RIPE NCC
RIPE NETWORK COORDINATION CENTRE

Advanced IPv6

Training Course

RIPE NCC Learning & Development

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**

RIPE NCC Training Material

Please find your training material at the following link

https://www.ripe.net/training-material

Introductions

- Name
- Number on the list
- Experience with:
  - IPv6
  - Cisco
  - OSPF
  - BGP
- Goals

Course Overview

1 - Section

Overview Day 1

- Introduction
- IPv6 Routing Basics
- Exercise: Enable IPv6
- OSPFv3
- Exercise: Configuring OSPFv3
- BGP
- Exercise: Configuring BGP
- Content
- Mobile Providers

Overview Day 2

- Transition Mechanisms
- Exercise: NAT64/DNS64
- Host Configuration
- Exercise: SLAAC
- DHCPv6
- Exercise: DHCPv6
- Security
- IP Address Management

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:db8:2000:1a2b: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:db8:2001:1a2b: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

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

Add IPv6 to Loopback & Links

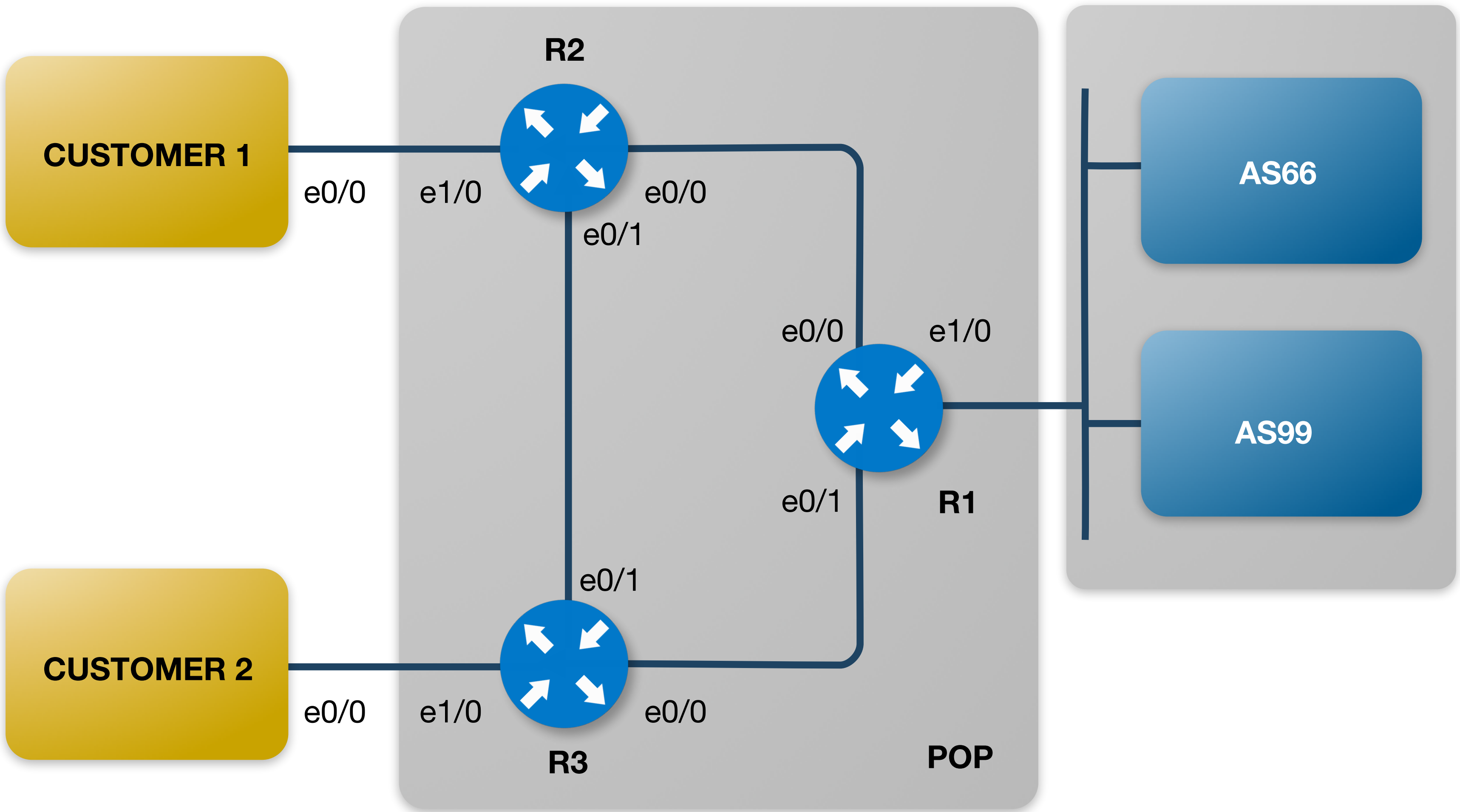
3 - Exercise

Discover the IPv4 Network

- Make sure you have connectivity
- Go to: **workbench.ripe.net**
- Choose LAB1 or LAB2 (trainer will tell you)
- Your login is your number on the attendee list
- We will provide you with the password

- Read instructions carefully
- First discover, then configure

Network Diagram



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

Adding IPv6 to the Network

- We will now add IPv6 to our existing network
- We will not change the network structure
- **We will not change IPv4 addresses**

- 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

```
ipv6 nd ra suppress all
```

- 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 router advertisements

```
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

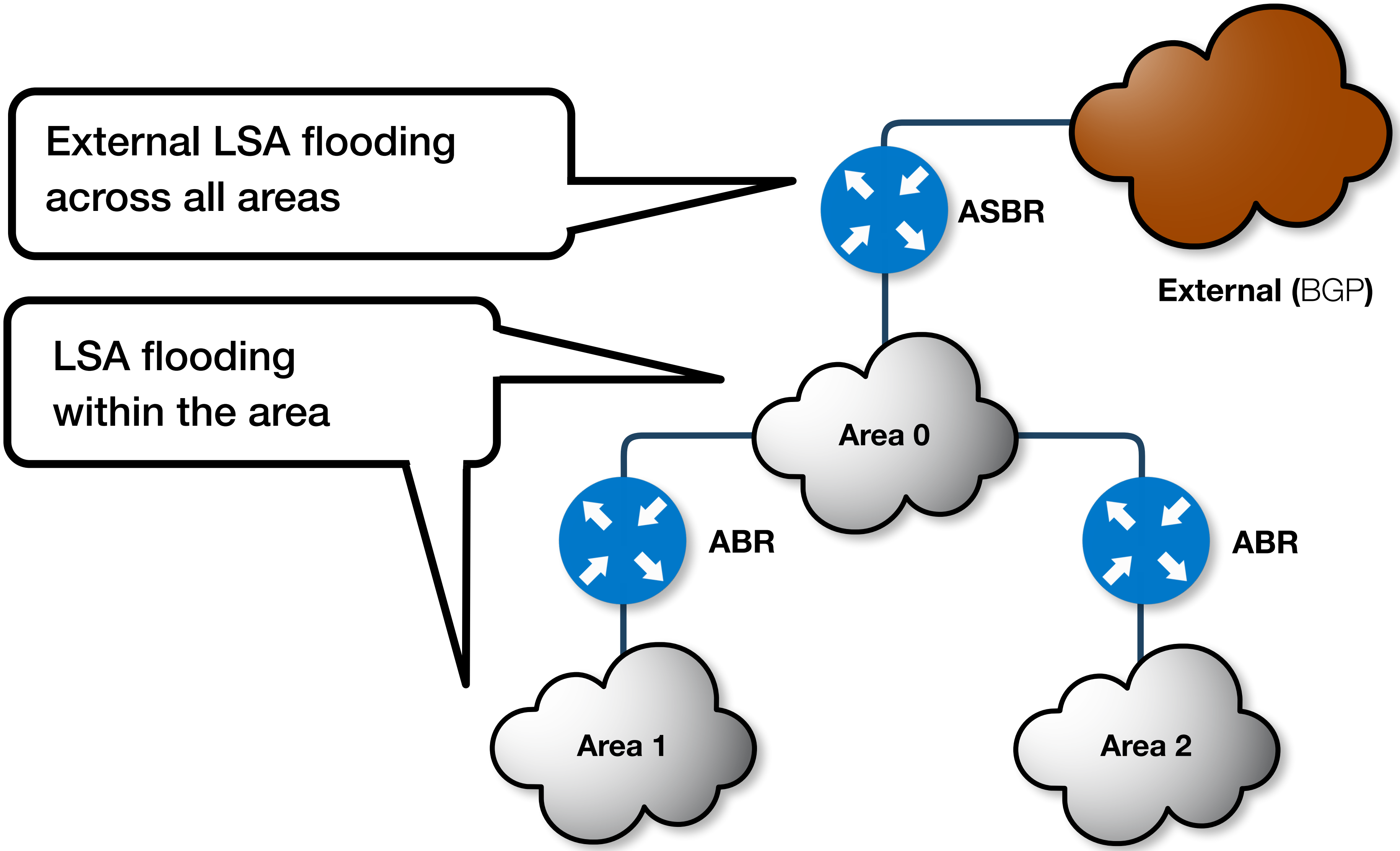
OSPF Characteristics

- 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
- DR/BDR selection
  - FF02::5 - all OSPF routers
  - FF02::6 - DR/BDR Routers

OSPF Refresher



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)
- **We have the separation of the physical topology and the IPv6 address information**
  - New LSA Types - LSA Type 8 & 9

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
  - There are new LSAs introduced: LSA type 8 & 9 for IPv6
- 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 e0/0
 network 172.16.11.8 0.0.0.3 area 1
 no passive-interface e0/1
 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 e1/1
 passive-interface e1/0
!
interface loopback 0
 ip ospf 1 area 1
!
interface e0/0
 ip ospf 1 area 1
!
interface e0/1
 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 e1/1
 passive-interface e1/0
!
interface loopback 0
 ipv6 ospf 1 area 1
!
interface e0/0
 ipv6 ospf 1 area 1
!
interface e0/1
 ipv6 ospf 1 area 1
!
```

OSPFv3 Question

Which of the options below is NOT a difference between OSPFv2 and OSPFv3?

a. Number of LSA types used
b. The length of the Router-ID
c. The separation of the physical topology and the IPv6 addresses
d. Multicast addresses that are being used

OSPFv3 Answer

Which of the options below is NOT a difference between OSPFv2 and OSPFv3?

a. Number of LSA types used

The length of the Router-ID

c. The separation of the physical topology and the IPv6 addresses

d. Multicast addresses that are being used

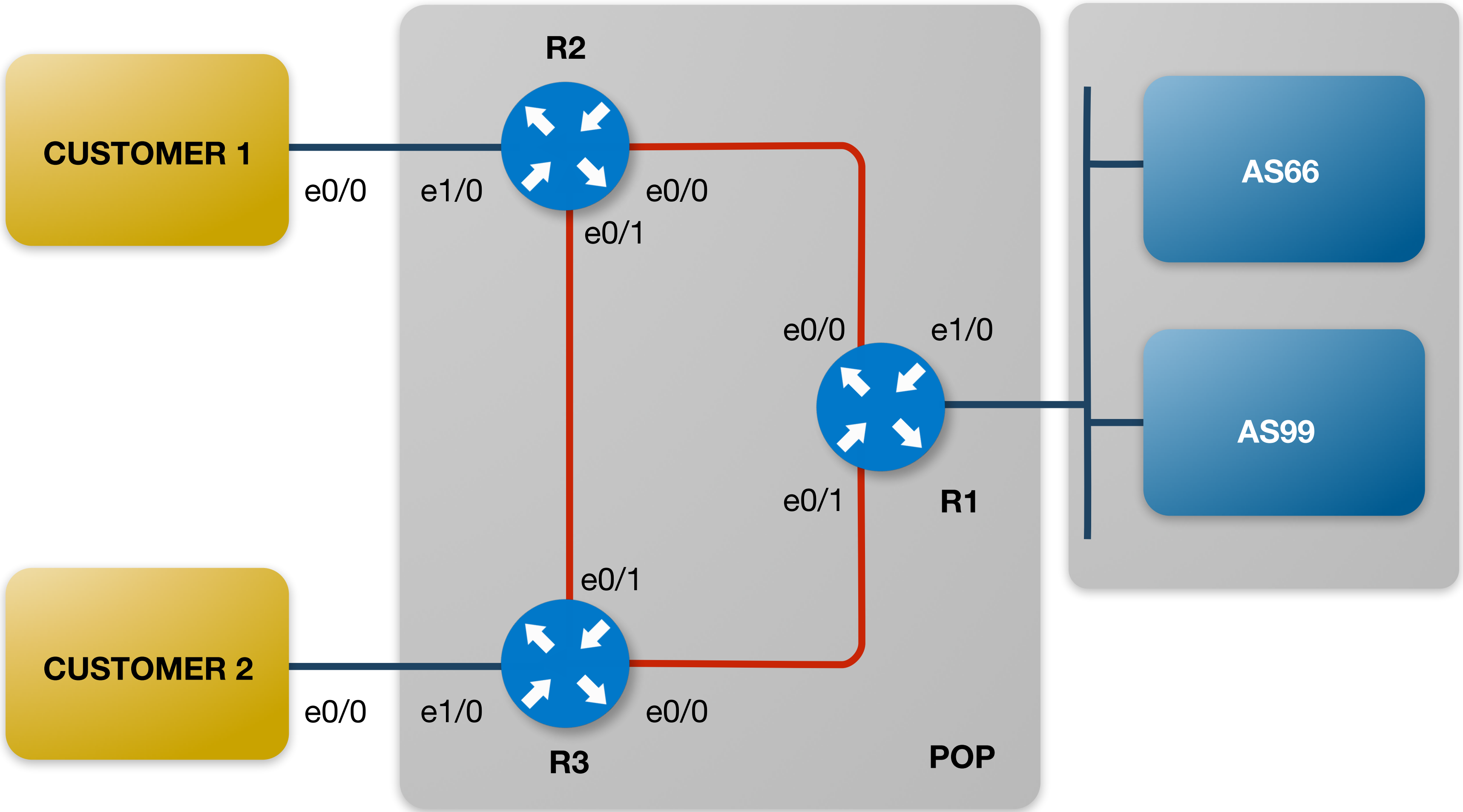
Configuring OSPFv3

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

Network Diagram



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 Ethernet1/0
 passive-interface Ethernet1/1
 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 ping the loopback on R3 from C1?
  - Can you ping the loopback on R2 from C2?

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

BGP

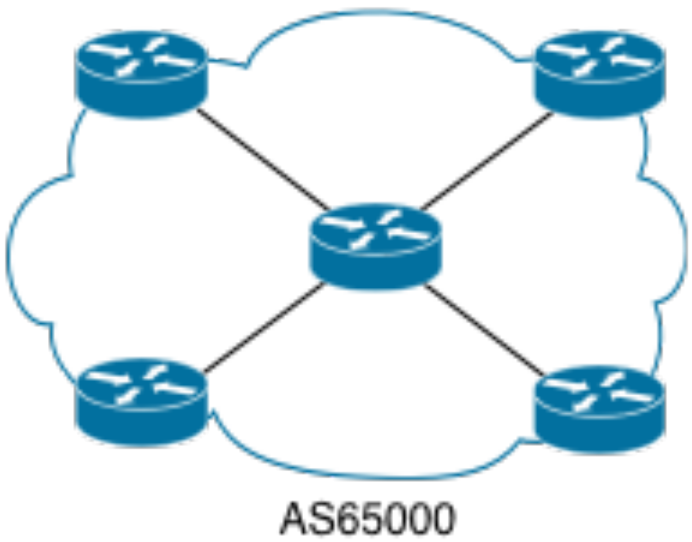
6 - Section

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

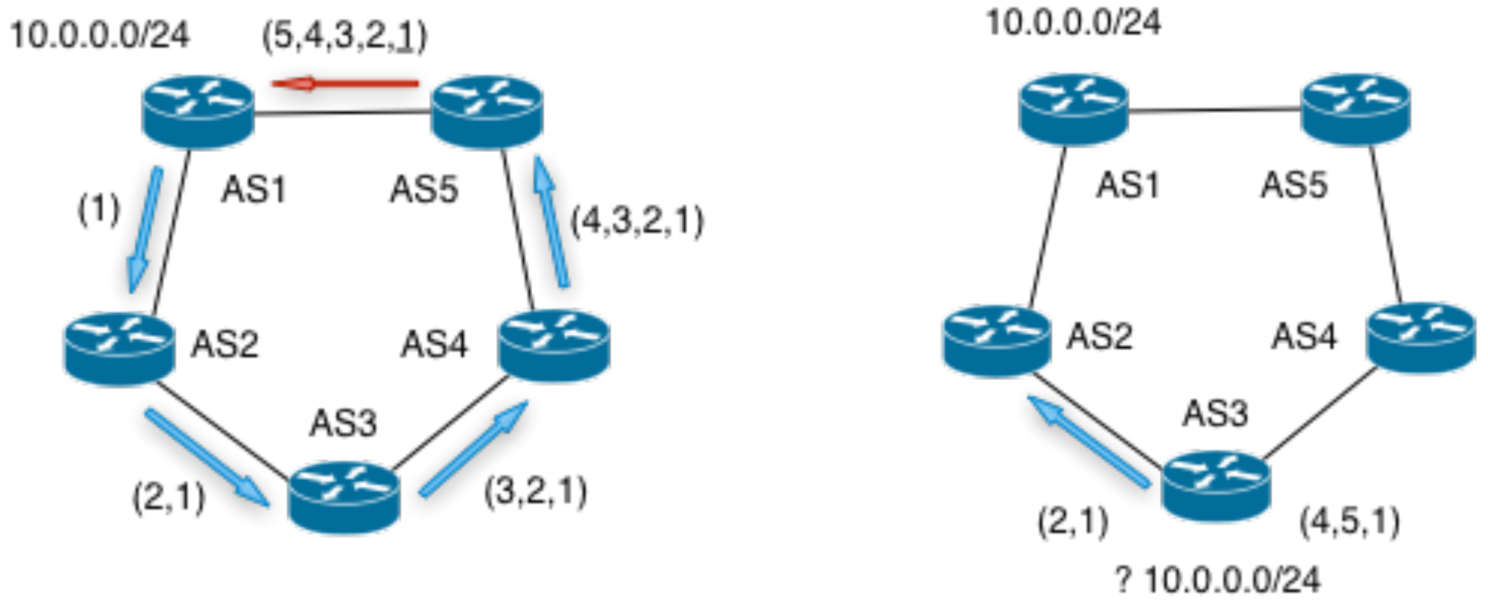
Autonomous System

- 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



AS Path

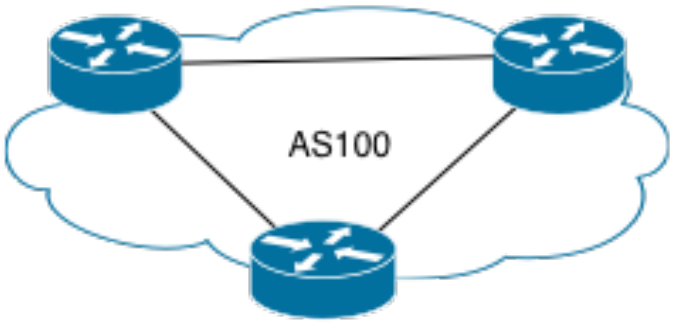
- Sequence of ASes a route has traversed
  - Loop detection
  - Path selection (AS-PATH length)



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, AS-path, AS-path attributes)

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

BGP Question

What allows BGP to support IPv6 (and the other address families)?

a. MD5 Hashing
b. IPSec
c. Multiprotocol Extensions
d. DS-LITE

BGP Answer

What allows BGP to support IPv6 (and the other address families)?

a. MD5 Hashing

b. IPSec

Multiprotocol Extensions

d. DS-LITE

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 (OPEN Message)

MP-BGP

- New features in OPEN Message:
  - **BGP Capabilities Advertisement:**
  - Address Family Identifier (**AFI**)
  - Subsequent Address Family Identifier (**SAFI**)
  - Multiprotocol Reachable Network Layer Reachability Information

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 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

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

Configuring MP-BGP & Customers

7 - Exercise

eBGP

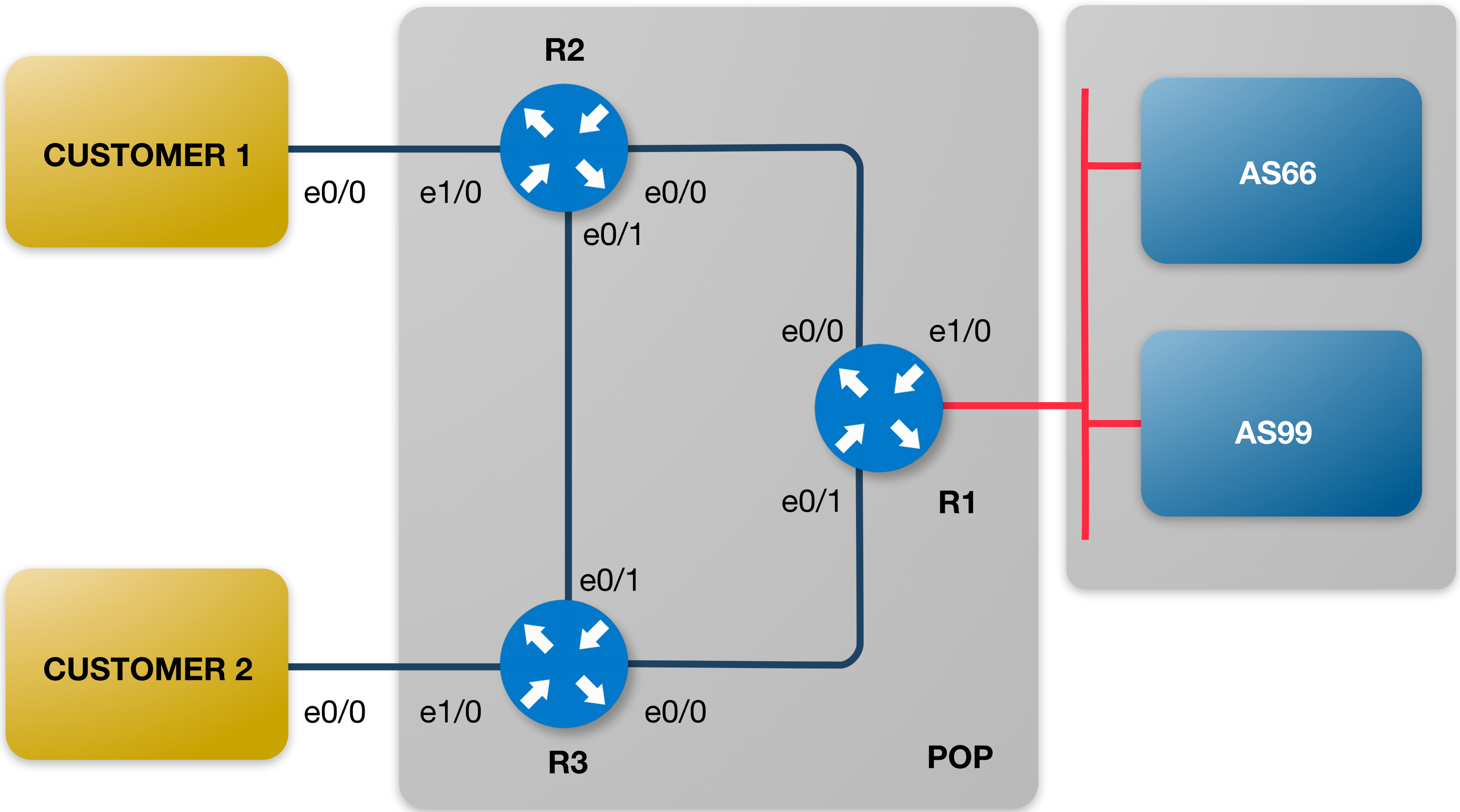
7.1 - Exercise

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
```

Network Diagram



Set the Route and Prefix list on R1

```
address-family ipv6
  network 2001:ffXX::/32
(exit) X 2
ipv6 route 2001:ffXX::/32 Null0
ipv6 prefix-list filter_v6 seq 5 permit 2001:ffXX::/32
```

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

```
router bgp 1XX
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
   redistribute static
  neighbor 2001:ff69::66 activate
  neighbor 2001:ff69::99 activate
  neighbor 2001:ff69::66 prefix-list filter_v6 out
   neighbor 2001:ff69::99 prefix-list filter_v6 out
```

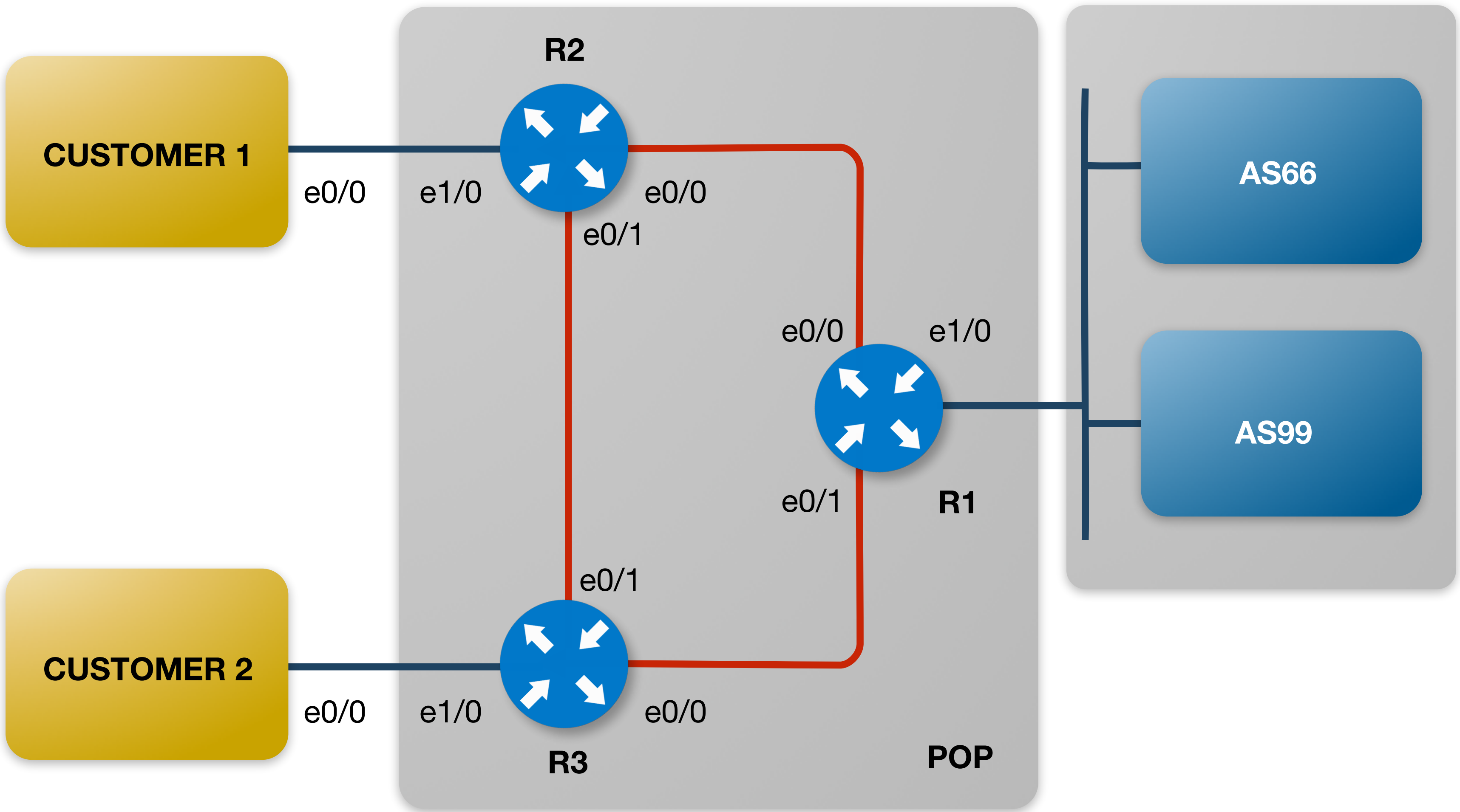
Filtering

- We filter the routes we announce
  - Why?
  - Why in this way?
  - What are the differences in IPv4 and IPv6 ?

iBGP

7.2 - Exercise

Network Diagram



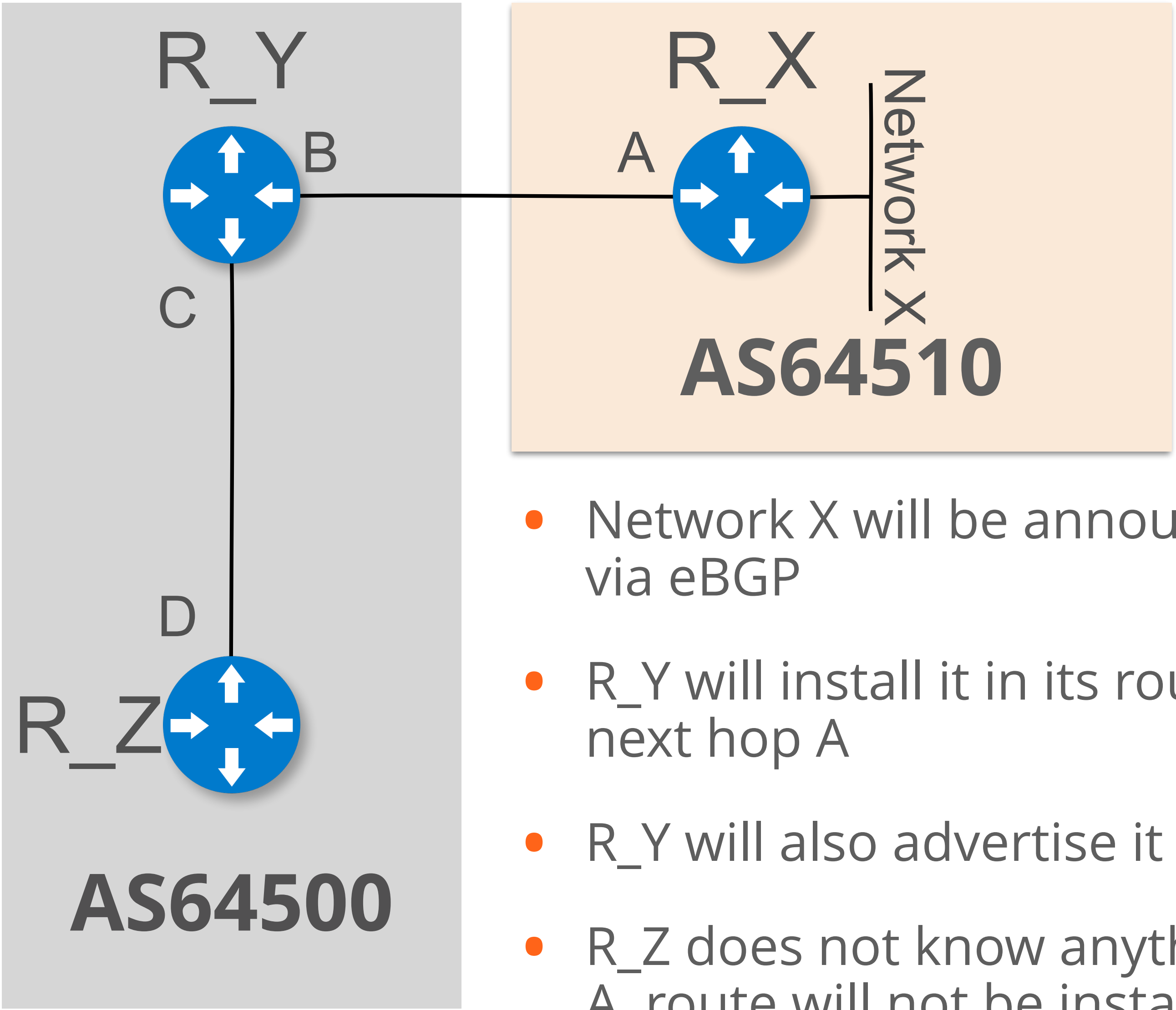
BGP Configuration R1

- 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

```
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
  redistribute static
  neighbor 2001:ffXX::2 activate
  neighbor 2001:ffXX::3 activate
  neighbor 2001:ffXX::2 next-hop-self
  neighbor 2001:ffXX::3 next-hop-self
```

Why do we use next-hop-self?



- Network X will be announced to R_Y by R_X via eBGP
- R_Y will install it in its routing table with the next hop A
- R_Y will also advertise it to R_Z via iBGP
- R_Z does not know anything about next hop A, route will not be installed
- Solution; **IGP or 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
```

```
  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
   redistribute static
    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
```

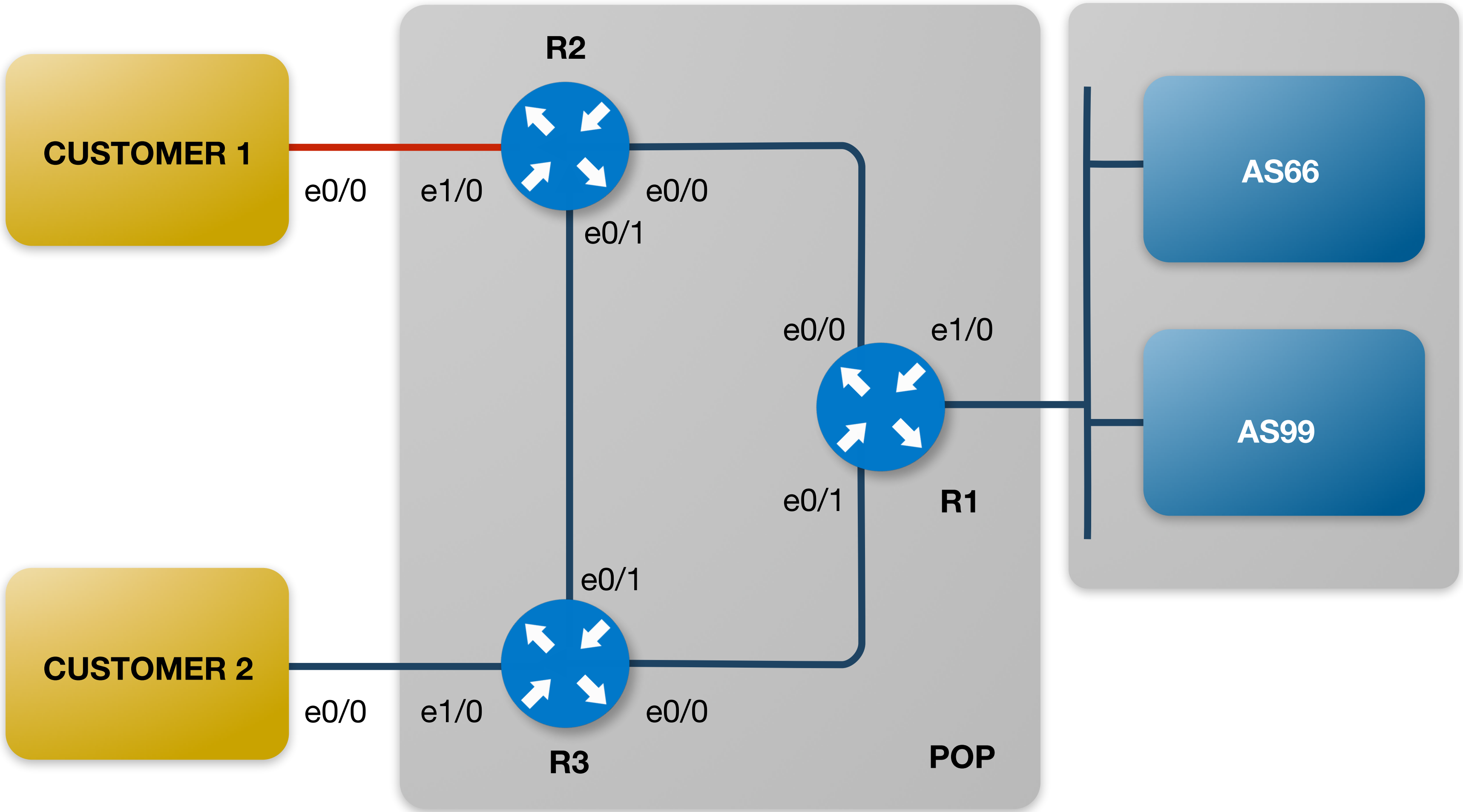
```
  neighbor 2001:ffXX::1 remote-as 1XX
  neighbor 2001:ffXX::1 update-source lo0
  neighbor 2001:ffXX::2 remote-as 1XX
  neighbor 2001:ffXX::2 update-source lo0
```

```
  address-family ipv6
   redistribute static
    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

Network Diagram



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:ffXX: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
```

```
clear bgp ipv6 unicast 2001:ffXX:0:ff01::a soft 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
  neighbor 2001:ffXX:0:ff01::b remote-as 1XX
```

```
address-family ipv6
  redistribute static
  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

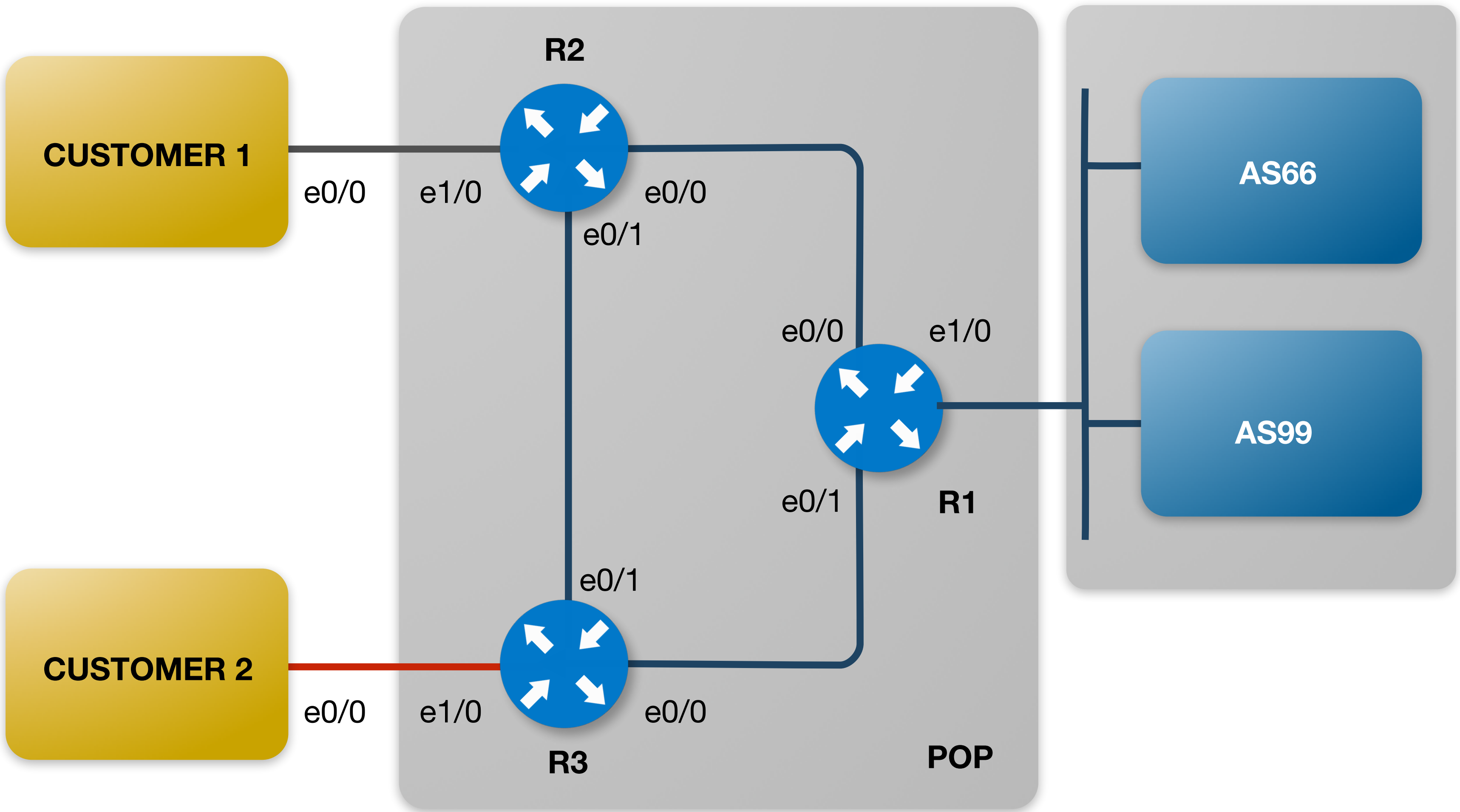
```
address-family ipv6
  network 2001:ffXX:ff01::/48
(exit) X 2
ipv6 route 2001:ffXX:ff01::/48 Null0
ipv6 prefix-list my_v6 seq 5 permit 2001:ffXX:ff01::/48
```

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

Challenge: BGP Customer 2

7.4 - Exercise

Network Diagram



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

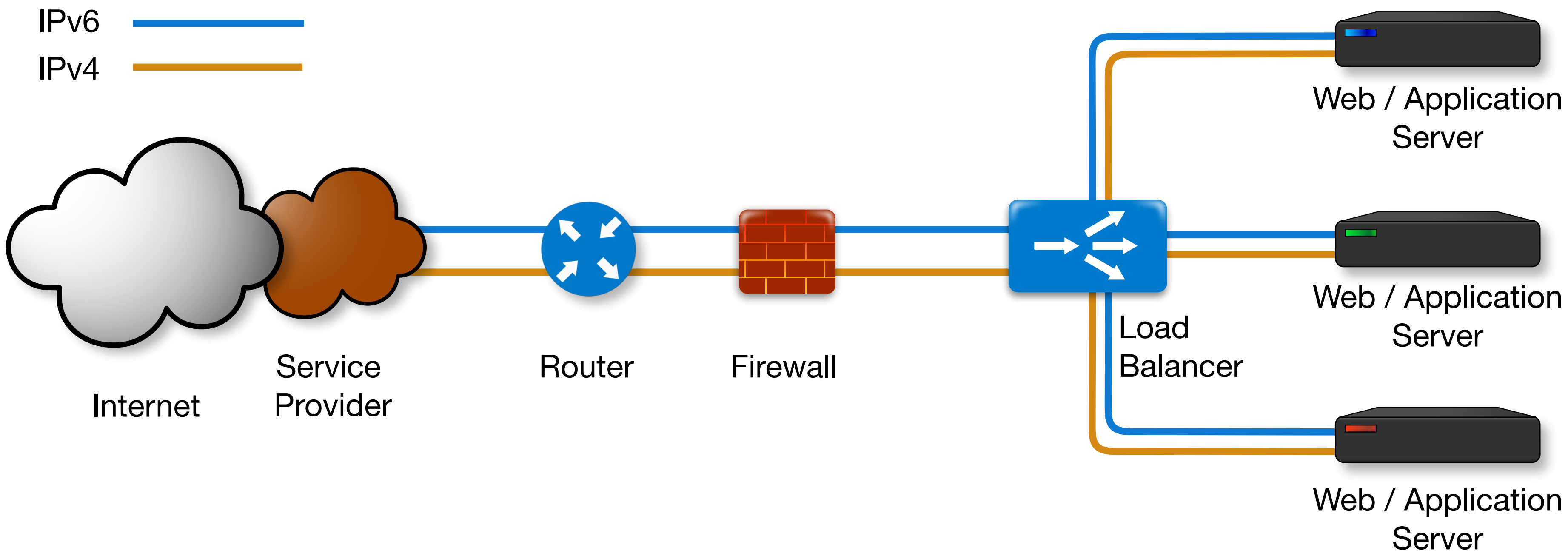
- This section is mostly about websites but it can also apply to:
  - SMTP
  - IMAP4
  - SSH
  - Remote Desktops
  - Cloud Services

Options

- Multiple ways to make content dual stack
  - Native dual stack
  - Dual stack load balancer
  - IPv6-to-IPv4 (reverse) proxy
  - NAT64

Native Dual Stack

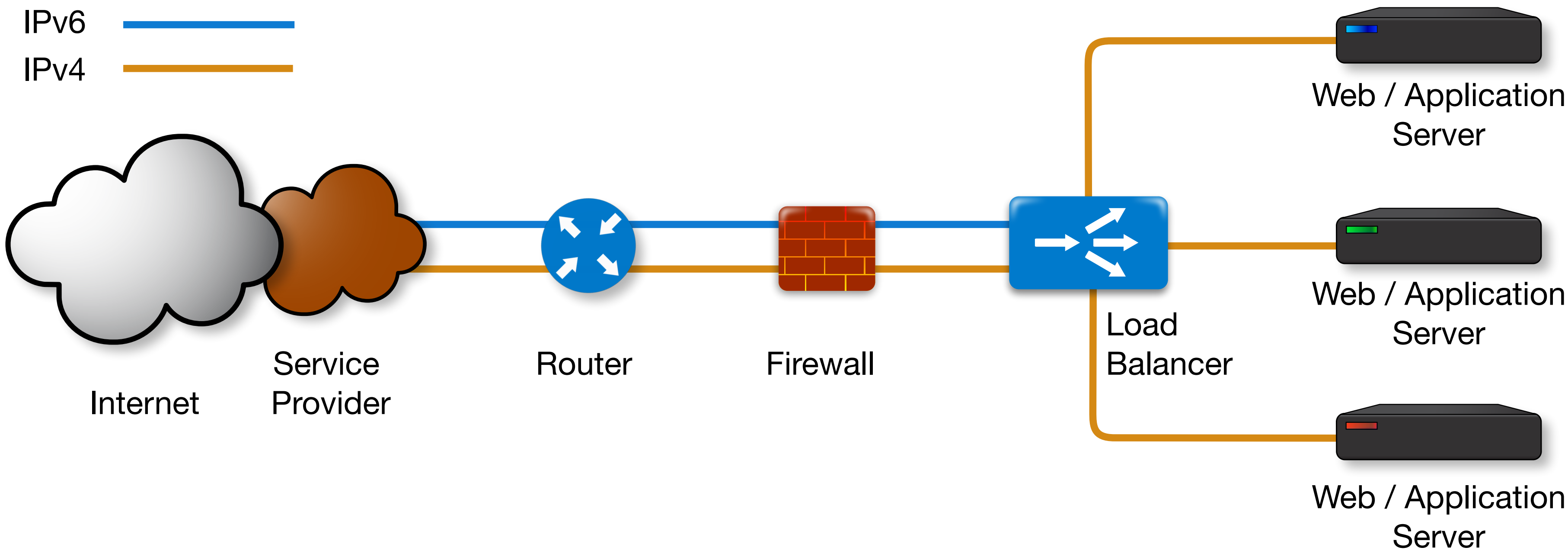
- If possible this is the preferred option



  - 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

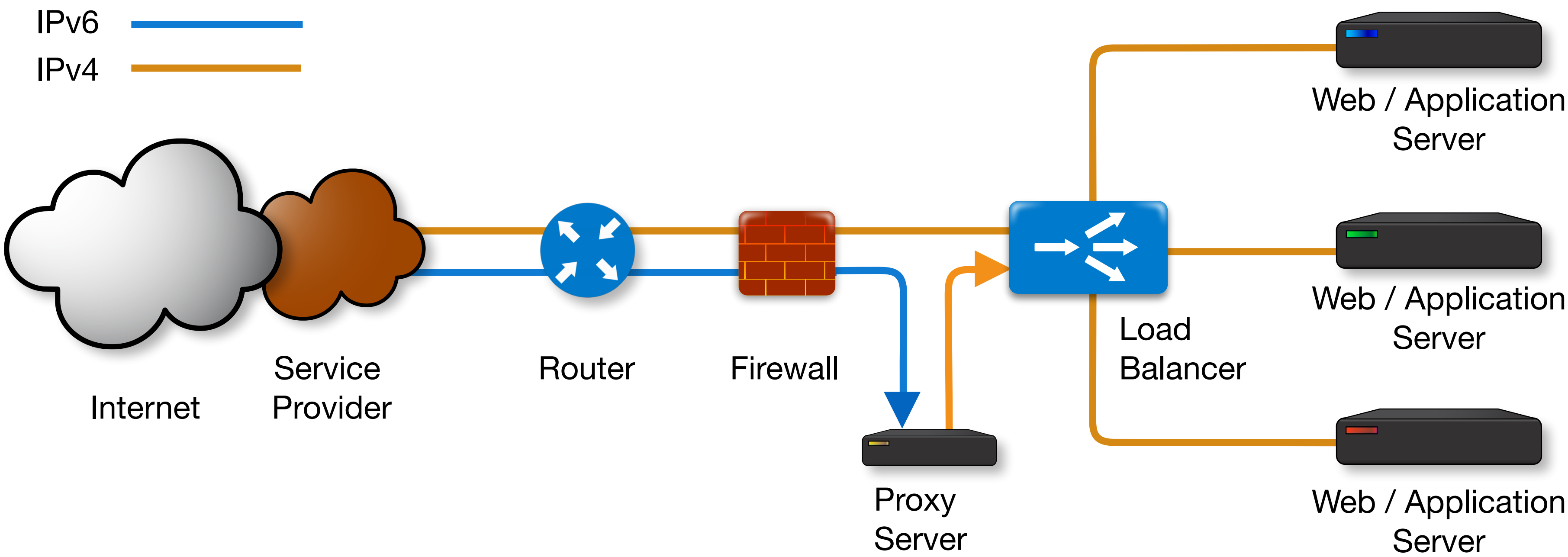
- If web servers can't handle IPv6



  - 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



  - 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
```

Happy Eyeballs Question

What is Happy Eyeballs?

a. An algorithm for determining which protocol is better to reach a network
b. A method for deploying IPv6 servers
c. A new protocol used instead of dual-stack
d. A medical term for the eye disorder

Happy Eyeballs Answer

What is Happy Eyeballs?

An algorithm for determining which protocol is better to reach a network

b. A method for deploying IPv6 servers

c. A new protocol used instead of dual-stack

d. A medical term for the eye disorder

Happy Eyeballs

- Makes dual-stacked websites more responsive to users
- If there is both A and AAAA
  - First IPv6 is used with a 300 ms head start
  - If that fails, IPv4 is used
- Implemented by all browsers
- Instable connections can cause problems with cookies

Happy Eyeballs v2 - RFC8305

- New enhancements over Happy Eyeballs v1
  - Asynchronous DNS queries
  - Sorting of resolved destination addresses
  - Asynchronous connection attempts
  - IPv4 Literals & Broken IPv6 Destination Addresses

IPv6 in the Root Servers and TLDs

- All 13 root servers have IPv6 AAAA records
- There are 1487 TLDs
  - 1465 of them are IPv6 capable (98.5%)
- More than 26% of top 1M domains have IPv6 address
- Over 9 billion websites have AAAA records

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

Mobile Providers

9 - Section

IPv6 in Mobile Networks

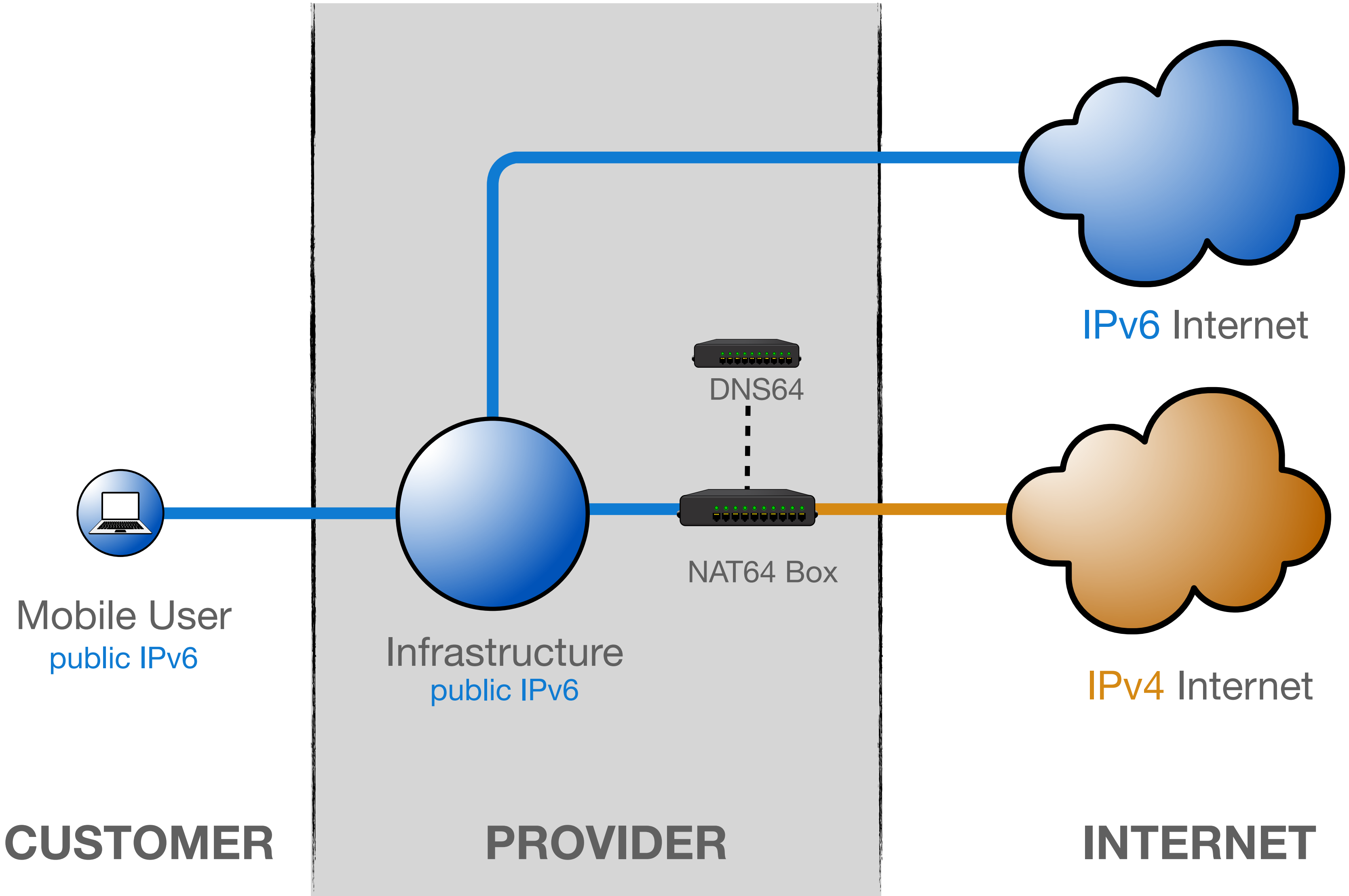
- IPv4 runout has a high and urgent impact on mobile internet providers
- Everyone has a smartphone
- Certain apps and protocols have problems with double NAT
- Do apps support IPv6?

Multiple Solutions

- Dual Stack users:
  - Public IPv4 and public IPv6
  - Private IPv4 and public IPv6
  - **Easier to implement, hard to maintain**

- IPv6 only users:
  - NAT64
  - IPv6 only
  - **Ultimate goal, needs considerable planning and work**

NAT64/DNS64

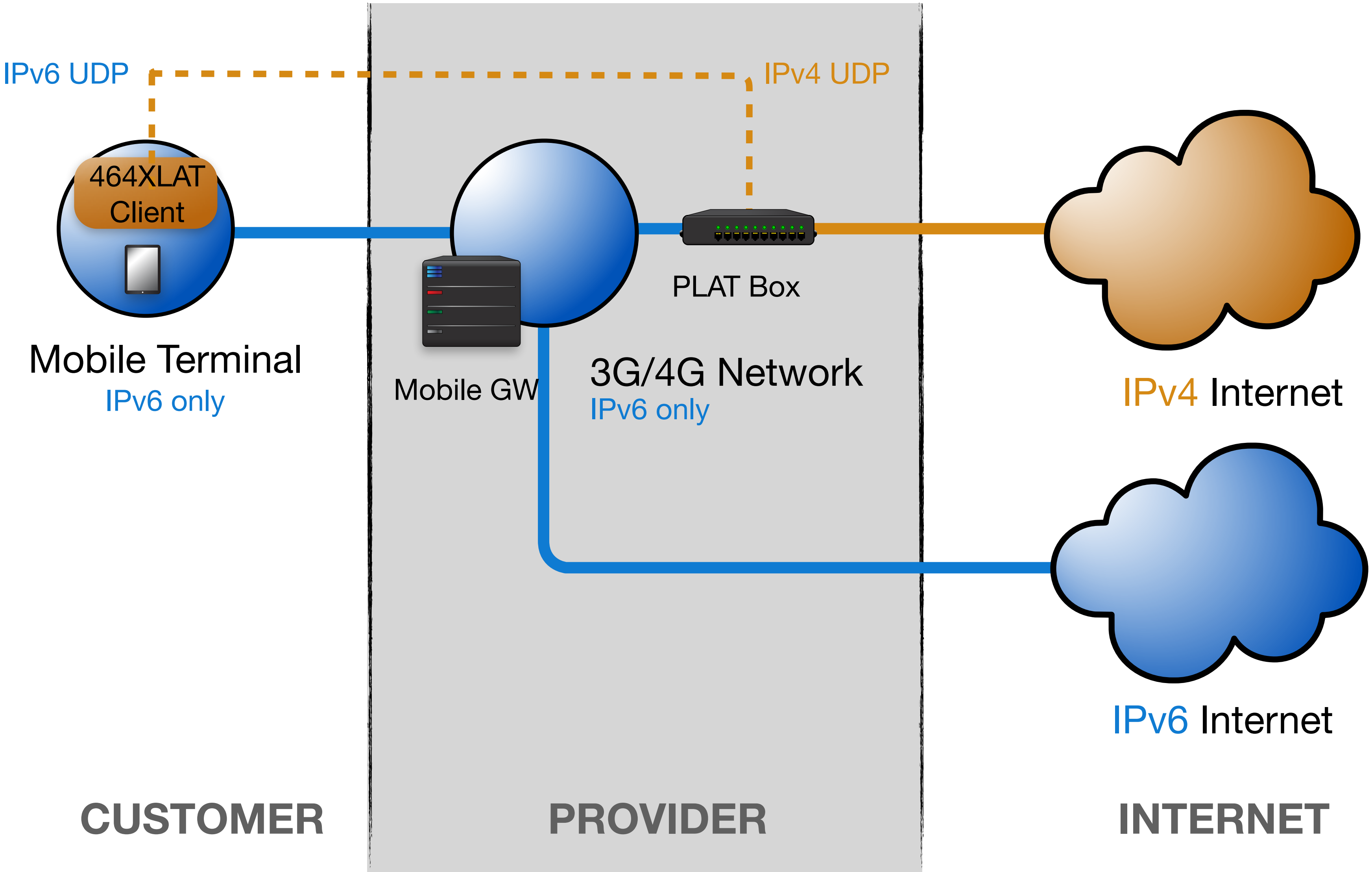

IPv6 Internet
DNS64
NAT64 Box
Mobile User
public IPv6
Infrastructure
public IPv6
IPv4 Internet
CUSTOMER
PROVIDER
INTERNET

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
  - 464XLAT has been supported since Android 4.4, so virtually every Android phone has it nowadays.

464XLAT


IPv6 UDP
IPv4 UDP
464XLAT
Client
Mobile Terminal
IPv6 only
Mobile GW
PLAT Box
3G/4G Network
IPv6 only
IPv4 Internet
IPv6 Internet
CUSTOMER
PROVIDER
INTERNET

Apple Approach

- Apple announced they will not support 464XLAT on the iPhone
- Instead they urge app developers to make apps work over IPv6-only
- That way, operators can use just NAT64 without 464XLAT

3G & 4G

- Stateful DHCPv6-based address configuration is not supported by 3GPP specifications*
- Only **SLAAC** & **Stateless DHCPv6** supported
- 3GPP relies on RAs
- Only one /64 prefix is allowed

RFC 6459 IPv6 in 3GPP EPS
https://datatracker.ietf.org/doc/html/rfc6459

RFC 7066 IPv6 for 3GPP Cellular Hosts - Appendix-A
https://datatracker.ietf.org/doc/html/rfc7066#appendix-A

3G

- 3G networks work on PDP concept
  - On the UE, a PDP context **=** network interface
- 3G networks support IPv6 since the beginning
- **IPv4v6** is supported since 3GPP Release 9
  - Dual-stack can also be provided by 2 different PDP contexts one per each protocol. But it means 2 different licenses and double resource consumption in the network
- SLAAC is supported

4G

- Works with Evolved Packet System (EPS) Bearer
  - Initiated by the phone to establish a connection
  - IPv4, IPv6 and IPv4v6 supported

- Always-on Packet Data Network (PDN) Connection
- Due to the need for supporting VoIP

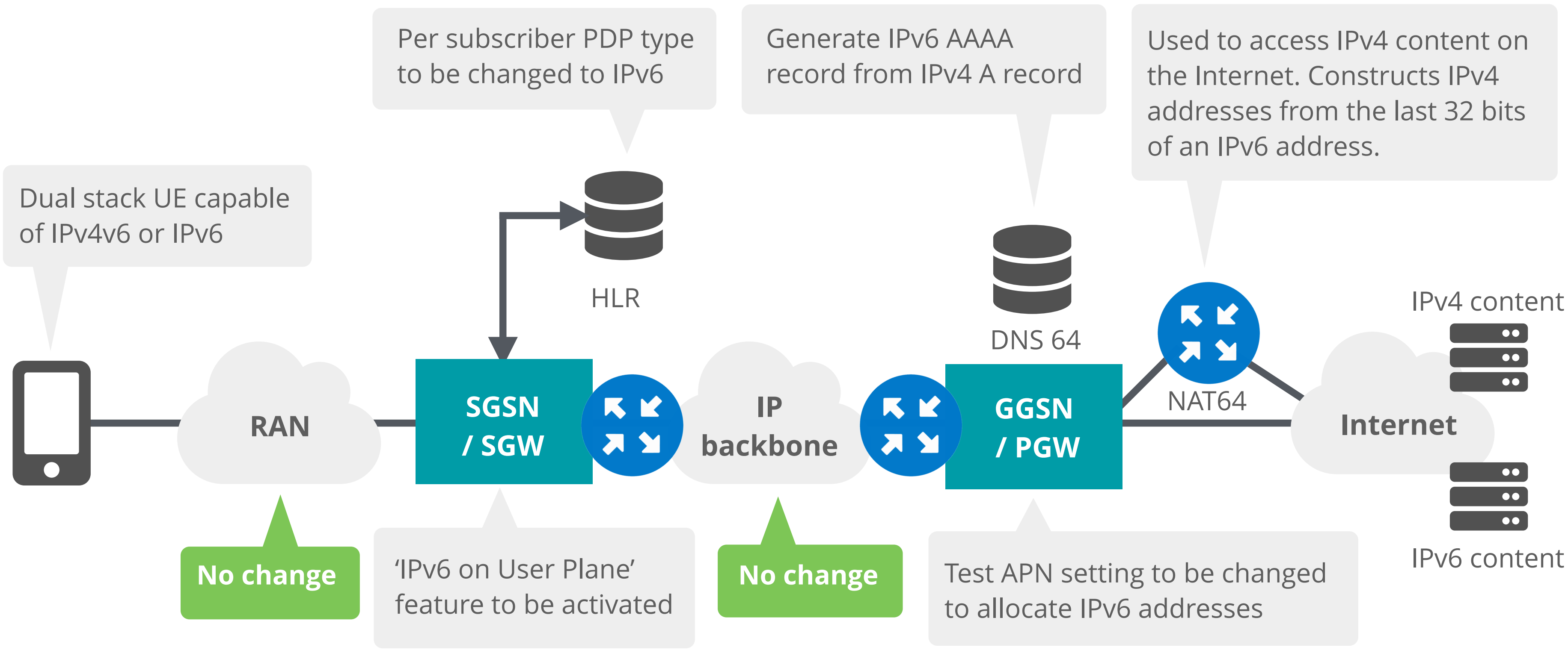
5G

- 5G is still in evolving phase

- IPv6 is a must for 5G networks as they bring massive amount of connections with mMTC

- Dual-Stack should probably still be supported - Due to the mixed nature of current networks

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)
- SGSN/SGW
  - ‘IPv6 or IPv4v6 on user plane’ needs to be enabled
  - Fallback strategy

What Needs To Be Done

- GGSN/PGW
  - 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.**

- Policy Decision Functions (PCRF/PCF)

Tethering & IPv6

- A /64 prefix is received through an RA to the phone
- An /128 from that /64 is used for the own WAN
- The same /64 is used for the LAN (and for tethering)
  - Tethering is done through RA
  - DAD is used to avoid duplicate addresses

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

Challenges - Roaming

- Major problems happen at three stages:

Attach

IPv4v6 PDP/PDN type may not be supported in visited networks which have old versions* of SGSNs.

PDP Creation

IPv4v6 and IPv6 PDP support on visited SGSN is the main concern

Single-stack IPv6 in the home routed mode is recommended

Service Request

464XLAT may cause problems

Disabling local-breakout scenario or supporting IPv4-only on roaming should be considered.

Overview Day 2

- Transition Mechanisms
- Exercise: NAT64/DNS64
- Host Configuration
- Exercise: SLAAC
- DHCPv6
- Exercise: DHCPv6
- Security
- IP Address Management

Transition Mechanisms

Section 10

Transitioning: Solving Two Problems

- Cope with the scarcity of IPv4 addresses
  - Our workarounds today; NAT/CGN/LSN
  - We need a better solution!
- Provide IPv6 connectivity to the host and to the network
  - We need to find a way to connect to the emerging IPv6-only networks.

Three Different Types of Transition

Tunnelling

- **v6inv4**
  - 6 in4
  - 6RD
- **v4inv6**
  - DS-Lite
  - MAP-E

Translation

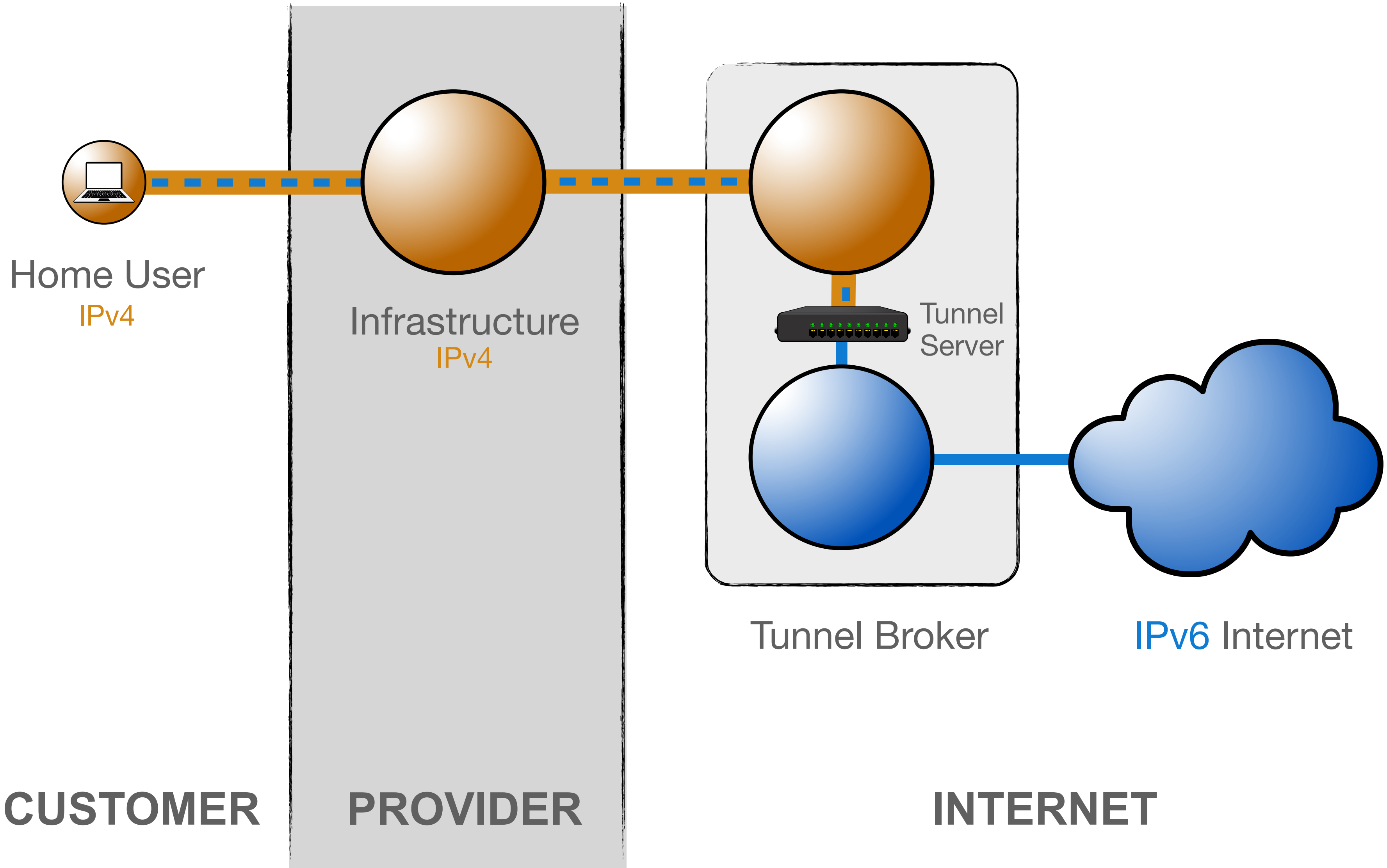
- **v6tov4**
  - NAT64
  - 464XLAT
  - MAP-T
- **v4tov6**
  - NOT USED

Dual-Stack

Tunnelling - 6in4

- Manually configured tunnels towards a fixed tunnel broker like Hurricane Electric or your own system
- Stable and predictable but not easily deployed to the huge residential markets
- MTU might cause issues

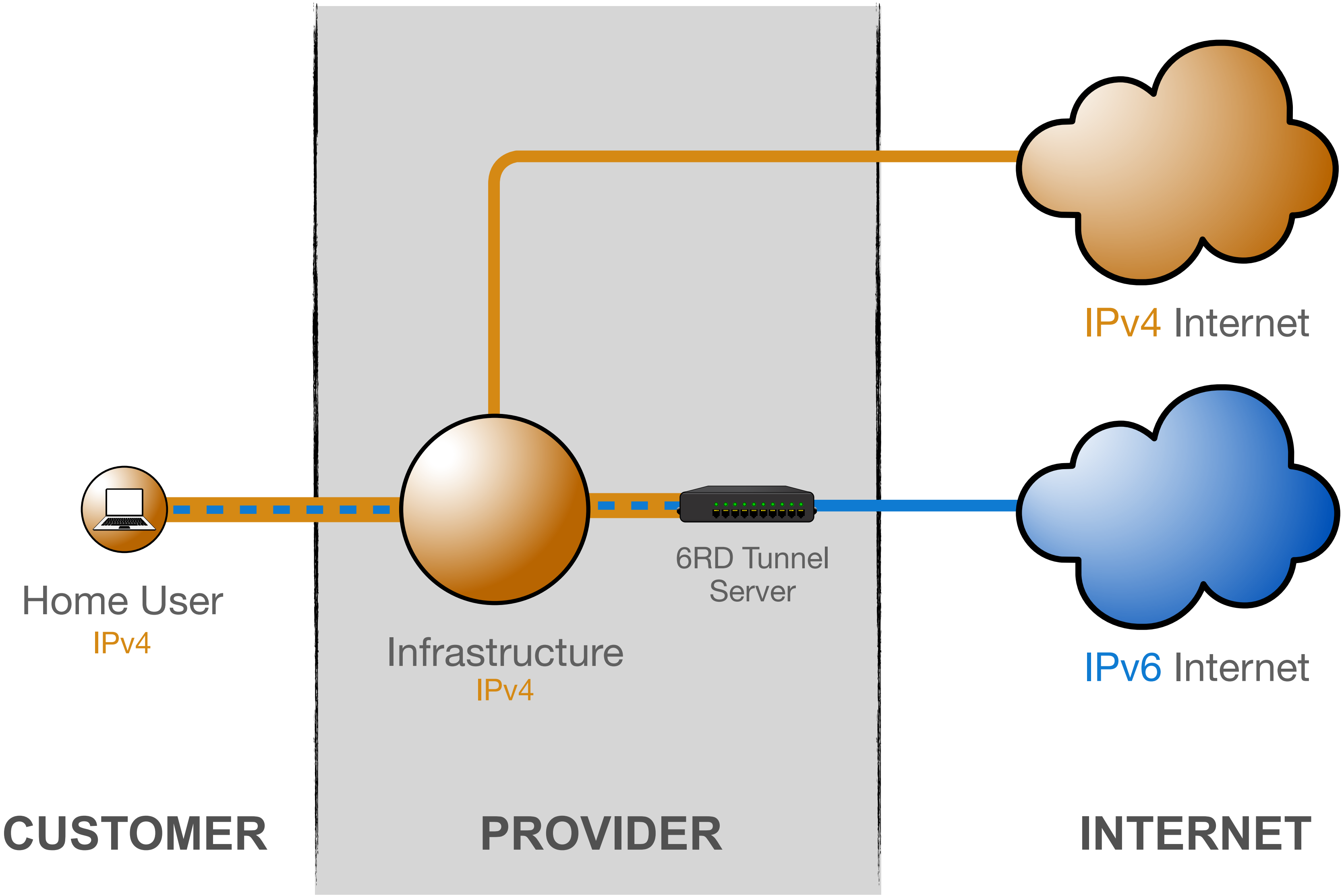
Tunnelling - 6in4



Tunnelling - 6RD

- Encodes the IPv4 address in the IPv6 prefix
- Uses address space assigned to the operator
- The operator has full control over the relay
- Can work with both public and private IPv4 space
- Needs additional software for signalling
- CPE should also support 6RD

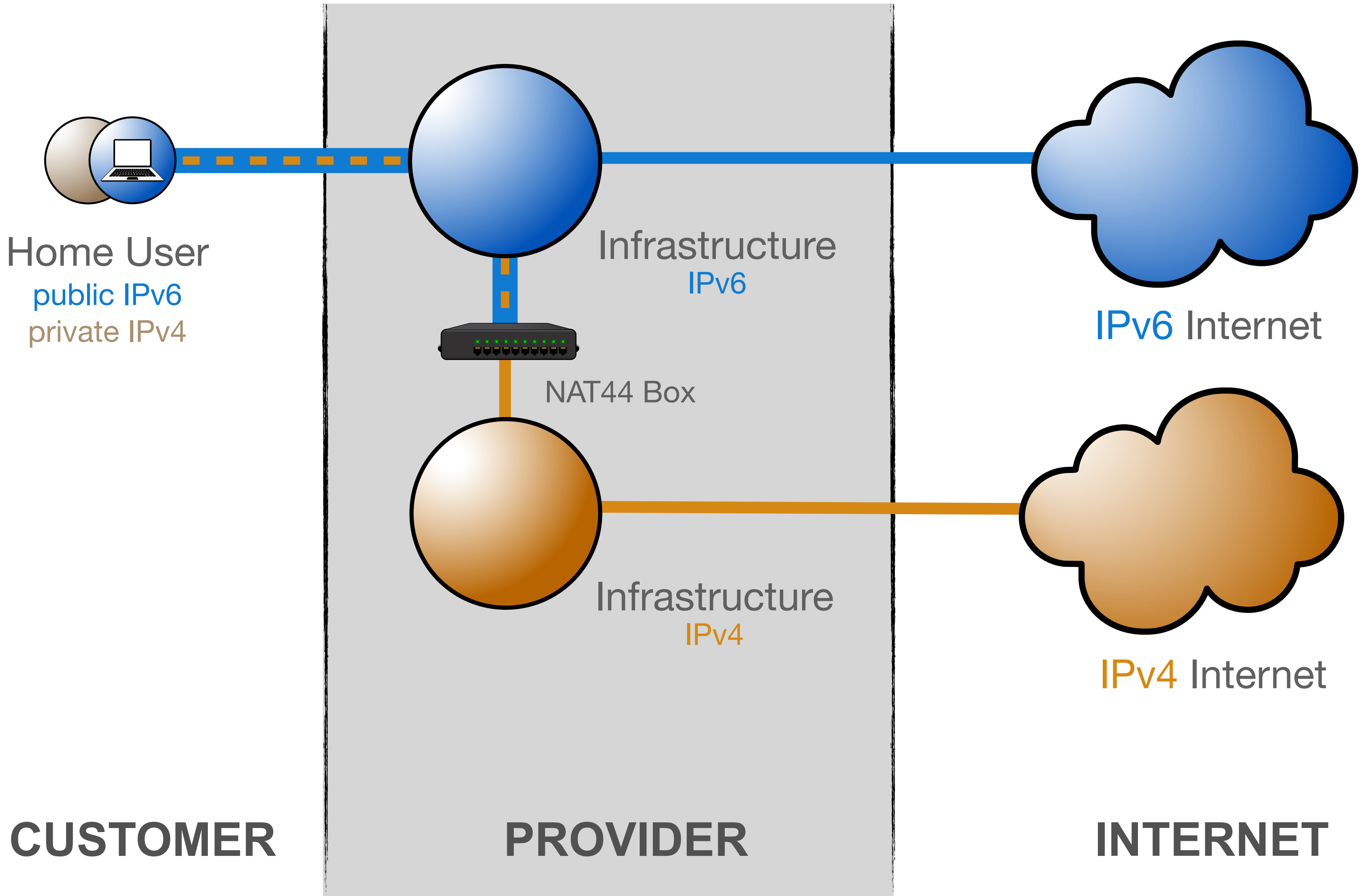
Tunnelling - 6RD



Tunnelling - DS-lite

- Tunnelling IPv4 over IPv6
- Allows clients to use RFC1918 addresses without doing NAT themselves
- NAT is centrally located at the provider
- Client’s IPv6 address is used to maintain state and to keep clients apart
    - Allows for duplicate IPv4 ranges

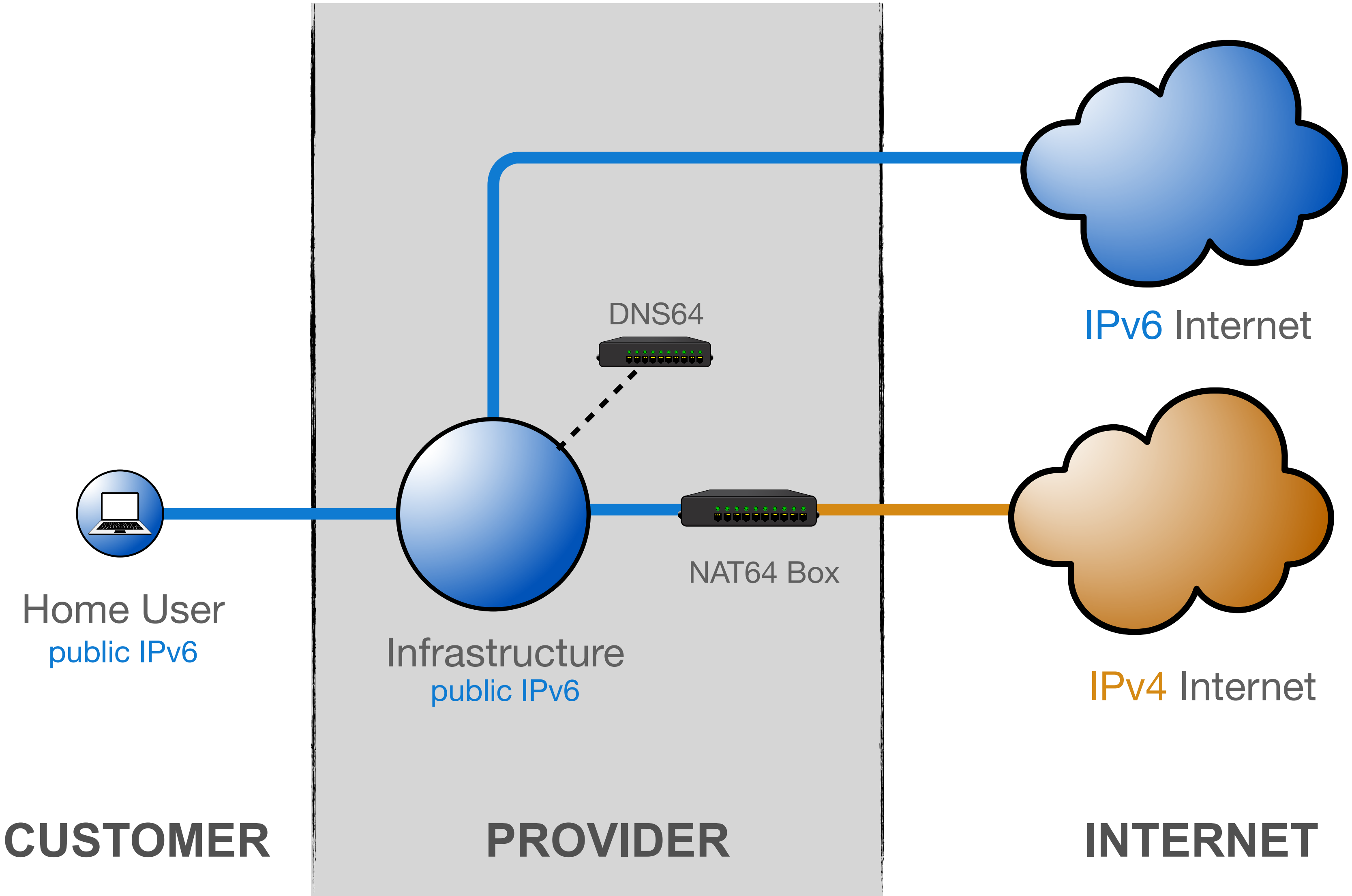
Tunnelling - DS-lite



Translation - NAT64 / DNS64

- Single-stack clients will only have IPv6
- Translator box will strip all headers and replace them with IPv4
- Requires some DNS “magic”
  - Capture responses and replace A with AAAA
  - Response is crafted based on target IPv4 address
- Usually implies address sharing on IPv4

Translation - NAT64 / DNS64



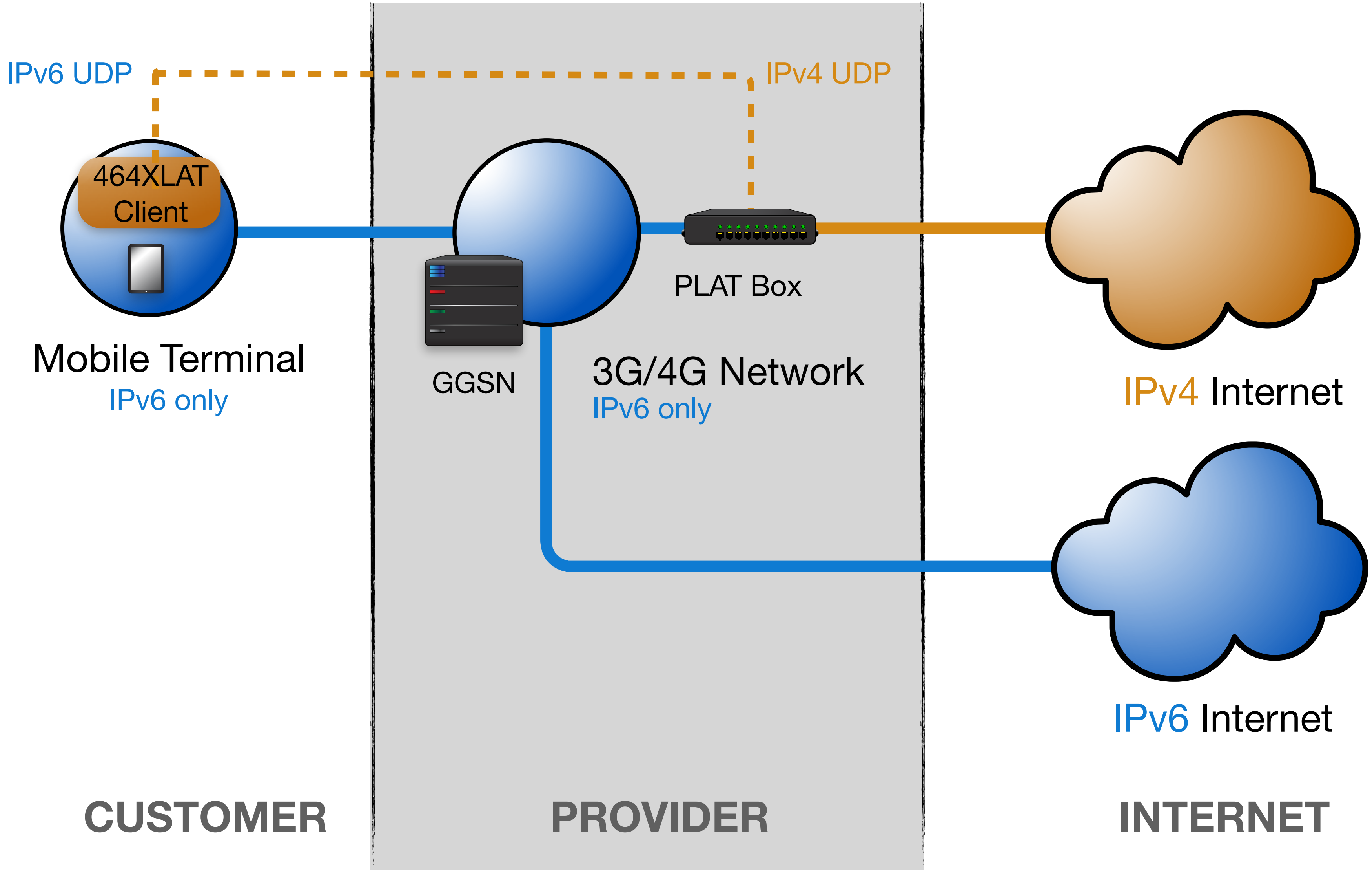
Translation - 464XLAT

- Extension to NAT64 to access IPv4-only applications (legacy applications)

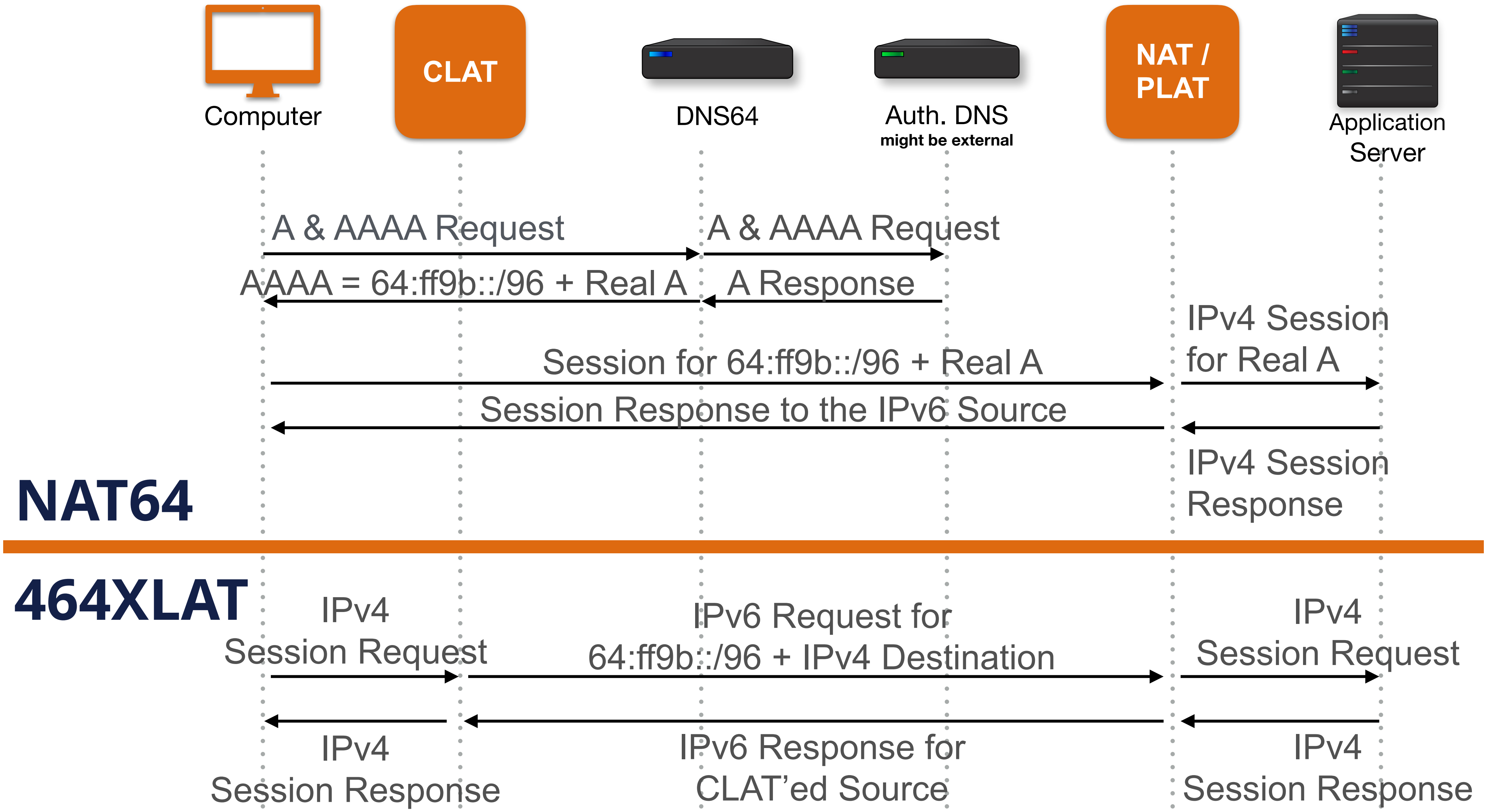
- Handset pretends there is an IPv4 address and the CLAT translates IPv4 packets to IPv6

- Then in the PLAT translates from IPv6 to IPv4

Translation - 464XLAT



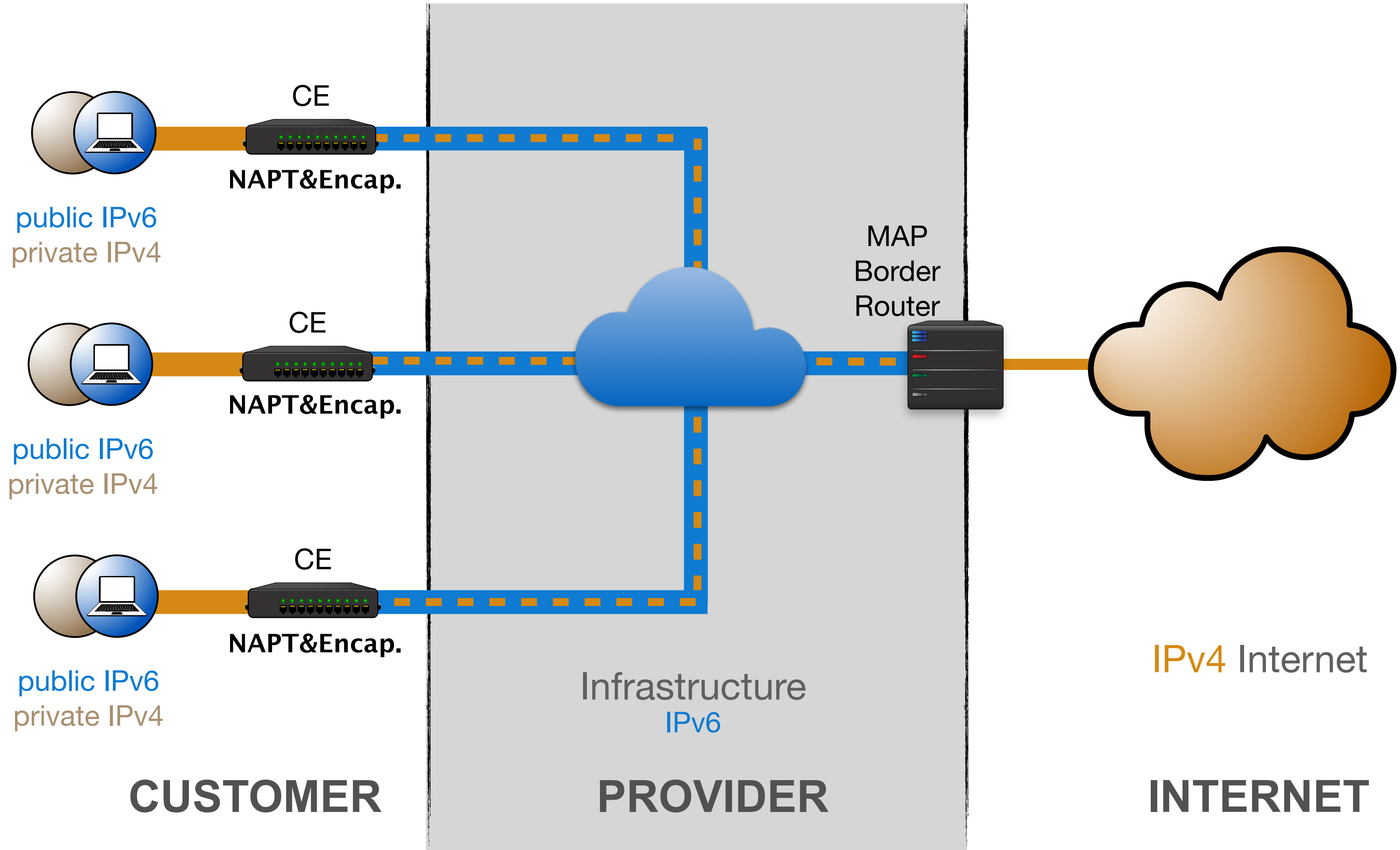
Translation - NAT64 & 464XLAT



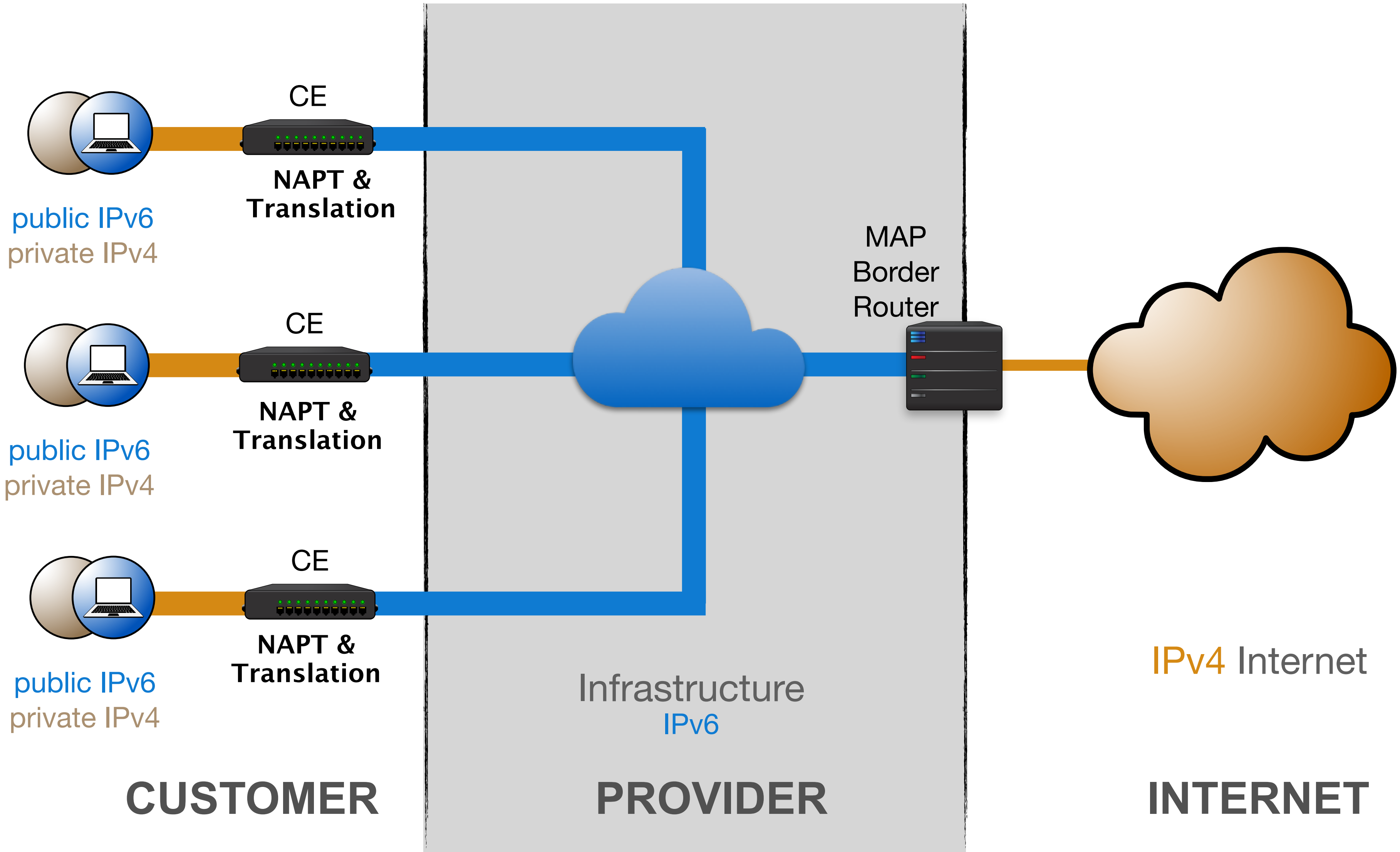
MAP-E / MAP-T

- IPv4 over IPv6 - Encapsulated or Translated
- Clients get private IPv4 and public IPv6
- IPv4 address/port mapped into IPv6 address
- Stateless NAT64 allows traffic to flow asymmetrically in and out of MAP domain

Tunnelling - MAP-E



Translation - MAP-T



Transition Question

Which of the matchings below is not correct?

a. 6RD; Tunnelling - v6 in v4
b. NAT64; Translation - v6 to v4
c. DS-LITE; Tunnelling - v4 in v6
d. Dual Stack; Translation - v6 to v4

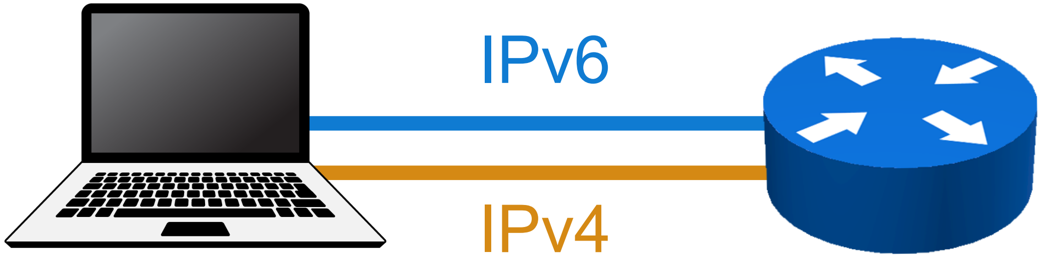
Transition Answer

Which of the matchings below is not correct?

a. 6RD; Tunnelling - v6 in v4
b. NAT64; Translation - v6 to v4
c. DS-LITE; Tunnelling - v4 in v6
d. **Dual Stack; Translation - v6 to v4**

What about Dual-Stack?

Dual Stack



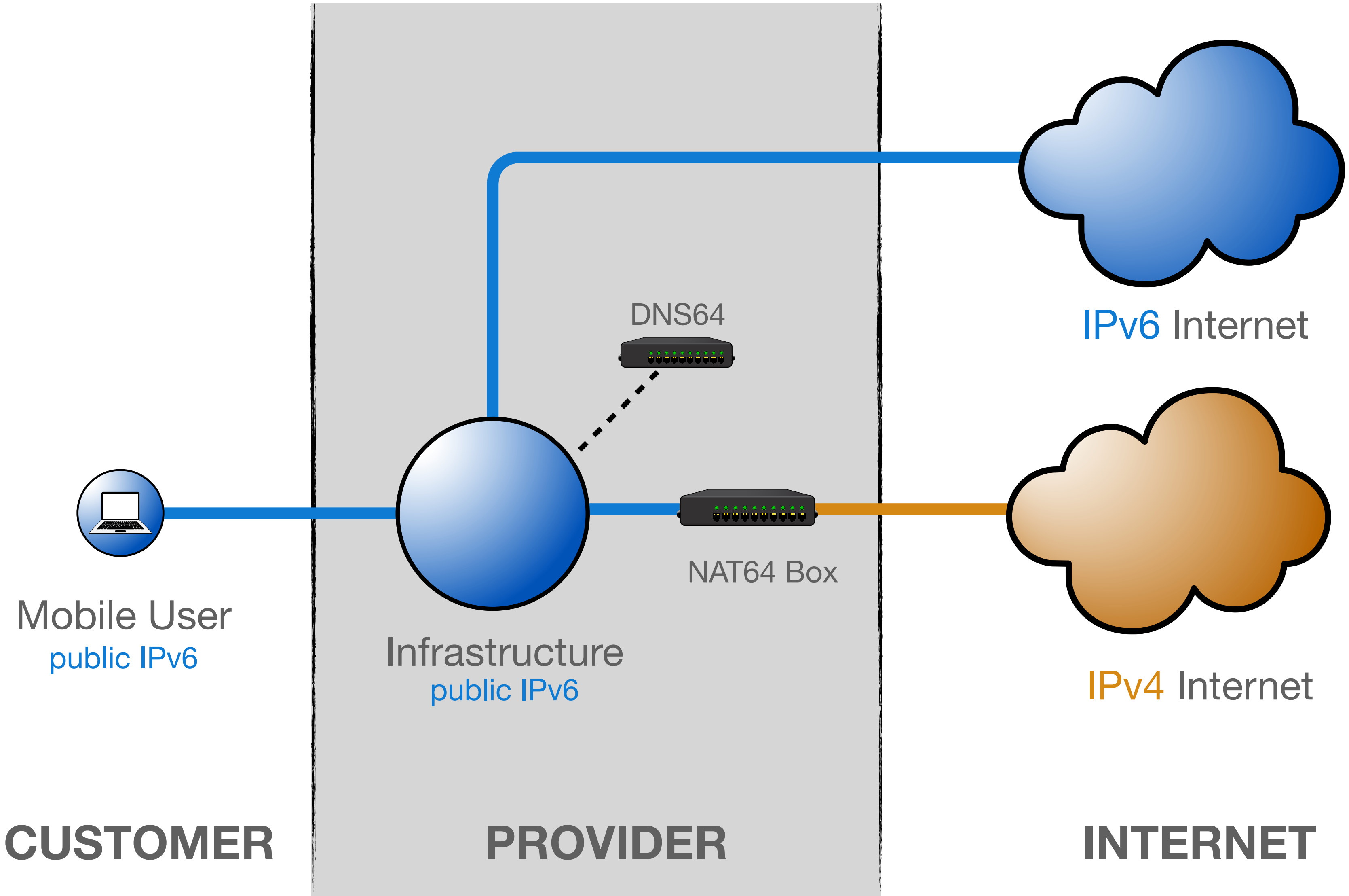
Configuring NAT64

Section 11

NAT64 / DNS64

- Single-stack clients will only have IPv6
- Translator box (NAT64) will strip all headers and replace them with IPv4
- Requires some DNS “magic”
    - Capture responses and replace A with AAAA
    - Response is crafted based on target IPv4 address
- Usually implies address sharing on IPv4

NAT64/DNS64


DNS64
IPv6 Internet
NAT64 Box
Mobile User
public IPv6
Infrastructure
public IPv6
IPv4 Internet
CUSTOMER
PROVIDER
INTERNET

Well Known Prefix

- 64:ff9b::/96
  - Algorithmic translation from an IPv4 address to an IPv6 address and vice

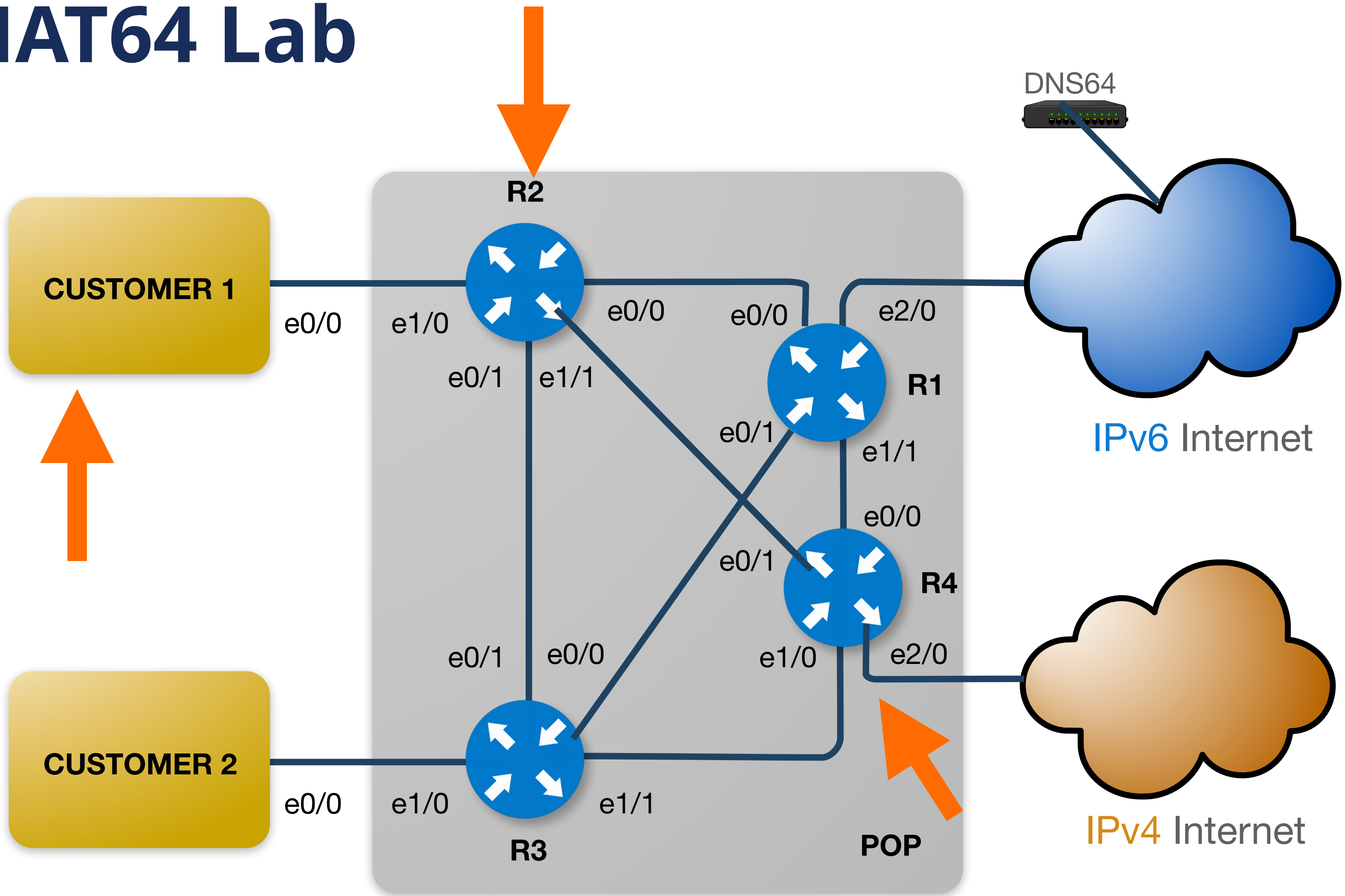
Well-Known Prefix	IPv4 address	IPv4-Embedded IPv6 address
64:ff9b::/96	192.0.2.33	64:ff9b::192.0.2.33

- Can not be used for private IPv4 addresses
- Only used within the operator, not announced in global routing table
- Or use your own prefix, but be careful

NAT64 Lab

- The problem is: We will have IPv6-only customers that cannot reach IPv4-only content
- Step 1: Configure C1 as an IPv6-only customer
- Step 2: Ping from C1 to www.example.com (dual-stack)
- Step 3: Ping from C1 to ipv4.example.com (v4 only)
- Step 4: Setup R4 as NAT64 box
- Step 5: Set static route on R2
- Step 6: Ping from customer to ipv4.example.com (v4 only)

NAT64 Lab


DNS64
R2
CUSTOMER 1
e0/0
e1/0
e0/0
e0/0
e2/0
e0/1
e1/1
R1
IPv6 Internet
e0/1
e1/1
e0/0
e0/1
R4
e0/1
e0/0
e1/0
e2/0
CUSTOMER 2
e0/0
e1/0
e1/1
R3
POP
IPv4 Internet

Step 1: Configure C1

- The customer will only have an IPv6 address

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

```
interface e0/0
 ipv6 address 2001:ffXX:0:ff01::a/64
 no ipv6 redirects
 ipv6 nd ra suppress all
 no shut
```

- Set up a static route to R2

```
ipv6 route 2000::/3 2001:ffXX:0:ff01::b
ipv6 route 64:ff9b::/96 2001:ffXX:0:ff01::b
```

- Set up a name server

```
ip domain lookup
ip name-server 2001:ff53::53
```

Step 2: Ping from C1 to dual-stack

- Ping from the customer to a dual-stacked website

```
ping www.example.com
```

Step 3: Ping from C1 to IPv4-only

- Ping from the customer to an IPv4-only website

```
ping ipv4.example.com
```

- What's the IPv6 address that ping tries to use?

Step 4: Setup R4 as NAT64 box

- Enable IPv6

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

- Configure the loopback interface for IPv4 & IPv6

```
interface lo0
 ipv6 address 2001:ffXX::4/128
 no ipv6 redirects
```

Step 4: Setup R4 as NAT64 box

- Configure the 3 internal interfaces

```
interface e0/0
 ipv6 address 2001:ffXX:0:04::a/127
 no ipv6 redirects
 ipv6 nd ra suppress all
```

```
interface e0/1
 ipv6 address 2001:ffXX:0:05::a/127
 no ipv6 redirects
 ipv6 nd ra suppress all
```

```
interface e1/0
 ipv6 address 2001:ffXX:0:06::a/127
 no ipv6 redirects
 ipv6 nd ra suppress all
```

Step 4: Setup R4 as NAT64 box

- Setup OSPFv3 on the router

```
ipv6 router ospf 1
 log-adjacency-changes
 router-id 172.X.255.Y    (Y is router number)
 passive-interface Ethernet2/0
 redistribute connected
```

- Setup OSPFv3 on the three interfaces : (e0/0, e0/1, e1/0)

```
interface xyz
 ipv6 ospf network point-to-point
 ipv6 ospf 1 area 0
 no shut
```

Step 4: Setup R4 as NAT64 box

- Configure the transit interface

```
(config)# interface Ethernet2/0
(config-if)# ip address 10.132.X.2 255.255.255.252
(config-if)# no shut
```

- Test if transit provider router is reachable

```
# ping 10.132.X.1
```

Step 4: Setup R4 as NAT64 box

- Create a filter

```
(config)# ip prefix-list transit-out-v4 seq 5 permit 10.X.0.0/22
```

- Configure the BGP session

```
(config)# router bgp 1XX
(config-router)# bgp log-neighbor-changes
(config-router)# neighbor 10.132.X.1 remote-as 44
(config-router)# neighbor 10.132.X.1 prefix-list transit-out-v4 out
```

- Set the network statement

```
(config-router)# network 10.X.0.0 mask 255.255.252.0
```

Step 4: Setup R4 as NAT64 box

- Insert static Null route
  - Before BGP advertised its network, it checks for an exact match of network number and mask on router's routing table

```
(config)# ip route 10.X.0.0 255.255.252.0 null0
```

Step 4: Setup R4 as NAT64 box

- From R4 ping the IPv4-only host behind the transit

```
ping 193.0.21.80
```

Step 4: enable NAT64 on interfaces

- Interface lo0, e0/0, e0/1, e1/0 and e2/0

```
interface xyz
 nat64 enable
```

- On the router define the prefix used for the translations

```
(config)# nat64 prefix stateful 64:ff9b::/96
```

Step 4: Setup R4 as NAT64 box

- Set up an access list

```
(config)# ipv6 access-list allow-nat64
(config-acl)# permit ipv6 2001:ffXX::/32 any
(config-acl)# exit
```

Step 4: Setup R4 as NAT64 box

- Define the pool of IPv4 addresses used for the translation

```
(config)# nat64 v4 pool nat64-v4-pool 10.X.3.0 10.X.3.255
```

- Map pool and access list

```
(config)#nat64 v6v4 list allow-nat64 pool nat64-v4-pool overload
```

Step 5: Setup a static route on R2

- We need a static route from R2 to R4

```
(config)# ipv6 route 64:ff9b::/96 2001:ffXX::4
```

- We need to route our special prefix “64:ff9b::/96” to the NAT64 box

Step 6: ping ipv4.example.com from C1

```
C1# ping ipv4.example.com
```

- On R4 verify how NAT64 is working

```
R4# show nat64 translation
```

Questions

Host Configuration

Section 12

Operating Systems

- We will look at Windows, OSX
- All of them support IPv6 natively

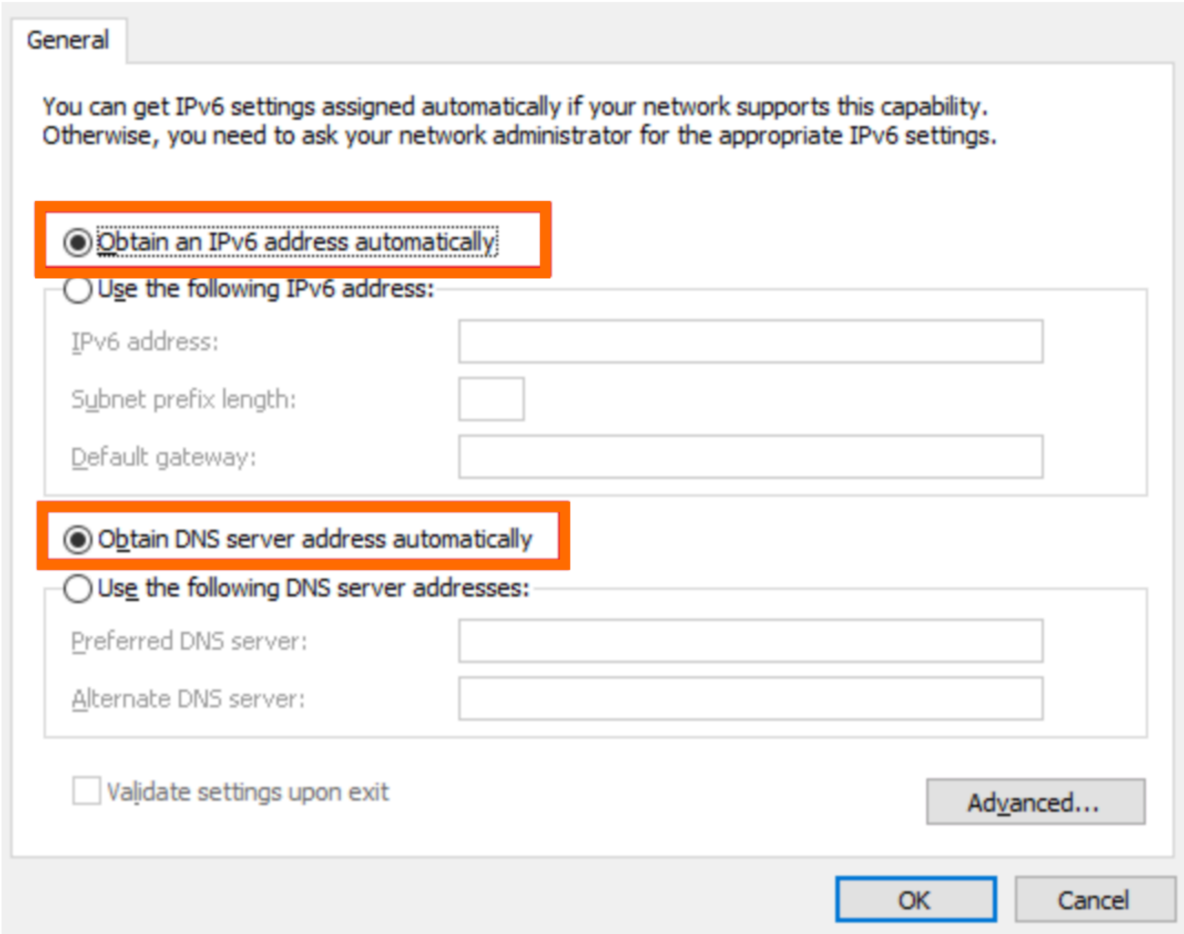
- We will check:
  - How to configure them for DHCPv6.
  - What is supported and what's not.
  - How to see the IPv6 configuration.
  - How to change the IPv6 configuration.

Managing clients

- Users might not notice that their computer is using IPv6
- For management purposes, you want control over addresses. You may want to disable;
    - SLAAC,
    - Privacy extensions
- Disabling SLAAC does not mean disabling Router Advertisements

Windows 10 & 11

- DHCPv6 works off the shelf
- GUI by default in auto configuration mode:



DHCPv6 Client on Windows

- Some versions did not do DHCP out-of-the-box
  - Some may have it disabled by default
  - Or it was somehow disabled

- Let’s see how to check it and enable it

DHCPv6 client on Windows

- First, get the interface ID:

```
netsh interface ipv6 show interfaces
```

```
Command Prompt
Microsoft Windows [Version 6.1.7601]
Copyright (c) 2009 Microsoft Corporation.  All rights reserved.

C:\Users\IEUser>netsh int ipv6 show int

Idx     Met         MTU          State                Name
---  ----------  ----------  ------------  ---------------------------
  1          50  4294967295  connected     Loopback Pseudo-Interface 1
 14          50        1280  disconnected  isatap.guestnet.ripe.net
 13          10        1500  connected     Local Area Connection 2

C:\Users\IEUser>_
```

Check DHCPv6 configuration

- To check the configuration (run as Admin):

```
netsh interface ipv6 show interface XX
```

- If it is not enabled:

```
Neighbor Discovery                        : enabled
Neighbor Unreachability Detection         : enabled
Router Discovery                          : enabled
Managed Address Configuration             : disabled
Other Stateful Configuration              : disabled
Weak Host Sends                           : disabled
Weak Host Receives                        : disabled
```

DHCPv6 client on Windows

- With the interface ID instead of the red **XX**, run the command (as Admin):

```
netsh interface ipv6 set interface XX
advertise=enabled managed=enabled
```

Check configuration

- To check the configuration (run as Admin):

```
netsh interface ipv6 show interface XX
```

- If it is enabled:

```
Neighbor Discovery                      : enabled
Neighbor Unreachability Detection       : enabled
Router Discovery                        : enabled
Managed Address Configuration           : enabled
Other Stateful Configuration            : disabled
Weak Host Sends                         : disabled
Weak Host Receives                      : disabled
```

Windows and DHCPv6

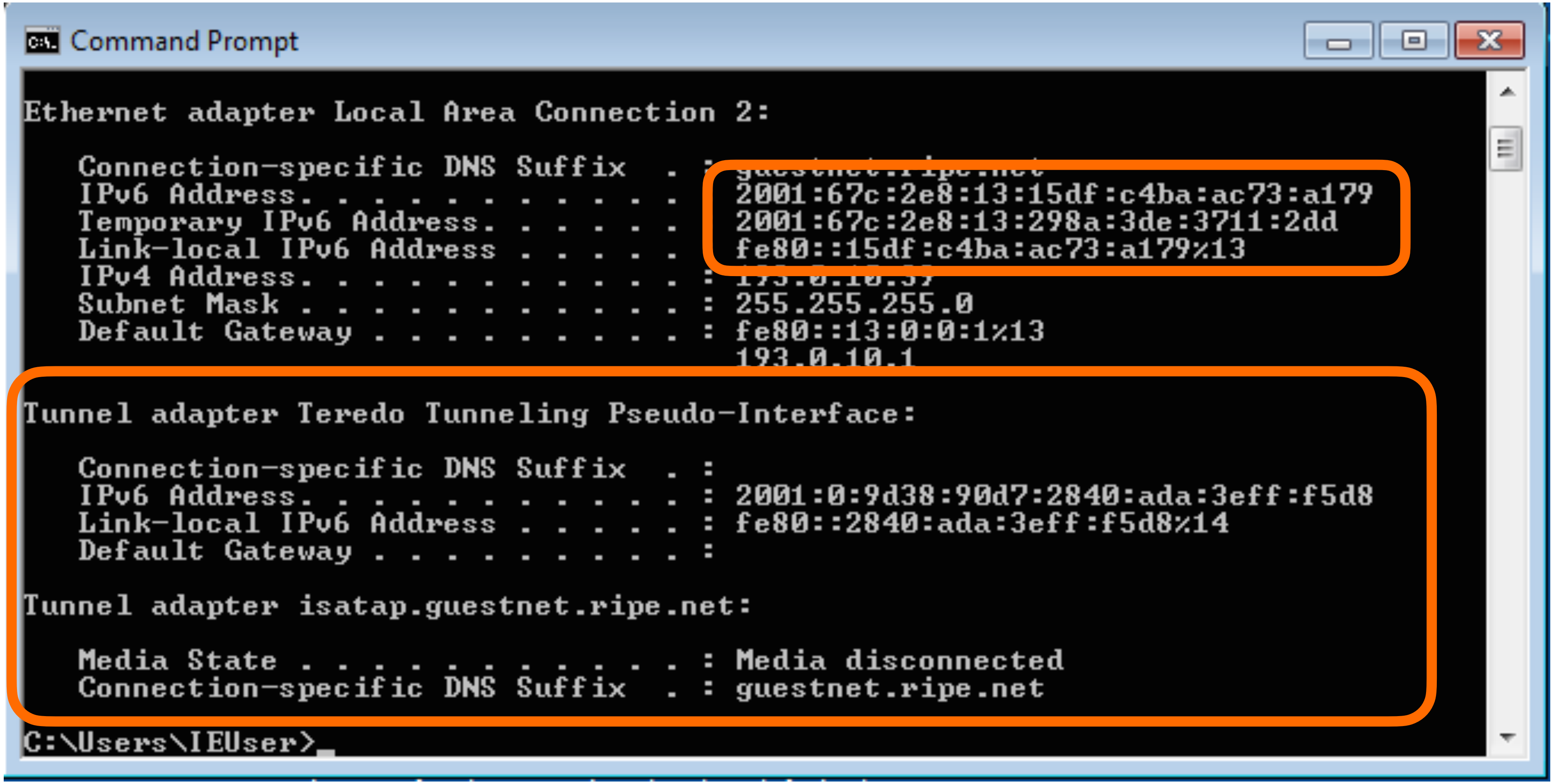
- You can either:
- Configure a router to supply the “M” flag
    - But with no prefix announced
- Or disable router discovery
    - And let other clients pick up addresses from SLAAC

Windows 7

- By default, many services/protocols are enabled:
  - Privacy extensions
  - Teredo
  - 6to4
  - ISATAP

- You might want to disable some/all of them

Windows 7: Before



De-configuring Windows 7

- First, disable all the transition methods

- On the command prompt, as administrator:

```
netsh interface ipv6 6to4 set state state=disabled
netsh interface ipv6 isatap set state state=disabled
netsh interface ipv6 set teredo disable
```

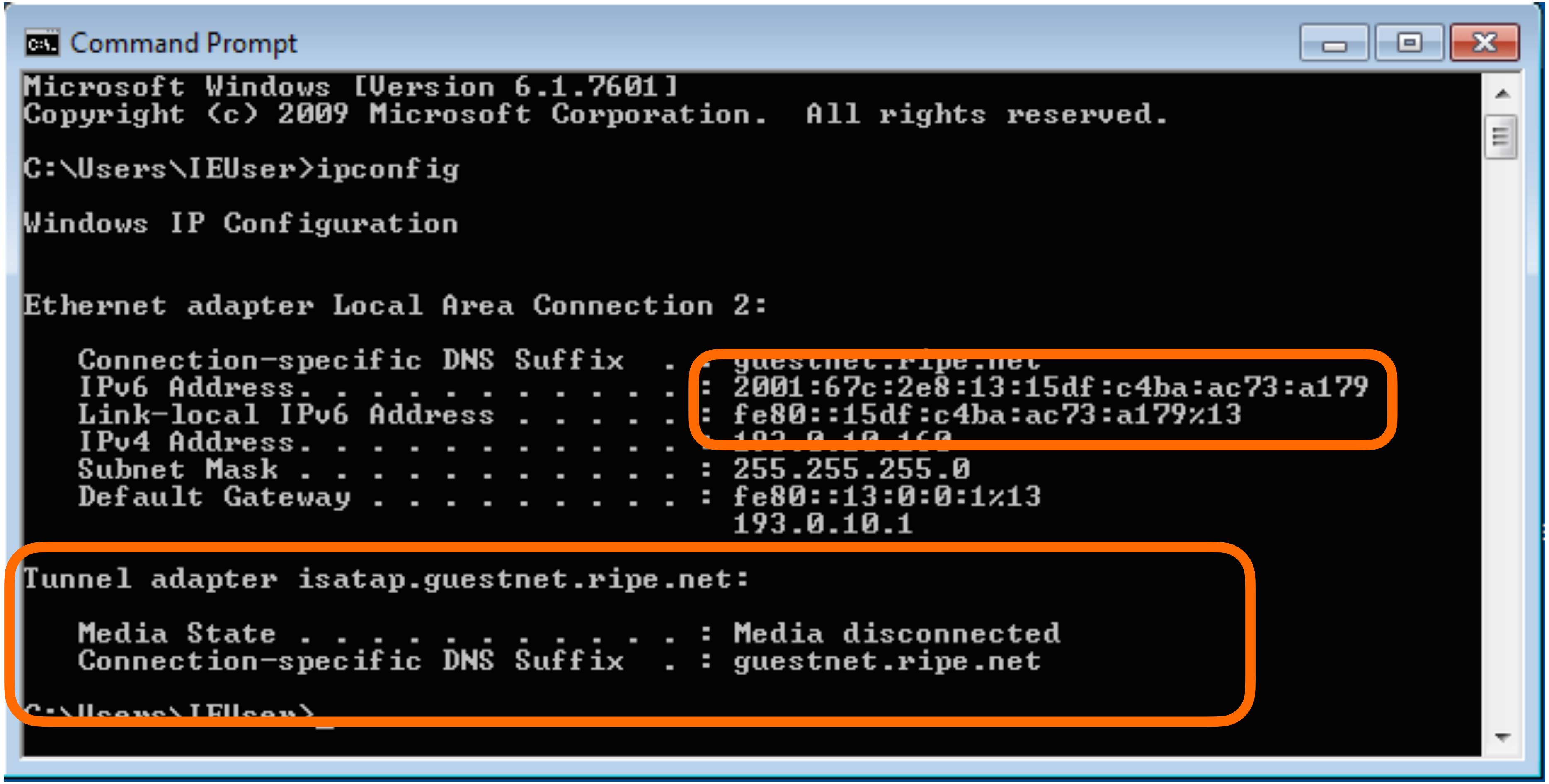
Windows 7 Privacy Extensions

- Disable privacy extensions

```
netsh interface ipv6 set privacy state=disable

netsh interface ipv6 set global randomizeidentifier=disabled
```

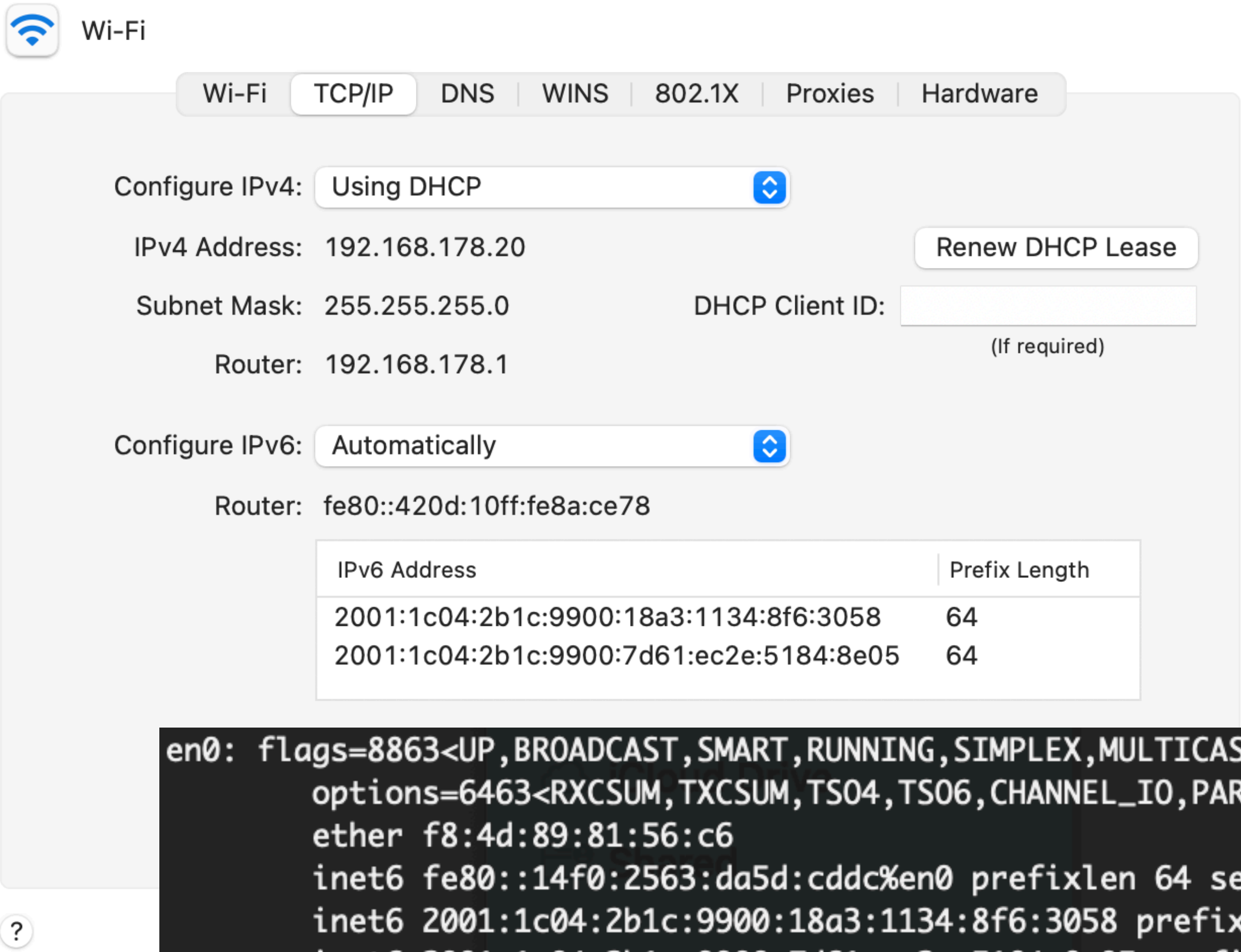
Windows 7:After



OSX

- It will automatically configure IPv6
- It will look in the RA messages to check M flag
  - If present, it will check with DHCPv6

OSX Configuration




```
en0: flags=8863<UP,BROADCAST,SMART,RUNNING,SIMPLEX,MULTICAST> mtu 1500
        options=6463<RXCSUM,TXCSUM,TSO4,TSO6,CHANNEL_IO,PARTIAL_CSUM,ZEROINVERT_CSUM>
        ether f8:4d:89:81:56:c6
        inet6 fe80::14f0:2563:da5d:cddc%en0 prefixlen 64 secured scopeid 0xe
        inet6 2001:1c04:2b1c:9900:18a3:1134:8f6:3058 prefixlen 64 autoconf secured
        inet6 2001:1c04:2b1c:9900:7d61:ec2e:5184:8e05 prefixlen 64 autoconf temporary
        inet 192.168.178.20 netmask 0xffffff00 broadcast 192.168.178.255
        nd6 options=201<PERFORMNUD,DAD>
        media: autoselect
        status: active
```

Linux

- As client, same behaviour as OSX
    - Everything works out of the box
    - IPv6 is enabled automatically

- As server, static configuration is required

Linux Static configuration

- For CentOS/Red Hat:
- /etc/sysconfig/network
- Add:

```
NETWORKING_IPV6=yes
```

Linux Static configuration

- In /etc/sysconfig/network-scripts/ifcfg-eth**X**
- Add:

```
IPV6INIT=yes
IPV6ADDR=2001:0db8:aaaa:bbbb:0000:0000:0000:0002/64
IPV6_DEFAULTGW=2001:db8:aaaa:bbbb:0000:0000:0000:0001
IPV6_AUTOCONF=no
```

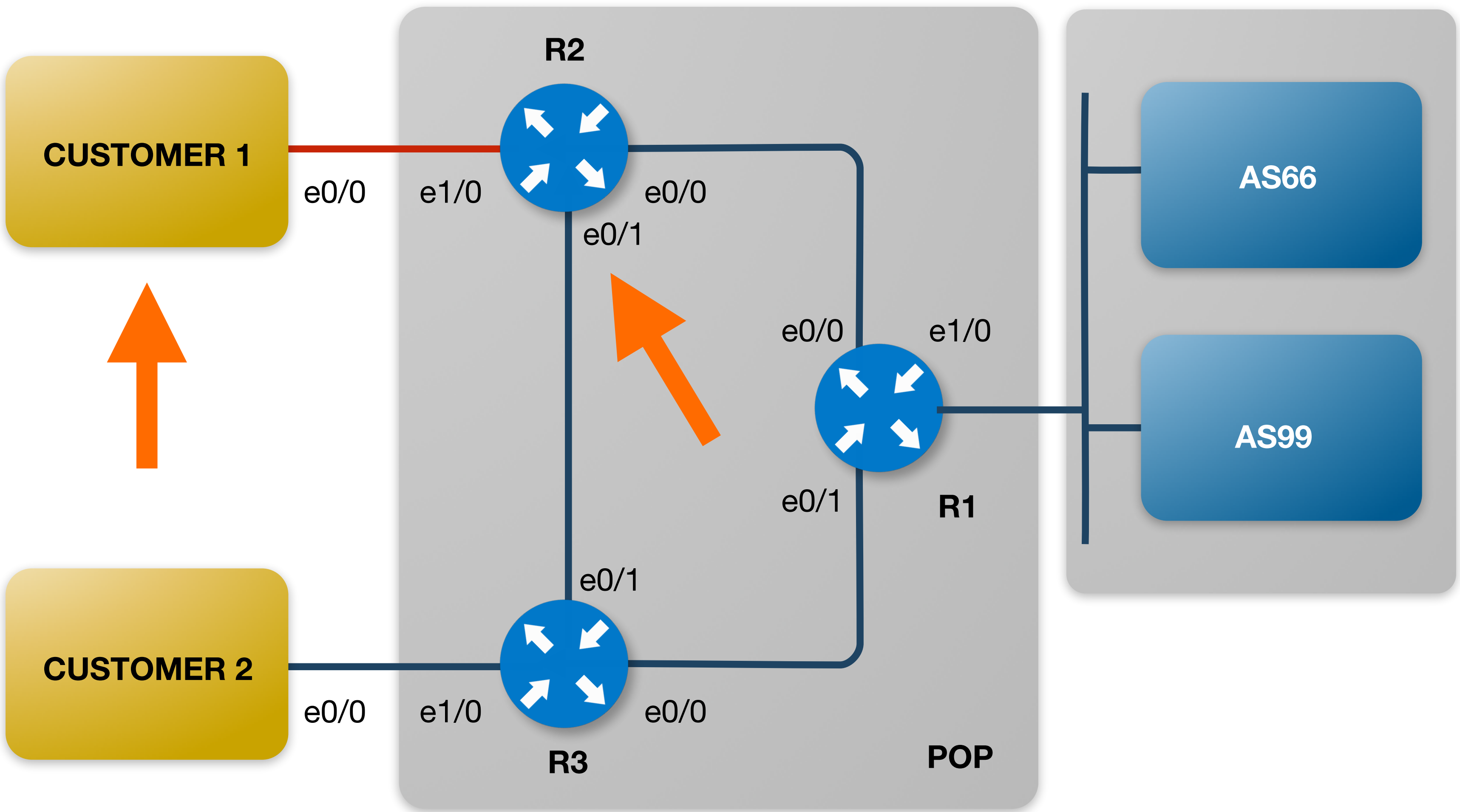
- Where **X** is the number of the interface, then:

```
service network restart
```

SLAAC

Section 13

SLAAC


R2
CUSTOMER 1
e0/0
e1/0
e0/0
e0/1
e0/0
e1/0
R1
e0/1
AS66
AS99
e0/1
CUSTOMER 2
e0/0
e1/0
e0/0
R3
POP

On C1

- Now we will enable SLAAC

```
interface e0/0
 ipv6 address autoconfig default
 no shutdown
```

- Leave configuration mode
- Enable debug ND: `debug ipv6 nd`
- To stop debug messages: `undebug all`

On R2

- Now we will remove the suppression

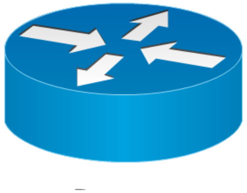
```
interface e1/0
  ipv6 address 2001:ffXX:0:ff01::b/64
  no ipv6 nd ra suppress all
  no shutdown
```

- Leave configuration mode

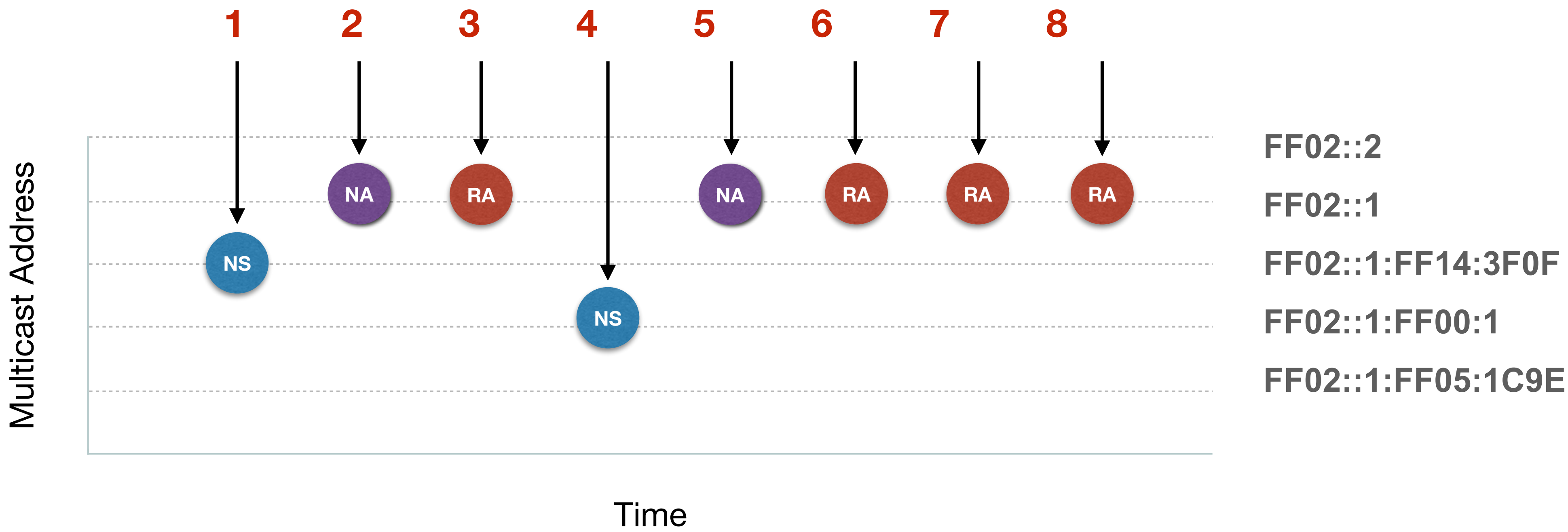
Debugging SLAAC

- Can you find the new IPv6 address?
- Look at the routing…
- Do you see any interesting debug messages?

SLAAC: Router Messages



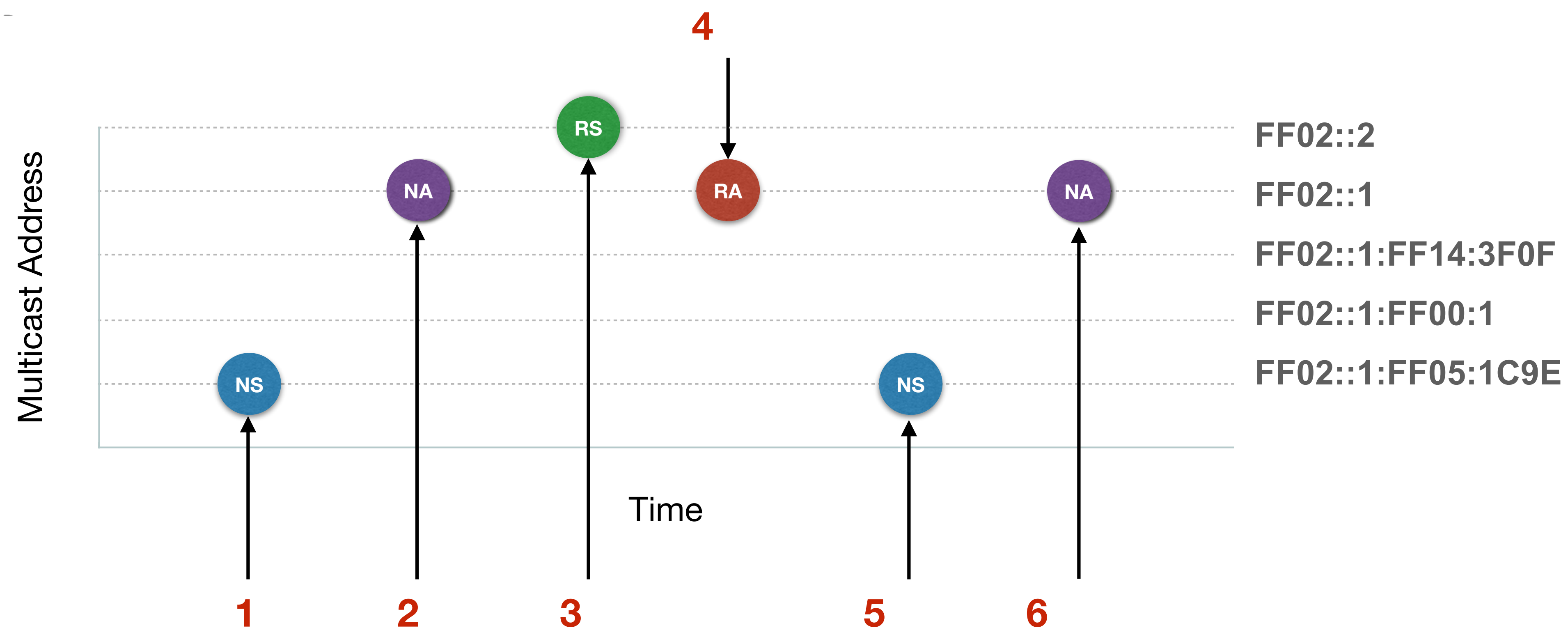
Link-local: fe80::a390:45ff:fe14:3f0f
Global unicast: 2001:db8:a:b::1



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

SLAAC: Client Messages

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



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

Questions

DHCPv6

Section 14

About DHCPv6

- 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, 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, domain name, TFTP server etc

DHCPv6 Fundamentals

- Client driven via DHCPv6 request message
- DHCPv6 uses;
  - UDP port 546 for clients
  - UDP port 547 for server
- DHCPv6 options are similar to those in DHCPv4
- DHCP-PD can deliver prefix information to the routers to be used by the host behind them.

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

Stateless DHCPv6

- **DHCPv6** used to configure (O)ther parameters (**DNS**)
- **SLAAC** (RAs) used for IPv6 **address** and **Gateway**

Stateful DHCPv6

- **DHCPv6** used for (M)anaged IPv6 **address** and other parameters (**DNS**)
- RAs used for **Gateway**

DHCPv6 Prefix Delegation

- Assigning blocks to be used in the networks behind a Router

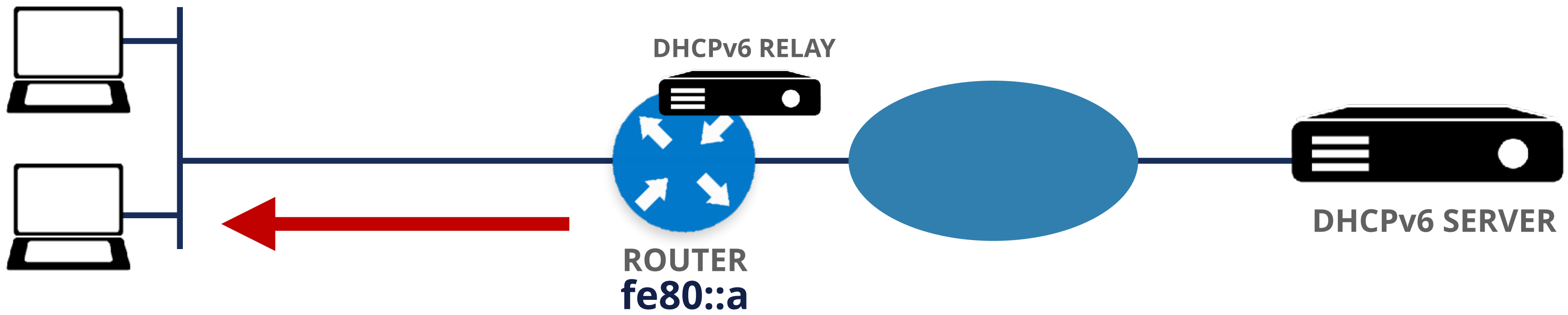
Stateless DHCPv6

- 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 Scenario



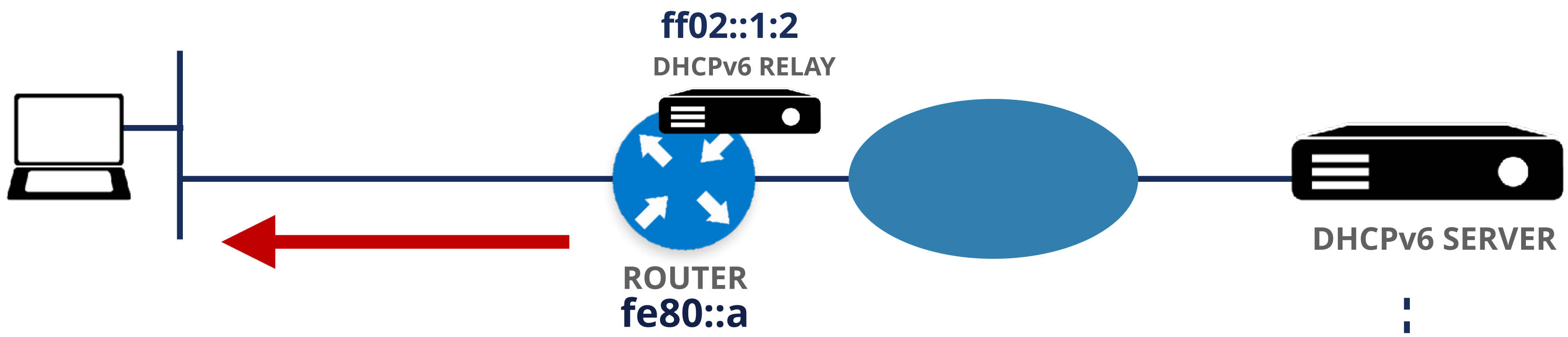
Router's link-local

Default Gateway	fe80::a

IPv6 Address	
2001:db8:1:1::/64	IID
Prefix in RA	Generated by Host

IPv6	ICMPv6 RA
IPv6.Source IPv6	fe80::a
IPv6.Destination IPv6	ff02::1
RA.M Flag	**0**
RA.O Flag	**1**
RA.Prefix Info. Option.Prefix	Prefix/64
RA.Prefix Info. Option.A Flag	**1**

Stateless DHCPv6 Scenario



IPv6 | **ICMPv6 RA**

Router's link-local

Default Gateway | **fe80::a**

IPv6 Address

2001:db8:1:1::/64	**IID**
Prefix in RA	Generated by Host

IPv6.Source IPv6	fe80::a
IPv6.Destination IPv6	ff02::1
RA.M Flag	**0**
RA.O Flag	**1**
RA.Prefix Info. Option.Prefix	Prefix/64
RA.Prefix Info. Option.A Flag	**1**

INFORMATION-REQUEST

R-F(INFORMATION-REQUEST)

REPLY

R-R (REPLY)

DNS Server

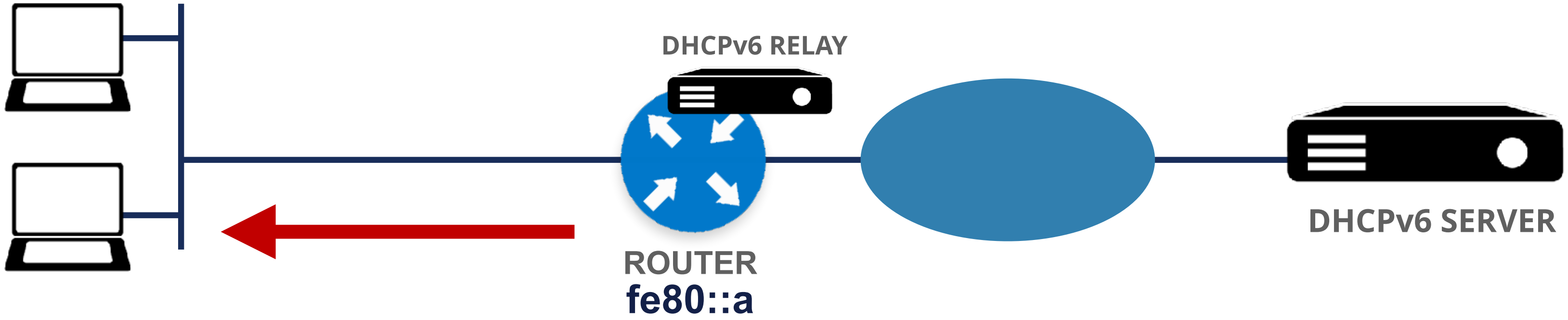
2001:db8:53::53

Recursive DNS server

Stateful DHCPv6

- Similar to DHCPv4
- A router can act as a DHCP server
- Configuration parameters include:
  - DHCP pool name
  - Prefix information
  - List of DNS servers
  - Addresses for clients
- Server holds the states of the clients

Stateful DHCPv6 Scenario



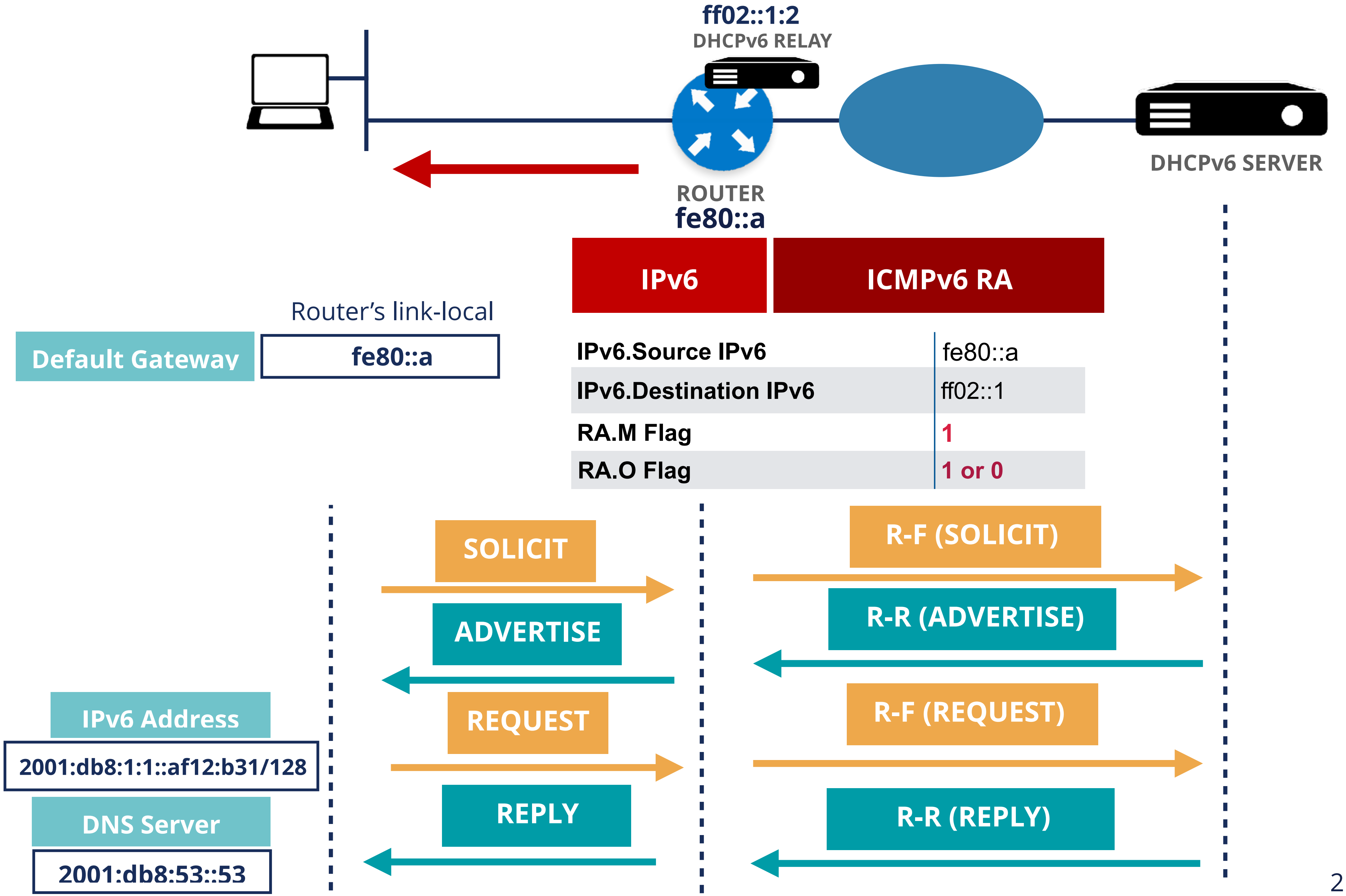
IPv6	ICMPv6 RA

Router's link-local

Default Gateway	fe80::a

IPv6.Source IPv6	fe80::a
IPv6.Destination IPv6	ff02::1
RA.M Flag	**1**
RA.O Flag	**1 or 0**

Stateful DHCPv6 Scenario

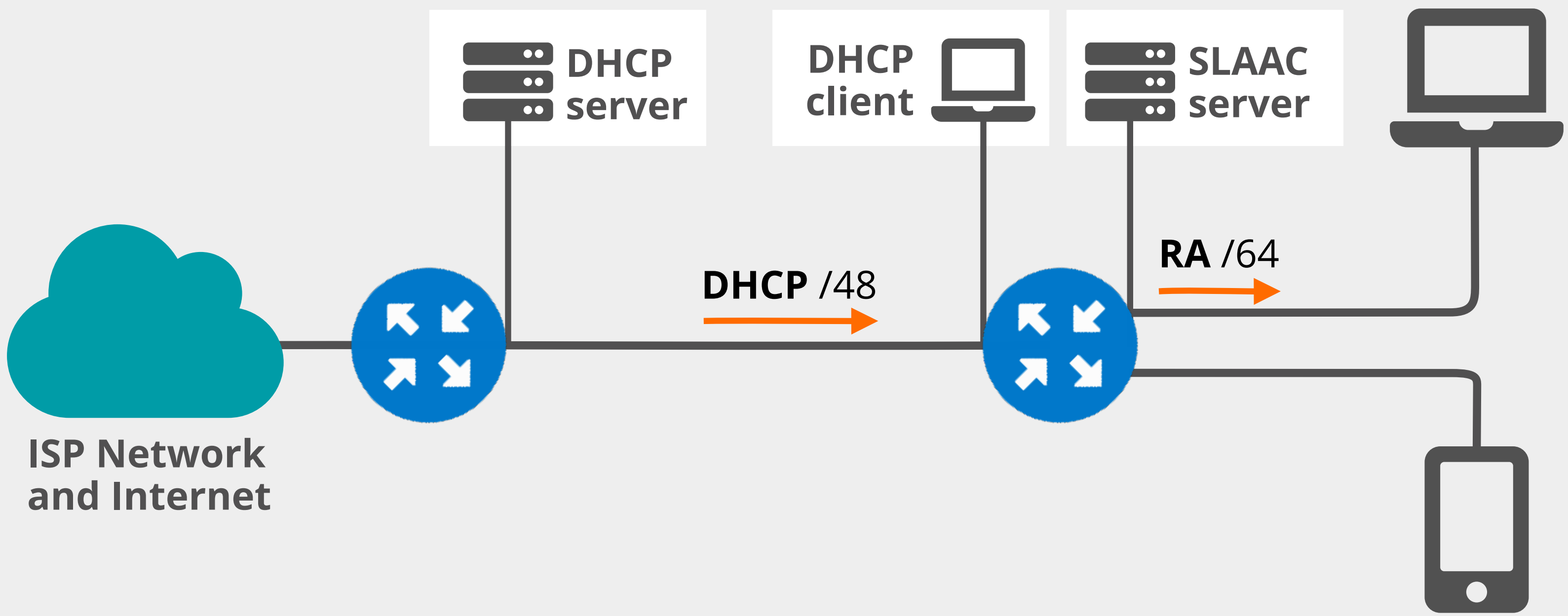


DHCPv6 Prefix Delegation

- It is new and only needed for IPv6
- It is stateful
- 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 (global addresses)
  - 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



DHCP Question

Why do we need DHCP-PD in IPv6?

a. Since we need a mechanism for the automation of assigning GUAs to the devices on the subscriber LAN
b. Since we need a mechanism for translation of the address used on the subscriber LAN
c. Since we need to use NDP over Internet for the devices behind the CPE
d. Since we need a low latency mechanism for IPv6 subscribers

DHCP Answer

Why do we need DHCP-PD in IPv6?

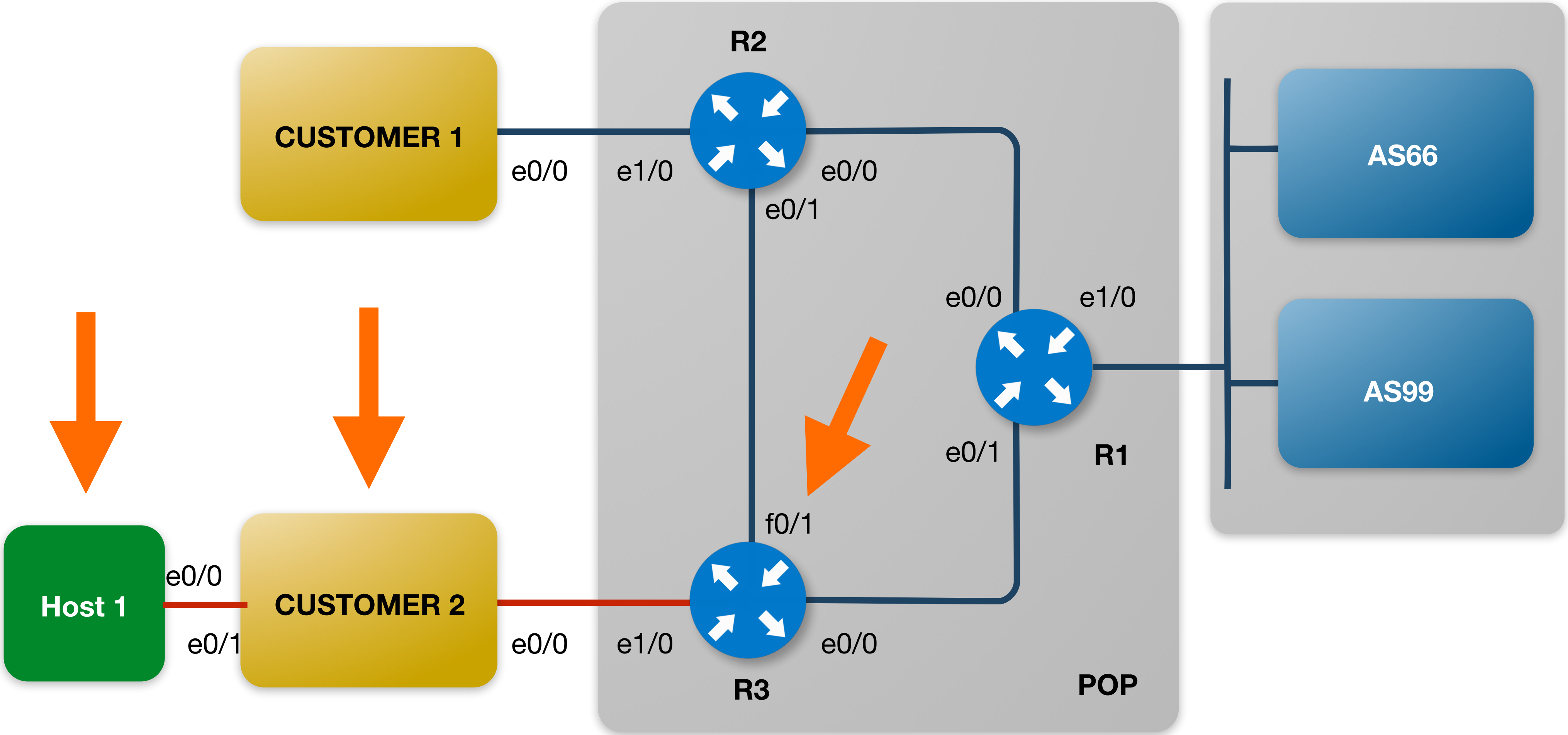
- **Since we need a mechanism for the automation of assigning GUAs to the devices on the subscriber LAN**
- b. Since we need a mechanism for translation of the address used on the subscriber LAN
- c. Since we need to use NDP over Internet for the devices behind the CPE
- d. Since we need a low latency mechanism for IPv6 subscribers

Questions

DHCPv6-PD

Exercise 15

DHCPv6



R2
CUSTOMER 1
e0/0
e1/0
e0/0
e0/1
e0/0
e1/0
e0/1
R1
AS66
AS99
f0/1
Host 1
e0/0
e0/1
CUSTOMER 2
e0/0
e1/0
e0/0
R3
POP

DHCPv6-PD Router Configuration

- DHCP pool named “DHCP_CUSTOMERS” references local pool “DHCP_POOL”
- DHCP_POOL details about the address pool
- **On R3**

```
ipv6 dhcp pool DHCP_CUSTOMERS
 prefix-delegation pool DHCP_POOL
!
interface e1/0
 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 C2 Configuration

- ISP facing interface is the DHCP client
- LAN facing interface is the IPv6 router sending RA message

```
interface e0/0
 ipv6 address autoconfig default
 ipv6 dhcp client pd PREFIX
 no shutdown
!
interface e0/1
 ipv6 address PREFIX ::1:b00c:caf3:bab3:1/64
 no ipv6 redirects
 no shutdown
```

On H1

- Enable IPv6 on the router
  - You know how
- And enable SLAAC

```
interface e0/0
 ipv6 address autoconfig default
 no shutdown
```

Summary

- We have now distributed an IPv6 prefix to Customer 2
- Customer has distributed prefixes to LAN interfaces automatically and distributed SLAAC to the host

- Can you find the DUID address of C2 ?

DHCPv6-PD
with static assignment

15-b - Exercise

DHCPv6-PD with Static Assignment

- Assign to Customer 2 static prefix:
  - 2001:ffXX:ff02:AB00::/56

On R3

- Find the DUID of the customer

```
#show ipv6 dhcp binding
```

- We have to create a pool, set-up prefix delegation and specify the DUID

```
(config)#ipv6 dhcp pool DHCP_CUSTOMERS
(config-dhcpv6)#prefix-delegation 2001:ffXX:ff02:AB00::/56 DUID
```

On C2

- To make sure the changes we made are propagated, we shut and no shut the interface towards R3

```
(config)# interface e0/0
(config-if) shut
(config-if) no shut
```

- It can take some time to propagate, up to 4 minutes

```
# show ipv6 interface brief
```

Security

16 - 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 should be supported in IPv6
  - PKI infrastructure costs time and money

RA Guard

- RFC7113
- 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

IP Address Management

Section 17

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!

Benefits of Using IPAM

- Repository of assignable IP addresses stays up-to-date
- Prevents duplicates in the networks
- Assists troubleshooting
- For regulatory or legal compliance

What Are the Functionalities?

- IP search functionality
- IP address/Device discovery
- Allocations & making reservations
- Connection to RIR DBs (pull and/or push information)
- DNS and DHCP integration - for example, DNS can update itself when it learns the IP address a client has obtained via DHCP
- Task creation and assignment (optional)
- Multiple access profile support (Admin, Operator, User/Read-only)
- Import/Export of files

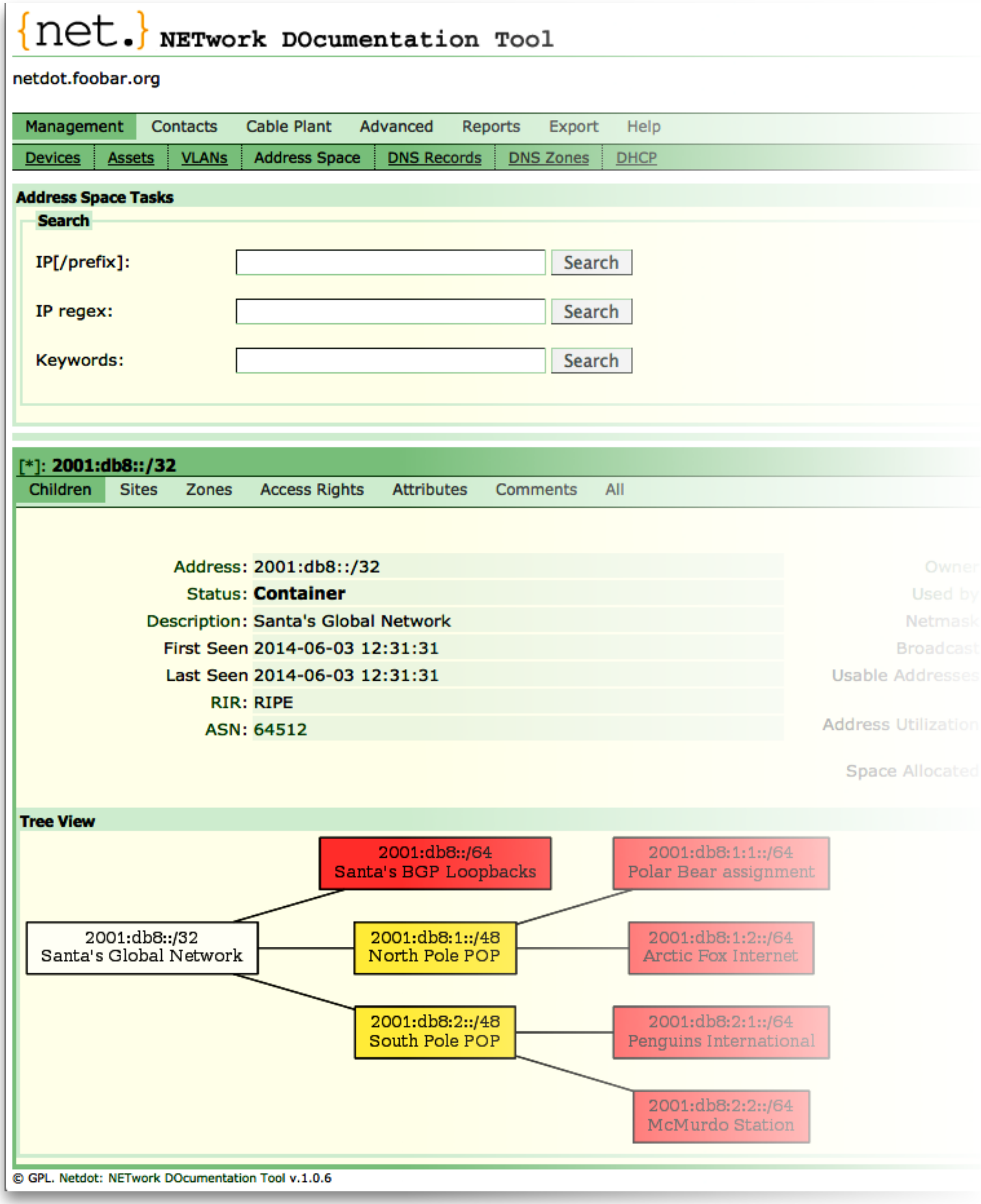
What Should You Compare?

- Is it for “data center/web service management” or “small/medium enterprise”?
- Is it easy to learn?
- Cleaner graphical user interface
- Paid vs Free - Customer support?
- Licensed vs Open-source
- Native VRF support
- File Import/Export support

Address Management

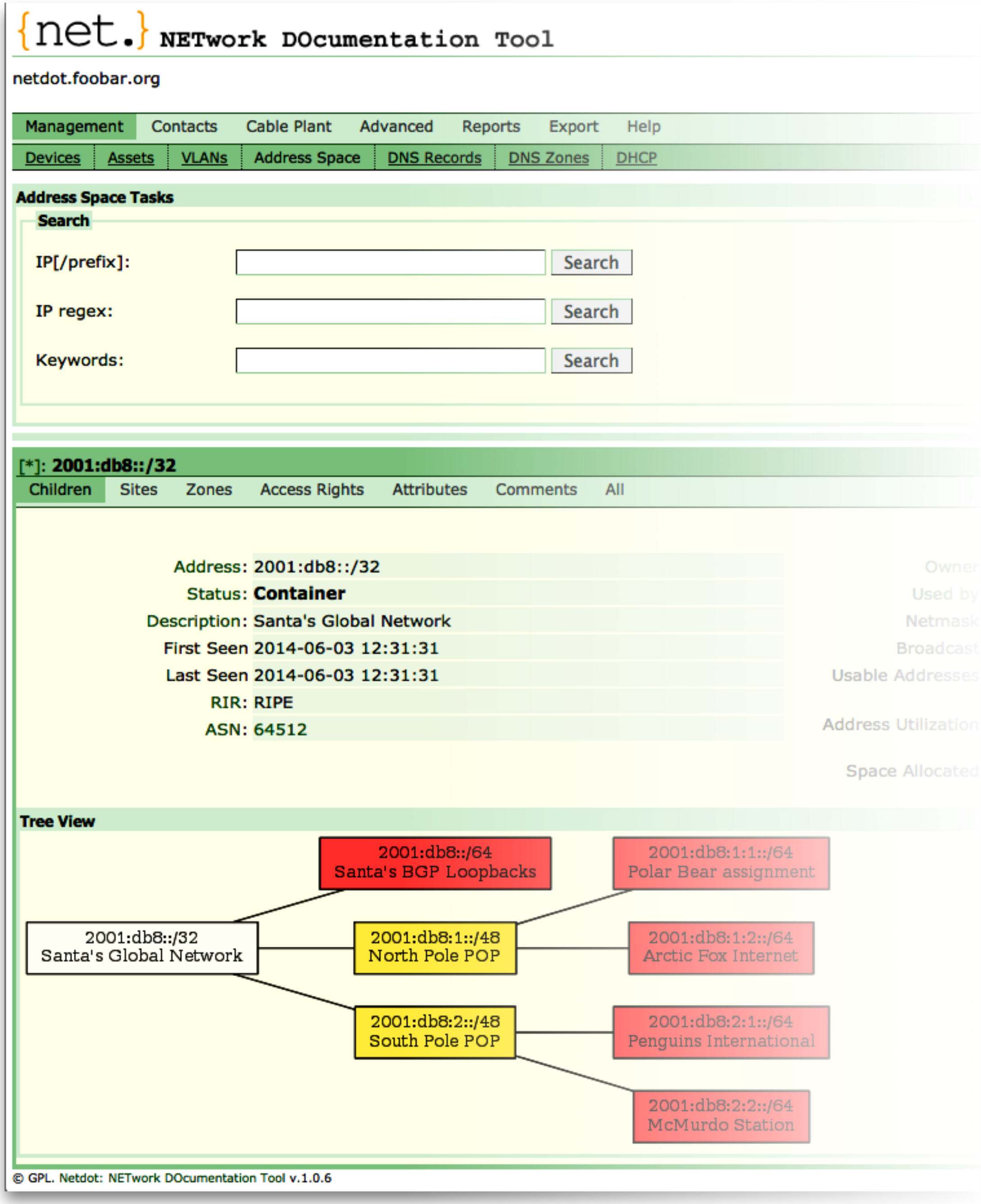
- There are many open source IPv6 IPAM tools
  - NetDot
  - GestióIP
  - phpIPAM
  - Netbox
  - NIPAP
  - NOCProject

NetDot



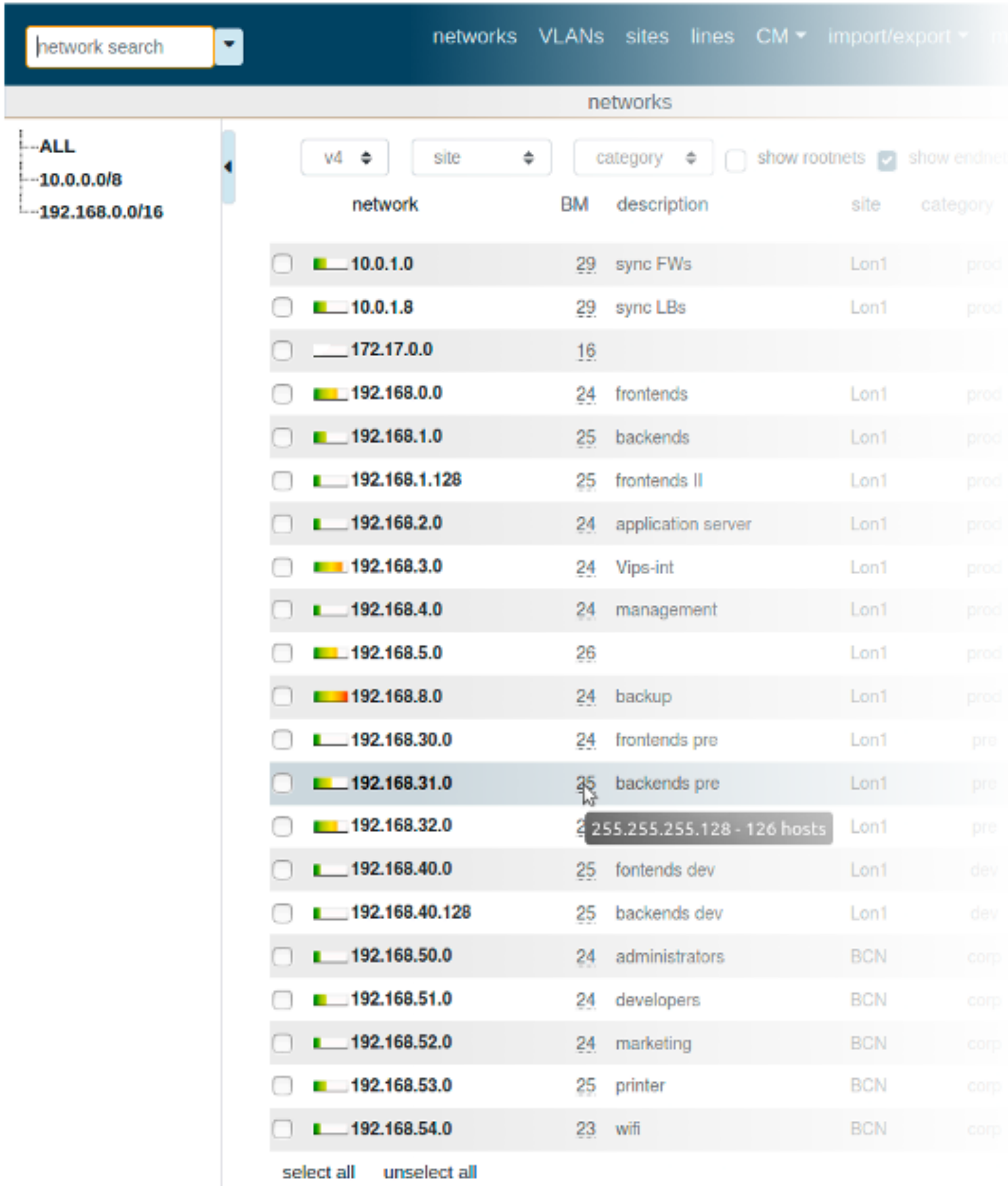
- Device discovery via SNMP
- DNS and DHCP config management
- IP&MAC address tracking
- BGP peer and AS Number tracking

NetDot



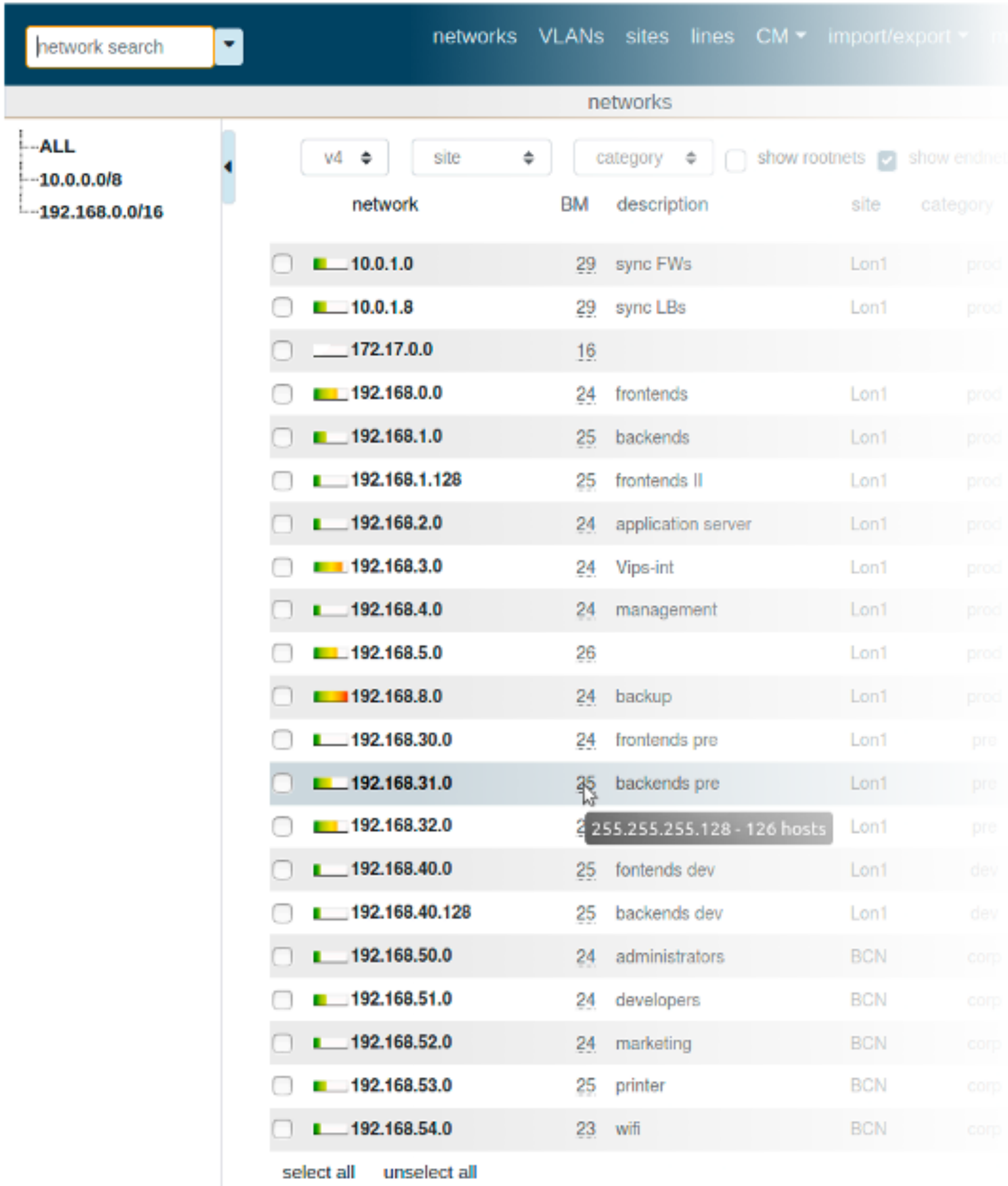
- Multi-level user access: Admin, Operator, User
- Export scripts for
  - Nagios
  - Cacti
  - RANCID

GestióIP



- Web based IPAM, easy usage
- Based on Surfnet document
- Shows free ranges
- VLAN management system
- Host discovery via SNMP and DNS

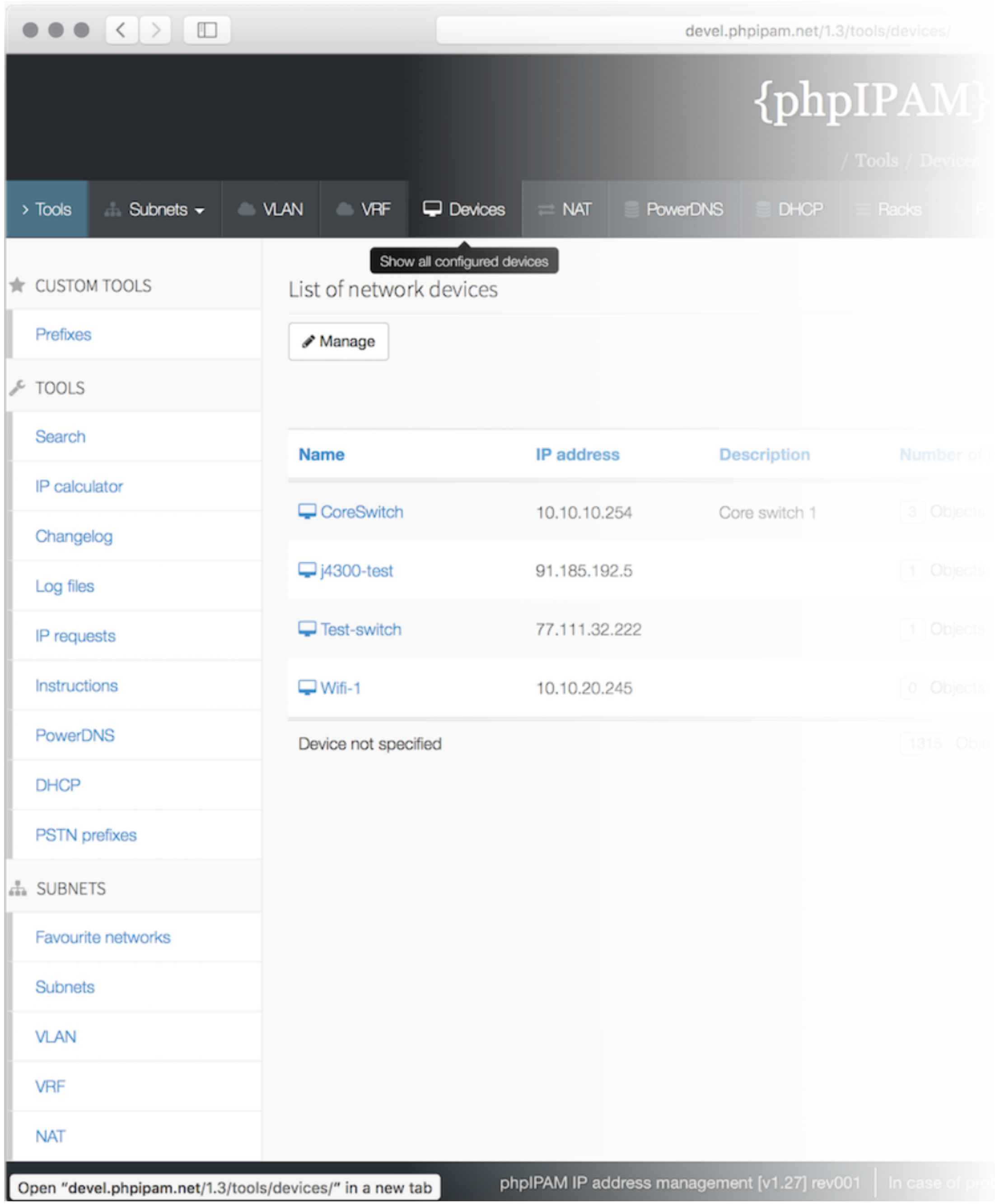
GestióIP



network	BM	description	site	category
10.0.1.0	29	sync FWs	Lon1	prod
10.0.1.8	29	sync LBs	Lon1	prod
172.17.0.0	16			
192.168.0.0	24	frontends	Lon1	prod
192.168.1.0	25	backends	Lon1	prod
192.168.1.128	25	frontends II	Lon1	prod
192.168.2.0	24	application server	Lon1	prod
192.168.3.0	24	Vips-int	Lon1	prod
192.168.4.0	24	management	Lon1	prod
192.168.5.0	26		Lon1	prod
192.168.8.0	24	backup	Lon1	prod
192.168.30.0	24	frontends pre	Lon1	pre
192.168.31.0	25	backends pre	Lon1	pre
192.168.32.0	2		Lon1	pre
192.168.40.0	25	fontends dev	Lon1	dev
192.168.40.128	25	backends dev	Lon1	dev
192.168.50.0	24	administrators	BCN	corp
192.168.51.0	24	developers	BCN	corp
192.168.52.0	24	marketing	BCN	corp
192.168.53.0	25	printer	BCN	corp
192.168.54.0	23	wifi	BCN	corp

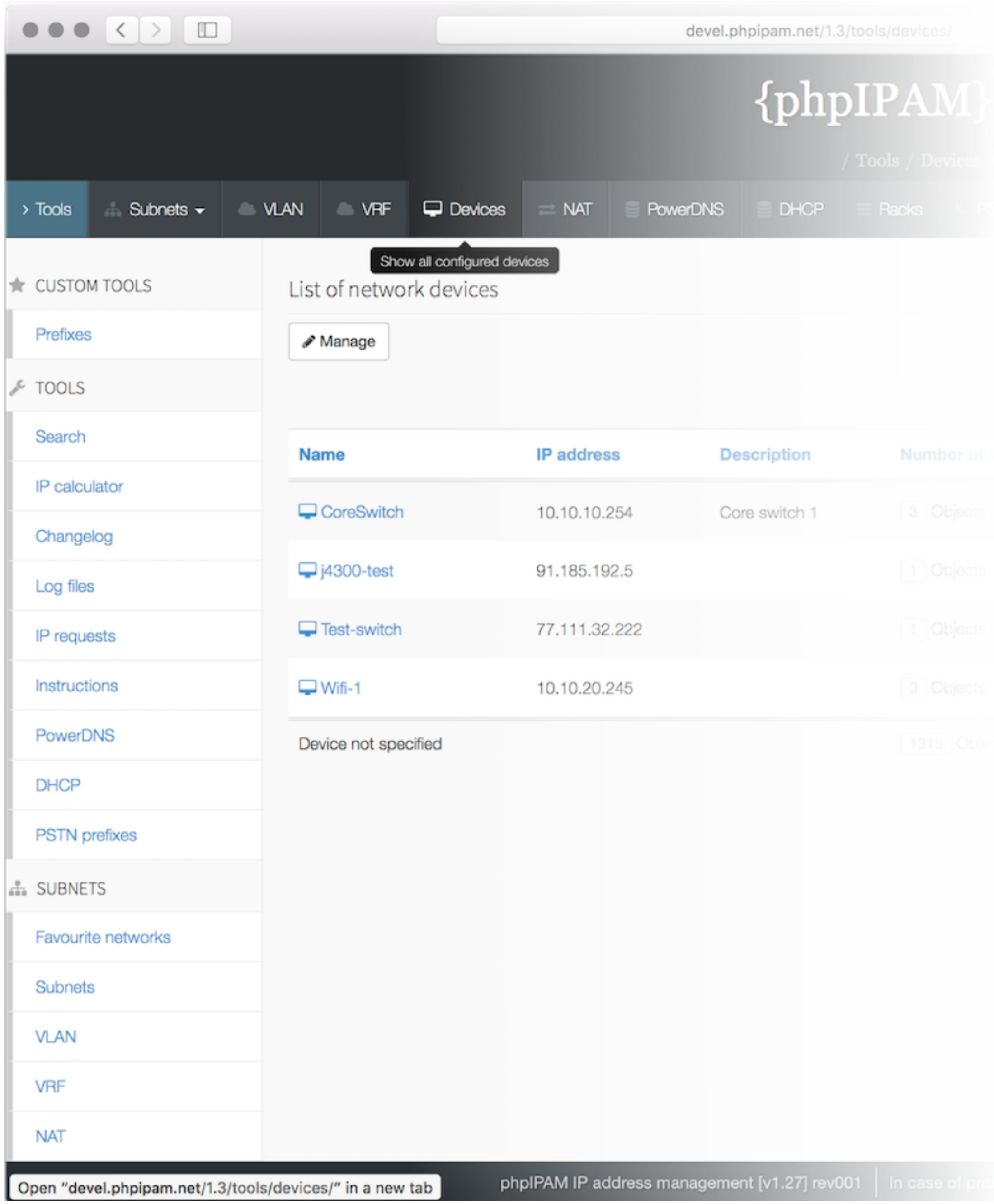
- Multi lingual
- DNS zone file generator for forward and reverse zones
  - Supports BIND and tinydns zone files
- Statistics about the ranges
- Offers subscription based cloud model

phpIPAM



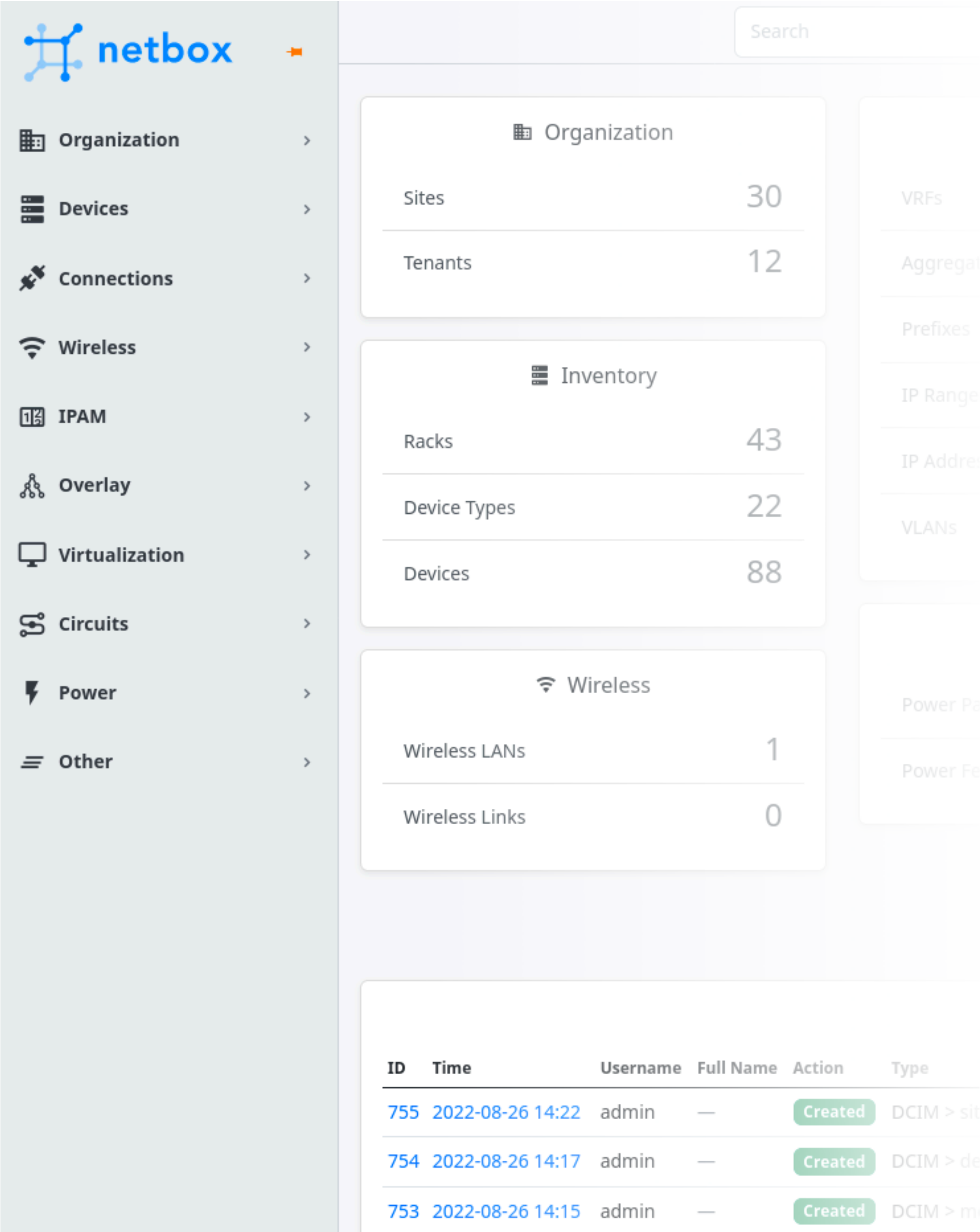
- AJAX based using jQuery libraries
  - PHP script, javascript and some HTML5/CSS3
  - Modern browser is preferred
- E-mail notifications
- Displays free ranges and numbers of clients

phpIPAM



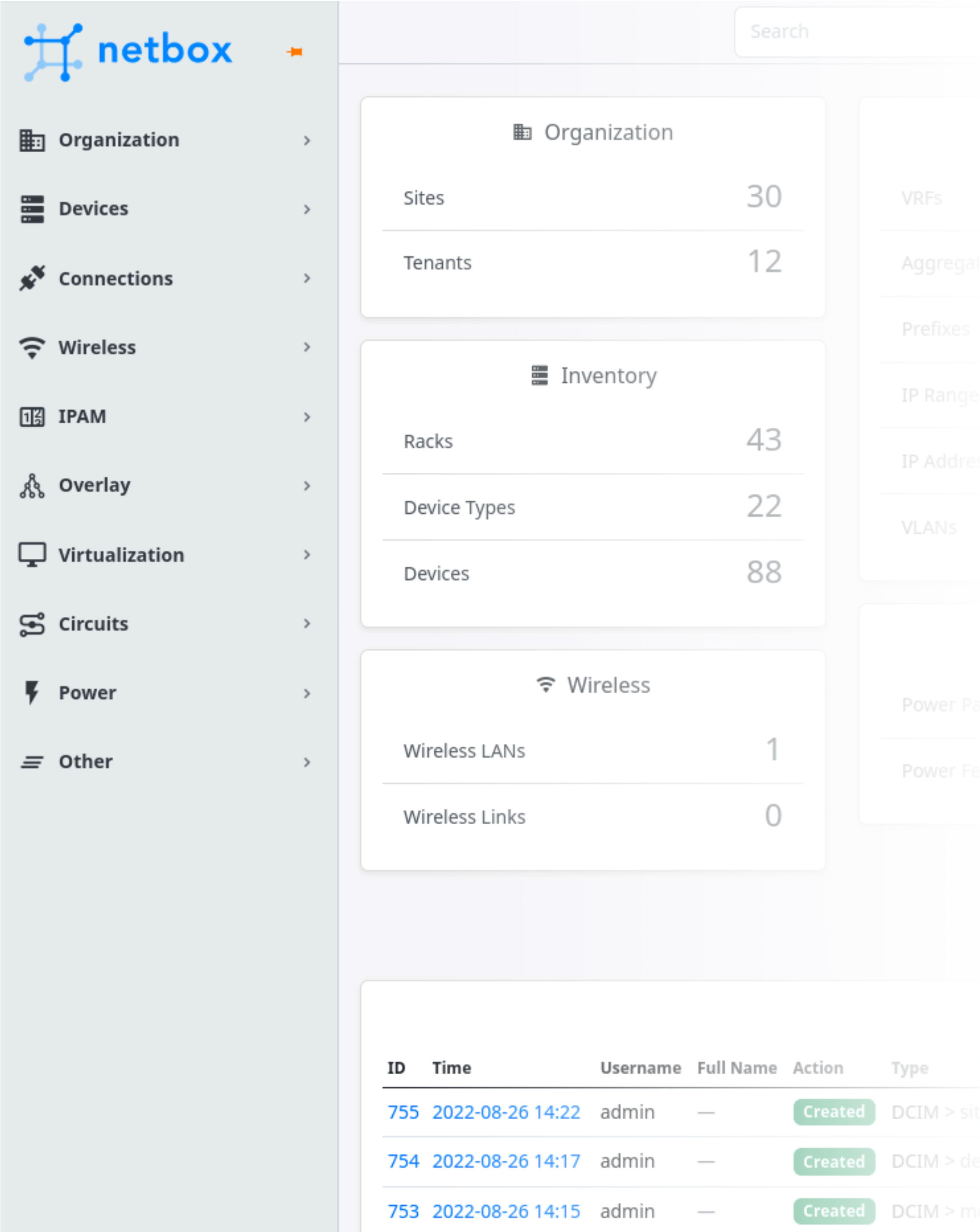
- Import and export to XLS files
- Can pull info from the RIPE DB
- VRF management/support

NetBox



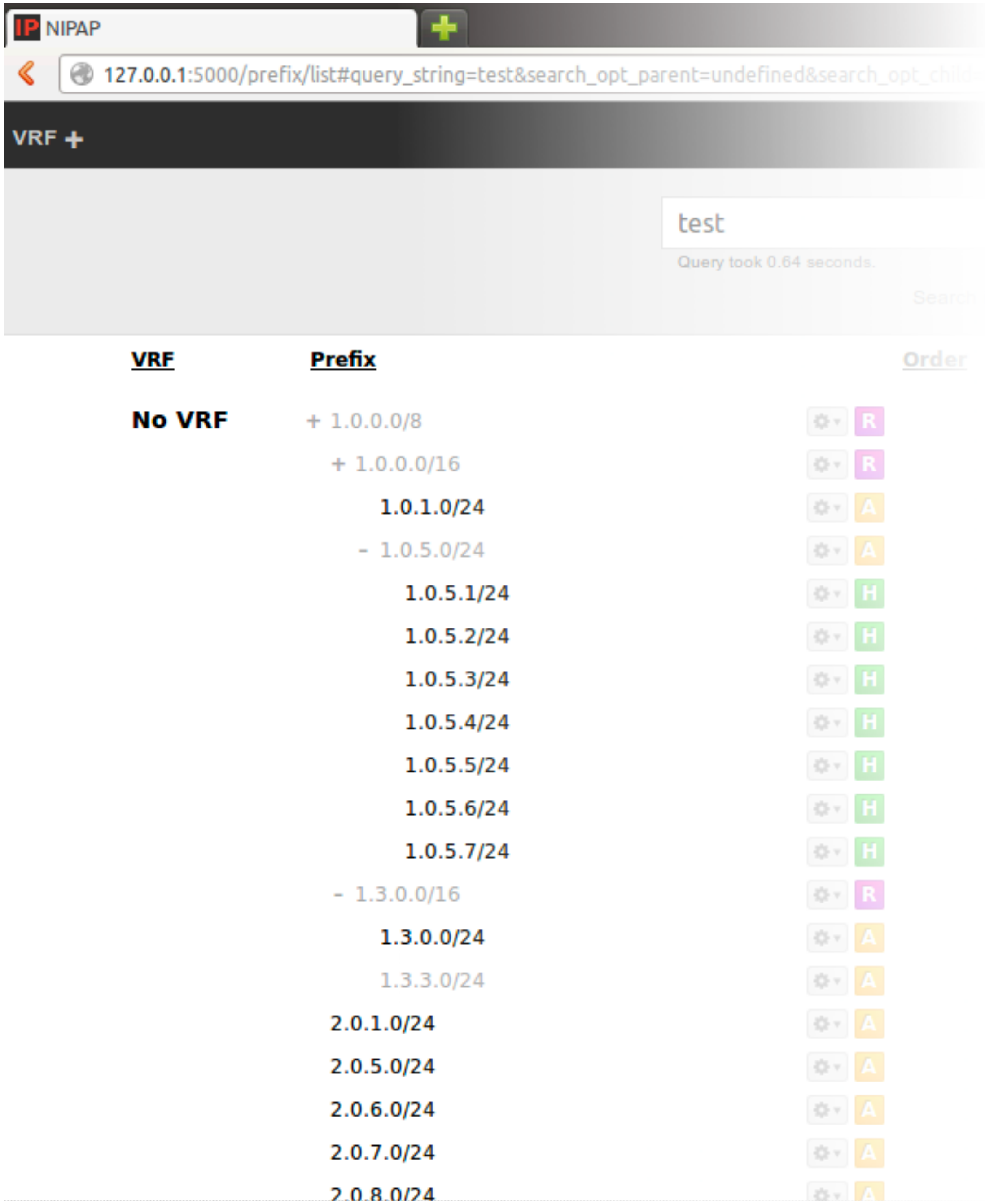
- Comprehensive tool for network management including IPAM functionality
- IPAM and DCIM (Datacenter Infrastructure Management)
- Written in Python

NetBox



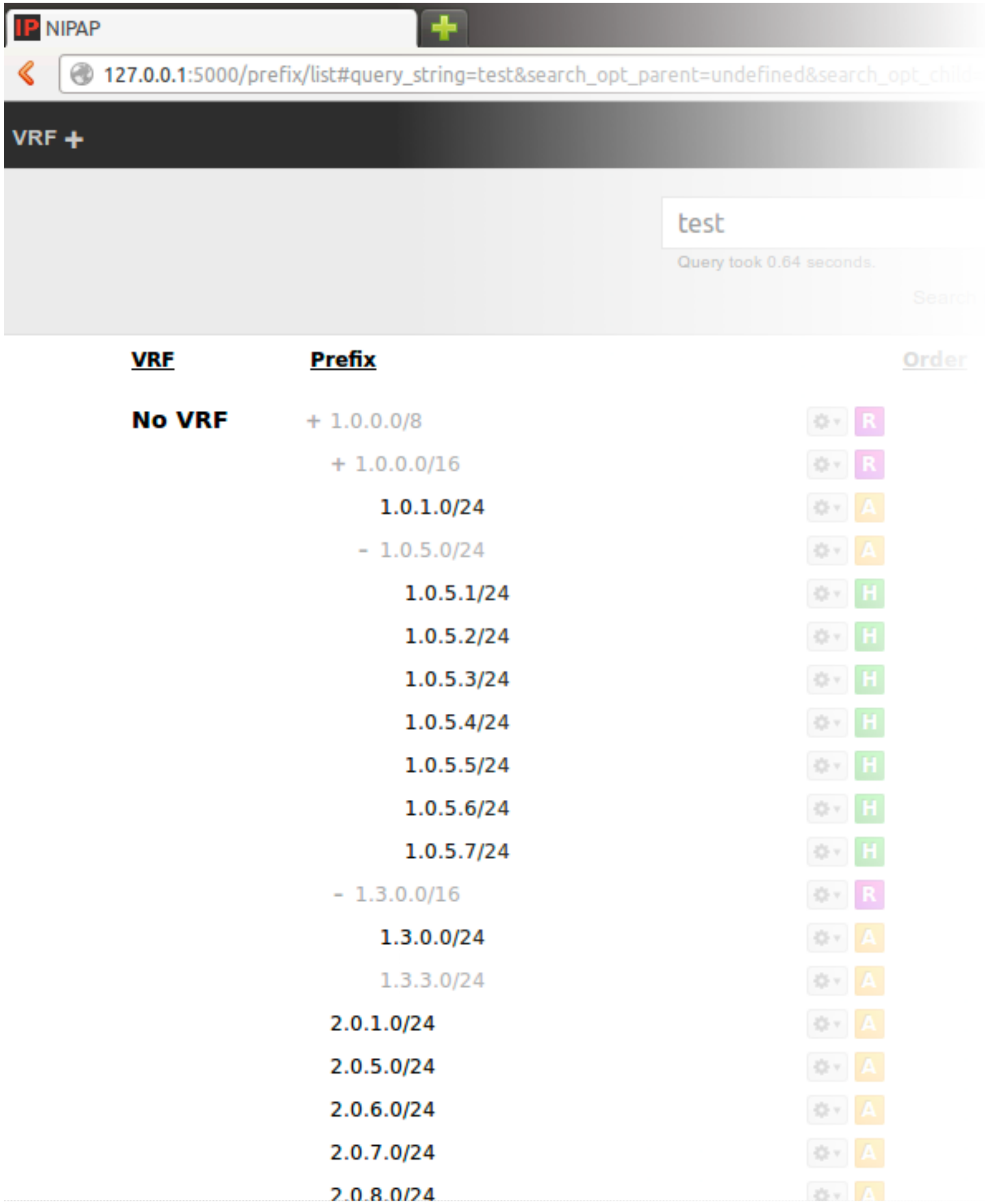
- Web application with PostgreSQL database
- No network monitoring, DNS, RADIUS, Config management

NIPAP



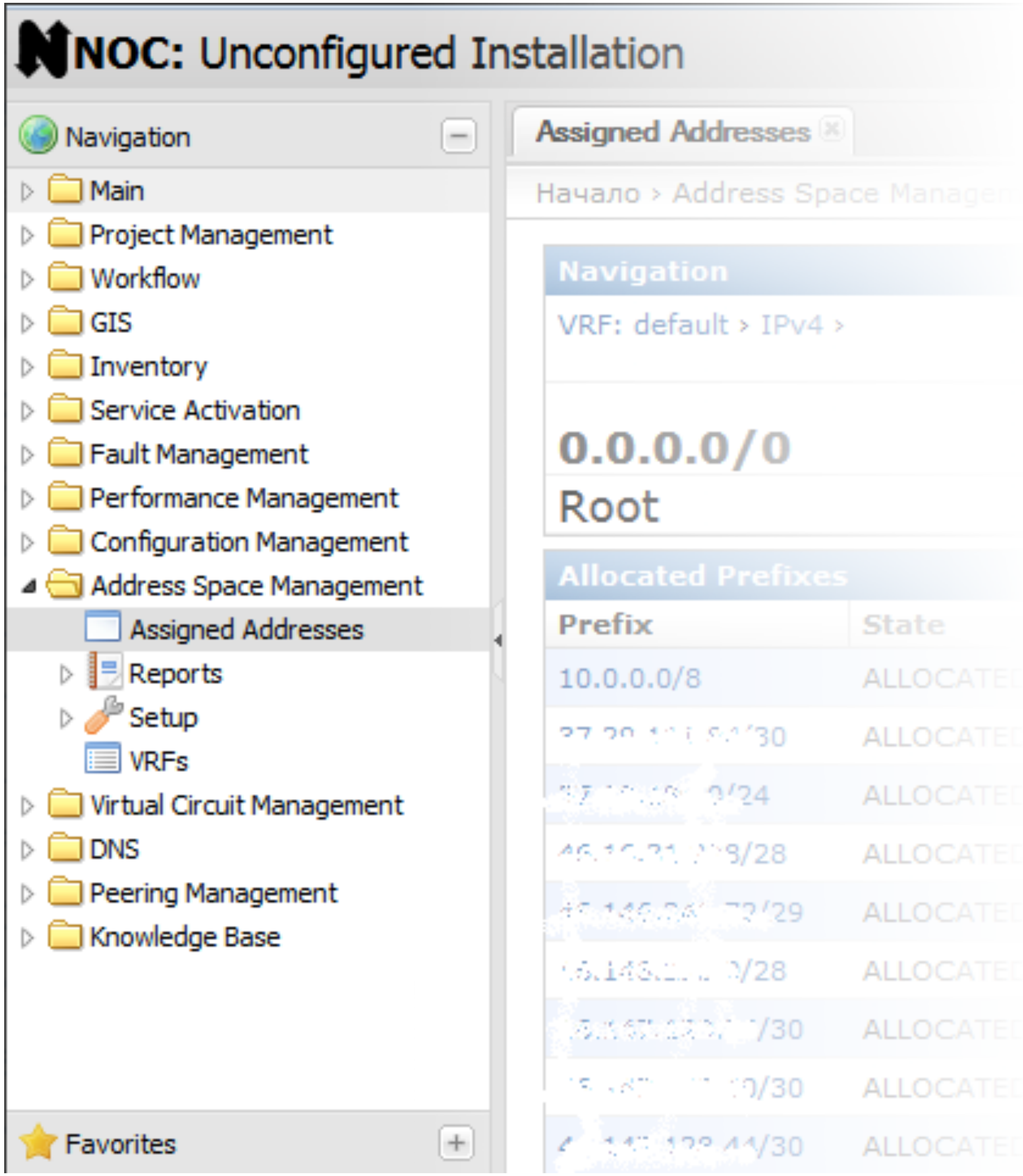
- Web and CLI interface
- Native support for IPv6 (full feature parity with IPv4)
- Native VRF support - overlapping prefixes in different VRFs
- Very **powerful search function** (featuring regexp)

NIPAP



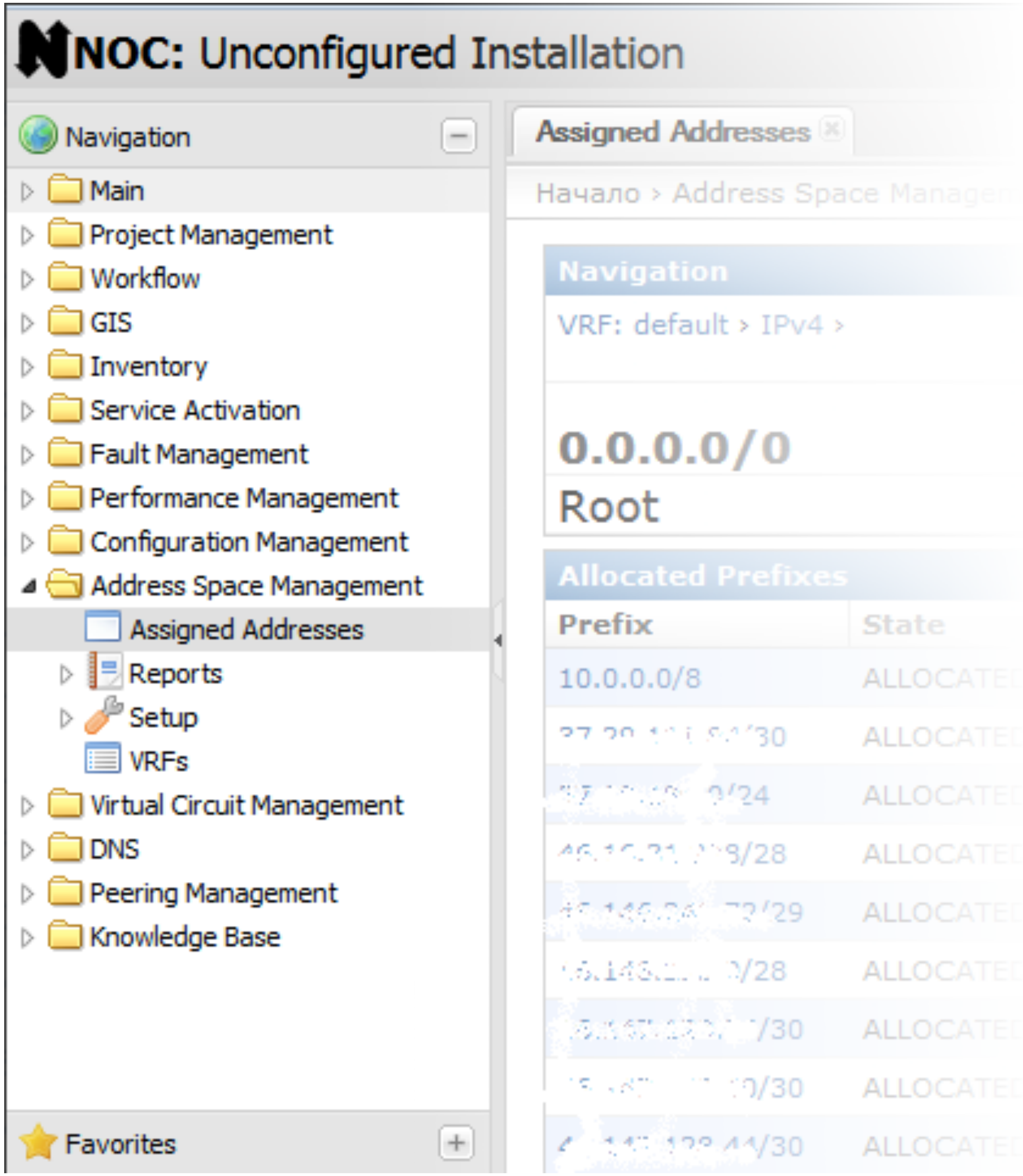
- Statistics over used and free addresses
- Integrated audit log
- IP address request system for automatically assigning suitable prefixes

NOC Project



- BSD licensed
- Complete OSS system
- Clean web interface
- DNS integration

NOC Project



- Reporting tools
- Quick view options (free space)
- Hierarchical user groups
- Large developer team

Questions

What's Next in IPv6

Webinars

Attend another webinar live wherever you are.

- Introduction to IPv6 (2 hrs)
- IPv6 Host Configuration (2 hrs)
- IPv6 Addressing Plan (1 hr)
- Basic IPv6 Protocol Security (2 hrs)
- IPv6 Associated Protocols (2 hrs)
- IPv6 Security Myths, Filtering and Tips (2 hrs)

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