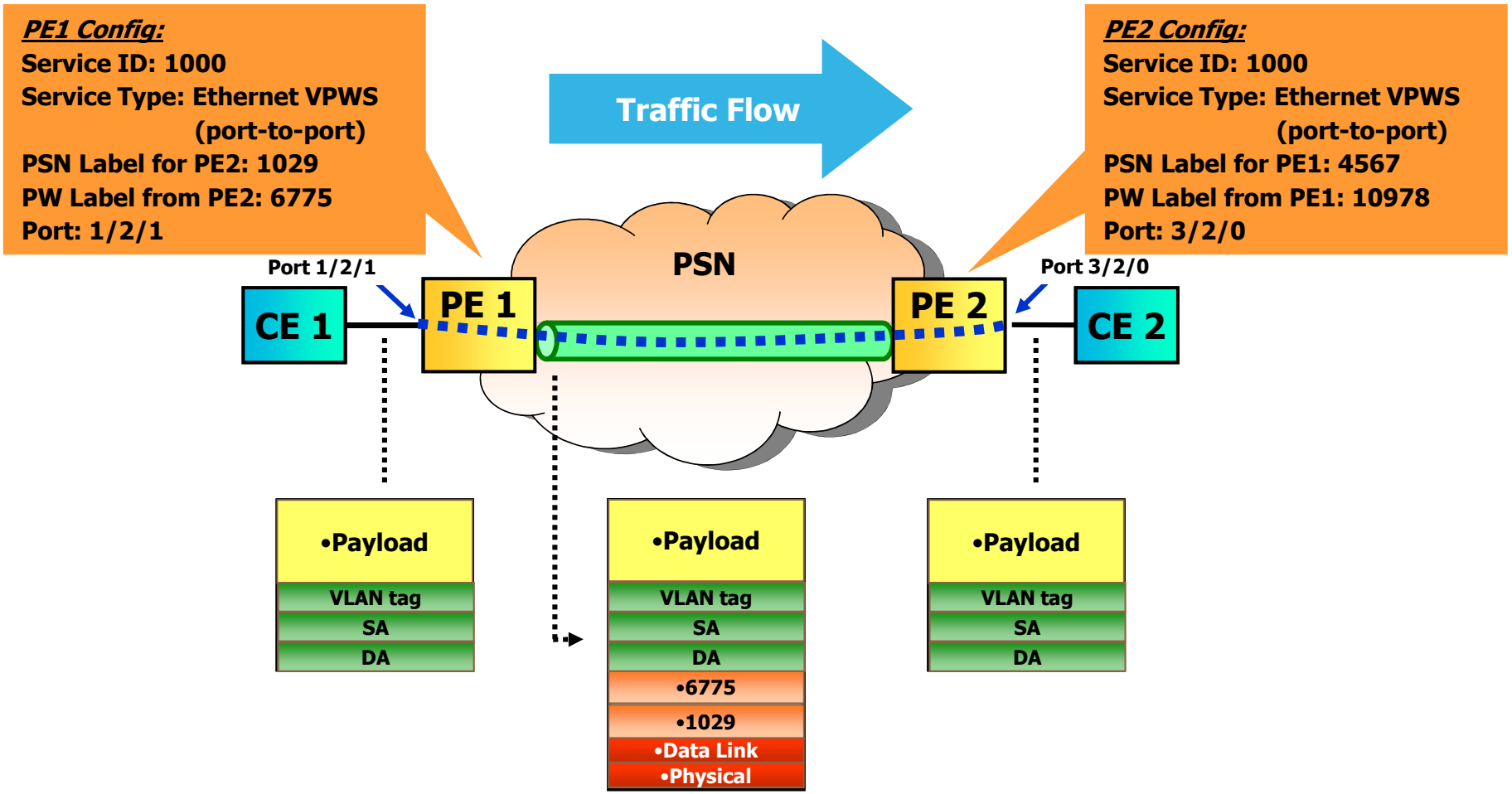
L2VPN – ETHERNET PSEUDOWIRES

POINT TO POINT LAYER 2 CONNECTION: VIRTUAL LEASED LINE (E-LINE)

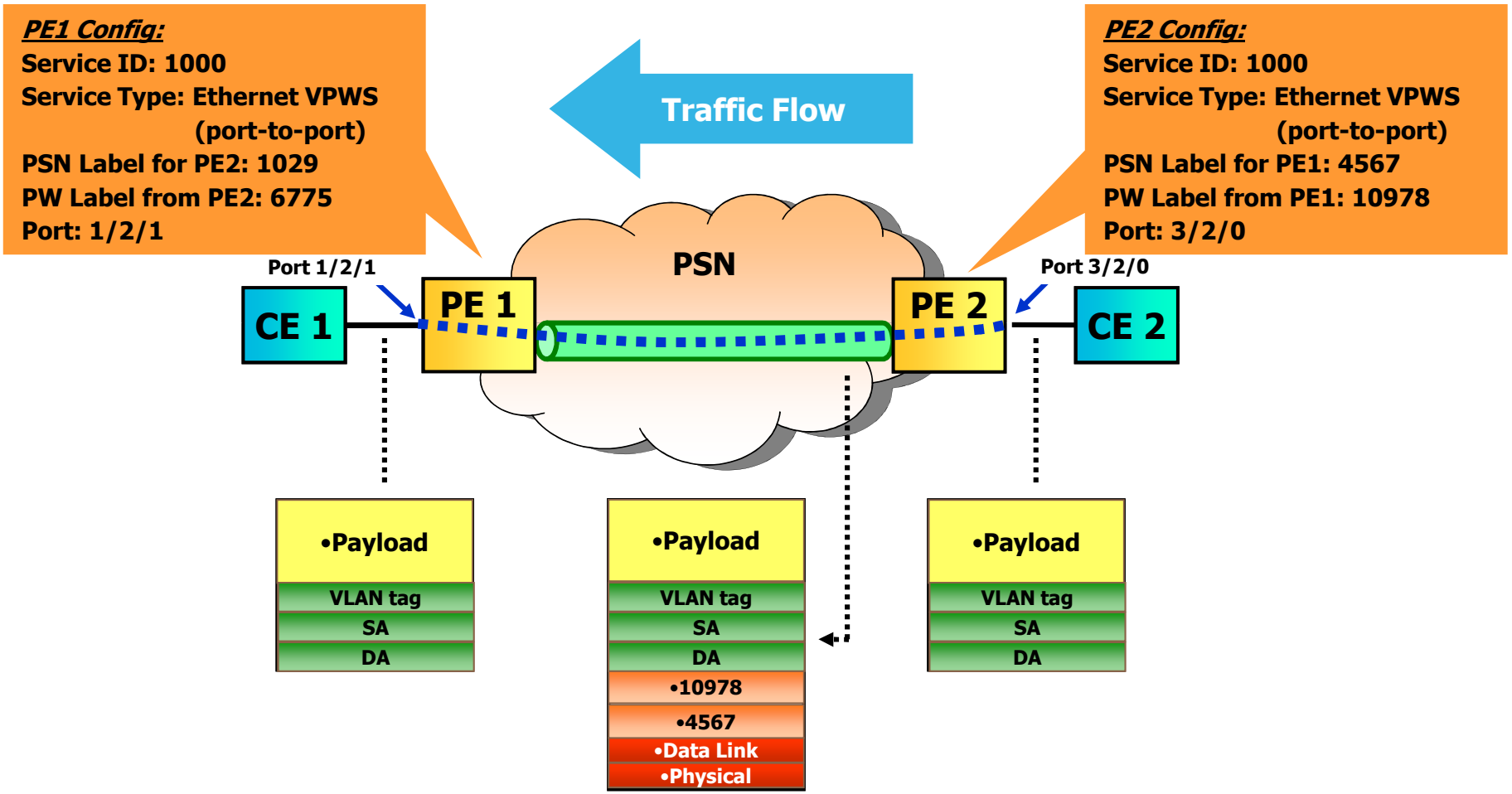
- Virtual Leased Line
- Draft-martini → **RFC-4905**
- Point-to-point FR, ATM, and Ethernet services
- Packet infrastructure is transparent to the end customer



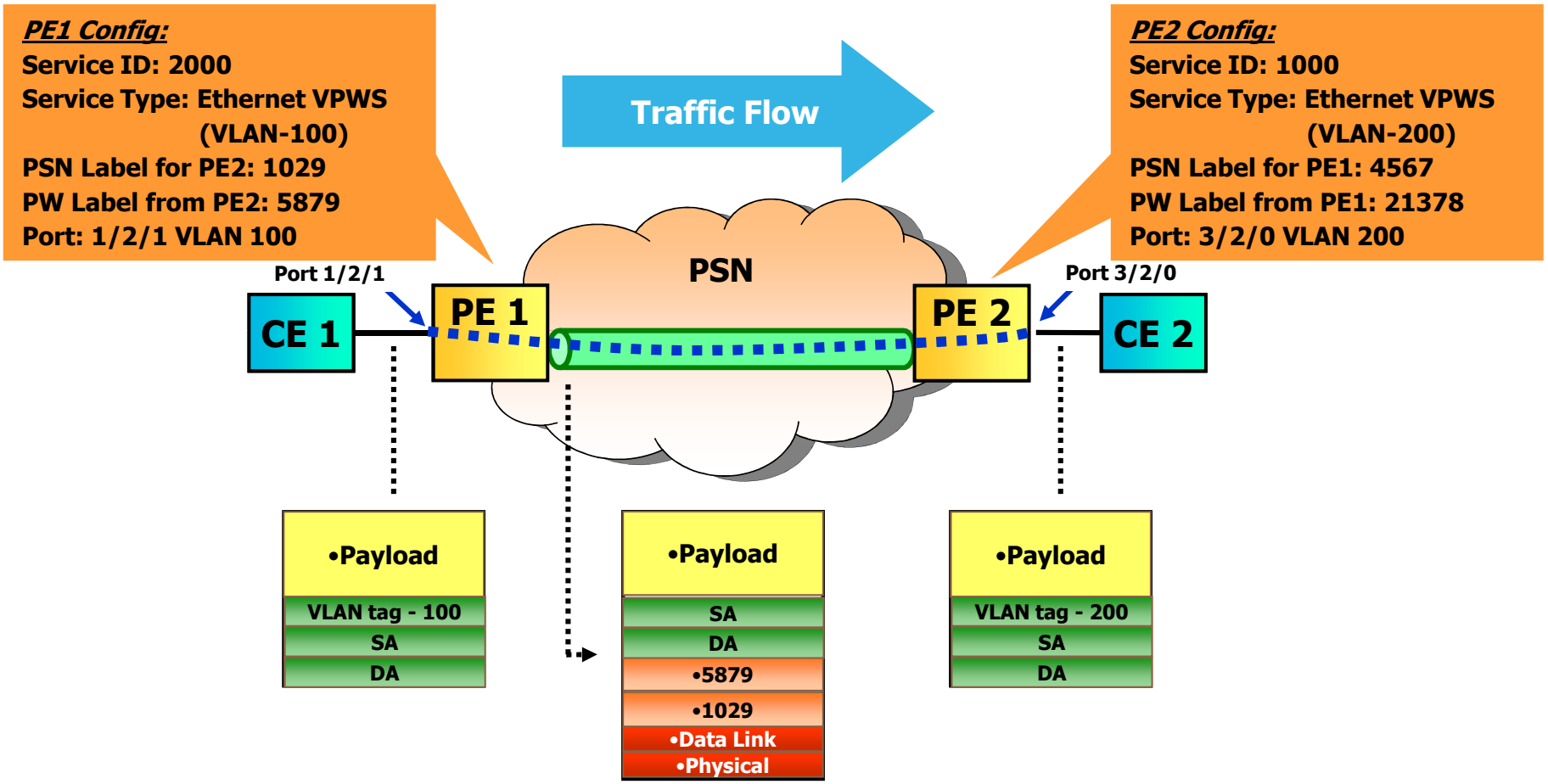
ETHERNET VPWS EXAMPLE 1
PORT BASED



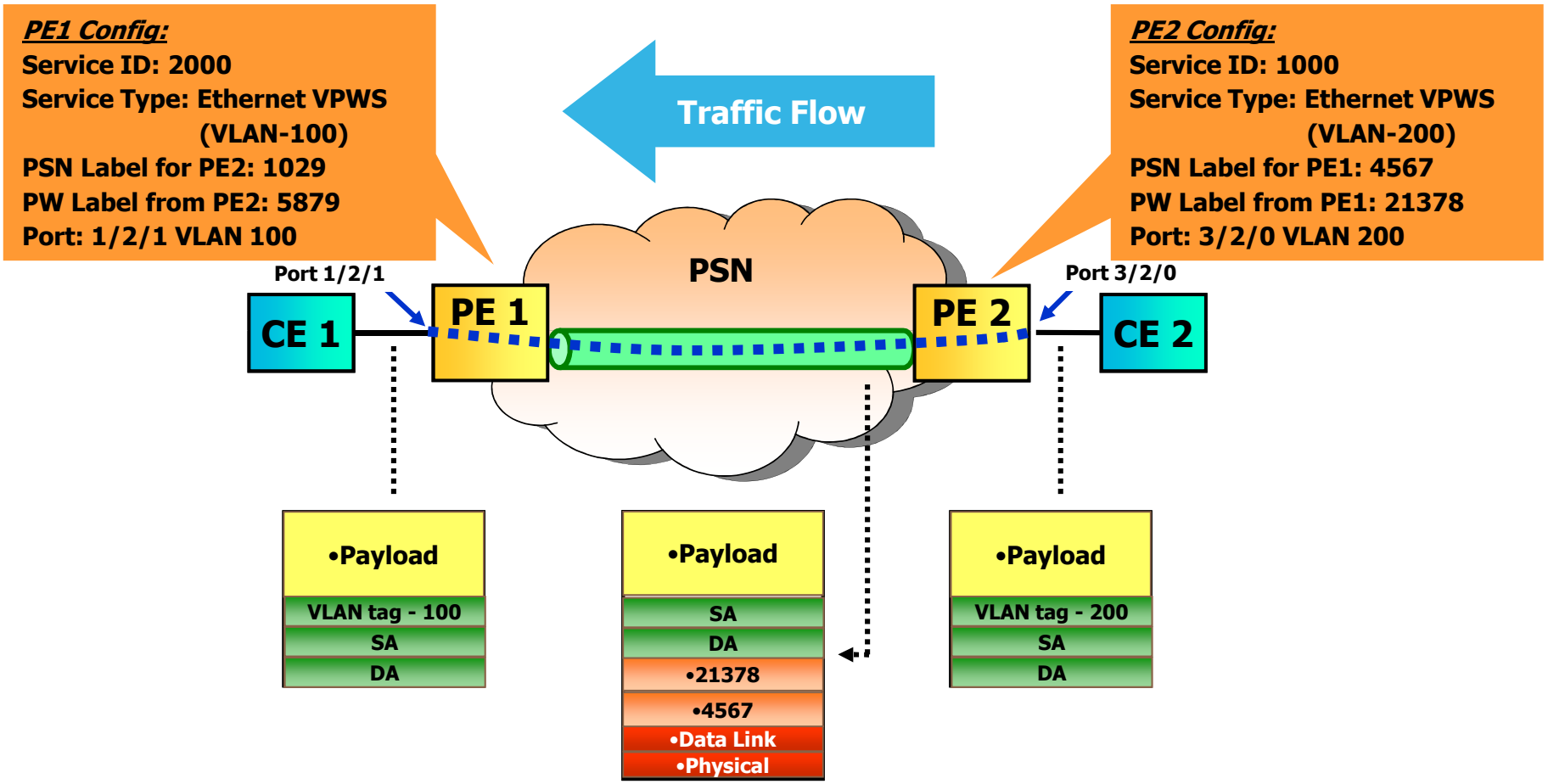
ETHERNET VPWS EXAMPLE 1
PORT BASED



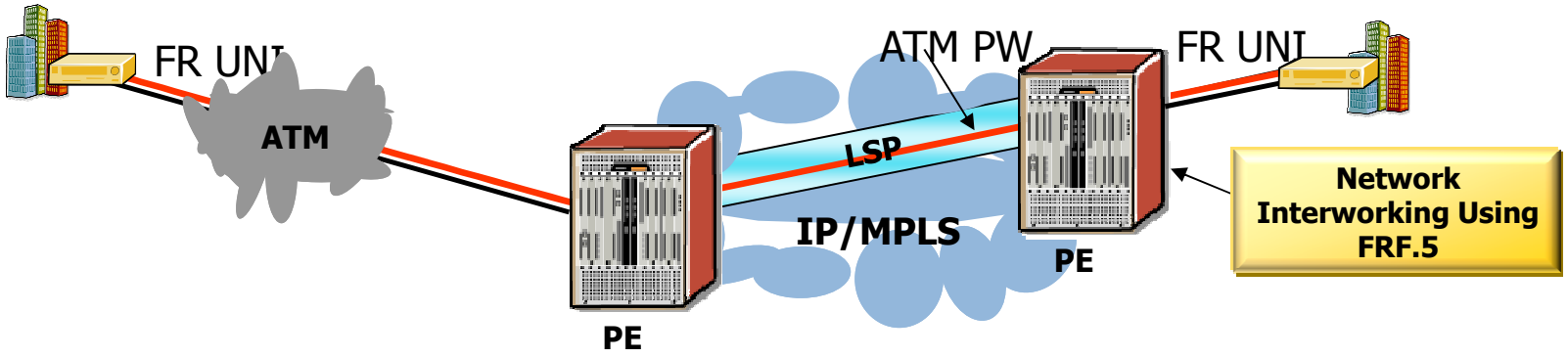
ETHERNET VPWS EXAMPLE 2
VLAN BASED



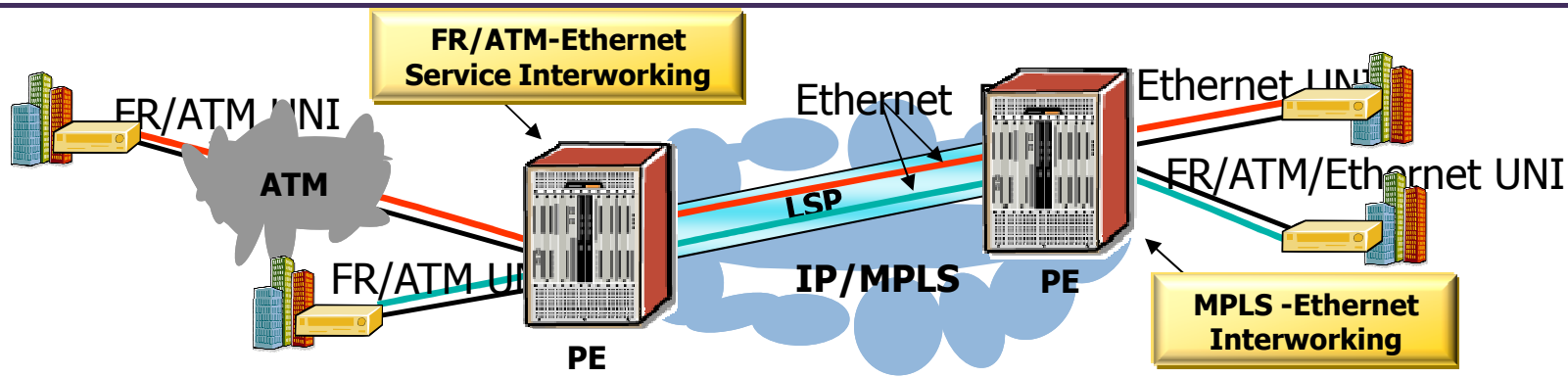
ETHERNET VPWS EXAMPLE 2
VLAN BASED



FR-ATM INTERWORKING AND ETHERNET INTERWORKING

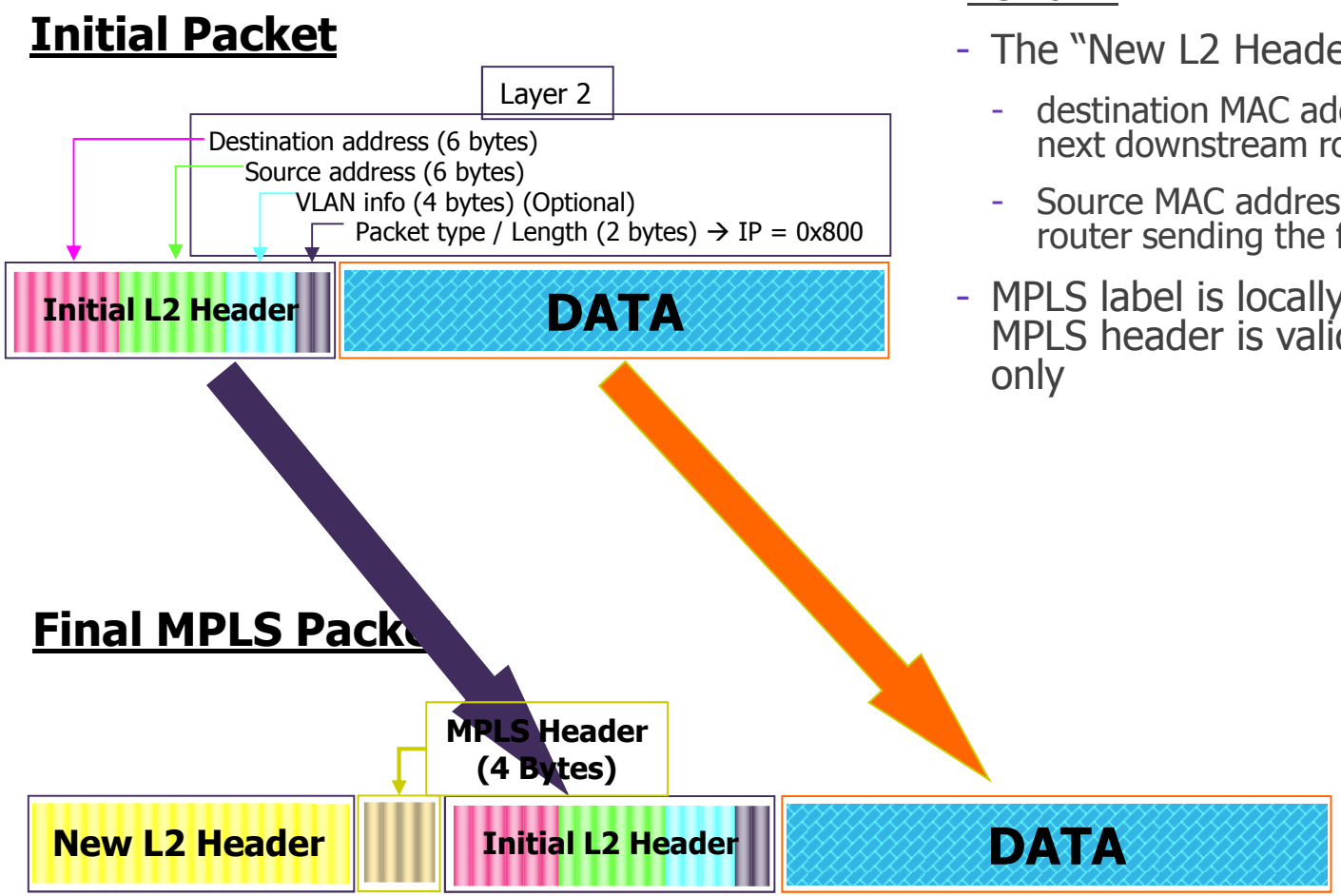


FR and ATM interworking ensures service continuity across the IP/MPLS network



Ethernet interworking provides ATM or FR access to an Ethernet endpoint and ensures service continuity across the IP/MPLS network

PSEUDOWIRE ENCAPSULATION



- Remark:
  - The "New L2 Header" is made using as
    - destination MAC address the MAC of the next downstream router
    - Source MAC address, the MAC of the current router sending the frame
  - MPLS label is locally significant so the MPLS header is valid for the current link only

WHERE ARE L2VPN/VLLs USEFUL?

- Anywhere transparency and MAC learning are really important
  - VLL has no MAC learning or encapsulation requirements
- Point-to-point services for customers
  - Office A to Office B networking where transparency is important
  - Customer wants to run their own encapsulation or possibly own MPLS network over the service – e.g. we must really act like a piece of wire
- Point-to-point services for infrastructure
  - Backhauling DSLAMs/MSANs over Metro Ethernet infrastructure from remote sites to central POPs
  - Backhauling cell site services
- Replacing legacy technologies
  - Replacement for FR or ATM services, where the logical service multiplexing (DLCI, VPI-VCI, or VLAN) is useful and high bandwidth requirements are needed

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L2VPN – ETHERNET VIRTUAL PRIVATE LAN SERVICE

MULTI POINT LAYER 2 CONNECTION:
THE INITIAL IDEA

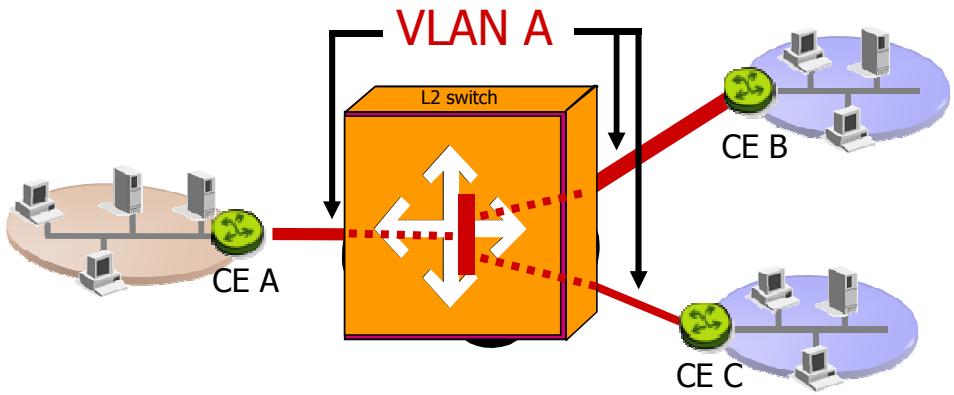
- How to interconnect multiple sites to multiple sites for a layer 2 connectivity using an MPLS based solution?

- Full mesh of point-to-point pseudowires
  - Create different pseudo-wires to each provider locations (PE)
  - Present those pseudo-wires to the outside world (CE) as different interfaces (Physical or Logical)
  - Connect those interfaces to a "customer switch"
    - Multiple connections going to the same customer
    - Manual creation of the pseudo-wire connections

- Virtual Private LAN Service
  - Create different pseudo-wires to each provider locations (PE) (Full Meshed)
  - Terminate those pseudo-wires inside an "internal process" of the PE router
  - The "Internal Process" must act as a Layer 2 switch
  - Add one external link (Physical or logical) to the Customer Edge (CE)
    - One connection is going to the customer
    - Full mesh of pseudo-wire can be automated

VPLS (ELAN):
CUSTOMER VIEW

- All locations appear to be on the same Ethernet LAN
- Entire provider network appears to be a Layer 2 switch

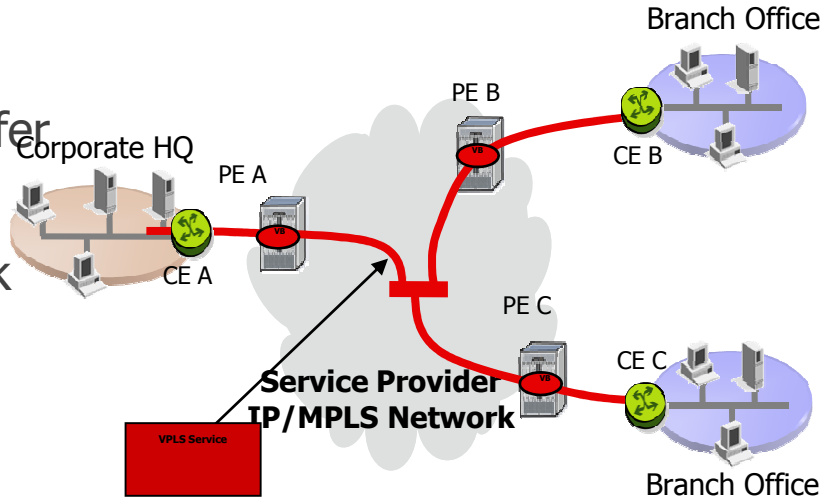


CE-PE interface

- Simple Ethernet interface
- Removes L2 protocol conversion between LAN and WAN
- No additional training required on WAN technologies such as FR

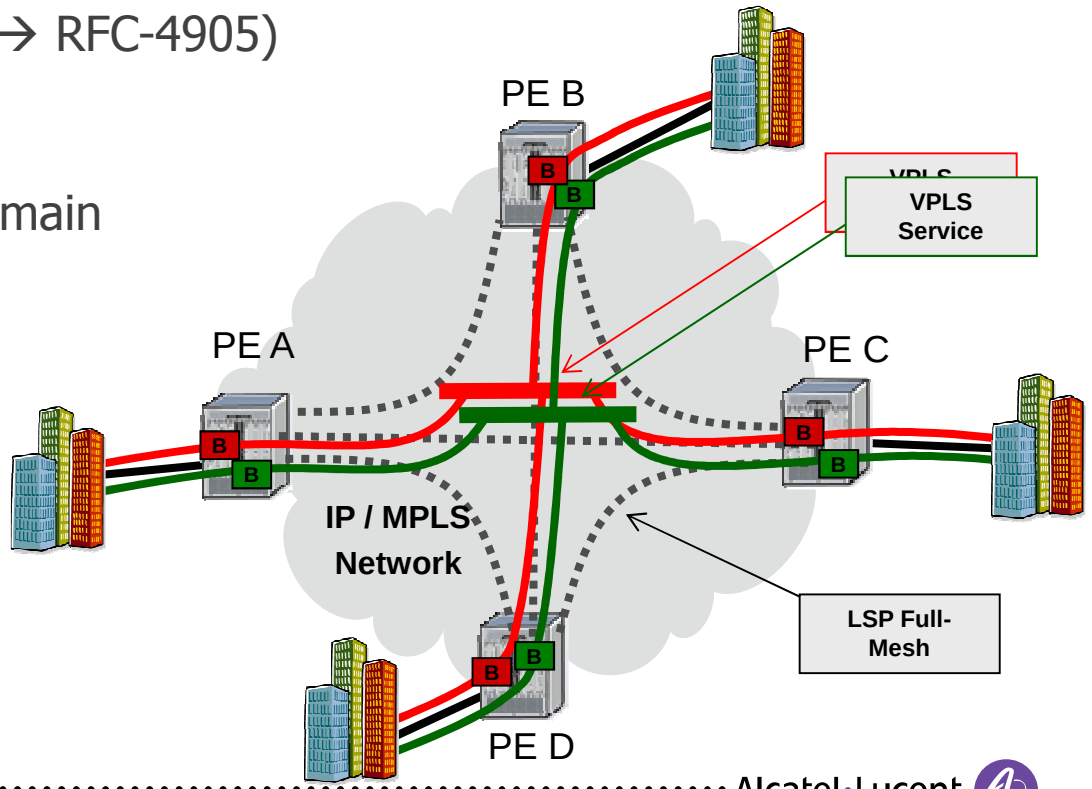
WHAT IS VIRTUAL PRIVATE LAN SERVICE ?

- VPLS
  - Is a class of VPN that allows the connection of **multiple sites** in a **single bridged domain** over a provider-managed MPLS network
- Customer perspective
  - It looks as if all sites are connected to a single switched VLAN
  - No interference with the Service Provider network
- Service provider
  - can reuse the IP/MPLS infrastructure to offer multiple services
  - No interference with the customer network



HOW IS VPLS PROVIDED OVER MPLS?

- Bridging capable PE routers
  - connected with a full mesh of MPLS LSP tunnels
- Per-Service VC labels
  - Negotiated using draft-Martini (→ RFC-4905)
- Unknown/broadcast
  - Traffic replicated in a service domain
- MAC learning
  - Over tunnels and access ports
  - Separate FIB per VPLS



VC LABEL SIGNALING

- VC-label Signaling between PEs per VPLS service instance
  - Each PE initiates a targeted LDP session to the far-end System IP address
  - Tells far-end what VC label to use when sending packets for each service

PE1->PE2: For Svc-id 101 UseVC-label pe2-1

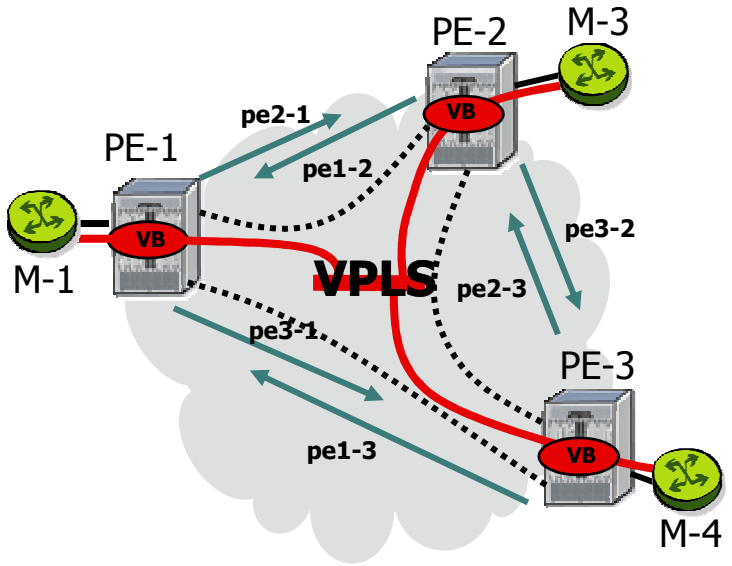
PE2->PE1: For Svc-id 101 Use VC-label pe1-2

PE1->PE3: For Svc-id 101 Use VC-label pe3-1

PE3->PE1: For Svc-id 101 Use VC-label pe1-3

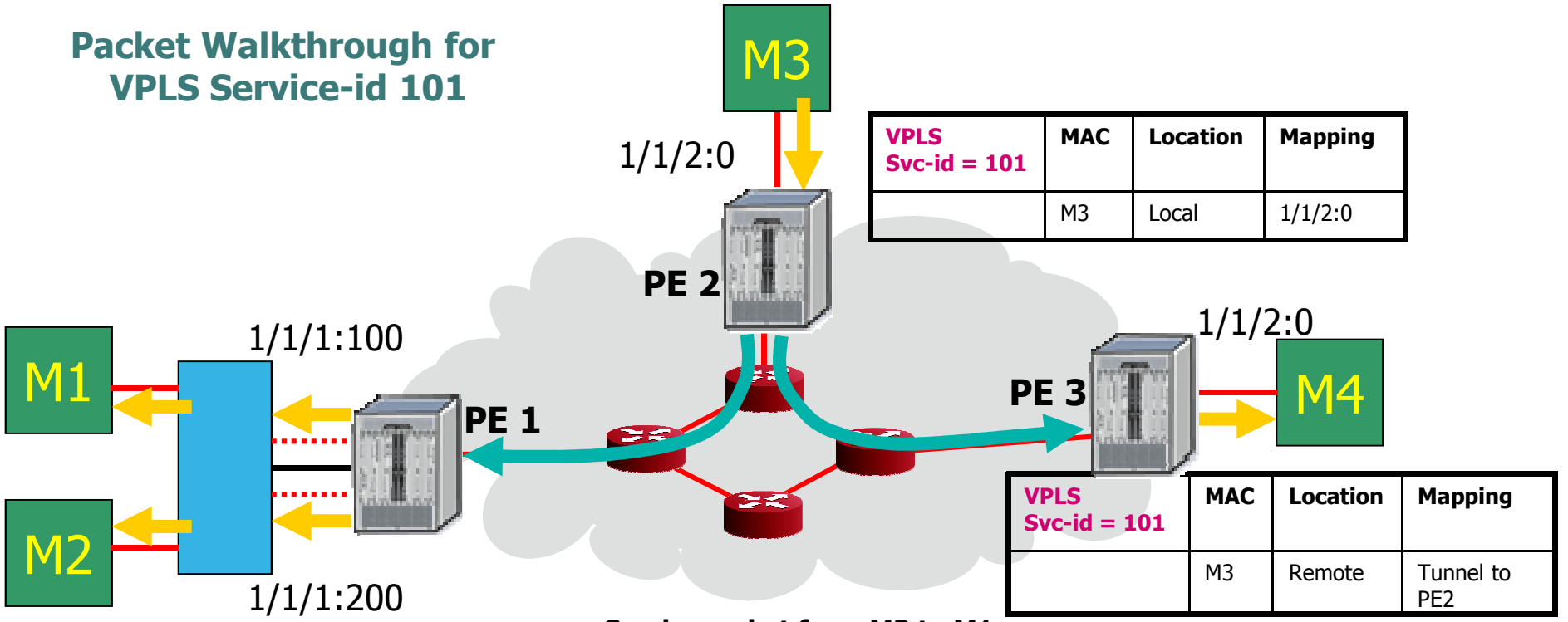
PE3->PE2: For Svc-id 101 Use VC-label pe2-3

PE2->PE3: For Svc-id 101 Use VC-label pe3-2



VPLS LEARNING

Packet Walkthrough for VPLS Service-id 101



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

VPLS Svc-id = 101	MAC	Location	Mapping
	M3	Remote	Tunnel to PE2

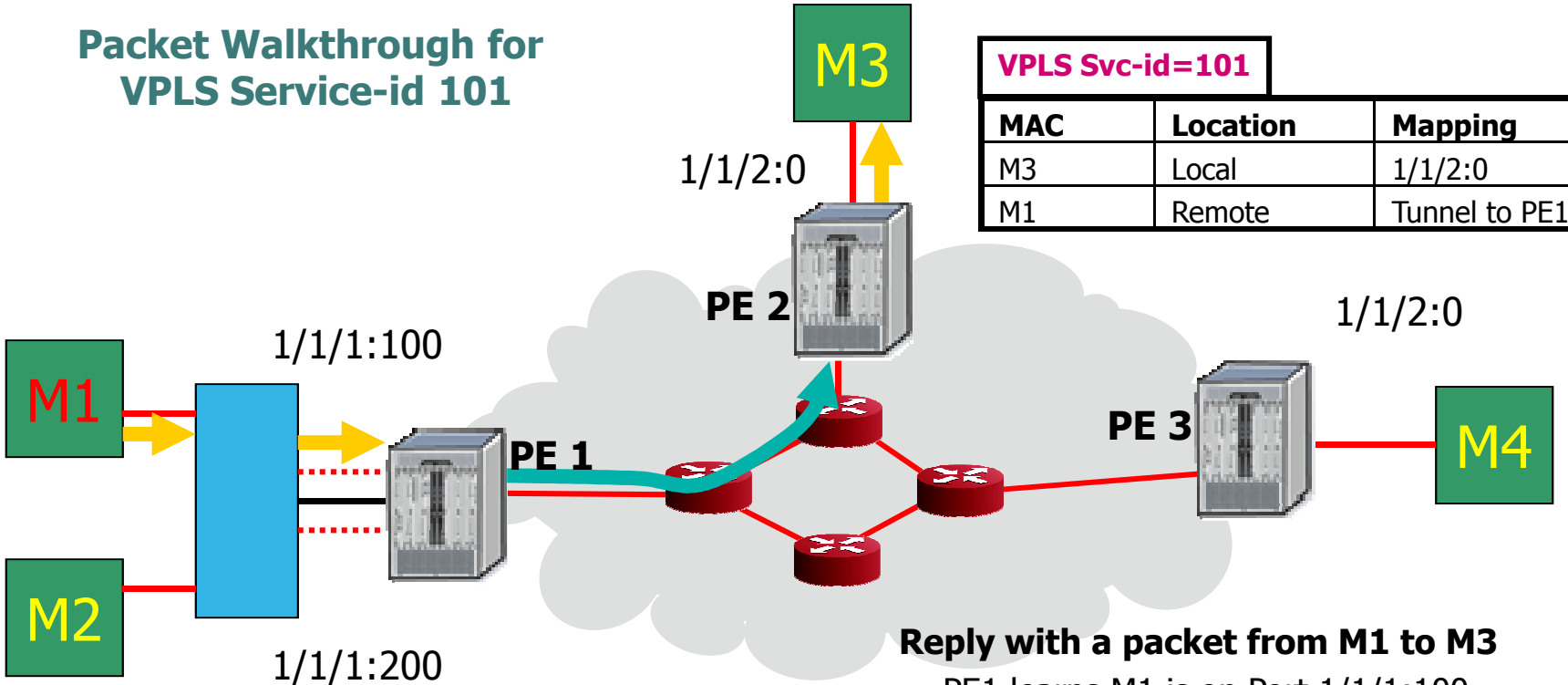
VPLS Svc-id = 101	MAC	Location	Mapping
	M3	Remote	Tunnel to PE2

Send a packet from M3 to M1

- PE2 learns that M3 is reached on Port 1/1/2:0
- PE2 floods to PE1 with VC-label pe2-1 and PE3 with VC-label pe2-3
- PE1 learns from the VC-label pe2-1that M3 is behind PE2
- PE1 sends on Port 1/1/1:100 & 1/1/1:200
- M1 receives packet
- PE3 learns from the VC-label pe2-3that M3 is behind PE2
- PE3 sends on Port 1/1/2:0

VPLS PACKET FORWARDING

Packet Walkthrough for VPLS Service-id 101



VPLS Svc-id=101

MAC	Location	Mapping
M3	Local	1/1/2:0
M1	Remote	Tunnel to PE1

VPLS Svc-id=101

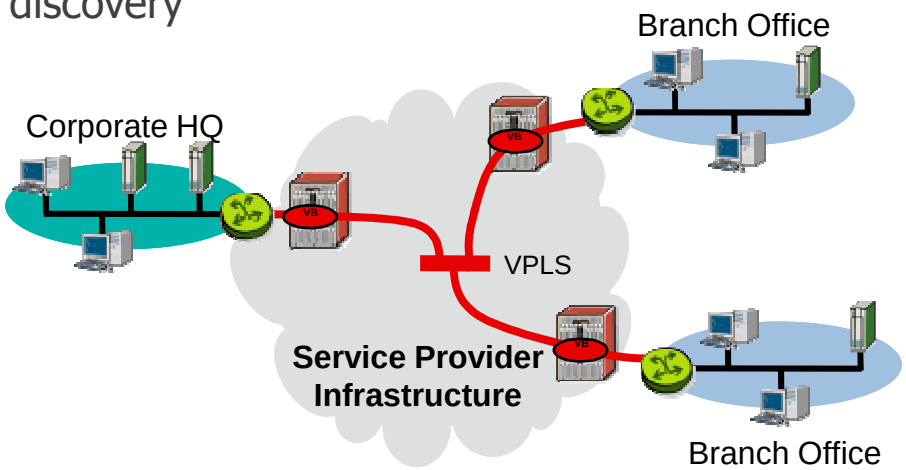
MAC	Location	Mapping
M3	Remote	Tunnel to PE2
M1	Local	1/1/1:100

Reply with a packet from M1 to M3

- PE1 learns M1 is on Port 1/1/1:100
- PE1 knows that M3 is reachable via PE2
- PE1 sends to PE2 using VC-label pe1-2
- PE2 knows that M3 is reachable on Port 1/1/2:0
- M3 receives packet

VPLS AND STANDARDIZATION

- 2 standards exist
  - RFC4761 (K. Kompella)
    - Uses BGP for both signaling and Auto-Discovery
  - RFC4762 (Laserre/V. Kompella)
    - Uses LDP for signaling
    - Optionally may use RADIUS for auto-PE discovery
- Multipoint Ethernet Service
- Customer hand-off is Ethernet



WHERE ARE VPLS USEFUL?

- Where MAC learning and multipoint topologies are important, but transparency may be sacrificed
- Multipoint services for customers
  - Office A to B, C, D, connectivity
  - Virtual switch in the sky
  - Multipoint topology for Carrier-supporting-Carrier
- Multipoint services for infrastructure
  - Bridging internal VLANs across multiple sites for datacenters, network management, etc
  - Some service backhaul (broadband, etc)
- Efficient Multicast services for customers or infrastructure

MPLS WORKSHOP
ADVANCED TOPICS

L2VPNs
ADVANCED TOPICS

- Scaling VPLS
  - H-VPLS
  - PBB-VPLS
- Scaling signalling
- Inter-AS connectivity
- Redundancy
  - In the metro Ethernet core
  - In the PE-CE (UNI) interface
- Multi segment pseudowires
- OAM

MPLS WORKSHOP
SUMMARY

L2VPNs
SUMMARY

- L2VPNs are a useful toolkit for service providers and end customers to build networks
- Most commonly deployed L2VPNs focus on Ethernet services
  - Standardized service offerings are defined by Metro Ethernet Forum (MEF)
- L2 services may also be used to transport other protocols
  - Mobile backhaul
  - Network transformation or legacy technology retirement
  - Unique protocol support requirements
- L2 services are not without deployment problems in the service provider and end user networks
  - Service scaling
  - Bandwidth consumption
  - And so on

L2VPN
COMPARISON OF VPN SERVICE TYPES

	IP-VPN	VPLS	VLL	Other PWE
Routing interaction	Required	No	No	No
Protocol support	IP only	Any	Any	Any
Topology paradigms	Any-to-Any	Any-to-Any Hub-spoke	Point-to-Point	Point-to-Point
VLAN Support	No	Yes	Yes	Depends
Interface types	Any	Many, but usually Ethernet	Many, but usually Ethernet	ATM FR CES Etc
Transport services	No	No	Ethernet only	Yes

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