



arnes 



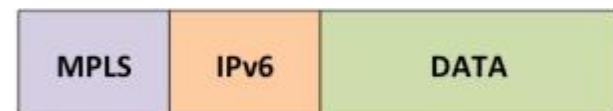
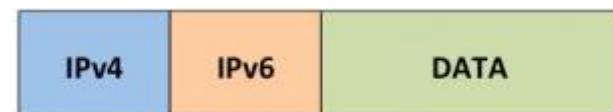
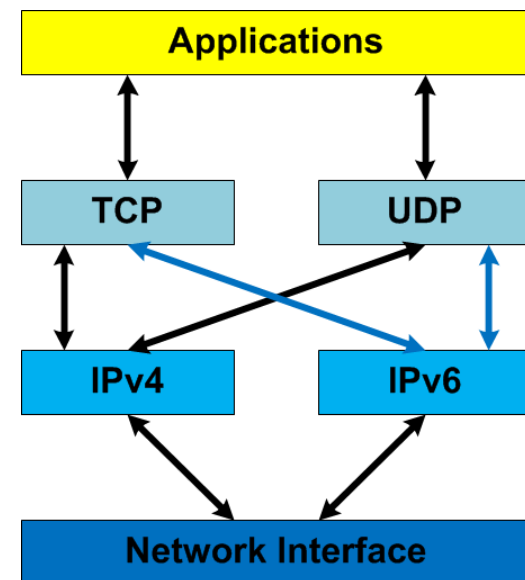
IPv4/IPv6 Transition Mechanisms

Luka Koršič, Matjaž Straus Istenič



IPv4/IPv6 Migration

- Both versions exist today simultaneously
- Dual-stack
 - IPv4 and IPv6 protocol stack
- Address translation
 - NAT44, LSN, NAT64
- Tunneling
 - IPv6 over IPv4 (RFC 2893)
 - IPv6 over GRE (RFC 2473)
 - IPv4-compatible addresses (RFC 2893)
 - IPv6 address is calculated from IPv4 address (::192.168.100.1)
 - 6to4 (RFC 3056)
 - 6rd – IPv6 Rapid Deployment (RFC 5569)
 - ISATAP (RFC 5214)
 - Teredo – NAT traversal (RFC 4380)
 - MPLS
 - 6PE (RFC 4798)
 - 6VPE (RFC 4659)





Address Translation



Address Translation

■ IPv4/IPv4 Address Translation

- Classic NAT/PAT
- NAT 44 (Large Scale NAT - LSN)
 - NAT – the whole access network is behind NAT
- NAT444 (LSN + NAT44)
- A+P (Address + Port)
 - dynamic port sharing on the same IPv4 address

■ IPv4/IPv6 Address Translation

- Enables communication between IPv4-only and IPv6-only devices
- NAT-PT (RFC 2766)
 - deprecated
- NAT64
 - Framework for IPv4/IPv6 Translation (RFC 6144)
 - IPv6 Addressing of IPv4/IPv6 Translators (RFC 6052)
 - DNS64: DNS Extensions for Network Address Translation from IPv6 Clients to IPv4 Servers (RFC 6147)
 - IP/ICMP Translation Algorithm (RFC 6145)



Stateless NAT64

„Stateless“ – no session preservation

- Algorithm for translating between IPv4 and IPv6 addresses
- Each IPv6 address is translated to exactly one IPv4 address
- Only IP and ICMP header is translated

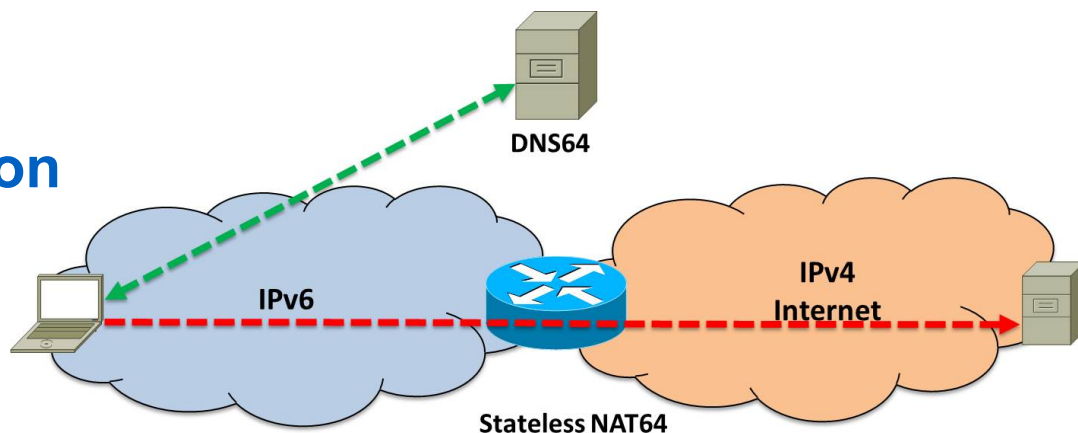
Direction of operation

- IPv6 → IPv4 internet
- IPv4 internet → IPv6
- IPv6 → IPv4
- IPv4 → IPv6

Header fields translation

- Addresses
- Hop Limit ⇔ TTL
- Payload Length
 - Header Length
 - Total Length

PL	0	32	40	48	56	64	72	80	88	96	104	
32	Prefix			v4 (32)		u	Suffix					
40	Prefix			v4 (24)		u (8)	Suffix					
48	Prefix			v4 (16)		u (16)	Suffix					
56	Prefix			(8)	u	v4 (24)		Suffix				
64	Prefix			u	v4 (32)			Suffix				
96	Prefix									v4 (32)		





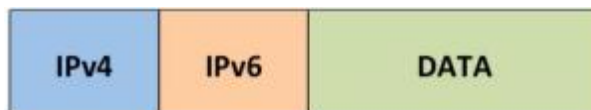
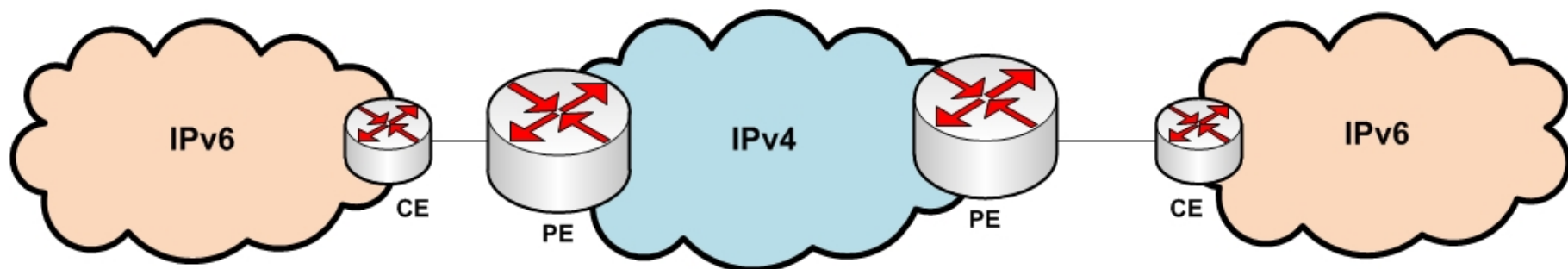
Tunneling



Manual Tunneling

- RFC 2893

- Transition Mechanisms for IPv6 Hosts and Routers



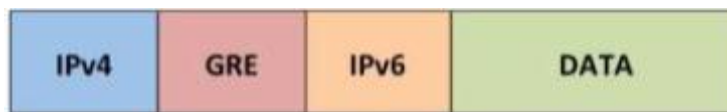
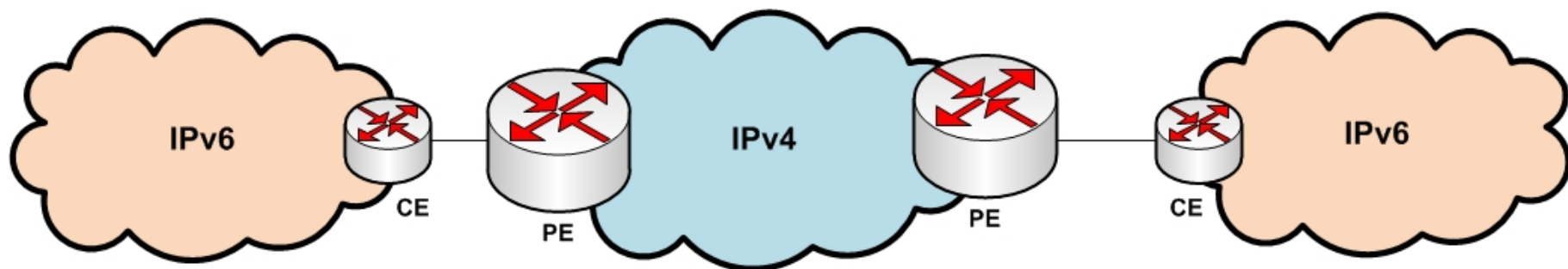
```
interface tunnel 100
  ipv6 address 201:300::1/64
  (no) ipv6 nd ra suppress
  tunnel source 200.15.15.1
  tunnel destination 200.13.13.1
  tunnel mode ipv6ip
```

```
interface tunnel 100
  ipv6 address 201:300::2/64
  (no) ipv6 nd ra suppress
  tunnel source 200.13.13.1
  tunnel destination 200.15.15.1
  tunnel mode ipv6ip
```



GRE Tunneling

- RFC 2473
 - Generic Packet Tunneling in IPv6 Specification
- GRE (Generic routing Encapsulation)



```
interface tunnel 2002
  ipv6 address 201:300::1/64
  tunnel source e0/0
  tunnel destination 200.13.13.1
  tunnel mode gre ip
```

```
interface tunnel 2002
  ipv6 address 201:300::2/64
  tunnel source e0/0
  tunnel destination 200.15.15.1
  tunnel mode gre ip
```




6to4 1/3

■ RFC 3056

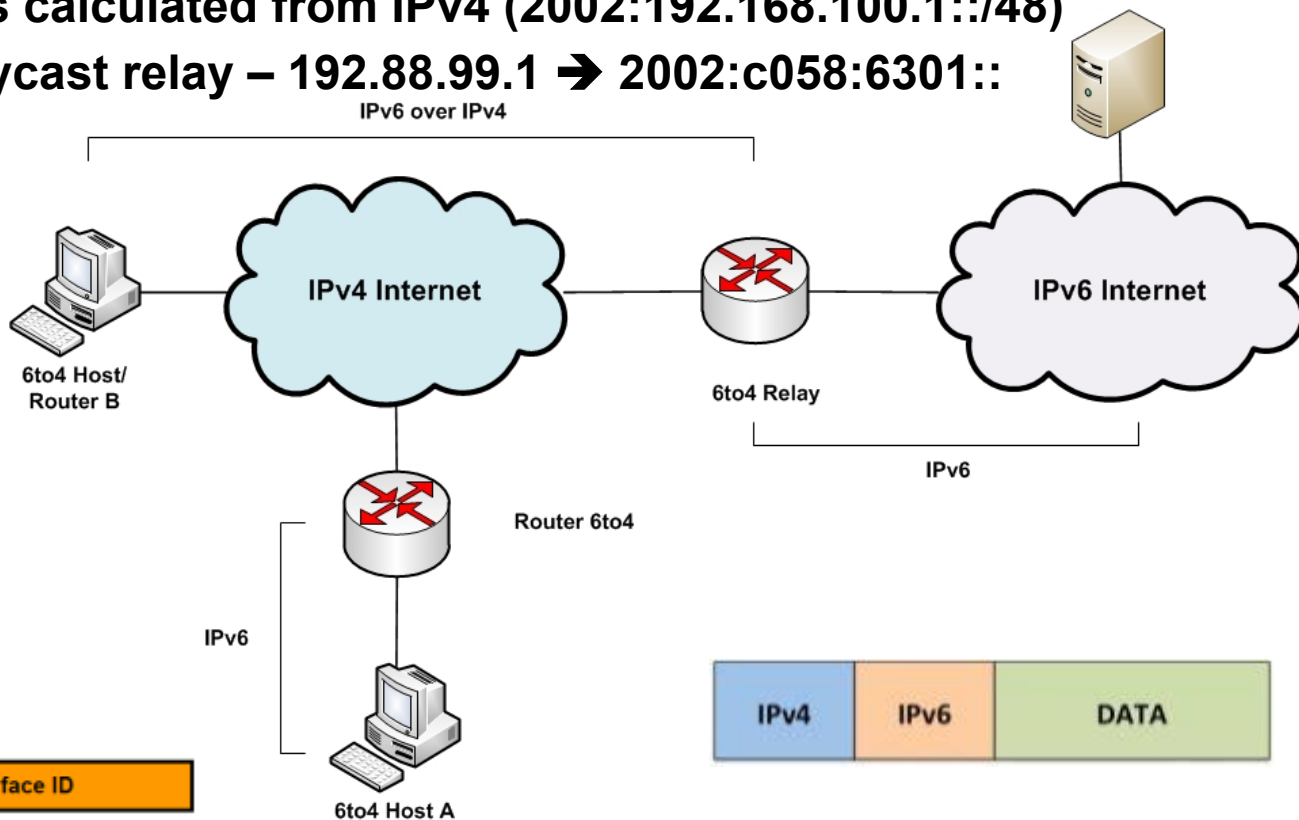
- Connection of IPv6 Domains via IPv4 Clouds

■ Features

- Automatic tunnel provisioning
- IPv6 address is calculated from IPv4 (2002:192.168.100.1::/48)
- Public 6to4 anycast relay – 192.88.99.1 → 2002:c058:6301::
 - (RFC3068)

■ Elements

- Hosts
- Routers
- Relays

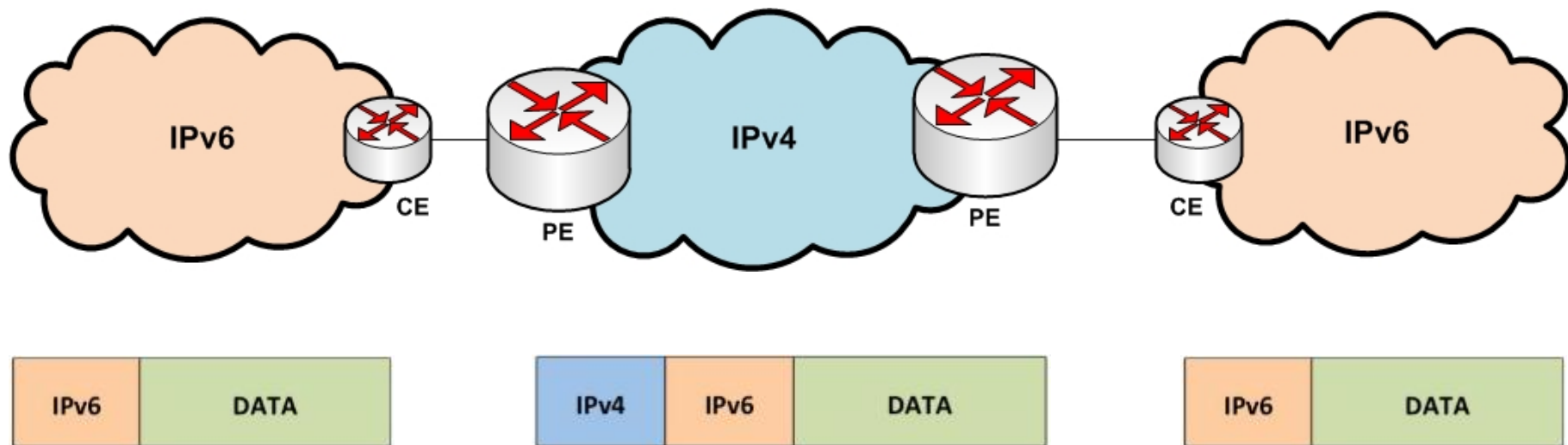


/16	/48	/64	
2002	IPv4 Addr (Hex)	SLA	Interface ID



6to4 2/3

■ Connecting remote IPv6 LANs



```
interface tunnel 2002
ipv6 address 2002:c80f:0f01::1/128
tunnel source ethernet0/0
tunnel mode ipv6ip 6to4

interface ethernet 0/0
ip address 200.15.15.1 255.255.255.0

interface ethernet 1/0
ipv6 address 2002:c80f:0f01:100::2/64
```

```
interface tunnel 2002
ipv6 address 2002:c80b:0b01::1/128
tunnel source ethernet0/0
tunnel mode ipv6ip 6to4

interface ethernet 0/0
ip address 200.11.11.1 255.255.255.0

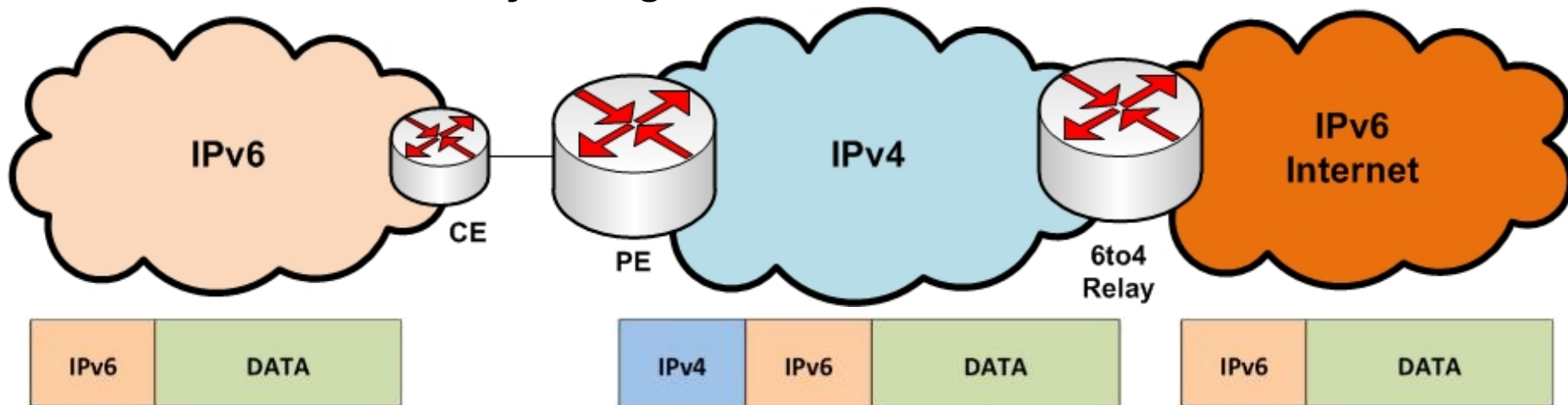
interface ethernet 1/0
ipv6 address 2002:c80b:0b01:100::2/64
```



6to4 3/3

■ IPv6 Internet Access

■ CE and 6to4 Relay configuration



```
interface tunnel 2002
ipv6 address 2002:c80f:0f01::1/128
tunnel source ethernet0/0
tunnel mode ipv6ip 6to4

interface ethernet 0/0
ip address 200.15.15.1 255.255.255.0

interface ethernet 1/0
ipv6 address 2002:c80f:0f01:100::2/64

ipv6 route 2002::/16 tunnel2002
ip route ::/0 2002:c058:6301::1
```

```
interface Loopback0
ip address 192.88.99.1 255.255.255.0
ipv6 address 2002:c058:6301::1/128

interface tunnel 2002
ipv6 unnumbered Loopback0
tunnel source Loopback0
tunnel mode ipv6ip 6to4

ipv6 route 2002::/16 tunnel2002
```



IPv6 Rapid Deployment (6rd) 1/4

■ RFC 5969

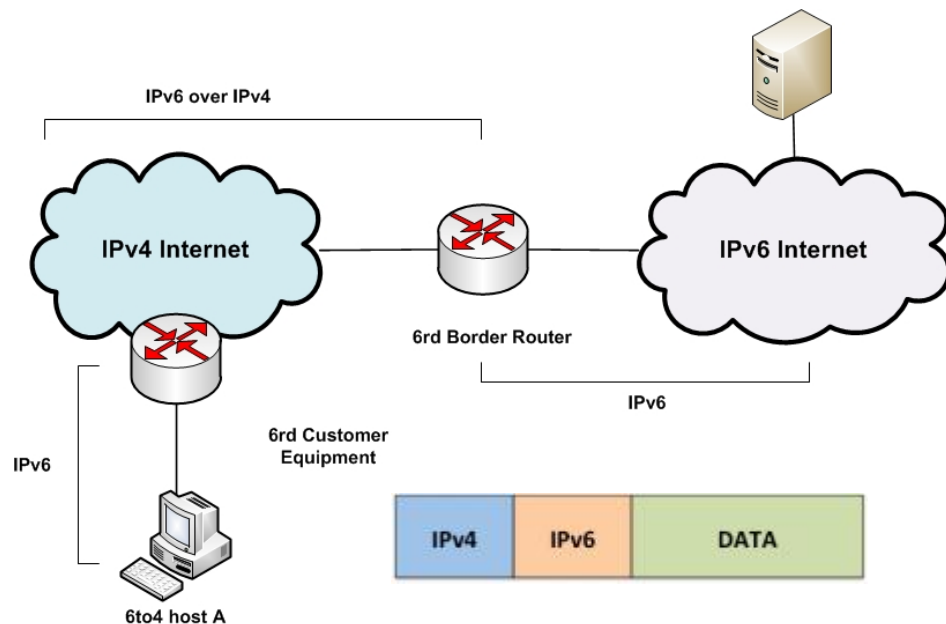
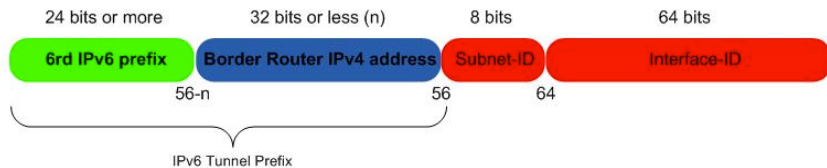
- IPv6 Rapid Deployment on IPv4 Infrastructure (6rd) – Protocol Specification

■ Features

- Automatic tunnel provisioning
- ISP IPv6 address space
- IPv6-only access network

■ Elements

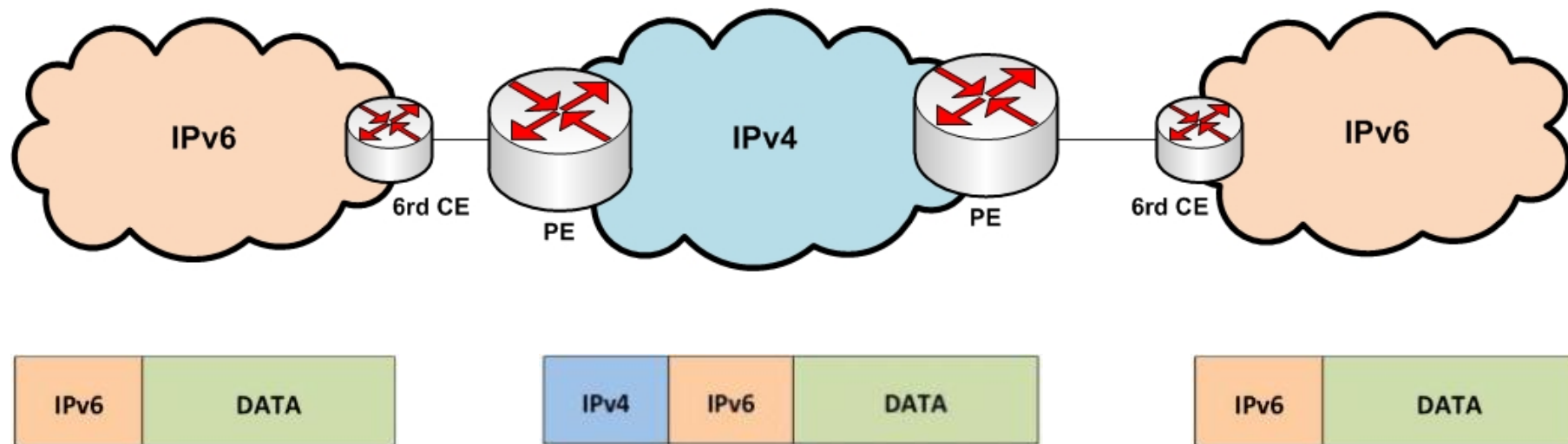
- Hosts
- 6rd Customer Equipment (CE)
- 6rd Border router (BR)





IPv6 Rapid Deployment (6rd) 2/4

■ Connecting remote IPv6 LANs



```
ipv6 general-prefix 6rd-prefix 6rd Tunnel 1
  ipv6 unicast routing
  ipv6 cef
```

```
interface Tunnel 1
  ipv6 enable
  tunnel source Ethernet 1/0
  tunnel mode ipv6ip 6rd
  tunnel 6rd prefix 2001:db8::/32
  tunnel 6rd ipv4 prefix-len 16
```

```
interface Ethernet 0/0
  description LAN1
  ipv6 address 6rd-prefix ::1/64
```

```
interface Ethernet 1/0
  description Towards LAN2
  ip address 200:15:15:1 255.255.255.0

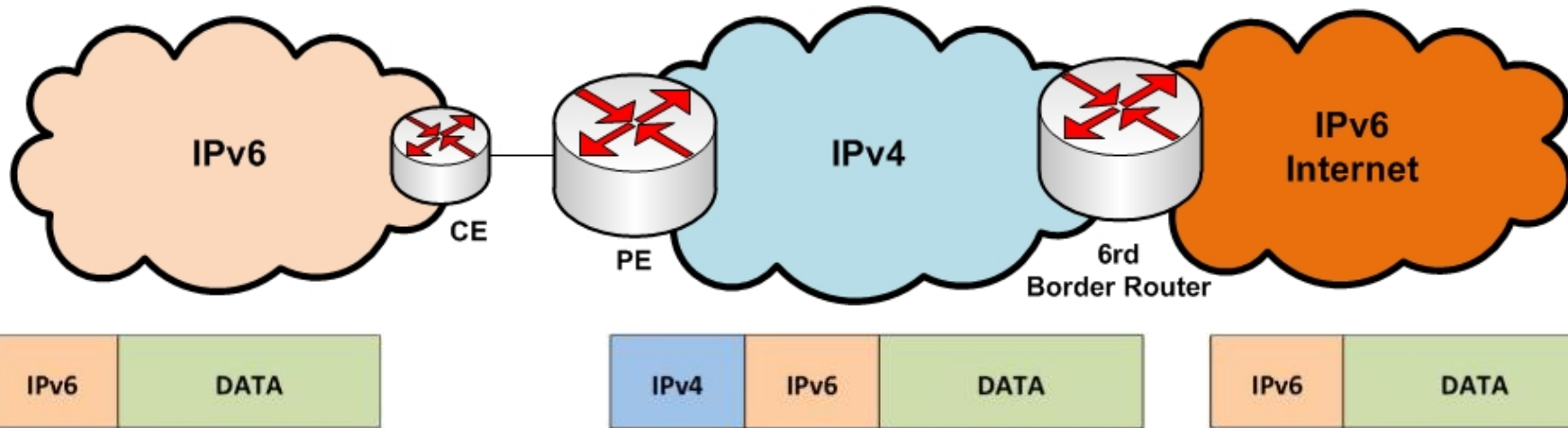
  ipv6 route 2001:db8::/32 tunnel 1
```



IPv6 Rapid Deployment (6rd) 3/4

■ IPv6 Internet Access

■ CE configuration



```

ipv6 general-prefix 6rd-prefix 6rd Tunnel 1
  ipv6 unicast routing
  ipv6 cef

```

```

Interface Tunnel 1
  ipv6 enable
  tunnel source Ethernet 1/0
  tunnel mode ipv6ip 6rd
  tunnel 6rd prefix 2001:db8::/32
  tunnel 6rd ipv4 prefix-len 16
  tunnel 6rd br 200.15.0.1

```

```

interface Ethernet0/0
  description Users
  ipv6 address 6rd-prefix ::1/64

interface Ethernet1/0
  description ISP
  ip address 200.15.15.1 255.255.255.0

  ipv6 route 2001:db8::/32 tunnel1
  ipv6 route ::/0 tunnel1 2001:db8:1::

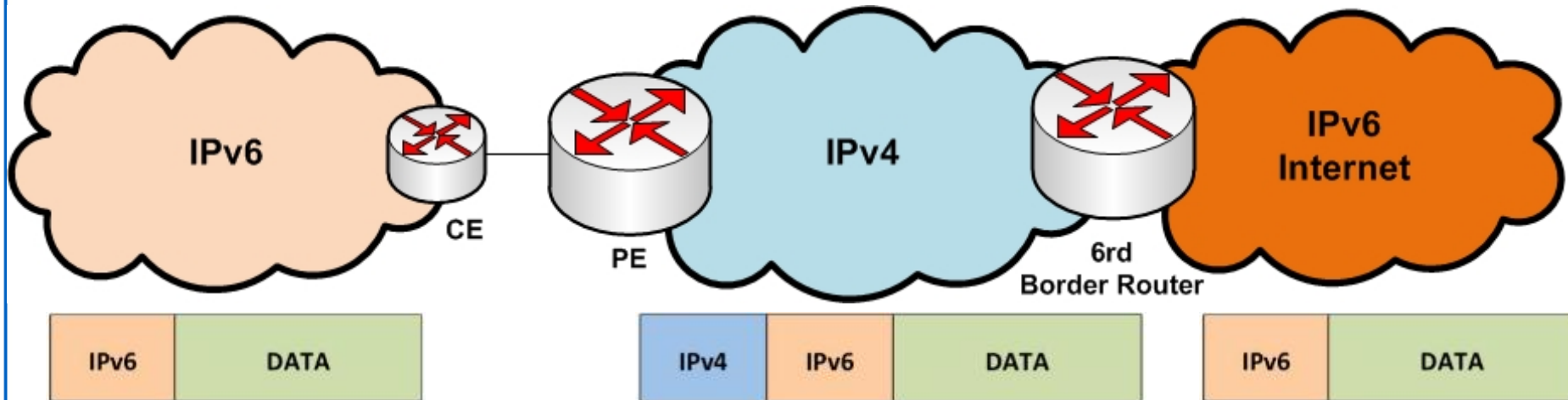
```



IPv6 Rapid Deployment (6rd) 4/4

■ IPv6 Internet Access

■ 6rd BR Configuration



```
ipv6 general-prefix 6rd-prefix 6rd Tunnel 1
  ipv6 unicast routing
  ipv6 cef
```

```
Interface Tunnel 1
  ipv6 enable
  tunnel source Loopback0
  tunnel mode ipv6ip 6rd
  tunnel 6rd prefix 2001:db8::/32
  tunnel 6rd ipv4 prefix-len 16
```

```
interface Ethernet0/0
  description IPv6 Internet
  ipv6 address 2001:db9::1/64

interface Loopback0
  description BR Address
  ip address 200.15.0.1 255.255.255.0

  ipv6 route 2001:db8::/32 tunnel1
  ipv6 route ::/0 2001:db9::2
```



Teredo

■ RFC 4380

- Teredo: Tunneling IPv6 over UDP through Network Address Translations (NATs)

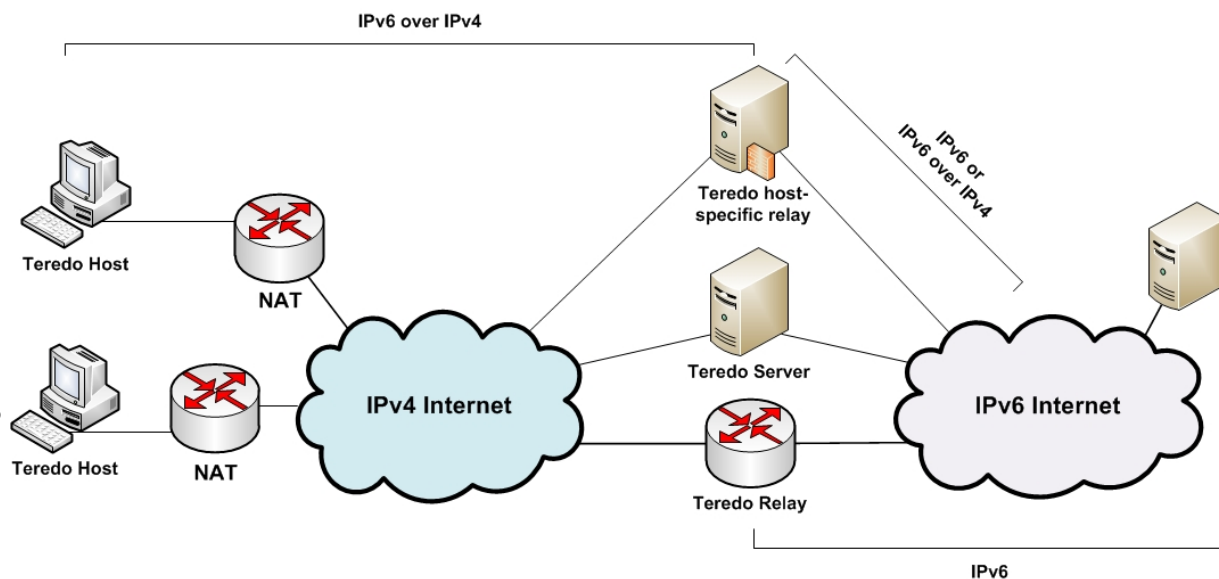
■ Features

- NAT traversing
- Supported “by default” on Microsoft OS
- Slow
- UDP



■ Elements

- Hosts/servers
- Relays
- Host-specific relays



Teredo prefix 2001:0000	Teredo Server IPv4 Address	Flags	UDP	External IPv4 Address
----------------------------	-------------------------------	-------	-----	--------------------------



ISATAP

■ RFC 5214

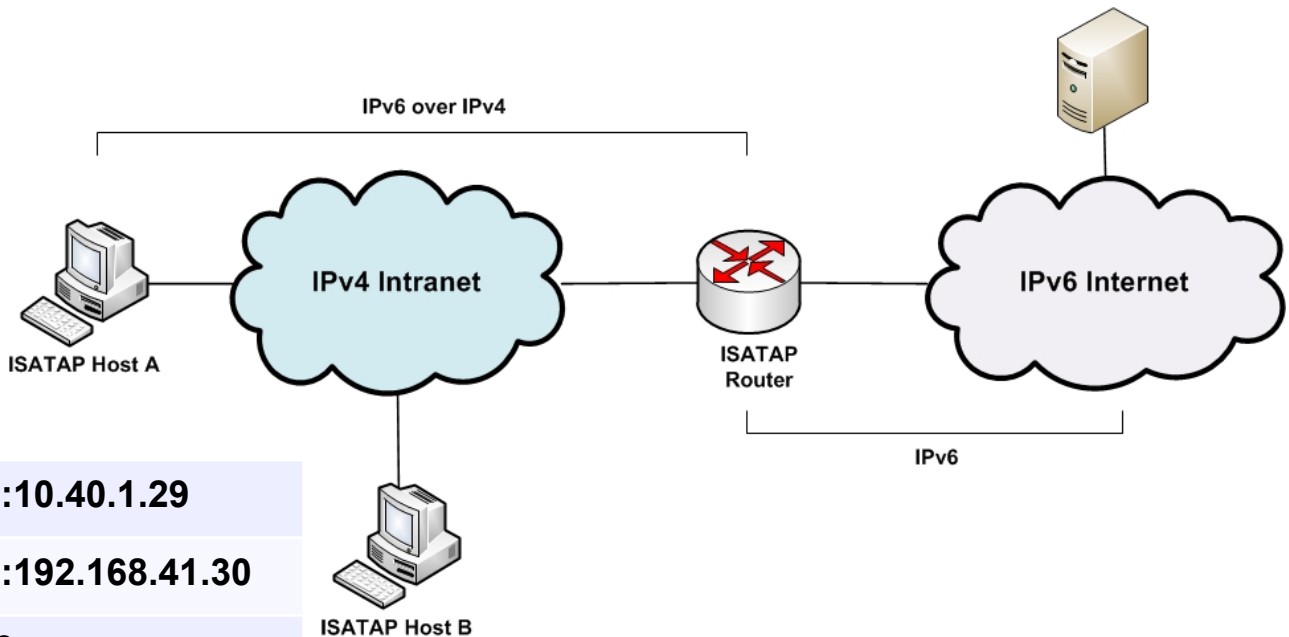
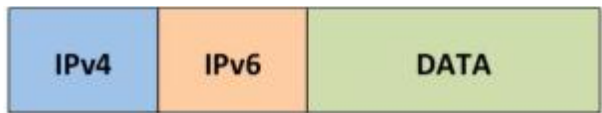
- Intra-Site Automation Tunnel Addressing Protocol (ISATAP)

■ Features

- Corporate & academic environments
- Single administrative domain

■ Elements

- Hosts
- Routers



IPv6 Source	fe80:5efe:10.40.1.29
-------------	----------------------

IPv6 Destination	fe80:5efe:192.168.41.30
------------------	-------------------------

IPv4 Source	10.40.1.29
-------------	------------

IPv4 Destination	192.168.41.30
------------------	---------------



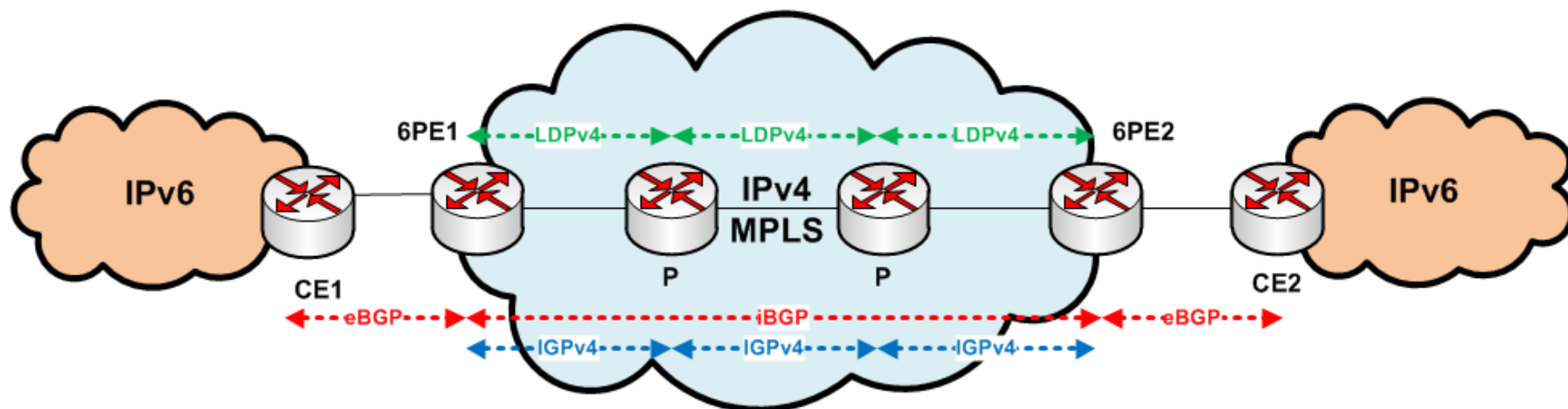
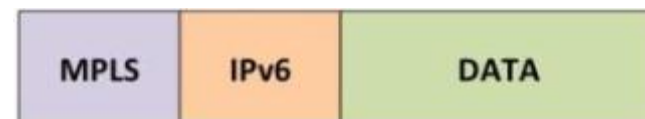
6PE 1/2

■ RFC 4798

- Configuring IPv6 Islands over IPv4 MPLS Using Provider Edge Routers

■ Features

- Core remains IPv4
- Edge devices (6PE) must support dual-stack
- IPv6 packets transported over LSP
- IPv4 Control plane (IGPv4, LDPv4, MP-BGP)
- Fast Re-Route (FRR), Traffic Engineering (TE)

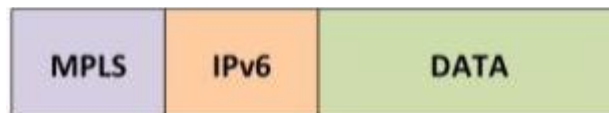
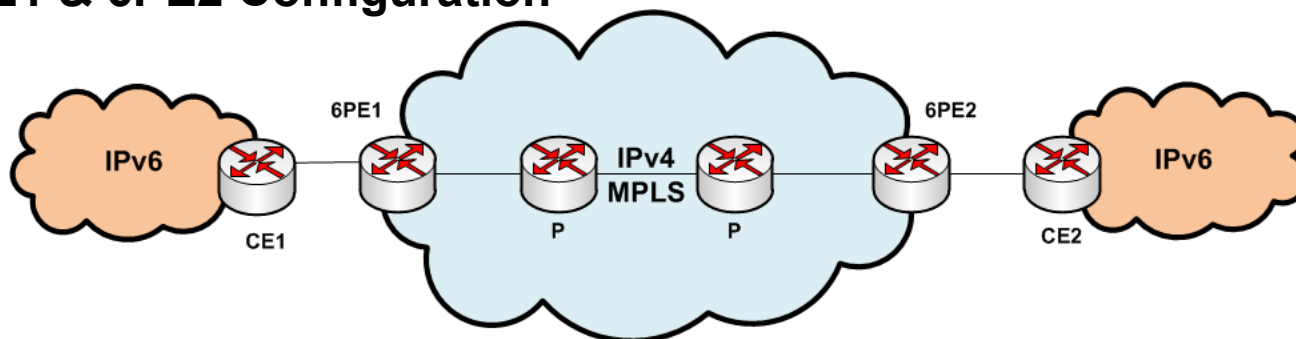




6PE 2/2

■ Connecting remote LANs

■ 6PE1 & 6PE2 Configuration



```
ipv6 cef
```

```
interface loopback0  
ip address 200.10.10.1 255.255.255.0
```

```
router bgp  
neighbor 2001:f00d:1::1 remote-as 65014  
neighbor 200.11.11.1 remote-as 100  
neighbor 200.11.11.1 update-source lo0
```

```
address-family ipv6  
neighbor 200.11.11.1 activate  
neighbor 200.11.11.1 send-label
```

```
ipv6 cef
```

```
interface loopback0  
ip address 200.11.11.1 255.255.255.0
```

```
router bgp  
neighbor 2001:db8:1::1 remote-as 65015  
neighbor 200.10.10.1 remote-as 100  
neighbor 200.10.10.1 update-source lo0
```

```
address-family ipv6  
neighbor 200.10.10.1 activate  
neighbor 200.10.10.1 send-label
```



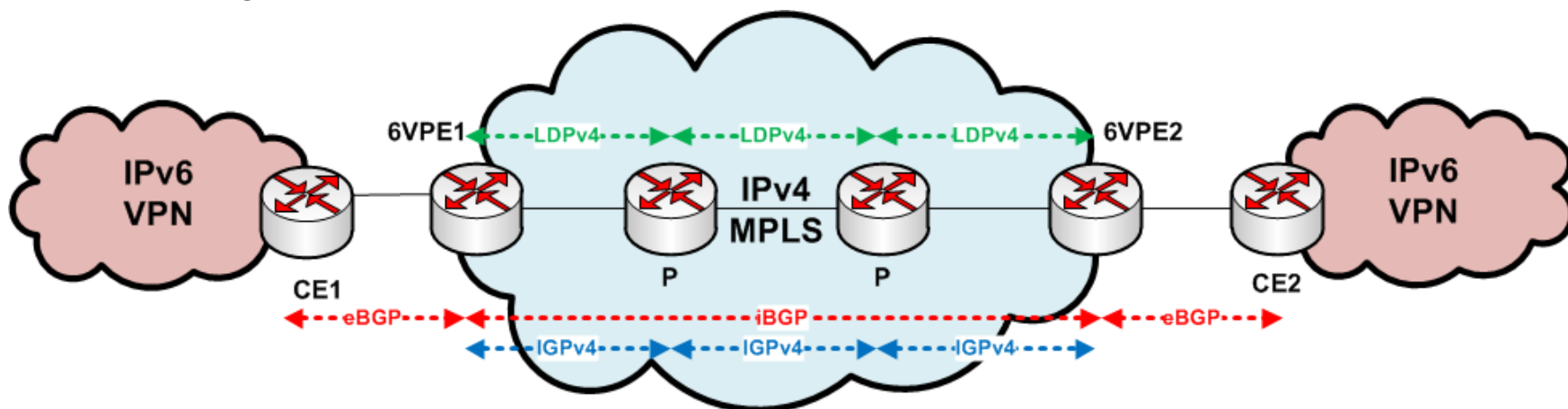
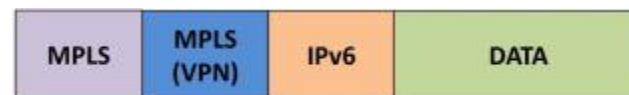
6VPE 1/5

■ RFC 4659

- BGP-MPLS IP Virtual Private Network (VPN) Extension for IPv6 VPN

■ Features

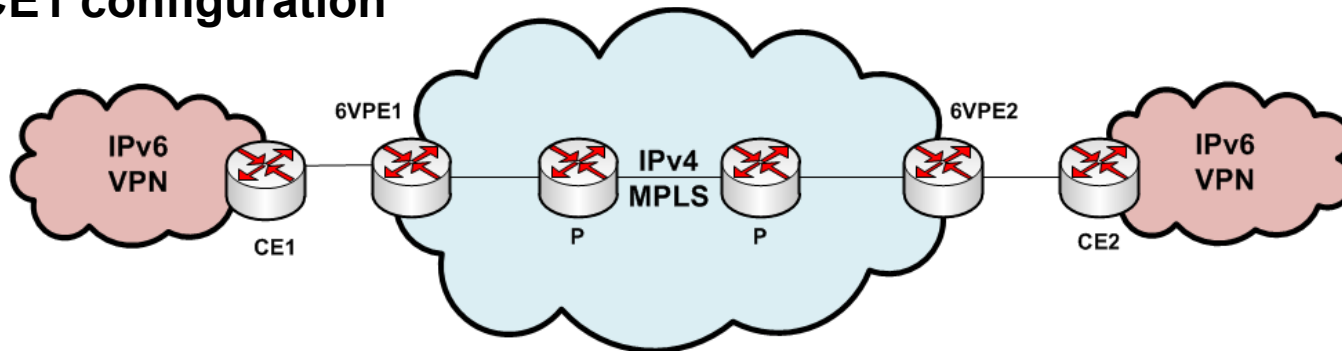
- IPv6 VPN provisioning over IPv4/MPLS
- Edge devices (6VPE) must support dual-stack
- Same MPLS VPN features as for IPv4
 - VRF, RT, RD
 - MP-NGP
- Mainly used in enterprises



6VPE 2/5

■ Connecting remote IPv6 VPN LANs

■ CE1 configuration



```
ipv6 unicast-routing
ipv6 cef

interface Ethernet0/0
description To the ISP
ip address 172.16.1.1 255.255.255.0
ipv6 address 2001:db8:cafe:1::1/64

interface Ethernet1/0
description ipv6VPN
ip address 10.1.1.1 255.255.255.0
ipv6 address 2001:db8:beef:1::1/64
ipv6 rip ipv6VPN enable
```

```
router bgp 500
neighbor 2001:db8:cafe:1::2 remote-as 100
neighbor 172.16.1.2 remote-as 100

address-family ipv4
redistribute eigrp 100
neighbor 172.16.1.2 activate
exit-address-family

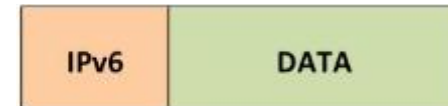
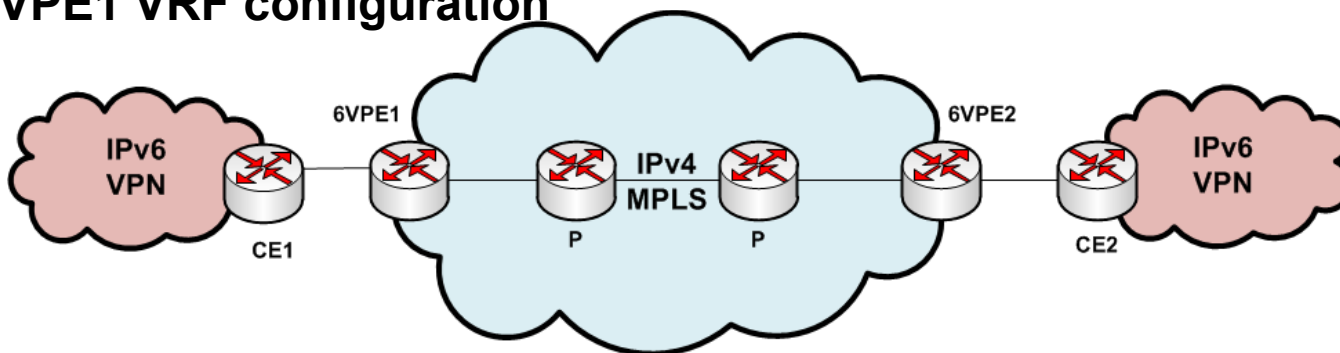
address-family ipv6
neighbor 2001:db8:cafe:1::2 activate
redistribute rip ipv6VPN
exit-address-family
```



6VPE 3/5

■ Connecting remote IPv6 VPN LANs

■ 6VPE1 VRF configuration



```
vrf definition ipv6VPN
  rd 200:1

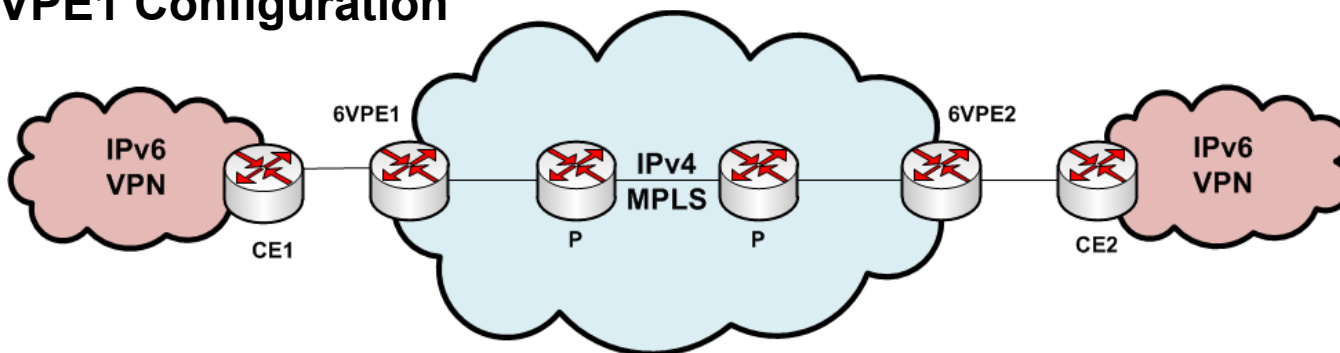
  address-family ipv4
  route-target export 200:1
  route-target import 200:1
  exit-address-family

  address-family ipv6
  route-target export 200:1
  route-target import 200:1
  exit-address-family
```

6VPE 4/5

■ Connecting remote IPv6 VPN LANs

■ 6VPE1 Configuration



IPv6

DATA

MPLS

MPLS
(VPN)

IPv6

DATA

IPv6

DATA

```
ipv6 unicast-routing
ipv6 cef
```

```
interface Loopback0
ip address 200.10.10.1 255.255.255.255
```

```
interface Ethernet0/0
description To the ipv6VPN on CE1
ip address 172.16.1.2 255.255.255.0
ipv6 address 2001:db8:cafe:1::2/64
```

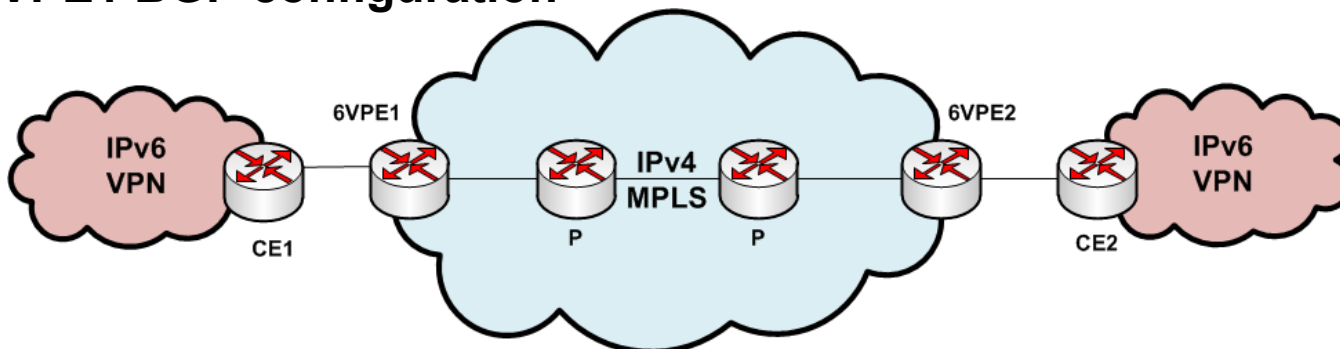
```
interface Ethernet2/0
description To the ISP
ip address 192.168.1.1 255.255.255.252
mpls ip
```

```
router ospf 1
log-adjacency-changes
redistribute connected subnets
passive-interface Loopback0
network 192.168.1.0 0.0.0.255 area 0
```

6VPE 5/5

■ Connecting remote IPv6 VPN LANs

■ 6VPE1 BGP configuration



```
router bgp 100
neighbor 200.11.11.1 remote-as 100
neighbor 200.11.11.1 update-source lo0
```

```
address-family ipv4
neighbor 200.11.11.1 activate
no auto-summary
no synchronization
exit-address-family
```

```
address-family vpnv4
neighbor 200.11.11.1 activate
neighbor 200.11.11.1 send-community ext
exit-address-family
```

```
address-family vpnv6
neighbor 200.11.11.1 activate
neighbor 200.11.11.1 send-community ext
exit-address-family
```

```
address-family ipv4 vrf ipv6VPN
redistribute connected
neighbor 172.16.1.1 remote-as 500
neighbor 172.16.1.1 activate
exit-address-family
```

```
!
address-family ipv6 vrf ipv6VPN
neighbor 2001:db8:cafe:1::1 remote-as 500
neighbor 2001:db8:cafe:1::1 activate
exit-address-family
```

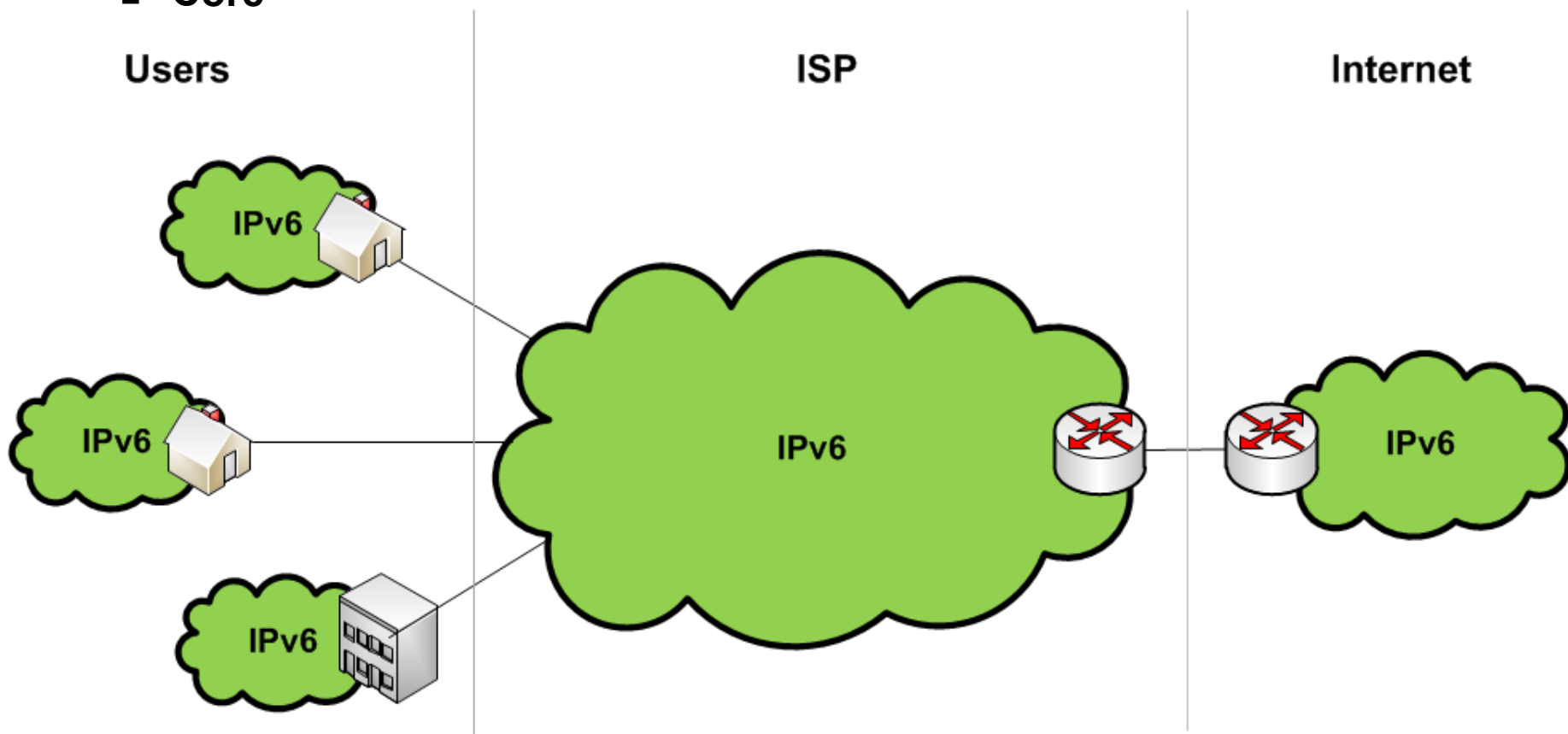



Operator & ISP networks



Goal

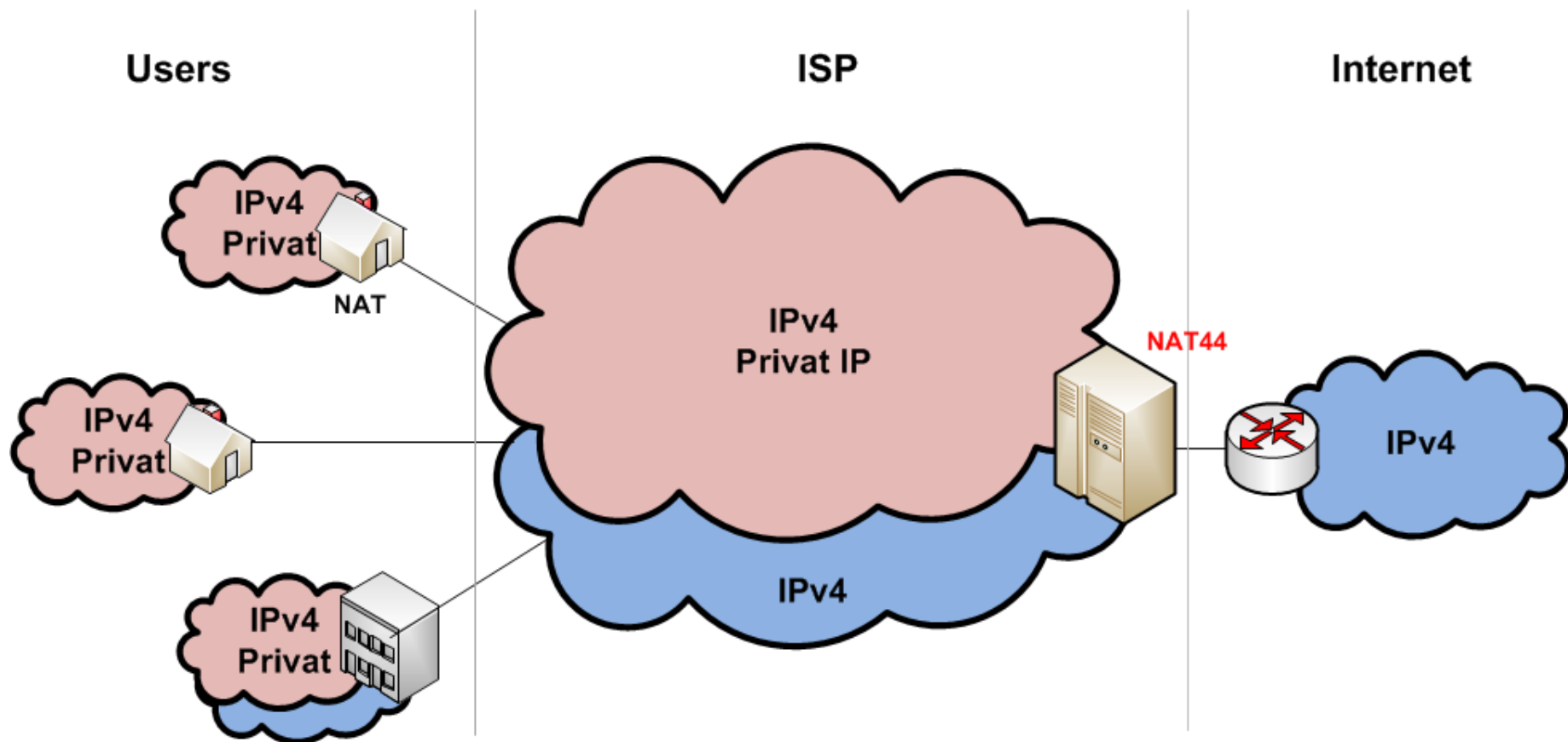
- Native IPv6
 - Access
 - Aggregation
 - Core





Access 1/4

- NAT 44 (Large Scale NAT)
 - Holding on to IPv4

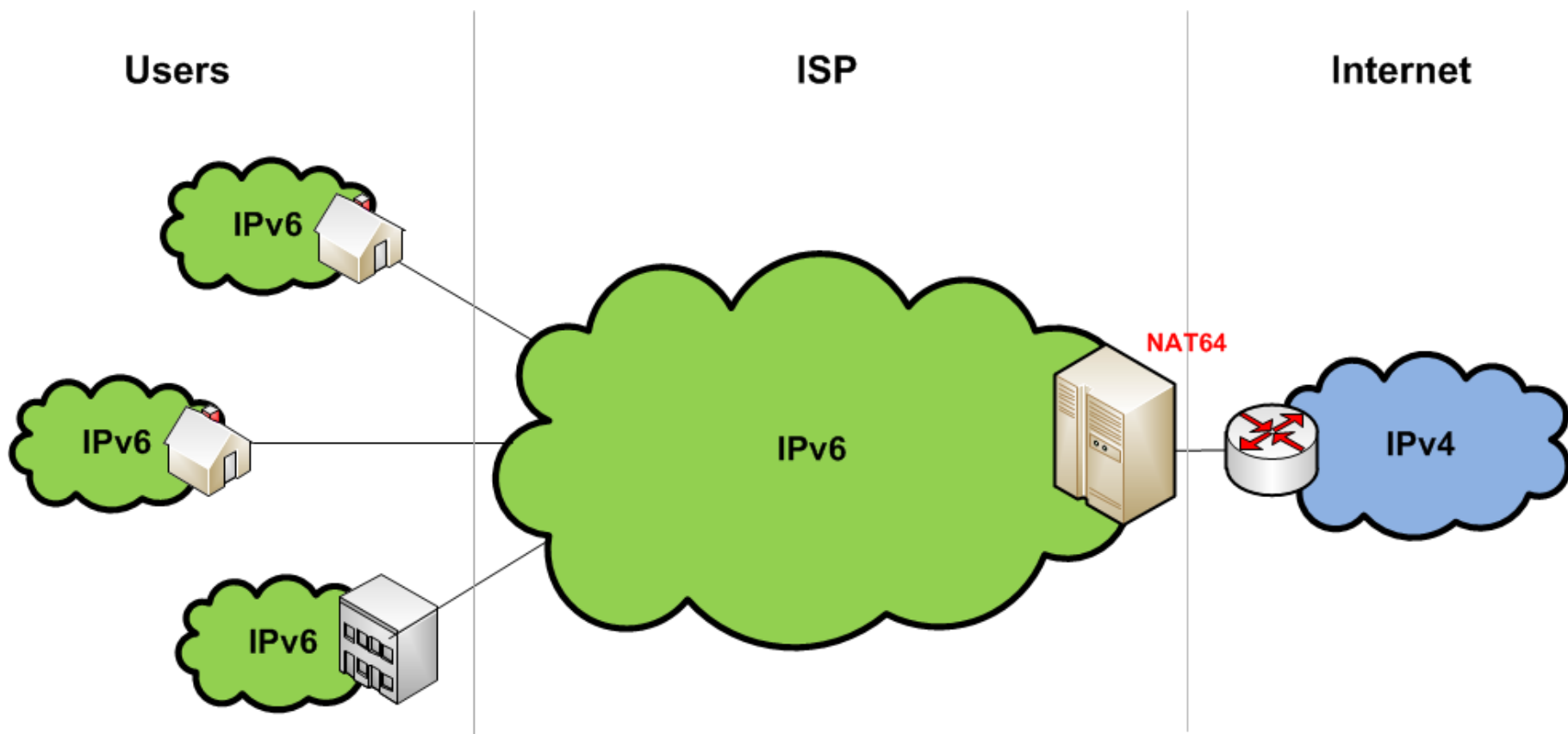




Access 2/4

■ NAT64

- AFT – Address Family Translation
- Stateless NAT64
 - Cisco

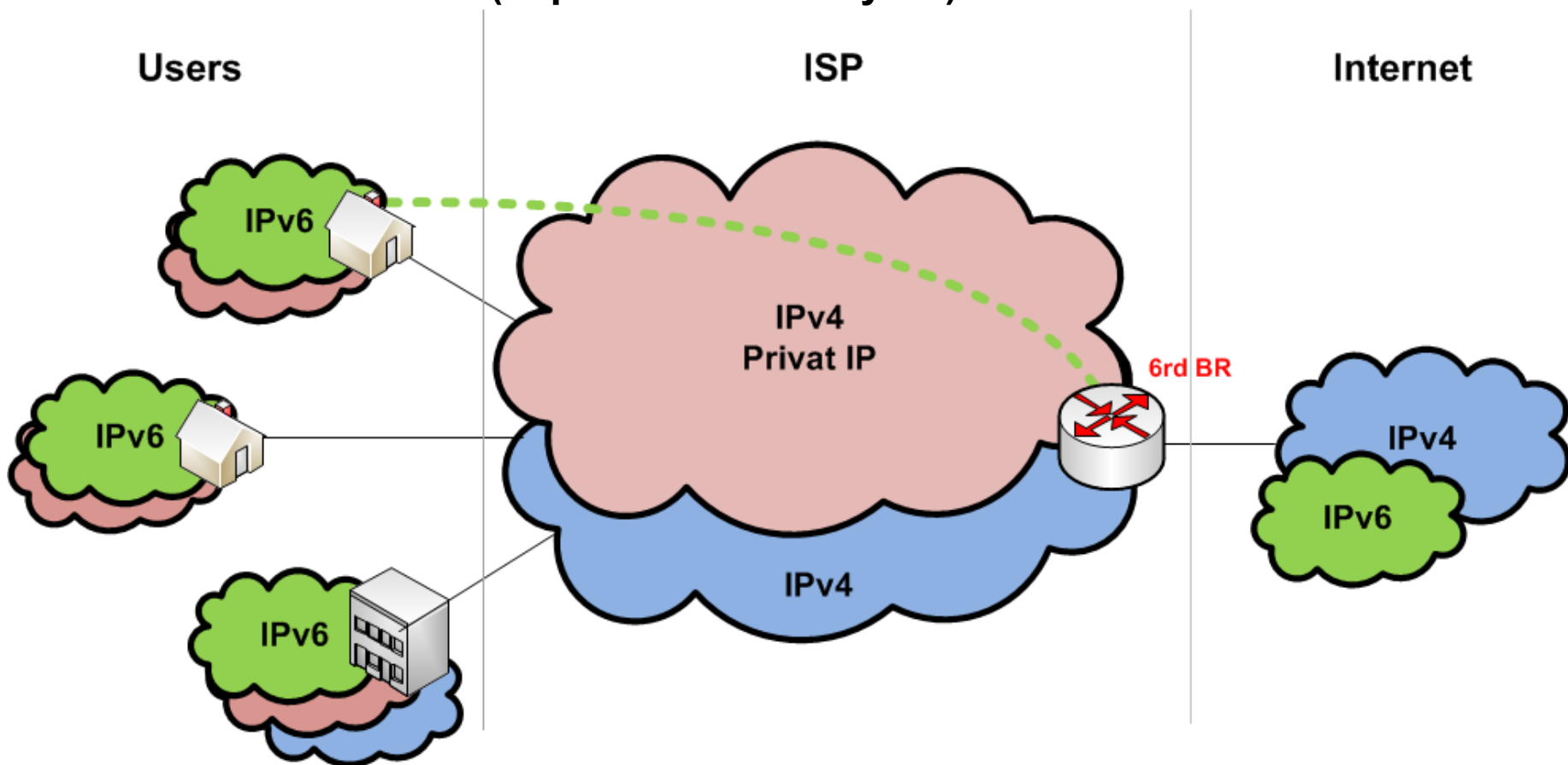




Access 3/4

■ 6rd

- IPv6 Rapid Deployment
- Swiss Telecom (in production this year)



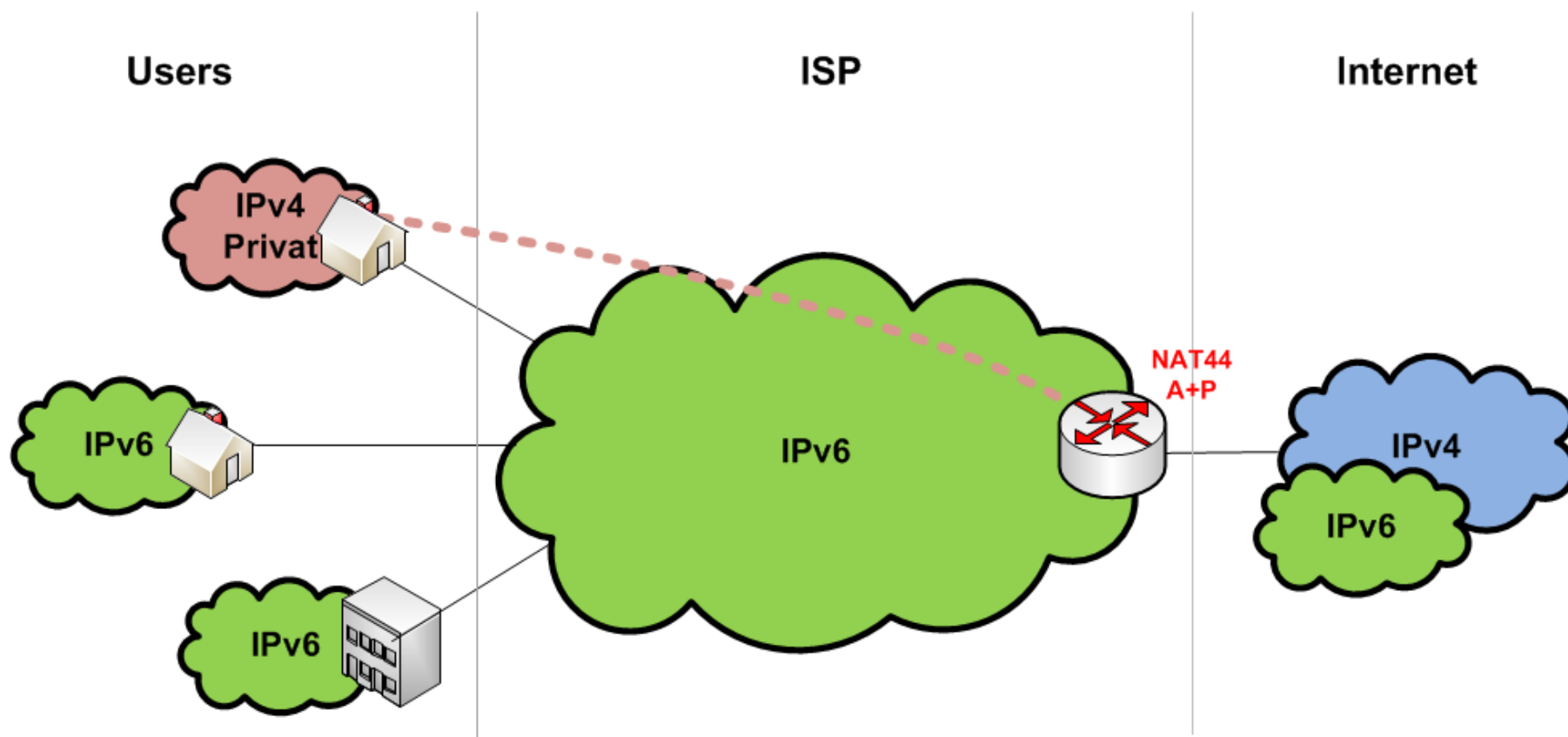


Access 4/4

■ DS-Lite

■ Dual-Stack Lite

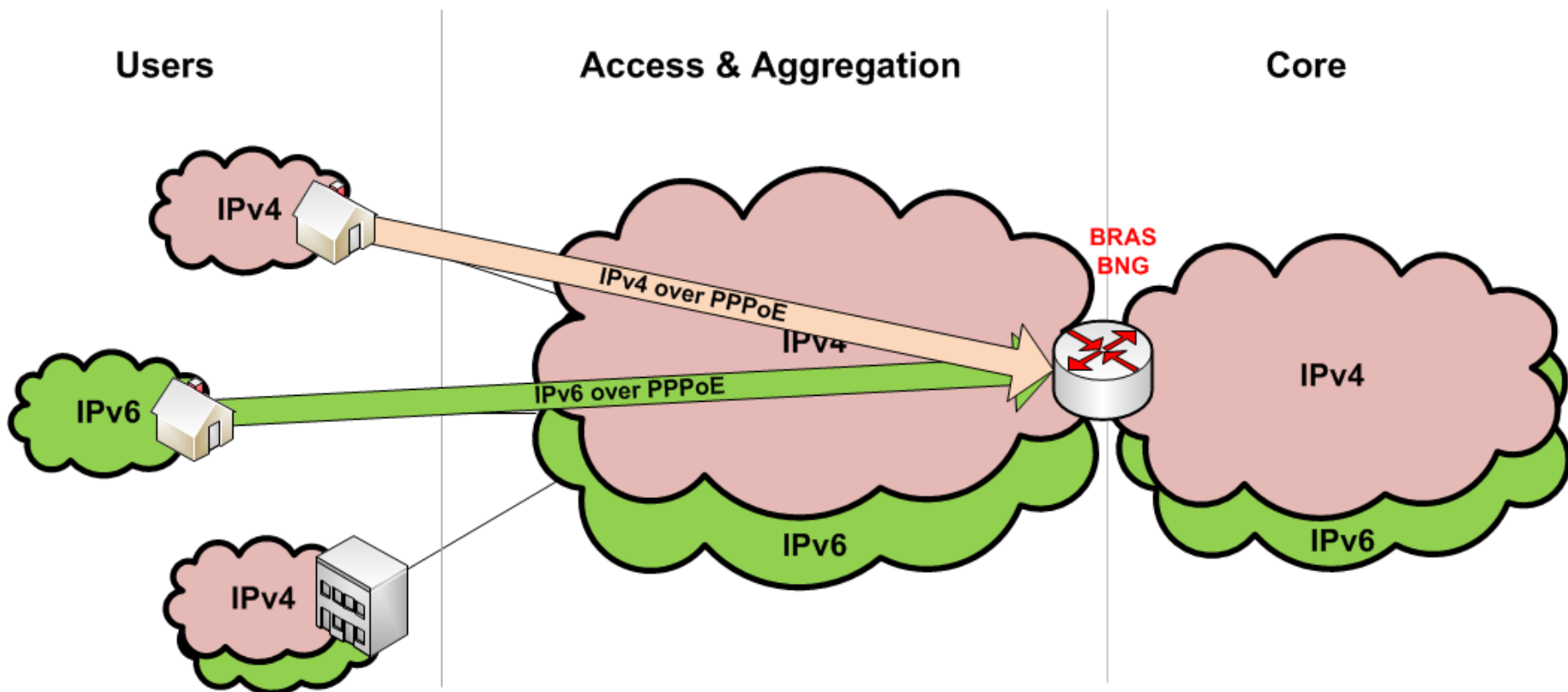
- NAT 44
- A+P





Access - PPPoE 1/3

- RFC 2472
 - IP version 6 over Point to Point Protocol (PPP)
- PPPoE
 - PPP over Ethernet





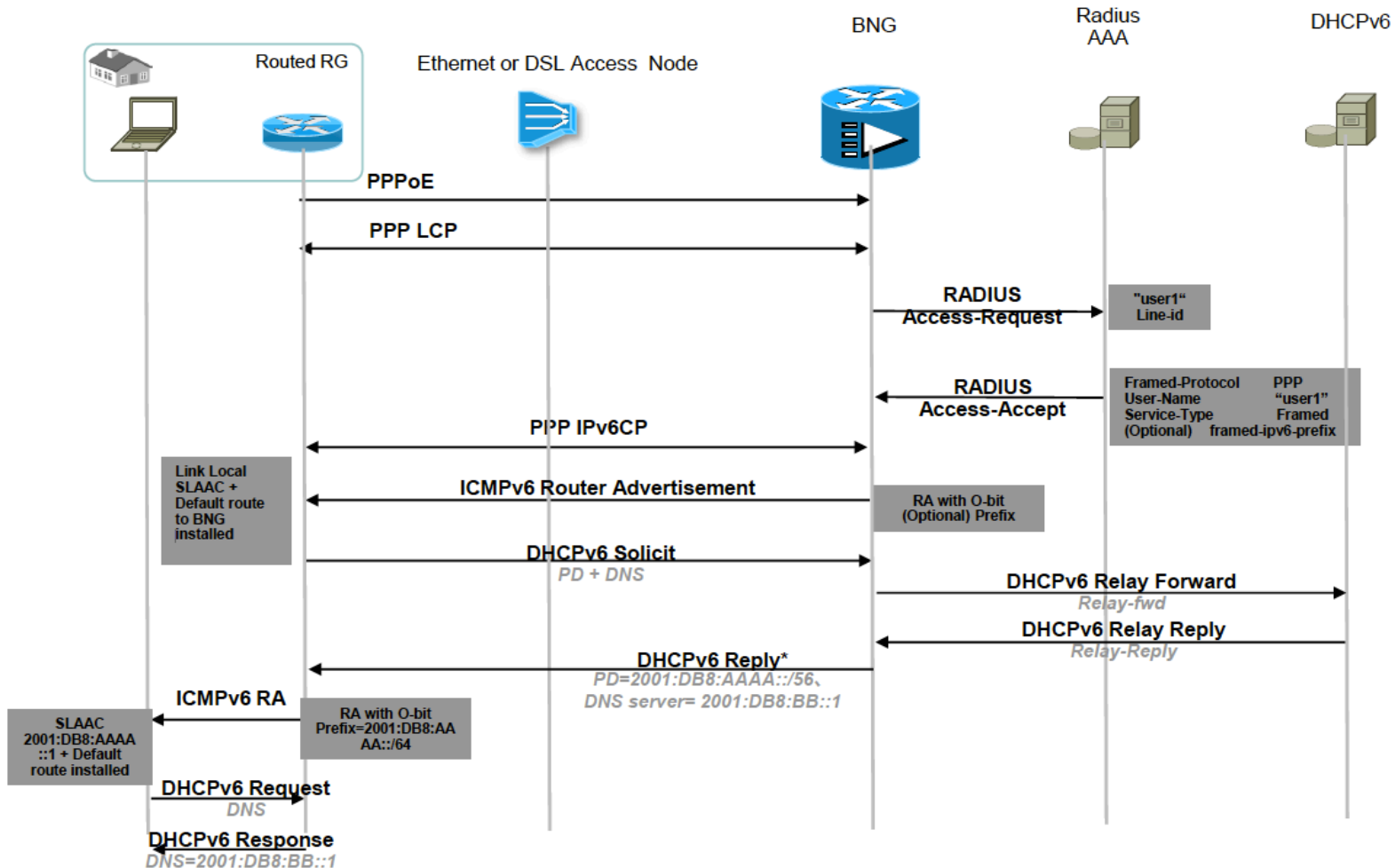
Access - PPPoE 2/3

- **IPv6 over PPPoE**
 - Lack of CPEs that support IPv6 over PPPoE
- **CPE**
 - Dual-stack IPv4/IPv6
- **Access and aggregation**
 - No upgrade required
- **Core**
 - IPv4/IPv6
- **Addressing subscriber devices**
 - SLAAC (Stateless Address Autoconfiguration)
 - DHCPv6-PD



Access - PPPoE 3/3

Basic authorization and DHCP-PD

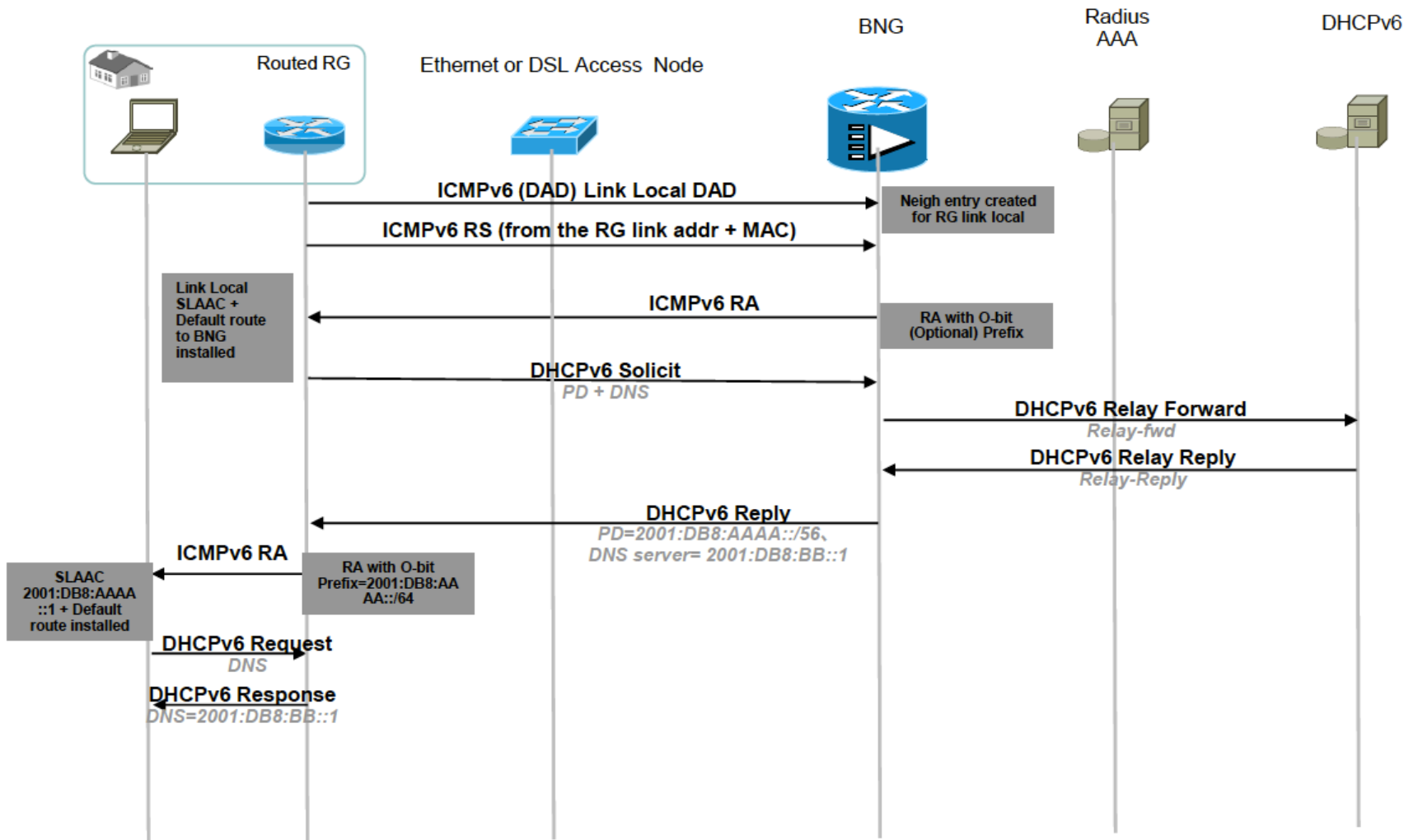


Source: Cisco



Access - IPv6oE 1/2

■ 1:1 VLAN + DHCP-PD

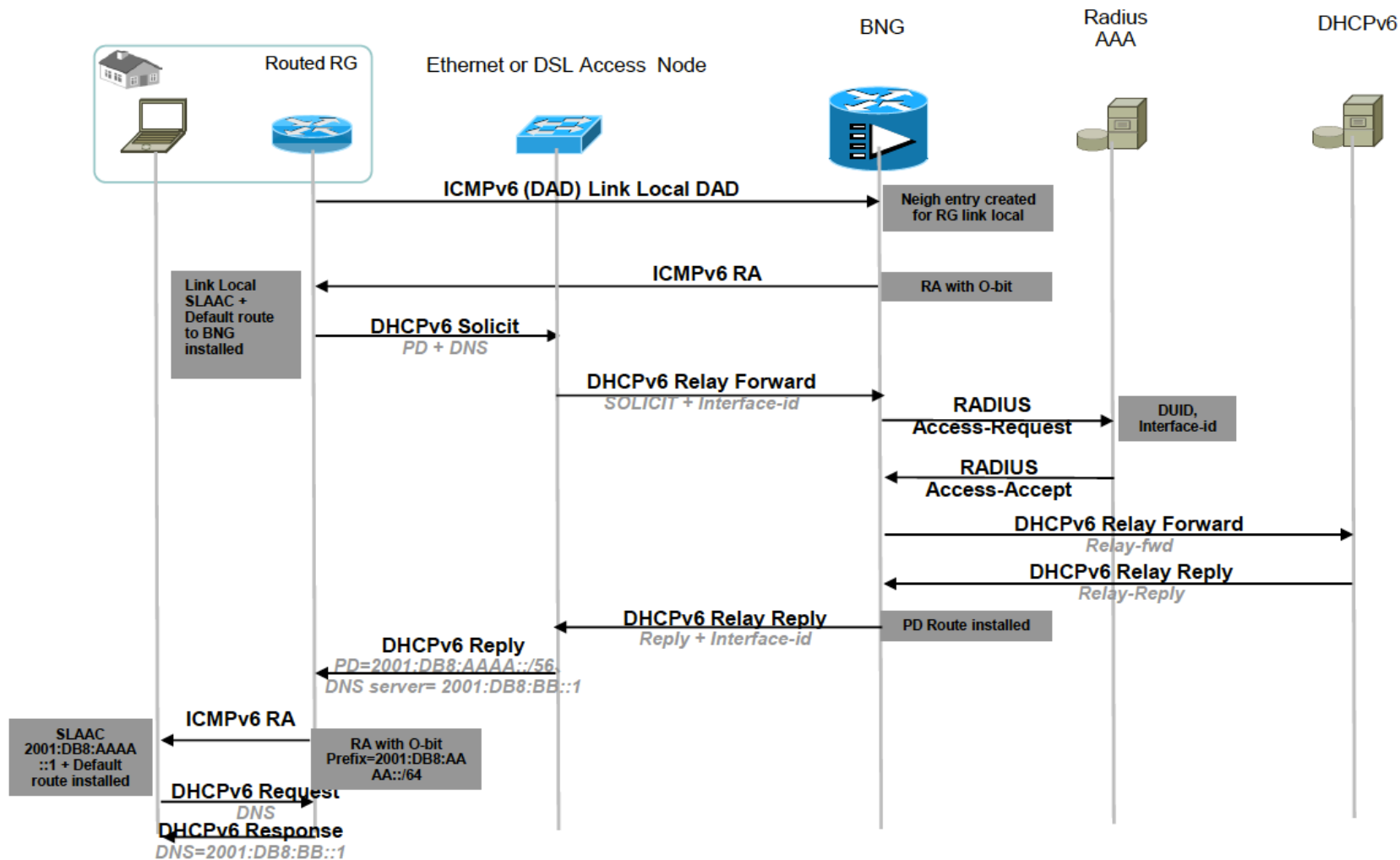


Source: Cisco



Access - IPv6oE 2/2

■ N:1 VLAN + DHCP-PD + AAA

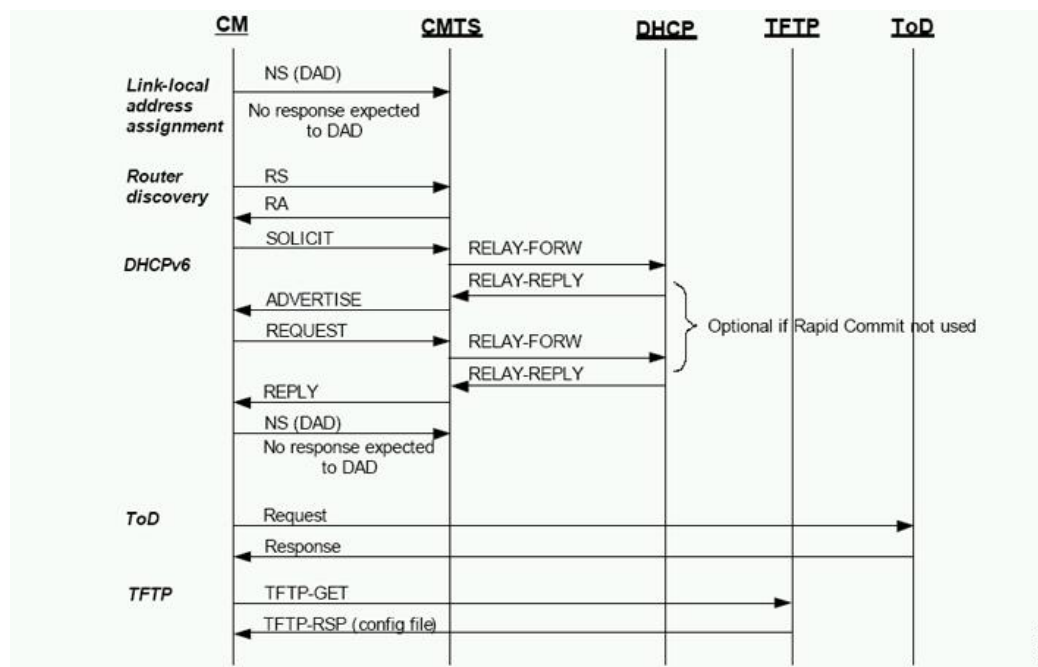


Source: Cisco



Cable Access

- IPv6 in cable networks exists for some time now
 - Lack of IPv4 private address space IPv4 (big cable operators)
- DOCSIS 3.0
 - IPv6 on CM (Cable Modem)
 - IPv6 on CMTS (Cable Modem Termination System)
 - IPv6 on terminal devices
 - Addressing
 - SLAAC
 - DHCPv6





Core 1/3

■ IPv4

- Separated IPv6 network (new devices)
- IPv6 tunneling
 - IPv6 over IPv4 (RFC 2893)
 - GRE (RFC 2473)
 - L2TPv3
- Dual-stack core devices
 - Careful planning with network resources!

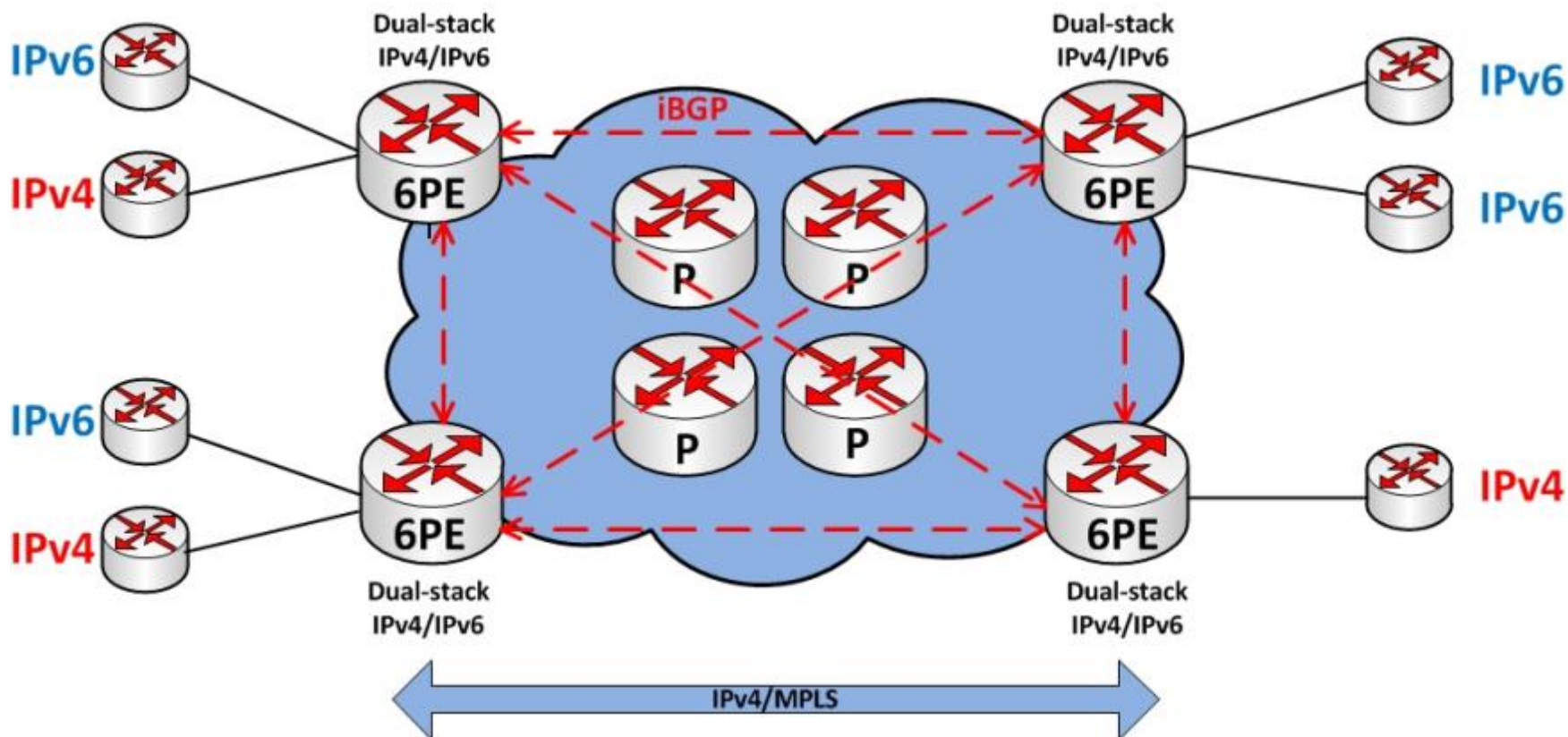
■ MPLS

- “Native” IPv6 MPLS
 - Poor support
- IPv6 over AToM (Any Transport over MPLS)
- IPv6 provider edge router (6PE) over MPLS
- IPv6 VPN provider edge (6VPE) over MPLS



Core 2/3

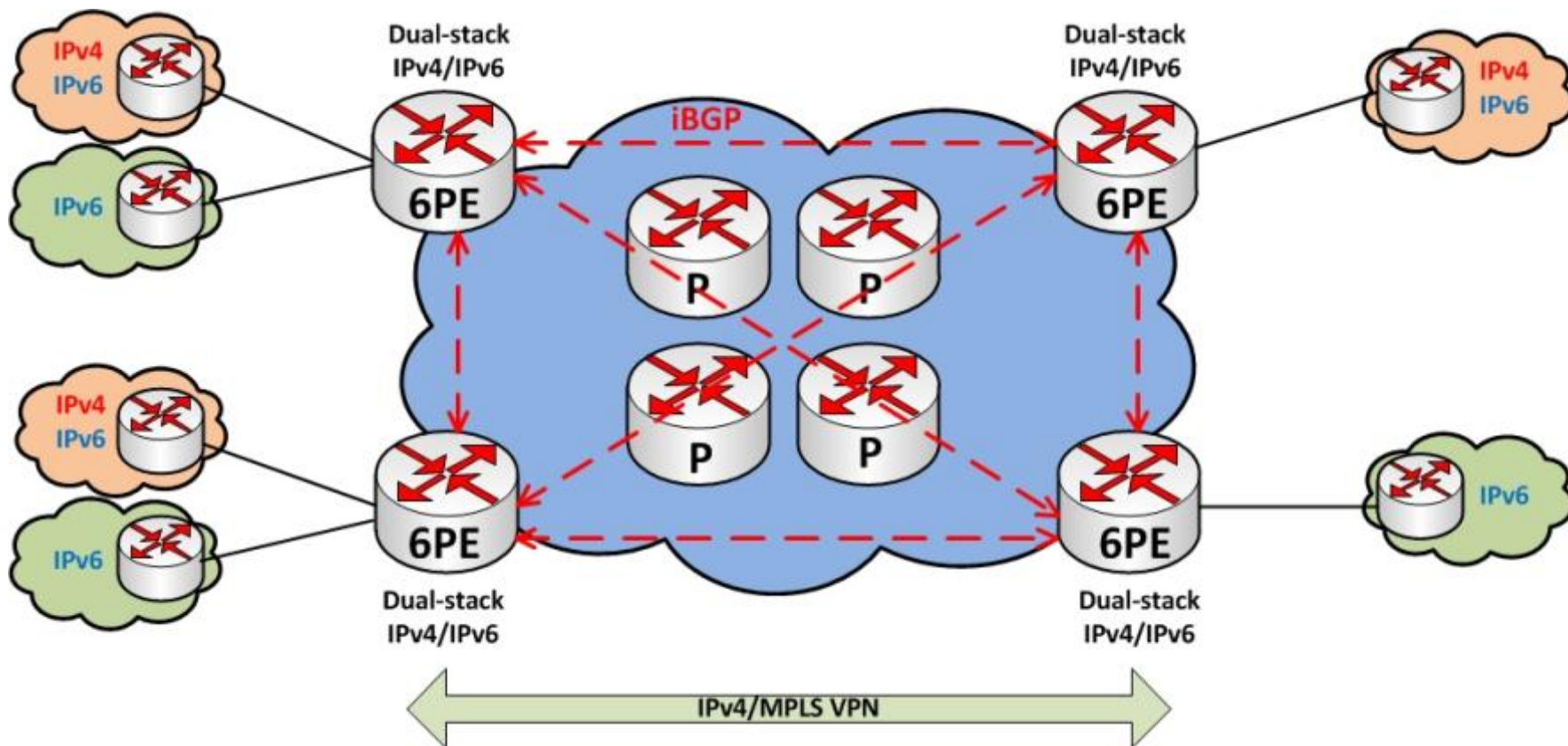
- IPv6 Provider Edge Router (6PE) over MPLS
 - Edge devices (PE) are “dual-stack”, core remains IPv4/MPLS





Core3/3

- IPv6 VPN provider edge (6VPE) over MPLS
 - BGP/MPLS VPN + 6PE ☺
 - Core remains IPv4/MPLS





Thank you!
