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Concepts and Operation
of
MPLS VPNs

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Reunion de Primavera
Veracruz, Ver.

Agenda

- **MPLS Concepts**

- **Label Structure**

- **Label assignment and distribution**

- **RD, RT and VRF instances**

- **Service Models**

- **MPLS/VPN Configuration**

MPLS Concepts

MPLS Concepts

- **MPLS: Multi Protocol Label Switching**

- **Packet forwarding is done based on Labels Multi-protocol Label Switching (MPLS) is a**

- **Labels may correspond to IP destination**

- **Labels can also correspond to other parameters (QoS, source address, ...).**

- **MPLS was designed to support forwarding of other protocols as well.**

MPLS/VPN Terminology

- **Provider Network (P-network)**

    backbone under the control of the Service Provider

- **Customer Network (C-network)**

    network under VPN customer control

- **CE Router**

    part of the C-network and interfaces to a PE router

- **PE Router**

    part of the P-network and interfaces to CE routers

MPLS/VPN Terminology
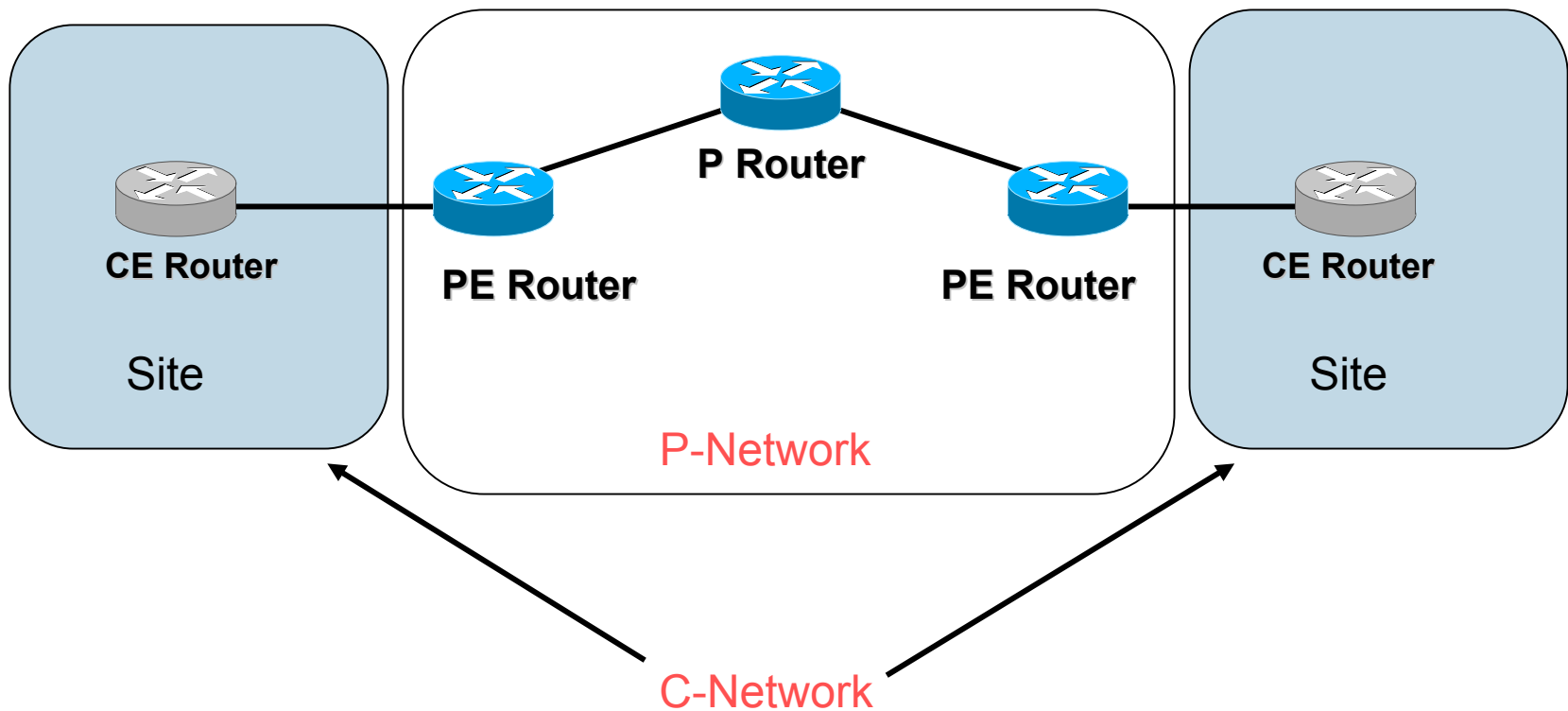
- **P Router**

    provider (core) router without knowledge of VPN

- **Site**

    set of (sub)networks which are part of the Customer network and co-located

    connected to the MPLS/VPN backbone through one of more PE/CE links

MPLS/VPN Model

CE Router

Site

PE Router

P Router

PE Router

CE Router

Site

P-Network

C-Network

Control Component

Protocols for label exchange:

Control Component is responsible for binding between labels and routes

LDP (646)/ TDP (711)

Label/Tag Distribution Protocol maps unicast IP destinations into labels

For Signalling and service control we have:

- **RSVP, CR-LDP**

   Used in traffic engineering

- **BGP/M-BGP**

   External labels (VPN)

- **PIM**

   For multicast states label mapping

MPLS Concepts

- **MPLS Switching defines traffic flows based on FECs**

- **FEC: Forwarding Equivalence Class**

- **A FEC can represent a: Destination address prefix, VPN, Traffic Engineering tunnel, Class of Service.**

MPLS Specific Tables

- ## Each LSR will use a LIB

  Label Information Base

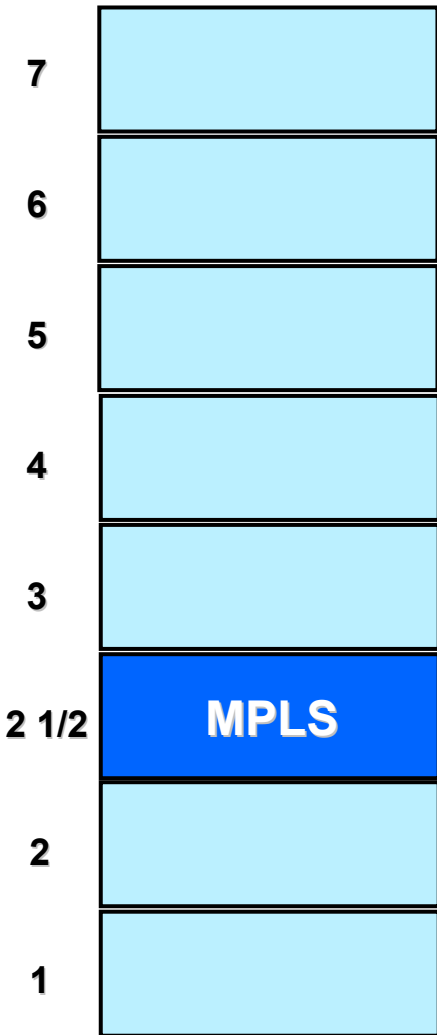 Contains all label/prefix mappings from all TDP/LDP neighbours

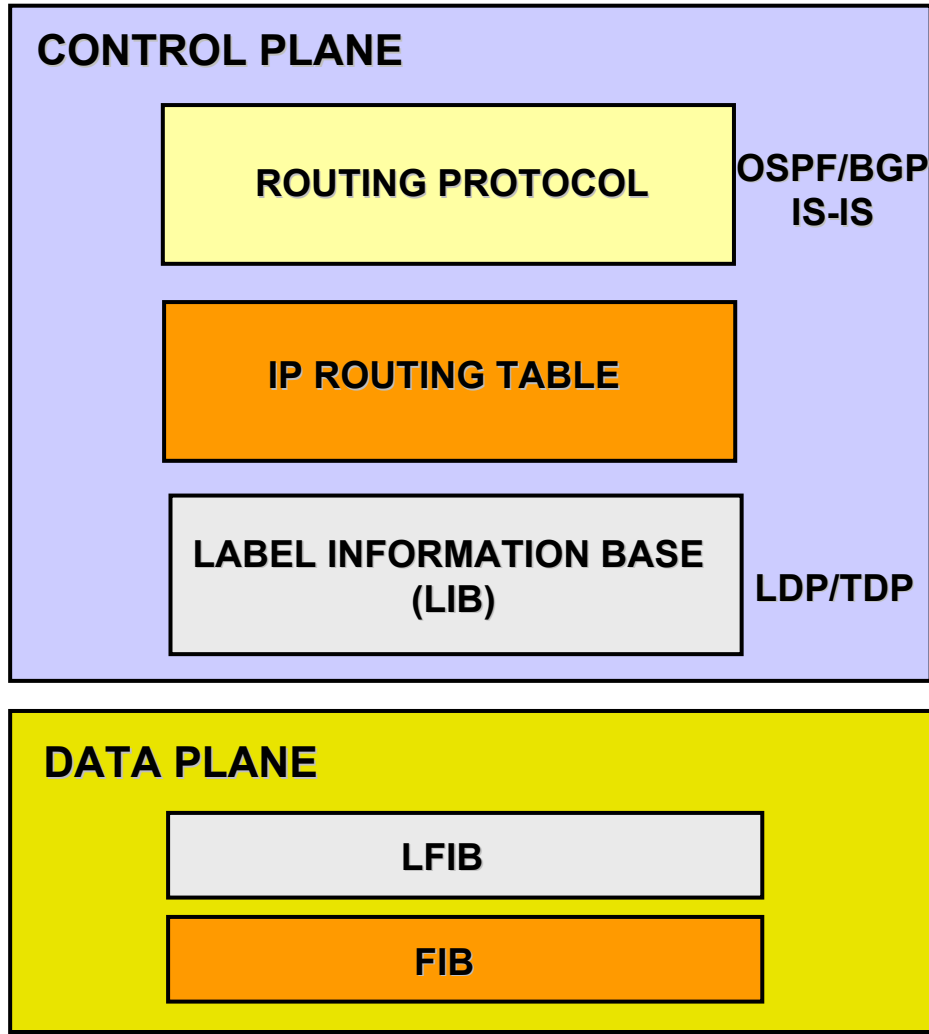- ## Each LSR will also use an LFIB

  Label Forwarding Information Base

  Contains only label/prefix mappings that are currently in use for label forwarding

MPLS Architecture

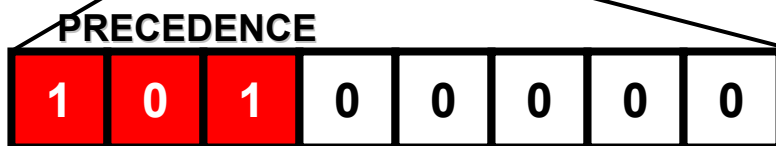## OSI

7	
6	
5	
4	
3	
2 1/2	**MPLS**
2	
1	

MPLS

CONTROL PLANE

ROUTING PROTOCOL — OSPF/BGP IS-IS

IP ROUTING TABLE

LABEL INFORMATION BASE (LIB) — LDP/TDP

DATA PLANE

LFIB

FIB

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Label Structure

MPLS Shim header structure

Version Length	ToS e	Len	ID	Flags/ offset	TTL	Proto	FCS	IP-SA	IP-DA	Data

IP v4 HEADER

PRECEDENCE

1	0	1	0	0	0	0	0

MPLS SHIM HEADER

LABEL	EXP	S	TTL

0   19 20   22 23 24   31

MPLS LABEL STACKING

Frame header	Label 1	Label 2	Label 3	IP header	Payload

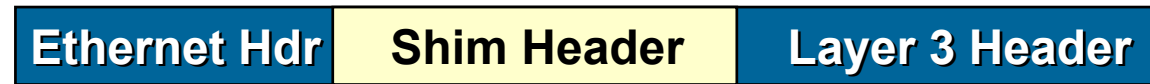PID=MPLS+P   S=0   S=0   S=1

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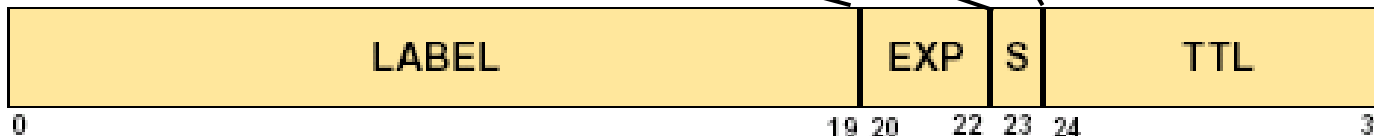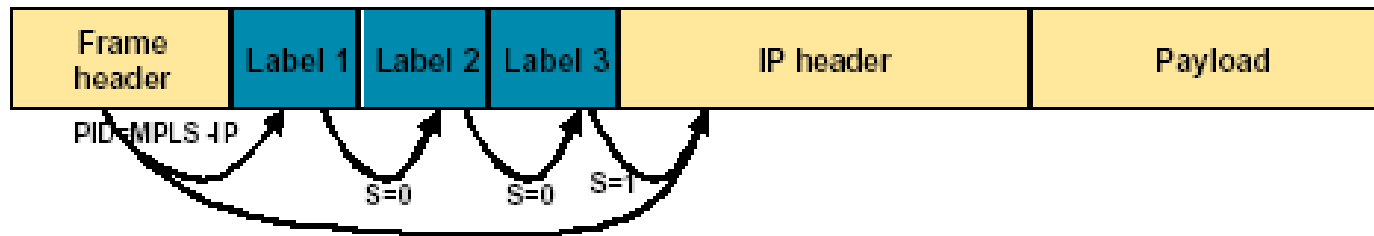
Label Structure

PPP Header(Packet over SONET/SDH)

PPP Header	Shim Header	Layer 3 Header

Ethernet

Ethernet Hdr	Shim Header	Layer 3 Header

Frame Relay

FR Hdr	Shim Header	Layer 3 Header

ATM Cell Header

GFC	VPI	VCI	PTI	CLP	HEC	DATA

Label

Subsequent cells

GFC	VPI	VCI	PTI	CLP	HEC	DATA
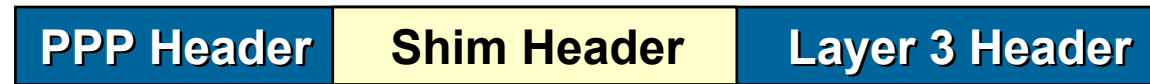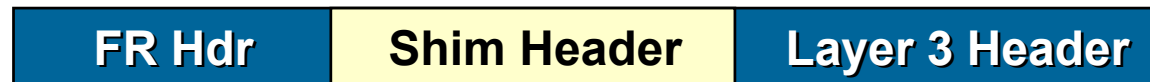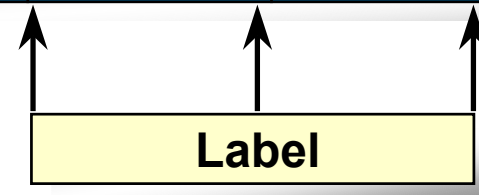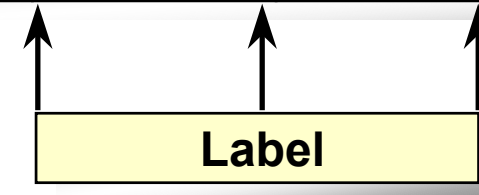
Label

Ether Type 0x8000 for unlabeled IP packet
0x8847 for labeled IP unicast packet
0x8848 for labeled IP multicast packet

Label assignment
and distribution

Label Imposition

- **CEF must be enabled on the interface where labels are first 'imposed'.** This is because the CEF mechanisms queries the LFIB in order to find which labels to apply.
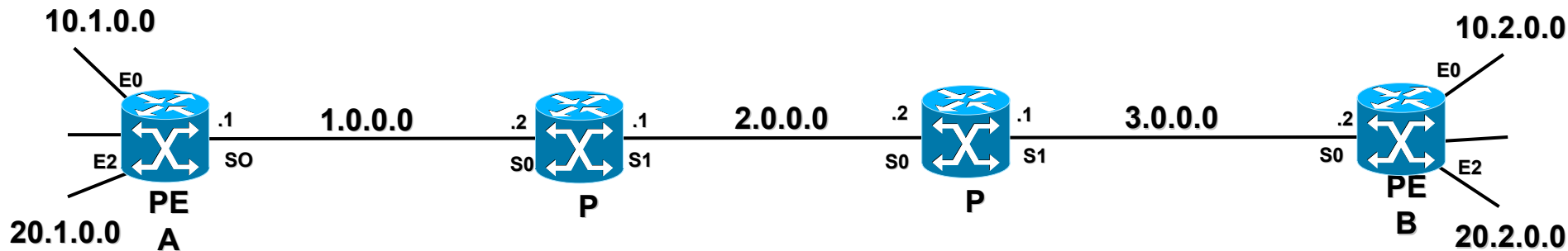
Label Imposition

Address	Prefix	Local Label
10.1.0.0	/16	1
10.2.0.0	/16	2
20.1.0.0	/16	3
20.2.0.0	/16	4
1.0.0.0	/16	5
2.0.0.0	/16	6
3.0.0.0	/16	7

Address	Prefix	Local Label
10.1.0.0	/16	8
10.2.0.0	/16	9
20.1.0.0	/16	10
20.2.0.0	/16	11
1.0.0.0	/16	12
2.0.0.0	/16	13
3.0.0.0	/16	14

Address	Prefix	Local label
10.1.0.0	/16	15
10.2.0.0	/16	16
20.1.0.0	/16	17
20.2.0.0	/16	18
1.0.0.0	/16	19
2.0.0.0	/16	20
3.0.0.0	/16	21

Address	Prefix	Local Label
10.1.0.0	/16	22
10.2.0.0	/16	23
20.1.0.0	/16	24
20.2.0.0	/16	25
1.0.0.0	/16	26
2.0.0.0	/16	27
3.0.0.0	/16	28

10.1.0.0   E0   .1   1.0.0.0   .2   .1   2.0.0.0   .2   .1   3.0.0.0   .2   E0   10.2.0.0

E2   S0   S0   S1   S0   S1   S0   E2

PE A   P   P   PE B

20.1.0.0   20.2.0.0

Address	Prefix	Next Hop
10.1.0.0	/16	Connected
10.2.0.0	/16	1.0.0.2
20.1.0.0	/16	Connected
20.2.0.0	/16	1.0.0.2
1.0.0.0	/16	Connected
2.0.0.0	/16	1.0.0.2
3.0.0.0	/16	1.0.0.2

Address	Prefix	Next Hop
10.1.0.0	/16	1.0.0.1
10.2.0.0	/16	2.0.0.2
20.1.0.0	/16	1.0.0.1
20.2.0.0	/16	2.0.0.2
1.0.0.0	/16	Connected
2.0.0.0	/16	Connected
3.0.0.0	/16	2.0.0.2

Address	Prefix	Next Hop
10.1.0.0	/16	2.0.0.1
10.2.0.0	/16	3.0.0.2
20.1.0.0	/16	2.0.0.1
20.2.0.0	/16	3.0.0.2
1.0.0.0	/16	2.0.0.1
2.0.0.0	/16	Connected
3.0.0.0	/16	Connected

Address	Prefix	Next Hop
10.1.0.0	/16	3.0.0.1
10.2.0.0	/16	Connected
20.1.0.0	/16	3.0.0.1
20.2.0.0	/16	Connected
1.0.0.0	/16	3.0.0.1
2.0.0.0	/16	3.0.0.1
3.0.0.0	/16	Connected

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LIB Content

LIB

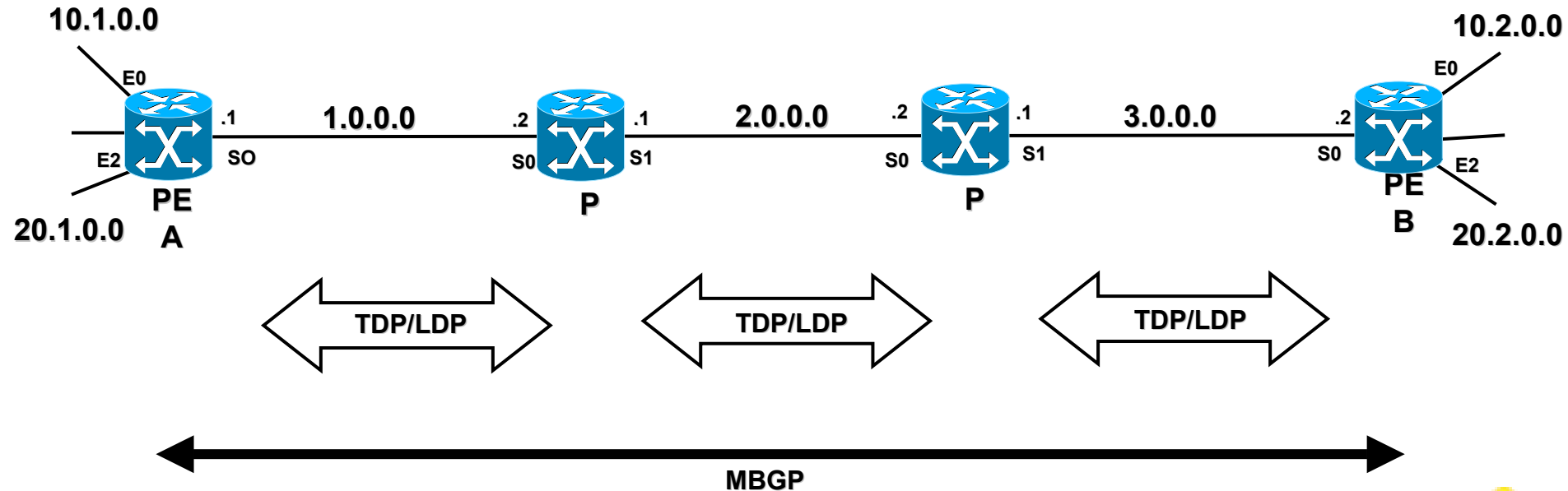| Address	Prefix	LocLbl	NHLbl
10.1.0.0	/16	1	Null
10.2.0.0	/16	2	2
20.1.0.0	/16	3	Null
20.2.0.0	/16	4	4
1.0.0.0	/16	5	Null
2.0.0.0	/16	6	POP
3.0.0.0	/16	7	7

LIB

Address	Prefix	LocLbl	NHLbl
10.1.0.0	/16	8,15	POP
10.2.0.0	/16	9,2	9
20.1.0.0	/16	10,17	POP
20.2.0.0	/16	11,4	11
1.0.0.0	/16	12,19	Null
2.0.0.0	/16	13,6	Null
3.0.0.0	/16	14,7	POP

LIB

Address	Prefix	LocLbl	NHLbl
10.1.0.0	/16	15,22	15
10.2.0.0	/16	9,16	POP
20.1.0.0	/16	17,24	17
20.2.0.0	/16	11,18	POP
1.0.0.0	/16	19,26	POP
2.0.0.0	/16	20,27	Null
3.0.0.0	/16	14,21	Null

LIB

Address	Prefix	LocLbl	NHLbl
10.1.0.0	/16	22	22
10.2.0.0	/16	23	Null
20.1.0.0	/16	24	24
20.2.0.0	/16	25	Null
1.0.0.0	/16	26	26
2.0.0.0	/16	27	POP
3.0.0.0	/16	28	Null

10.1.0.0

10.2.0.0

E0

.1   **1.0.0.0**   .2   .1   **2.0.0.0**   .2   .1   **3.0.0.0**   .2

E0

E2   SO   S0   S1   S0   S1   S0   E2

PE A   **P**   **P**   **PE B**

20.1.0.0   20.2.0.0

TDP/LDP   **TDP/LDP**   **TDP/LDP**

MBGP

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LFIB Creation

LIB

Address	Prefix	LocLbl	NHLbl
10.1.0.0	/16	1	Null
10.2.0.0	/16	23	2
20.1.0.0	/16	3	Null
20.2.0.0	/16	4	4
1.0.0.0	/16	5	Null
2.0.0.0	/16	6	POP
3.0.0.0	/16	7	7

LIB

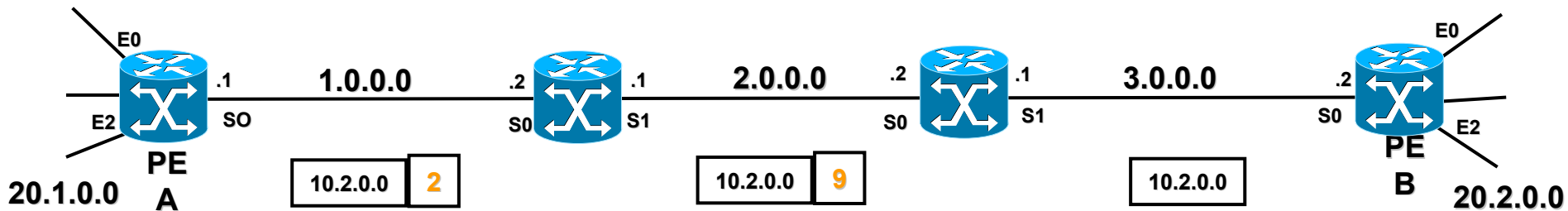| Address	Prefix	LocLbl	NHLbl
10.1.0.0	/16	8,15	POP
10.2.0.0	/16	9,2	9
20.1.0.0	/16	10,17	POP
20.2.0.0	/16	11,4	11
1.0.0.0	/16	12,19	Null
2.0.0.0	/16	13,6	Null
3.0.0.0	/16	14,7	POP

LIB

Address	Prefix	LocLbl	NHLbl
10.1.0.0	/16	15,22	15
10.2.0.0	/16	9,16	POP
20.1.0.0	/16	17,24	17
20.2.0.0	/16	11,18	POP
1.0.0.0	/16	19,26	POP
2.0.0.0	/16	20,27	Null
3.0.0.0	/16	14,21	Null

LIB

Address	Prefix	LocLbl	NHLbl
10.1.0.0	/16	22	22
10.2.0.0	/16	23	Null
20.1.0.0	/16	24	24
20.2.0.0	/16	25	Null
1.0.0.0	/16	26	26
2.0.0.0	/16	27	POP
3.0.0.0	/16	28	Null

10.1.0.0   E0   .1   **1.0.0.0**   .2   .1   **2.0.0.0**   .2   .1   **3.0.0.0**   .2   E0   10.2.0.0

E2   SO   S0   S1   S0   S1   S0   E2

PE A   20.1.0.0   **PE B**   20.2.0.0

10.2.0.0	2

10.2.0.0	9

10.2.0.0	

LFIB

Lbl IN	LblOUT	O/IF	MAC Hdr
2	2	S0	ABCD
4	4	S0	ABCD
6	POP	S0	ABCD
7	7	S0	ABCD

LFIB

Lbl IN	LblOUT	O/IF	MAC Hdr
8,10,15,17	POP	S0	AD8F
9,2	9	S1	DCBA
11,4	11	S1	DCBA
14,7	POP	S1	DCBA

LFIB

Lbl IN	LblOUT	O/IF	MAC Hdr
9,16,11,18	POP	S1	1A2B
15,22	15	S0	2B3C
17,24	17	S0	2B3C
19,26	POP	S0	2B3C

LFIB

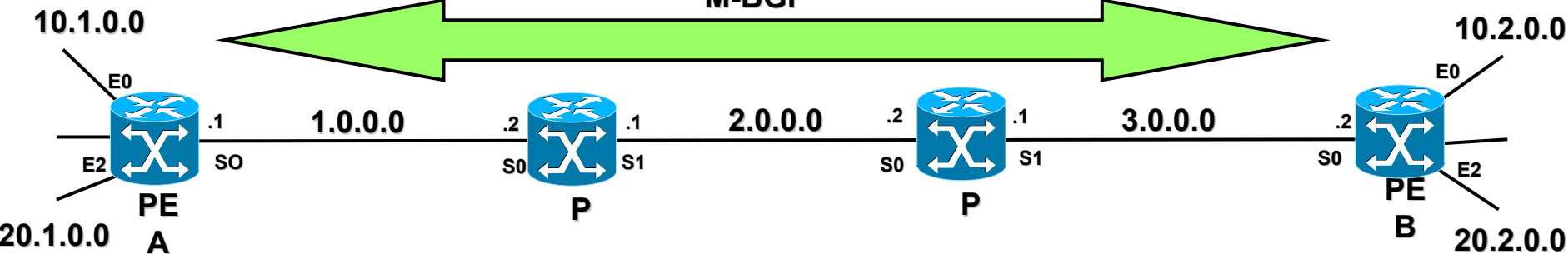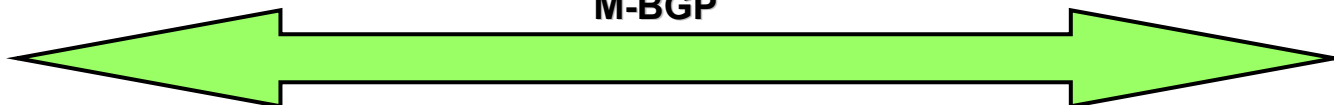| Lbl IN	LblOUT	O/IF	MAC Hdr
22	22	S0	3C4D
24	24	S0	3C4D
26	26	S0	3C4D
27	POP	S0	3C4D

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Using 2ⁿᵈ Label for VPN service

Address	Prefix	Local Label
10.1.0.0	/16	1
10.2.0.0	/16	2
20.1.0.0	/16	3
20.2.0.0	/16	4
1.0.0.0	/16	5
2.0.0.0	/16	6
3.0.0.0	/16	7

Address	Prefix	Local Label
10.1.0.0	/16	22
10.2.0.0	/16	23
20.1.0.0	/16	24
20.2.0.0	/16	25
1.0.0.0	/16	26
2.0.0.0	/16	27
3.0.0.0	/16	28

M-BGP

10.1.0.0

10.2.0.0

E0

E0

.1   1.0.0.0   .2   .1   2.0.0.0   .2   .1   3.0.0.0   .2

E2   SO

S0   S1

S0   S1

S0   E2

PE A

P

P

PE B

20.1.0.0

20.2.0.0

| 2 | 23 | PAYLOAD |

S=0

| 9 | 23 | PAYLOAD |

S=0

| 23 | PAYLOAD |

S=1

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RD, RT and VRF instances

Route Distinguisher (RD)

- **New address family: VPN-IP addresses**

  VPN-IP address = Route Distinguisher (RD) + IP address

  RDs are assigned by a service provider to each PE

  convert non-unique IP addresses into unique VPN-IP addresses

- **Route Distinguisher:**

  Used to create a unique IP address within MPLS Domain, VPNv4 address format would look like:

  2586:10:192.168.23.0

  RD   IP Add

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Route Target (RT)

- **RT controls the import/export**

- **BGP Extended Community:**

  Used to filter routing information

  Identifies VRFs that may receive set of routes tagged with given Route Target
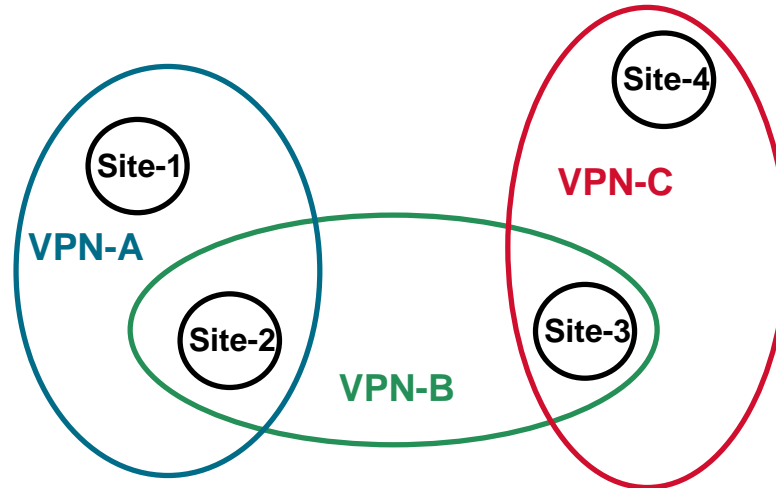
  Example - 2856:101

  Same format as RDs - NOT the same function!

MP-BGP Update

- **Extended Community attribute (64 bits)**

    Site of Origin (SOO): identifies the
    originating site

    Route-target (RT): identifies the set of sites
    the
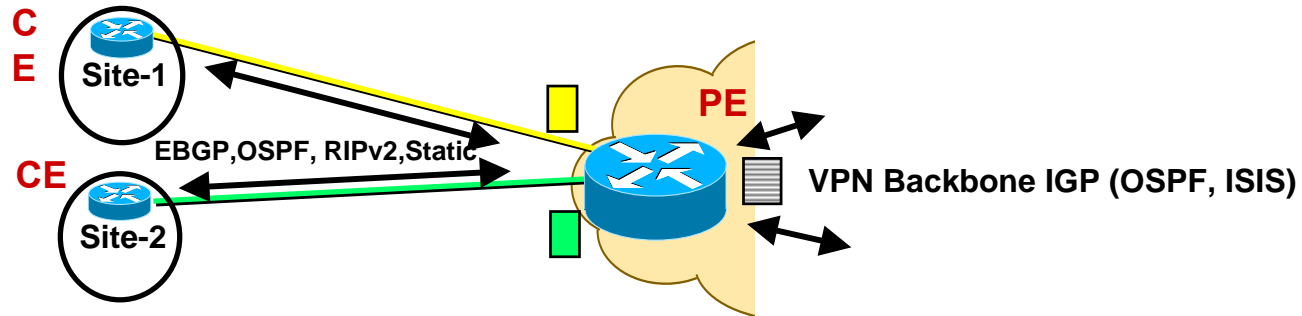   route has to be advertised to

Service Models

MPLS VPN Connection Model

- **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**

MPLS VPN Connection Model

- **PE routers maintain separate routing tables**

  The global routing table

  > **With all PE and P routes
  > Populated by the VPN backbone IGP (ISIS or OSPF)**

  VRF (VPN Routing and Forwarding)

  > **Routing and Forwarding table associated with one or more directly connected sites (CEs)**
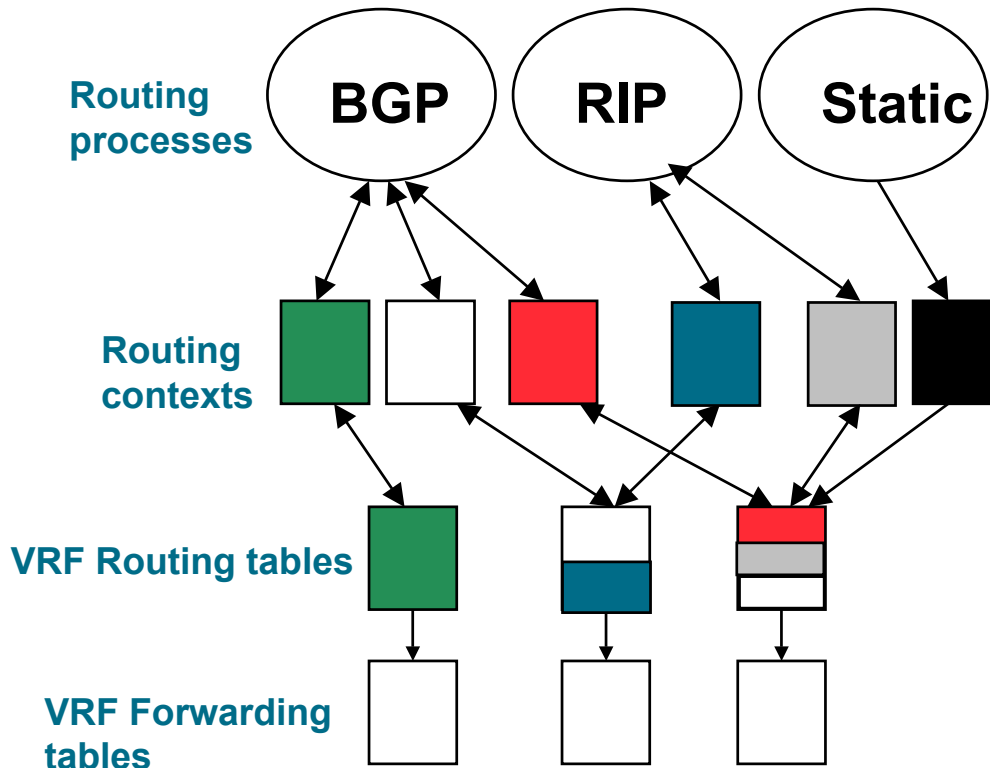
  > **VRF are associated to (sub/virtual/tunnel)interfaces**

  > **Interfaces may share the same VRF if the connected sites may share the same routing information**

MPLS VPN mechanisms
VRF and Multiple Routing Instances

Routing processes

BGP RIP Static

Routing contexts

VRF Routing tables

VRF Forwarding tables

- **Routing processes run within specific routing contexts**

- **Populate specific VPN routing table and FIBs (VRF)**

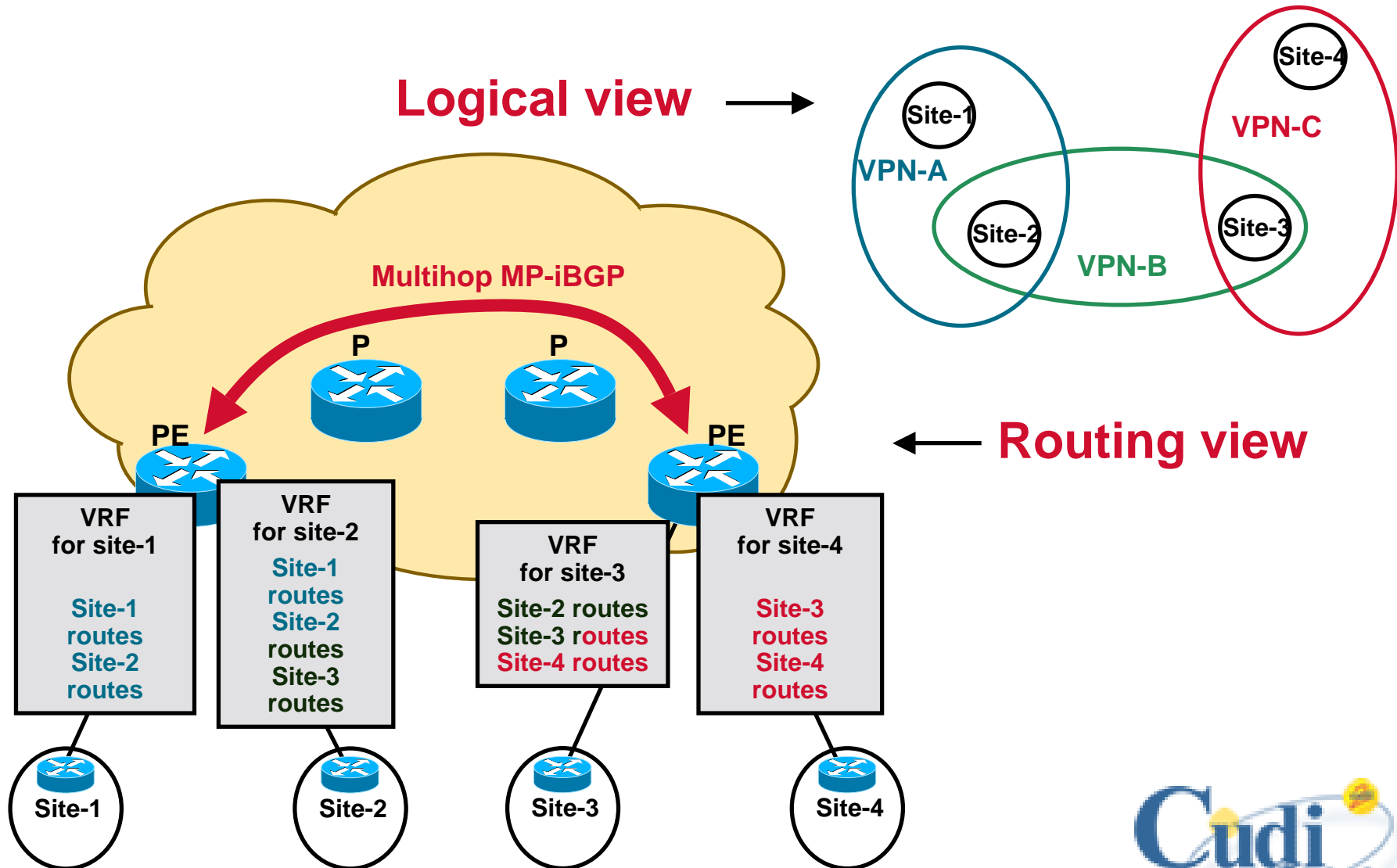- **Interfaces are assigned to VRFs**

MPLS VPN Connection Model
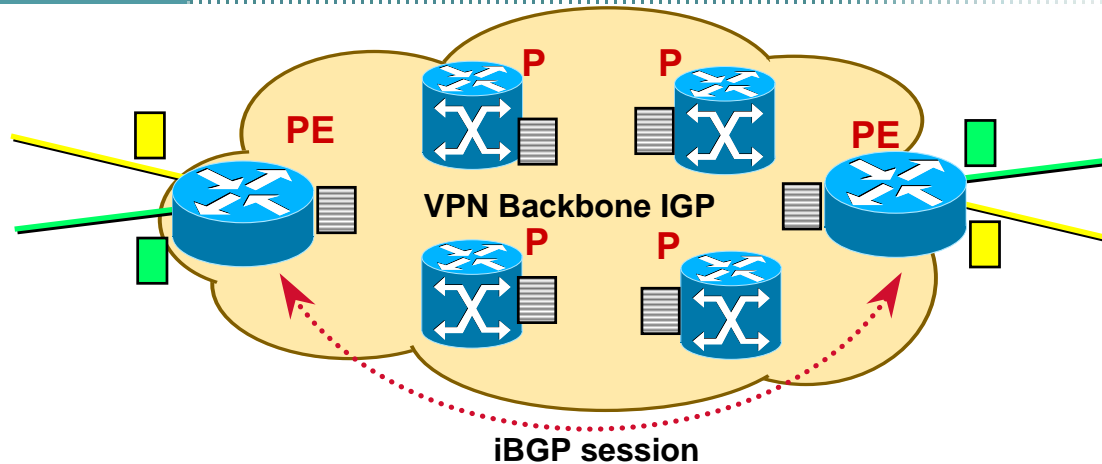
- **PE and P routers share a common IGP** (ISIS or OSPF)

- **PEs establish MP-iBGP sessions between them**

- **PEs use MP-BGP to exchange** routing **information related to the** connected sites and **VPNs**

  VPN-IPv4 addresses, Extended Community, Label

MPLS VPN mechanisms
VRF and Multiple Routing Instances

Logical view →

VPN-A

Site-1

Site-4

VPN-C

Site-2

VPN-B

Site-3

Multihop MP-iBGP

P

P

PE

PE

← **Routing view**

VRF for site-1

**Site-1 routes
Site-2 routes**

VRF for site-2

**Site-1 routes
Site-2 routes
Site-3 routes**

VRF for site-3

**Site-2 routes
Site-3 routes
Site-4 routes**

VRF for site-4

**Site-3 routes
Site-4 routes**

Site-1

Site-2

Site-3

Site-4

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MPLS/VPN Configuration

MPLS VPN - Configuration

- **The following global commands are mandatory BEFORE configuring MPLS**

  Ip cef

  Mpls ip

  No tag-switching ip propagate-ttl (optional if no ttl propagation is needed)

- **VRF configuration command**

```
ip vrf <vrf-symbolic-name>
  rd <route-distinguisher-value>
  route-target import <community>
  route-target export <community>
```

MPLS VPN - Configuration
PE/CE routing protocols

- **PE/CE may use BGP, RIPv2, OSPF or Static routes**

- **A routing context is used for each VRF**

- **Routing contexts are defined within the routing protocol instance**

    Address-family router sub-command

    Router rip
    version 2
    address-family ipv4 vrf <vrf-symbolic-name>
    …
       any common router sub-command
    …

MPLS VPN - Configuration
PE/CE routing protocols

- **BGP uses same "address-family" command**

  Router BGP <asn>

  ...
  address-family ipv4 vrf <vrf-symbolic-name>

  …
  any common router BGP sub-command

  …

- **Static routes are configured per VRF**

  ip route vrf <vrf-symbolic-name> …

MPLS VPN – Configuration Verification

- **All show commands are VRF based**

    Show ip route vrf <vrf-symbolic-name> ...

    Show ip protocol vrf <vrf-symbolic-name>

    Show ip cef <vrf-symbolic-name> …

    …

- **PING and Telnet commands are VRF based**

    telnet /vrf <vrf-symbolic-name>

    ping vrf <vrf-symbolic-name>

Suggested reading

draft-ietf-mpls-arch-05.txt

draft-ietf-mpls-label-encaps-04.txt

draft-ietf-mpls-atm-02.txt

draft-ietf-mpls-ldp-03.txt

www.cisco.com/go/mpls