Advanced IPv6

Training Course

Schedule

09:00 - 09:30	**Coffee, Tea**
11:00 - 11:15	**Break**
13:00 - 14:00	**Lunch**
15:30 - 15:45	**Break**
17:30	**End**

Introductions

- **Name**

- **Number in the list**

- **Experience with IPv6, Cisco, OSPF, BGP**

- **Goals**

Overview Day 1

- **IPv6 Packets**

- **IPv6 Routing Basics**

- **Exercise: Enable IPv6**

- **OSPFv3**

- **Exercise: Configuring OSPFv3**

- **BGP**

- **Exercise: Configuring BGP**

- **Content**

Overview Day 2

- **Mobile Providers**

- **Exercise: SLAAC**

- **DHCPv6**

- **Exercise: DHCPv6**

- **Security**

- **Exercise: 6rd**

- **IP Address Management**

- **Tips & Tricks**

IPv6 Packets

1 - Section

IPv6 Header Format

- **Fixed length**

  - Optional headers are daisy-chained

- **IPv6 header is twice as long (40 bytes) as IPv4 header without options (20 bytes)**

IPv6 Header

IPv4 Header

Version	IHL	Type of Service	Total Length
Identification		Flags	Fragment Offset
Time to Live	Protocol	Header Checksum
Source Address
Destination Address
Options	Padding

IPv6 Header

| Version | Traffic Class | Flow Label |
| Payload Length | Next Header | Hop Limit |
| Source Address |
| Destination Address |
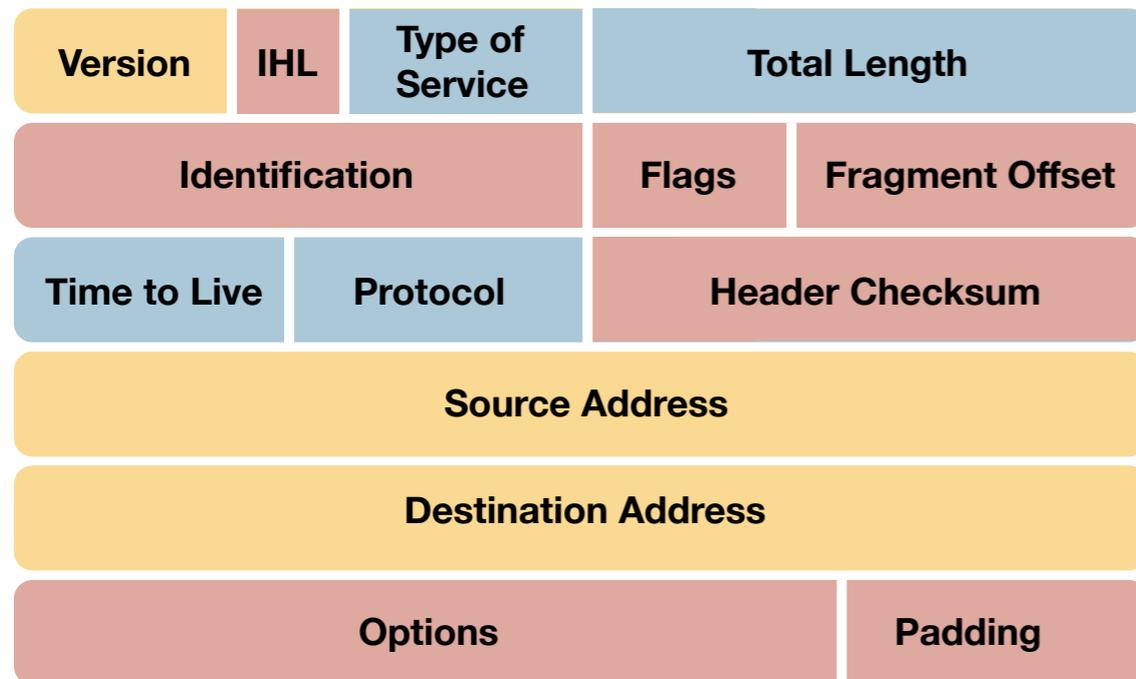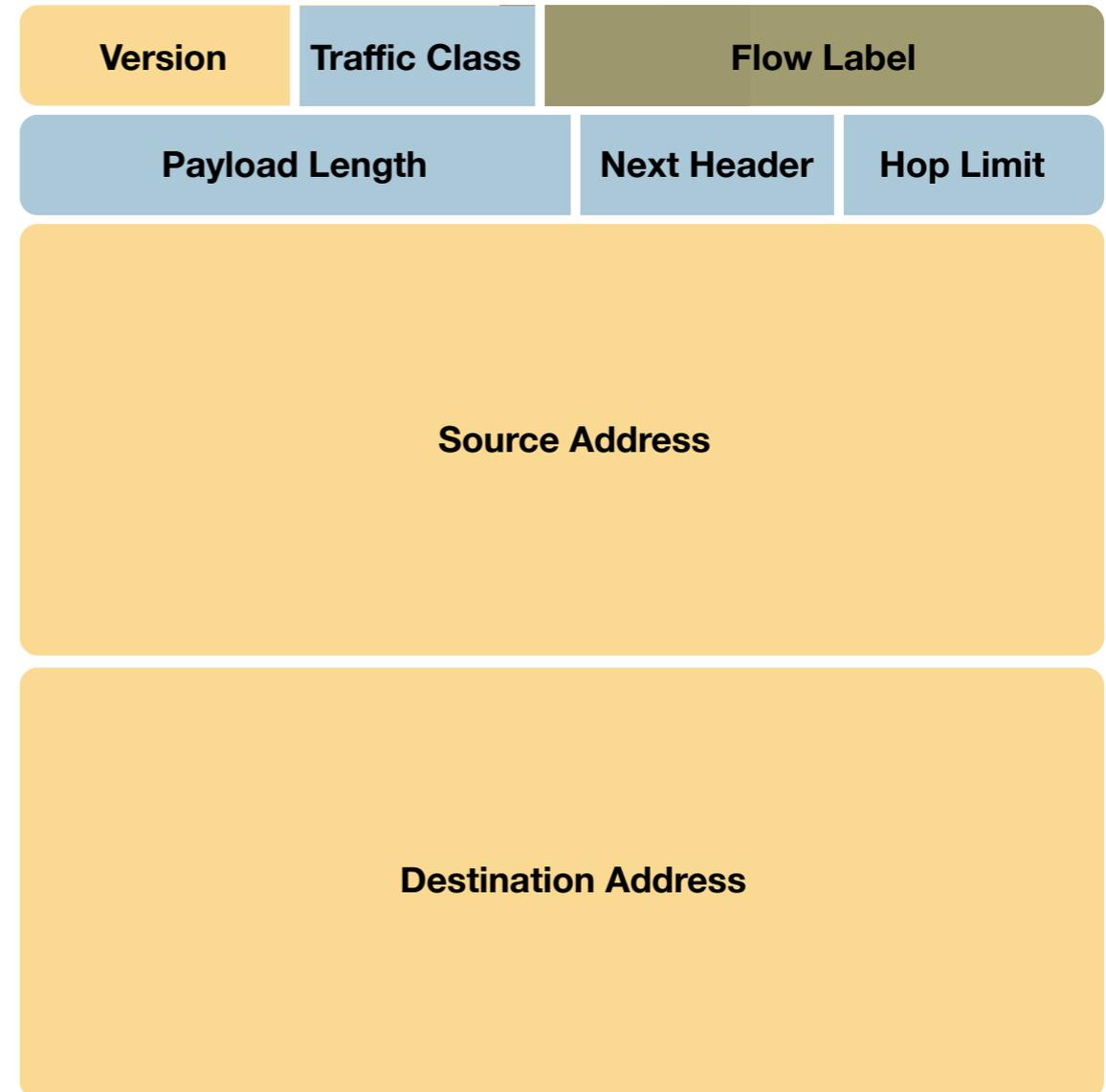
LEGEND

- Field's name kept from IPv4 to IPv6
- Field not kept in IPv6
- Name and position changed in IPv6
- New field in IPv6

8

IPv6 Header

- Optional fields go into extension headers
- Daisy-chained after the main header

IPv6 Header —————— Next Header: TCP	TCP Header	Data

IPv6 Header —————— Next Header: Routing	Routing Header —————— Next Header: TCP	TCP Header	Data

IPv6 Header —————— Next Header: Routing	Routing Header —————— Next Header: Fragment	Fragment Header —————— Next Header: TCP	TCP Header	Data
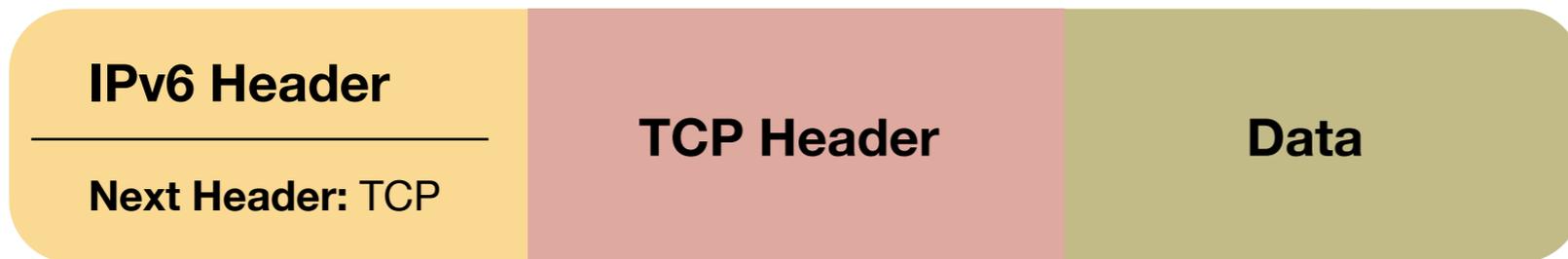
Common Headers

- **Common values of Next Header Fields:**

  - 0   Hop-by-hop option (extension)

  - 6   TCP (payload)

  - 17   UDP (payload)

  - 43   Routing (extension)

  - 44   Fragmentation (extension)

  - 50   Encrypted Security Payload (extension)

  - 58   ICMPv6

Fragmentation

- **Routers don't fragment packets with IPv6**

  - More efficient handling of packets in the core

  - Fragmentation is being done by host

- **If a packet is too big for next hop:**

  - "Packet too big" error message

  - This is an ICMPv6 message

  - Filtering ICMPv6 causes problems

Path MTU Discovery

- **A sender who gets this "message-too-big" ICMPv6 error tries again with a smaller packet**

  - A hint of size is in the error message

  - This is called Path MTU Discovery

MTU
1500

MTU
1492

MTU
1280

MTU
1500

Web Server
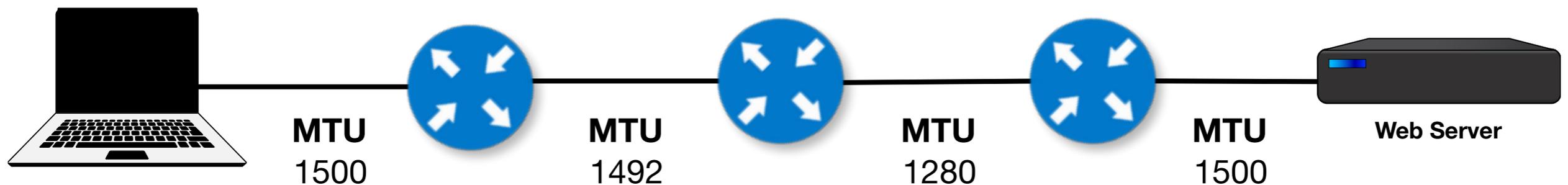
Ordering of Headers

- **Order is important:**

  - Only hop-by-hop header has to be processed by every node

  - Routing header needs to be processed by every router

  - Fragmentation has to be processed before others at the destination

Broadcast

- **IPv6 has no broadcast**

- **There is an "all nodes" multicast group**

  - ff02::1

- **Disadvantages of broadcast:**

  - It wakes up all nodes

  - Only a few devices are involved

  - Can create broadcast storms

Neighbor Discovery

- **IPv6 has no ARP**

- **Replacement is called Neighbor Discovery**

  - Uses ICMPv6

  - Uses Multicast

- **Every ARP request wakes up every node**

- **Each ND request only wakes up a few nodes**

Neighbor Discovery

- **ND is used by nodes:**

  - For address resolution

  - To find neigboring routes

  - To track address changes

  - To check neighbor reachability

  - To do Duplicate Address Detection

- **ND uses 5 different ICMPv6 packet types**

Neighbor Discovery Protocol

- **Router Solicitation**
  - When an interface becomes active, the host will send out Router Solicitations that request routers to send out a Router Advertisement immediately

Is there a router?
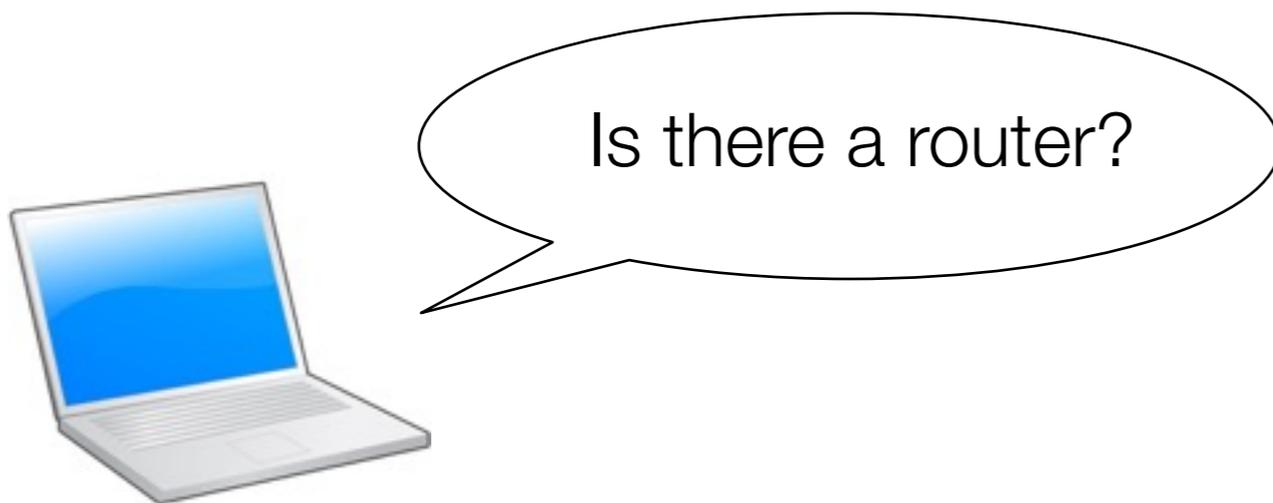
Neighbor Discovery Protocol

- **Router Advertisement**

  - Routers advertise their presence periodically or in response to a Router Solicitation message

  - Has a lot of important information for the host

Yes, I am here!
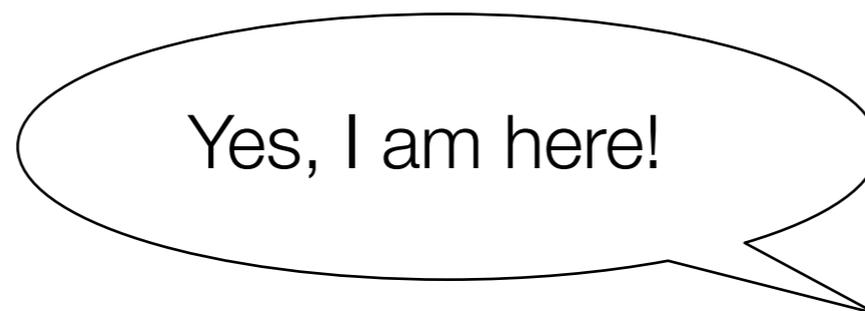
Neighbor Discovery Protocol

- **Neighbor Solicitation**
  - Sent by a node to find the MAC-address of the neighbor, or to check if the neighbor is still reachable

Are you still there?
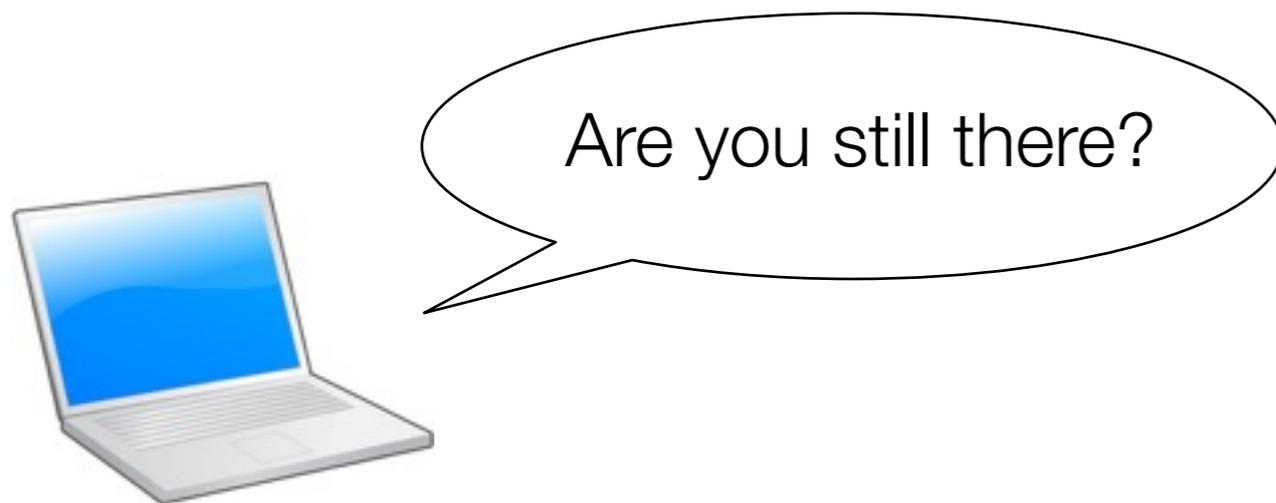
Neighbor Discovery Protocol

- **Neighbor Advertisement**

  - A response to a neighbor solicitation message

Yes, I am still here!

Neighbor Discovery Protocol

- **Redirect**
  - A router points the host to a better first hop router for a destination

You can better go see that guy over there!

Questions

IPv6 Routing Basics

2 - Section

IPv6 Routing Basics

- **IPv6 routing is the same as IPv4 routing**

  - Longest matching prefix

  - Same structure and concepts

  - Some technical differences

Longest Matching Prefix

- **Example routing table:**

Route	Next-Hop
::/0	2001:db8:aaa:bbb::cdef:1
2001:db8::/32	2001:db8:bcd:aaa::1
2001:db8::/48	2001:db8:cde:bbb::1
2001:db8:1000::/36	2001:db8:ffff:eeee::1
2001:db8:1000::/48	2001:db8:def:bbb::1
2001:db8:2000::/48	2001:db8:def:bbb::2

Longest Matching Prefix

- **Matches for a packet with destination:**

  2001:db8:2000:1a2b:02ab:9eff:fe01:f5b1

Route	Next-Hop
::/0	**2001:db8:aaa:bbb::cdef:1**
2001:db8::/32	**2001:db8:bcd:aaa::1**
2001:db8::/48	2001:db8:cde:bbb::1
2001:db8:1000::/36	2001:db8:ffff:eeee::1
2001:db8:1000::/48	2001:db8:def:bbb::1
2001:db8:2000::/48	**2001:db8:def:bbb::2**

Longest Matching prefix

- **Matches for a packet with destination:**

  2001:db8:2001:1a2b:02ab:9eff:fe01:f8b2

Route	Next-Hop
::/0	**2001:db8:aaa:bbb::cdef:1**
2001:db8::/32	**2001:db8:bcd:aaa::1**
2001:db8::/48	2001:db8:cde:bbb::1
2001:db8:1000::/36	2001:db8:ffff:eeee::1
2001:db8:1000::/48	2001:db8:def:bbb::1
2001:db8:2000::/48	2001:db8:def:bbb::2

Longest Matching Prefix

- **Matches for a packet with destination:**

  2001:db8:1001:1a2b:02ab:92ff:fe01:f8b2

Route	Next-Hop
::/0	**2001:db8:aaa:bbb::cdef:1**
2001:db8::/32	**2001:db8:bcd:aaa::1**
2001:db8::/48	2001:db8:cde:bbb::1
2001:db8:1000::/36	**2001:db8:ffff:eeee::1**
2001:db8:1000::/48	2001:db8:def:bbb::1
2001:db8:2000::/48	2001:db8:def:bbb::2

Summary

- **IPv6 routing uses the same structure as IPv4 routing**

    - Addresses are longer

    - Prefixes are longer

Questions

Add IPv6 to Loopback & Links

3 - Exercise

Discover the IPv4 Network

- **Make sure you have connectivity**

- **Go to: workbench.ripe.net**

- **Your login is your number on the attendee list**

- **We will provide you with the password**

- **Read instructions carefully**

- **First discover, then configure**

Discover the IPv4 Network

- **Routing Protocol**

  - IGP (OSPF) is used for loopback addresses and point-to-point links

  - EGP (BGP) is used for the edge core routers

- **R1 announces a default route via OSPF**

- **Keeps routing tables in the area smaller**

  - All inter-area traffic must pass R1

Network Diagram
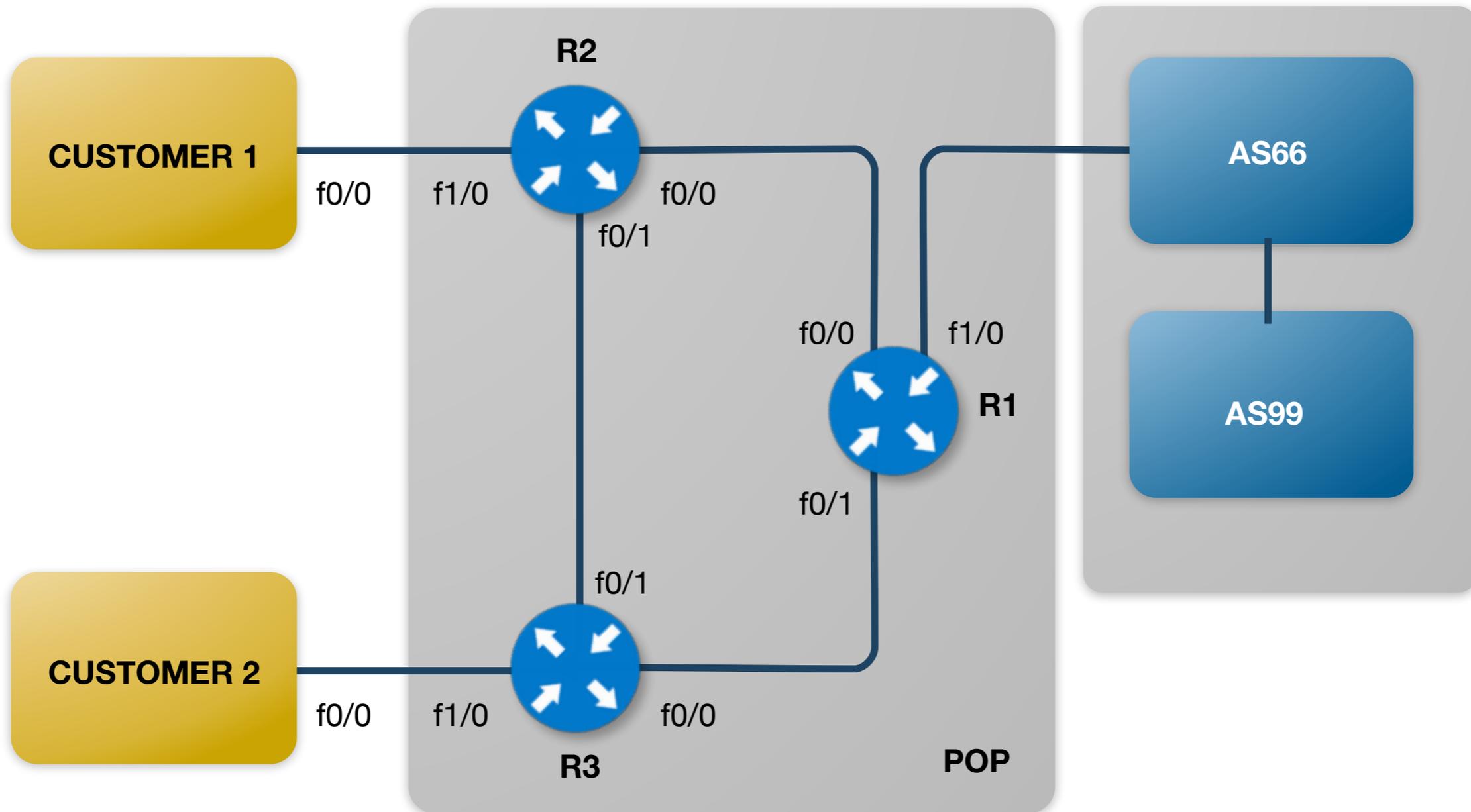
Adding IPv6 to the Network

- **We will now add IPv6 to our existing network**

- **We will not change the network structure**

- **First step: Addressing Structure**

- **Find the addresses on the handout**

Addressing with IPv6

Where X is your number on the attendee list!

- **Loopbacks:**

  - There is a /32 (IPv4): 172.X.255.Y(router number)

  - Use a /128 (IPv6) 2001:ffXX::Y(router number)/128

- **Point-to-point core:**

  - There is a /30 (IPv4) from 10.X.0.0/24

  - Use a /127 from 2001:ffXX::/60 for core links

  - Use a /64 from 2001:ffXX::/60 for the customer links

Interface IPv6 Settings Routers

- **Disable Router Advertisements**

  - On point-to-point interfaces

  - On LANs where unprepared devices are connected

- **Otherwise they will suddenly be globally reachable over IPv6 without being configured, prepared and/ or protected**

Basic IPv6 Settings

- **Before configuring IPv6 on your router interfaces, the basic IPv6 settings need to be set up on the router**

- **For R1, R2, R3 and the Customers**

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

Interface IPv6 Settings Routers

- Use the information in the handouts

- Give the correct IPv6 addresses to the interfaces

- Start with the loopback interface

- Then configure the point-to-point links

- Fill in the appropriate interface name, IPv6 address and prefix length

```
interface xyz
 ipv6 address ...
 no ipv6 redirects
 ipv6 nd ra suppress all
```

Interface IPv6 Settings Customers

- Use the information in the handouts

- Give the correct IPv6 addresses to the interfaces

- We don't configure loopback interfaces

- Then configure the point-to-point link

- Fill in the appropriate interface name, IPv6 address and prefix length (/64)

- We don't disable route advertisement

```
interface xyz
 ipv6 address ...
 no ipv6 redirects
```

Interface IPv6 Settings Customers

- We will set a default route for the customers

- This is a manual configuration

- This is not needed if you use SLAAC

```
ipv6 route ::/0 2001:ffXX:0:ff01::b (customer 1)
ipv6 route ::/0 2001:ffXX:0:ff02::b (customer 2)
```

- **XX** is your number on the list

Checking Your Configuration

- **Check your own configuration**

  - Can you ping your own IPv6 loopback address?

  - Can you ping your own side of the point-to-point link?

Questions

OSPFv3

4 - Section

OSPF Characteristics

- **OSPF = Open Shortest Path First**

- **Link State Protocol**

- **OSPFv3 is an implementation of OSPF for IPv6**

- **OSPFv2 (for IPv4) and OSPFv3 run independently on the router**

- **Most OSPFv3 functions are the same as OSPFv2**

OSPF Refresher

- **Link state protocol**

  - Every router has full insight into network topology of the area

  - Routes are sent to other routers using Link State Advertisements (LSAs)

- **Role of Area Border Routers:**

  - Limit the flooding of LSAs to isolate topology changes within the area

OSPF Refresher

External LSA flooding across all areas

LSA flooding within the area

ASBR

External (BGP)

Area 0

ABR

ABR

Area 1

Area 2
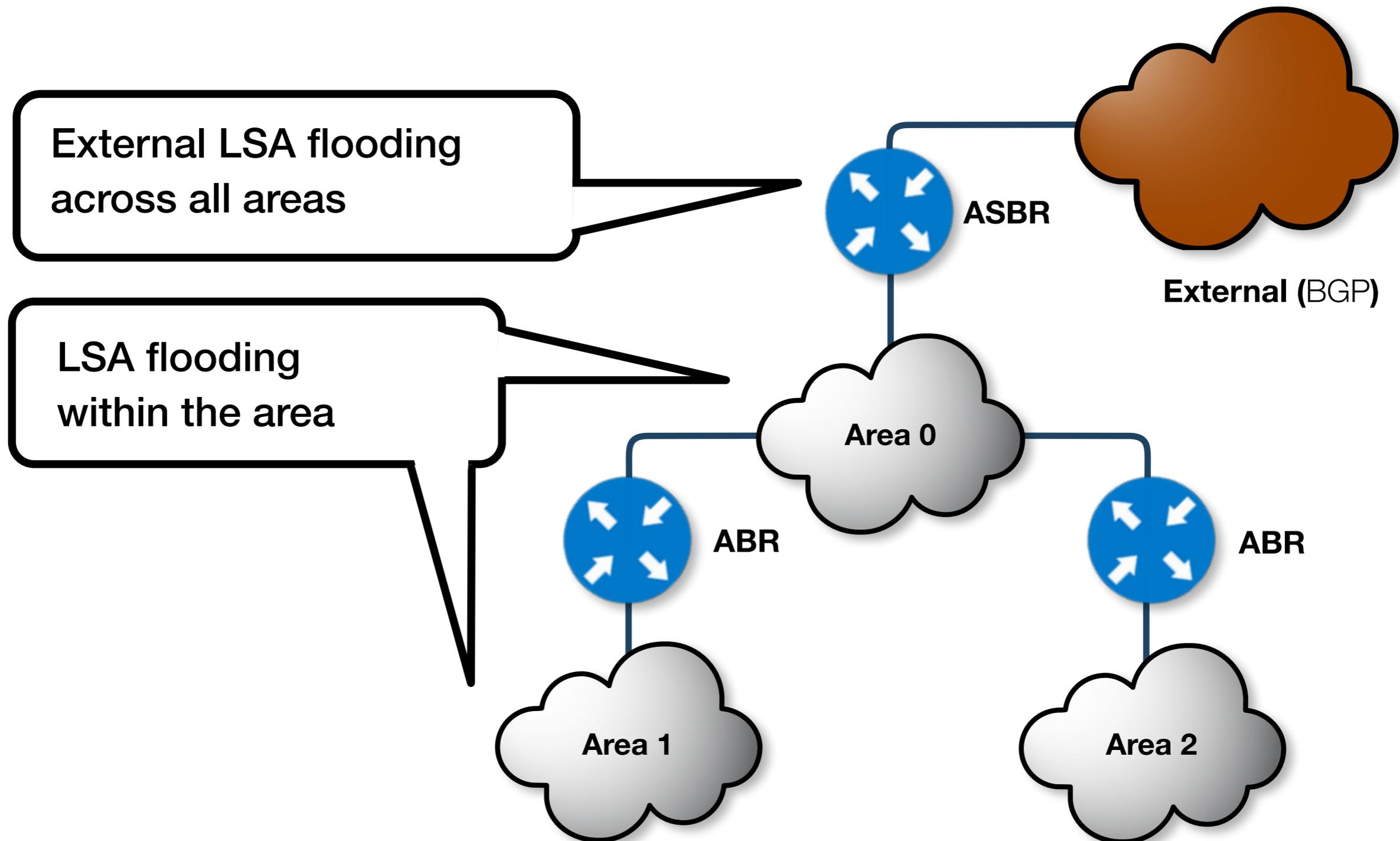
OSPF for IPv6

- **Multiple instances of OSPFv3 can be run on a link**

  - Unlike in OSPFv2

- **OSPFv3 still uses 32-bit numbers as a router ID**

  - If no IPv4 address is configured on any interface, the router ID command is required to set the 32-bit router ID (for IPv6-only networks)

OSPF for IPv6

- **Router ID is a unique identifier for the router**

    - Must be configured in the routing process

    - Is still a 32-bit number, written in 4 octets

    - It is used to sign routing updates

- **But to make your life easy, you can use an IPv4 loopback address**

OSPF for IPv6

- **OSPF for IPv4 (OSPFv2) can be configured:**
  - on each subnet or,
  - on each link

- **OSPF for IPv6 (OSPFv3) can be configured:**
  - on each link

- **Interface mode configuration will automatically activate the OSPF process on your running config**

OSPF for IPv6

- **LSA types and functions in OSPF are almost the same as for OSPFv2**

  - But there is no authentication in OSPFv3

- **OSPFv3 uses multicast addresses:**

  - ff02::5 for All OSPFv3 Routers

  - ff02::6 for All OSPFv3 Designated Routers

- **All OSPFv3 adjacencies are formed using link-local addresses**

  - From fe80::/10 IPv6's link-local address scope

Configuration of OSPF as IGP

- **Example of OSPF for IPv4 per-subnet configuration**

```
router ospf 1
 log-adjacency-changes
 passive-interface default
 network 172.16.1.1 0.0.0.0 area 1
 no passive-interface f0/0
 network 172.16.11.8 0.0.0.3 area 1
 no passive-interface f0/1
 network 172.16.11.0 0.0.0.3 area 1
```

Configuration of OSPF as IGP

- **Example of OSPF for IPv4 per-link configuration**

```
router ospf 1
 log-adjacency-changes
 passive-interface f1/1
 passive-interface f1/0
!
interface loopback 0
 ip ospf 1 area 1
!
interface f0/0
 ip ospf 1 area 1
!
interface f0/1
 ip ospf 1 area 1
!
```

Configuration of OSPF as IGP

- **Example of OSPF for IPv6 per-link configuration**

```
ipv6 router ospf 1
 log-adjacency-changes
 passive-interface f1/0
 passive-interface f1/1
!
interface loopback 0
 ipv6 ospf 1 area 1
!
interface f0/0
 ipv6 ospf 1 area 1
!
interface f0/1
 ipv6 ospf 1 area 1
!
```

Questions

Configuring OSPFv3

5 - Exercise

Overview of IGP Configuration

- **You have to configure OSPFv3 as IGP for IPv6**

- **Dual Stack will be used to ensure both IPv4 and IPv6 operation**

- **OSPFv2 is already set up**

Have a good look…

- **At the IPv4 configuration….**

```
show running-config | s router ospf
```

OSPFv3 Global Settings

- **Tell the router to do OSPFv3 and the process-id**

- **Log adjacency changes**

- **Set a router ID**

- **Define passive interface**

```
ipv6 router ospf 1
 log-adjacency-changes
 router-id 172.X.255.Y    (Y is router number)
 passive-interface FastEthernet1/0
 passive-interface FastEthernet1/1
 redistribute connected
```

- **On router 1 also add:**

```
ipv6 router ospf 1
 default-information originate always
```

OSPFv3 Interface Settings

- **OSPFv3 interface settings**

```
interface xyz
 ipv6 ospf network point-to-point
 ipv6 ospf 1 area 0
```

- **Fill in the appropriate interface names and OSPF area**

Checking Your Configuration

- **Check your own configuration**

  - Can you still ping your own loopback address?

  - Can you still ping your own point-to-point links?

Checking Your Configuration

- **You should now have a running IPv6 core network!**

- **For every internal IPv4 route there should be a corresponding IPv6 route**

- **Try to ping and traceroute point-to-point connections and loopback addresses in your part of the network**

Questions

BGP

6 - Section

BGP Overview

- **Routing Protocol used to exchange routing information between networks**

    - Exterior Gateway Protocol

- **It is based on Path Vector Protocol**

    - Similar to Distance Vector

- **Each border router sends to its neigbors the full route to one destination, not just the distance**

Autonomous System

- **Collection of networks with the same routing policy**

- **Usually under single ownership and administrative control**

  - Single routing policy

- **Identified by 16 or 32 bit numbers**

  - 16bit: 0 - 65,535

  - 32bit: 65,536 - 4,294,967,295

AS65000
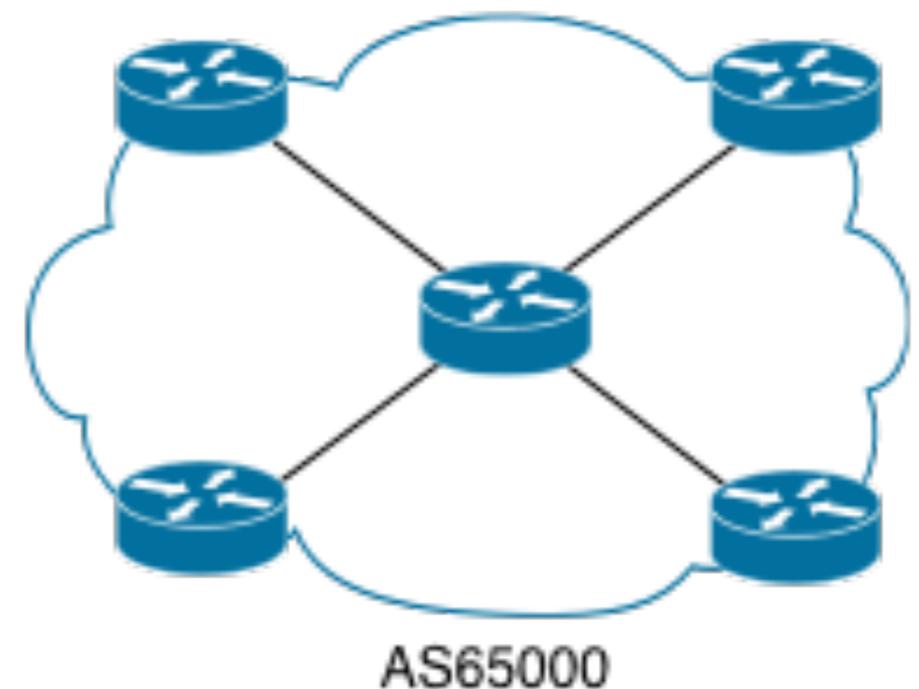
AS Path

- **Sequence of ASes a route has traversed**

  - Loop detection

  - Path selection (AS-PATH length)
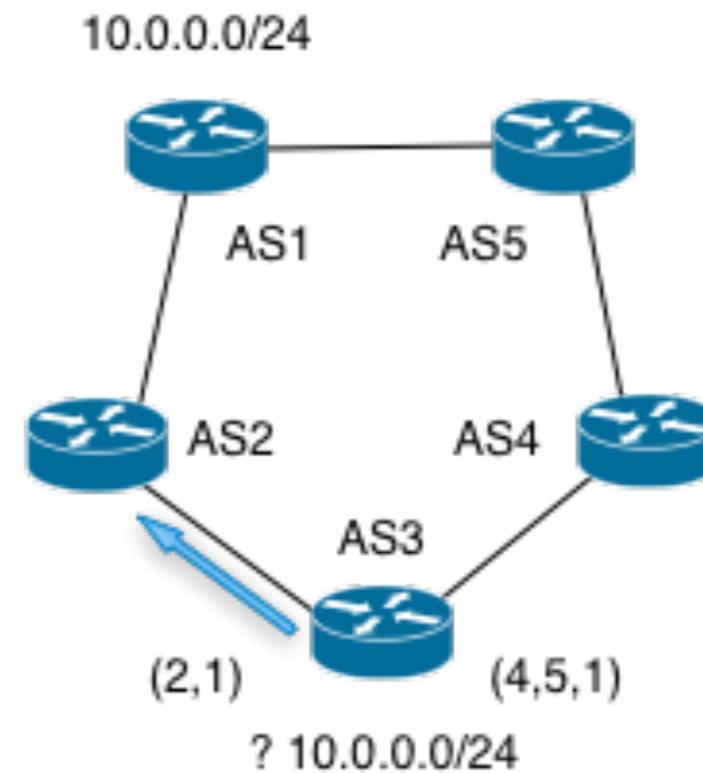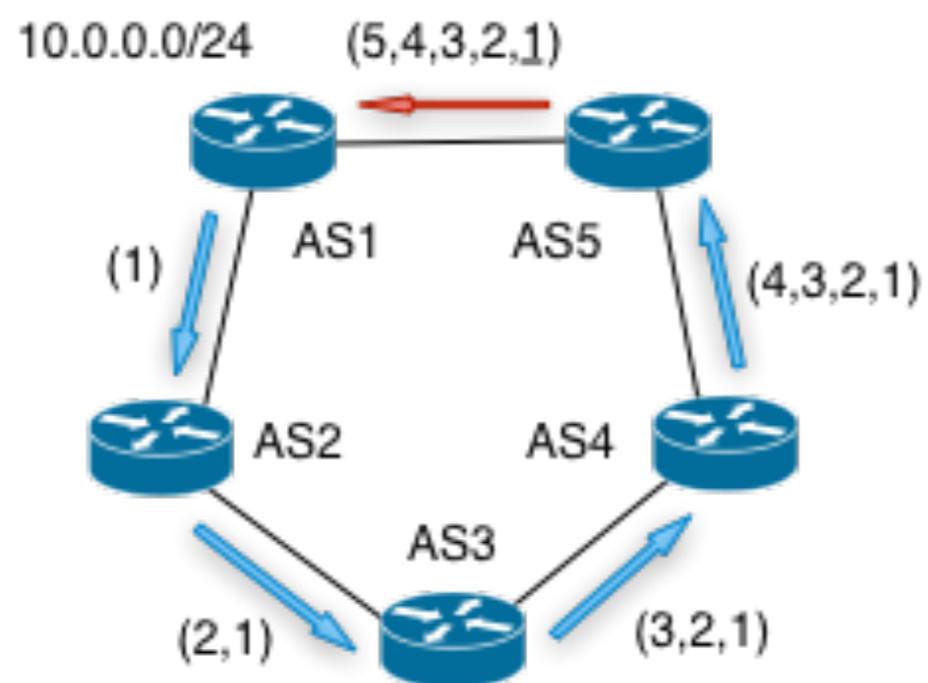
BGP Modes

- e**BGP**: Between BGP speakers in a different AS
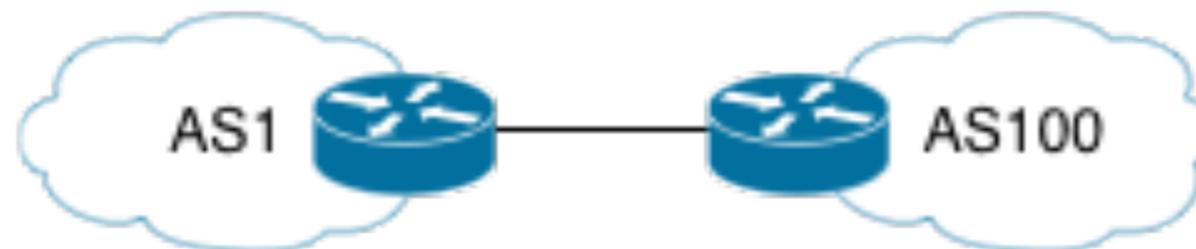
- i**BGP**: Between BGP speakers within the same AS
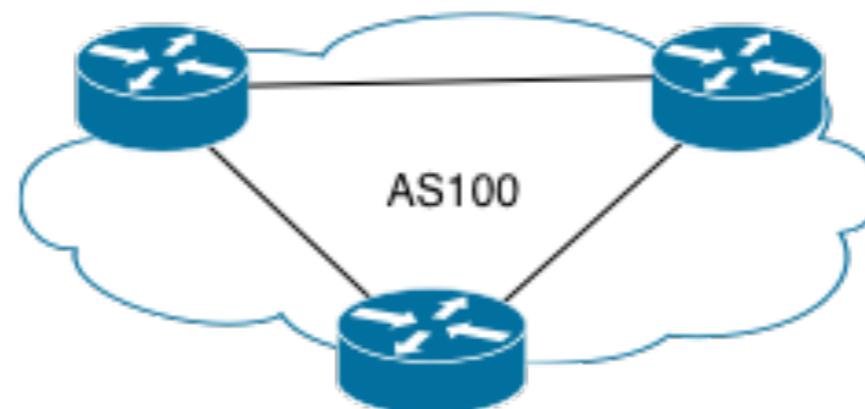
BGP Messages

- **OPEN**

  - opens the tcp session

- **KEEPALIVE**

  - keeps the session running

- **NOTIFICATION**

  - error handling

- **UPDATE**

  - actual route updates (NLRI)

NLRI

- **Network Layer Reachability Information**

  - Used to advertise feasible routes

  - Composed of:

    - Network Prefix

    - Mask Length

BGP Path Attributes

- **Well known**

  - They are known by all the routers and passed to BGP neighbors

  - Mandatory and are included in the UPDATE messages

- **Optional**

  - May not be supported by all BGP implementations

  - The transitive bit determines if an optional attribute is passed to BGP neighbors

Multiprotocol BGP (MP-BGP)

- **Extension to the BGP protocol**

- **Carries routing information about other protocols:**

  - Multicast

  - MPLS VPN

  - IPv6

- **Multi-Protocol NLRI exchange is negotiated at session set up**

MP-BGP

- **New features:**

  - Address Family Identifier (**AFI**)

  - Subsequent Address Family Identifier (**SAFI**)

  - Multiprotocol Reachable Network Layer Reachability Information

  - BGP Capabilities Advertisement

MP-BGP Path Attributes

- **New non-transitive and optional attributes**

    - **MP_REACH_NLRI**

        - set of reachable destinations together with the next-hop information

    - **MP_UNREACH_NLRI**

        - set of unreachable destinations

AFI / SAFI

- **Address Family Identifier (AFI)**
  - Identifies Address Type
    - AFI = 1 (IPv4)
    - AFI = 2 (IPv6)

- **Subsequent Address Family Identifier (SAFI)**
  - Sub category for AFI Field
    - Address Family Identifier (AFI)
    - Sub-AFI = 1 (NLRI is used for unicast)
    - Sub-AFI = 2 (NLRI is used for multicast RPF check)
    - Sub-AFI = 3 (NLRI is used for both unicast and multicast RPF check)
    - Sub-AFI = 4 (label)
    - Sub-AFI = 128 (VPN)

MP-BGP Path Attributes

- **Attribute contains one or more triples**

    - Address Family Identifier (AFI) with SAFI

- **Identifies the protocol information carried in the Network Layer reachability Info (NLRI) field**

- **Next-hop information**

    - Next-hop address must be of the same family

MP-BGP Capabilities Negotiation

- **BGP routers establish peering sessions through the OPEN message**

- **OPEN message contains optional parameters**

- **BGP session is terminated if OPEN parameters are not recognised**

- **A new optional parameter: CAPABILITIES containing its capabilities:**
  - Multiprotocol extension (AFI/SAFI)
  - Route Refresh
  - Outbound Route Filtering

MP-BGP for IPv6

- **Scoped addresses**

- **NEXT_HOP, AGGREGATOR and NLRI**

- **Address Family Identifier (AFI) = 2 (IPv6)**

  - Sub-AFI = 1 (NLRI is used for unicast)

Managing Multiple Protocols

- **Independent operation**

    - One RIB per protocol

    - Distinct policies per protocol (IP address specific route maps and prefix lists must be adjusted)

        - Make separate route maps for IPv4 and IPv6

        - Prefix lists are always separate

        - It is common to use a **_v4** and a **_v6** suffix to names

Questions

Configuring MP-BGP & Customers

7 - Exercise

eBGP

7.1 - Exercise

BGP Configuration R1

- **Cisco defaults to address-family IPv4**

- **This must be disabled before configuring IPv6**

- **Your AS Number is 1 + your number on the participants list (e.g. 109)**

```
router bgp 1XX
 no bgp default ipv4-unicast
```

BGP Configuration R1

- **Now we are going to set up BGP to our upstreams**

- **We use the same settings for IPv6 as we have for IPv4**

- **Only configure R1**

```
redistribute static
neighbor 2001:ff69::66 remote-as 66
neighbor 2001:ff69::99 remote-as 99
```

BGP Configuration R1

- **And activate the external session in the correct address family**

```
address-family ipv6
  neighbor 2001:ff69::66 activate
  neighbor 2001:ff69::99 activate
```

BGP Configuration R1

- **Now add the prefix lists and static route**

```
address-family ipv6
  network 2001:ffXX::/32
(exit)
ipv6 route 2001:ffXX::/32 Null0
ipv6 prefix-list filter_v6 seq 5 permit 2001:ffXX::/32
```

```
router bgp 1XX
 address-family ipv6
 neighbor 2001:ff69::66 prefix-list filter_v6 out
 neighbor 2001:ff69::99 prefix-list filter_v6 out
```

Filtering

- **We filter the routes we announce**

    - Why?

    - Why in this way?

    - What are the differences in IPv4 and IPv6 ?

iBGP

7.2 - Exercise

BGP Configuration R1

- **Now we are going to set up BGP on top of our IPv4 core**

- **We use the same settings for IPv6 as we have for IPv4**

```
redistribute static
neighbor 2001:ffXX::2 remote-as 1XX
neighbor 2001:ffXX::2 update-source lo0
neighbor 2001:ffXX::3 remote-as 1XX
neighbor 2001:ffXX::3 update-source lo0
```

```
address-family ipv6
  neighbor 2001:ffXX::2 activate
  neighbor 2001:ffXX::3 activate
  neighbor 2001:ffXX::2 next-hop-self
  neighbor 2001:ffXX::3 next-hop-self
```

BGP Configuration R2

- **Now we are going to set up BGP on top of our IPv4 core**

- **We use the same settings for IPv6 as we have for IPv4**

```
router bgp 1XX
  no bgp default ipv4-unicast
```

```
  redistribute static
  neighbor 2001:ffXX::1 remote-as 1XX
  neighbor 2001:ffXX::1 update-source lo0
  neighbor 2001:ffXX::3 remote-as 1XX
  neighbor 2001:ffXX::3 update-source lo0
```

```
  address-family ipv6
    neighbor 2001:ffXX::1 activate
    neighbor 2001:ffXX::3 activate
    neighbor 2001:ffXX::1 next-hop-self
    neighbor 2001:ffXX::3 next-hop-self
```

BGP Configuration R3

- **Now we are going to set up BGP on top of our IPv4 core**

- **We use the same settings for IPv6 as we have for IPv4**

```
router bgp 1XX
  no bgp default ipv4-unicast
```

```
  redistribute static
  neighbor 2001:ffXX::1 remote-as 1XX
  neighbor 2001:ffXX::1 update-source lo0
  neighbor 2001:ffXX::2 remote-as 1XX
  neighbor 2001:ffXX::2 update-source lo0
```

```
  address-family ipv6
    neighbor 2001:ffXX::1 activate
    neighbor 2001:ffXX::2 activate
    neighbor 2001:ffXX::1 next-hop-self
    neighbor 2001:ffXX::2 next-hop-self
```

BGP Customer1

7.3 - Exercise

BGP Configuration Customer 1

- We will remove the default route for the customers

```
no ipv6 route ::/0 2001:ffXX:0:ff01::b
```

BGP Configuration Router 2

- **The AS number for customer is 2 + your number on the participants list (e.g. 209)**

- **Add BGP session for Customer 1**

```
router bgp 1XX
  neighbor 2001:ffXX:0:ff01::a remote-as 2XX
```

```
 address-family ipv6
   neighbor 2001:ffXX:0:ff01::a activate
```

BGP Configuration Router 2

- **Now add customer prefix to the prefix list**

  - Customer 1 prefix: 2001:ff**XX**:ff01::/48

```
ipv6 prefix-list customer1_v6 seq 5 permit 2001:ffXX:ff01::/48
```

```
router bgp 1XX
 address-family ipv6
   neighbor 2001:ffXX:0:ff01::a prefix-list customer1_v6 in
```

BGP Configuration Customer 1

- **The AS number for customer is 2 + your number on the participants list (e.g. 209)**

- **Configure BGP session with R2**

```
router bgp 2XX
  no bgp default ipv4-unicast
```

```
  redistribute static
  neighbor 2001:ffXX:0:ff01::b remote-as 1XX
```

```
  address-family ipv6
    neighbor 2001:ffXX:0:ff01::b activate
```

BGP Configuration Customer 1

- **Now add the prefix, prefix list and static route**

  - Customer1 prefix: 2001:ffXX:ff01::/48

```
address-family ipv6
  network 2001:ffXX:ff01::/48
(exit)
ipv6 route 2001:ffXX:ff01::/48 Null0
ipv6 prefix-list my_v6 seq 5 permit 2001:ffXX:ff01::/48
```

```
router bgp 2XX
 address-family ipv6
   neighbor 2001:ffXX:0:ff01::b prefix-list my_v6 out
```

Challenge: BGP Customer 2

7.4 - Exercise

BGP Configuration Customer 2

- **Configure BGP session between Customer 2 router and provider R3**

- **The AS number for customer is 3 + your number on the participants list (e.g. 309)**

- **Add the prefix, prefix list and static route**

  - Customer2 prefix: 2001:ffXX:ff02::/48

Summary

- **We now added IPv6 to…**

  - Links/interfaces

  - IGP (OSPF)

  - EGP (BGP)

  - Customers

- **How difficult was it?**

- **Any surprises?**

Questions

Content

8 - Section

Definition

- **This section is mostly about websites but it can also apply to:**

  - SMTP

  - POP3

  - IMAP4

  - SSH

  - Remote Desktops

  - Cloud Services

Options

- **Multiple ways to make content dual stack**

  - Native dual stack

  - Dual stack load balancer

  - IPv6-to-IPv4 (reverse) proxy

  - NAT64

Native Dual Stack

- **If possible this is the preferred option**

IPv6
IPv4

Internet   Service   Router   Firewall   Load   Web / Application
            Provider   Balancer   Server

Web / Application Server

Web / Application Server
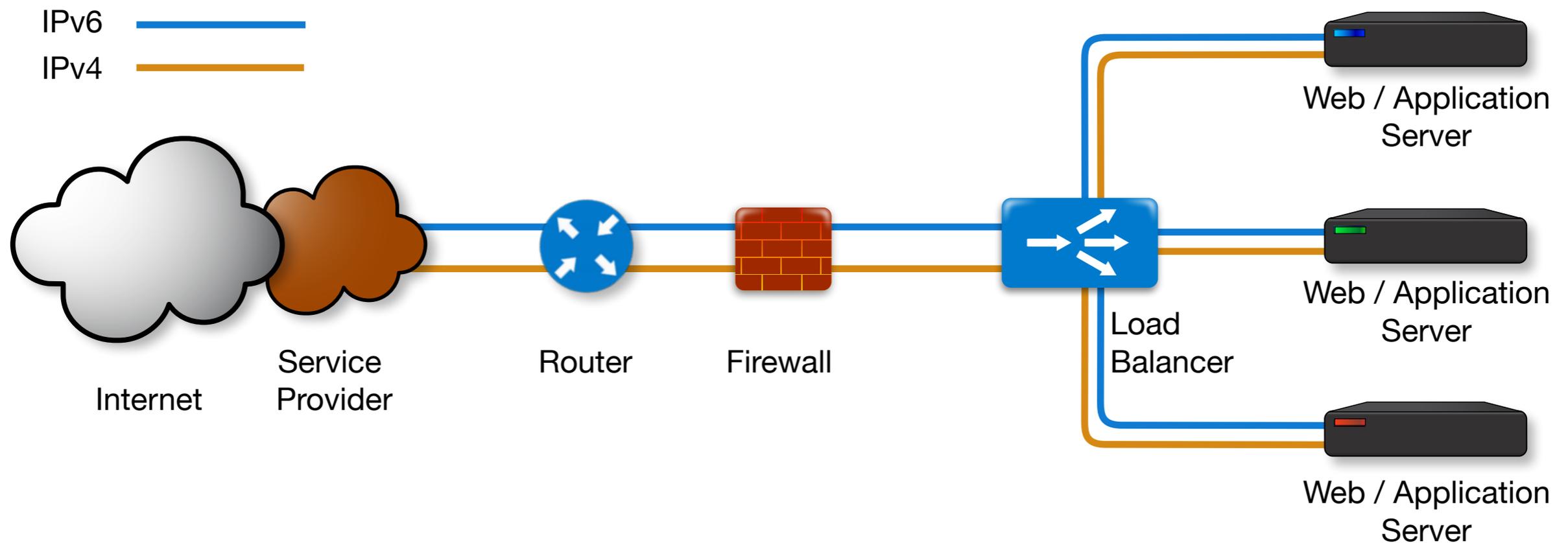
- Cleanest option: no mixing of IPv4 and IPv6

- Needs a fully dual stacked network

- All addresses fully visible where possible

Load Balancer with NAT or Proxy

- **If web servers can't handle IPv6**

IPv6 ——————
IPv4 ——————

Internet   Service Provider   Router   Firewall   Load Balancer   Web / Application Server   Web / Application Server   Web / Application Server
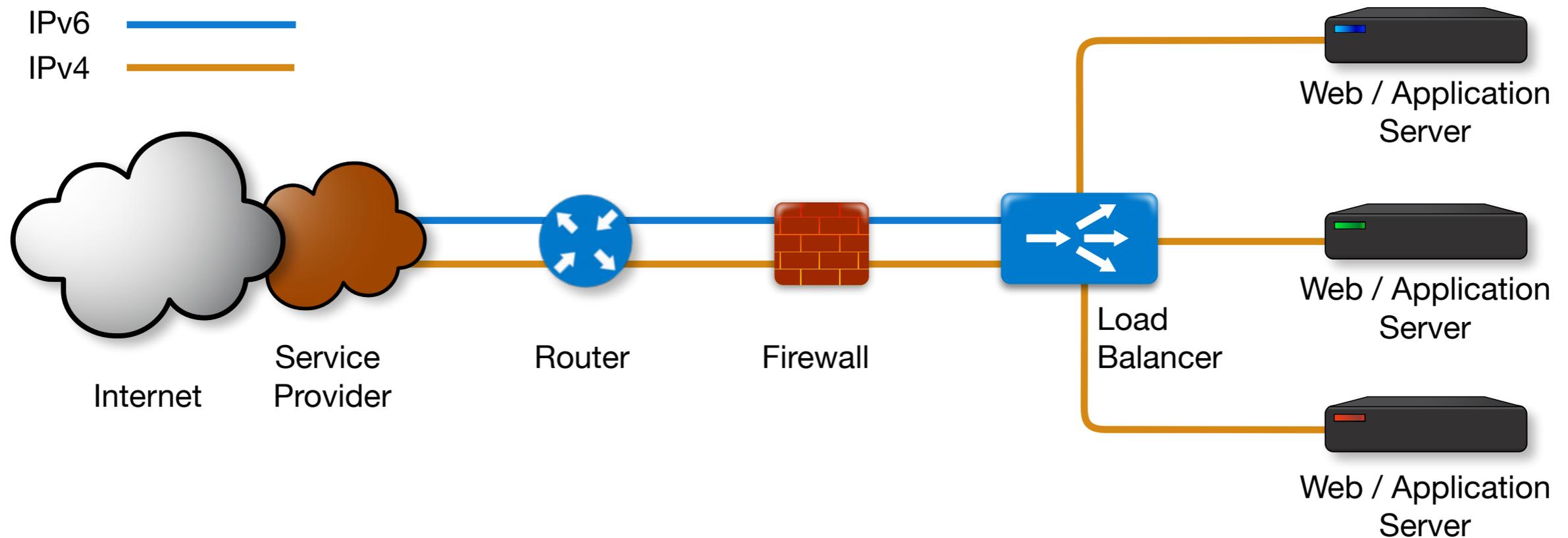
- Needs a fully dual stacked network up to the load balancer

- Web servers might not see IPv6 addresses

IPv6-to-IPv4 Proxy

- **If the load balancer or part of the network can't handle IPv6**

IPv6 ———
IPv4 ———

Internet

Service Provider

Router

Firewall

Proxy Server

Load Balancer

Web / Application Server

Web / Application Server

Web / Application Server
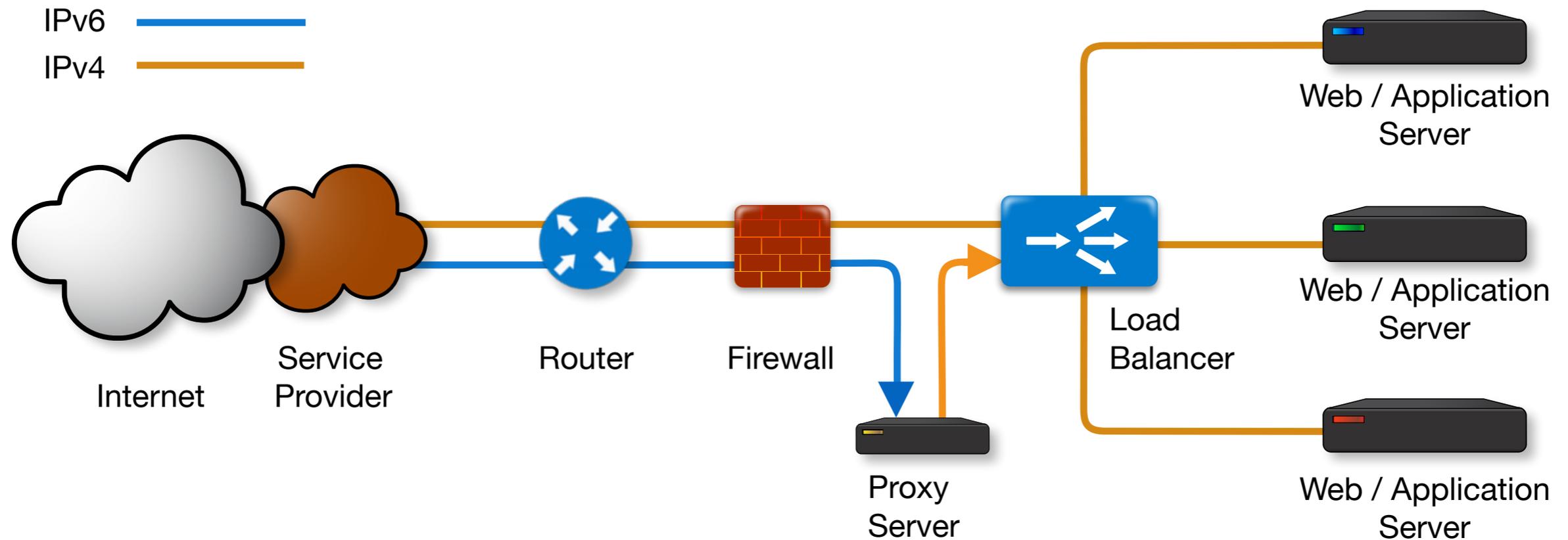
- Web servers might not see IPv6 addresses

Proxy Protocol Level

- **You can proxy on**

  - Layer 4 (TCP)

  - Layer 7 (HTTP/HTTPS)

- **Both have advantages and disadvantages**

Proxy on Layer 4

- **Very easy to configure**

  - Doesn't need to know about the protocol

  - Doesn't need to be configured with host name

  - Don't need SSL/TLS keys on the proxy server

- **Just map an IPv6 address+port to an IPv4 address+port**

- **Cannot provide information to the servers**

Proxy on Layer 4

- **This example shows haproxy**

  - Note the confusing notation in the config file

  - IPv6 address = 2001:db8:abc:123::cafe **port 25**

```
listen smtp1
  bind 2001:db8:abc:123::cafe:25
  mode tcp
  server smtp1 192.0.2.1:25
```

Proxy on Layer 7

- **Bit more work to configure**

  - Needs to know about the protocol or application

  - Might need to be configured with host name

  - Needs SSL/TLS keys on the proxy server

- **Can provide information to the servers**

  - Like X-Forwarded-For header

Proxy on Layer 7

- This example shows **haproxy**

```
listen website1
  bind 2001:db8:abc:123::cafe:80
  mode http
  option forwardfor
  server website1 192.0.2.1:80
```

- With **SSL**

```
listen website1-ssl
  bind 2001:db8:abc:123::cafe:443 ssl
    crt /etc/haproxy/website-ssl.pem
  mode http
  option forwardfor
  server website1 192.0.2.1:443 ssl
```

IPv6 in the Root Servers and TLDs

- **11 of 13 root servers have IPv6 AAAA records**

    - E and G root servers don't have IPv6 yet

- **There are 1061 TLDs**

    - 1032 of them are IPv6 capable (97.3%)

- **Almost 7 billion websites have AAAA records**

Source: http://bgp.he.net/ipv6-progress-report.cgi

Questions

Overview Day 2

- **Mobile Providers**

- **Exercise: SLAAC**

- **DHCPv6**

- **Exercise: DHCPv6**

- **Security**

- **Exercise: 6rd**

- **IP Address Management**

- **Tips & Tricks**

Mobile Providers

9 - Section

IPv6 in Mobile Networks

- **IPv4 runout has a high and urgent impact on mobile internet providers**

- **Everyone has a smartphone**

- **Certain apps and protocols have problems with double NAT**

- **Do apps support IPv6?**

Multiple Solutions

- **Dual Stack users:**

  - Public IPv4 and public IPv6

  - Private IPv4 and public IPv6

- **IPv6 only users:**

  - NAT64

  - IPv6 only

NAT64/DNS64

Mobile User
public IPv6

Infrastructure
public IPv6

DNS64

NAT64 Box

IPv6 Internet

IPv4 Internet

CUSTOMER   **PROVIDER**   **INTERNET**
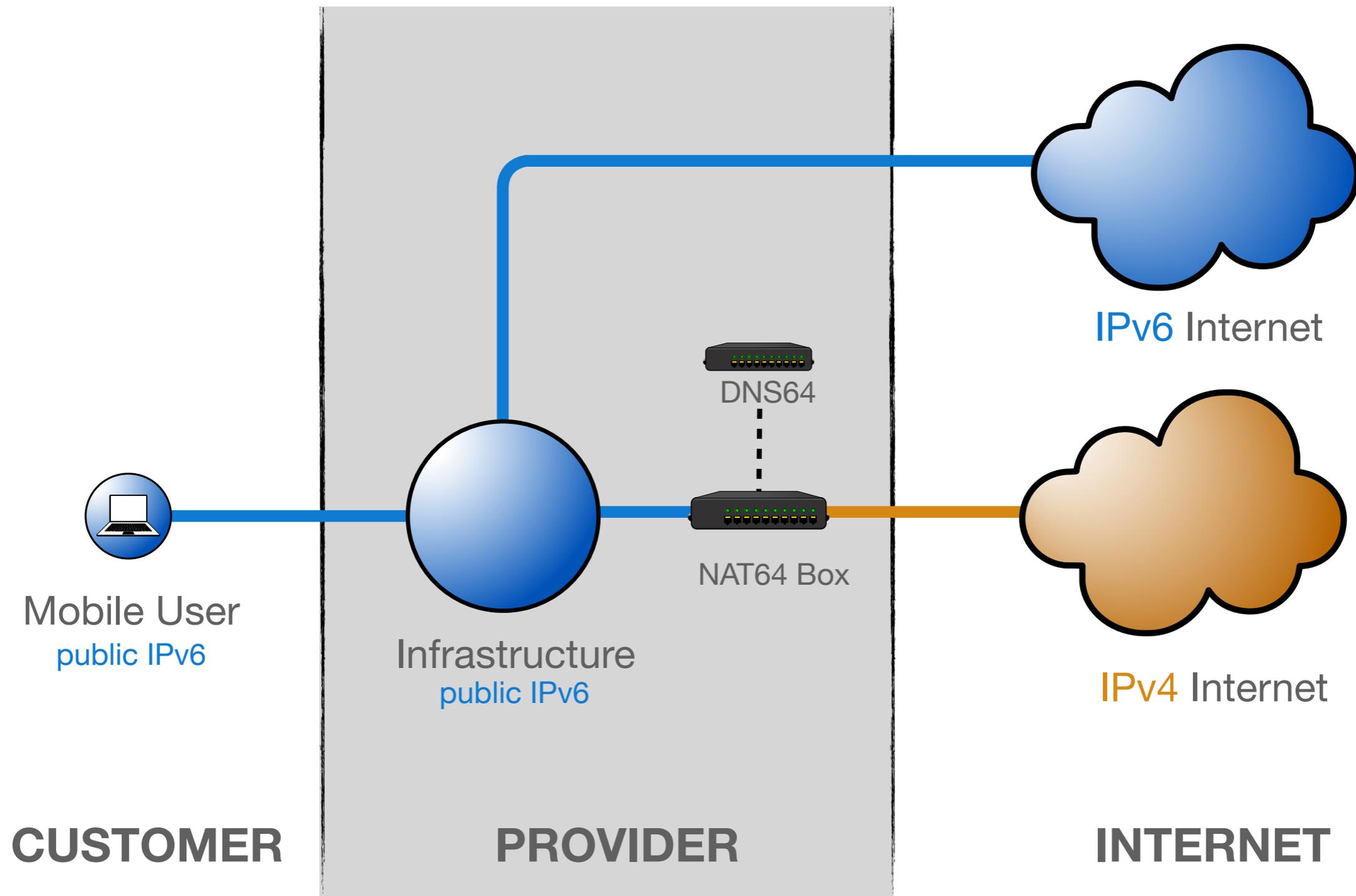
464XLAT

- **Extension to NAT64 to access IPv4-only applications (like Skype or Whatsapp)**

- **Handset pretends there is an IPv4 address (CLAT) and sends IPv4 packets in UDP over IPv6**

  - Support from: Android 4.4 and Samsung Galaxy Note, Galaxy Light and Google Nexus
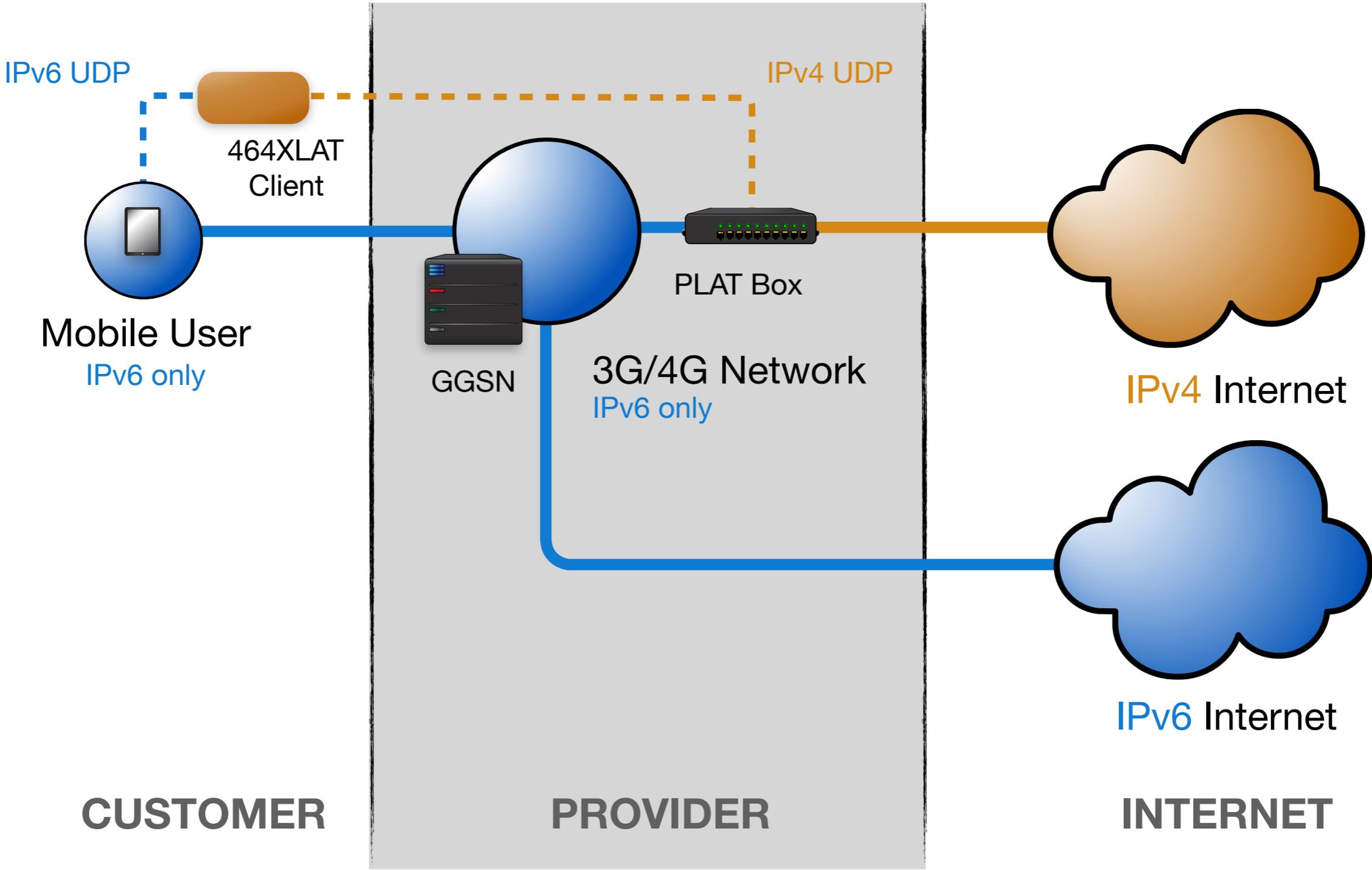
Apple Approach

- **Apple recently announced they will not support 464XLAT on the iPhone**

- **Instead they urge app developers to make apps work over IPv6**

- **That way, operators can use just NAT64 without 464XLAT**

3G

- **Works with Packet Data Protocol (PDP) Contexts**

  - Initiated by the phone to establish a connection

  - IPv4, IPv6 and IPv4v6

- **No requirement for always-on connection**

- **Only works with SLAAC**

4G

- **Works with Evolved Packet System (EPS) Bearer**

    - Initiated by the phone to establish a connection

    - IPv4, IPv6 and IPv4v6

- **Always-on Packet Data Network (PDN) Connection**

- **Due to the need for supporting VoIP**

What Needs To Be Done
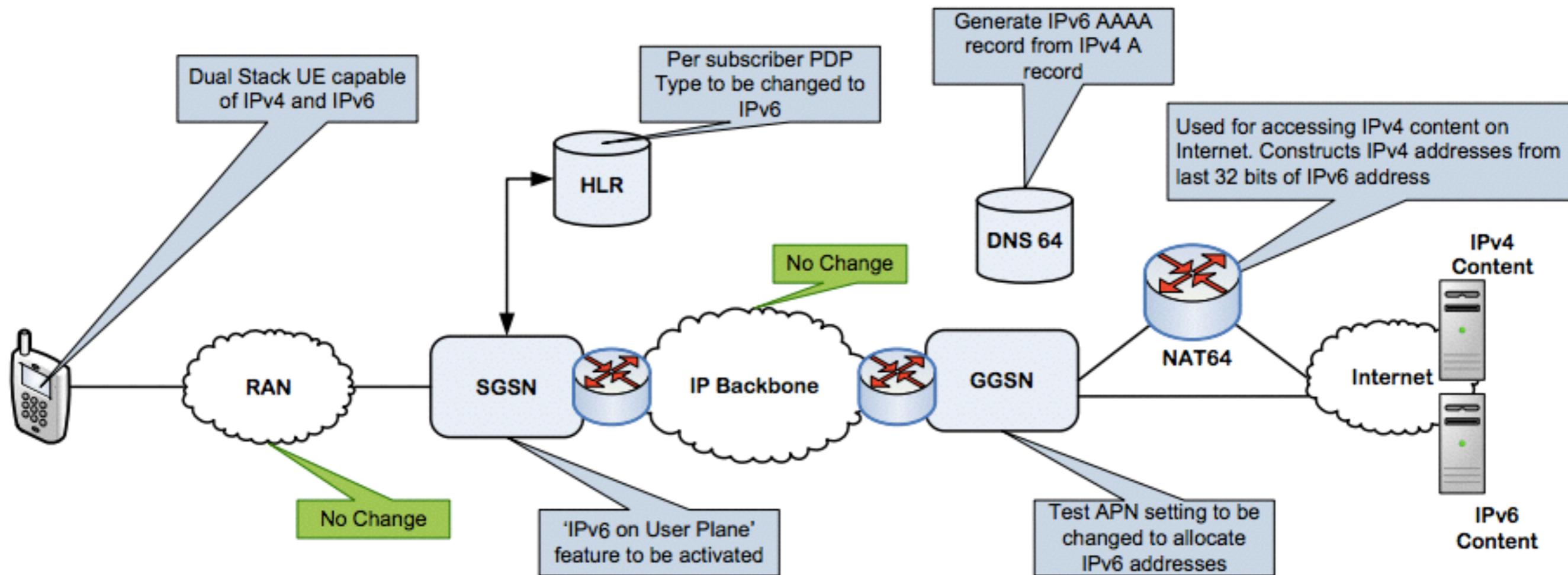
Source: Cameron Byrne T-Mobile USA

What Needs To Be Done

- **Handset:**

  - IPv6 capable

- **Home Location Register (HLR)**

  - Subscriber management needs to understand new PDP types (IPv6, IPv4v6)

- **Serving GPRS Support Node (SGSN)**

  - 'IPv6 on user plane' needs to be enabled

  - Fallback strategy

What Needs To Be Done

- **Gateway GPRS Support Node (GGSN)**

  - New PDP types (IPv6, IPv6v4)

  - IPv6 routing

  - DHCPv6

  - Neighbor Discovery Protocol

  - DNS Configuration

  - Fallback strategy

  - Billing

What Needs To Be Done

- **And the usual….**

  - **Firewalls, servers, etc.**

Challenges

- **Only 1 IPv4 address and 1 IPv6 subnet on a handset**

- **Fallback from IPv4v6 to IPv4-only or IPv6-only is difficult in some cases**

Questions

SLAAC

10 - Exercise

SLAAC
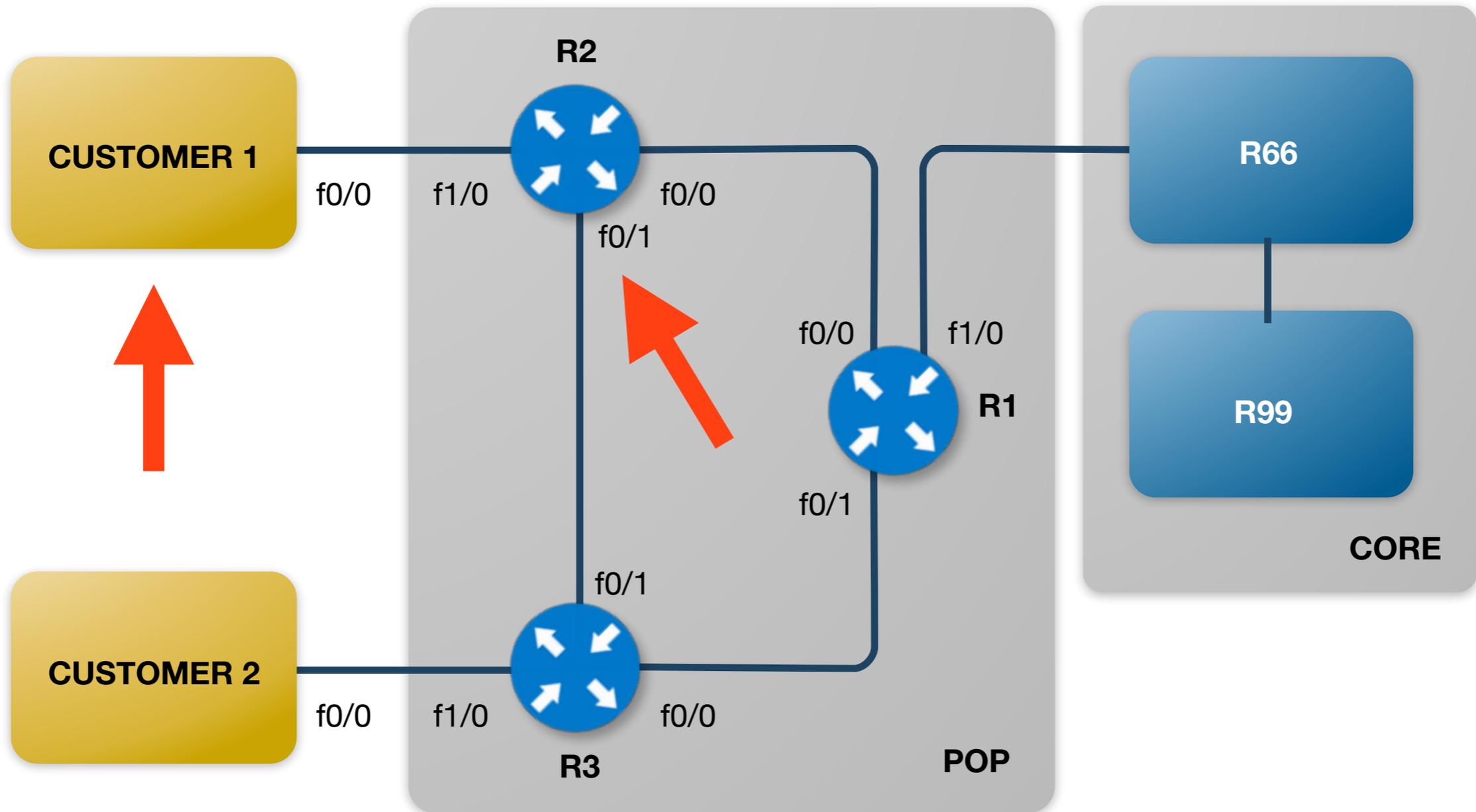
On C1

- **Now we will enable SLAAC**

```
interface f0/0
 ipv6 address autoconfig default
 no shutdown
```

- **Leave configuration mode**

- **Enable debug ND**

```
debug ipv6 nd
```

On R2

- **Now we will remove the suppression**

```
interface f1/0
  ipv6 address 2001:ffxx:0:ff01::b/64
  no ipv6 nd ra suppress all
  no shutdown
```

- **Leave configuration mode**

- **To stop debug messages on C1**

```
undebug all
```

Debugging SLAAC

- Can you find the new IPv6 address?

- Look at the routing…

- Do you see any interesting debug messages?

SLAAC: Router Messages

SLAAC: Client Messages
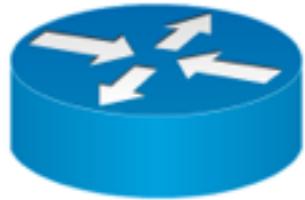
Link-local: fe80::a390:45ff:fe14:3f0f
Global unicast: 2001:db8:a:b::1

FF02::2
FF02::1
FF02::1:FF14:3F0F
FF02::1:FF00:1
FF02::1:FF05:1C9E

Multicast Address

Time
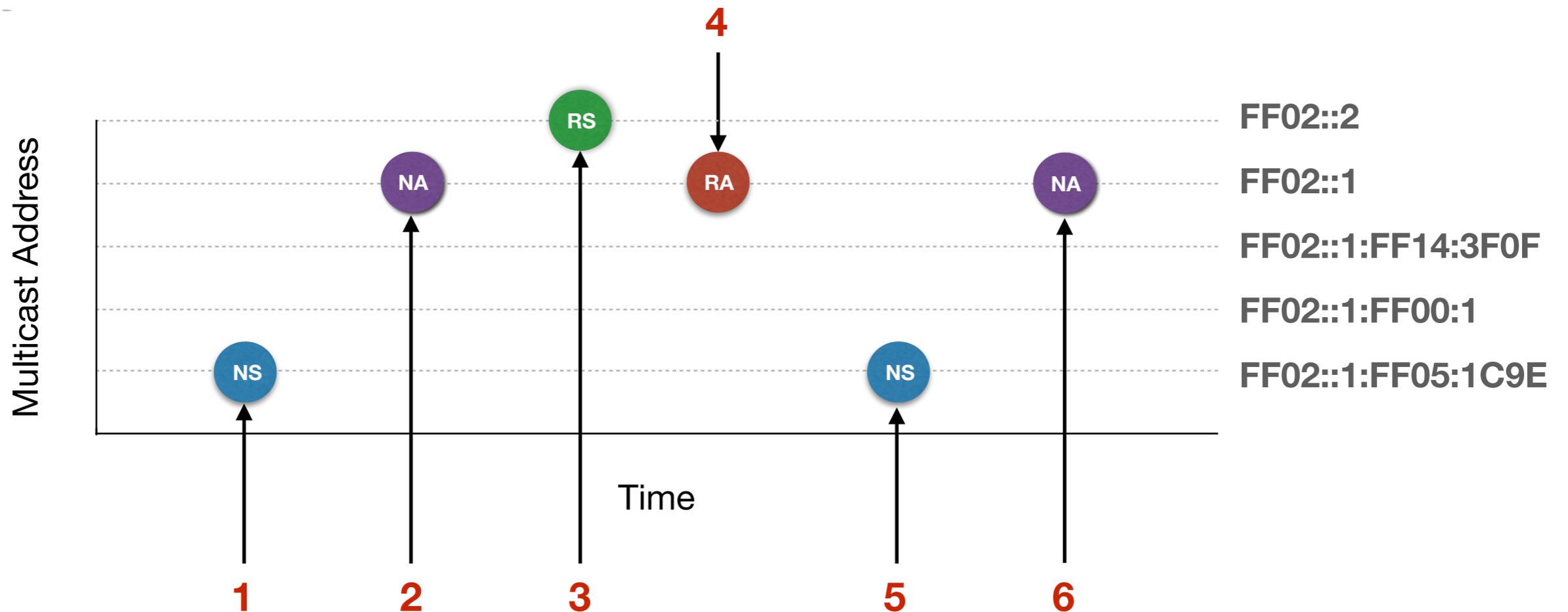
Link-local: fe80::ba8d:12ff:fe05:1c9e
Global unicast: 2001:db8:a:b:ba8d:12ff:fe05:1c9e

Questions

DHCPv6

11 - Section

About DHCPv6

- **New protocol**

- **Requires IPv6 transport**

- **Offer similar functionality to DHCPv4 but for IPv6**

- **Allows more control than SLAAC**

  - Routers and servers can have static or dynamic assignments

- **Is supported by Cisco IOS, Microsoft, Juniper, Linux, BSD, Solaris, etc.**

Information provided by DHCPv6

- **No routing information is distributed**

  - no default route (routers in IPv6 have different roles in the network)

- **Only host configuration protocol**

- **Other configuration parameters**

  - includes DNS, NTP etc

DHCPv6 Fundamentals

- **Client driven via DHCPv6 request message**

- **Solely layer 3 protocol unlike DHCPv4:**
  - port 546 for clients
  - port 547 for server

- **DHCPv6 options are similar to those in DHCPv4**

DHCPv6 Operation

- **Client first detects the presence of routers on link**

- **Client examines router advertisements to check if DHCP can be used (managed flag)**

- **If no router is found or if DHCP can be used, the client:**

  - sends DHCP solicit message to "all-DHCP-agents" multicast address (ff02::1:2)

  - uses link-local address as source address

DUID

- **DHCP Unique IDentifier**

- **A globally unique identifier used to identify the single machine/device**

    - One DUID per DHCPv6 client

- **DHCPv6 does not use only MAC address as identifier**

- **Variable length between 96 - 160 bits**

    - Example Client DUID: 00030001001A2F875602

DHCPv6 Modes

- **Stateful**
  - Also requesting an address
  - **M** flag

- **Stateless**
  - Only other configuration parameters
  - **O** flag

- **Prefix Delegation**

Stateful DHCPv6

- **Similar to DHCPv4 today**

- **A router can act as a DHCP server**

- **Configuration paramenters include:**

  - DHCP pool name

  - Prefix information

  - List of DNS servers

  - Addresses for clients

Stateful DHCPv6 Server

- **Responds to requests from clients to:**

  - Offer IPv6 addresses

  - Other configuration parameters (DNS servers...)

- **Listens on the following multicast addresses:**

  - All_DHCP_Relay_Agents_and_Servers (FF02::1:2)

  - All_DHCP_Servers (FF05::1:3)

- **Usually stores client's state**

Stateful DHCPv6 Client and Relay

- **Client**

  - Initiates requests on a link to obtain configuration
  - Uses its link local address to connect the server
  - **Sends requests to FF02::1:2** multicast address

- **Relay agent**

  - A node that acts as an intermediary to deliver DHCP messages between clients and servers
  - On the same link as the client
  - **Listens on FF02::1:2** multicast address

Stateful DHCPv6 Messages

SERVER

CLIENT

SOLICIT

ADVERTISE

REQUEST

REPLY
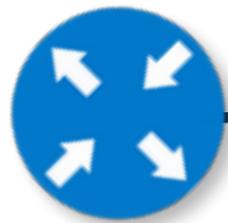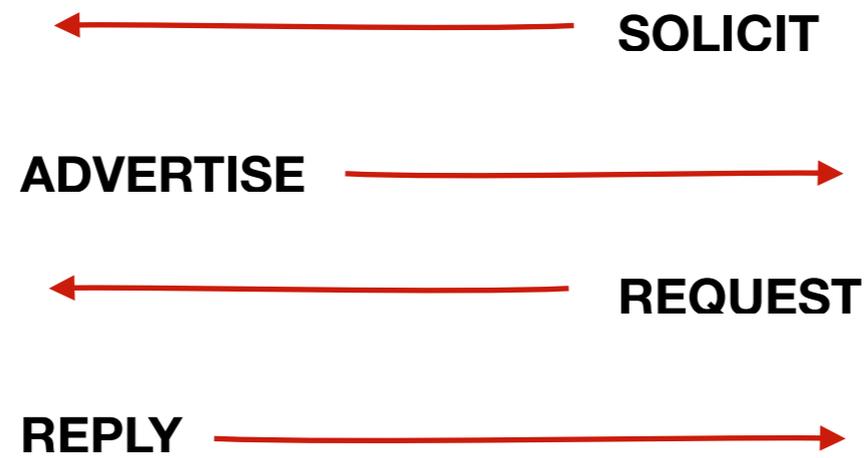
Stateless DHCPv6

- **Complements SLAAC configuration:**
  - I.e: host obtain the address using SLAAC and the DNS server address from DHCPv6
    - In dual-stack networks we can obtain IPv4 DNS server addresses from DHCPv4

- **Configure a DHCP pool with additional parameters:**
  - DNS Server
  - Domain name
  - NTP

- **Activated by "other configuration" flag in ND**

Stateless DHCPv6 Messages

SERVER

CLIENT

INFORMATION-REQUEST

REPLY

IPv6 Prefix Delegation

- **IPv4 deployments:**

  - ISP only has to deliver a public IPv4 address

    - NAT is used for translation using RFC1918

- **IPv6 deployments:**

  - IPv6 end-to-end reachability:

  - Home network gets its own IPv6 prefix (public address)

  - No NAT

DHCPv6 Prefix Delegation

- **ISP assigns a block of addresses for delegation to customers (e.g. /48)**

- **Customer assigns /64 prefixes to LAN interfaces**

ISP Network
and Internet

DHCP

RA
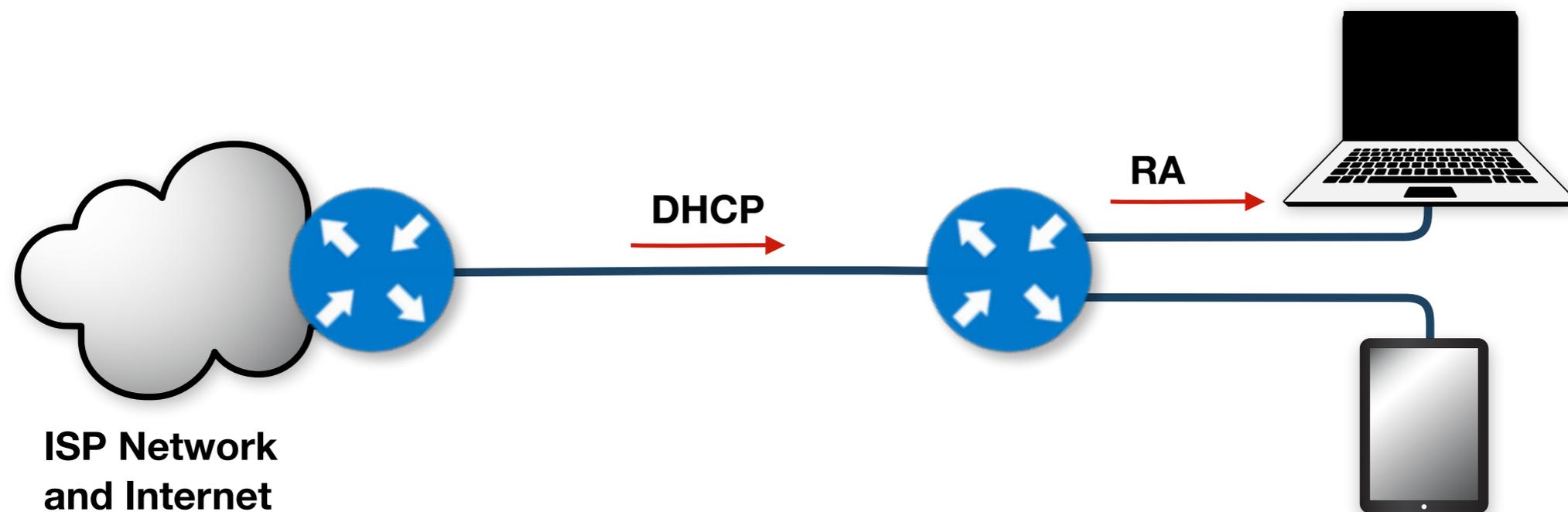
DHCPv6 Prefix Delegation

- **Provider edge as delegating DHCP server**

- **CPE as DHCP client and IPv6 router**
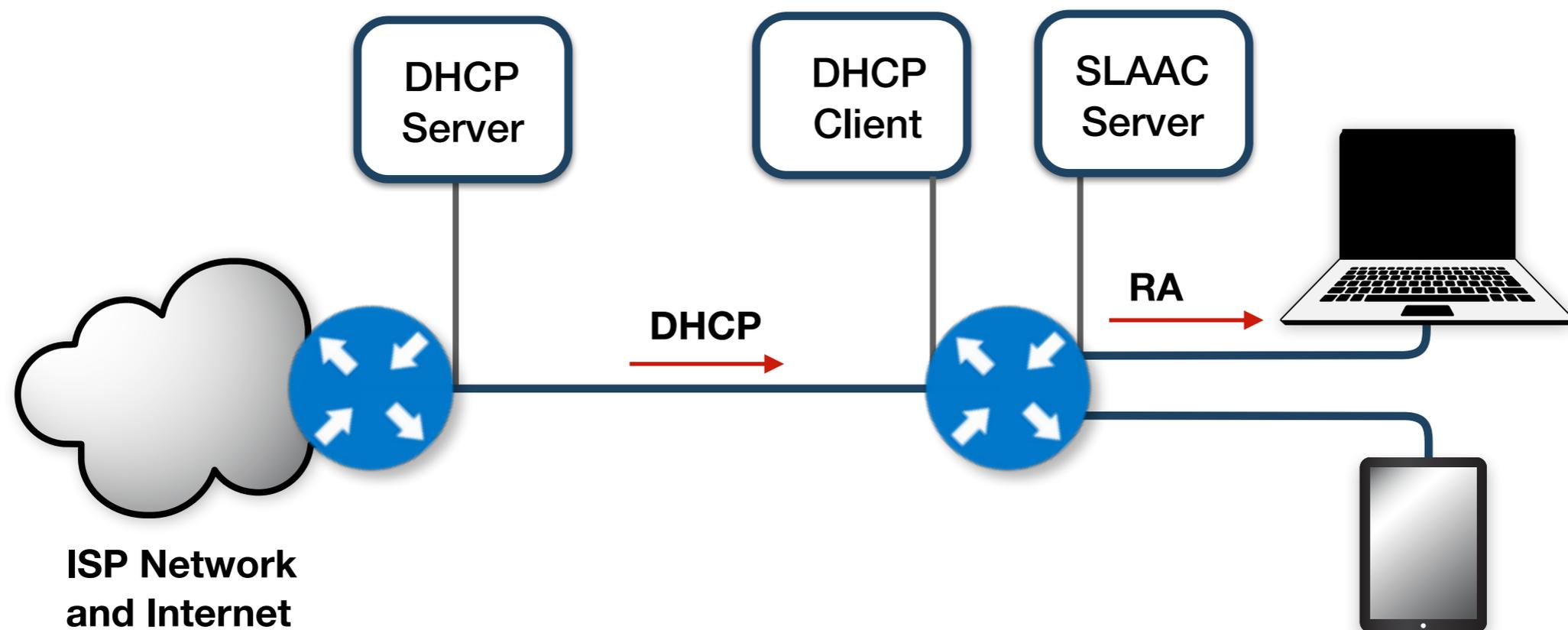
DHCPv6 PD Messages

SERVER   **CLIENT**

SOLICIT ←

ADVERTISE →

← REQUEST

REPLY →
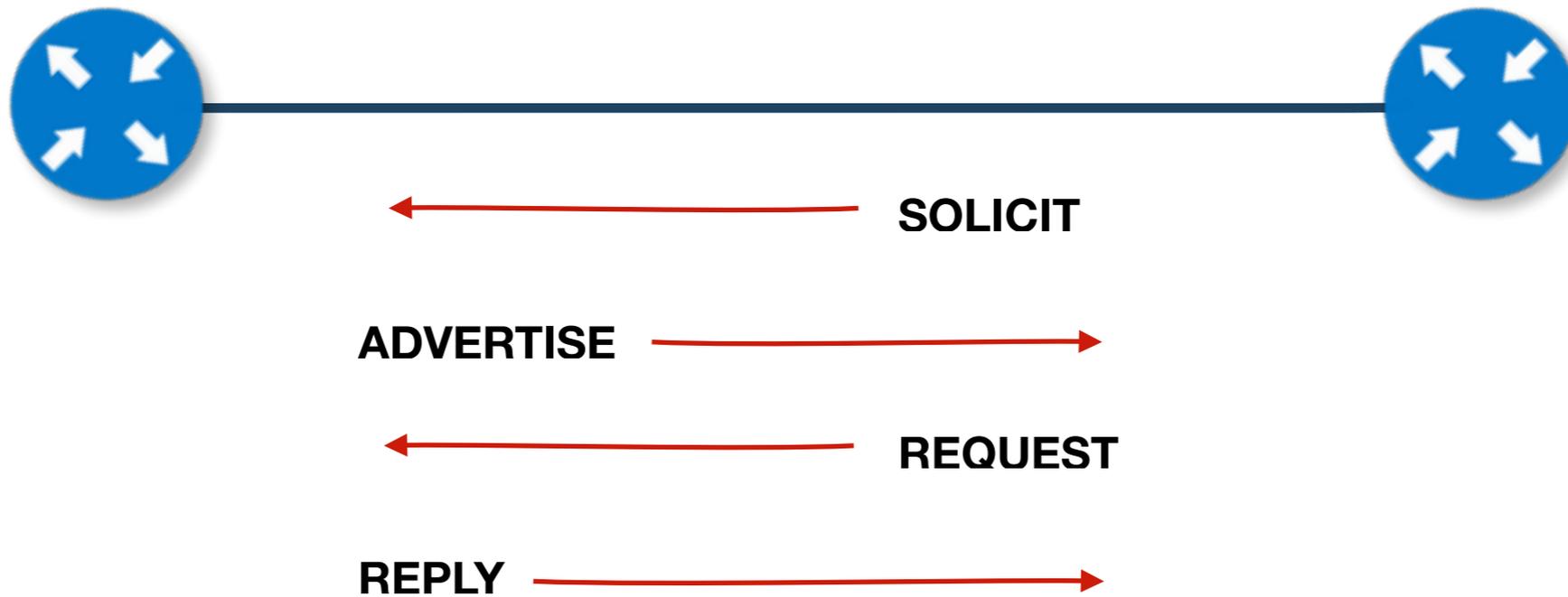
Questions

DHCPv6-PD

12 - Exercise

DHCPv6
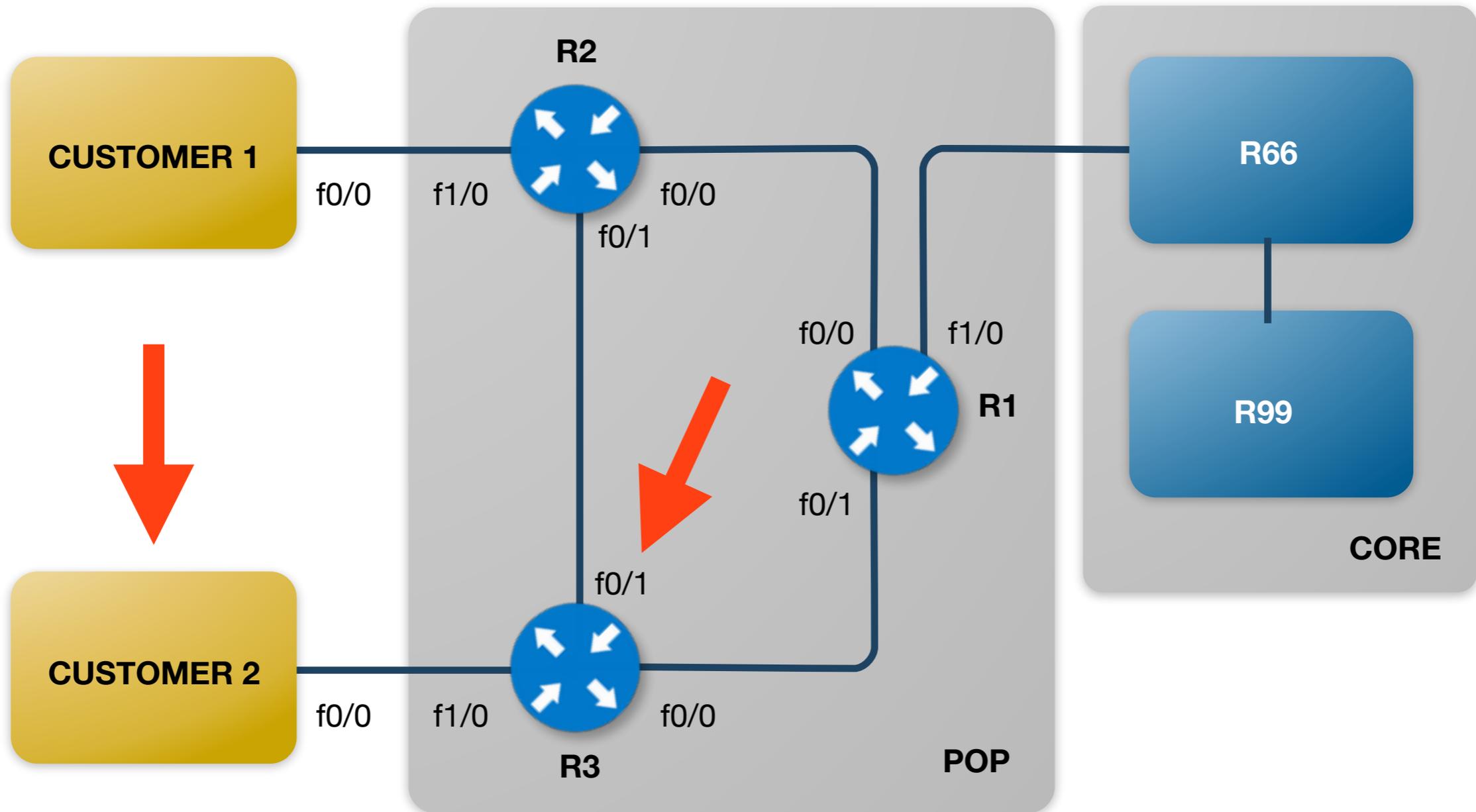
DHCPv6-PD Router Configuration

- **DHCP pool named "DHCP_CUSTOMERS" references local pool "DHCP_POOL"**

- **DHCP_POOL details about the address pool**

```
ipv6 dhcp pool DHCP_CUSTOMERS
 prefix-delegation pool DHCP_POOL
!
interface f1/0
 ipv6 address 2001:ffXX:0:ff02::b/64
 ipv6 dhcp server DHCP_CUSTOMERS
 no shutdown
!
ipv6 local pool DHCP_POOL 2001:ffXX:ff02::/48 56
```

DHCPv6-PD CPE Configuration

- **ISP facing interface is the DHCP client**

- **LAN facing interface is the IPv6 router sending RA message**

```
interface f0/0
 ipv6 address 2001:ffXX:0:ff02::a/64
 ipv6 dhcp client pd PREFIX
 no shutdown
!
interface f0/1
 ipv6 address PREFIX ::1:0:0:0:1/64
 no shutdown
```

Summary

- **We have now distributed an IPv6 prefix to Customer 2**

- **Customer has distributed prefixes to LAN interfaces automatically**

- **Can you find the client DUID address?**

Challenge: DHCPv6-PD with static assignment

12 - Exercise

DHCPv6-PD with Static Assignment

- **Assign to Customer 2 static prefix:**

    - 2001:ffXX:ff02:AB00::/56

Questions

Security

13 - Section

IPv6 Security - Why Does It Matter?

- **Most operating systems have IPv6 enabled by default nowadays**

- **IPv6 is present in your IPv4-only networks**

  - tunnels

  - autoconfiguration on hosts

- **The default IPv6 policies will not be what you need**

- **Often everything open**

Subnet Scanning

- **In IPv6, scanning the whole address space is not possible anymore, but people use:**

  - words (dead, beef, babe, cafe)

  - lower numbers (::1, ::2, ::3)

  - IPv4 based addresses (2001:db8::192:168:1:1/128)

Subnet Scanning

- **Scanning multicast addresses**

  - ff02::1 - all hosts

  - ff05::5 - all DHCP servers

  - ff05::2 - all routers

- **You can use easy to remember addresses, but remember that scanning will work the same as in IPv4**

ICMPv6

- **ICMPv6 is used to report errors, ping and discover others (Neighbor Discovery)**

- **ICMPv6 is an integral part of IPv6**

- **Disabling ICMPv6 will break your network**

Firewall Filtering and ICMPv6

- **IPv6 border filter example**

Action	Src	Dst	ICMPv6 type	ICMPv6 Code	Name
Permit	Any	A	128	0	echo reply
Permit	Any	A	129	0	echo request
Permit	Any	A	1	0	no route to dest
Permit	Any	A	2	0	packet too big
Permit	Any	A	3	0	TTL exceded
Permit	Any	A	4	0	parameter problem

IPv6 Headers

- **In IPv6, the header of a packet can be extended**

- **Extension headers are used for routing, fragmentation, IPSEC, etc.**

- **Some Intrusion Detection Systems find it hard to figure out where layer 4 starts and the extension header ends**

IPSec

- **IPSec in IPv6 is the same as in IPv4**

- **There is nothing automatically secure in IPv6**

- **IPSec "support" is mandatory in IPv6**

  - Not IPSec usage

  - PKI infrastructure costs time and money

RA Guard

- **RFC6105**

- **Implement on a L2 switch, so they can filter out rogue or misconfigured routers sending router advertisements**

- **Filtering based on:**

  - MAC address

  - Port where the RA was received

  - IP source address

Hosts

- **Hosts can get an IPv6 address unnoticed**

- **Hosts can set up tunnels**

- **Keep software up-to-date**

- **Host security controls should inspect IPv4 and IPv6**

  - Firewalls

  - VPN clients

Routers

- **Protect vty lines**

```
ipv6 access-list line-vty-in
 remark company management prefix
 permit ipv6 2001:db8:0:1::/64 any
```

```
line vty 0 15
 ipv6 access-class line-vty-in in
```

- **Use a /127 for point-to-point links if possible**

IPv6 Bogons

- **Documentation prefix**

  - 2001:db8::/32

- **6bone**

  - 3ffe::/16

  - Returned to the IANA pool

- **Cymru bogon list (very long!)**

  - Also available as BGP feed

  - https://www.team-cymru.org/Services/Bogons/fullbogons-ipv6.txt

Questions

6rd

- Quite similar to 6to4

  - Encodes the IPv4 address in the IPv6 prefix

- Uses address space assigned to the operator

- The operator has full control over the relay

- Traffic is symmetric across a relay

  - Or at least stays in your domain

- Can work with both public and private space

- Needs additional software for signalling
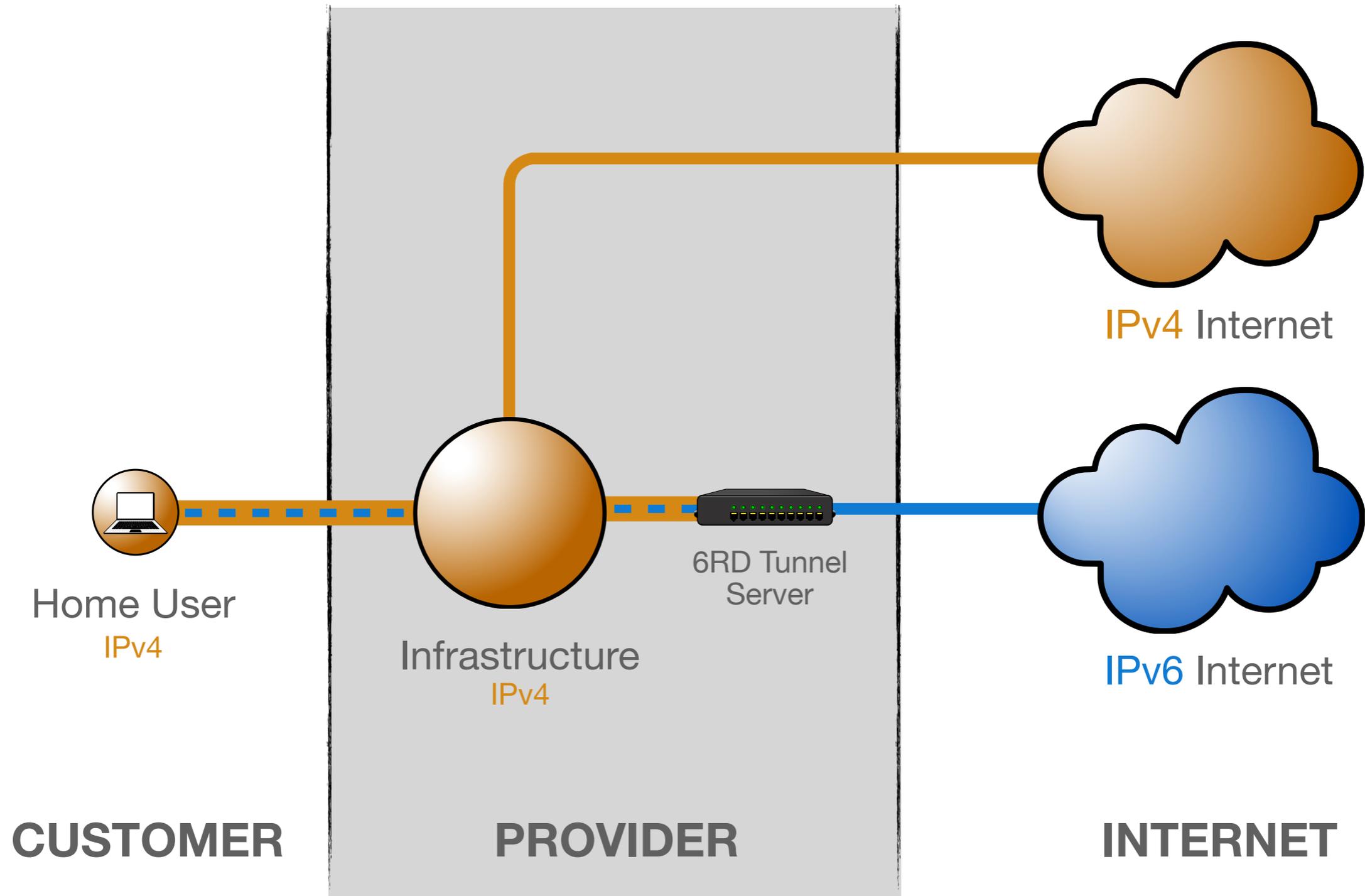
6rd Lab

- **In this lab we will set up 6rd**

  - Routers R2 and R3 cannot do IPv6

  - R1 has IPv6 and is the 6rd Border Relay (BR)

  - The customers will get IPv6 using 6rd

- **IPv4 is already set up**

- **This is a different configuration from the previous exercises, we will start from the beginning**

6rd Lab

- **Step 1: Determine which addresses to use**

- **Step 2: Configure R1 as a 6rd Border Router**

- **Step 3: Configure C1 and C2 to use the Border Router**

  - We will configure 6rd manually on the client

6rd Lab
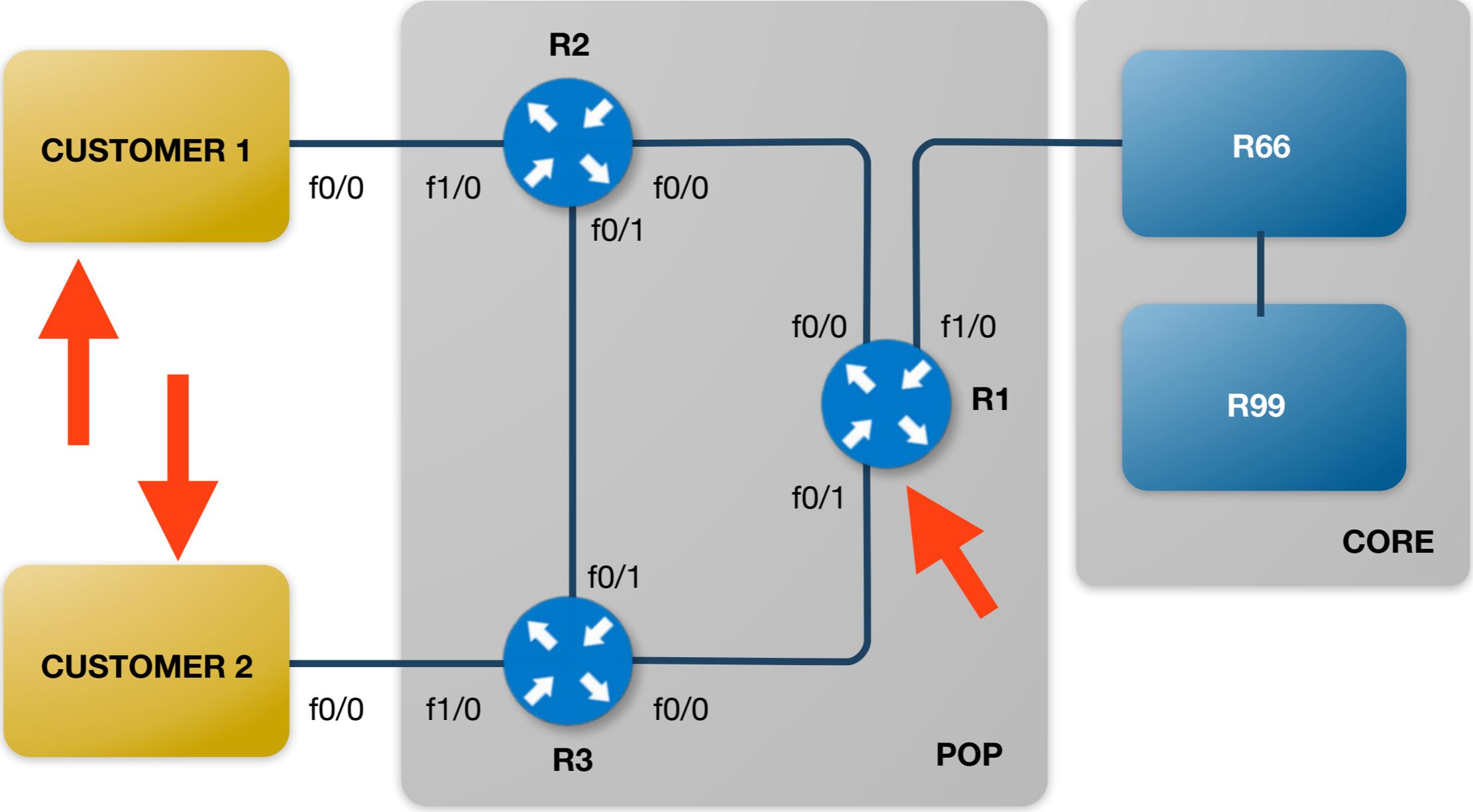
6rd Lab: Step 1

- **Determine the 6rd mapping:**

  - Which IPv4 addresses will be able to use the BR?

  - How will IPv4 addresses be mapped to the IPv6 prefix?

  - Which address will the BR get?

6rd Lab: Step 1

- **We provide 6rd for 10.X.0.0/22**

- **We use 2001:ffXX:ff00::/42 for the 6rd setup**

  - The last 10 bits in the IPv4 address are used in the mapping

6rd Lab: BR IPv4 Address

- **The border router must have an IPv4 address in the IPv4 range**

    - In this example we use 10.X.3.255

- **The BR must also have the first IPv6 address in its own mapped IPv6 range**

    - 10.X.3.255   2001:ffXX:ff00::/42

                    ⟶

6rd Lab: Configuring the BR

- **Configure the IPv4 address on an extra loopback interface**

```
interface loopback6
 ip address 10.X.3.255 255.255.255.255
 no shutdown
```

6rd Lab: Configuring the BR

- **We configure 6rd as a tunnel**

```
interface tunnel6
 tunnel source loopback6
 tunnel mode ipv6ip 6rd
 tunnel 6rd ipv4 prefix-len 22
 tunnel 6rd prefix 2001:ffXX:ff00::/42
 ipv6 address 2001:ffXX:ff3f:f000::/128 anycast
```

6rd Lab: Configuring the BR

- **Configure routes to the tunnel and our own /52**

```
ipv6 route 2001:ffXX:ff00::/42 tunnel6
ipv6 route 2001:ffXX:ff3f:f000::/52 Null0
```

6rd Lab: BR Summary

- **Add an IPv4 address on an extra loopback**

- **Add a tunnel interface (6rd)**

- **Route the IPv6 prefix of the 6rd tunnel**

- **Route the IPv6 address**

6rd Lab: Configuring Customers

- **Do the basic setup for IPv6:**

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

6rd Lab: Configuring Customers

- **Create a variable for the prefix**

  - Because we don't know what we will get from the BR

  ```
  ipv6 general-prefix DELEGATED_PREFIX 6rd tunnel6
  ```

- **This "DELEGATED_PREFIX" will be automatically set to the right 6rd prefix**

6rd Lab: Configuring Customers

- **Set up 6rd tunnel**

```
interface tunnel6
 tunnel source f0/0
 tunnel mode ipv6ip 6rd
 tunnel 6rd ipv4 prefix-len 22
 tunnel 6rd prefix 2001:ffXX:ff00::/42
 tunnel 6rd br 10.X.3.255
 ipv6 address DELEGATED_PREFIX ::/128 anycast
```

- **The "DELEGATED_PREFIX" is used for the address**

6rd Lab: Configuring Customers

- **Set up 6rd and default route**

```
ipv6 route 2001:ffXX:ff00::/42 tunnel6
ipv6 route ::/0 tunnel6 2001:ffXX:ff3f:f000::
```

- **Set up interfaces**

```
interface loopback 0
 ipv6 address DELEGATED_PREFIX ::1/128

interface f0/1
 ipv6 address DELEGATED_PREFIX 0:0:0:1::/64 eui-64
 no ipv6 redirects
```

6rd Labs: Customers Summary

- **Basic IPv6 configuration**

- **Define a prefix variable**

- **Set up the tunnel**

- **Set up routing**

- **Set addresses on interfaces**

6rd Lab: Wrap Up

- **You should now be able to ping all IPv6 nodes**

- **For example:**

  - Border Relay

  - Core router?

  - Your neighbor?

6rd on a Linksys Router

IP Address Management

15 - Section

Why IP Address Management?

- **How do you currently keep track?**

  - There are many subnets in IPv6

  - Your spreadsheet might not scale

  - And you want to take care of DNS/reverse DNS

- **There are 524288 /48s in a /29**

- **That is 34359738368 /64s!**

Address Management

- **There are many open source IPv6 IPAM tools**

  - NetDot

  - GestióIP

  - phpIPAM

  - IPplan

  - NIPAP

- **And of course our own IP Analyser**

NetDot

- **Device discovery via SNMP**

- **DNS and DHCP config management**

- **MAC address tracking**

- **BGP and AS Number tracking**

- **Export scripts for**

  - Nagios

  - Smokeping

  - Cacti

  - RANCID

NetDot

GestióIP

- **Web based IPAM software**

- **Structure based on Surfnet document**

- **Shows free ranges**

- **Incorporated VLAN management system**

- **Host discovery via SNMP and DNS**

- **Multi lingual (Russian, Italian, French, Catalan, etc….)**

- **DNS zone file generator for forward and reverse zones**
  - Supporting BIND and tinydns zone files

GestióIP

phpIPAM

- **AJAX based using jQuery libraries**

  - PHP script, javascript and some HTML5/CSS3

  - Modern browser is preferred

- **E-mail notifications**

- **Displays free ranges and numbers of clients**

- **Import and export to XLS files**

- **Can pull info from the RIPE DB**

- **Does not update DNS server**

phpIPAM

NIPAP

- **Written in Python**

- **Web and CLI**

- **Integrated audit log**

- **IP request system**

- **XML-RPC middleware**

  - Easy integration with other applications

NIPAP

Query took 0.044 seconds.   search help?   Add prefix ▾

Search interpretation : text matching "

VRF	Prefix	Node	Order	Customer	Description
RT: -	− 94.142.240.0/21	⚙▾ R			Coloclue PA
default	+ 94.142.240.0/24	⚙▾ A 🔗			EUNetworks shared subnet
	+ 94.142.241.0/24	⚙▾ R 🔗			member subnets
	+ 94.142.242.0/24	⚙▾ R 🔗			member subnets
	+ 94.142.244.0/24	⚙▾ A 🔗			DCG Shared subnet
	+ 94.142.245.0/24	⚙▾ R 🔗			member subnets
	94.142.246.0/24			62	Soleus
	+ 94.142.247.0/24			0	Coloclue infra
	− 185.52.224.0/22				Coloclue PA from final /8
	+ 185.52.224.0/24				Member subnets
	194.1.163.0/24			146	Pim van Pelt
	195.114.12.0/24	⚙▾ A		90	Melchior Aelmans
	− 2a02:898::/32	⚙▾ R			Coloclue PA
	− 2a02:898::/48	⚙▾ R			Coloclue infrastructure
	2a02:898:0:d::/64	⚙▾ A 🔗			AMS-IX Out of band EUNetworks
	2a02:898:0:e::/64	⚙▾ A			TransIP OOB

Context menu:
- Prefix
- Edit
- Remove
- Add prefix from prefix

IPPlan

- **Web based**

- **Multi lingual**

- **DNS administration (forward and reverse zones)**

- **Audit log**

- **Statistics**

- **Importing network information from routing tables**

IPPlan

Main   Customers ▼   Network ▼   DNS ▼   Options ▼   Admin ▼   Help ▼   Logout   Logged in as test

Search for IP subnets between 0.0.0.0 and 255.255.255.255 for customer 'Test customer 2'

[   ]   Refine Search

Base address	Subnet size	Subnet mask	Description	Last modified	Changed by	SWIP sent
172.16.100.0	16	255.255.255.240/28	NET-172-16-100-0	Jan 08 2005 15:49:11	test	
172.16.100.16	16	255.255.255.240/28	NET-172-16-100-16	Jan 08 2005 15:49:12	test	
172.16.100.32	16	255.255.255.240/28	NET-172-16-100-32	Jan 08 2005 15:49:12	test	
172.16.100.48	16	255.255.255.240/28	NET-172-16-100-48	Jan 08 2005 15:49:12	test	
172.16.100.64	16	255.255.255.240/28	NET-172-16-100-64	Jan 08 2005 15:49:12	test	
172.16.100.80	16	255.255.255.240/28	NET-172-16-100-80	Jan 08 2005 15:49:12	test	
172.16.100.96	16	255.255.255.240/28	NET-172-16-100-96	Jan 08 2005 15:49:12	test	
172.16.100.112	16	255.255.255.240/28	NET-172-16-100-112	Jan 08 2005 15:49:12	test	
172.16.100.128	16	255.255.255.240/28	NET-172-16-100-128	Jan 08 2005 15:49:12	test	
172.16.100.144	16	255.255.255.240/28	NET-172-16-100-144	Jan 08 2005 15:49:12	test	
172.16.100.160	16	255.255.255.240/28	NET-172-16-100-160	Jan 08 2005 15:49:12	test	
172.16.100.176	16	255.255.255.240/28	NET-172-16-100-176	Jan 08 2005 15:49:12	test	
172.16.100.192	16	255.255.255.240/28	NET-172-16-100-192	Jan 08 2005 15:49:12	test	
172.16.100.208	16	255.255.255.240/28	NET-172-16-100-208	Jan 08 2005 15:49:12	test	
172.16.100.224	16	255.255.255.240/28	NET-172-16-100-224	Jan 08 2005 15:49:12	test	
172.16.100.240	16	255.255.255.240/28	NET-172-16-100-240	Jan 08 2005 15:49:12	test	
172.16.101.0	16	255.255.255.240/28	NET-172-16-101-0	Jan 08 2005 15:49:12	test	
172.16.101.16	16	255.255.255.240/28	NET-172-16-101-16	Jan 08 2005 15:49:12	test	
172.16.101.32	16	255.255.255.240/28	NET-172-16-101-32	Jan 08 2005 15:49:13	test	
172.16.101.48	16	255.255.255.240/28	NET-172-16-101-48	Jan 08 2005 15:49:13	test	
172.16.101.64	16	255.255.255.240/28	NET-172-16-101-64	Jan 08 2005 15:49:13	test	
172.16.101.80	16	255.255.255.240/28	NET-172-16-101-80	Jan 08 2005 15:49:13	test	
172.16.101.96	16	255.255.255.240/28	NET-172-16-101-96	Jan 08 2005 15:49:13	test	
172.16.101.112	16	255.255.255.240/28	NET-172-16-101-112	Jan 08 2005 15:49:13	test	
172.16.101.128	16	255.255.255.240/28	NET-172-16-101-128	Jan 08 2005 15:49:13	test	

IP Analyser

- **Available through the LIR Portal**

- **Get a visual insight into your RIPE Database objects**

  - Hierarchical view of **used** address space

- **Create new objects using an easy to use wizard**

  - Interface seamlessly with the RIPE Database

  - Explain the different options well

  - Use sensible defaults

  - Delete redundant objects directly from the UI

IP Analyser
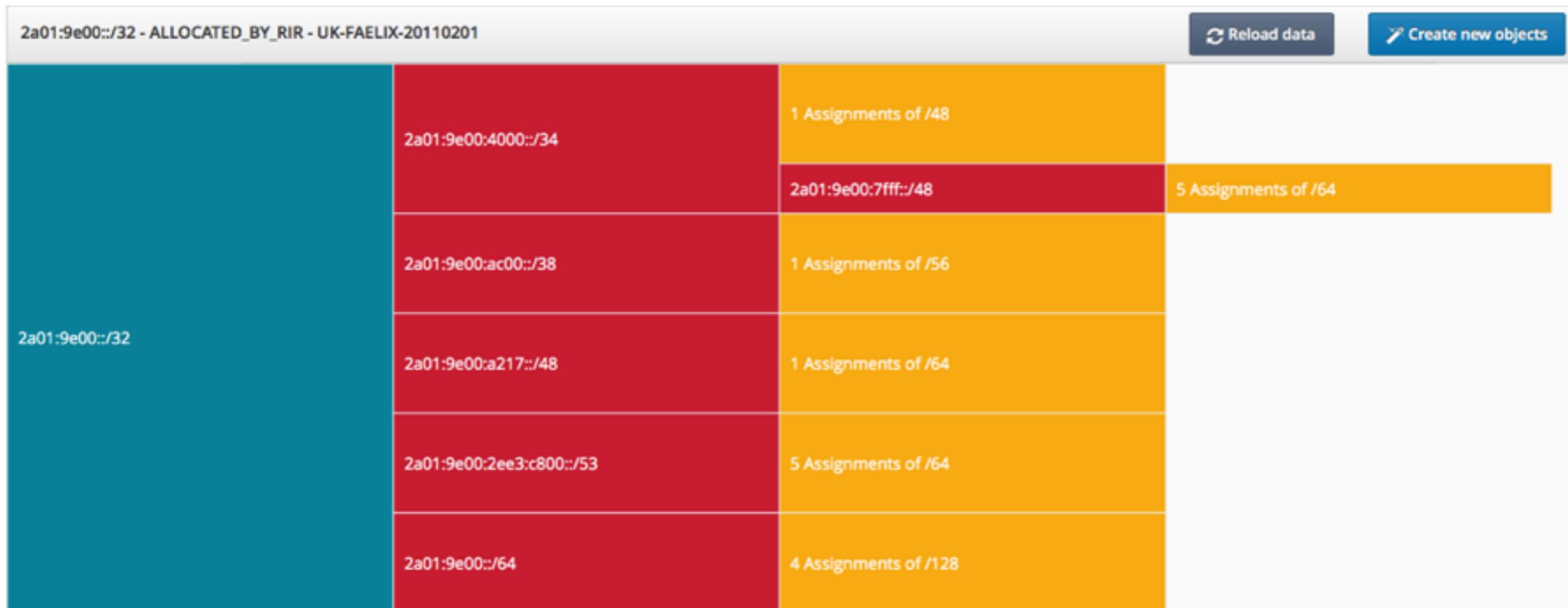
Questions

Tips and Tools

16 - Section

Graduate to the next level!

http://academy.ripe.net

Feedback!

https://www.ripe.net/lir-services/training/courses/advanced-ipv6/feedback-2016

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The End!

Край

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Fí

Finis

النهاية

Соңы

Վերջ

Liðugt

Ende

Finvezh

Кінець

Konec

Kraj

Ënn

Fund

پایان

Lõpp

Beigas

Vége

Son

Кpaj

An Críoch

הסוף

Fine

Endir

Sfârşit

Fin

Τέλος

Einde

Конец

Slut

Slutt

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