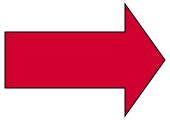
MPLS based Virtual Private Networks

Sources:

V. Alwayn, *Advanced MPLS Design and Implementation*, Cisco Press
B. Davie and Y. Rekhter, *MPLS Technology and Applications*, Morgan Kaufmann

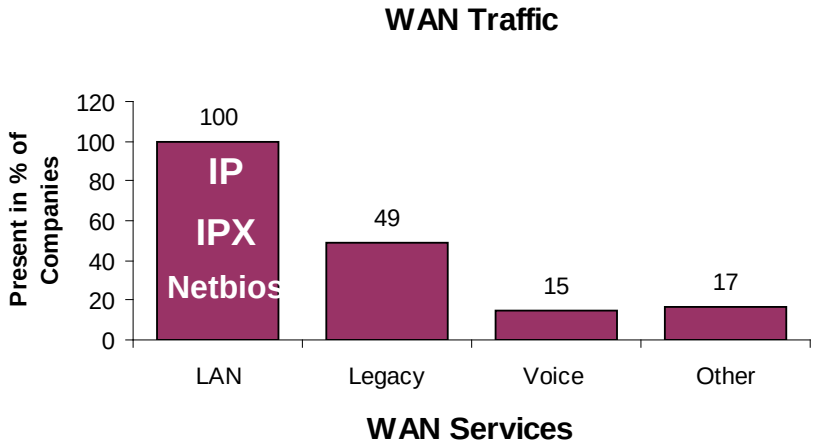
MPLS VPN Agenda...

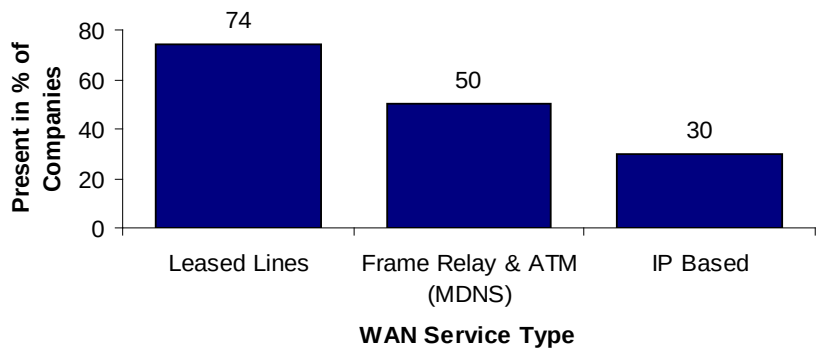


- Layer 2 MPLS VPN
  - ✓ Pseudo Wire Emulation Edge to Edge - PWE3
    - Martini Draft Encapsulation
    - Point to Point services
    - Encapsulation modes
- Provider Provisioned VPN - PPVPN
  - ✓ Draft status and review

VPNs

The "Evidence" and Need for Layer 2



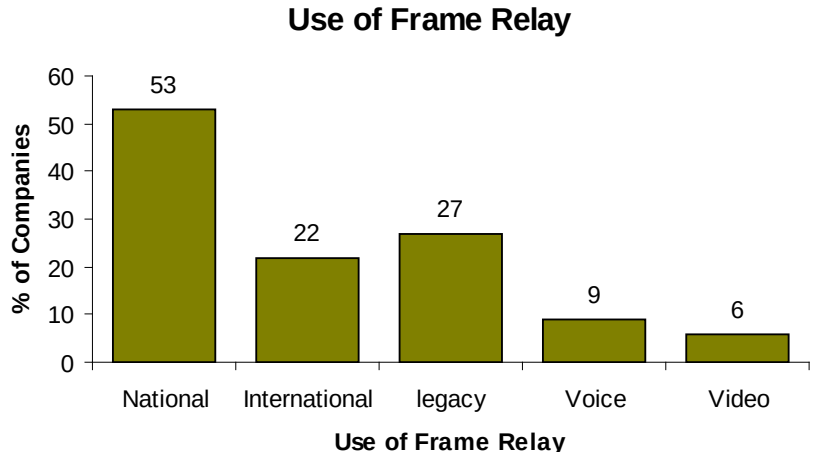


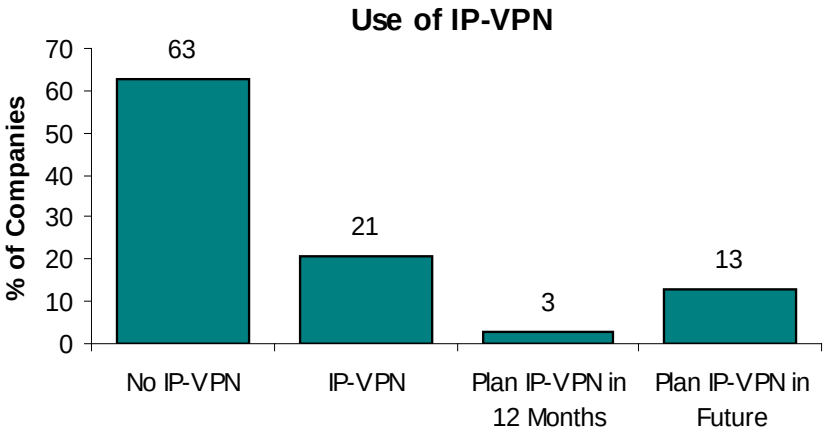
IDC WAN Manager Survey 2001

- WAN Traffic:
  - LAN is <u>not</u> pure IP and includes Netbios, IPX
  - Legacy traffic includes SNA and DECnet
  - ***Layer 3 Services (IP) address less than 50% of the market***
- WAN Services:
  - Leased lines and Frame Relay are dominant
  - Integrate existing services at Layer 2
  - ***Layer 2 Services are important for Frame Relay and ATM integration***

VPNs

The "Evidence" and Need for Layer 2





IDC WAN Manager Survey 2001

- Use of Frame Relay;
  - Layer 2 VPN for HQ and regional sites
  - Used for legacy and international traffic
  - ***Smaller addressable market without Frame Relay integration***
- Use of IP VPNs
  - Acceptance is low, few IP only customers
  - Predominantly used for remote access
  - ***Smaller addressable market with Layer 3 IP only services***

VPN Market Drivers

What can we conclude?

- Layer 3 IP is not the only traffic
  - Still a lot of legacy SNA, IPX etc
  - Large enterprises have legacy protocols
- Layer 3 IP VPNs are not the whole answer
  - IP VPNs cannot handle legacy traffic
- Layer 2 Frame Relay VPNs widely deployed
  - Used for multiple protocols including IP and legacy

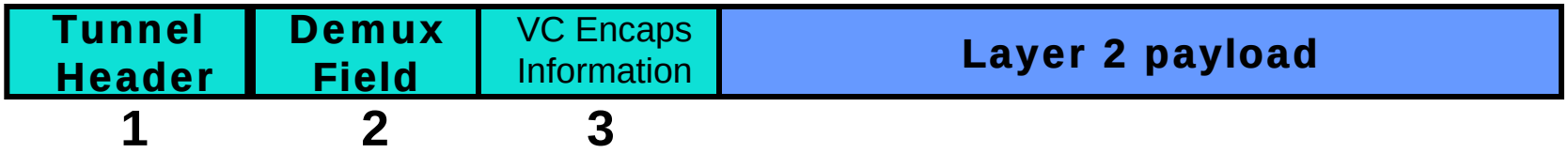
Carriers need to support Layer 2 and Layer 3 VPNs

MPLS Layer 2 VPNs

- Point-to-point layer 2 solutions
  - Similar to ATM / FR services, uses tunnels and connections (LSPs)
  - Customer gets connectivity only from provider
  - Encapsulate Ethernet, ATM, FR, TDM, SONET, etc
- Multi-point layer 2 solutions
  - Virtual Private LAN Services (VPLS) aka TLS
  - Ethernet Metro VLANs / TLS over MPLS
  - Independent of underlying core transport
  - All drafts support Martini Ethernet encapsulation
  - Differences in drafts for discovery and signaling

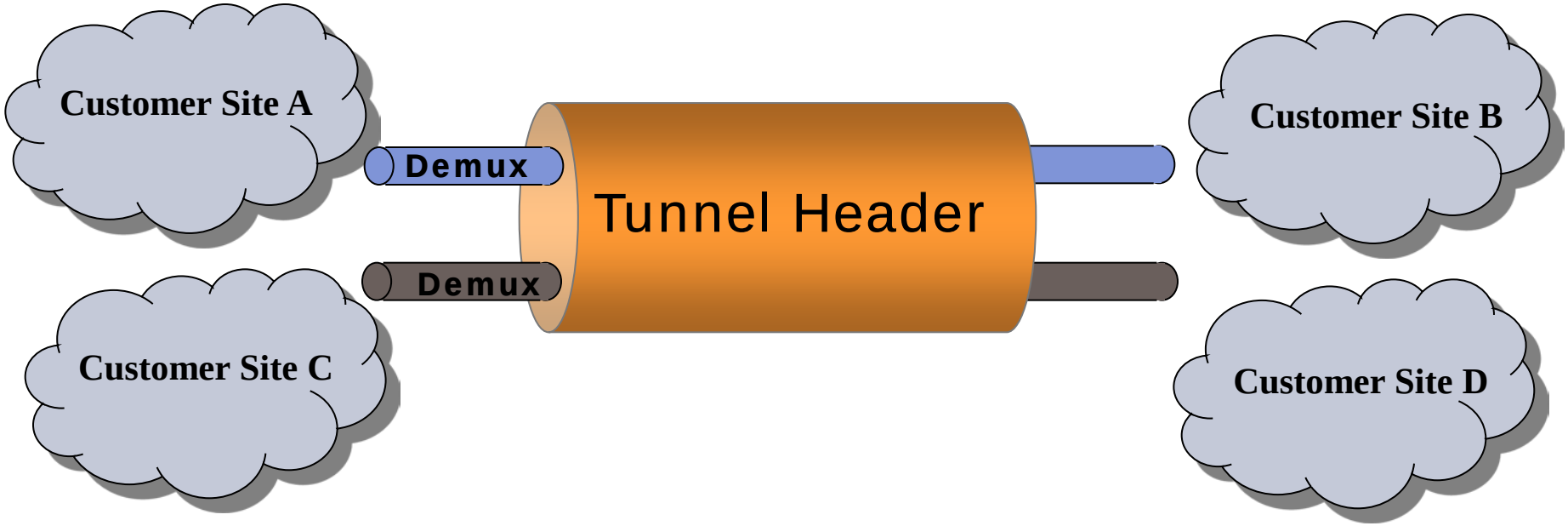
MPLS Point-to-Point Services

Label Stacking



- Three Layers of Encapsulation
  1) Tunnel Header: Contains information needed to transport the PDU across the IP or MPLS network
  2) Demultiplexer Field: Used to distinguish individual emulated VCs within a single tunnel
  3) Emulated VC Encapsulation: Contains the information about the enclosed PDU (known as Control Word)
- Tunnel Header determines path through network
- Demultiplexer Field identifies VLAN, VPN, or connection at the end point
- All services look like a Virtual Circuit to MPLS network

MPLS Point-to-Point Service



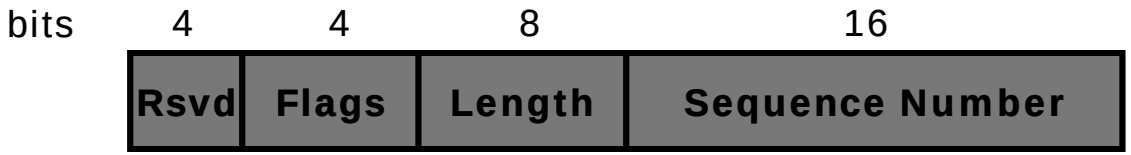
- Tunnel Label determines path through network
- VC Label identifies VLAN, VPN, or connection at the end point

Layer 2 encapsulation

draft-martini-l2circuit-encap-mpls-04.txt

- **Martini defines the following encapsulations over MPLS**
  - **ATM AAL5 (draft – April 2002)**
  - **ATM cell (draft – April 2002)**
  - **Frame Relay (draft – June 2002)**
  - **Ethernet / 802.1q VLAN (draft – July 2002)**
  - **PPP/HDLC (draft – July 2002)**
- **Martini defines a new Control Word and a new VC FEC Element**

New Control Word



Control Word

- Layer 2 header fields may be discarded at ingress
- Control word carries “flag” bits depending on encapsulation
  - (FR: FECN, BECN, C/R, DE, ATM: CLP, EFCI, C/R, etc)
- Length required when padding small frames on links which have a minimum frame size
- Sequence number is optional. It is used to detect out of order delivery of frames.

LDP - Label Mapping Message

Label Mapping	Message Length
Message ID	
FEC TLV	
Label TLV	
Label Request Message ID TLV	
LSPID TLV (optional)	
Traffic TLV (optional)	

New VC FEC Element Defined

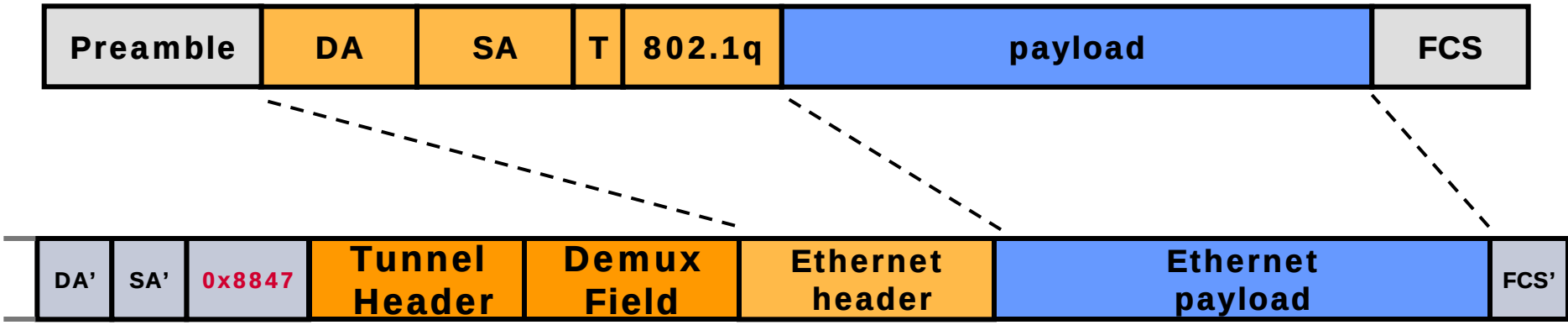
VC TLV	C	VC Type	VC Info Length
Group ID			
VC ID			
Interface Parameters			

- Virtual Circuit FEC Element
  - C - Control Word present
  - VC Type - FR, ATM, Ethernet, HDLC, PPP, ATM cell
  - VC Info Length - length of VCID field
  - Group ID - user configured - group of VCs representing port or tunnel index
  - VC ID - used with VC type to identify unique VC
  - Interface Parameters - Specific I/O parameters

MPLS Ethernet Encapsulation

draft-martini-ethernet-encap-mpls-01.txt

Original Ethernet frame

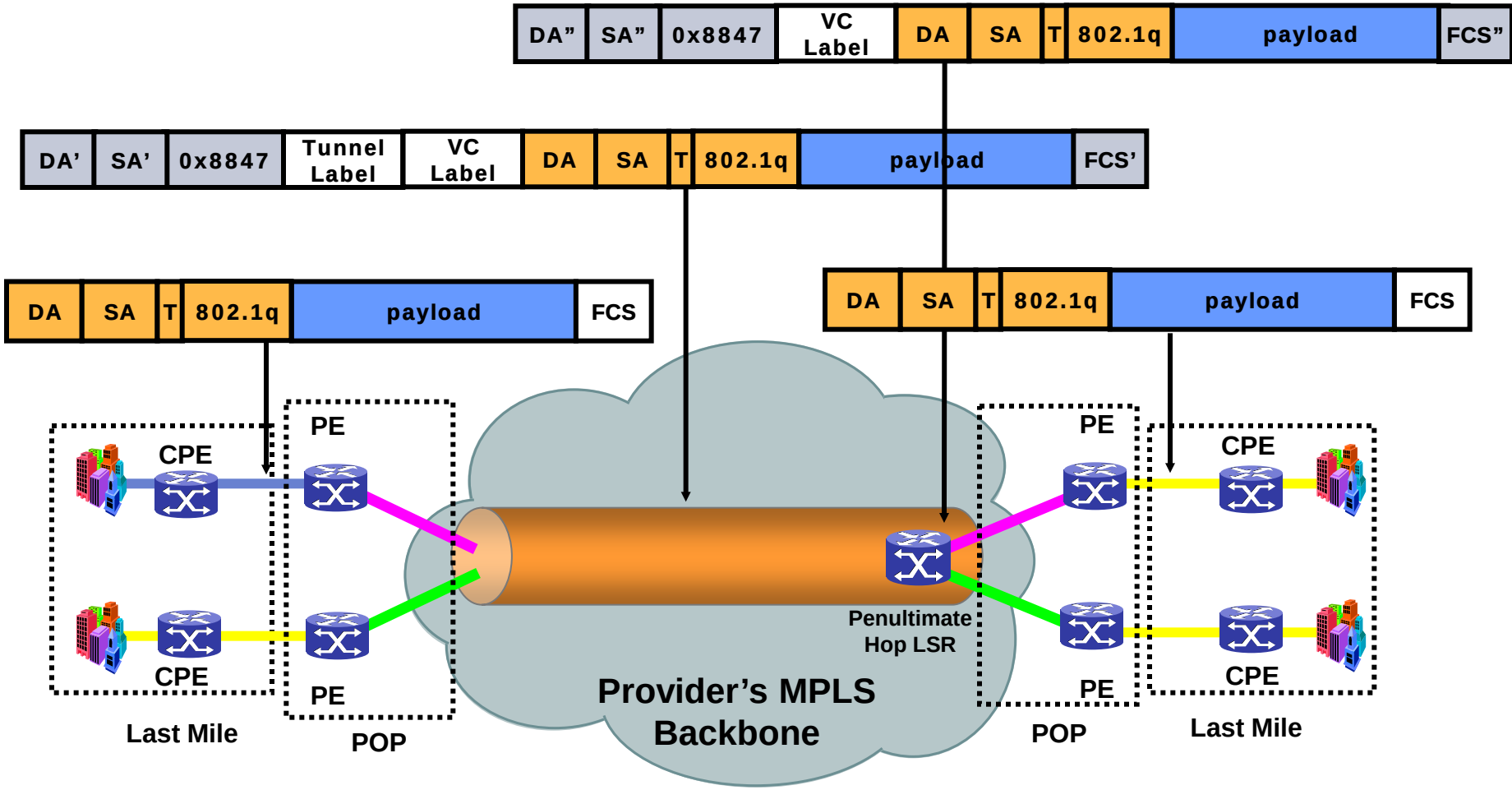


Encapsulated Ethernet over MPLS

- Ingress device strips the Ethernet preamble and FCS
- Ethernet header becomes “control word”
- New MPLS Ethernet header (type 0x8847) and new FCS is added to MPLS Ethernet packet

Life of a Frame

Ethernet over Ethernet MPLS



MPLS ATM standards work - Forums

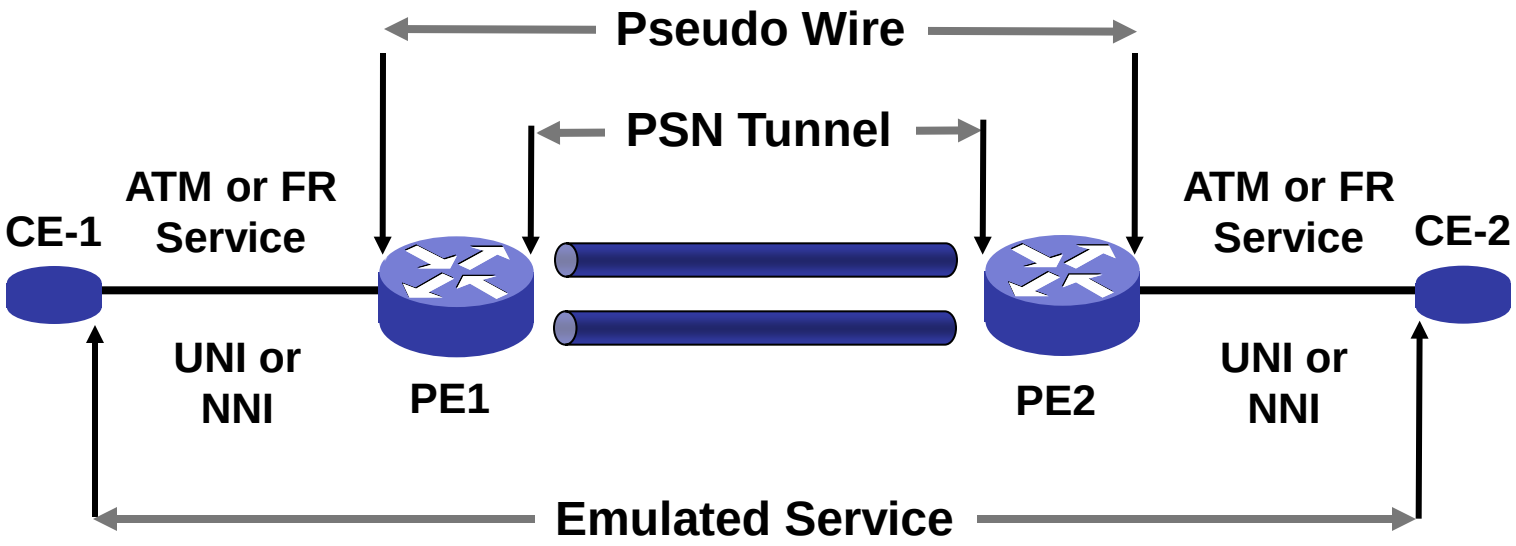
- MPLS Forum work
  - PNNI, UNI baseline interworking documents
  - PVC UNI Baseline
  - UNI Service Framework
  - Comments docs
- ATM Forum work
  - Btf-aic-mpls-niwf-02.02 – new doc April 2002
  - ATM MPLS Network Interworking Version 2
- ITU-T interworking study group 13 (y.ATMPLS)
- All groups working together and with IETF

MPLS ATM standards work - IETF

- IETF PWE3 WG
  - Pseudo Wire Emulation Edge to Edge
- IETF ATM Service Descriptions
  - Draft-martini-atm-encap-mpls-00.txt
    - ✓ June 2002 *New draft*
  - Draft-brayley-pwe3-atm-service-01.txt
    - ✓ *Expired and merged* into martini-atm-encaps
    - ✓ June 2002
  - Draft-fisher-pwe3-atm-service-02.txt
    - ✓ *Expired, but backs* atm forum doc
    - ✓ June 2002

ATM and Frame Relay Service

Reference Model

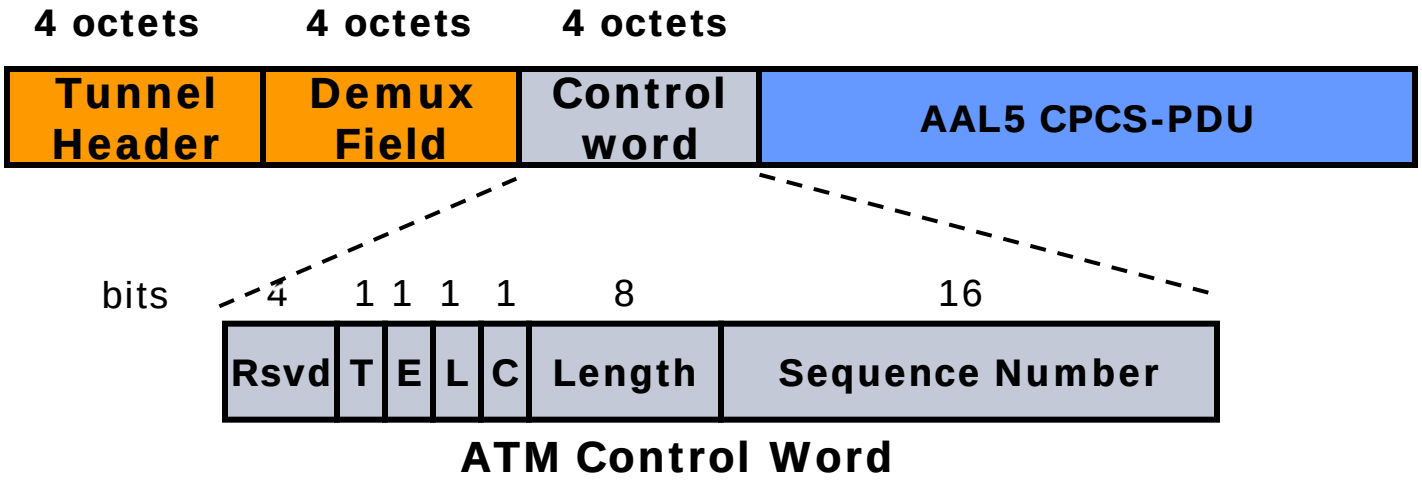


PE = Provider Edge
CE = Customer Edge

Requirements for Pseudo Wire Emulation Edge-to Edge (PWE3)

ATM AAL5 Encapsulation

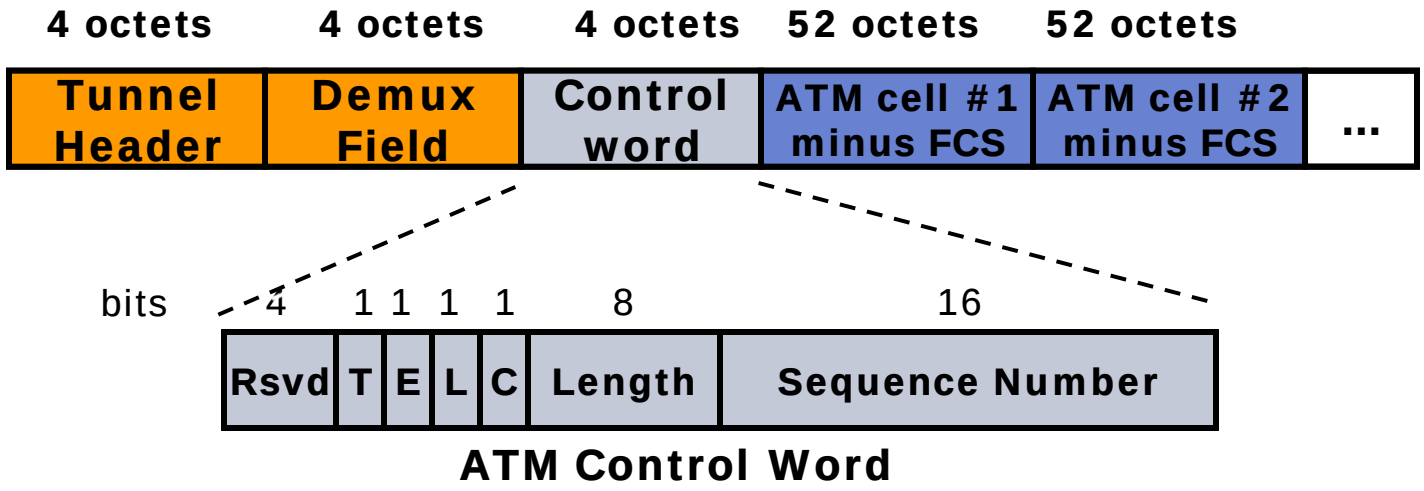
draft-martini-atm-encap-mpls-00.txt



- Ingress reassembles AAL5 frames and strips 8 octet AAL5 trailer
- Required control word includes:
  - T = Transport type bit
    - ✓ Common Part Convergence Sublayer-Protocol Data Unit (AAL5 CPCS-PDU)
    - ✓ Or ATM Cell
  - E = EFCI bit - Efficient Forward Congestion
  - L = CLP bit - Cell Loss Priority
  - C = Command / Response bit

ATM Cell Mode Encapsulation

draft-martini-atm-encap-mpls-00.txt



- Ingress performs no reassembly
- Control word is optional:
  - Length may be used to infer number of cells
  - Flags set to zero

MPLS Frame Relay standards

- IETF PWE3: Frame Relay Service Description
  - Draft-martini-frame-encap-mpls-01.txt (new draft – June 2002)
  - Draft-kamapabhava-fr-pwe3-00.txt *merged into martini*
  - Draft-bryant-pwe3-fr-encap-00.txt *expired*
- Frame Relay Forum Work
  - Frame Relay Multiprotocol Encapsulation Implementation Agreement
- Frame Relay & MPLS Forums are jointly working on an implementation agreement
  - FR and MPLS Network Interworking IA - Baseline

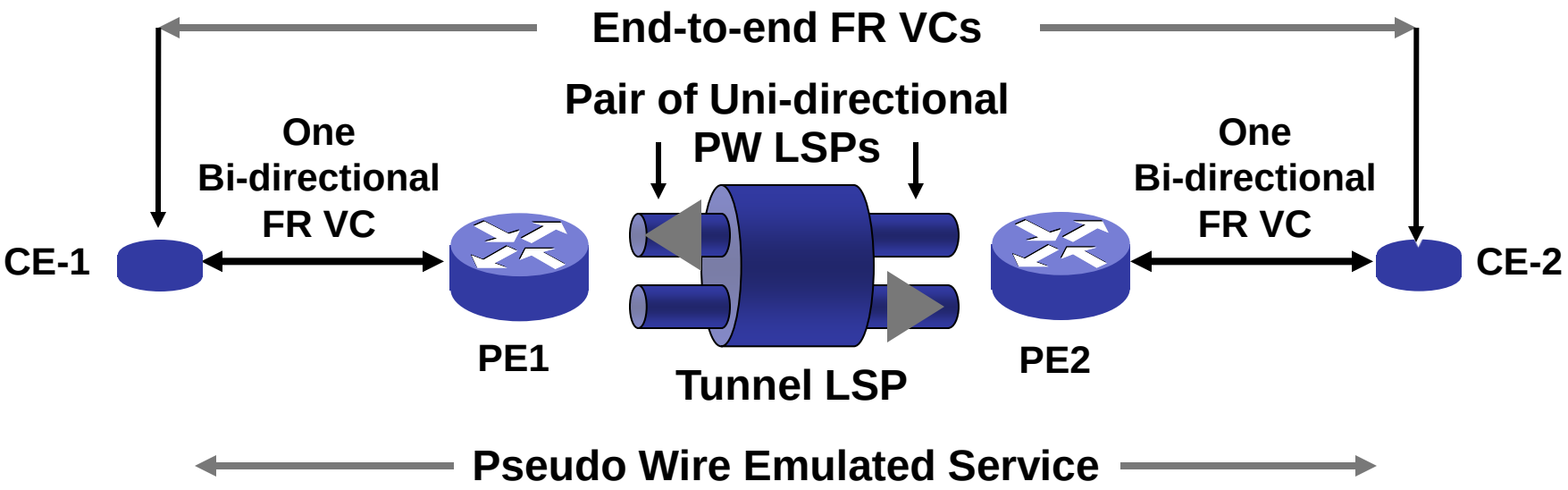
MPLS PWE3 FR Encapsulation

Draft-martini-frame-encap-mpls-01.txt

- Main Functions: FR over Pseudo Wire - FRoPW
  - Encapsulation of FR specific information in a suitable FRoPW packet (ingress function)
  - Transfer of a FRoPW packet through IP / MPLS network
  - Extraction of FR specific information from a FRoPW packet (egress function)
  - Generation of native FR frames at egress
  - Other operations to support FR services

MPLS PWE3 FR Encapsulation

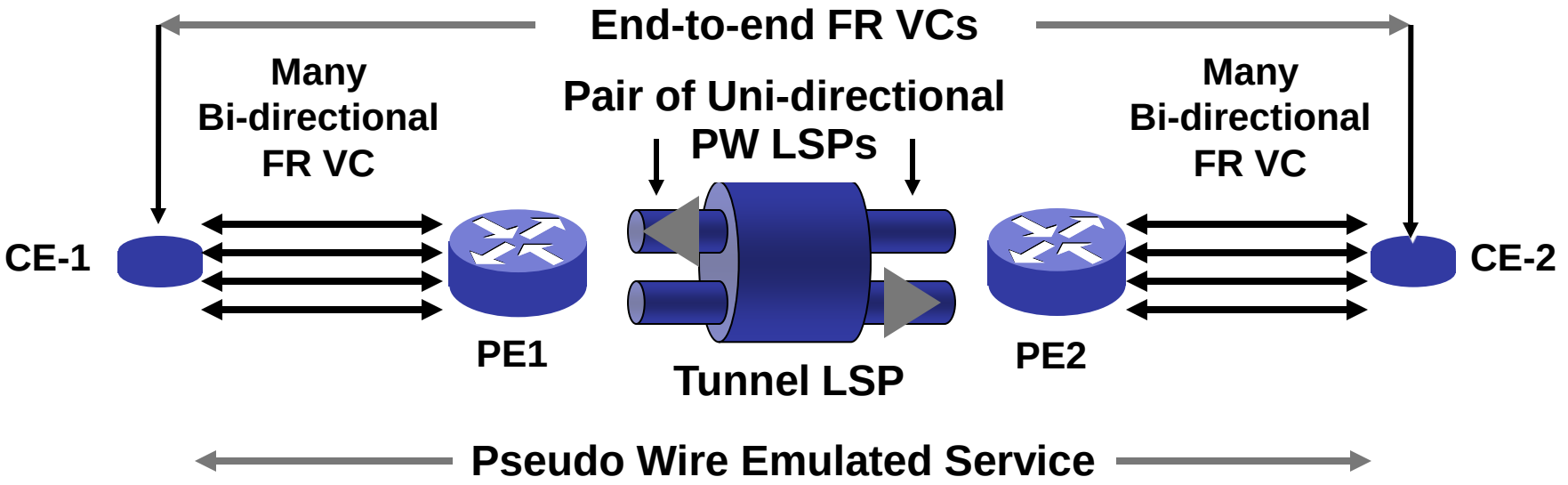
Draft-martini-frame-encap-mpls-01.txt



- Two Mapping modes defined between FR VCs and FR PWs
  - One-to-one mapping
  - One FR VC mapped to a pair of unidirectional PWs

MPLS PWE3 FR Encapsulation

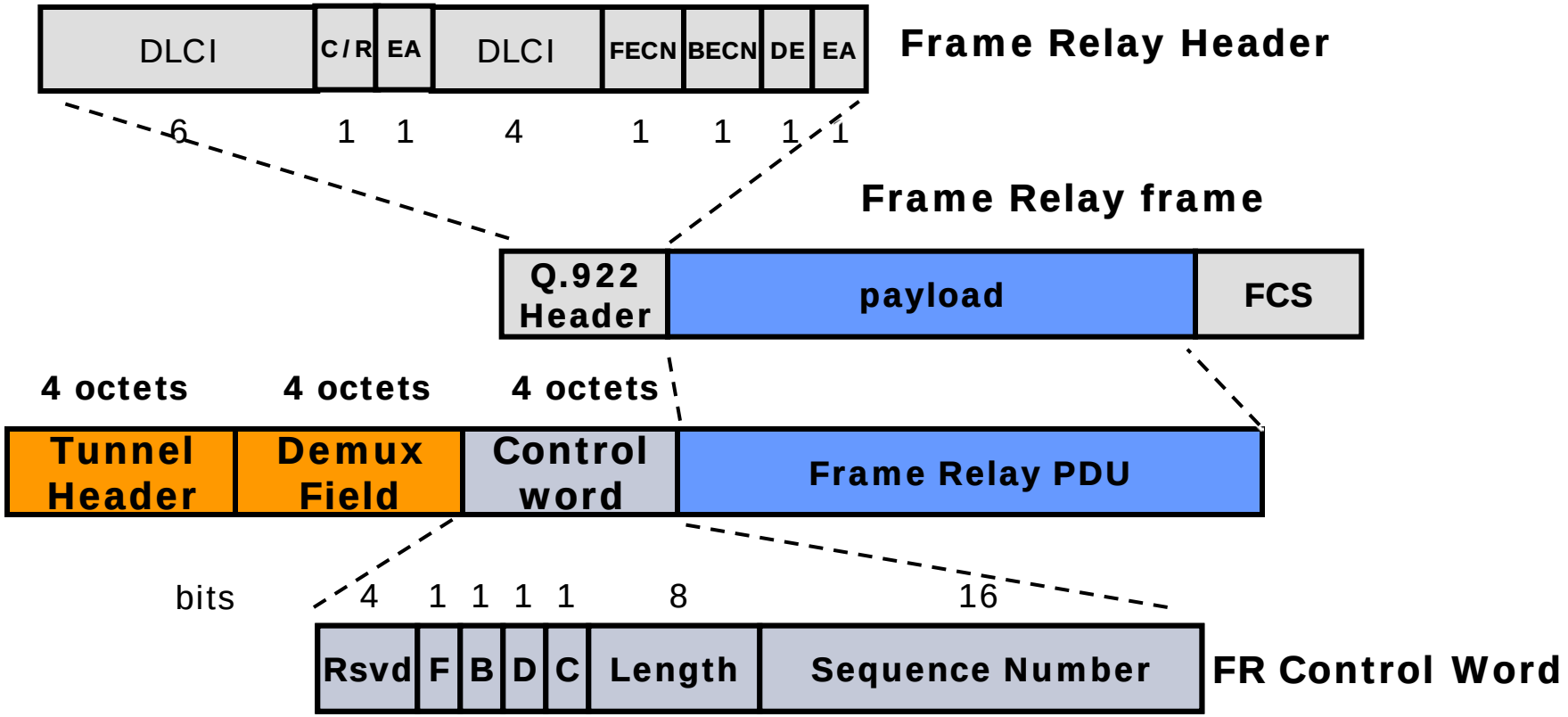
Draft-martini-frame-encap-mpls-01.txt



- Two Mapping modes defined between FR VCs and FR PWs
  - Many-to-one or port mode mapping (Optional)
  - Many FR VCs mapped to a pair of Unidirectional PWs

MPLS Frame Relay Encapsulation

draft-martini-frame-encap-mpls-00.txt



- F = FECN (Forward Explicit Congestion Notification)
- B = BECN (Backward Explicit Congestion Notification)
- D = DE (Discard Eligibility Indicator)
- C = C/R (Command / Response Field)

MPLS VPN Tutorial Agenda...

- Layer 2 MPLS VPN
  - ✓ Pseudo Wire Emulation Edge to Edge - PWE3
    - Martini Draft Encapsulation
    - LDP Review
    - Point to Point services
    - Encapsulation modes
  - ✓ Life of a Frame across a Pseudo Wire
- Provider Provisioned VPN - PPVPN
  - ✓ Draft status and review

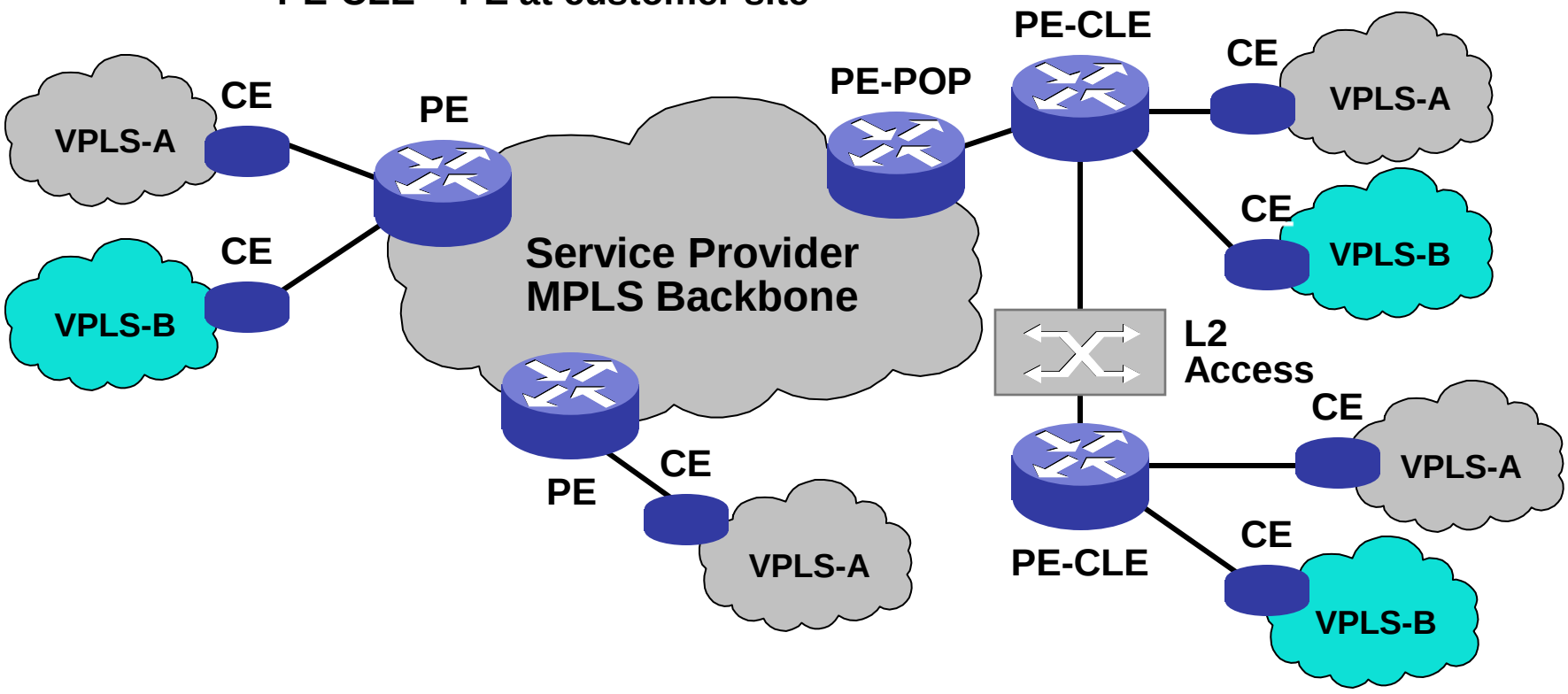
MPLS Layer 2 Multipoint Services
IETF Overview PPVPN Drafts

- Draft-ietf-ppvpn-vpls-requirements-00.txt
  - March 02 – expires September 02
  - Describes service requirements related to emulating a Virtual Private LAN segment over an IP or MPLS network
  - States that VPLS topology “may” be;
    - ✓ Point-to-point, Point-to-multipoint, Any-to-any (full mesh), Mixed (partial mesh), Hierarchical
  - Service to the customers “must” retain the typical LAN any-to-any connectivity
- Draft-sajassi-vpls-architectures-00.txt
  - February 02 – expires September 02
  - Defines the reference architecture for a VPLS system

MPLS Layer 2 Multipoint Services
IETF VPLS and other Drafts

- VPLS drafts
  - draft-lasserre-vkompella-ppvpn-vpls-01.txt
  - Draft-kompella-ppvpn-l2vpn-02.txt
  - draft-ouldbrahim-l2vpn-lpe-02.txt
- Other drafts
  - Draft-chen-ppvpn-compare-00.txt
    - ✓ Compares old DTLS model to HVPLS
  - Draft-shah-ppvpn-vpls-pe-mtu-signaling-00.txt
    - ✓ Suggests and describes signaling between CE (L2PE or MTU-s for DTLS and HVPLS

MPLS Layer 2 Multipoint Services
Architecture



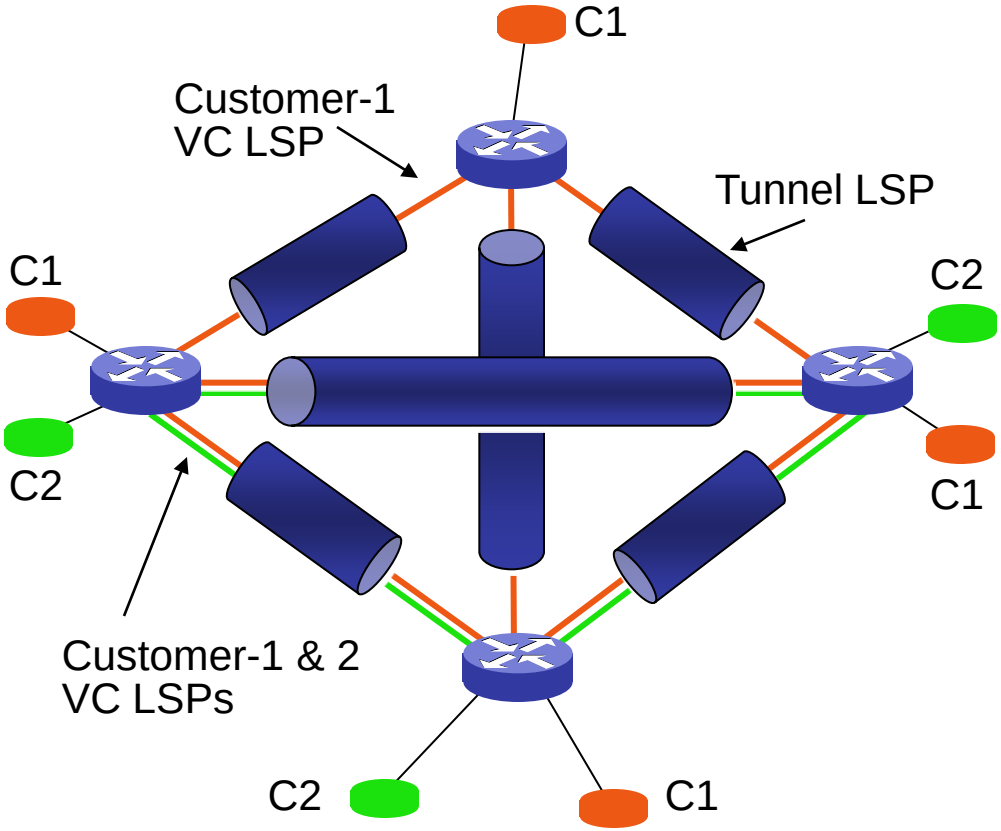
Virtual Private LAN Services over MPLS

draft-lasserre-vkompella-ppvpn-vpls-01.txt

- Defines an Ethernet (IEEE802.1D) learning bridge model over MPLS Martini Ethernet circuits
- Defines the LER function for an MPLS VPLS network
- Creates a layer 2 broadcast domain closed to a set of users
- MAC address learning and aging on a per LSP basis
- Packet replication across LSPs for multicast, broadcast, and unknown unicast traffic
- Now includes HVPLS
  - ✓ formerly draft-khandekar-ppvpn-hvpls-mpls-00.txt

Virtual Private LAN Services over MPLS

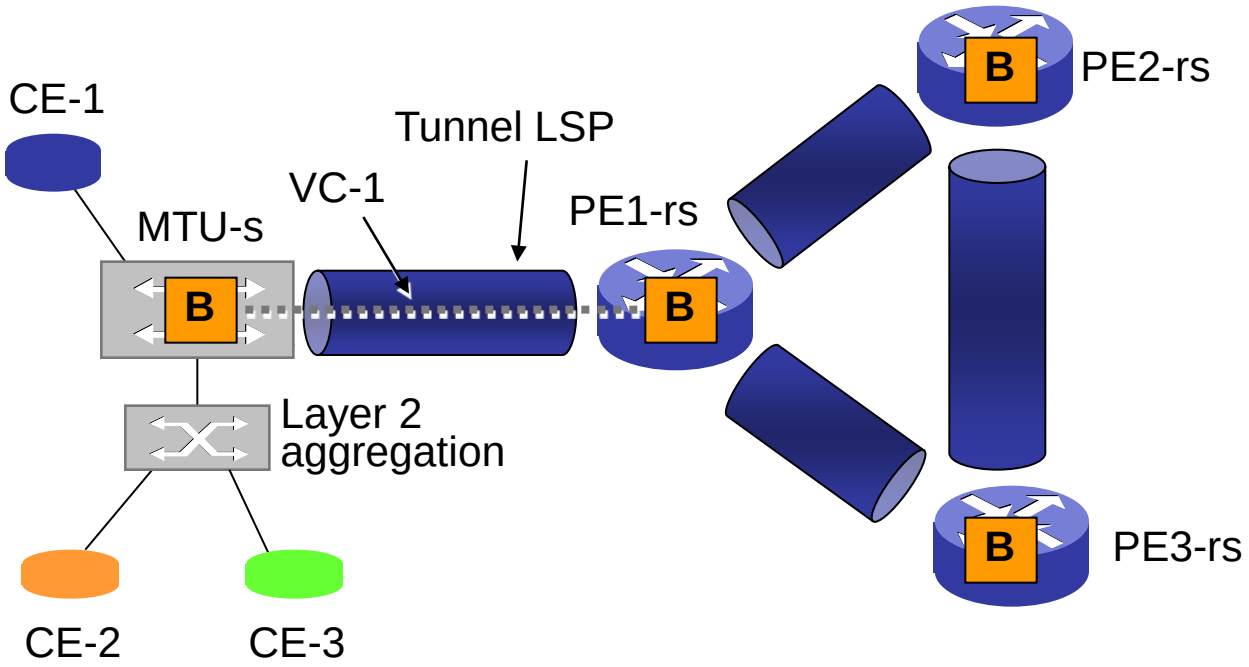
draft-lasserre-vkompella-ppvpn-vpls-01.txt



- Tunnel LSPs are established between PEs
- Users designated C1 and C2 are part of two independent Virtual Private LANs
- Layer 2 VC LSPs are set up in Tunnel LSPs
- Core MPLS network acts as a LAN switch

Virtual Private LAN Services over MPLS

draft-lasserre-vkompella-ppvpn-vpls-01.txt



VC-1 = Single pt-to-pt Martini Tunnel LSP

MTU-s = Bridging Capable MTU

PE-rs = VPLS Capable PE

B = Virtual VPLS (Bridge) Instance

- **Reduces signaling and packet replication to allow large scale deployment of VPLS**
- **Uses Martini VC / LSPs between edge MTU and VPLS aware PE devices**

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.

Why Ethernet?

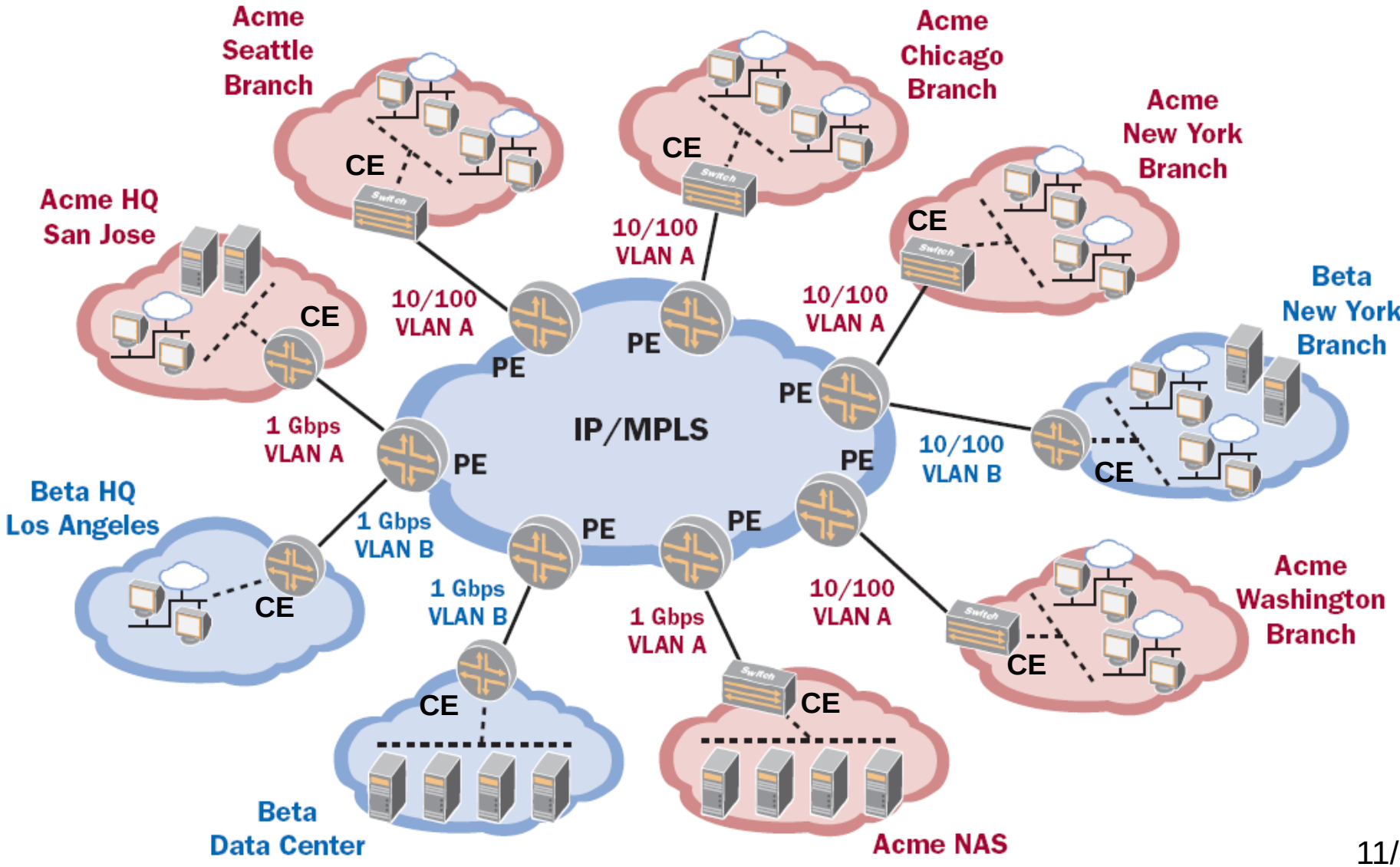
- Over 100 million Ethernet interfaces and growing fast
- Significant innovation
  - Throughput increases
    - ✓ from 10 Mbps all the way to 10 Gbps (100Gbps has been tested in Labs)
  - Protocol enhancements
    - ✓ extending Ethernet's physical reach to function as a wide area network (WAN) solution WAN solution

VPLS over MPLS

Following are few of the benefits of VPLS that it inherited from MPLS

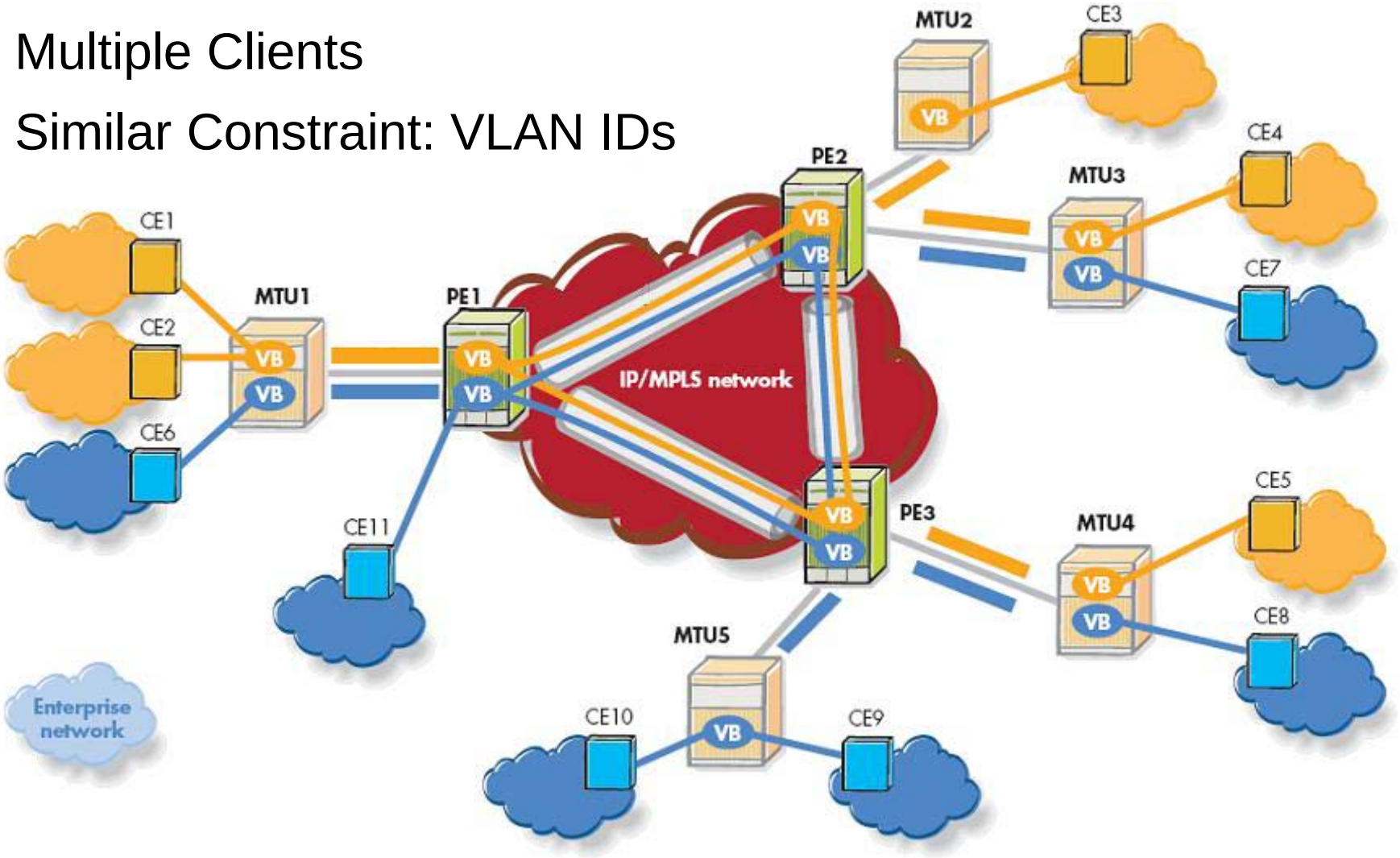
- Network Convergence
- Traffic Engineering
- Multi-point VPN
- BGP-free Core

VPLS – a big picture



Hierarchal VPLS - overview

- Multiple Clients
- Similar Constraint: VLAN IDs



Layer 2 PPVPN
draft-kompella-ppvpn-l2vpn-02.txt

- Defines the provisioning of Layer 2 VPNs using MP-BGP
- Defines the interworking functions of a Layer 2 VPN if IP is the layer 3 protocol
- Compares and contrasts Layer 2 vs Layer 3 MPLS VPN solutions
- Describes PE configuration, advertisement, and adding new sites

Virtual Private LAN Services over MPLS

VPLSs using Logical PE Architecture

- draft-ouldbrahim-l2vpn-lpe-02
- Draft proposal that introduces a “logical PE” function
- PE is divided into core and edge functions
- PE-core devices connect to other PE-core and P devices
  - Transport Tunnel within NSP core and between PE-cores
  - VPLS configuration and membership
  - VPLS signaling and discovery
- PE-edge devices connect to other PE-edge devices and PE-core devices
  - MAC address learning and STP
  - Traffic Prioritizing, policing, shaping
  - Customer VLAN processing

Comparison of “some” Layer 2 drafts

	draft-lasserre-vkompella-ppvpn-vpls-01.txt	draft-kompella-ppvpn-l2vpn-02.txt	draft-ouldbrahim-l2vpn-lpe-02.txt
Description	**Virtual Private LAN Services**	**Provisioning MPLS L2 VPNs**	VPLS using Logical PE Architecture
Date of draft / Expires	**March 2002 / Sept 2002**	**June 2002 / December 2002**	**March 2002 / August 2002**
Discovery of VPLS members	**Static / LDP**	**Dynamic / BGP**	**Static / LDP**
Signaling of VC LSPs	**LDP**	**BGP**	**LDP**
Encapsulation	**Martini Ethernet**	**Martini Ethernet**	**Martini Ethernet**
Scaling	**HVPLS included** formerly draft-khandekar-ppvpn-hvpls-mpls-00.txt	**Scope of draft**	**Inherent**

VPLS Conclusion

- VPLS Standardization and convergence are happening and well accepted
  - Several complementary proposals
  - IETF PPVPN Design Team;
    - ✓ To issue applicability statements
    - ✓ Sort out various drafts
    - ✓ Work on possible convergence
    - ✓ Identifies open issues

MPLS VPNs Summary

- Layer 2 versus Layer 3
  - Apples and Oranges
- Layer 3 MPLS VPNs
  - Deployed and at RFC stage
- Layer 2 MPLS VPNs
  - Lot’s of Interest from Carriers and Vendors
  - Many new competing drafts – some consolidation
  - Many different models for the same solution
  - We are in “concept” stage

For More Information. . . .

- http://mplsforum.com
- http://www.ietf.org
- http://www.itu.int
- http://www.frforum.com
- http://www.atmforum.com
- http://www.mplsrc.com