IPv6 over MPLS
Cisco IPv6 Provider
Edge Router (6PE)
Cisco IPv6 VPN
Provider Edge
Router (6VPE)

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# IPv6 Deployment Scenario for ISP

<table>
<thead>
<tr>
<th>Environment</th>
<th>Scenario</th>
<th>Cisco IOS support</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Access</strong></td>
<td>Few customers, no native IPv6 service form the PoP or Data link is not (yet) native IPv6 capable, ie: Cable Docsis (*)</td>
<td>Tunnels</td>
</tr>
<tr>
<td></td>
<td>Native IPv4-IPv6 services between aggregation and end-users</td>
<td>Dual Stack</td>
</tr>
<tr>
<td></td>
<td>Dedicated circuits – IPv4 – IPv6</td>
<td>Dual Stack</td>
</tr>
<tr>
<td><strong>Core</strong></td>
<td>Native IP – Core is IPv6 aware</td>
<td>Dual Stack</td>
</tr>
<tr>
<td></td>
<td>MPLS – Core is IPv6 unaware</td>
<td>6PE/6VPE</td>
</tr>
</tbody>
</table>

(*) Before DOCSIS 3.0
IPv6 Over MPLS

- Why deploy IPv6 over MPLS?
- What technology?
- 6PE deep-dive
- 6VPE deep-dive
Why Deploying IPv6 Over MPLS?

- Because you already have an MPLS core and want to provide IPv6 access and transit services to your customers
  - IPv6 access to IPv6 services and resources that you provide
  - IPv6 access to IPv6 services and resources reachable via your network
  - VPNv6 services

- Pre-existing MPLS core = IPv4 services; think co-existence

- Because you want to provide IPv6 access and transit services, and MPLS is a cool technology to do so? (speed, traffic engineering, QoS, VPN, resiliency)
What Core? IPv4 or IPv6 Signaled LSP?

- **Pre-existing MPLS core ➔ L2-based or IPv4-based**
  Stick with what you have (L2-based/L3-based, LDP/RSVP, etc.) and use 6PE/6VPE

- **New core**
  Providing mixed (IPv4/IPv6) services ➔ IPv4-based (“4PE” is a challenge)
  IPv6-only ➔ No LDPv6 availability yet
  Your “only” option today is to go with a v4-based core
## What Technology?

<table>
<thead>
<tr>
<th>Mechanism</th>
<th>Primary Use</th>
<th>Benefits</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>IPv6 over a circuit transport over MPLS</td>
<td>SP with circuit to the CE (ATM, Ethernet, etc.)</td>
<td>Transparent to the SP</td>
<td>Scalability</td>
</tr>
<tr>
<td>IPv6 over IPv4 tunnels over MPLS</td>
<td>SP willing to offer IPv6 service on top of an existing IPv4 MPLS service</td>
<td>Impact limited to PE</td>
<td>Tunnel overhead Configuration</td>
</tr>
<tr>
<td>IPv6 MPLS with IPv4-based core (6PE/6VPE)</td>
<td>SP willing to offer IPv6 service on top of an existing IPv4 MPLS service</td>
<td>Impact limited to PE</td>
<td>Core is unaware of IPv6: limitations in load-balancing and troubleshooting</td>
</tr>
<tr>
<td>IPv6 MPLS with IPv6-based core</td>
<td>SP willing to offer MPLS services in an IPv6-only context</td>
<td>Full MPLS-IPv6 functionality</td>
<td>Impact on entire MPLS Infrastructure</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Complexity if coexistence with an IPv4-MPLS service</td>
</tr>
</tbody>
</table>
IPv6 Tunnels Configured on CE

- No impact on existing IPv4 or MPLS Core (IPv6 unaware)
- Only CEs have to be IPv6-aware (Dual stack)
- Mesh of IPv6 over IPv4 Tunnels CE-to-CE
- Overhead: IPv4 header + MPLS header
- MPLS/VPN support IPv4-native and IPv6 tunnels
- Service Provider can’t delegate his IPv6 prefix to the CE routers
IPv6 Over “Circuit_over_MPLS”

- No impact on existing IPv4 or MPLS Core (IPv6 unaware)
- Edge MPLS Routers need to support “Circuit_over_MPLS”
- Mesh of “Circuit_Over_MPLS” PE-to-PE
- PE routers can also be regular IPv6 Routers (IPv6 over ATM, IPv6 over FR, IPv6 over Ethernet, etc.) to aggregate Customers IPv6 routers
IPv6 Over MPLS (v4-Signalled LSP)
6PE/6VPE

IPv6 network
2001:100:1000::/48

PE1
200.10.10.1

PE2
200.11.11.1

CE1
200.10.10.1

CE2
2001:100:1100::/48

LSP setup: iGP + LDP
MP-iBGP peering
IPv6+label
VPNv6

router bgp 100
bgp log-neighbor-changes
neighbor 200.11.11.1 remote-as 100
address-family ipv6
neighbor 200.11.11.1 activate
neighbor 200.11.11.1 send-label
address-family vpnv6
neighbor 200.11.11.1 activate

MPLS label
BGP label
IPv6 packet

Interface Ethernet 1/0
ip address 40.1.1.2 255.255.255.0
ip router isis
mpls is

IPv6 network
2001:100:1000::/48

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bgp log-neighbor-changes
neighbor 200.10.10.1 remote-as 100
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address-family vpnv6
neighbor 200.10.10.1 activate
IPv6 Over MPLS (v6-Signalled LSP)

MPLS Label Switch Paths for IPv6

All routers are IPv6-aware

- Core Infrastructure requires full Control Plane upgrade to IPv6
  - IPv6 Routing in core
  - IPv6 Label Distribution Protocol in core
- Dual Control Plane management if IPv4 and IPv6 services or a need for “4PE” design – based on IETF Softwire WG?
IPv6 Over MPLS

- Why deploy IPv6 over MPLS?
- What technology?
- 6PE deep-dive
- 6VPE deep-dive
6PE (RFC 4798) —What is it?

- Provides IPv6 global connectivity over an IPv4-MPLS core
- Transitioning mechanism for providing unicast IPv6 access over IPv4-signaled MPLS
- Coexistence mechanism for combining IPv4 and IPv6 services over an MPLS backbone
- As other IPv6 “tunnel” technologies, it enables services such as
  - “IPv6 Internet Access”
  - Peer-to-peer connectivity
  - Access to IPv6 services supplied by the SP itself
Minimum Infrastructure Upgrade for 6PE

- 6PE – RFC 4798 – defined by Cisco and available from IOS
- MPLS/IPv4 Core Infrastructure is IPv6-unaware
- PEs are updated to support Dual Stack/6PE
- IPv6 reachability exchanged among 6PEs via iBGP (MP-BGP)
- IPv6 packets transported from 6PE to 6PE inside MPLS
6PE: The Technology

- It’s an implicit method to tie-up a v4-signalled Label Switch Path with IPv6 routes announced via MP-BGP

- Apply RFC2547bis architecture to IPv6
  - IPv4/MPLS Core Infrastructure remains IPv6-unaware
  - PEs are updated to support Dual Stack/6PE
  - IPv6 reachability exchanged among 6PEs via MP-iBGP
  - IPv6 packets transported from 6PE to 6PE inside IPv4 LSPs
6PE Overview

MP-BGP sessions

IPv6 unaware
No core upgrade

V6: IGP/BGP

IGPv4
MPLS V4:
- LDPv4
- (TE v4)

Dual Stack
6PE LSP Setup

Regular IPv4 Routing and IPv4 Label Distribution

IGPv4 advertises reachability of 200.11.11.1/32

LDPv4 binds label Lb to 200.11.11.1

LDPv4 binds Implicit-Null (ie pop) to 200.11.11.1

LDPv4 binds label Lc to 200.11.11.1
6PE: Routing

IGPv6 or MP-BGP advertising 2001:100:1000::/48

6PE1 sends MP-iBGP advertisement to 6PE2:
2001:100:1000::/48 is reachable via BGP Next Hop = 200.11.11.1 (6PE1)
bind BGP label L1 to 2001:100:1000::/48

IGPv6 or MP-BGP advertising 2001:100:1000::/48
6PE: Building the Label Stack

```
Prefix  Next Hop  Label
Net1    ::FFFF:PE1v4  L1

MP-iBGP IPv6+label update:
Net1, Next-hop=::FFFF:PE1v4, Label=L1
```

IPv6 table

```
Prefix  Layer2  Label stack
Net1    MacP2  Lc
```

IPv4 table

```
Prefix  Next Hop  Adjacency
PE1     P2        MacP2
```
6PE + CsC – To Include IPv6 on Existing VPN

Loopback addresses: 10.10.10.x
Link addresses: 10.0.Y.0 /24

IPv6 Addresses: 2001:Y::/64
Cisco IOS Software Releases for 6PE

- IPv6 Start Here


- Since Release 12.0(22)S on Cisco 12000 Series
  - Release 12.0(25)S for 6PE Hardware Assistance on Engine 3
  - Release 12.0(27)S 6PE Hardware Acceleration on Engine 4/4+
  - Release 12.0(31)S 6PE Hardware Acceleration on Engine 5

- Available on Cisco 7600, Release 12.2SR and Catalyst 6500, Release 12.2SX
  - Initially available from Release 12.2(14)S on Cisco 7200/7400/7500 Series
Cisco IOS Software Releases for 6PE (Cont.)

- Introduced on Cisco IOS Software Release 12.2(15)T, then Release 12.3 mainline and later releases
- Since Cisco IOS Software Release 12.2(31)SB on Cisco 10000
IPv6 over MPLS

- Why deploying IPv6 over MPLS?
- What technology?
- 6PE deep-dive
- 6VPE deep-dive
6VPE (RFC 4659) —What Is It?

- For VPN customers, IPv6 VPN service is exactly the same as IPv4 VPN service.
- Current 6PE is “like VPN” but this is NOT VPN – ie: global reachability.
- Coexistence mechanism for combining IPv4 and IPv6 VPN services over an MPLS backbone.
- It enables services such as
  - “IPv6 VPN Access”
  - Carriers Supporting Carriers
  - Access to IPv6 services supplied by the SP itself.
### 6VPE—The Technology

<table>
<thead>
<tr>
<th></th>
<th>VPNv4</th>
<th>6VPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>RD</td>
<td>2bytes:6bytes</td>
<td>2bytes:6bytes</td>
</tr>
<tr>
<td></td>
<td>TYPE:VALUE</td>
<td>TYPE:VALUE</td>
</tr>
<tr>
<td>RT (extended community)</td>
<td>2bytes:6bytes</td>
<td>2bytes:6bytes</td>
</tr>
<tr>
<td></td>
<td>TYPE:VALUE</td>
<td>TYPE:VALUE</td>
</tr>
<tr>
<td>VPN address</td>
<td>8bytes:4bytes</td>
<td>[8bytes]16bytes</td>
</tr>
<tr>
<td></td>
<td>RD:IPv4-address</td>
<td>[RD]IPv6-address</td>
</tr>
<tr>
<td>MP_REACH-NLRI</td>
<td>AFI=1</td>
<td>AFI=2</td>
</tr>
<tr>
<td></td>
<td>SAFI=128</td>
<td>SAFI=128</td>
</tr>
<tr>
<td>NLRI</td>
<td>&lt;length, IPv4-prefix, label&gt;</td>
<td>&lt;length, IPv4-prefix, label&gt;</td>
</tr>
<tr>
<td>VRF (Virtual Routing &amp; forwarding instance)</td>
<td>1 VRF = 1 RIB + 1 FIB</td>
<td>MP-VRF</td>
</tr>
<tr>
<td>Nexthop</td>
<td>0:IPv4-address</td>
<td>[0]:::FFFF:IPv4-address</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[0]:IPv6-address</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[0]:IPv6-LL-address</td>
</tr>
<tr>
<td>Peering</td>
<td>IPv4-address</td>
<td>IPv4-address</td>
</tr>
<tr>
<td></td>
<td></td>
<td>IPv6-address</td>
</tr>
<tr>
<td></td>
<td></td>
<td>IPv6-LL-address</td>
</tr>
</tbody>
</table>
Routing Protocols Leveraged with 6VPE

- IPv4-signalled LSP
- iBGP VPNv6 AF peering between 6VPE (PE1, PE2)
- eBGP IPv6+vrf AF peering with CE
- Only eBGP and Static Route within VRF between CE-PE
Routing Tables

At the 6VPE
- A set of private IPv6 routing tables (red, blue)
- A default routing table (IPv4 or IPv6)
- A BGP table (AF VPNv6)
Routing Tables: Details
Routing Tables: Examples

PE1#show ipv6 route vrf blue
IPv6 Routing Table - blue - 7 entries
C 2001:100::/64 [0/0]
   via Ethernet4/0, directly connected
B 2001:300::/64 [200/0]
   via 200.10.10.1%Default-IP-Routing-Table, indirectly connected

PE1#show ipv6 route vrf red
IPv6 Routing Table - red - 10 entries
C 2001:200::/64 [0/0]
   via Ethernet0/0, directly connected
B 2001:400::/64 [200/0]
   via 200.10.10.1%Default-IP-Routing-Table, indirectly connected

PE1#show ip  route
200.10.10.0/32 is subnetted, 1 subnets
i L1   200.10.10.1 [115/30] via 40.1.1.3, Ethernet1/0
31.0.0.0/24 is subnetted, 1 subnets
i L1   31.1.1.0 [115/30] via 40.1.1.3, Ethernet1/0
200.11.11.0/32 is subnetted, 1 subnets
C 200.11.11.1 is directly connected, Loopback0
## BGP VPNv6 Table Example

```
PE1#show bgp vpnv6 unicast all

<table>
<thead>
<tr>
<th>Network</th>
<th>Next Hop</th>
<th>Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001:100::/64</td>
<td>2001:100::72a</td>
<td>0</td>
</tr>
<tr>
<td>*&gt;</td>
<td>::</td>
<td>0</td>
</tr>
<tr>
<td>*&gt;i2001:300::/64</td>
<td>::FFFF:200.10.10.1</td>
<td>0</td>
</tr>
</tbody>
</table>

Route Distinguisher: 200:1 (default for vrf red)

| *> 2001:200::/64 | ::                  | 0      |
| *> 2001:400::/64 | ::FFFF:200.10.10.1  | 0      |
```
Building the Label Stack for 6VPE
Multi-Protocol VRF

**vrf red**

<table>
<thead>
<tr>
<th>I/F list</th>
<th>IF1, IF2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protocols</td>
<td>IPv4</td>
</tr>
<tr>
<td></td>
<td>IPv6</td>
</tr>
<tr>
<td>Common policies</td>
<td>Route-targets</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>I/F list</th>
<th>IF3, IF4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protocols</td>
<td>IPv6</td>
</tr>
<tr>
<td>Specific Policies</td>
<td>Route-map</td>
</tr>
<tr>
<td></td>
<td>Route-targets</td>
</tr>
</tbody>
</table>

**vrf yellow**

<table>
<thead>
<tr>
<th>I/F list</th>
<th>IF3, IF4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protocols</td>
<td>IPv6</td>
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<tr>
<td>Specific Policies</td>
<td>Route-map</td>
</tr>
<tr>
<td></td>
<td>Route-targets</td>
</tr>
</tbody>
</table>
**Multi-Protocol VRF Deployment**

Dual-stack network

Site-1

CE1

PE1

Dual-stack
ipv4 addresses: 10.100/16
ipv6 addresses: 2001:100::/64

MP-eBGP session
Address-family IPv4
Address-family IPv6

PE2

P2

iGP-v4 (OSPF, ISIS)
LDP-v4

vrf
Address-family IPv4
Address-family IPv6

CE2

Site-2

Dual-stack network

Dual stack server

vrf definition site1
rd 100:1
route-target import 100:1
route-target export 100:1
address-family ipv4
address-family ipv6

interface ethernet0/0
vrf forwarding site1
ip address 10.100.1.2 255.255.0.0
ipv6 address 2001:100::72b/64
**6VPE Configuration Examples—IPv6**

**VRF Configuration**
- vrf definition site1
  - rd 1000:1
  - route-target export 1000:1
  - address-family ipv4
  - address-family ipv6

**Interface Configuration**
- interface Ethernet0/0
  - vrf forwarding site1
  - ipv6 address 2001:100::72b/64
  - ip address 10.100.1.2 255.255.255.0

**BGP Configuration**
- router bgp 100
  - neighbor 200.10.10.1 remote-as 100
  - neighbor 200.10.10.1 update-source Loopback0
  - address-family ipv4 vrf site1
    - neighbor 10.100.1.1 remote-as 200
    - neighbor 10.100.1.1 activate
  - address-family ipv6 vrf site1
    - neighbor 2001:100::72a remote-as 200
    - neighbor 2001:100::72a activate
  - address-family vpnv4
    - neighbor 200.10.10.1 activate
    - neighbor 200.10.10.1 send-community extended
  - address-family vpnv6
    - neighbor 200.10.10.1 activate
    - neighbor 200.10.10.1 send-community extended
6VPE Deployment Scaling Considerations

- Route Reflectors
- Route Refresh and Automatic Route Filtering
- Outbound Route Filtering (ORF)
**Route-Reflector Based 6VPE Example**

```
router bgp 101
no bgp default route-target filter
neighbor 200.11.11.1 remote-as 101
neighbor 200.10.10.1 remote-as 101
neighbor 200.11.11.1 update-source Loopback0
neighbor 200.10.10.1 update-source Loopback0
!
address-family vpnv6
neighbor 200.11.11.1 activate
neighbor 200.11.11.1 route-reflector-client
neighbor 200.11.11.1 send-community extended
neighbor 200.10.10.1 activate
neighbor 200.10.10.1 route-reflector-client
neighbor 200.10.10.1 send-community extended
```

---

**Diagram**: A network diagram illustrates the routing between Site-1 and Site-2 through PE1 and PE2. The diagram includes MP-iBGP and MP-eBGP sessions with appropriate address families for IPv6 and VPNv6. CE1 and CE2 are connected to PE1 and PE2 respectively. Site-1 and Site-2 are connected via PE1 and PE2 with VRF red.
IPv6 Integration on MPLS VPN Infrastructure

- **MPLS/IPv4 Core Infrastructure is IPv6-unaware**
- **PEs are updated to support Dual Stack/6VPE**
- **IPv6 VPN can co-exist with IPv4 VPN – same scope and policies**
- **6VPE – RFC 4659 – Cisco authored for IPv6 VPN over MPLS/IPv4 infrastructure**
- **Cisco IOS Release 12.2(33)SRB on Cisco 7600, IOS-XR 3.5 on Cisco 12000**
Conclusions

- IPv6 migration does not “need” MPLS but, where MPLS is deployed, it enables attractive approaches for IPv6 integration

- Cisco IPv6 and MPLS solutions provides the broadest deployment scenario feature set

- Cisco 6PE & 6VPE are ones such IPv6 integration approach over IPv4 MPLS, which offers IPv6 deployment at marginal cost/risk
  - No upgrade/reconfiguration in IPv4/MPLS core
  - IPv6 simultaneously with IPv4, IPv4 VPNs, L2 services, etc.
Q and A
More Information

- CCO IPv6 - [http://www.cisco.com/ipv6](http://www.cisco.com/ipv6)
Cisco Press Books

Deploying IPv6 Networks
An essential, comprehensive, and practical guide to IPv6 concepts, service implementation, and interoperability in existing IPv4 environments
Ciprian Popoviciu, CCE® No. 4499
Eric Levy-Abegnoli
Patrick Grossetete

going soon

Global IPv6 Strategies
From Business Analysis to Operational Planning
Patrick Grossetete
Ciprian P. Popoviciu
Fred Wettling

Cisco Self-Study:
Implementing Cisco IPv6 Networks (IPV6)
Design, build, configure, and support networks based on Version 6 of the Internet Protocol
Cisco Press
Edited by: Régis Desmeules