
cisco Live!
Let's go

The bridge to possible

VRF, MPLS and MP-BGP Fundamentals

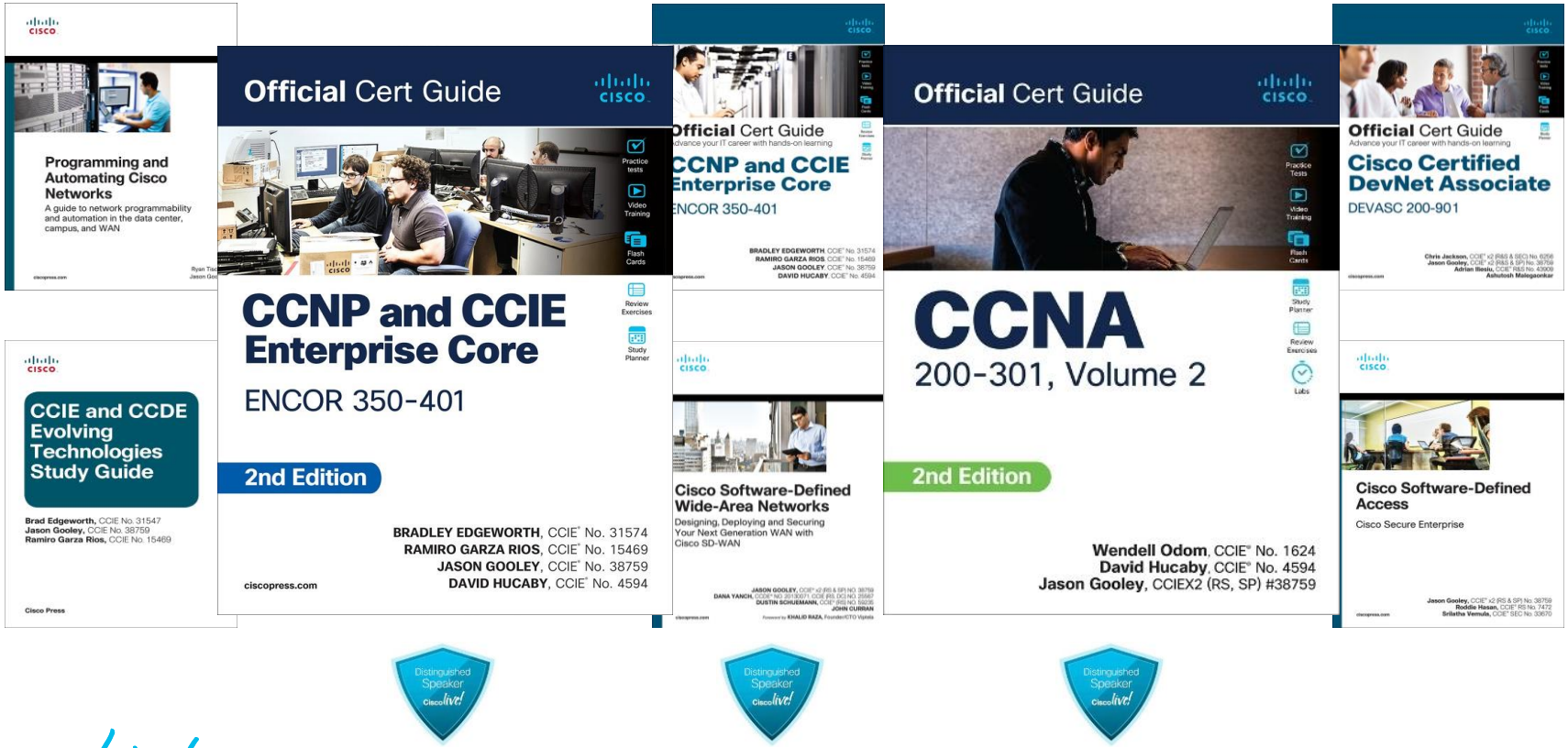
Jason Gooley, CCIEx2 (RS, SP) #38759
Technical Solutions Architect – WW EN Sales, Cisco

@Jason_Gooley

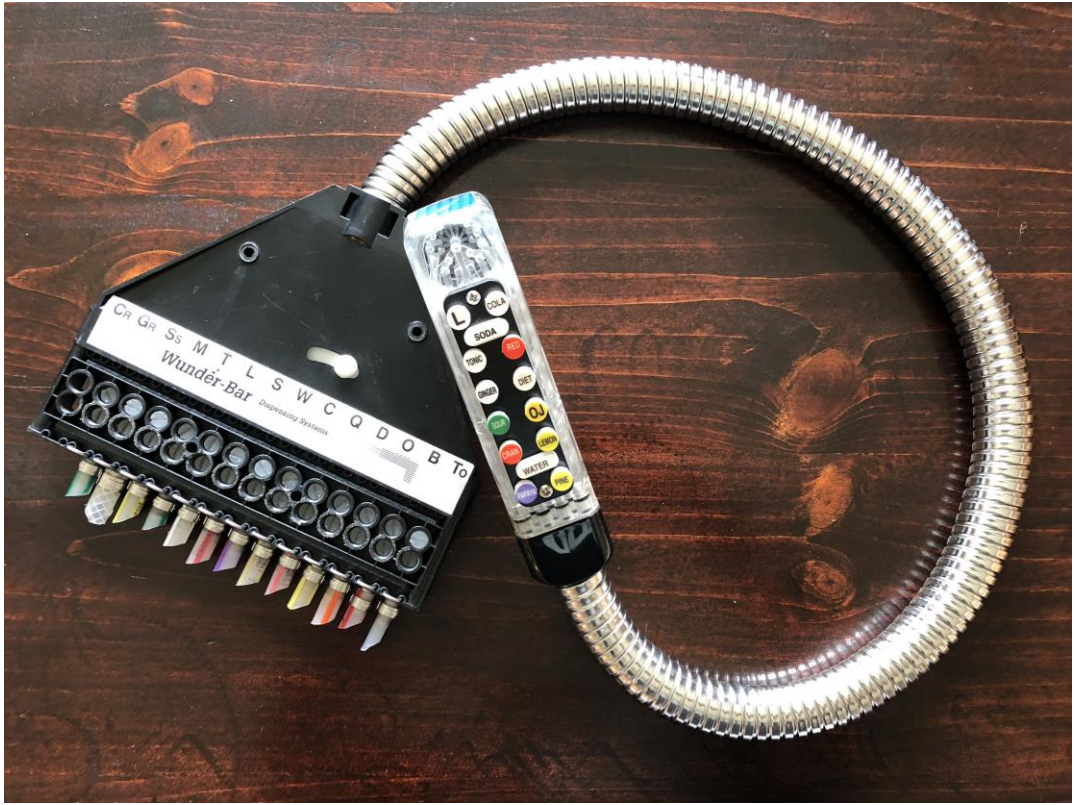
Agenda

- Introduction to Virtualization
- VRF-Lite
- MPLS & BGP Free Core
- Multiprotocol BGP (MP-BGP)
- Conclusion
- Q & A

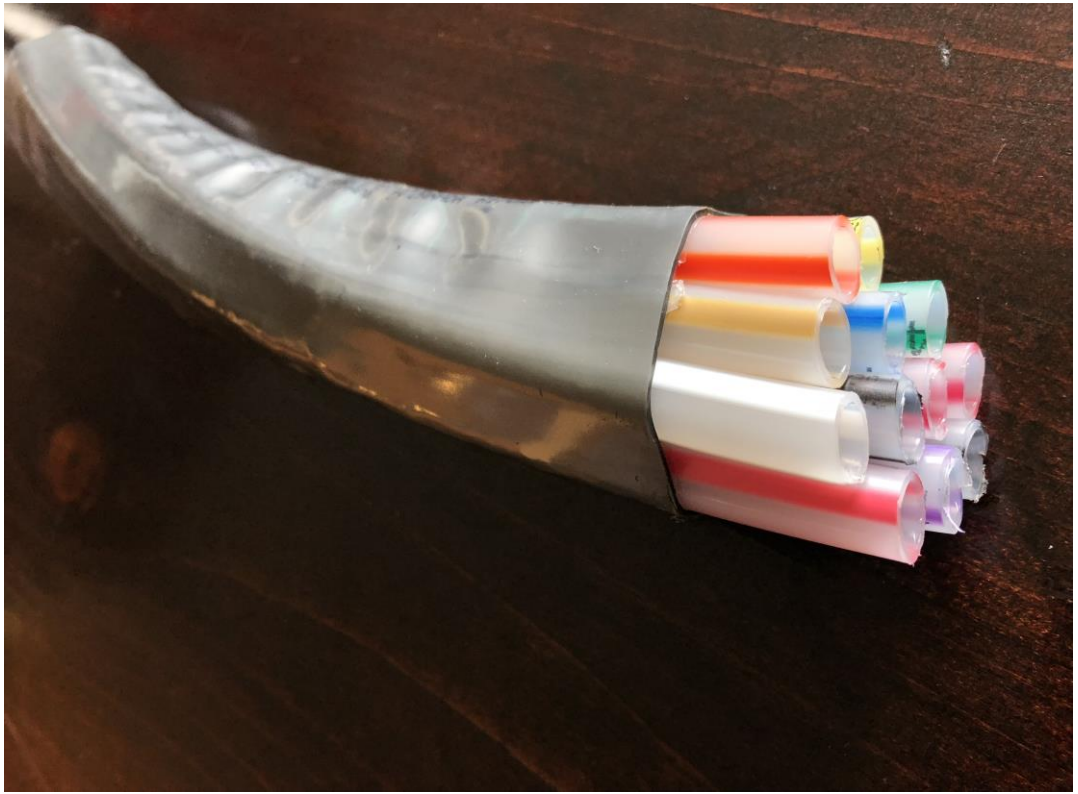
Who is Jason and What is a Technical Evangelist?



3 Networks Walk into a...



What is a VRF?



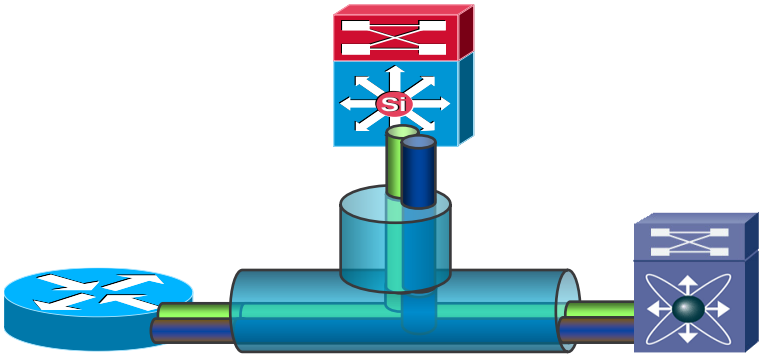
Enterprise Network Virtualization

Key Building Blocks

Device Partitioning

“virtualizing” the Routing and Forwarding of the Device

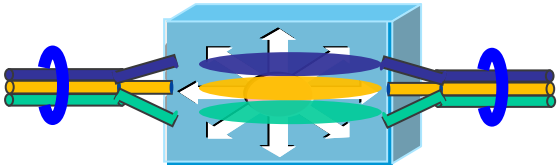
Virtualized Interconnect



Extending and Maintaining the “virtualized” Devices/Pools over Any Media

Device Partitioning

Layer 2 vs. Layer 3 Virtualization



VLAN—Virtual LAN

- Virtualize at Layer 2 forwarding
- Associates to one or more L2 interfaces on switch
- Has its own MAC forwarding table and spanning-tree instance per VLAN
- Interconnect options?

  VLANs are extended via a physical cable or virtual 802.1q trunk

VRF—Virtual Routing and Forwarding

- Virtualize at Layer 3 forwarding
- Associates to one or more Layer 3 interfaces on router/switch
- Each VRF has its own

  Forwarding table (CEF)

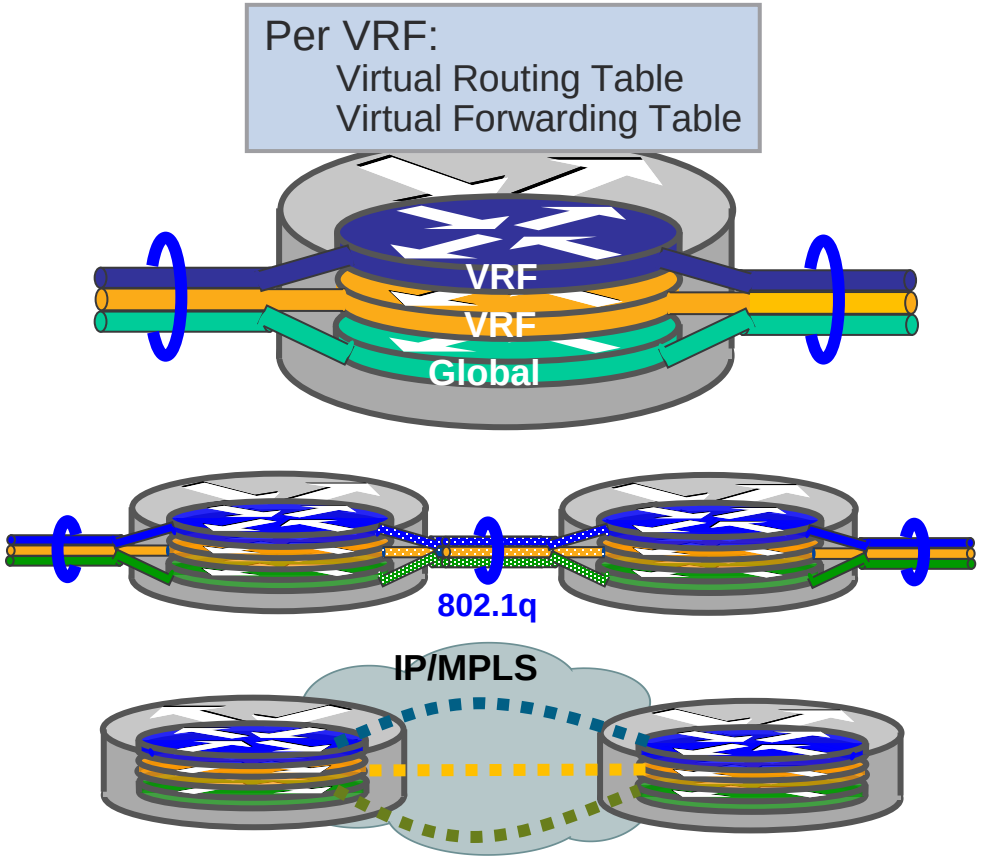
  Routing process (RIP, EIGRP, OSPF, BGP)
- Interconnect options (VRF-Lite)?

  802.1q, GRE, sub-interfaces, physical cables, signaling

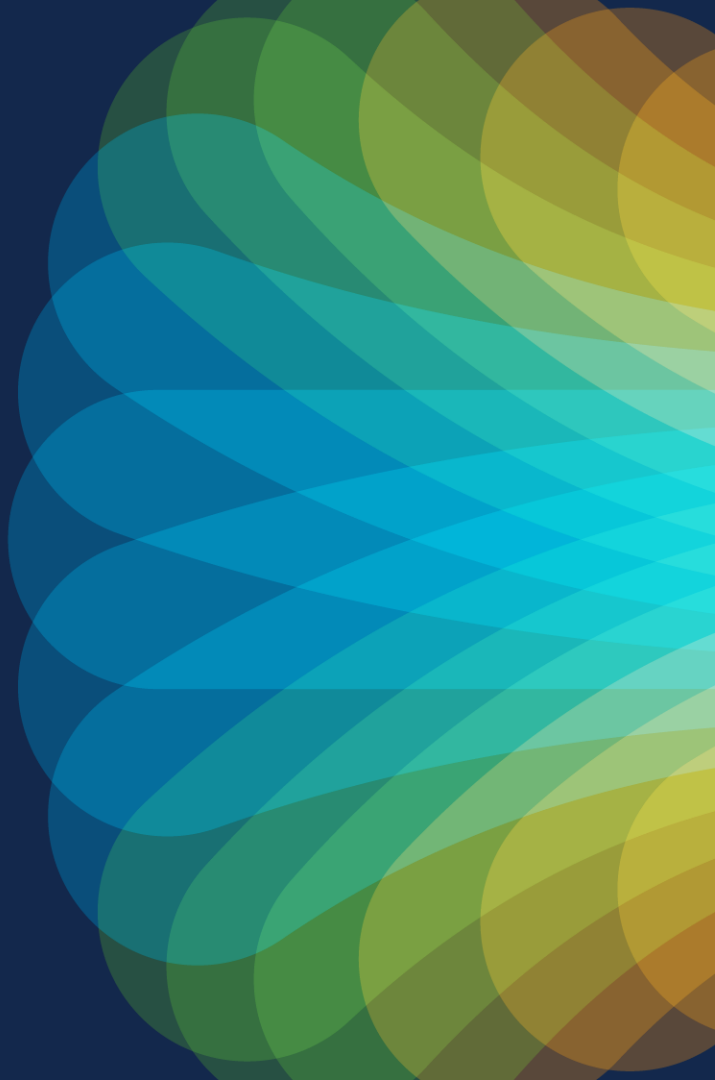
Path Isolation

Functional Components

- Device Virtualization
  - Control plane Virtualization
  - Data plane Virtualization
  - Services Virtualization
- Data path Virtualization
  - Hop-by-Hop - VRF-Lite End-to-End
  - Multi-Hop - VRF-Lite GRE
  - MPLS-VPN
  - MPLS VPN over IP
  - MPLS VPN over DMVPN
  - MPLS VPN o GRE/mGRE

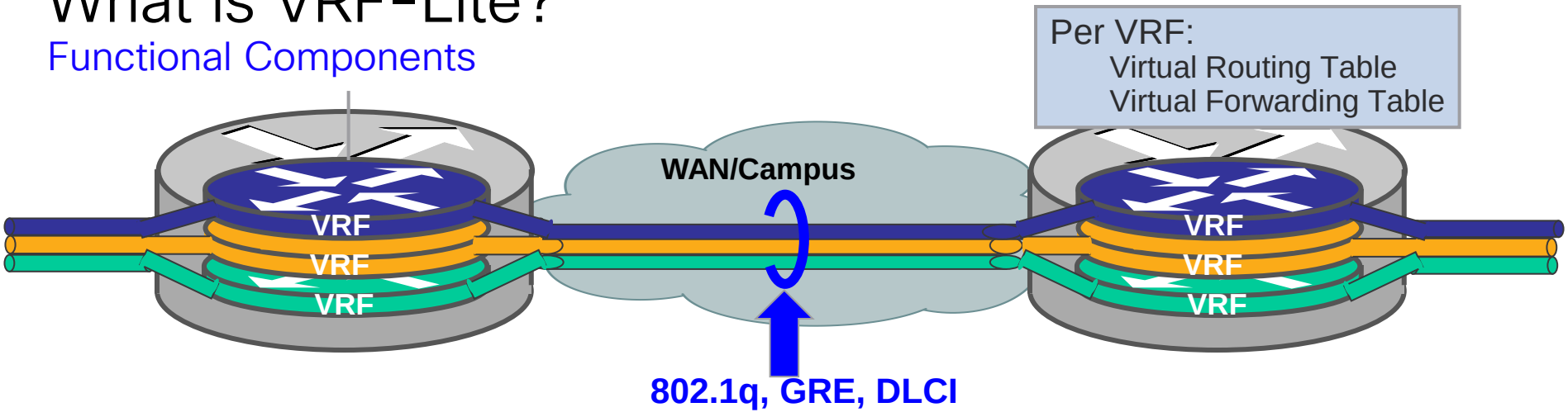


VRF-Lite



What is VRF-Lite?

Functional Components

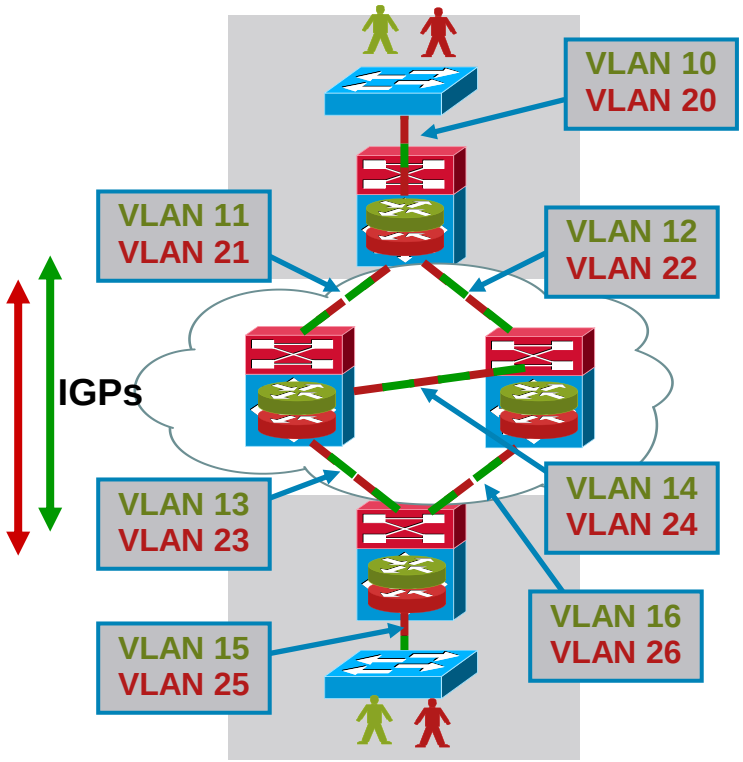


- A VRF supports it's own **Routing Information Base (RIB)** and **Forwarding Information Base (FIB)**
- Leverages "Virtual" encapsulation for separation:
  - Ethernet/802.1Q, GRE, Frame Relay
- Routing protocols are "VRF aware"
  - RIP/v2, EIGRP, OSPF, BGP, static (per VRF)
- Layer 3 interfaces can only belong to a single VRF

VRF-Lite

Things to Remember

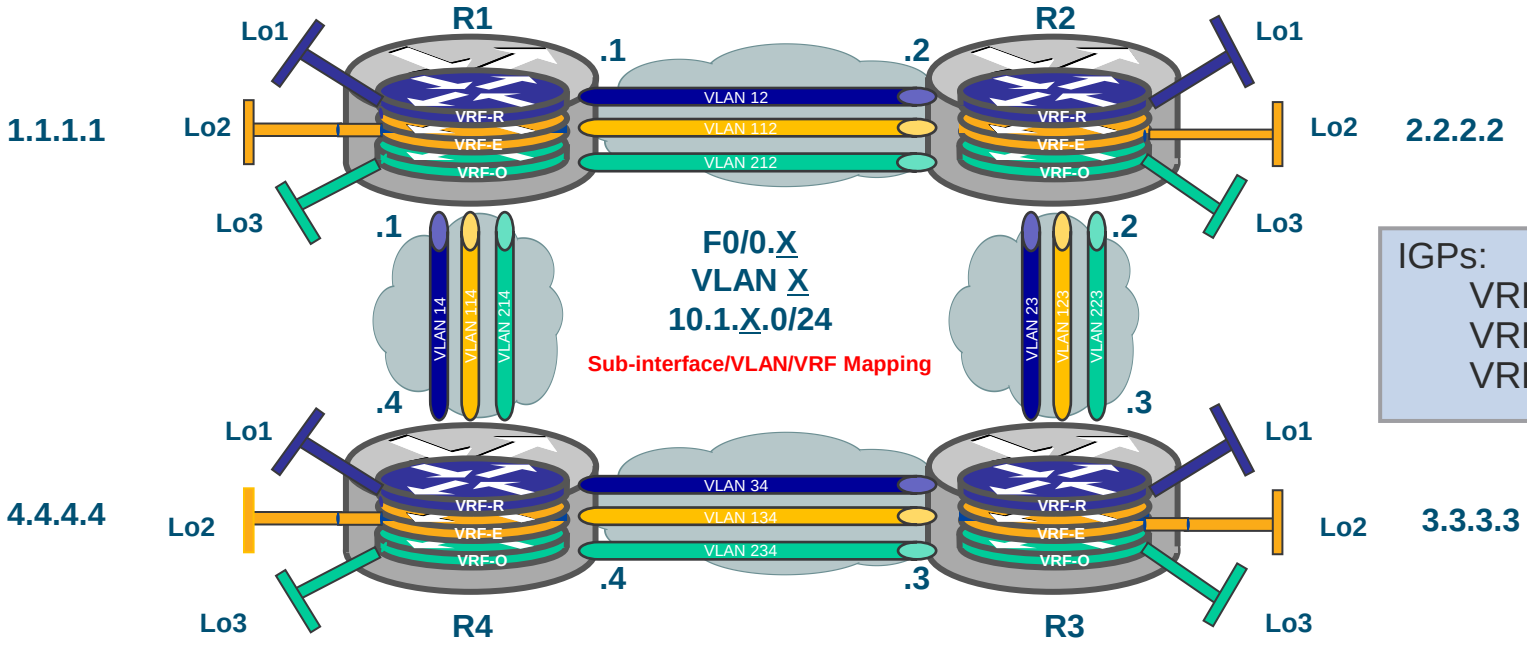
- End-to-End segmentation is done on a per VRF and per hop basis
- MP-BGP or control plane signaling is not required
- Labels are not required (i.e. MPLS)
- Scaling should be limited to a small number of VRFs



VRF-Lite

Sub-interface Example

Per VRF:
- Virtual Routing Table
- Virtual Forwarding Table
- Locally Significant



IGPs:
- VRF-R = RIP
- VRF-E = EIGRP
- VRF-O = OSPF

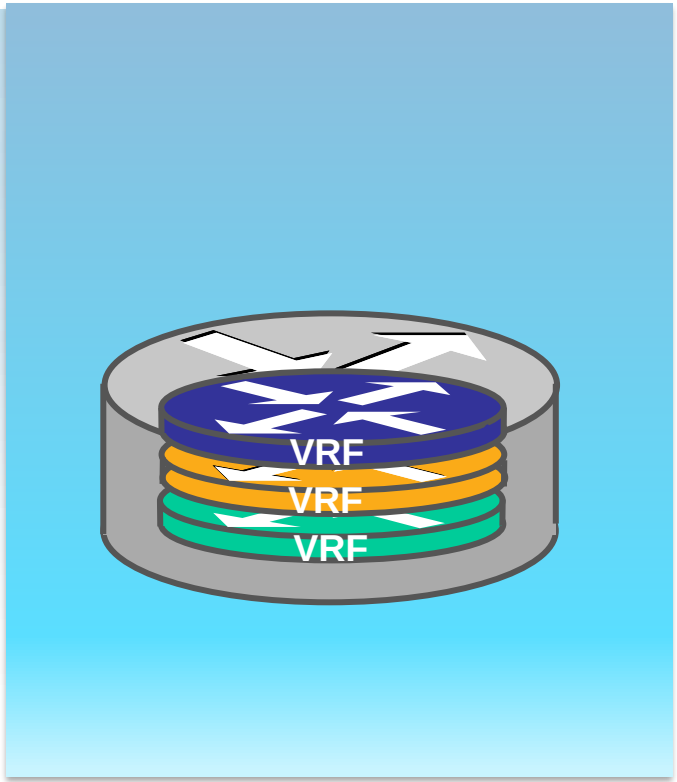
VRF-Lite Sub-interface Configuration

Command Line Interface (CLI) Review

```
ip vrf VRF-R

interface FastEthernet0/0.12
 ip vrf forwarding VRF-R

interface Loopback1
 ip vrf forwarding VRF-R
```

```
ip vrf VRF-E

interface FastEthernet0/0.112
 ip vrf forwarding VRF-E

interface Loopback2
 ip vrf forwarding VRF-E
```

```
ip vrf VRF-O

interface FastEthernet0/0.212
 ip vrf forwarding VRF-O

interface Loopback3
 ip vrf forwarding VRF-O
```

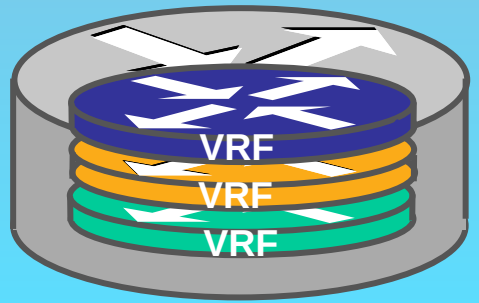


VRF-Lite Sub-interface Configuration

Command Line Interface (CLI) Review – VRF Definition Example

```
vrf definition VRF-R
 address-family ipv4

interface FastEthernet0/0.12
 vrf forwarding VRF-R

interface Loopback1
 vrf forwarding VRF-R
```

```
vrf definition VRF-O
 address-family ipv4

interface FastEthernet0/0.212
 vrf forwarding VRF-O

interface Loopback3
 vrf forwarding VRF-O
```



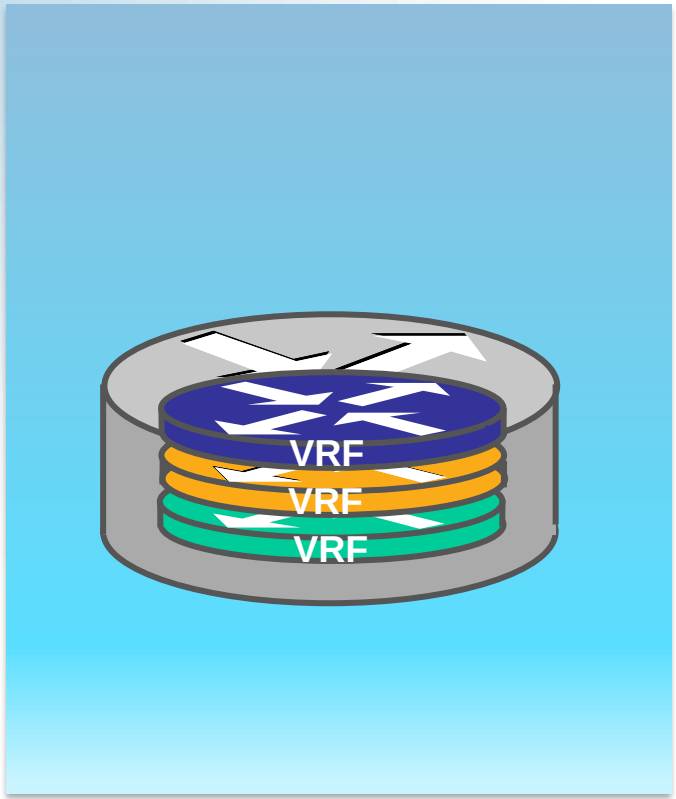
Multiprotocol VRF Conversion Configuration

Command Line Interface (CLI) Review

vrf upgrade-cli multi-af-mode {**common-policies** | **non-common-policies**} [**vrf** *vrf-name*]

```
PE1(config)#vrf upgrade-cli multi-af-mode common-policies
You are about to upgrade to the multi-AF VRF syntax commands.
You will lose any IPv6 addresses configured on interfaces
belonging to upgraded VRFs.

Are you sure ? [yes]:
Number of VRFs upgraded: 1
```

```
interface Ethernet0/1
 vrf forwarding VRF
 ip address 10.1.78.7 255.255.255.0

PE1(config)#do sh run | se vrf
vrf definition VRF
 rd 7:1
 route-target export 7:1
 route-target import 5:1
```



VRF Aware RIP Configuration

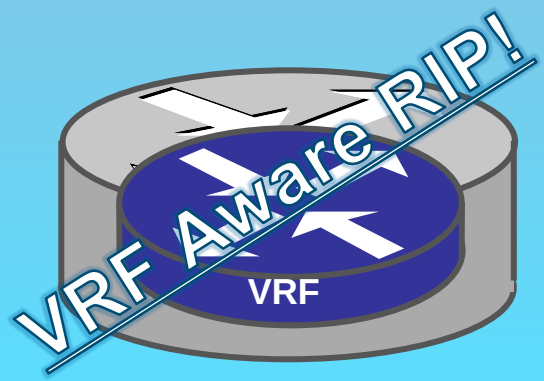
Command Line Interface (CLI) Review

```
router rip
 version 2
 network 1.0.0.0
 network 10.0.0.0
 no auto-summary
```

```
router rip
 !
 address-family ipv4 vrf VRF-R
  network 1.0.0.0
  network 10.0.0.0
  no auto-summary
  version 2
 exit-address-family
```

RIP leverages address-family ipv4 vrf _____

Leverage what you already know!



VRF Aware EIGRP Configuration

Command Line Interface (CLI) Review

```
router eigrp 10
  network 1.1.1.1 0.0.0.0
  network 10.1.112.0 0.0.0.255
  no auto-summary
```

```
router eigrp 10 (AS can be the same or different as one of the VRFs!!!)
 auto-summary
 !
 address-family ipv4 vrf VRF-E
  network 1.1.1.1 0.0.0.0
  network 10.1.112.0 0.0.0.255
  no auto-summary
  autonomous-system 10
 exit-address-family
```

EIGRP leverages address-family ipv4 vrf _____

Set unique autonomous system number per VRF

Leverage what you already know!

VRF Aware OSPF Configuration

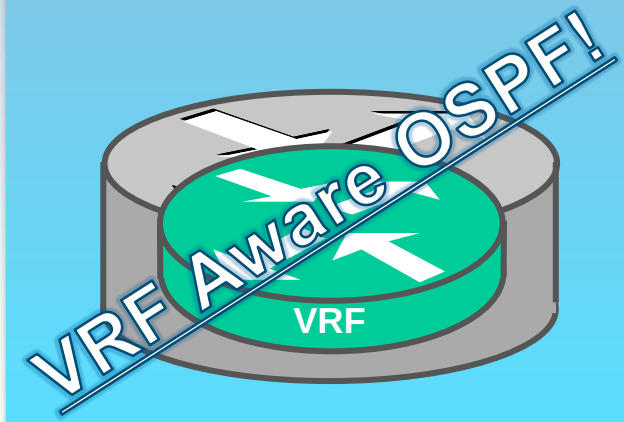
Command Line Interface (CLI) Review

```
router ospf 1
 log-adjacency-changes
 network 1.1.1.1 0.0.0.0 area 1
 network 10.1.212.0 0.0.0.255 area 0
```

```
router ospf 2 vrf VRF-O
 log-adjacency-changes
 network 1.1.1.1 0.0.0.0 area 1
 network 10.1.212.0 0.0.0.255 area 0
```

OSPF leverages vrf _____ after the unique process number

Leverage what you already know!

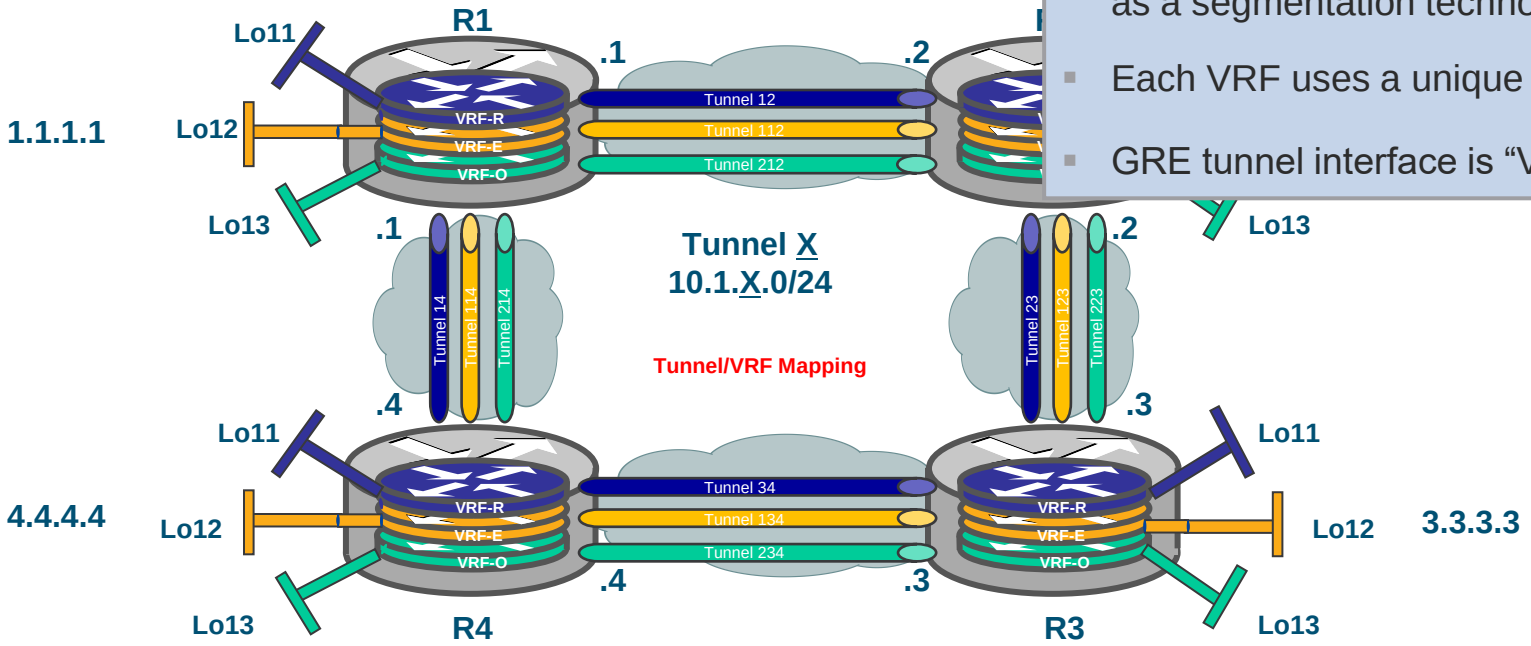


Live Exploration

No Sub-interface Support? No Problem!

GRE Example

- VRF-Lite can also leverage GRE tunnels as a segmentation technology
- Each VRF uses a unique GRE tunnel
- GRE tunnel interface is “VRF aware”



Configuration Note: Each GRE Tunnel Could Require Unique Source/Destination IP (Platform Dependent)

VRF-Lite Tunnel Configuration

Command Line Interface (CLI) Review

```
ip vrf VRF-S
 rd 11:11

interface Loopback101
 ip address 11.11.11.11 255.255.255.255 (Global Routing Table)

interface Tunnel12
 ip vrf forwarding VRF-S
 ip address 10.1.12.1 255.255.255.0
 tunnel source Loopback101
 tunnel destination 22.22.22.22

ip vrf VRF-S
 rd 22:22

interface Loopback102
 ip address 22.22.22.22 255.255.255.255 (Global Routing Table)

interface Tunnel12
 ip vrf forwarding VRF-S
 ip address 10.1.12.2 255.255.255.0
 tunnel source Loopback102
 tunnel destination 11.11.11.11
```

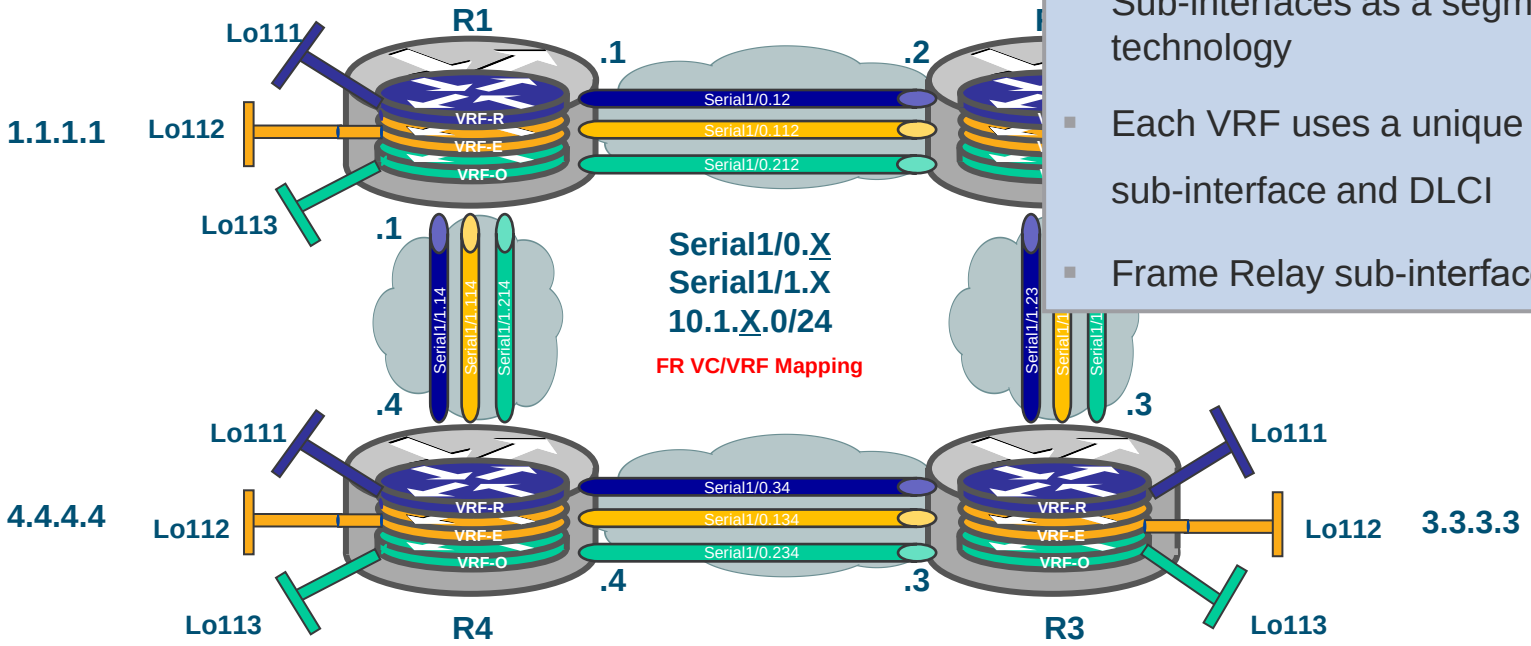
Leverage what you already know!

```
ip route vrf VRF-S 2.2.2.2 255.255.255.255 10.1.12.2
```


```
ip route vrf VRF-S 1.1.1.1 255.255.255.255 10.1.12.1
```

Layer 2 Serial Link? No Problem?

Back-to-Back Frame Relay Example



- VRF-Lite can also leverage Frame Relay Sub-interfaces as a segmentation technology
- Each VRF uses a unique Frame-Relay sub-interface and DLCI
- Frame Relay sub-interface is “VRF aware”

Configuration Note: Leveraging Back-to-Back Frame-Relay Configuration

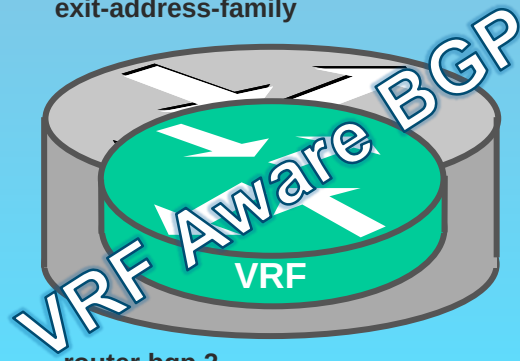
VRF-Lite Back-to-Back Frame Relay Configuration

Command Line Interface (CLI) Review

```
ip vrf VRF-B
 rd 111:111

interface Serial1/0
 encapsulation frame-relay
 no keepalive

Interface Serial1/0.12 point-to-point
 ip vrf forwarding VRF-B
 ip address 10.1.12.1 255.255.255.0
 frame-relay interface-dlci 201

ip vrf VRF-B
 rd 222:222

interface Serial1/0
 encapsulation frame-relay
 no keepalive

Interface Serial1/0.12 point-to-point
 ip vrf forwarding VRF-B
 ip address 10.1.12.2 255.255.255.0
 frame-relay interface-dlci 201
```

Leverage what you already know!

```
router bgp 1
 address-family ipv4 vrf VRF-B
  neighbor 10.1.12.2 remote-as 2
  neighbor 10.1.12.2 activate
  no synchronization
  network 1.1.1.1 mask 255.255.255.255
 exit-address-family
```



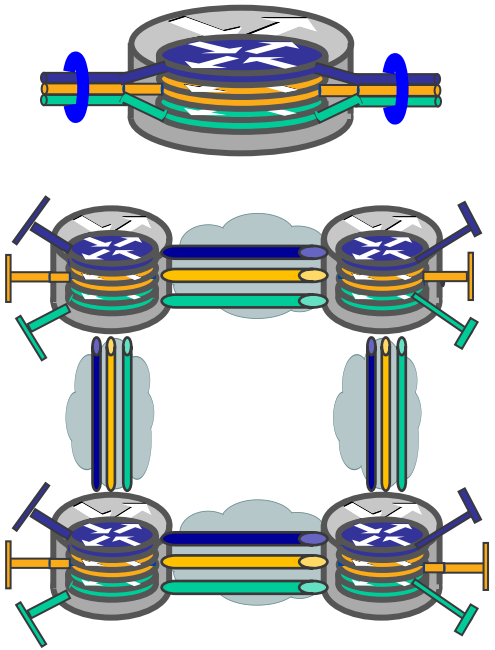

```
router bgp 2
 address-family ipv4 vrf VRF-B
  neighbor 10.1.12.1 remote-as 1
  neighbor 10.1.12.1 activate
  no synchronization
  network 2.2.2.2 mask 255.255.255.255
 exit-address-family
```

Live Exploration

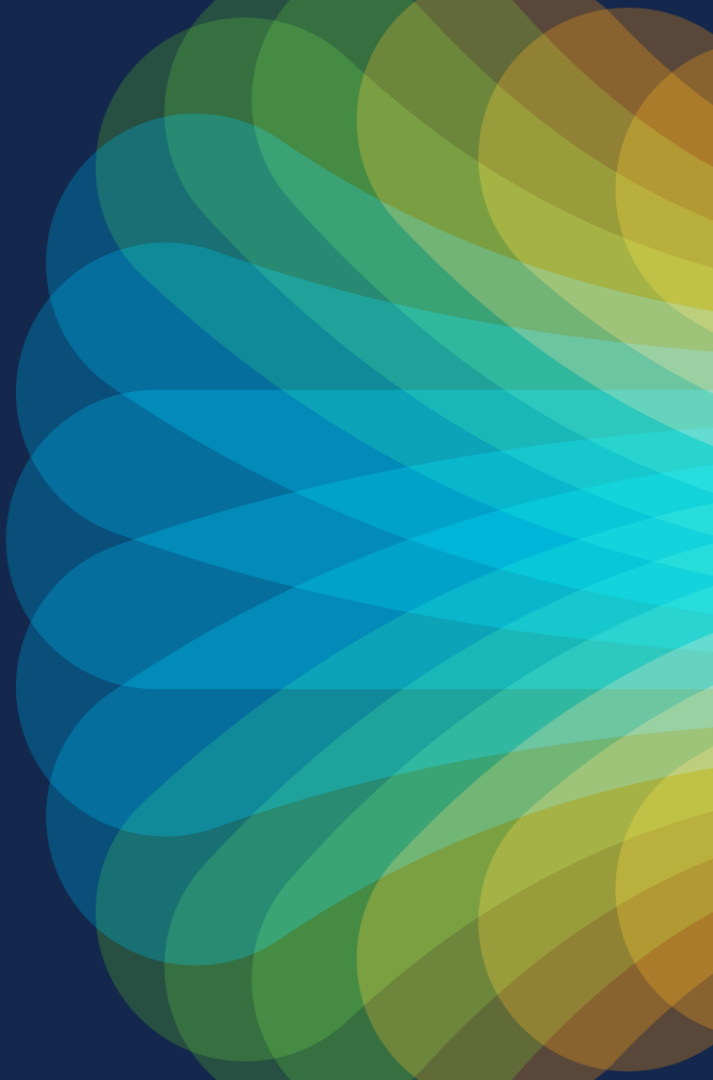
VRF-Lite

Summary

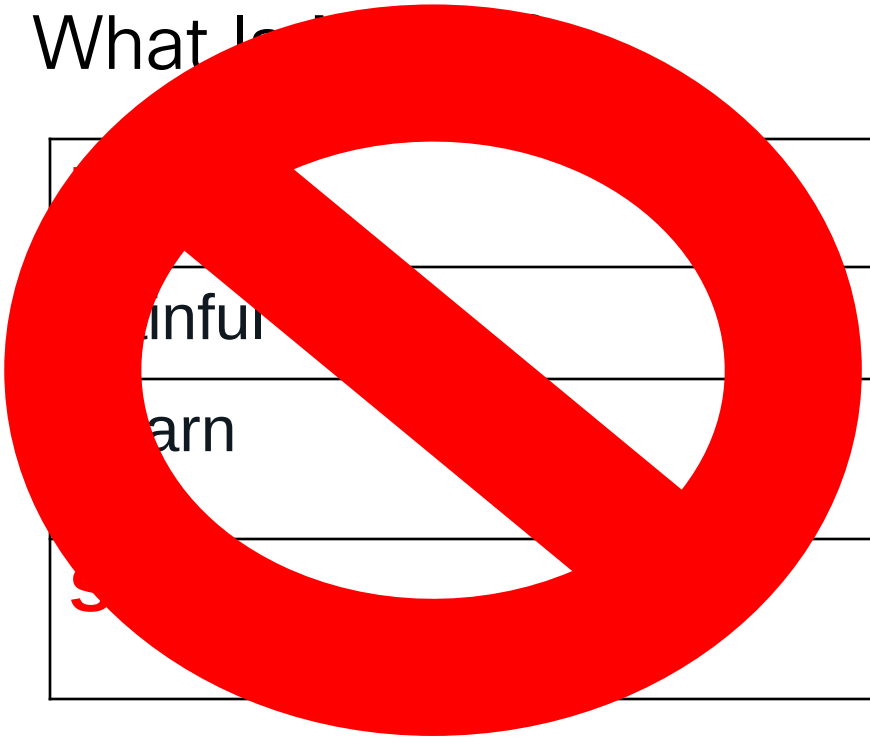
- Create a VRF in router for RIB/FIB and interface segmentation
- No MPLS, LDP, or MP-BGP required
- Optimal solution when VRF count is small (~ <8)
- Supports multicast and QoS solutions
- Leverage current routing protocol knowledge and apply it to PE-CE VRF Routing



MPLS & BGP Free Core



What I



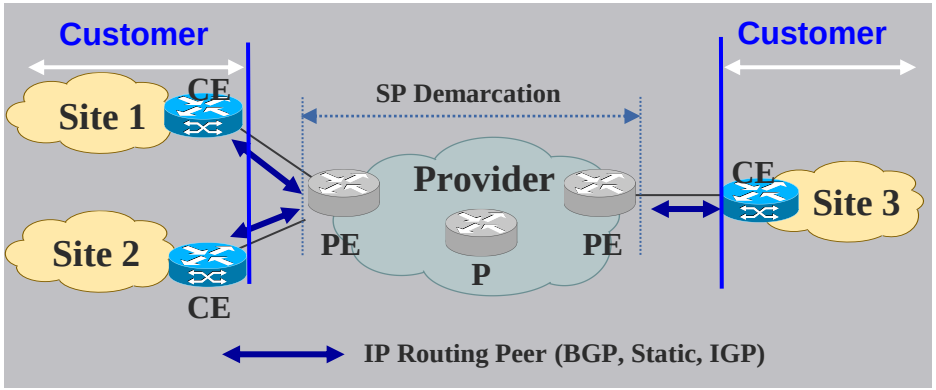
What Is MPLS?

Multi	Multi-Protocol: The ability to carry any payload Have: IPv4, IPv6, Ethernet, ATM, FR
Protocol	
Label	Uses Labels to tell a node what to do with a packet; separates forwarding (hop by hop behavior) from routing (control plane)
Switching	Routing based on IPv4/IPv6 lookup. Everything else is label switching.

MPLS

Component Overview

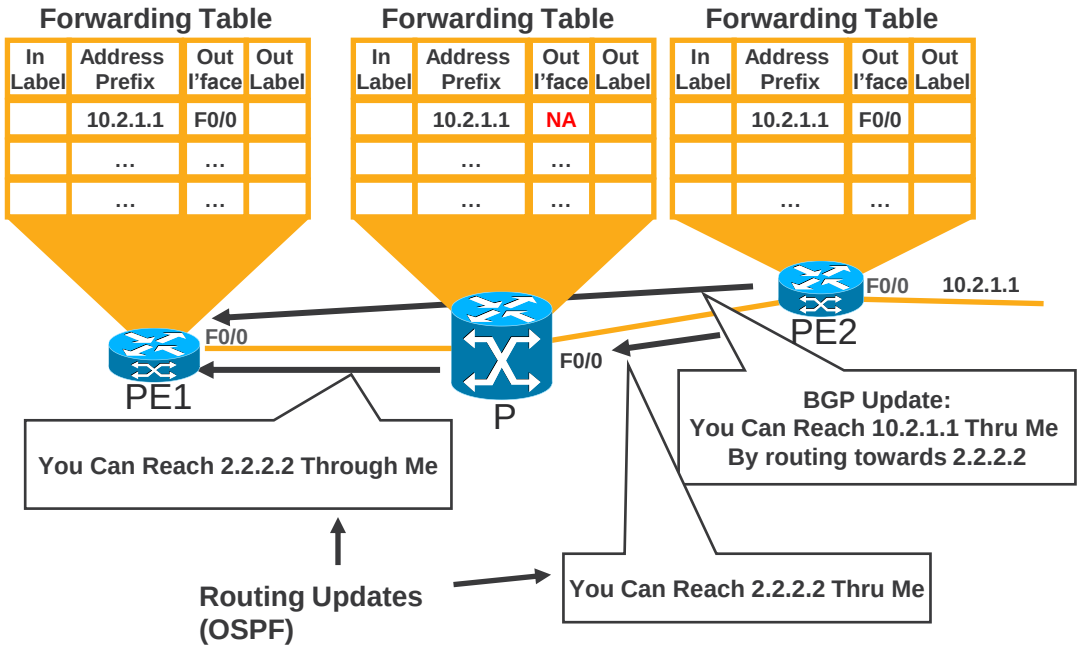
- CE routers owned by customer
- PE routers owned by SP
- P routers owned by SP
- Customer “peers” to “PE” via IP
- Exchanges routing with SP via routing protocol (or static route)*
- SP advertises CE routes to other CEs



* Labels are not exchanged with the SP

IP Routing
IGP vs. BGP

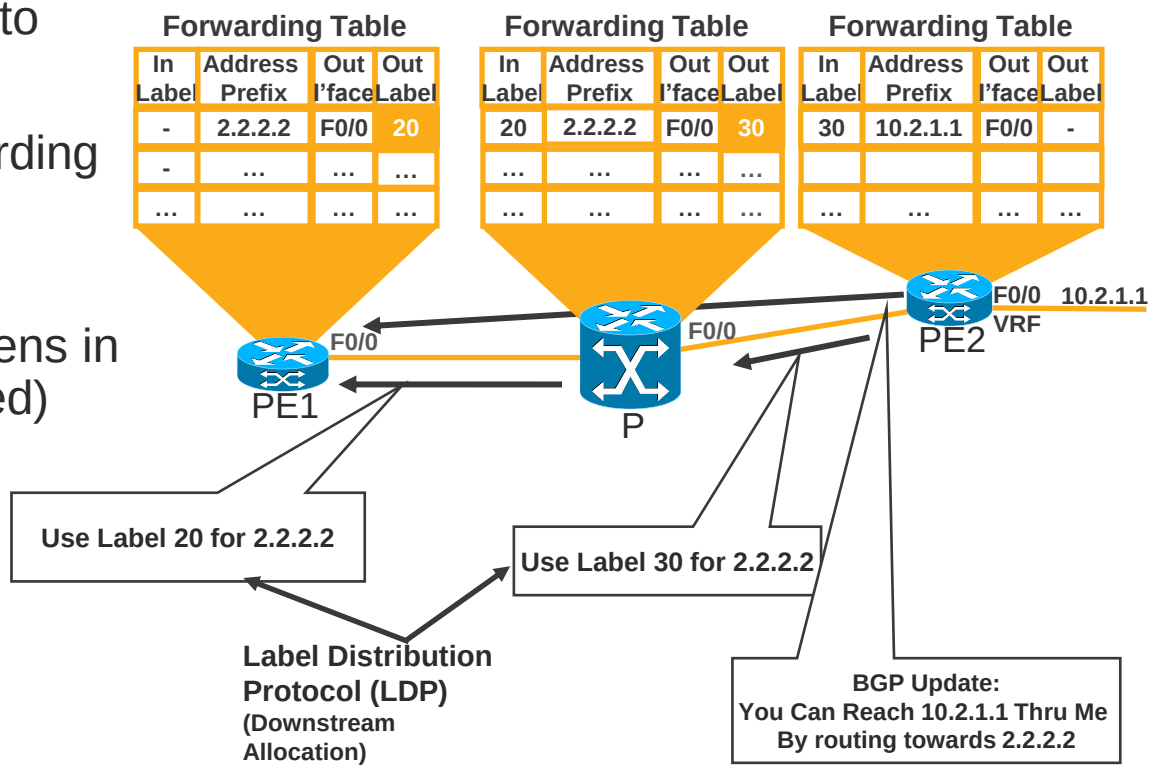
- Exchange of IP routes for Loopback Reachability
  - OSPF, IS-IS, EIGRP, etc.
- iBGP neighbour peering over IGP transport
- Route towards BGP Next-Hop



MPLS Label Switched Path (LSP) Setup with LDP

Assignment of Remote Labels

- Local label mappings are sent to connected nodes
- Receiving nodes update forwarding table
  - Out label
- LDP label advertisement happens in parallel (downstream unsolicited)



Control Plane for VPN Routes

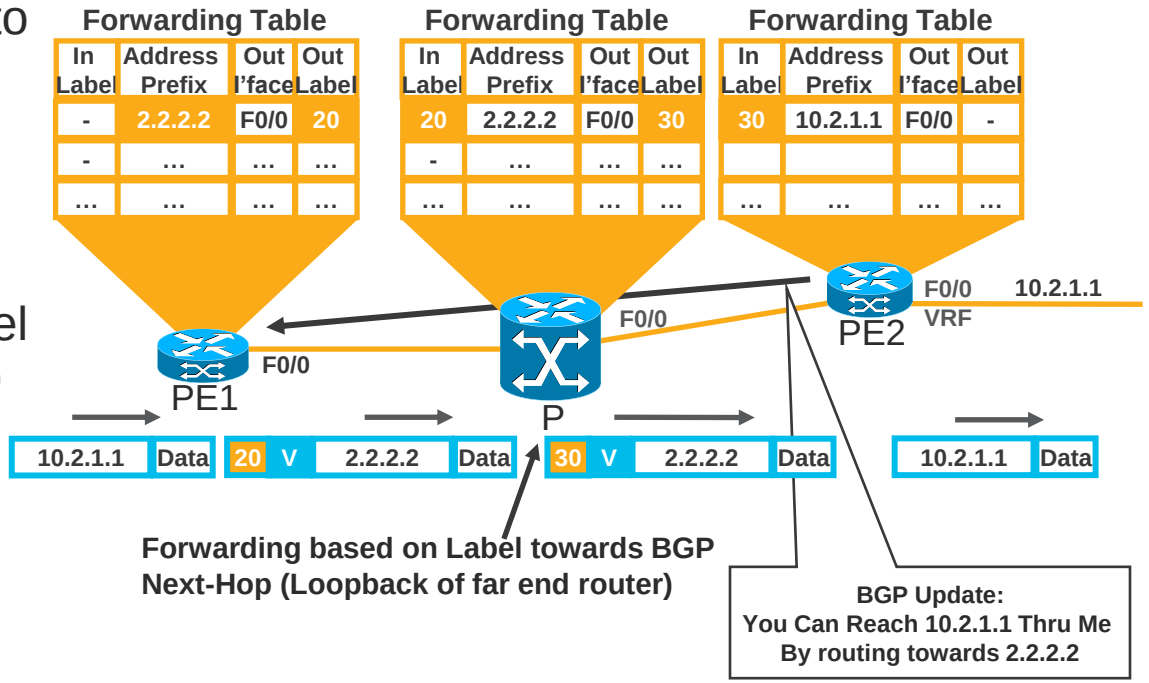
Assignment of VPN Labels

- PE2 tells PE1 what its VPN label is for customer network 10.2.1.1 (v)

MPLS Traffic Forwarding with LDP

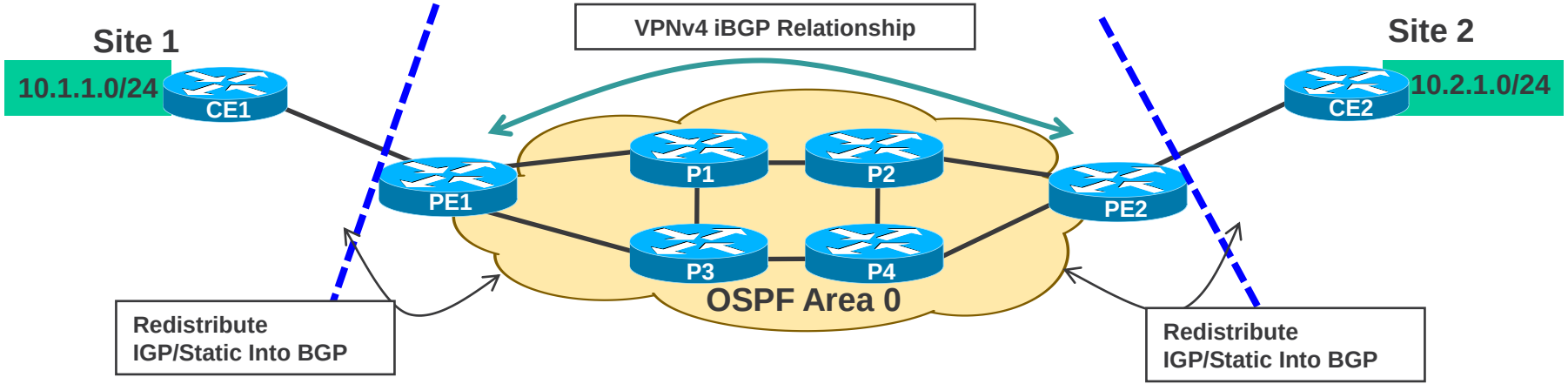
Hop-by-hop Traffic Forwarding Using Labels

- Ingress PE node adds labels to packet (push)
  - Via MPLS forwarding table
  - Transport label
  - VPN label (VRF)
- Downstream P node uses label for forwarding decision (swap)
  - Outgoing interface
  - Out label
- Egress PE removes label and forwards original packet (pop)



BGP Free Core

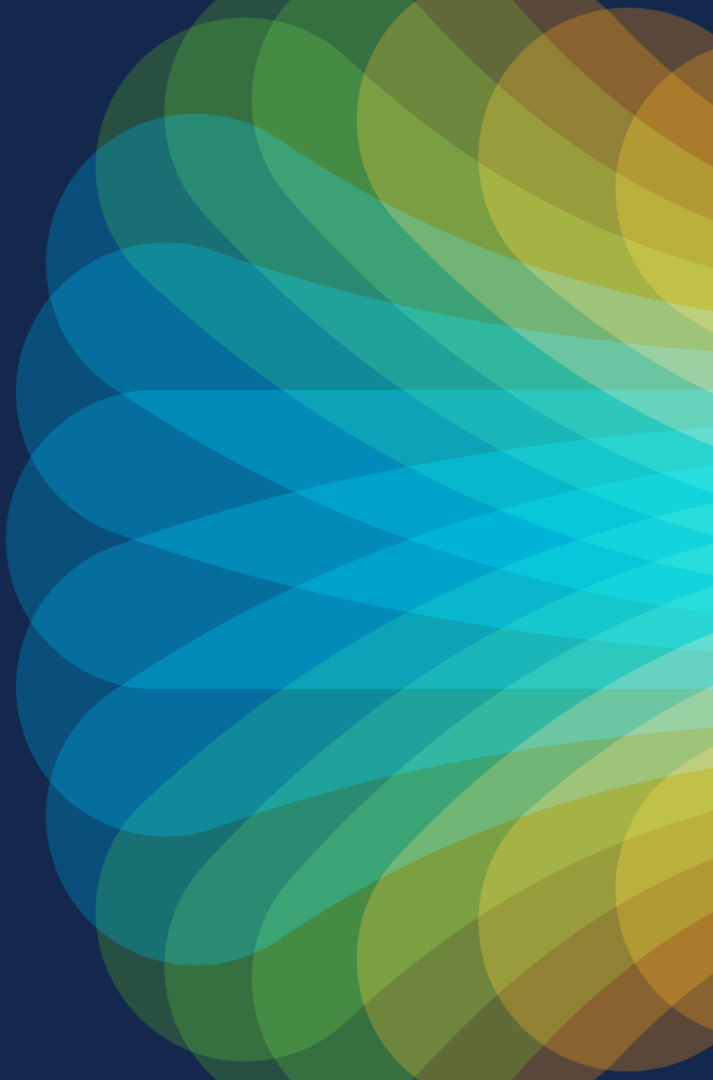
Component Overview



1. Always route towards BGP Next-Hop
2. Routes will be valid on PE Routers
3. Will label switch towards BGP Next-Hop of PE with MPLS enabled

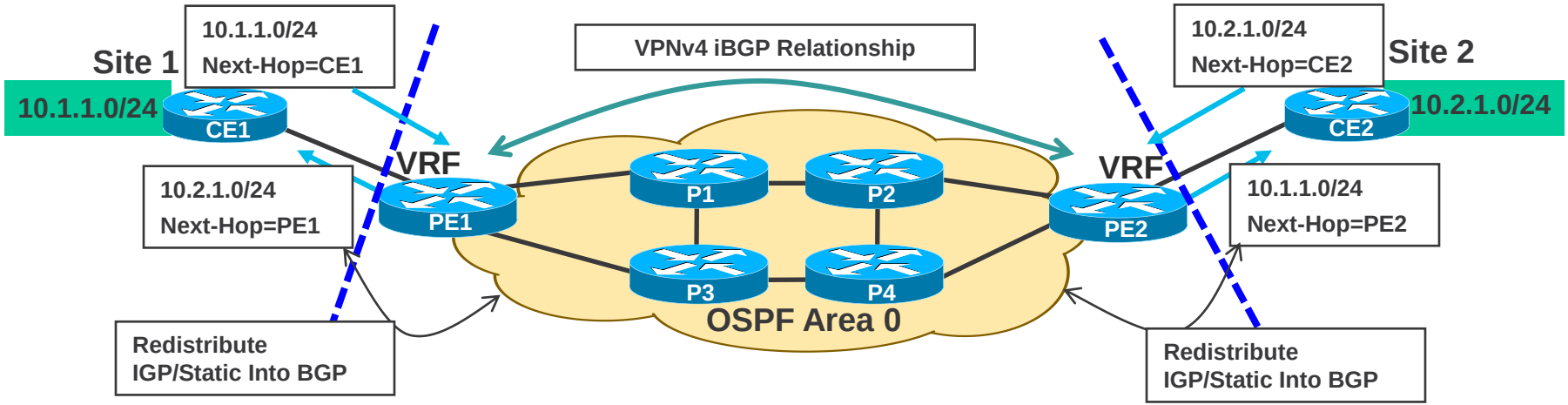
End-to-End BGP and redistribution of routes into OSPF core not necessary!

Multiprotocol BGP (MP-BGP)



Multiprotocol BGP (MP-BGP)

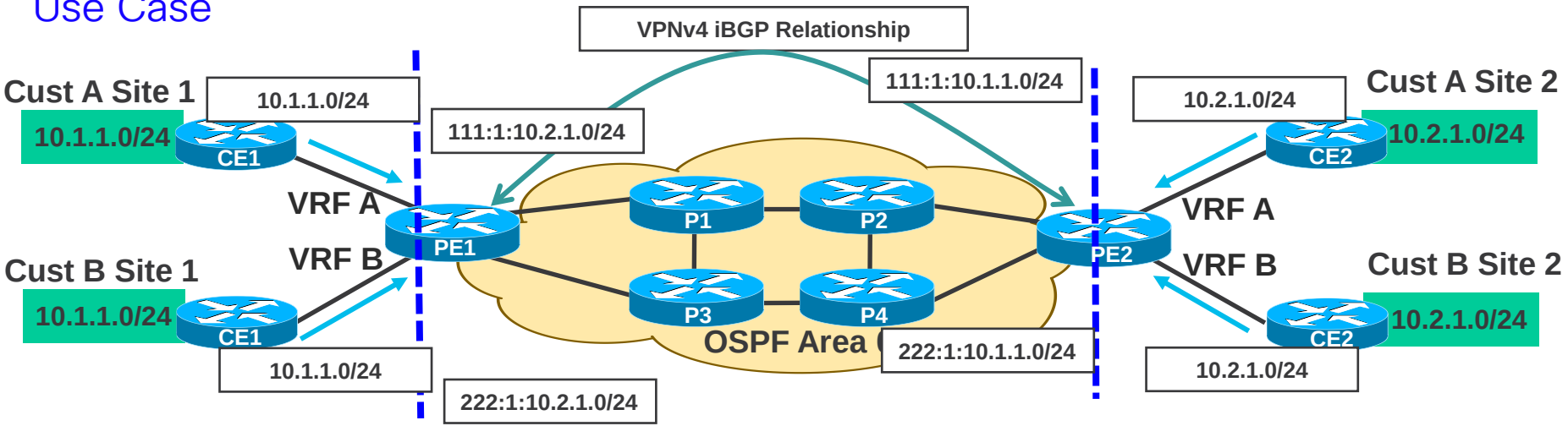
Bringing It All Together



1. PE receives an IPv4 update on a VRF interface (eBGP/OSPF/RIP/EIGRP)
2. PE translates it into VPNv4 address (96-bit address) (64-bit RD + 32 bit IPv4 address)
   - Assigns an RT per VRF configuration
   - Rewrites next-hop attribute to itself
   - Assigns a label based on VRF and/or interface
3. PE sends MP-iBGP update to other PE routers

What is a VPNv4 Address?

Use Case

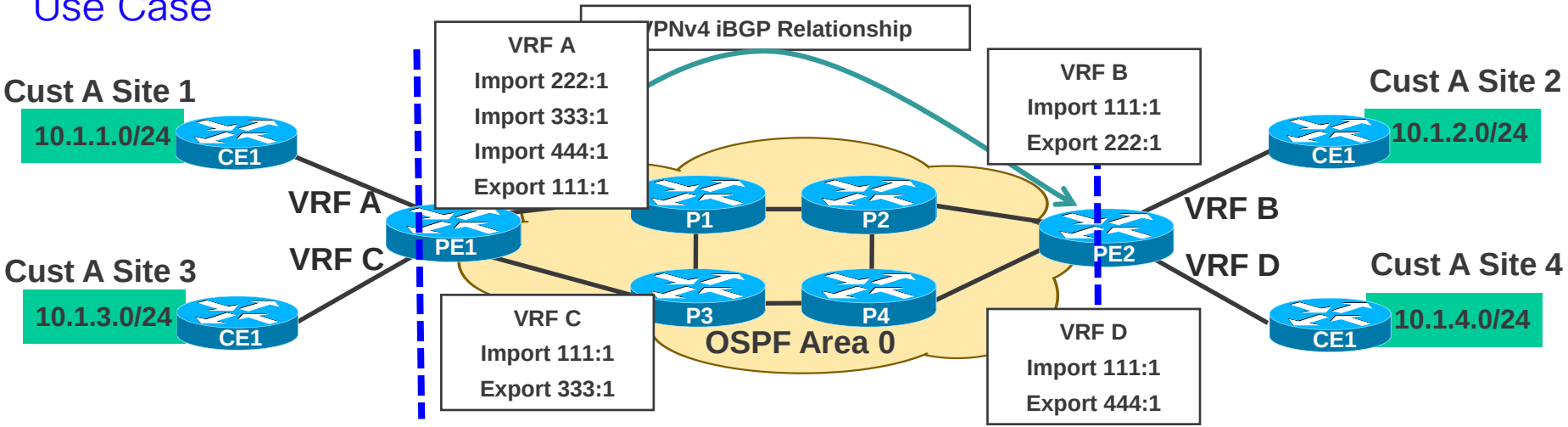


1. PE routers service multiple customers
2. Once PE redistributes customer routes into MP-BGP, they must be unique
3. RD is prepended to each prefix to make routes unique

VPNv4 prefixes are the combination of a 64-bit RD and a 32-bit IPv4 prefix. VPNv4 prefixes are 96-bits in length

To Import or Not to Import? That IS the Question!

Use Case

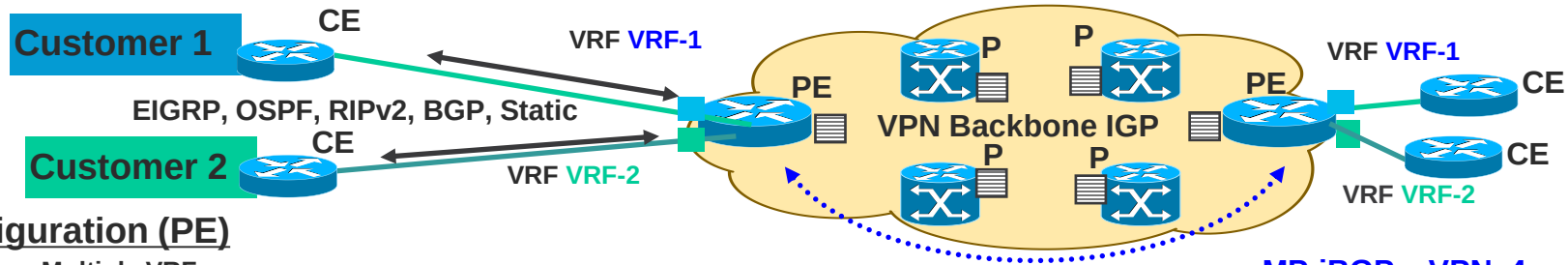


1. Route Targets dictate which VRF will receive what routes
2. Can be used to allow specific sites access to centralized services
3. Cust A Site 2, Site 3 and Site 4 will not be able to exchange routes with each other

Route Targets are a 64-bit value and are carried in BGP as an extended community

MPLS VPN and MP-BGP

Command Line Interface (CLI) Review



VRF Configuration (PE)

```
! PE Router – Multiple VRFs
ip vrf VRF-1
 rd 65100:10
 route-target import 65102:10
 route-target export 65102:10
ip vrf VRF-2
 rd 65100:20
 route-target import 65102:20
 route-target export 65102:20
!
Interface FastEthernet0/1.10
 ip vrf forwarding VRF-1
Interface FastEthernet0/1.20
 ip vrf forwarding VRF-2
```

MP-iBGP Configuration (PE)

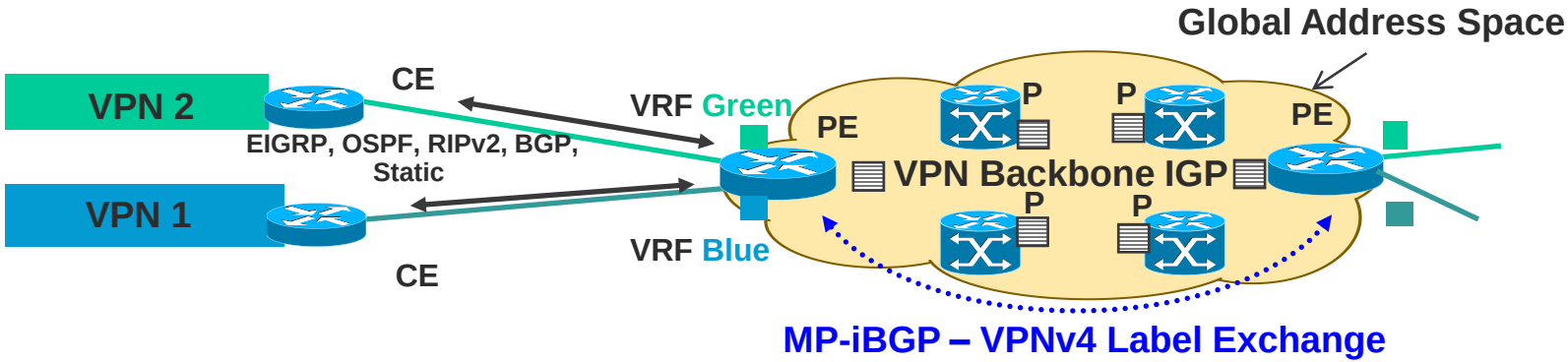
MP-iBGP – VPNv4 Label Exchange

```
! PE router
router bgp 65102
 no bgp default ipv4-unicast
 neighbor 2.2.2.2 remote-as 65102
 !
 address-family vpnv4
 neighbor 2.2.2.2 activate
 neighbor 2.2.2.2 send-community extended
 exit-address-family
 !
 address-family ipv4 vrf VRF-1
 redistribute rip
 exit-address-family
```

Live Exploration

MPLS VPN Technology Summary

MPLS VPN Connection Model



CE Routers

- Sends routes to PE
  - via (static, RIP, BGP, EIGRP, OSPF)
  - Unlabeled IP packets

PE Routers

- MPLS Edge routers with VRF(s)
- MPLS forwarding to P routers
- IGP/BGP – IP to CE routers
- Distributes VPN information through MP-BGP to other PE routers with VPNv4 addresses, extended community, VPN labels
- Push labels onto incoming IP packets

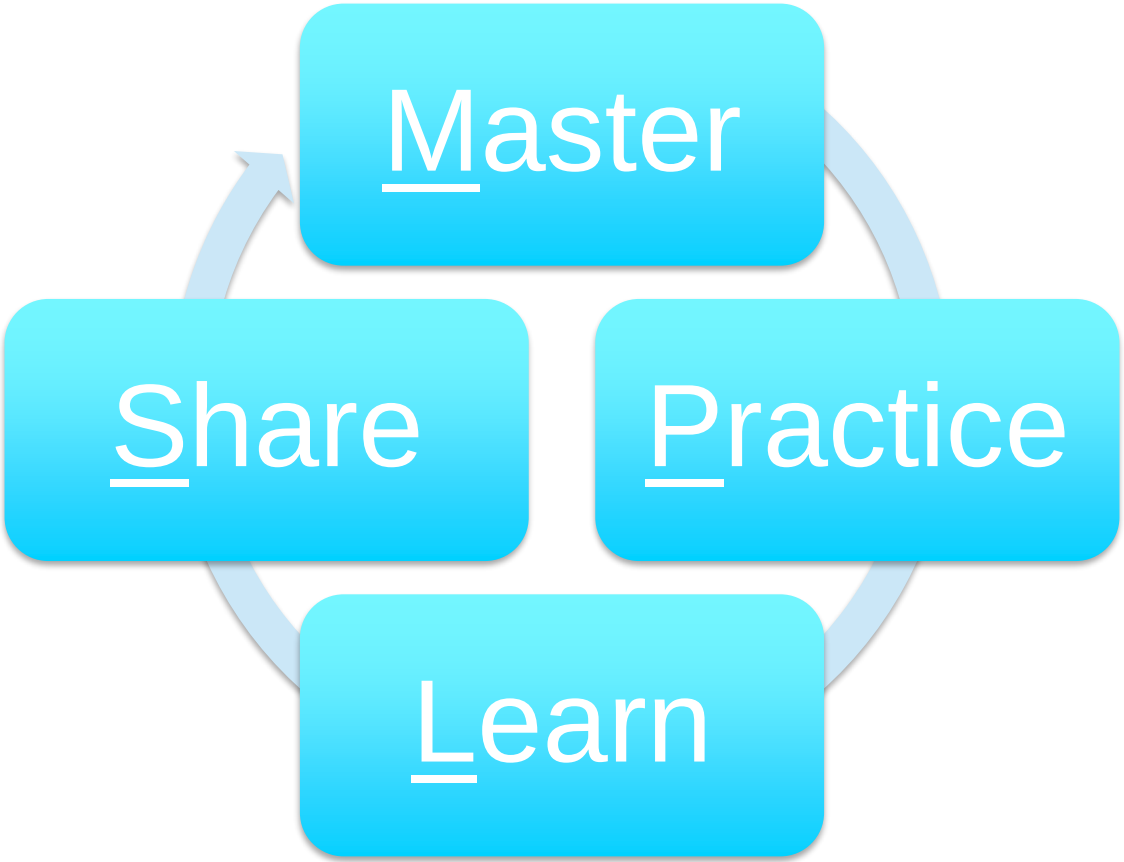
P Routers

- P routers are in the core of the MPLS cloud
- P routers do not need to run BGP
- Do not have knowledge of VPNs
- Switch packets based on labels (swap/pop) not IP

Closing Thoughts

- Break MPLS into smaller, more manageable chunks to accelerate learning
- Leverage current routing protocol knowledge learning PE-CE VRF routing
- MP-BGP and traditional IPv4 BGP configuration is very similar
- If routes are not present on CE routers check route-target import/export, communities and redistribution between IPv4 VRF address-families under IGP and BGP
- If routes are present but you are having problems with reachability, check MPLS configuration
- Remember on PE devices you are living in a VRF world (Ping, Traceroute etc.)
- HAVE FUN !!!!! Remember, it’s a journey not a destination!

What Is MPLS?



Q & A


cisco
The bridge to possible
Thank you
cisco Live!


cisco Live!
Let's go