IPv6 Technology Overview

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IPv6 options over MPLS network

- IPv6 over MPLS Pseudowires
  - Transparent to service provider
- IPv6 over IPv4 tunnels over MPLS (Manual Tunnels)
  - PE must be IPv6 aware, core remains IPv4
- IPv6 Transit using MPLS 6PE
  - PE must be IPv6 aware, core remains IPv4
- IPv6 VPN using MPLS 6VPE
  - PE provide VPN services for IPv6, core remains IPv4
- ~~No LDPv6 available as yet~~
  - ~~Core control plane must be MPLS+LDP using IPv4 IGP~~

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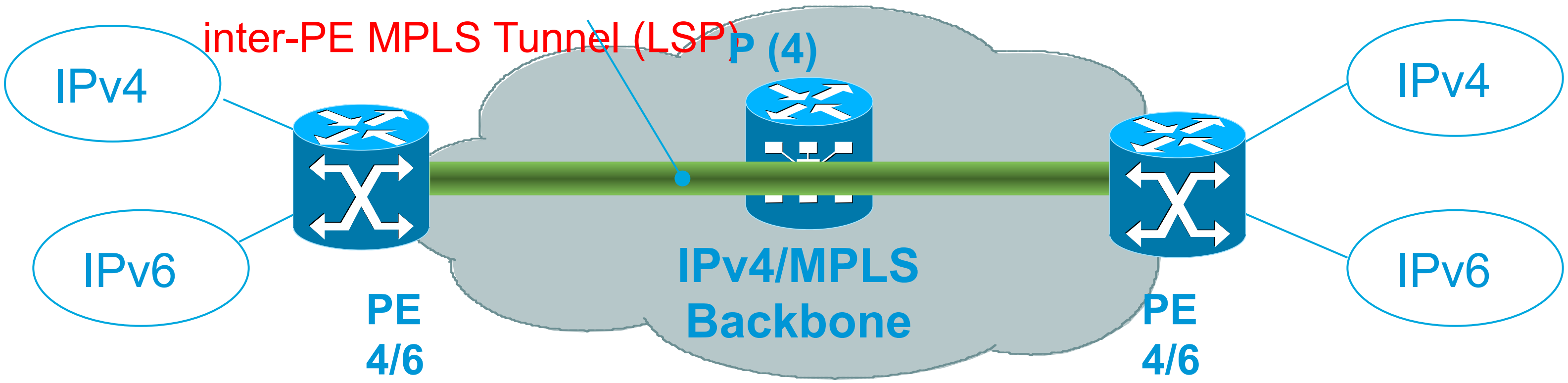
IPv6 over MPLS

- Many service providers have already deployed MPLS in their IPv4 backbone for various reasons
- MPLS can be used to facilitate IPv6 integration
- Dual stack PE routers accommodating both IPv4 and IPv6 client networks
- IPv4 or MPLS core infrastructure is IPv6-unaware
- Benefits from MPLS features such as FRR, TE



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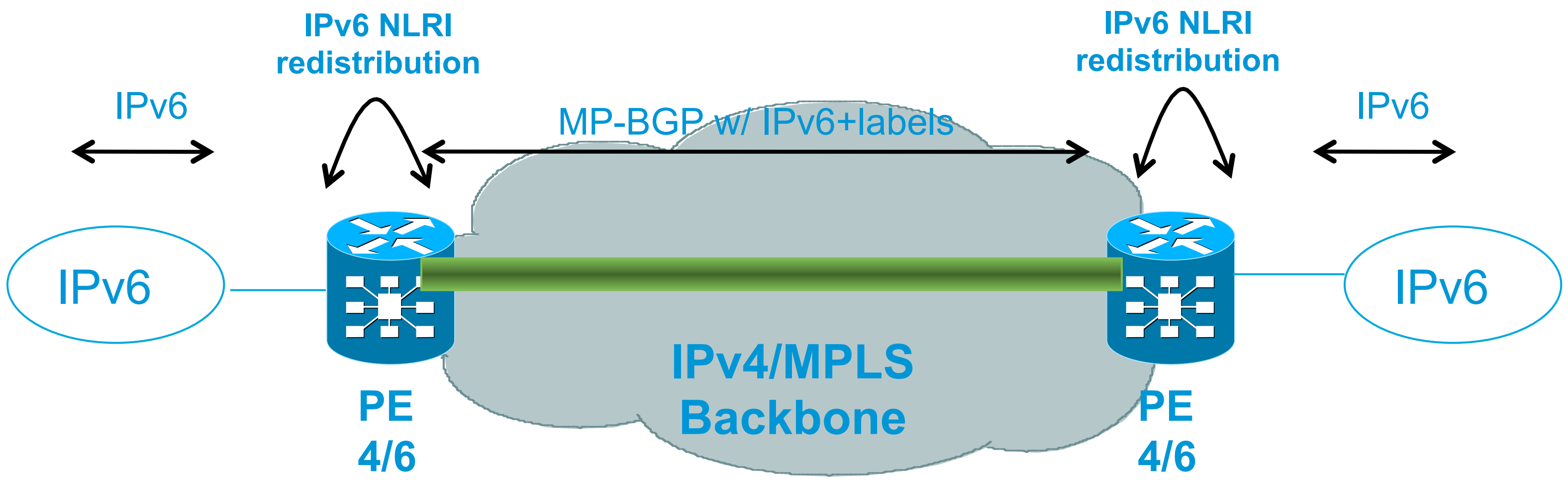
MPLS Tunnels – 6PE/6VPE



- IPv6 packets transported from 6PE to 6PE over Label Switch Path

  RFC 4798: IPv6 provider edge router (6PE) over MPLS offers global IPv6 connectivity across IP/MPLS backbone (PSN)

  RFC 4659: IPv6 VPN provider edge (6VPE) over MPLS offers global or VPN IPv6 connectivity across IP/MPLS backbone (PSN)

- BGP exchanges “external” client prefixes, labels, etc.

  IPv6prefixes +Label for 6PE

  VPNv6 prefixes for 6VPE

- In both cases backbone runs IPv4 control plane (plus label control for MPLS forwarding used)

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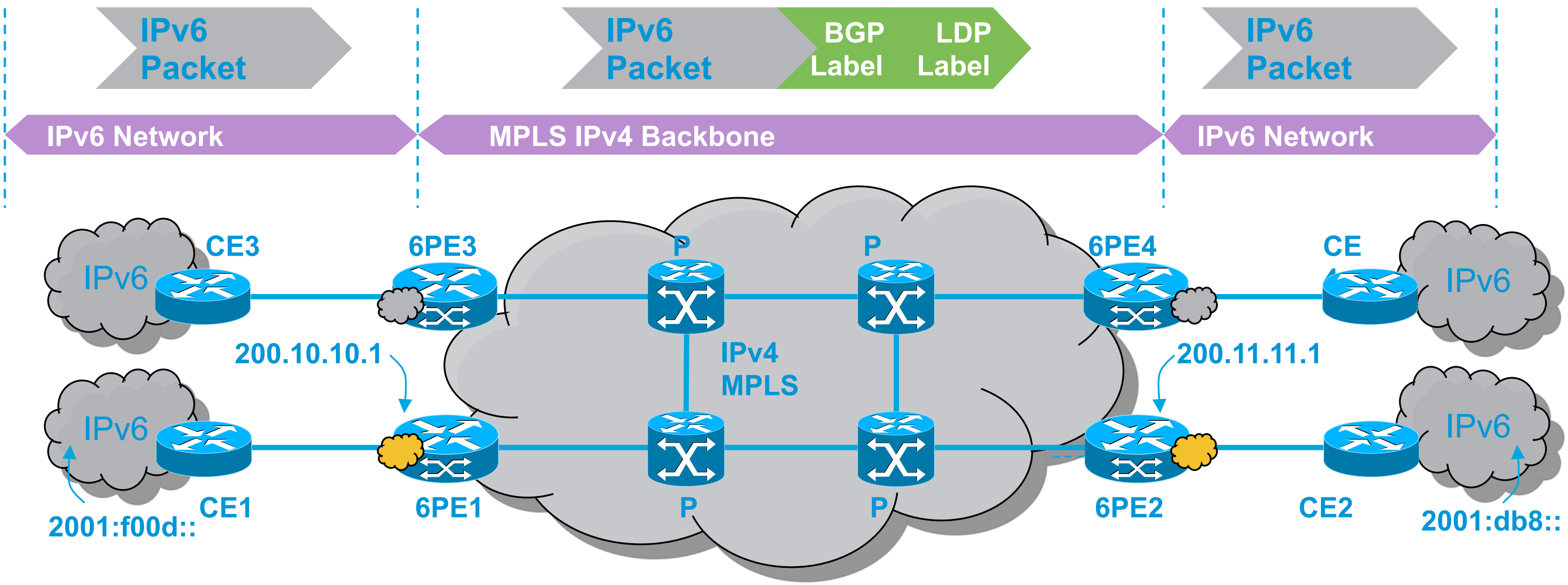
Services Using MPLS 6PE



- Connects IPv6 islands over MPLS core (Transits edge to edge)
- Transition mechanism for providing unicast IPv6 access
- Coexistence mechanism for combining IPv4 and IPv6 services
- As other IPv6 “tunnel” technologies, enables services such as
    - IPv6 Internet Access
    - Peer-to-peer connectivity
    - Access to IPv6 services supplied by the SP itself

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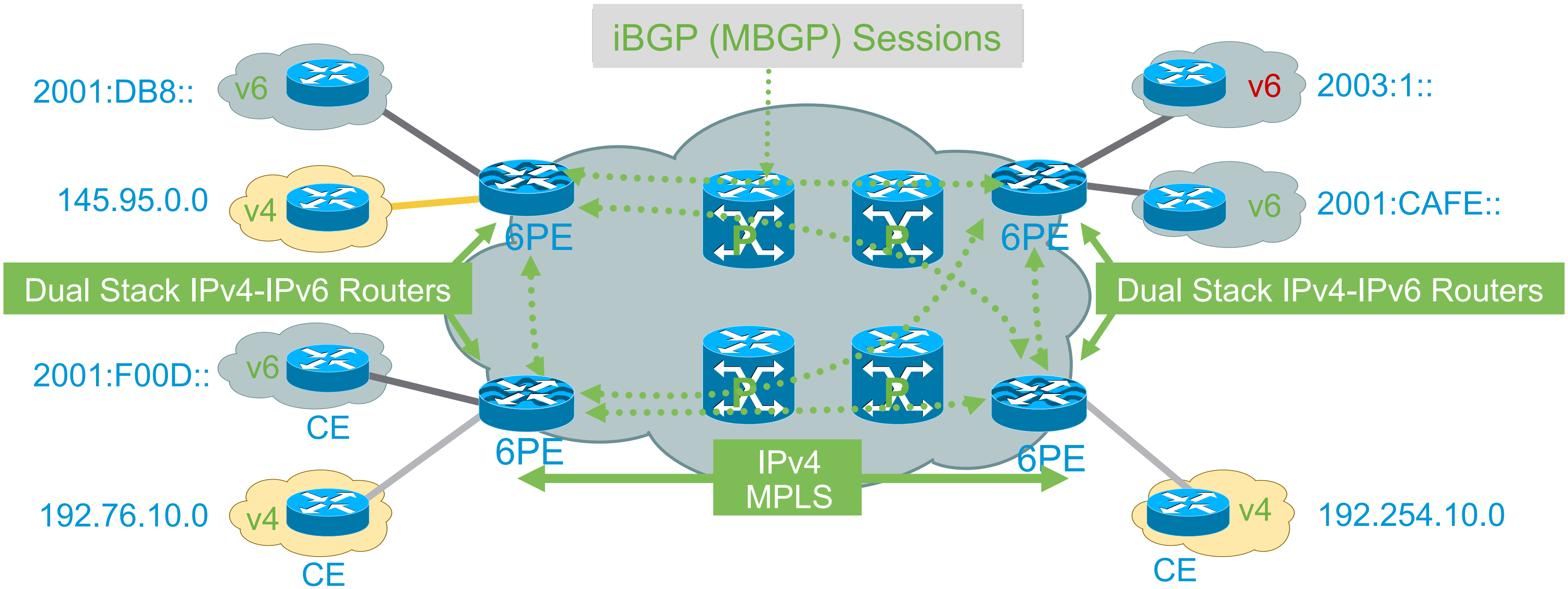
IPv6 Provider Edge Router (6PE) over MPLS



- 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

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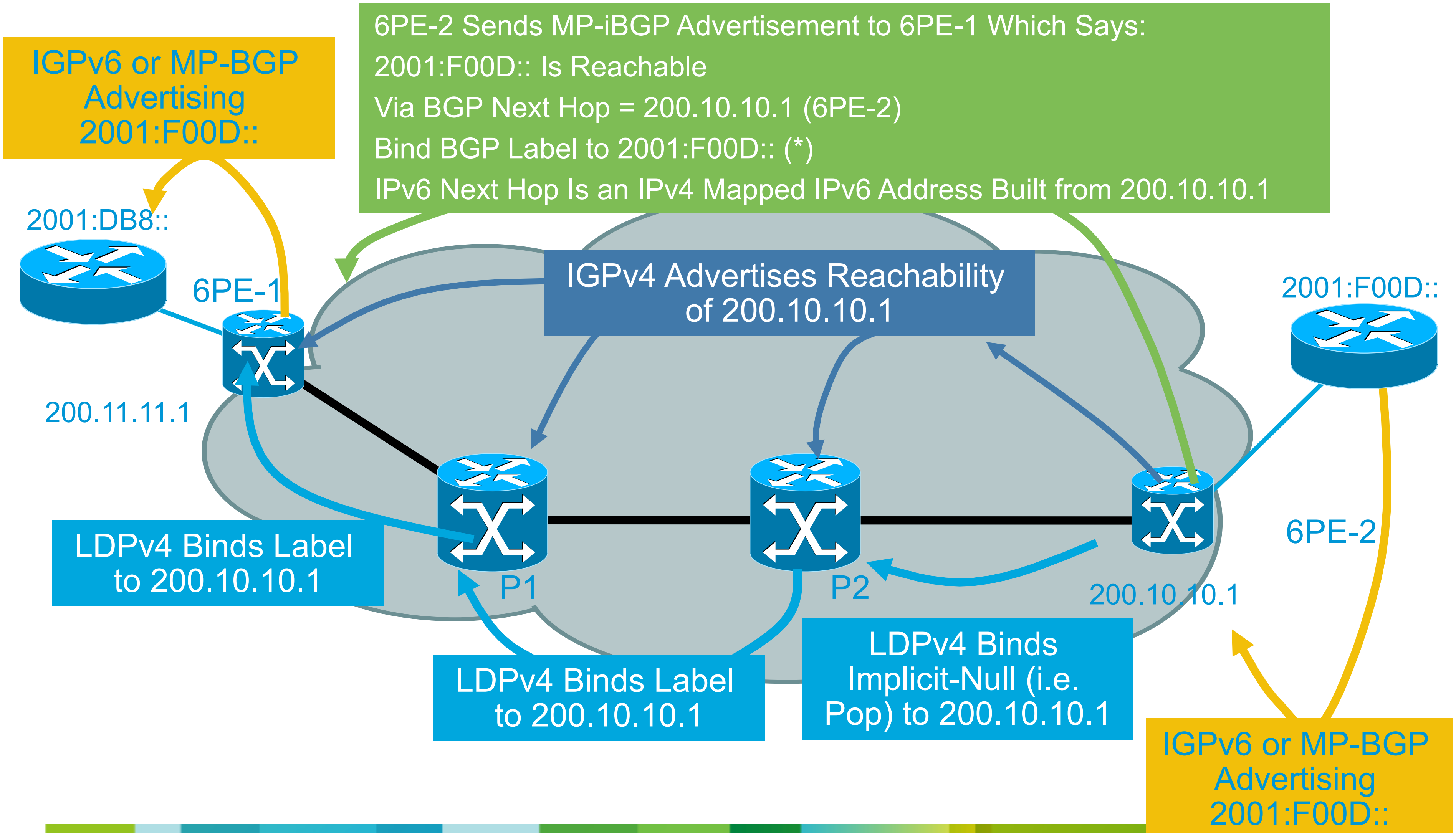
6PE Routing/Label Distribution



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6PE Notes

- LDP Label
  - Top label that provides connectivity to the destination 6PE
- MP-BGP Label
  - Bottom label used by egress 6PE for IPv6 forwarding
  - Single pool of 16 labels shared amongst all IPv6 prefixes
    - P routers hash the bottom label if payload is not IPv4
    - Different label values allow load balancing
  - This label needed to avoid PHP dropping IPv6 packet
- BGP Label also referred to as “Aggregate IPv6 Label”
  - Aggregate labels execute “pop label + IPv6 lookup” at egress 6PE
- BGP NH is a “Special Use” IPv4 to IPv6 Mapped Address

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6PE Summary

- Core network (Ps) untouched
- IPv6 traffic inherits MPLS benefits (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, trace route)
- Scalability issues arise as a separate RIB and FIB is required for each connected customer
- Good solution only for SPs with limited devices in PE role
- Cisco 6PE Documentation/Presentations:
  http://www.cisco.com/en/US/products/sw/iosswrel/ps1835/products_data_sheet09186a008052edd3.html

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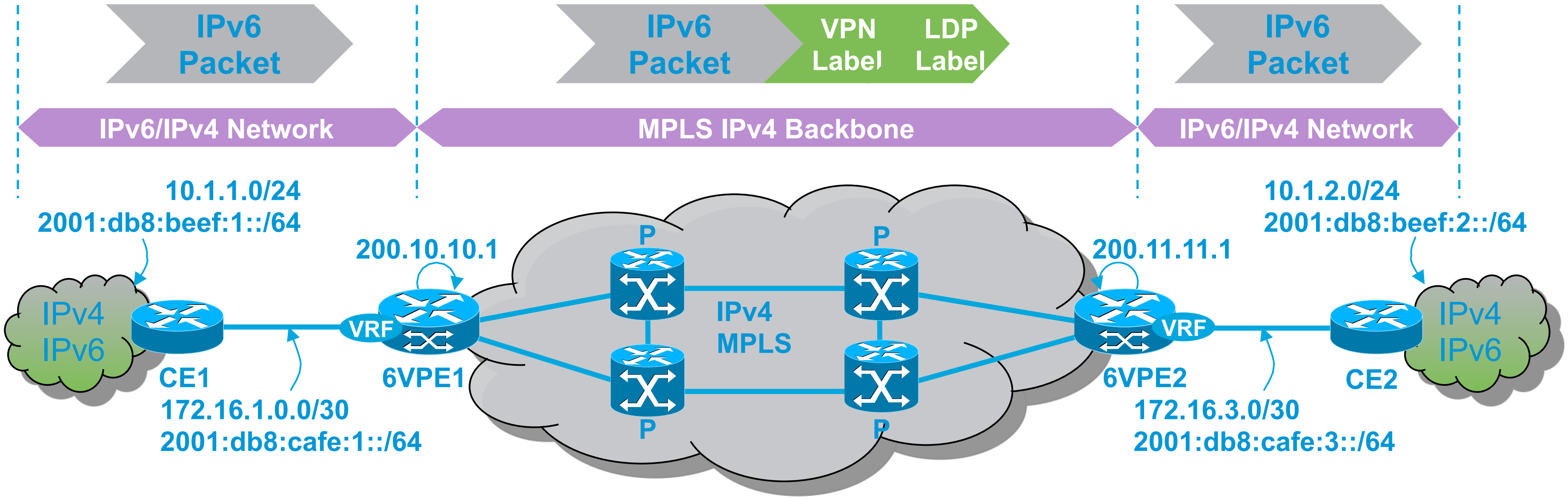
Services Using 6VPE



- For VPN customers, IPv6 VPN service is exactly as IPv4 VPN service
- 6PE is "like VPN" but this is NOT VPN, 6PE = global reachability
- It enables services such as

  IPv6 VPN Access

  Carriers Supporting Carrier

  Access to IPv6 services supplied by the SP itself

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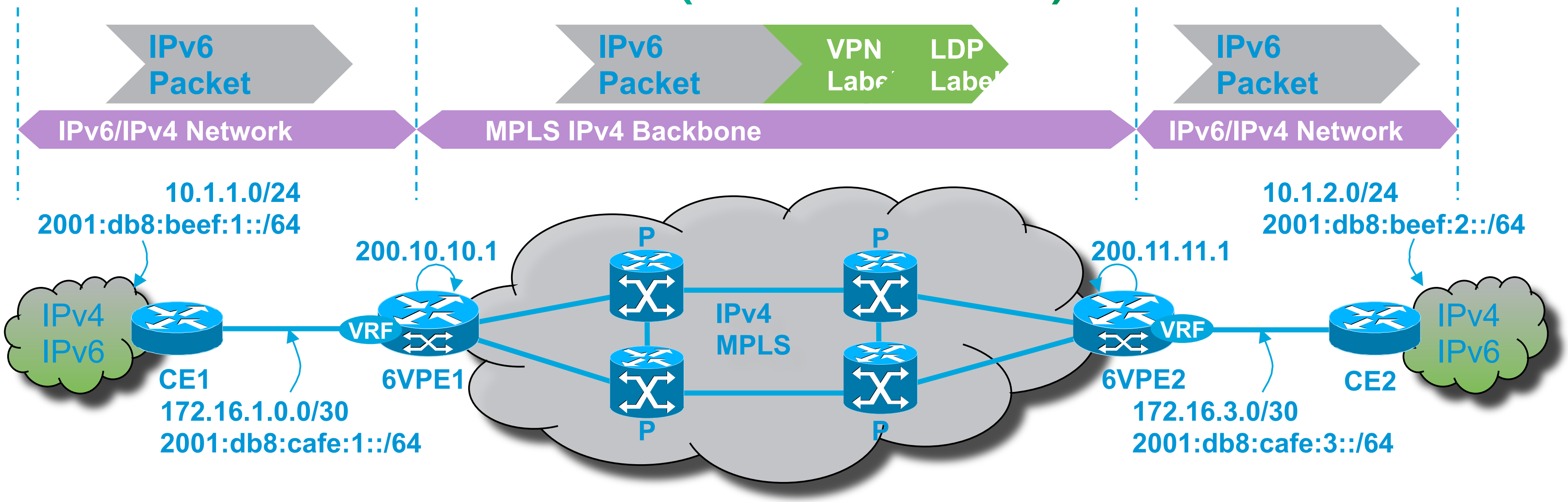
IPv6 VPN 6VPE (RFC 4659)



- 6VPE uses existing IPv4 MPLS infrastructure to provide IPv6 VPN
  - Core uses IPv4 control plane (LDPv4, TEv4, IGPv4)
- PEs must support dual stack IPv4+IPv6
- Offers same architectural features as MPLS-VPN for IPv4
  - RTs, VRFs, RDs are appended to IPv6 to form VPNv6 address
  - MP-BGP distributed both VPN address families
  - BGP NH uses IPv4 to IPv6 mapped address format ::ffff:A.B.C.D
- VRF can contain both VPNv4 and VPNv6 routes

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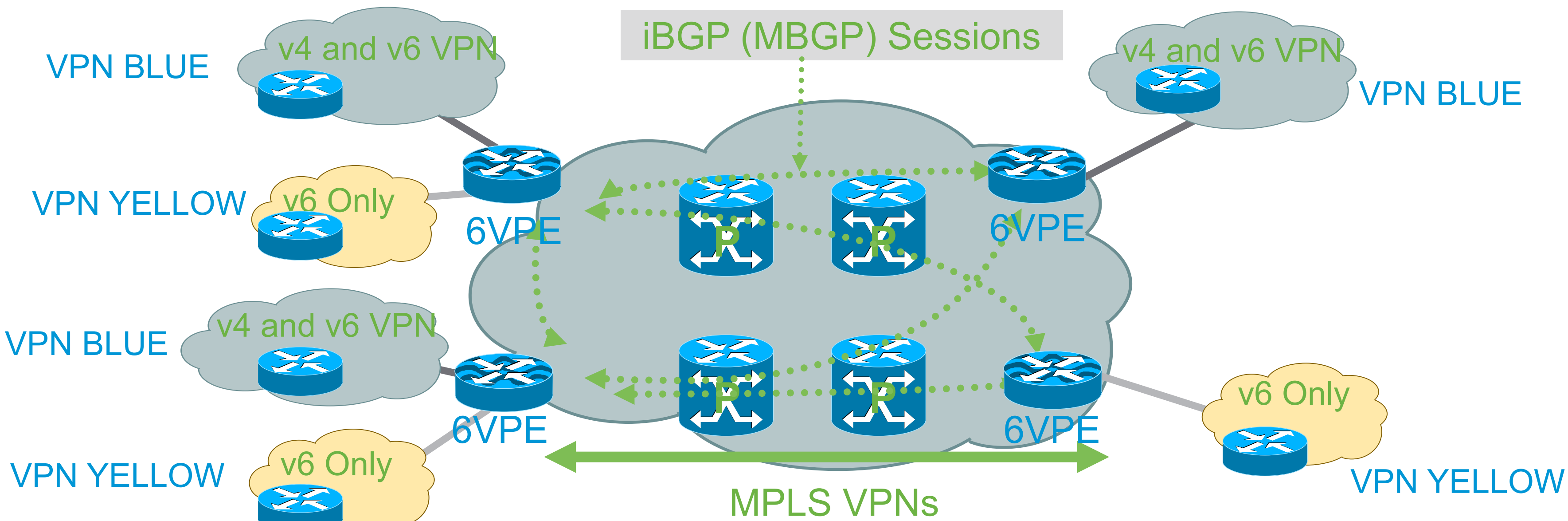
6VPE over MPLS



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

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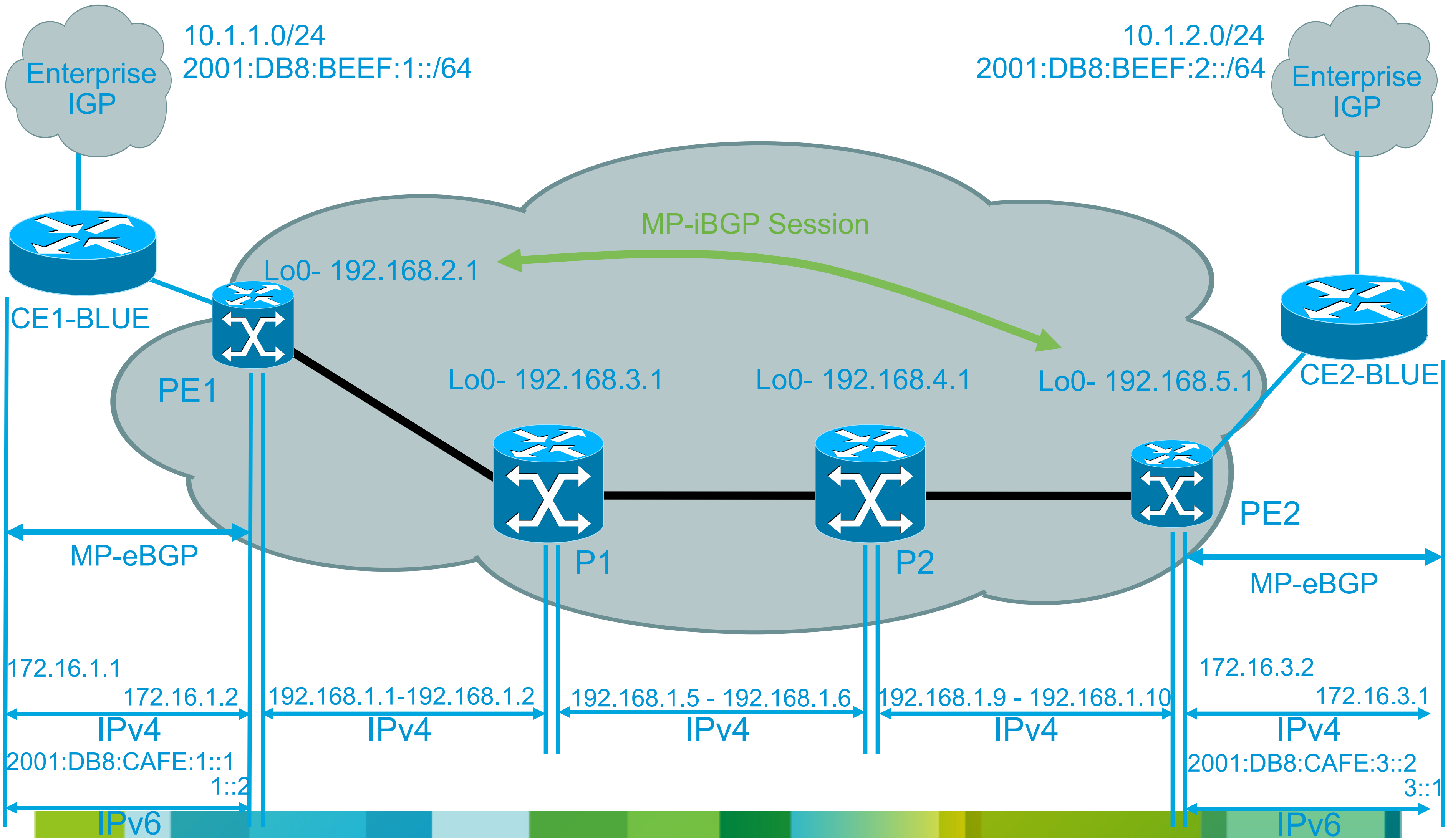
6VPE Example Design
Addressing/Routing



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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

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IPv6 Routing Protocol

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Routing: The IPv4 – IPv6 Parallel

BGP	MP-BGP Same protocol for IPv4, vpnv4, IPv6, vpnv6
OSPF	OSPFv2 for IPv4 OSPFv3 for IPv6 Distinct but similar protocols with OSPFv3 being a cleaner implementation that takes advantage of IPv6 specificities
IS-IS	Extended to support IPv6 Natural fit to some of the IPv6 foundational concepts Supports Single and Multi Topology operation
Others	Static route is always supported for both IPv4 and IPv6 VRFv4: PE-CE routing support Static, RIP, OSPF, BGP VRFv6: PE-CE routing support Static, BGP

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Integrated IS-IS for IPv6 Overview

- Integrated IS-IS supports multiple address families, namely CLNS, IPv4 and now IPv6.
- IS-IS for IPv6 can be run in two modes, single-topology or multi-topology.
- Single-topology:
  - One network topology for all address families. One SPF computation.
  - All the routers in the area/domain must be configured to run both IPv4 and IPv6.
  - All the interfaces must be configured with both IPv4 and IPv6.
  - The same interface metric applies to both IPv4 and IPv6.
- Multi-topology:
  - Different topology for IPv6 address family is allowed. Independent SPF computation, administrative distance, maximum paths, etc.
  - IPv4 and IPv6 can have different metrics for the same interface.
  - IPv6 requires extended metrics (wide)
  - Transition mode allows for a smooth transition from single to multi-topology.

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Integrated IS-IS for IPv6 Overview

- Two new TLVs added to introduce IPv6 routing
- IPv6 Reachability TLV (0xEC) - 236

  Describes network reachability such as IPv6 routing prefix, metric information and some option bits. The option bits indicates the advertisement of IPv6 prefix from a higher level, redistribution from other routing protocols.

  Equivalent to IP Internal/External Reachability TLVs described in RFC1195 (TLV 128 and 130)

- IPv6 Interface Address TLV (0xE8) - 232

  Contains 128 bit address

  For Hello PDUs, must contain the link-local address (FE80::/10)

  For LSP, must only contain the non link-local address

- A new Network Layer Protocol Identifier (NLPID) is defined in TLV 129

  Allowing IS-IS routers with IPv6 support to advertise IPv6 prefix payload using 0x8E value (IPv4 & OSI uses 0xCC, CLNP is 0x81)

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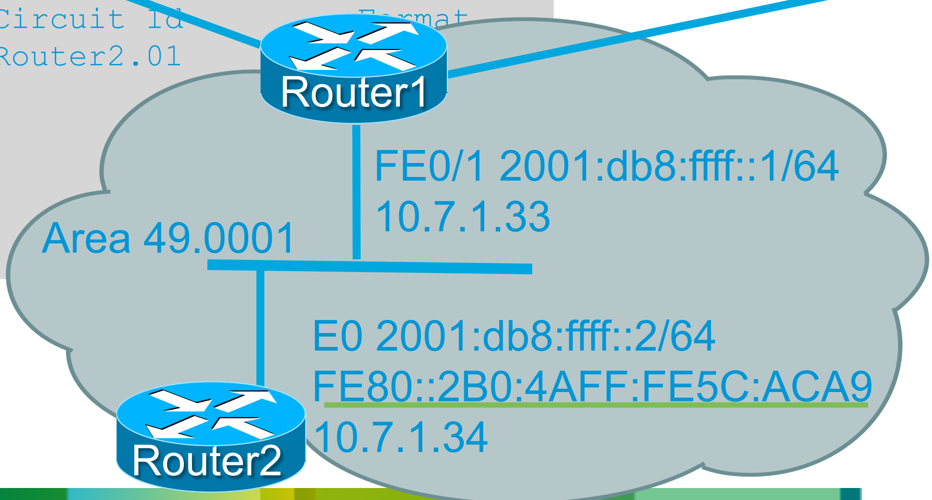
IS-IS Single-topology Example

```
Router1#show isis database verbose level-1
IS-IS Level-1 Link State Database:
LSPID                 LSP Seq Num    LSP Checksum    LSP Holdtime    ATT/P/OL
Router2.00-00         0x0000000B     0xAB35          1020            0/0/0
  Area Address: 49.0001
  NLPID:        0xCC 0x8E
  Hostname: Router2
  IP Address:   10.7.1.34
  Metric: 10         IP 10.7.1.32 255.255.255.252
  IPv6 Address: 2001:db8:FFFF::2
  Metric: 10         IPv6 2001:db8:FFFF::/64
  Metric: 10         IS Router2.01
```

```
router isis example-area
 net 49.0001.0000.0000.0001.00
!
interface FastEthernet0/1
 ip address 10.7.1.33 255.255.255.252
 ip router isis example-area
 ipv6 address 2001:db8:FFFF::1/64
 ipv6 enable
 ipv6 router isis example-area
```

```
Router1#show clns is-neighbors detail
System Id      Interface   State  Type Priority  Circuit Id     Format
Router2        Fa0/1       Up     L1L2 64/64     Router2.01
  Area Address(es): 49.0001
  IP Address(es):  10.7.1.34*
  IPv6 Address(es): FE80::2B0:4AFF:FE5C:ACA9
  Uptime: 00:01:25
  NSF capable
```



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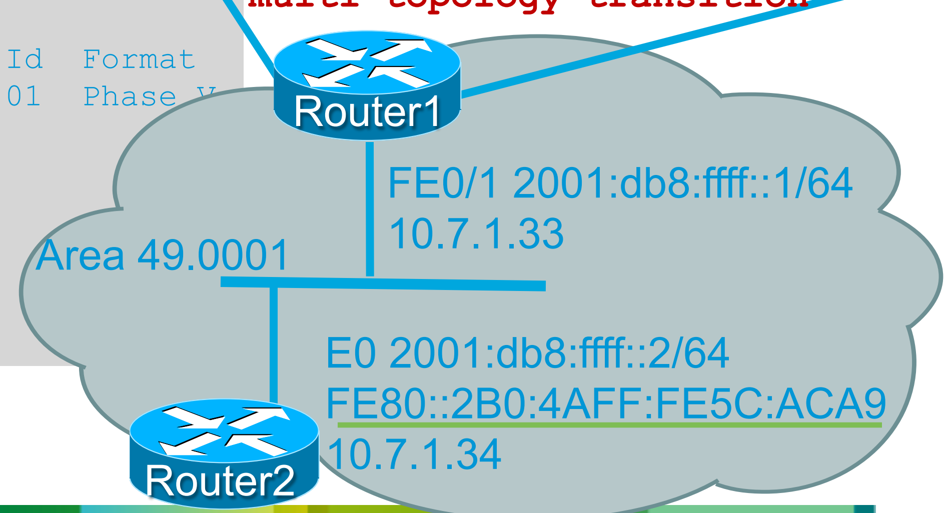
IS-IS Multi-topology Example

```
Router1#show isis database verbose level-1
IS-IS Level-1 Link State Database:
LSPID             LSP Seq Num  LSP Checksum  LSP Holdtime  ATT/P/OL
Router2.00-00     0x00000014   0x8B3E        1086          0/0/0
  Area Address: 49.0001
  Topology:     IPv4 (0x0) IPv6 (0x2)
  NLPID:        0xCC 0x8E
  Hostname: Router2
  IP Address:   10.7.1.34
  Metric: 10         IP 10.7.1.32/30
  IPv6 Address: 2001:db8:FFFF::2
  Metric: 10         IPv6 (MT-IPv6) 2001:db8:FFFF::/64
  Metric: 10         IS (MT-IPv6) Router2.01
```

```
router isis example-area
 net
49.0001.0000.0000.0001.00
 metric-style wide transition
 !
 address-family ipv6
 multi-topology transition
```

```
Router1#show clns is-neighbors detail
System Id  Interface State Type Priority Circuit Id  Format
Router2    Fa0/1     Up    L1L2 64/64    Router2.01  Phase V
  Area Address(es): 49.0001
  IP Address(es):  10.7.1.34*
  IPv6 Address(es): FE80::2B0:4AFF:FE5C:ACA9
  Uptime: 00:00:14
  NSF capable
  Topology: IPv4, IPv6
```



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OSPFv3

Differences from OSPFv2

- OSPF Packet Type:

  OSPFv3 will have the same 5 packet type but some fields have been changed

- All OSPFv3 packets have a 16 bytes header versus the 24 bytes header in OSPFv2

Packet type	Descrption
1	Hello
2	Database Description
3	Link State Request
4	Link State Update
5	Link State Acknowledgment

OSPFv2

Version	Type	Packet Length
Router ID		
Area ID		
Checksum		Autype
Authentication		
Authentication		

OSPFv3

Version	Type	Packet Length	
Router ID			
Area ID			
Checksum		Instance ID	0

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OSPFv3 (cont'd)
Differences from OSPFv2

- Uses link local addresses to identify the OSPFv3 adjacency neighbors
- Two New LSA Types
  - Link-LSA (LSA Type 0x2008)
    - There is one Link-LSA per link. This LSA advertises the router's link-local address, list of all IPv6 prefixes and options associated with the link to all other routers attached to the link
  - Intra-Area-Prefix-LSA (LSA Type 0x2009)
    - Carries all IPv6 prefix information that in IPv4 is included in Router-LSAs and Network-LSAs
- Two LSAs are Renamed
  - Type-3 summary-LSAs, renamed to "Inter-Area-Prefix-LSAs"
  - Type-4 summary LSAs, renamed to "Inter-Area-Router-LSAs"

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OSPFv3 (cont'd)

Differences from OSPFv2

- Multicast Addresses
  - FF02::5 – Represents all SPF routers on the link local scope, Equivalent to 224.0.0.5 in OSPFv2
  - FF02::6 – Represents all DR routers on the link local scope, Equivalent to 224.0.0.6 in OSPFv2
- Removal of Address Semantics
  - IPv6 addresses are no longer present in OSPF packet header (part of payload information)
  - Router LSA, Network LSA do not carry IPv6 addresses
  - Router ID, Area ID and Link State ID remains at 32 bits
  - DR and BDR are now identified by their Router ID and no longer by their IP address
- Security
  - OSPFv3 uses IPv6 AH & ESP extension headers instead of variety of mechanisms defined in OSPFv2

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LSA Types

Name	Number	Type
Router	1	0x2001
Network	2	0x2002
Inter-Area-Prefix	3	0x2003
Inter-Area-Router	4	0x2004
AS external	5	0x4005
Group-Membership	6	0x2006
Type 7	7	0x2007
Link	8	0x0008
Intra-Area-Prefix	9	0x2009

Changed name (Inter-Area-Prefix, Inter-Area-Router)

New (Link, Intra-Area-Prefix)

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OSPFv3 Configuration Example

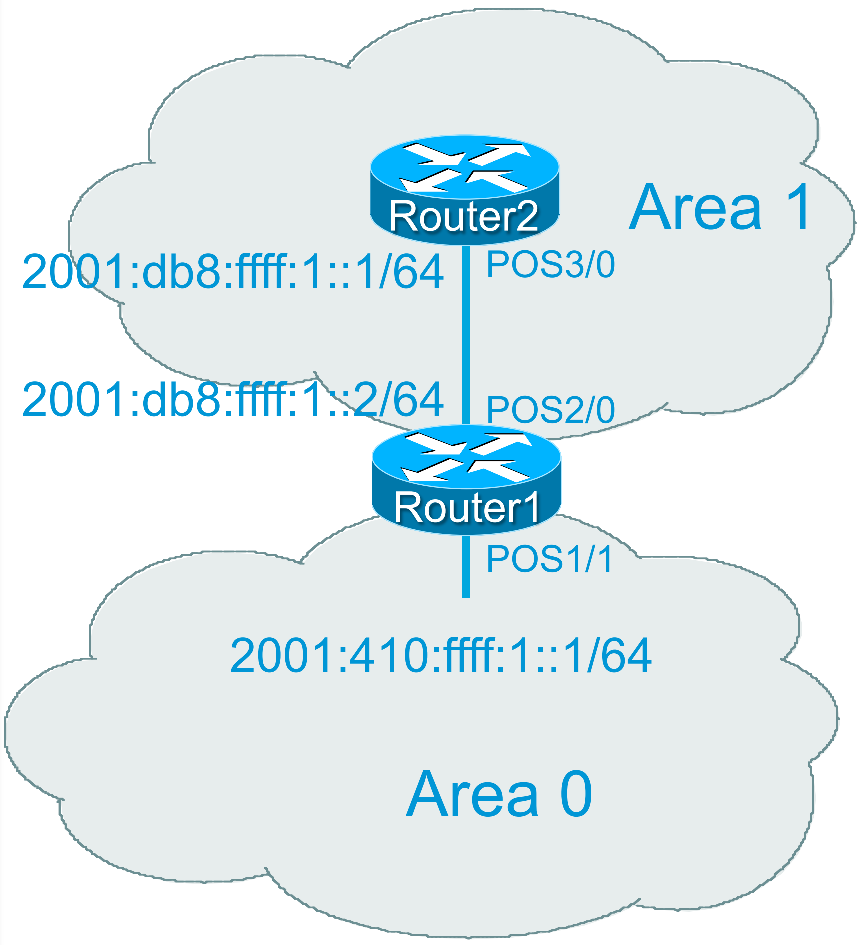
```
Router1#
interface POS1/1
 ipv6 address 2001:410:FFFF:1::1/64
 ipv6 enable
 ipv6 ospf 100 area 0

interface POS2/0
 ipv6 address 2001:db8:FFFF:1::2/64
 ipv6 enable
 ipv6 ospf 100 area 1

 ipv6 router ospf 100
   router-id 10.1.1.3

Router2#
interface POS3/0
 ipv6 address 2001:db8:FFFF:1::1/64
 ipv6 enable
 ipv6 ospf 100 area 1

ipv6 router ospf 100
   router-id 10.1.1.4
```



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BGP-4 Extensions for IPv6

- Defined in RFC 2545
- Relies on MP-BGP (multiprotocol) adding 3 new address families: IPv6 unicast, IPv6 multicast, or VPNv6.
- New optional and non-transitive BGP attributes:
  - MP_REACH_NLRI (Attribute code: 14)
    - "Carry the set of reachable destinations together with the next-hop information to be used for forwarding to these destinations" (RFC2858)
  - MP_UNREACH_NLRI (Attribute code: 15)
    - Carry the set of unreachable destinations
- Attribute 14 and 15 contains one or more Triples:
    - Address Family Information (AFI) – 2 for IPv6
    - Next-Hop Information (must be of the same address family)
    - NLRI
- Router ID
  - When no IPv4 is configured, an explicit 'bgp router-id' needs to be configured
  - This is needed as a BGP identifier, it is used as a tie breaker, and is sent within the OPEN message

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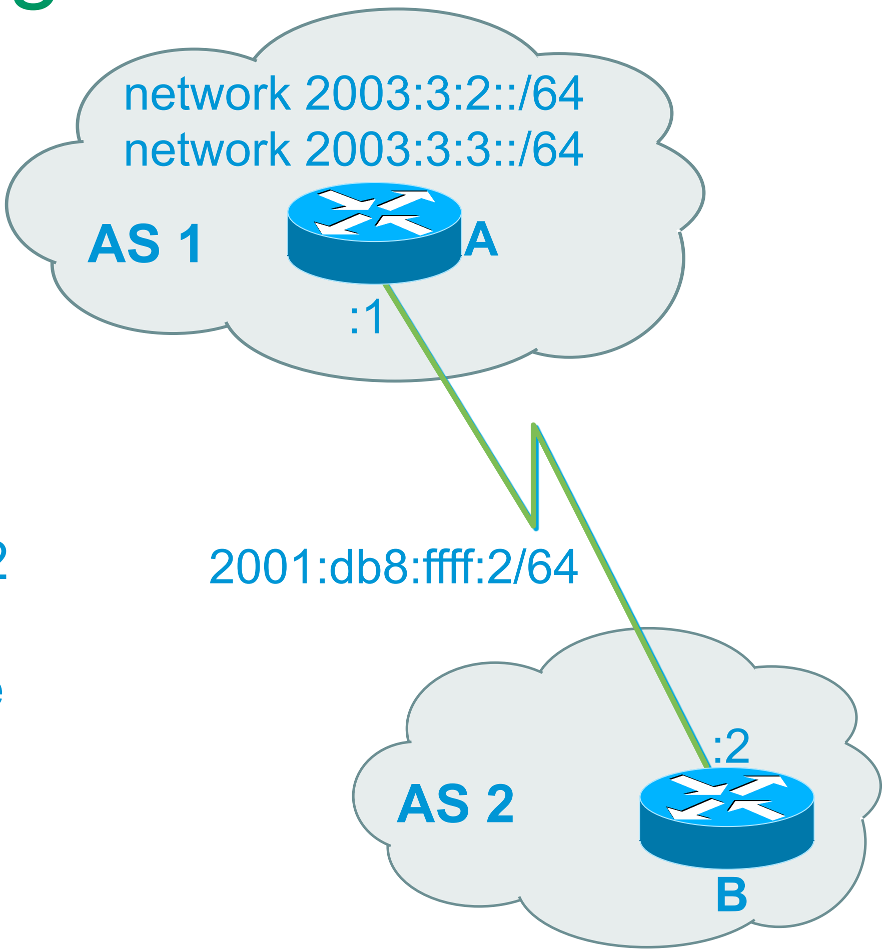
BGP-4 Configurations for IPv6 Non Link Local Peering

Router A

```
router bgp 1
no bgp default ipv4 unicast
bgp router-id 1.1.1.1
neighbor 2001:db8:ffff:2::2 remote-as 2
      address-family ipv6
      neighbor 2001:db8:ffff:2::2 activate
       network 2003:3:2::/64
       network 2003:3:3::/64
```



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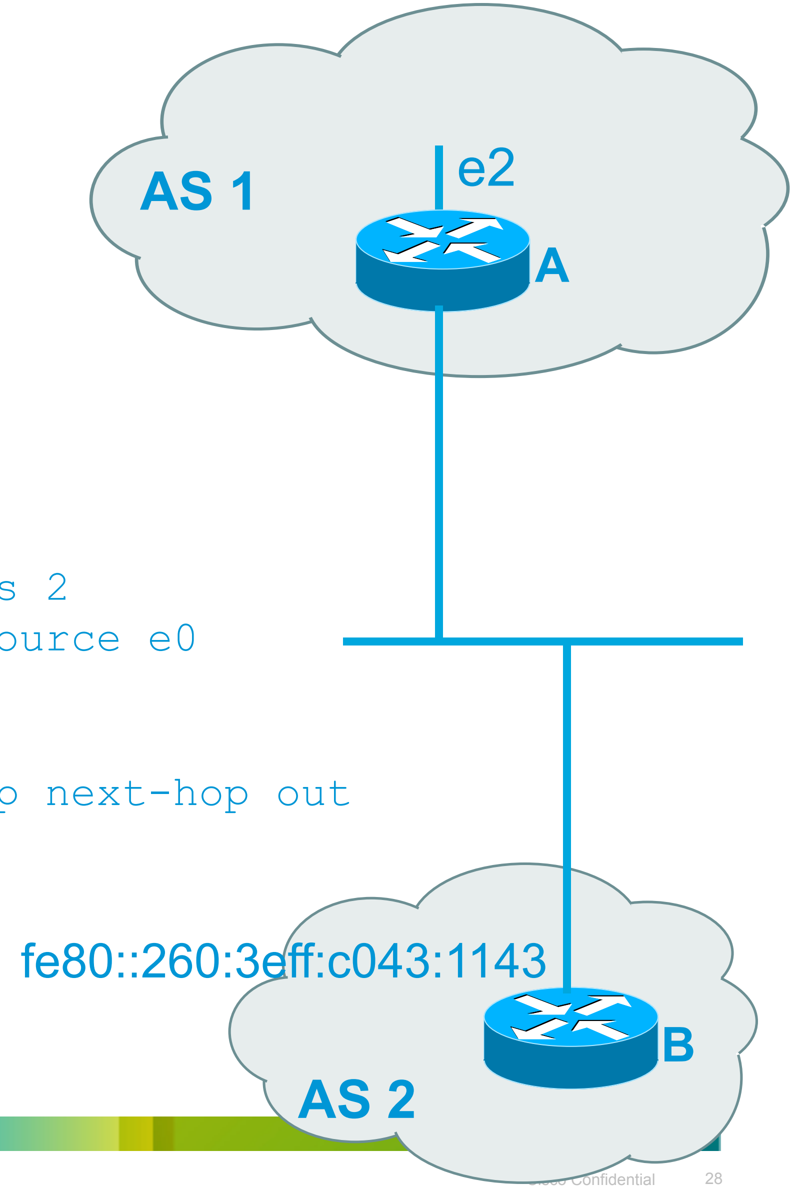
BGP-4 Configurations for IPv6 Link Local Peering

Router A

```
interface e2
ipv6 address 2001:412:ffco:1::1/64

router bgp 1
no bgp default ipv4 unicast
bgp router-id 1.1.1.1
neighbor fe80::260:3eff:c043:1143 remote-as 2
neighbor fe80::260:3eff:c043:1143 update source e0
address-family ipv6
neighbor fe80::260:3eff:c043:1143 activate
neighbor fe80::260:3eff:c043:1143 route-map next-hop out

route-map next-hop
set ipv6 next-hop 2001:412:ffco:1::1
```



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BGP-4 for IPv6 « Show Command »

show bgp ipv6 summary

Displays summary information regarding the state of the BGP neighbors

```
RouterA# show bgp ipv6 summary
BGP router identifier 1.1.1.1, local AS number 1
BGP table version is 69046, main routing table version 69046
92 network entries and 92 paths using 17756 bytes of memory
826 BGP path attribute entries using 43108 bytes of memory
703 BGP AS-PATH entries using 19328 bytes of memory
0 BGP route-map cache entries using 0 bytes of memory
745 BGP filter-list cache entries using 8940 bytes of memory
BGP activity 22978/18661 prefixes, 27166/22626 paths, scan interval 15 secs

Neighbor       V    AS  MsgRcvd MsgSent   TblVer  InQ OutQ Up/Down  State/PfxRcd
2001:db8:FFFF:2::2
               4    2   84194   14725    69044    0    0  3d08h           92
```

Neighbor Information

BGP Messages Activity

Thank you.