MPLS based
Virtual Private Network Services

An MFA Forum Sponsored Tutorial

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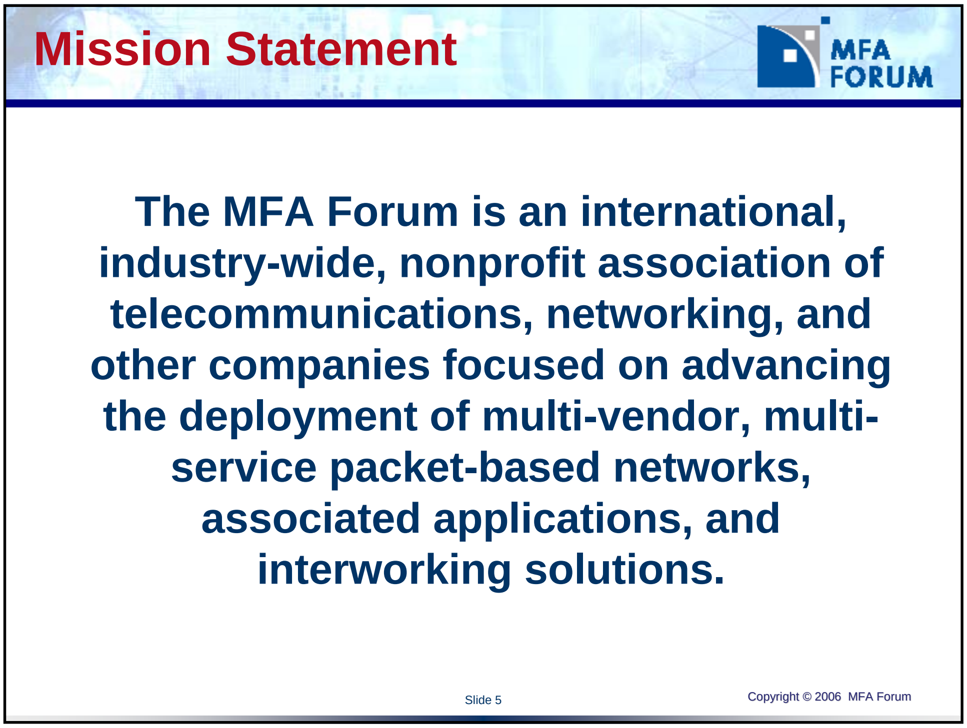
MPLS VPN Tutorial Agenda

- Introduction to the MFA Forum
- Introduction to MPLS and MPLS VPNs
  - Defining Layer 2 and 3 VPNs
- Layer 3 MPLS VPN
  - BGP Review
  - RFC 2547bis Key Characteristics
  - BGP/MPLS VPN Architecture Overview
    - VPN Routing and Forwarding (VRF) Tables
    - Overlapping VPNs
    - VPN Route Distribution
    - VPN Packet Forwarding
    - Scaling L3VPNs and Route Reflectors

MPLS VPN Tutorial Agenda

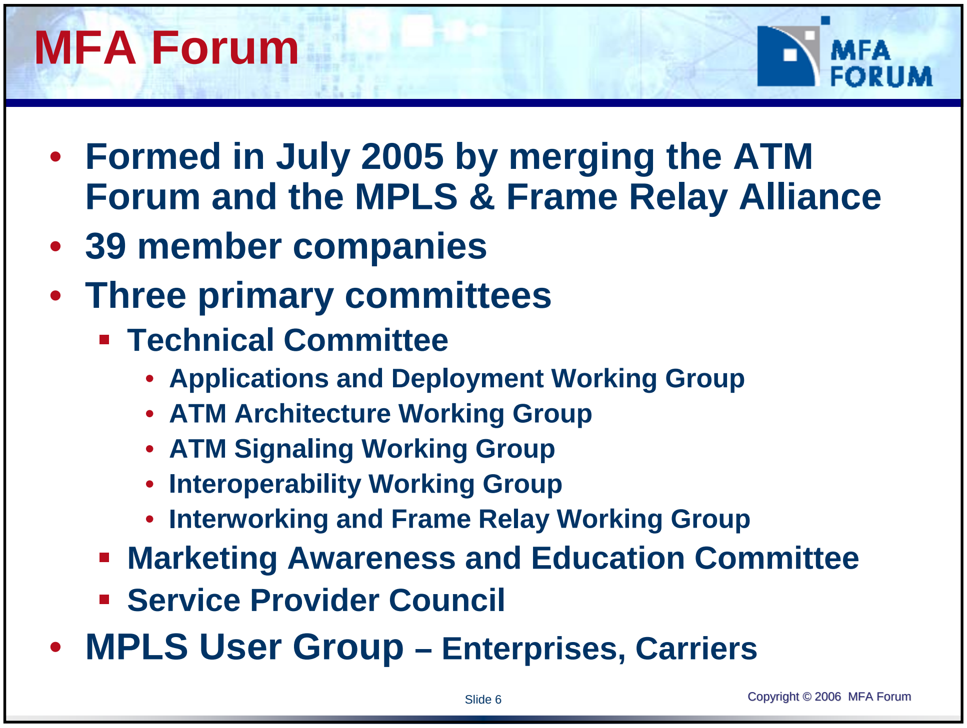
- Layer 2 VPNs
  - IETF PWE3 and L2VPN WG update
  - Encapsulation and Label Stacking
  - Virtual Private Wire Services – VPWS
    - Pt-to-pt Ethernet, Pt-to-pt ATM, Pt-to-pt Frame Relay
  - Virtual Private LAN Services – VPLS
- Introduction to Multi-Service Interworking
  - Carrier Challenges at the Edge
  - Interworking History and Definition
  - Network and Service Interworking (FRF.5 and FRF.8.1)
  - MPLS FR Alliance Multi-Service Interworking Work Actions

Introduction to the MFA Forum



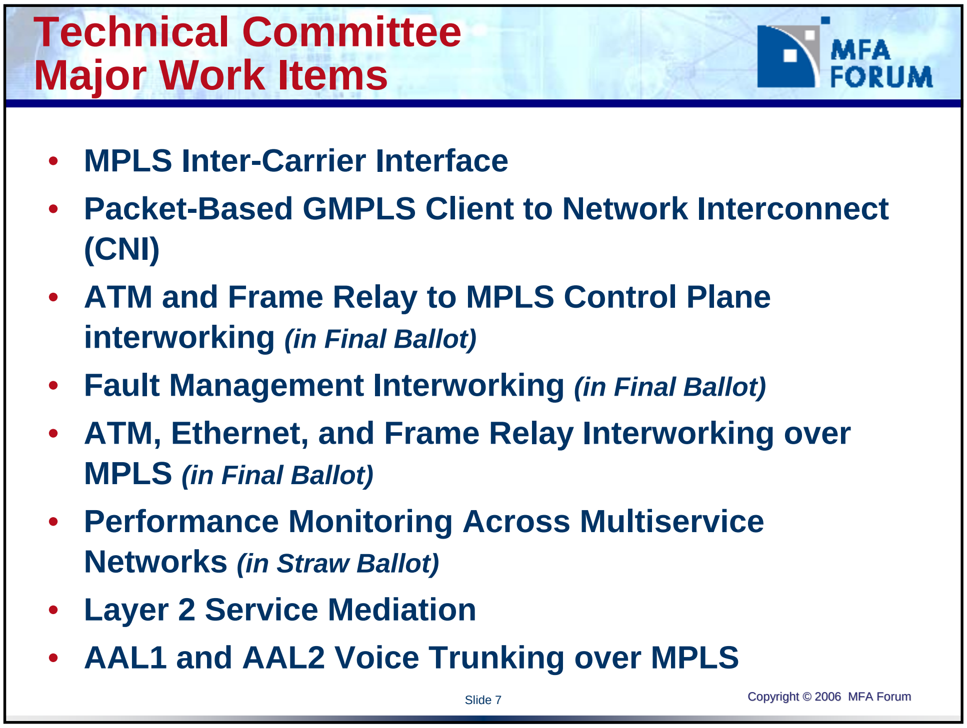
Mission Statement

The MFA Forum is an international, industry-wide, nonprofit association of telecommunications, networking, and other companies focused on advancing the deployment of multi-vendor, multi-service packet-based networks, associated applications, and interworking solutions.



MFA Forum

- Formed in July 2005 by merging the ATM Forum and the MPLS & Frame Relay Alliance
- 39 member companies
- Three primary committees
  - Technical Committee
    - Applications and Deployment Working Group
    - ATM Architecture Working Group
    - ATM Signaling Working Group
    - Interoperability Working Group
    - Interworking and Frame Relay Working Group
  - Marketing Awareness and Education Committee
  - Service Provider Council
- MPLS User Group – Enterprises, Carriers



Technical Committee Major Work Items

- MPLS Inter-Carrier Interface
- Packet-Based GMPLS Client to Network Interconnect (CNI)
- ATM and Frame Relay to MPLS Control Plane interworking *(in Final Ballot)*
- Fault Management Interworking *(in Final Ballot)*
- ATM, Ethernet, and Frame Relay Interworking over MPLS *(in Final Ballot)*
- Performance Monitoring Across Multiservice Networks *(in Straw Ballot)*
- Layer 2 Service Mediation
- AAL1 and AAL2 Voice Trunking over MPLS

MFA Forum

- Market Awareness & Education
  - Tutorials

Introduction to MPLS	½ day and full day
MPLS Virtual Private Networks	½ day and full day
MPLS VPN Security	½ day
Traffic Engineering	½ day
GMPLS	½ day
Migrating Legacy Services to MPLS	½ day
MPLS OAM	½ day
Voice over MPLS	½ day

    - New tutorials based upon demand
  - Conferences and exhibitions
    - MFA Forum speaker at almost every MPLS conference globally
  - Website and Newsletter
  - Public message board
- Next meeting: June 27-29 in Vancouver, BC, Canada
- Please join us!
  - Subscribe to information mail list info@mfaforum.org
  - To join the Forum contact Alexa Morris, Executive Director
    E-Mail: amorris@mfaforum.org Phone: 510 608-5914

Section 1

Introduction to MPLS and MPLS VPNs

Why MPLS ?

A Common Control Plane

Best of the packet-switched and circuit-switched worlds

Enhancement and scalability of IP

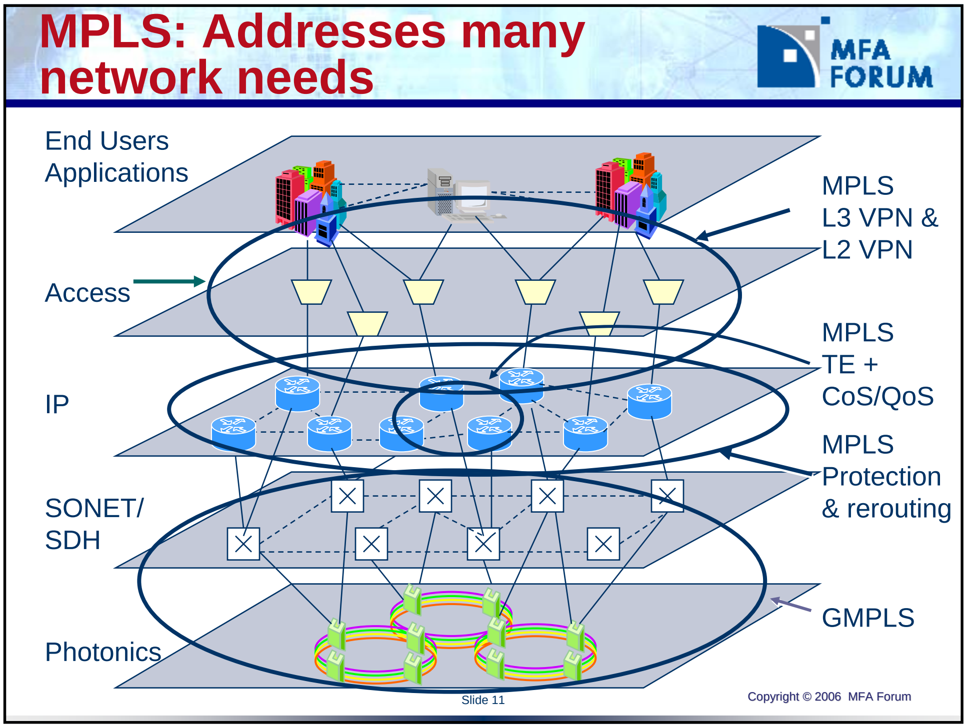
Metro Ethernet Services

Legacy Network Migration

Differentiated Services - CoS and QoS

Layer 2 and Layer 3 VPNs

Link Resiliency and Path Protection



MPLS: Addresses many network needs

End Users Applications

Access

IP

SONET/ SDH

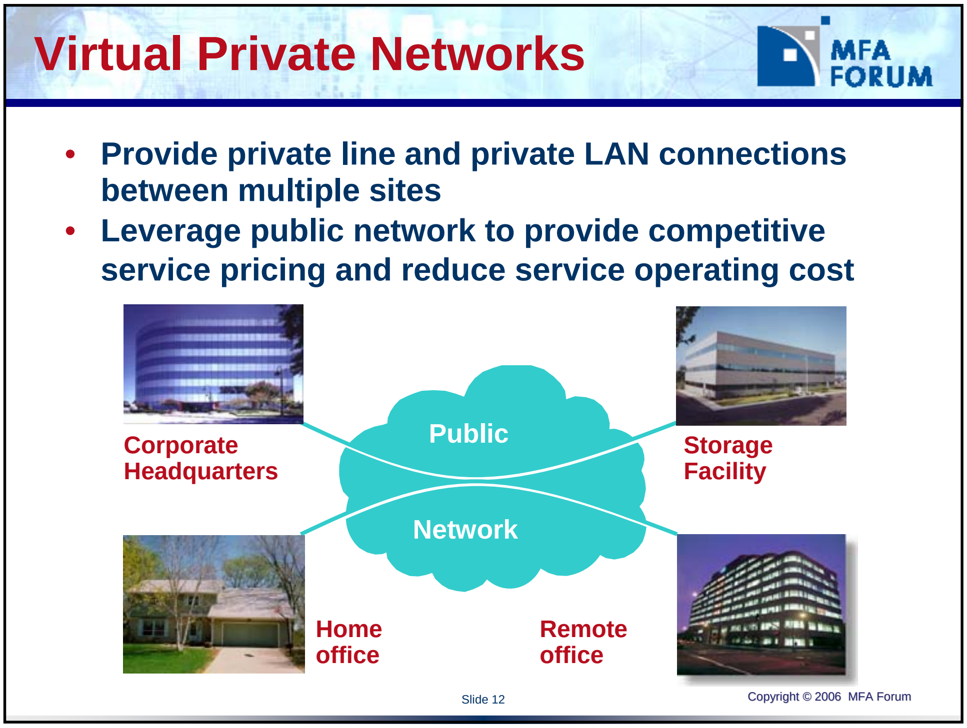
Photonics

MPLS L3 VPN & L2 VPN

MPLS TE + CoS/QoS

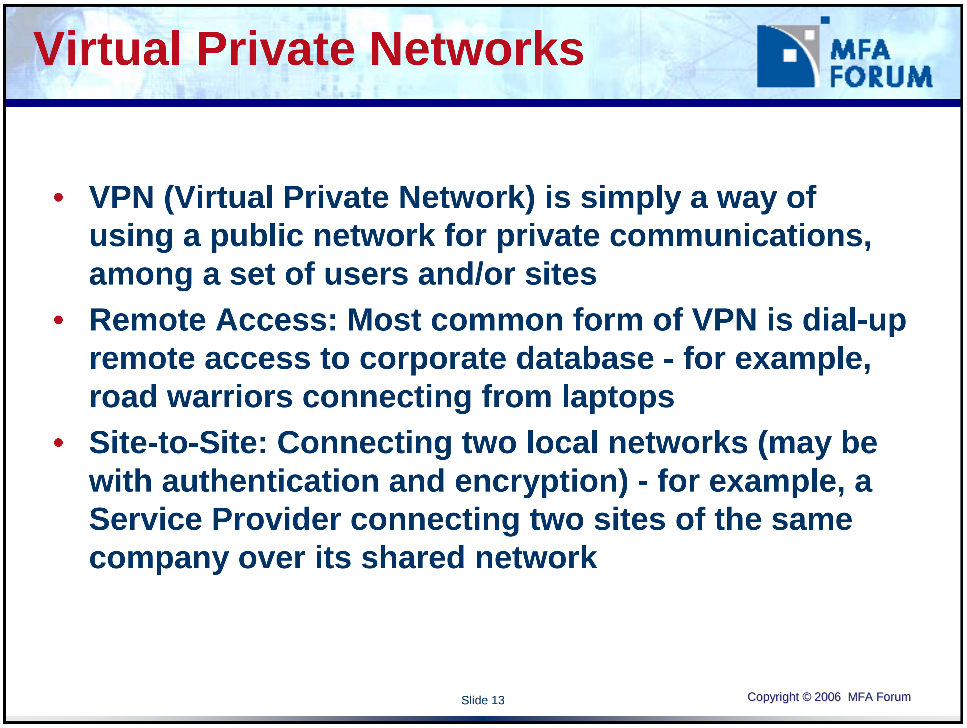
MPLS Protection & rerouting

GMPLS



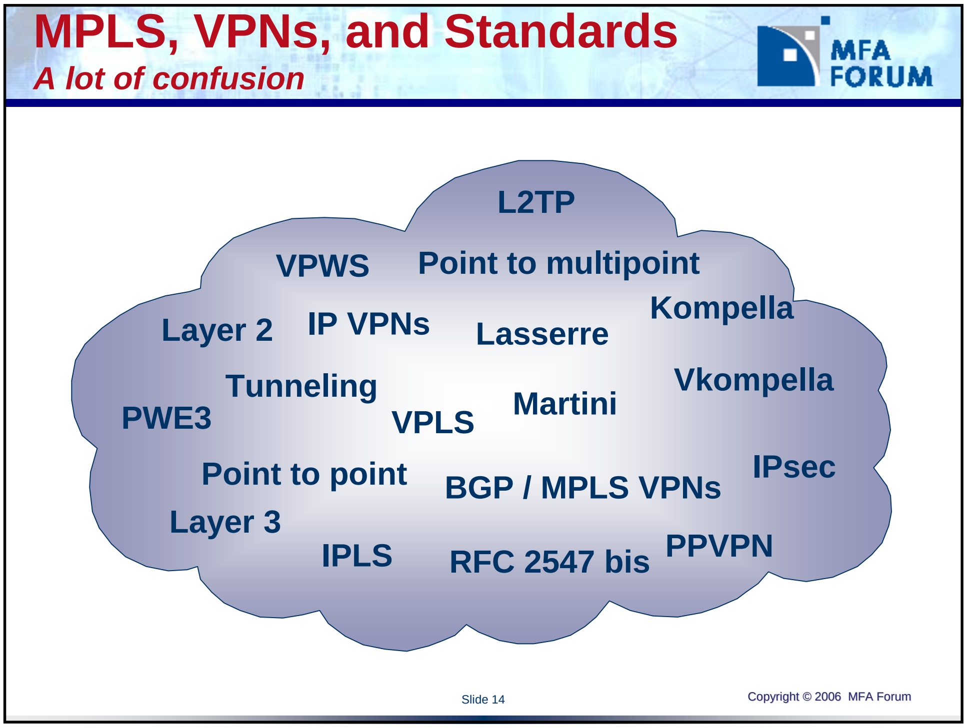
Virtual Private Networks

- Provide private line and private LAN connections between multiple sites
- Leverage public network to provide competitive service pricing and reduce service operating cost



Virtual Private Networks

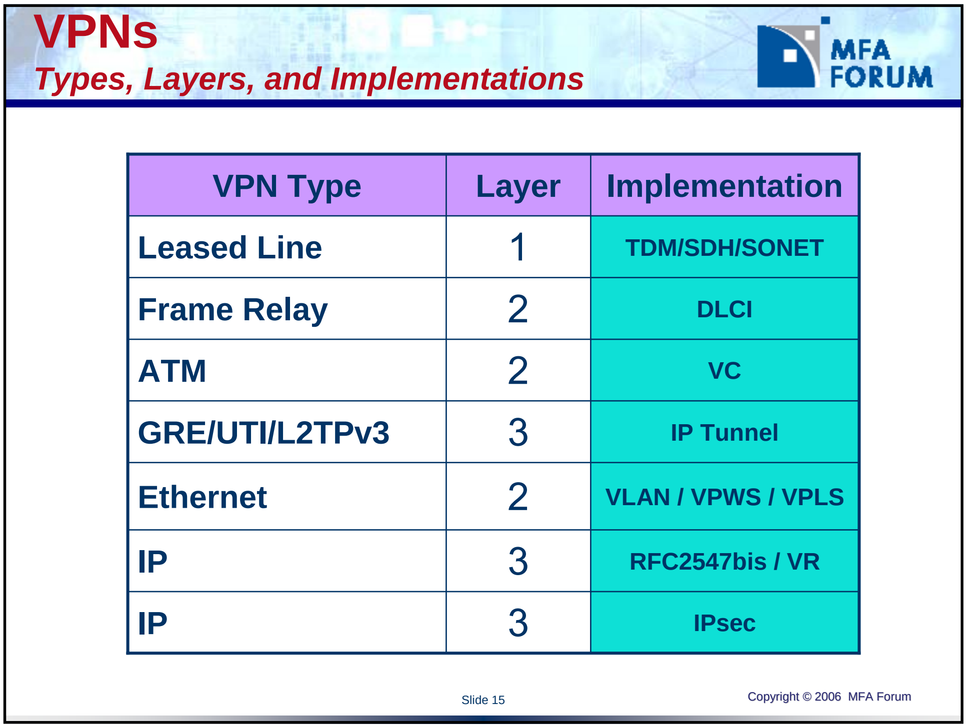
- VPN (Virtual Private Network) is simply a way of using a public network for private communications, among a set of users and/or sites
- Remote Access: Most common form of VPN is dial-up remote access to corporate database - for example, road warriors connecting from laptops
- Site-to-Site: Connecting two local networks (may be with authentication and encryption) - for example, a Service Provider connecting two sites of the same company over its shared network



MPLS, VPNs, and Standards

A lot of confusion

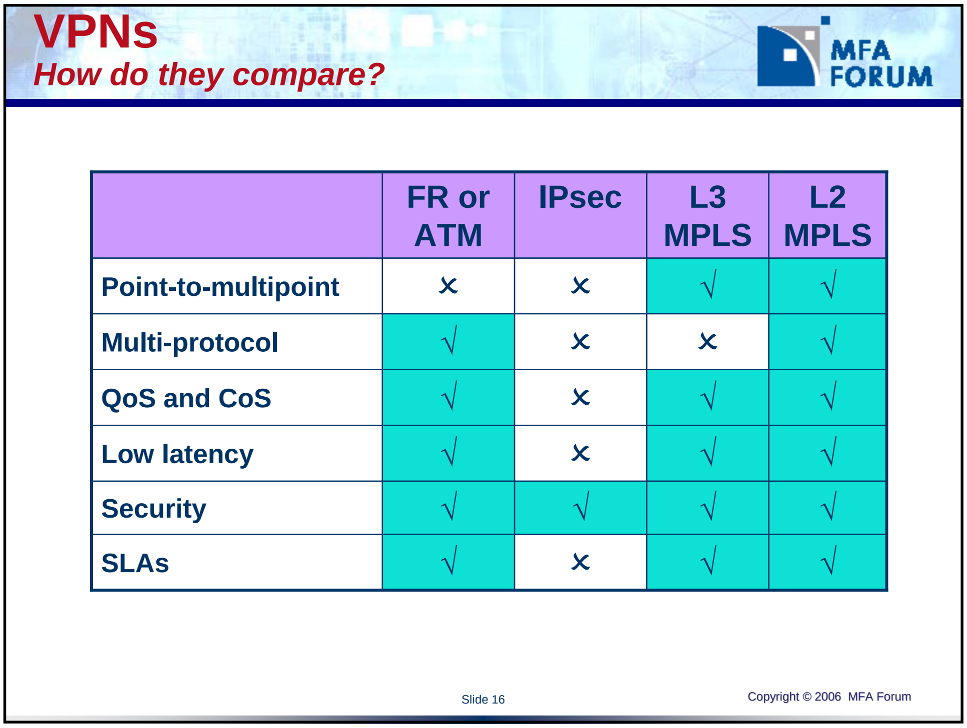
L2TP
VPWS
Point to multipoint
Layer 2
IP VPNs
Lasserre
Kompella
Tunneling
Vkompella
PWE3
VPLS
Martini
Point to point
BGP / MPLS VPNs
IPsec
Layer 3
IPLS
RFC 2547 bis
PPVPN



VPNs

Types, Layers, and Implementations

VPN Type	Layer	Implementation
Leased Line	1	**TDM/SDH/SONET**
Frame Relay	2	**DLCI**
ATM	2	**VC**
GRE/UTI/L2TPv3	3	**IP Tunnel**
Ethernet	2	**VLAN / VPWS / VPLS**
IP	3	**RFC2547bis / VR**
IP	3	**IPsec**

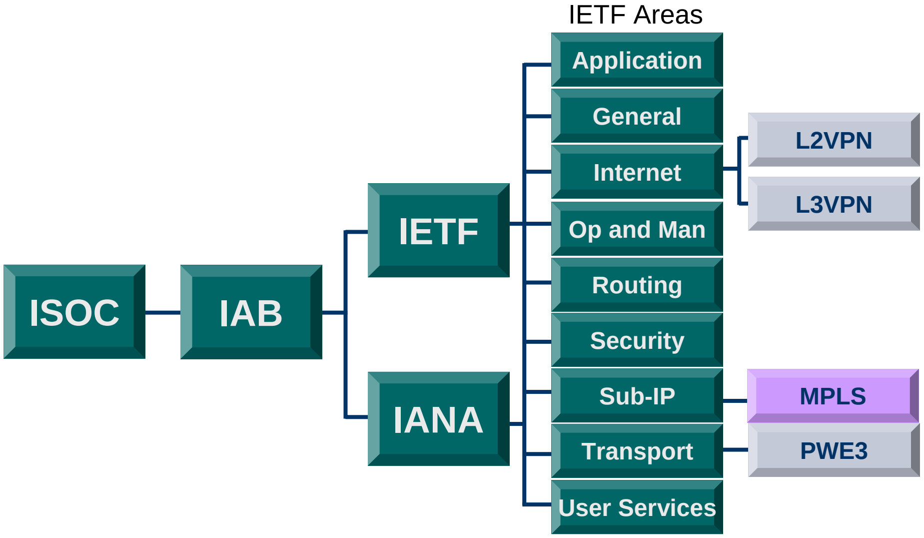


VPNs

How do they compare?

	FR or ATM	IPsec	L3 MPLS	L2 MPLS
Point-to-multipoint	×	×	√	√
Multi-protocol	√	×	×	√
QoS and CoS	√	×	√	√
Low latency	√	×	√	√
Security	√	√	√	√
SLAs	√	×	√	√

MPLS VPNs in the IETF



IETF Areas

ISOC

IAB

IETF

IANA

Application

General

Internet

Op and Man

Routing

Security

Sub-IP

Transport

User Services

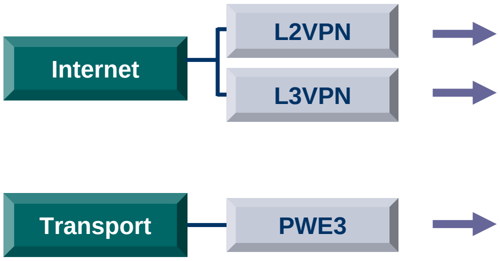
L2VPN

L3VPN

MPLS

PWE3

MPLS VPNs in the IETF



Internet

L2VPN

L3VPN

- Layer 2 VPNs
- Layer 3 VPLS

Transport

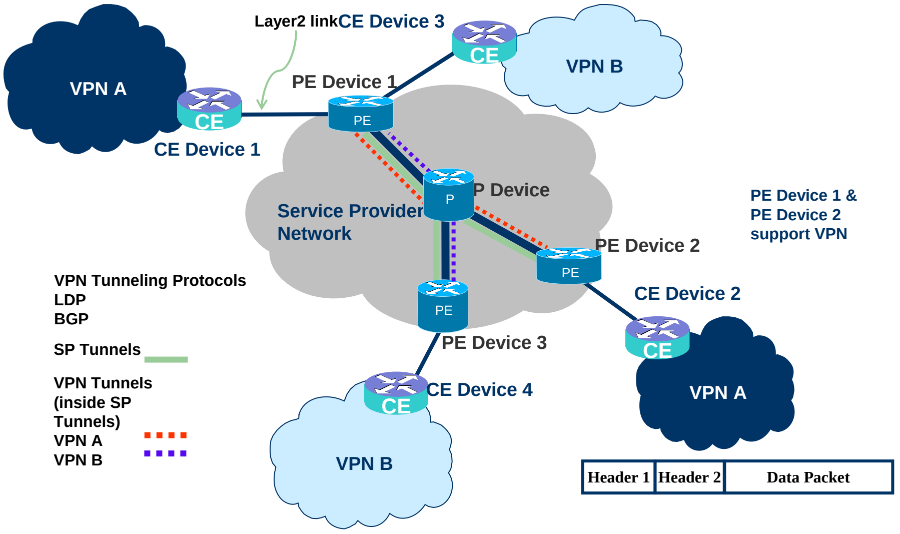
PWE3

- Pt-to-Pt circuits
- Encapsulations
  - ATM
  - FR
  - Ethernet
  - PPP/HDLC
  - SONET/SDH

What are Layer 2, Layer 3 VPNs

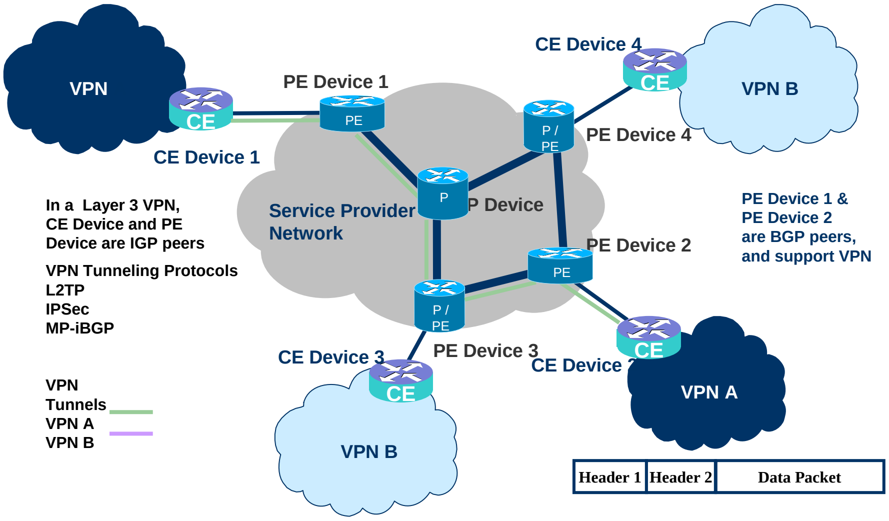
- VPNs based on a Layer 2 (Data Link Layer) technology and managed at that layer are defined as Layer 2 VPNs (MPLS, ATM, Frame Relay)
- VPNs based on tunneling at Layer 3 (Network Layer) are Layer 3 VPNs, (BGP/MPLS, VR, IPSec)

Visually - Layer 2 VPN



PE Device 1 &
PE Device 2
support VPN

Visually - Layer 3 VPN



In a Layer 3 VPN,
CE Device and PE
Device are IGP peers

VPN Tunneling Protocols
L2TP
IPSec
MP-iBGP

VPN
Tunnels
VPN A ▬
VPN B ▬

PE Device 1 &
PE Device 2
are BGP peers,
and support VPN

Section 2

Layer 3 MPLS VPN

MPLS VPN Tutorial Agenda

Layer 3 MPLS VPN

- BGP Review
- RFC 2547bis Key Characteristics
- BGP/MPLS VPN Architecture Overview
    - VPN Routing and Forwarding (VRF) Tables
    - Overlapping VPNs
    - VPN Route Distribution
    - VPN Packet Forwarding
    - Scaling L3VPNs and Route Reflectors

What is BGP?

- BGP is an exterior gateway protocol that allows IP routers to exchange network reachability information.
- BGP published as RFC 1105 in 1989 and after several updates, the current version, BGP-4 was published in 1995 as RFC 1771.
- Numerous other RFCs and Internet Drafts focus on various aspects and extensions including multiprotocol extensions, extended communities, carrying label information in BGP, etc

IGP vs. EGP

- Interior Gateway Protocols
  - RIP, OSPF, IS-IS
  - Dynamic, some more than others
  - Define the routing needed to pass data ***within*** a network
- Exterior Gateway Protocol
  - BGP
  - Less Dynamic than IGPs
  - Defines the routing needed to pass data ***between*** networks

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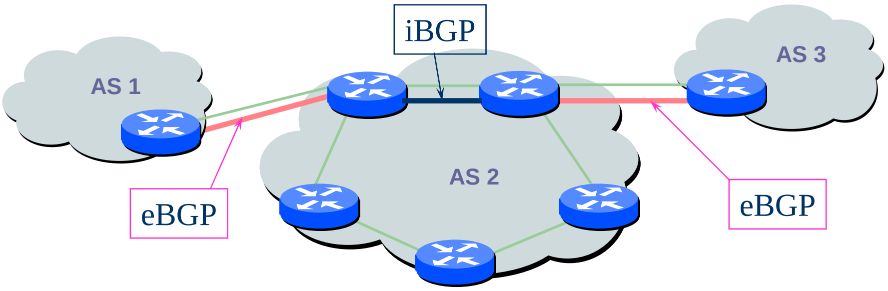
Internal Border Gateway Protocol

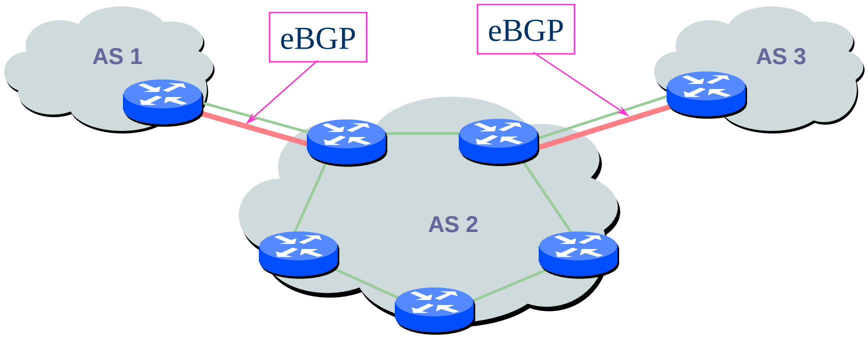
iBGP - **BGP between border routers in the same AS.**



Provides a consistent view within the AS
of the routes exterior to the AS.

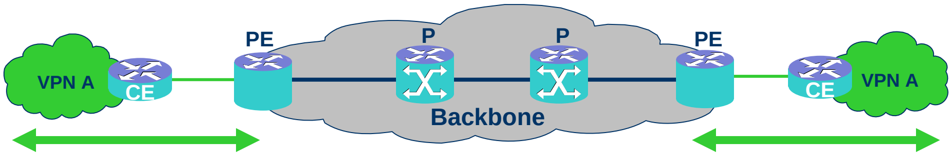
External Border Gateway Protocol

eBGP - **BGP between border routers in two different AS's.**



BGP/MPLS IP VPN (RFC 2547bis)

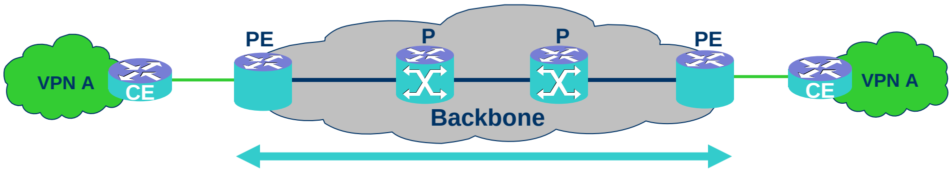
Key Characteristics



- **Requirements:**
  - **Support for overlapping, private IP address space**
  - **Different customers run different IGPs (i.e. RIP, OSPF, IS-IS)**
- **Solution:**
  - **VPN network layer is terminated at the edge (PE)**
    - **PE routers use plain IP with CE routers**

BGP/MPLS IP VPN

Key Characteristics



- P routers (LSRs) are in the core of the MPLS cloud
- P and PE (LERs) routers run an IGP and a label distribution protocol
  - Labelled VPN packets are transported over MPLS core
- PE routers are MP-iBGP fully meshed
  - for dissemination of **VPN membership and reachability information** between PEs

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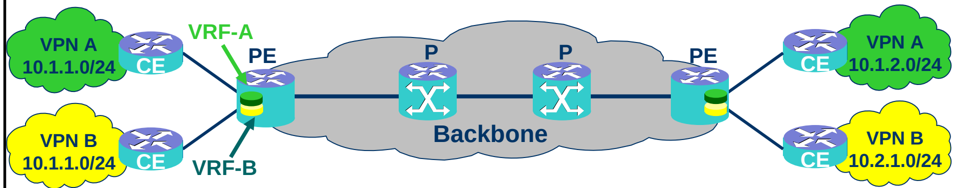
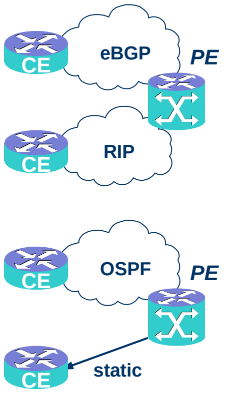
Virtual Routing and Forwarding (VRF) Tables



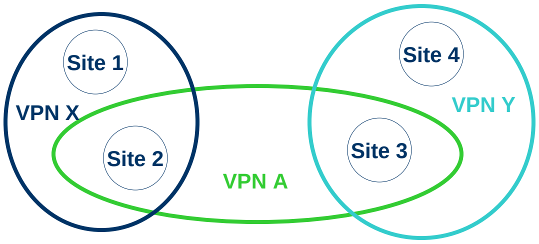
- Each VPN needs a separate **Virtual routing and forwarding instance (VRF)** in each PE router to
  - Provides VPN isolation
  - Allows overlapping, private IP address space by different organizations

Virtual Routing and Forwarding (VRF) *PE to CE Router Connectivity*



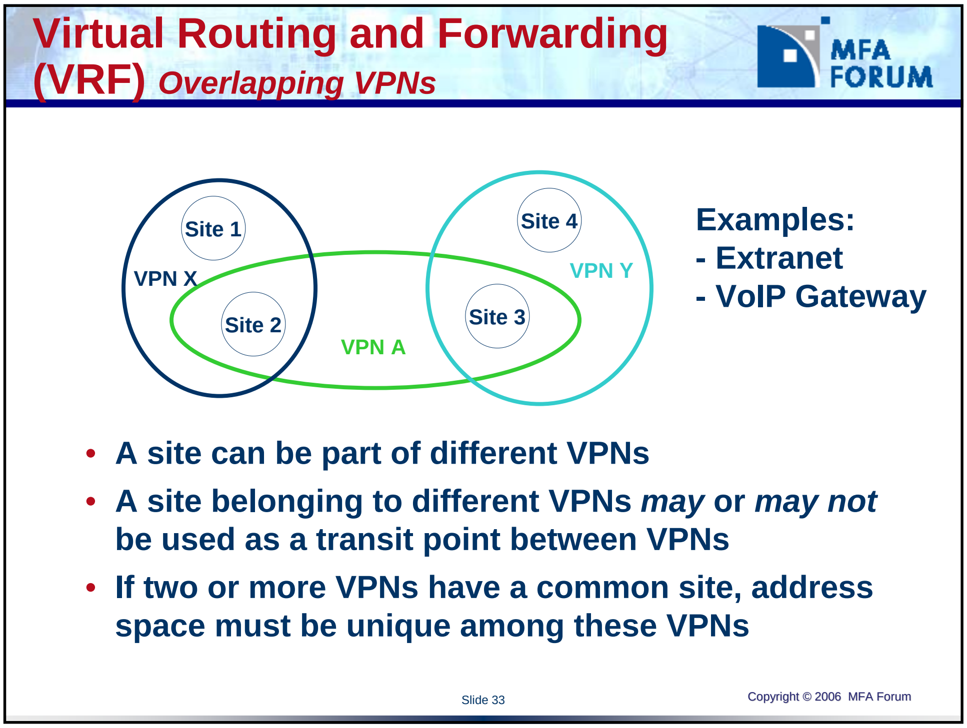
- Protocols used between CE and PE routers to populate VRFs with customer routes
  - BGP-4
    - useful in stub VPNs and transit VPNs
  - RIPv2
  - OSPF
  - static routing
    - particularly useful in stub VPNs
- Note:
  - Customer routes need to be advertised between PE routers
  - Customer routes are not leaked into backbone IGP

Virtual Routing and Forwarding (VRF) *Overlapping VPNs*



Examples:
- Extranet
- VoIP Gateway

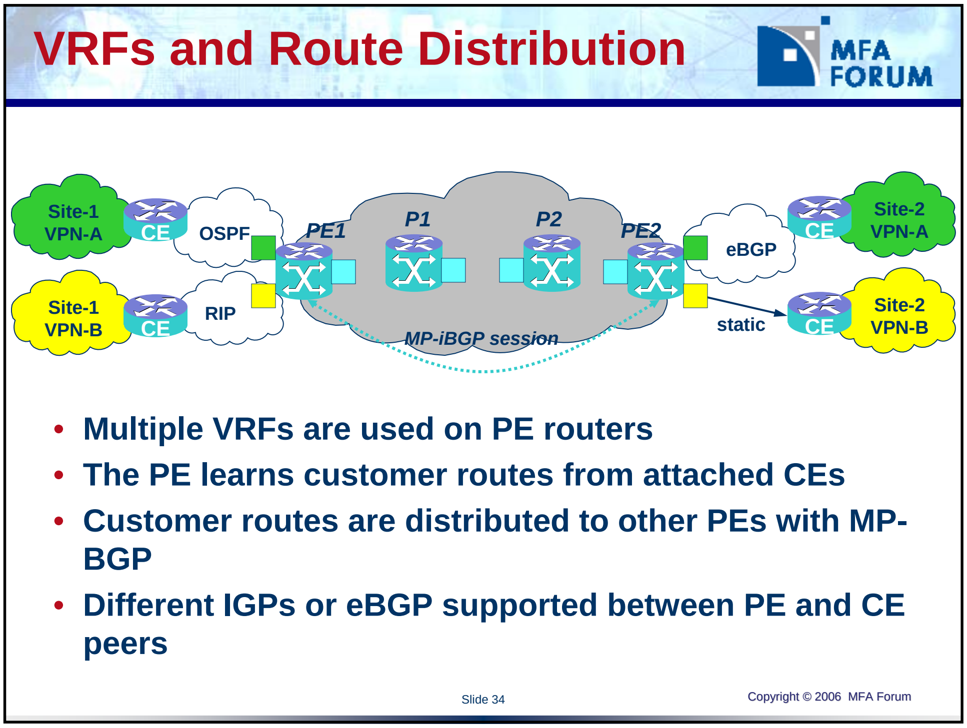
- A VPN is a collection of <u>sites</u> sharing a common routing information (routing table)
- A VPN can be viewed as a community of interest (or Closed User Group)



Virtual Routing and Forwarding (VRF) *Overlapping VPNs*

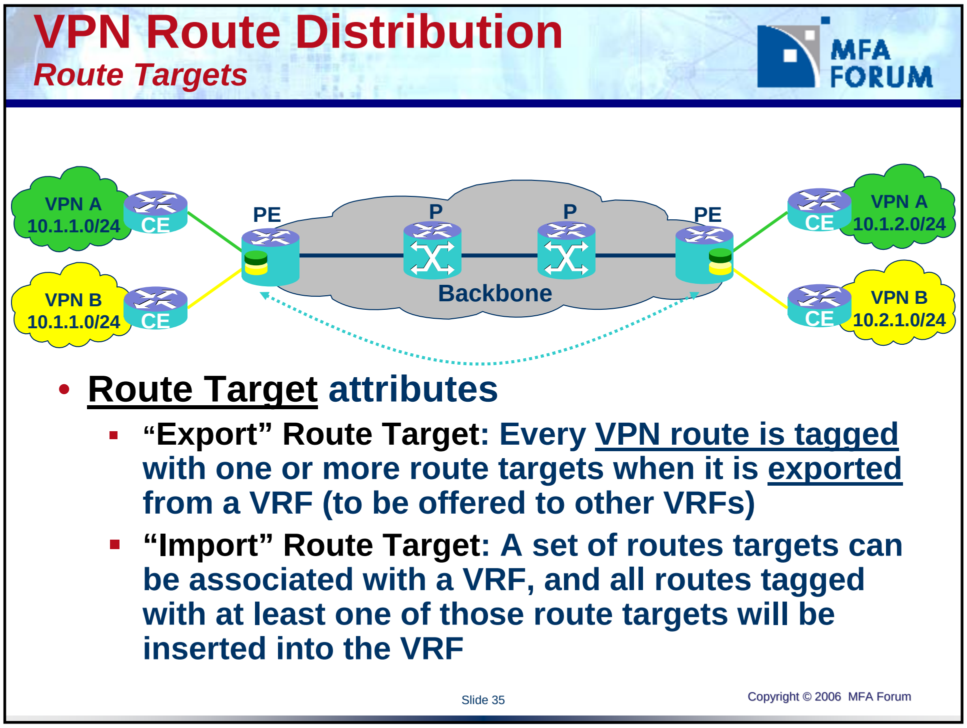
Examples:
- Extranet
- VoIP Gateway

- A site can be part of different VPNs
- A site belonging to different VPNs *may* or *may not* be used as a transit point between VPNs
- If two or more VPNs have a common site, address space must be unique among these VPNs



VRFs and Route Distribution

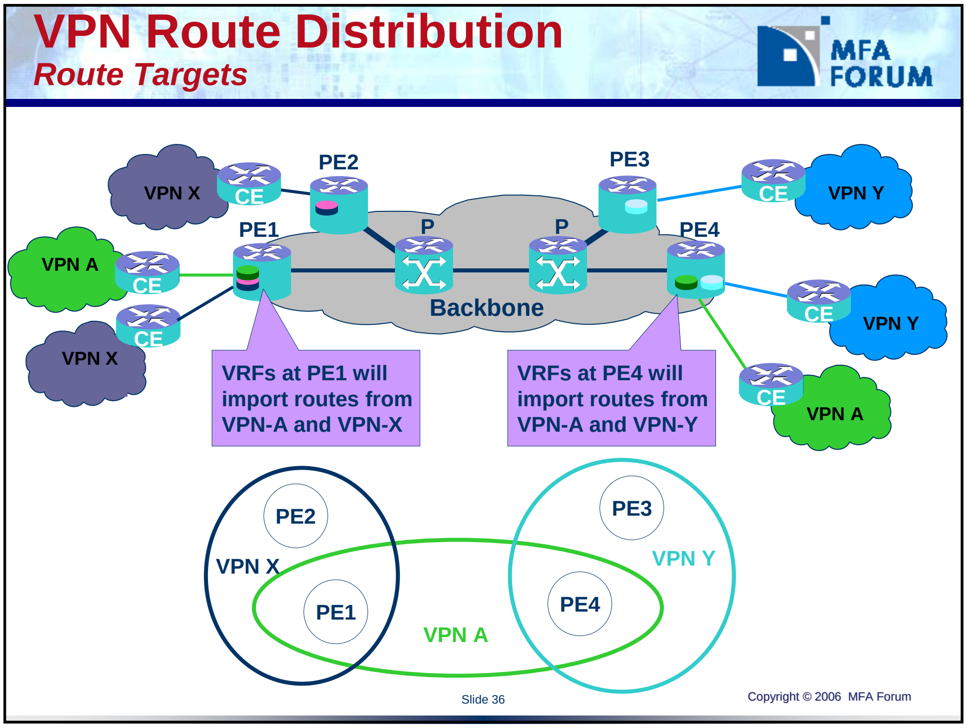
- Multiple VRFs are used on PE routers
- The PE learns customer routes from attached CEs
- Customer routes are distributed to other PEs with MP-BGP
- Different IGPs or eBGP supported between PE and CE peers



VPN Route Distribution

Route Targets

- **Route Target** attributes
  - **"Export" Route Target:** Every VPN route is tagged with one or more route targets when it is exported from a VRF (to be offered to other VRFs)
  - **"Import" Route Target:** A set of routes targets can be associated with a VRF, and all routes tagged with at least one of those route targets will be inserted into the VRF

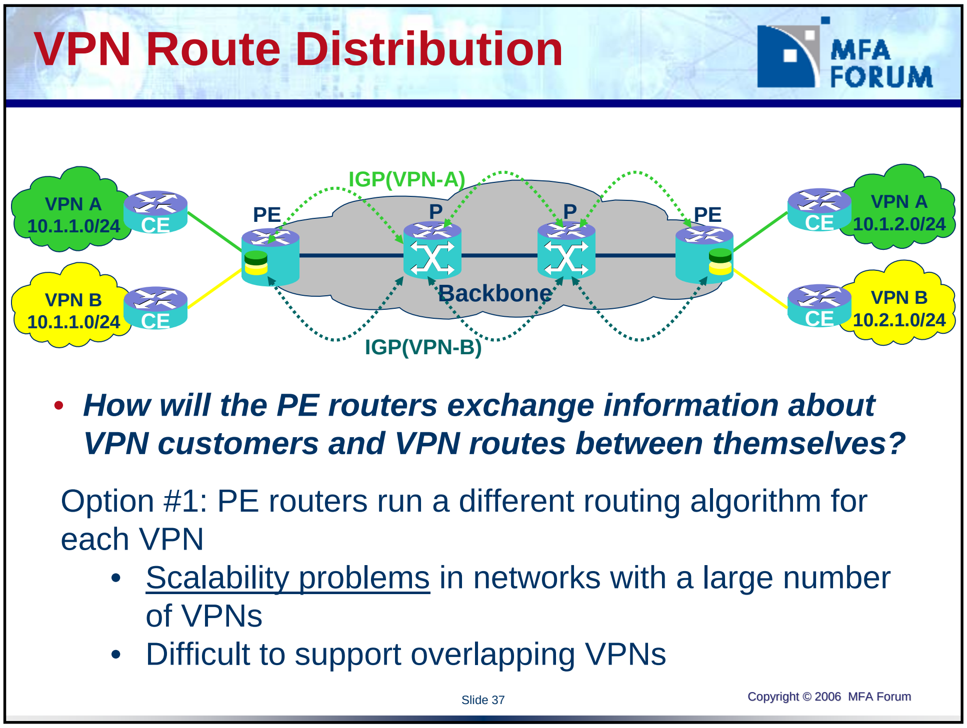


VPN Route Distribution

Route Targets

VRFs at PE1 will import routes from VPN-A and VPN-X

VRFs at PE4 will import routes from VPN-A and VPN-Y



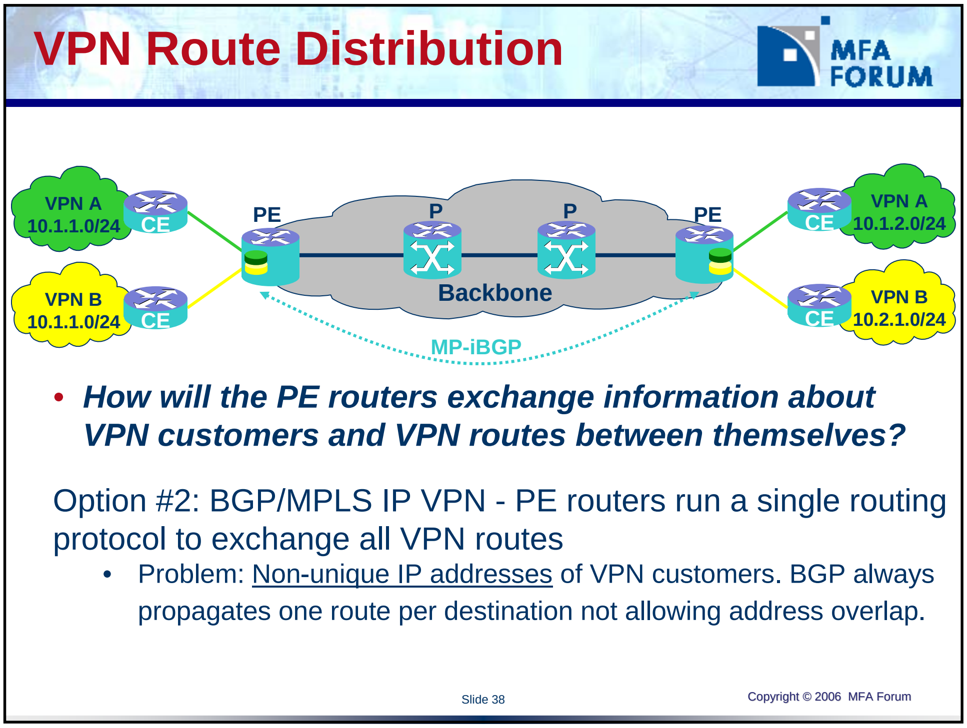
VPN Route Distribution

- ***How will the PE routers exchange information about VPN customers and VPN routes between themselves?***

Option #1: PE routers run a different routing algorithm for each VPN

  - Scalability problems in networks with a large number of VPNs
  - Difficult to support overlapping VPNs

Slide 37



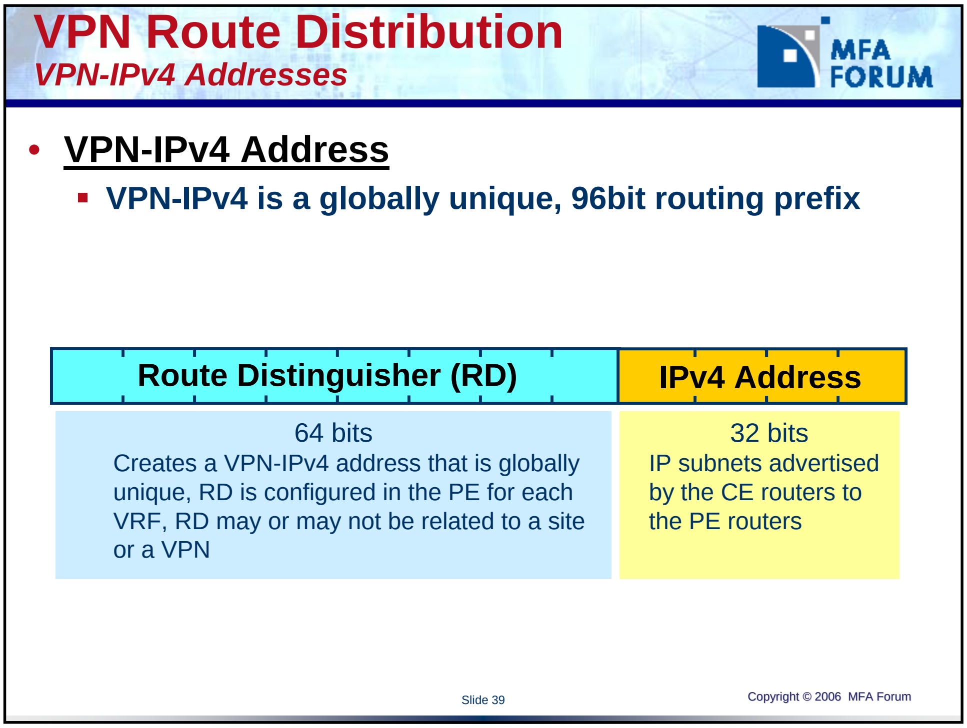
VPN Route Distribution

- ***How will the PE routers exchange information about VPN customers and VPN routes between themselves?***

Option #2: BGP/MPLS IP VPN - PE routers run a single routing protocol to exchange all VPN routes

  - Problem: Non-unique IP addresses of VPN customers. BGP always propagates one route per destination not allowing address overlap.

Slide 38

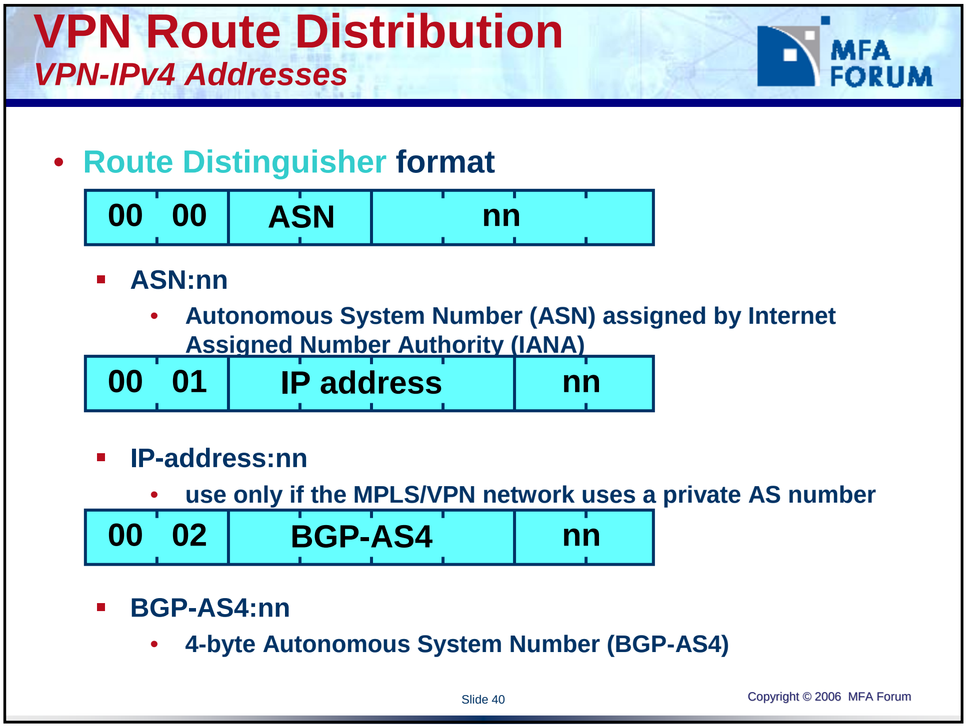


VPN Route Distribution

VPN-IPv4 Addresses

- **VPN-IPv4 Address**
  - **VPN-IPv4 is a globally unique, 96bit routing prefix**

Route Distinguisher (RD)	**IPv4 Address**
64 bits Creates a VPN-IPv4 address that is globally unique, RD is configured in the PE for each VRF, RD may or may not be related to a site or a VPN	32 bits IP subnets advertised by the CE routers to the PE routers



VPN Route Distribution

VPN-IPv4 Addresses

- Route Distinguisher **format**

00	00	ASN	nn

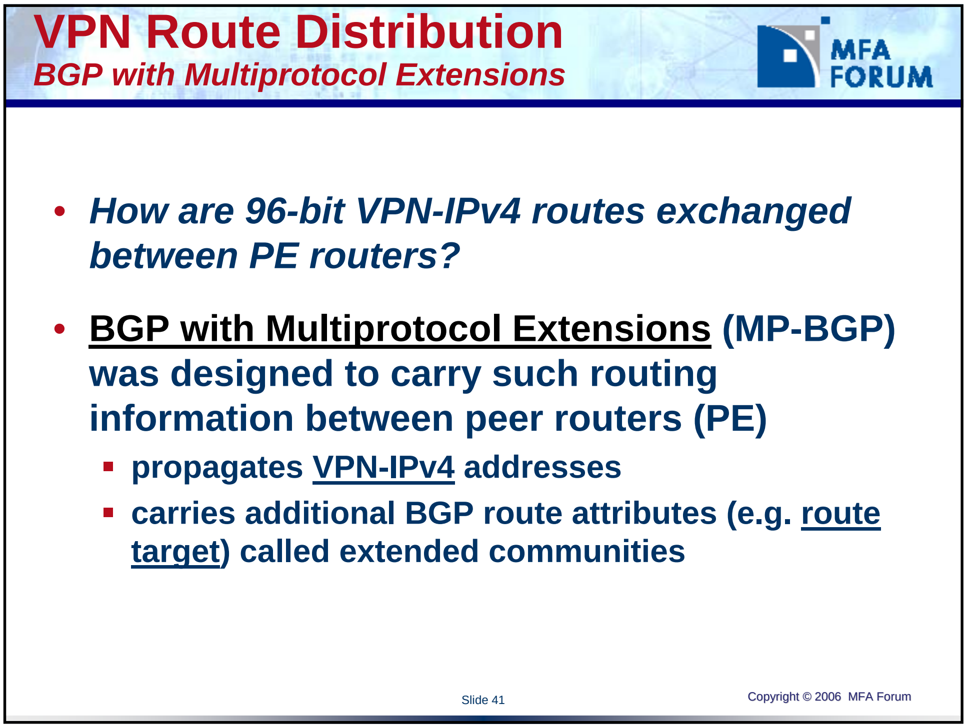
  - **ASN:nn**
    - **Autonomous System Number (ASN) assigned by Internet Assigned Number Authority (IANA)**

00	01	IP address	nn

  - **IP-address:nn**
    - **use only if the MPLS/VPN network uses a private AS number**

00	02	BGP-AS4	nn

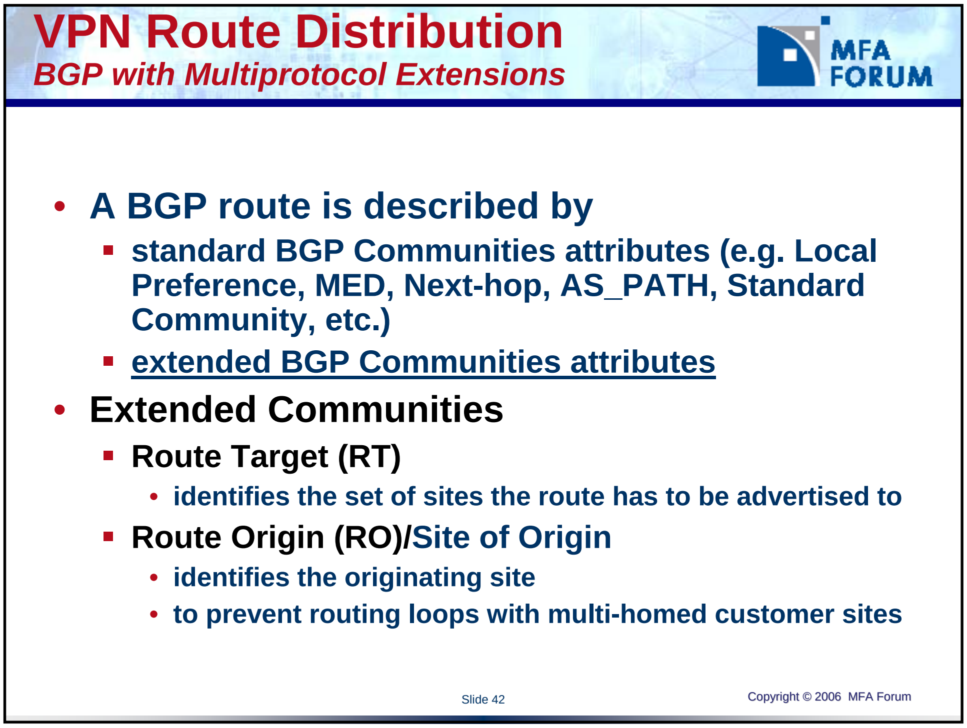
  - **BGP-AS4:nn**
    - **4-byte Autonomous System Number (BGP-AS4)**



VPN Route Distribution

BGP with Multiprotocol Extensions

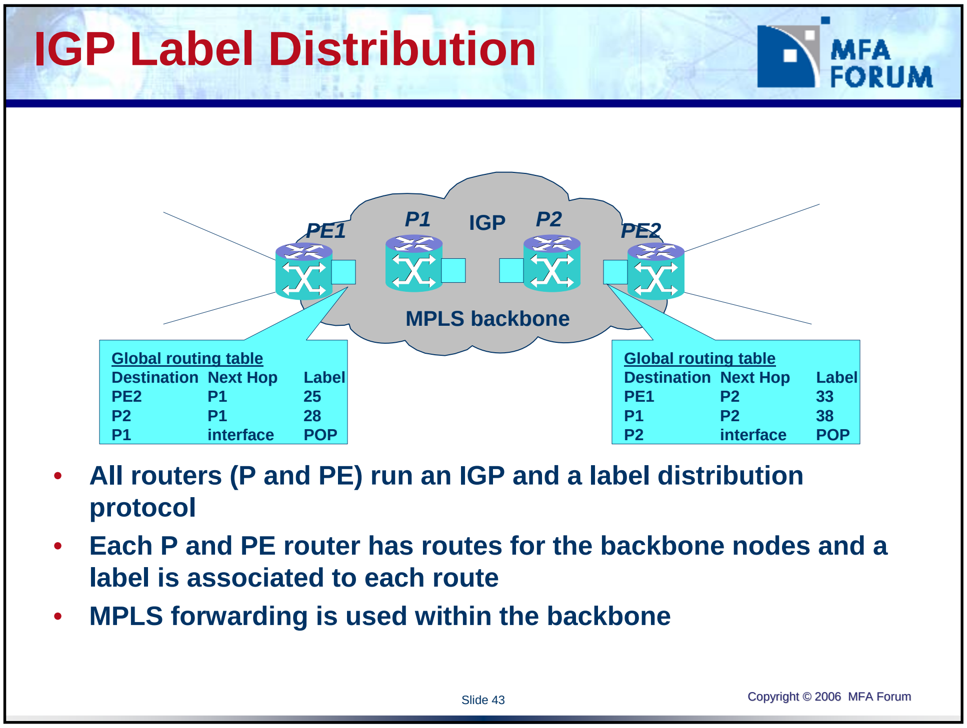
- ***How are 96-bit VPN-IPv4 routes exchanged between PE routers?***
- **BGP with Multiprotocol Extensions (MP-BGP) was designed to carry such routing information between peer routers (PE)**
  - **propagates VPN-IPv4 addresses**
  - **carries additional BGP route attributes (e.g. route target) called extended communities**



VPN Route Distribution

BGP with Multiprotocol Extensions

- **A BGP route is described by**
  - **standard BGP Communities attributes (e.g. Local Preference, MED, Next-hop, AS_PATH, Standard Community, etc.)**
  - **extended BGP Communities attributes**
- **Extended Communities**
  - **Route Target (RT)**
    - **identifies the set of sites the route has to be advertised to**
  - **Route Origin (RO)/Site of Origin**
    - **identifies the originating site**
    - **to prevent routing loops with multi-homed customer sites**



IGP Label Distribution

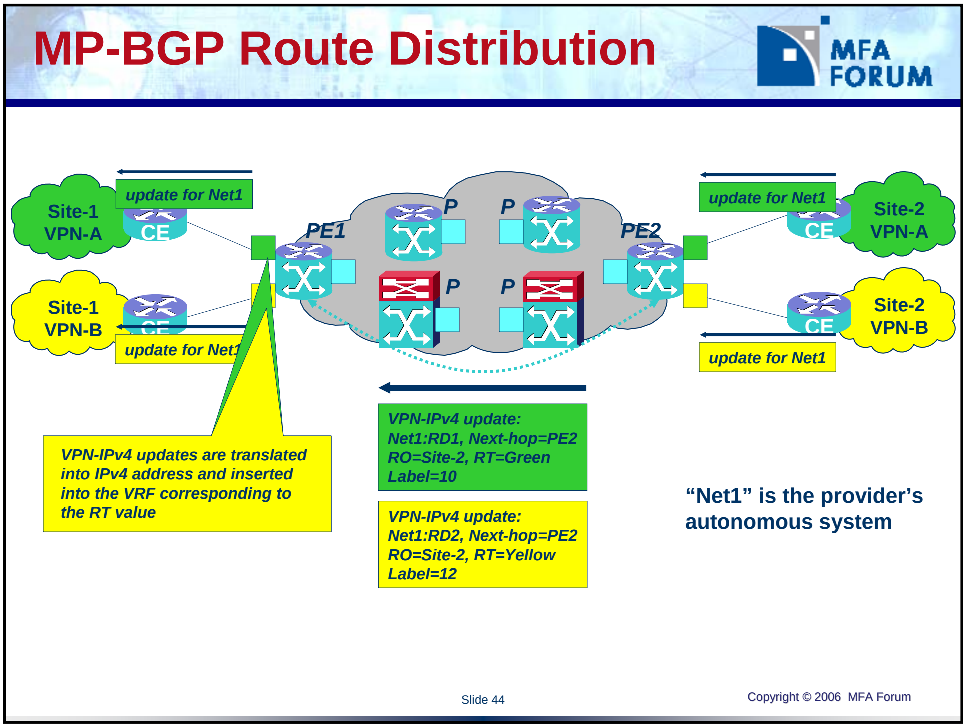
Global routing table

Destination	Next Hop	Label
PE2	P1	25
P2	P1	28
P1	interface	POP

Global routing table

Destination	Next Hop	Label
PE1	P2	33
P1	P2	38
P2	interface	POP

- All routers (P and PE) run an IGP and a label distribution protocol
- Each P and PE router has routes for the backbone nodes and a label is associated to each route
- MPLS forwarding is used within the backbone



MP-BGP Route Distribution

VPN-IPv4 updates are translated into IPv4 address and inserted into the VRF corresponding to the RT value

VPN-IPv4 update:
Net1:RD1, Next-hop=PE2
RO=Site-2, RT=Green
Label=10

VPN-IPv4 update:
Net1:RD2, Next-hop=PE2
RO=Site-2, RT=Yellow
Label=12

"Net1" is the provider's autonomous system

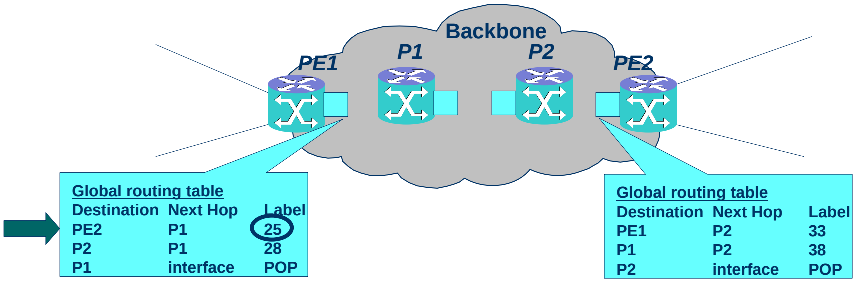
MP-BGP Route Distribution

Summary

- VPN Routing and Forwarding (VRF) Table
  - Multiple routing tables (VRFs) are used on PEs
    - VPNs are isolated
- Customer addresses can overlap
  - Need for unique VPN route prefix
  - PE routers use MP-BGP to distribute VPN routes to each other
  - For security and scalability, MP-BGP only propagates information about a VPN to other routers that have interfaces with the same Route Target value.

MP-BGP = BGP with Multiprotocol Extensions

VPN Packet Forwarding



Global routing table

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PE2	P1	25
P2	P1	28
P1	interface	POP

Global routing table

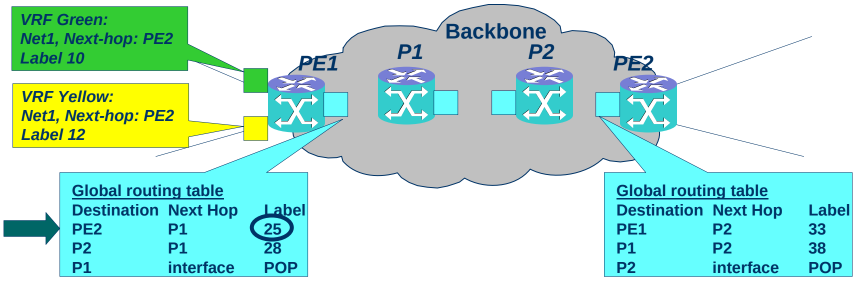
Destination	Next Hop	Label
PE1	P2	33
P1	P2	38
P2	interface	POP

PE-to-PE connectivity via LSPs

- All routers (P and PE) run an IGP and a label distribution protocol
- Each P and PE router has routes for the backbone nodes and a label is associated to each route
- MPLS forwarding is used within the backbone

VPN Packet Forwarding

Label Stacking



VRF Green:
Net1, Next-hop: PE2
Label 10

VRF Yellow:
Net1, Next-hop: PE2
Label 12

Global routing table

Destination	Next Hop	Label
PE2	P1	25
P2	P1	28
P1	interface	POP

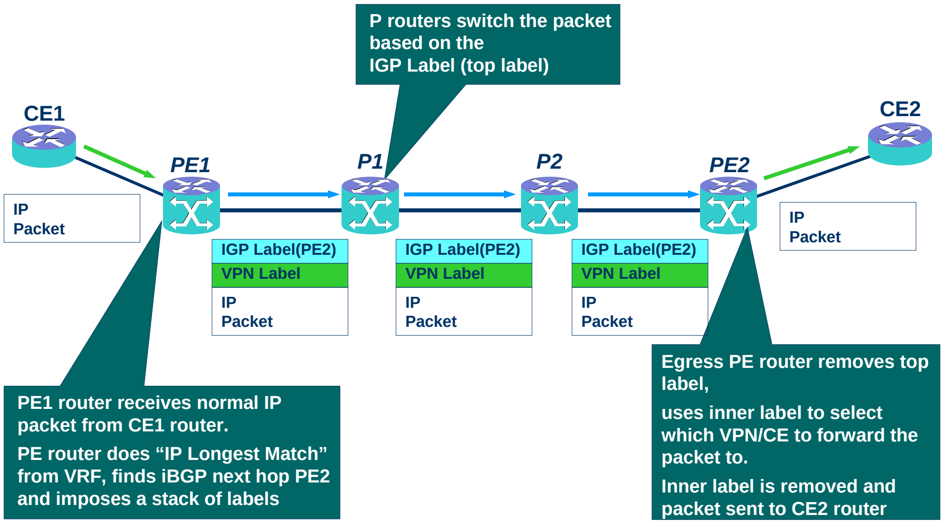
Global routing table

Destination	Next Hop	Label
PE1	P2	33
P1	P2	38
P2	interface	POP

- **Ingress PE router uses two-level label stack**
  - VPN label **(inner label) assigned by the egress PE router**
  - IGP label **(top label) identifying the PE router**
- **Label stack is attached in front of the IP packet that belongs to a VPN**
- **The MPLS packet is forwarded across the P routers in the backbone network**

VPN Packet Forwarding

Label Stacking



P routers switch the packet based on the IGP Label (top label)

PE1 router receives normal IP packet from CE1 router.

PE router does “IP Longest Match” from VRF, finds iBGP next hop PE2 and imposes a stack of labels

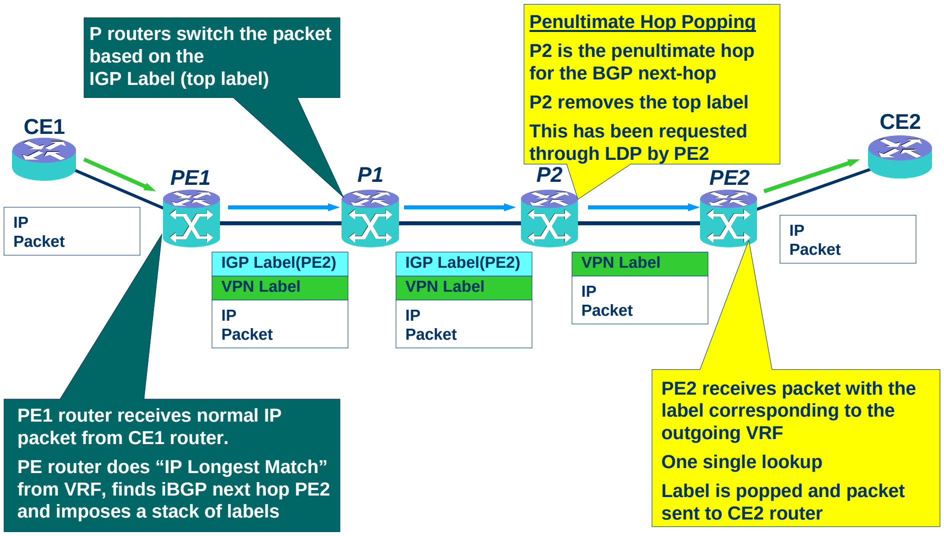
Egress PE router removes top label,

uses inner label to select which VPN/CE to forward the packet to.

Inner label is removed and packet sent to CE2 router

VPN Packet Forwarding

Penultimate Hop Popping



P routers switch the packet based on the IGP Label (top label)

Penultimate Hop Popping

P2 is the penultimate hop for the BGP next-hop

P2 removes the top label

This has been requested through LDP by PE2

PE1 router receives normal IP packet from CE1 router.

PE router does “IP Longest Match” from VRF, finds iBGP next hop PE2 and imposes a stack of labels

PE2 receives packet with the label corresponding to the outgoing VRF

One single lookup

Label is popped and packet sent to CE2 router

Core Routers (P Routers)

- Not involved in MP-BGP
- Does not make routing decision based on VPN addresses
- Forwards packet based on the top label value
- P routers do not need to carry VPN routing information or Internet routing information, thus providing better network scalability

Scaling BGP/MPLS VPNs

- Scalability of BGP/MPLS VPNs
  - Expanding the MPLS core network
    - without impact on the VPN services, e.g. adding P routers (LSRs), new or faster links
  - Label stacking
    - allows reducing the number of LSPs in the network core and avoiding LSP exhaustion
  - VPN Route Distribution
    - Route Reflectors

Scaling BGP/MPLS VPNs

Route Reflectors

- BGP Route Reflectors
  - Existing BGP technique, can be used to scale VPN route distribution
    - PEs don’t need full mesh of BGP connections, only connect to RRs
    - By using multiple RRs, no one box needs to have all VPN routes
  - Each edge router needs only the information for the VPNs it supports
    - directly connected VPNs

Reference Material

Books:

"BGP4 Inter-Domain Routing in the Internet" by John Stewart ISBN 0-201-37951-1

"Internet Routing Architectures" by Bassam Halabi ISBN 1-56205-652-2

"Interconnections: Bridges and Routers" by Radia Perlman ISBN

“Internetworking with TCP/IP Volume 1” by Douglas Comer ISBN 0-13-468505-9

“TCP/IP Network Administration - Second Edition” by Craig Hunt ISBN 1-56592-322-7

"Routing in the Internet" by Christian Huitema ISBN 0-13-132192-7

Mail Lists:

SSR mailinglist - majordomo@cabletron.com

GateD mailinglists - See www.gated.org

North American Network Operators Group (NANOG) mailist - See www.merit.org

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Reference Material

Request For Comments - RFCs

08/98 - RFC2385PS "Protection of BGP Sessions via the TCP MD5 Signature Option"
02/98 - RFC 2283PS "Multiprotocol Extensions for BGP-4"
01/97 - RFC 2042 "Registering New BGP Attribute Types"
08/96 - RFC 1998 "An Application of the BGP Community Attribute in Multi-home Routing"
08/96 - RFC 1997 "BGP Communities Attribute"
06/96 - RFC 1966 "BGP Route Reflection An alternative to full mesh"
06/96 - RFC 1965 "Autonomous System Confederations for BGP"
10/95 - RFC 1863 "A BGP/IDRP Route Server alternative to a full mesh routing"
08/95 - RFC 1817 “CIDR and Classful Routing”
03/95 - RFC 1774 "BGP-4 Protocol Analysis"
03/95 - RFC 1773 "Experience with the BGP-4 protocol"
03/95 - RFC 1772 "Application of the Border Gateway Protocol in the Internet"
03/95 - RFC 1771 "A Border Gateway Protocol 4 (BGP-4)
12/94 - RFC 1745 "BGP4/IDRP for IP---OSPF Interaction"
07/94 - RFC 1657 "Definitions of Managed Objects for BGP-4 using SMIv2"
09/93 - RFC 1520 “Exchanging Routing Information Across Provider Boundaries in CIDR”
09/93 - RFC 1519 “CIDR; an Address Assignment and Aggregation Strategy”
09/93 - RFC 1518 “An Architecture for IP Address Allocation with CIDR”

Reference Material

Internet Drafts

08/98 "LDP Specification"
08/98 "Border Gateway Multicast Protocol (BGMP): Protocol Specification"
08/98 "A Framework for Inter-Domain Route Aggregation"
08/98 "Routing Policy Configuration Language (RPCL)"
08/98 "Carrying Label Information in BGP-4"
08/98 "Capabilities Negotiation with BGP-4"
08/98 "BGP Security Analysis"
08/98 "A Border Gateway Protocol 4 (BGP-4)"
07/98 "Using RPSL in Practice"
07/98 "Multiprotocol Label Switching Architecture"
06/98 "NHRP for Destinations off the NBMA Subnetwork"
05/98 "BGP Route Flap Damping"
04/98 "BGP-4 Capabilities Negotiation for BGP Multiprotocol Extensions"
03/98 "To Be Multihomed: Requirements & Definitions"
03/98 "BGP-4 over ATM and Proxy PAR"
02/98 "Use of BGP-4 Multiprotocol Extensions for IPv6 Inter-Domain Routing"
02/98 "Carrying Label Information in BGP-4"
01/98 "DNS-base NLRI origin AS verification in BGP"

Section 3

Layer 2 VPNs

MPLS VPN Tutorial Agenda

Layer 2 VPNs

- IETF PWE3 and L2VPN WG update
- Encapsulation and Label Stacking
- Virtual Private Wire Services – VPWS
  - Pt-to-pt Ethernet, Pt-to-pt ATM, Pt-to-pt Frame Relay
- Virtual Private LAN Services – VPLS

MPLS L2 VPN Market Drivers

What can we conclude?

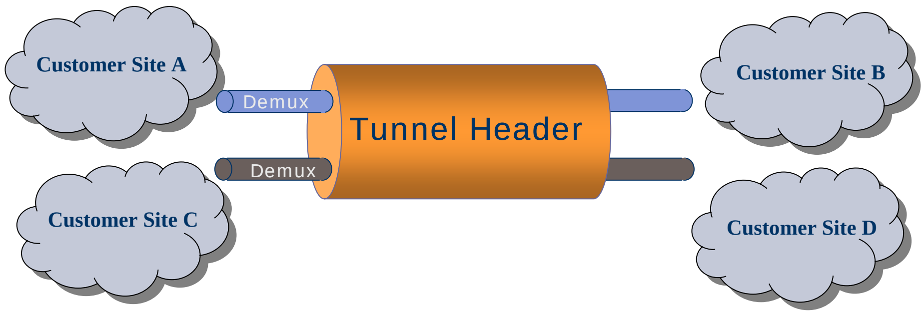
- Layer 3 IP is not the only traffic
  - Still a lot of legacy SNA, IPX etc
  - Large enterprises have legacy protocols
- Layer 3 IP VPNs are not the whole answer
  - IP VPNs cannot handle legacy traffic
- Layer 2 legacy traffic widely deployed

Carriers need to support
Layer 2 and Layer 3 VPNs

MPLS Layer 2 VPNs

- **Point-to-point layer 2 solutions**
  - Virtual Private Wire Services **- VPWS**
  - **Similar to ATM / FR services, uses tunnels and connections (LSPs)**
  - **Customer gets connectivity only from provider**
  - **Ongoing work to encapsulate Ethernet, ATM, FR, TDM, SONET, etc**
- **Multi-point layer 2 solutions**
  - Virtual Private LAN Services **- VPLS**
  - **Virtual Private LAN Services aka Transparent LAN Service (TLS)**
  - **Ethernet Metro VLANs / TLS over MPLS**
  - **Independent of underlying core transport**
  - **All drafts "currently" support PWE3 (Martini) Ethernet encapsulation**
  - **Differences in drafts for discovery and signaling**

MPLS Point-to-Point Service



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

MPLS Point-to-Point Services

Label Stacking

Tunnel Header	Demux Field	VC Encaps Information	Layer 2 payload
1	2	3	

- Three Layers of Encapsulation
  1) <u>Tunnel Header:</u> Contains information needed to transport the PDU across the IP or MPLS network
  2) <u>Demultiplexer Field:</u> Used to distinguish individual emulated VCs within a single tunnel
  3) <u>Emulated VC Encapsulation:</u> 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

Encaps Information Field

bits	0-3	4-7	8-9	10-15	16-31
	Reserved	Flags	FRG	Length	Sequence Number

FRG: Fragmentation

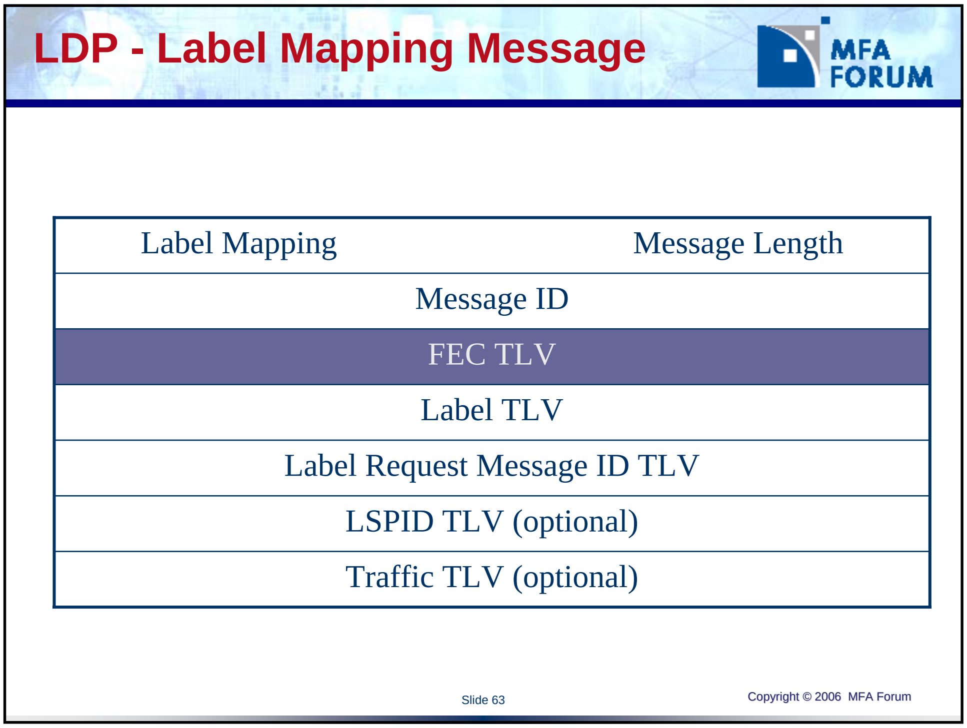
Generic Control Word

- 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.

bits	0-3	4-7	8-15	16-31
	Reserved	Version	Reserved	Channel Type

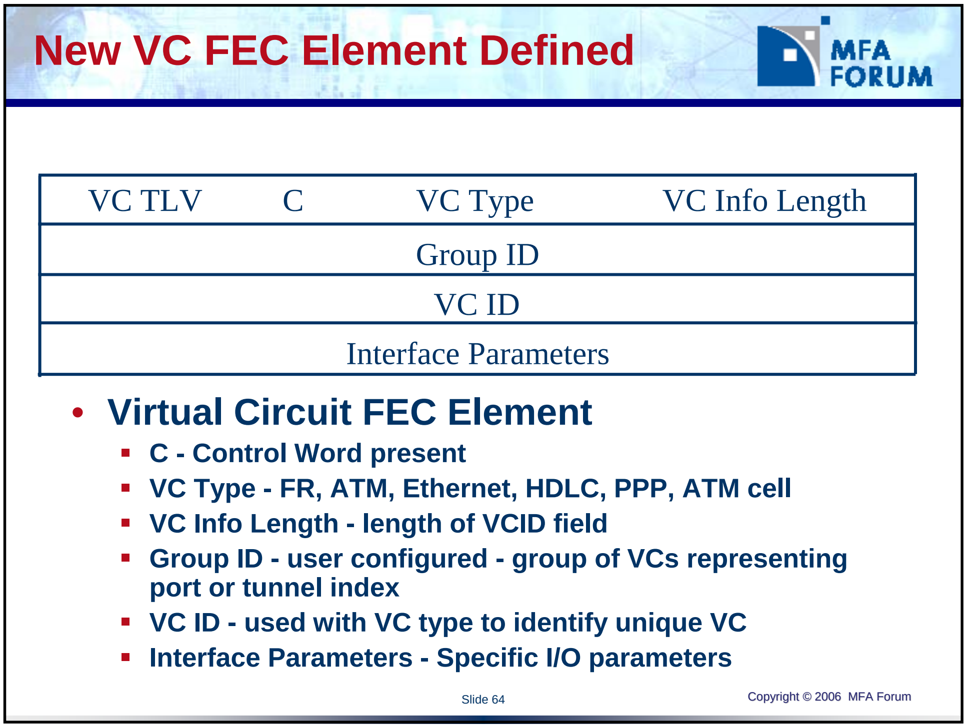
Control Word for PW Associated Channel

Draft-ietf-pwe3-cw-06.txt



LDP - Label Mapping Message

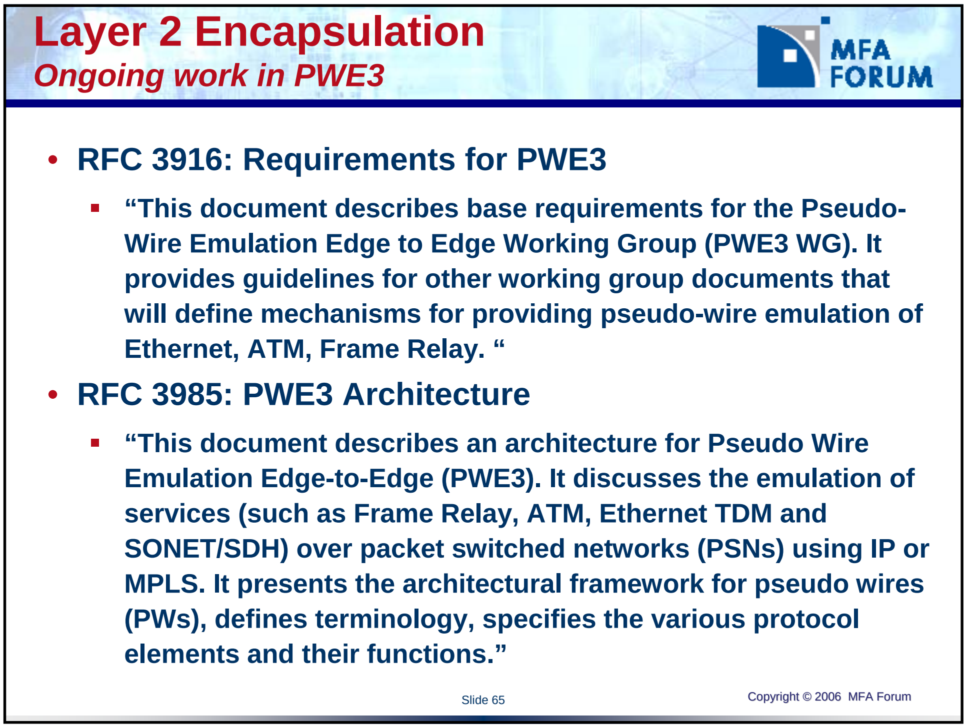
Label Mapping	Message Length
Message ID	
FEC TLV	
Label TLV	
Label Request Message ID TLV	
LSPID TLV (optional)	
Traffic TLV (optional)	



New VC FEC Element Defined

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

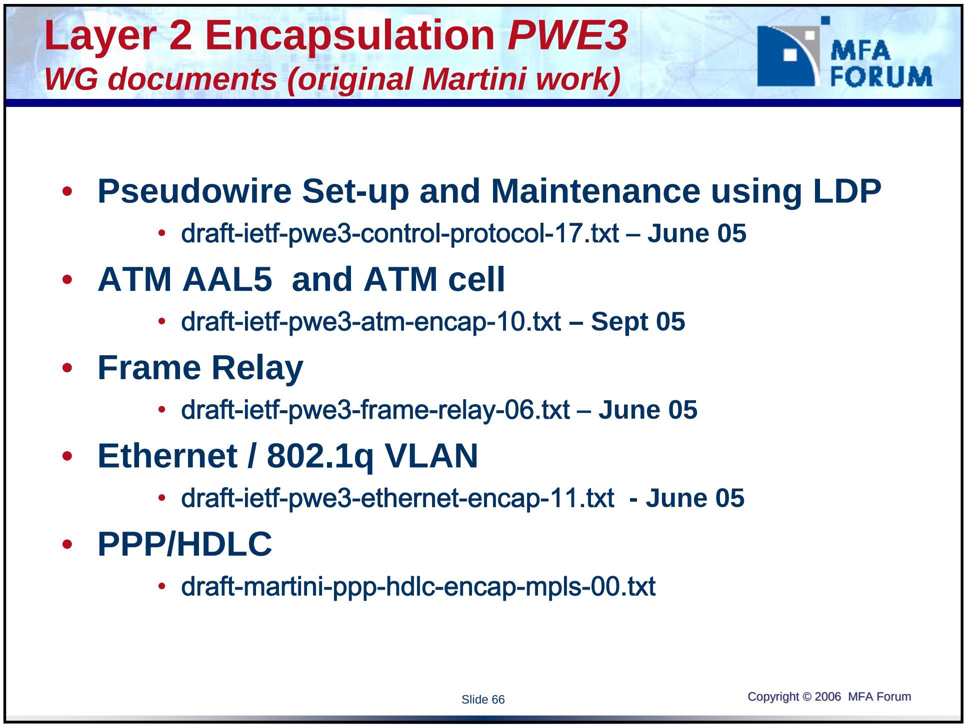
- **Virtual Circuit FEC Element**
  - **C - Control Word present**
  - **VC Type - FR, ATM, Ethernet, HDLC, PPP, ATM cell**
  - **VC Info Length - length of VCID field**
  - **Group ID - user configured - group of VCs representing port or tunnel index**
  - **VC ID - used with VC type to identify unique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



Layer 2 Encapsulation

Ongoing work in PWE3

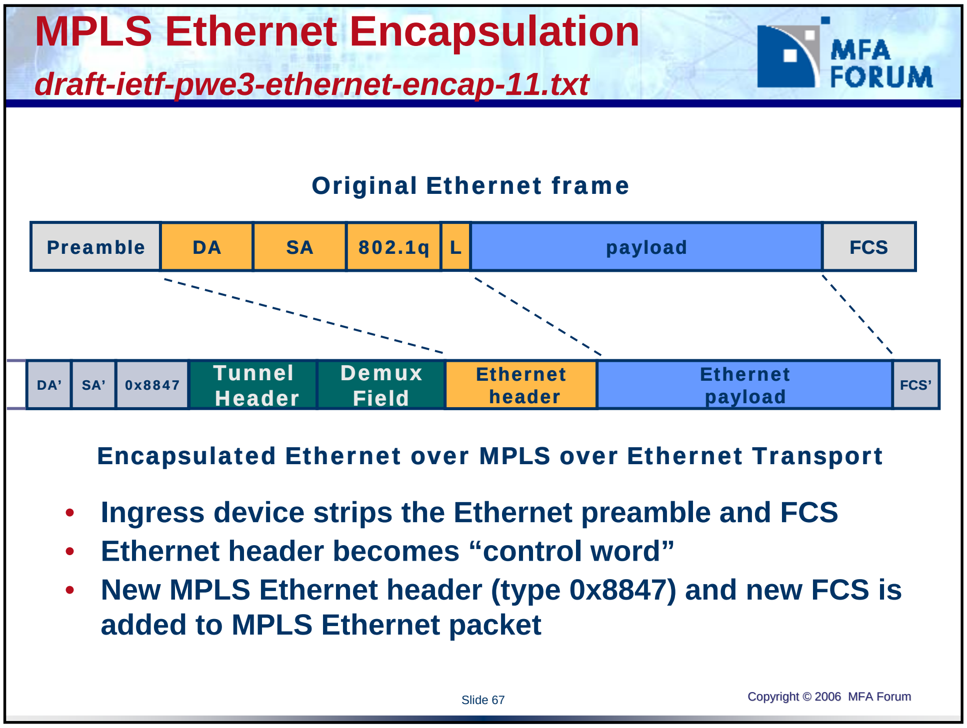
- **RFC 3916: Requirements for PWE3**
  - **"This document describes base requirements for the Pseudo-Wire Emulation Edge to Edge Working Group (PWE3 WG). It provides guidelines for other working group documents that will define mechanisms for providing pseudo-wire emulation of Ethernet, ATM, Frame Relay. "**
- **RFC 3985: PWE3 Architecture**
  - **"This document describes an architecture for Pseudo Wire Emulation Edge-to-Edge (PWE3). It discusses the emulation of services (such as Frame Relay, ATM, Ethernet TDM and SONET/SDH) over packet switched networks (PSNs) using IP or MPLS. It presents the architectural framework for pseudo wires (PWs), defines terminology, specifies the various protocol elements and their functions."**



Layer 2 Encapsulation *PWE3*

WG documents (original Martini work)

- **Pseudowire Set-up and Maintenance using LDP**
  - draft-ietf-pwe3-control-protocol-17.txt – **June 05**
- **ATM AAL5 and ATM cell**
  - draft-ietf-pwe3-atm-encap-10.txt **– Sept 05**
- **Frame Relay**
  - draft-ietf-pwe3-frame-relay-06.txt – **June 05**
- **Ethernet / 802.1q VLAN**
  - draft-ietf-pwe3-ethernet-encap-11.txt **- June 05**
- **PPP/HDLC**
  - draft-martini-ppp-hdlc-encap-mpls-00.txt



MPLS Ethernet Encapsulation

draft-ietf-pwe3-ethernet-encap-11.txt

Original Ethernet frame

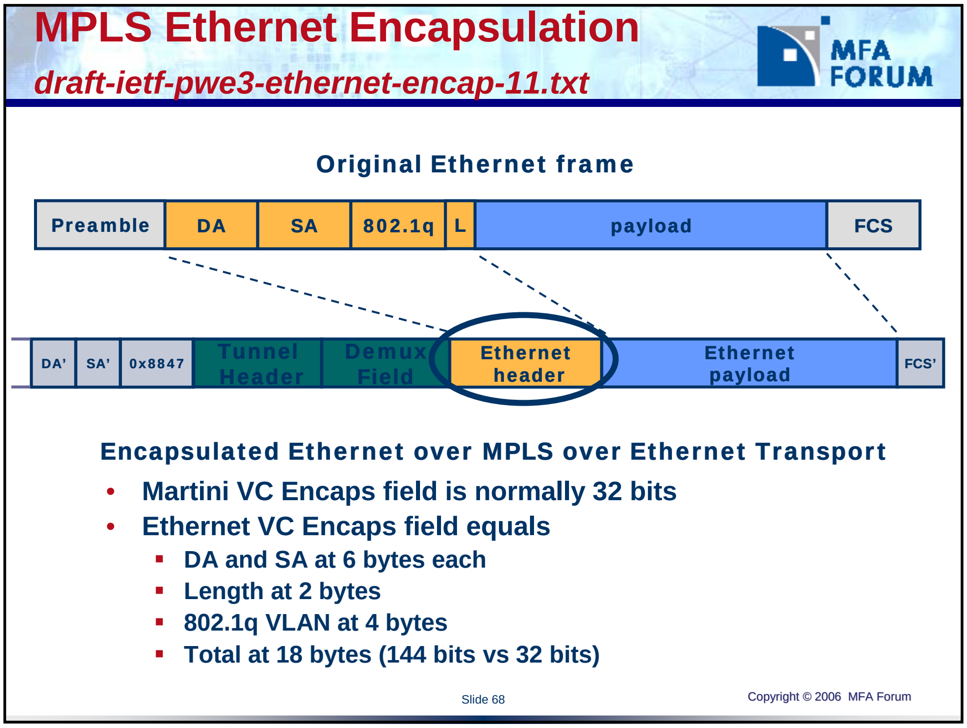
Preamble	DA	SA	802.1q	L	payload	FCS

DA'	SA'	0x8847	Tunnel Header	Demux Field	Ethernet header	Ethernet payload	FCS'

Encapsulated Ethernet over MPLS over Ethernet Transport

- 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

Slide 67



MPLS Ethernet Encapsulation

draft-ietf-pwe3-ethernet-encap-11.txt

Original Ethernet frame

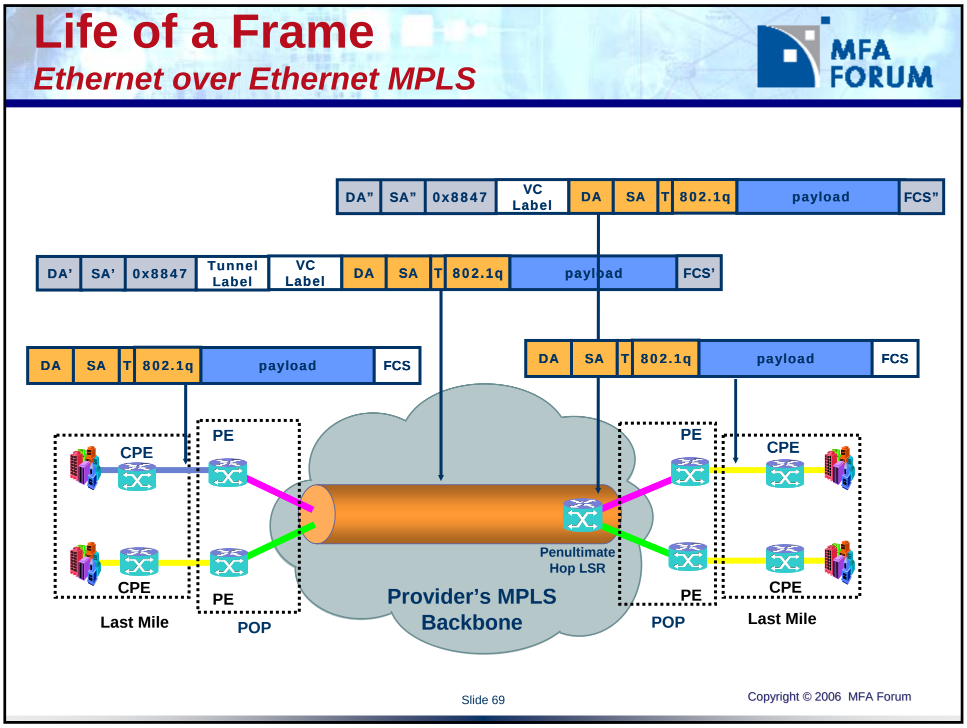
Preamble	DA	SA	802.1q	L	payload	FCS

DA'	SA'	0x8847	Tunnel Header	Demux Field	Ethernet header	Ethernet payload	FCS'

Encapsulated Ethernet over MPLS over Ethernet Transport

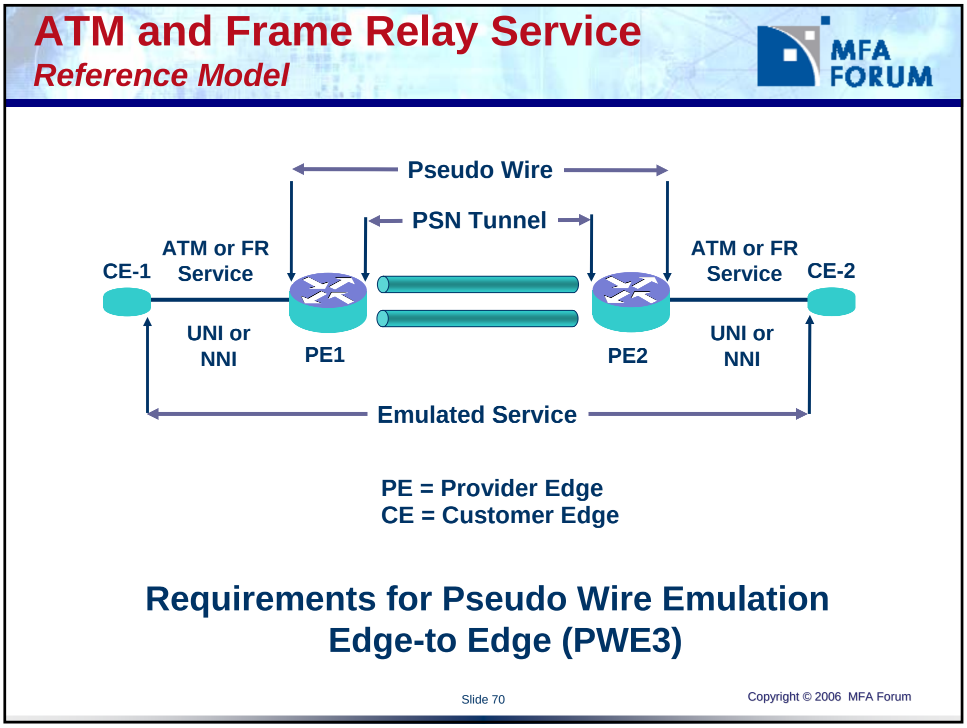
- Martini VC Encaps field is normally 32 bits
- Ethernet VC Encaps field equals
    - DA and SA at 6 bytes each
    - Length at 2 bytes
    - 802.1q VLAN at 4 bytes
    - Total at 18 bytes (144 bits vs 32 bits)

Slide 68



Life of a Frame

Ethernet over Ethernet MPLS



ATM and Frame Relay Service

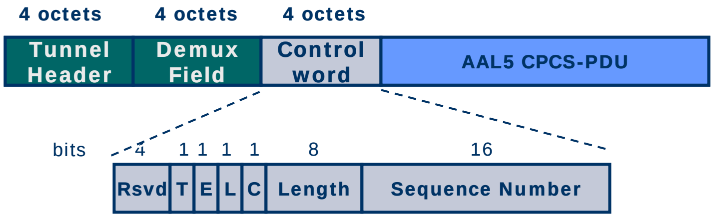
Reference Model

PE = Provider Edge
CE = Customer Edge

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

ATM AAL5 Encapsulation

draft-ietf-pwe3-atm-encap-10.txt



4 octets	4 octets	4 octets	
Tunnel Header	Demux Field	Control word	AAL5 CPCS-PDU

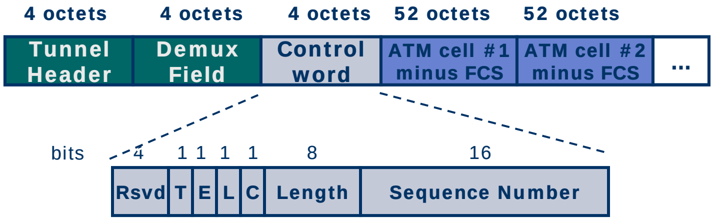
bits	4	1	1	1	1	8	16
	Rsvd	T	E	L	C	Length	Sequence Number

ATM Control Word

- 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-ietf-pwe3-atm-encap-10.txt



4 octets	4 octets	4 octets	52 octets	52 octets	
Tunnel Header	Demux Field	Control word	ATM cell #1 minus FCS	ATM cell #2 minus FCS	...

bits	4	1	1	1	1	8	16
	Rsvd	T	E	L	C	Length	Sequence Number

ATM Control Word

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

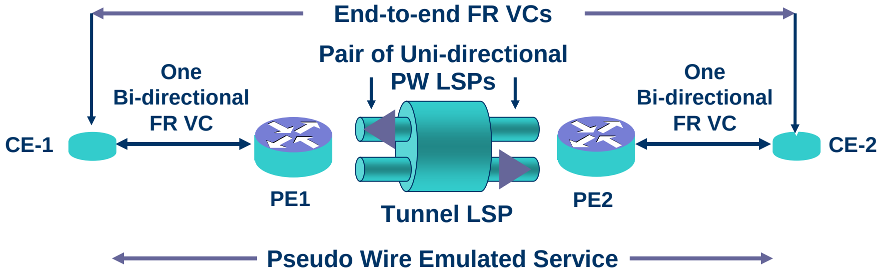
MPLS PWE3 FR Encapsulation

draft-ietf-pwe3-frame-relay-06.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-ietf-pwe3-frame-relay-06.txt



End-to-end FR VCs

Pair of Uni-directional PW LSPs

One Bi-directional FR VC

One Bi-directional FR VC

CE-1

CE-2

PE1

PE2

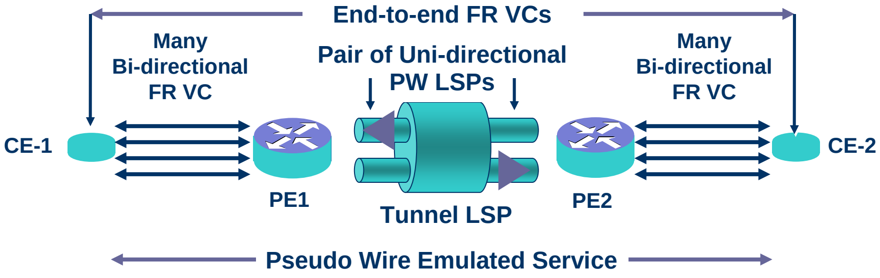
Tunnel LSP

Pseudo Wire Emulated Service

- 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-ietf-pwe3-frame-relay-06.txt



End-to-end FR VCs

Many Bi-directional FR VC

Pair of Uni-directional PW LSPs

Many Bi-directional FR VC

CE-1

PE1

Tunnel LSP

PE2

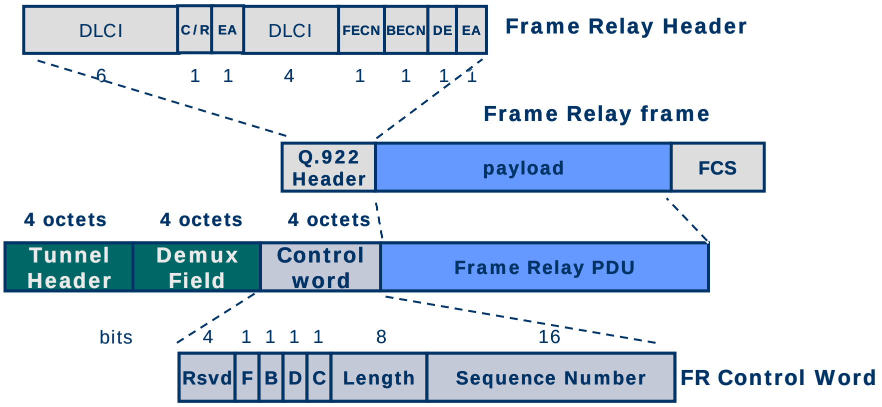
CE-2

Pseudo Wire Emulated Service

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

MPLS Frame Relay Encapsulation

draft-ietf-pwe3-frame-relay-06.txt



Frame Relay Header

DLCI	C / R	EA	DLCI	FECN	BECN	DE	EA
6	1	1	4	1	1	1	1

Frame Relay frame

Q.922 Header	payload	FCS

Tunnel Header	Demux Field	Control word	Frame Relay PDU
4 octets	4 octets	4 octets	

FR Control Word

	Rsvd	F	B	D	C	Length	Sequence Number
bits	4	1	1	1	1	8	16

- 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 VPNs

- IETF PWE3 and L2VPN WG update
- Encapsulation and Label Stacking
- Virtual Private Wire Services – VPWS
  - Pt-to-pt Ethernet, Pt-to-pt ATM, Pt-to-pt Frame Relay
- Virtual Private LAN Services – VPLS

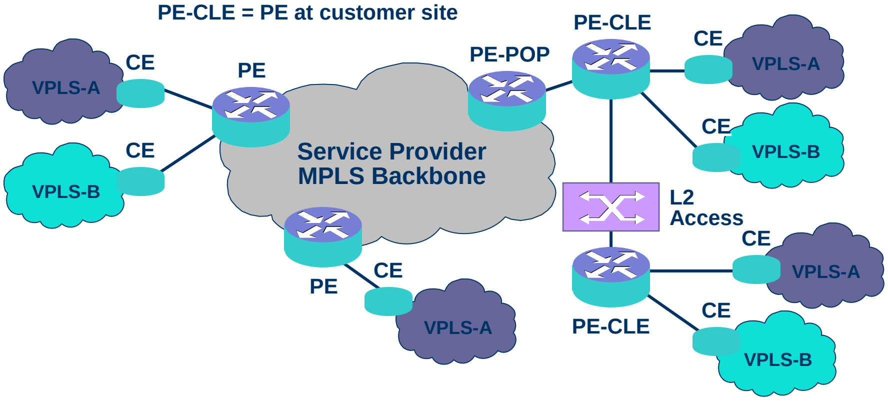
IETF Layer 2 VPNs

- draft-ietf-l2vpn-requirements-01.txt – Nov 05
  - Provides requirements for Layer 2 Provider Provisioned Virtual Private Networks (L2VPNs) Provides taxonomy and terminology and states generic and general services requirements. It covers point-to-point VPNs referred to as Virtual Provate Wire Services (VPWS), as well as multipoint-to-multipoint VPNs as known as Virtual Private LAN services (VPLS)
  - This document provides a framework for Layer 2 Provider Provisioned Virtual Private Networks (L2VPNs). This framework is intended to aid in standardizing protocols and mechanisms to support interoperable L2VPNs.

MPLS VPLS

Architecture

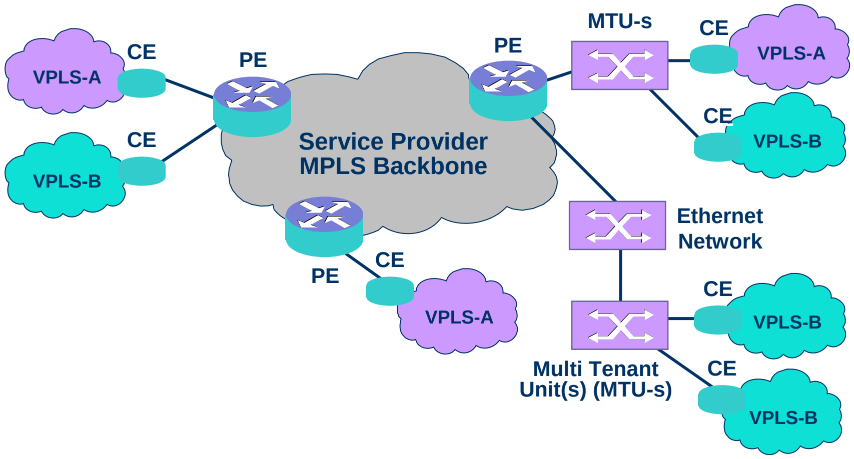
Distributed PE functions
PE-POP = PE at SP POP
PE-CLE = PE at customer site



Slide 79

MPLS VPLS

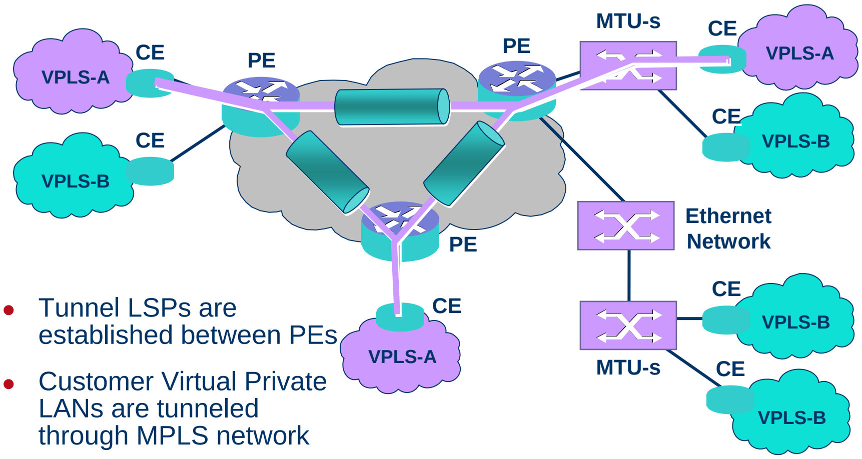
VPLS Reference Model



Slide 80

MPLS VPLS

VPLS Reference Model



- Tunnel LSPs are established between PEs
- Customer Virtual Private LANs are tunneled through MPLS network

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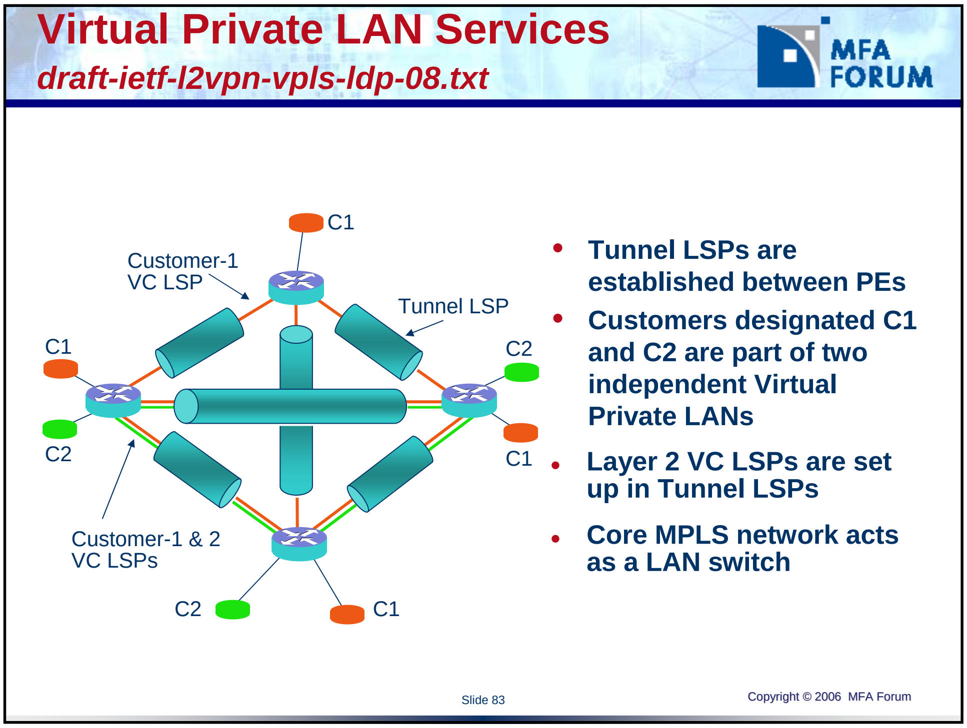
Virtual Private LAN Services

draft-ietf-l2vpn-vpls-ldp-08.txt

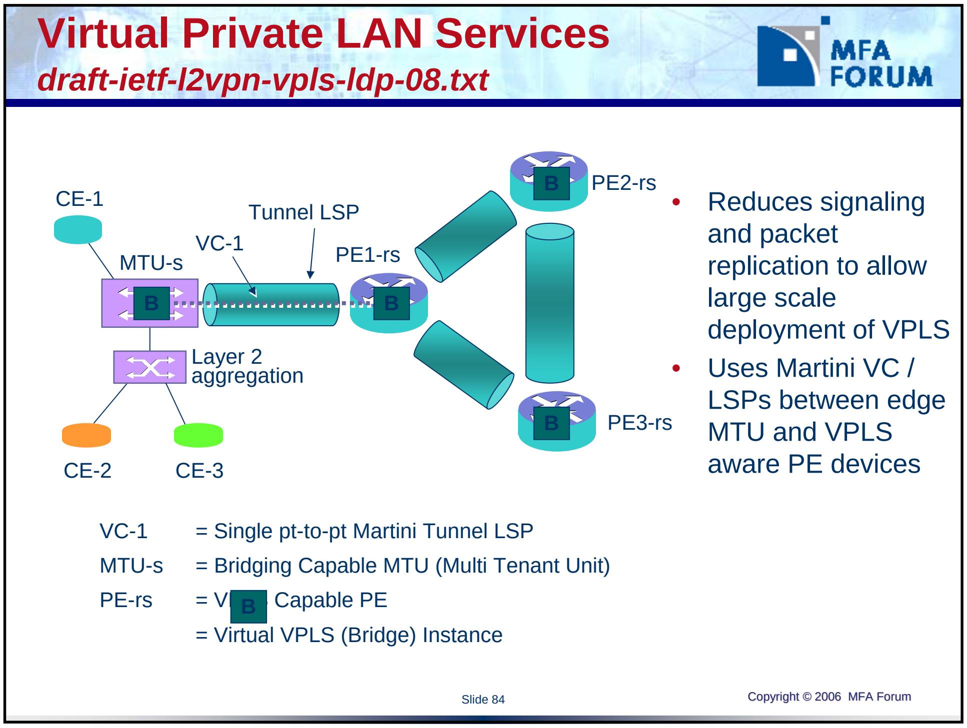
- **Updated November 2005**
- **Defines an Ethernet (IEEE 802.1D) learning bridge model over MPLS Martini Ethernet circuits**
- **Defines the LER (PE) function for an MPLS VPLS network**
- **Creates a layer 2 broadcast domain for a closed group of users**
- **MAC address learning and aging on a per LSP basis**
- **Packet replication across LSPs for multicast, broadcast, and unknown unicast traffic**
- Includes Hierarchical VPLS
  - formerly draft-khandekar-ppvpn-hvpls-mpls-00.txt



Virtual Private LAN Services

draft-ietf-l2vpn-vpls-ldp-08.txt

- **Tunnel LSPs are established between PEs**
- **Customers 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**



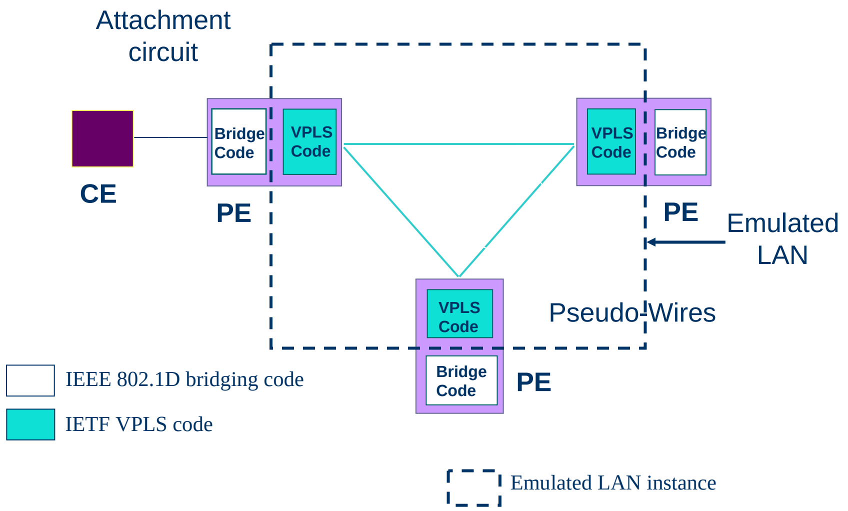
Virtual Private LAN Services

draft-ietf-l2vpn-vpls-ldp-08.txt

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

VC-1 = Single pt-to-pt Martini Tunnel LSP
MTU-s = Bridging Capable MTU (Multi Tenant Unit)
PE-rs = V B Capable PE
= Virtual VPLS (Bridge) Instance

VPLS Internal PE Architecture



Attachment circuit

CE

PE

Bridge Code

VPLS Code

Emulated LAN

Pseudo-Wires

☐ IEEE 802.1D bridging code

🟦 IETF VPLS code

Emulated LAN instance

VPLS Code

- **VPLS Forwarding**
  - **Learns MAC addresses per pseudo-wire (VC LSP)**
  - **Forwarding based on MAC addresses**
  - **Replicates multicast & broadcast frames**
  - **Floods unknown frames**
  - **Split-horizon for loop prevention**
- **VPLS Signaling**
  - **Establishes pseudo-wires per VPLS between relevant PEs**
- **VPLS Discovery (Manual, LDP, BGP, DNS)**

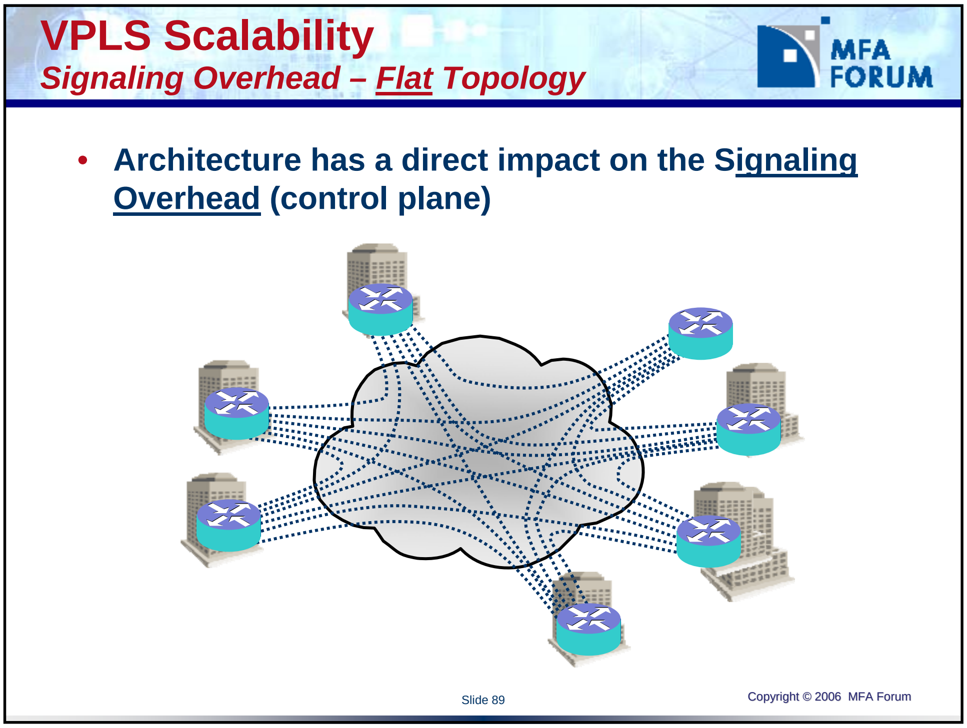
Bridging Code

- Standard IEEE 802.1D code
  - Used to interface with customer facing ports
  - Might run STP with CEs
  - Used to interface with VPLS
  - Might run STP between PEs

VPLS Scalability

Parameters

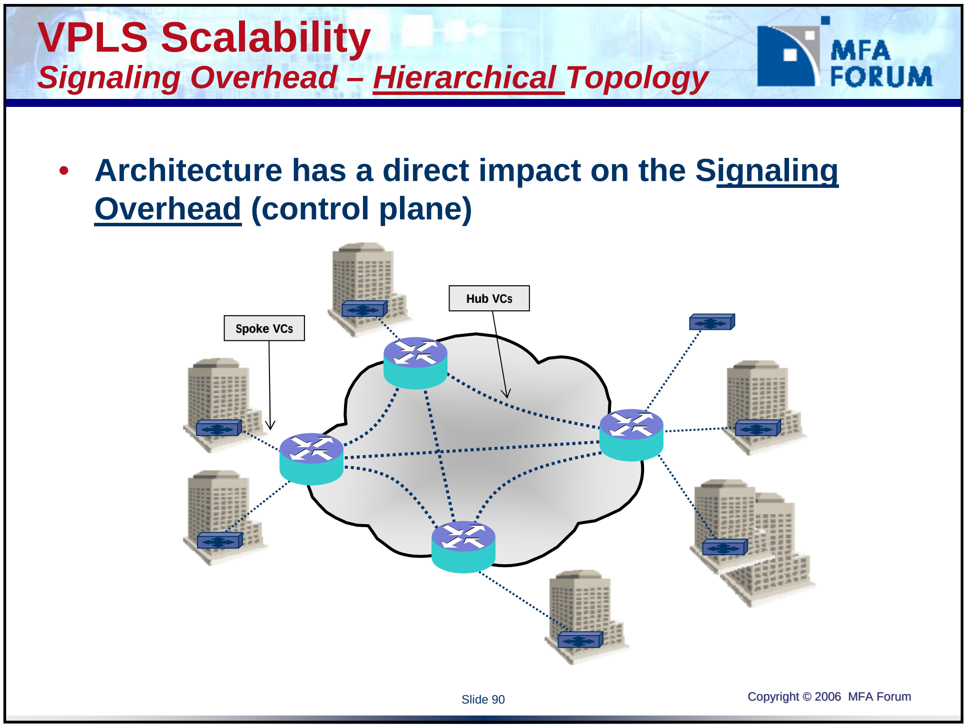
- Number of MAC Addresses
- Number of replications
- Number of LSPs
- Number of VPLS instances
- Number of LDP peers
- Number of PEs



VPLS Scalability

Signaling Overhead – Flat Topology

- **Architecture has a direct impact on the Signaling Overhead (control plane)**



VPLS Scalability

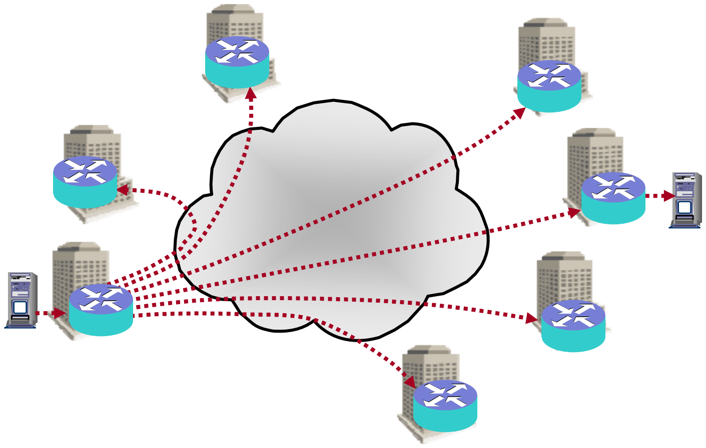
Signaling Overhead – Hierarchical Topology

- **Architecture has a direct impact on the Signaling Overhead (control plane)**

VPLS Scalability

Replication Overhead – <u>Flat</u> Topology

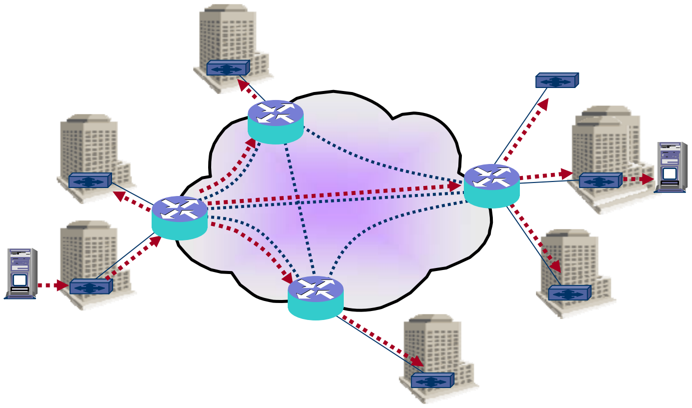
- **Architecture has a direct impact on <u>Replication Overhead</u> (forwarding plane)**

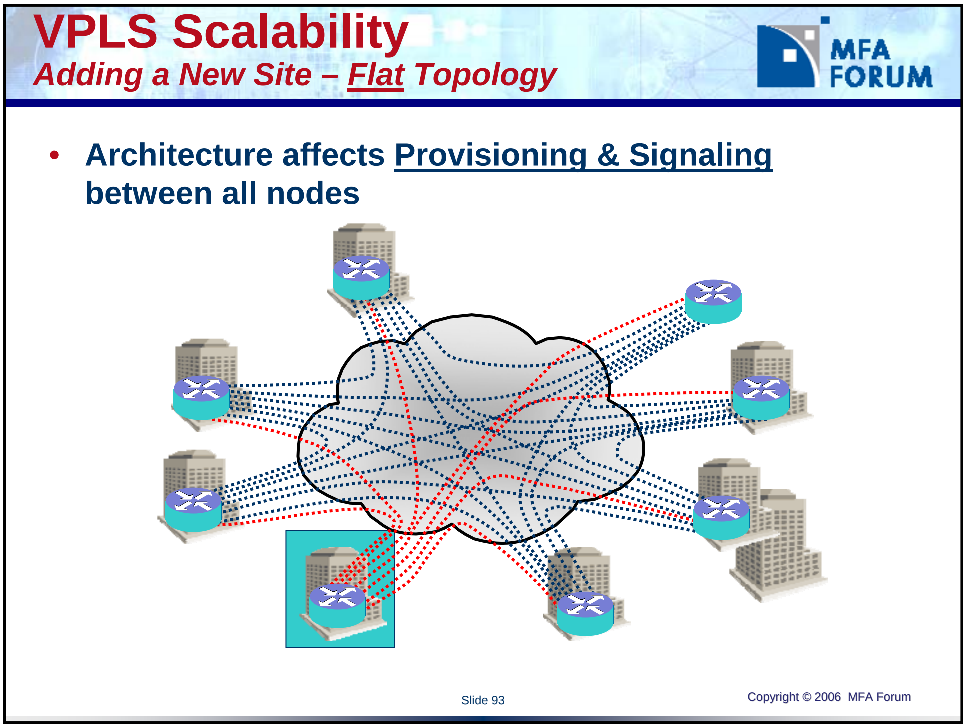


VPLS Scalability

Replication Overhead – <u>Hierarchical</u> Topology

- **Architecture has a direct impact on <u>Replication Overhead</u> (forwarding plane)**





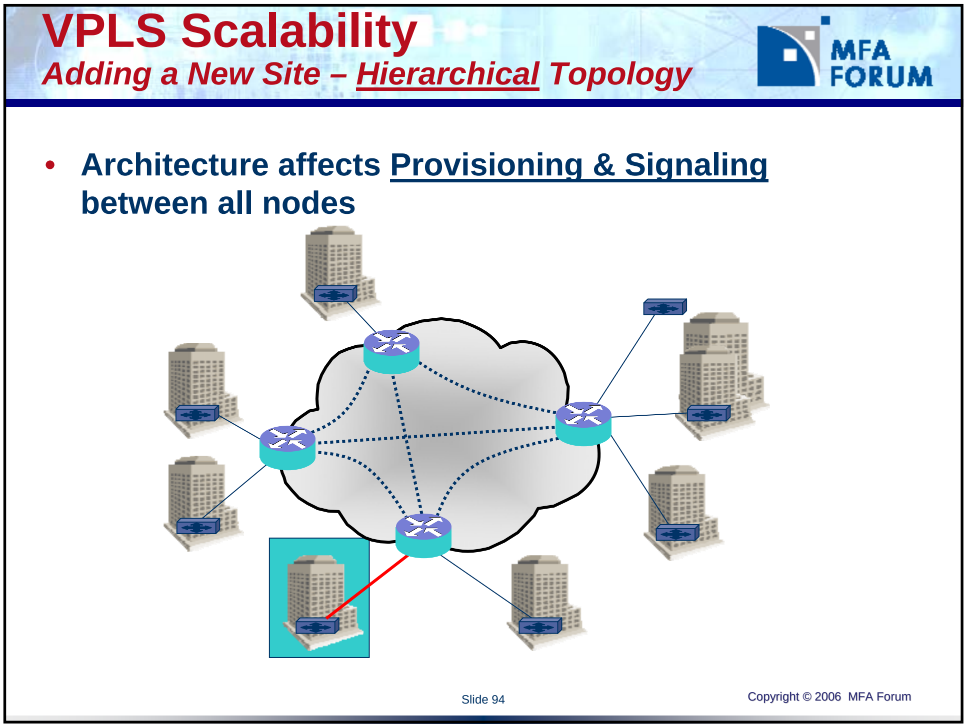
VPLS Scalability

Adding a New Site – <u>Flat</u> Topology

MFA FORUM

- Architecture affects <u>Provisioning & Signaling</u> between all nodes

Slide 93



VPLS Scalability

Adding a New Site – <u>Hierarchical</u> Topology

MFA FORUM

- Architecture affects <u>Provisioning & Signaling</u> between all nodes

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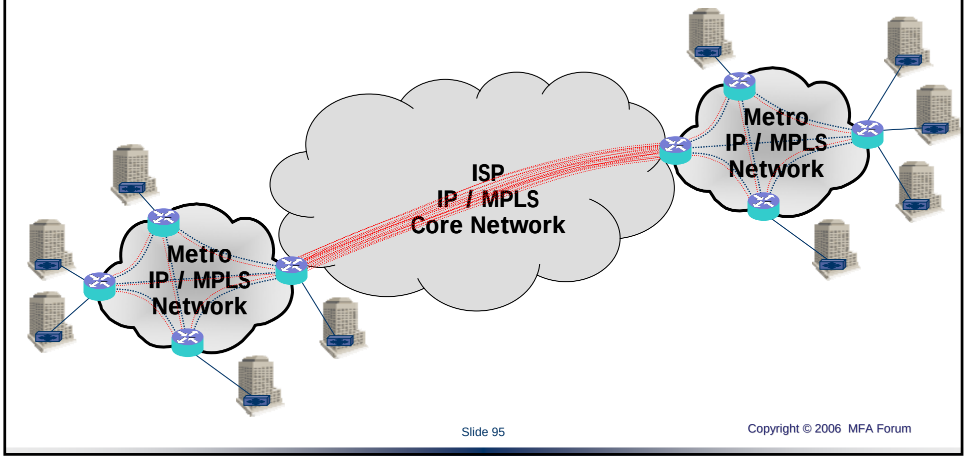
VPLS Scalability

Inter-Metro Service

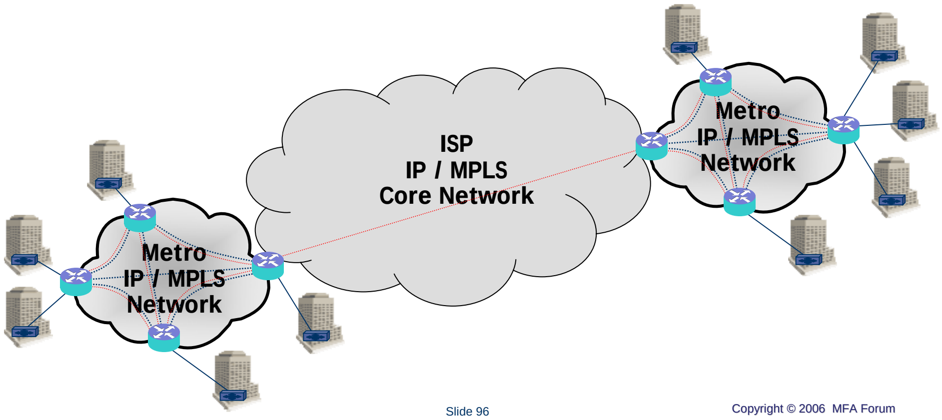
- **Architecture has a direct impact on <u>ability to offer Inter-Metro Service</u>**



VPLS Scalability

Inter-Metro Service

- **Architecture has a direct impact on <u>ability to offer Inter-Metro Service</u>**



VPLS Scalability

FIB Size

- VPLS FIB size depends on the type of Service Offering:
  - Multi-protocol Inter-connect service
    - Mimics the DSL Tariff Model
    - Customers are charged per site per block of MAC addresses
  - Router Inter-connect
    - One MAC address per site
- Same Network Design principles apply for
  - MAC FIB Size of VPLS Service and,
  - Route Table Size of Virtual Private Routed Network (VPRN) Service

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MPLS VPNs Summary

- Layer 2 versus Layer 3
  - Apples and Oranges
- Layer 3 MPLS VPNs
  - Deployed with Internet Draft 2547bis
- Layer 2 MPLS VPNs
  - Lots of Interest from Carriers and Vendors
  - Many new drafts – lots of consolidation
  - We are in “concept” stage
  - Solutions available

Section 4

Introduction to Multi-Service Interworking

Why Interwork?

- Carriers want a common edge infrastructure to support and “Interwork” with legacy and new services
- Carriers want to support all legacy transports technologies and services
- Carriers are planning to converge on an IP / MPLS core
- Carriers want to seamlessly introduce Metro Ethernet services and IP VPNs

Interworking

History

- The Frame Relay Forum defined the Network Interworking function between Frame Relay and ATM in the FRF.5 document finalized in1994.
- The Frame Relay Forum defined the Service interworking function between Frame Relay and ATM in the FRF.8.1 document finalized in 2000.
- Why define FR and ATM interworking?
  - ATM cores with FR access services deployed
  - ATM and Frame Relay circuits are point-to-point
  - Both data links have services that are somewhat similar in nature even though the signaling is different

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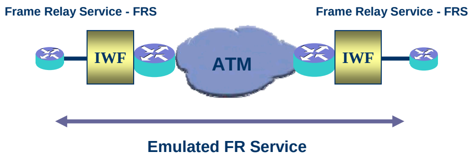
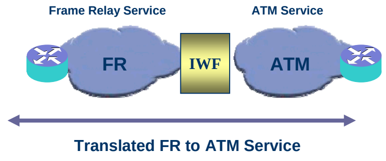
InterWorking Function - IWF

Network vs Service IWF

Network Interworking



Service Interworking

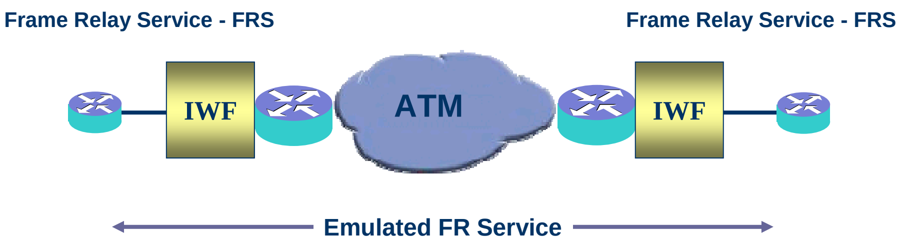


- Network Interworking is used when one protocol is "tunneled" across another "intermediary" network / protocol
- The Network Interworking function "terminates" and "encapsulates" the protocol over a Pt-to-Pt connection

- Service Interworking is required to "translate" one protocol to another protocol – used between two unlike protocols
- The Service Interworking function "translates" the control protocol information transparently by an interworking function (IWF)

Network Interworking FRF.5

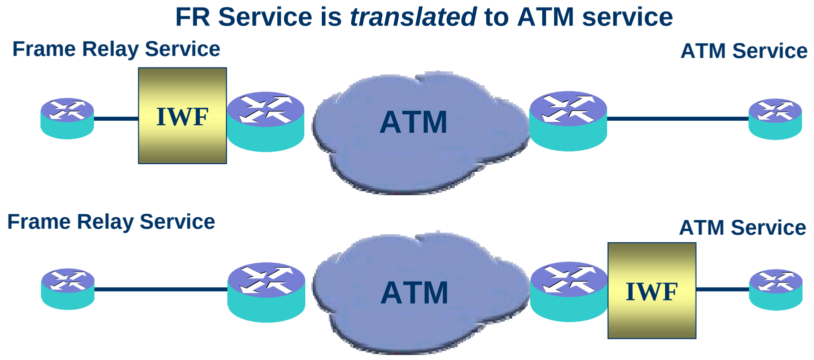
Reference Model



- ***Network*** Interworking ***encapsulates*** the L2 Service
- FRS is ***encapsulated*** and sent across ATM network
- Service at end points ***has to be*** the same

Service Interworking FRF.8.1

Reference Model



- ***Service*** Interworking ***translates*** the L2 Service
- FR service is ***translated*** into ATM service
- Services at the end points ***are not*** the same

Why not continue with ATM IW?

- ATM is optimized for voice transport – cell overhead etc
- Cells are simply fixed length packets and can be carried unchanged across an MPLS network
- Packets are not cells and must be adapted to be carried across ATM
- MPLS is optimized for packet transport
- Carriers want to converge on IP/MPLS cores supporting both new and legacy services

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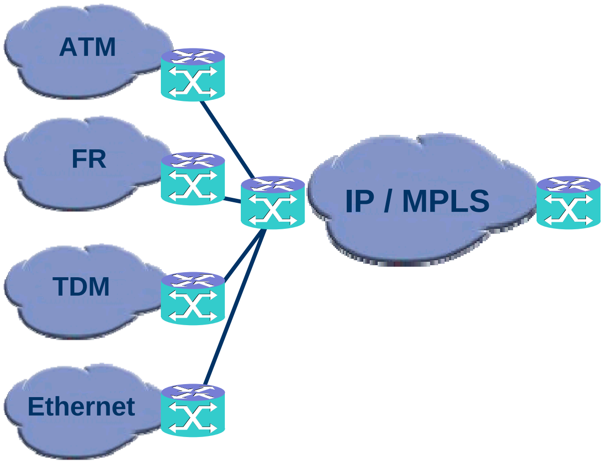
Why Migrate to MPLS?

- MPLS allows service providers to converge onto a single infrastructure while offering existing services
- MPLS enables new service offerings and simplifies service provisioning
- MPLS supports rapid growth in IP applications and services
- MPLS allows the integration of services management into a common OSS strategy
- MPLS supports the integration of packet technologies and optical cores

MPLS Multi-Service Interworking

MPLS Connects Services at the Edge



ATM

FR

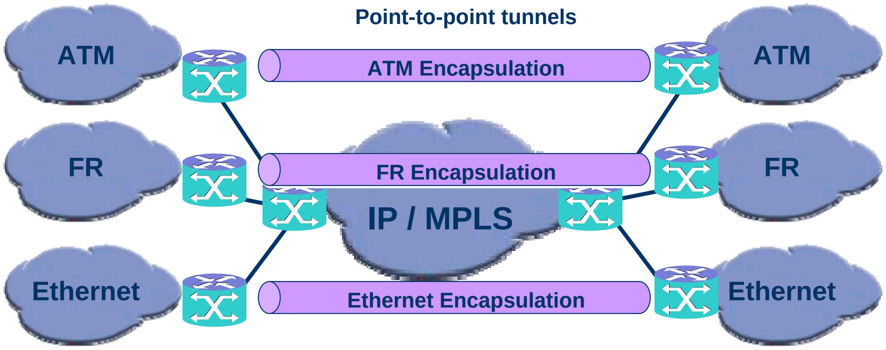
TDM

Ethernet

IP / MPLS

MPLS Network Interworking

IETF PWE3 Pt-to-Pt Encapsulation



Point-to-point tunnels

ATM

ATM Encapsulation

ATM

FR

FR Encapsulation

FR

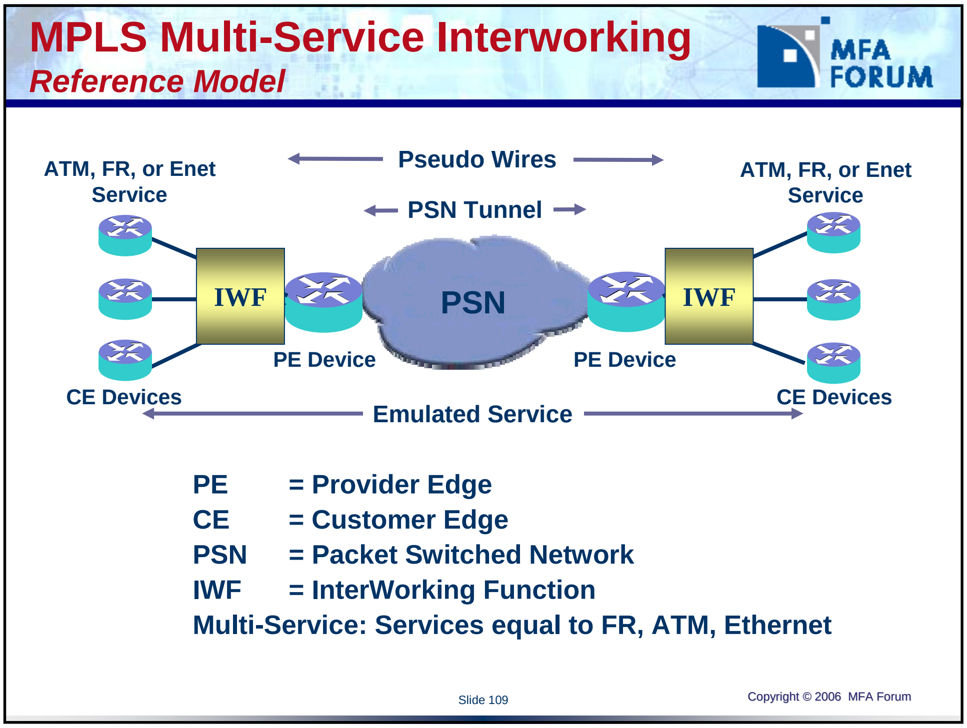
IP / MPLS

Ethernet

Ethernet Encapsulation

Ethernet

Service has to be pt-to-pt between like services: ATM to ATM, FR to FR, Enet to Enet, etc



MPLS Multi-Service Interworking

Reference Model

MFA FORUM

ATM, FR, or Enet Service

Pseudo Wires

PSN Tunnel

ATM, FR, or Enet Service

IWF

PSN

IWF

PE Device

PE Device

CE Devices

Emulated Service

CE Devices

PE = Provider Edge

CE = Customer Edge

PSN = Packet Switched Network

IWF = InterWorking Function

Multi-Service: Services equal to FR, ATM, Ethernet

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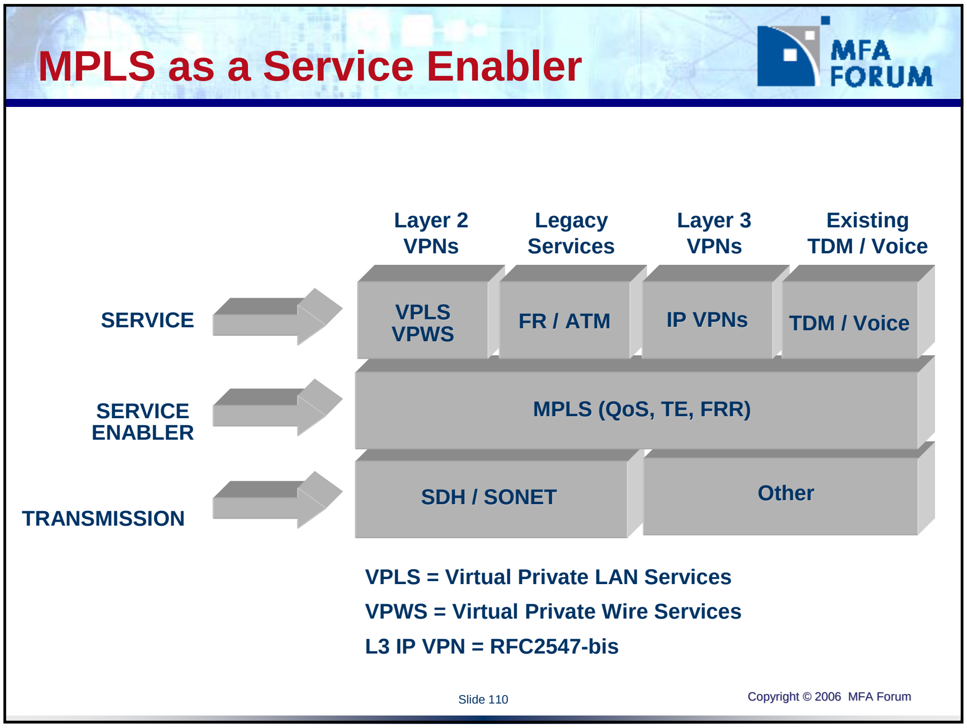

MPLS as a Service Enabler

MFA FORUM

Layer 2 VPNs

Legacy Services

Layer 3 VPNs

Existing TDM / Voice

SERVICE

VPLS VPWS

FR / ATM

IP VPNs

TDM / Voice

SERVICE ENABLER

MPLS (QoS, TE, FRR)

TRANSMISSION

SDH / SONET

Other

VPLS = Virtual Private LAN Services

VPWS = Virtual Private Wire Services

L3 IP VPN = RFC2547-bis

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For More Information. . .

- http://www.mfaforum.org
- http://www.ietf.org
- http://www.itu.int
- http://www.mplsrc.com

For questions, utilize the MFA Forum Message Board

Website: http://www.mfaforum.org/board/

Thank you **for attending the**

MPLS based
Virtual Private Network Services
Tutorial