# Introduction to MPLS

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BUILT FOR THE HUMAN NETWORK

# Session Goals

## Objectives

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

# Agenda

## Topics

- Introduction
- MPLS Technology Basics
- MPLS Layer-3 VPNs
- MPLS Layer-2 VPNs
- Advanced Topics
- Summary

# Introduction

# What is MPLS?

## Brief Summary

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

# Technology Comparison

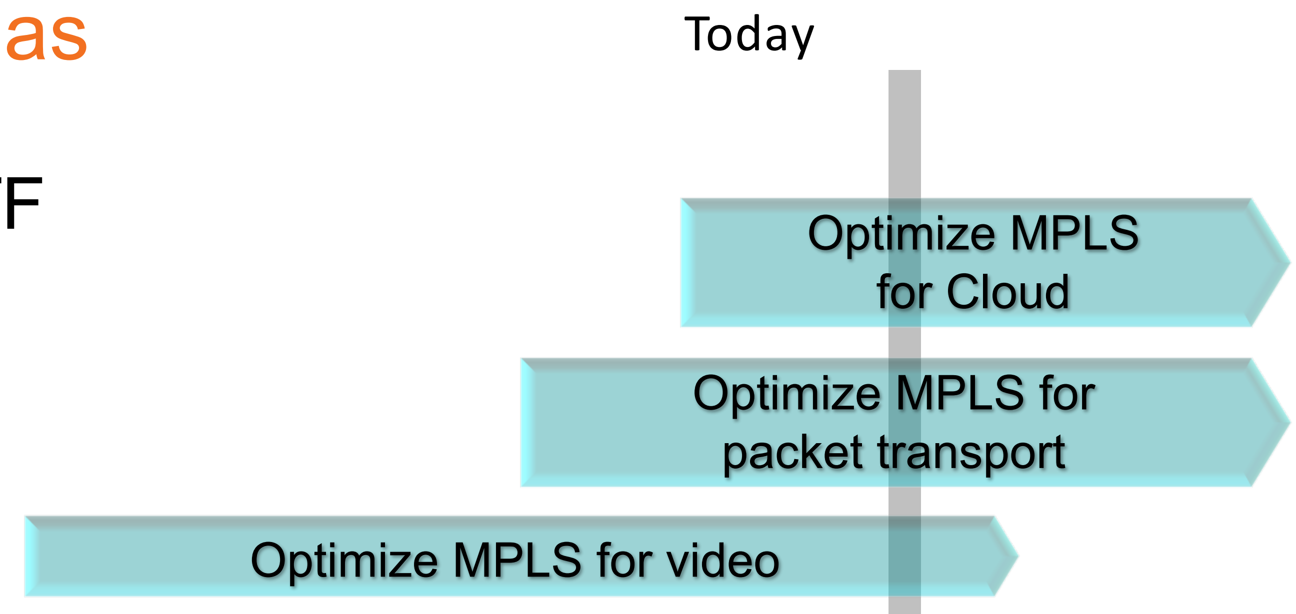
## Key Characteristics of IP, Native Ethernet, and MPLS

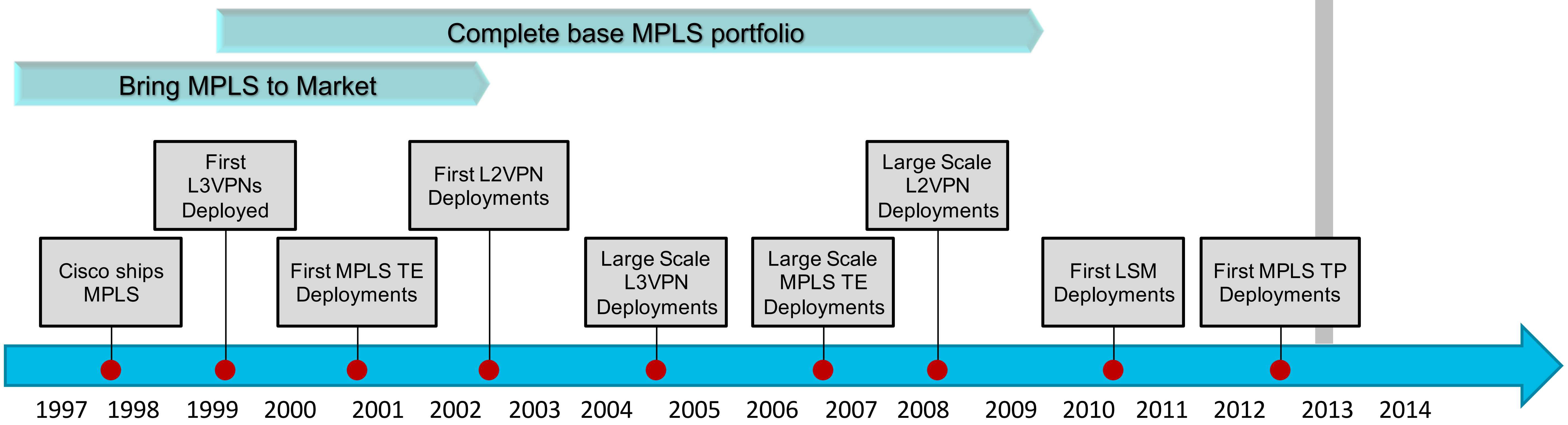
| | IP | Native Ethernet | MPLS |
|---|---|---|---|
| **Forwarding** | Destination address based<br>Forwarding table learned from control plane<br>TTL support | Destination address based<br>Forwarding table learned from data plane<br>No TTL support | Label based<br>Forwarding table learned from control plane<br>TTL support |
| **Control Plane** | Routing Protocols | Ethernet Loop avoidance and signaling protocols | Routing Protocols<br>MPLS protocols |
| **Packet Encapsulation** | IP Header | 802.3 Header | MPLS shim header |
| **QoS** | 8 bit TOS field in IP header | 3-bit 802.1p field in VLAN tag | 3 bit TC field in label |
| **OAM** | IP ping, traceroute | E-OAM | MPLS OAM |

# Evolution of MPLS

## Technology Evolution and Main Growth Areas

- Evolved from tag switching in 1996 to full IETF standard, covering over 130 RFCs
- Key application initially were Layer-3 VPNs, followed by Traffic Engineering (TE), and Layer-2 VPNs



# Market Segments

## MPLS Business Drivers and Typical Deployment Characteristics

| | Business Drivers | Business Goals | MPLS Capabilities |
|---|---|---|---|
| Service Provider | • Networking service reliability<br>• Cost effective service bandwidth<br>• Flexible enablement of existing and new services | • Leverage single network for scalable delivery of multiple services<br>• Optimize network capacity to meet current and future growth of service bandwidth<br>• Deliver premium services with guaranteed SLAs | Layer-3 VPN<br>Layer-2 VPN<br>MPLS TE<br>MPLS OAM, QoS |
| Enterprise | • Mergers and acquisitions<br>• Network consolidation<br>• Shared services<br>• Compliance | • Network Segmentation<br>• Network integration | Layer-3 VPN |
| Data Center | • Multi-tenant hosting<br>• Data Center Interconnect | • Leverage single data center infrastructure for multiple users and services<br>• Deliver geographic independent services from any data center | Layer-2 VPN<br>Layer-3 VPN |

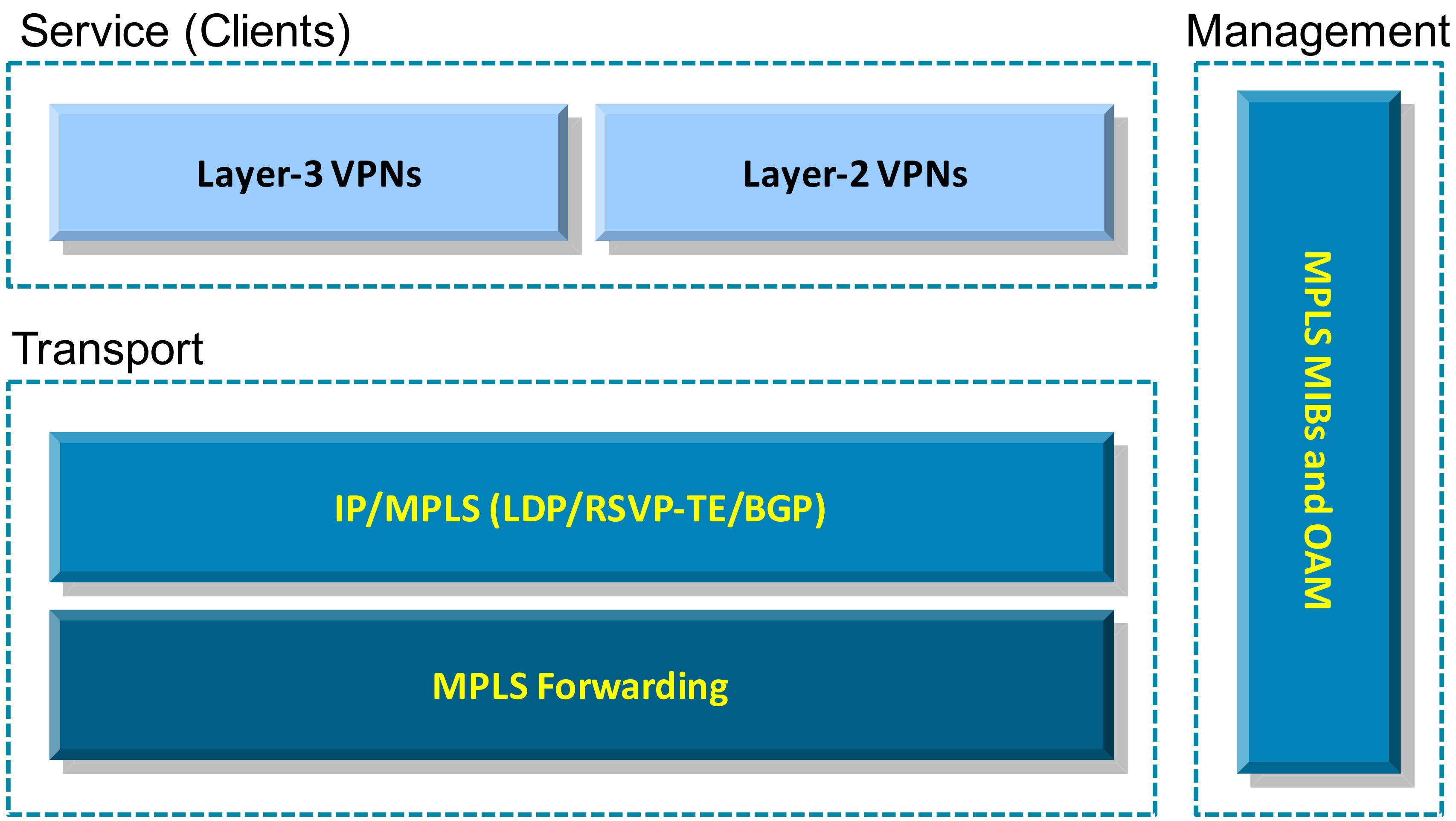
# MPLS Technology Basics

## Technology Building Blocks of MPLS

# Topics

## Basics of MPLS Signaling and Forwarding

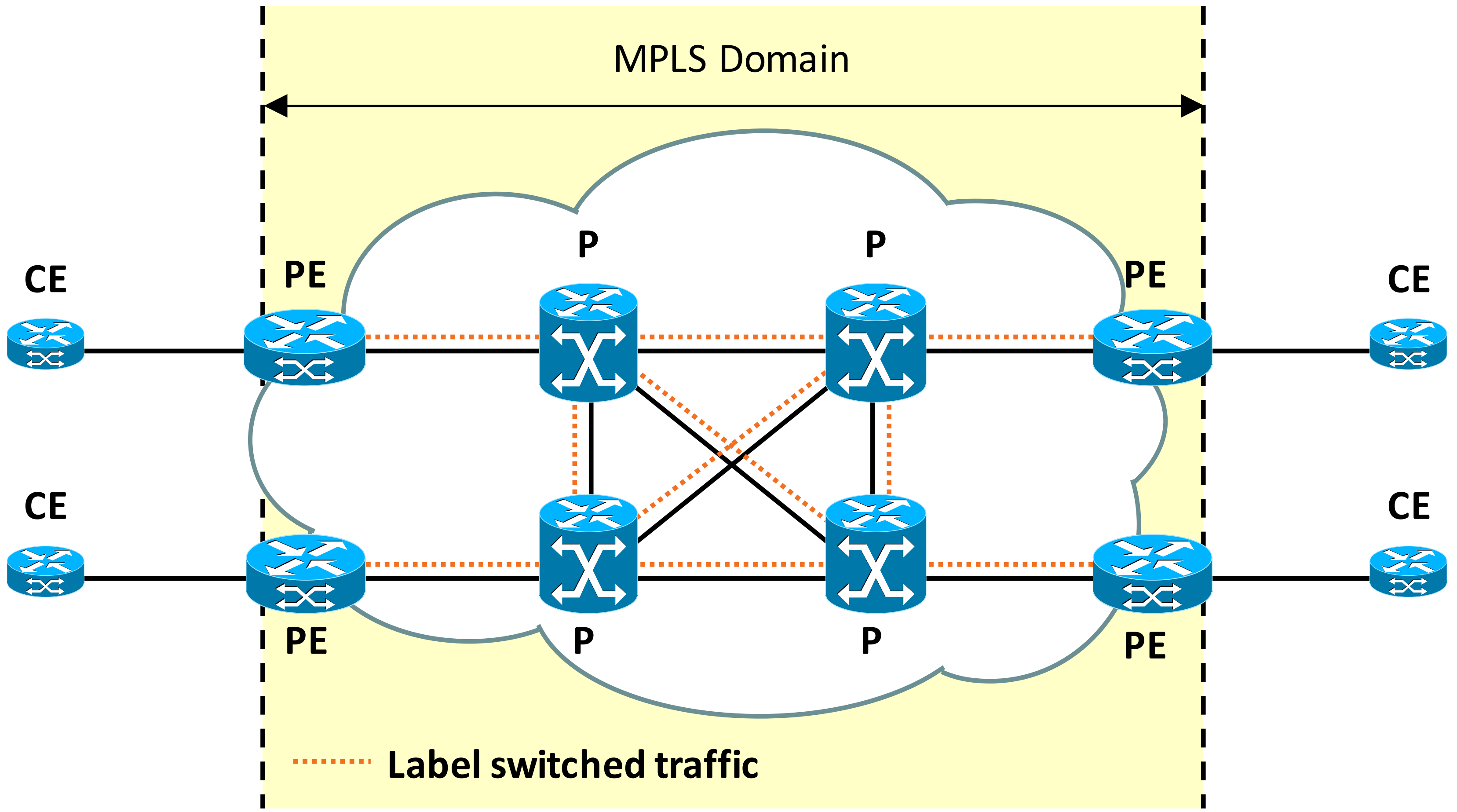
- MPLS reference architecture
- MPLS Labels
- MPLS signaling and forwarding operations
- MPLS Traffic Engineering
- MPLS OAM and MIBs



# MPLS Reference Architecture

## Different Type of Nodes in a MPLS Network

- P (Provider) router
  - – Label switching router (LSR)
  - – Switches MPLS-labeled packets
- PE (Provider Edge) router
  - – Edge router (LER)
  - – Imposes and removes MPLS labels
- CE (Customer Edge) router
  - – Connects customer network to MPLS network

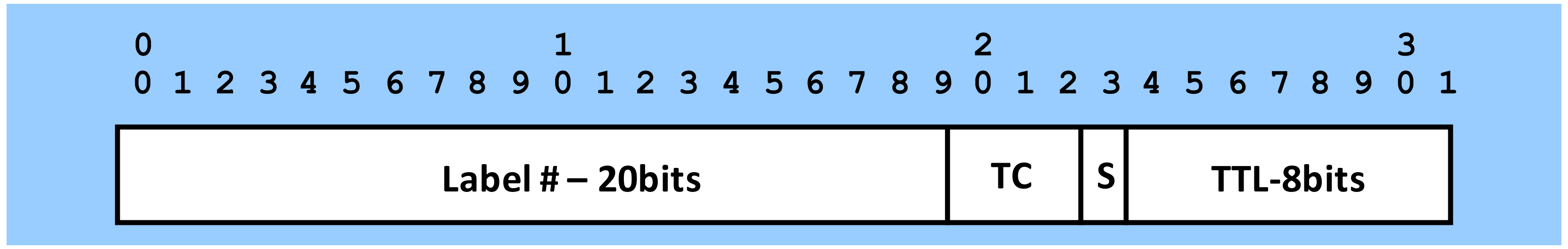


# MPLS Shim Labels

## Label Definition and Encapsulation

- Labels used for making forwarding decision
- Multiple labels can be used for MPLS packet encapsulation
  - Creation of a label stack
- Outer label always used for switching MPLS packets in network
- Remaining inner labels used to specific services (e.g., VPNs)

**MPLS Label**




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

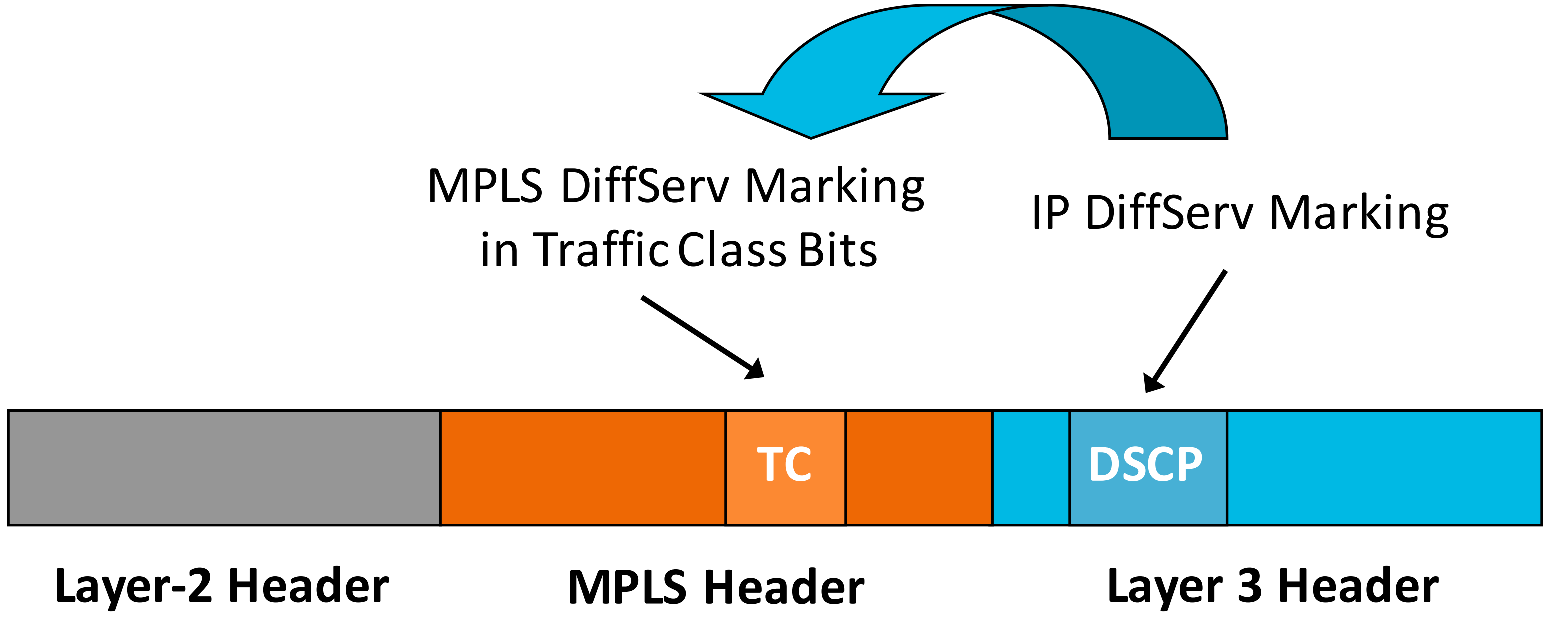
**MPLS Label Encapsulation**


**MPLS Label Stack**

# MPLS QoS

## QoS Marking in MPLS Labels

- MPLS label contains 3 TC bits
- Used for packet classification and prioritization
  - Similar to Type of Service (ToS) field in IP packet (DSCP values)
- DSCP values of IP packet mapped into TC bits of MPLS label
  - At ingress PE router
- Most providers have defined 3–5 service classes (TC values)
- Different DSCP <-> TC mapping schemes possible
  - Uniform mode, pipe mode, and short pipe mode

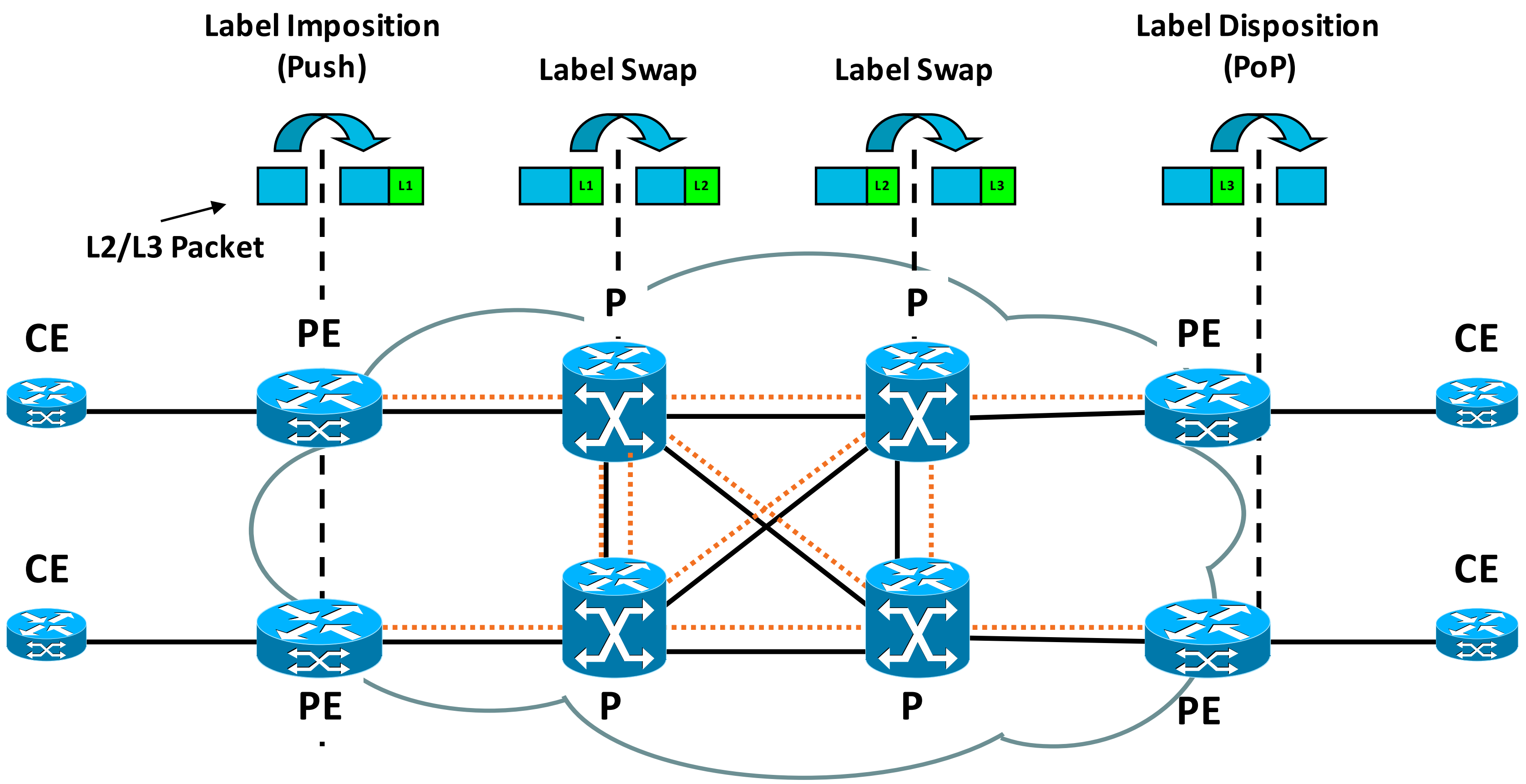


# Basic MPLS Forwarding Operations

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

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



# MPLS Path (LSP) Setup and Traffic Forwarding

## MPLS Traffic Forwarding and MPLS Path (LSP) Setup

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

| | IP | MPLS |
|---|---|---|
| **Forwarding** | Destination address based<br>Forwarding table learned from control plane<br>TTL support | Label based<br>Forwarding table learned from control plane<br>TTL support |
| **Control Plane** | OSPF, IS-IS, BGP | OSPF, IS-IS, BGP<br>LDP, RSVP |
| **Packet Encapsulation** | IP Header | One or more labels |
| **QoS** | 8 bit TOS field in IP header | 3 bit TC field in label |
| **OAM** | IP ping, traceroute | MPLS OAM |

* LDP signaling assumed for next the examples

# MPLS Path (LSP) Setup

## Signaling Options

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

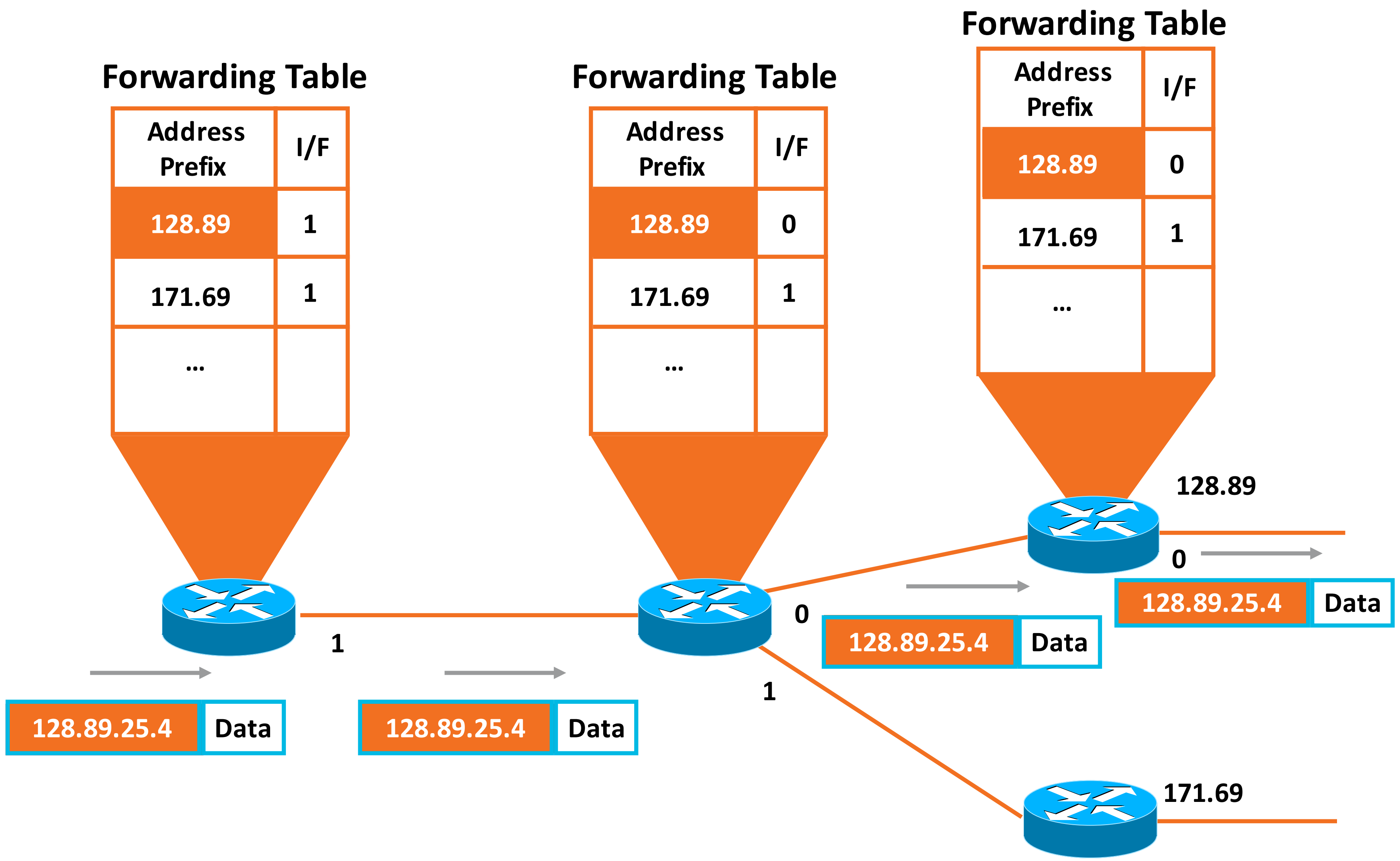
| | LDP | RSVP |
|---|---|---|
| **Forwarding path** | LSP | LSP or TE Tunnel<br>Primary and, optionally, backup |
| **Forwarding Calculation** | Based on IP routing database<br>Shortest-Path based | Based on TE topology database<br>Shortest-path and/or other constraints<br>(CSPF calculation) |
| **Packet Encapsulation** | Single label | One or two labels |
| **Signaling** | By each node independently<br>Uses existing routing protocols/information | Initiated by head-end node towards tail-end node<br>Uses routing protocol extensions/information<br>Supports bandwidth reservation<br>Supports link/node protection |

# IP Packet Forwarding Example

## Basic IP Packet Forwarding

- IP routing information exchanged between nodes
  – Via IGP (e.g., OSFP, IS-IS)
- Packets being forwarded based on destination IP address
  – Lookup in routing table (RIB)



# MPLS Path (LSP) Setup

## Step 1: IP Routing (IGP) Convergence

- Exchange of IP routes
  – OSPF, IS-IS, EIGRP, etc.
- Establish IP reachability

Forwarding Table

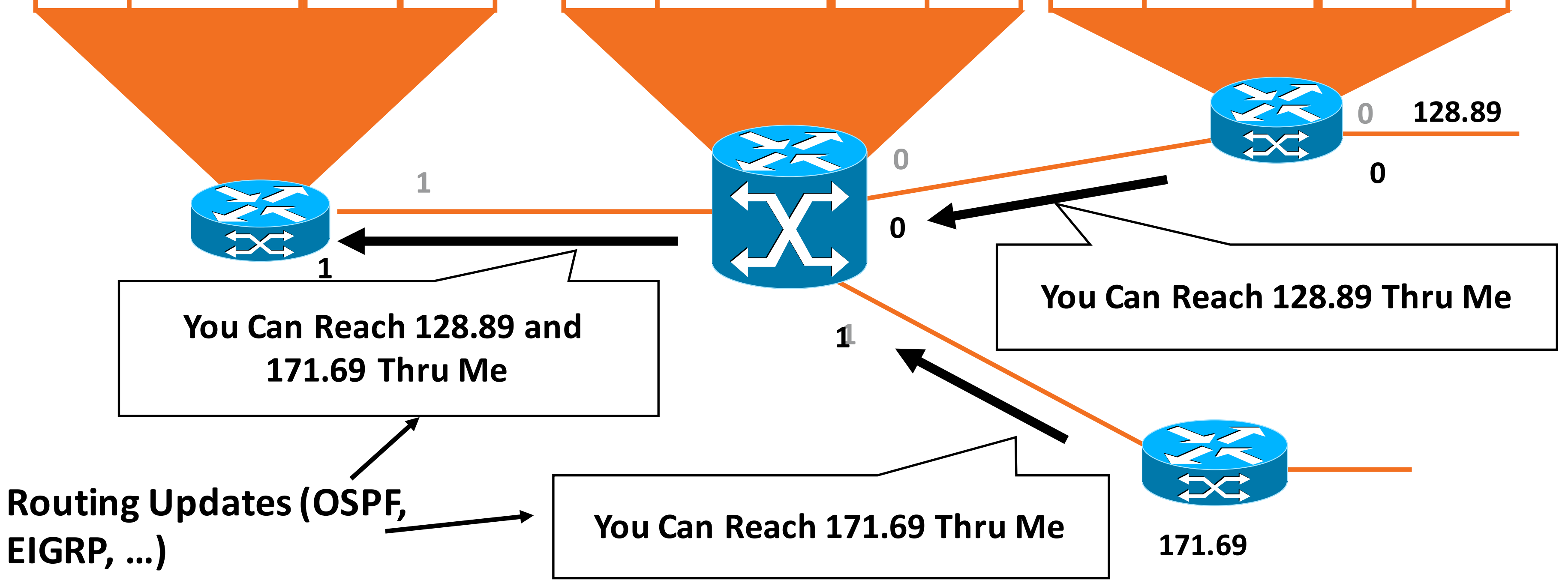
| In Label | Address Prefix | Out I'face | Out Label |
|---|---|---|---|
| | 128.89 | 1 | |
| | 171.69 | 1 | |
| | ... | ... | |

Forwarding Table

| In Label | Address Prefix | Out I'face | Out Label |
|---|---|---|---|
| | 128.89 | 0 | |
| | 171.69 | 1 | |
| | ... | ... | |

Forwarding Table

| In Label | Address Prefix | Out I'face | Out Label |
|---|---|---|---|
| | 128.89 | 0 | |
| | | | |
| | ... | ... | |



# MPLS Path (LSP) Setup

## Step 2A: Assignment of Local Labels

- Each MPLS node assigns a local label to each route in local routing table
  - In label

**Forwarding Table**

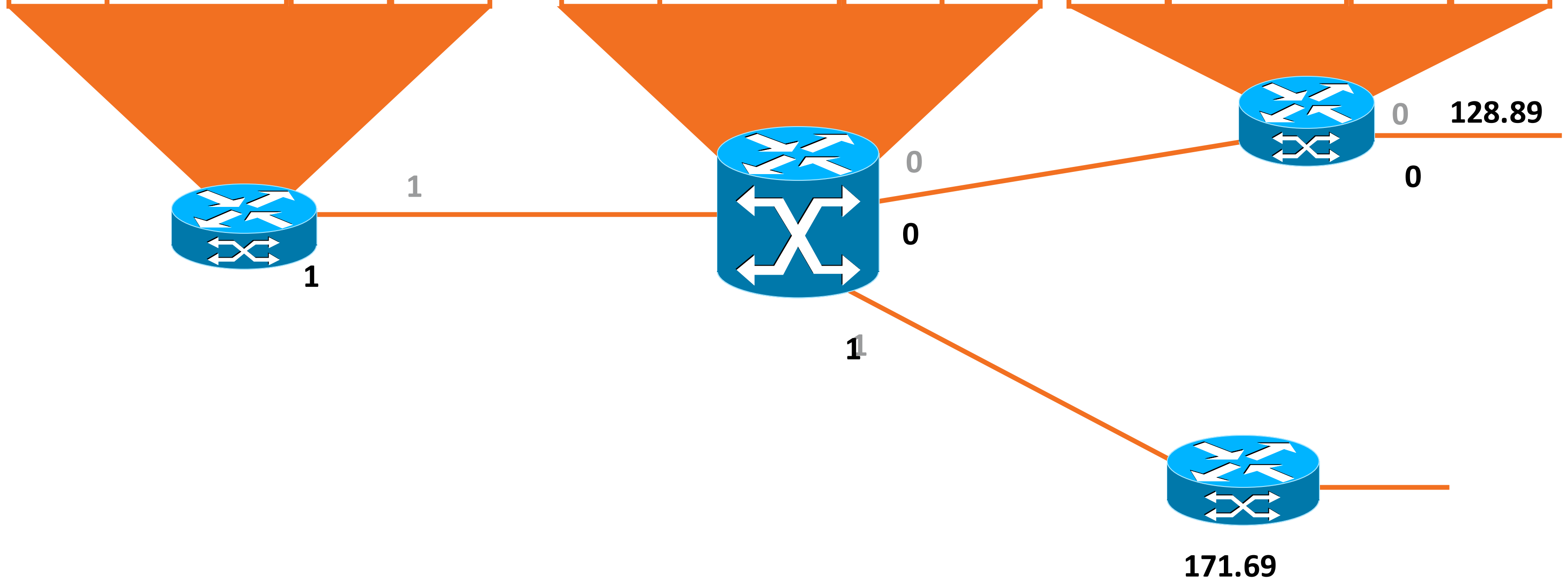
| In Label | Address Prefix | Out I'face | Out Label |
|---|---|---|---|
| - | 128.89 | 1 | |
| - | 171.69 | 1 | |
| ... | ... | ... | ... |

**Forwarding Table**

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

**Forwarding Table**

| In Label | Address Prefix | Out I'face | Out Label |
|---|---|---|---|
| 30 | 128.89 | 0 | - |
| | | | |
| ... | ... | ... | ... |



# MPLS Path (LSP) Setup

## Step 2B: Assignment of Remote Labels

- Local label mapping are sent to connected nodes
- Receiving nodes update forwarding table
  - Out label

**Forwarding Table**

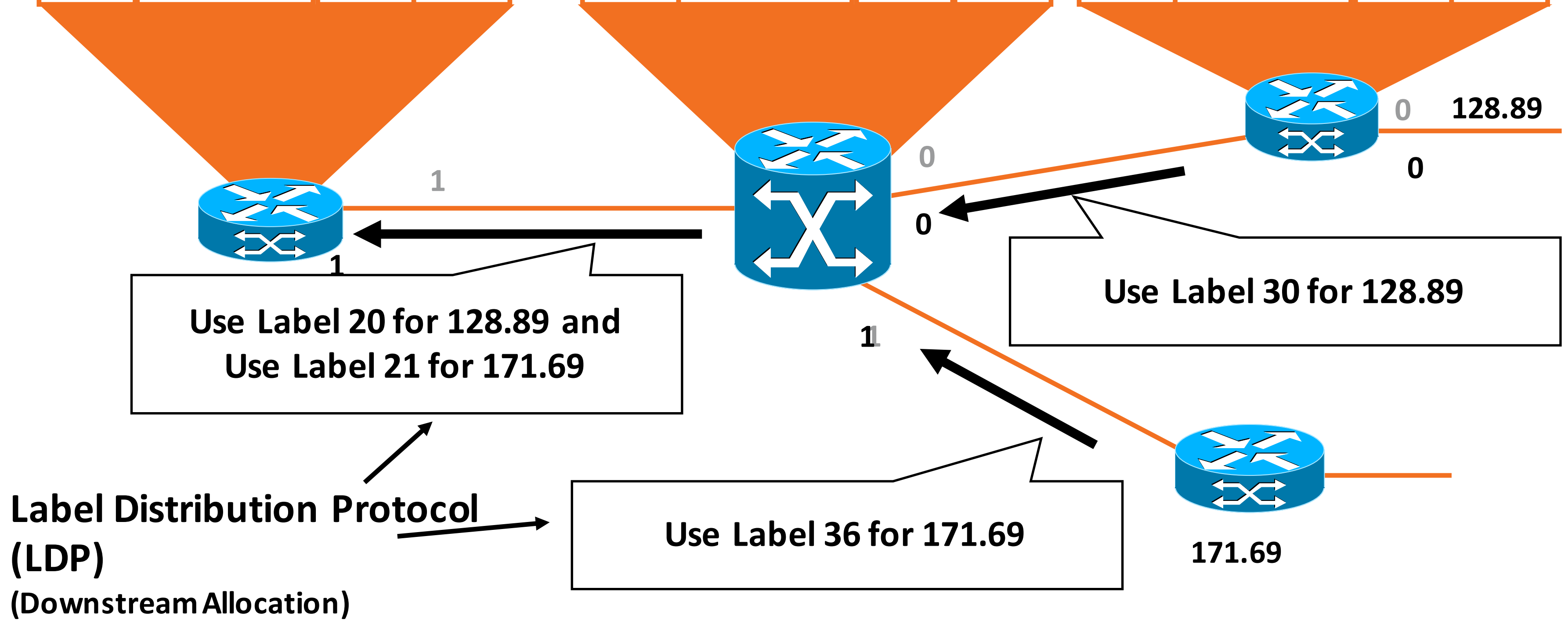
| In Label | Address Prefix | Out I'face | Out Label |
|---|---|---|---|
| - | 128.89 | 1 | 20 |
| - | 171.69 | 1 | 21 |
| … | … | … | … |

**Forwarding Table**

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

**Forwarding Table**

| In Label | Address Prefix | Out I'face | Out Label |
|---|---|---|---|
| 30 | 128.89 | 0 | - |
| | | | |
| … | … | … | … |



# MPLS Traffic Forwarding

## Hop-by-hop Traffic Forwarding Using Labels

- Ingress PE node adds label to packet (push)
  - Via forwarding table
- Downstream node use label for forwarding decision (swap)
  - Outgoing interface
  - Out label
- Egress PE removes label and forwards original packet (pop)

Forwarding Table

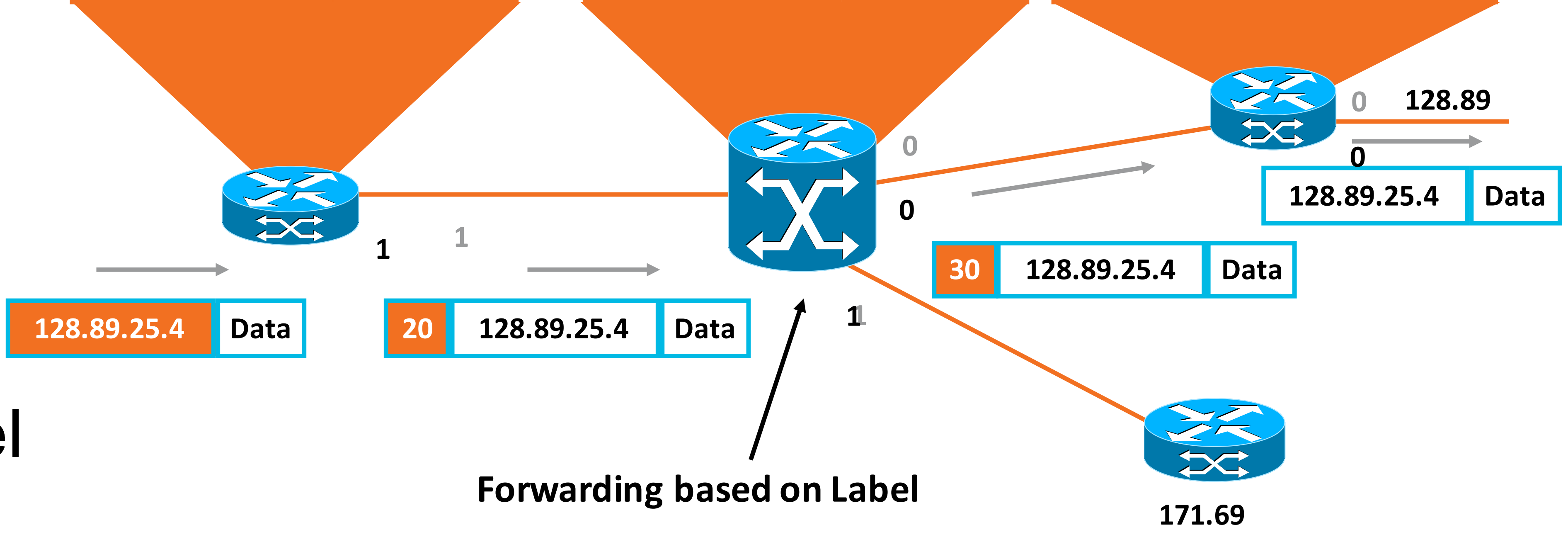
| In Label | Address Prefix | Out I'face | Out Label |
|---|---|---|---|
| - | 128.89 | 1 | 20 |
| - | 171.69 | 1 | 21 |
| … | … | … | … |

Forwarding Table

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

Forwarding Table

| In Label | Address Prefix | Out I'face | Out Label |
|---|---|---|---|
| 30 | 128.89 | 0 | - |
| | | | |
| … | … | … | … |



# MPLS SNMP MIBs

## SNMP Management Access to MPLS Resources

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

# MPLS OAM

## Tools for Reactive and Proactive Trouble Shooting of MPLS Connectivity

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

# Why MPLS QoS

For your reference only

## The Need for Differentiated Services

- Typically different traffic types (packets) sent over MPLS networks
  - E.g., Web HTTP, VoIP, FTP, etc.
- Not all traffic types/flows have the same performance requirements …
  - Some require low latency to work correctly; e.g., video
- MPLS QoS used for traffic prioritization to guarantee minimal traffic loss and delay for high priority traffic
  - Involves packet classification and queuing
- MPLS leverages mostly existing IP QoS architecture
  - Based on Differentiated Services (DiffServ) model; defines per-hop behavior based on IP Type of Service (ToS) field

# Summary

## Key Takeaways

- MPLS networks consist of PE routers at in/egress and P routers in core
- Traffic is encapsulated with label(s) at ingress (PE router)
- Labels are removed at egress (PE router)
- MPLS forwarding operations include label imposition (PUSH), swapping, and disposition (POP)
- LDP and RSVP can be used for signaling label mapping information to set up an end-to-end Label Switched Path (LSP)
- RSVP label signaling enables setup of TE tunnels, supporting enhanced traffic engineering capabilities; traffic protection and path management
- MPLS OAM and MIBs can be used for MPLS connectivity validation and troubleshooting

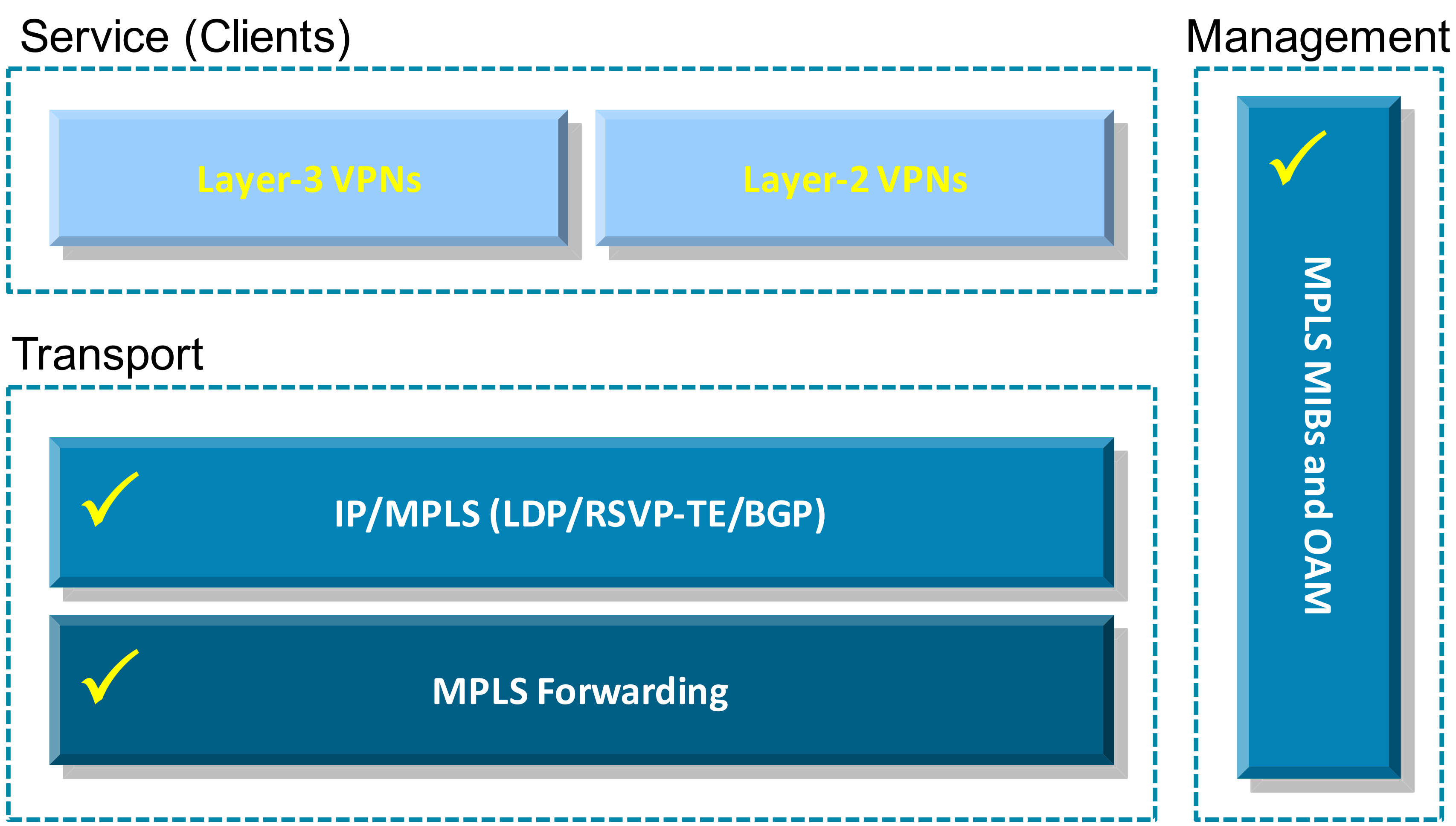
# MPLS Virtual Private Networks

## Technology Overview

# MPLS Virtual Private Networks

## Topics

- Definition of MPLS VPN service
- Basic MPLS VPN deployment scenario
- Technology options



# What Is a Virtual Private Network?

## Definition

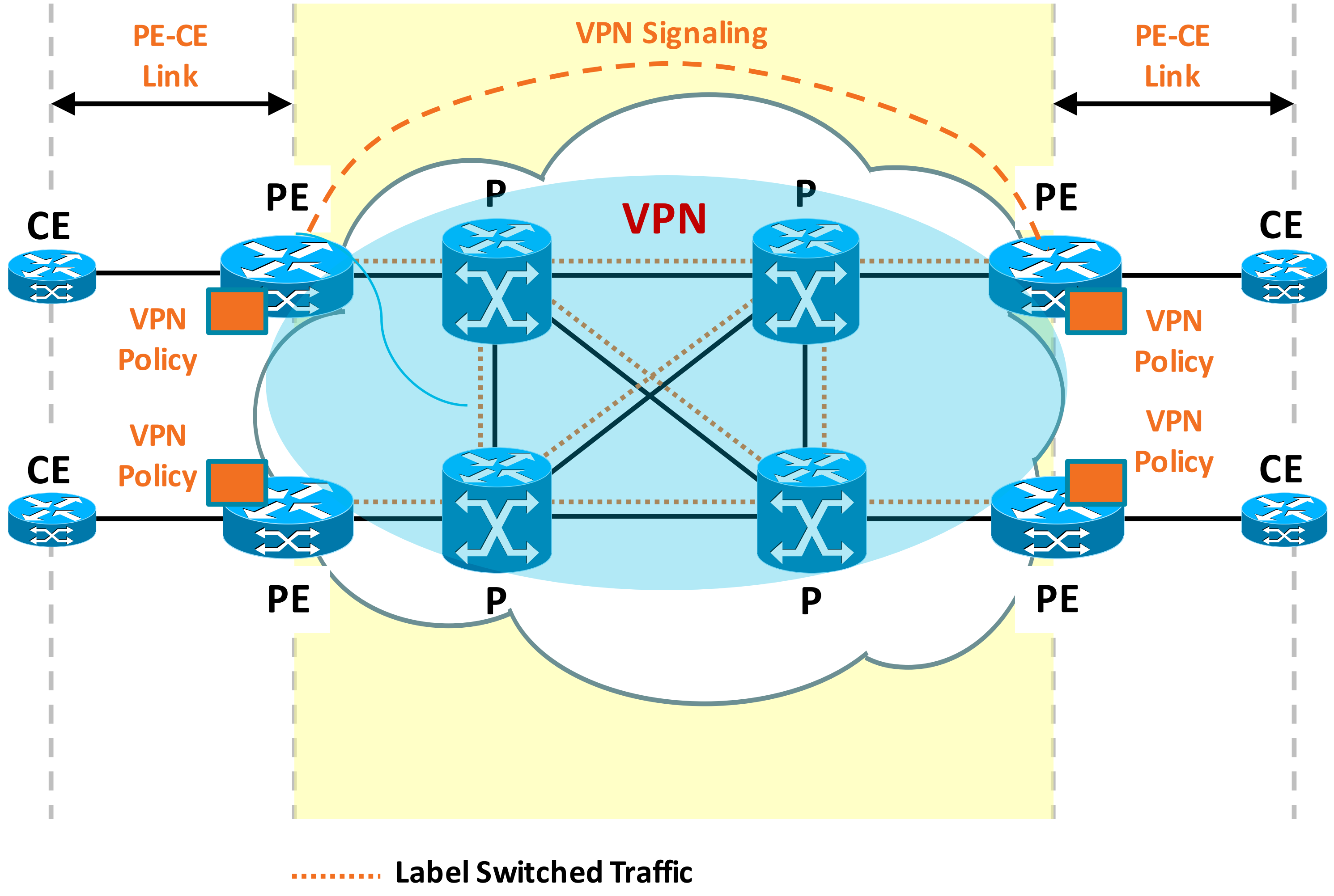
- Set of sites which communicate with each other in a secure way
  - Typically over a shared public or private network infrastructure
- Defined by a set of administrative policies
  - Policies established by VPN customers themselves (DIY)
  - Policies implemented by VPN service provider (managed/unmanaged)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

# MPLS VPN Example

## Basic Building Blocks

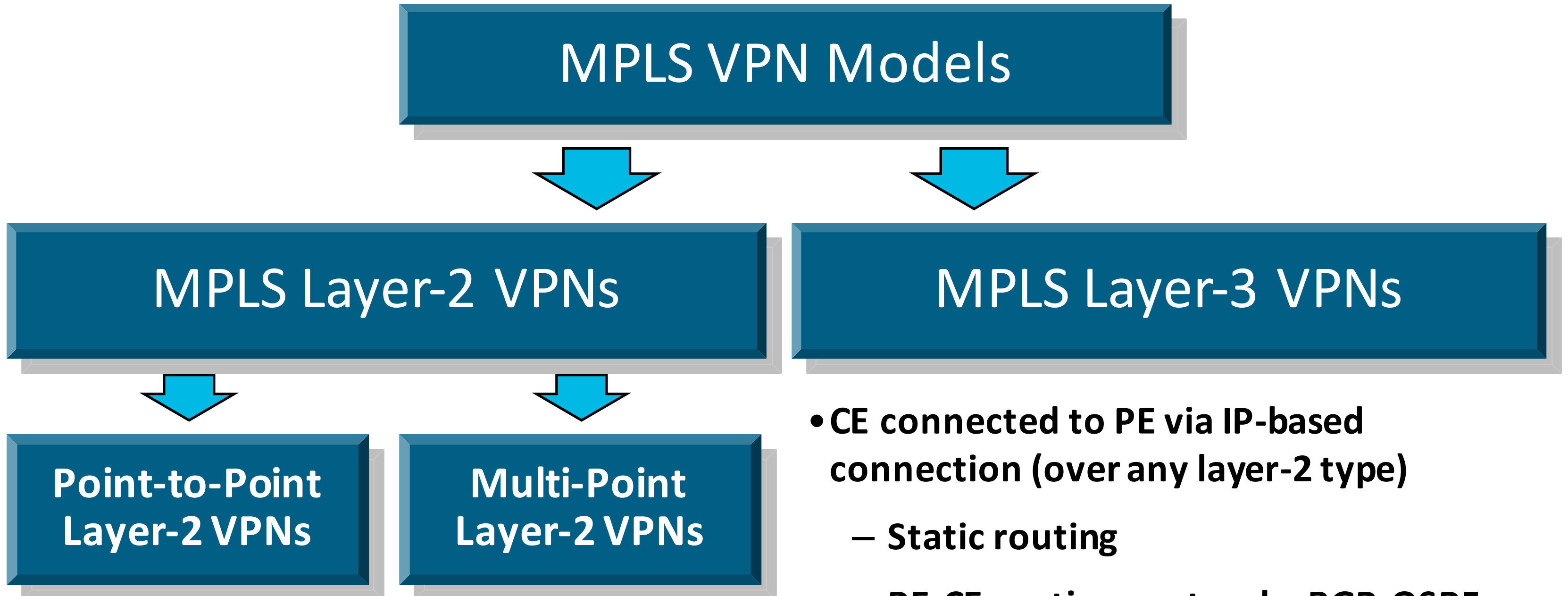
- VPN policies
  – Configured on PE routers (manual operation)
- VPN signaling
  – Between PEs
  – Exchange of VPN policies
- VPN traffic forwarding
  – Additional VPN-related MPLS label encapsulation
- PE-CE link
  – Connects customer network to MPLS network; either layer-2 or layer-3



# MPLS VPN Models

## Technology Options

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




**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**

**MPLS Layer-3 VPNs**

- **CE connected to PE via IP-based connection (over any layer-2 type)**
  - **Static routing**
  - **PE-CE routing protocol; eBGP, OSPF, IS-IS**
- **CE routing has peering relationship with PE router; PE routers are part of customer routing**
- **PE routers maintain customer-specific routing tables and exchange customer=specific routing information**

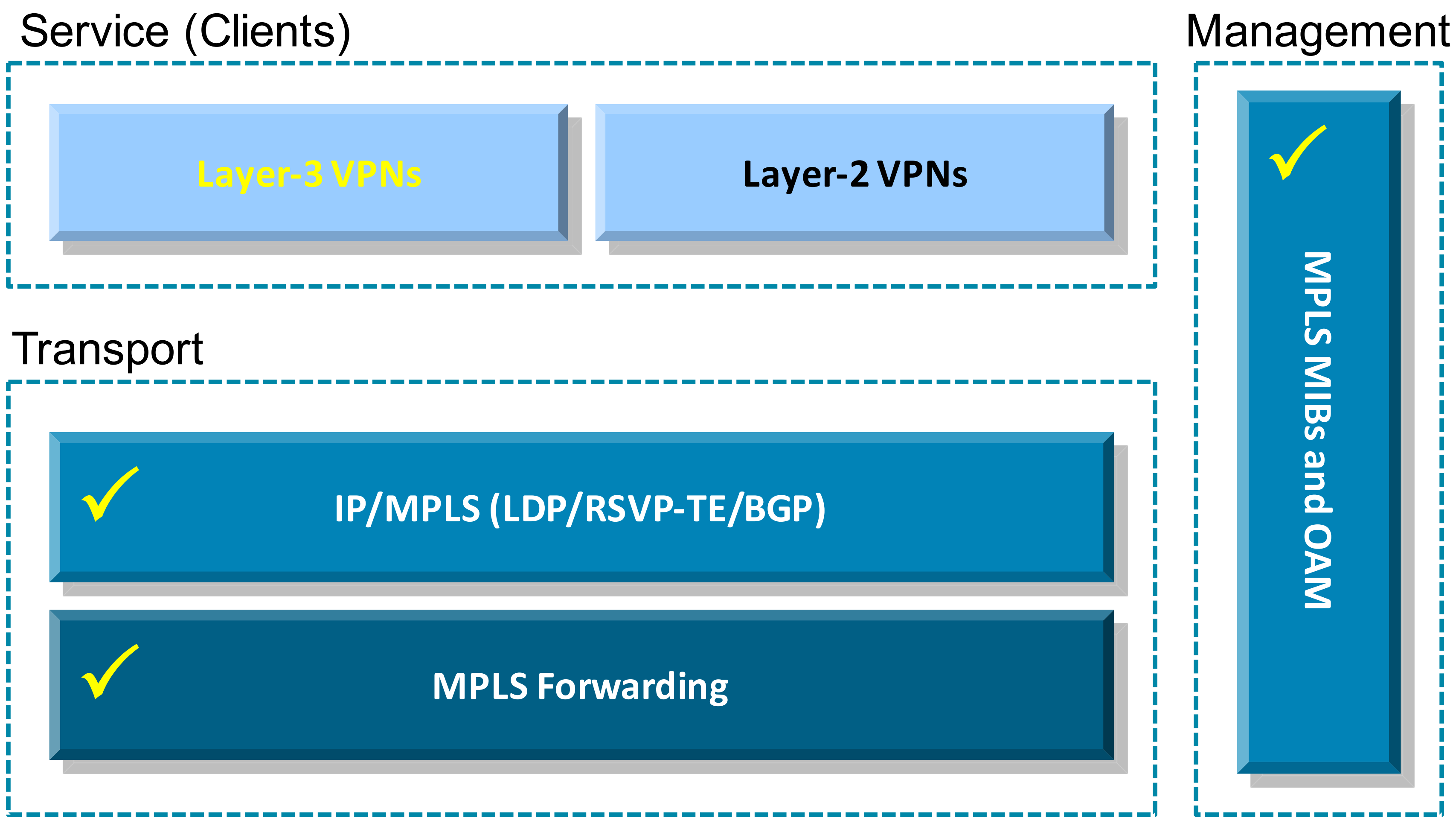
# MPLS Layer-3 Virtual Private Networks

## End-to-end Layer-3 Services Over MPLS Networks

# MPLS Layer-3 Virtual Private Networks

## Topics

- Technology components
- VPN control plane mechanisms
- VPN forwarding plane
- Deployment use cases
  - Business VPN services
  - Network segmentation
  - Data Center access



# MPLS Layer-3 VPN Overview

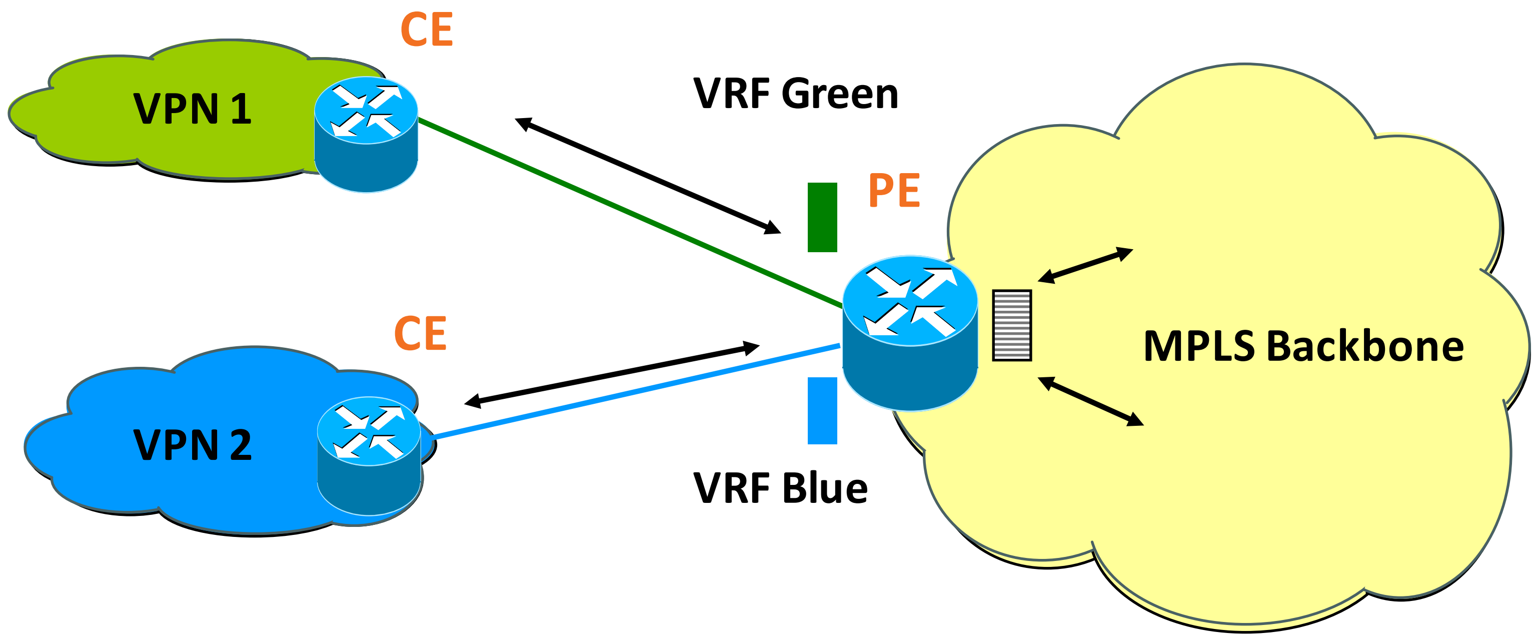
## Technology Components

- VPN policies
  - Separation of customer routing via virtual VPN routing table (VRF)
  - In PE router, customer interfaces are connected to VRFs
- VPN signaling
  - Between PE routers: customer routes exchanged via BGP (MP-iBGP)
- VPN traffic forwarding
  - Separation of customer VPN traffic via additional VPN label
  - VPN label used by receiving PE to identify VPN routing table
- PE-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

# Virtual Routing and Forwarding Instance

## Virtual Routing Table and Forwarding to Separate Customer Traffic

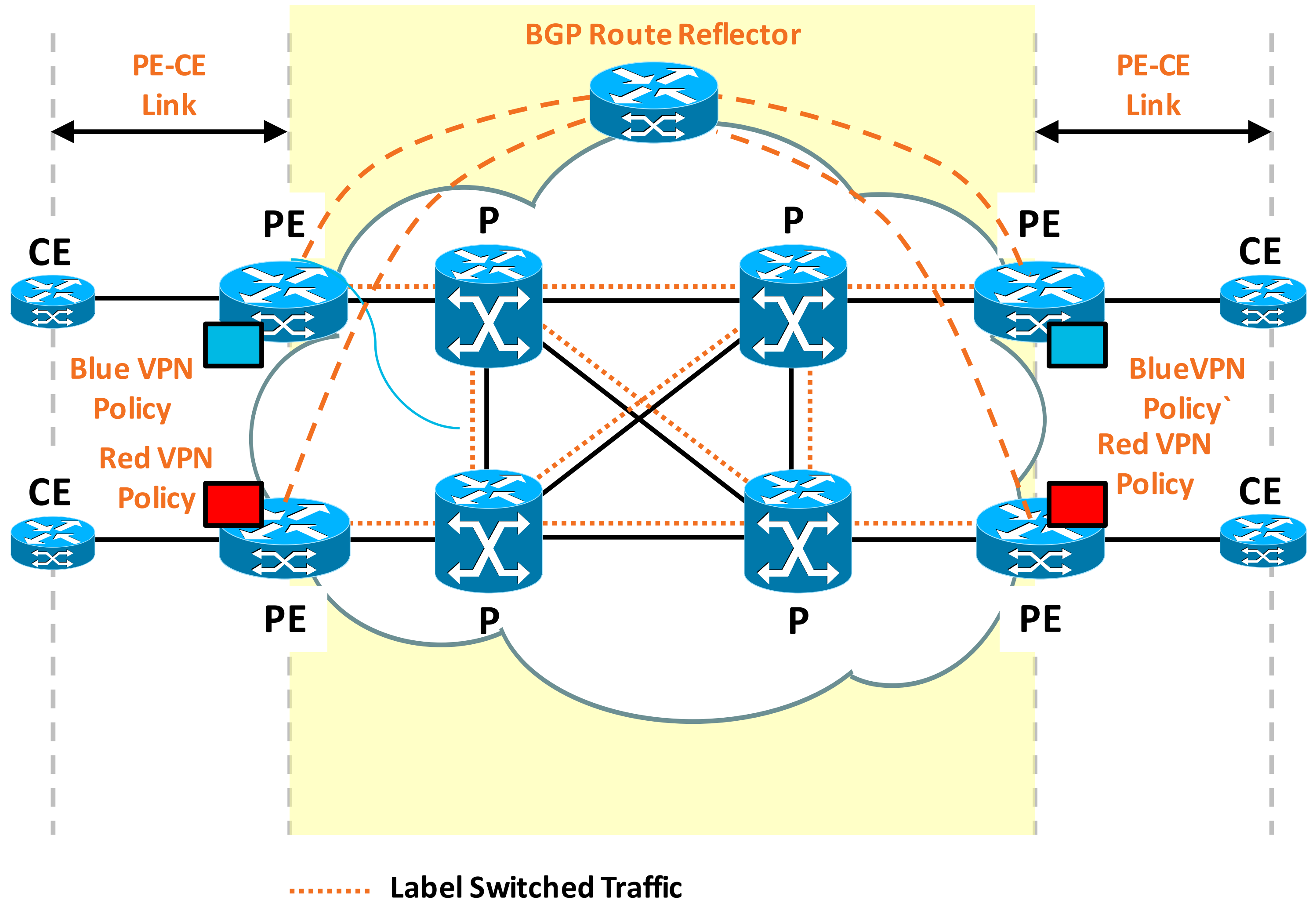
- Virtual routing and forwarding table
  - On PE router
  - Separate instance of routing (RIB) and forwarding table
- Typically, VRF created for each customer VPN
  - Separates customer traffic
- VRF associated with one or more customer interfaces
- VRF has its own routing instance for PE-CE configured routing protocols
  - E.g., eBGP



# VPN Route Distribution

## Exchange of VPN Policies Among PE Routers

- Full mesh of BGP sessions among all PE routers
  - BGP Route Reflector
- Multi-Protocol BGP extensions (MP-iBGP) to carry VPN policies
- PE-CE routing options
  - Static routes
  - eBGP
  - OSPF
  - IS-IS



# VPN Control Plane Processing

## VRF Parameters

Make customer routes unique:

- **Route Distinguisher (RD):** 8-byte field, VRF parameters; unique value to make VPN IP routes unique
- **VPNv4 address**: RD + VPN IP prefix

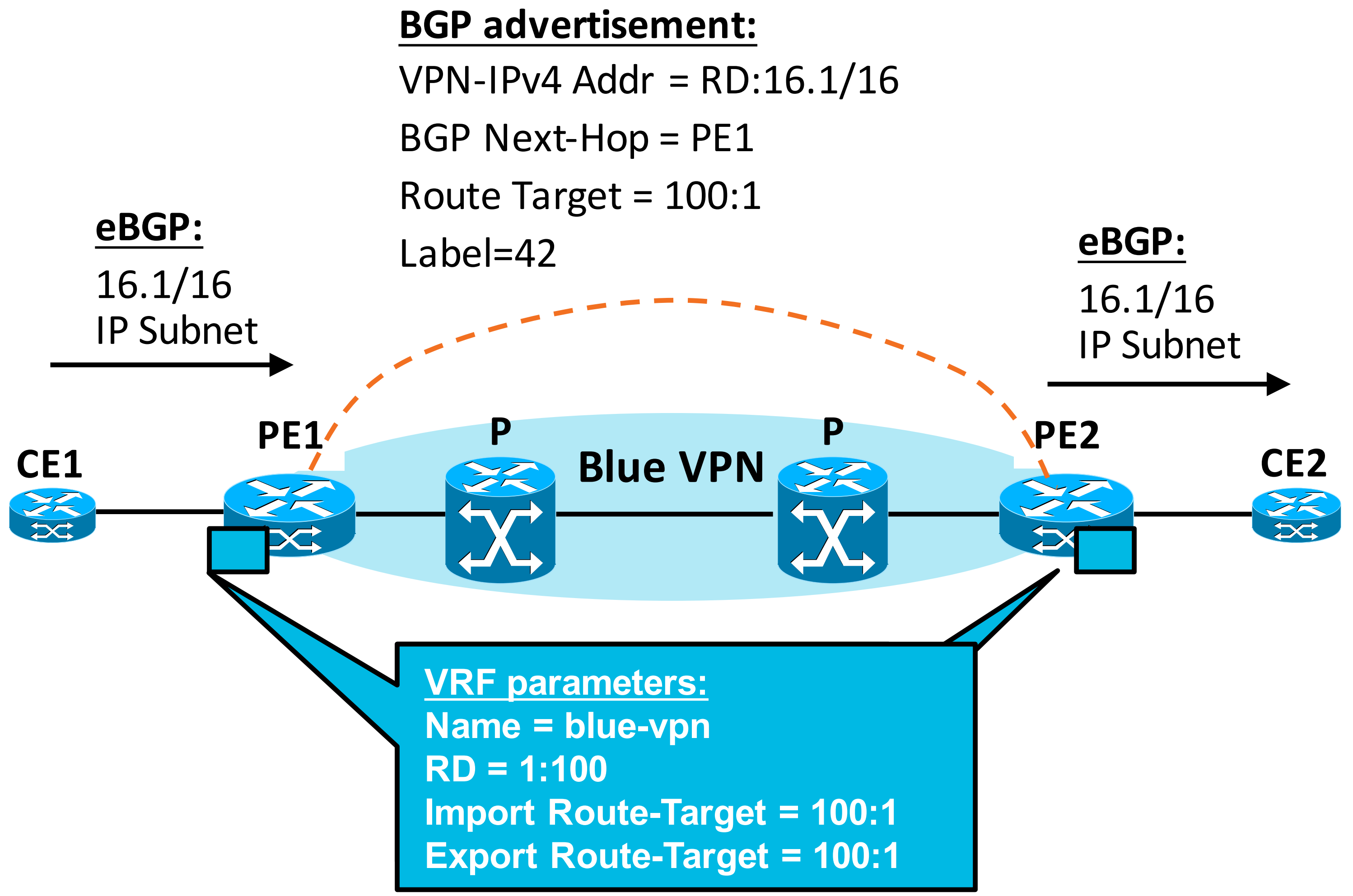
Selective distribute VPN routes:

- **Route Target (RT):** 8-byte field, VRF parameter, unique value to define the import/export rules for VPNv4 routes
- MP-iBGP: advertises VPNv4 prefixes + labels

# VPN Control Plane Processing

## Interactions Between VRF and BGP VPN Signaling

1. CE1 redistribute IPv4 route to PE1 via eBGP
2. PE1 allocates VPN label for prefix learnt from CE1 to create unique VPNv4 route
3. PE1 redistributes VPNv4 route into MP-iBGP, it sets itself as a next hop and relays VPN site routes to PE2
4. PE2 receives VPNv4 route and, via processing in local VRF (green), it redistributes original IPv4 route to CE2

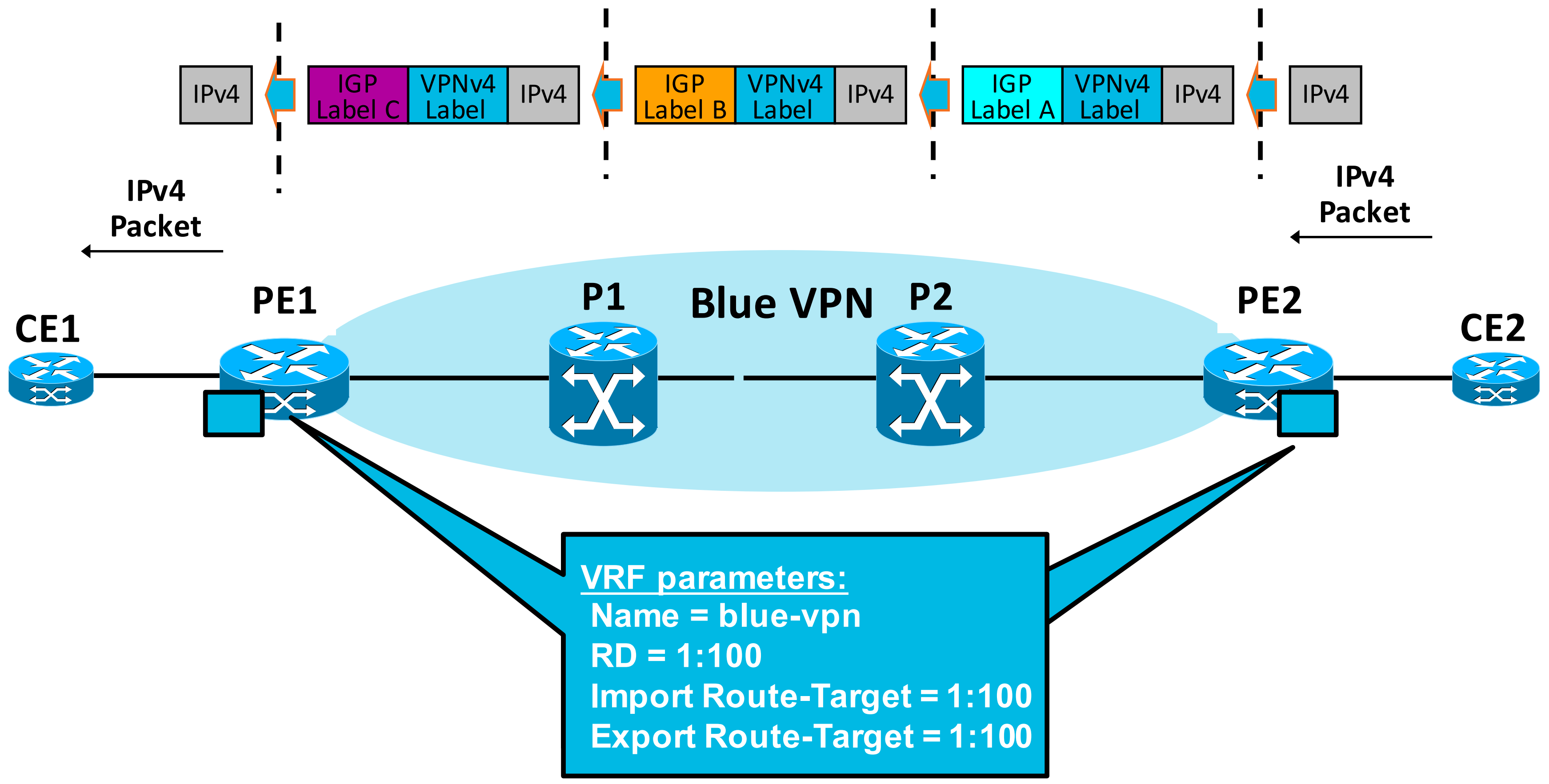


# VPN Forwarding Plane Processing

## Forwarding of Layer-3 MPLS VPN Packets

1. CE2 forwards IPv4 packet to PE2
2. PE2 imposes pre-allocated VPN label to IPv4 packet received from CE2
   - Learned via MP-IBGP
3. PE2 imposes outer IGP label A (learned via LDP) and forwards labeled packet to next-hop P-router P2
4. P-routers P1 and P2 swap outer IGP label and forward label packet to PE1
   - A->B (P2) and B->C (P1)
5. Router PE1 strips VPN label and IGP labels and forwards IPv4 packet to CE1

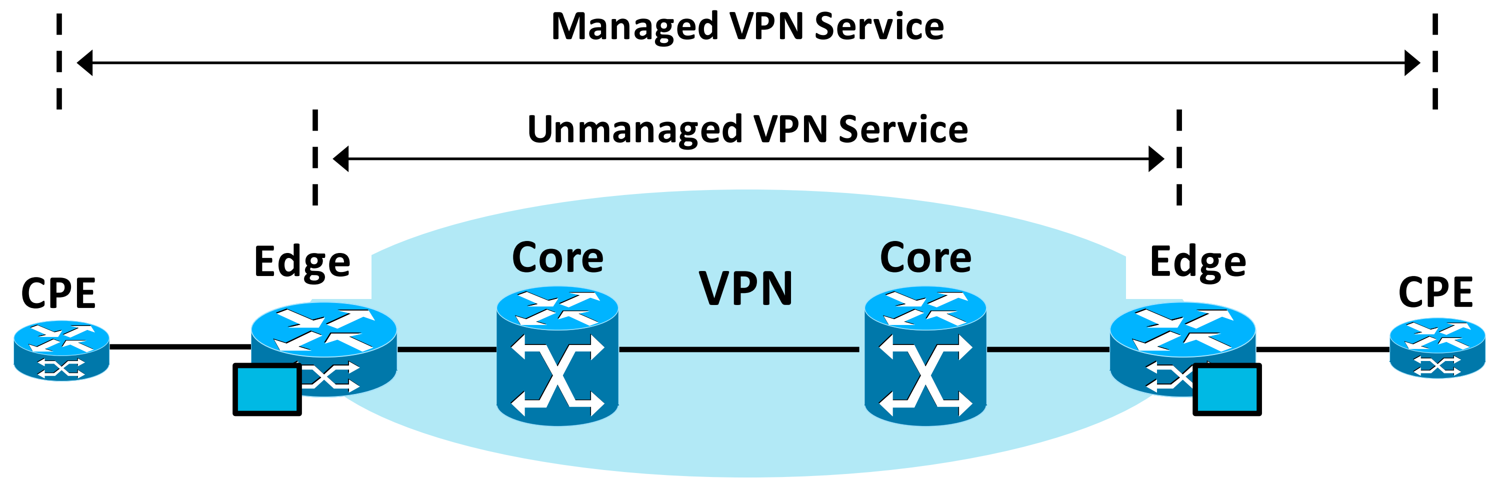


# Service Provider Deployment Scenario

## MPLS Layer-3 VPNs for Offering Layer-3 Business VPN Services

- Deployment Use Case
  - Delivery of IP VPN services to business customers
- Benefits
  - 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

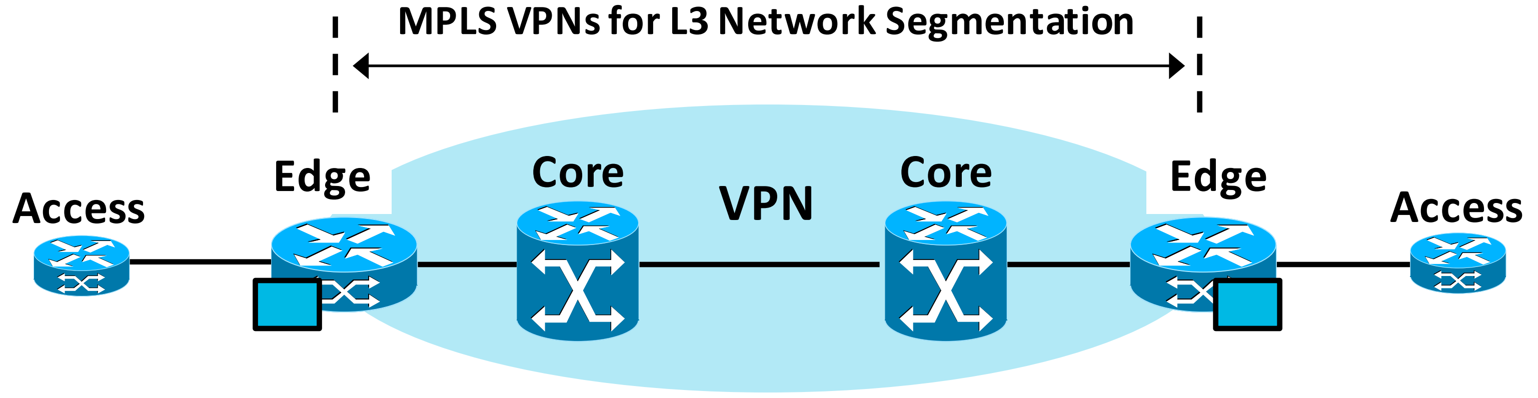



| Network Segment | CPE | Edge | Core |
|---|---|---|---|
| **MPLS Node** | CE | PE | P |
| **Typical Platforms** | ASR1K<br>ISR/G2 | ASR9K<br>7600<br>ASR1K<br>ASR903<br>ME3800X | CRS-1<br>GSR<br>ASR9K |

# Enterprise Deployment Scenario

## MPLS Layer-3 VPNs for Implementing Network Segmentation

- Deployment Use Case
  - Segmentation of enterprise network to provide selective connectivity for specific user groups and organizations
- Benefits
  - Network segmentation only requires edge node configuration
  - Flexible routing; different IP connectivity can be easily configured; e.g., full/partial mesh

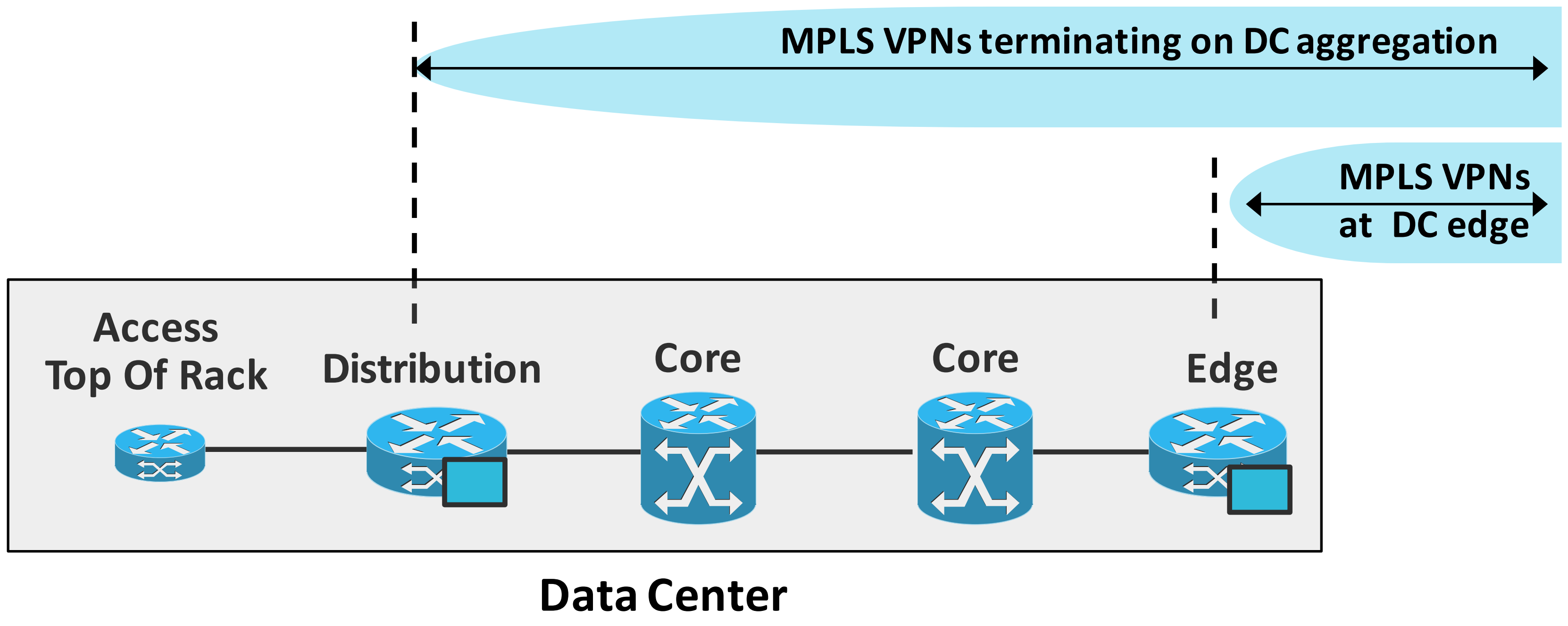



| Network Segment | Access | Edge | Core |
|---|---|---|---|
| **MPLS Node** | CE | PE | P |
| **Typical Platforms** | ASR1K<br>ISR/G2 | 7600<br>ASR1K | CRS-1<br>GSR<br>ASR9K<br>7600<br>6500 |

# Data Center Deployment Scenario

## MPLS Layer-3 VPNs for Segmented L3 Data Center Access and Interconnect

- Deployment Use Case
  - Segmented WAN Layer-3 at Data Center edge
  - Layer-3 segmentation in Data Center
- Benefits
  - Only single Data Center edge node needed for segmented layer-3 access
  - Enables VLAN/Layer-2 scale (> 4K)




| Network Segment | Distribution | Core | Edge |
|---|---|---|---|
| **MPLS Node** | CE or PE | P or CE | PE |
| **Typical Platforms** | N7K<br>6500 | N7K<br>6500 | ASR9K<br>7600 |

# Summary

## Key Takeaways

- MPLS Layer-3 VPNs provide IP connectivity among CE sites
  - MPLS VPNs enable full-mesh, hub-and-spoke, and hybrid IP connectivity
- CE sites connect to the MPLS network via IP peering across PE-CE links
- MPLS Layer-3 VPNs are implemented via VRFs on PE edge nodes
  - VRFs providing customer routing and forwarding segmentation
- BGP used for signaling customer VPN (VPNv4) routes between PE nodes
- To ensure traffic separation, customer traffic is encapsulated in an additional VPN label when forwarded in MPLS network
- Key applications are layer-3 business VPN services, enterprise network segmentation, and segmented layer-3 Data Center access

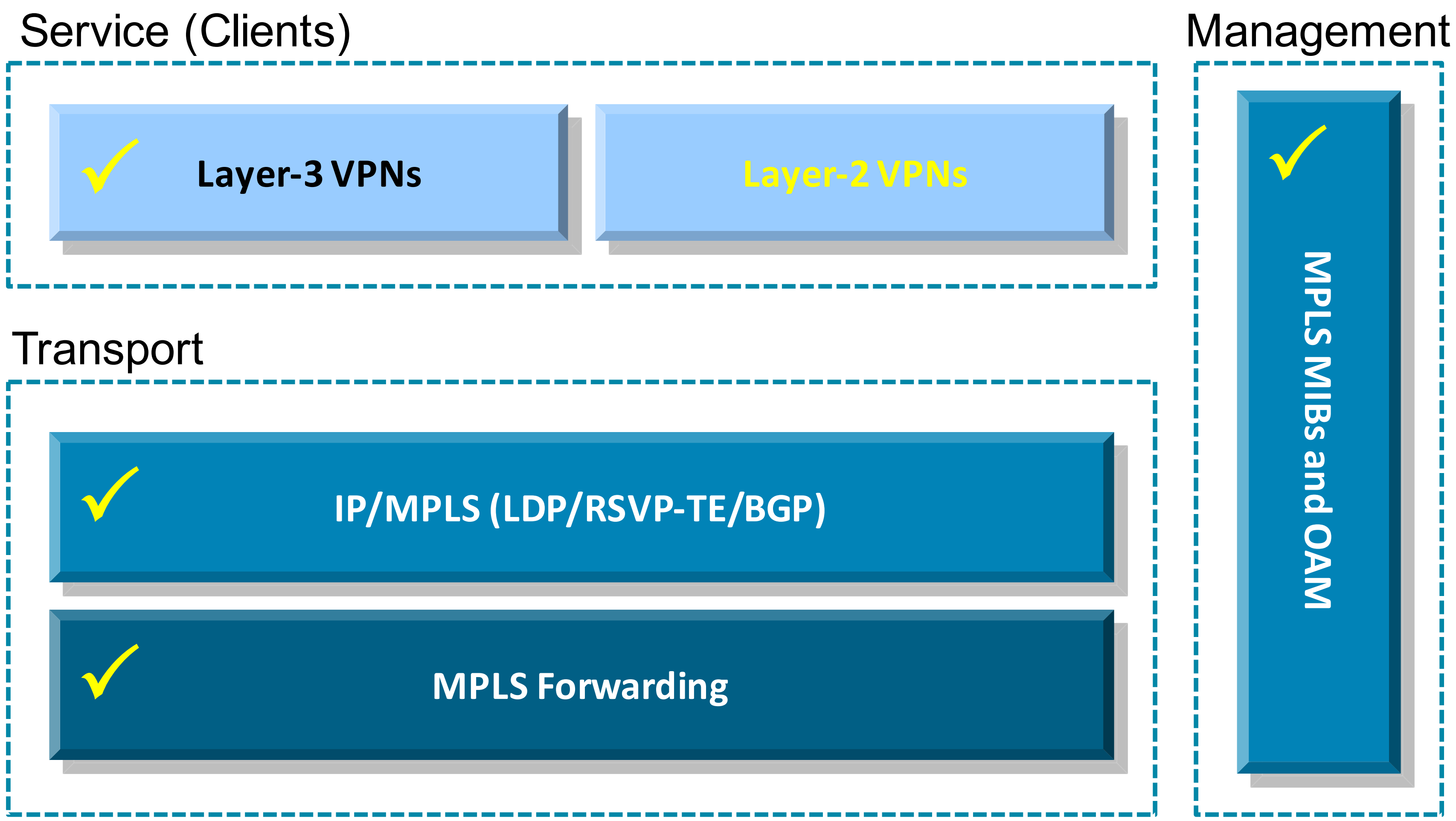
# MPLS Layer-2 Virtual Private Networks

## End-to-end Layer-2 Services Over MPLS Networks

# MPLS Layer-2 Virtual Private Networks

## Topics

- L2VPN technology options
- P2P VPWS services (PWs)
  - Overview & Technology Basics
  - VPN control plane
  - VPN forwarding plane
- MP2MP VPLS services
  - Overview & Technology Basics
  - VPN control plane
  - VPN forwarding plane
- Deployment use cases
  - L2 Business VPN services
  - Data Center Interconnect



# MPLS Layer-2 Virtual Private Networks

## Technology Options

- VPWS services
  - Point-to-point
  - Referred to as Pseudowires (PWs)*
- VPLS services
  - Multipoint-to-Multipoint

**MPLS Layer-2 VPNs**

| Point-to-Point Layer-2 VPNs (PWs) | Multipoint-to-Multipoint Layer-2 VPNs (VPLS) |
|---|---|
| • CE connected to PE via p2p L2 connection (e.g., FR, ATM)<br>• CEs peer with each other (IP routing) via p2p layer-2 VPN connection<br>• CE-CE routing; no MPLS network involvement | • CE connected to PE via Ethernet connection (VLAN)<br>• CEs peer with each other via fully/partial mesh Layer-2 VPN connection<br>• CE-CE routing; no MPLS network involvement |

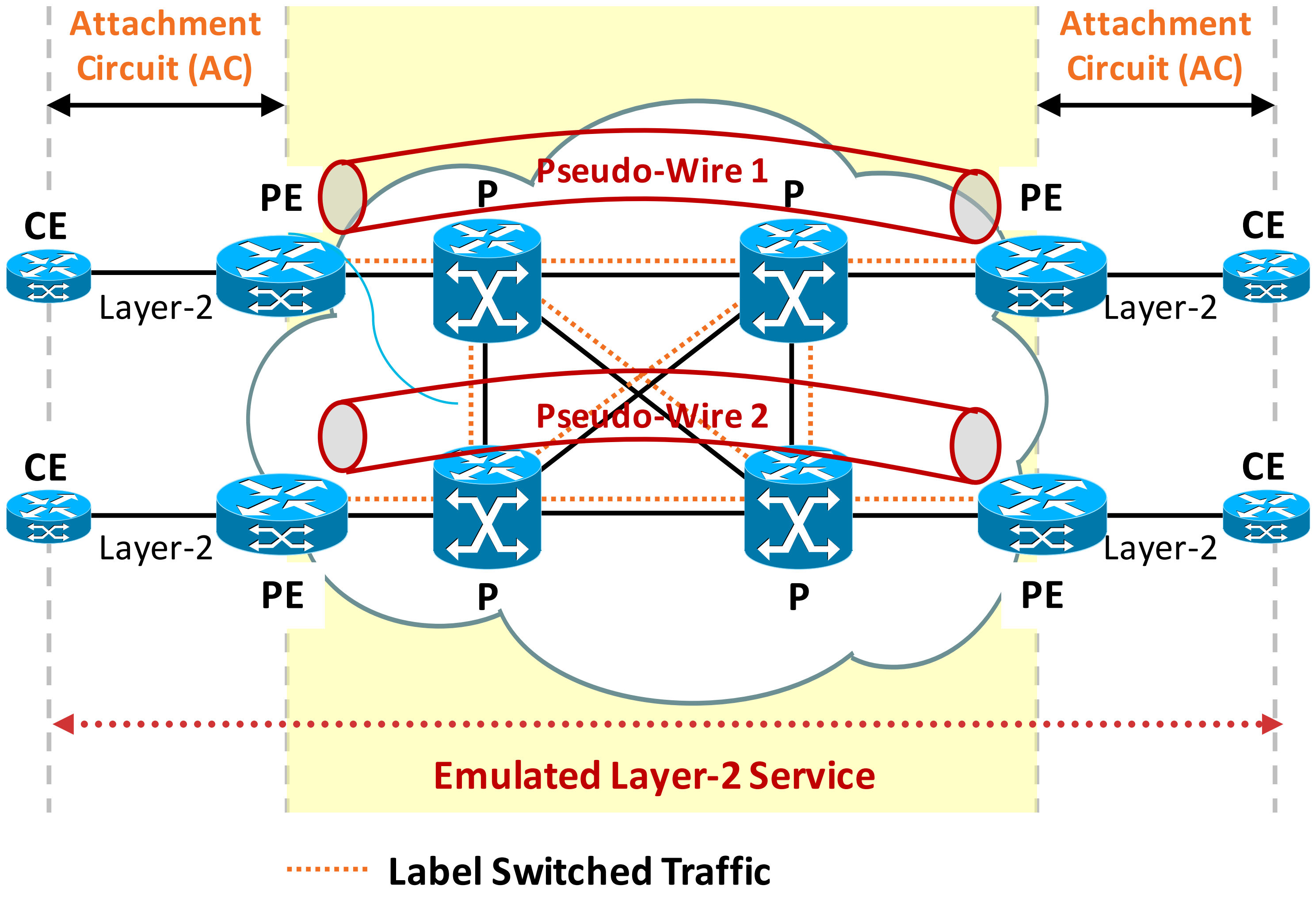
* Used to be referred to as Any Transport over MPLS or AToM as well.

# Virtual Private Wire Services (VPWS)

## Overview of Pseudowire (PW) Architecture

- Based on IETF's Pseudo-Wire (PW) Reference Model
- Enables transport of any Layer-2 traffic over MPLS
- Includes additional VC label encapsulation and translation of L2 packets
  - – ATM, ATM, FR, or PPP
- PE-CE link is referred to as Attachment Circuit (AC)
- Support for L2 interworking
- PWs are bi-directional



# Virtual Private Wire Services (VPWS)

## Technology Components

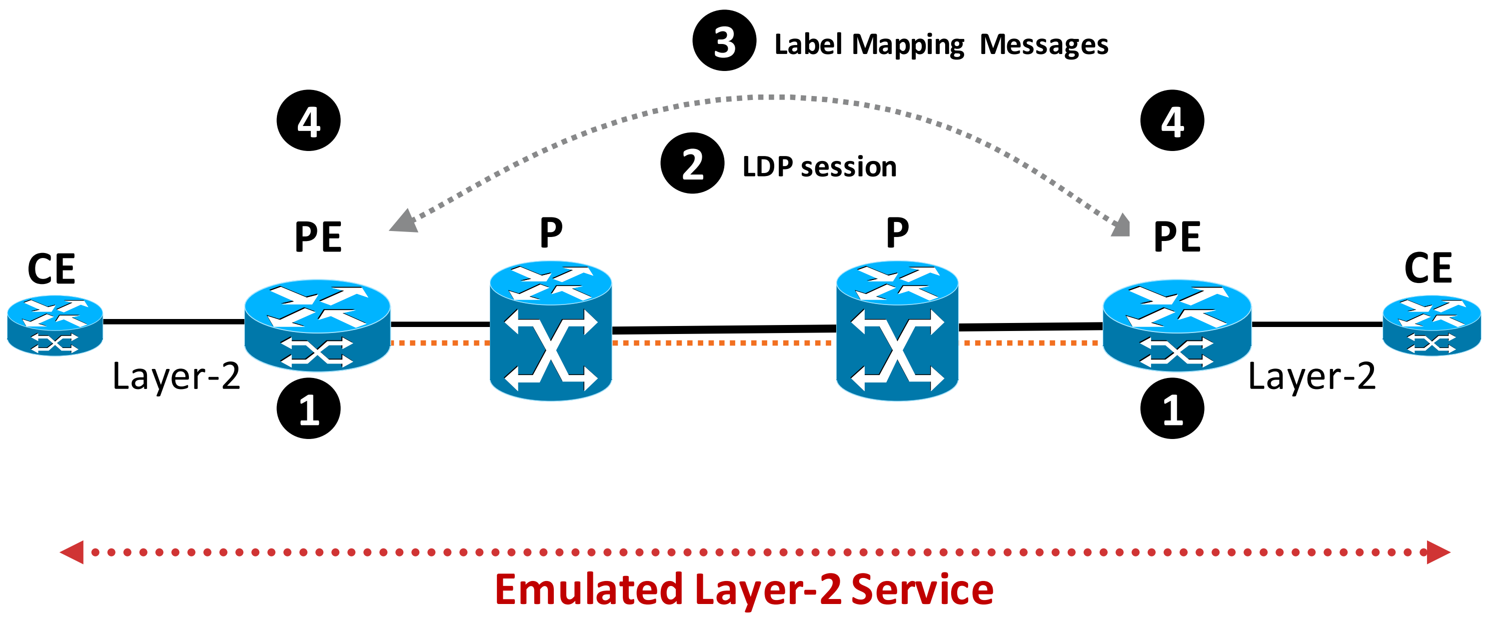
- VPN policies
  - Virtual cross-connect (Xconnect)
  - Maps customer interface (AC) to PW (1:1 mapping)
- VPN signaling
  - Targeted LDP* or BGP session between ingress and egress PE router
  - Virtual Connection (VC)-label negotiation, withdrawal, error notification
- VPN traffic forwarding
  - 1 or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

* LDP is assumed as signaling protocol for next examples

# VPWS Control Plane Processing

## Signaling of a New Pseudo-Wire

1. New Virtual Circuit (VC) cross-connect connects customer L2 interface (AC) to new PW via VC ID and remote PE ID
2. New targeted LDP session between PE1 and PE2 is established, in case one does not already exist
3. PE binds VC label with customer layer-2 interface and sends label-mapping to remote PE
4. Remote PE receives LDP label binding message and matches VC ID with local configured VC cross-connect

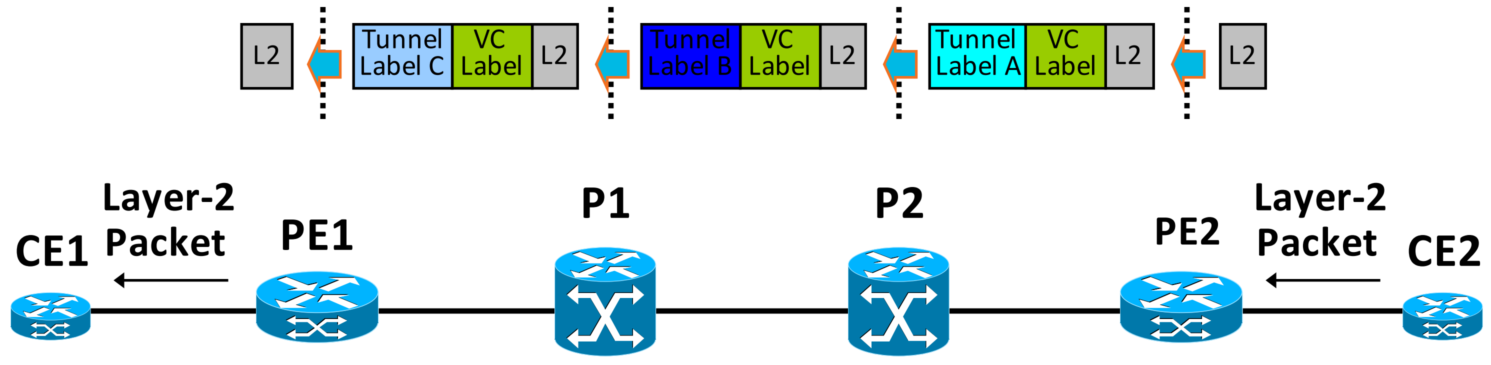


# VPWS Forwarding Plane Processing

## Forwarding of Layer-2 Traffic Over PWs

1. CE2 forwards L2 packet to PE2.
2. PE2 pushes VC (inner) label to L2 packet received from CE2
   – Optionally, a control word is added as well (not shown)
3. PE2 pushed outer (Tunnel) label and forwards packet to P2
4. P2 and P1 forward packet using outer (tunnel) label (swap)
5. Router PE2 pops Tunnel label and, based on VC label, L2 packet is forwarded to customer interface to CE1, after VC label is removed
   – In case control word is used, new layer-2 header is generated first

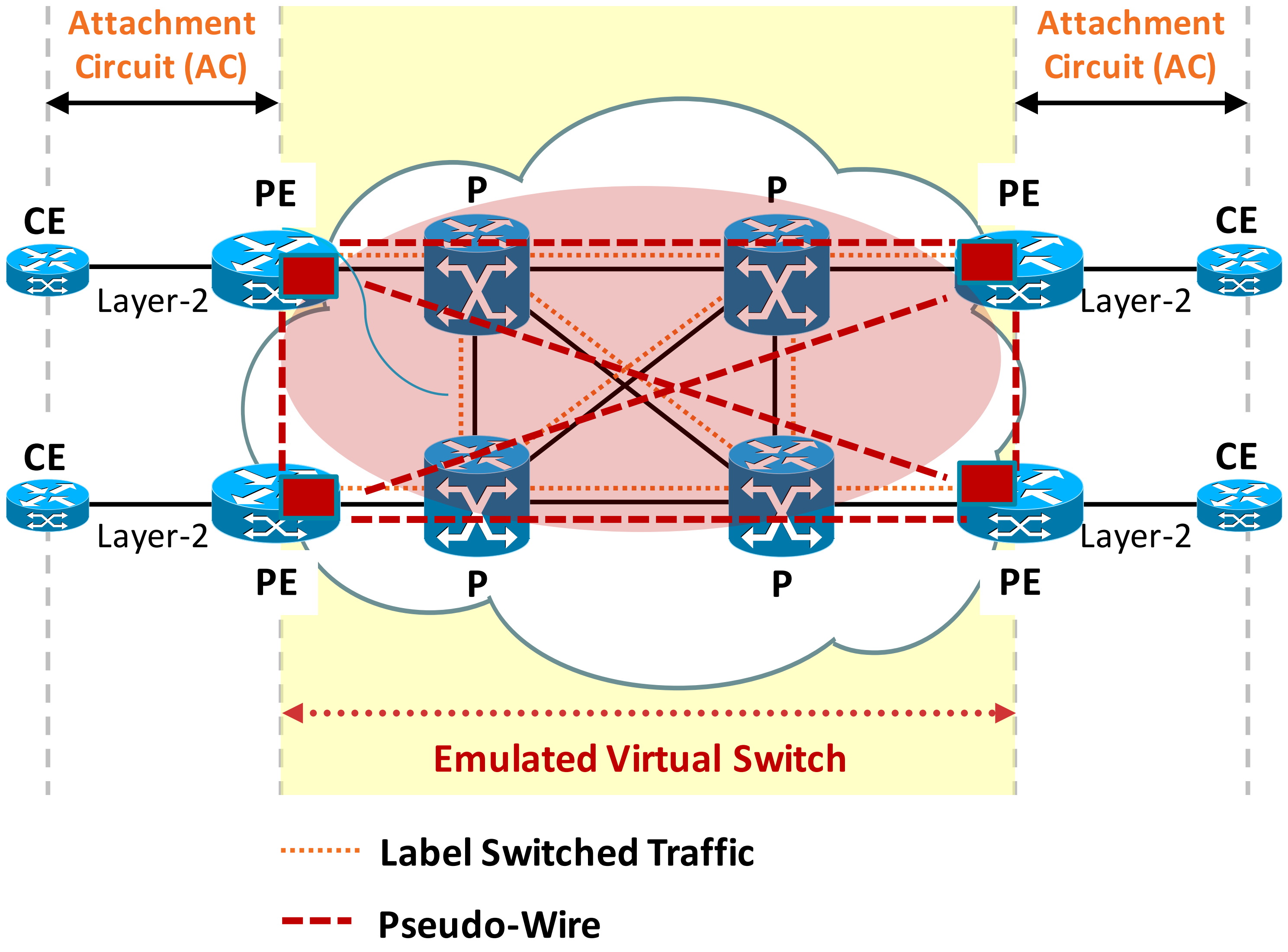


# Virtual Private LAN Services

## Overview of VPLS Architecture

- Architecture for Ethernet Multipoint Services over MPLS
- VPLS network acts like a virtual switch that emulates conventional L2 bridge
- Fully meshed or Hub-Spoke topologies supported
- PE-CE link is referred to as Attachment Circuit (AC)
  – Always Ethernet



# Virtual Private LAN Services (VPLS)

## Technology Components

- VPN policies
  - Virtual 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
- VPN signaling
  - Full mesh of targeted LDP* (VC exchange) and/or BGP sessions (discovery and VC exchange)
  - Virtual Connection (VC)-label negotiation, withdrawal, error notification
- VPN traffic forwarding
  - 1 VC label used for encapsulation + 1 (IGP) label for forwarding
  - Inner de-multiplexer (VC) label: identifies VSI
  - Outer tunnel (IGP) label: to get from ingress to egress PE using MPLS LSP
- PE-CE link
  - Referred to as Attachment Circuit (AC)
  - Ethernet VCs are either port mode or VLAN ID

* LDP is assumed as signaling protocol for next examples

# VPLS Forwarding Plane Processing

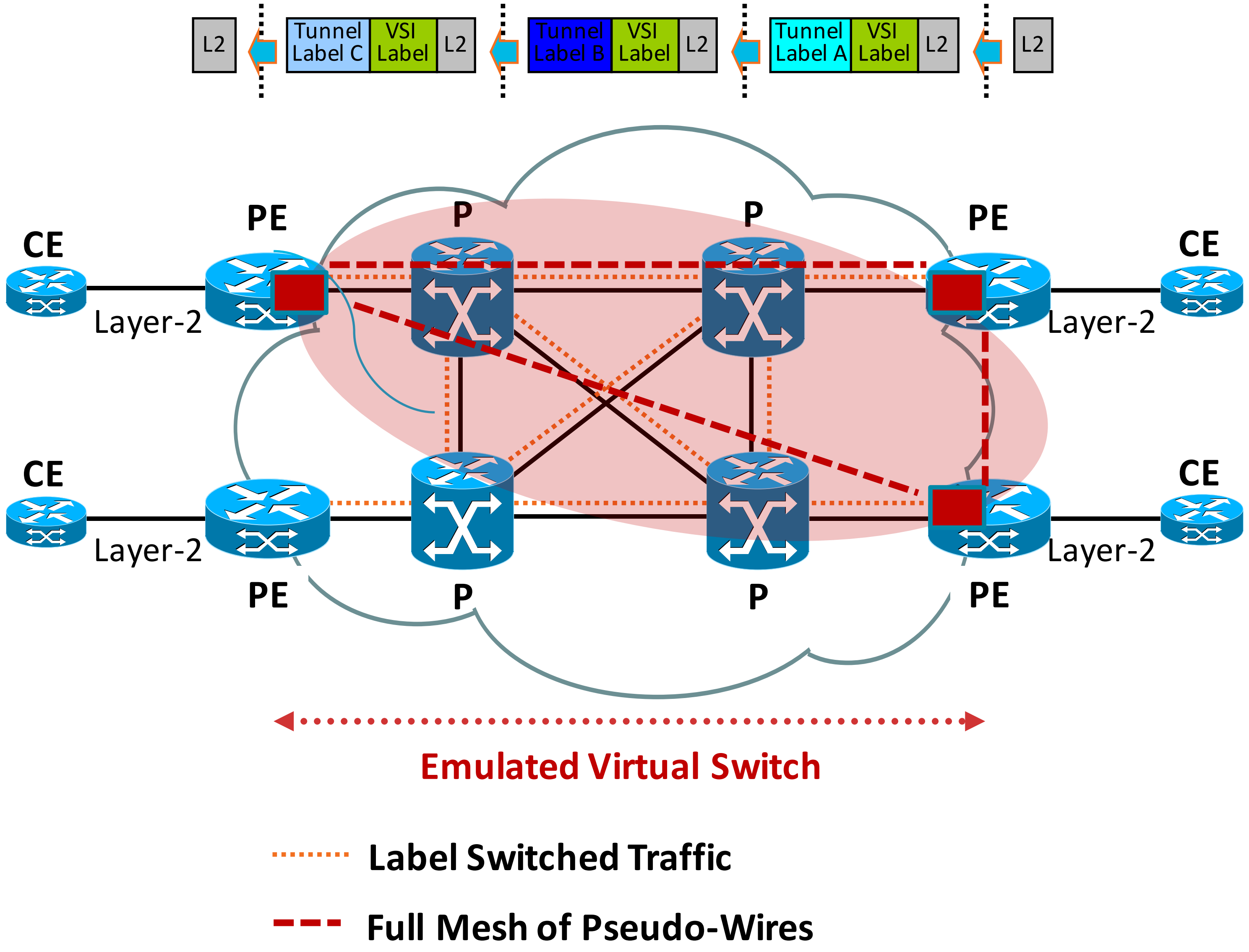
## Forwarding of Layer-2 Traffic Over VPLS Network

MAC learning:

- For new L2 packets
- VSI forwarding table updated
- Packets flooded to all PEs over PWs

Layer-2 Packet Forwarding:

- For L2 packets with known destination MAC addresses
- Lookup in VSI forwarding table
- L2 packet forwarded onto PWs to remote PE/VSI



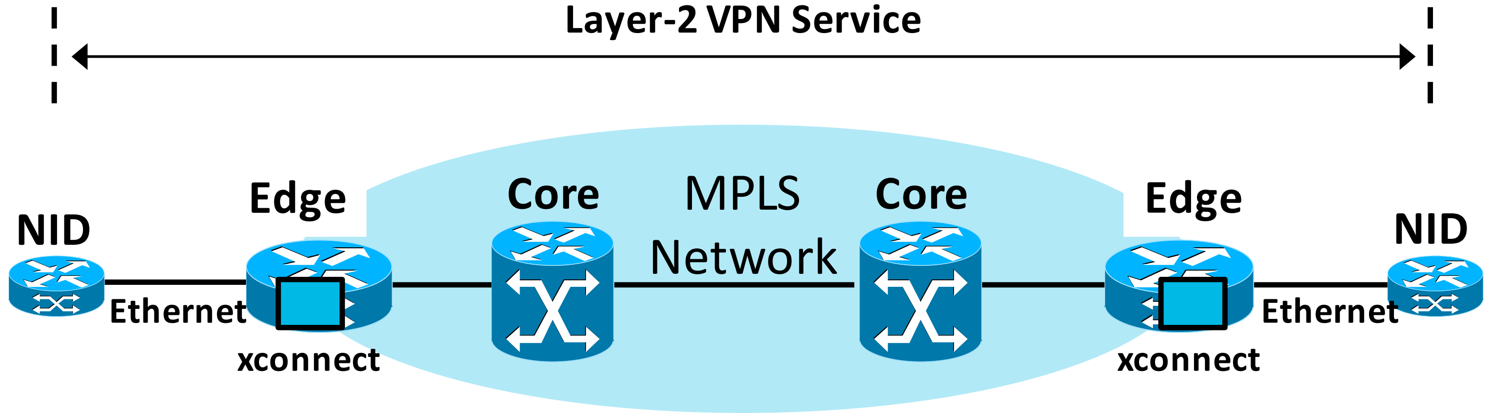

 

# Service Provider Deployment Scenario

## PWs for Offering Layer-2 Business VPN Services

- Deployment Use Case
  - Delivery of E-LINE services to business customers
- Benefits
  - Leverage same network for multiple services and customers (CAPEX)

    Highly scalable
  - Service enablement only requires edge node configuration (OPEX)




| Network Segment | NID * | Edge | Core |
|---|---|---|---|
| **MPLS Node** | CE | U-PE | P |
| **Typical Platforms** | M3400<br>ASR901 | ME3800X<br>ASR903<br>ASR9K | CRS-1<br>GSR<br>ASR9K |

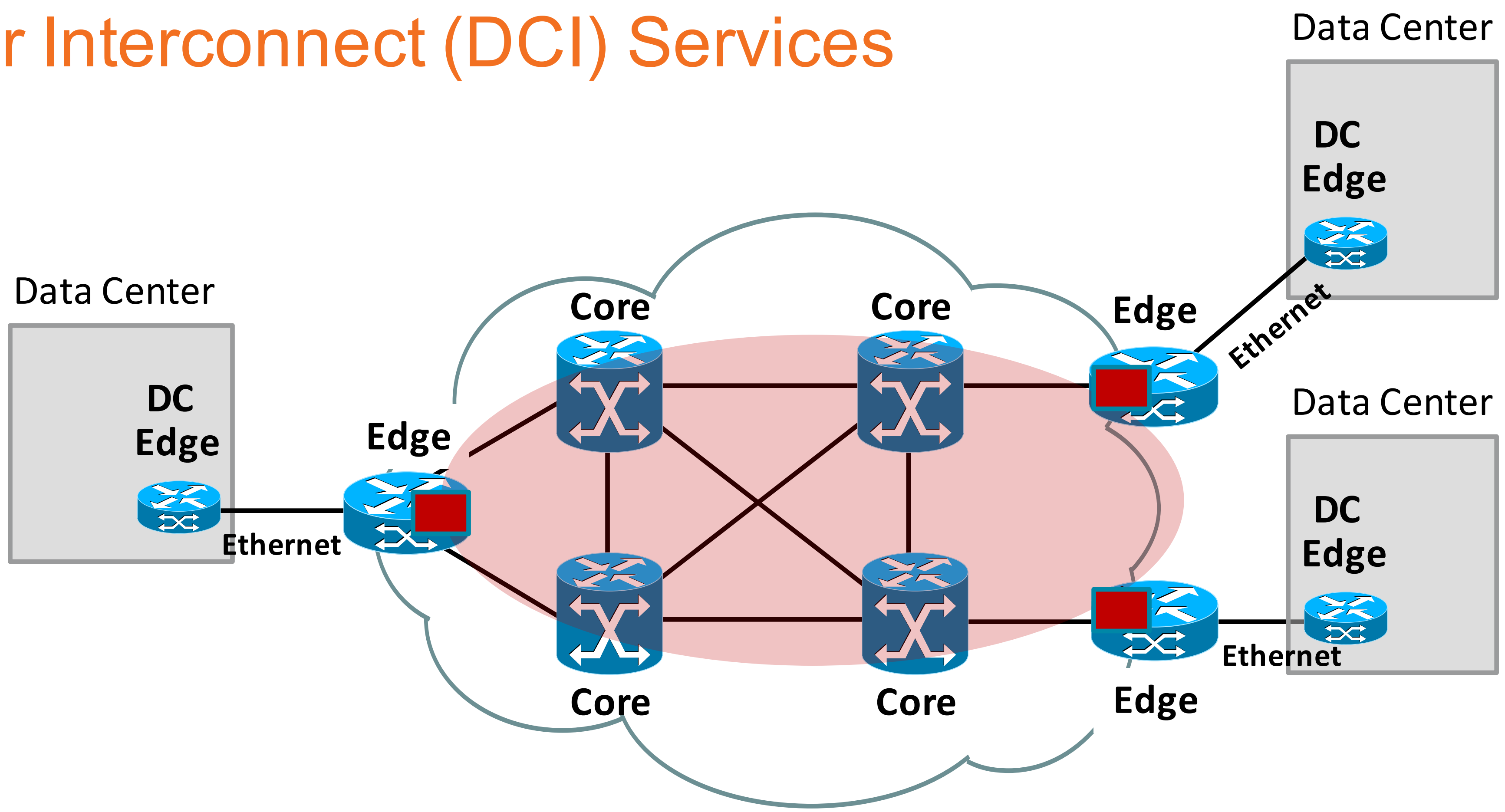
* NID : Network Interface Device

# Data Center Deployment Scenario

## VPLS for Layer-2 Data Center Interconnect (DCI) Services

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




| Network Segment | DC Edge | Core | Edge |
|---|---|---|---|
| **MPLS Node** | CE | P | PE |
| **Typical Platforms** | ASR9K<br>7600<br>6500 | CRS-1<br>GSR<br>ASR9K | ASR9K<br>7600 |

# Summary

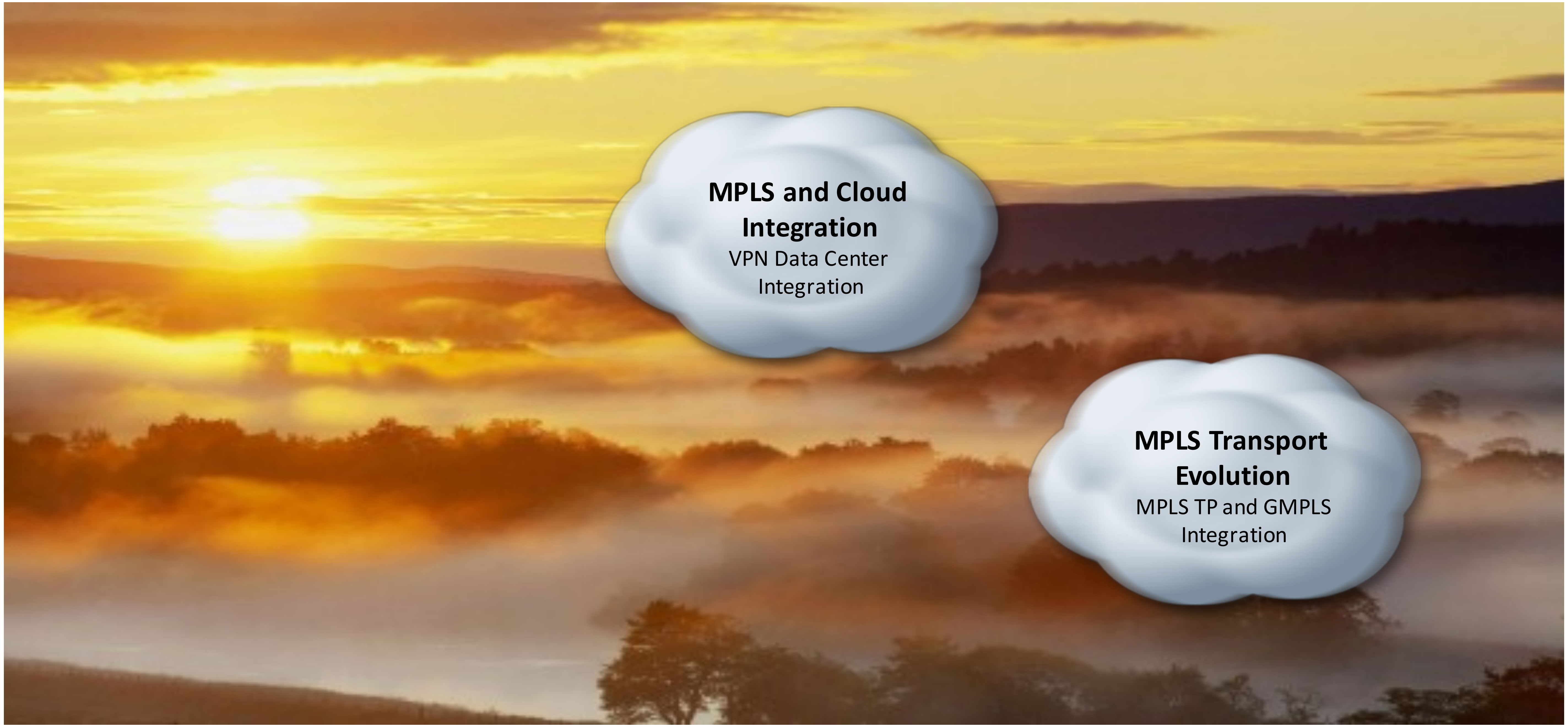
## Key Takeaways

- L2VPNs enable transport of any Layer-2 traffic over MPLS network
- L2 packets encapsulated into additional VC label
- Both LDP and BGP can be used L2VPN signaling
- PWs suited for implementing transparent point-to-point connectivity between Layer-2 circuits (E-LINE services)
- VPLS suited for implementing transparent point-to-multipoint connectivity between Ethernet links/sites (E-LAN services)
- Typical applications of L2VPNs are layer-2 business VPN services and Data Center interconnect

# Futures

## New MPLS Developments on the Horizon



# Summary

## Final Notes and Wrap Up

# Summary

## Key Takeaways

- It's all about labels …
  - Label-based forwarding and protocol for label exchange
  - Best of both worlds … L2 deterministic forwarding and scale/flexible L3 signaling
- Key MPLS applications are end-to-end VPN services
  - Secure and scalable layer 2 and 3 VPN connectivity
- MPLS supports advanced traffic engineering capabilities
  - QoS, bandwidth control, and failure protection
- MPLS is a mature technology with widespread deployments
  - Defacto for most SPs, large enterprises, and increasingly in Data Centers
- Ongoing technology evolution
  - IPv6, optimized video transport, TP transport evolution, and cloud integration

# Consider MPLS When …

## Decision Criteria

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

# Terminology Reference

## Acronyms Used in MPLS Reference Architecture

| Terminology | Description |
|---|---|
| AC | Attachment Circuit. An AC Is a Point-to-Point, Layer 2 Circuit Between a CE and a PE. |
| AS | Autonomous System (a Domain) |
| CoS | Class of Service |
| ECMP | Equal Cost Multipath |
| IGP | Interior Gateway Protocol |
| LAN | Local Area Network |
| LDP | Label Distribution Protocol, RFC 3036. |
| LER | Label Edge Router. An Edge LSR Interconnects MPLS and non-MPLS Domains. |
| LFIB | Labeled Forwarding Information Base |
| LSP | Label Switched Path |
| LSR | Label Switching Router |
| NLRI | Network Layer Reachability Information |
| P Router | An Interior LSR in the Service Provider's Autonomous System |
| PE Router | An LER in the Service Provider Administrative Domain that Interconnects the Customer Network and the Backbone Network. |
| PSN Tunnel | Packet Switching Tunnel |

# Terminology Reference

## Acronyms Used in MPLS Reference Architecture

| Terminology | Description |
| --- | --- |
| Pseudo-Wire | A Pseudo-Wire Is a Bidirectional “Tunnel" Between Two Features on a Switching Path. |
| PWE3 | Pseudo-Wire End-to-End Emulation |
| QoS | Quality of Service |
| RD | Route Distinguisher |
| RIB | Routing Information Base |
| RR | Route Reflector |
| RT | Route Target |
| RSVP-TE | Resource Reservation Protocol based Traffic Engineering |
| VPN | Virtual Private Network |
| VFI | Virtual Forwarding Instance |
| VLAN | Virtual Local Area Network |
| VPLS | Virtual Private LAN Service |
| VPWS | Virtual Private WAN Service |
| VRF | Virtual Route Forwarding Instance |
| VSI | Virtual Switching Instance |

# Further Reading

## MPLS References at Cisco Press and cisco.com

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

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