Service Provider IPv6 Deployment

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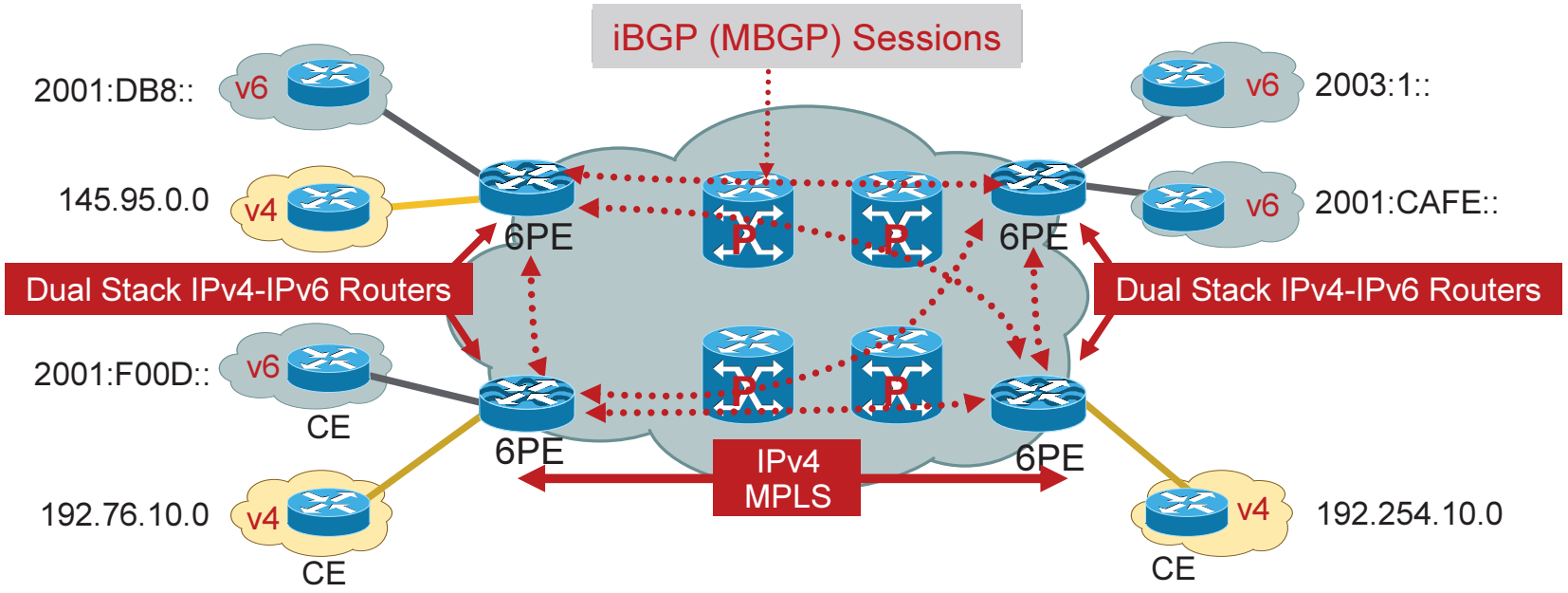
IPv6 over MPLS

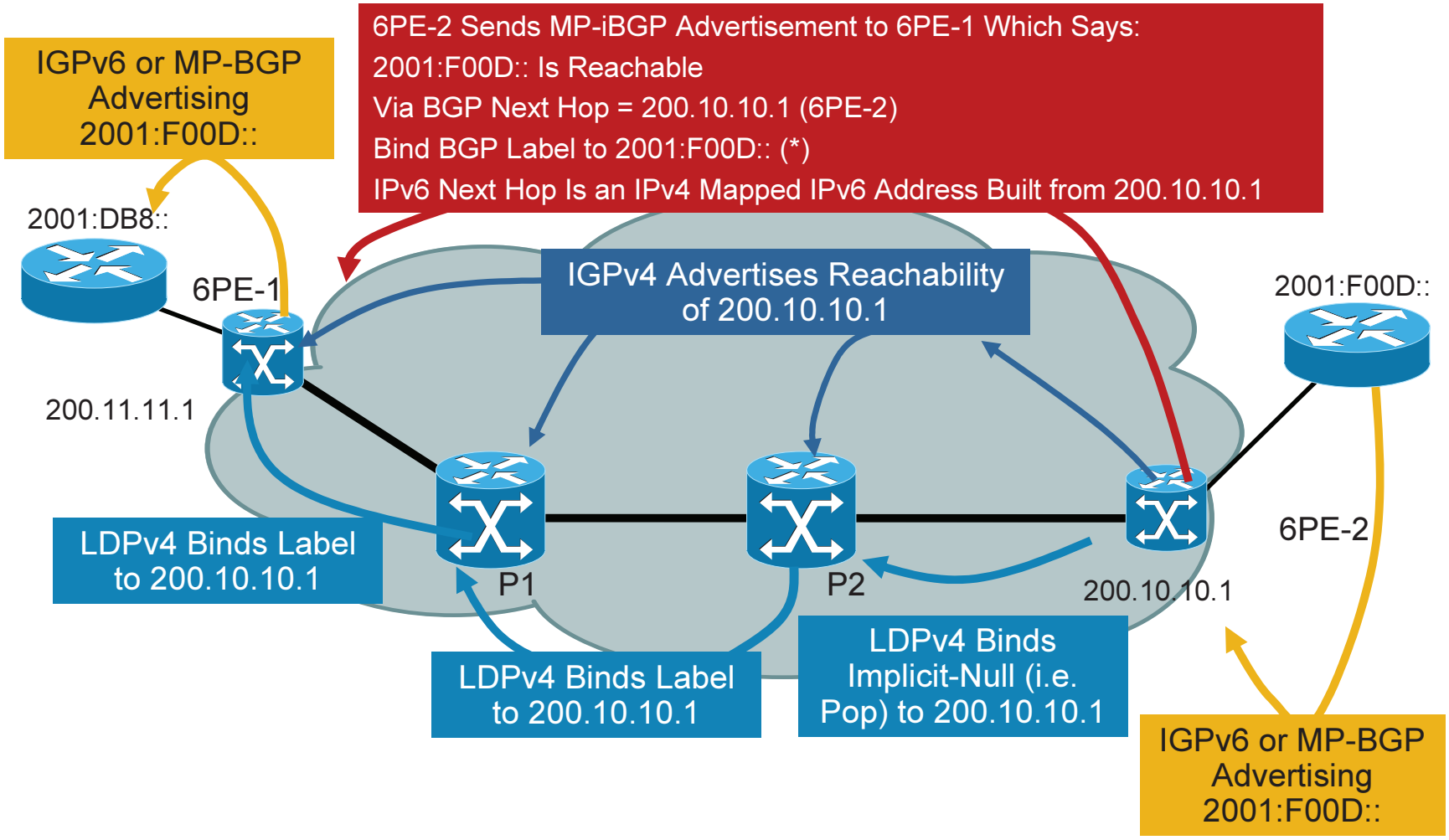
- Many ways to deliver IPv6 services to end users
  - Most important is end-to-end IPv6 traffic forwarding
- Many service providers have already deployed MPLS in their IPv4 backbone for various reasons
- MPLS can be used to facilitate IPv6 integration
- Multiple approaches for IPv6 over MPLS:
  - IPv6 over L2TPv3
  - IPv6 over EoMPLS/AToM
  - IPv6 CE-to-CE IPv6 over IPv4 tunnels
  - IPv6 Provider Edge Router (6PE) over MPLS
  - IPv6 VPN Provider Edge (6VPE) over MPLS
  - Native IPv6 MPLS

IPv6 Provider Edge Router (6PE) over MPLS

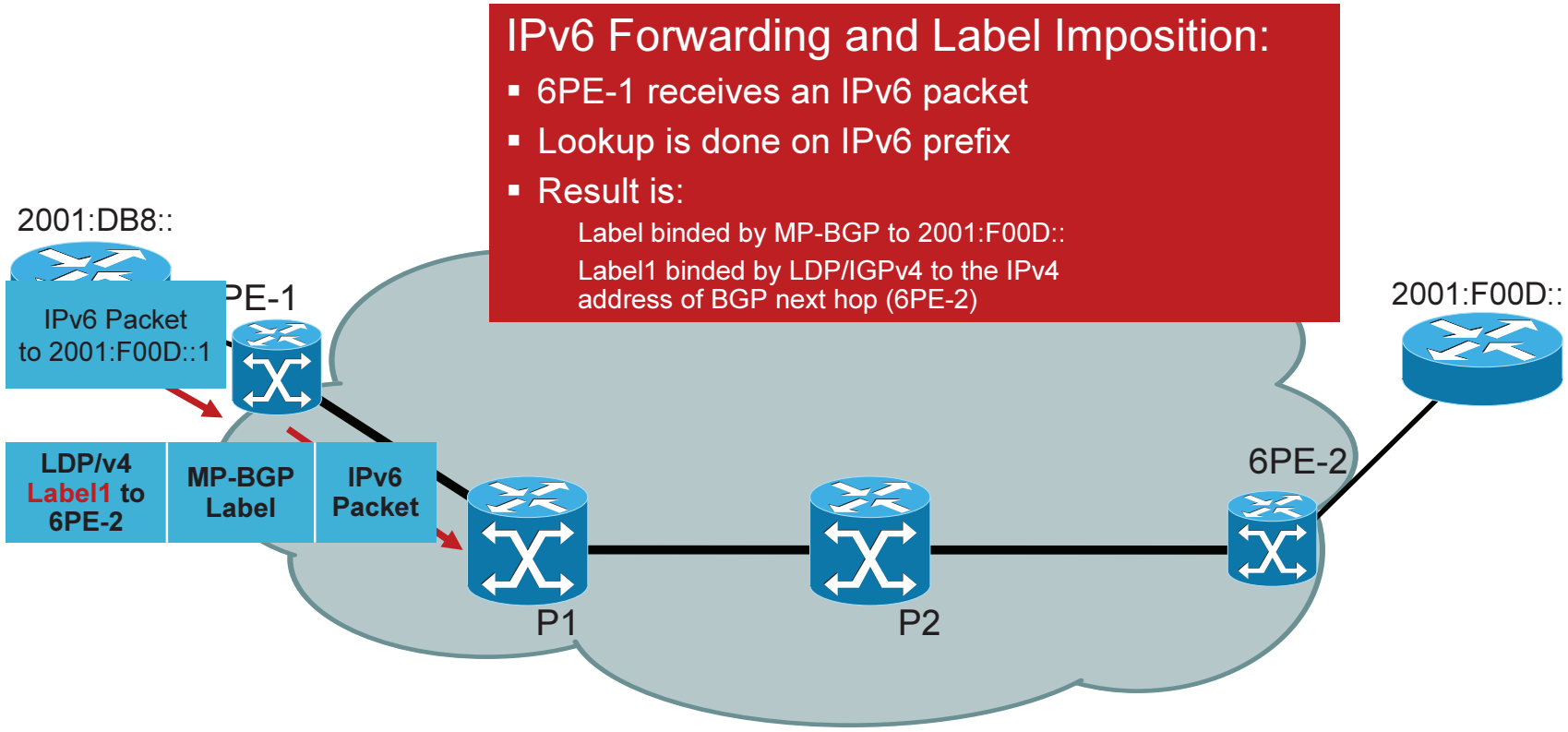


- IPv6 global connectivity over and IPv4-MPLS core
- Transitioning mechanism for providing unicast IP
- PEs are updated to support dual stack/6PE
- IPv6 reachability exchanged among 6PEs via iBGP (MBGP)
- IPv6 packets transported from 6PE to 6PE inside MPLS

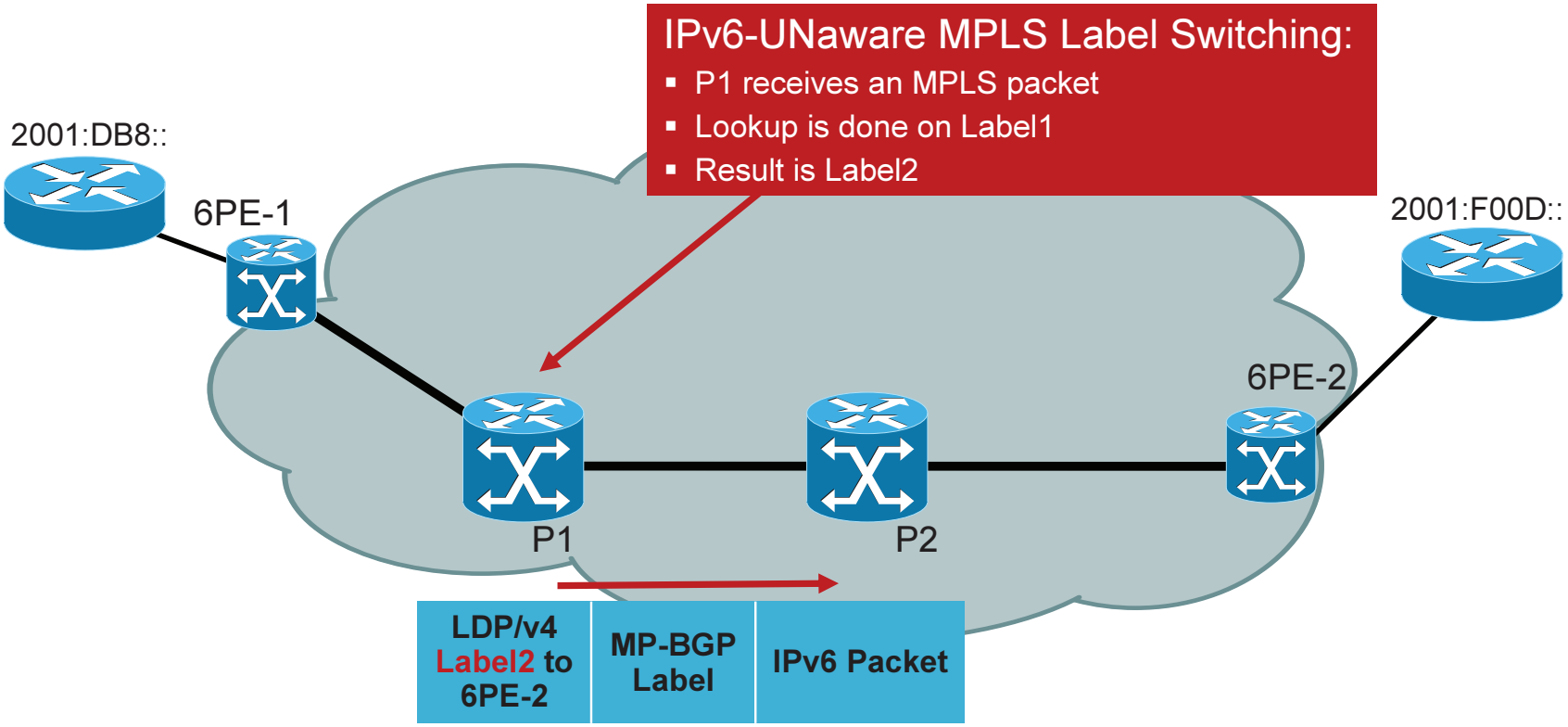
6PE Routing/Label Distribution



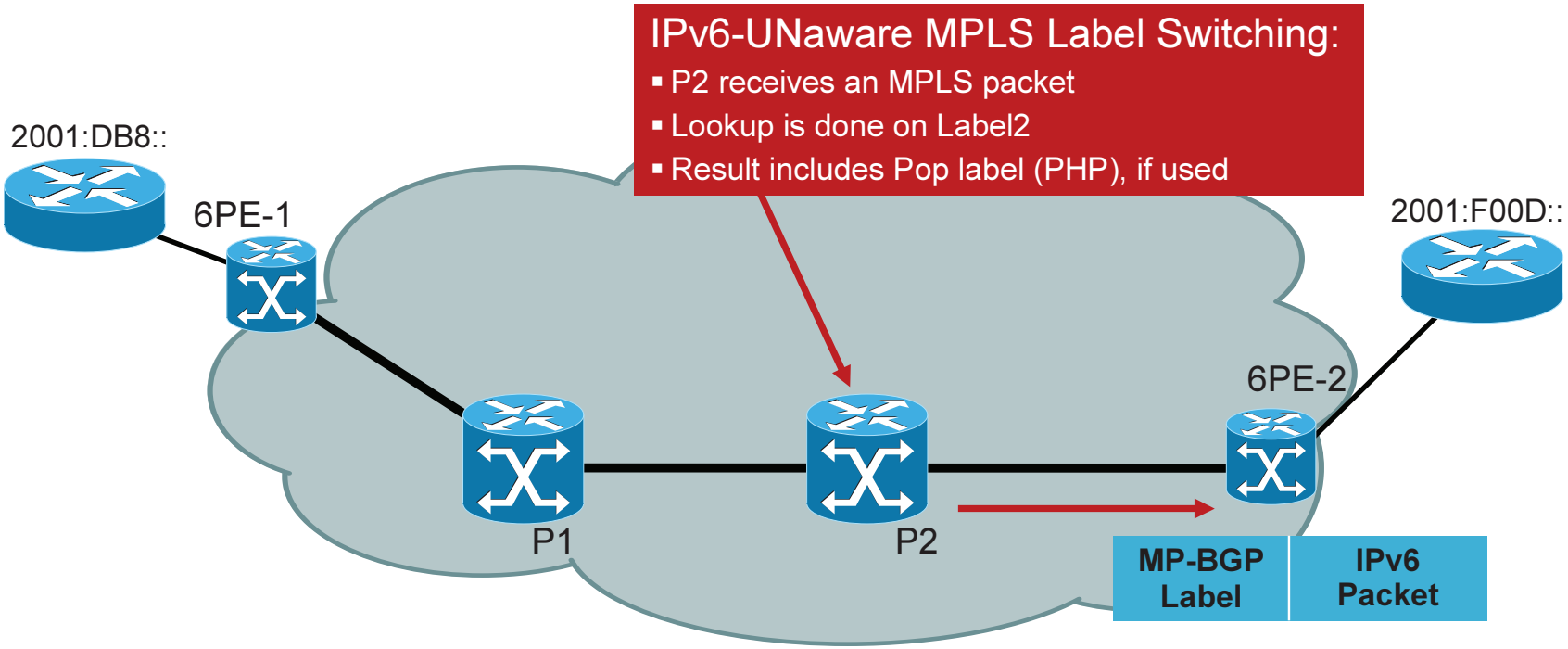
6PE Forwarding (6PE-1)



6PE Forwarding (P1)

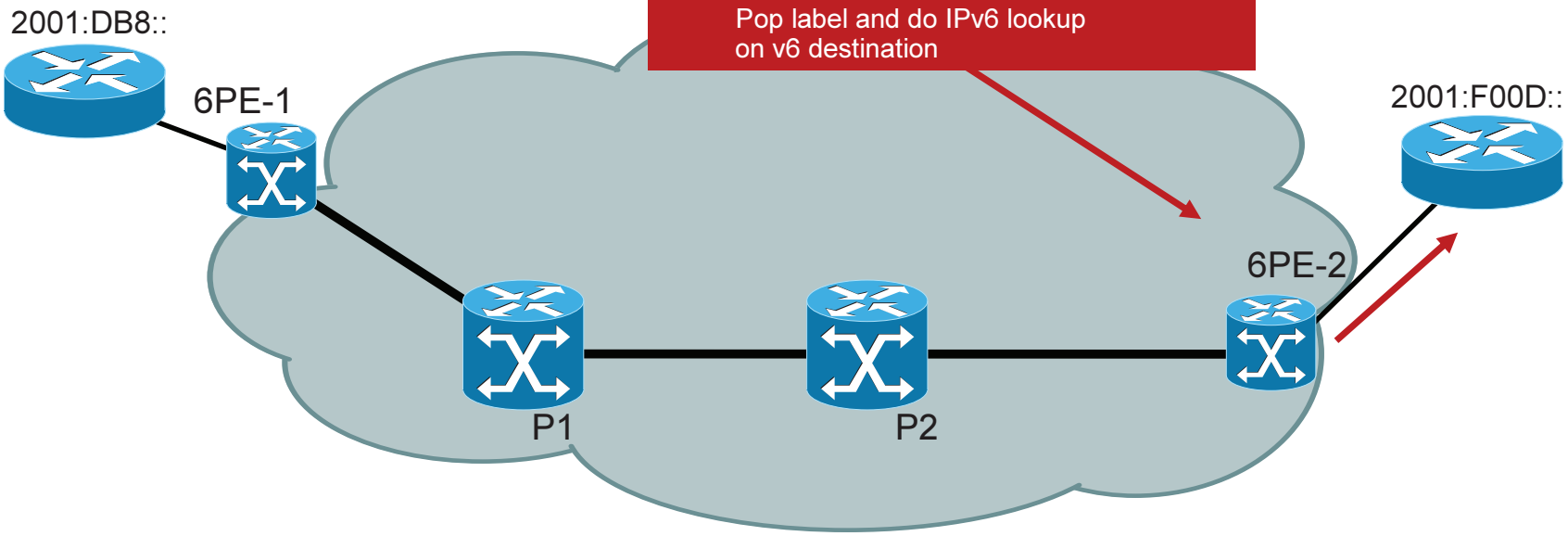


6PE Forwarding (P2)



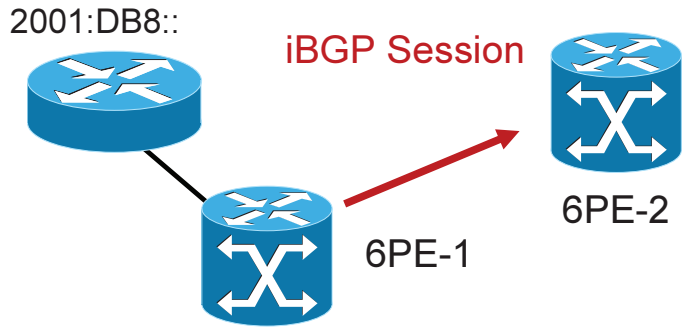
6PE Forwarding (6PE-2)

- MPLS label forwarding:
- 6PE-2 receives an MPLS packet
- Lookup is done on label
- Result is:
  - Pop label and do IPv6 lookup on v6 destination



6PE-1 Configuration

```
ipv6 cef
!
mpls label protocol ldp
!
router bgp 100
 no synchronization
 no bgp default ipv4 unicast
 neighbor 2001:DB8:1::1 remote-as 65014
 neighbor 200.10.10.1 remote-as 100
 neighbor 200.10.10.1 update-source Loopback0
 !
 address-family ipv6
 neighbor 200.10.10.1 activate
 neighbor 200.10.10.1 send-label
 neighbor 2001:DB8:1::1 activate
 redistribute connected
 no synchronization
 exit-address-family
```



2001:DB8:1::1 Is the Local CE

200.10.10.1 Is the Remote 6PE

Send Labels Along with IPv6 Prefixes by Means of MP-BGP Note: Will Cause Session to Flap

6PE Show Output

```
6PE-1#show ip route 200.10.10.1
Routing entry for 200.10.10.1/32
 Known via "isis", distance 115, metric 20, type level-2
[snip]
  * 10.12.0.1, from 200.10.10.1, via FastEthernet1/0
    Route metric is 20, traffic share count is 1
```

```
6PE-1#show ipv6 route
B   2001:F00D::/64 [200/0]
    via ::FFFF:200.10.10.1, IPv6-mpls
```

```
6PE-1#show ipv6 cef internal #hidden command
.. OUTPUT TRUNCATED ..
2001:F00D::/64,
  nexthop ::FFFF:200.10.10.1
 fast tag rewrite with F0/1, 10.12.0.1, tags imposed {17 28}
```

Other Useful Output:

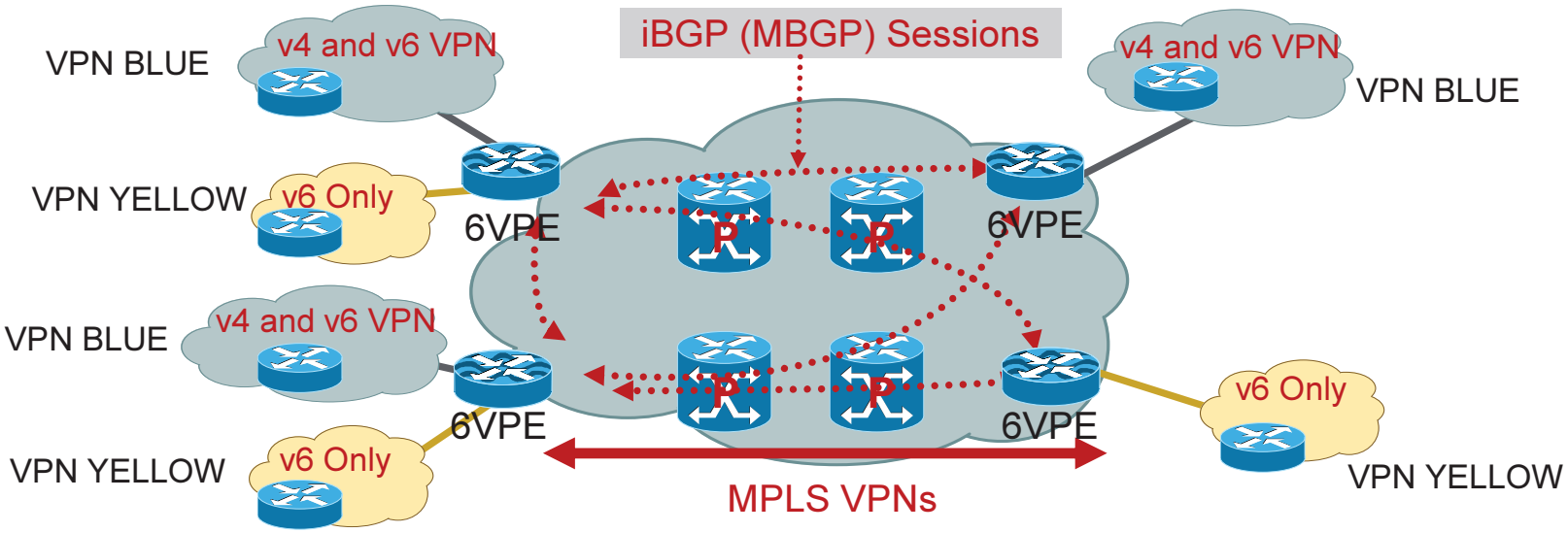
```
show bgp ipv6 neighbors
show bgp ipv6 unicast
show mpls forwarding #more on this later
```

6PE Benefits/Drawbacks

- Core network (Ps) untouched (no HW/SW upgrade, no configuration change)
- IPv6 traffic inherits MPLS benefits (wire-rate, fast re-route, TE, etc.)
- Incremental deployment possible (i.e., only upgrade the PE routers which have to provide IPv6 connectivity)
- Each site can be v4-only, v4VPN-only, v4+v6, v4VPN+v6
- P routers won't be able to send ICMPv6 messages (TTL expired, traceroute)
- Cisco 6PE Documentation/Presentations:

  http://www.cisco.com/en/US/products/sw/iosswrel/ps1835/products_data_sheet09186a008052edd3.html

6VPE Deployment



- 6VPE ~ IPv6 + BGP-MPLS IPv4VPN + 6PE
- Cisco 6VPE is an implementation of RFC4659
- VPNv6 address:

  Address including the 64 bits route distinguisher and the 128 bits IPv6 address

- MP-BGP VPNv6 address-family:

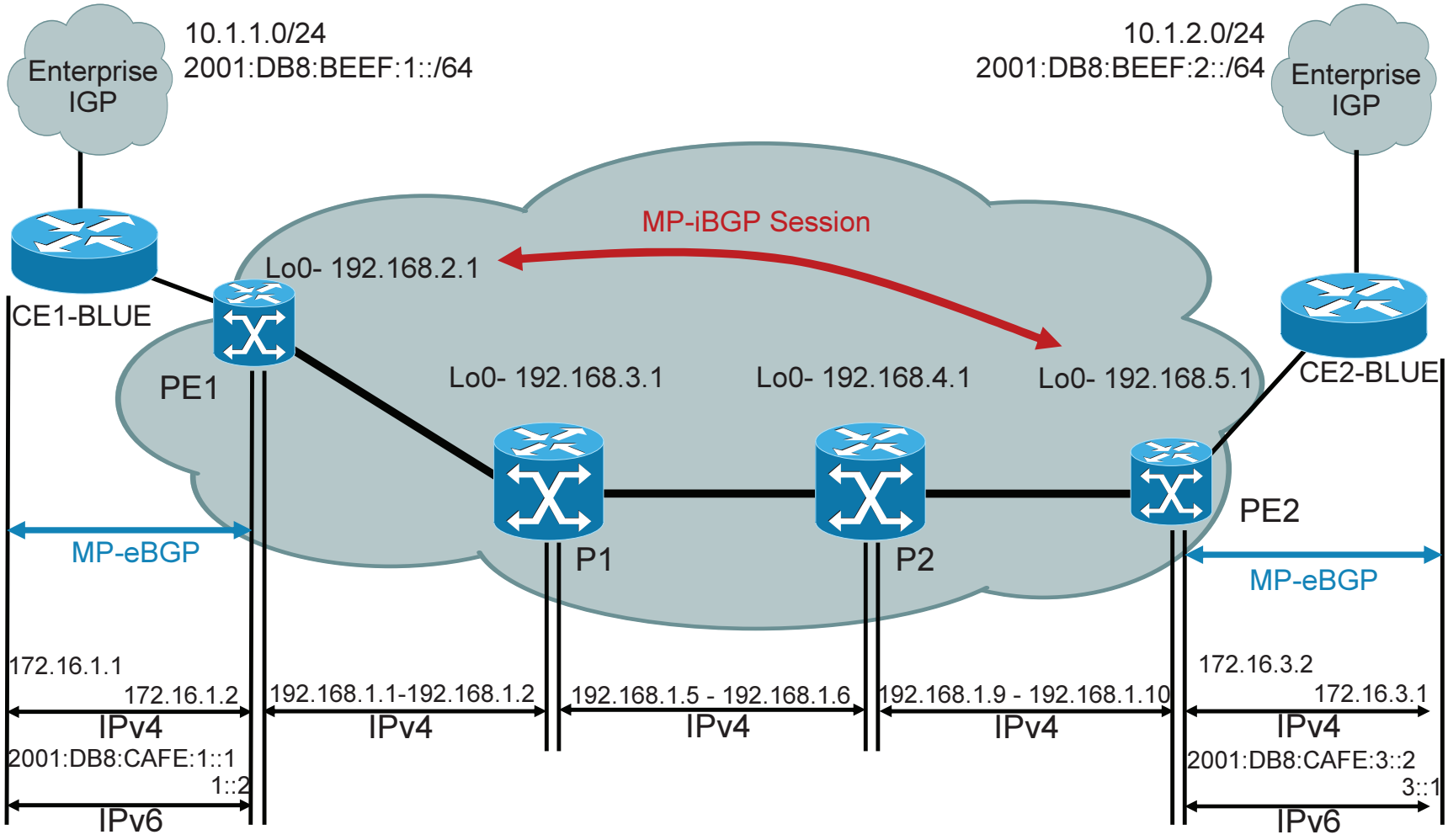
  AFI “IPv6” (2), SAFI “VPN” (128)

- VPN IPv6 MP_REACH_NLRI

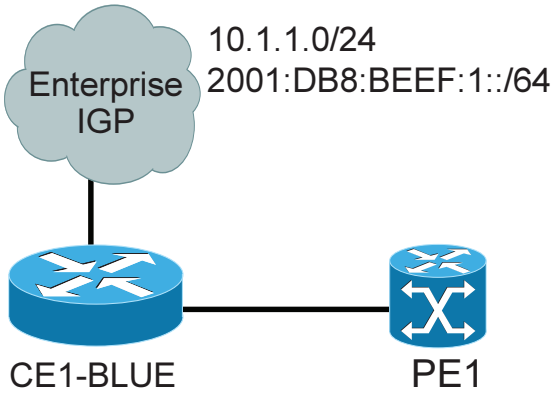
  With VPNv6 next-hop (192bits) and NLRI in the form of <length, IPv6-prefix, label>

- Encoding of the BGP next-hop

6VPE Example Design
Addressing/Routing



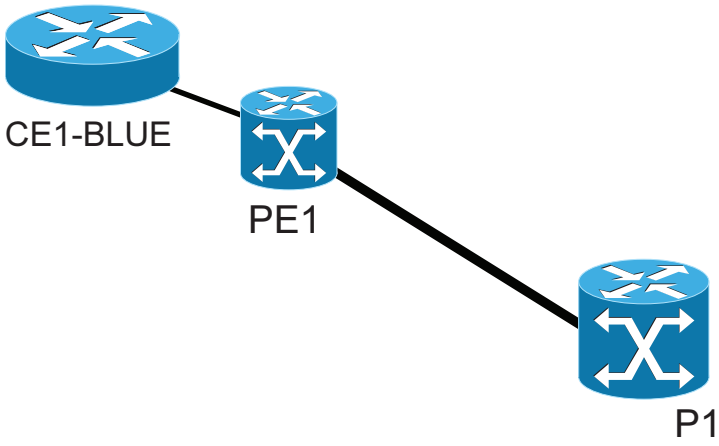
6VPE Configuration Example
CE1-BLUE to PE1




```
ipv6 unicast-routing
ipv6 cef
!
interface Ethernet0/0
 description to PE1
 ip address 172.16.1.1 255.255.255.0
 ipv6 address 2001:DB8:CAFE:1::1/64
!
interface Ethernet1/0
 description to BLUE LAN
 ip address 10.1.1.1 255.255.255.0
 ipv6 address 2001:DB8:BEEF:1::1/64
 ipv6 rip BLUE enable
```

```
router bgp 500
 bgp log-neighbor-changes
 no bgp default ipv4 unicast
 neighbor 2001:DB8:CAFE:1::2 remote-as 100
 neighbor 172.16.1.2 remote-as 100
 !
 address-family ipv4
 redistribute connected
 redistribute eigrp 100
 neighbor 172.16.1.2 activate
 no auto-summary
 no synchronization
 exit-address-family
 !
 address-family ipv6
 neighbor 2001:DB8:CAFE:1::2 activate
 redistribute connected
 redistribute rip BLUE
 no synchronization
 exit-address-family
!
ipv6 router rip BLUE
 redistribute bgp 500
```

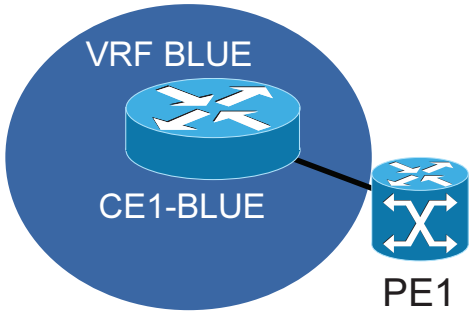
6VPE Configuration Example
PE1 Connections



- Standard MPLS configuration between PE-P
- Running IGP in the cloud (OSPF)

```
ipv6 unicast-routing
ipv6 cef
mpls ldp router-id Loopback0
!
interface Loopback0
 ip address 192.168.2.1 255.255.255.255
!
interface Ethernet0/0
 description to CE1-BLUE
 vrf forwarding BLUE
 ip address 172.16.1.2 255.255.255.0
 ipv6 address 2001:DB8:CAFE:1::2/64
!
interface Ethernet2/0
 description to P1
 ip address 192.168.1.1 255.255.255.252
 mpls ip
!
router ospf 1
 log-adjacency-changes
 redistribute connected subnets
 passive-interface Loopback0
 network 192.168.1.0 0.0.0.255 area 0
```

6VPE Configuration Example
PE1 VRF Definitions



VRF
BLUE
(RD - 200:1)
PE1/PE2 Will Hold
CE1 Routes
CE2 Routes

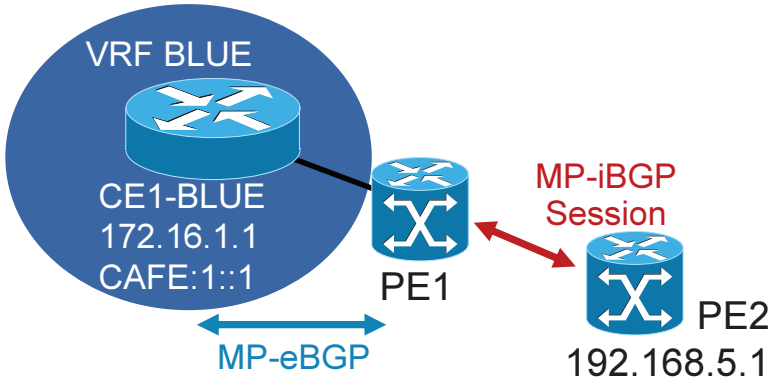
```
vrf definition BLUE
 rd 200:1
 !
 route-target export 200:1
 route-target import 200:1
 !
 address-family ipv4
 exit-address-family
 !
 address-family ipv6
 exit-address-family
```

- Migration commands available for VPNv4 to multi-protocol VRF

```
(config)#vrf upgrade-cli multi-af-mode {common-policies |
non-common-policies} [vrf <name>]
```

- This command forces migration from old CLI for IPv4 VRF to new VRF multi-AF CLI

6VPE Configuration Example
PE1 BGP Setup




```
router bgp 100
 bgp log-neighbor-changes
 neighbor 192.168.5.1 remote-as 100
 neighbor 192.168.5.1 update-source
Loopback0
 !
 address-family ipv4
 neighbor 192.168.5.1 activate
 no auto-summary
 no synchronization
 exit-address-family
 !
 address-family vpnv4
 neighbor 192.168.5.1 activate
 neighbor 192.168.5.1 send-community
extended
 exit-address-family
```

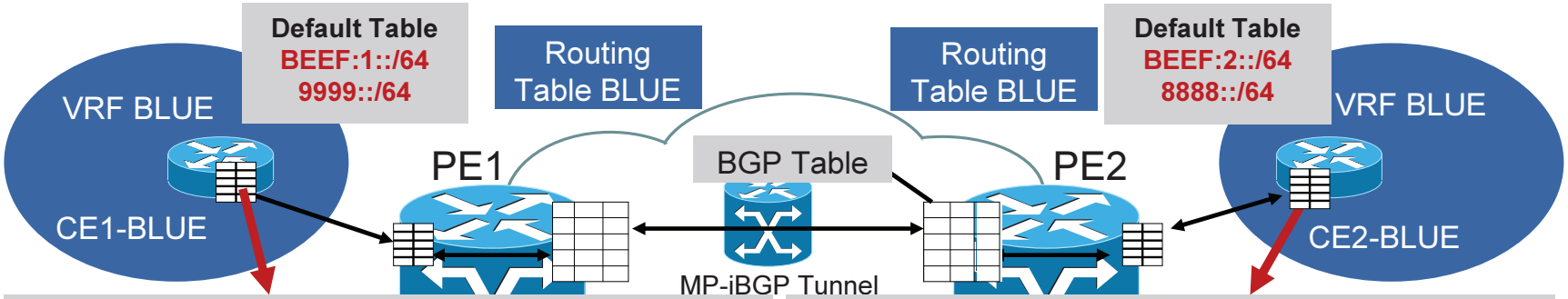
```
 address-family vpnv6
 neighbor 192.168.5.1 activate
 neighbor 192.168.5.1 send-community
extended
 exit-address-family
!
 address-family ipv4 vrf BLUE
 redistribute connected
 neighbor 172.16.1.1 remote-as 500
 neighbor 172.16.1.1 activate
 no auto-summary
 no synchronization
 exit-address-family
 !
 address-family ipv6 vrf BLUE
 neighbor 2001:DB8:CAFE:1::1 remote-as
500
 neighbor 2001:DB8:CAFE:1::1 activate
 redistribute connected
 no synchronization
 exit-address-family
```

6VPE Configuration Example
P Connections


```
mpls ldp router-id Loopback0
!
interface Loopback0
 ip address 192.168.3.1 255.255.255.255
!
interface Ethernet0/0
 description to PE1
 ip address 192.168.1.2 255.255.255.252
 mpls ip
!
interface Ethernet1/0
 description to P2
 ip address 192.168.1.5 255.255.255.252
 mpls ip
!
router ospf 1
 log-adjacency-changes
 redistribute connected subnets
 passive-interface Loopback0
 network 192.168.1.0 0.0.0.255 area 0
```

```
mpls ldp router-id Loopback0
!
interface Loopback0
 ip address 192.168.4.1 255.255.255.255
!
interface Ethernet0/0
 description to P1
 ip address 192.168.1.6 255.255.255.252
 mpls ip
!
interface Ethernet1/0
 description to PE2
 ip address 192.168.1.9 255.255.255.252
 mpls ip
!
router ospf 1
 log-adjacency-changes
 redistribute connected subnets
 passive-interface Loopback0
 network 192.168.1.0 0.0.0.255 area 0
```

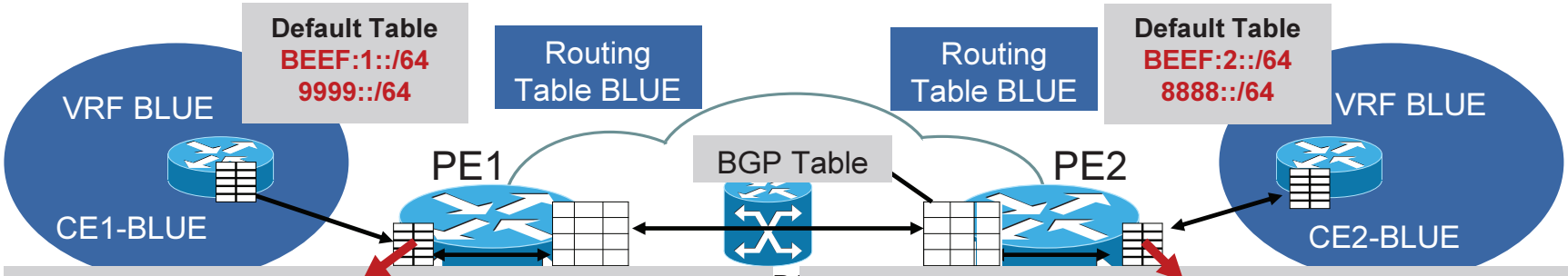
IPv6 Routing Tables
CE1-CE2




```
ce1-blue#show ipv6 route
C   2001:DB8:BEEF:1::/64 [0/0]
    via Ethernet1/0, directly connected
L   2001:DB8:BEEF:1::1/128 [0/0]
    via Ethernet1/0, receive
B   2001:DB8:BEEF:2::/64 [20/0]
    via FE80::A8BB:CCFF:FE01:F600, Ethernet0/0
C   2001:DB8:CAFE:1::/64 [0/0]
    via Ethernet0/0, directly connected
L   2001:DB8:CAFE:1::1/128 [0/0]
    via Ethernet0/0, receive
B   2001:DB8:CAFE:3::/64 [20/0]
    via FE80::A8BB:CCFF:FE01:F600, Ethernet0/0
B   8888::/64 [20/0]
    via FE80::A8BB:CCFF:FE01:F600, Ethernet0/0
R   9999::/64 [120/2]
    via FE80::A8BB:CCFF:FE01:9000, Ethernet1/0
L   FF00::/8 [0/0]
    via Null0, receive
```

```
ce2-blue#show ipv6 route
B   2001:DB8:BEEF:1::/64 [20/0]
    via FE80::A8BB:CCFF:FE01:F901, Ethernet0/0
C   2001:DB8:BEEF:2::/64 [0/0]
    via Ethernet1/0, directly connected
L   2001:DB8:BEEF:2::1/128 [0/0]
    via Ethernet1/0, receive
B   2001:DB8:CAFE:1::/64 [20/0]
    via FE80::A8BB:CCFF:FE01:F901, Ethernet0/0
C   2001:DB8:CAFE:3::/64 [0/0]
    via Ethernet0/0, directly connected
L   2001:DB8:CAFE:3::1/128 [0/0]
    via Ethernet0/0, receive
R   8888::/64 [120/2]
    via FE80::A8BB:CCFF:FE02:5800, Ethernet1/0
B   9999::/64 [20/0]
    via FE80::A8BB:CCFF:FE01:F901, Ethernet0/0
L   FF00::/8 [0/0]
    via Null0, receive
```

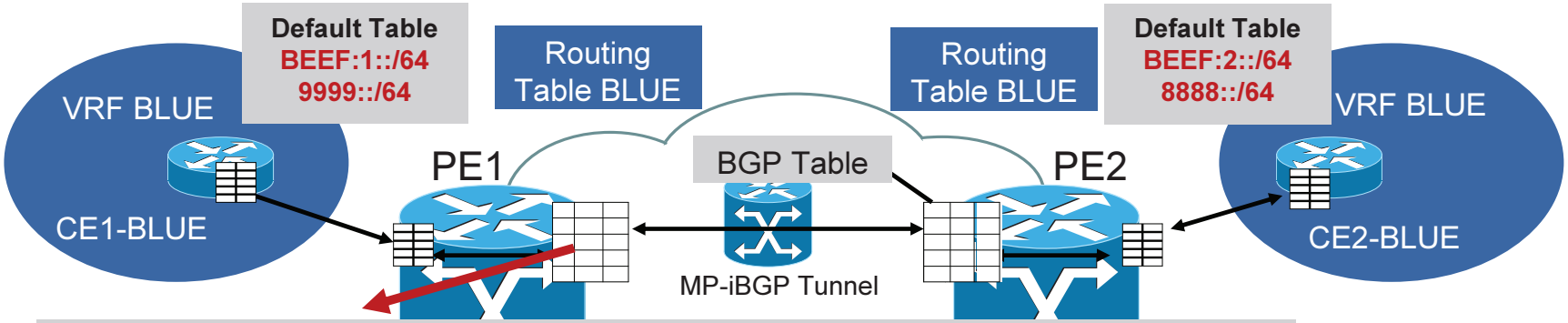
IPv6 Routing Tables
PE1-PE2




```
pe1#show ipv6 route vrf BLUE
B   2001:DB8:BEEF:1::/64 [20/0]
    via FE80::A8BB:CCFF:FE01:F400, Ethernet0/0
B   2001:DB8:BEEF:2::/64 [200/0]
    via 192.168.5.1%Default-IP-Routing-Table,
indirectly connected
C   2001:DB8:CAFE:1::/64 [0/0]
    via Ethernet0/0, directly connected
L   2001:DB8:CAFE:1::2/128 [0/0]
    via Ethernet0/0, receive
B   2001:DB8:CAFE:3::/64 [200/0]
    via 192.168.5.1%Default-IP-Routing-Table,
indirectly connected
B   8888::/64 [200/2]
    via 192.168.5.1%Default-IP-Routing-Table,
indirectly connected
B   9999::/64 [20/2]
    via FE80::A8BB:CCFF:FE01:F400, Ethernet0/0
L   FF00::/8 [0/0]
    via Null0, receive
```

```
pe2#show ipv6 route vrf BLUE
B   2001:DB8:BEEF:1::/64 [200/0]
    via 192.168.2.1%Default-IP-Routing-Table,
indirectly connected
B   2001:DB8:BEEF:2::/64 [20/0]
    via FE80::A8BB:CCFF:FE01:FA00, Ethernet1/0
B   2001:DB8:CAFE:1::/64 [200/0]
    via 192.168.2.1%Default-IP-Routing-Table,
indirectly connected
C   2001:DB8:CAFE:3::/64 [0/0]
    via Ethernet1/0, directly connected
L   2001:DB8:CAFE:3::2/128 [0/0]
    via Ethernet1/0, receive
B   8888::/64 [20/2]
    via FE80::A8BB:CCFF:FE01:FA00, Ethernet1/0
B   9999::/64 [200/2]
    via 192.168.2.1%Default-IP-Routing-Table,
indirectly connected
L   FF00::/8 [0/0]
    via Null0, receive
```

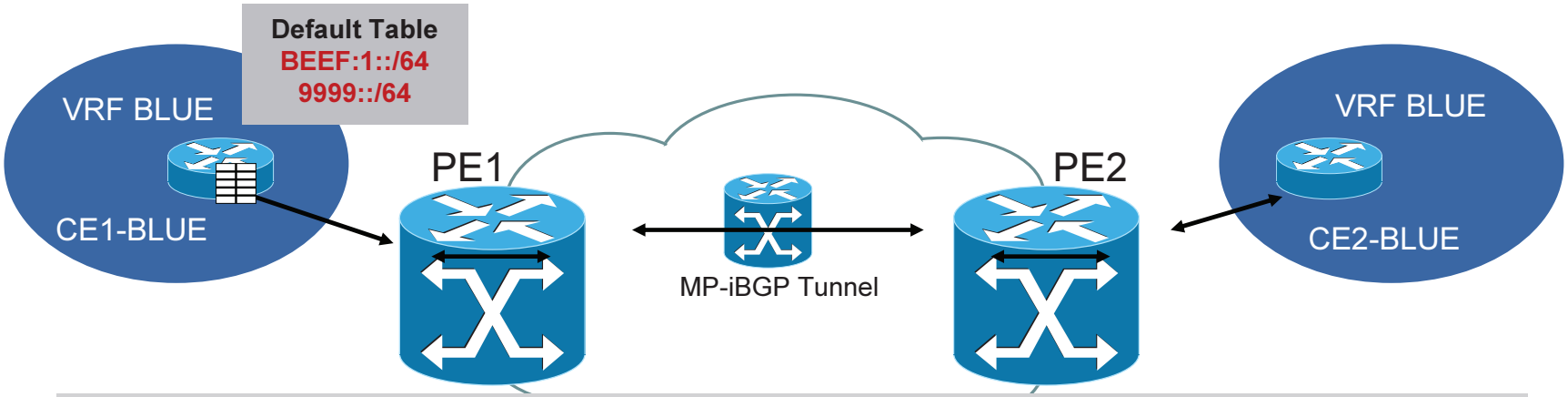
IPv6 Routing Tables
PE1 BGP Next-Hop




```
pe1#show bgp vpnv6 unicast all  #OUTPUT SHORTENED FOR CLARITY
Network              Next Hop            Metric LocPrf Weight Path
Route Distinguisher: 200:1 (default for vrf BLUE)
*> 2001:DB8:BEEF:1::/64
                     2001:DB8:CAFE:1::1
                                              0             0 500 ?
*>i2001:DB8:BEEF:2::/64
                     ::FFFF:192.168.5.1
                                              0    100      0 506 ?
*>i2001:DB8:CAFE:3::/64
                     ::FFFF:192.168.5.1
                                              0    100      0 ?
*>i8888::/64         ::FFFF:192.168.5.1
                                              2    100      0 506 ?
*> 9999::/64         2001:DB8:CAFE:1::1
                                              2             0 500 ?
```

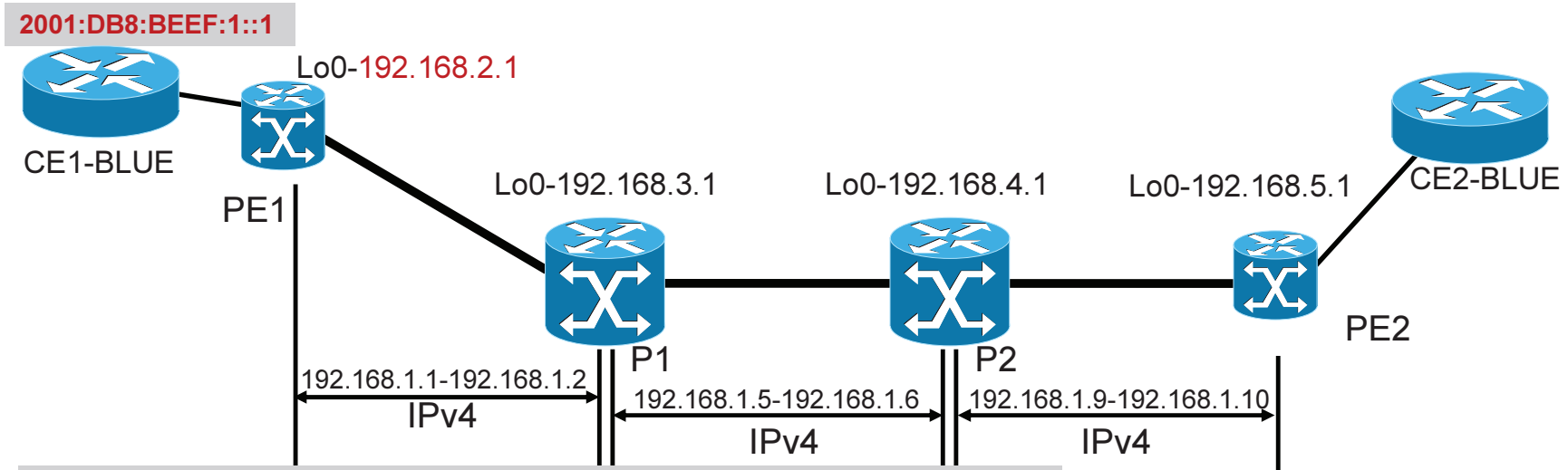
IPv4-Mapped IPv6 Address (IPv4-Based LSP Setup)

MPLS Forwarding
PE1




```
pe1#show mpls forwarding
Local   Outgoing      Prefix              Bytes Label   Outgoing    Next Hop
Label   Label or VC   or Tunnel Id        Switched      interface
16      Pop Label     192.168.1.4/30      0             Et2/0       192.168.1.2
17      16            192.168.1.8/30      0             Et2/0       192.168.1.2
18      Pop Label     192.168.3.1/32      0             Et2/0       192.168.1.2
19      18            192.168.4.1/32      0             Et2/0       192.168.1.2
20      19            192.168.5.1/32      0             Et2/0       192.168.1.2
21      No Label      10.1.1.0/24[V]      0             Et0/0       172.16.1.1
22      Aggregate     172.16.1.0/24[V]    570           BLUE
25      No Label      2001:DB8:BEEF:1::/64[V]    \
                                          570           Et0/0       FE80::A8BB:CCFF:FE01:F400
26      Aggregate     2001:DB8:CAFE:1::/64[V]    \
                                          35456         BLUE
27      No Label      9999::/64[V]        570           Et0/0       FE80::A8BB:CCFF:FE01:F400
```

A Look at Forwarding




```
pe1#show mpls forwarding
Local Outgoing Prefix        Outgoing  Next Hop
Label Label                interface
25    No Label 2001:DB8:BEEF:1::/64 Et0/0    FE80::A8BB:CCFF:FE01:F400
```

```
p1#show mpls forwarding
Local Outgoing Prefix        Outgoing  Next Hop
Label Label                interface
17    Pop Label   192.168.2.1/32  Et0/0   192.168.1.1
```

```
p2#show mpls forwarding
Local Outgoing Prefix        Outgoing  Next Hop
Label Label                interface
18    17      192.168.2.1/32  Et0/0   192.168.1.5
```

```
pe2#sh ipv6 cef vrf BLUE
2001:DB8:BEEF:1::/64
 nexthop 192.168.1.9 Ethernet0/0 label 18 25
```

6VPE Summary

- RFC4659: BGP-MPLS IP Virtual Private Network (VPN) Extension for IPv6 VPN
- 6VPE simply adds IPv6 support to current IPv4 MPLS VPN offering
- For end-users: v6-VPN is same as v4-VPN services (QoS, hub and spoke, internet access, etc.)
- For operators:

  Same configuration operation for v4 and v6 VPN

  No upgrade of IPv4/MPLS core (IPv6 unaware)
- Cisco 6VPE Documentation:

  http://www.cisco.com/en/US/docs/net_mgmt/ip_solution_center/5.2/mpls_vpn/user/guide/ipv6.html

Reference Materials

- "Deploying IPv6 in Broadband Access Networks" Adeel Ahmed, Salman Asadullah – ISBN0470193387, John Wiley & Sons Publications®
- "Deploying IPv6 Networks" Ciprian Popoviciu, Patrick Grossetete, Eric Levy-Abegnoli, ISBN1587052105 - Cisco Press®
- "IPv6 Security" Scott Hogg, Eric Vyncke, ISBN1587055945 – Cisco Press®
- www.cisco.com/go/ipv6 - CCO IPv6 Main Page
- www.cisco.com/go/srnd - Cisco Network Design Central
- www.ietf.org
- www.ipv6forum.org
- www.ipv6.org
- www.nav6tf.org/
- www.6net.org