Apricot MPLS workshop 2015

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Introduction to MPLS

ssion Goals

ctives

- derstand history and business drivers for MPLS
- arn about MPLS customer and market segments
- derstand the problems MPLS is addressing
- derstand the major MPLS technology components
- derstand typical MPLS applications
- derstand benefits of deploying MPLS
- arn about MPLS futures; where MPLS is going

enda

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roduction

PLS Technology Basics

PLS Layer-3 VPNs

PLS Layer-2 VPNs

lvanced Topics

ımmary

oduction

at is MPLS ?

Summary

- s all about labels …
- e the best of both worlds
  - ayer-2 (ATM/FR): efficient forwarding and traffic engineering
  - ayer-3 (IP): flexible and scalable
- PLS forwarding plane
  - Jse of labels for forwarding Layer-2/3 data traffic
  - abeled packets are being switched instead of routed
    - Leverage layer-2 forwarding efficiency
- PLS control/signaling plane
  - Jse of existing IP control protocols extensions + new protocols to exchange label information
    - Leverage layer-3 control protocol flexibility and scalability

chnology Comparison

Characteristics of IP, Native Ethernet, and MPLS

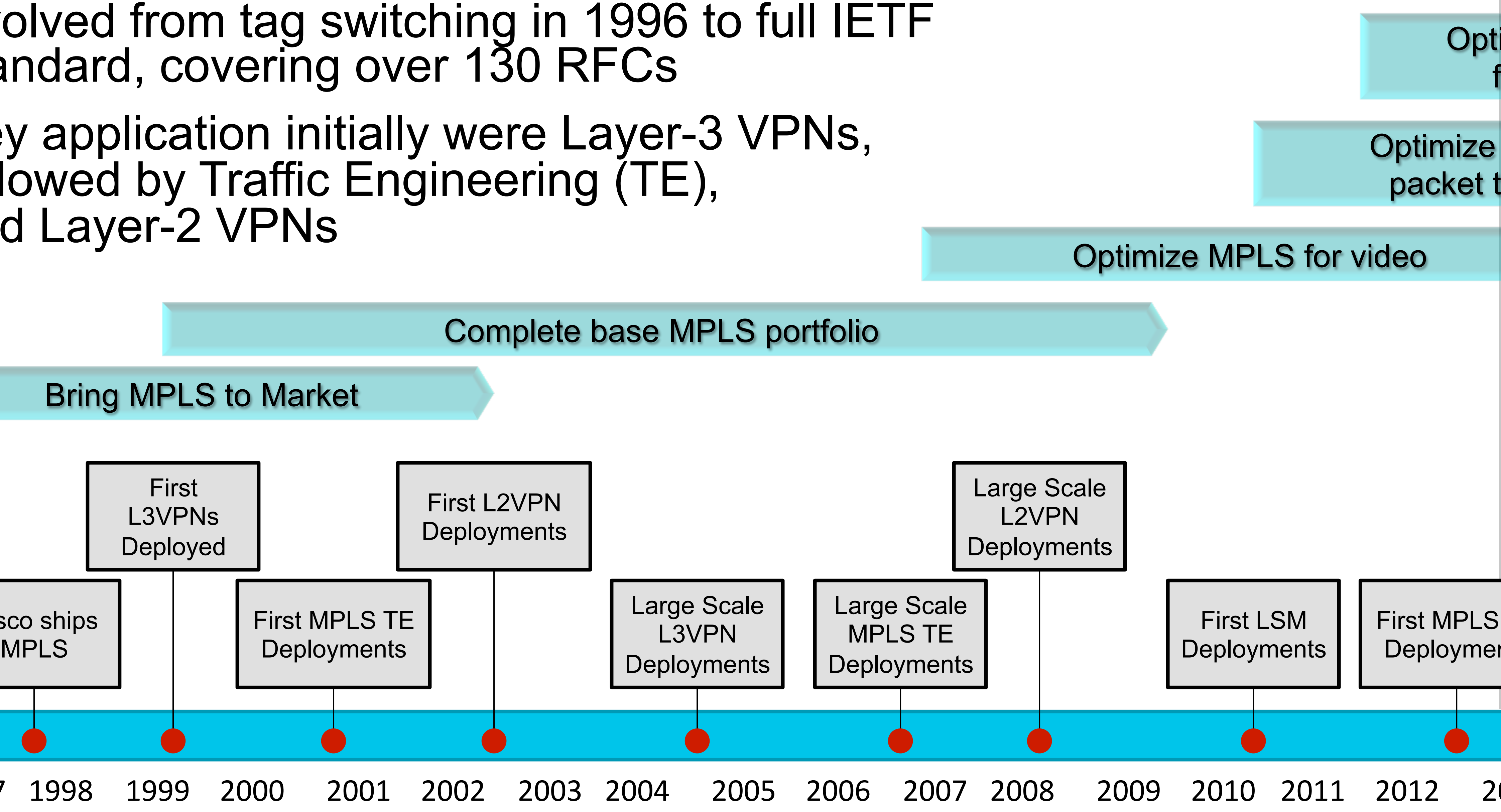
	IP	Native Ethernet	
warding	Destination address based Forwarding table learned from control plane TTL support	Destination address based Forwarding table learned from data plane No TTL support	La Forwarding con TT
trol Plane	Routing Protocols	Ethernet Loop avoidance and signaling protocols	Routi MPL
ket Encapsulation	IP Header	802.3 Header	MPLS
	8 bit TOS field in IP header	3-bit 802.1p field in VLAN tag	3 bit T
	IP ping, traceroute	E-OAM	MP

olution of MPLS

nology Evolution and Main Growth Areas

Today

- olved from tag switching in 1996 to full IETF andard, covering over 130 RFCs
- y application initially were Layer-3 VPNs, lowed by Traffic Engineering (TE), d Layer-2 VPNs



Opti
f

Optimize
packet t

Optimize MPLS for video

Complete base MPLS portfolio

Bring MPLS to Market

sco ships
MPLS

First
L3VPNs
Deployed

First MPLS TE
Deployments

First L2VPN
Deployments

Large Scale
L3VPN
Deployments

Large Scale
MPLS TE
Deployments

Large Scale
L2VPN
Deployments

First LSM
Deployments

First MPLS
Deployme

7 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 20

rket Segments

S Business Drivers and Typical Deployment Characteristics

	Business Drivers	Business Goals	MPL
ervice Provider	• Networking service reliability • Cost effective service bandwidth • Flexible enablement of existing and new services	• Leverage single network for scalable delivery of multiple services • Optimize network capacity to meet current and future growth of service bandwidth • Deliver premium services with guaranteed SLAs	L L MP
nterprise	• Mergers and acquisitions • Network consolidation • Shared services • Compliance	• Network Segmentation • Network integration	La
ata Center	• Multi-tenant hosting • Data Center Interconnect	• Leverage single data center infrastructure for multiple users and services • Deliver geographic independent services from any data center	L L

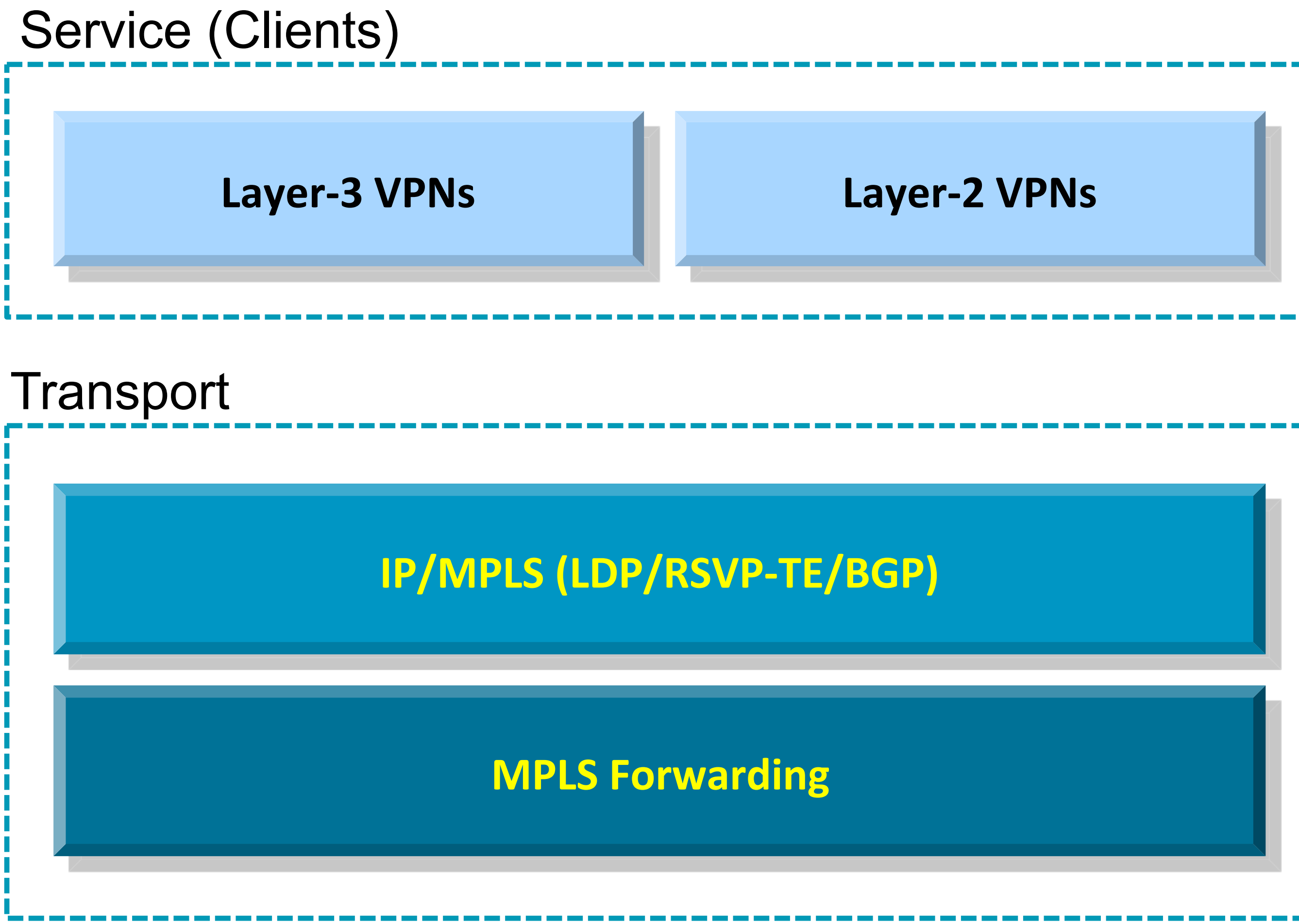
LS Technology Basics

ology Building Blocks of MPLS

pics

cs of MPLS Signaling and Forwarding

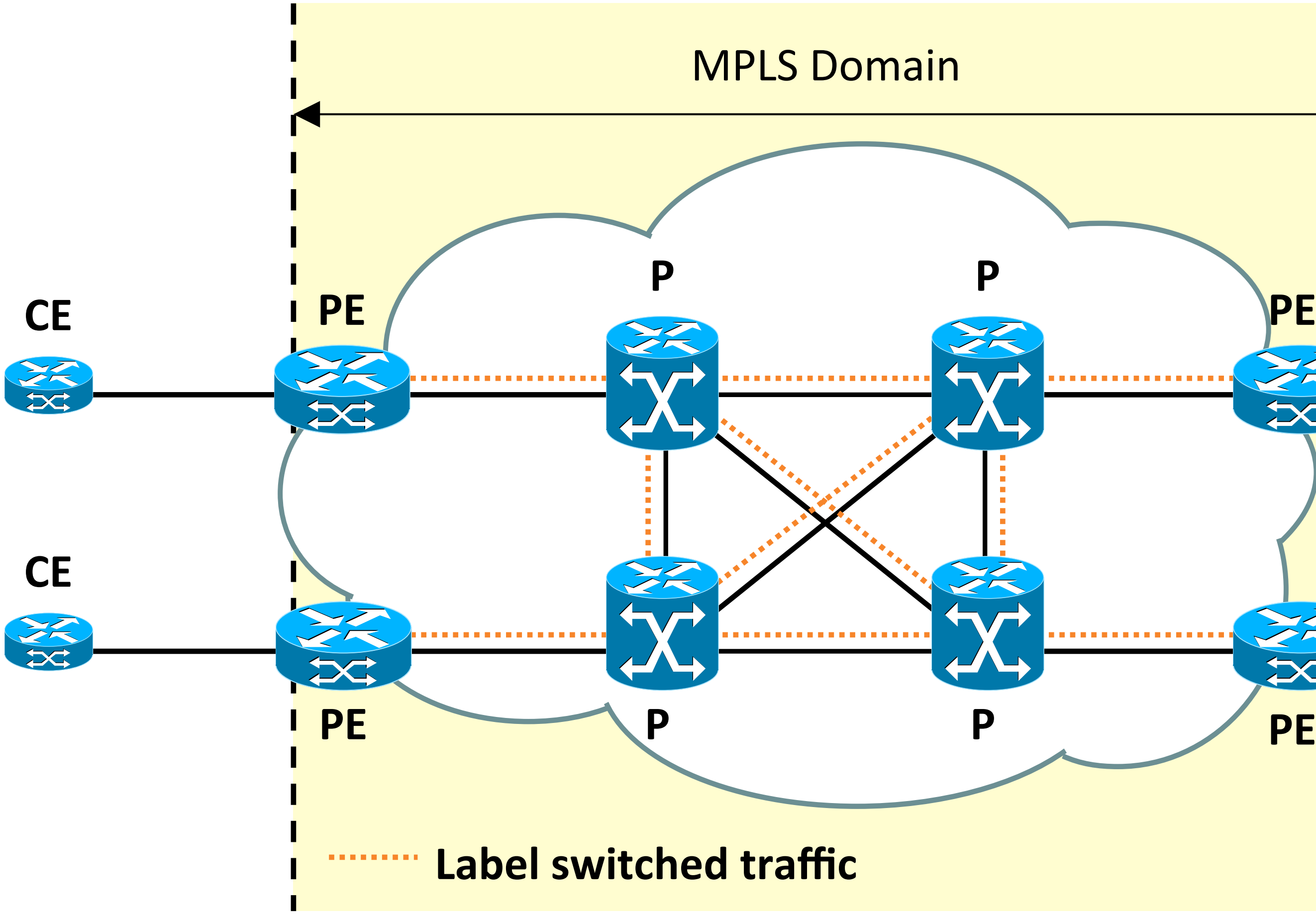
- PLS reference chitecture
- PLS Labels
- PLS signaling and warding operations
- PLS Traffic Engineering
- PLS OAM and MIBs



LS Reference Architecture

rent Type of Nodes in a MPLS Network

- Provider) router
  - Label switching router (LSR)
  - Switches MPLS-labeled packets
- (Provider Edge) router
  - Edge router (LER)
  - mposes and removes MPLS labels
- (Customer Edge) router
  - Connects customer network to MPLS network

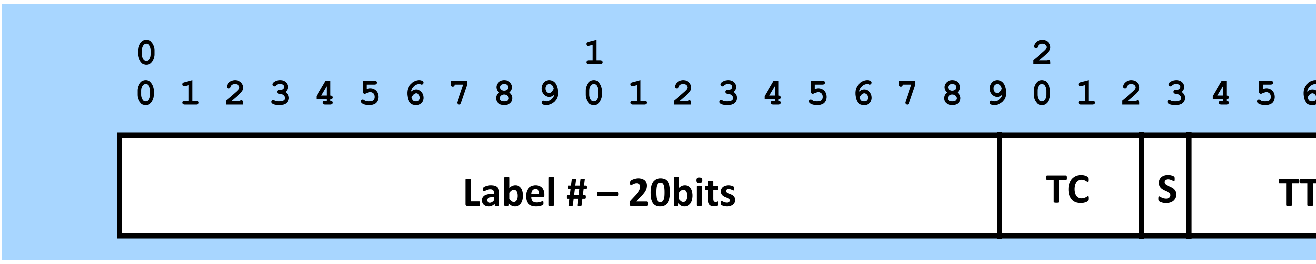


PLS Shim Labels

el Definition and Encapsulation

- bels used for making warding decision
- ltiple labels can be used MPLS packet capsulation
  - Creation of a label stack
- ter label always used for itching MPLS packets in twork
- maining inner labels used specific services g., VPNs)

MPLS Label



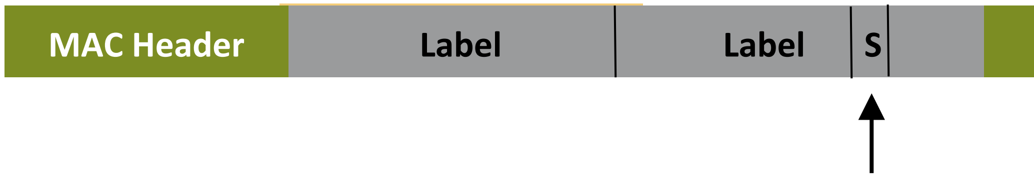
TC = Traffic Class: 3 Bits; S = Bottom of Stack; TTL = Time to Live

MPLS Label Encapsulation

LAN MAC Label Header

MPLS Label Stack

LAN MAC Label Header

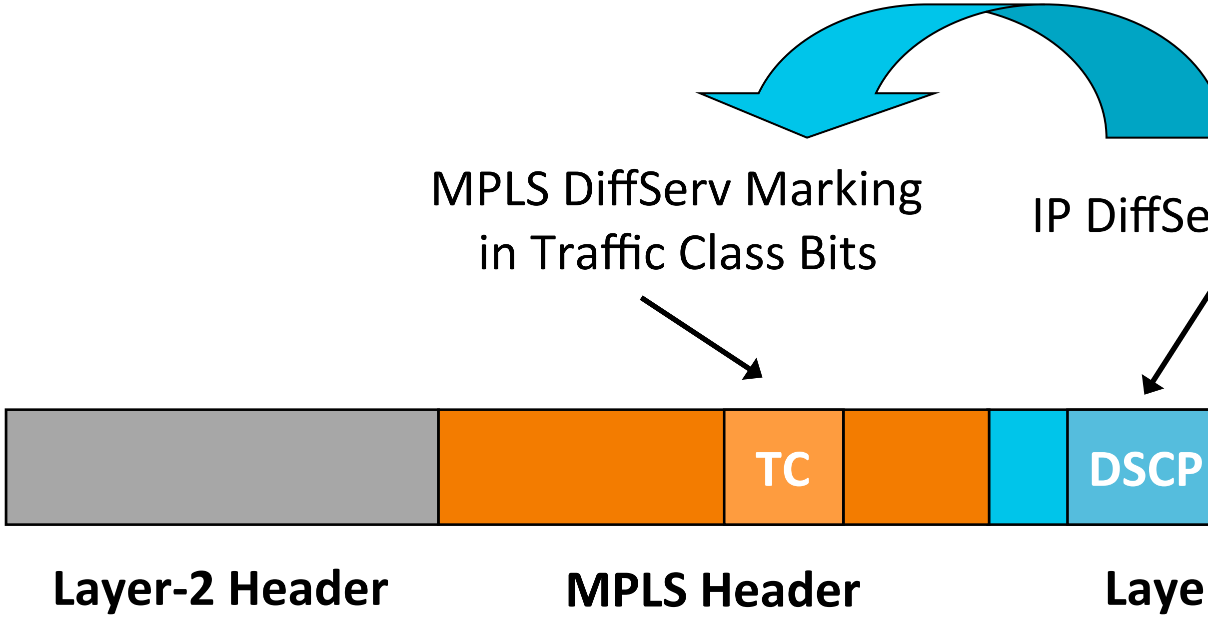


Bottom of Stack Bit S

LS QoS

Marking in MPLS Labels

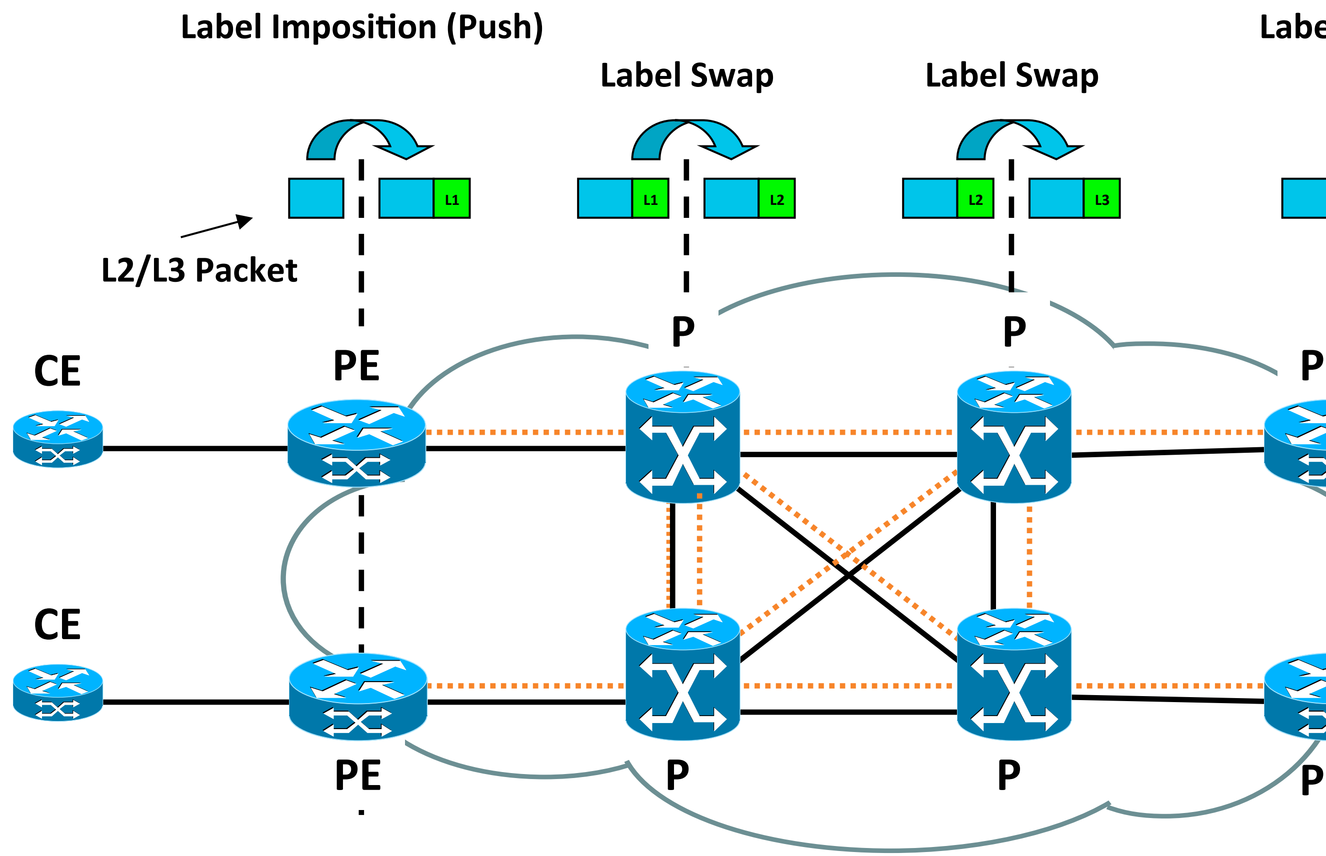
- LS label contains 3 TC bits
- ed for packet classification and oritization
  - Similar to Type of Service (ToS) field in IP packet (DSCP values)
- CP values of IP packet mapped TC bits of MPLS label
  - At ingress PE router
- st providers have defined 3–5 vice classes (TC values)
- ferent DSCP <-> TC mapping hemes possible
  - Uniform mode, pipe mode, and short pipe mode



sic MPLS Forwarding Operations

Labels Are Being Used to Establish End-to-end Connectivity

- bel imposition (PUSH)
  - By ingress PE router; classify and label packets
  - Based on Forwarding Equivalence Class (FEC)
- bel swapping or switching
  - By P router; forward packets using labels; indicates service class & destination
- bel disposition (POP)
  - By egress PE router; remove label and forward original packet to destination CE



LS Path (LSP) Setup and Traffic Forw

S Traffic Forwarding and MPLS Path (LSP) Setup

- P signaling
  - Either LDP* or RSVP
  - Leverages IP routing
  - Routing table (RIB)
- change of labels
  - Label bindings
  - Downstream MPLS node advertises what label to use to send traffic to node
- PLS forwarding
  - MPLS Forwarding table (FIB)

	IP	MP
Forwarding	Destination address based Forwarding table learned from control plane TTL support	Label Forwarding ta from cont TTL su
Control Plane	OSPF, IS-IS, BGP	OSPF, IS- LDP, F
Packet Encapsulation	IP Header	One or mo
QoS	8 bit TOS field in IP header	3 bit TC fie
OAM	IP ping, traceroute	MPLS

ling assumed for next the examples

PLS Path (LSP) Setup

aling Options

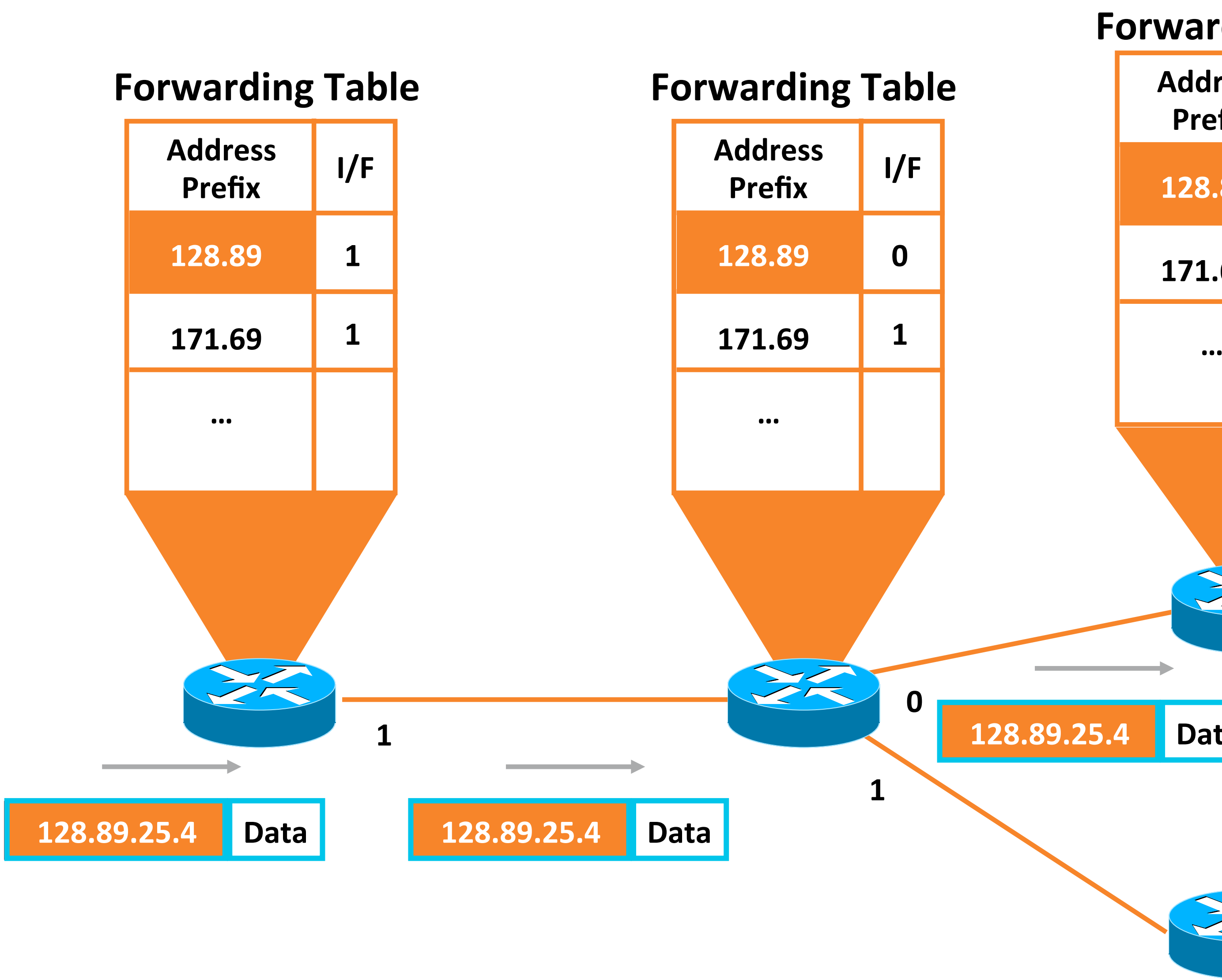
- P signaling
  - Leverages existing routing
- SVP signaling
  - Aka MPLS RSVP/TE
  - Enables enhanced capabilities, such as Fast ReRoute (FRR)

	LDP	R
Forwarding path	LSP	LSP o Primary and,
Forwarding Calculation	Based on IP routing database Shortest-Path based	Based o da Shortest-pa co (CSPF
Packet Encapsulation	Single label	One o
Signaling	By each node independently Uses existing routing protocols/information	Initiated by towards Uses ro extensio Supports ban Supports lin

Packet Forwarding Example

c IP Packet Forwarding

- routing information changed between des
  - Via IGP (e.g., OSFP, IS-IS)
- ckets being warded based on stination IP address
  - Lookup in routing table (RIB)



Forwarding Table

Address Prefix	I/F
128.89	1
171.69	1
…	

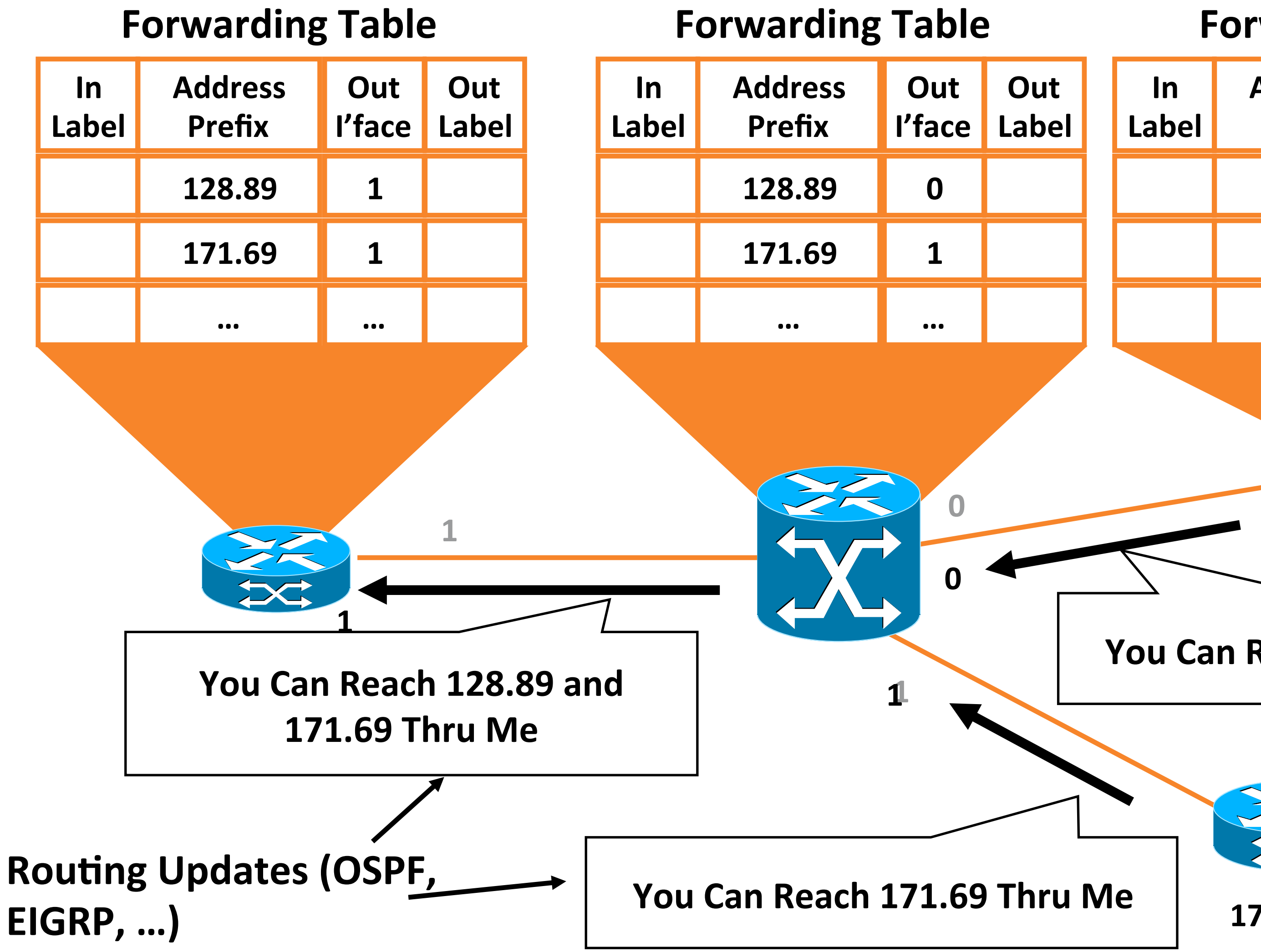
Forwarding Table

Address Prefix	I/F
128.89	0
171.69	1
…	

PLS Path (LSP) Setup

1: IP Routing (IGP) Convergence

- change of IP routes
  - OSPF, IS-IS, EIGRP, etc.
- tablish IP achability



Forwarding Table

In Label	Address Prefix	Out I'face	Out Label
	128.89	1	
	171.69	1	
	…	…	

Forwarding Table

In Label	Address Prefix	Out I'face	Out Label
	128.89	0	
	171.69	1	
	…	…	

You Can Reach 128.89 and 171.69 Thru Me

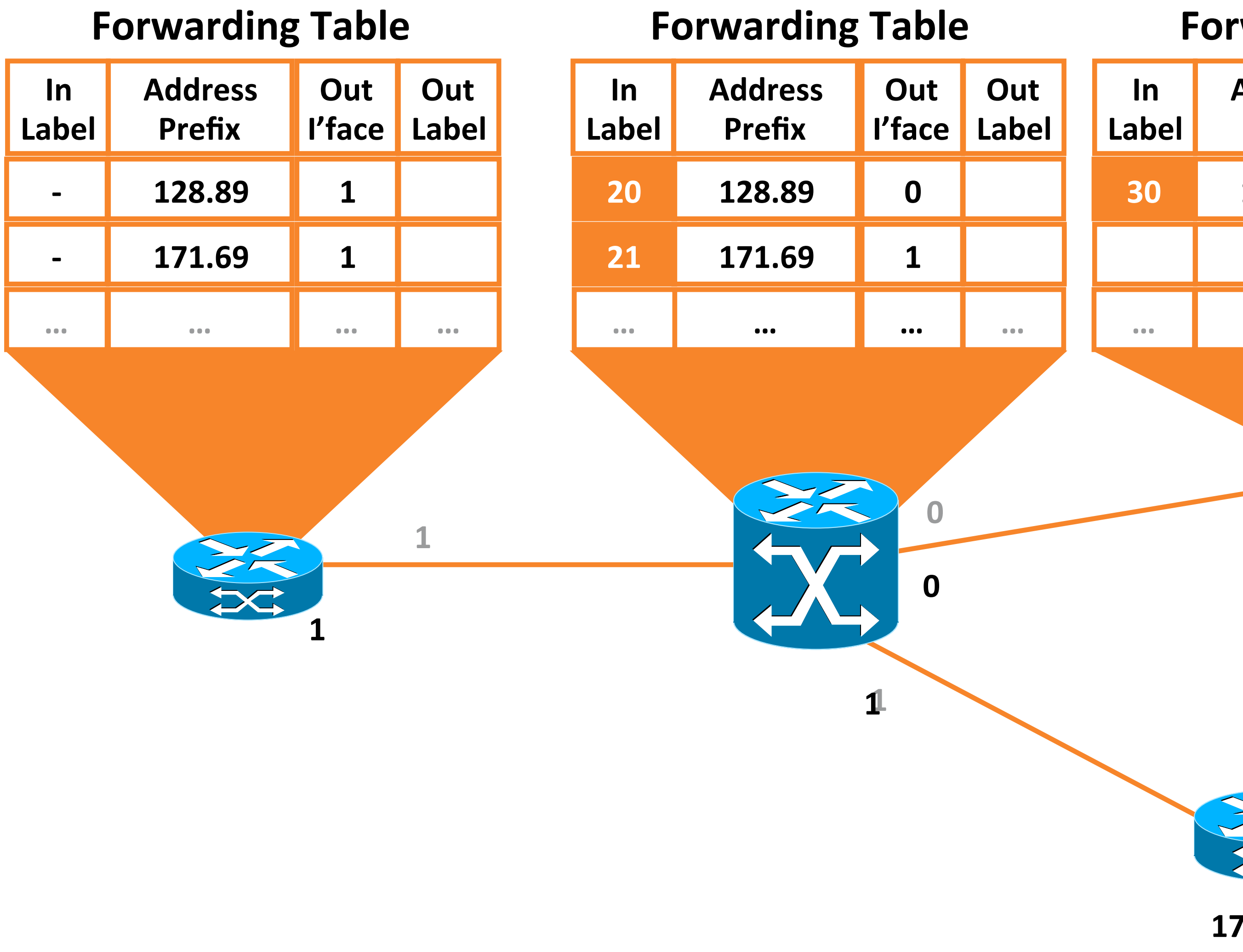
You Can Reach 171.69 Thru Me

Routing Updates (OSPF, EIGRP, …)

PLS Path (LSP) Setup

2A: Assignment of Local Labels

- ach MPLS node
signs a local label to
ch route in local
uting table
  - In label



Forwarding Table

In Label	Address Prefix	Out I'face	Out Label
-	128.89	1	
-	171.69	1	
...	...	...	...

Forwarding Table

In Label	Address Prefix	Out I'face	Out Label
20	128.89	0	
21	171.69	1	
...	...	...	...

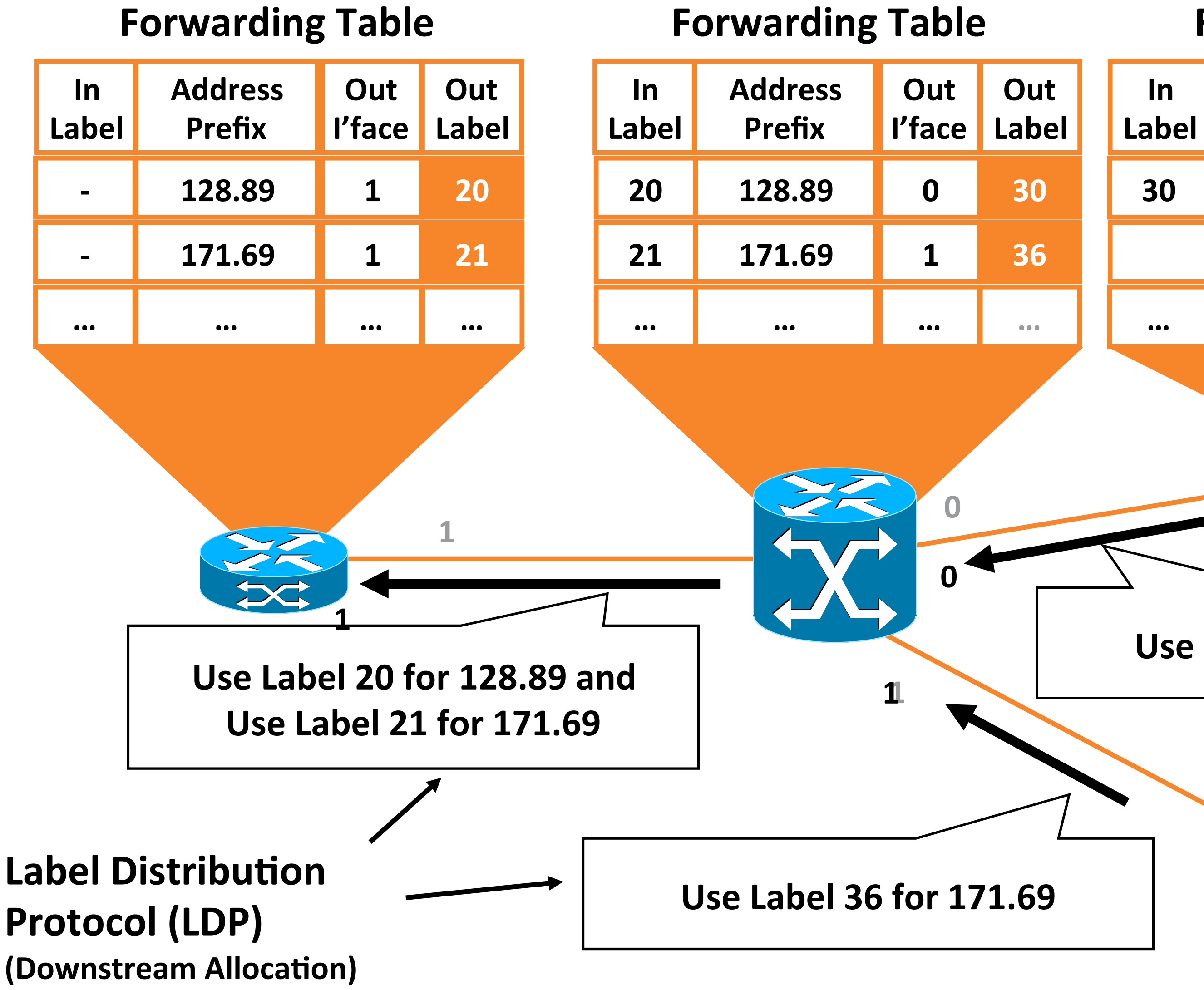
For

In Label	A
30	
...	

LS Path (LSP) Setup

2B: Assignment of Remote Labels

- cal label mapping
e sent to connected
des
- eceiving nodes
date forwarding
ble
- Out label



Forwarding Table

In Label	Address Prefix	Out I'face	Out Label
-	128.89	1	20
-	171.69	1	21
...	...	...	...

Forwarding Table

In Label	Address Prefix	Out I'face	Out Label
20	128.89	0	30
21	171.69	1	36
...	...	...	...

F

In Label
30
...

Use Label 20 for 128.89 and
Use Label 21 for 171.69

Use

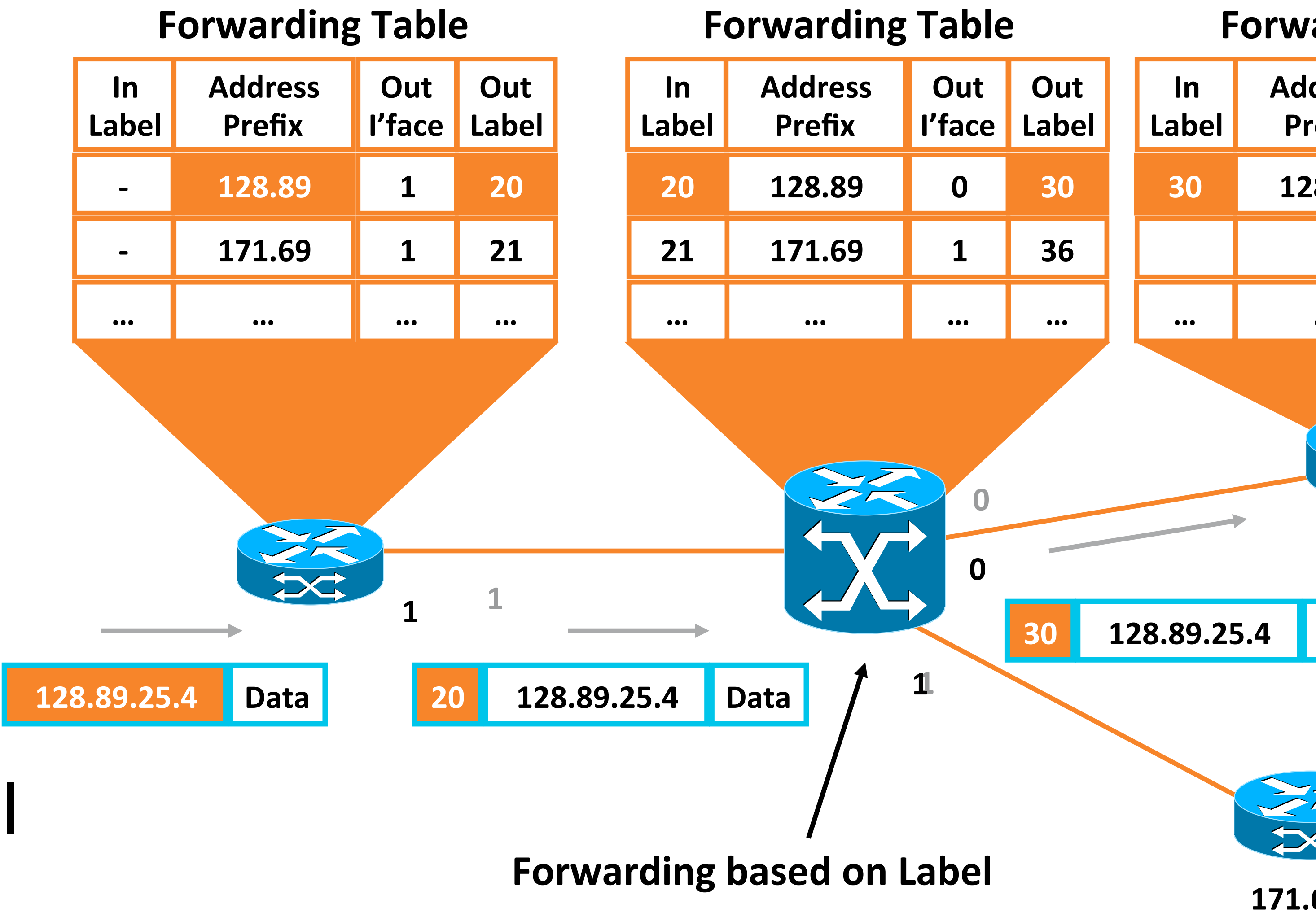
Use Label 36 for 171.69

Label Distribution Protocol (LDP)
(Downstream Allocation)

PLS Traffic Forwarding

by-hop Traffic Forwarding Using Labels

- gress PE node adds bel to packet (push)
  - Via forwarding table
- wnstream node use bel for forwarding cision (swap)
  - Outgoing interface
  - Out label
- ress PE removes label d forwards original cket (pop)



Forwarding Table

In Label	Address Prefix	Out I'face	Out Label
-	128.89	1	20
-	171.69	1	21
…	…	…	…

Forwarding Table

In Label	Address Prefix	Out I'face	Out Label
20	128.89	0	30
21	171.69	1	36
…	…	…	…

Forwa

In Label	Add Pr
30	12
…	.

Forwarding based on Label

PLS SNMP MIBs

IP Management Access to MPLS Resources

- PLS-LSR-STD-MIB
  - Provides LSP end-point and LSP cross-connect information
  - Frequently used: none ☹
- PLS-LDP-STD-MIB
  - Provides LDP session configuration and status information
  - Frequently used: LDP session status Trap notifications
- PLS-L3VPN-STD-MIB
  - Provides VRF configuration and status information and associated interfac
  - Frequently used: VRF max-route Trap notifications
- PLS-TE-STD-MIB
  - Provides TE tunnel configuration and status information
  - Frequently used: TE Tunnel status Trap notifications

PLS OAM

s for Reactive and Proactive Trouble Shooting of MPLS Connect

- PLS LSP Ping
  - Jsed for testing end-to-end MPLS connectivity similar to IP ping
  - Can we used to validate reach ability of LDP-signaled LSPs, TE tunnels, a
- PLS LSP Trace
  - Jsed for testing hop-by-hop tracing of MPLS path similar to traceroute
  - Can we used for path tracing LDP-signaled LSPs and TE tunnels
- PLS LSP Multipath (ECMP) Tree Trace
  - Jsed to discover of all available equal cost LSP paths between PEs
  - Jnique capability for MPLS OAM; no IP equivalent!
- to IP SLA
  - Automated discovery of all available equal cost LSP paths between PEs
  - LSP pings are being sent over each discovered LSP path

ny MPLS QoS

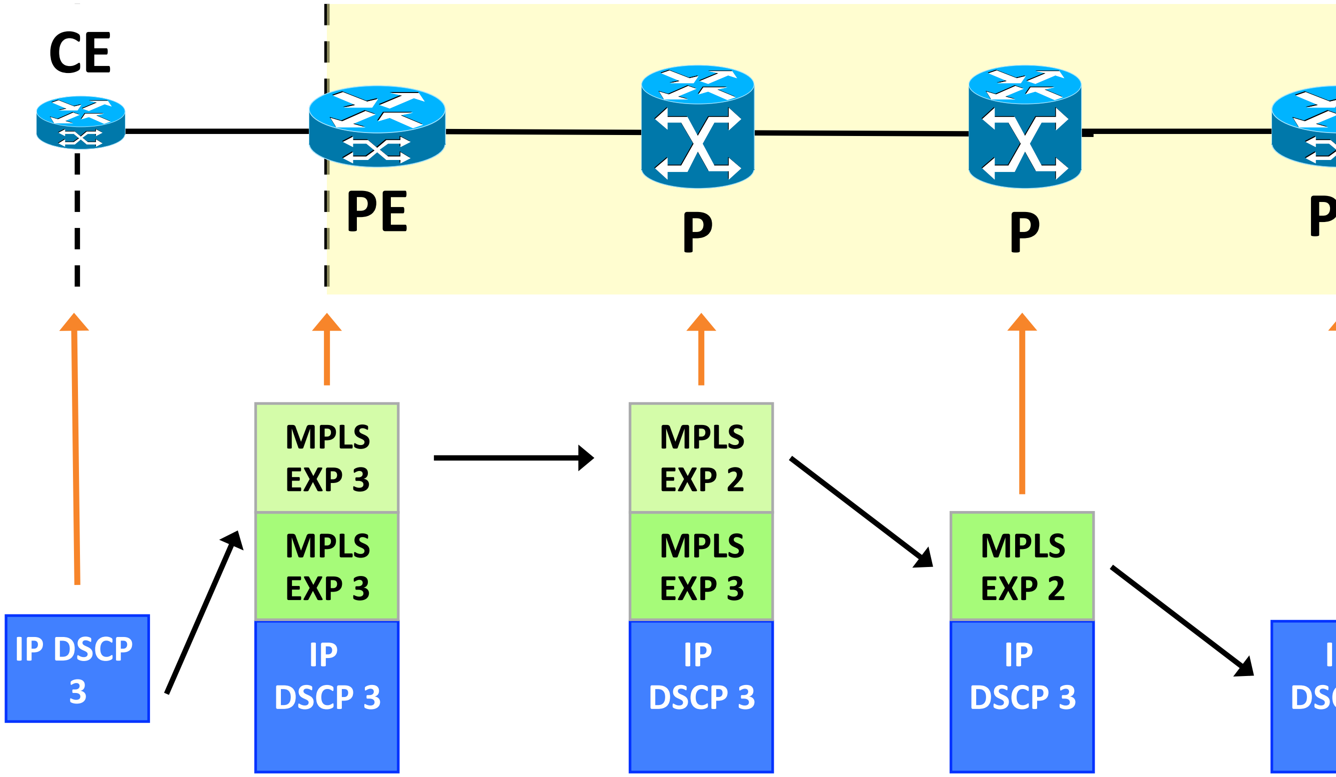
Need for Differentiated Services

- pically different traffic types (packets) sent over MPLS netwo
  - E.g., Web HTTP, VoIP, FTP, etc.
- t all traffic types/flows have the same performance requirem
  - Some require low latency to work correctly; e.g., video
- PLS QoS used for traffic prioritization to guarantee minimal t
d delay for high priority traffic
  - Involves packet classification and queuing
- PLS leverages mostly existing IP QoS architecture
  - Based on Differentiated Services (DiffServ) model; defines per-hop b
based on IP Type of Service (ToS) field

PLS Uniform Mode

Field Assignments in MPLS Network

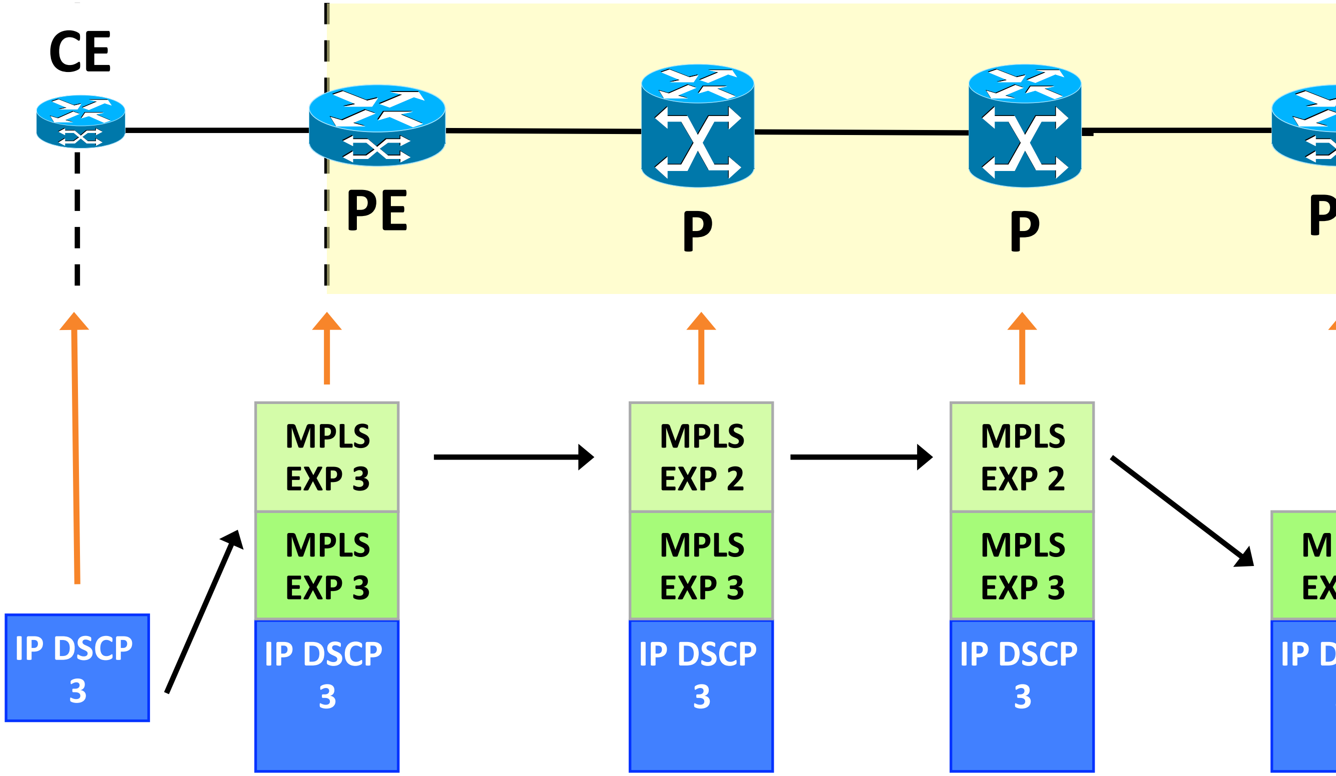
- d-to-end behavior:
  - Original IP DSCP value not preserved
- ingress PE:
  - P DSCP value copied in EXP value of MPLS label
  - P value changed in the PLS core
  - Based on traffic load and congestion
- egress PE:
  - EXP value copied back into IP DSCP value



PLS Pipe Mode

Field Assignments in MPLS Network

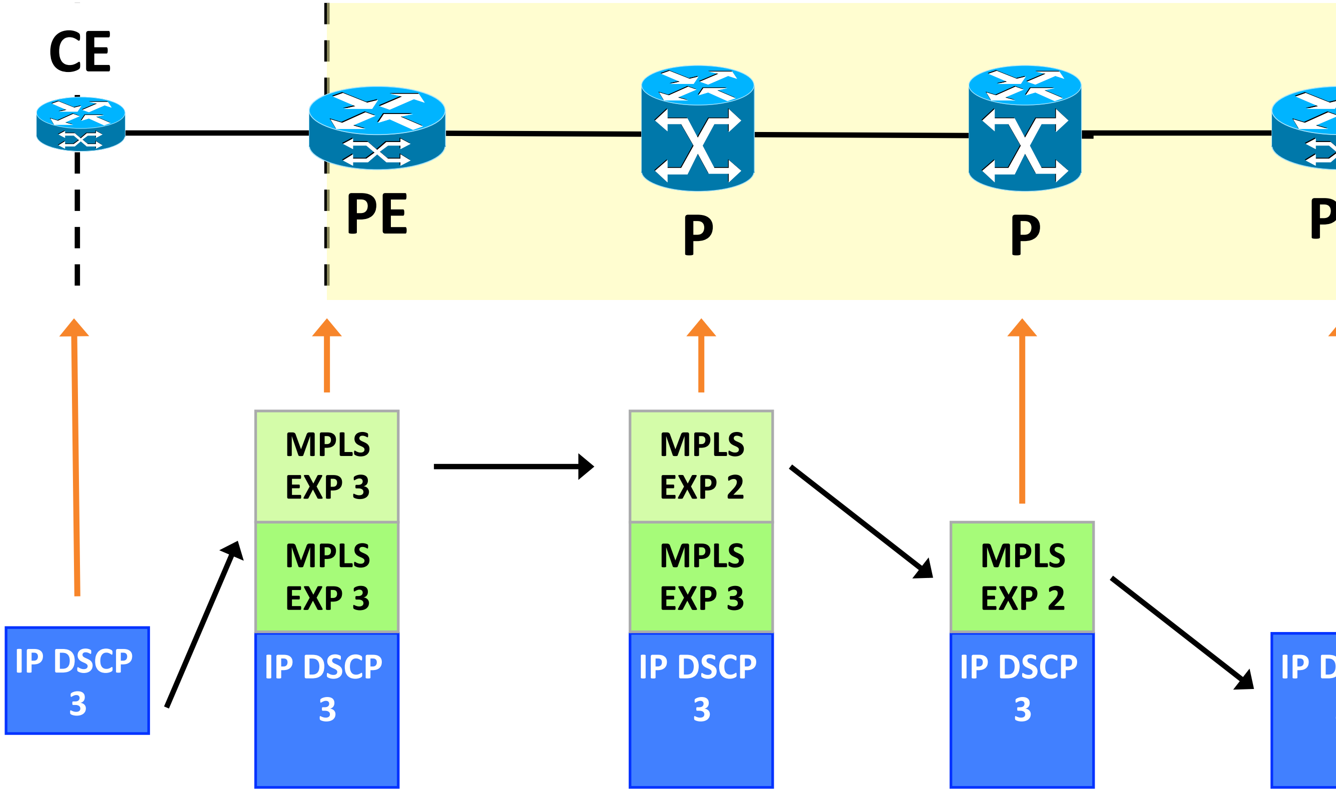
- d-to-end behavior:
  - Original IP DSCP is preserved
- ingress PE:
  - EXP value set based on ngress classification
- P changed in the MPLS re
  - Based on traffic load and congestion
- egress PE:
  - EXP value not copied back nto IP DSCP value



LS Short Pipe Mode

Field Assignments in MPLS Network

- d-to-end behavior:
  - Original IP DSCP is preserved
- ingress PE:
  - EXP value set based on ngress classification
- P changed in the MPLS re
  - Based on traffic load and congestion
- egress PE:
  - Original IP DSCP value used for QoS processing



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Takeaways

- PLS networks consist of PE routers at in/egress and P route
- affic is encapsulated with label(s) at ingress (PE router)
- bels are removed at egress (PE router)
- PLS forwarding operations include label imposition (PUSH), d disposition (POP)
- P and RSVP can be used for signaling label mapping inform an end-to-end Label Switched Path (LSP)
- SVP label signaling enables setup of TE tunnels, supporting ffic engineering capabilities; traffic protection and path mana
- PLS OAM and MIBs can be used for MPLS connectivity valid ubleshooting

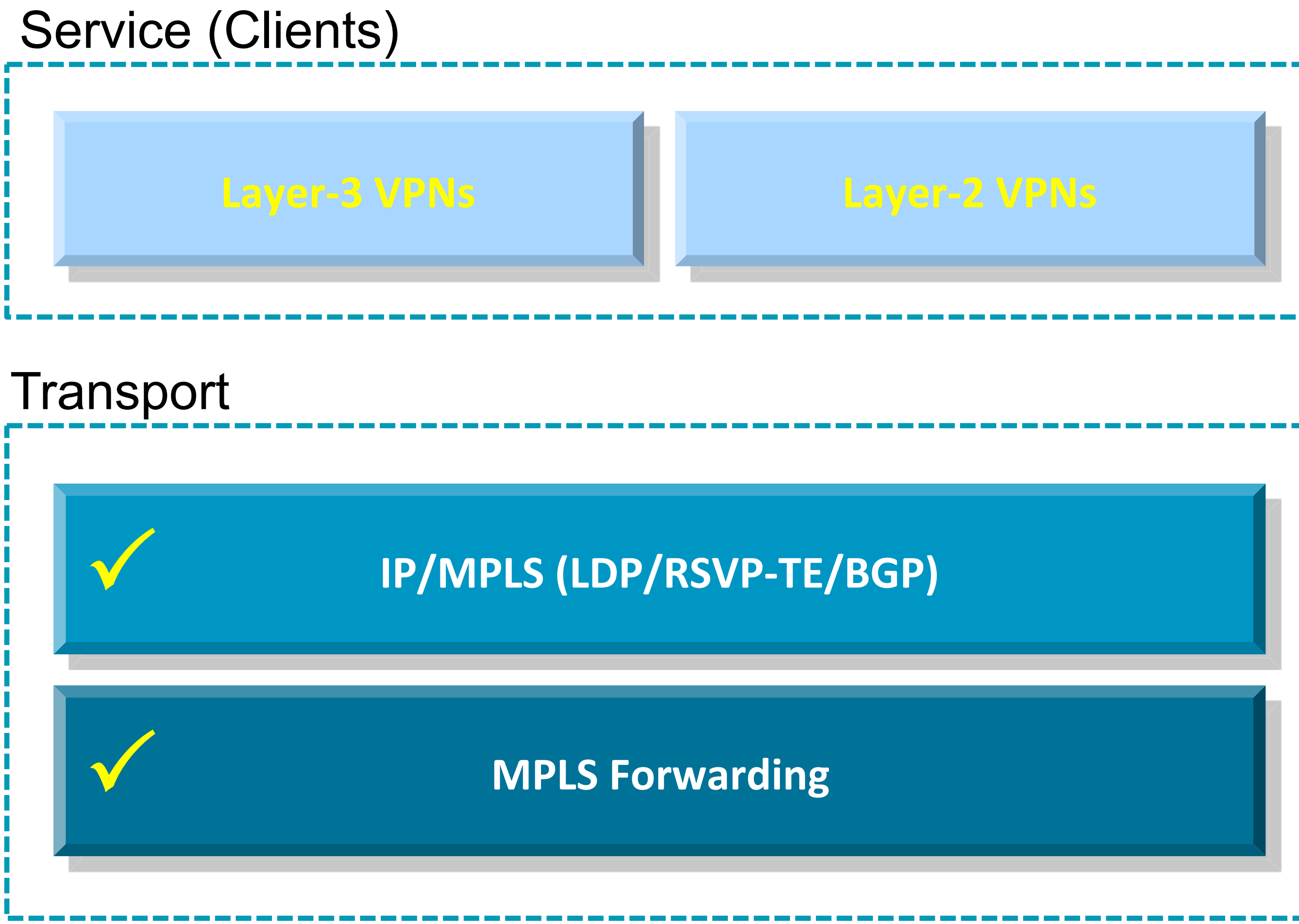
LS Virtual Private Networks

ology Overview

PLS Virtual Private Networks

cs

- finition of MPLS VPN rvice
- sic MPLS VPN ployment scenario
- chnology options



at is a Virtual Private Network?

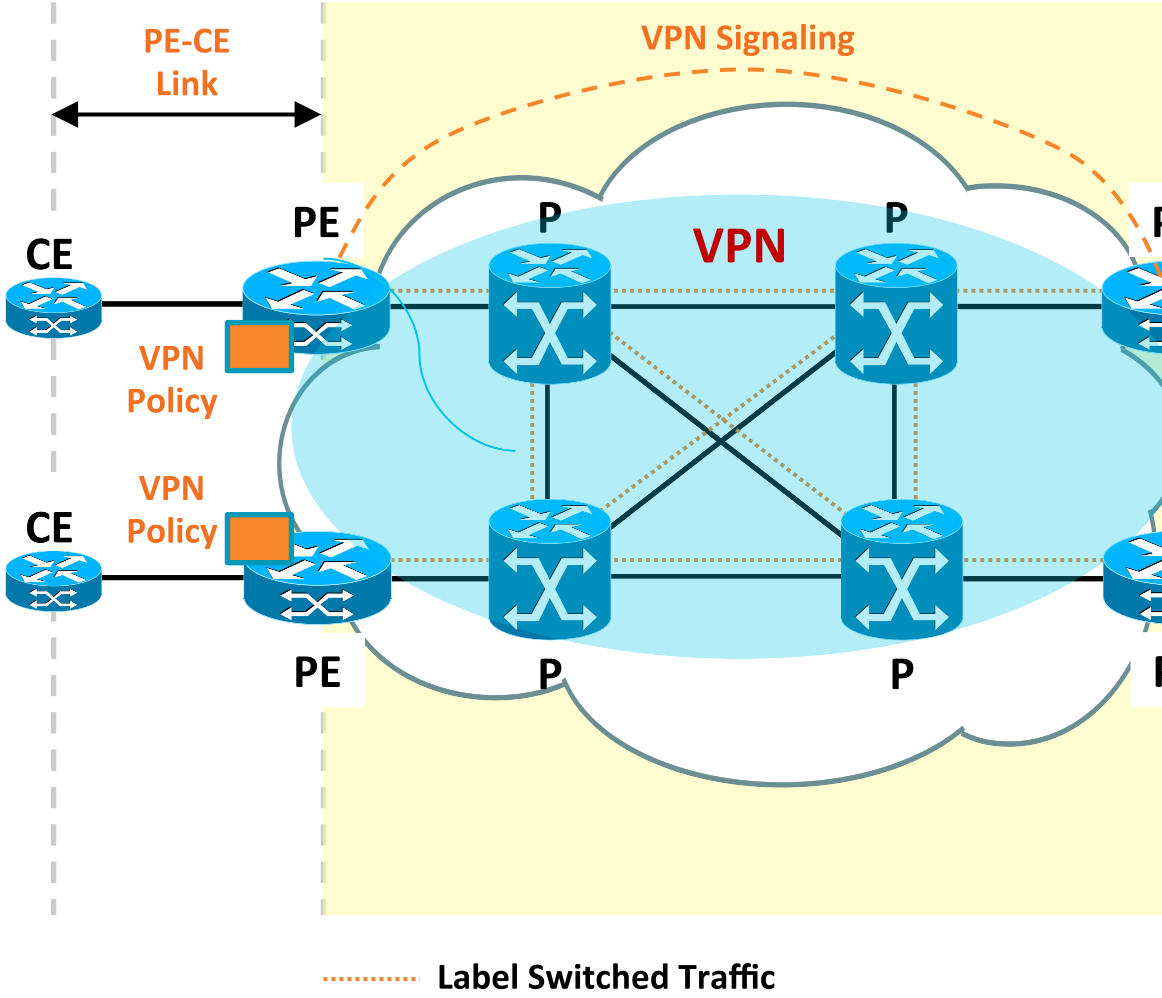
nition

- t of sites which communicate with each other in a secure wa
  - Typically over a shared public or private network infrastructure
- fined by a set of administrative policies
  - Policies established by VPN customers themselves (DIY)
  - Policies implemented by VPN service provider (managed/unmanage
- fferent inter-site connectivity schemes possible
  - Full mesh, partial mesh, hub-and-spoke, etc.
- N sites may be either within the same or in different organiz
  - VPN can be either intranet (same org) or extranet (multiple orgs)
- Ns may overlap; site may be in more than one VPN

PLS VPN Example

c Building Blocks

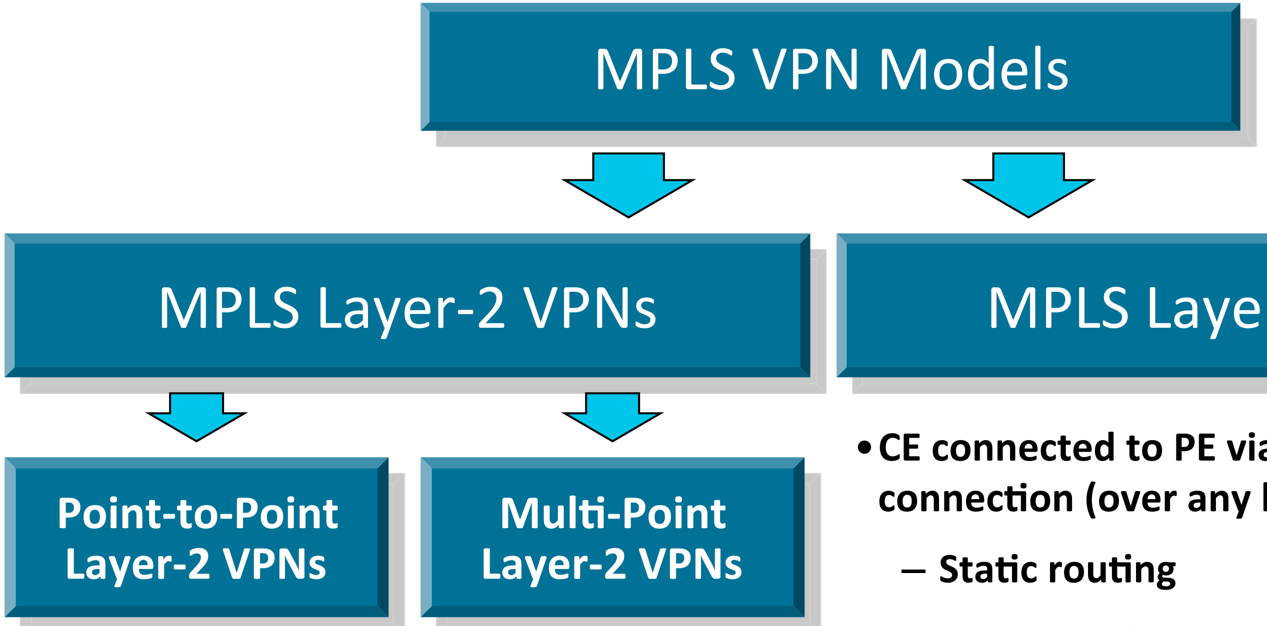
- N policies
  - Configured on PE routers (manual operation)
- N signaling
  - Between PEs
  - Exchange of VPN policies
- N traffic forwarding
  - Additional VPN-related MPLS label encapsulation
- -CE link
  - Connects customer network to MPLS network; either layer-2 or layer-3



PLS VPN Models

nology Options

- PLS Layer-3 VPNs
  - Peering relationship between CE and PE
- PLS Layer-2 VPNs
  - Interconnect of layer-2 Attachment Circuits (ACs)



MPLS VPN Models

MPLS Layer-2 VPNs

MPLS Laye

Point-to-Point Layer-2 VPNs

- CE connected to PE via p2p L2 connection (FR, ATM)
- CEs peer with each other (IP routing) via p2p layer-2 VPN connection
- CE-CE routing; no SP involvement

Multi-Point Layer-2 VPNs

- CE connected to PE via Ethernet connection (VLAN)
- CEs peer with each other via fully/ partial mesh Layer-2 VPN connection
- CE-CE routing; no SP involvement

- CE connected to PE via connection (over any l
  - Static routing
  - PE-CE routing proto IS-IS
- CE routing has peering PE router; PE routers a customer routing
- PE routers maintain cu routing tables and exc customer=specific rou

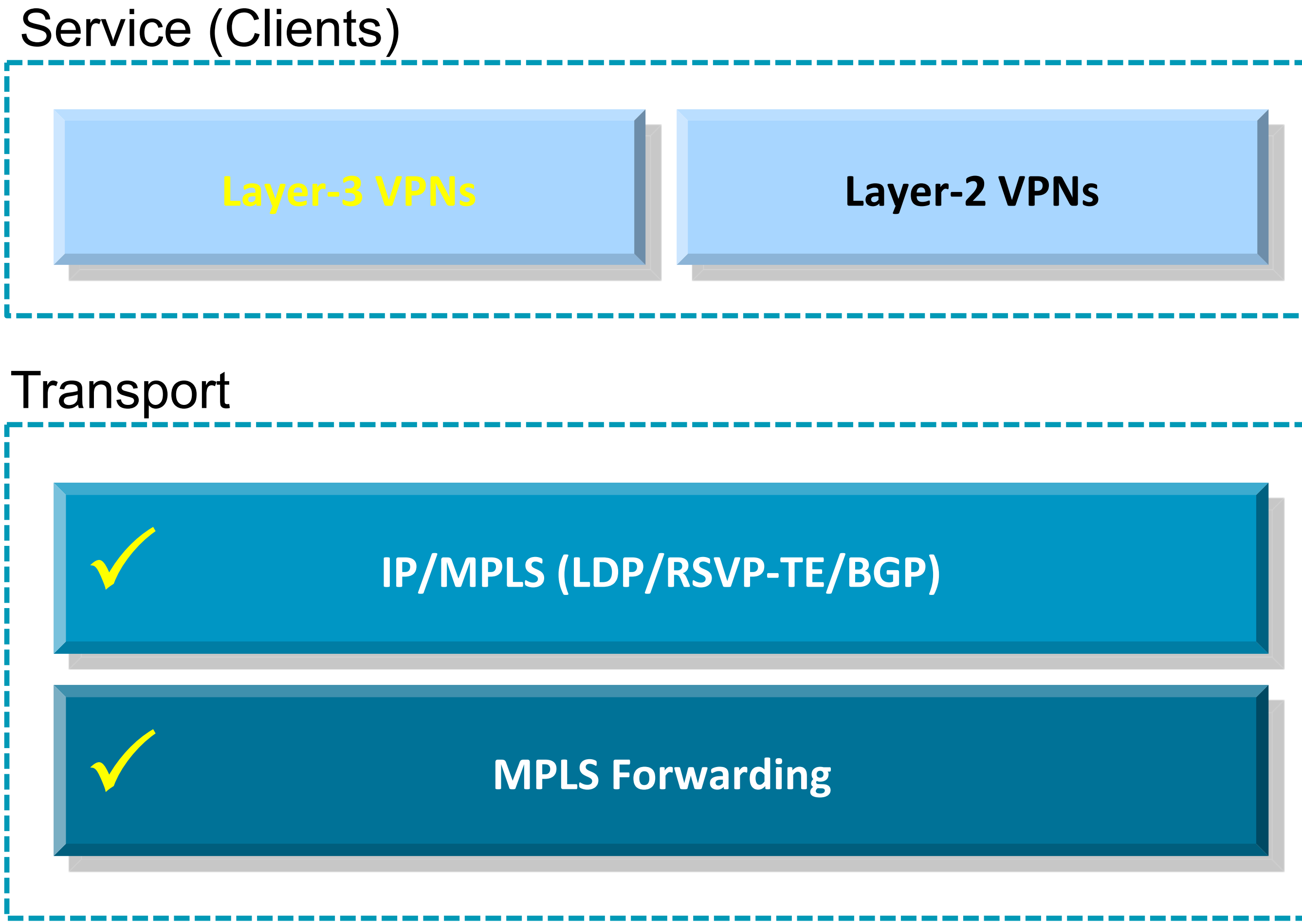
LS Layer-3 Virtual Private Networks

-end Layer-3 Services Over MPLS Networks

PLS Layer-3 Virtual Private Networks

cs

- chnology components
- N control plane echanisms
- N forwarding plane
- ployment use cases
  - Business VPN services
  - Network segmentation
  - Data Center access



Service (Clients)

Layer-3 VPNs

Layer-2 VPNs

Transport

✓ IP/MPLS (LDP/RSVP-TE/BGP)

✓ MPLS Forwarding

LS Layer-3 VPN Overview

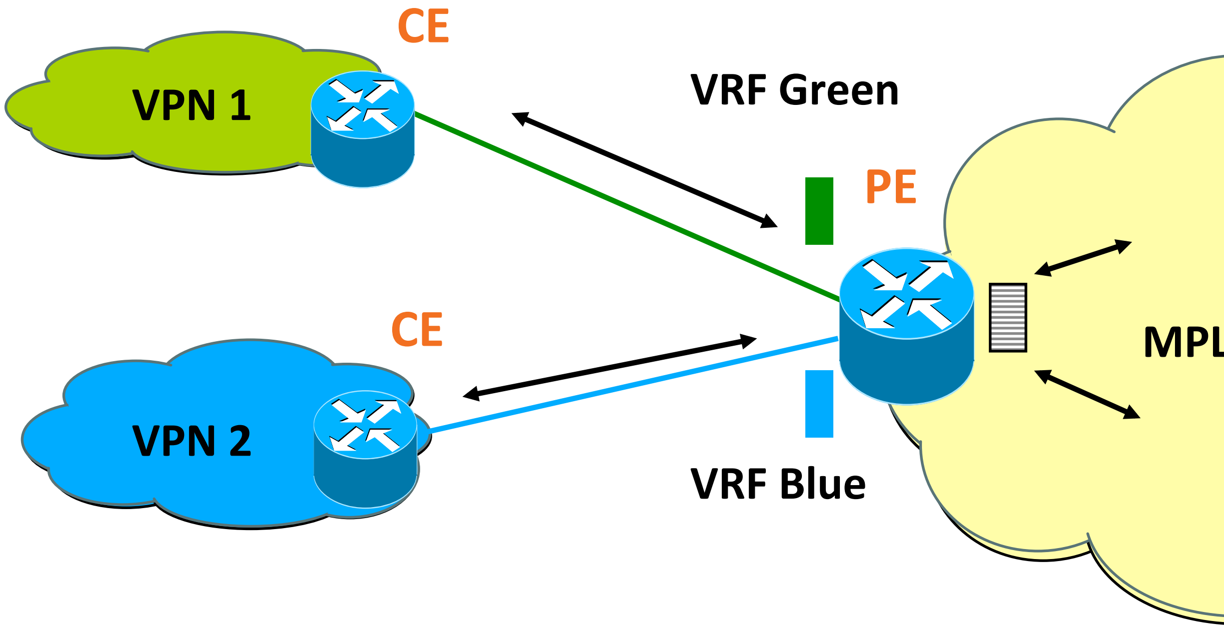
nology Components

- N policies
  - Separation of customer routing via virtual VPN routing table (VRF)
  - n PE router, customer interfaces are connected to VRFs
- N signaling
  - Between PE routers: customer routes exchanged via BGP (MP-iBGP)
- N traffic forwarding
  - Separation of customer VPN traffic via additional VPN label
  - VPN label used by receiving PE to identify VPN routing table
- -CE link
  - Can be any type of layer-2 connection (e.g., FR, Ethernet)
  - CE configured to route IP traffic to/from adjacent PE router
  - Variety of routing options; static routes, eBGP, OSPF, IS-IS

tual Routing and Forwarding Instanc

al Routing Table and Forwarding to Separate Customer Traffic

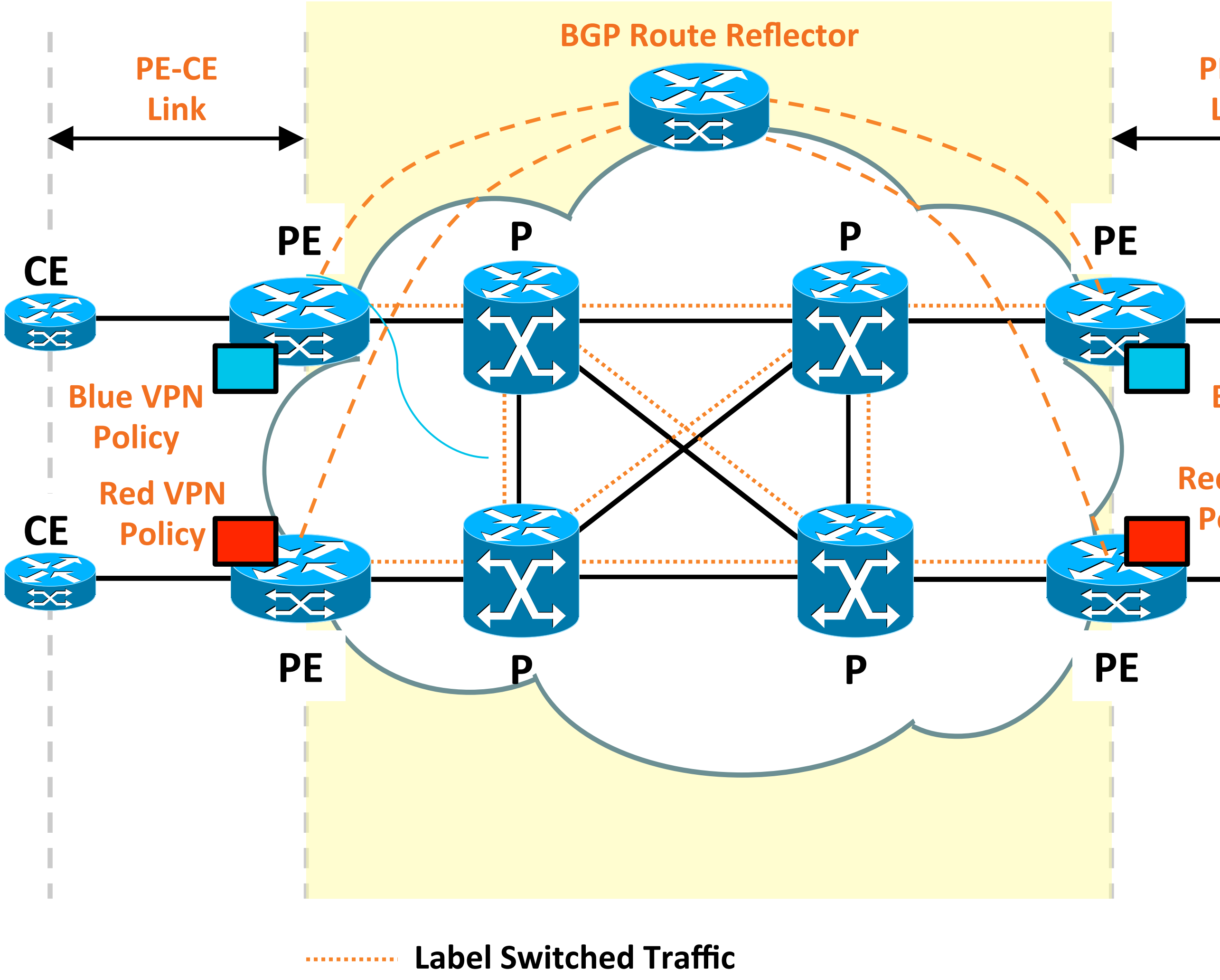
- tual routing and forwarding le
  - On PE router
  - Separate instance of routing (RIB) and forwarding table
- pically, VRF created for each stomer VPN
  - Separates customer traffic
- F associated with one or re customer interfaces
- F has its own routing tance for PE-CE configured ting protocols
  - E.g., eBGP



N Route Distribution

ange of VPN Policies Among PE Routers

- ll mesh of BGP sessions
nong all PE routers
- BGP Route Reflector
- lti-Protocol BGP
tensions (MP-iBGP) to
rry VPN policies
- E-CE routing options
  - Static routes
  - eBGP
  - OSPF
  - IS-IS



N Control Plane Processing

Parameters

e customer routes unique:

- **ute Distinguisher (RD):** byte field, VRF parameters; que value to make VPN IP tes unique
- **Nv4 address**: RD + VPN prefix

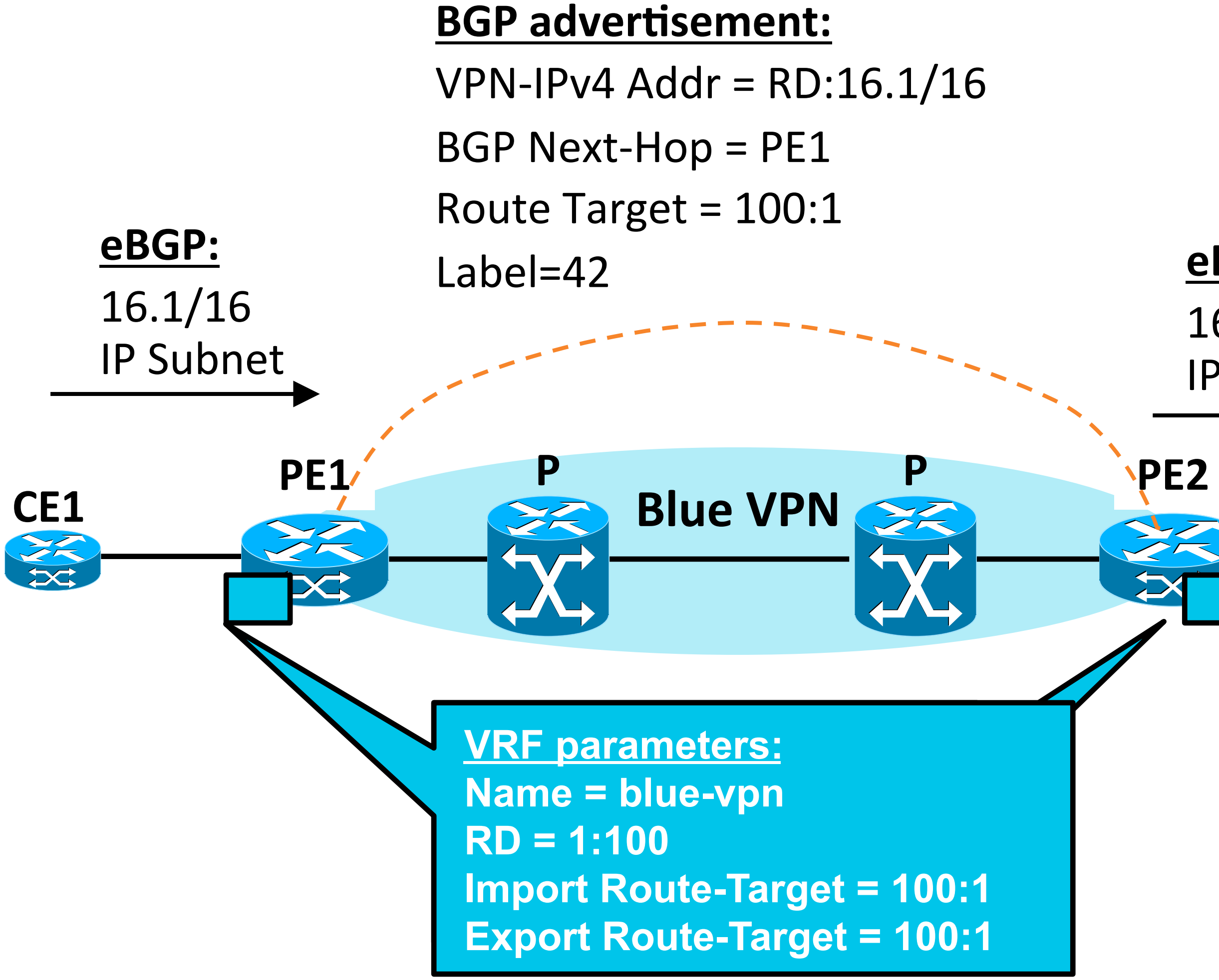
ctive distribute VPN routes:

- **ute Target (RT):** 8-byte d, VRF parameter, unique ue to define the import/ port rules for VPNv4 routes
- P-iBGP: advertises VPNv4 efixes + labels

N Control Plane Processing

actions Between VRF and BGP VPN Signaling

- E1 redistribute IPv4 route PE1 via eBGP
- E1 allocates VPN label for efix learnt from CE1 to eate unique VPNv4 route
- E1 redistributes VPNv4 ute into MP-iBGP, it sets self as a next hop and lays VPN site routes to E2
- E2 receives VPNv4 route nd, via processing in local RF (green), it redistributes iginal IPv4 route to CE2



BGP advertisement:

VPN-IPv4 Addr = RD:16.1/16

BGP Next-Hop = PE1

Route Target = 100:1

Label=42

eBGP:

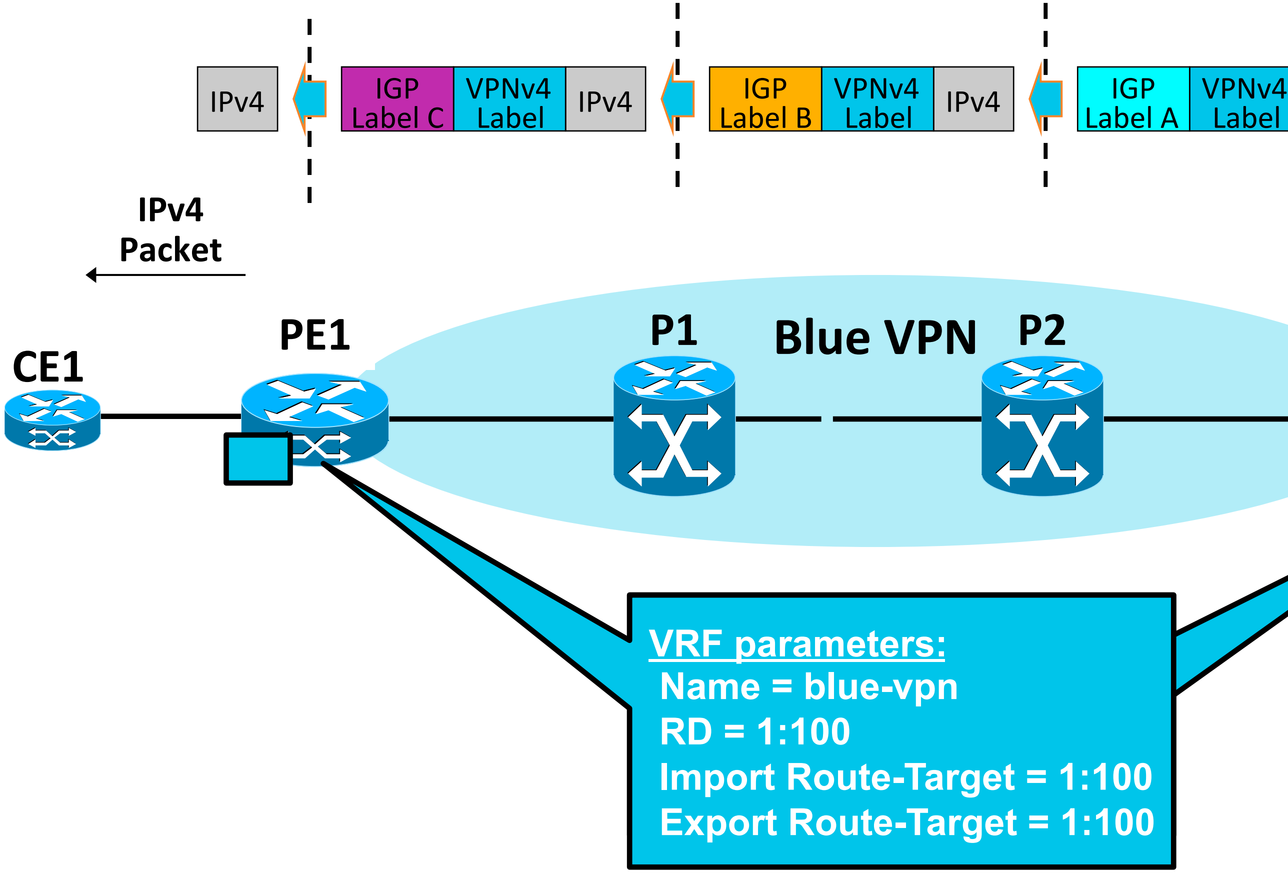
16.1/16
IP Subnet

VRF parameters:
Name = blue-vpn
RD = 1:100
Import Route-Target = 100:1
Export Route-Target = 100:1

N Forwarding Plane Processing

arding of Layer-3 MPLS VPN Packets

- E2 forwards IPv4 packet to PE2
- E2 imposes pre-allocated VPN bel to IPv4 packet received from E2
  - Learned via MP-IBGP
- E2 imposes outer IGP label A earned via LDP) and forwards beled packet to next-hop -router P2
- -routers P1 and P2 swap outer GP label and forward label acket to PE1
  - A->B (P2) and B->C (P1)
- outer PE1 strips VPN label and GP labels and forwards IPv4 acket to CE1



VRF parameters:
Name = blue-vpn
RD = 1:100
Import Route-Target = 1:100
Export Route-Target = 1:100

rvice Provider Deployment Scenario

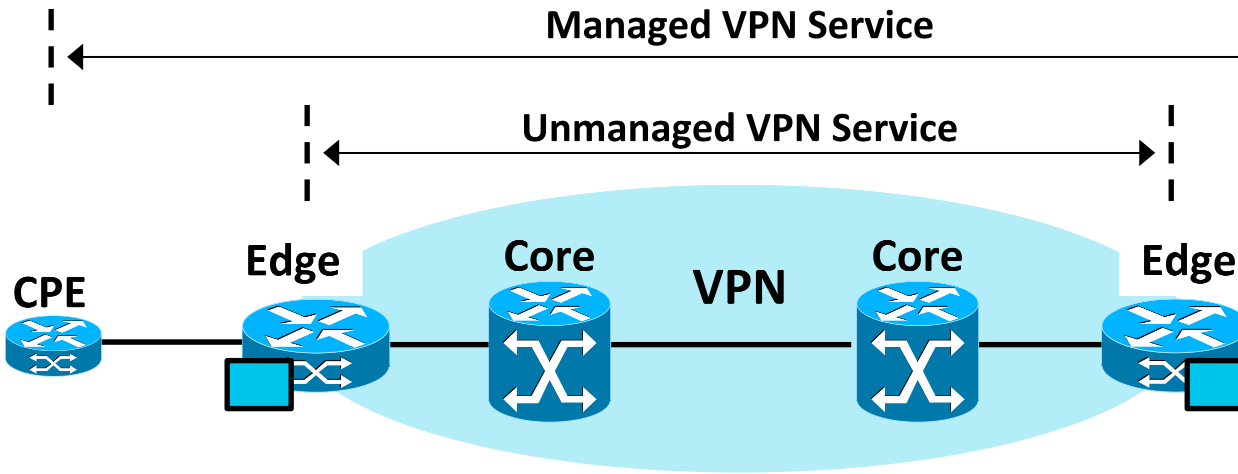
S Layer-3 VPNs for Offering Layer-3 Business VPN Services

ployment Use Case

Delivery of IP VPN services to business customers

nefits

- Leverage same network for multiple services and customers (CAPEX)
- Highly scalable
- Service enablement only requires edge node configuration (OPEX)
- Different IP connectivity can be easily configured; e.g., full/partial mesh



Network Segment	CPE	Edge
MPLS Node	CE	PE
Typical Platforms	ASR1K ISR/G2	ASR9K 7600 ASR1K ASR903 ME3800X

terprise Deployment Scenario

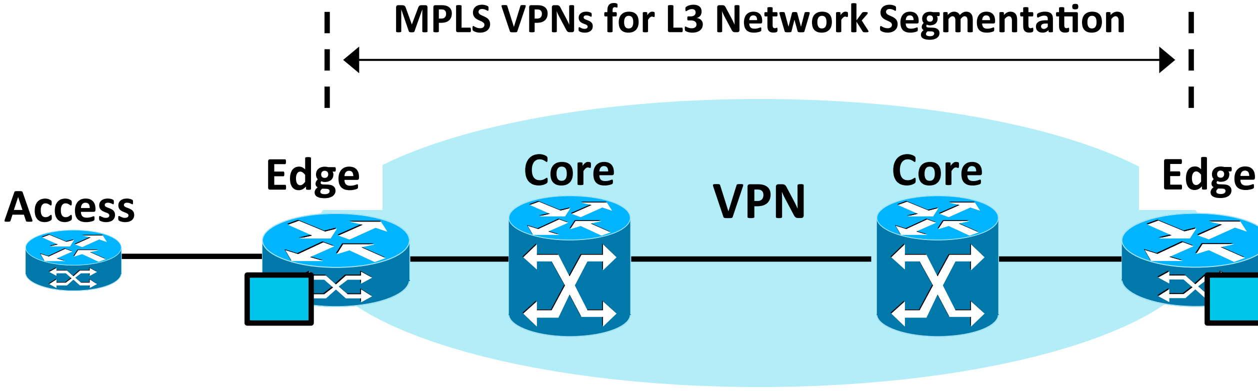
S Layer-3 VPNs for Implementing Network Segmentation

ployment Use Case

- Segmentation of enterprise network to provide selective connectivity for specific user groups and organizations

nefits

- Network segmentation only requires edge node configuration
- Flexible routing; different IP connectivity can be easily configured; e.g., full/partial mesh



Network Segment	Access	Edge
MPLS Node	CE	PE
Typical Platforms	ASR1K ISR/G2	7600 ASR1K

ta Center Deployment Scenario

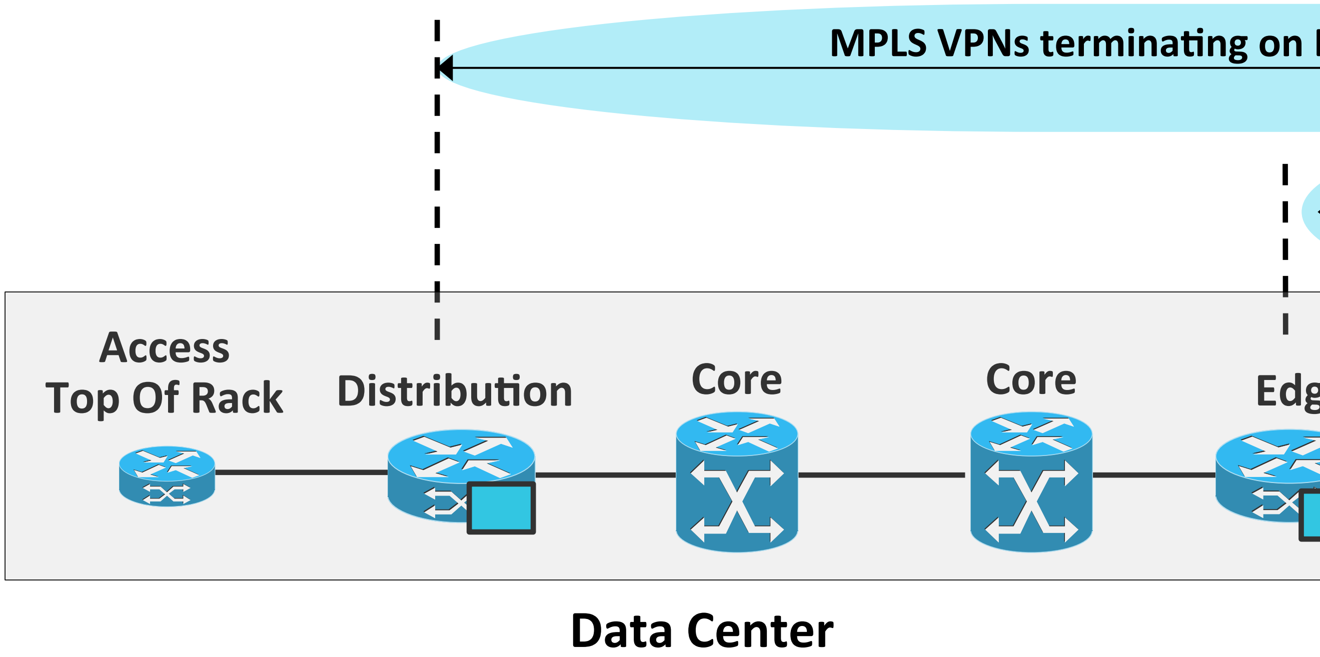
S Layer-3 VPNs for Segmented L3 Data Center Access and Inte

ployment Use Case

- Segmented WAN Layer-3 at Data Center edge
- Layer-3 segmentation in Data Center

nefits

- Only single Data Center edge node needed for segmented layer-3 access
- Enables VLAN/Layer-2 scale (> 4K)



Network Segment	Distribution	Core
MPLS Node	CE or PE	P or CE
Typical Platforms	N7K 6500	N7K 6500

mmary

Takeaways

- PLS Layer-3 VPNs provide IP connectivity among CE sites
  - MPLS VPNs enable full-mesh, hub-and-spoke, and hybrid IP connec
- E sites connect to the MPLS network via IP peering across P
- PLS Layer-3 VPNs are implemented via VRFs on PE edge n
  - VRFs providing customer routing and forwarding segmentation
- GP used for signaling customer VPN (VPNv4) routes betwee
- ensure traffic separation, customer traffic is encapsulated in ditional VPN label when forwarded in MPLS network
- ey applications are layer-3 business VPN services, enterprise gmentation, and segmented layer-3 Data Center access

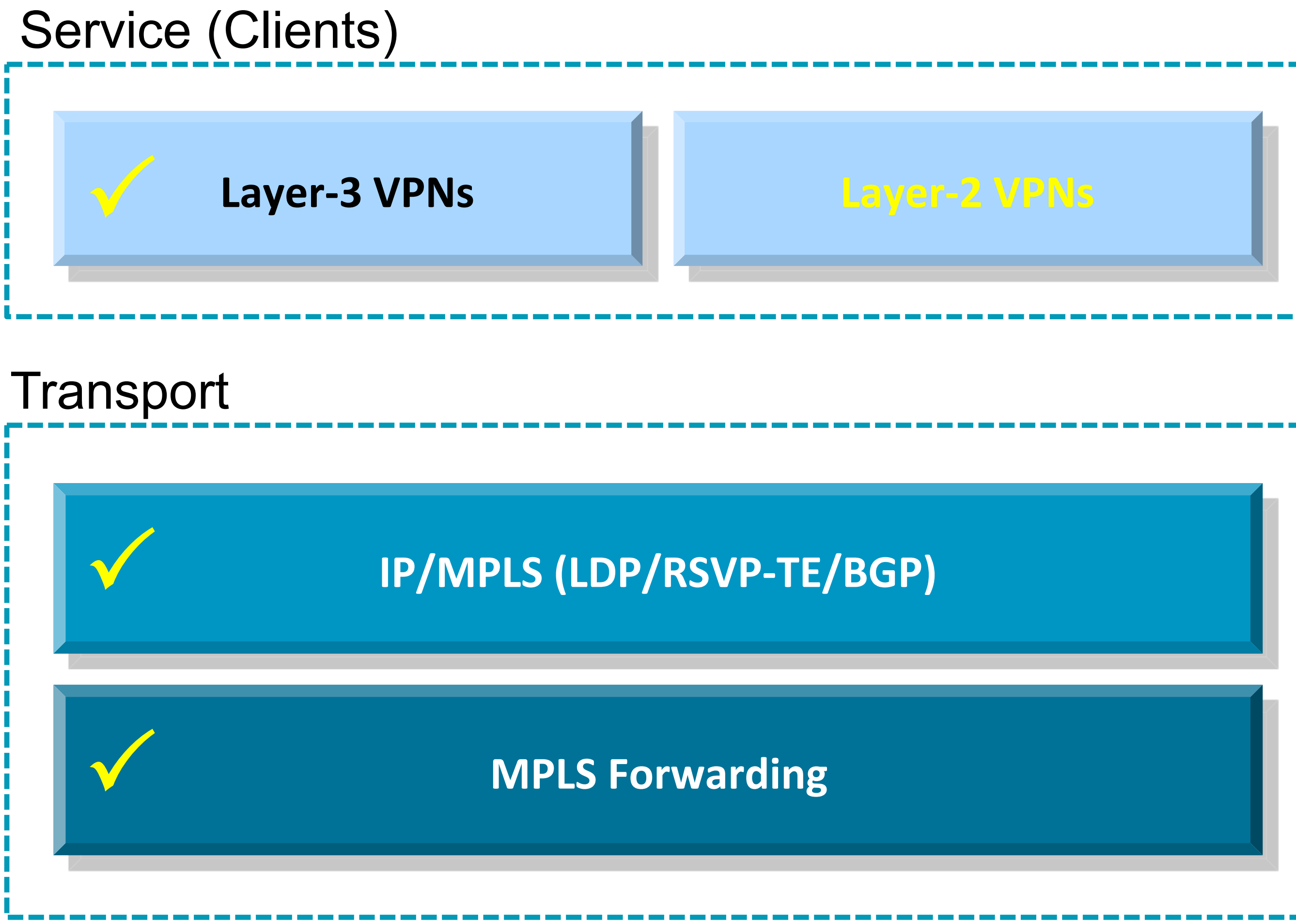
LS Layer-2 Virtual Private Networks

-end Layer-2 Services Over MPLS Networks

PLS Layer-2 Virtual Private Networks

cs

- /PN technology options
- P VPWS services (PWs)
- Overview & Technology Basics
- /PN control plane
- /PN forwarding plane
- 2MP VPLS services
- Overview & Technology Basics
- /PN control plane
- /PN forwarding plane
- ployment use cases
- 2 Business VPN services
- Data Center Interconnect



LS Layer-2 Virtual Private Networks

nology Options

- WS services
  - Point-to-point
  - Referred to as Pseudowires (PWs)*
- LS services
  - Multipoint-to-Multipoint

MPLS Layer-2 VPNs

Point-to-Point Layer-2 VPNs (PWs)

- **CE connected to PE via p2p L2 connection (e.g., FR, ATM)**
- **CEs peer with each other (IP routing) via p2p layer-2 VPN connection**
- **CE-CE routing; no MPLS network involvement**

Multipoint-to-Multi
Layer-2 VPNs (VP

- **CE connected to PE**
  Ethernet connectio
- **CEs peer with each**
  fully/partial mesh L
  VPN connection
- **CE-CE routing; no M**
  network involveme

to be referred to as Any Transport over MPLS or AToM as well.

tual Private Wire Services (VPWS)

rview of Pseudowire (PW) Architecture

sed on IETF’s Pseudo-
re (PW) Reference Model

ables transport of any
yer-2 traffic over MPLS

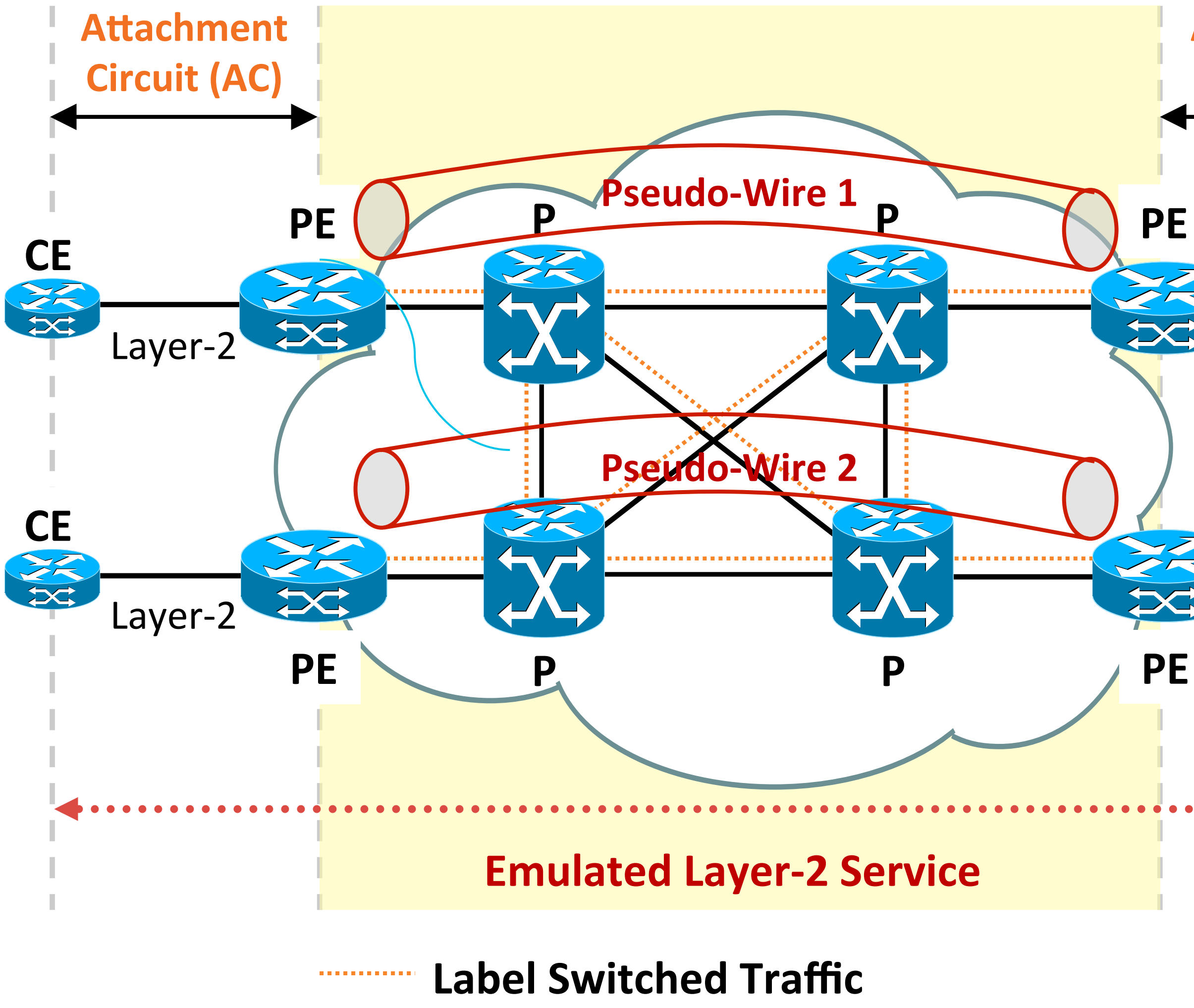
ludes additional VC label
capsulation and
nslation of L2 packets

ATM, ATM, FR, or PPP

-CE link is referred to as
achment Circuit (AC)

pport for L2 interworking

/s are bi-directional



tual Private Wire Services (VPWS)

nology Components

- N policies
  - Virtual cross-connect (Xconnect)
  - Maps customer interface (AC) to PW (1:1 mapping)
- N signaling
  - Targeted LDP* or BGP session between ingress and egress PE router
  - Virtual Connection (VC)-label negotiation, withdrawal, error notification
- N traffic forwarding
  - 1 or 2 labels used for encapsulation + 1 (IGP) label for forwarding: VC label + optional c
  - nner de-multiplexer (VC) label: identifies L2 circuit (packet)
  - Control word: replaces layer-2 header at ingress; used to rebuild layer-2 header at egre
  - Outer tunnel (IGP) label: to get from ingress to egress PE using MPLS LSP
- -CE link
  - Referred to as Attachment Circuit (AC)
  - Can be any type of layer-2 connection (e.g., FR, ATM)

assumed as signaling protocol for next examples

WS Control Plane Processing

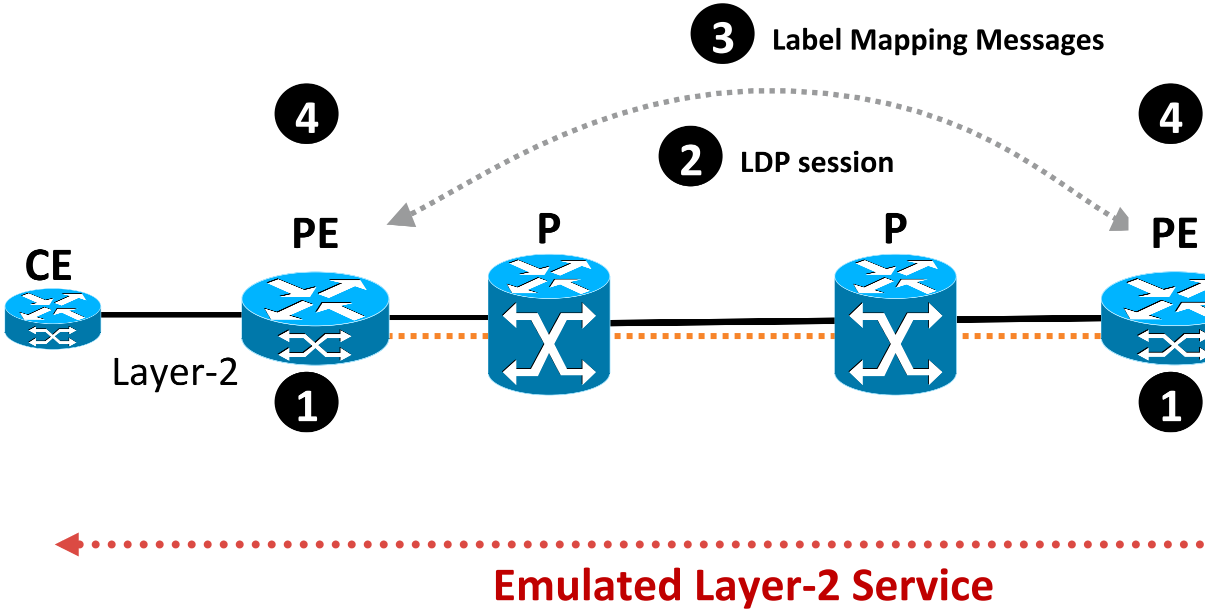
aling of a New Pseudo-Wire

w Virtual Circuit (VC) cross-
nnect connects customer L2
erface (AC) to new PW via
ID and remote PE ID

w targeted LDP session
tween PE1 and PE2 is
tablished, in case one
es not already exist

binds VC label with
stomer layer-2 interface and
nds label-mapping to
mote PE

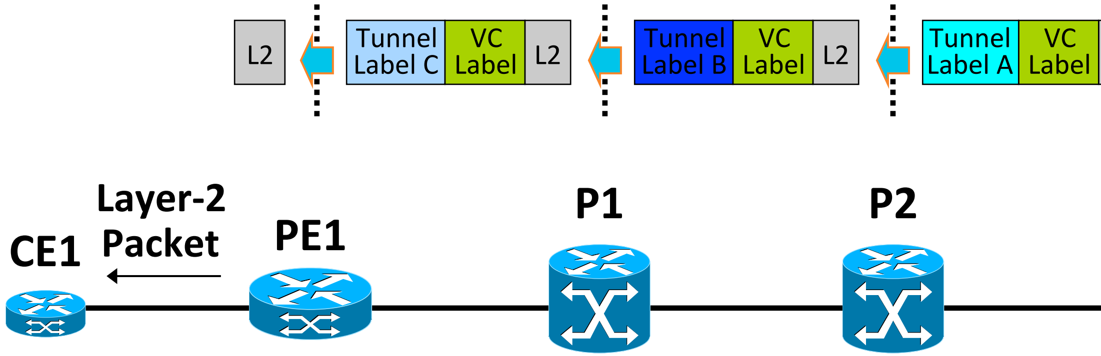
mote PE receives LDP label
ding message and matches
ID with local configured VC
oss-connect



WS Forwarding Plane Processing

arding of Layer-2 Traffic Over PWs

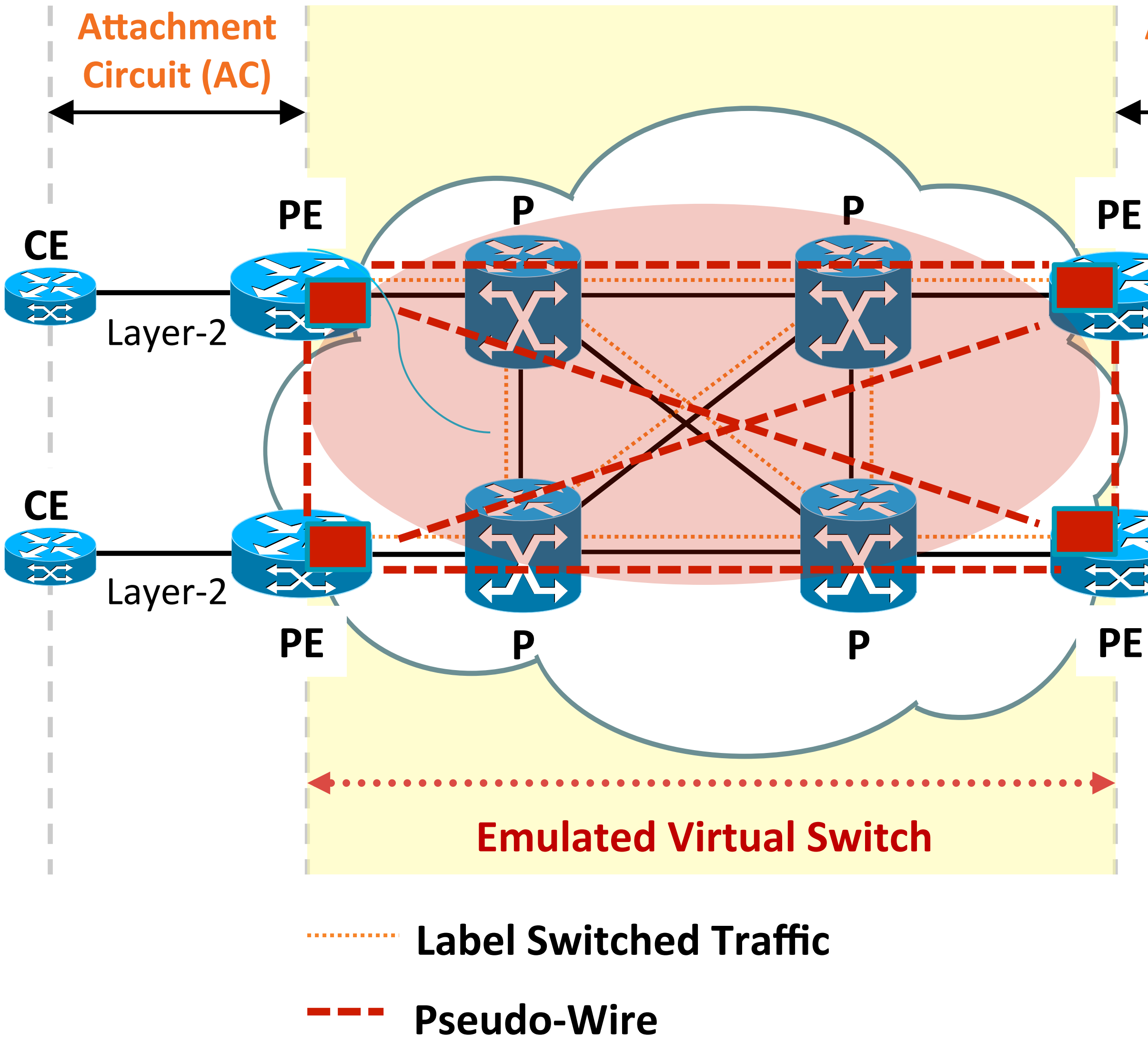
- 2 forwards L2 packet to PE2.
- 2 pushes VC (inner) label to L2 cket received from CE2
  - Optionally, a control word is added as well (not shown)
- 2 pushed outer (Tunnel) label d forwards packet to P2
- and P1 forward packet using ter (tunnel) label (swap)
- uter PE2 pops Tunnel label and, sed on VC label, L2 packet is warded to customer interface to 1, after VC label is removed
  - In case control word is used, new layer-2 header is generated first



tual Private LAN Services

rview of VPLS Architecture

- chitecture for Ethernet ultipoint Services over PLS
- PLS network acts like a tual switch that emulates nventional L2 bridge
- lly meshed or Hub-oke topologies pported
- -CE link is referred to Attachment Circuit (AC)
  - Always Ethernet



tual Private LAN Services (VPLS)

nology Components

- N policies
  - /irtual Switching Instance or VSI
  - One or more customer interfaces are connected to VSI
  - One or more PWs for interconnection with related VSI instances on remote PE
- N signaling
  - Full mesh of targeted LDP* (VC exchange) and/or BGP sessions (discovery and VC exc
  - /irtual Connection (VC)-label negotiation, withdrawal, error notification
- N traffic forwarding
  - 1 VC label used for encapsulation + 1 (IGP) label for forwarding
  - nner de-multiplexer (VC) label: identifies VSI
  - Outer tunnel (IGP) label: to get from ingress to egress PE using MPLS LSP
- -CE link
  - Referred to as Attachment Circuit (AC)
  - Ethernet VCs are either port mode or VLAN ID

assumed as signaling protocol for next examples

LS Forwarding Plane Processing

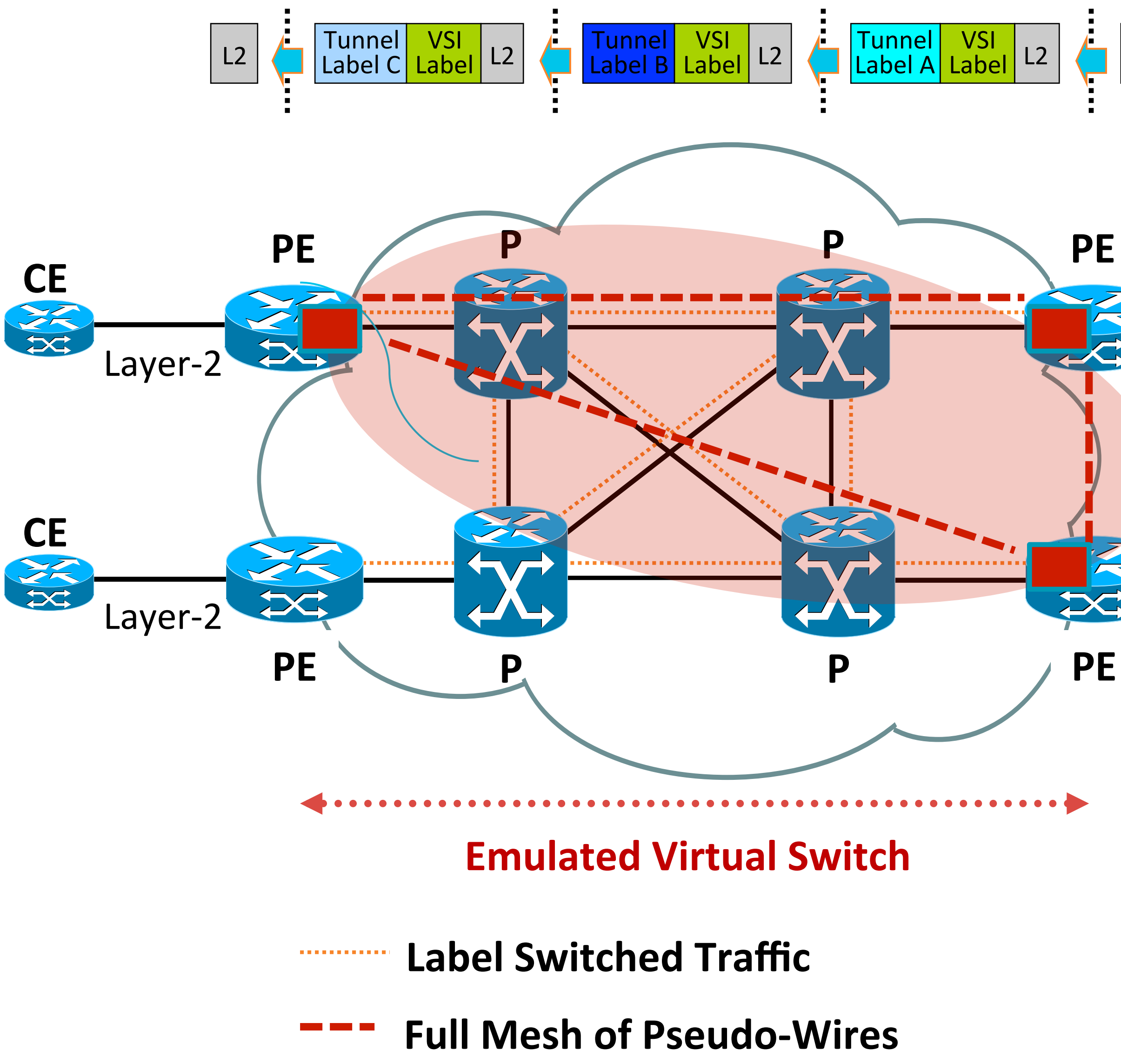
arding of Layer-2 Traffic Over VPLS Network

learning:

- r new L2 packets
- I forwarding table updated
- ckets flooded to all PEs er PWs

-2 Packet Forwarding:

- r L2 packets with known stination MAC addresses
- okup in VSI forwarding le
- packet forwarded onto Vs to remote PE/VSI



rvice Provider Deployment Scenario

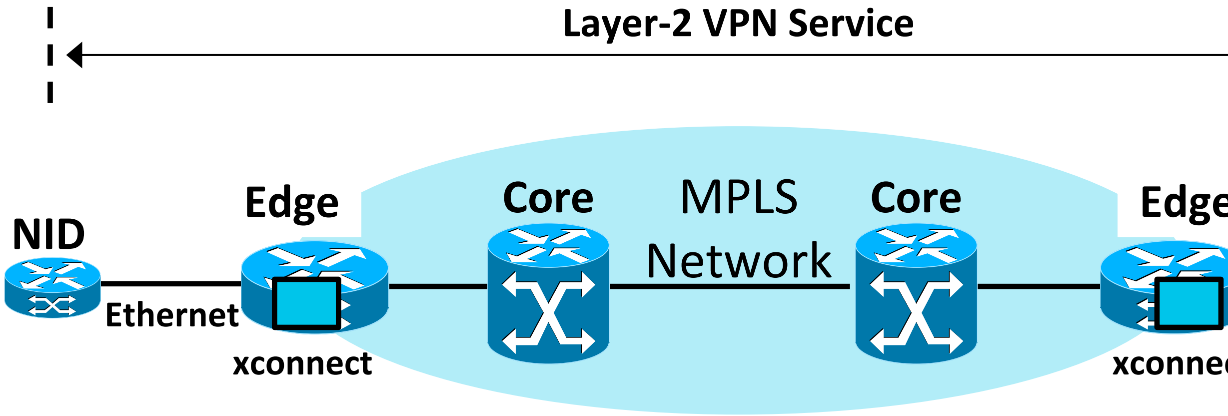
for Offering Layer-2 Business VPN Services

ployment Use Case

Delivery of E-LINE services to business customers

nefits

- Leverage same network for multiple services and customers (CAPEX)
- Highly scalable
- Service enablement only requires edge node configuration (OPEX)



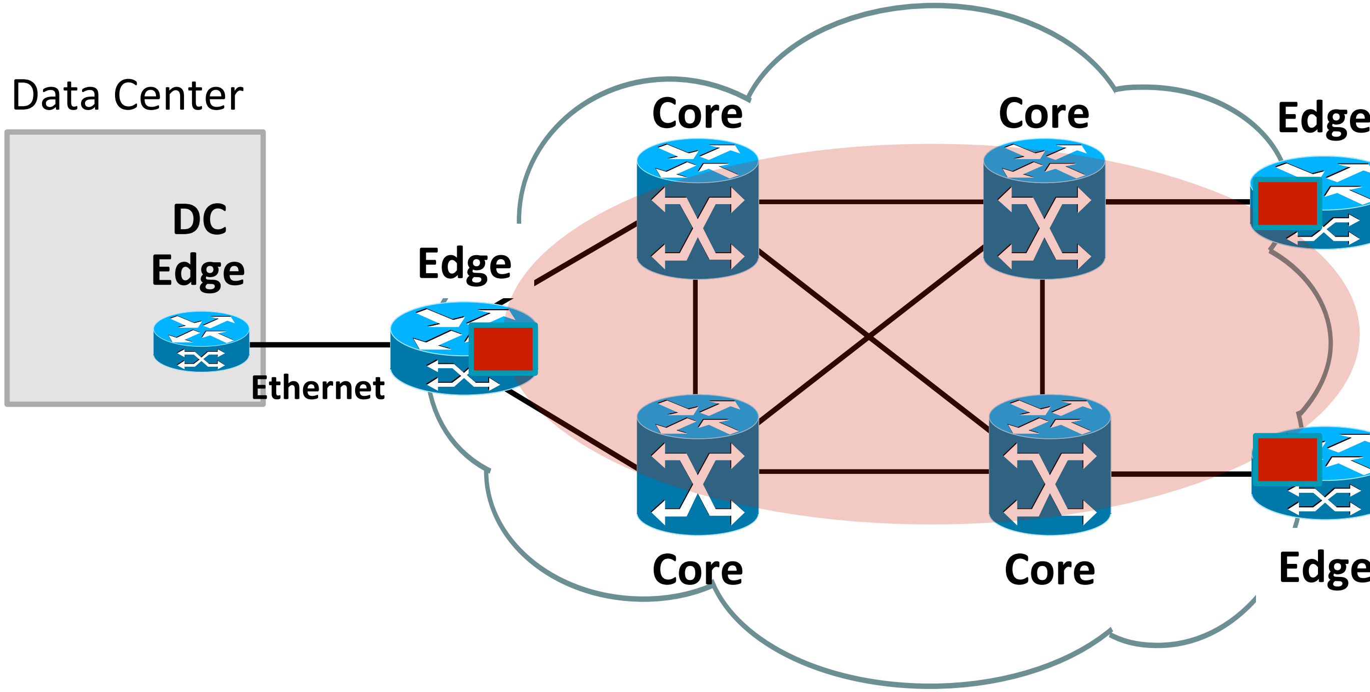
Network Segment	NID *	Edge
MPLS Node	CE	U-PE
Typical Platforms	M3400 ASR901	ME3800X ASR903 ASR9K

* NID : Network Interface Device

ta Center Deployment Scenario

S for Layer-2 Data Center Interconnect (DCI) Services

- ployment Use Case
  - E-LAN services for Data Center interconnect
- nefits
  - Single WAN uplink to connect to multiple Data Centers
  - Easy implementation of segmented layer-2 traffic between Data Centers



Network Segment	DC Edge	Core
MPLS Node	CE	P
Typical Platforms	ASR9K 7600 6500	CRS-1 GSR ASR9K

mmary

Takeaways

- VPNs enable transport of any Layer-2 traffic over MPLS net
- packets encapsulated into additional VC label
- th LDP and BGP can be used L2VPN signaling
- Vs suited for implementing transparent point-to-point connec tween Layer-2 circuits (E-LINE services)
- PLS suited for implementing transparent point-to-multipoint c tween Ethernet links/sites (E-LAN services)
- pical applications of L2VPNs are layer-2 business VPN serv ta Center interconnect

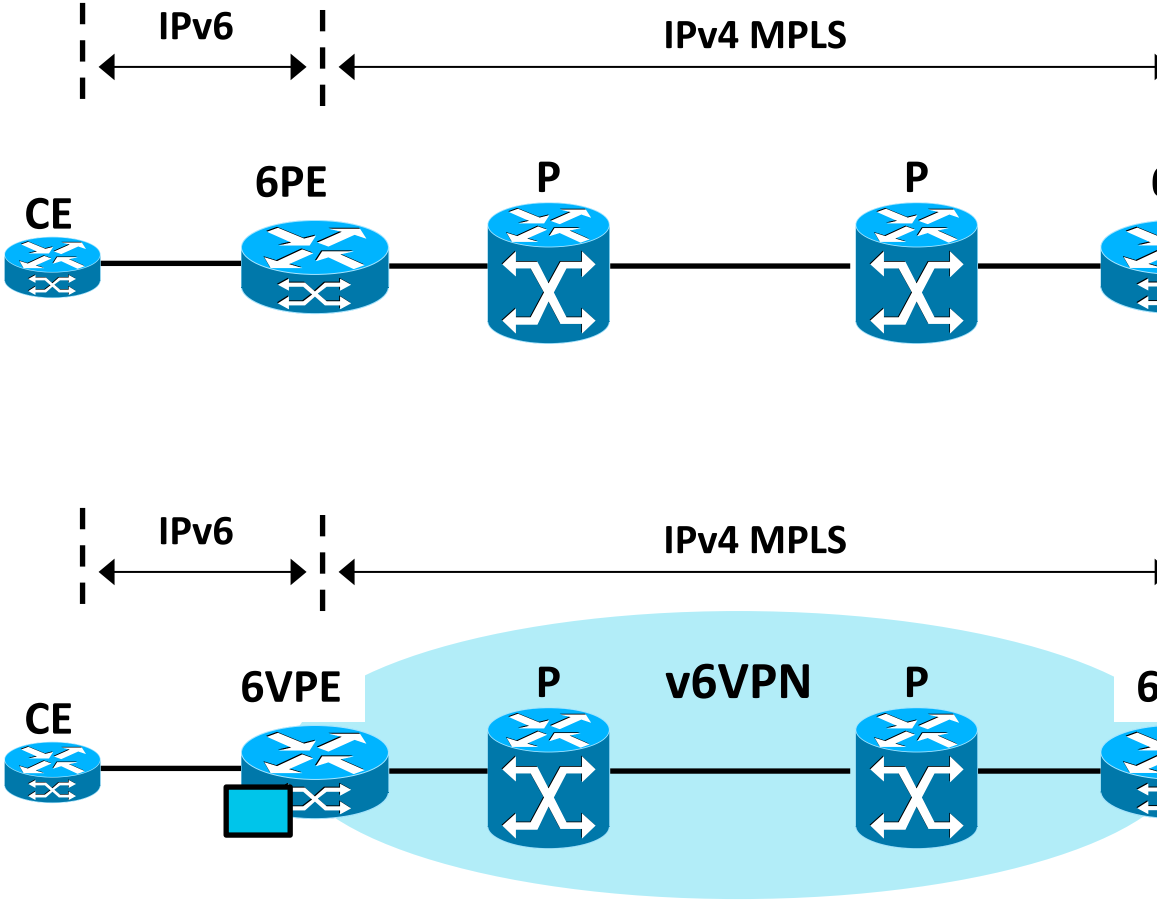
vanced Topics

MPLS Technology Developments, Trends, and Futures

PLS And IPv6

Support for Native MPLS Deployments and MPLS Layer-3 Serv

- v6 traffic carried over IPv4 PLS network
- capsulation of IPv6 into v4 LSP (6PE)
- capsulation of IPv6 into PLS layer-3 VPN (6VPE)
- Translation of IPv6 to IPv4 at PE edge

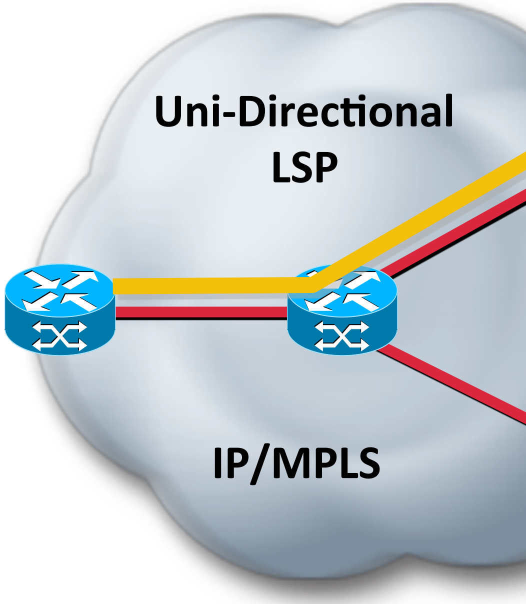


bel Switched Multicast (LSM)

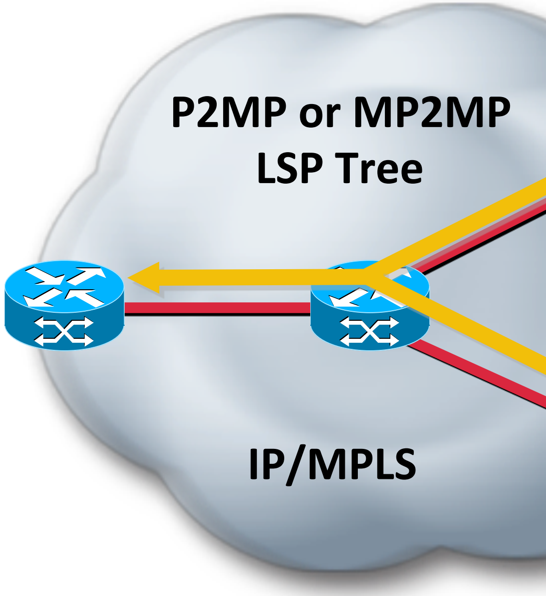
t-to-Multi-Point MPLS Signaling and Connectivity

- at is Label Switched Multicast?
  - MPLS extensions to provide P2MP connectivity
  - RSVP extensions and multicast LDP
- y Label-Switched Multicast?
  - Enables MPLS capabilities, which can not be applied to IP multicast traffic (e.g., FRR)
- nefits of Label-Switched lticast
  - Efficient IP multicast traffic forwarding
  - Enables MPLS traffic protection and BW control of IP multicast traffic

MPLS / IP



Label Switched Multicast (LSM)



LS Transport Profile (TP)

rectional MPLS Tunnel Extensions For Transport Oriented Conn

at is MPLS TP?

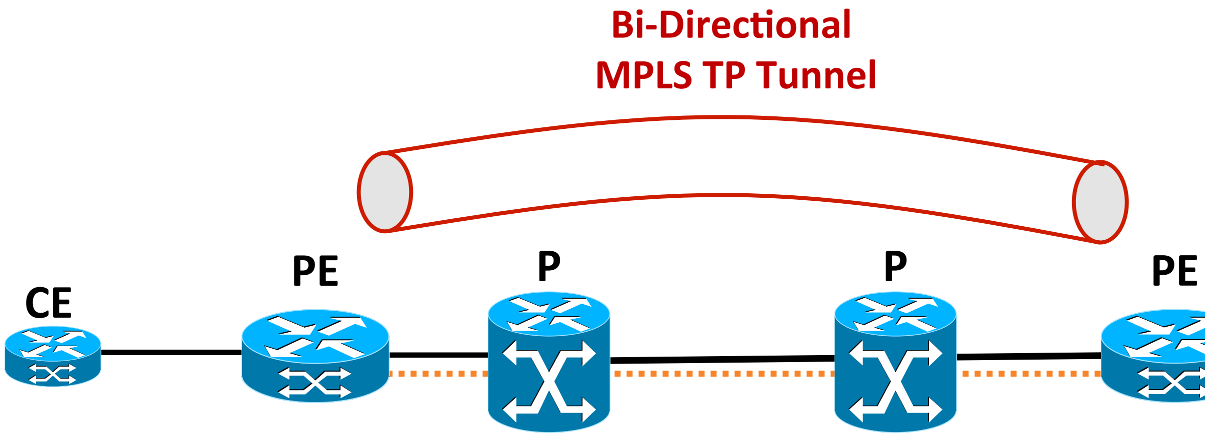
- Point-to-point static LSPs which are co-routed
- Bi-directional TP tunnel

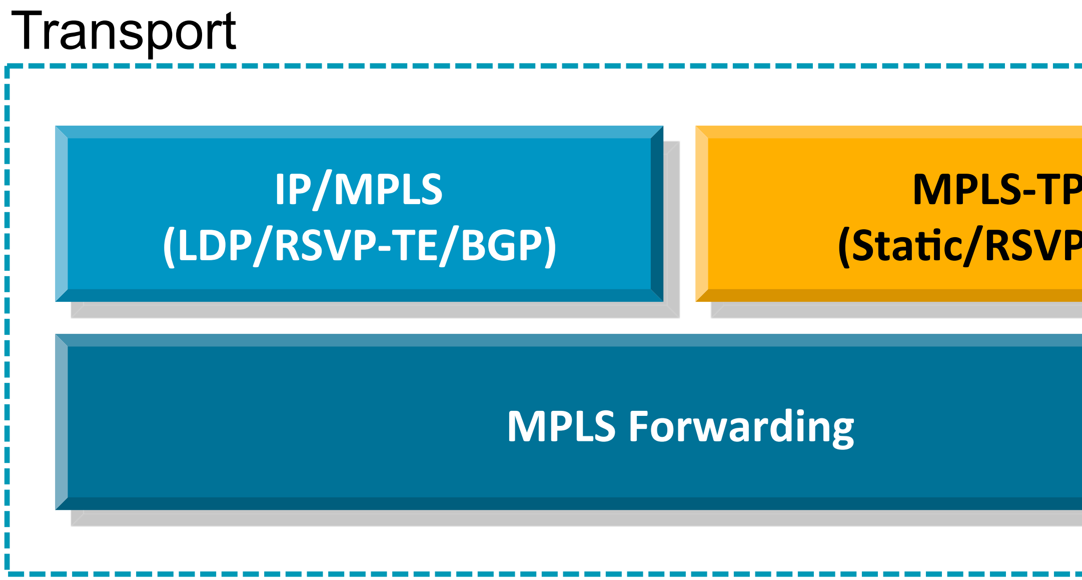
y MPLS TP?

- Migration of TDM legacy networks often assume continuation of connection-oriented operations model
- MPLS TP enables packet-based transport with connection-oriented connectivity

efits of MPLS TP

- Meets transport-oriented operations requirements
- Enables seamless migration to dynamic MPLS




Transport

IP/MPLS
(LDP/RSVP-TE/BGP)

MPLS-TP
(Static/RSVP

MPLS Forwarding

tures

MPLS Developments on the Horizon

MPLS and Cloud Integration

VPN Data Center Integration

MPLS Transport Evolution

MPLS TP and GMPLS Integration

nmary

lotes and Wrap Up

mmary

Takeaways

- all about labels …
  - Label-based forwarding and protocol for label exchange
  - Best of both worlds … L2 deterministic forwarding and scale/flexible L3 sig
- y MPLS applications are end-to-end VPN services
  - Secure and scalable layer 2 and 3 VPN connectivity
- PLS supports advanced traffic engineering capabilities
  - QoS, bandwidth control, and failure protection
- PLS is a mature technology with widespread deployments
  - Defacto for most SPs, large enterprises, and increasingly in Data Centers
- ngoing technology evolution
  - Pv6, optimized video transport, TP transport evolution, and cloud integrat

nsider MPLS When …

sion Criteria

- there a need for network segmentation?
  - Segmented connectivity for specific locations, users, applications, etc.
- there a need for flexible connectivity?
  - E.g., Flexible configuration of full-mesh or hub-and-spoke connectivity
- there a need for implementing/supporting multiple (integrated) s
  - Leverage same network for multiple services
- e there specific scale requirements?
  - Large number of users, customer routes, etc.
- there a need for optimized network availability and performance
  - Node/link protection, pro-active connectivity validation
  - Bandwidth traffic engineering and QoS traffic prioritization

rminology Reference

nyms Used in MPLS Reference Architecture

inology	Description
	Attachment Circuit. An AC Is a Point-to-Point, Layer 2 Circuit Between a CE and a PE.
	Autonomous System (a Domain)
	Class of Service
	Equal Cost Multipath
	Interior Gateway Protocol
	Local Area Network
	Label Distribution Protocol, RFC 3036.
	Label Edge Router. An Edge LSR Interconnects MPLS and non-MPLS Domains.
	Labeled Forwarding Information Base
	Label Switched Path
	Label Switching Router
	Network Layer Reachability Information
er	An Interior LSR in the Service Provider's Autonomous System
uter	An LER in the Service Provider Administrative Domain that Interconnects the Customer Network and th
unnel	Packet Switching Tunnel

rminology Reference

nyms Used in MPLS Reference Architecture

inology	Description
-Wire	A Pseudo-Wire Is a Bidirectional “Tunnel" Between Two Features on a Switching Path.
	Pseudo-Wire End-to-End Emulation
	Quality of Service
	Route Distinguisher
	Routing Information Base
	Route Reflector
	Route Target
TE	Resource Reservation Protocol based Traffic Engineering
	Virtual Private Network
	Virtual Forwarding Instance
	Virtual Local Area Network
	Virtual Private LAN Service
	Virtual Private WAN Service
	Virtual Route Forwarding Instance
	Virtual Switching Instance

rther Reading

S References at Cisco Press and cisco.com

- p://www.cisco.com/go/mpls
- p://www.ciscopress.com
- PLS and VPN Architectures — Cisco Press®
  - Jim Guichard, Ivan Papelnjak
- affic Engineering with MPLS — Cisco Press®
  - Eric Osborne, Ajay Simha
- yer 2 VPN Architectures — Cisco Press®
  - Wei Luo, Carlos Pignataro, Dmitry Bokotey, and Anthony Chan
- PLS QoS — Cisco Press ®
  - Santiago Alvarez

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