IPv6 Advanced Concepts

RST-3300

Cisco Networkers 2006

Agenda

- **IPv6 in MPLS Environments**
  - **6PE**
  - **6VPE**
- **IPv6 in Broadband Environments**
  - **xDSL**
  - **ETTH**
  - **WLAN**
  - **CABLE**
- **IPv6 Mobility—MIPv6**

Prerequisites: Session Abstract

- **This session focuses on advanced IPv6 concepts; the session continues the discussions covered in the "IPv6 Deployment" session at a much deeper level and also introduces new topics; the concepts covered help the network designer/administrator to understand the operation and implementation of advanced technologies and features with IPv6 such as: 6PE/6VPE (IPv6 over MPLS), IPv6 in broadband networks, multicast and mobility**
- **Attendee must have a solid foundation of IPv6 basics (addressing, routing), MPLS, multicast, IPv4 broadband networks and provisioning and IPv4 mobility**

Associated Sessions

- TECRST-2003 IPv6 Techtorial
- LABIPV61300 IPv6 Mini Techtorial/Hands on Lab
- RST-1300 Introduction to IPv6
- SEC-2003 IPv6 Security
- RST-2300 IPv6 Deployment
- RST-3301 IPv6 Routing Considerations

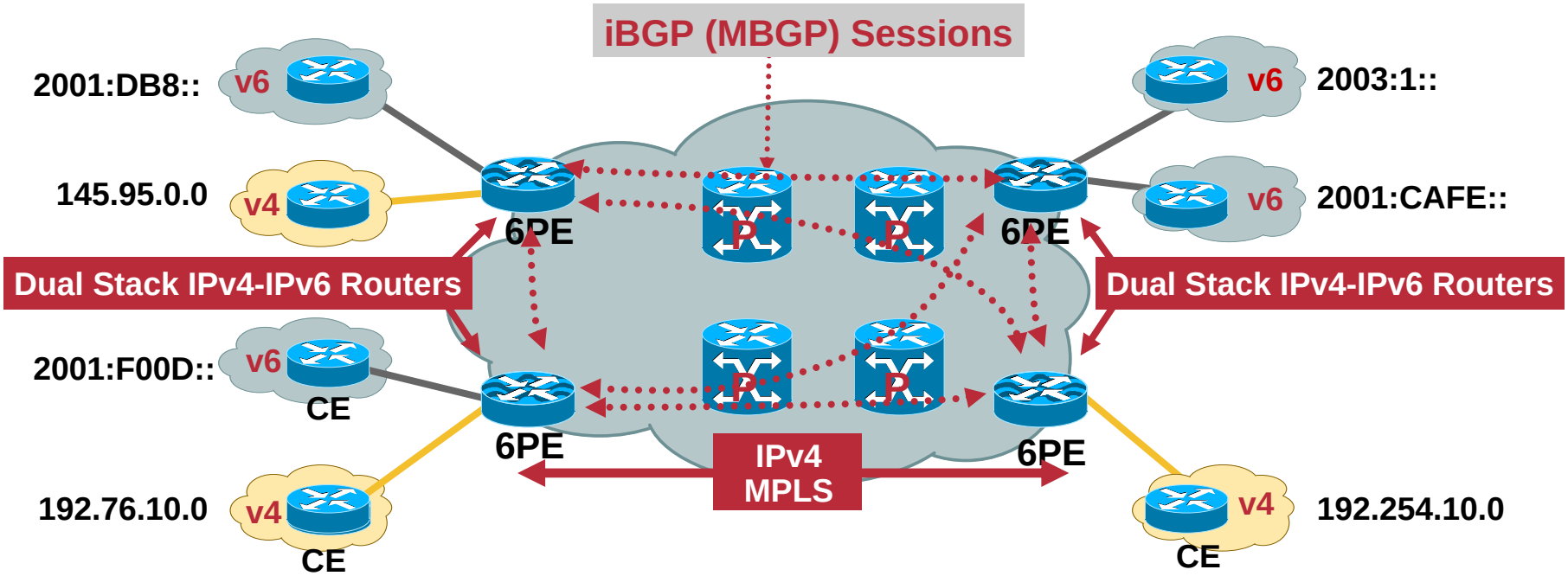
IPv6 in MPLS Environments

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**

6PE Overview

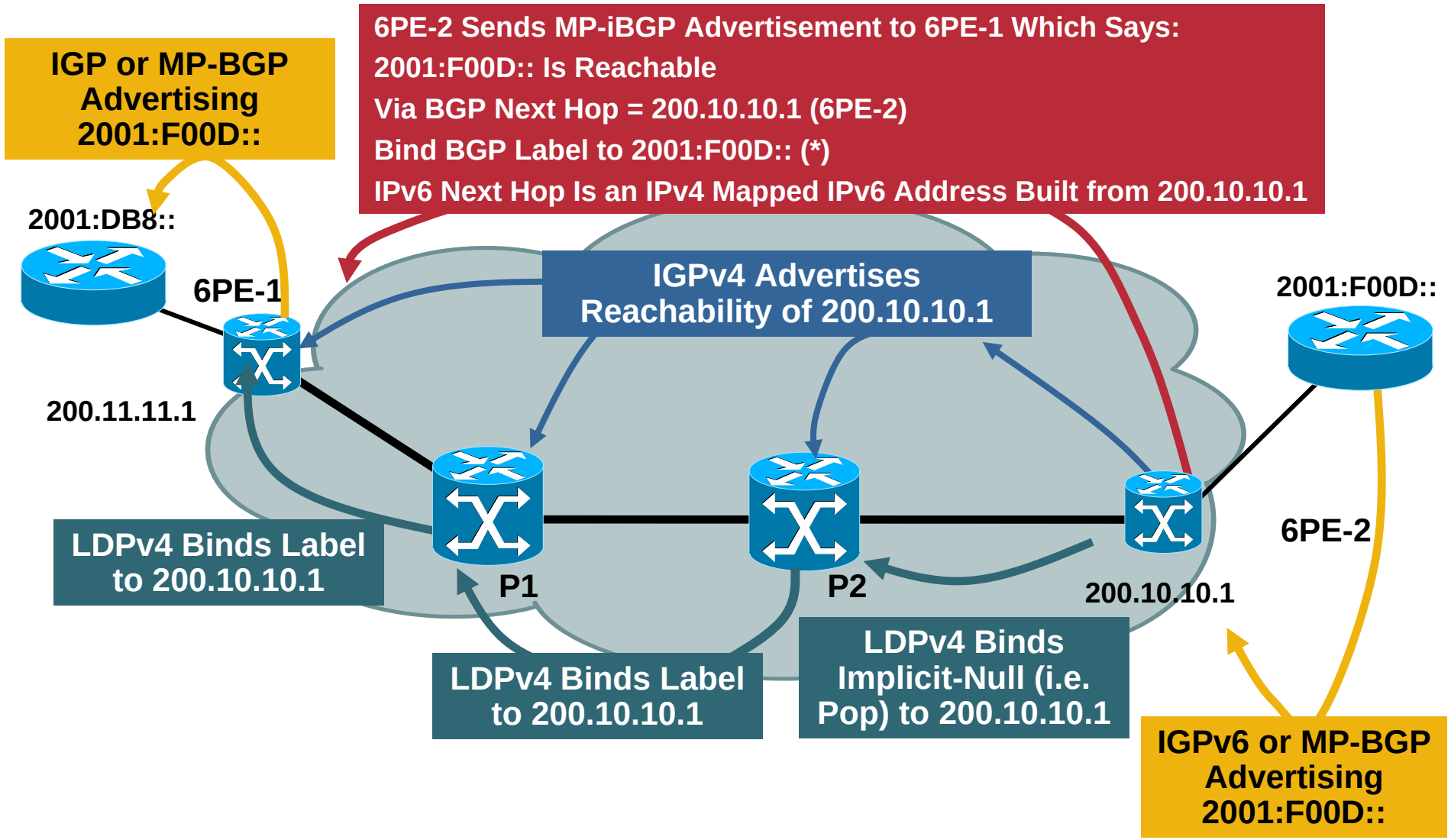
IPv6 Provider Edge Router (6PE) over MPLS



- 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

http://www.cisco.com/warp/public/cc/pd/iosw/prodlit/iosip_an.htm

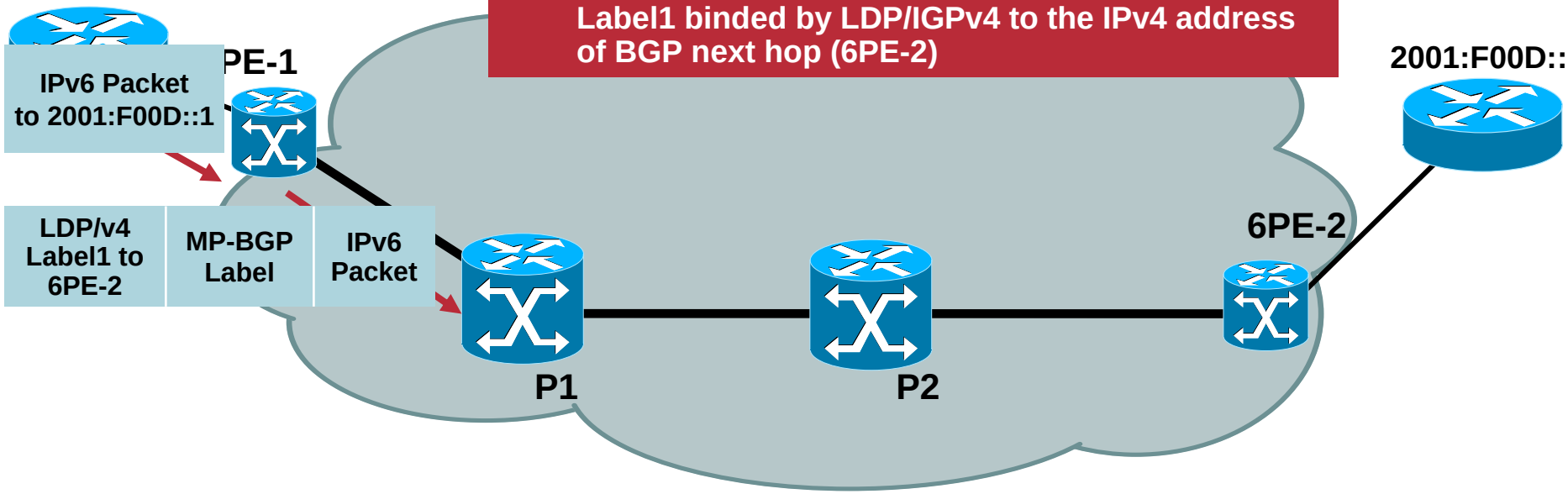
6PE Routing/Label Distribution



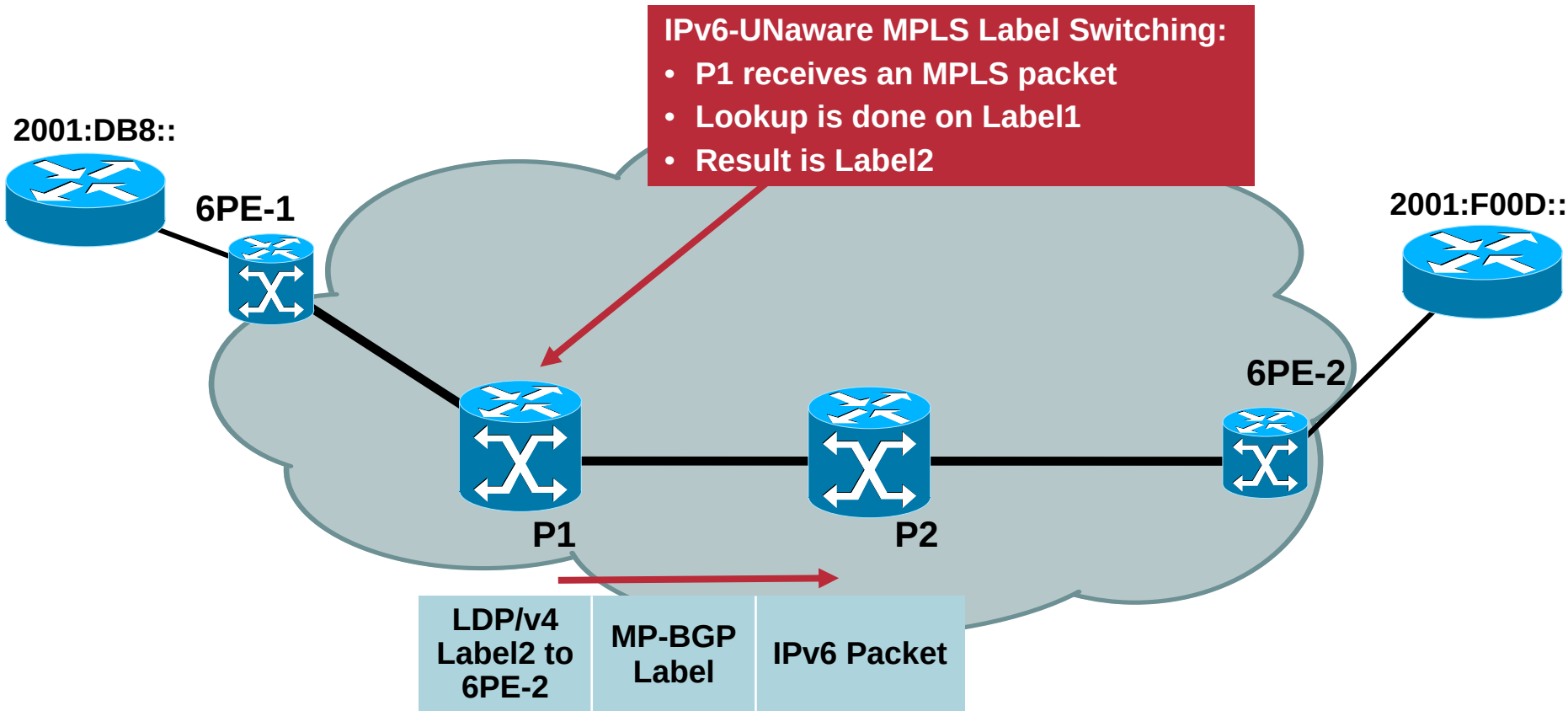
6PE Forwarding (6PE-1)

IPv6 Forwarding and Label Imposition:

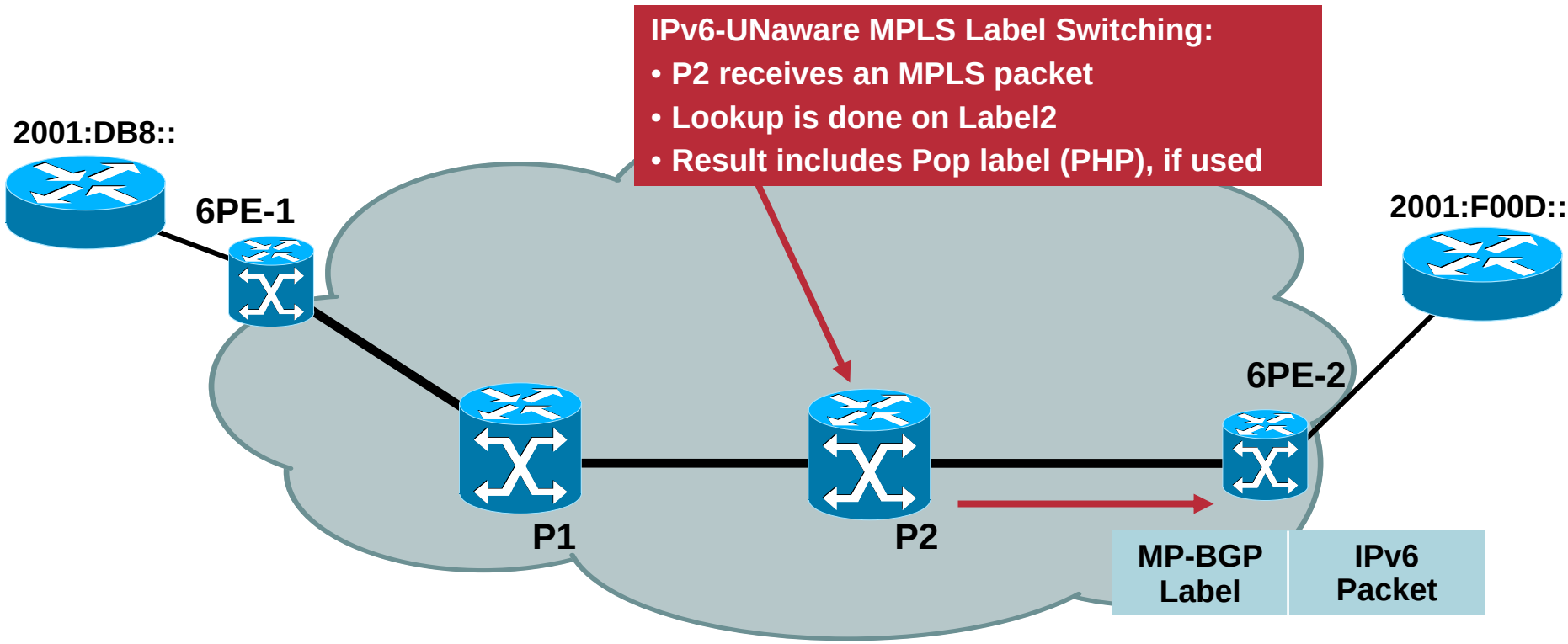
- 6PE-1 receives an IPv6 packet
- Lookup is done on IPv6 prefix
- Result is:
  - Label binded by MP-BGP to 2001:F00D::
  - Label1 binded by LDP/IGPv4 to the IPv4 address of BGP next hop (6PE-2)



6PE Forwarding (P1)

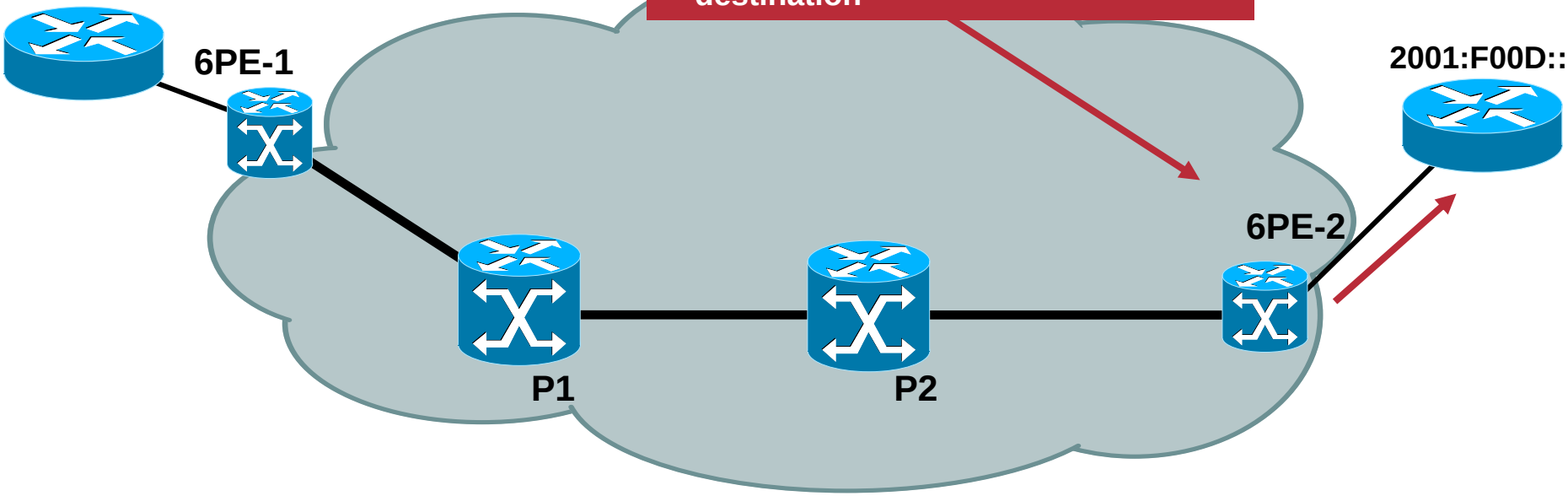


6PE Forwarding (P2)



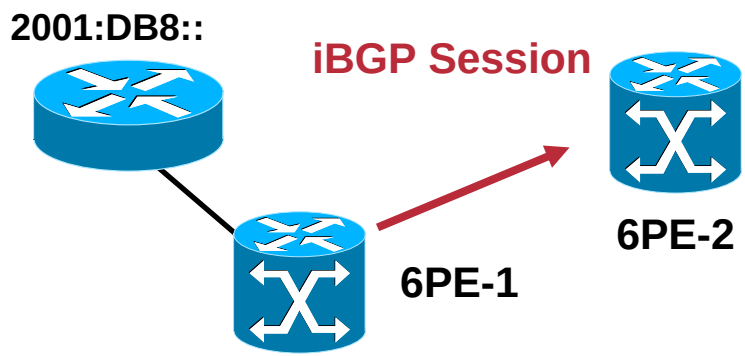
6PE Forwarding (6PE-2)

- 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 ICMP messages (TTL expired, traceroute)**

Application Note—IPv6 over MPLS (Cisco® 6PE)

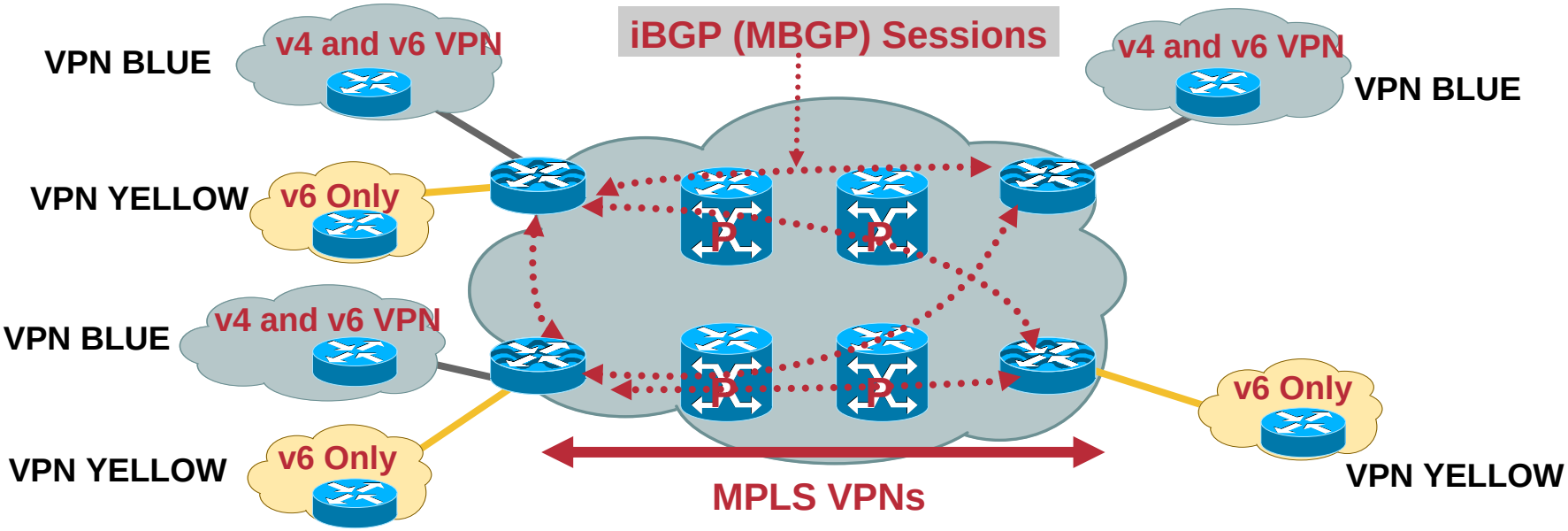
http://www.cisco.com/warp/public/cc/pd/iosw/prodlit/iosip_an.htm

"IPv6 Over MPLS" presentation:

http://www.cisco.com/warp/public/732/Tech/ipv6/docs/IPV6overMPLS.pdf

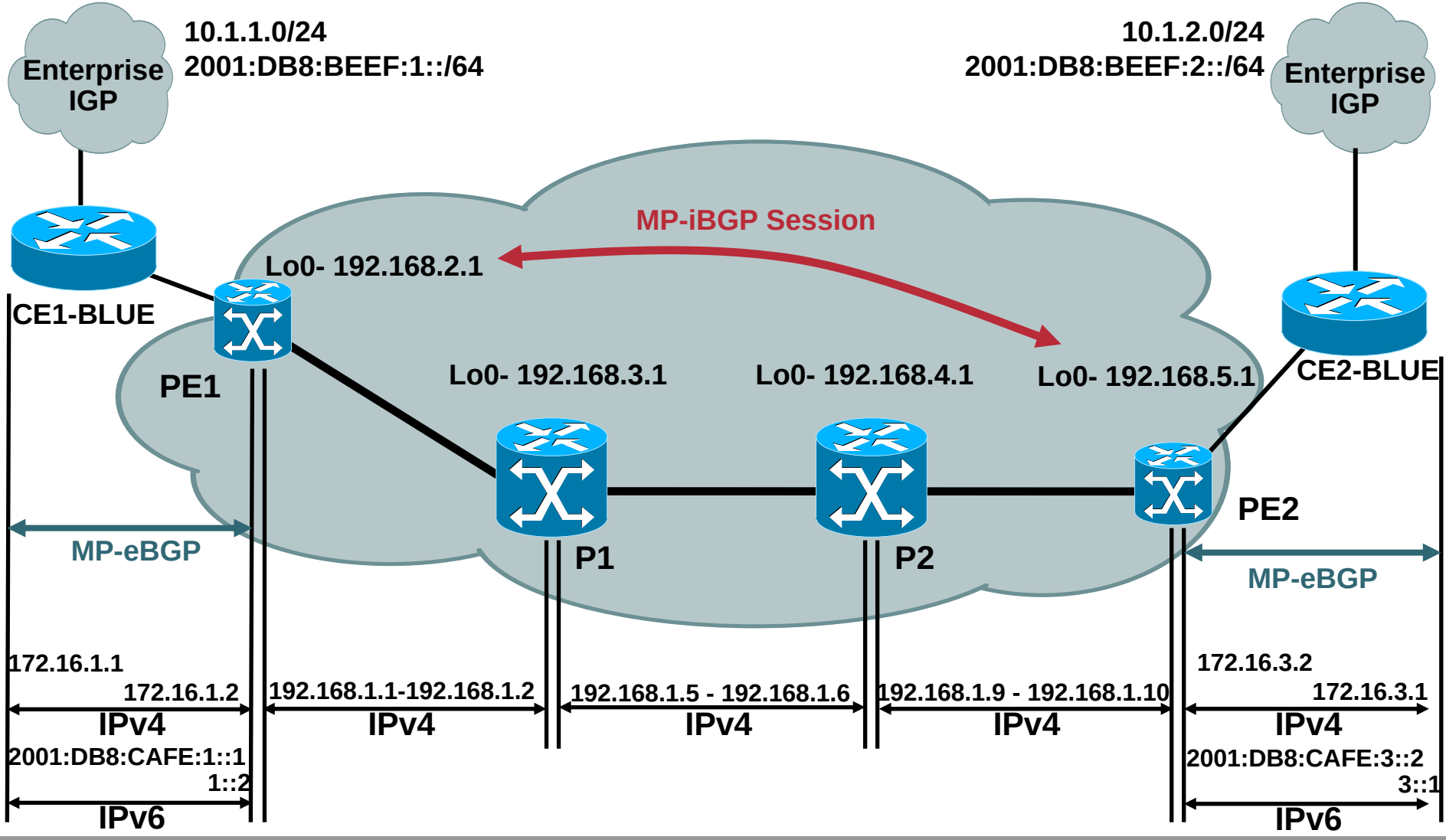
6VPE Overview

6VPE Deployment

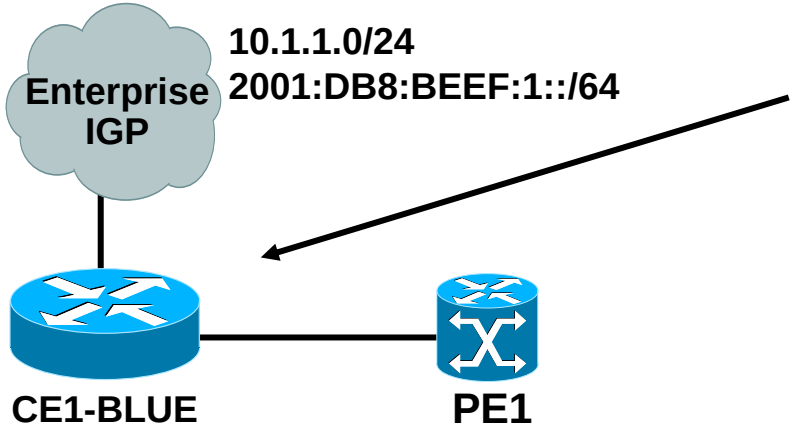


- 6VPE ~ IPv6 + BGP-MPLS IPv4 VPN + 6PE
- Cisco 6VPE is an implementation of <draft-ietf-bgp-ipv6-vpn> over MPLS/IPv4
- VPNv6 address:
  - Address including the 64 bits route distinguisher and the 128 bits IPv6 address
- MP-BGP VPNv6 address-family:
  - AFI “IPv6” (2), SAFI “VPN” (128)
- VPN IPv6 MP_REACH_NLRI
  - 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



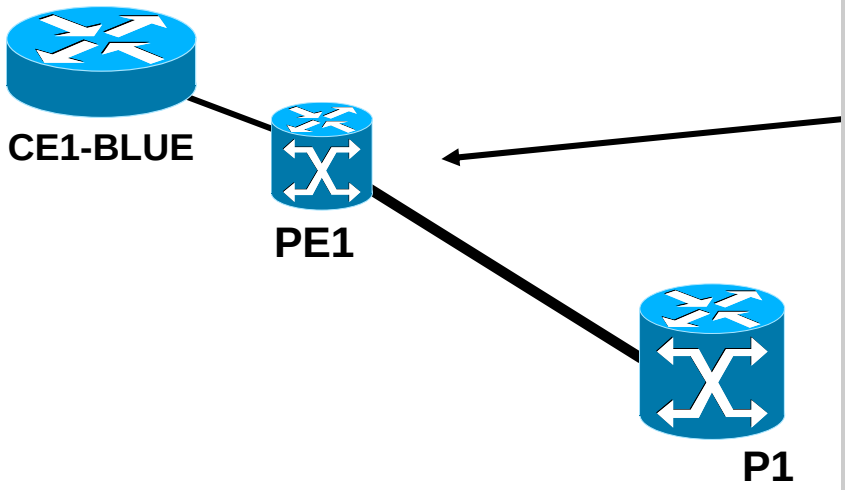
6VPE Configuration Example
CE1-BLUE to PE1




```
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
 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
 no neighbor 2001:DB8:CAFE:1::2 activate
 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
```

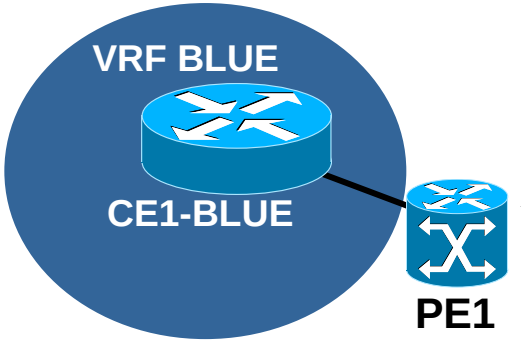
6VPE Configuration Example
PE1 Connections



- **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

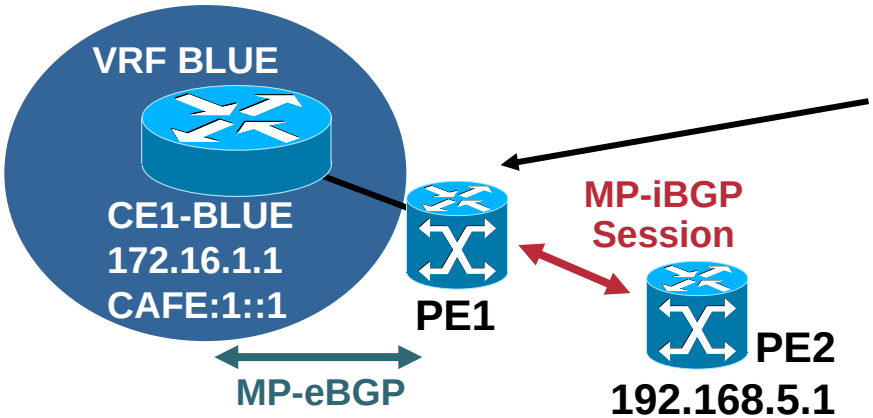


VRF
BLUE
(RD - 200:1)
PE1/PE2 Will Hold
CE1 Routes
CE2 Routes

```
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
```

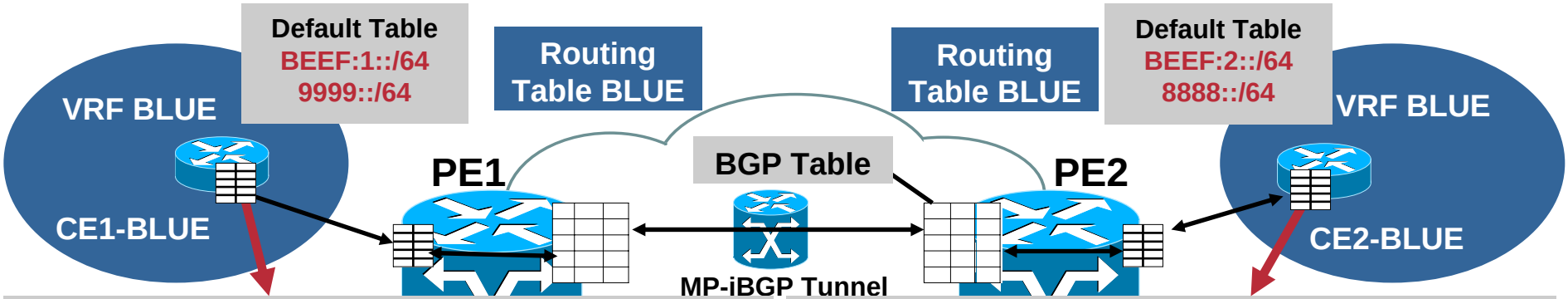
```
 address-family vpnv6
 neighbor 192.168.5.1 activate
 neighbor 192.168.5.1 send-community
extended
 exit-address-family
!
 address-family ipv4 vrf BLUE
 redistribute connected
 neighbor 172.16.1.1 remote-as 500
 neighbor 172.16.1.1 activate
 no auto-summary
 no synchronization
 exit-address-family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

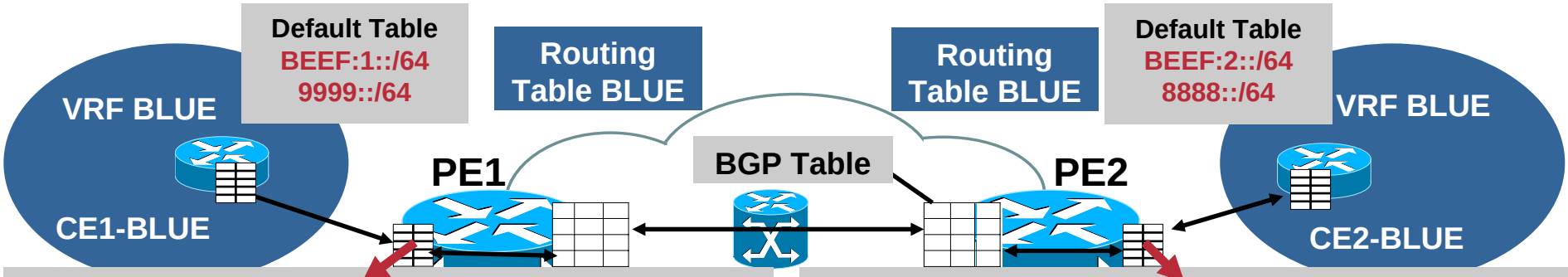
IPv6 Routing Tables
CE1-CE2




```
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
```

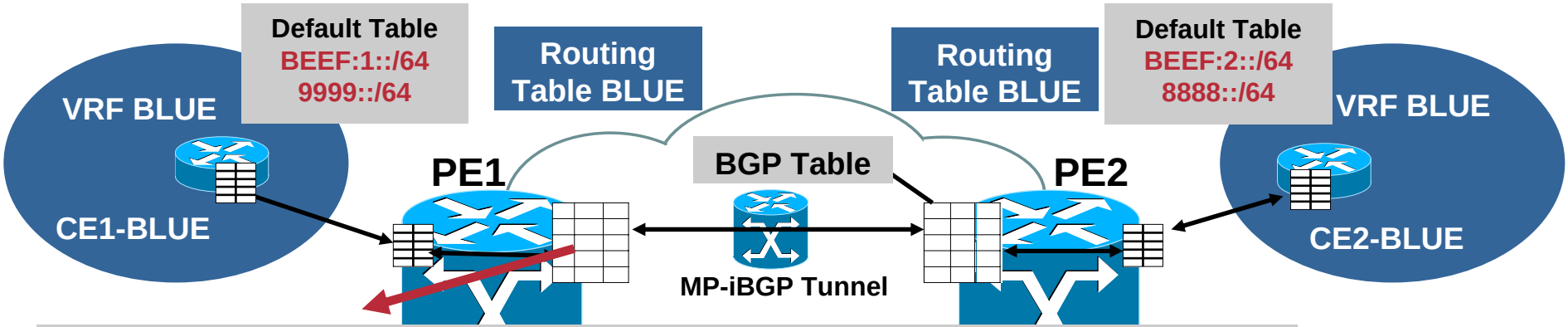
IPv6 Routing Tables
PE1-PE2




```
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
```

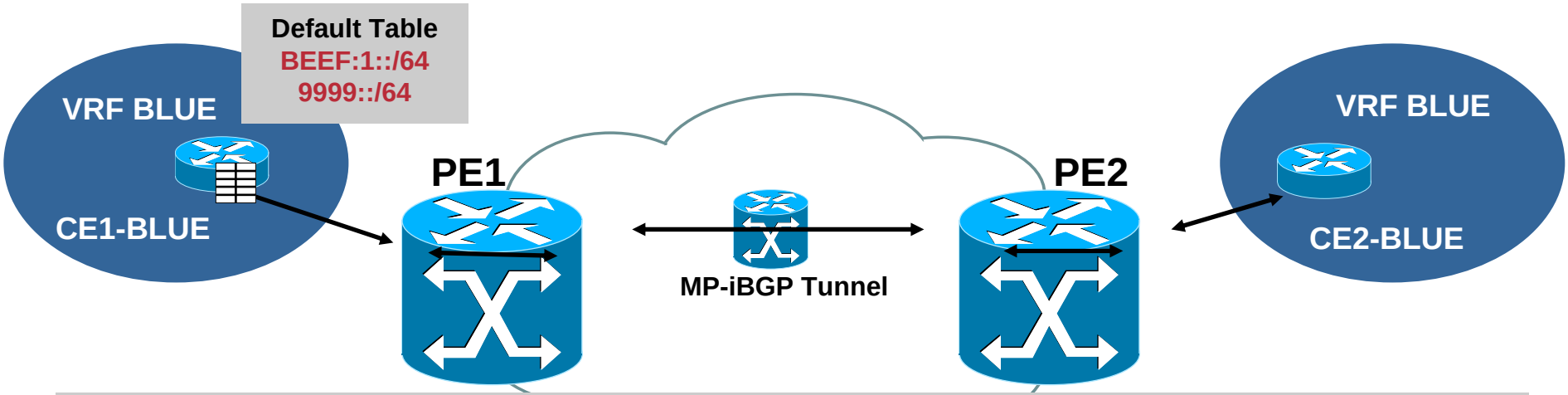
IPv6 Routing Tables
PE1 BGP Next-Hop




```
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 ?
```

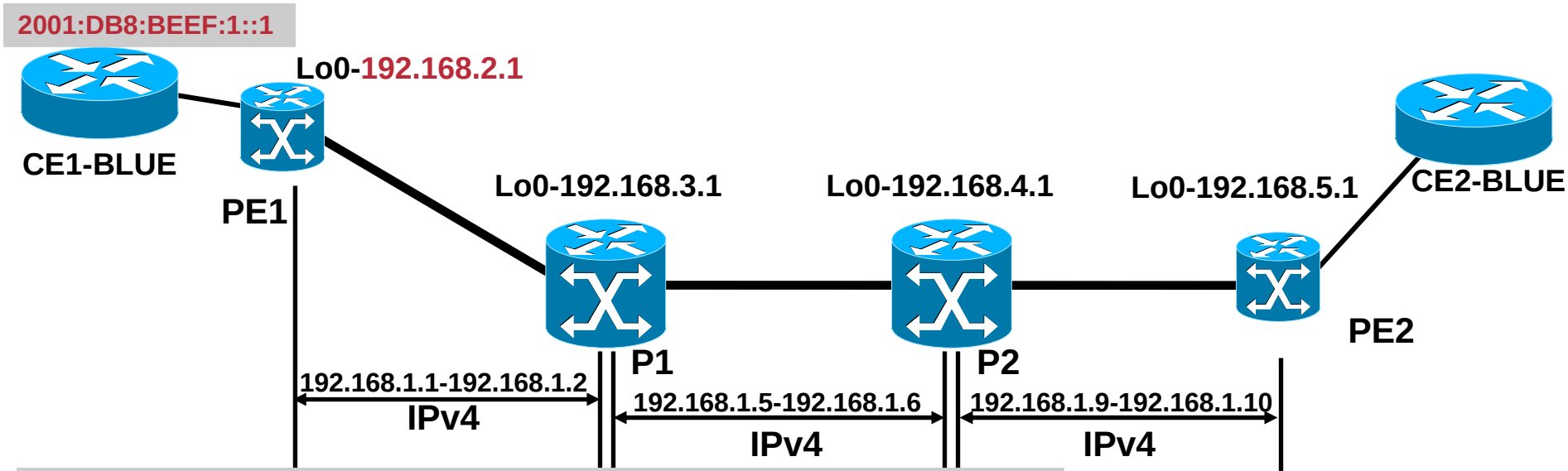
IPv4-Mapped IPv6 Address (IPv4-Based LSP Setup)

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 ipv cef vrf BLUE
2001:DB8:BEEF:1::/64
 nexthop 192.168.1.9 Ethernet0/0 label 18 25
```

6VPE Summary

- **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 is an implementation of <draft-ietf-bgp-ipv6-vpn> over MPLS/IPv4**
- **<draft-ietf-l3vpn-bgp-ipv6-xx>**
  - **BGP-MPLS VPN extension for IPv6 VPN**
  - **Generic for operations over any tunneling technique (MPLS, IPsec, L2TPv3, GRE)**

IPv6 in Broadband Environments

Drivers for IPv6 in Broadband

- **Network Management:** **The most striking aspect of Broadband Access Services is the large number of users that imply a larger number of devices to be managed by providers. Even the private IPv4 address space will be unable to withstand the expected needs. IPv6 is seen as the answer to this problem.**
- **New Services:** **The current business models for Network Access Provider (wholesale model) avoid handling users at Layer 3 at the access layer. These models do not scale for services such as Multicast. IPv6 offers the address resources needed to deploy such services optimally.**
- **Prepare for the Future:** **Build an infrastructure that would be ready for the new services and IP enabled appliances.**

IPv6 Multicast-Based Multimedia Services

- **Problem: IPv4 multicast services cannot be deployed in a scalable manner by a wholesale Access Provider. Since the replication can be done only by the Content Provider, the network resources of the Access Provider are over utilized, the service would not scale.**
- **Opportunity: The high bandwidth access available at reasonable prices through Broadband services offers the means to deliver multimedia streaming content to subscribers. These capabilities offer Service Providers the opportunity to roll out new services.**

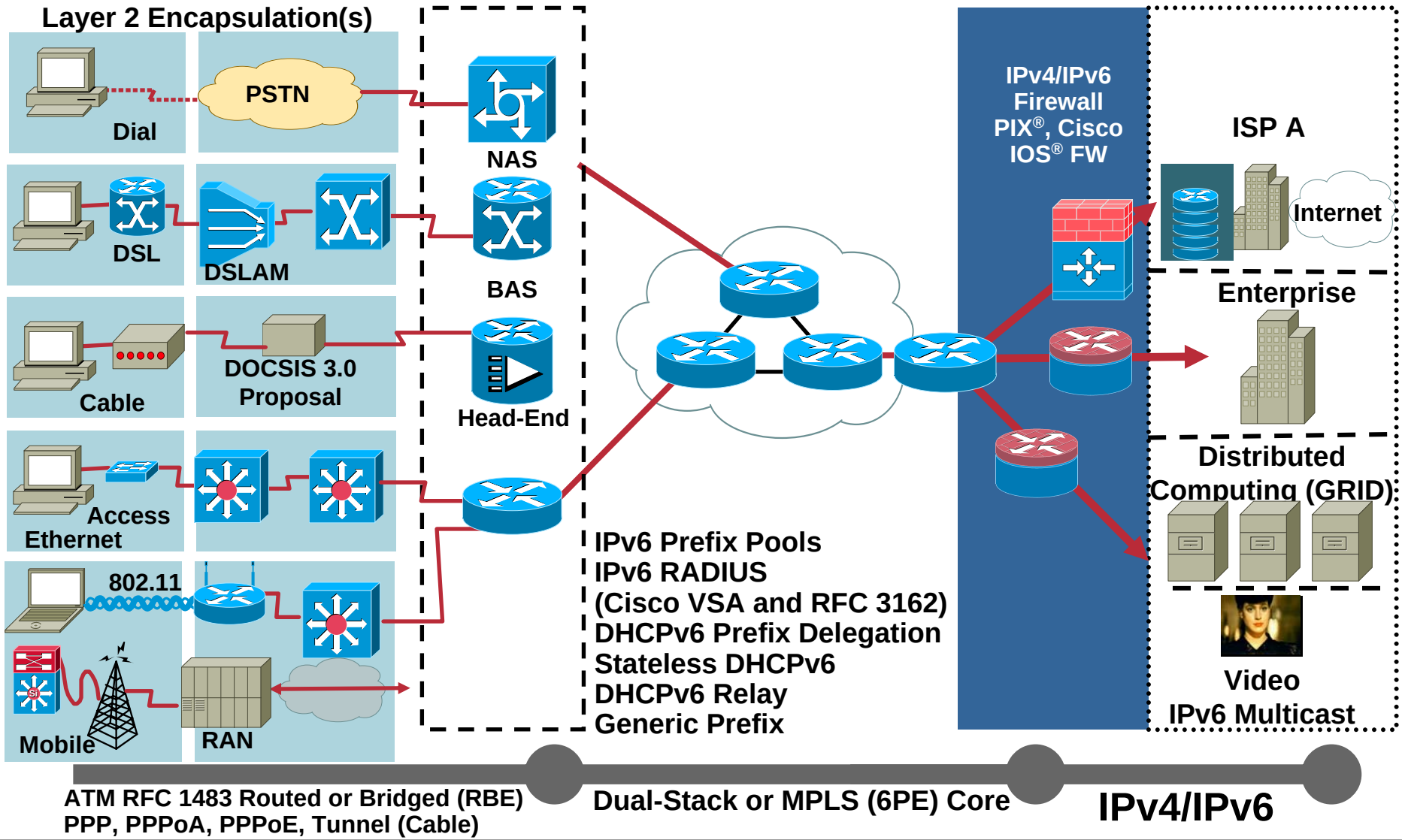
IPv6 Multicast-Based Multimedia Services (NTT-East Example)

- **NTT-East rolled out native IPv6 multicast services instead of IPv4 offering IPTV, music and games:**

  http://www.ipv6style.jp/en/action/20040902/index.shtml

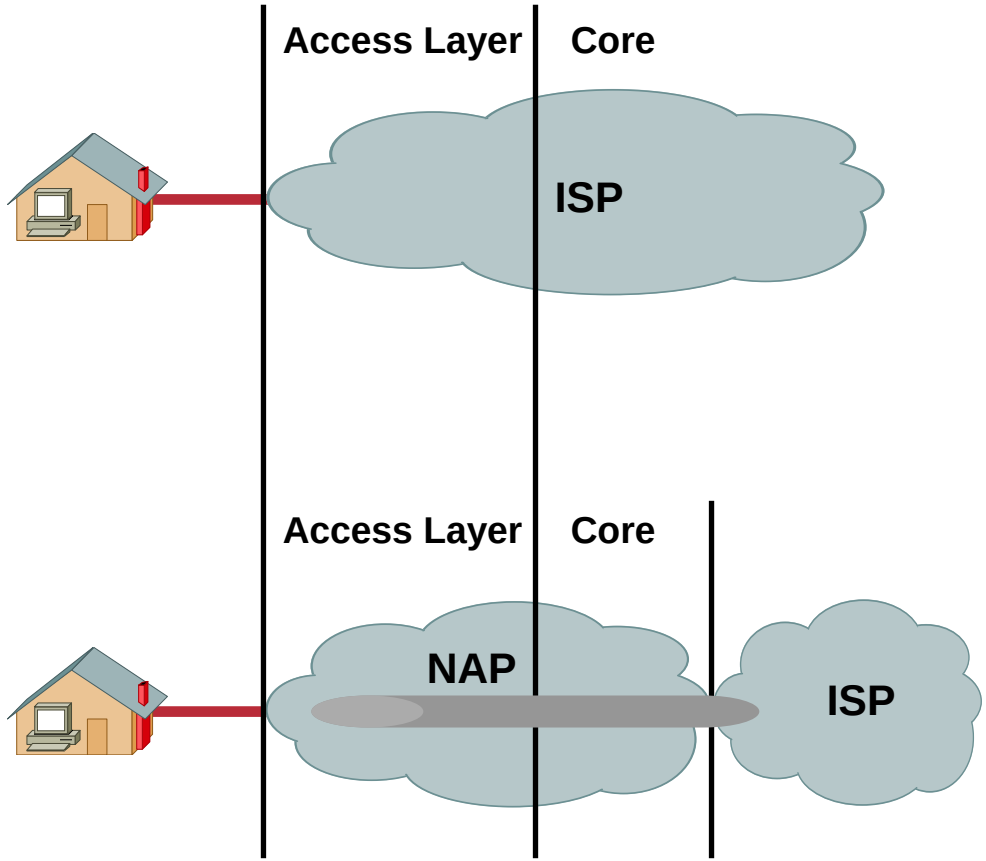
- **The IPv6 solution is scaleable since it allows for the replication to be performed at the access layer**

Cisco IOS IPv6 Broadband Access Solutions



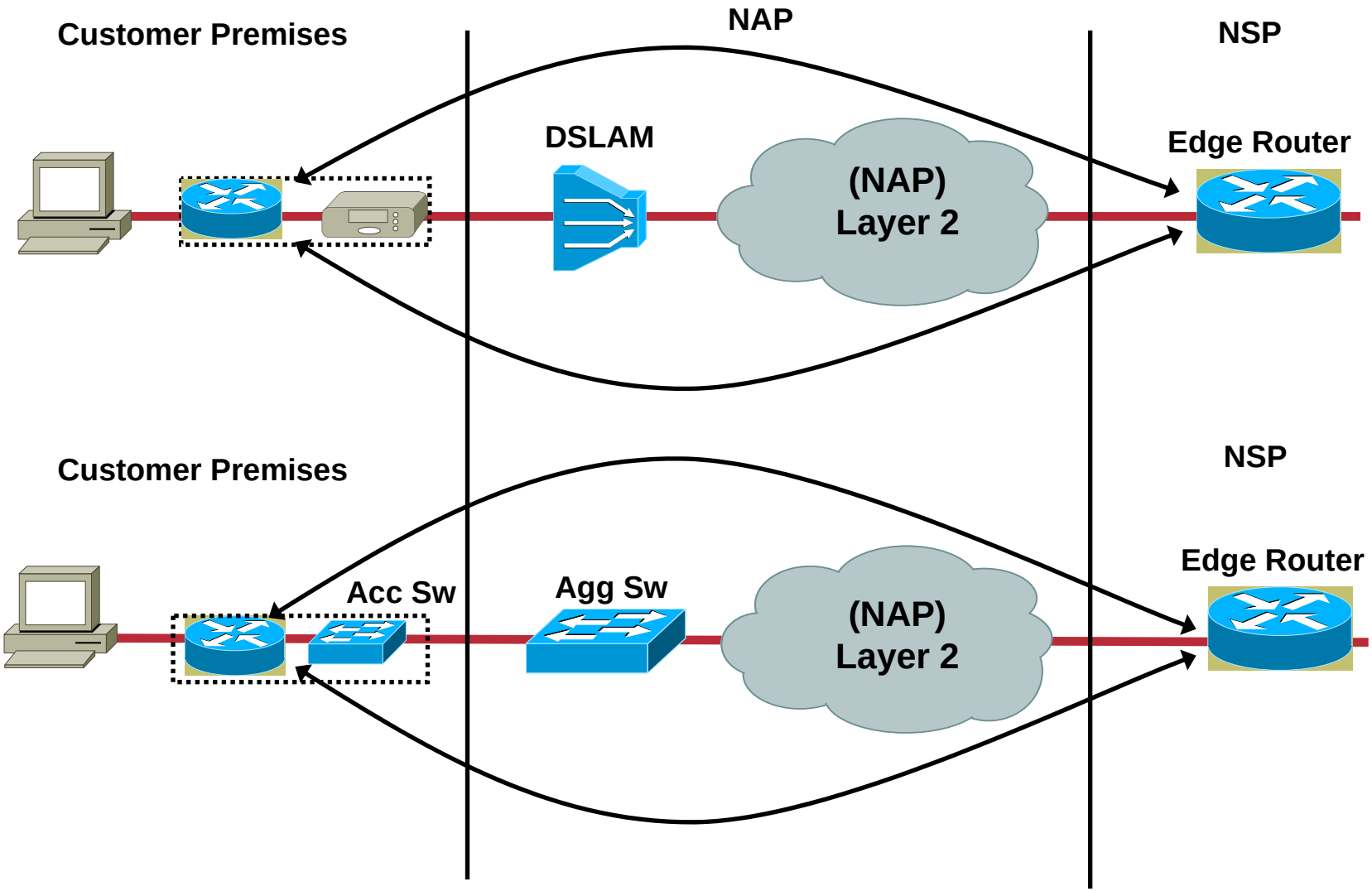
Two Broadband Access Models Today

- **Network access provider = internet service provider**
- **Network access provider # internet service provider**

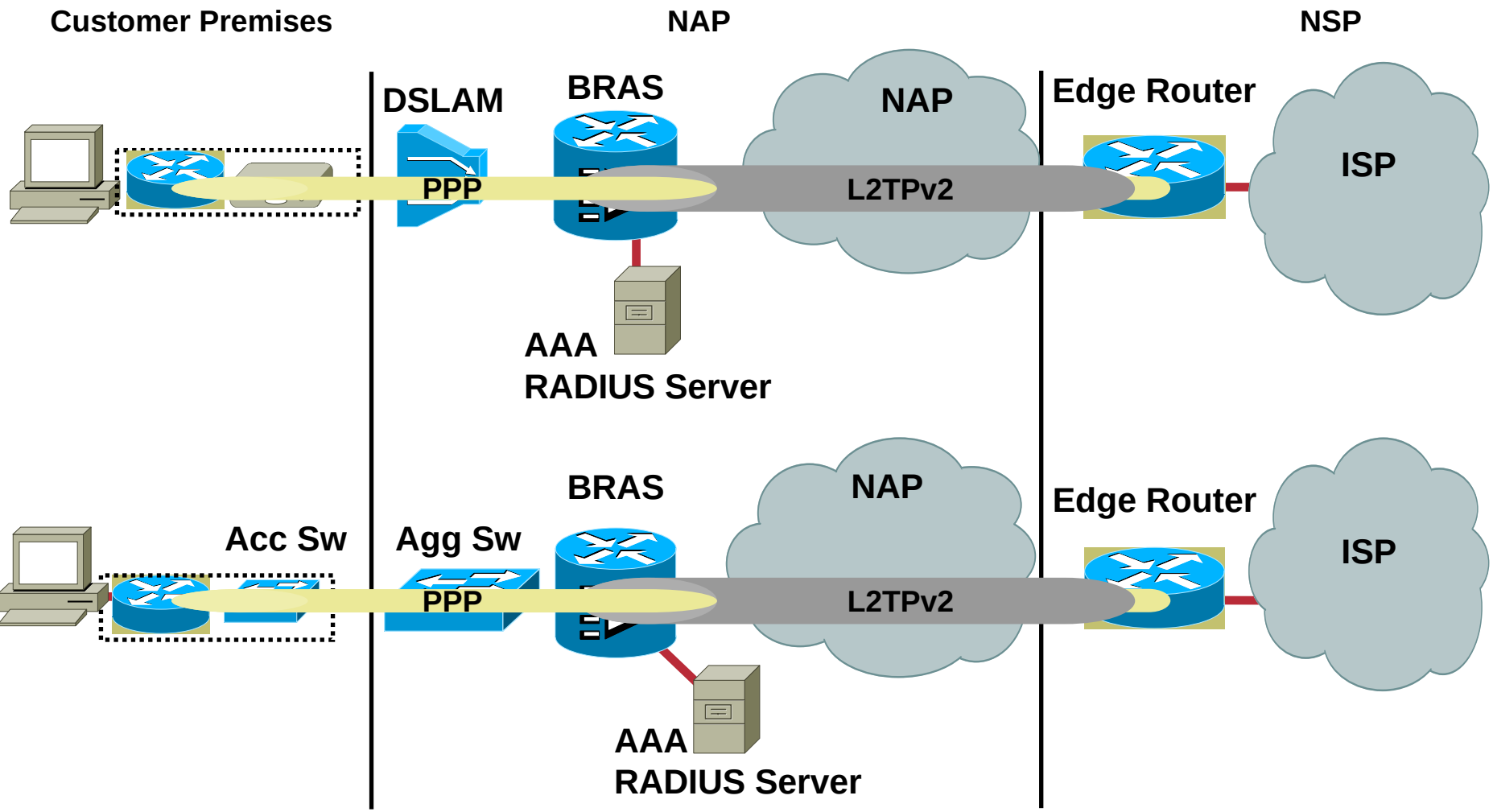


xDSL, ETTH and WLAN Networks

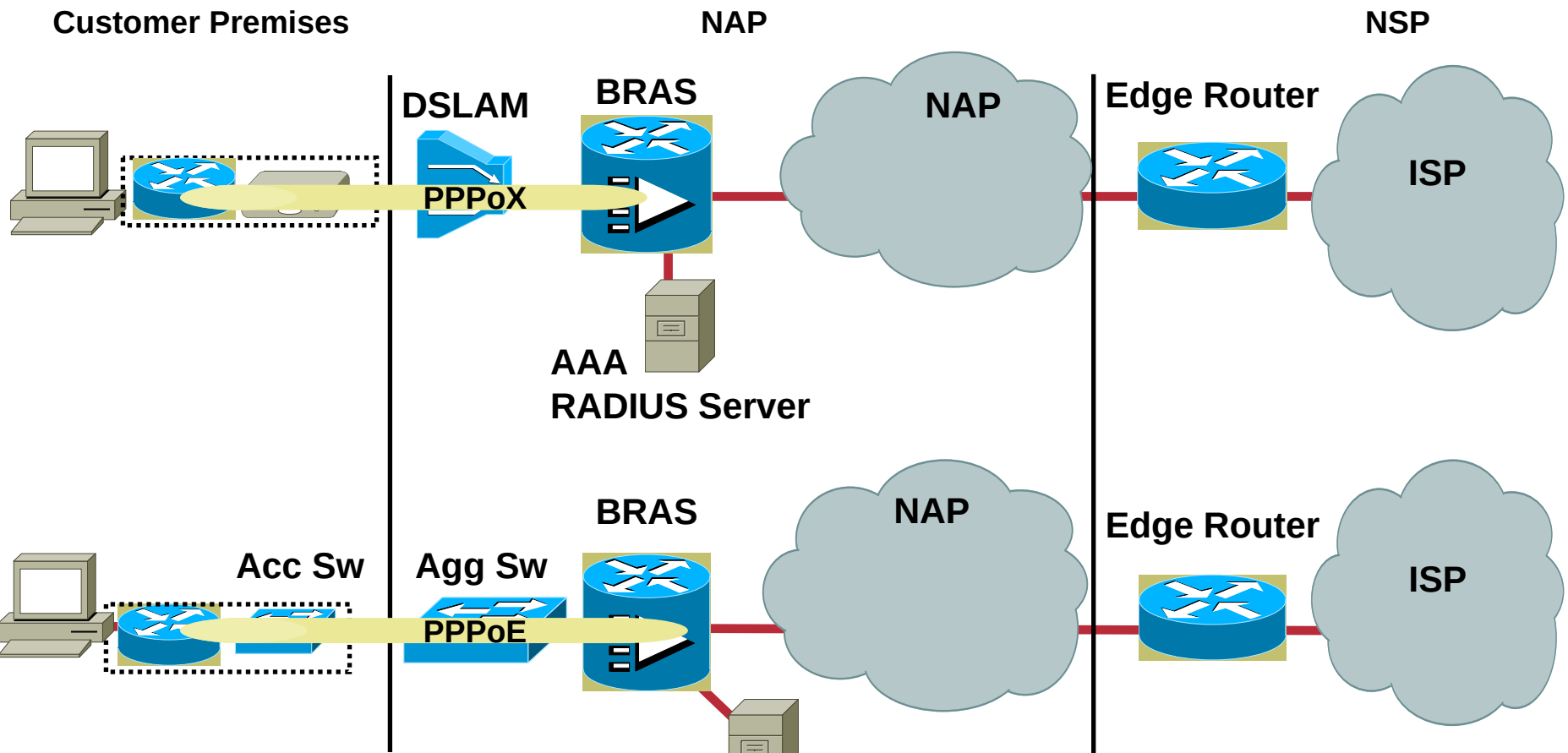
Point-to-Point Model



L2TPv2 Access Aggregation (LAA) Model

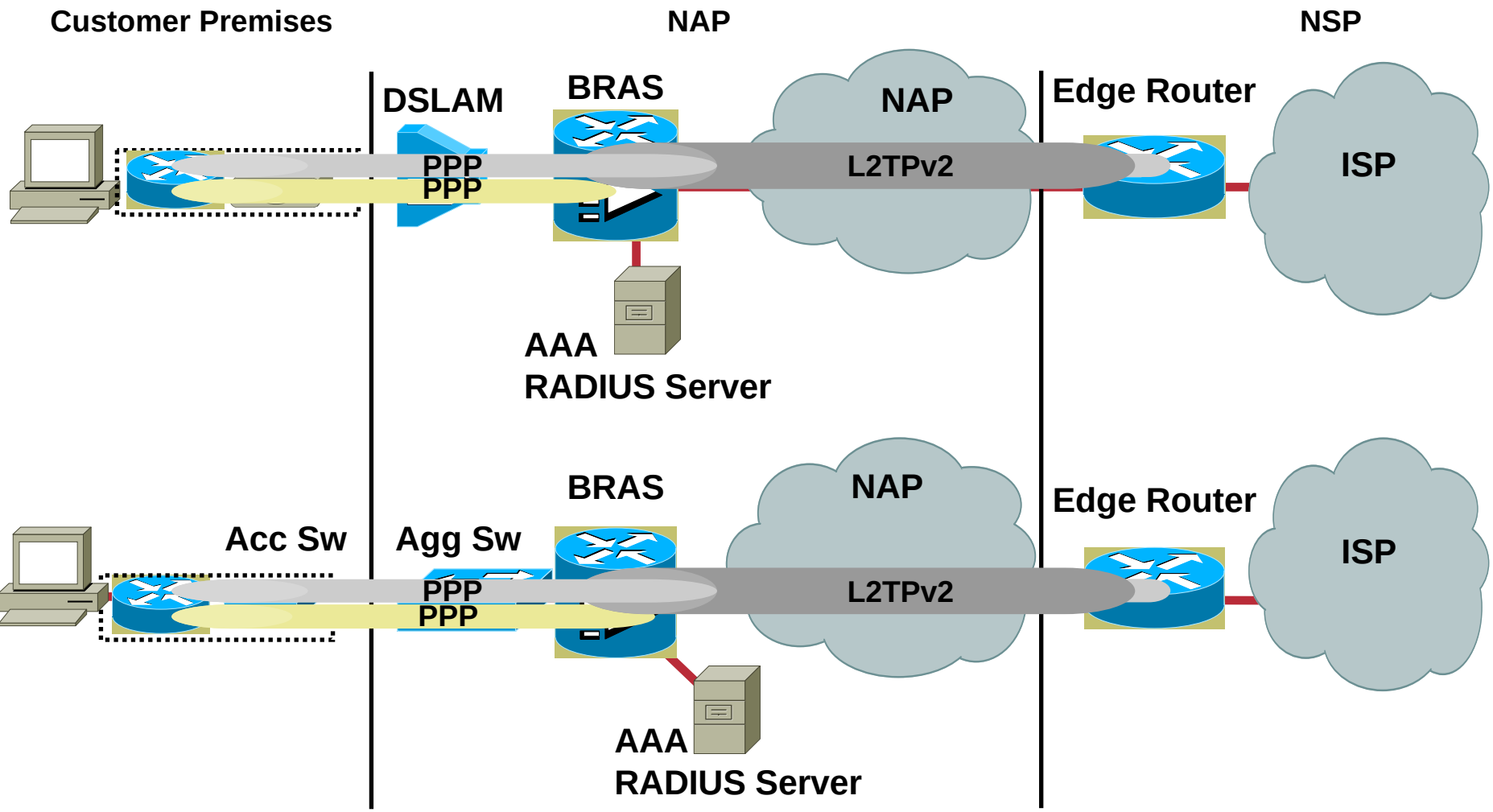


PPP Terminated Aggregation (PTA) Model



- Only one PPPoA session per PVC
- Multiple PPPoE sessions per VLAN
- The PPPoE sessions can be initiated by the hosts or the CPE

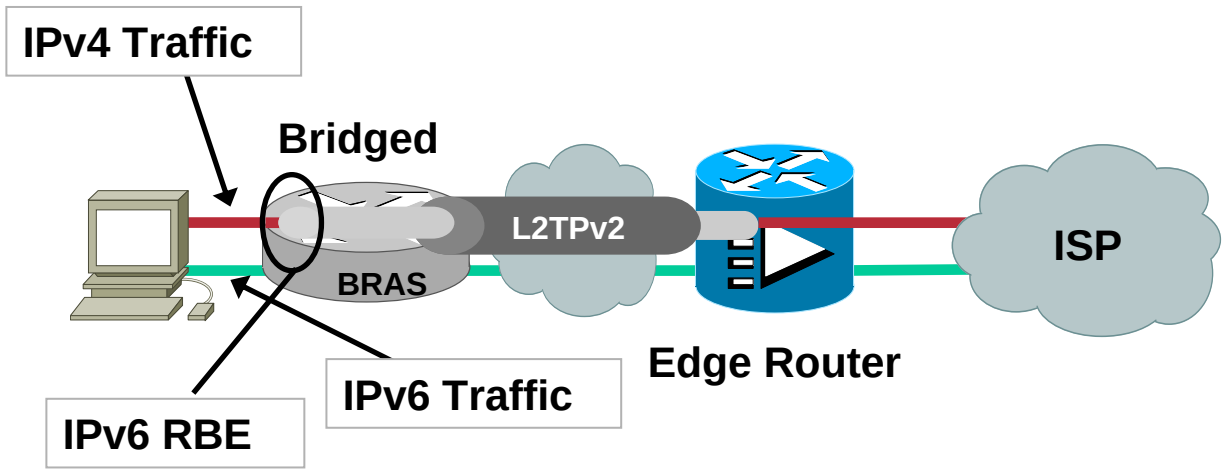
Hybrid: IPv4 LAA Model and IPv6 PTA Model



IPv6 RBE

Different Then IPv4 RBE:

- Pick out the 0x86DD type and route the traffic
- Enabled per PVC, IPv6 address is configured per PVC, each PVC supports a different subnet



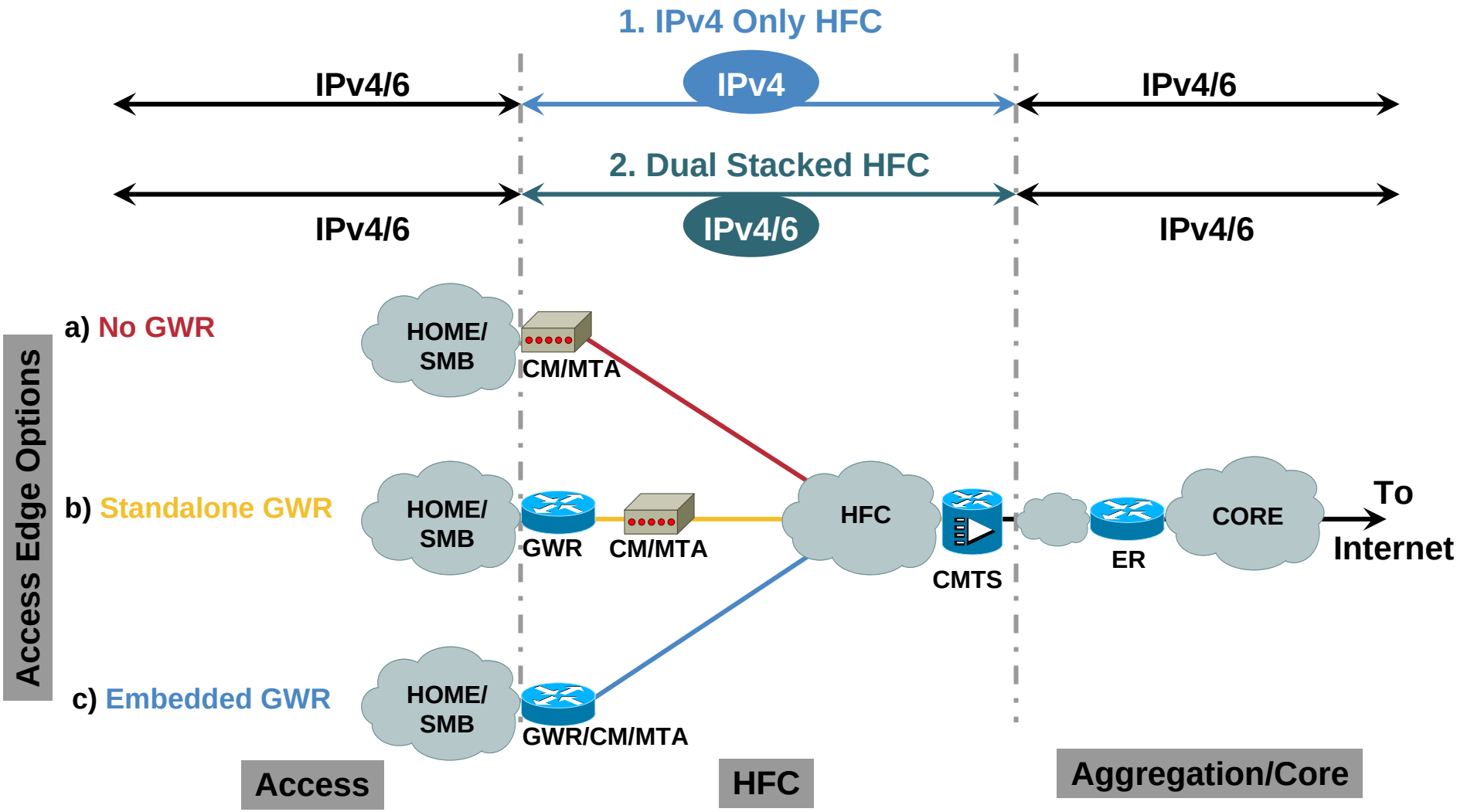
Cable Networks

Drivers for IPv6 in Cable

- **Use IPv6 for managing large number of devices on the network**
  - **Exponential growth in number of IP-enabled devices connected to CMTS**
  - **Cable MSOs in the US would like to use IPv6 to manage CM/MTA**
  - **Currently RFC1918 addresses assigned to CM for management**
- **RFC 1918 provides 16 million 10.net addresses, plus:**
  - **1M addresses under 172.16.0.0/12**
  - **65K addresses under 192.168/16**
- **Moreover, address utilization efficiency for large numbers decreases with topology hierarchies***
  - **6.5M addresses for 4M CMs**
  - **Only 61.5% efficient use**
  - **Density of only 9.8M CMs exhausts all 16M RFC1918 addresses**

***See HD Ratio, RFC1715 and RFC3194**

IPv6 Deployment Models for Cable



IPv6 Deployment Challenges in Cable

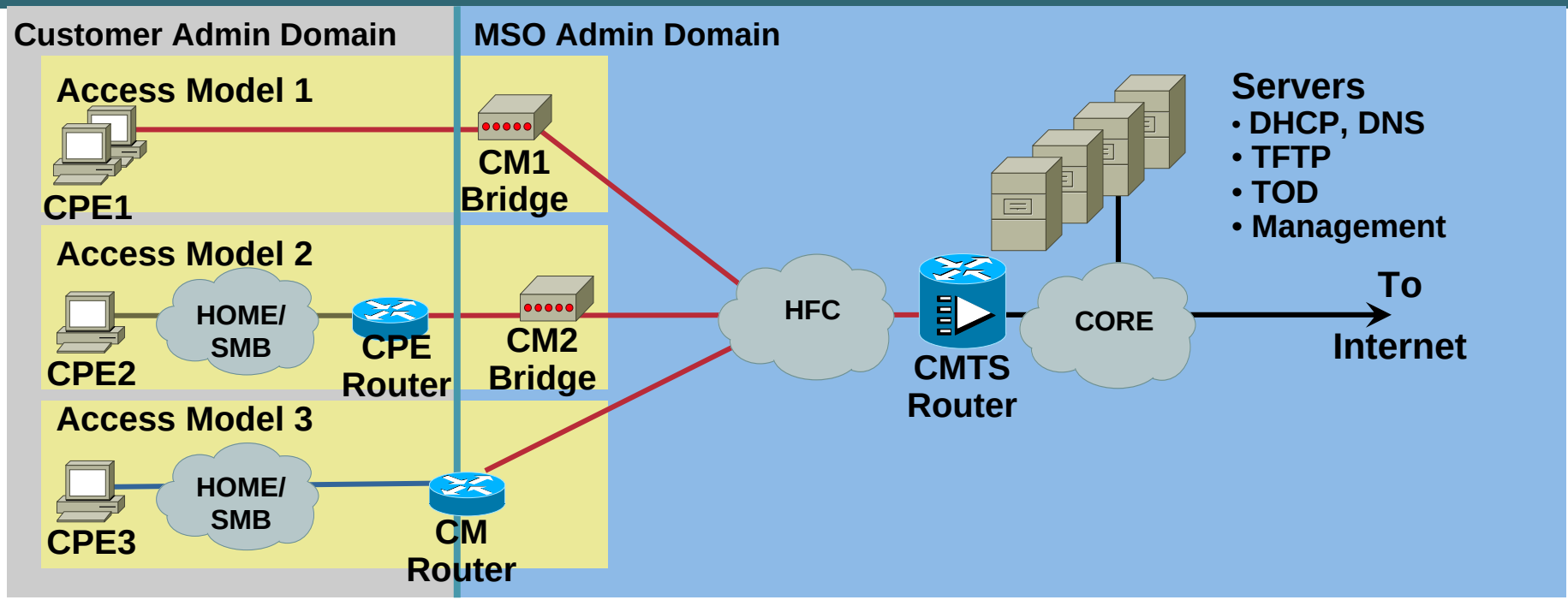
- **Problems with Neighbor Discovery (ND) on CM and CMTS, due to lack of IGMPv3/MLDv2 or v1 snooping support**
- **No way to classify IPv6 traffic on the CM and CMTS. Cannot provide appropriate QoS to traffic, everything sent as Best Effort (BE).**
- **Changes needed in the DOCSIS RFI specification to support native IPv6 deployment over cable**

Addressed in DOCSIS 3.0 Standardization

CableLabs IPv6 Decision and Approach

- **CableLabs members put IPv6 in consideration for DOCSIS 3.0**
  - **Cisco responded with proposal for IPv6 architecture and features**
  - **IPv6 identified as one of top three ranked order priorities by MSOs**
- **Decision: DOCSIS 3.x MUST fully support IPv6**
  - **Cisco primary author for DOCSIS 3.0 IPv6 and enhanced IPv4/6 Multicast specifications**
- **Rationale**
  - **Increased address space for CM management**
  - **New CPE services**
- **Proposed phases**
  - **Phase 1—CM hardware impacting features, CM provisioning and management over IPv6, embedded IPv6 router in CM**
  - **Phase 2—remaining IPv6 features for CPE services, for example IPv6 CPE provisioning and IPv6 service support**

IPv6 Deployment Models for DOCSIS 3.0



Management Prefix: 2001:DB8:FFFF:0::/64
Service Prefix: 2001:DB8:FFFE:0::/64
Customer 2 Prefix: 2001:DB8:2::/48
Customer 3 Prefix: 2001:DB8:3::/48

HFC Link; Assigned 2001:DB8:FFFF:0::/64 (Mgmt) and 2001:DB8:FFFE:0::/64 (Serv)
Customer 2 Premises Link; Assigned 2001:DB8:2:0::/64
Customer 3 Premises Link; Assigned 2001:DB8:3:0::/64

Routers Span Customer and MSO Administrative Domains

Provisioning in IPv6 Broadband Environments

IPv6 Address Patterns

- **Broadband—long-lived connections**

  Pooling ineffective as conservation mechanism, and conservation not needed anyway

- **Devices—act as servers**

  Relatively stable address required

- **Home networks**

- **Roaming users still need a temporary address**

  Mobile IPv6

- **How is IPv6 PPP access different from IPv4:**

  Address assignment is moved from the PPP layer to IPv6; as well are negotiation of DNS server, WINS, etc.

IPv6 Address Allocation Guidelines

"…recommends the assignment of /48 in the general case, /64 when it is known that one and only one subnet is needed…"

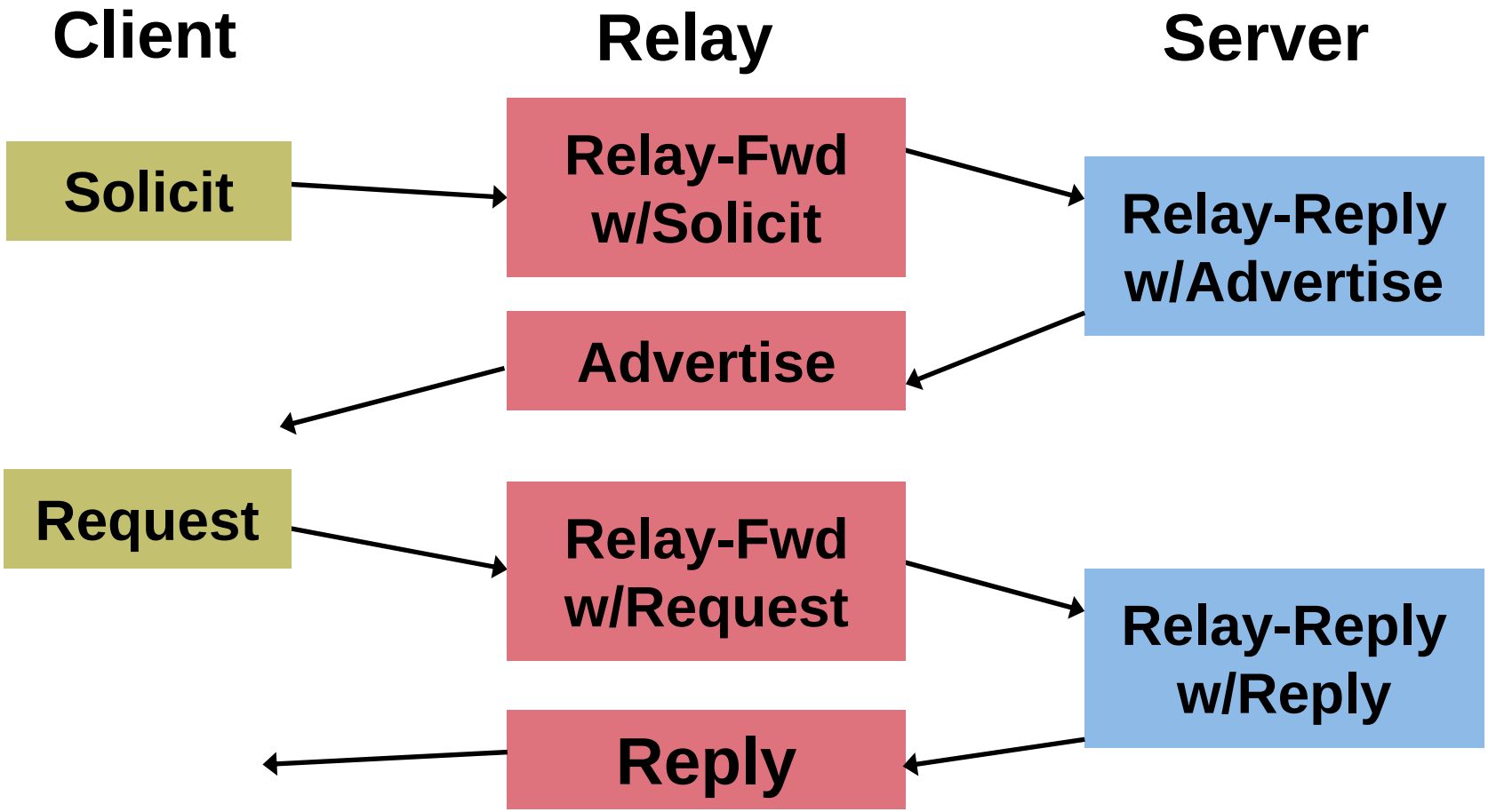
RFC3177
IAB/IESG Recommendations on IPv6 Address Allocations to Sites

Note: /128 Assignment Can Be Used When It Is Absolutely Known That One and Only One Device Is Connecting

DHCPv6 Overview

- **Operational model based on DHCPv4**
- **Details are different**
  - **Client uses link-local address for message exchanges**
  - **Server can assign multiple addresses per client through identity associations**
  - **Clients and servers identified by DUID**
  - **Address assignment**
  - **Prefix delegation**
  - **Message exchanges similar, but will require new protocol engine**
  - **Server-initiated configuration, authentication part of the base specification**
  - **Extensible option mechanism**
  - **Relay-agents**
- **Allows both stateful and stateless configuration**
- **RFC 3315 (DHCPv6)**
  - **Additional options:**
    - **DNS configuration—RFC 3646**
    - **Prefix delegation—RFC 3633**
    - **NTP servers**
    - **Stateless DHCP for IPv6—RFC 3736**

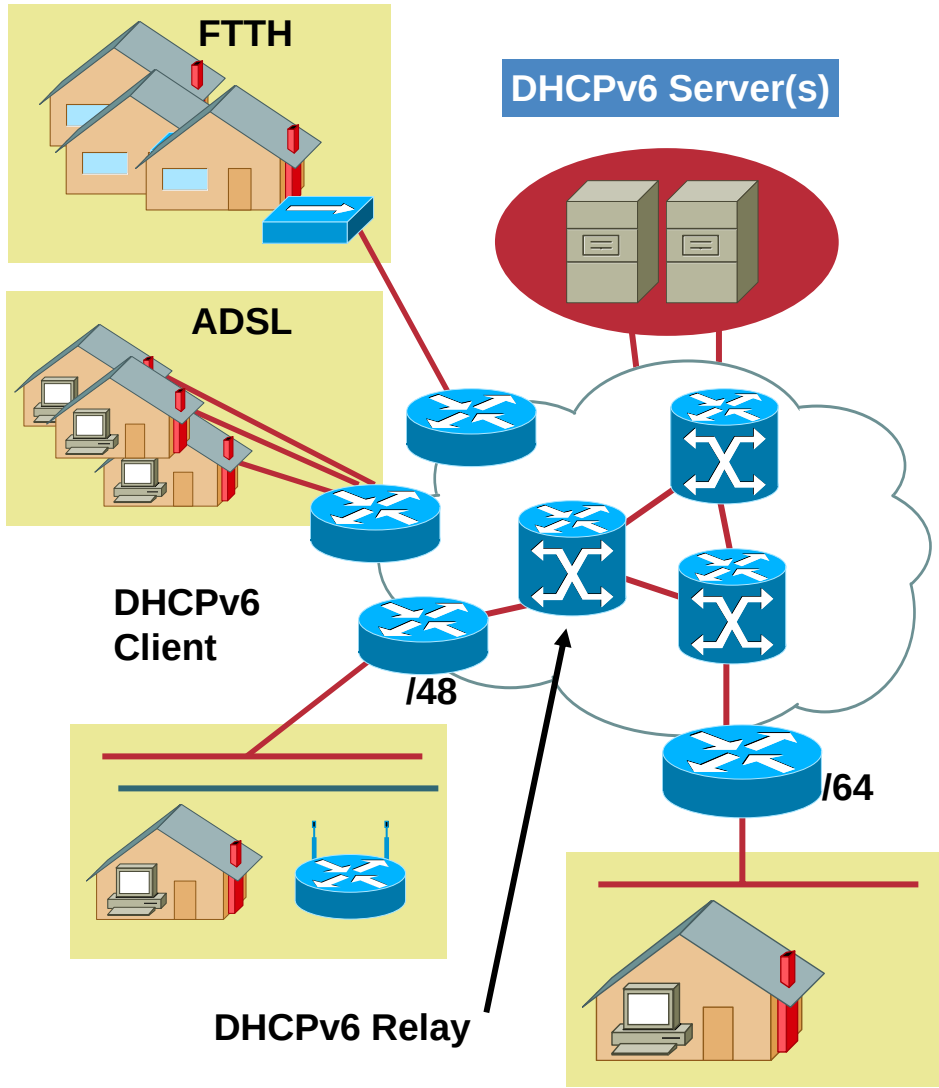
DHCPv6 Operation



- All_DHCP_Relay_Agents_and_Servers (FF02::1:2)
- All_DHCP_Servers (FF05::1:3)
- DHCP Messages: Clients listen UDP port 546. Servers and relay agents listen on UDP port 547

DHCPv6 PD: RFC 3633

- **Media independence**
  - **E.g., ADSL, FTTH**
  - **Only knows identity of requesting router**
- **Leases for prefixes**
- **Flexible deployments**
  - **Client/relay/server model**
- **Requesting router includes request for prefixes in DHCP configuration request**
- **Delegating router assigns prefixes in response along with other DHCP configuration information**



Router Advertisement

Source of RA	User of RA	A Bit		M/O Bits	
		A	Operation	M/O	Operation
PE	CPE E1	0	Don't Do Stateless Address Assignment	11	Use Dhcpv6 for Address + Other Config. (I.E. Stateful Dhcpv6)
CPE Router	Host	1	Do Stateless Address Assignment	01	Use Dhcpv6 for Other Config. (I.E. Stateless Dhcpv6)

Stateless (RFC2462)
RS Are Sent by Booting Nodes to Request RAs for Configuring the Interfaces; Host Autonomously Configures Its Own Link-Local Address

Prefix/Options Assignment

1. CPE Sends DHCP Solicit with ORO = PD
2. PE Sends RADIUS Request for the User
3. RADIUS Responds with User's Prefix(es)
4. PE Sends DHCP REPLY with Prefix Delegation Options
5. CPE Configures Addresses from The Prefix on Its Downstream Interfaces, and Sends an RA. O-bit Is Set to On
6. Host Configures Addresses Based on the Prefixes Received In the RA. As the O-bit Is on, It Sends a DHCP Information-request Message, with an ORO = DNS
7. CPE Sends a DHCP REPLY Containing Request Options

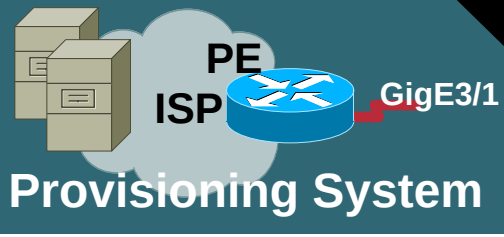
AAA | DHCP | ND/DHCP

PE/CE IPv6 Debugs

debug ipv6 nd
debug ipv6 dhcp detail
debug ipv6 dhcp relay

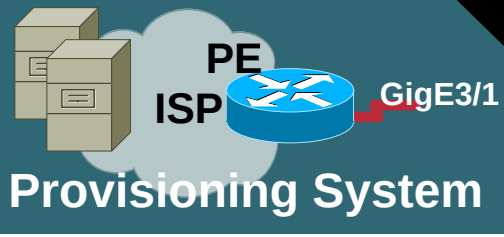
PE#show debug
Generic IPv6:
ICMP Neighbor Discovery events debugging is on
IPv6 DHCP debugging is on (detailed)
IPv6 DHCP relay debugging is on

PE Configuration




```
!
hostname PE_Router
!
interface GigabitEthernet3/1
ipv6 address 2001:420:3800:800:0:1:0:1/96
 ipv6 enable
 ipv6 nd ra-interval 5
 ipv6 nd prefix default no-advertise
 ipv6 nd managed-config-flag
 ipv6 nd other-config-flag
 ipv6 rip PE_Router enable
 ipv6 mld static-group FF0E:0:0:1::1000
 ipv6 dhcp relay destination 2001:420:3800:801:A00:20FF:FEE5:63E3 GigabitEthernet0/1
!
interface GigabitEthernet0/1
ip address 10.89.240.235 255.255.255.248
 ip pim sparse-mode
 negotiation auto
 ipv6 address 2001:420:3800:800::12/124
 ipv6 enable
 ipv6 router isis
 ipv6 mld static-group FF0E:0:0:1::1000
 hold-queue 2048 in
!
```

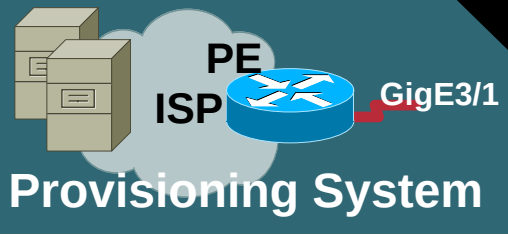
PE Debugs: ND-SOLICIT




```
*Feb 15 21:35:16.946: ICMPv6-ND: Received NS for FE80::207:EFF:FE03:6E65 on GigE3/1 from ::
[DAD request from CPE for Link-local Address]
*Feb 15 21:35:17.650: ICMPv6-ND: Sending RA to FF02::1 on GigE3/1
*Feb 15 21:35:17.650: ICMPv6-ND:   MTU = 1500
*Feb 15 21:35:17.934: ICMPv6-ND: Received NA for FE80::207:EFF:FE03:6E65 on GigE3/1 from
FE80::207:EFF:FE03:6E65
[CPE assigns Link-local Address and sends NA]
```

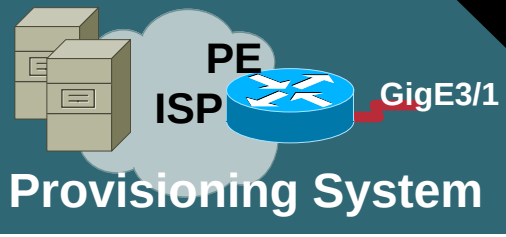
```
*Feb 15 21:35:19.862: IPv6 DHCP: Received SOLICIT from FE80::207:EFF:FE03:6E65 on GigE3/1
*Feb 15 21:35:19.862: IPv6 DHCP: detailed packet contents
*Feb 15 21:35:19.862:  src FE80::207:EFF:FE03:6E65 (GigE3/1)
*Feb 15 21:35:19.862:  dst FF02::1:2
*Feb 15 21:35:19.862:  type SOLICIT(1), xid 13518535
*Feb 15 21:35:19.862:  option ELAPSED-TIME(8), len 2
*Feb 15 21:35:19.862:   elapsed-time 0
*Feb 15 21:35:19.862:  option CLIENTID(1), len 10
*Feb 15 21:35:19.862:   0003000100070E036E65
*Feb 15 21:35:19.862:  option IA-NA(3), len 12
*Feb 15 21:35:19.862:   IAID 0x00020001, T1 0, T2 0
*Feb 15 21:35:19.862:  option IA-PD(25), len 12
*Feb 15 21:35:19.862:   IAID 0x00020001, T1 0, T2 0
*Feb 15 21:35:19.862:  option ORO(6), len 4
*Feb 15 21:35:19.862:   DNS-SERVERS,DOMAIN-LIST
```

PE Debugs: RELAY-FORWARD w/ SOLICIT



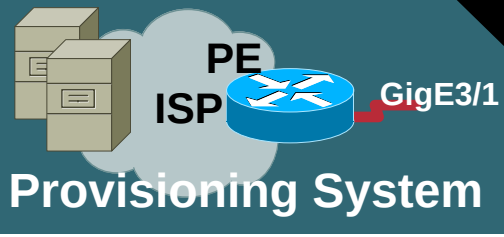

```
*Feb 15 21:35:19.862: IPv6 DHCP_RELAY: Relaying SOLICIT from FE80::207:EFF:FE03:6E65 on
GigE3/1 [PE received SOLICIT request from CPE]
*Feb 15 21:35:19.862: IPv6 DHCP_RELAY: to 2001:420:8:1:5::2 via GigabitEthernet0/1
*Feb 15 21:35:19.862: IPv6 DHCP: Sending RELAY-FORWARD to 2001:420:8:1:5::2 on
GigabitEthernet0/1 next hop FE80::201:97FF:FE39:2070 [Forwarding the SOLICIT message to
DHCPv6 server]
*Feb 15 21:35:19.862: IPv6 DHCP: detailed packet contents
*Feb 15 21:35:19.862:  src 2001:420:8:1:1::2
*Feb 15 21:35:19.862:  dst 2001:420:8:1:5::2 (GigabitEthernet0/1)
*Feb 15 21:35:19.862:  type RELAY-FORWARD(12), hop 0
*Feb 15 21:35:19.862:  link 2001:420:8:1:6:1:1:1
*Feb 15 21:35:19.862:  peer FE80::207:EFF:FE03:6E65
*Feb 15 21:35:19.862:  option RELAY-MSG(9), len 64
*Feb 15 21:35:19.862:   type SOLICIT(1), xid 13518535
*Feb 15 21:35:19.862:   option ELAPSED-TIME(8), len 2
*Feb 15 21:35:19.862:    elapsed-time 0
*Feb 15 21:35:19.862:   option CLIENTID(1), len 10
*Feb 15 21:35:19.862:    0003000100070E036E65
*Feb 15 21:35:19.862:   option IA-NA(3), len 12
*Feb 15 21:35:19.862:    IAID 0x00020001, T1 0, T2 0
*Feb 15 21:35:19.862:   option IA-PD(25), len 12
*Feb 15 21:35:19.862:    IAID 0x00020001, T1 0, T2 0
*Feb 15 21:35:19.862:   option ORO(6), len 4
*Feb 15 21:35:19.862:    DNS-SERVERS,DOMAIN-LIST
*Feb 15 21:35:19.862:  option INTERFACE-ID(18), len 4
*Feb 15 21:35:19.862:   0x00000007
```

PE Debugs: RELAY-REPLY w/ ADVERTISE



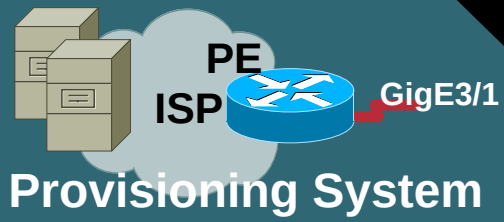

```
*Feb 15 21:35:19.866: IPv6 DHCP: Received RELAY-REPLY from 2001:420:8:1:5::2 on GigabitEthernet0/1
[PE received ADVERTISE from DHCPv6 server]
*Feb 15 21:35:19.866: IPv6 DHCP: detailed packet contents
*Feb 15 21:35:19.866:  src 2001:420:8:1:5::2 (GigabitEthernet0/1)
*Feb 15 21:35:19.866:  dst 2001:420:8:1:1::2
*Feb 15 21:35:19.866:  type RELAY-REPLY(13), hop 0
*Feb 15 21:35:19.866:  link 2001:420:8:1:6:1:1:1
*Feb 15 21:35:19.866:  peer FE80::207:EFF:FE03:6E65
*Feb 15 21:35:19.866:  option INTERFACE-ID(18), len 4
*Feb 15 21:35:19.866:   0x00000007
*Feb 15 21:35:19.866:  option RELAY-MSG(9), len 206
*Feb 15 21:35:19.866:   type ADVERTISE(2), xid 13518535
*Feb 15 21:35:19.866:   option CLIENTID(1), len 10
*Feb 15 21:35:19.866:    0003000100070E036E65
*Feb 15 21:35:19.866:   option SERVERID(2), len 14
*Feb 15 21:35:19.866:    0001000143BF22B6080020E8FAC0
*Feb 15 21:35:19.866:   option IA-NA(3), len 40
*Feb 15 21:35:19.866:    IAID 0x00020001, T1 302400, T2 483840
*Feb 15 21:35:19.866:    option IAADDR(5), len 24
*Feb 15 21:35:19.866:     IPv6 address 2001:420:8:1:6:1:1:EBF1
*Feb 15 21:35:19.866:     preferred 604800, valid 1209600
*Feb 15 21:35:19.866:   option IA-PD(25), len 41
*Feb 15 21:35:19.866:    IAID 0x00020001, T1 302400, T2 483840
*Feb 15 21:35:19.866:    option IAPREFIX(26), len 25
*Feb 15 21:35:19.866:     preferred 604800, valid 1209600, prefix 2001:420:8:1:7::/80
*Feb 15 21:35:19.866:   option DNS-SERVERS(23), len 16
*Feb 15 21:35:19.866:    2001:420:3800:801:A00:20FF:FEE5:63E3
*Feb 15 21:35:19.866:   option DOMAIN-LIST(24), len 14
*Feb 15 21:35:19.866:    v6.cisco.com
```

PE Debugs: ADVERTISE



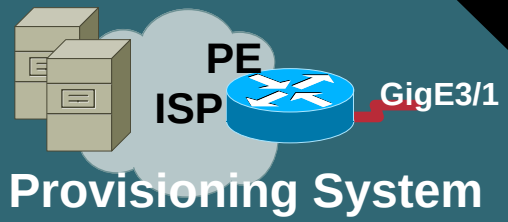

```
*Feb 15 21:35:19.866: IPv6 DHCP: Sending ADVERTISE to FE80::207:EFF:FE03:6E65 on GigE3/1 [PE forwards ADVERTISE message to CPE]
*Feb 15 21:35:19.866: IPv6 DHCP: detailed packet contents
*Feb 15 21:35:19.866:  src FE80::21A:C4FF:FE29:1155
*Feb 15 21:35:19.866:  dst FE80::207:EFF:FE03:6E65 (GigE3/1)
*Feb 15 21:35:19.866:  type ADVERTISE(2), xid 13518535
*Feb 15 21:35:19.866:  option CLIENTID(1), len 10
*Feb 15 21:35:19.866:   0003000100070E036E65
*Feb 15 21:35:19.866:  option SERVERID(2), len 14
*Feb 15 21:35:19.866:   0001000143BF22B6080020E8FAC0
*Feb 15 21:35:19.866:  option IA-NA(3), len 40
*Feb 15 21:35:19.866:   IAID 0x00020001, T1 302400, T2 483840
*Feb 15 21:35:19.866:   option IAADDR(5), len 24
*Feb 15 21:35:19.866:    IPv6 address 2001:420:8:1:6:1:1:EBF1
*Feb 15 21:35:19.866:    preferred 604800, valid 1209600
*Feb 15 21:35:19.866:  option IA-PD(25), len 41
*Feb 15 21:35:19.866:   IAID 0x00020001, T1 302400, T2 483840
*Feb 15 21:35:19.866:   option IAPREFIX(26), len 25
*Feb 15 21:35:19.866:    preferred 604800, valid 1209600, prefix 2001:420:8:1:7::/80
*Feb 15 21:35:19.866:  option DNS-SERVERS(23), len 16
*Feb 15 21:35:19.866:   2001:420:3800:801:A00:20FF:FEE5:63E3
*Feb 15 21:35:19.866:  option DOMAIN-LIST(24), len 14
*Feb 15 21:35:19.866:   v6.cisco.com
```

PE Debugs: REQUEST



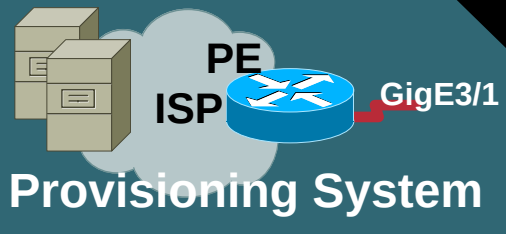

```
*Feb 15 21:35:20.938: IPv6 DHCP: Received REQUEST from FE80::207:EFF:FE03:6E65 on GigE3/1
[PE received REQUEST from CPE]
*Feb 15 21:35:20.938: IPv6 DHCP: detailed packet contents
*Feb 15 21:35:20.938:  src FE80::207:EFF:FE03:6E65 (GigE3/1)
*Feb 15 21:35:20.938:  dst FF02::1:2
*Feb 15 21:35:20.938:  type REQUEST(3), xid 13530568
*Feb 15 21:35:20.938:  option ELAPSED-TIME(8), len 2
*Feb 15 21:35:20.938:   elapsed-time 0
*Feb 15 21:35:20.938:  option CLIENTID(1), len 10
*Feb 15 21:35:20.938:   0003000100070E036E65
*Feb 15 21:35:20.938:  option IA-NA(3), len 40
*Feb 15 21:35:20.938:   IAID 0x00020001, T1 0, T2 0
*Feb 15 21:35:20.938:   option IAADDR(5), len 24
*Feb 15 21:35:20.938:    IPv6 address 2001:420:8:1:6:1:1:EBF1
*Feb 15 21:35:20.938:    preferred 0, valid 0
*Feb 15 21:35:20.938:  option IA-PD(25), len 12
*Feb 15 21:35:20.938:   IAID 0x00020001, T1 0, T2 0
*Feb 15 21:35:20.938:  option ORO(6), len 4
*Feb 15 21:35:20.938:   DNS-SERVERS,DOMAIN-LIST
*Feb 15 21:35:20.938:  option SERVERID(2), len 14
*Feb 15 21:35:20.938:   0001000143BF22B6080020E8FAC0
```

PE Debugs: RELAY-FORWARD w/ REQUEST



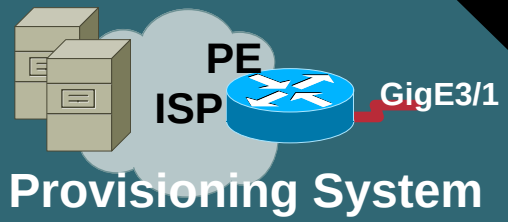

```
**Feb 15 21:35:20.938: IPv6 DHCP: Sending RELAY-FORWARD to 2001:420:8:1:5::2 on
GigabitEthernet0/1 next hop FE80::201:97FF:FE39:2070 [PE forwards REQUEST to DHCPv6 server]
*Feb 15 21:35:20.938: IPv6 DHCP: detailed packet contents
*Feb 15 21:35:20.938:  src 2001:420:8:1:1::2
*Feb 15 21:35:20.938:  dst 2001:420:8:1:5::2 (GigabitEthernet0/1)
*Feb 15 21:35:20.938:  type RELAY-FORWARD(12), hop 0
*Feb 15 21:35:20.938:  link 2001:420:8:1:6:1:1:1
*Feb 15 21:35:20.938:  peer FE80::207:EFF:FE03:6E65
*Feb 15 21:35:20.938:  option RELAY-MSG(9), len 110
*Feb 15 21:35:20.938:   type REQUEST(3), xid 13530568
*Feb 15 21:35:20.938:   option ELAPSED-TIME(8), len 2
*Feb 15 21:35:20.938:    elapsed-time 0
*Feb 15 21:35:20.938:   option CLIENTID(1), len 10
*Feb 15 21:35:20.938:    0003000100070E036E65
*Feb 15 21:35:20.938:   option IA-NA(3), len 40
*Feb 15 21:35:20.938:    IAID 0x00020001, T1 0, T2 0
*Feb 15 21:35:20.938:    option IAADDR(5), len 24
*Feb 15 21:35:20.938:     IPv6 address 2001:420:8:1:6:1:1:EBF1
*Feb 15 21:35:20.938:     preferred 0, valid 0
*Feb 15 21:35:20.938:   option IA-PD(25), len 12
*Feb 15 21:35:20.938:    IAID 0x00020001, T1 0, T2 0
*Feb 15 21:35:20.938:   option ORO(6), len 4
*Feb 15 21:35:20.938:    DNS-SERVERS,DOMAIN-LIST
*Feb 15 21:35:20.938:   option SERVERID(2), len 14
*Feb 15 21:35:20.938:    0001000143BF22B6080020E8FAC0
```

PE Debugs: RELAY-REPLY w/ REPLY



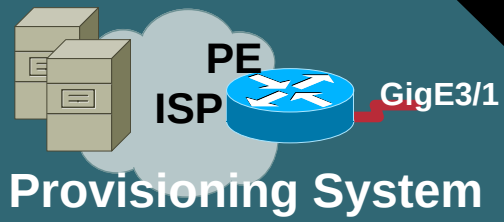

```
*Feb 15 21:35:20.942: IPv6 DHCP: Received RELAY-REPLY from 2001:420:8:1:5::2 on GigabitEthernet0/1
[PE received REPLY from DHCPv6 server]
*Feb 15 21:35:20.942: IPv6 DHCP: detailed packet contents
*Feb 15 21:35:20.942:  src 2001:420:8:1:5::2 (GigabitEthernet0/1)
*Feb 15 21:35:20.942:  dst 2001:420:8:1:1::2
*Feb 15 21:35:20.942:  type RELAY-REPLY(13), hop 0
*Feb 15 21:35:20.942:  link 2001:420:8:1:6:1:1:1
*Feb 15 21:35:20.942:  peer FE80::207:EFF:FE03:6E65
*Feb 15 21:35:20.942:  option INTERFACE-ID(18), len 4
*Feb 15 21:35:20.942:   0x00000007
*Feb 15 21:35:20.942:  option RELAY-MSG(9), len 206
*Feb 15 21:35:20.942:   type REPLY(7), xid 13530568
*Feb 15 21:35:20.942:   option CLIENTID(1), len 10
*Feb 15 21:35:20.942:    0003000100070E036E65
*Feb 15 21:35:20.942:   option SERVERID(2), len 14
*Feb 15 21:35:20.942:    0001000143BF22B6080020E8FAC0
*Feb 15 21:35:20.942:   option IA-NA(3), len 40
*Feb 15 21:35:20.942:    IAID 0x00020001, T1 302400, T2 483840
*Feb 15 21:35:20.942:    option IAADDR(5), len 24
*Feb 15 21:35:20.942:     IPv6 address 2001:420:8:1:6:1:1:EBF1
*Feb 15 21:35:20.942:     preferred 604800, valid 1209600
*Feb 15 21:35:20.942:   option IA-PD(25), len 41
*Feb 15 21:35:20.942:    IAID 0x00020001, T1 302400, T2 483840
*Feb 15 21:35:20.942:    option IAPREFIX(26), len 25
*Feb 15 21:35:20.942:     preferred 604800, valid 1209600, prefix 2001:420:8:1:7::/80
*Feb 15 21:35:20.942:   option DNS-SERVERS(23), len 16
*Feb 15 21:35:20.942:    2001:420:3800:801:A00:20FF:FEE5:63E3
*Feb 15 21:35:20.942:   option DOMAIN-LIST(24), len 14
*Feb 15 21:35:20.942:    v6.cisco.com
```

PE Debugs: REPLY




```
*Feb 15 21:35:20.942: IPv6 DHCP: Sending REPLY to FE80::207:EFF:FE03:6E65 on GigE3/1     [PE forwards REPLY message to CPE]
*Feb 15 21:35:20.942: IPv6 DHCP: detailed packet contents
*Feb 15 21:35:20.942:  src FE80::21A:C4FF:FE29:1155
*Feb 15 21:35:20.942:  dst FE80::207:EFF:FE03:6E65 (GigE3/1)
*Feb 15 21:35:20.942:  type REPLY(7), xid 13530568
*Feb 15 21:35:20.942:  option CLIENTID(1), len 10
*Feb 15 21:35:20.942:   00030001000070E036E65
*Feb 15 21:35:20.942:  option SERVERID(2), len 14
*Feb 15 21:35:20.942:   0001000143BF22B6080020E8FAC0
*Feb 15 21:35:20.942:  option IA-NA(3), len 40
*Feb 15 21:35:20.942:   IAID 0x00020001, T1 302400, T2 483840
*Feb 15 21:35:20.942:   option IAADDR(5), len 24
*Feb 15 21:35:20.942:    IPv6 address 2001:420:8:1:6:1:1:EBF1
*Feb 15 21:35:20.942:    preferred 604800, valid 1209600
*Feb 15 21:35:20.942:  option IA-PD(25), len 41
*Feb 15 21:35:20.942:   IAID 0x00020001, T1 302400, T2 483840
*Feb 15 21:35:20.942:   option IAPREFIX(26), len 25
*Feb 15 21:35:20.942:    preferred 604800, valid 1209600, prefix 2001:420:8:1:7::/80 [DHCP-PD]
*Feb 15 21:35:20.946:  option DNS-SERVERS(23), len 16
*Feb 15 21:35:20.946:   2001:420:3800:801:A00:20FF:FEE5:63E3
*Feb 15 21:35:20.946:  option DOMAIN-LIST(24), len 14
*Feb 15 21:35:20.946:   v6.cisco.com
```

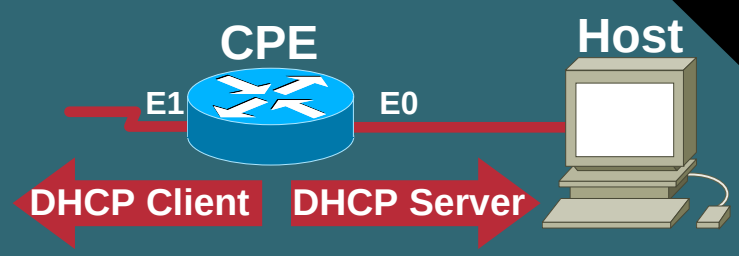
PE Debugs: ND



*Feb 15 21:35:20.970: ICMPv6-ND: Received NS for 2001:420:8:1:6:1:1:EBF1 on GigE3/1 from :: [DAD Request from CPE]
*Feb 15 21:35:21.490: ICMPv6-ND: Sending RA to FF02::1 on GigE3/1
*Feb 15 21:35:21.490: ICMPv6-ND: MTU = 1500
*Feb 15 21:35:21.974: ICMPv6-ND: Received NA for 2001:420:8:1:6:1:1:EBF1 on GigE3/1 from 2001:420:8:1:6:1:1:EBF1 [CPE Assigns Address & Sends NA to PE]

*Feb 15 21:35:24.866: ICMPv6-ND: DELAY -> PROBE: FE80::207:EFF:FE03:6E65
*Feb 15 21:35:24.866: ICMPv6-ND: Sending NS for FE80::207:EFF:FE03:6E65 on GigE3/1 [PE sends NS to CPE]
*Feb 15 21:35:24.878: ICMPv6-ND: Received NA for FE80::207:EFF:FE03:6E65 on GigE3/1 from FE80::207:EFF:FE03:6E65 [CPE responds with NA to PE]
*Feb 15 21:35:24.878: ICMPv6-ND: PROBE -> REACH: FE80::207:EFF:FE03:6E65
*Feb 15 21:35:26.102: ICMPv6-ND: Sending RA to FF02::1 on GigE3/1
*Feb 15 21:35:26.102: ICMPv6-ND: MTU = 1500
*Feb 15 21:35:28.942: ICMPv6-ND: Received NS for FE80::21A:C4FF:FE29:1155 on GigE3/1 from FE80::207:EFF:FE03:6E65 [PE receives NS from CPE for it's Link-local]
*Feb 15 21:35:28.942: ICMPv6-ND: Sending NA for FE80::21A:C4FF:FE29:1155 on GigE3/1 [PE send NA to CPE]
*Feb 15 21:35:30.302: ICMPv6-ND: Sending RA to FF02::1 on GigE3/1
*Feb 15 21:35:30.302: ICMPv6-ND: MTU = 1500

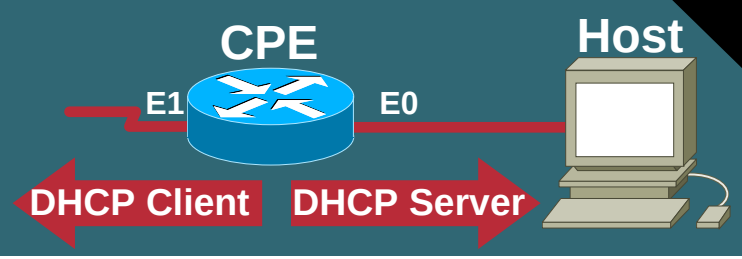
CPE Router Configuration




```
ip dhcp pool CPEv4
  network 192.168.51.0 255.255.255.0
  dns-server 80.10.0.1
  domain-name cisco.com
  default-router 80.10.0.1
!
ip multicast-routing
ipv6 unicast-routing
ipv6 dhcp pool v6transfer-pool
 dns-server 2001:420:3800:801:A00:20FF:FEE5:63E3
 domain-name v6.cisco.com
!
interface Ethernet0
 ip address 192.168.51.1 255.255.255.0
 ip pim sparse-mode
 ip virtual-reassembly
 load-interval 30
 ipv6 address v6Prefix 0:0:0:1::/64 eui-64
 ipv6 enable
 ipv6 nd other-config-flag
 ipv6 nd ra interval 5
 ipv6 dhcp server v6transfer-pool
 hold-queue 2048 out
```

```
interface Ethernet1
 ip pim sparse-mode
 ip virtual-reassembly
 load-interval 30
 ipv6 address autoconfig default
 ipv6 enable
 ipv6 nd ra suppress
 ipv6 dhcp client pd v6Prefix
 ipv6 rip RIP enable
 no keepalive
 hold-queue 2048 in
!
ip pim rp-address 10.89.240.226
!
ipv6 router rip RIP
 redistribute connected
```

CPE Router: ND

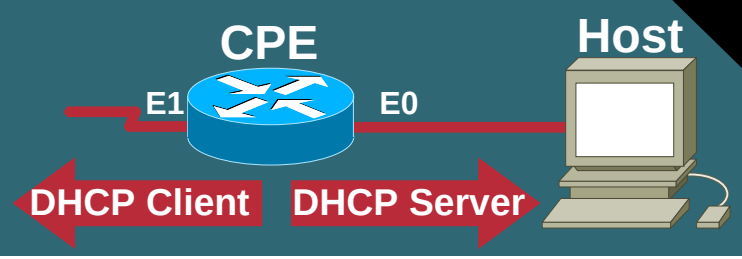


*Mar 2 02:44:54.349: ICMPv6-ND: Received RA from FE80::21A:C4FF:FE29:1155 on Ethernet1
*Mar 2 02:44:54.349: ICMPv6-ND: Selected new default router FE80::21A:C4FF:FE29:1155 on Eth1
*Mar 2 02:44:54.353: ICMPv6-ND: checking DHCP
*Mar 2 02:44:54.353: ICMPv6-ND: stateless DHCP
*Mar 2 02:44:54.357: ICMPv6-ND: statefull DHCP
*Mar 2 02:44:54.357: ICMPv6-ND: M bit set; checking prefix delegation DHCP
*Mar 2 02:44:54.357: ICMPv6-ND: O bit set; [Since M and O bit are set, do statefull DHCPv6]

*Mar 2 02:45:02.709: ICMPv6-ND: Sending NS for FE80::207:EFF:FE03:6E65 on Ethernet1 [DAD Request for Linklocal Address]
*Mar 2 02:45:03.709: ICMPv6-ND: DAD: FE80::207:EFF:FE03:6E65 is unique.
*Mar 2 02:45:03.709: ICMPv6-ND: Sending NA for FE80::207:EFF:FE03:6E65 on Ethernet1
*Mar 2 02:45:03.709: ICMPv6-ND: Linklocal FE80::207:EFF:FE03:6E65 on Ethernet1, Up
*Mar 2 02:45:03.717: ICMPv6-ND: Address FE80::207:EFF:FE03:6E65/10 is up on Ethernet1

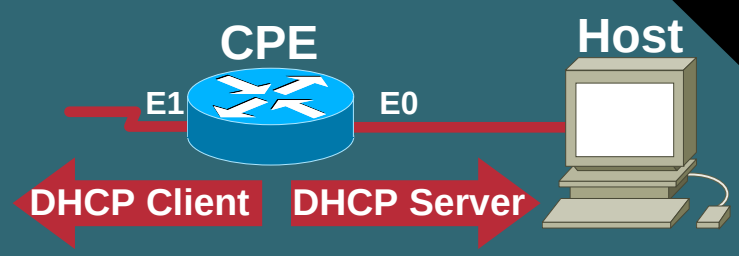
*Mar 2 02:45:04.221: ICMPv6-ND: Received RA from FE80::21A:C4FF:FE29:1155 on Ethernet1
*Mar 2 02:45:04.225: ICMPv6-ND: checking stateless DHCP
*Mar 2 02:45:04.225: ICMPv6-ND: O bit set;
*Mar 2 02:45:06.509: ICMPv6-ND: Prefix Information change for 2001:420:8:1:7::/80 [DHCP-PD Prefix]
*Mar 2 02:45:06.509: ICMPv6-ND: Adding prefix 2001:420:8:1:7::/80 to Ethernet0
*Mar 2 02:45:06.513: ICMPv6-ND: Sending NS for 2001:420:8:1:7::1 on Ethernet0
*Mar 2 02:45:06.513: ICMPv6-ND: Prefix Information change for 2001:420:8:1:6:1:1:EBF1/128
*Mar 2 02:45:06.517: ICMPv6-ND: Adding prefix 2001:420:8:1:6:1:1:EBF1/128 to Ethernet1
*Mar 2 02:45:06.517: ICMPv6-ND: Sending NS for 2001:420:8:1:6:1:1:EBF1 on Ethernet1
*Mar 2 02:45:07.517: ICMPv6-ND: DAD: 2001:420:8:1:6:1:1:EBF1 is unique.
*Mar 2 02:45:07.517: ICMPv6-ND: Sending NA for 2001:420:8:1:6:1:1:EBF1 on Ethernet1
*Mar 2 02:45:07.517: ICMPv6-ND: Address 2001:420:8:1:6:1:1:EBF1/128 is up on Ethernet1

CPE Router: ND



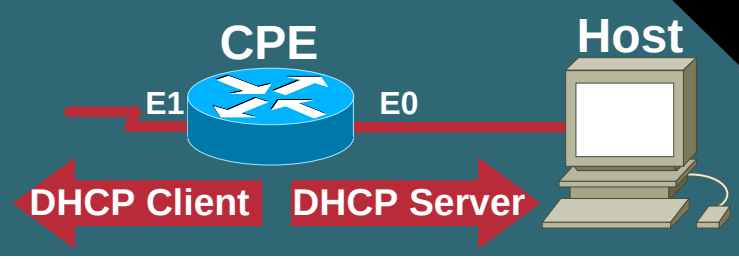

```
*Mar 2 02:45:07.193: ICMPv6-ND: Request to send RA for FE80::207:EFF:FE03:6E64
*Mar 2 02:45:07.193: ICMPv6-ND: Sending RA from FE80::207:EFF:FE03:6E64 to FF02::1 on Ether0
*Mar 2 02:45:07.193: ICMPv6-ND: Prefix = 2001:420:8:1:7::/80 onlink autoconfig
*Mar 2 02:45:07.193: ICMPv6-ND:          1209600/604800 (valid/preferred)
*Mar 2 02:45:07.513: ICMPv6-ND: DAD: 2001:420:8:1:7::1 is unique.
*Mar 2 02:45:07.513: ICMPv6-ND: Sending NA for 2001:420:8:1:7::1 on Ethernet0
*Mar 2 02:45:07.513: ICMPv6-ND: Address 2001:420:8:1:7::1/80 is up on Ethernet0

*Mar 2 02:45:07.717: ICMPv6-ND: STALE -> DELAY: FE80::21A:C4FF:FE29:1155
*Mar 2 02:45:10.353: ICMPv6-ND: Received NS for FE80::207:EFF:FE03:6E65 on Ether1 from
FE80::21A:C4FF:FE29:1155 [PE to CPE]
*Mar 2 02:45:10.353: ICMPv6-ND: Sending NA for FE80::207:EFF:FE03:6E65 on Ether1 [CPE to PE]

*Mar 2 02:45:12.717: ICMPv6-ND: DELAY -> PROBE: FE80::21A:C4FF:FE29:1155
*Mar 2 02:45:12.717: ICMPv6-ND: Sending NS for FE80::21A:C4FF:FE29:1155 on Ether1 [CPE to PE]
*Mar 2 02:45:12.733: ICMPv6-ND: Received NA for FE80::21A:C4FF:FE29:1155 on Ether1 from
FE80::21A:C4FF:FE29:1155 [PE to CPE]
*Mar 2 02:45:12.737: ICMPv6-ND: PROBE -> REACH: FE80::21A:C4FF:FE29:1155
```

CPE Router: SOLICIT



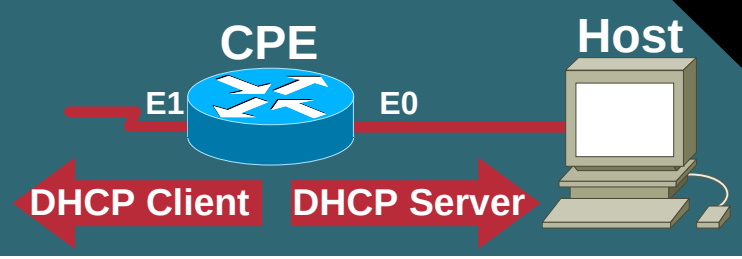

```
*Mar 2 03:39:22.613: IPv6 DHCP: Sending SOLICIT to FF02::1:2 on Ethernet1
*Mar 2 03:39:22.613: IPv6 DHCP: detailed packet contents
*Mar 2 03:39:22.613:  src FE80::207:EFF:FE03:6E65
*Mar 2 03:39:22.613:  dst FF02::1:2 (Ethernet1) [All_DHCP_Relay_Agents_and_Servers Address]
*Mar 2 03:39:22.613:  type SOLICIT(1), xid 16585219
*Mar 2 03:39:22.617:  option ELAPSED-TIME(8), len 2
*Mar 2 03:39:22.617:   elapsed-time 0
*Mar 2 03:39:22.617:  option CLIENTID(1), len 10
*Mar 2 03:39:22.617:   0003000100070E036E65
*Mar 2 03:39:22.617:  option IA-NA(3), len 12
*Mar 2 03:39:22.617:   IAID 0x00020001, T1 0, T2 0
*Mar 2 03:39:22.617:  option IA-PD(25), len 12
*Mar 2 03:39:22.617:   IAID 0x00020001, T1 0, T2 0
*Mar 2 03:39:22.621:  option ORO(6), len 4
*Mar 2 03:39:22.621:   DNS-SERVERS,DOMAIN-LIST
```

CPE Router: ADVERTISE



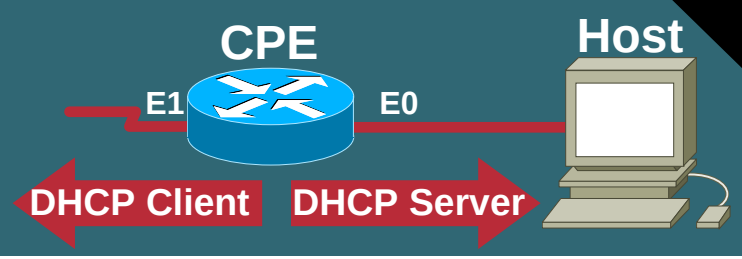

```
*Mar 2 03:39:22.657: IPv6 DHCP: Received ADVERTISE from FE80::21A:C4FF:FE29:1155 on Ether1
*Mar 2 03:39:22.657: IPv6 DHCP: detailed packet contents
*Mar 2 03:39:22.657:  src FE80::21A:C4FF:FE29:1155 (Ethernet1) [Link-local Address of PE]
*Mar 2 03:39:22.657:  dst FE80::207:EFF:FE03:6E65 [Link-local Address of CPE Ether1]

*Mar 2 03:39:22.657:  type ADVERTISE(2), xid 16585219
*Mar 2 03:39:22.657:  option CLIENTID(1), len 10
*Mar 2 03:39:22.657:   0003000100070E036E65
*Mar 2 03:39:22.661:  option SERVERID(2), len 14
*Mar 2 03:39:22.661:   0001000143BF22B6080020E8FAC0
*Mar 2 03:39:22.661:  option IA-NA(3), len 40
*Mar 2 03:39:22.661:   IAID 0x00020001, T1 302400, T2 483840
*Mar 2 03:39:22.661:   option IAADDR(5), len 24
*Mar 2 03:39:22.661:    IPv6 address 2001:420:8:1:6:1:1:EBF1
*Mar 2 03:39:22.661:    preferred 604800, valid 1209600
*Mar 2 03:39:22.665:  option IA-PD(25), len 41
*Mar 2 03:39:22.665:   IAID 0x00020001, T1 302400, T2 483840
*Mar 2 03:39:22.665:   option IAPREFIX(26), len 25
*Mar 2 03:39:22.665:    preferred 604800, valid 1209600, prefix 2001:420:8:1:7::/80
*Mar 2 03:39:22.669:  option DNS-SERVERS(23), len 16
*Mar 2 03:39:22.669:   2001:420:3800:801:A00:20FF:FEE5:63E3
*Mar 2 03:39:22.669:  option DOMAIN-LIST(24), len 14
*Mar 2 03:39:22.669:   v6.cisco.com
```

CPE Router: REQUEST



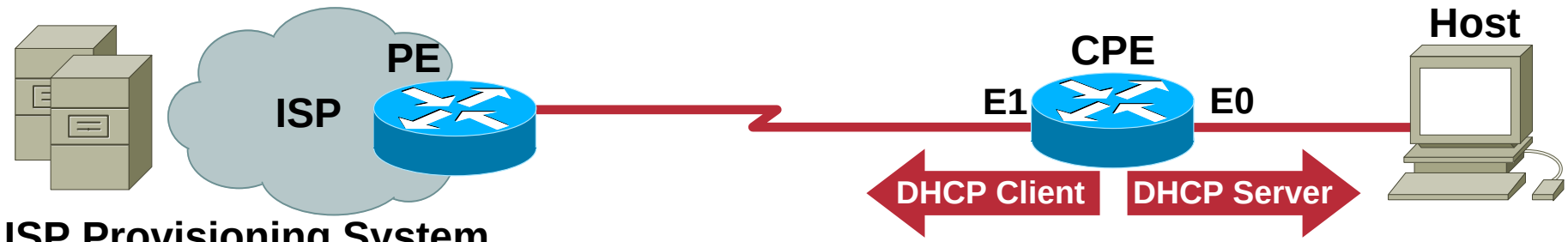

```
*Mar 2 03:39:23.741: IPv6 DHCP: Sending REQUEST to FF02::1:2 on Ethernet1
*Mar 2 03:39:23.741: IPv6 DHCP: detailed packet contents
*Mar 2 03:39:23.745:  src FE80::207:EFF:FE03:6E65 [Link-local Address of CPE Ether1]
*Mar 2 03:39:23.745:  dst FF02::1:2 (Ethernet1) [All_DHCP_Relay_Agents_and_Servers Address]
*Mar 2 03:39:23.745:  type REQUEST(3), xid 16596644
*Mar 2 03:39:23.745:  option ELAPSED-TIME(8), len 2
*Mar 2 03:39:23.745:   elapsed-time 0
*Mar 2 03:39:23.745:  option CLIENTID(1), len 10
*Mar 2 03:39:23.749:   0003000100070E036E65
*Mar 2 03:39:23.749:  option IA-NA(3), len 40
*Mar 2 03:39:23.749:   IAID 0x00020001, T1 0, T2 0
*Mar 2 03:39:23.749:   option IAADDR(5), len 24
*Mar 2 03:39:23.749:    IPv6 address 2001:420:8:1:6:1:1:EBF1
*Mar 2 03:39:23.749:    preferred 0, valid 0
*Mar 2 03:39:23.749:  option IA-PD(25), len 12
*Mar 2 03:39:23.753:   IAID 0x00020001, T1 0, T2 0
*Mar 2 03:39:23.753:  option ORO(6), len 4
*Mar 2 03:39:23.753:   DNS-SERVERS,DOMAIN-LIST
*Mar 2 03:39:23.753:  option SERVERID(2), len 14
*Mar 2 03:39:23.753:   0001000143BF22B6080020E8FAC0
```

CPE Router: REPLY




```
*Mar 2 03:39:23.797: IPv6 DHCP: Received REPLY from FE80::21A:C4FF:FE29:1155 on Ether1
*Mar 2 03:39:23.797: IPv6 DHCP: detailed packet contents
*Mar 2 03:39:23.797:  src FE80::21A:C4FF:FE29:1155 (Ethernet1) [Link-local Address of PE]
*Mar 2 03:39:23.797:  dst FE80::207:EFF:FE03:6E65 [Link-local Address of CPE Ether1]
*Mar 2 03:39:23.801:  type REPLY(7), xid 16596644
*Mar 2 03:39:23.801:  option CLIENTID(1), len 10
*Mar 2 03:39:23.801:   0003000100070E036E65
*Mar 2 03:39:23.801:  option SERVERID(2), len 14
*Mar 2 03:39:23.801:   0001000143BF22B6080020E8FAC0
*Mar 2 03:39:23.801:  option IA-NA(3), len 40
*Mar 2 03:39:23.801:   IAID 0x00020001, T1 302400, T2 483840
*Mar 2 03:39:23.801:   option IAADDR(5), len 24
*Mar 2 03:39:23.805:    IPv6 address 2001:420:8:1:6:1:1:EBF1
*Mar 2 03:39:23.805:    preferred 604800, valid 1209600
*Mar 2 03:39:23.805:  option IA-PD(25), len 41
*Mar 2 03:39:23.805:   IAID 0x00020001, T1 302400, T2 483840
*Mar 2 03:39:23.805:   option IAPREFIX(26), len 25
*Mar 2 03:39:23.805:    preferred 604800, valid 1209600, prefix 2001:420:8:1:7::/80
*Mar 2 03:39:23.809:  option DNS-SERVERS(23), len 16
*Mar 2 03:39:23.809:   2001:420:3800:801:A00:20FF:FEE5:63E3
*Mar 2 03:39:23.809:  option DOMAIN-LIST(24), len 14
*Mar 2 03:39:23.809:   v6.cisco.com
```

CPE Router: Ethernet Interfaces




```
CPE Router#show ipv6 interface e1
cable-modem0 is up, line protocol is up
 IPv6 is enabled, link-local address is FE80::207:EFF:FE03:6E65
 No Virtual link-local address(es):
 Global unicast address(es):
  2001:420:8:1:6:1:1:EBF1, subnet is 2001:420:8:1:6:1:1:EBF1/128 [CAL/PRE] [Address    assigned by
DHCPv6]
    valid lifetime 1121384 preferred lifetime 516584
```

```
CPE Router#show ipv6 interface e0
Ethernet0 is up, line protocol is up
 IPv6 is enabled, link-local address is FE80::207:EFF:FE03:6E64
 No Virtual link-local address(es):
 Global unicast address(es):
  2001:420:8:1:7::1, subnet is 2001:420:8:1:7::/80 [CAL/PRE] [Address assigned using DHCP-PD]
    valid lifetime 1121385 preferred lifetime 516585
```

Provisioning Tools

AAA/RADIUS

- RADIUS attributes and IPv6 (RFC3162)—Cisco IOS 12.3(4)T
- RADIUS Server support requires an upgrade (supporting RFC3162) Few RADIUS solutions support RFC3162 functionality today
- Prefix pools and pool names are configurable through AAA
- The following RADIUS attributes as described in RFC 3162 are supported for IPv6: Framed-Interface-Id, Framed-IPv6-Prefix, Login-IPv6-Host, Framed-IPv6-Route, Framed-IPv6-Pool
- IPv6 AAA/RADIUS configuration

  http://www.cisco.com/warp/public/cc/pd/iosw/prodlit/ipv6a_wp.htm

RADIUS Configuration with Permanently Assigned /64:

```
Auth-Type = Local, Password = "foo"
User-Service-Type = Framed-User,
Framed-Protocol = PPP,
cisco-avpair = "ipv6:prefix=2001:DB8:1:1::/64"
```

Interface Identifier Attribute (Framed-Interface-Id) Can Be Used:

```
Interface-Id = "0:0:0:1",
```

CNR 6.2 - DHCPv6 Supports

- Links and prefixes—similar to DHCPv4's networks and scopes. These define the network topology—each link can have one or more prefixes. Links are optional.
- Policies and options—allows attributes and options to be assigned to links, prefixes, and clients
- VPN support—allows for multiple numbering spaces
- Client classing—allows for clients to be classified and prefixes to be selected based on known clients or packet based expressions
- Static reservations—allows for clients to receive predetermined addresses
- Statistics collection—allows for monitoring the server's activities
- Logging—allows for monitoring the server's activities

IPv6 BB Summary

- **Existing IPv4 BB networks can implement/integrate IPv6**
- **ISP IPv6 Deployment Scenarios in Broadband Access Networks IETF draft covers ETTH, DSL, WLAN, PLC and Cable:**

  <draft-ietf-v6ops-bb-deployment-scenarios-04.txt>
- **Some issues in order to deploy native IPv6 in BB Cable networks which are being addressed in DOCSIC 3.0 standardization. These issues are highlighted in:**

  <draft-ietf-v6ops-bb-deployment-scenarios-04.txt>

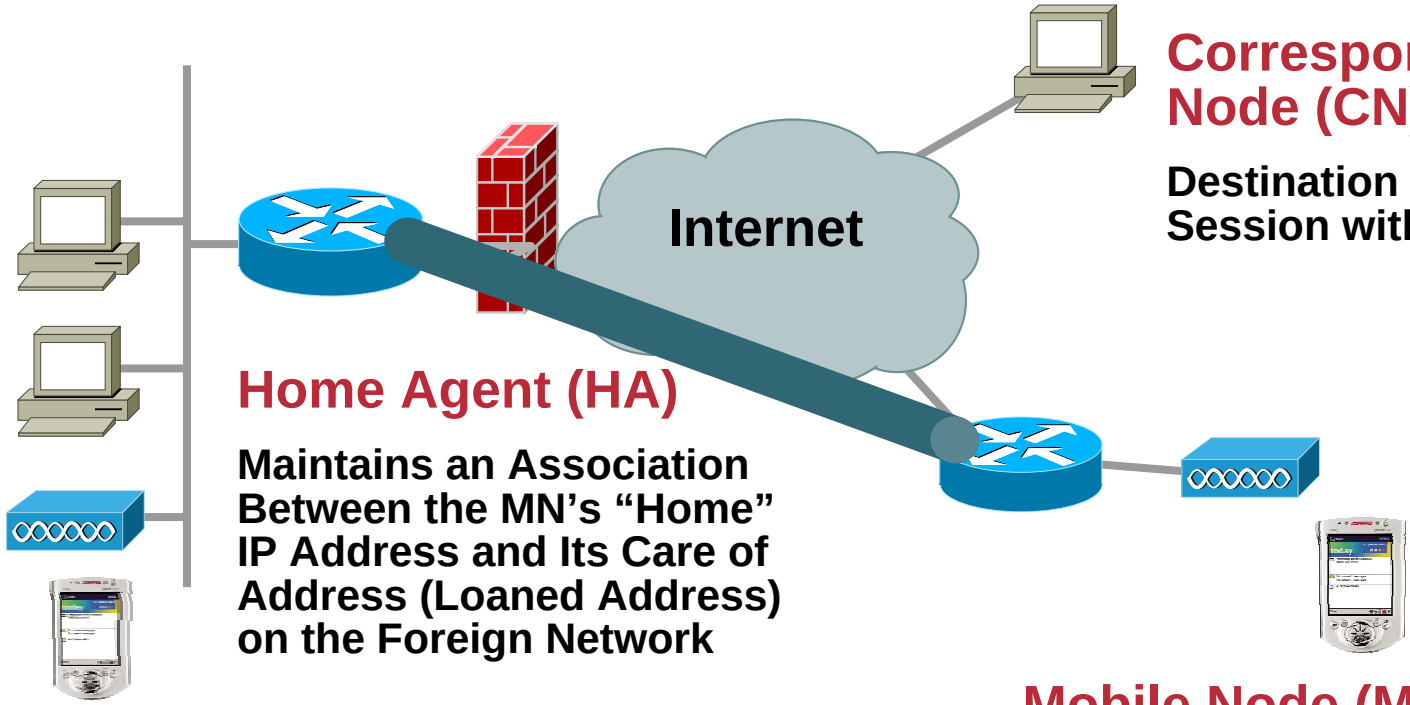
  <draft-mule-cablelabs-docsis3-ipv6-00.txt>

Mobile IPv6

Mobile IPv6 Benefits

- IPv6 address space enables mobile IP deployment in any kind of large environment
- No foreign agent needed in MIPv6
  - Infrastructure does not need an upgrade to accept Mobile IPv6 nodes
- IPv6 autoconfiguration simplifies MN CoA assignment
- MIPv6 takes advantage of IPv6 protocol itself
  - E.g., option headers, neighbor discovery
- Optimized routing—avoids triangular routing
  - Scale easier but network management challenges
- MN's work transparently even with other nodes that do not support mobility
  - Albeit without route optimization

Mobile IPv6: Key Components



Correspondent Node (CN)

Destination IP Host in Session with a Mobile Node

Home Agent (HA)

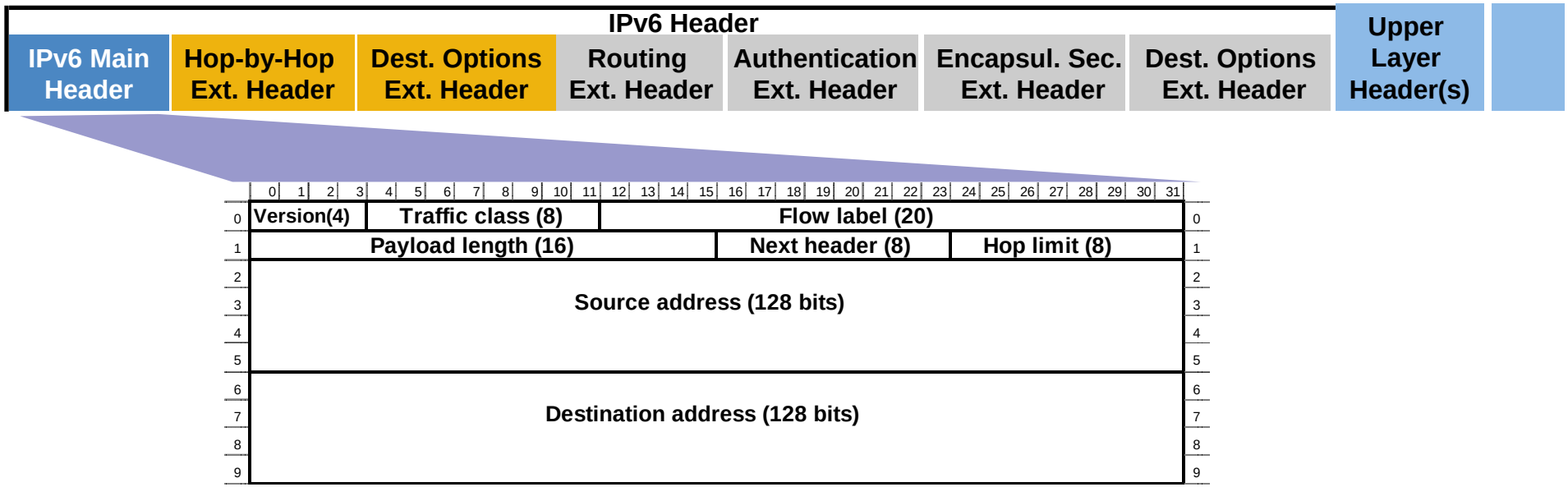
Maintains an Association Between the MN's "Home" IP Address and Its Care of Address (Loaned Address) on the Foreign Network

Mobile Node (MN)

An IP Host that Maintains Network Connectivity Using Its "Home" IP Address, Regardless of which Link (or Network) It Is Connected To

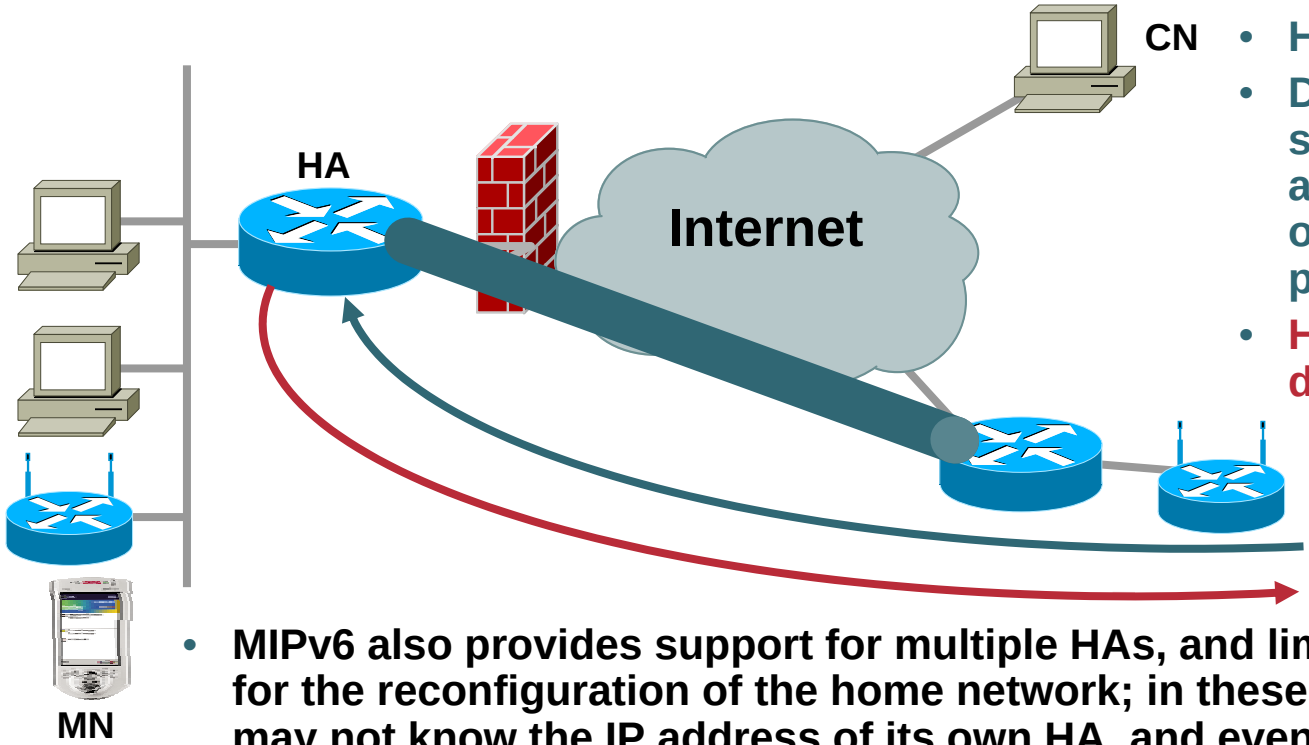
Mobile IPv6: a Native Extension of IPv6

Unfragmented Packet Example:



- Take advantage of the IPv6 packet structure as defined in RFC 2460
- Create new extension header—mobility header
- Add new routing header type
- Add new destination option

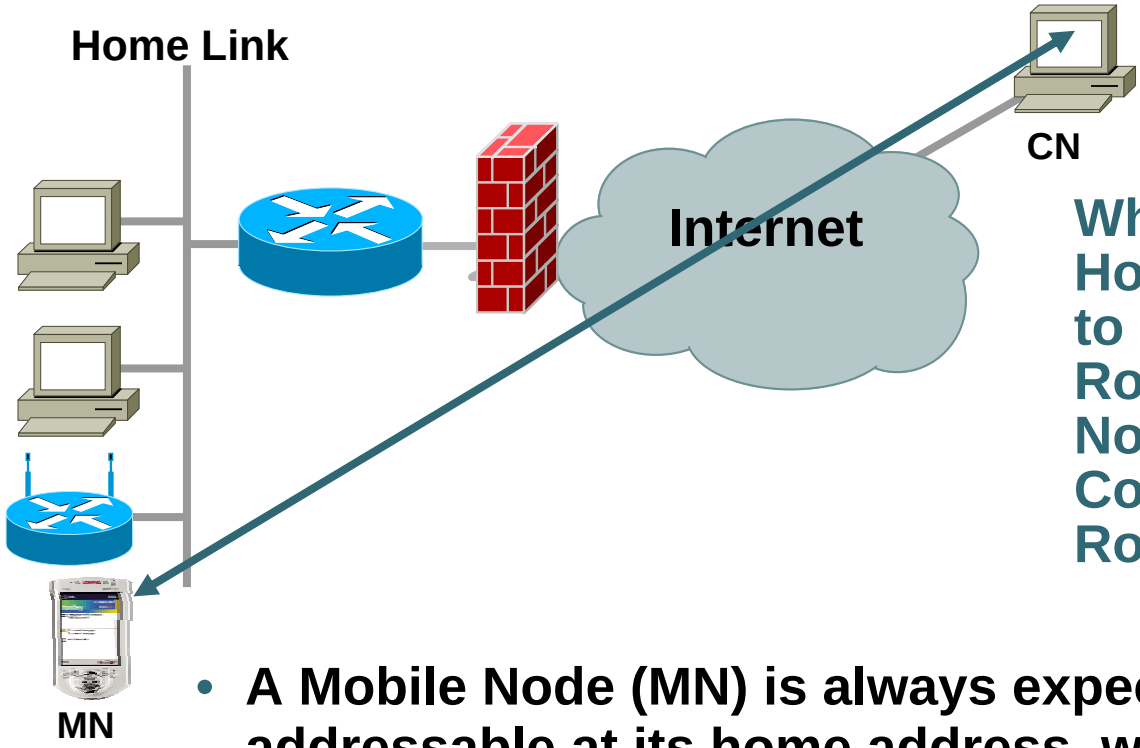
Dynamic Home Agent Address Discovery
DHAAD



- Home agent address
- Discovery request sent to home agents anycast address of its own home subnet prefix
- Home agent address discovery reply

- MIPv6 also provides support for multiple HAs, and limited support for the reconfiguration of the home network; in these cases, the MN may not know the IP address of its own HA, and even the home subnet prefixes may change over time
- A mechanism, known as "dynamic home agent address discovery (DHAAD)" allows a MN to dynamically discover the IP address of a HA on its home link, even when the MN is away from home
- MN can also learn new information about home subnet prefixes through the "mobile prefix discovery" mechanism

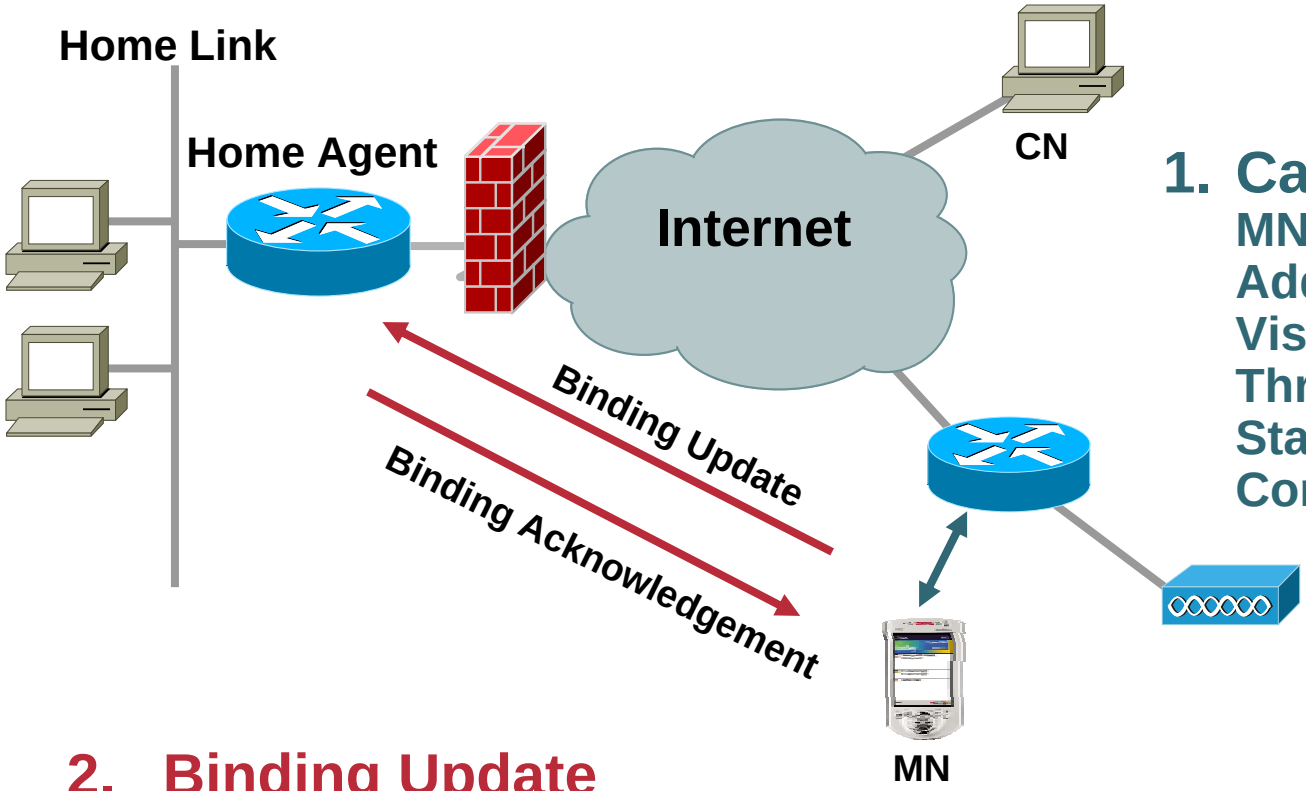
MIPv6 Operations: MN on Its Home Network



While a Mobile Node Is at Home, Packets Addressed to Its Home Address Are Routed to the Mobile Node's Home Link, Using Conventional Internet Routing Mechanisms

- **A Mobile Node (MN) is always expected to be addressable at its home address, whether it is currently attached to its home link or is away from home**
- **The “home address” is an IP address assigned to MN within its home subnet prefix on its home link**

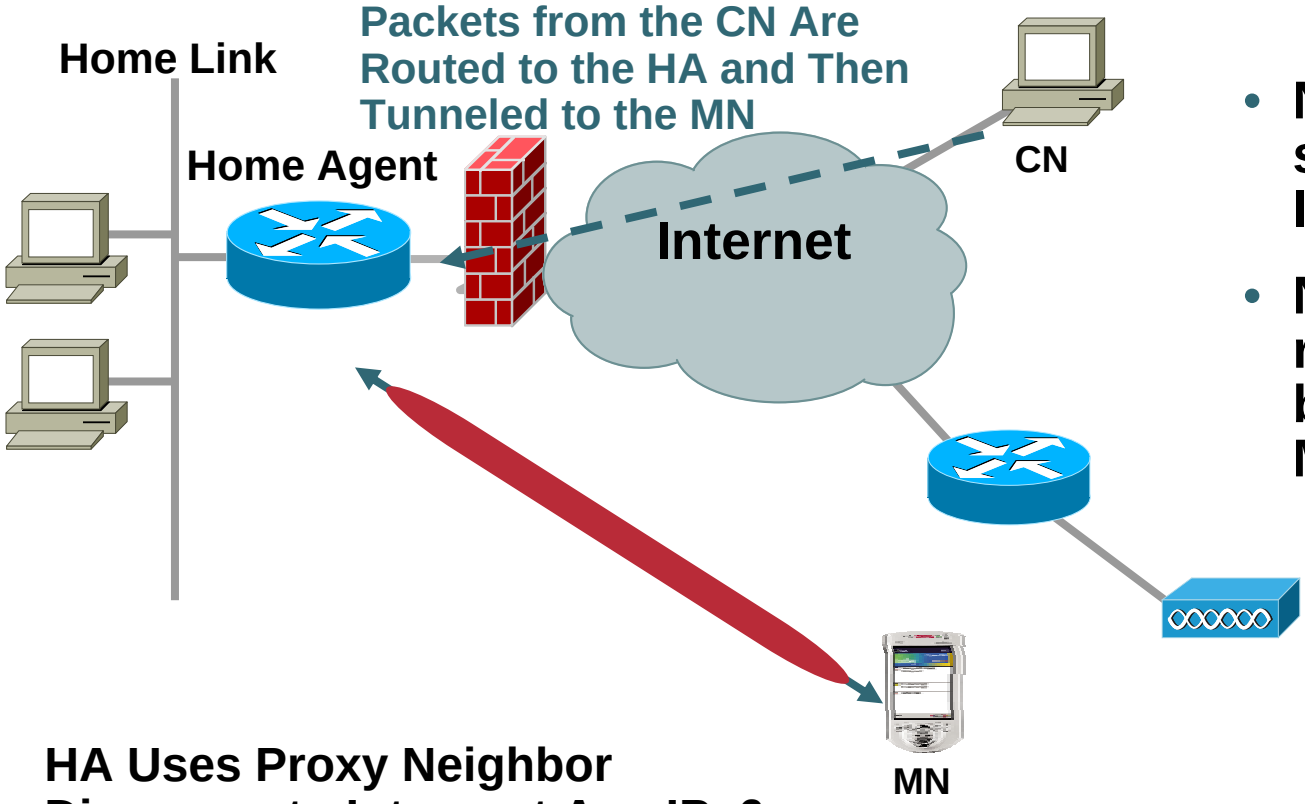
MIPv6 Operations: MN Moving to a New Link



1. **Care-Of Address**
   MN Obtains an IPv6 Address in the Visited Network Through Stateless or Stateful Auto-Configuration

2. **Binding Update**
   While Away From Home, a MN Registers Its Primary Care-Of Address with a Router on Its Home Link, Requesting this Router to Function as the "Home Agent" for the MN

Packet Forwarding
Bidirectional Tunneling Mode

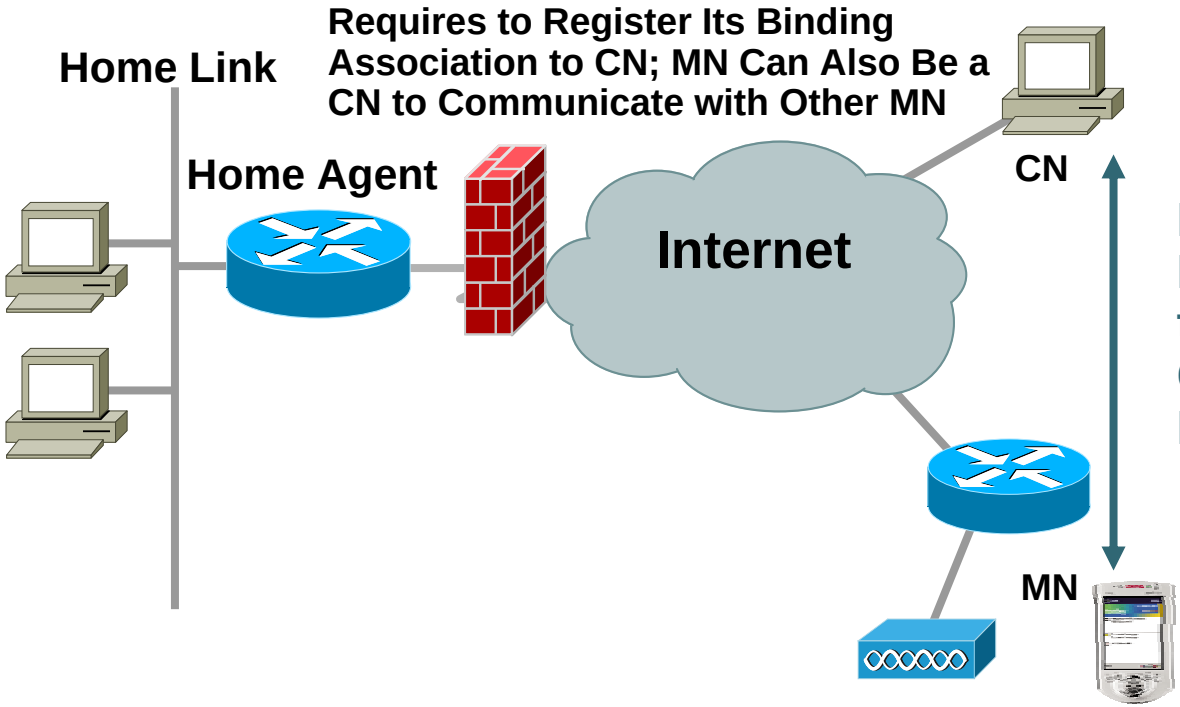


- Not required to support mobile IPv6 on the CN
- No binding registration between MN and CN

HA Uses Proxy Neighbor Discovery to Intercept Any IPv6 Packets Addressed to the MN's Home Address on the Home Link; Each Intercepted Packet Is Tunneled to the MN's CoA

Packets to the CN Are Tunneled from the MN to the HA ("Reverse Tunneled") and then Routed Normally from the Home Network to the CN

Packet Forwarding
Route Optimization Mode



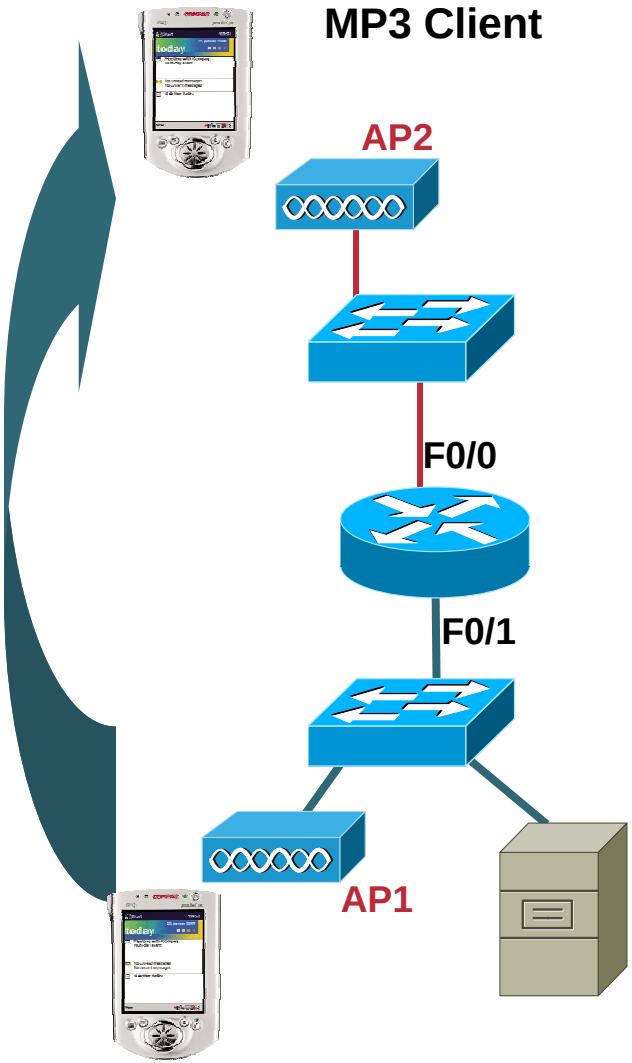
Packets from CN Are Routed Directly to the CoA of MN by Checking the Binding Cache Table

Traffic Is Going Through HA Until the Return Routability Procedure Is Performed

Signaling via HA, and Home Registrations Still Keep HA Informed

When Routing Packets Directly to CN, MN Sets the Source Address in the Packet's IPv6 Header to Its Current CoA

Cisco IOS Mobile IPv6 Home Agent



- **MIPv6 home agent**
  - **Authentication support planned**
  - **Binding update can be filtered by source address using ACL**
  - **Anycast support for HA**
- **In early field trials—tested with BSD, Linux, and Windows MIPv6 client**

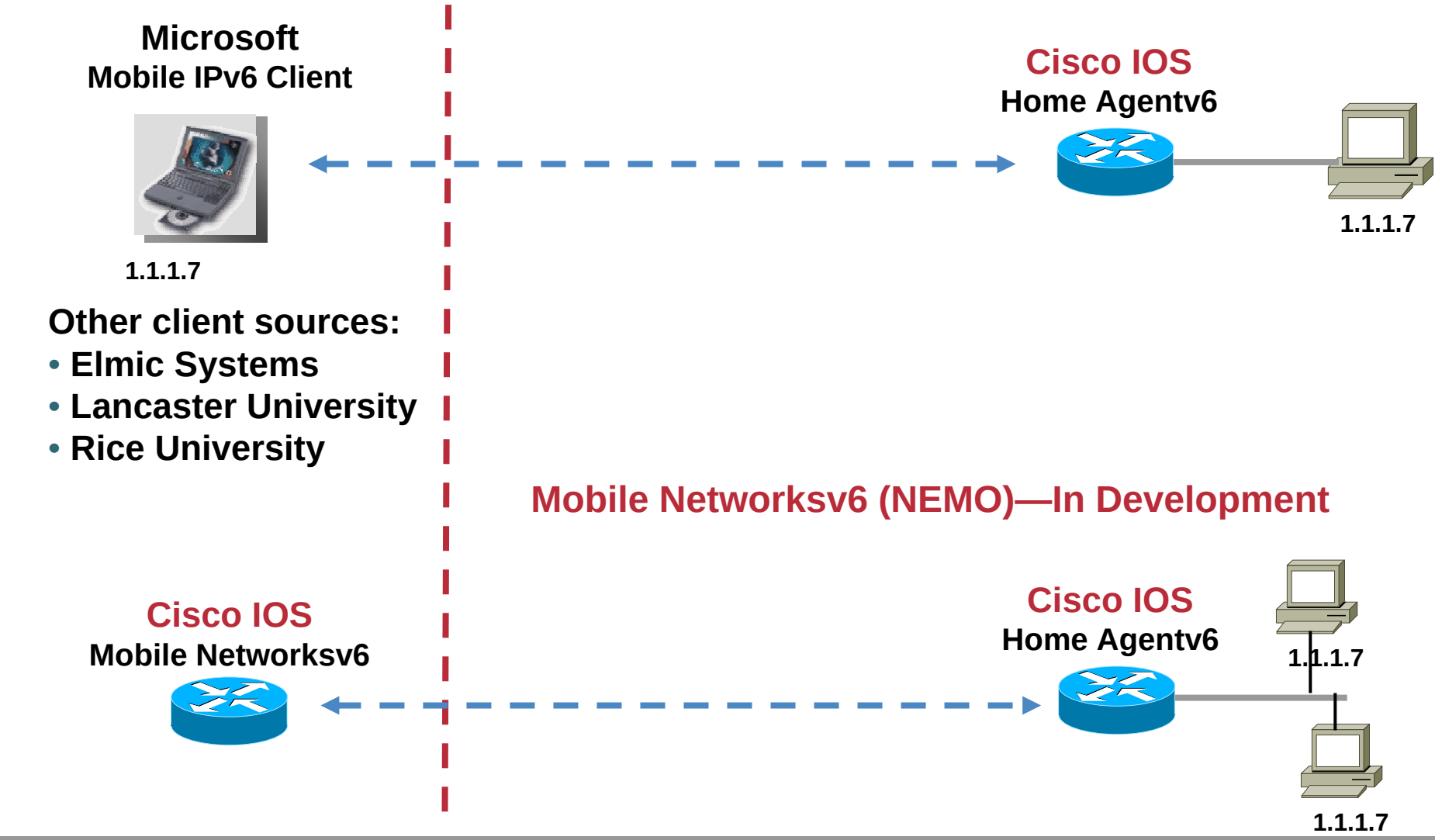
```
ipv6 unicast-routing
ipv6 cef
!
interface FastEthernet0/0
 ipv6 address 2001:DB8:C003:1101::45A/64
 ipv6 cef
 ipv6 mobile home-agent
!
interface FastEthernet0/1
 ipv6 address 2001:DB8:C003:1102::45C/64
 ipv6 cef
 ipv6 mobile home-agent
```

Don’t Forget About Mobile Routing (MR3200, 26,28,37,3800)

Mobile IPv6 at Cisco

- **Home agent**
  - **In field trial since CY ’01**
  - **RFC3775 compliant**
    - **http://www.ietf.org/internet-drafts/draft-ietf-mobileip-ipv6-24.txt**
    - **Some issues from TAHI—Dynamic HA Address Discovery, Mobile Prefix Discovery—being worked on**
  - **Available from Cisco IOS 12.3(14)T**
  - **Enhanced ACL—routing type filtering capability—planned**
  - **Light authentication planned**
- **Mobile IPv6 is part of the planned IPv6 rollouts**
  - **http://www.cisco.com/warp/public/732/Tech/ipv6/ipv6_learnabout.shtml**
  - **http://www.cisco.com/warp/public/732/Tech/ipv6/**

Mobile IPv6 at Cisco



Reference Materials

- **“Deploying IPv6 Networks” by Patrick Grossetete, Eric Levy-Abegnoli, Ciprian Popoviciu—Cisco Press (ISBN: 1587052105)**
- **“Understanding IPv6” by Joseph Davies—Microsoft Press (ISBN: 0735612455)**
- **“IPv6 Essentials” by Silvia Hagen—O’Reilly & Associates (ISBN: 0596001258)**
- **www.cisco.com/go/ipv6—CCO IPv6 main page**
- **www.cisco.com/go/srnd—CISCO NETWORK DESIGN CENTRAL**
- **www.cisco.com/go/fn—select “Feature” and search for “IPv6”, then select “IPv6 for Cisco IOS Software”**
- **www.ietf.org**
- **www.hs247.com**
- **www.ipv6forum.com**
- **www.ipv6.org**
- **www.nav6tf.org/**
- **www.usipv6.com**
- **www.6net.org**

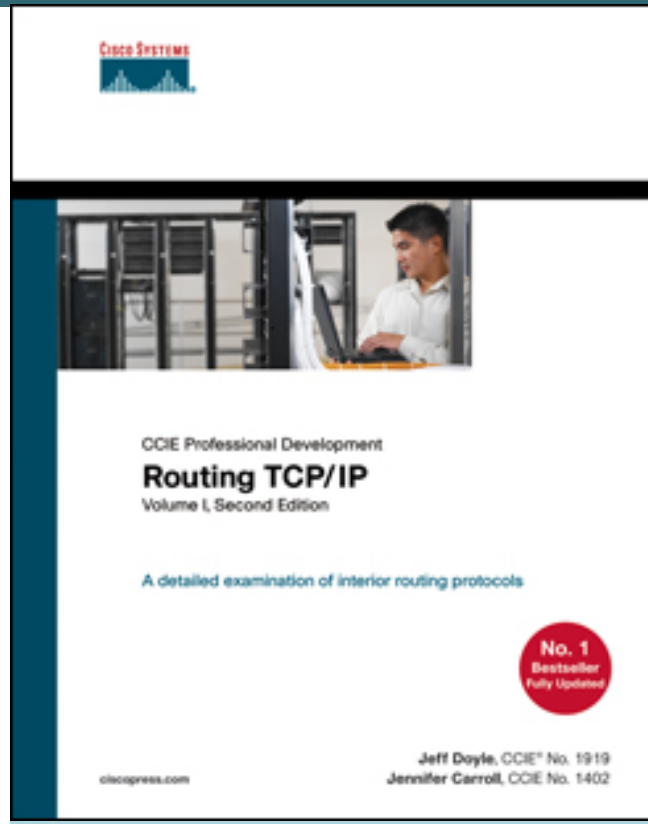
Conclusion

- **Start now rather than later**
  - **Purchase for the future and test, test and then test some more**
  - **Start moving legacy application towards IPv6 support**
- **Things we did not talk about, but they are very important to consider**
  - **ISP multihoming solutions (Multi6 WG)—"Goals for IPv6 Site-Multihoming Architectures" (RFC 3582)—http://www.ietf.org/html.charters/multi6-charter.html**
  - **Other transition methods such as EoMPLS, L2TPv3**
- **Things to consider:**
  - **Don't assume your favorite vendor/app/gear has an IPv6 plan**
  - **Full parity between IPv4 and IPv6 is still a ways off**
- **Enterprise and SP deployment sScenarios**
  - **http://www.ietf.org/internet-drafts/draft-ietf-v6ops-bb-deployment-scenarios-04.txt**
  - **Scenarios and Analysis for Introducing IPv6 into ISP Networks (RFC 4029)**
  - **IPv6 Enterprise Network Scenarios (RFC 4057)**
  - **Procedures for Renumbering an IPv6 Network without a Flag Day (RFC 4192)**
- **What we hope to discuss next time**
  - **Native IPv6 MPLS/recommendations for an IPv6-enabled SP core**
- **What would you like to see/hear next time?**

Q and A

Recommended Reading

- **Continue your Cisco Networkers learning experience with further reading from Cisco Press**
- **Check the Recommended Reading flyer for suggested books**



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  Wednesday, June 21 at 12:15 p.m.

  Thursday, June 22 at 12:15 p.m. and 2:00 p.m.