RIPE NCC
RIPE NETWORK COORDINATION CENTRE

IPv6 Fundamentals

Training Course

December 2024

RIPE NCC Training Material

Please find your training material at the following link

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

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
- Experience with IPv6
- Goals

Overview

- IPv4?
- IPv6 Address Basics
- Getting it
- Exercise: Making Assignments
- IPv6 Protocol Basics
- Exercise: Addressing Plan
- IPv6 Packets
- Deploying
- Exercise: Configuring IPv6
- Real Life IPv6 Deployment
- Tips

IPv4?

Section 1

Reaching the next billion

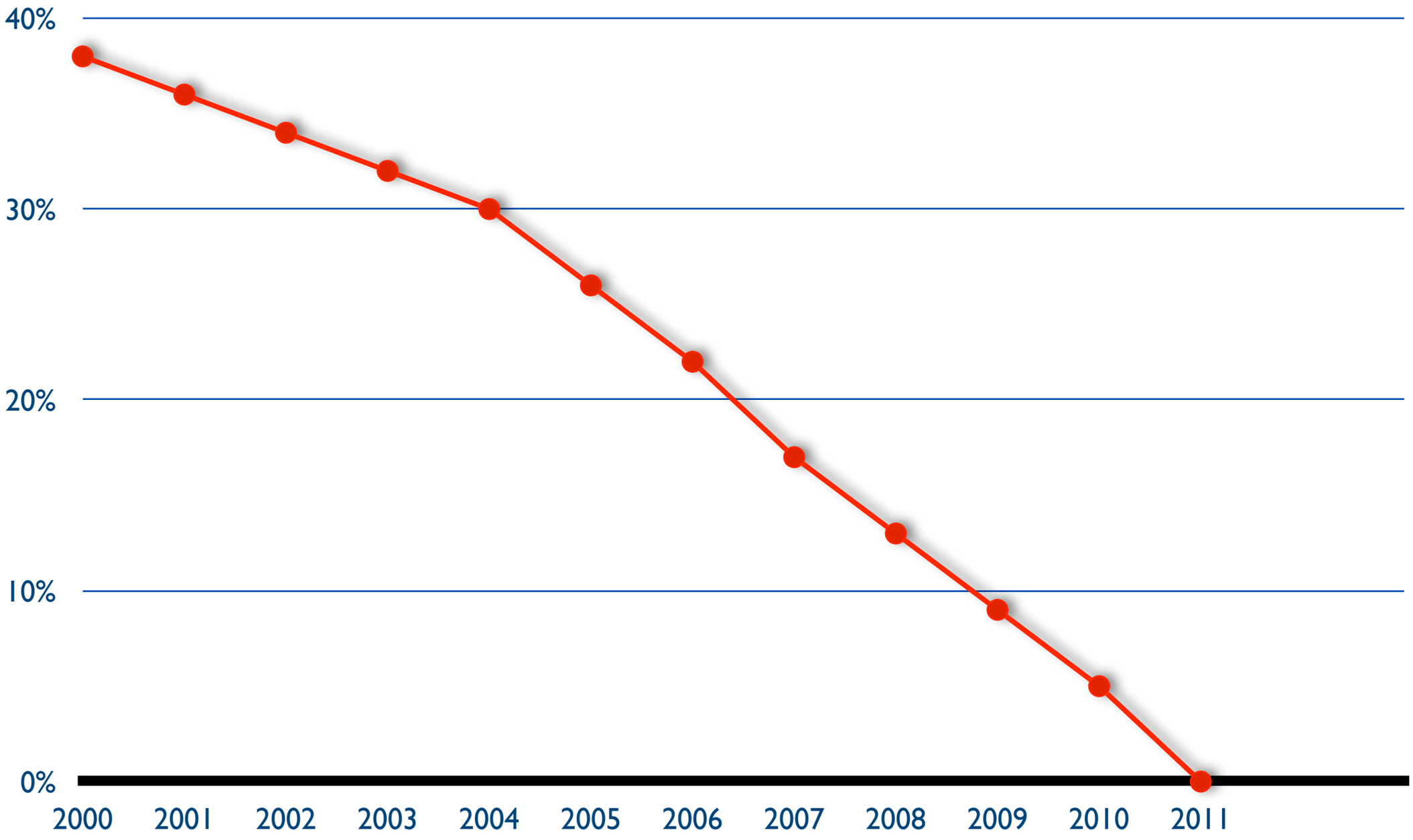
- Around 5,385 billion Internet users now
  - around 67.9 % of all people in the world
- Phones, IP Cameras, “Smart” devices / Gateways are Internet devices
- The Internet of Things
  - How will the Internet look like in 5 - 10 years?

The Internet of Things

Libelium Smart World

http://www.libelium.com/top_50_iot_sensor_applications_ranking

IANA IPv4 Pool



IPv4 Exhaustion

“On 14 September 2012, the RIPE NCC ran out of their regular pool of IPv4”

IPv4 run-out

“Today, at 15:35 (UTC+1) on 25 November 2019, we made our final /22 IPv4 allocation from the last remaining addresses in our available pool. We have now run out of IPv4 addresses.”

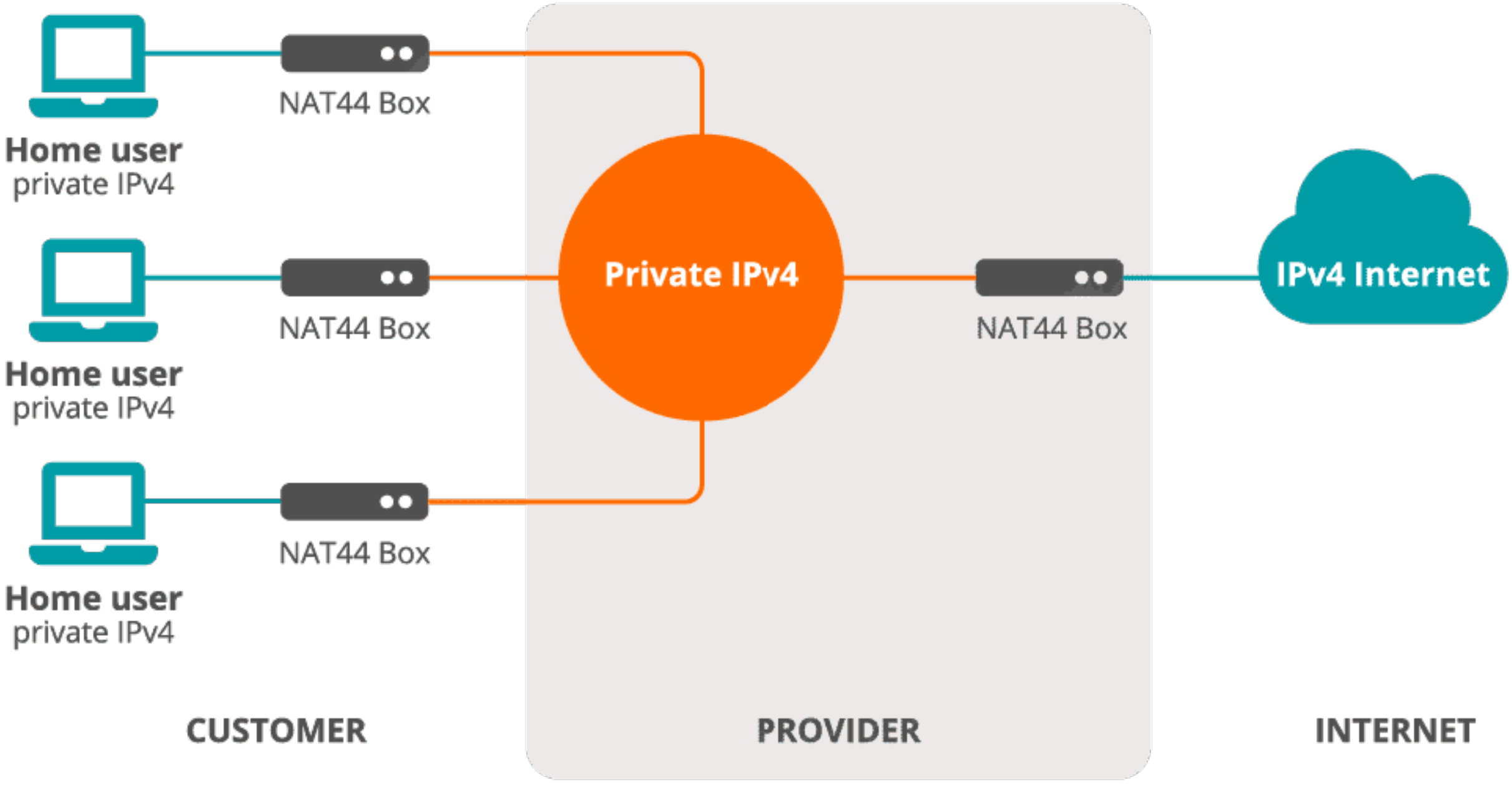
Our Reality: The Waiting List

1. Submit the IPv4 allocation request form at the LIR Portal (/24)
2. Wait

Network Address Translation

- Extends the capacity of the IPv4 address space by sharing an IPv4 address between clients
- Fairly common technology, used everywhere
- Breaks the end to end connectivity model
- It doesn’t allow communication with IPv6!
- You are probably going to need it in some form

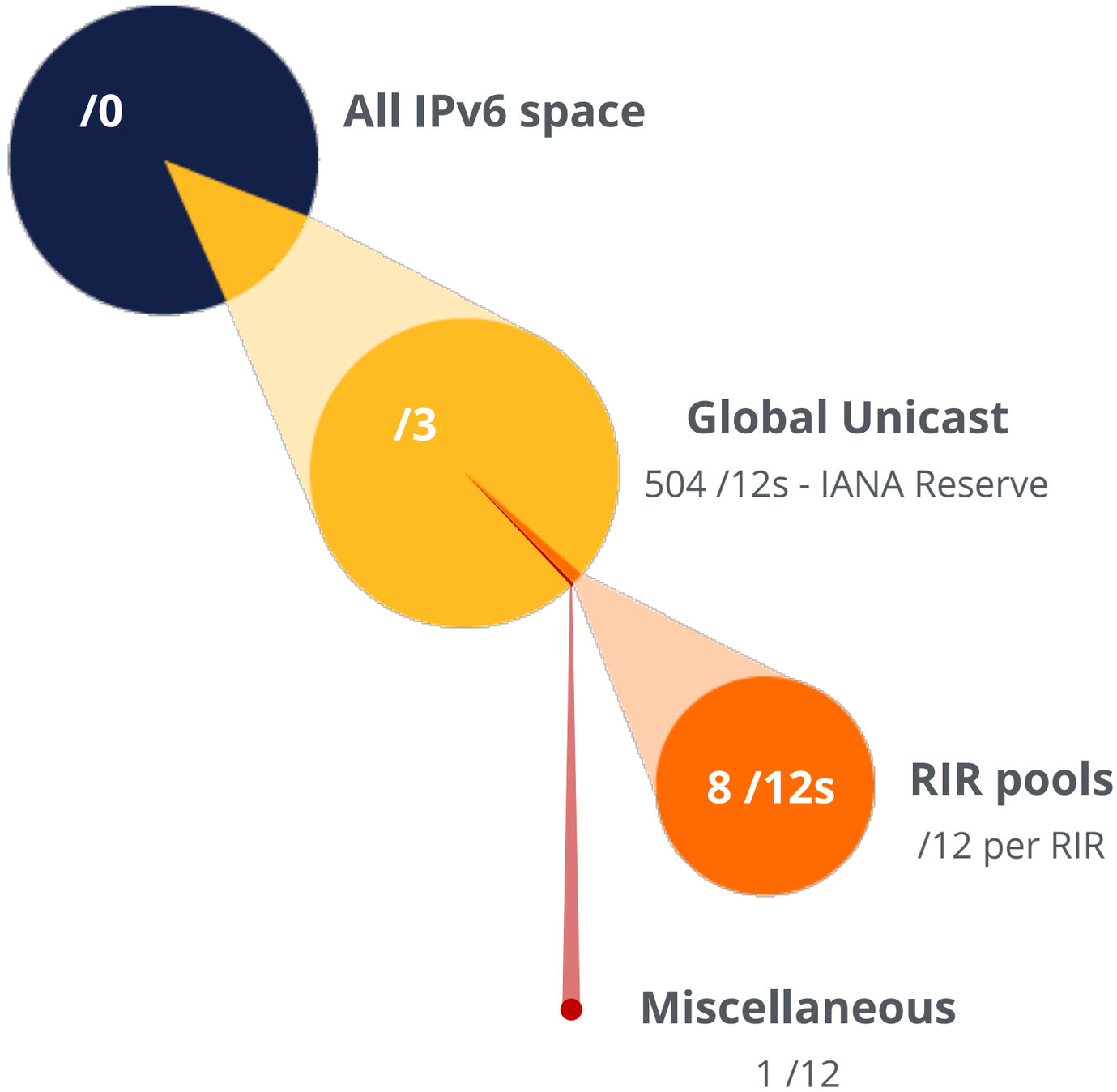
Large Scale NAT



IPv6 Address Basics

Section 2

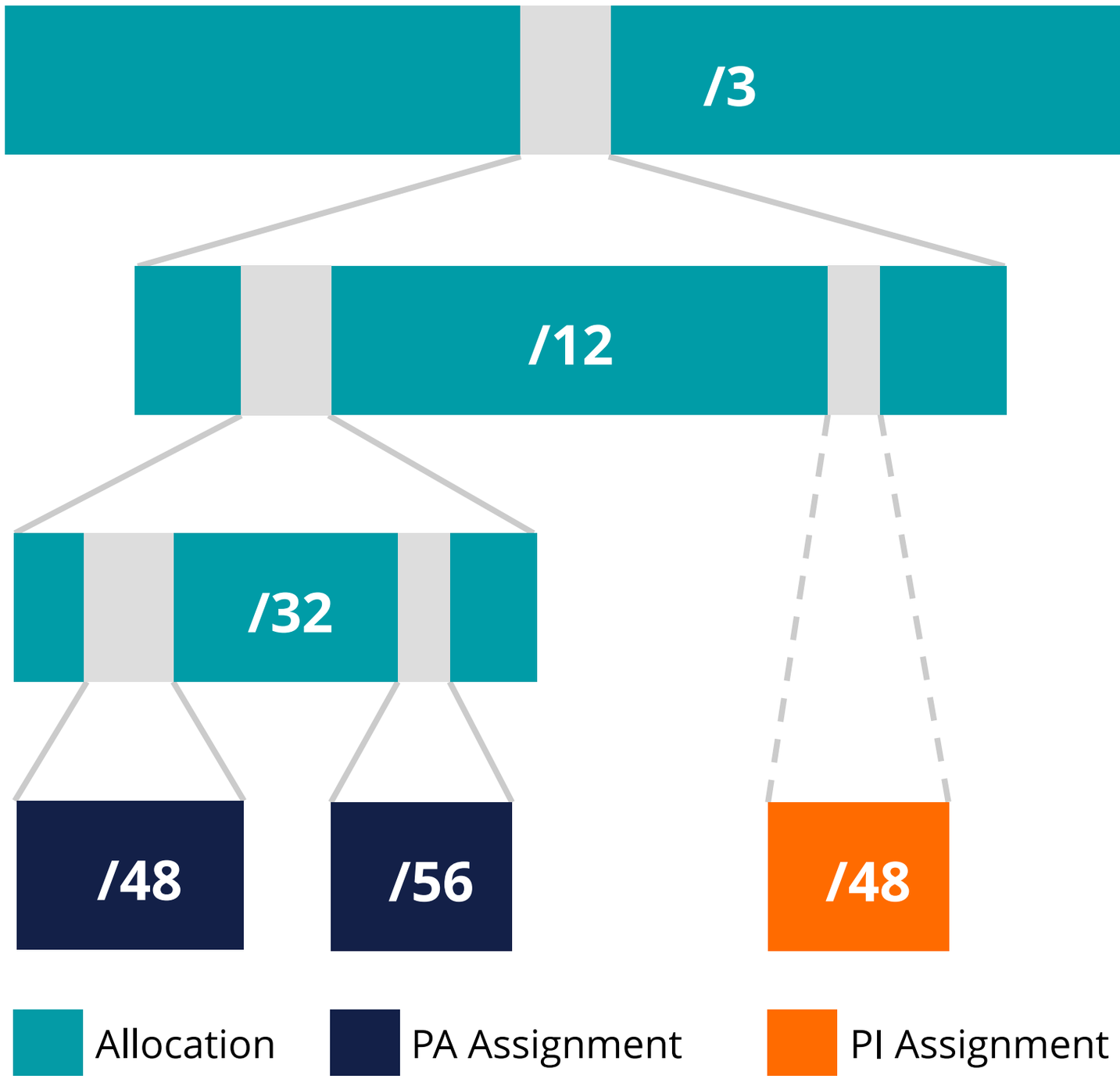
IP Address Distribution

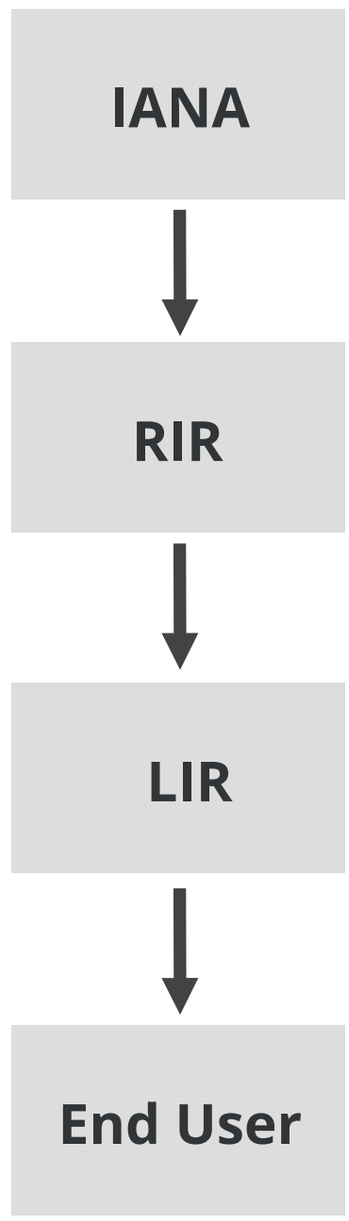


RIR Pools

	RIR	IPv6 Range
October 2006	**AFRINIC**	2C00:0000::/12
	APNIC	2400:0000::/12
	ARIN	2600:0000::/12
	LACNIC	2800:0000::/12
	RIPE NCC	2A00:0000::/12
June 2019	**RIPE NCC**	2A10:0000::/12
November 2019	**ARIN**	2630:0000::/12
November 2024	**APNIC**	2410:0000::/12

IP Address Distribution





IPv6 Address Basics

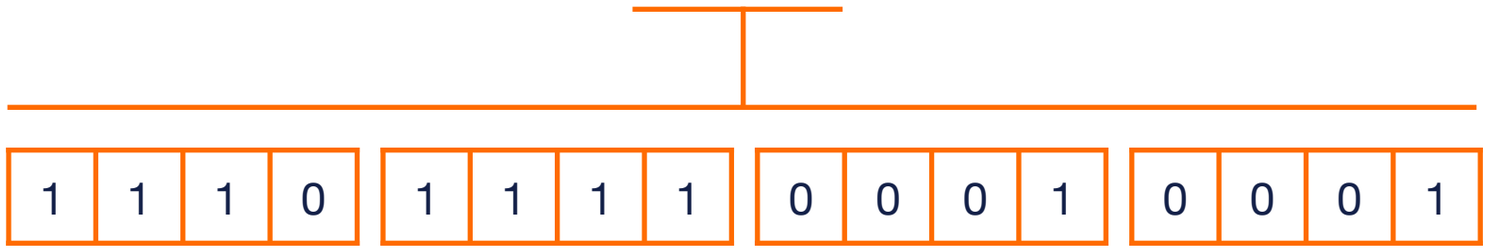
- IPv6 address: **128 bits**
  - 32 bits in IPv4
- Every subnet should be a **/64**
- Customer assignments (sites) between:
  - **/64** (1 subnet)
  - **/48** (65,536 subnets)
- Minimum allocation size **/32**
  - 65,536 /48s
  - 16,777,216 /56s

Address Notation

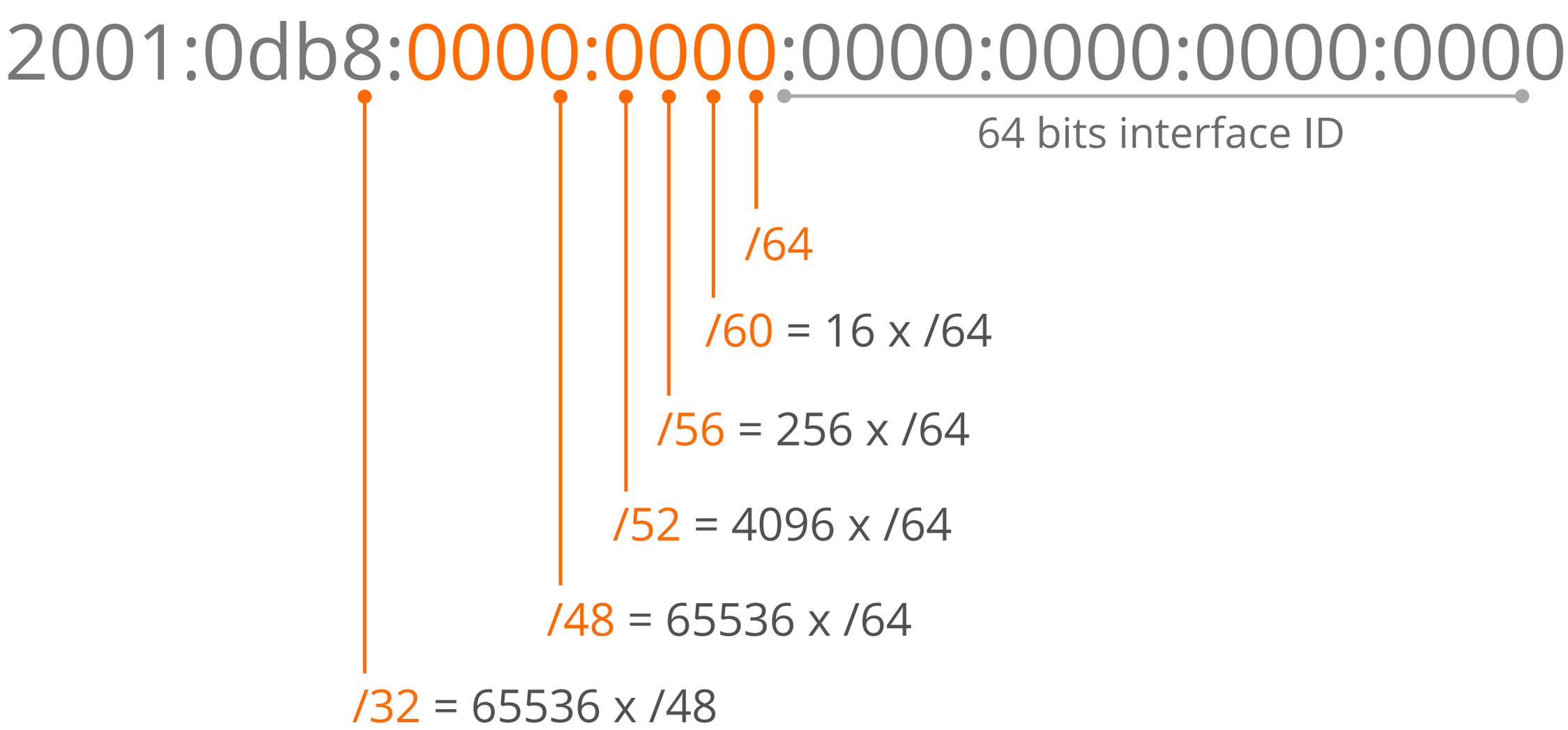
2001:0db8:003e:ef11:0000:0000:c100:004d

2001:0db8:003e:ef11:0000:0000:c100:004d

2001:db8:3e:ef11:0:0:c100:4d



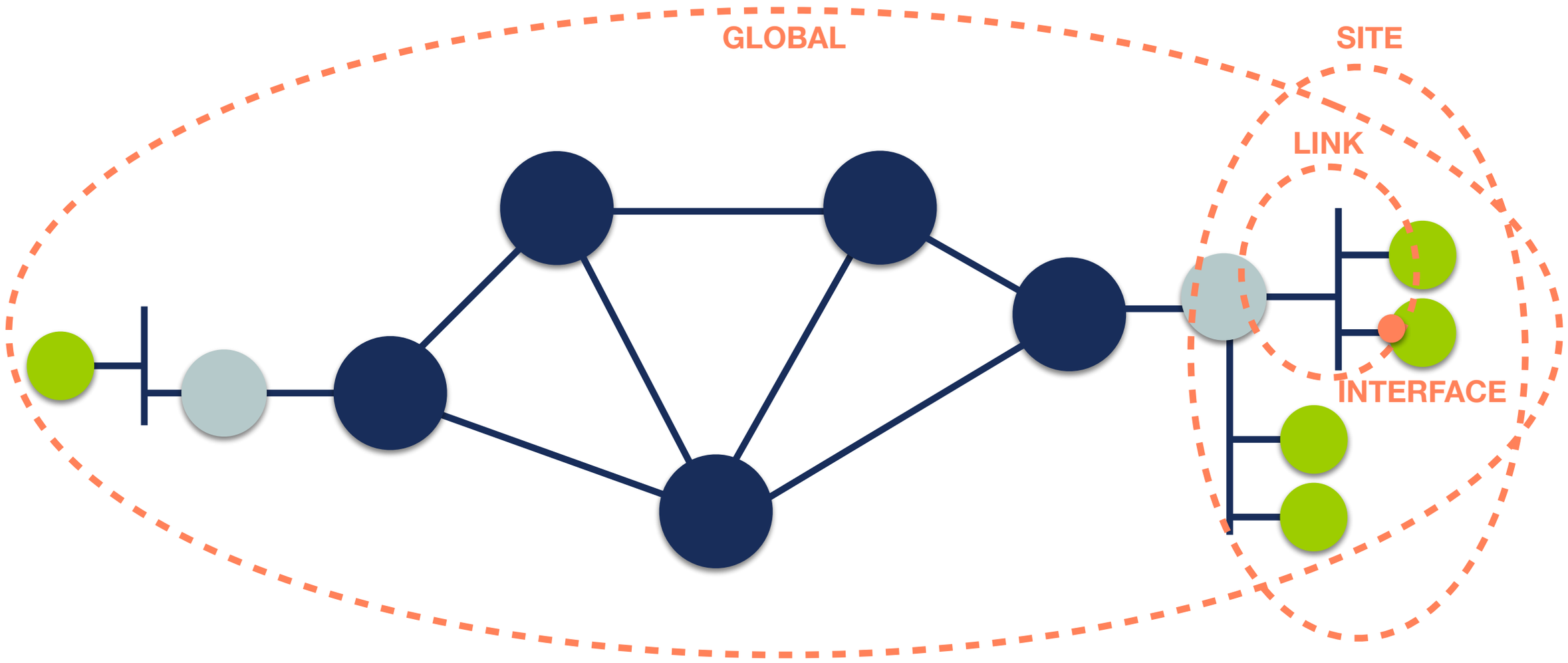
IPv6 Subnetting



Multiple address types

Addresses	Range	Scope
Unspecified	::/128	n/a
Loopback	::1	host
IPv4-Embedded	64:ff9b::/96	n/a
Discard-Only	100::/64	n/a
Link Local	fe80::/10	link
Global Unicast	2000::/3	global
Unique Local	fc00::/7	global
Multicast	ff00::/8	variable

IPv6 Address Scope



FE80::A:B:100

FF01::2

2001:67C:2E:1::C1

FD00:A:B::100

FF05::1:3

FF02::1

IPv6 Address Notation

Exercise

Question #1

You have a /32 prefix starting with **2001:0db8**.

How do you search for it in the RIPE Database?

a. 2001:0db8
b. 2001:0db8/32
c. 2001:0db8::/32
d. 2001:db8::/32

Question #1 Answer

You have a /32 prefix starting with **2001:0db8**.

How do you search for it in the RIPE Database?

a. 2001:0db8
b. 2001:0db8/32
c. 2001:0db8::/32
d. 2001:db8::/32

Question #2

How do you correctly compress the following IPv6 address:

2001:0db8:0000:0000:0000:0000:0000:0c50

a. 2001:0db8:0:0:0:0:0:0c50
b. 2001:0db8::0c50
c. 2001:db8::c50
d. 2001:db8::c5

Question #2 Answer

How do you correctly compress the following IPv6 address:

2001:0db8:0000:0000:0000:0000:0000:0c50

a. 2001:0db8:0:0:0:0:0:0c50
b. 2001:0db8::0c50
c. 2001:db8::c50 *
d. 2001:db8::c5

Question #3

How do you correctly compress the following IPv6 address:

2001:0db8:0000:0000:b450:0000:0000:00b4

a. 2001:db8::b450::b4
b. 2001:db8::b450:0:0:b4
c. 2001:db8::b45:0000:0000:b4
d. 2001:db8:0:0:b450::b4

Question #3 Answer

How do you correctly compress the following IPv6 address:

2001:0db8:0000:0000:b450:0000:0000:00b4

a. 2001:db8::b450::b4
b. 2001:db8::b450:0:0:b4 *
c. 2001:db8::b45:0000:0000:b4
d. 2001:db8:0:0:b450::b4

Question #4

How do you correctly compress the following IPv6 address:

2001:0db8:00f0:0000:0000:03d0:0000:00ff

a. 2001:0db8:00f0::3d0:0:00ff
b. 2001:db8:f0:0:0:3d0:0:ff
c. 2001:db8:f0::3d0:0:ff
d. 2001:0db8:0f0:0:0:3d0:0:0ff

Question #4 Answer

How do you correctly compress the following IPv6 address:

2001:0db8:00f0:0000:0000:03d0:0000:00ff

a. 2001:0db8:00f0::3d0:0:00ff
b. 2001:db8:f0:0:0:3d0:0:ff
c. 2001:db8:f0::3d0:0:ff *
d. 2001:0db8:0f0:0:0:3d0:0:0ff

Question #5

How do you correctly compress the following IPv6 address:

2001:0db8:0f3c:00d7:7dab:03d0:0000:00ff

a. 2001:db8:f3c:d7:7dab:3d:0:ff
b. 2001:db8:f3c:d7:7dab:3d0:0:ff
c. 2001:db8:f3c:d7:7dab:3d0::ff
d. 2001:0db8:0f3c:00d7:7dab:03d::00ff

Question #5 Answer

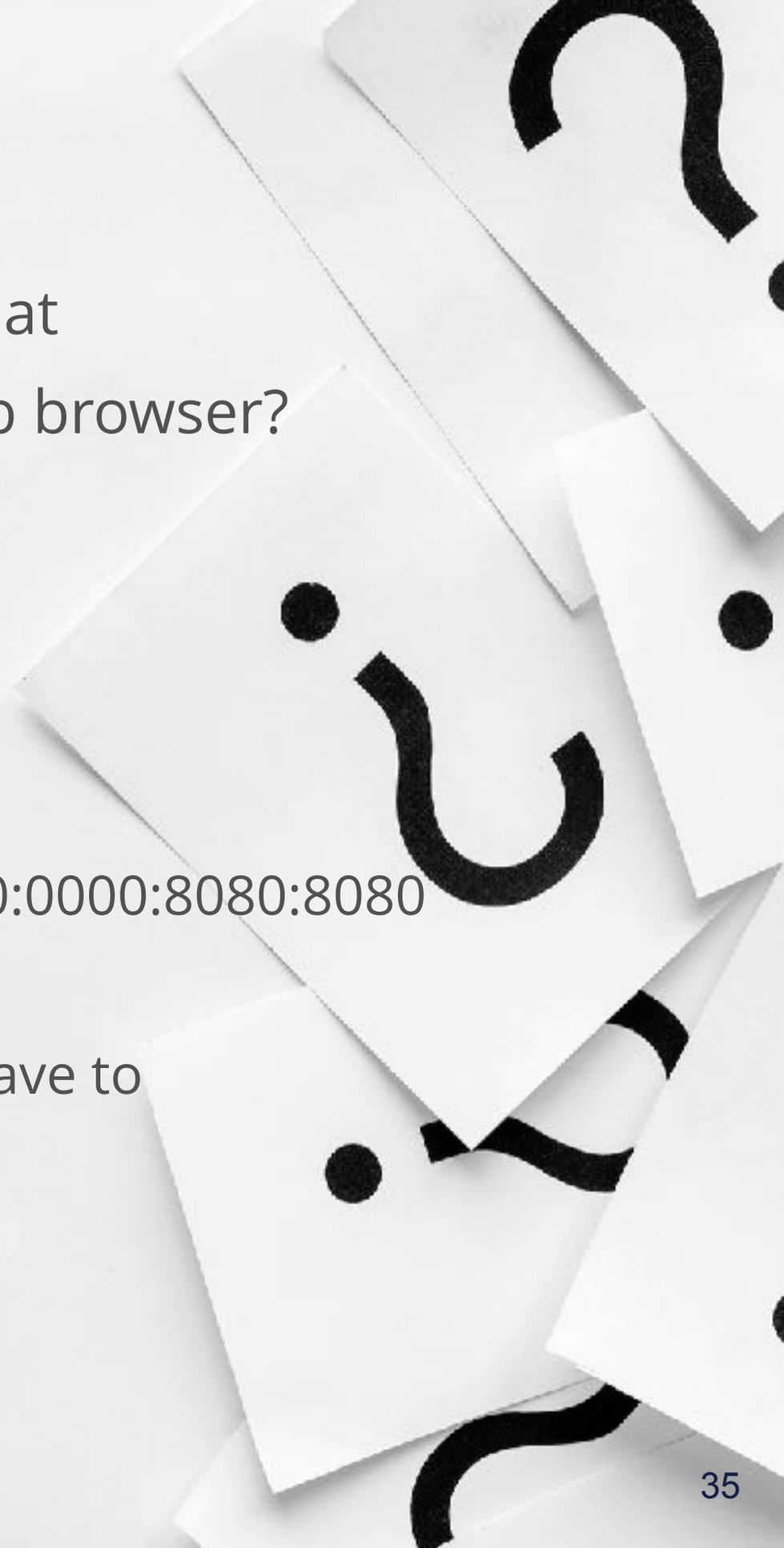
How do you correctly compress the following IPv6 address:

2001:0db8:0f3c:00d7:7dab:03d0:0000:00ff

a. 2001:db8:f3c:d7:7dab:3d:0:ff
b. 2001:db8:f3c:d7:7dab:3d0:0:ff *
c. 2001:db8:f3c:d7:7dab:3d0::ff
d. 2001:0db8:0f3c:00d7:7dab:03d::00ff

Question #6

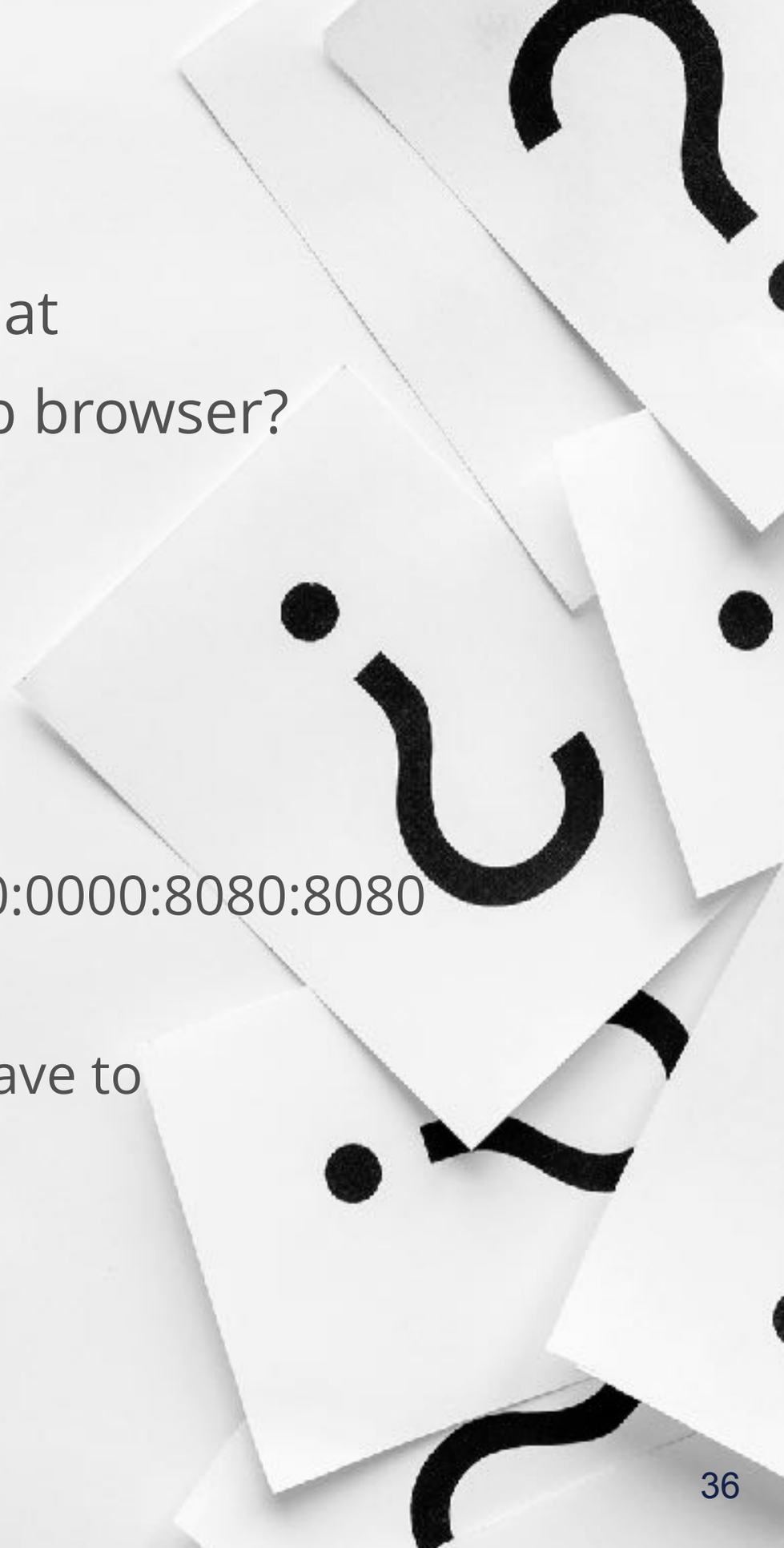
How do you access your IPv6 web server at **2001:db8::8080** on port 8080 using a web browser?



a. https://2001:db8::8080:8080
b. https://2001:0db8:0000:0000:0000:0000:0000:8080:8080
c. https://[2001:db8::8080]:8080
d. You cannot use the IPv6 address, you have to rely on DNS

Question #6 Answer

How do you access your IPv6 web server at **2001:db8::8080** on port 8080 using a web browser?

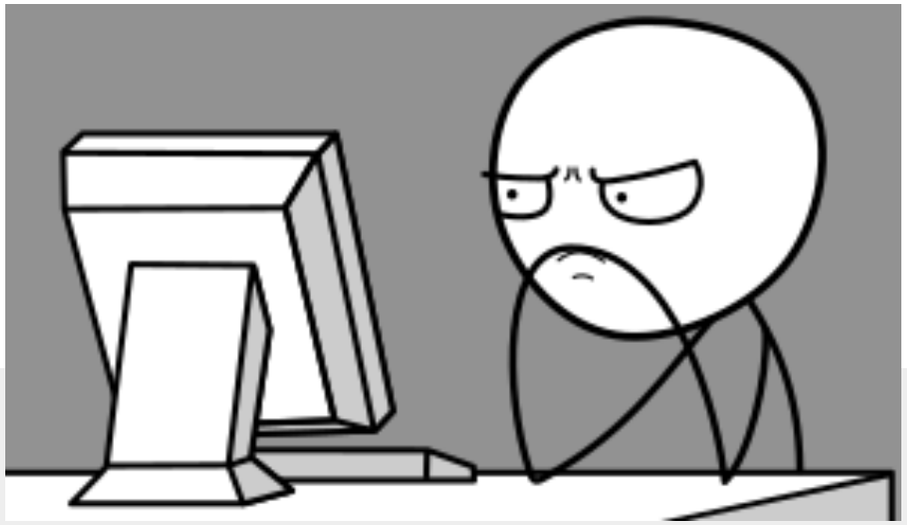


a. https://2001:db8::8080:8080
b. https://2001:0db8:0000:0000:0000:0000:0000:8080:8080
c. https://[2001:db8::8080]:8080
d. You cannot use the IPv6 address, you have to rely on DNS

IPv6 Notation - RFC 5952

For more information, please read RFC 5952:

“A Recommendation for IPv6 Address Text Representation”



Link to the RFC:

https://datatracker.ietf.org/doc/html/rfc5952

Questions

Getting It

Section 3

Getting an IPv6 allocation

- To qualify, an organisation **must**:
  - Be an LIR
  - Have a plan for making assignments within two years
- Minimum allocation size **/32**
  - **Up to a /29** without additional justification
  - More if justified by customer numbers and network extension
  - Additional bits based on hierarchical and geographical structure, planned longevity and security levels

Customer Assignments

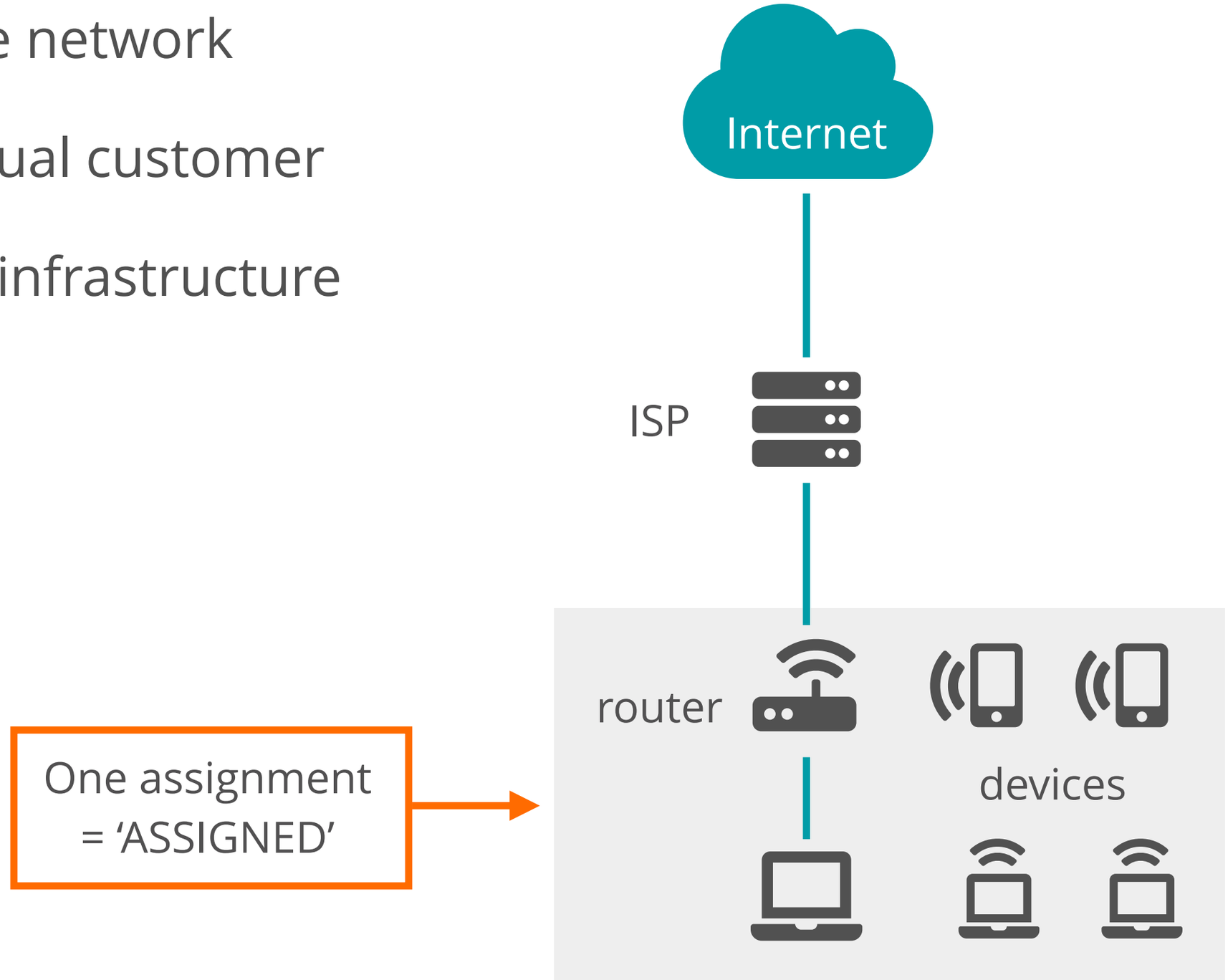
- Give your customers enough addresses
  - **Minimum /64**
  - There is **no maximum assignment size**
- Keep good documentation in case of an audit or if you request a subsequent allocation
- Every assignment **must be registered** in the RIPE Database

Comparison IPv4 and IPv6 status

IPv4		IPv6
ALLOCATED PA	**Allocation**	ALLOCATED-BY-RIR
ASSIGNED PA	**Assignment**	ASSIGNED
AGGREGATED-BY-LIR	**Group of Assignments**	AGGREGATED-BY-LIR
SUB-ALLOCATED PA	**Sub-Allocation**	ALLOCATED-BY-LIR
ASSIGNED PI	**PI Assignment**	ASSIGNED PI

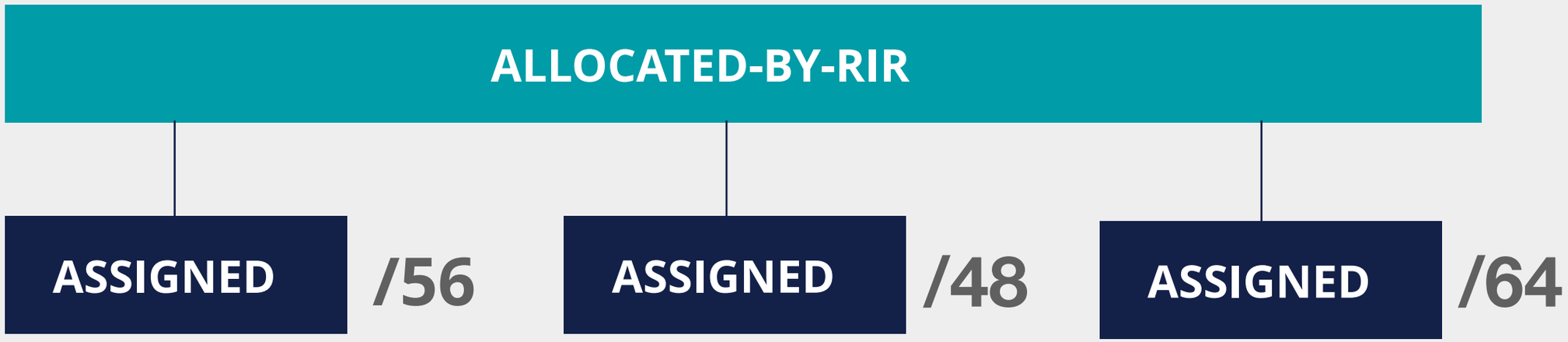
Examples ASSIGNED

- One single network
- An individual customer
- Your own infrastructure



Using ASSIGNED

- Represents one assignment
- Minimum assignment size is a /64



Using ASSIGNED - Example Object

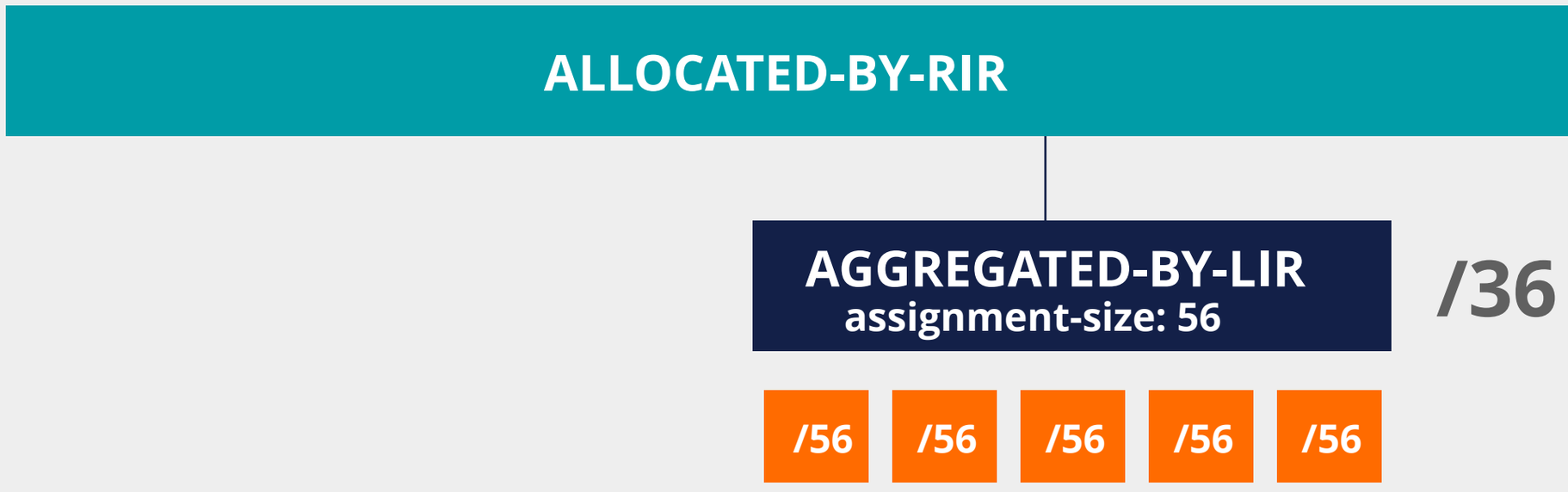
inet6num:	**2001:db8:1000::/48**
netname:	CUSTOMER-NET
country:	NL
admin-c:	ADM321-RIPE
tech-c:	NOC123-RIPE
status:	**ASSIGNED**
mnt-by:	LIR-MNT
created:	2015-05-31T08:23:35Z
last-modified:	2015-05-31T08:23:35Z

Examples AGGREGATED-BY-LIR

- Group of customers
- Same assignment size

Using AGGREGATED-BY-LIR

- Can be used to group customers
  - For example: Residential broadband customers
- **“assignment-size:”** = assignment of each customer



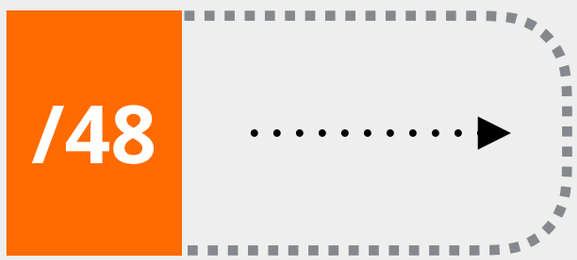
Using AGGREGATED-BY-LIR - Example

inet6num:	**2001:db8:1000::/36**
netname:	DSL-Broadband-Pool
country:	NL
admin-c:	ADM321-RIPE
tech-c:	NOC123-RIPE
status:	**AGGREGATED-BY-LIR**
assignment-size:	**56**
mnt-by:	LIR-MNT
notify:	noc@example.net
created:	2015-05-31T08:23:35Z
last-modified:	2015-05-31T08:23:35Z
source:	RIPE

Examples ALLOCATED-BY-LIR

Reservation for a large customer

Large Customer



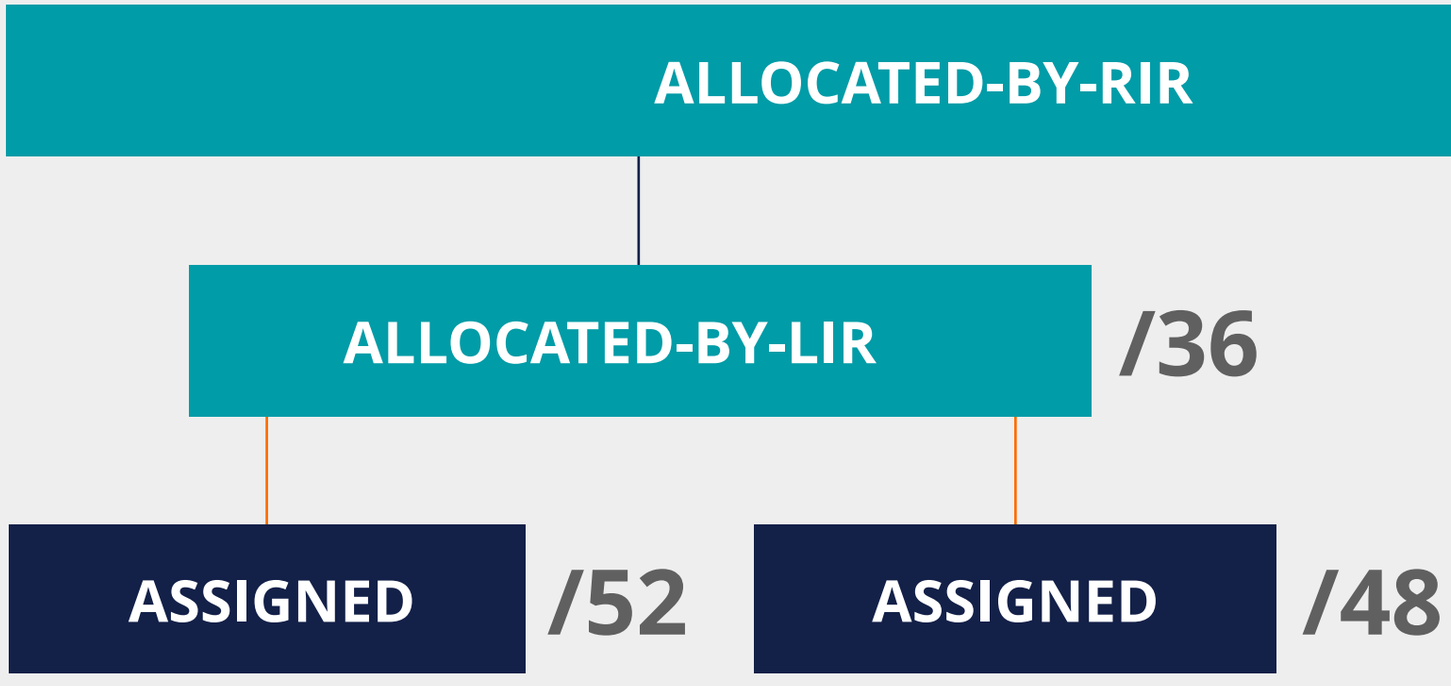
Branch office or department

Branch Office

Using ALLOCATED-BY-LIR

Can be used for customers with **potential for growth**

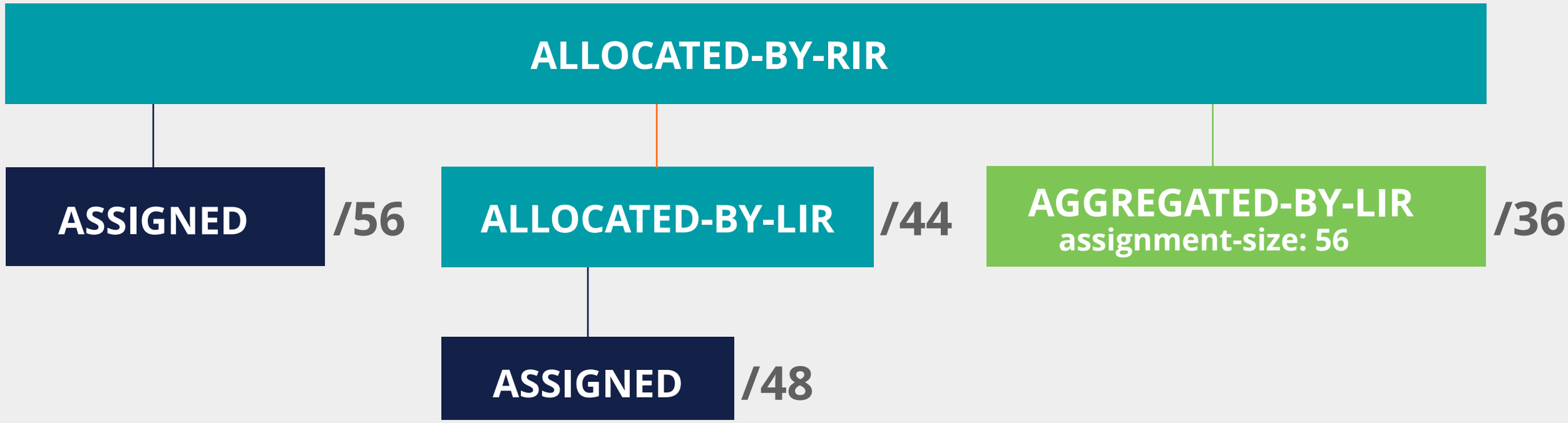
- Or for your own infrastructure
- Or to delegate address space to a downstream ISP



Using ALLOCATED-BY-LIR - Example

inet6num:	**2001:db8:50::/44**
netname:	Branch-Office-Network
country:	NL
admin-c:	ADM321-RIPE
tech-c:	NOC123-RIPE
status:	**ALLOCATED-BY-LIR**
mnt-by:	**LIR-MNT**
mnt-lower:	**BRANCH-OFFICE-MNT**
notify:	noc@example.net
created:	2015-05-31T08:23:35Z
last-modified:	2015-05-31T08:23:35Z
source:	RIPE

Overview


ALLOCATED-BY-RIR
ASSIGNED
/56
ALLOCATED-BY-LIR
/44
AGGREGATED-BY-LIR
assignment-size: 56
/36
ASSIGNED
/48

Getting IPv6 PI Address Space

- To qualify, an organisation must:
  - **Meet** the contractual **requirements** for provider independent resources
  - LIRs must demonstrate special **routing requirements**
- Minimum assignment size: **/48**
- PI space **cannot** be used for sub-assignments

Unique Local Addresses

- Prefixes from fc00::/7
  - Only from the **fd00::/8** block
- Should **not** be routed on the Internet
- Generate a random 40-bit Global ID and insert it into fdxx:xxxx:xxxx

Global ID:	da24154e1d
Prefix:	fdda:2415:4e1d::/48

Making Assignments

Exercise

Create assignments for a smart city!

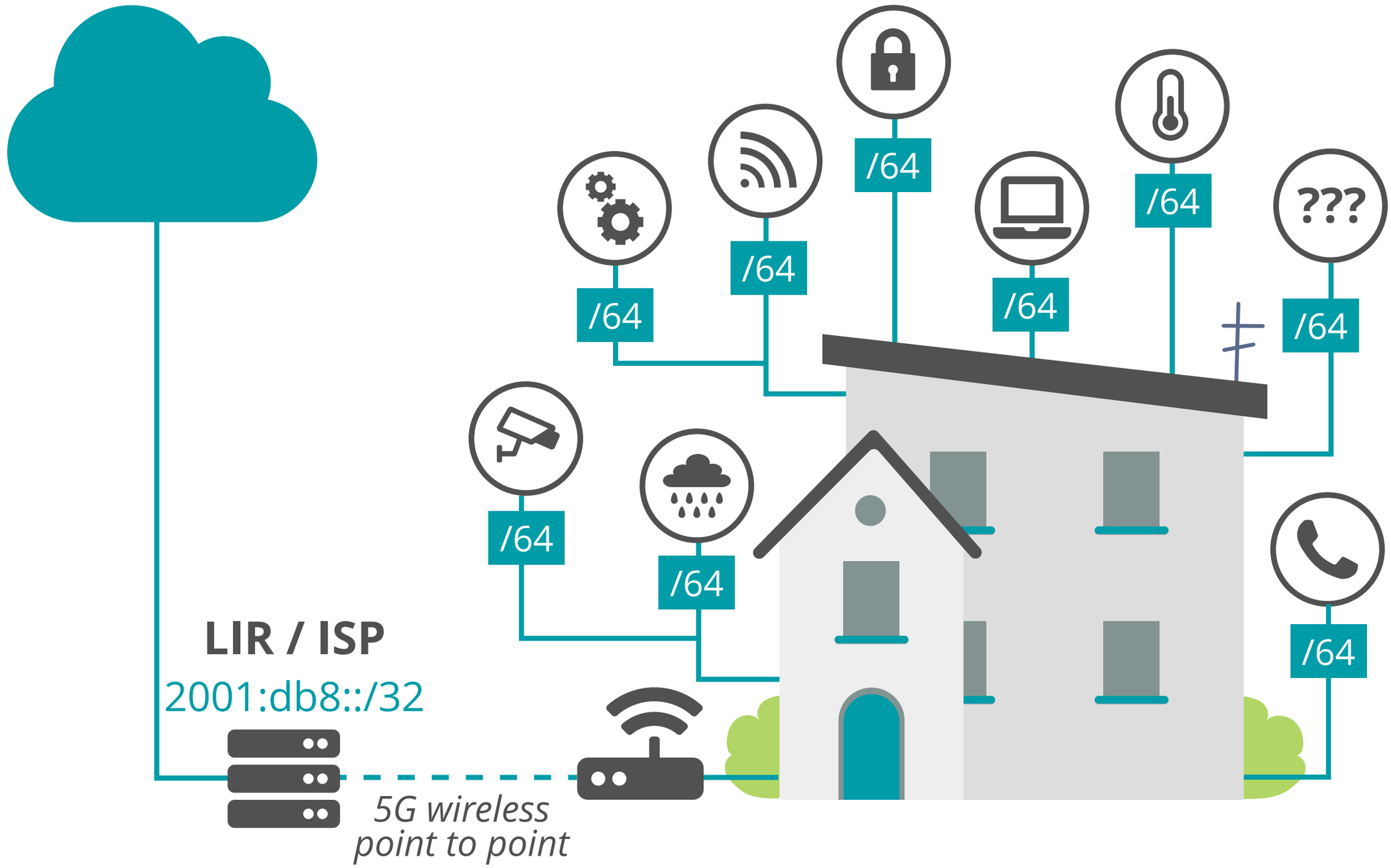
Context

- You work for the LIR: **nl.ripencc-ts**
- Your LIR has a /32 allocation: **2001:db8::/32**
- Your customer Future Casa is working on a project called “Smart Home 6”
- They need IPv6 addresses from your address space
- Future Casa wants to connect **1 million** Smart Homes

Product Description

- Each home will be equipped with a 4G-enabled base unit
- The base unit will be the central gateway for smart services inside the house
- Each smart service runs on a **dedicated subnet**
- Services can be enabled or disabled at any point from a user’s smartphone app
- Future Casa will be rolling out **new services in the future**

Smart Home 6 Network Diagram



Calculations...

- **/64 = 1 subnet**
  - Not enough. We need one subnet alone for the p2p conn.
- **/63 = 2 subnets**
  - Not enough subnets.
  - Not on the 4-bit boundary!
- **/60 = 16 subnets**
  - Is it enough to meet the future needs?
  - You want to avoid having to renumber!

Calculations…

- **/56 = 256 subnets**
  - Sounds reasonable. How many subnets can a house need?

- **/52 = 4096 subnets**
  - More than enough.

- **/48 = 65K subnets**
  - Definitely more than enough.

Calculations…

One million smart homes

X

/56 per home

=

/36

Possible options for /36 subnets

2001:db8:0000::/36

2001:db8:1000::/36

2001:db8:2000::/36

2001:db8:3000::/36

2001:db8:4000::/36

2001:db8:5000::/36

2001:db8:6000::/36

2001:db8:7000::/36

2001:db8:8000::/36

2001:db8:9000::/36

2001:db8:a000::/36

2001:db8:b000::/36

2001:db8:c000::/36

2001:db8:d000::/36

2001:db8:e000::/36

2001:db8:f000::/36

Solution RIPE Database object

inet6num:	2001:db8:1000::/36
netname:	SMART-HOME-6
descr:	Smart Home 6 network
country:	NL
admin-c:	RM1204-RIPE
tech-c:	RM1204-RIPE
status:	**AGGREGATED-BY-LIR**
assignment-size:	**56**
mnt-by:	**LIR-MNT**
notify:	noc@lir-example.com
created:	2015-05-31T12:34:01Z
last-modified:	2015-05-31T12:34:01Z
source:	RIPE

Solution RIPE Database object

inet6num:	2001:db8:1000::/36
netname:	SMART-HOME-6
descr:	Smart Home 6 network
country:	NL
admin-c:	RM1204-RIPE
tech-c:	RM1204-RIPE
status:	**ALLOCATED-BY-LIR**
mnt-by:	**LIR-MNT**
mnt-lower:	**SMART-CASA-MNT**
notify:	noc@lir-example.com
created:	2015-05-31T12:34:01Z
last-modified:	2015-05-31T12:34:01Z
source:	RIPE

IPv6 Protocol Basics

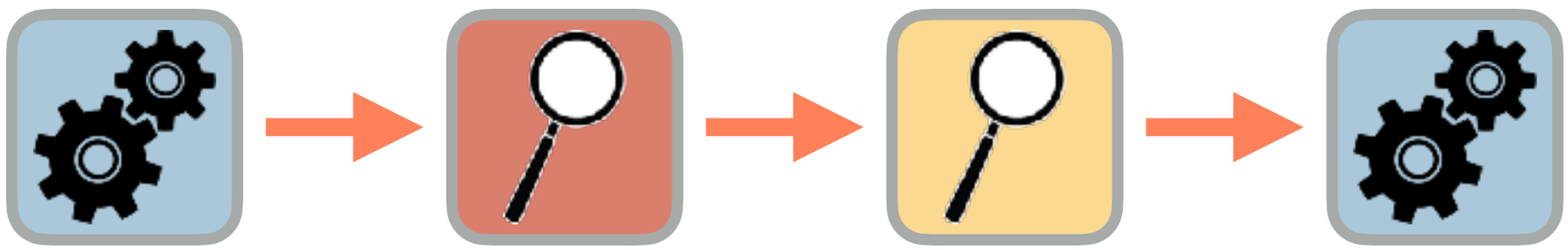
Section 4

IPv6 Protocol Functions

- **Address Autoconfiguration**
  - Supported by Neighbor Discovery
  - Stateless - with SLAAC
  - Stateful - with DHCPv6
- **Neighbor Discovery Protocol**
  - Replaces ARP from IPv4
  - Uses ICMPv6 and Multicast
  - Finds the other IPv6 devices on the link
  - Keeps track of reachability

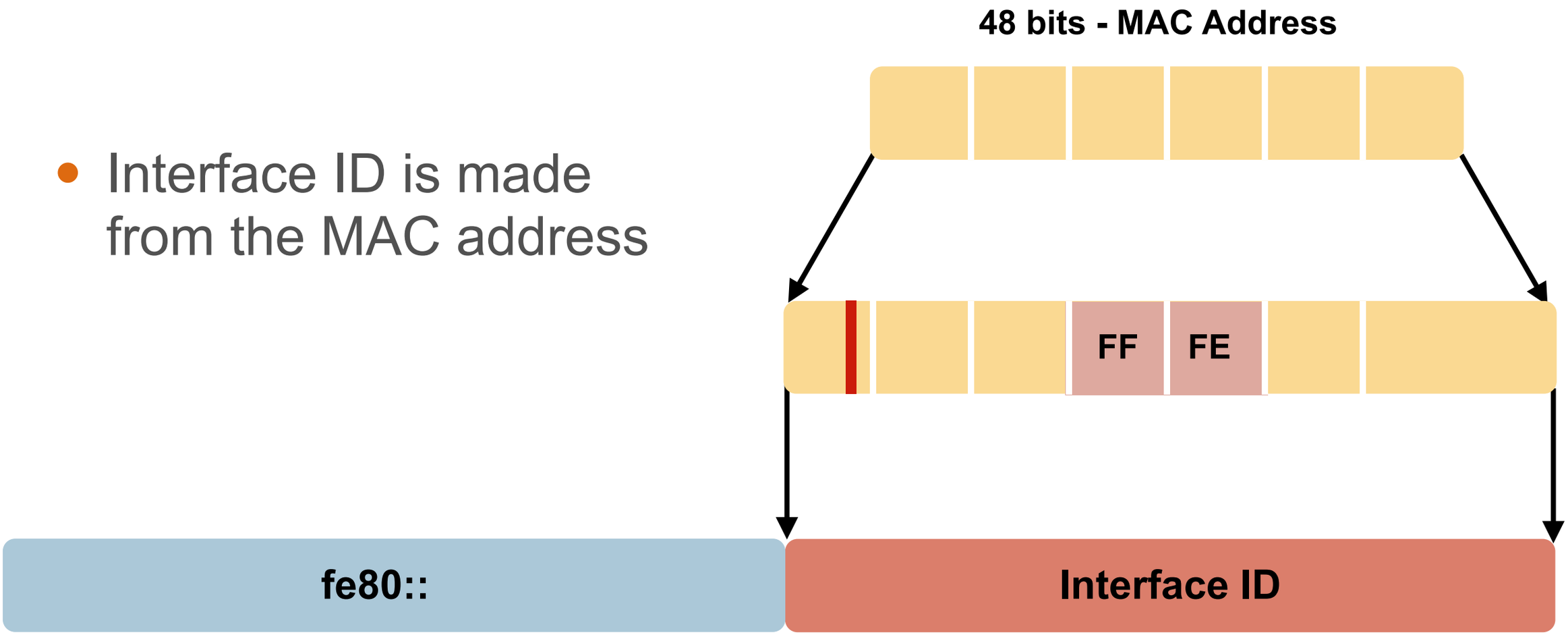
The Autoconfiguration Process

1. Make a Link-Local address
2. Check for duplicates on the link
3. Search for a router
4. Make a Global Unicast address



Making a Link-Local Address

- Interface ID is made from the MAC address



- fe80:: + Interface ID = Link-Local address for the host

Checking for Duplicates

Neighbor Solicitation

Hello! Is this IPv6 address in use?
Can you tell me your MAC address?

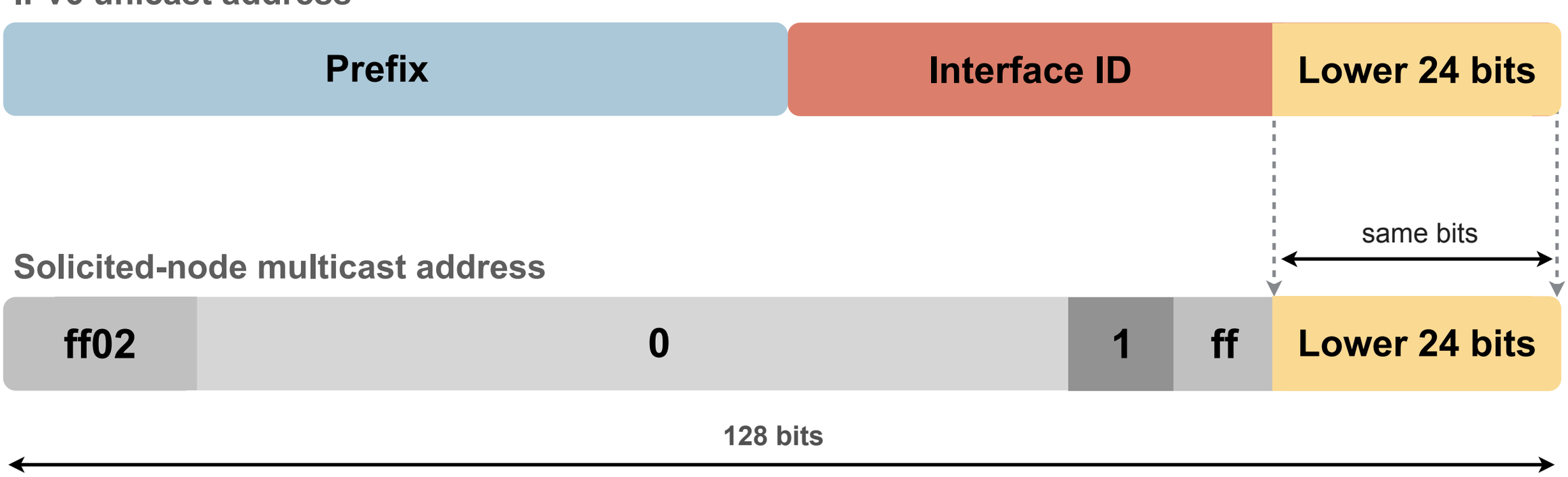
Neighbor Advertisement

Hello! Yes, I'm using that IPv6 address.
My MAC address is 72:D6:0C:2F:FC:01

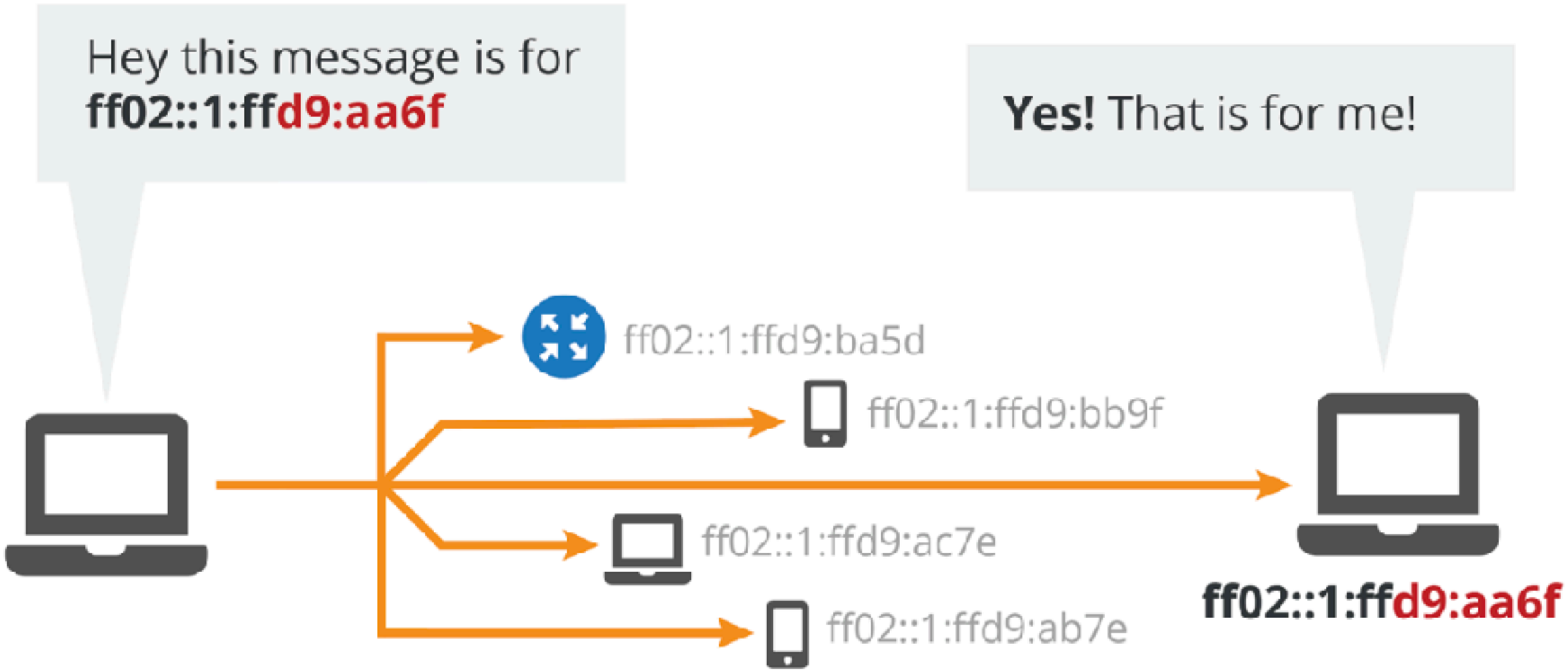
If nobody replies to the Neighbor Solicitation, the host uses the generated link-local address

Solicited Node Multicast Address

- Used in Neighbor Discovery Protocol for obtaining the layer 2 link-layer (MAC) addresses



Solicited Node Multicast Address



Searching for Routers

Router Solicitation

Hello! Is there a router out there?

Router Advertisement

Hello! I'm a router and I have some information for you…

The Router Advertisement gives the host more information to get an IPv6 address and set up a connection

Stateless Address Auto-Configuration

- **The Router Advertisement message tells the host:**
  - Router's address
  - Zero or more link prefixes
  - SLAAC allowed (yes/no)
  - DHCPv6 options
  - MTU size (optional)

Interfaces will have multiple addresses

- Unicast
  - Link Local fe80::5a55:caff:fef6:bdbf/64
  - Global Unicast 2001::5a55:caff:fef6:bdbf/64 (multiple)
- Multicast
  - All Nodes ff02::1 (scope: link)
  - Solicited Node ff02::1:fff6:bdbf (scope: link)
- Routers
  - All Routers ff02::2 (scope: link)

Verifying Reachability

Neighbor Solicitation

Hello! Are you still out there?
Is your MAC address still valid?

Neighbor Advertisement

Hello! Yes, I'm still online.
My MAC address is 72:D6:0C:2F:FC:01

If the target does not reply to the Neighbor Solicitation, the sender removes the MAC address from the cache

Redirects

IPv6 Packet

This packet is for an IPv6 host.

Redirect

Hello! That destination you wanted?
I know a better way to reach it.

- **Hosts can be redirected to a better first-hop router**
- **They can also be informed that the destination is a neighbor on the link**

Questions

Addressing Plans

Section 5

Why Create an Addressing Plan?

- **Benefits of an IPv6 addressing plan**
  - Mental health during implementation (!)
  - Easier implementation of security policies
  - Efficient addressing plans are scalable
  - More efficient route aggregation

IPv6 Address Management

- **Your spreadsheet might not scale**
  - There are 65.536 /64s in a /48
  - There are 65.536 /48s in a /32
  - There are 524.288 /48s in a /29
  - There are **16.777.216** /56s in a /32
  - There are **134.217.728** /56s in a /29
- Find a suitable IPAM solution

Addressing Plan

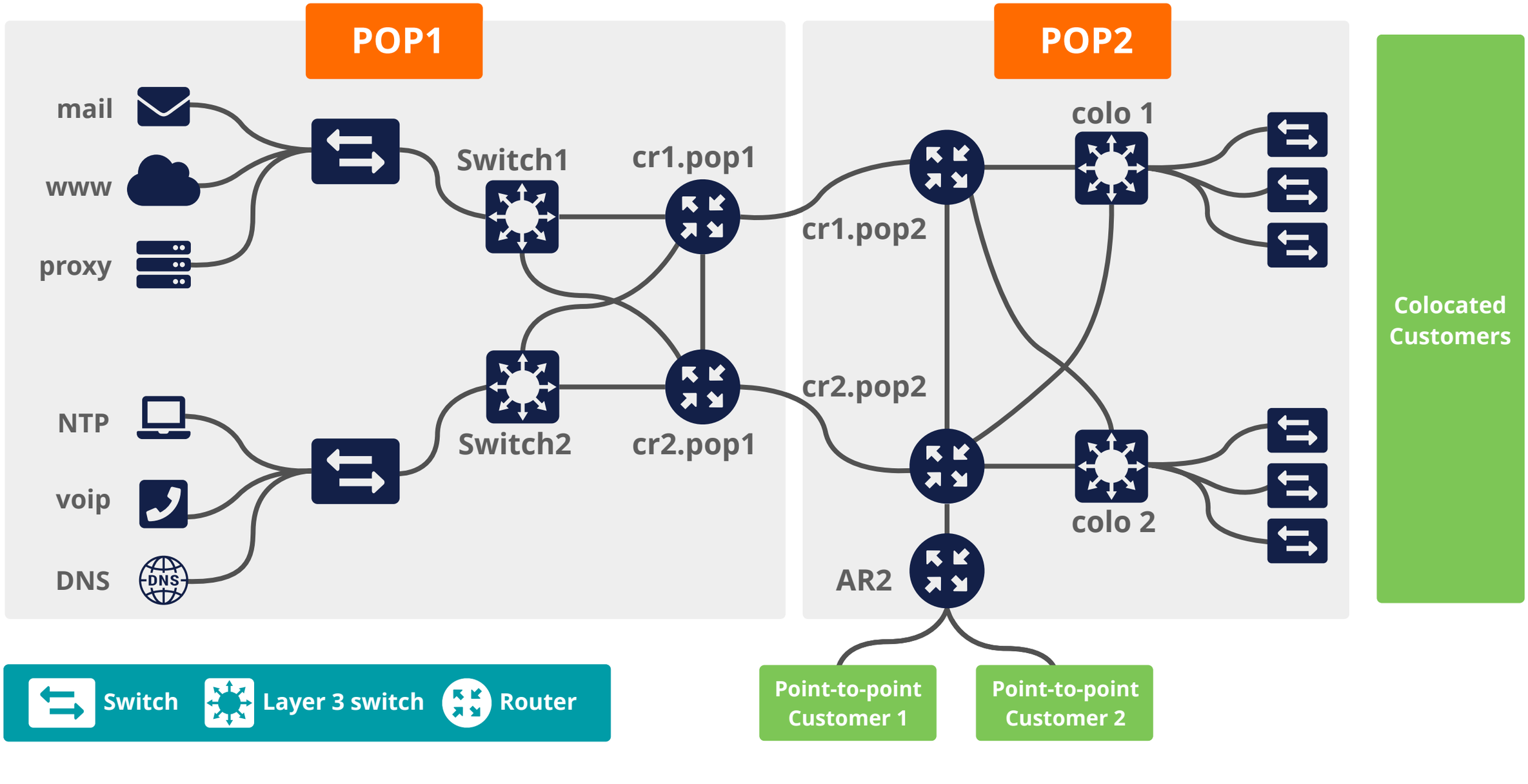
Exercise

Addressing Plan Exercise

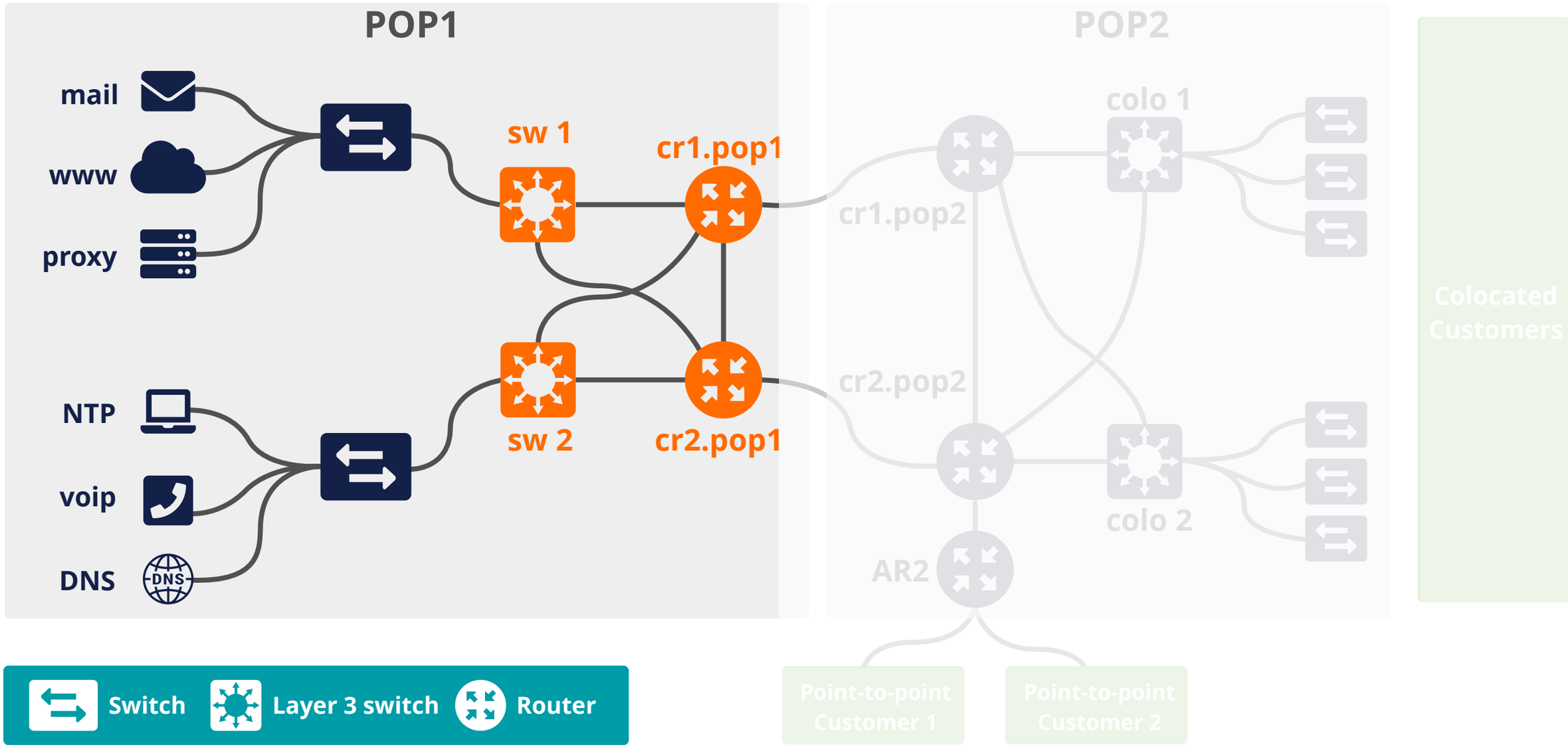
- Things to consider
  - administrative ease!
  - use assignments on 4 bit boundary
  - 2 possible scenarios for network
  - 5 possible scenarios for customer assignments

- 20 minutes preparation time
- 10 minutes discussion

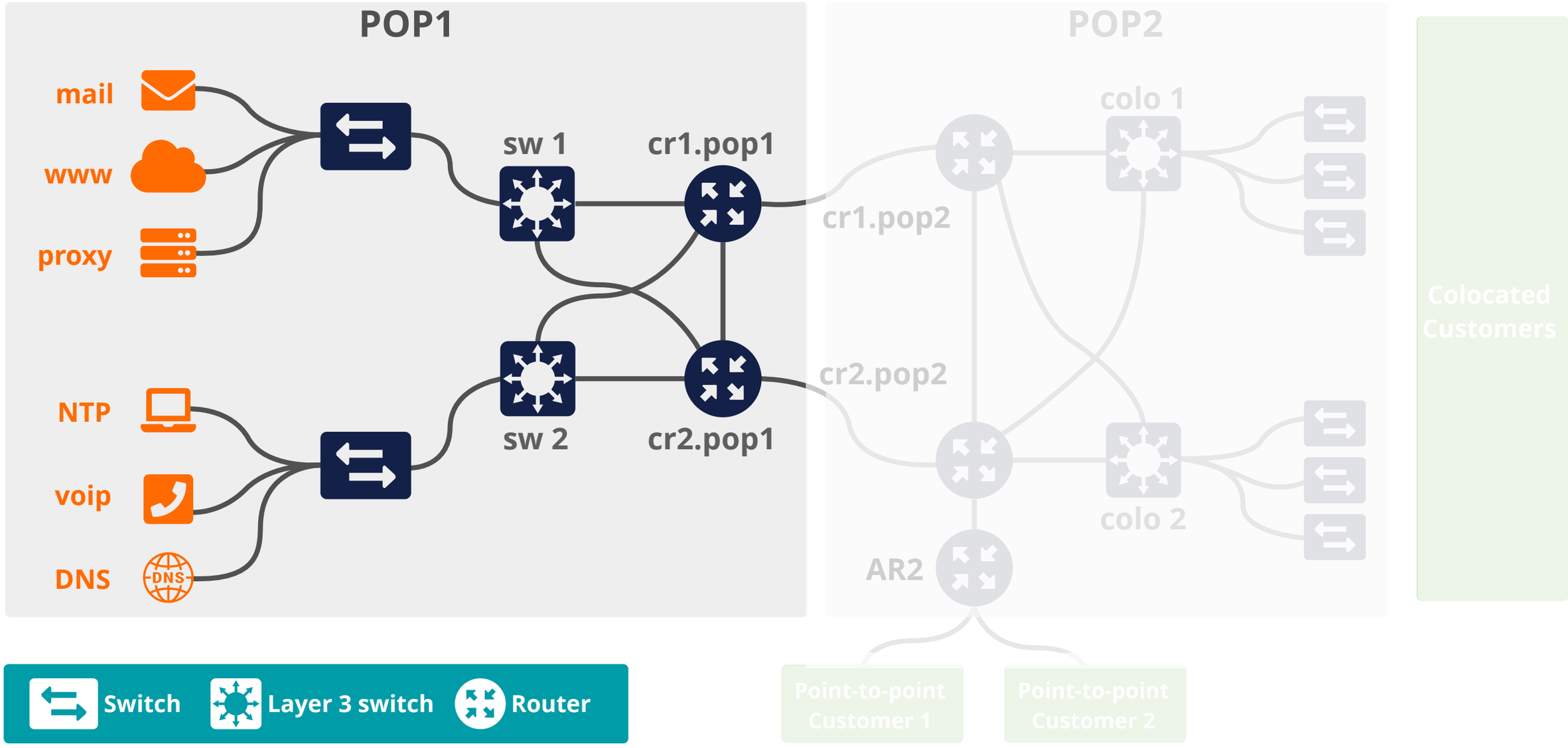
Network Diagram - POPs



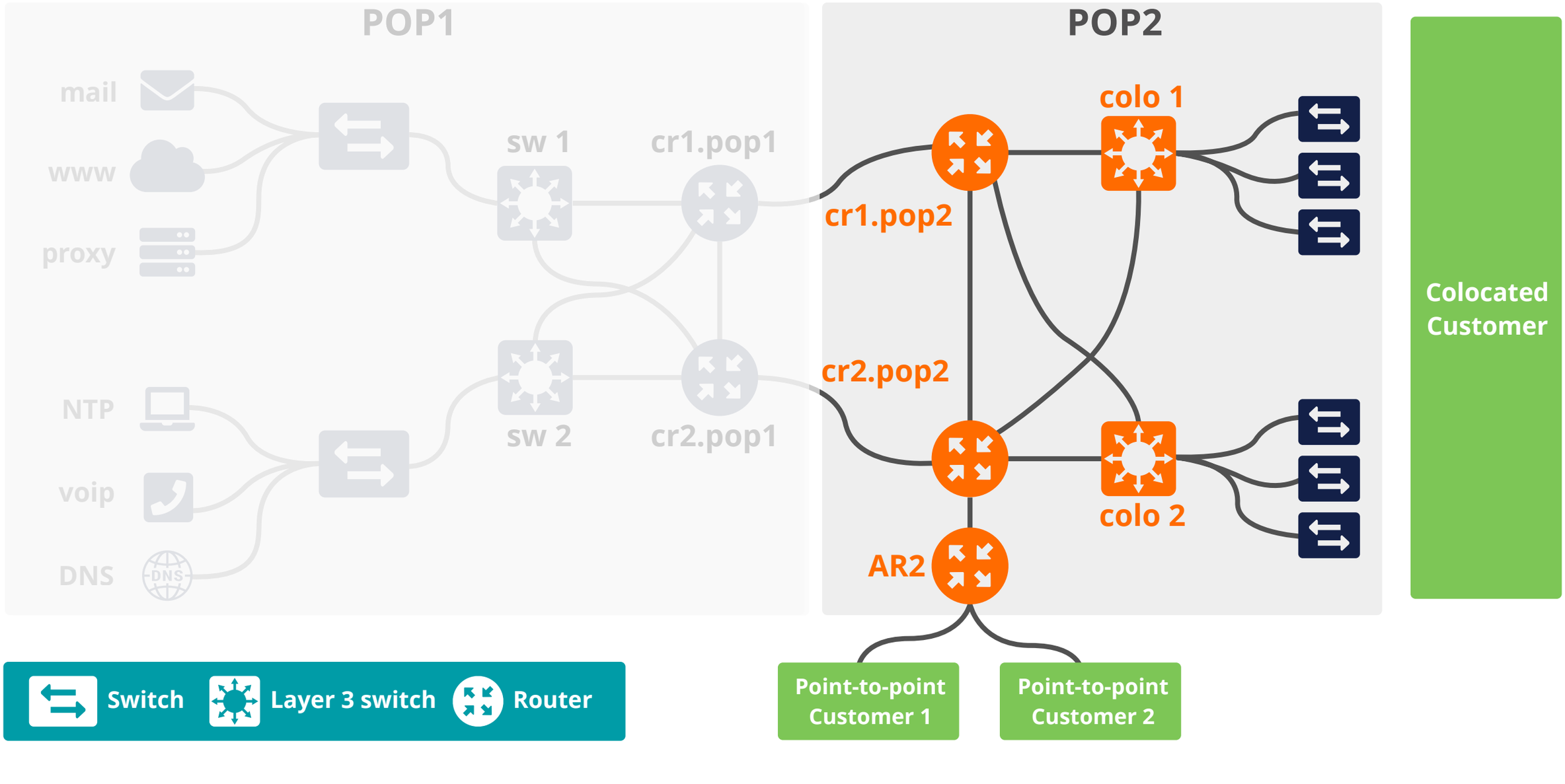
Network Diagram - POP1



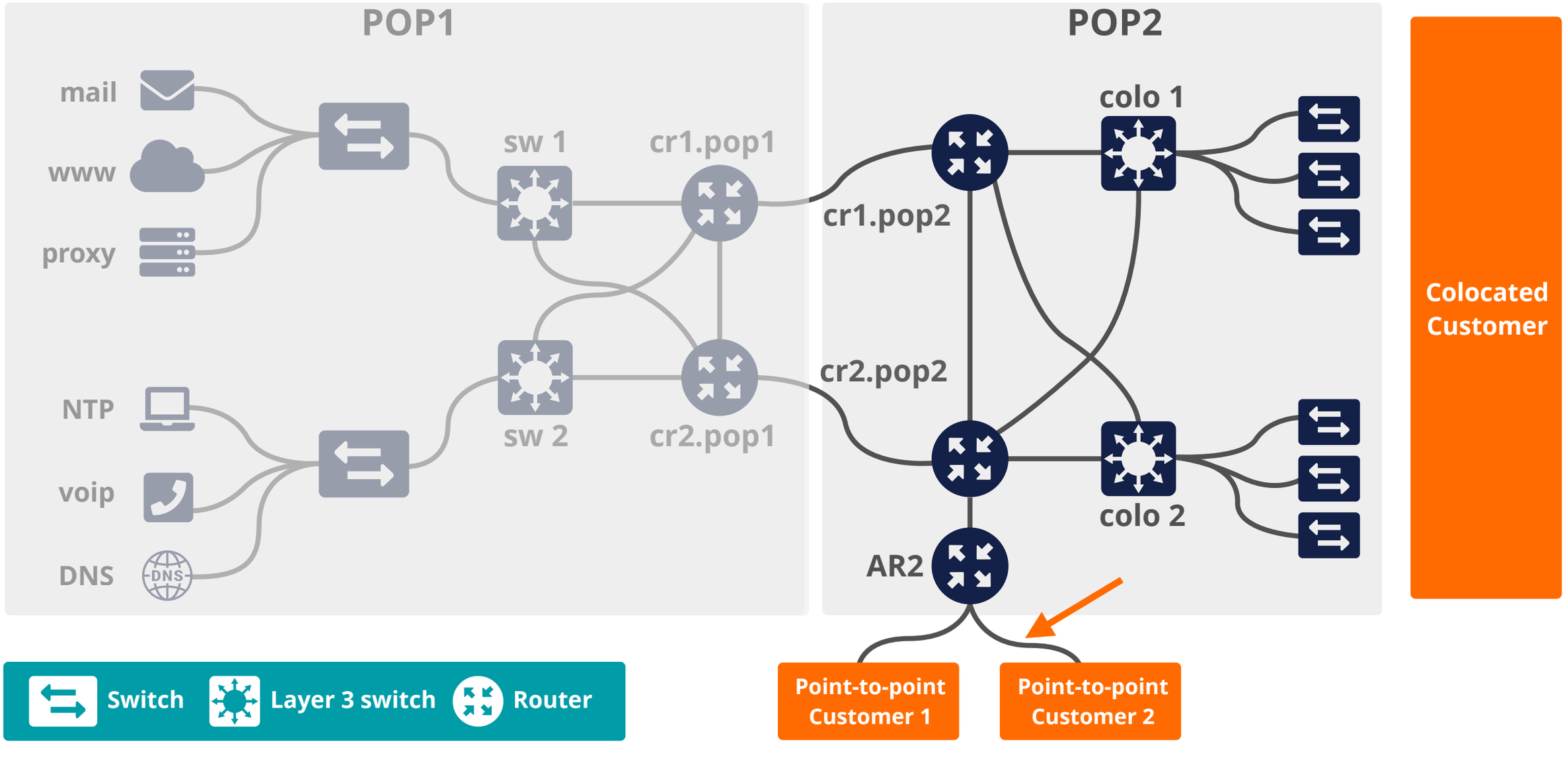
Network Diagram - POP1



Network Diagram - POP2



Network Diagram - POP2



Addressing plans

- /64 for each subnet
- Number of hosts in a /64 is irrelevant
- Multiple /48s per pop can be used
  - separate blocks for infrastructure and customers
  - document address needs for allocation criteria
- Use one /64 block per site for loopbacks

The /64 story

- “Every interface ID must be a /64” (RFC 4291)
- Because of SLAAC
- Other RFCs followed this
- The **only** exception is a /127 for point-to-point links

More on Addressing Plans

- For private networks, consider ULA
- For servers you want a manual configuration
- Avoid embedding service information in IP addresses
  - pop server = 2001:db8:1::110 ❌
  - dns server = 2001:db8:1::53 ❌
- Instead, use DNS for service discovery
  - POP server: 2001:db8:1::1 (resolvable as pop.example.com)
  - DNS server: 2001:db8:1::2 (resolvable as dns.example.com)

Questions

IPv6 Packets

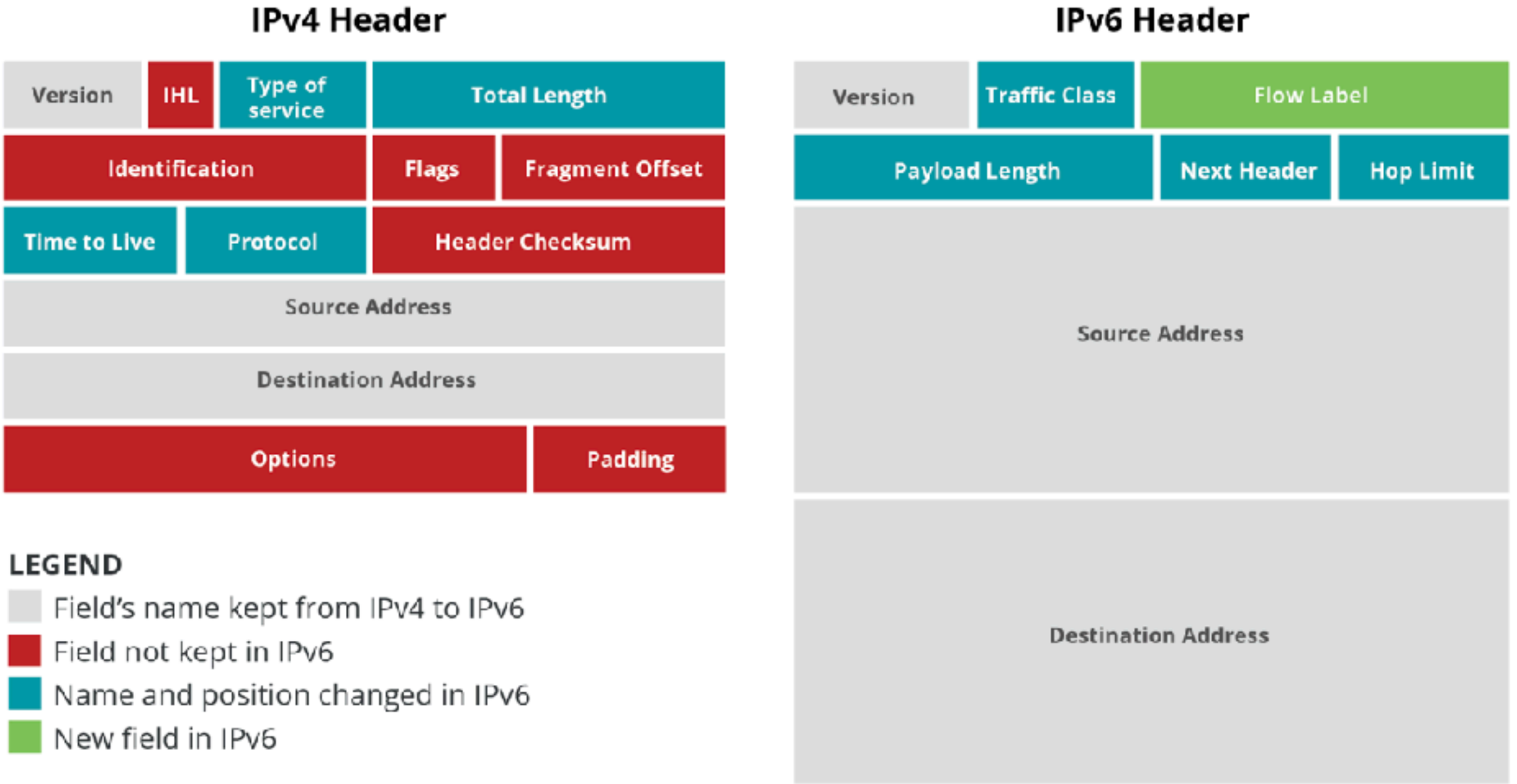
Section 6

IPv6 Header Format

- Fixed length
  - Optional headers are daisy-chained

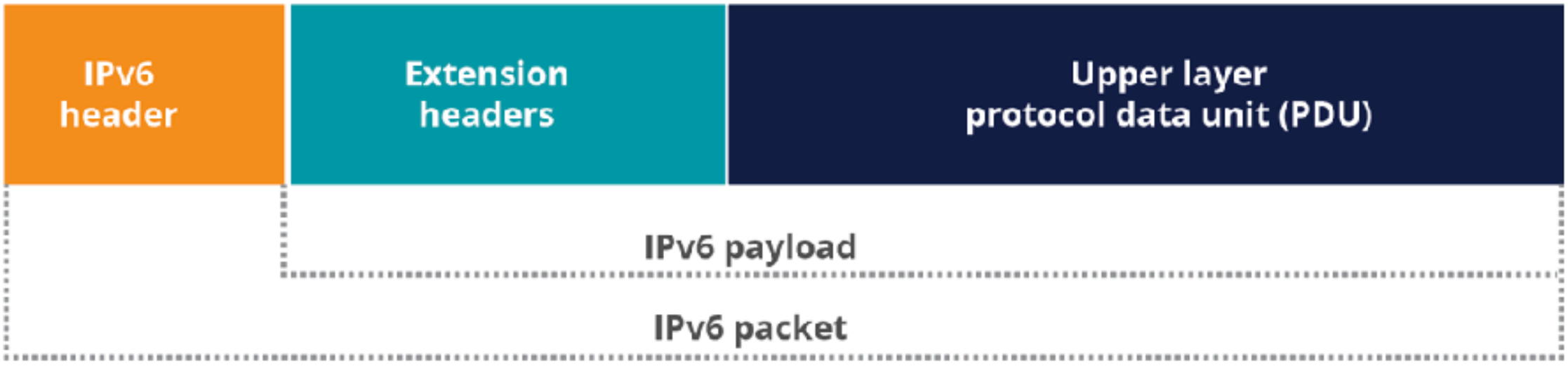
- IPv6 header is twice as long (40 bytes) as IPv4 header without options (20 bytes)

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

IPv6 Header

- Optional fields go into extension headers



IPv6 Header

- Daisy-chained after the main header

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

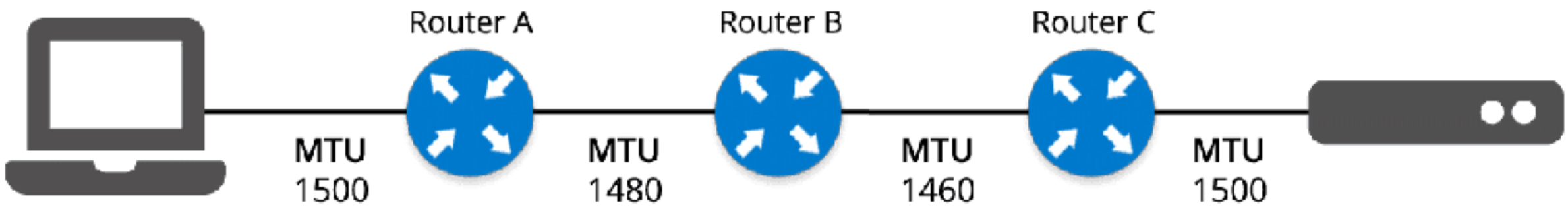
Fragmentation

- 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

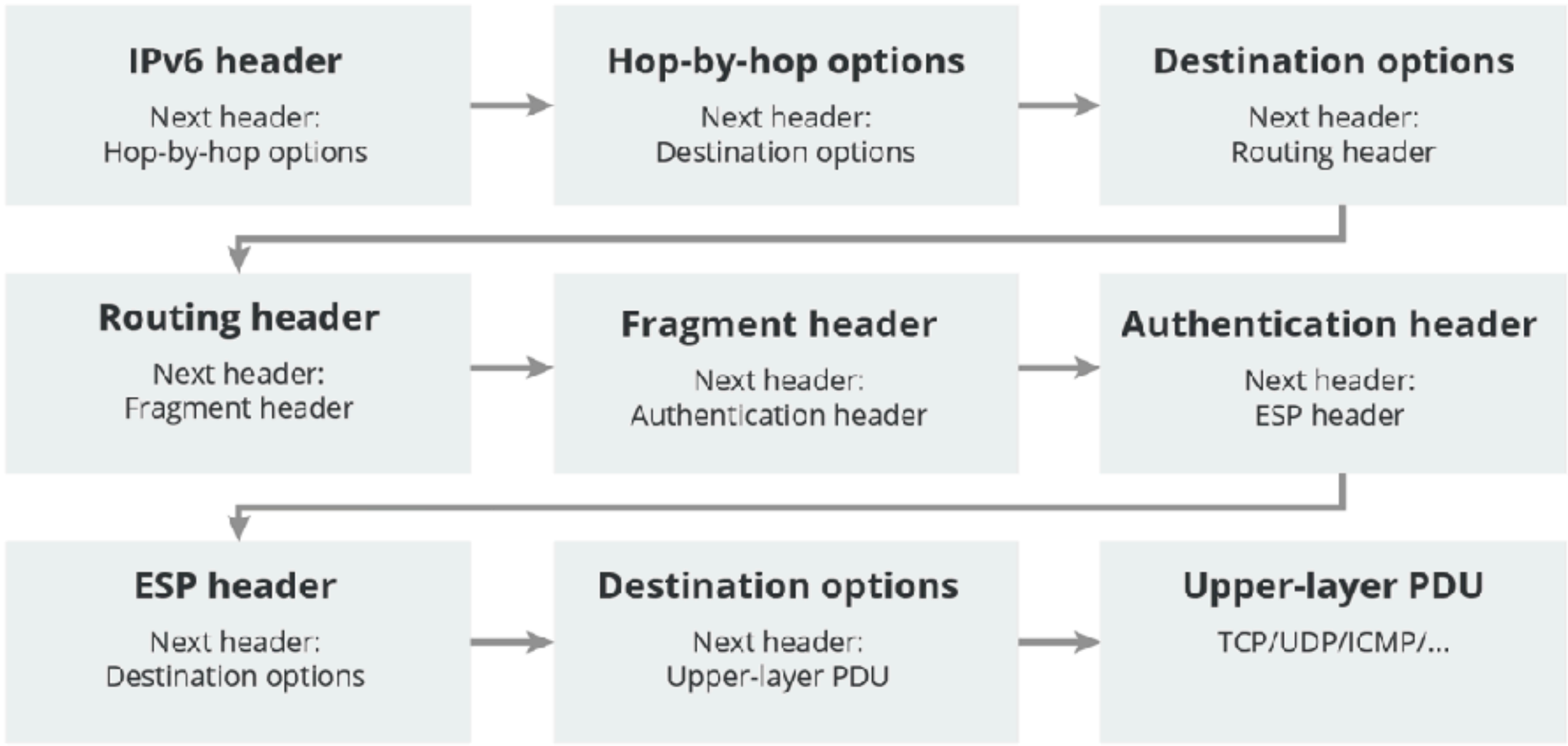
- A sender who gets this “message-too-big” ICMPv6 error tries again with a smaller packet
  - A hint of size is in the error message
  - This is called Path MTU Discovery



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

Ordering of Headers



Questions

Deploying IPv6

Section 7

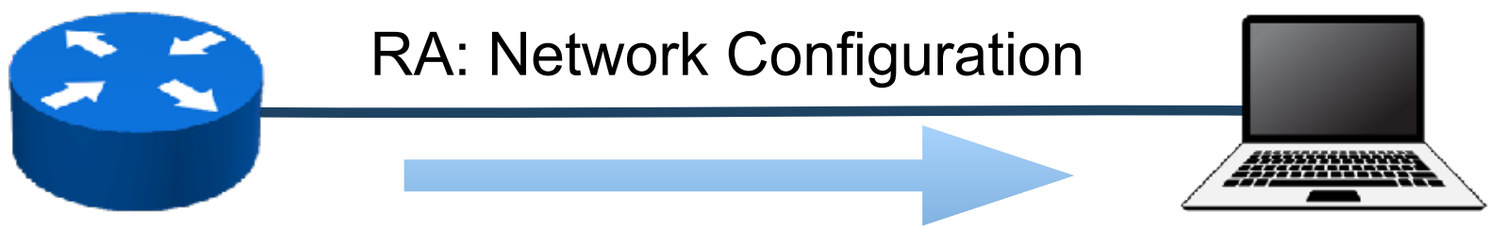
Assigning Addresses

- **Routers influence how hosts connect to network**
- Several options:
  - Manual configuration
  - Router Advertisement only (SLAAC)
  - RA + DHCPv6 (‘M’ flag on)
  - RA + DHCPv6 (‘O’ flag on)
  - RA (‘A’ flag off) + DHCPv6 (‘M’ flag on)

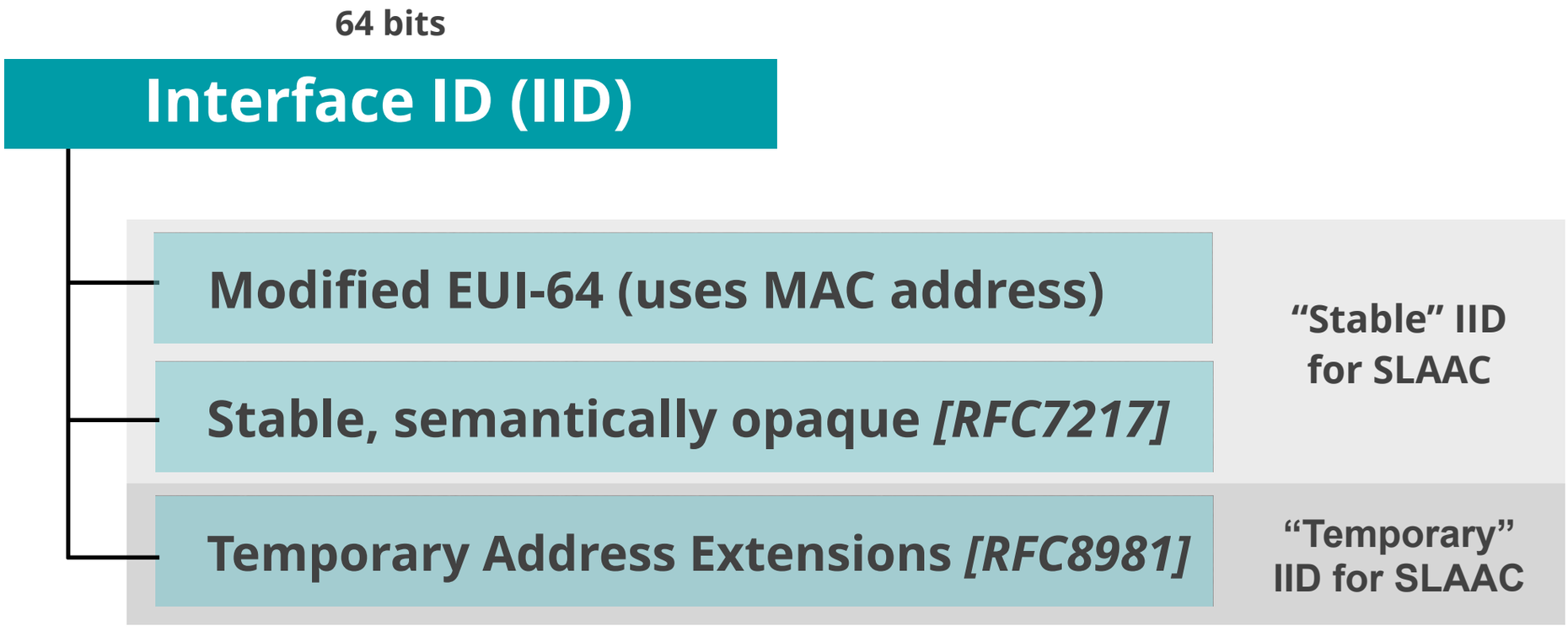
- **Gateway is always provided by the RA**

Router Advertisement Options

- **RA message** is used to provide configuration info
  - Default gateway address
  - Which prefix(es) to use on the link? Prefix length?
  - Is SLAAC allowed?
  - Is DHCPv6 available? For address/options? Only options?
  - What is the preference of a router on the link?
  - DNS servers / Domain (optional)
  - MTU size (optional)



SLAAC IID Generation Options



Stable, Semantically Opaque IID

- Consider IID bits "**opaque**", no value or meaning *[RFC7136]*

How to generate IIDs *[RFC7217]*
Different for each interface in the same network prefix
Not related to any fixed interface identifier
Always the same when same interface connected to same network

- Widely used and standardised for "**stable**" addresses *[RFC8064]*

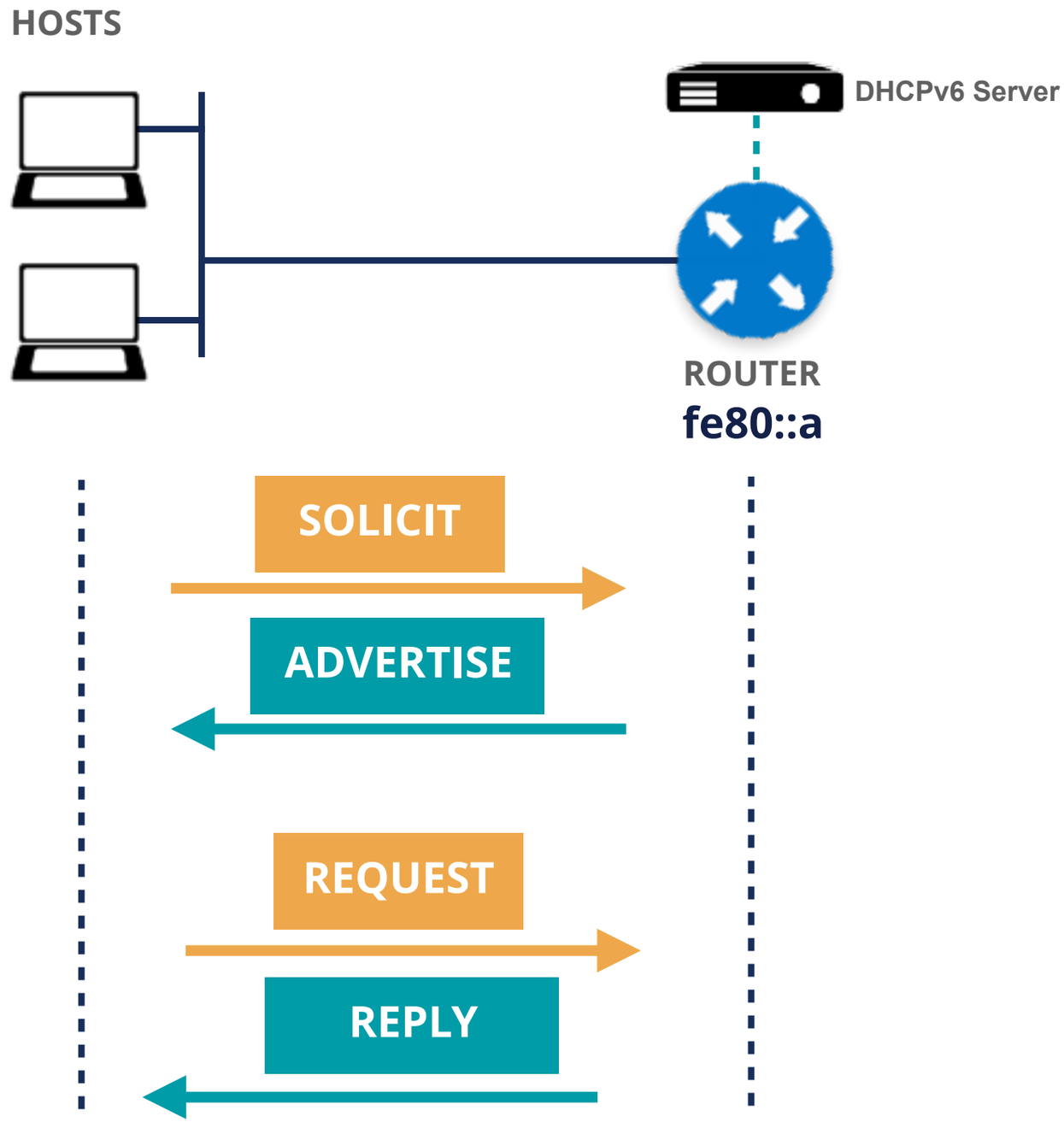
DHCPv6

- Used to give additional information like DNS servers or to manage the address pool

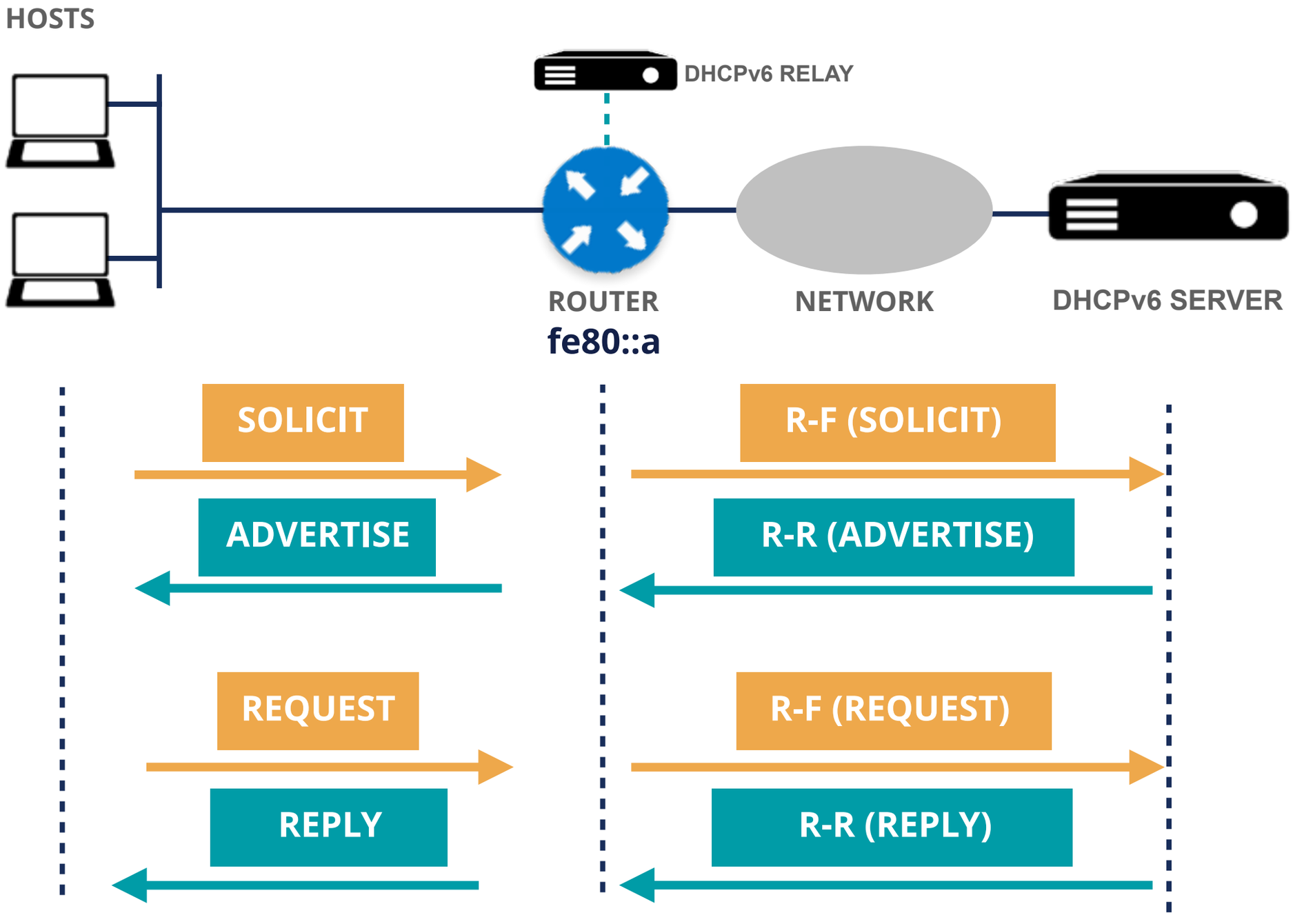
- Router Advertisement message contains hints
  - If “managed” flag = ‘1’ ⇒ can use DHCPv6 to get an address
  - Optionally provide the address of a DNS server (RFC 8106)

- Using additional flags, the network admin can disable SLAAC and force DHCPv6

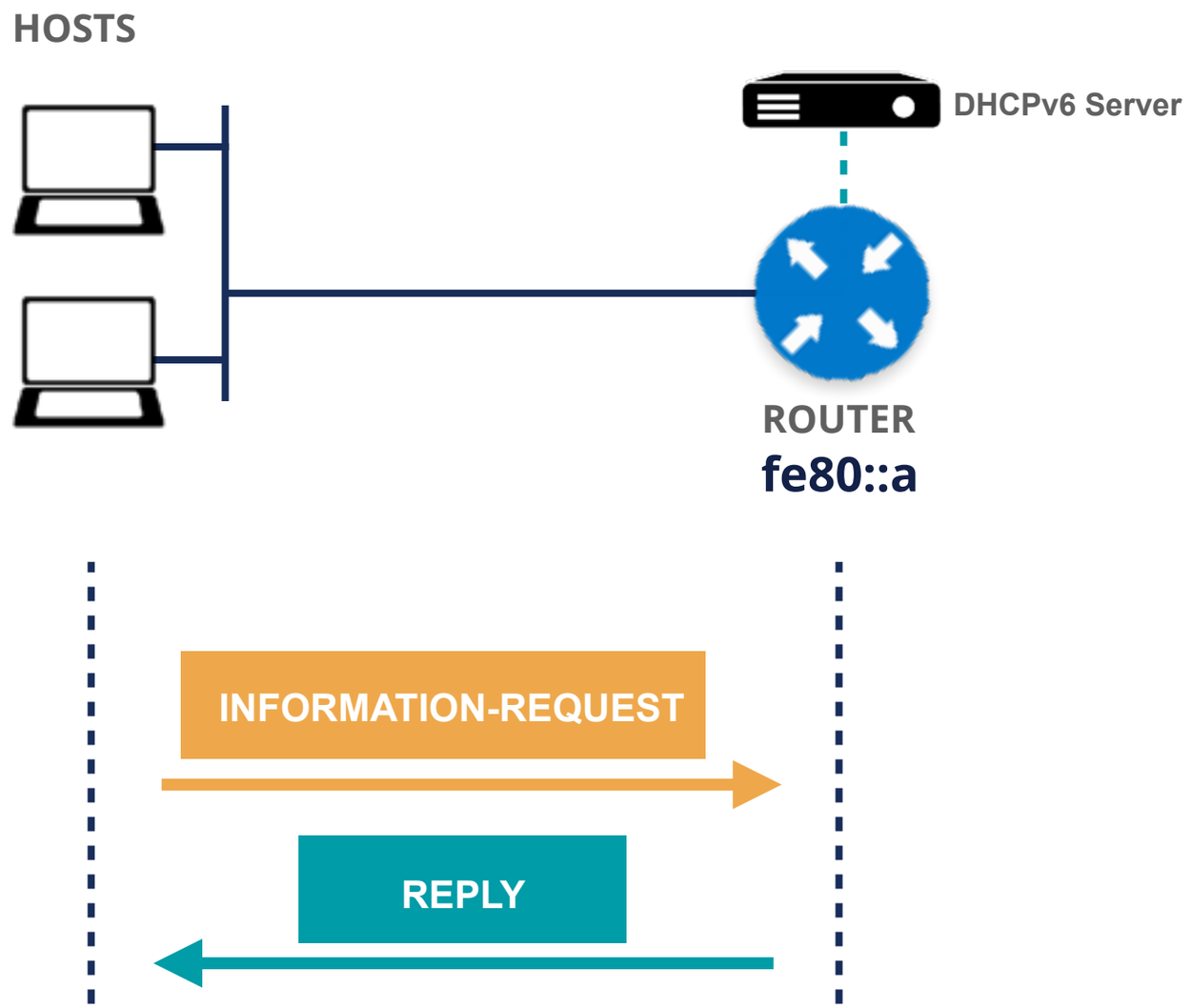
DHCPv6 (M=1)


HOSTS
DHCPv6 Server
ROUTER
fe80::a
SOLICIT
ADVERTISE
REQUEST
REPLY

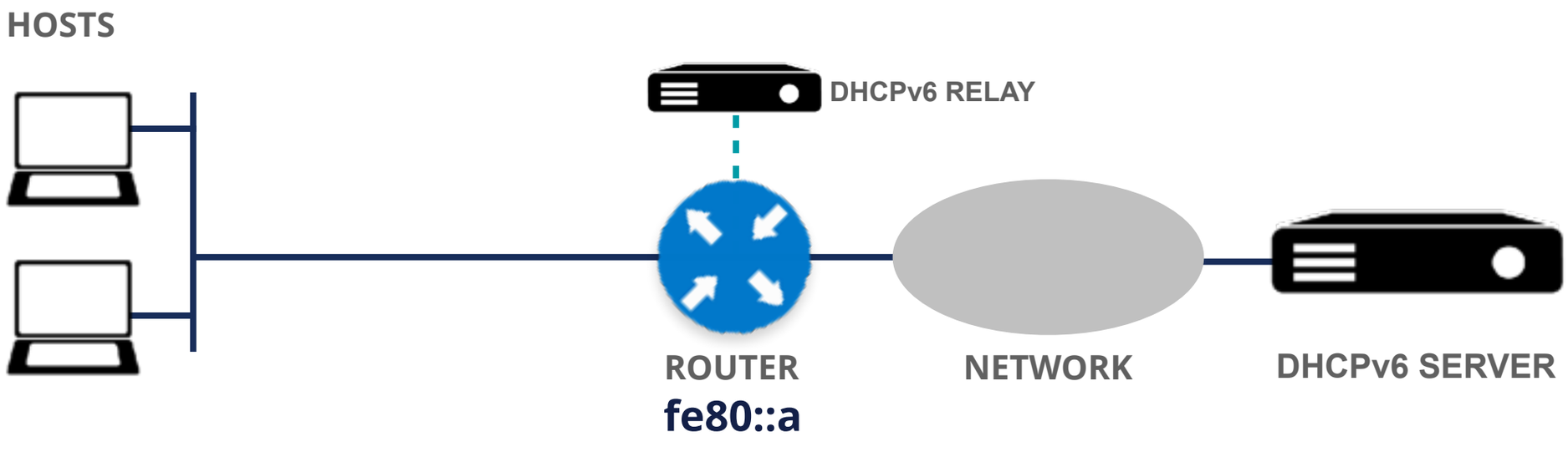
DHCPv6 (M=1)

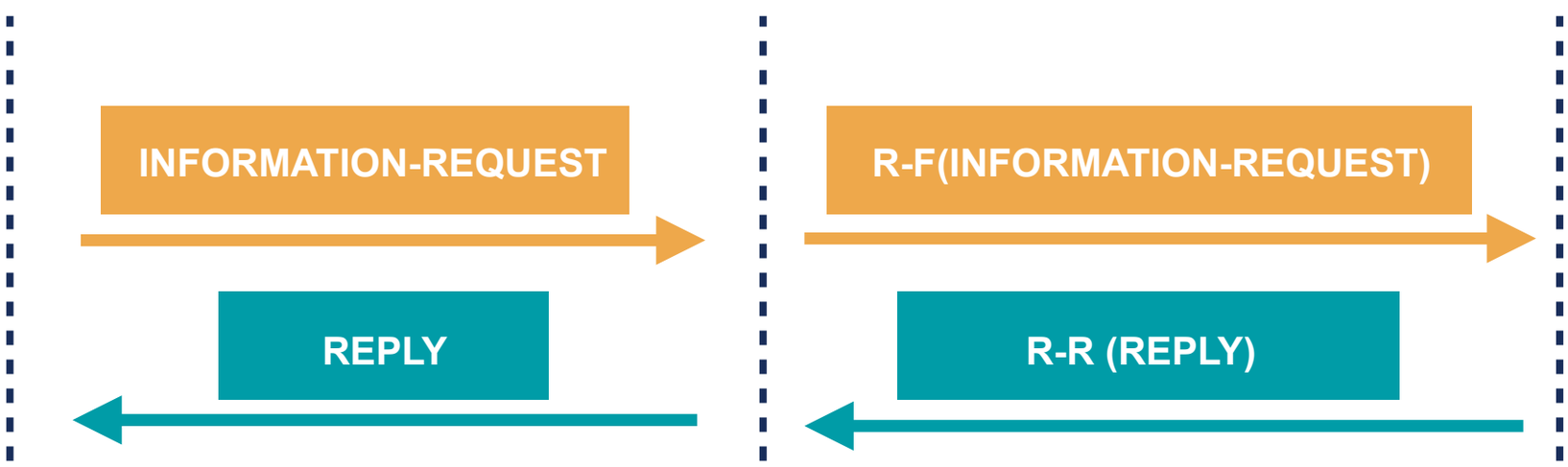

HOSTS
DHCPv6 RELAY
ROUTER
fe80::a
NETWORK
DHCPv6 SERVER
SOLICIT
ADVERTISE
REQUEST
REPLY
R-F (SOLICIT)
R-R (ADVERTISE)
R-F (REQUEST)
R-R (REPLY)

DHCPv6 (M=0, O=1)


HOSTS
DHCPv6 Server
ROUTER
fe80::a
INFORMATION-REQUEST
REPLY

DHCPv6 (M=0, O=1)


HOSTS
DHCPv6 RELAY
ROUTER
fe80::a
NETWORK
DHCPv6 SERVER


INFORMATION-REQUEST
REPLY
R-F(INFORMATION-REQUEST)
R-R (REPLY)

MLD

- **Multicast Listener Discovery** (MLD) is an important component of IPv6

- IPv6 routers use MLD to discover multicast listeners on a directly attached link, similar to IGMP in IPv4

- MLD is embedded in ICMPv6. Two versions exist:
  - MLDv1 similar to IGMPv2
  - MLDv2 similar to IGMPv3

MLD

- 3 types of messages: **Query**, **Report**, **Done**

MLD	IGMP	Message Type	ICMPv6 Type	Function
MLDv1 (RFC2710)	IGMPv2	Listener Query	130	Discover multicast listeners
		Listener Report	131	Response to a Query, joins a group
		Listener Done	132	Node reports that it has stopped listening
MLDv2 (RFC3810)	IGMPv3	Listener Query	130	Discover multicast listeners
		Listener Report	143	Current multicast listening state, or changes

DNS in IPv6 is difficult?

- **DNS** is not IP layer dependent
- **A** record for **IPv4**
- **AAAA** record for **IPv6**

- Don't answer based on incoming protocol
- Only challenges are for translations
  - NAT64, proxies

Reverse DNS

2001:db8:3e:ef11::c100:4d

Reverse DNS

2001:0db8:003e:ef11:0000:0000:c100:004d

. . . . . .ip6.arpa.

d.4.0.0.0.0.1.c.0.0.0.0.0.0.0.0.0.1.1.f.e.e.3.0.0.8.b.
d.0.1.0.0.2.ip6.arpa. PTR
yourname.domain.tld.

d.4.0.0.0.0.1.c.0.0.0.0.0.0.0.0.0.1.1.f.e.e.3.0.0.8.b.d.0.1.0.0.2.ip6.arpa. PTR yourname.domain.tld.

IPv6 and Domain Objects

- IPv6 prefix: 2001:db8::/32
- Domain object:

```
domain:          8.b.d.0.1.0.0.2.ip6.arpa
descr:           rDNS for my whole IPv6 network
admin-c:         NOC12-RIPE
tech-c:          NOC12-RIPE
zone-c:          NOC12-RIPE
nserver:         pri.example.net
nserver:         sns.company.org
ds-rdata:        45062 8 2 275d9acbf3d3fec11b6d6…
mnt-by:          EXAMPLE-LIR—MNT
created:         2015-01-21T13:52:29Z
last-modified:   2016-02-07T15:09:46Z
source:          RIPE
```

Security Considerations

- Everybody can claim to be a router
  - **Use RA Guard to filter unauthorised RAs**
    - RFC 6105
  - **Secure Neighbour Discovery (SEND)**
    - RFC 3971
  - Neighbour Solicitation/Advertisement spoofing
  - DoS Attack
  - Router Solicitation and Advertisement Attacks

Security Considerations

- **Leaking router advertisements**
  - Cisco enables RA by default
  - Windows, MacOS and others will default accept
  - A machine can easily get IPv6 unnoticed

- **Big threat today in IPv6 is human error**
  - lack of knowledge / training
  - typos
  - Maintaining two IP protocols

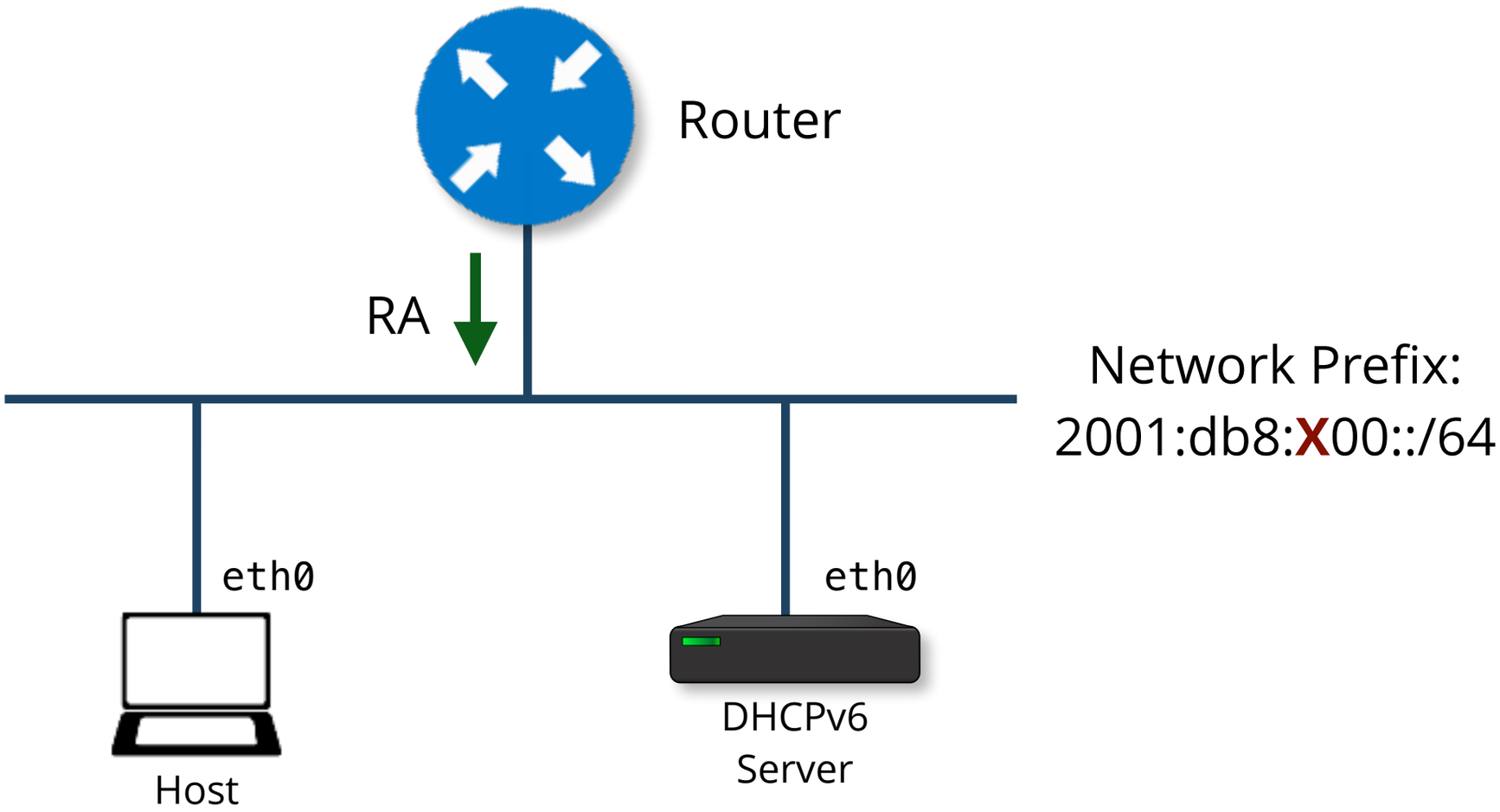
Configuring IPv6

Exercise

Assigning Addresses

- **Router** will send the Router Advertisements
- **Host** will get IPv6 configuration info in four ways:
  - RA + SLAAC only
  - RA + SLAAC + RDNSS option for DNS servers
  - RA + SLAAC + ‘O’ flag (DHCPv6 Other Configuration)
  - RA + **no SLAAC** + ‘M’ flag (DHCPv6 Managed)
- The DHCPv6 server is already configured

Network Diagram



Exercise: IPv6 Host Configuration

- Make sure you have connectivity
- Go to: https://workbench.ripe.net
- Choose the lab (ask the trainers)
- Your login is your assigned number
- The trainers will provide the password

- Choose “**IPv6 Fundamentals**” from the menu

Host: Check the Configuration

- Verify that the **Host** has **no IPv6 address or DNS servers configured**

```
ip addr
```

```
ip -6 route
```

```
cat /etc/resolv.conf
```

Router : Enable RAs

- Enable the **RA** messages on eth0

```
router# configure
```

```
router(config)# interface eth0
```

```
router(config-if)# no ipv6 nd suppress-ra
```

```
router(config-if)# end
```

Host: Check the Configuration

- Verify that the **Host** now has an **IPv6 address**
- But still **no DNS servers**

```
ip addr
```

```
ip -6 route
```

```
cat /etc/resolv.conf
```

Router : Provide DNS via RDNSS

- Configure **RDNSS** and restart RA messages

```
router# configure
```

```
router(config)# interface eth0
```

```
router(config-if)# ipv6 nd rdnss 2001:db8::53
```

```
router(config-if)# ipv6 nd suppress-ra
```

```
router(config-if)# no ipv6 nd suppress-ra
```

```
router(config-if)# end
```

Host: Check the Configuration

- Verify that the **Host** now has a **DNS server**

```
cat /etc/resolv.conf
```

Router : Provide DNS via DHCPv6

- Enable the **O-flag** and restart RA messages

```
router# configure
```

```
router(config)# interface eth0
```

```
router(config-if)# ipv6 nd other-config-flag
```

```
router(config-if)# ipv6 nd suppress-ra
```

```
router(config-if)# no ipv6 nd suppress-ra
```

```
router(config-if)# end
```

Host: Check the Configuration

- Verify that the **Host** now has <u>two</u> **DNS servers**

```
cat /etc/resolv.conf
```

Router : Everything via DHCPv6

- Enable **M-flag** and disable **A-flag** (no-autoconfig)

```
router# configure
```

```
router(config)# interface eth0
```

```
router(config-if)# ipv6 nd managed-config-flag
```

```
# ipv6 nd prefix 2001:db8:X00::/64 no-autoconfig
```

```
router(config-if)# no ipv6 nd rdnss 2001:db8::53
```

```
router(config-if)# ipv6 nd suppress-ra
```

```
router(config-if)# no ipv6 nd suppress-ra
```

```
router(config-if)# end
```

Host: Restart Network Manager

- We restart the network manager on Host to pick up new configuration faster

```
dhcpcd -k
```

Host: Check the Configuration

- Verify that the **Host** has **an IPv6 address and DNS servers configured**

```
ip addr
```

```
ip -6 route
```

```
cat /etc/resolv.conf
```

Questions

Real Life IPv6 Deployment

Section 8

Colocation Provider

- 30 staff
- Routing
  - Dual Stack!
  - Possible IGP combinations were:
    - OSPFv2 for IPv4, IS-IS for IPv6 (only)
    - OSPFv2 for IPv4, OSPFv3 for IPv6
    - IS-IS for IPv4, OSPFv3 for IPv6
    - IS-IS for both IPv4 and IPv6 (**their solution**)

- Check internal routing before going external!

Colocation Provider

- Checklist
  - set access lists on network equipment
  - set up monitoring (SNMP)
  - have working DNS
- Subnetting tools
  - sipcalc, IPv6calc, apps
- Every customer gets a /48 assignment
  - and a /64 for the connection

Colocation Provider

- Points of attention:
  - stateless auto configuration can assign a subnet “unexpectedly”
  - not all firewalls support IPv6
  - be careful with statement “*IPv6 ready*”

ISP xDSL

- 200 staff
- 2 /32 prefixes (due to merger)
  - not enough
  - make a plan before requesting allocation
- /48 per POP
- /56 per router
- /64 per customer vlan

ISP xDSL

- Servers
  - no EUI-64
  - no autoconfig
  - port number for services (i.e. POP3 at ::110)
  - default gateway manually set to, for example:
    - 2001:db8::1/64 *(usually)*

ISP xDSL

- Network links (point-to-point)
  - core
    - /64 per link
    - ::1 - ::2
    - no auto configuration
    - easy to remember
- You don’t want your router link at:
  - 2001:db8:cf9d:7631:cd01:fe55:4532:ae60/64
- You want your router link at:
  - 2001:db8:1:1::/64

Large Enterprise

- Approx. 550 IT staff
- Several locations worldwide
- Most of their business processes rely heavily on the Internet
- Driven to IPv6 by need to continue doing business as usual

Large Enterprise

- Make an inventory of IT needs
  - Hardware / Software / Services
  - Talk to your ISPs early during preparation
- Evaluate the current IPv6 offerings
  - Don’t trust your vendor on “full IPv6 support”
  - Basic network functions are not the issue
  - Check cloud solutions
- Train your IT staff
  - Make them understand the WHY of IPv6
  - Focus on the people responsible for applications

Large Enterprise

- Build a testlab (and start testing!)
- Make an IPv6 Roadmap
  - Dedicated IT group approves roadmap and tracks status
  - “IPv6 Readiness” required for all new purchases
  - Plan replacement of solutions that don’t do IPv6
  - Point out the risks of apps not doing IPv6
- Phased Approach to Deployment
  - Phase 1: dual stack all external facing services
  - Phase 2: datacenter and internal network

Tips

Section 9

How to get started

- Change purchasing procedure (feature parity)
- Check your current hardware and software
- Plan every step and test
- One service at a time
  - face first
  - core
  - customers
- Create a lessons learned document
- Update your marketing team promptly and appropriately

RIPE-772 Document

- “Requirements for IPv6 in ICT Equipment”
  - Best Current Practice describing what to ask for when requesting IPv6 Support
  - Useful for tenders and RFPs
  - Original version was ripe-554
  - Ripe-554 Originated by the Slovenian Government
  - Adopted by various others (Germany, Sweden)

Link to the document:

https://www.ripe.net/publications/docs/ripe-772

Troubleshooting for ISP Helpdesks

- Most ISP connectivity problems are not IPv6 related
- Helpdesks can get confused!
  - IPv6 is new for them
  - They don’t have experience with IPv6 issues

- A generic troubleshooting guide can help!
- Based on the open source testipv6.com tool
- Customisable

https://www.ripe.net/ripe/docs/ripe-631

Customers And Their /48

- Customers have no idea how to handle **65,536 subnets**!
- Provide them with information!

Link to the document:

https://www.ripe.net/support/training/material/basicipv6-addressing-plan-howto.pdf

Also useful

- Websites
  - http://www.getipv6.info
  - http://www.ipv6actnow.org
  - http://datatracker.ietf.org/wg/v6ops/
  - https://www.ripe.net/publications/docs/ripe-772
- Mailing lists
  - http://lists.cluenet.de/mailman/listinfo/ipv6-ops
  - http://www.ripe.net/mailman/listinfo/ipv6-wg

Don'ts

- Don't separate IPv6 features from IPv4
- Don't do everything in one go
- Don't appoint an IPv6 specialist
  - do you have an IPv4 specialist?
- Don't see IPv6 as a product
  - the Internet is the product!

Questions

We want your feedback!

What did you think about this session?

Take our survey at:

https://www.ripe.net/s/feedback/v6fun/

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Ende
Koniec
Son
დასასრული
הסוף
Кінець
Finis
Lõpp
Amaia
Tmiem
Loppu
Liðugt
Kpaj
Sfârşit
Slutt
Fund
Kraj
النهاية
Конец
Konec
Τέλος
Fin
Fine
Fí
Край
Einde
Pabaiga
Slut
Fim
Beigas
E1 N1 D2

What's Next in IPv6

Webinars

Attend another webinar live wherever you are.

- Introduction to IPv6 (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)

For more info click the link below

learning.ripe.net

Face-to-face

Meet us at a location near you for a training session delivered in person.

- IPv6 Fundamentals (8.5 hrs)
- Advanced IPv6 (17 hrs)
- IPv6 Security (8.5 hrs)

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