Service Provider IPv6 Deployment
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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 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-2 Sends MP-iBGP Advertisement to 6PE-1 Which Says:
- 2001:F00D:: Is Reachable
- Via BGP Next Hop = 200.10.10.1 (6PE-2)
- Bind BGP Label to 2001:F00D:: (*)
- IPv6 Next Hop Is an IPv4 Mapped IPv6 Address Built from 200.10.10.1

IGPv4 Advertises Reachability of 200.10.10.1

LDPv4 Binds Label to 200.10.10.1

IGPv6 or MP-BGP Advertising 2001:F00D::

6PE-1

2001:DB8::

200.11.11.1

LDPv4 Binds Label to 200.10.10.1

LDPv4 Binds Label to 200.10.10.1

LDPv4 Binds Implicit-Null (i.e. Pop) to 200.10.10.1

IGPv6 or MP-BGP Advertising 2001:F00D::

2001:F00D::

200.10.10.1

6PE-2

200.10.10.1
IPv6 Forwarding and Label Imposition:
- 6PE-1 receives an IPv6 packet
- Lookup is done on IPv6 prefix
- Result is:
  Label binded by MP-BGP to 2001:F00D::
  Label1 binded by LDP/IGPv4 to the IPv4 address of BGP next hop (6PE-2)
6PE Forwarding (P1)

IPv6-UNaware MPLS Label Switching:
- P1 receives an MPLS packet
- Lookup is done on Label1
- Result is Label2
6PE Forwarding (P2)

IPv6-UNaware MPLS Label Switching:
- P2 receives an MPLS packet
- Lookup is done on Label2
- Result includes Pop label (PHP), if used
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

Diagram:
- 2001:DB8::
- 6PE-1
- 2001:F00D::
- 6PE-2
- P1
- P2
6PE-1 Configuration

```conf
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
```

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

2001:DB8:1::1 Is the Local CE
200.10.10.1 Is the Remote 6PE
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:
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

PE1
Lo0- 192.168.2.1

MP-iBGP Session

PE2
Lo0- 192.168.5.1

CE1-BLUE
Lo0- 192.168.3.1

Enterprise IGP
10.1.1.0/24
2001:DB8:BEEF:1::/64

MP-eBGP

CE2-BLUE
Lo0- 192.168.4.1

Enterprise IGP
10.1.2.0/24
2001:DB8:BEEF:2::/64

IPv4
172.16.1.1
IPv4
172.16.1.2
IPv4
192.168.1.1-192.168.1.2
IPv4
192.168.1.5 - 192.168.1.6
IPv4
192.168.1.9 - 192.168.1.10
IPv4

IPv6
2001:DB8:CAFE:1::1
IPv6
2001:DB8:CAFE:3::2
IPv6

CE1-BLUE
IPv4
172.16.3.1
IPv6
2001:DB8:CAFE:1::1
IPv6
2001:DB8:CAFE:3::2
IPv4
172.16.3.2
IPv4
172.16.3.1
IPv4
192.168.1.1-192.168.1.2
IPv6
2001:DB8:CAFE:1::1
IPv4
192.168.1.5 - 192.168.1.6
IPv6
2001:DB8:CAFE:3::2
IPv4
192.168.1.9 - 192.168.1.10
IPv6
2001:DB8:CAFE:3::2
6VPE Configuration Example
CE1-BLUE to PE1

```
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
```

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
6VPE Configuration Example
PE1 Connections

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

```lua
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
```
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

VRF BLUE
CE1-BLUE
172.16.1.1
CAFE:1::1

MP-iBGP Session

MP-eBGP
PE1

PE2
192.168.5.1

address-family vpnv6
neighbor 192.168.5.1 activate
eighbor 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

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
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
!
routing 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
!
routing 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

Default Table
BEEF:1::/64
9999::/64
Routing Table BLUE
Routing Table BLUE
Routing Table BLUE
Routing Table BLUE
Default Table
BEEF:2::/64
8888::/64

PE1
BGP Table
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 Null10, receive
**IPv6 Routing Tables**

**PE1 BGP Next-Hop**

- **Default Table**
  - BEEF:1::/64
  - 9999::/64

- **Routing Table BLUE**

- **Default Table**
  - BEEF:2::/64
  - 8888::/64

---

```
pe1#show bgp vpnv6 unicast all

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 ?

* 2001:DB8:BEEF:2::/64
   ::FFFF:192.168.5.1
      0 100 0 506 ?

* 2001:DB8:CAFE:3::/64
   ::FFFF:192.168.5.1
      0 100 0 ?

* 8888::/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

#### PE2

---

**Default Table**
- **BEEF:1::/64**
- **9999::/64**

---

```
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:
Reference Materials

- [www.cisco.com/go/ipv6](http://www.cisco.com/go/ipv6) - CCO IPv6 Main Page
- [www.cisco.com/go/srnd](http://www.cisco.com/go/srnd) - Cisco Network Design Central
- [www.ietf.org](http://www.ietf.org)
- [www.ipv6forum.org](http://www.ipv6forum.org)
- [www.ipv6.org](http://www.ipv6.org)
- [www.nav6tf.org/](http://www.nav6tf.org/)
- [www.6net.org](http://www.6net.org)