RIPE NCC
RIPE NETWORK COORDINATION CENTRE

Basic IPv6 Course

Training Course

August 2018

Schedule

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

Introductions

- Name
- Number in the list
- Experience with IPv6
- 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

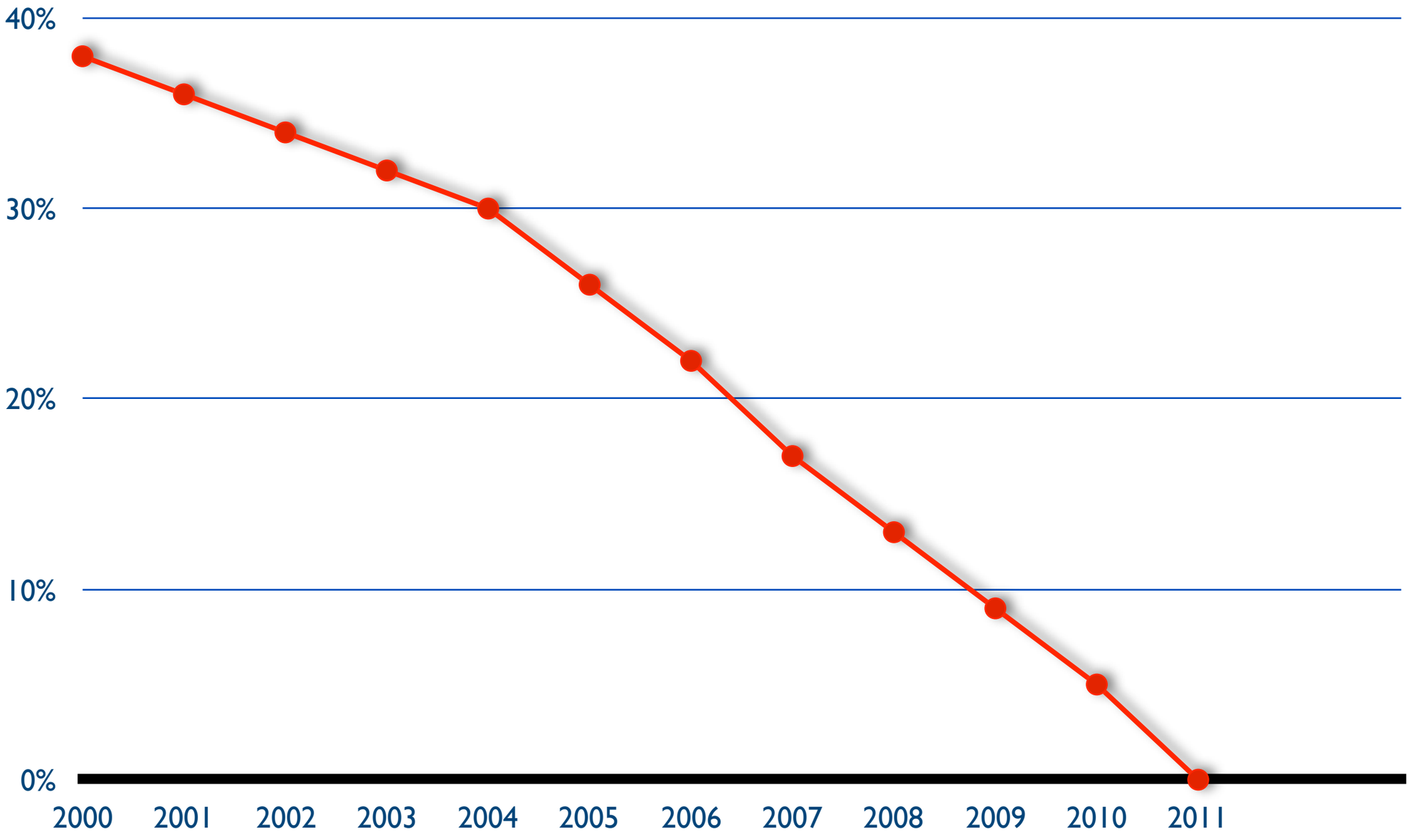
- Around 4,157 billion Internet users now
  - around 54,4 % of all people in the world
- Mobile phones are Internet devices
- The Internet of Things
  - How will the Internet look like in 5 - 10 years?

The Internet of Things

Libelium Smart World

http://www.libelium.com/top_50_iot_sensor_applications_ranking

IANA IPv4 Pool



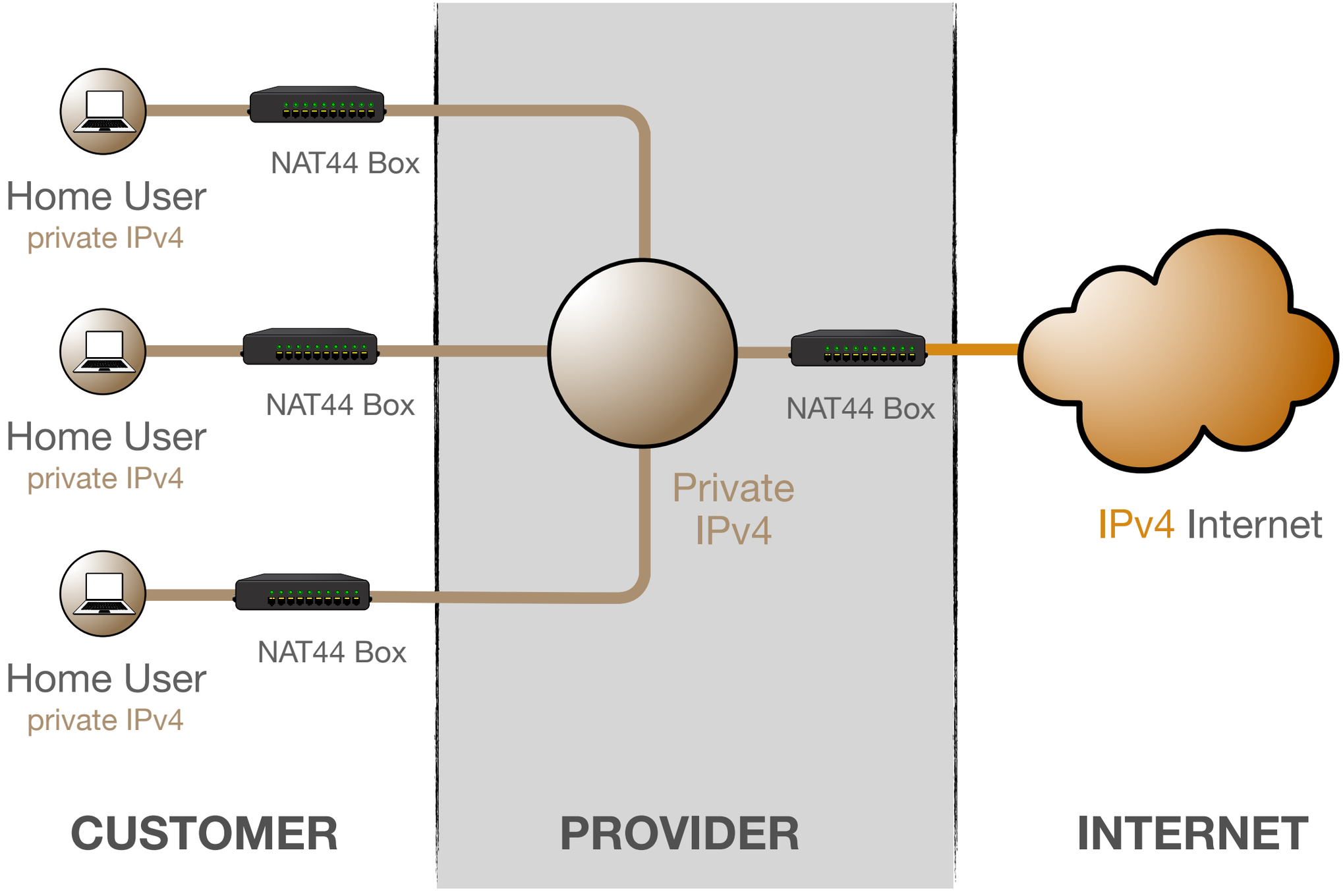
IPv4 Exhaustion

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

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

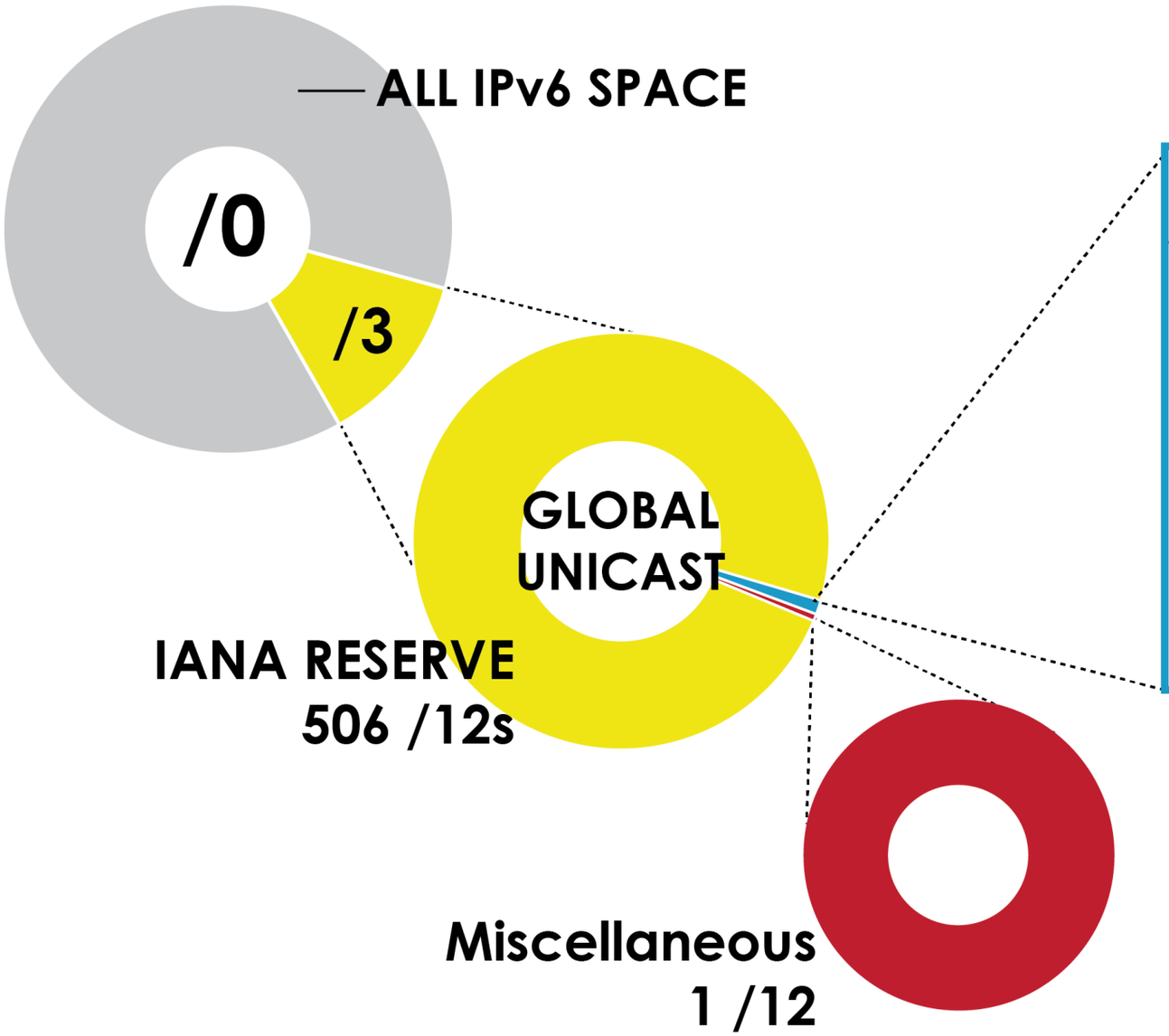
Large Scale NAT



IPv6 Address Basics

Section 2

IP Address Distribution

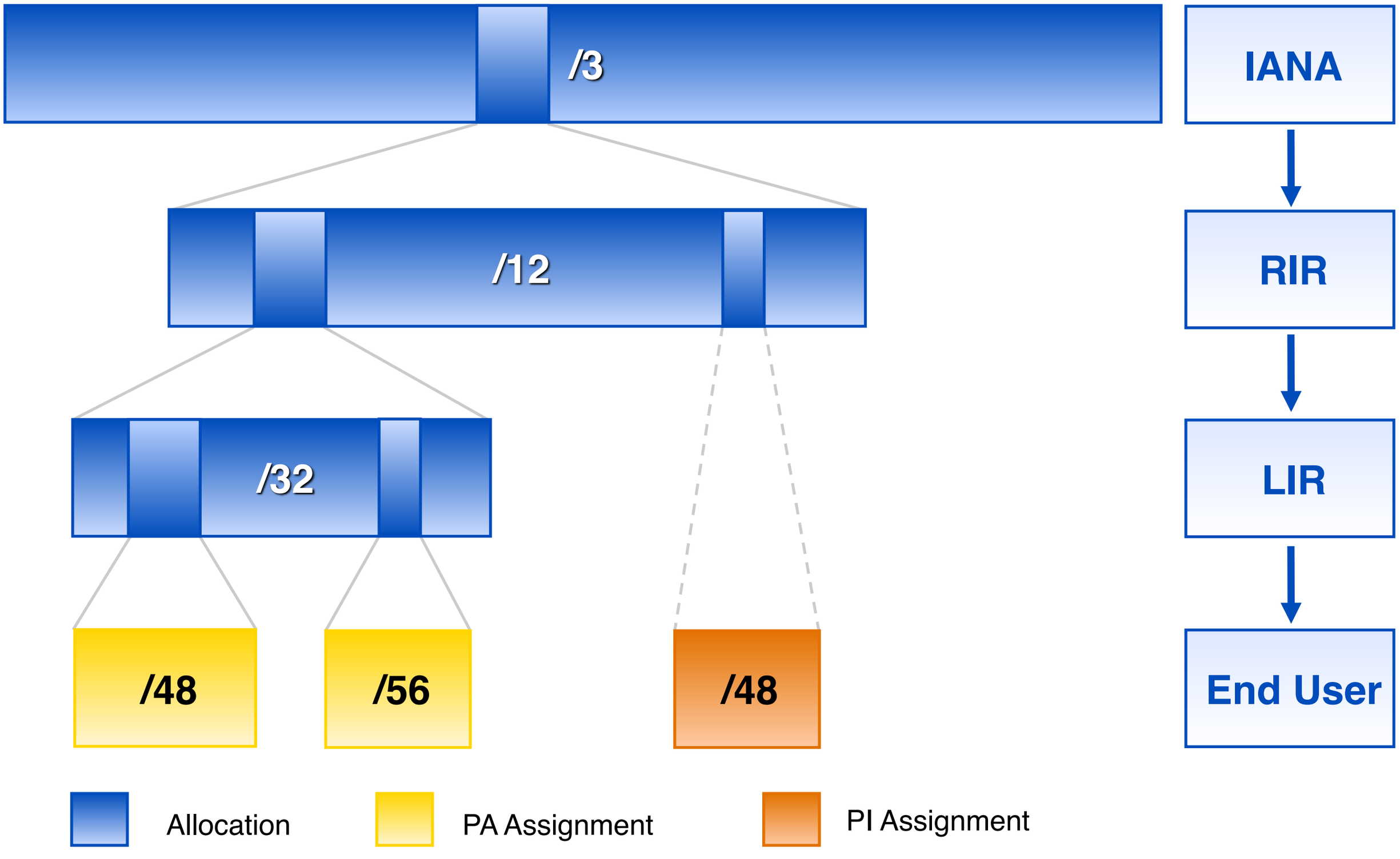


RIRs 5 /12s (October 2006)

RIR	IPv6 ADDRESS
AFRINIC	2C00:0000::/12
APNIC	2400:0000::/12
ARIN	2600:0000::/12
LACNIC	2800:0000::/12
RIPE NCC	2A00:0000::/12

Source: https://www.nro.net/statistics
Number Resource Organisation

IP Address Distribution



IPv6 Address Basics

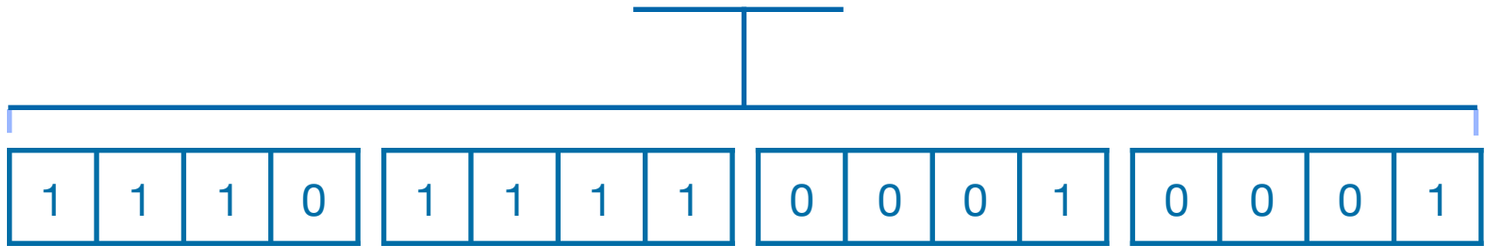
- IPv6 address: 128 bits
  - 32 bits in IPv4
- Every subnet should be a /64
- Customer assignments (sites) between:
  - /64 (1 subnet)
  - /48 (65,536 subnets)
- Minimum allocation size /32
  - 65,536 /48s
  - 16,777,216 /56s

Address Notation

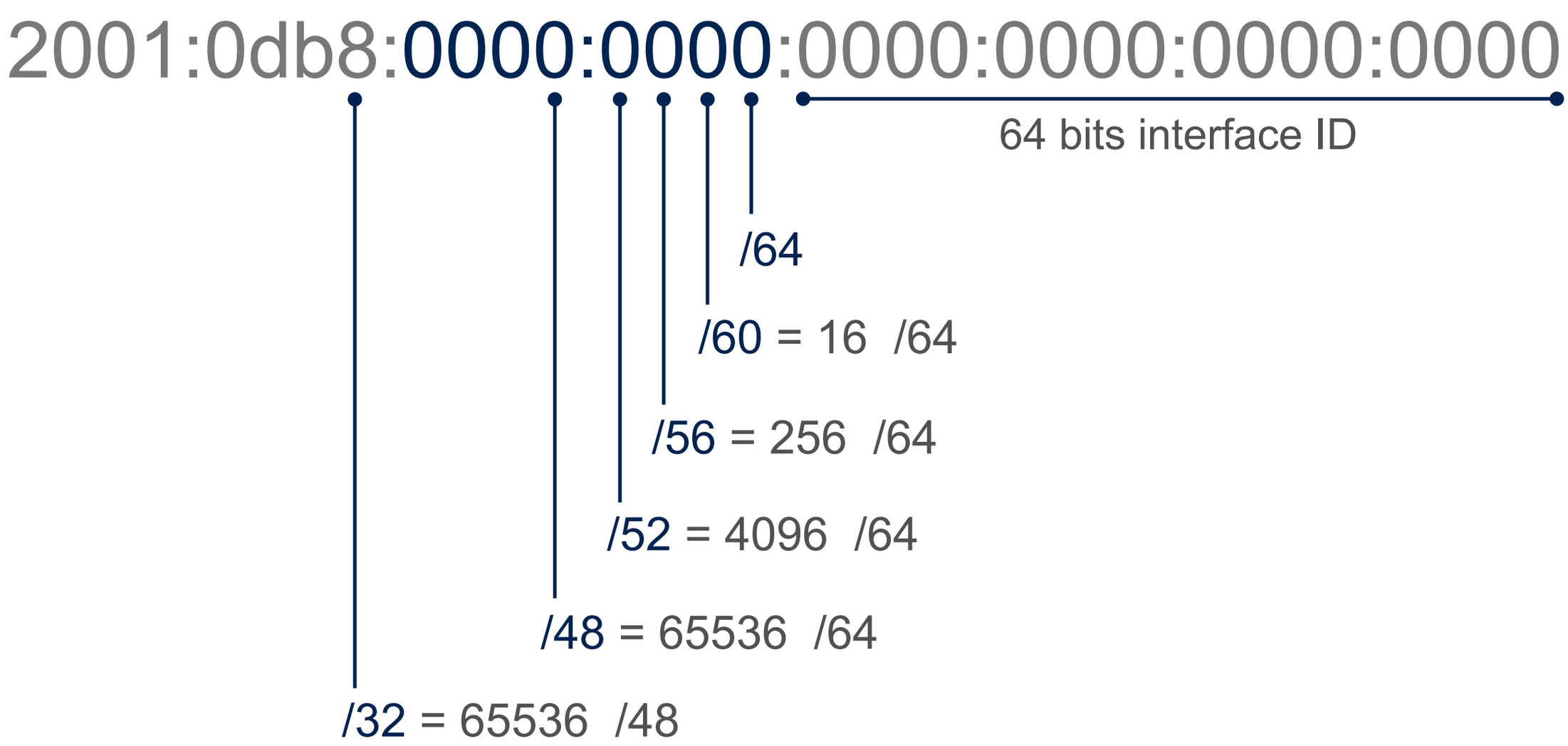
2001:0db8:003e:ef11:0000:0000:c100:004d

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

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



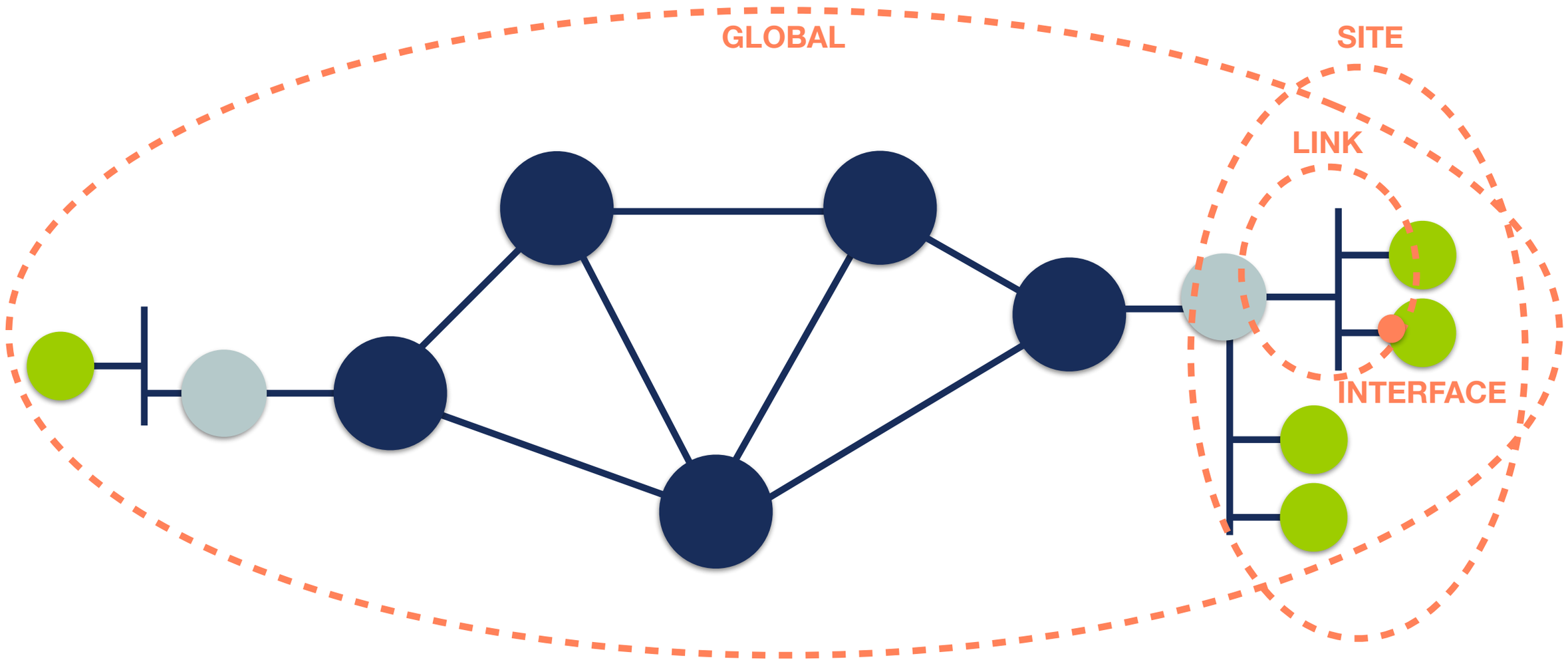
IPv6 Subnetting



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

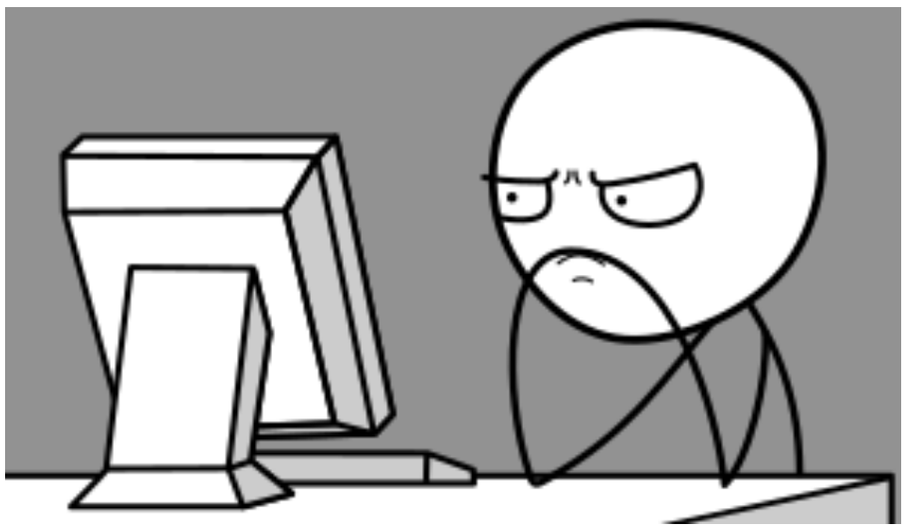
Exercise

IPv6 Notation - RFC 5952

- For more information, please read RFC 5952

  “A Recommendation for IPv6 Address Text Representation”

  http://tools.ietf.org/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
  - Up to /48

- More than /48, send in request form
  - alternatively, make a sub-allocation

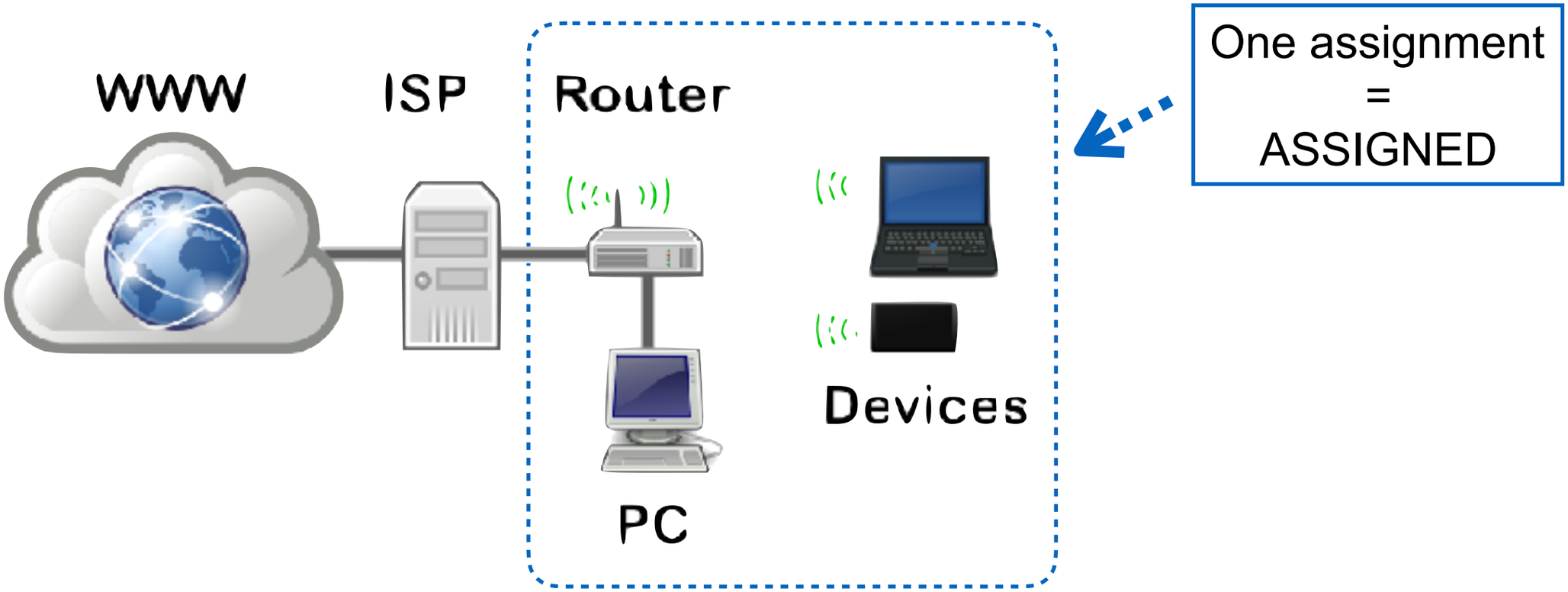
- Every assignment must be registered in the RIPE Database

Comparison IPv4 and IPv6 status

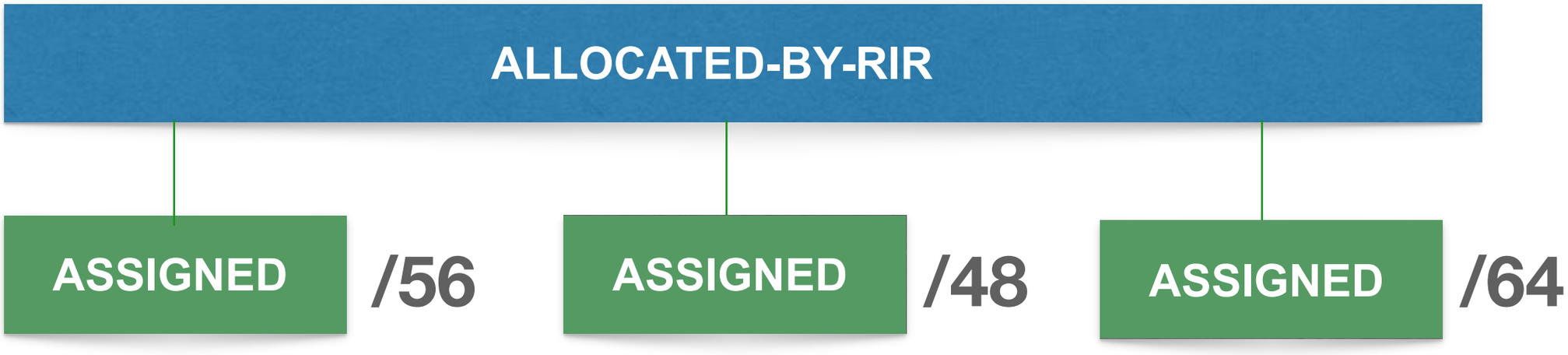
IPv4		IPv6
ALLOCATED PA	Allocation	ALLOCATED-BY-RIR
ASSIGNED PA	Assignment	ASSIGNED
	Group of Assignments	AGGREGATED-BY-LIR
SUB-ALLOCATED PA	Sub-Allocation	ALLOCATED-BY-LIR
ASSIGNED PI	PI Assignment	ASSIGNED PI

Examples ASSIGNED

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



Using ASSIGNED



- Represents one assignment
- Minimum assignment size is a /64
- For more than a /48, send a request form

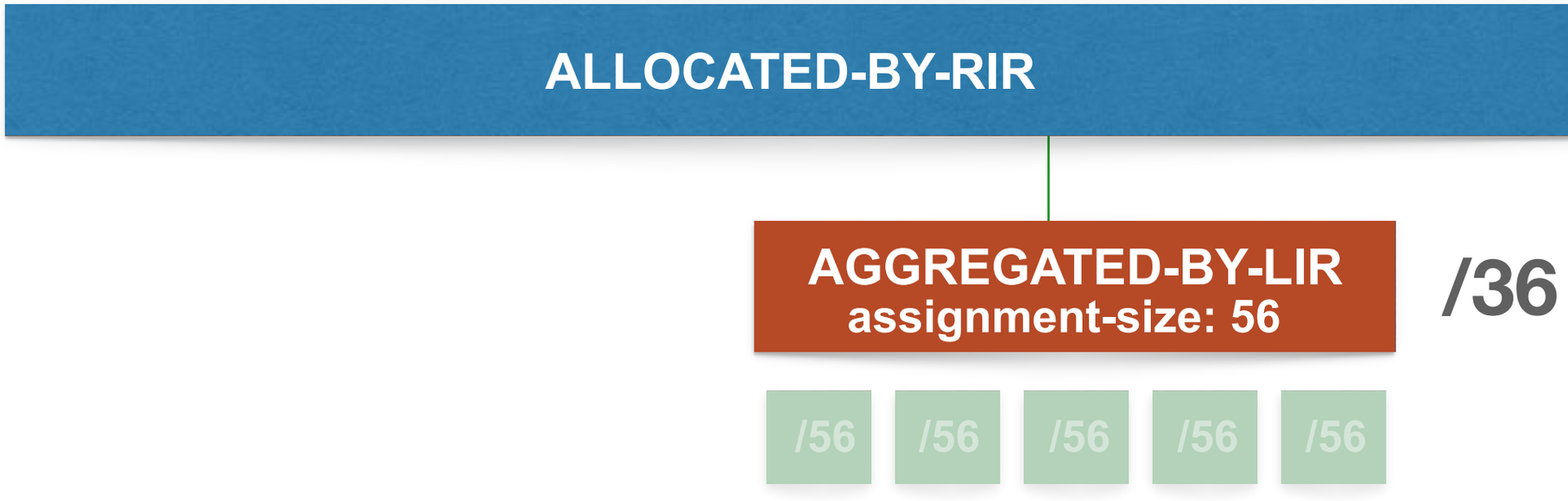
Using ASSIGNED - Example Object

```
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
source:         RIPE
```

Examples AGGREGATED-BY-LIR

- Group of customers
- Same assignment size

Using AGGREGATED-BY-LIR



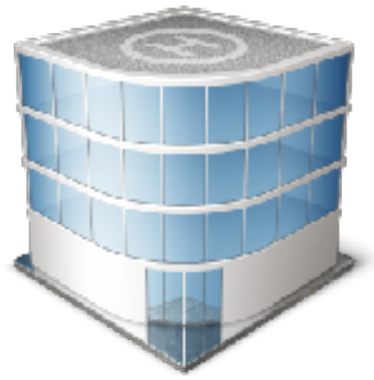
- Can be used to group customers
  - example: residential broadband customers
- “**assignment size:**” = assignment of each customer

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
```

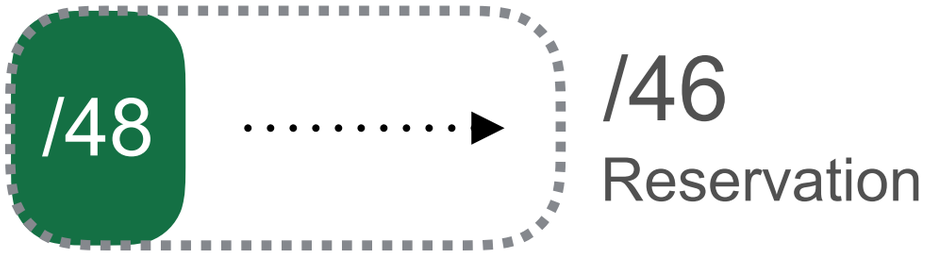
Examples ALLOCATED-BY-LIR

- Reservation for a large customer
- Branch office or department

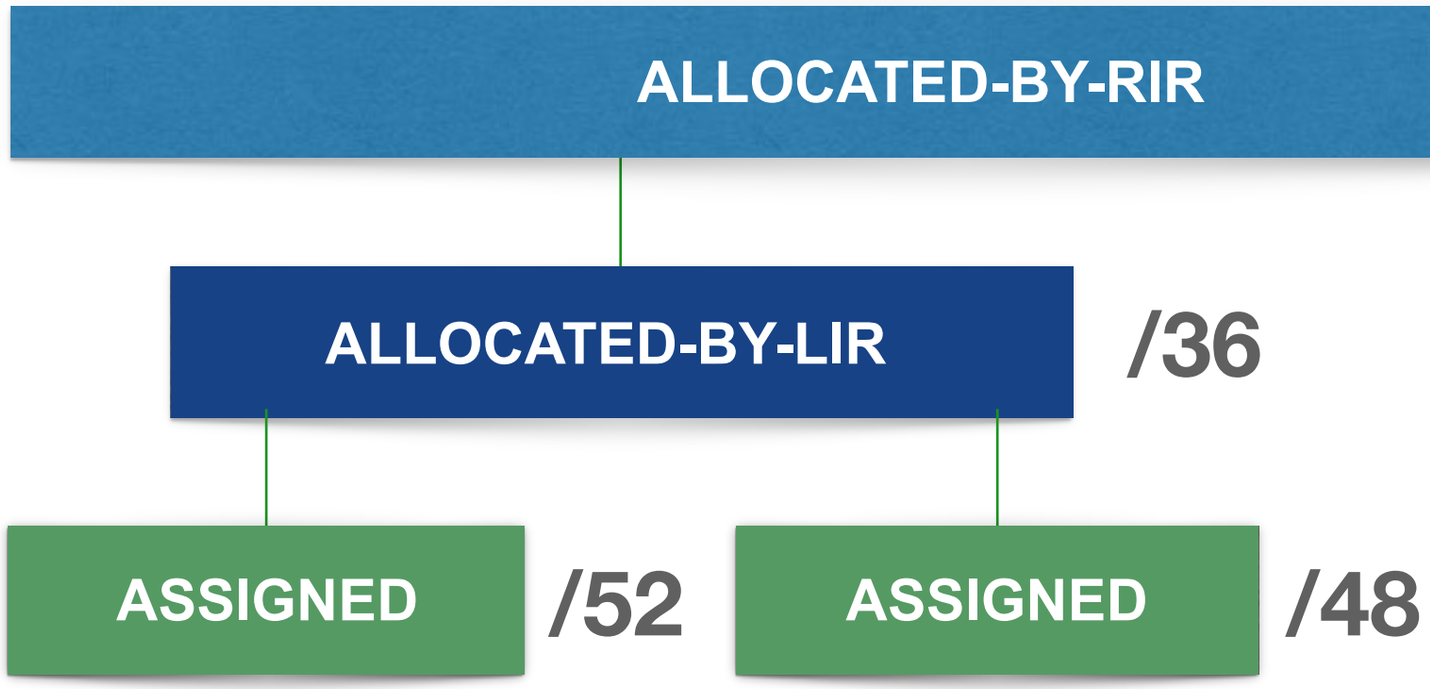


Large Customer

Branch Office



Using ALLOCATED-BY-LIR

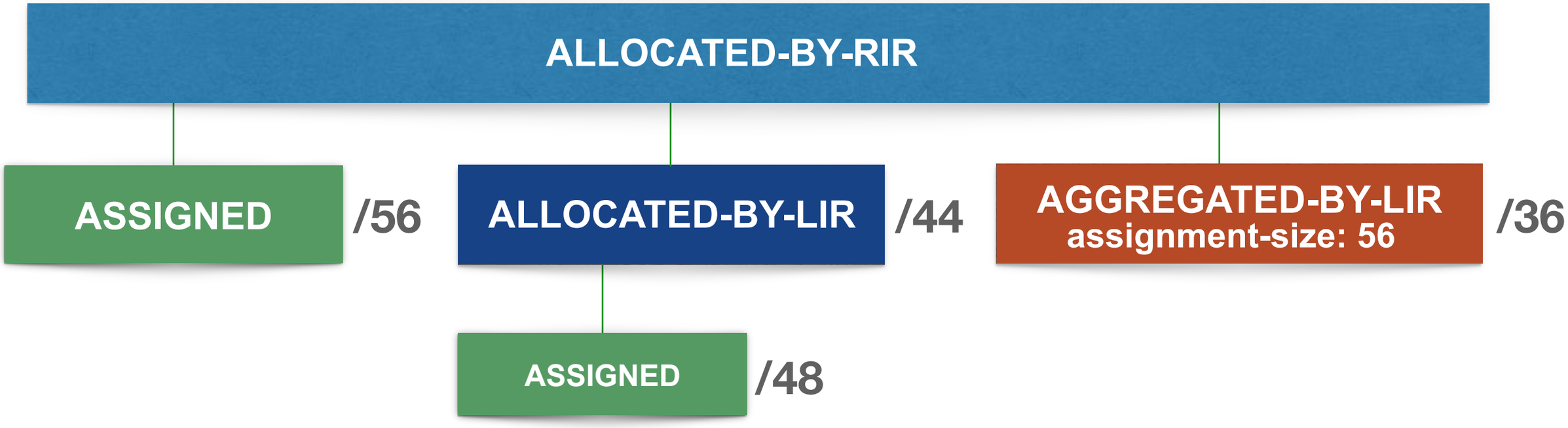


- Can be used for customers with potential for growth
  - or for your own infrastructure
  - or to delegate address space to a downstream ISP

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 can not be used for sub-assignments
  - not even 1 IP address!

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

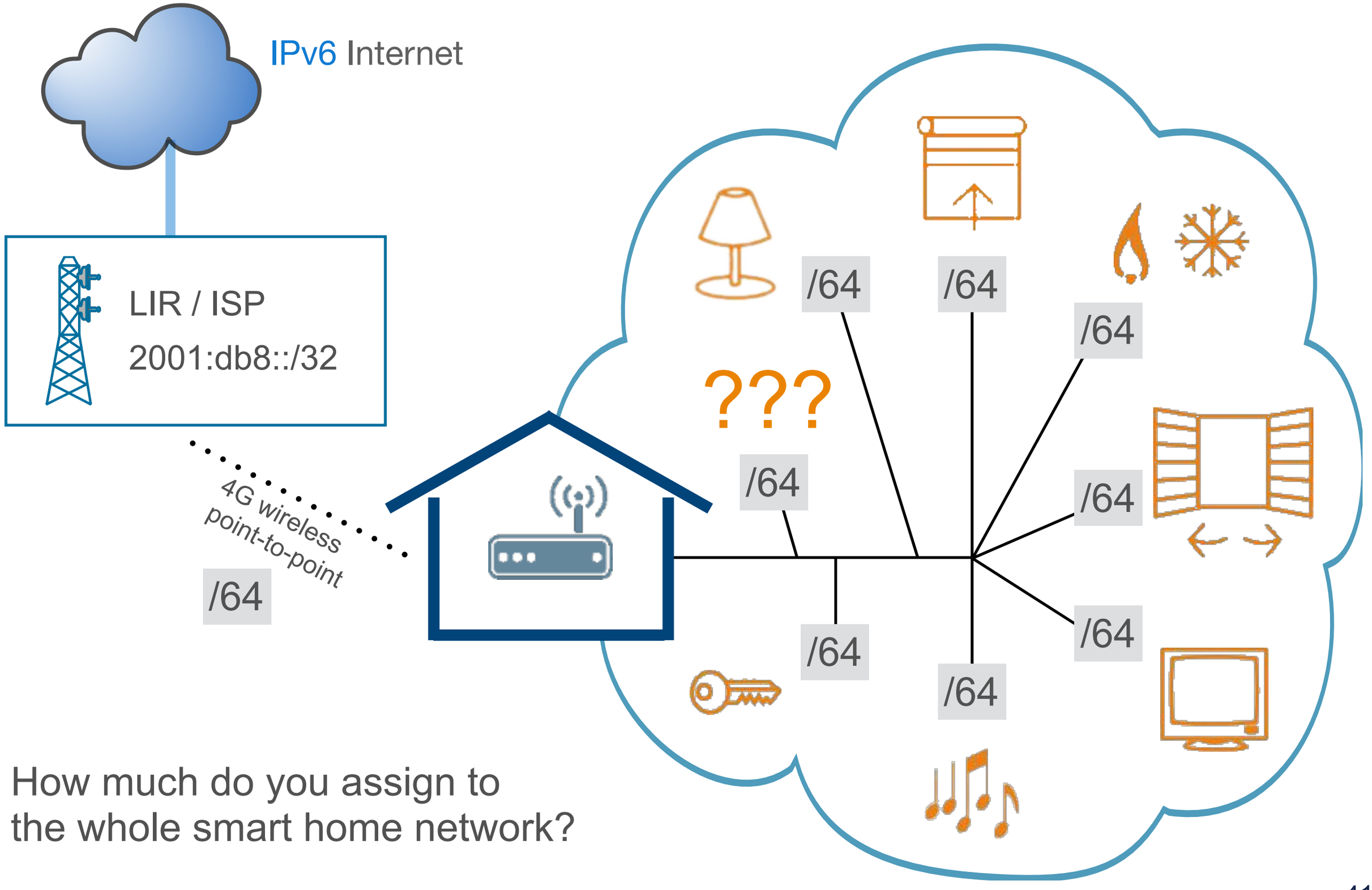
Exercise

Making Assignments Exercise

Smart Home 6!

- 20 minutes preparation time
- 10 minutes discussion

Smart Home 6 Network Diagram



How much do you assign to
the whole smart home network?

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

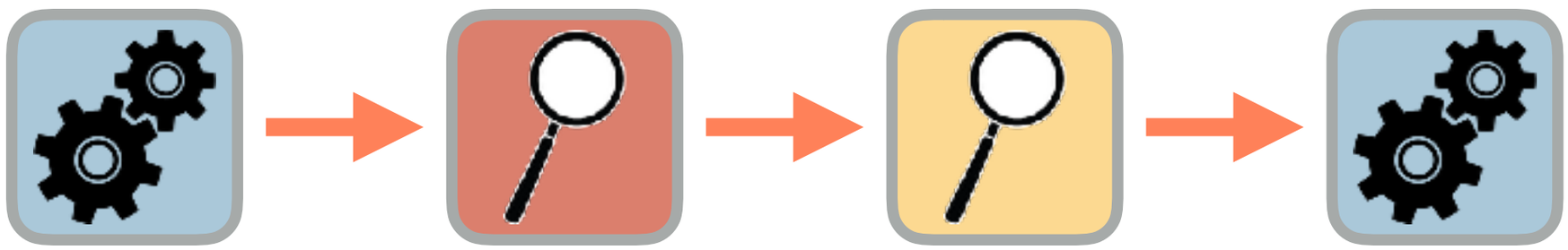
Section 4

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

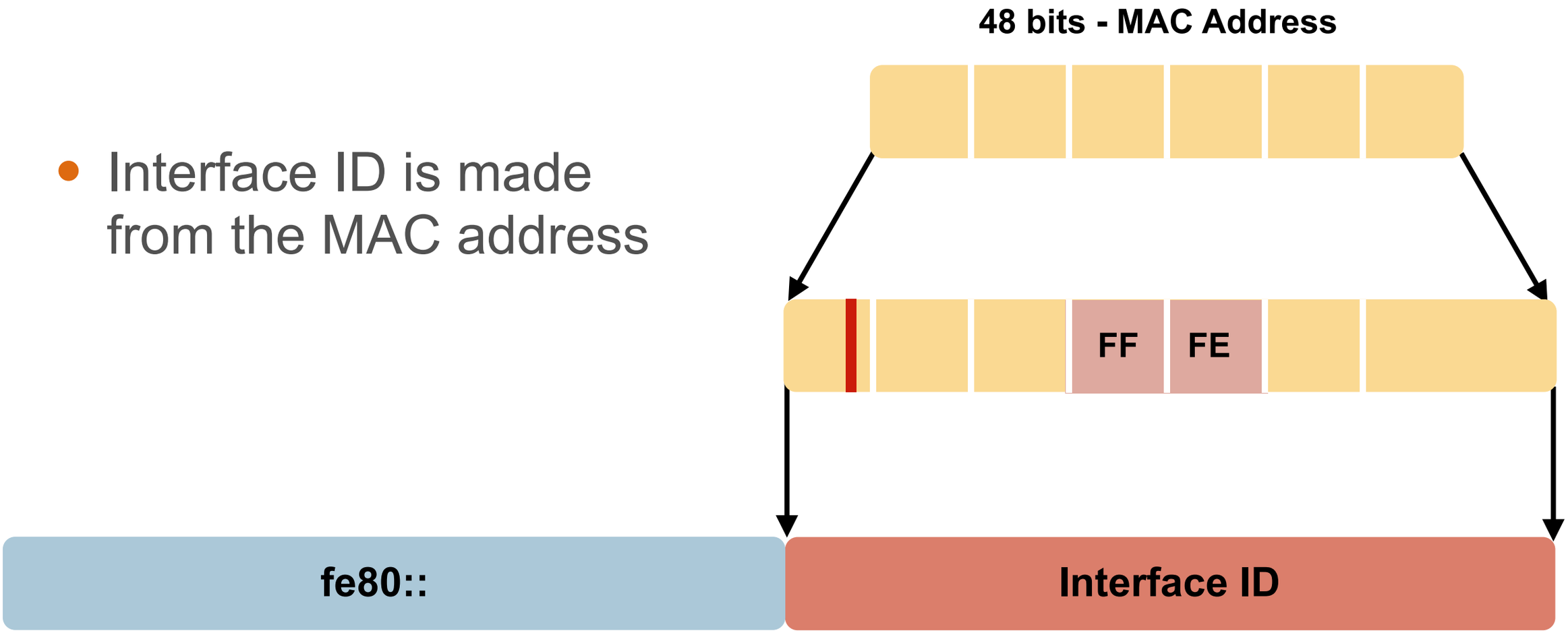
The Autoconfiguration Process

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?

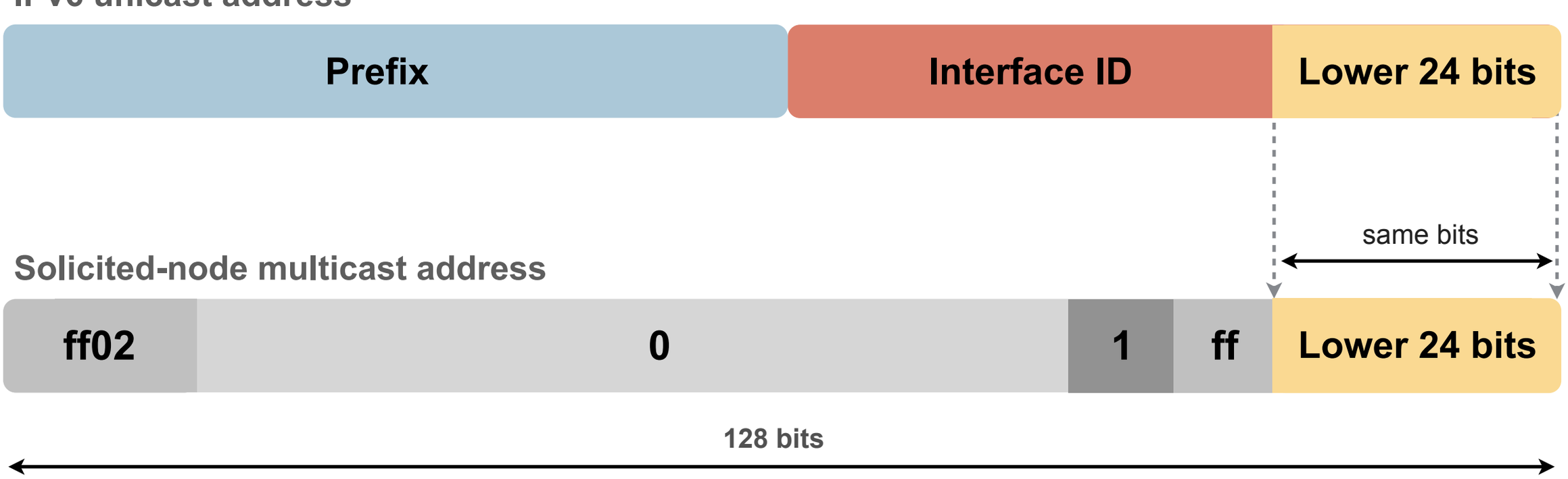
Neighbor Advertisement

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

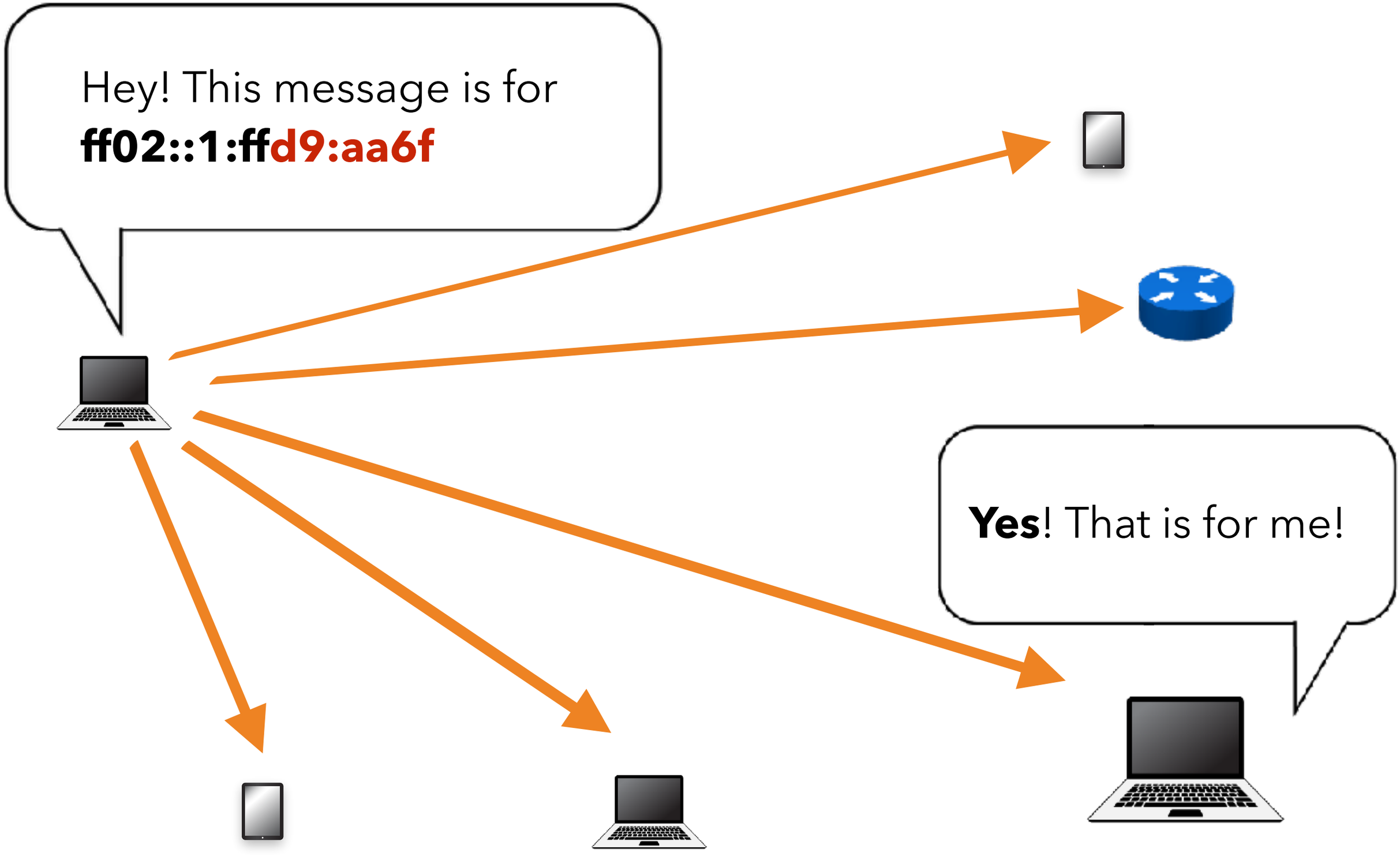
If nobody replies to the Neighbor Solicitation, the host uses the generated link-local address

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 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

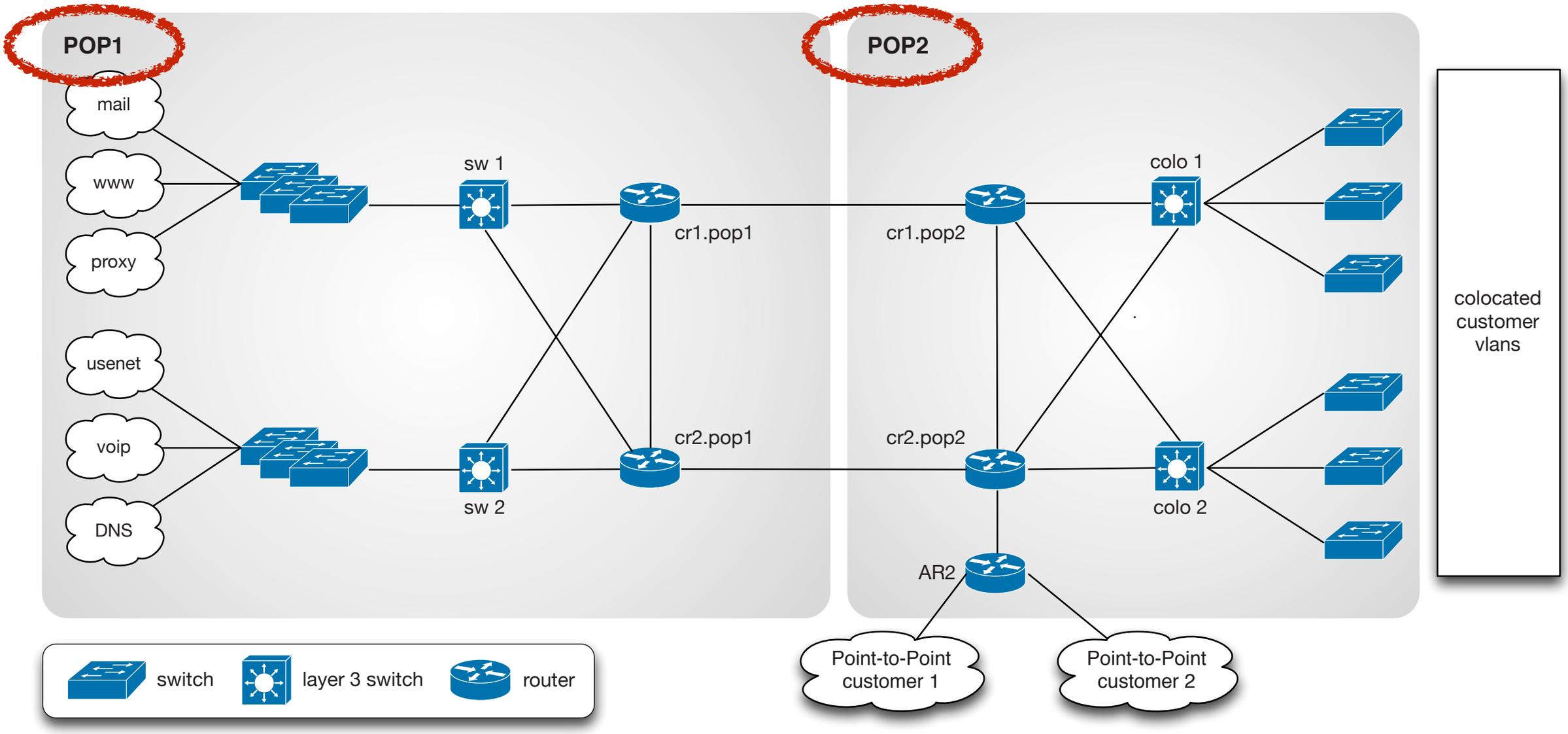
Exercise

Addressing Plan Exercise

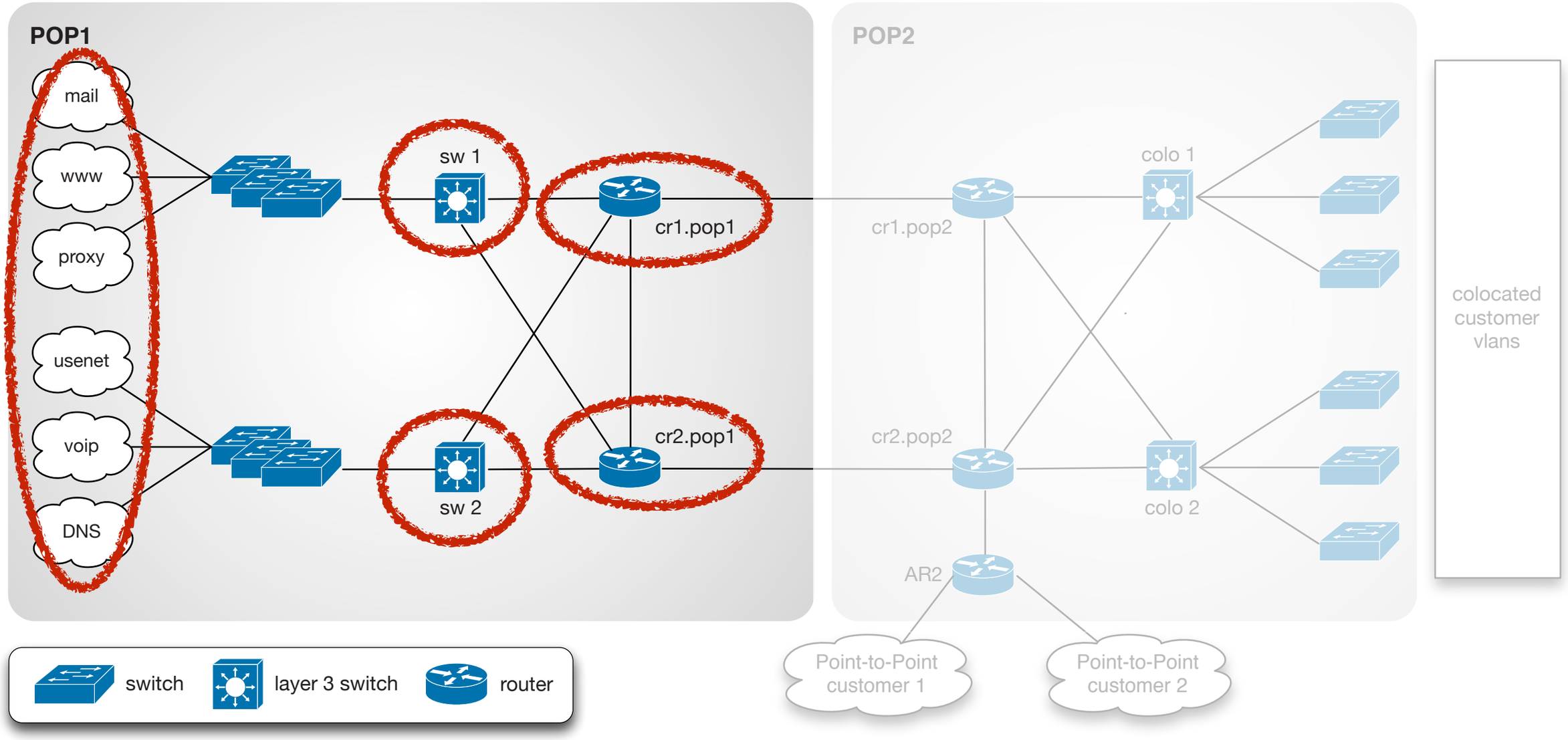
- Things to consider
  - administrative ease!
  - use assignments on 4 bit boundary
  - 2 possible scenarios for network
  - 5 possible scenarios for customer assignments

- 20 minutes preparation time
- 10 minutes discussion

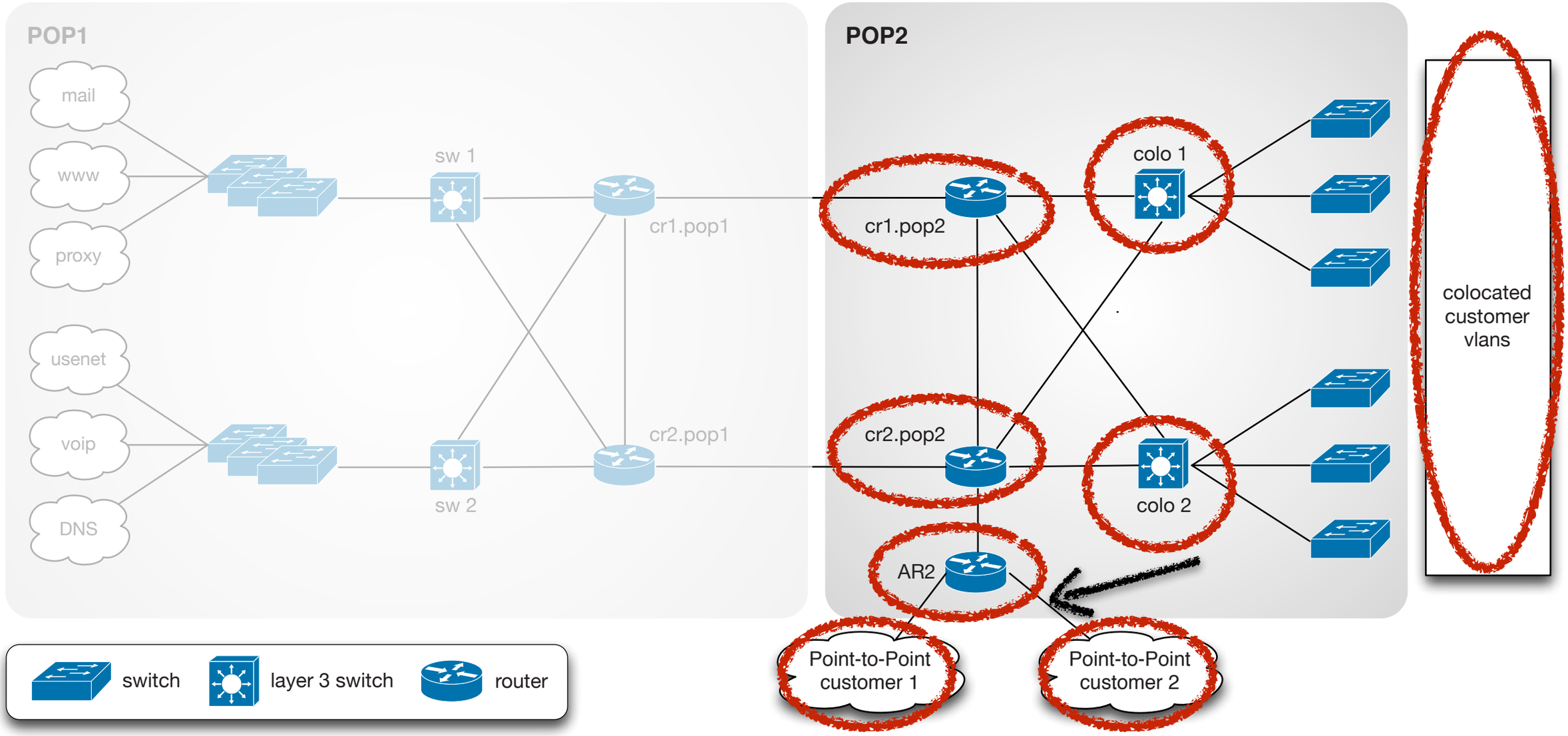
Network Diagram - POPs



Network Diagram - POP1



Network Diagram - 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

More on Addressing Plans

- For private networks, consider ULA
- For servers you want a manual configuration
- Use port numbers for addresses
  - pop server 2001:db8:1::110
  - dns server 2001:db8:1::53
  - etc…

Questions

IPv6 Packets

Section 6

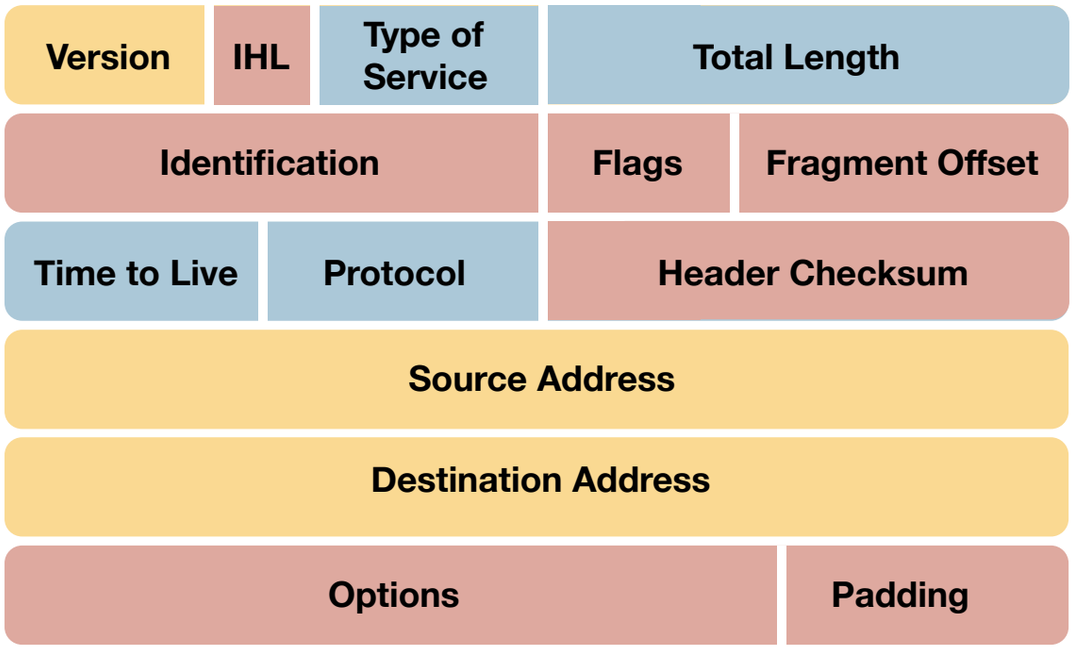
IPv6 Header Format

- Fixed length
  - Optional headers are daisy-chained

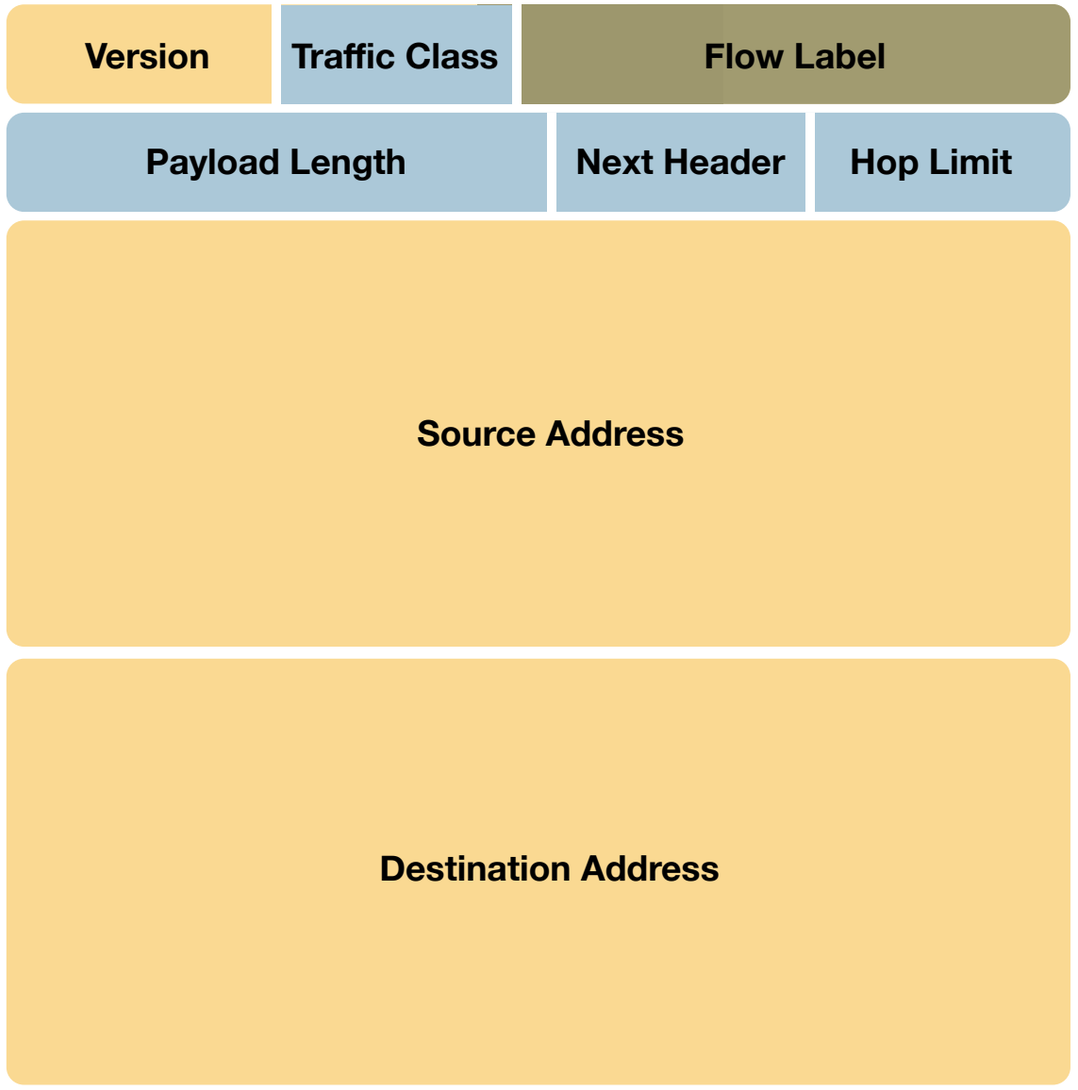
- IPv6 header is twice as long (40 bytes) as IPv4 header without options (20 bytes)

IPv6 Header

IPv4 Header



IPv6 Header

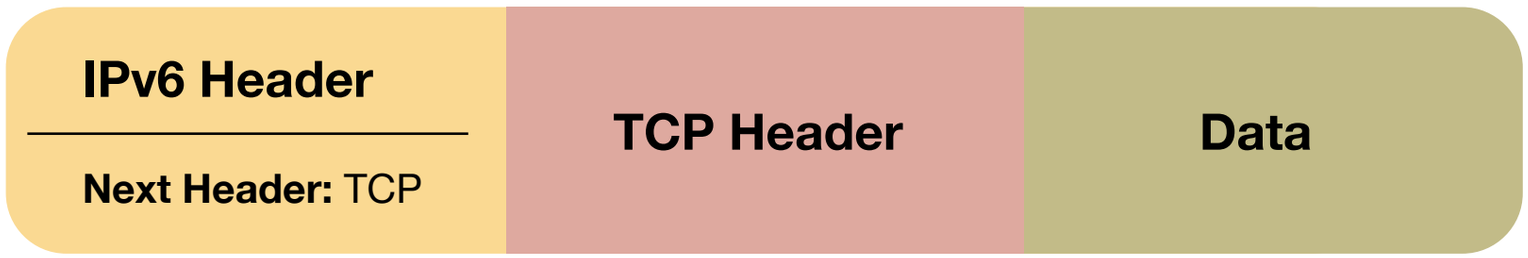


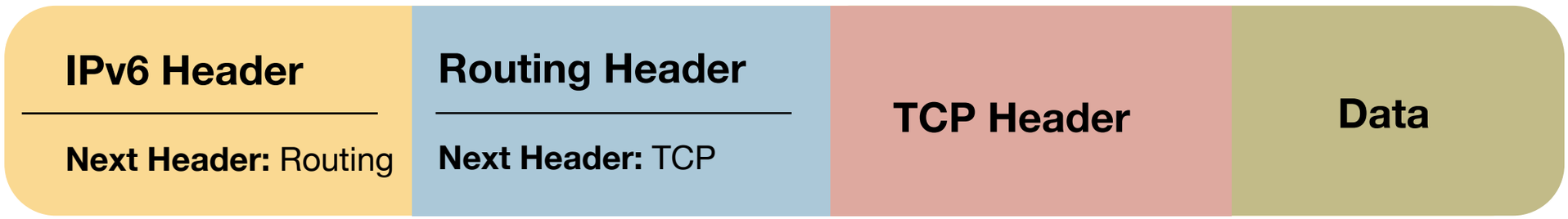
LEGEND

- 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
- 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

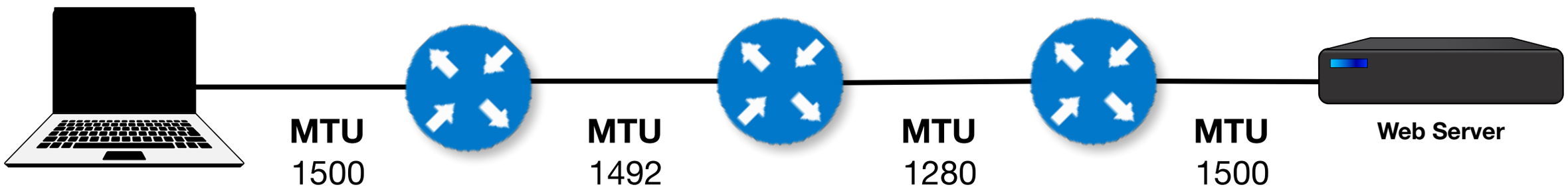
Fragmentation

- 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

Broadcast

- IPv6 has no broadcast
- There is an “all nodes” multicast group
  - ff02::1

- Disadvantages of broadcast:
  - It wakes up all nodes
  - Only a few devices are involved
  - Can create broadcast storms

Neighbor Discovery

- IPv6 has no ARP
- Replacement is called Neighbor Discovery
  - Uses ICMPv6
  - Uses Multicast
- Every ARP request wakes up every node
- Each ND request only wakes up a few nodes

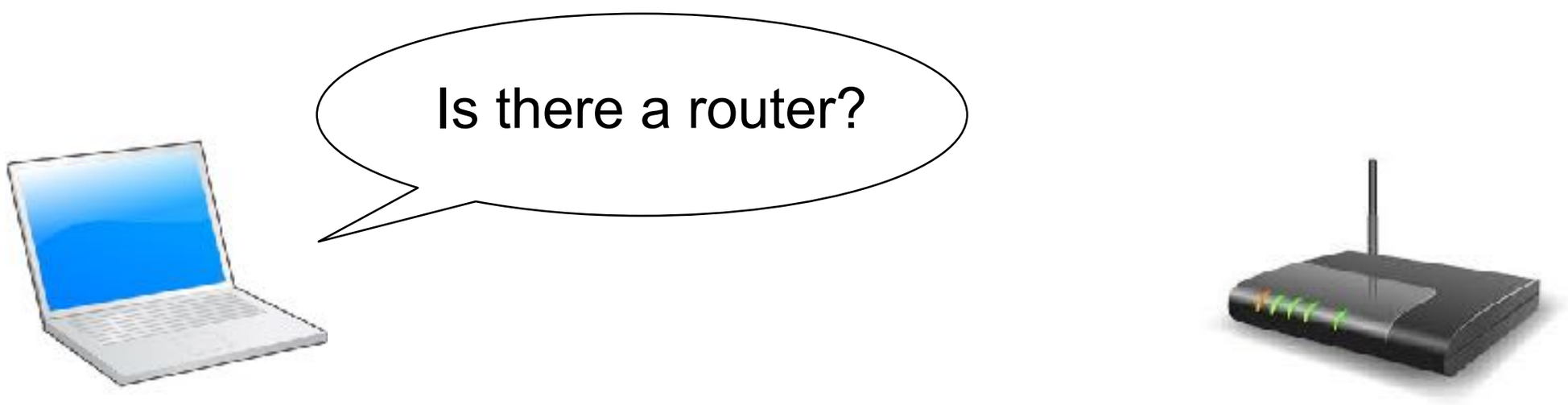
Neighbor Discovery

- ND is used by nodes:
  - For address resolution
  - To find neighboring routers
  - To track address changes
  - To check neighbor reachability
  - To do Duplicate Address Detection

- ND uses 5 different ICMPv6 packet types

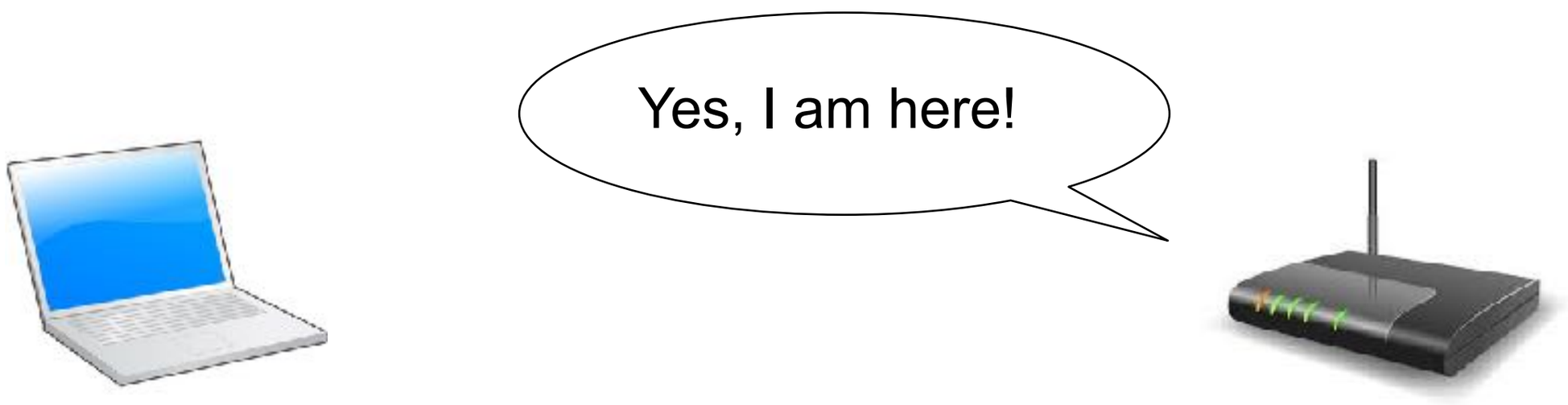
Neighbor Discovery Protocol

- **Router Sollicitation - ICMPv6 Type 133**
  - Hosts sends an ICMPv6 message to inquire if there is a router on the link



Neighbor Discovery Protocol

- Router Advertisement - ICMPv6 Type 134
  - Routers advertise their presence periodically or in response to a Router Solicitation message
  - Has a lot of important information for the host



Neighbor Discovery Protocol

- Neighbor Solicitation - ICMPv6 Type 135
  - Sent by a node to find the MAC-address of the neighbor, or to check if the neighbor is still reachable

Neighbor Discovery Protocol

- Neighbor Advertisement - ICMPv6 Type 136
  - A response to a neighbor solicitation message

Neighbor Discovery Protocol

- Redirect - ICMPv6 Type 137
  - A router points the host to a better first hop router for a destination

Questions

Deploying IPv6

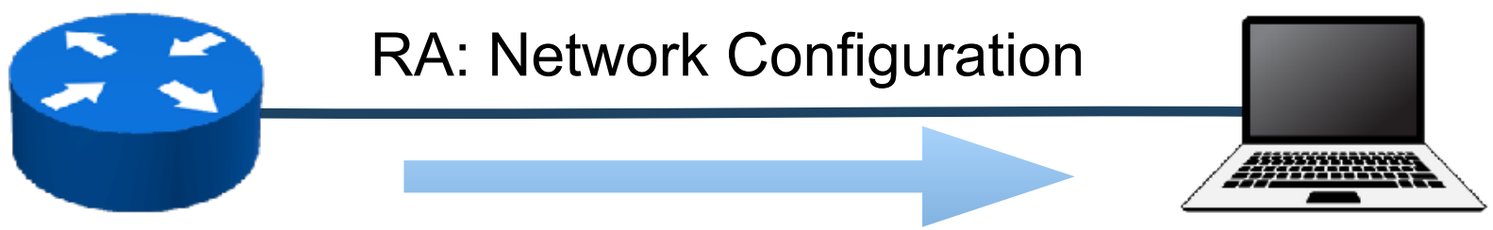
Section 7

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

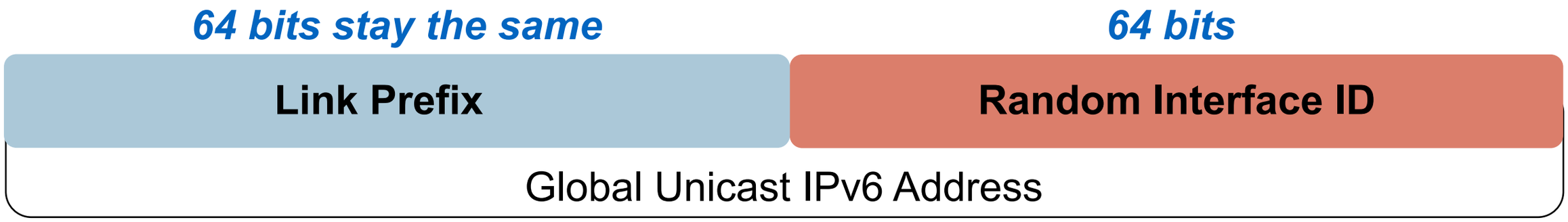
Router Advertisement Options

- 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)

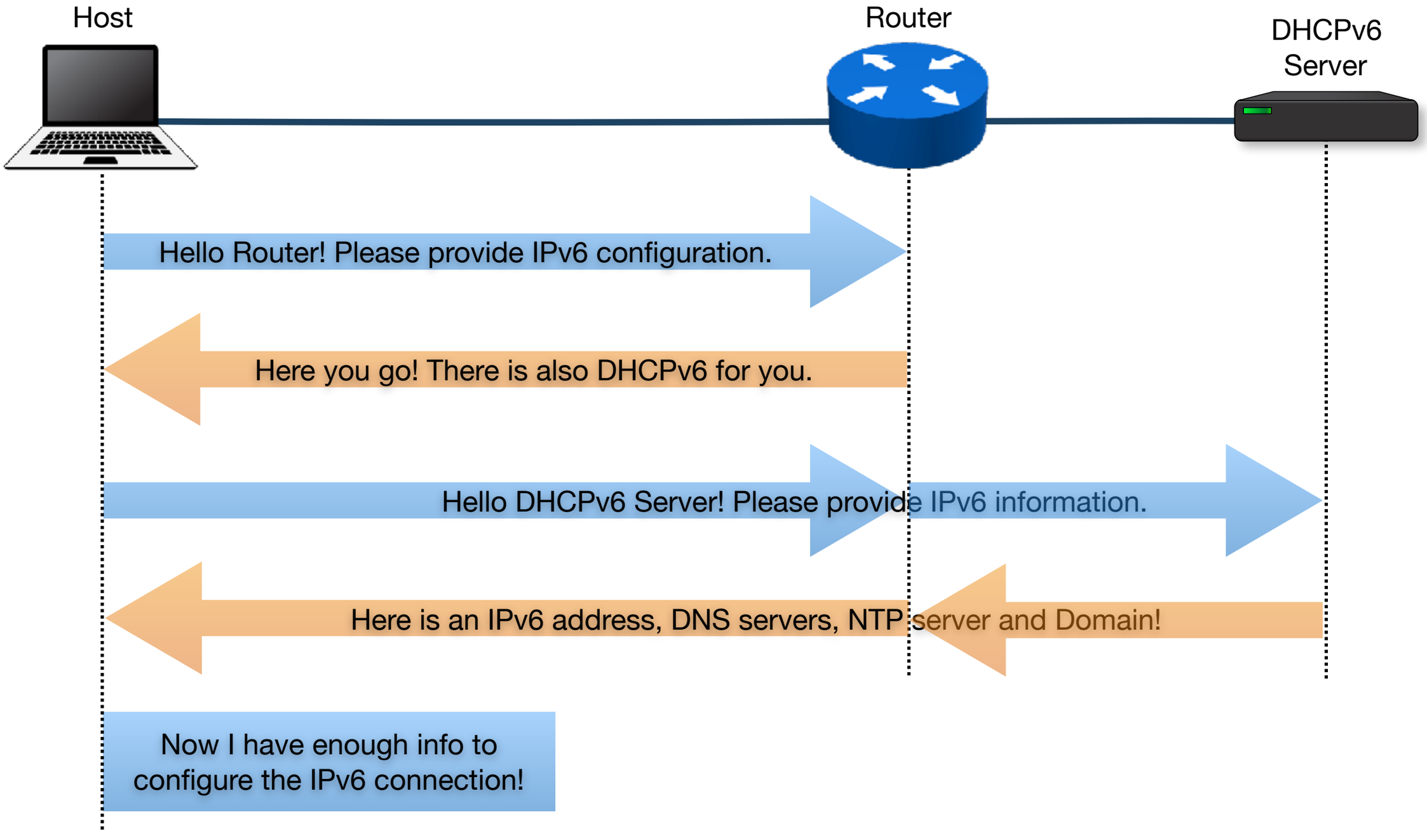


Privacy Extensions for SLAAC & CGA

- Provides privacy for users
- Privacy Extensions changes the interface ID randomly over time
- Cryptographically Generated Addresses (CGA) replaces the interface ID with a cryptographic hash of the public key of the address owner with other parameters
- Duplicate Address Detection ensures uniqueness
- In case of collision, a new address should be generated



DHCPv6


Host
Router
DHCPv6 Server
Hello Router! Please provide IPv6 configuration.
Here you go! There is also DHCPv6 for you.
Hello DHCPv6 Server! Please provide IPv6 information.
Here is an IPv6 address, DNS servers, NTP server and Domain!
Now I have enough info to configure the IPv6 connection!

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

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.0.0.0.0.0.0.0.0.1.1.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.0.0.0.0.0.0.0.0.1.1.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, OS X 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

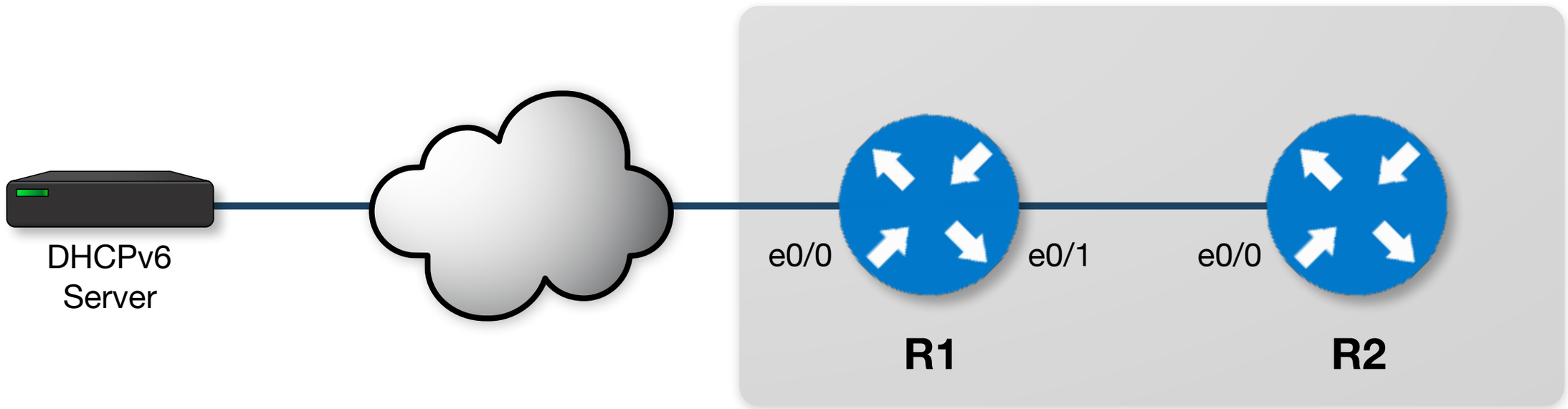
Configuring IPv6

Exercise

Assigning Addresses

- **R1** will send the RAs and act as DHCPv6 Relay Agent
- **R2** will get IPv6 configuration info in three ways:
  - RA + SLAAC only
  - RA + SLAAC + ‘O’ flag (DHCPv6 Other Configuration)
  - RA + **no SLAAC** + ‘M’ flag (DHCPv6 Managed)
- The DHCPv6 server is already configured

Network Diagram



Router roles:

R1: Default gateway router
DHCPv6 relay agent

R2: Client device
SLAAC
DHCPv6 client

Exercise: Configuring IPv6

- Make sure you have connectivity
- Go to: workbench.ripe.net
- Choose the lab (ask the trainers)
- Your login is your number on participants list
- The trainers will provide the password
- Choose “**RA and DHCPv6**” from the menu

Check R2

- Verify that the interface e0/0 has no address yet

```
show ipv6 interface brief
```

Basic IPv6 Settings

- Before configuring IPv6 on your router interfaces, the basic IPv6 settings must be enabled

- On both **R1** and **R2**

```
configure terminal
```

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

1st Case: SLAAC only (Router)

- On **R1** we will configure an IPv6 address from a /64 prefix on interface e0/1

```
interface e0/1
  ipv6 address 2001:ffxx:1::a/64
```

Where xx is your number on the attendee list!

1 = 01

2 = 02

10 = 10

11 = 11

1st Case: SLAAC only (Client)

- On **R2** we will configure SLAAC on the interface e0/0

```
interface e0/0
  ipv6 address autoconfig default
```

Check R2

- Verify that the interface e0/0 has an IPv6 address

```
end    (exits config mode)
```

```
show ipv6 interface e0/0
```

- And a default route

```
show ipv6 route
```

Check R2

- Unfortunately, **R2** has no DNS name servers

```
show ip dns view
```

- This information was not provided in the RA from **R1**

2nd Case: SLAAC + O flag (Router)

- On **R1** we will configure the ‘O’ flag for the RAs on interface e0/1

```
interface e0/1
  ipv6 nd other-config-flag
```

2nd Case: SLAAC + O flag (Client)

- On **R2** we will first bring down the interface e0/0

```
configure terminal
interface e0/0
  shutdown
```

- And then bring it back up…

```
  no shutdown
```

2nd Case: SLAAC + O flag (Client)

- Verify that the interface e0/0 has an IPv6 address and other configuration

```
end    (exits config mode)
```

```
show ipv6 interface e0/0
```

```
show ip dns view
```

```
show ipv6 dhcp interface e0/0
```

3rd Case: RA + M flag (Router)

- On **R1** we will configure the ‘M’ flag for the RAs on interface e0/1

```
interface e0/1
  no ipv6 nd other-config-flag
  ipv6 nd managed-config-flag
```

3rd Case: RA + M flag (Client)

- On **R2** we will first bring down the interface e0/0

```
configure terminal
interface e0/0
 shutdown
```

- Remove the SLAAC configuration

```
no ipv6 address autoconfig default
```

3rd Case: RA + M flag (Client)

- On **R2**, configure the DHCP client

```
ipv6 address dhcp
ipv6 enable
ipv6 nd autoconfig default-route
```

- And then bring the interface back up…

```
no shutdown
```

3rd Case: RA + M flag (Client)

- Verify that the interface e0/0 has an IPv6 address and other configuration

```
end    (exits config mode)
```

```
show ipv6 interface e0/0
```

```
show ipv6 dhcp interface e0/0
```

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

RIPE-554 Document

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

https://www.ripe.net/ripe/docs/ripe-554

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

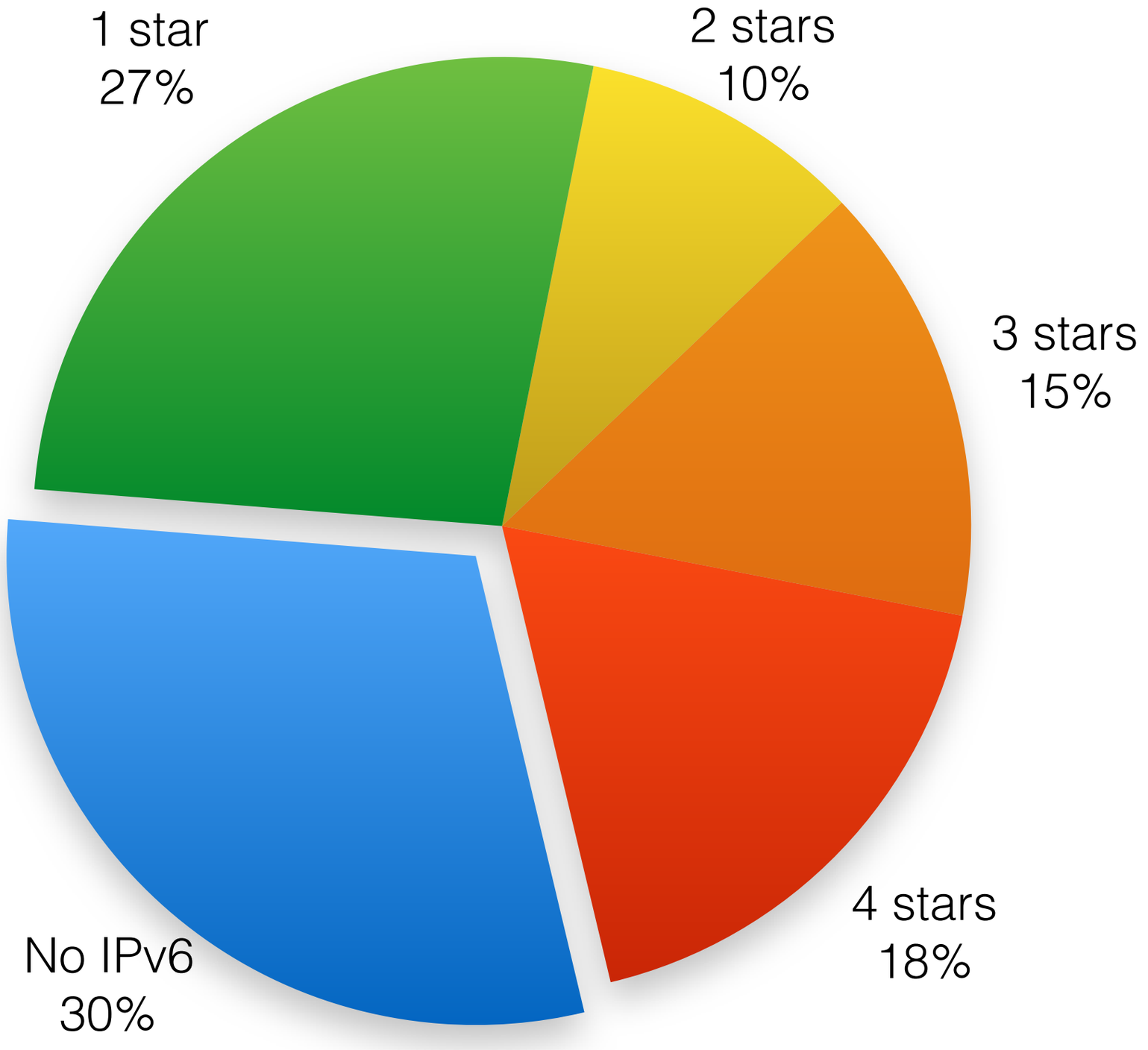
- A generic troubleshooting guide can help!
- Based on the open source testipv6.com tool
- Customisable

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

IPv6 Ripeness

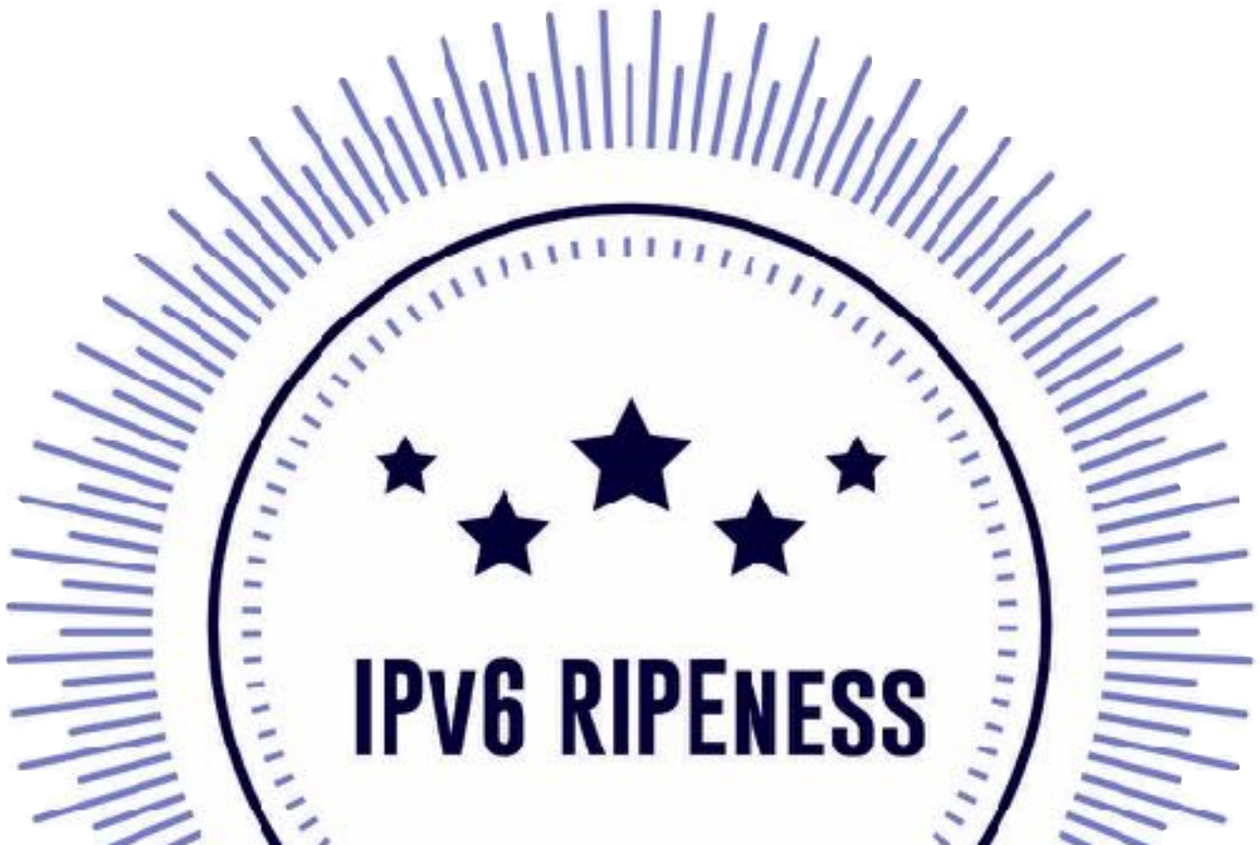
- Rating system:
  - One star if the LIR has an IPv6 allocation
  - Additional stars if:
    - IPv6 Prefix is announced on router
    - A route6 object is in the RIPE Database
    - Reverse DNS is set up
- A list of 4 star LIRs:
  - http://ripeness.ripe.net

IPv6 RIPEness: 19665 LIRs



IPv6 RIPEness: the 5th star

- You already earned 4 stars…
- Actual IPv6 deployment is the 5th star!
- Two ways to get it:
  - Provide content over IPv6
  - Provide IPv6 access to users
- Ask for your t-shirt!!!



Customers And Their /48

- Customers have no idea how to handle 65536 subnets!
- Provide them with information
  - 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/
  - http://www.ripe.net/ripe/docs/ripe-554.html
- 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

Feedback!

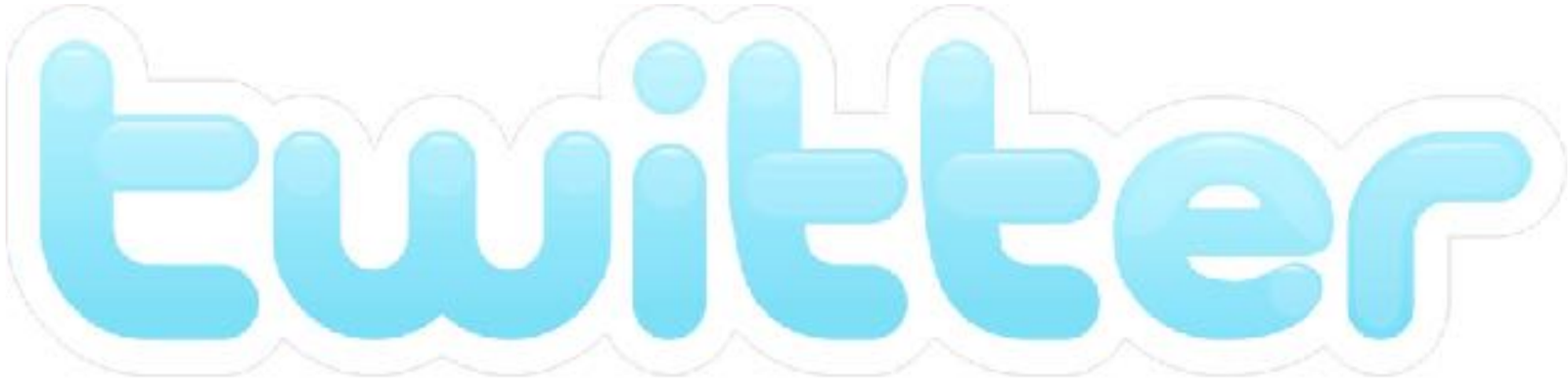
https://www.ripe.net/training/basic-ipv6/survey

RIPE NCC
Academy

Graduate to the next level!

http://academy.ripe.net

Follow us!



@TrainingRIPENCC

The End!

Край

Y Diwedd

Fí

Finis

النهاية

Соңы

Վերջ

Liðugt

Ende

Finvezh

Кінець

Konec

Kraj

Ënn

Fund

پایان

Kpaj

Lõpp

Beigas

Vége

Son

An Críoch

הסוף

Endir

Fine

Sfârşit

Fin

Τέλος

Einde

Конец

Slut

Slutt

დასასრული

Pabaiga

Tmiem

Koniec

Fim

Amaia

Loppu

English
The End!

Bulgarian
Край
(Kraj)

Welsh
Y Diwedd

Arabic
النهاية
(An-Nahaya)

Kazakh
Соңы

Armenian
վերջ
(Verj)

Catalan
Fí

Latin
Finis

Faroese
Liðugt

German
Ende

Breton
Finvezh

Ukrainian
Кінець
(Kinec))

Czech
Konec

Letzeburgisch(LUX)
Ënn

Albanian
Fund

Persian
پایان
(Payan)

Croatian
Kraj

Serbian
Крај
(Kraj)

Estonian
Lõpp

Latvian
Beigas

Hungarian
Vége

Turkish
Son

Irish
An Críoch

Hebrew
הסוף
(Ha-sof))

Icelandic
Endir

Romanian
Sfârşit

Italian
Fine

French
Fin

Greek
Τέλος
(Telos))

Dutch
Einde

Belorussian
Канец
(Kanec))

Russian
Конец
(Konec))

Swedish, Danish
Slut

Norwegian
Slutt

Georgian
დასასრული
(Dasasruli))

Lithuanian
Pabaiga

Maltese
Tmiem

Polish, Slovak
Koniec

Portuguese
Fim

Basque
Amaia

Finnish
Loppu

ANNEX

Transition Mechanisms

Annex 1

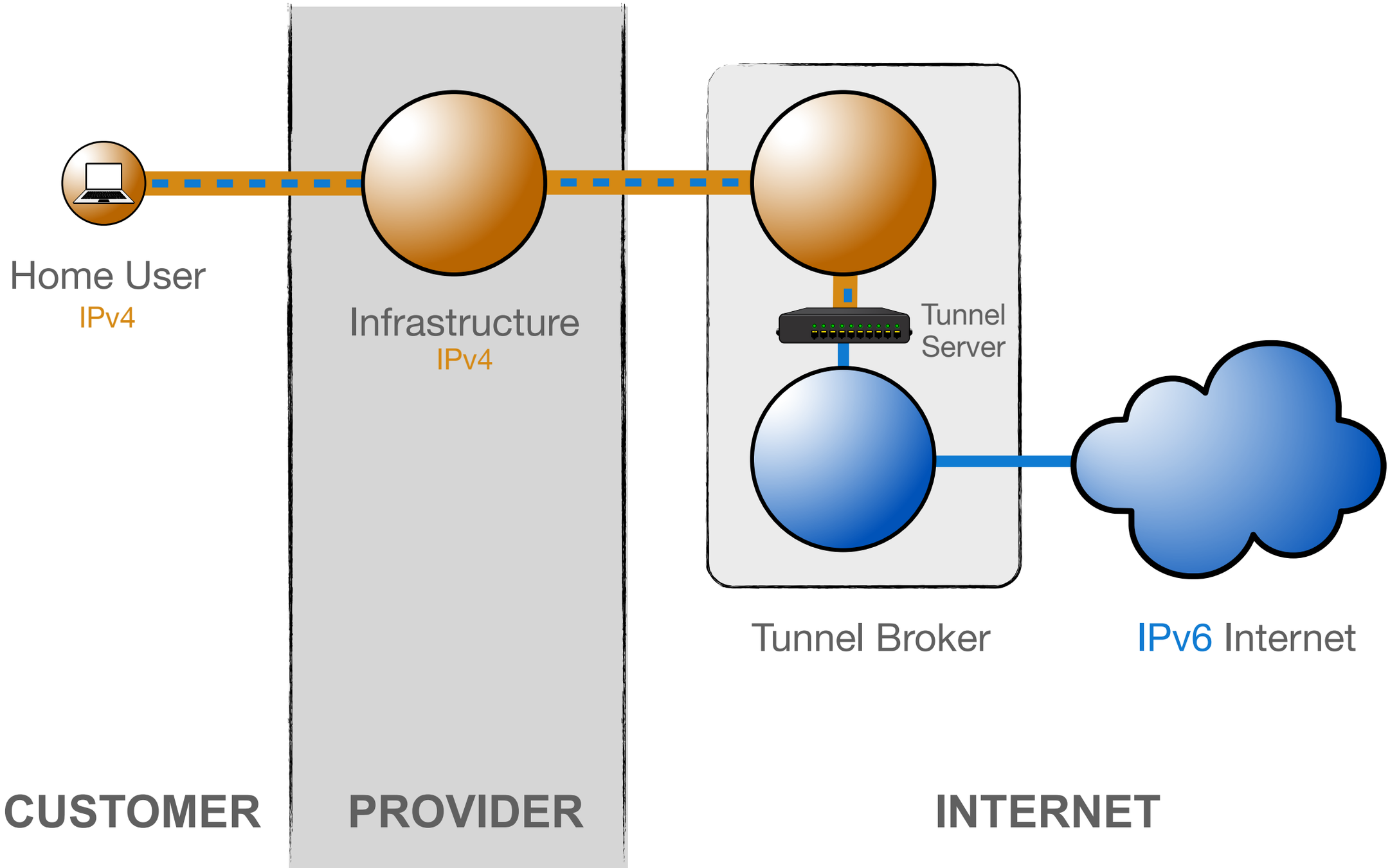
Transitioning: Solving Two Problems

- Maintaining connectivity to IPv4 hosts by sharing IPv4 addresses between clients
  - Extending the address space with NAT/CGN/LSN
  - Translating between IPv6 and IPv4
- Provide a mechanism to connect to the emerging IPv6-only networks
  - Tunnelling IPv6 packets over IPv4-only networks

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

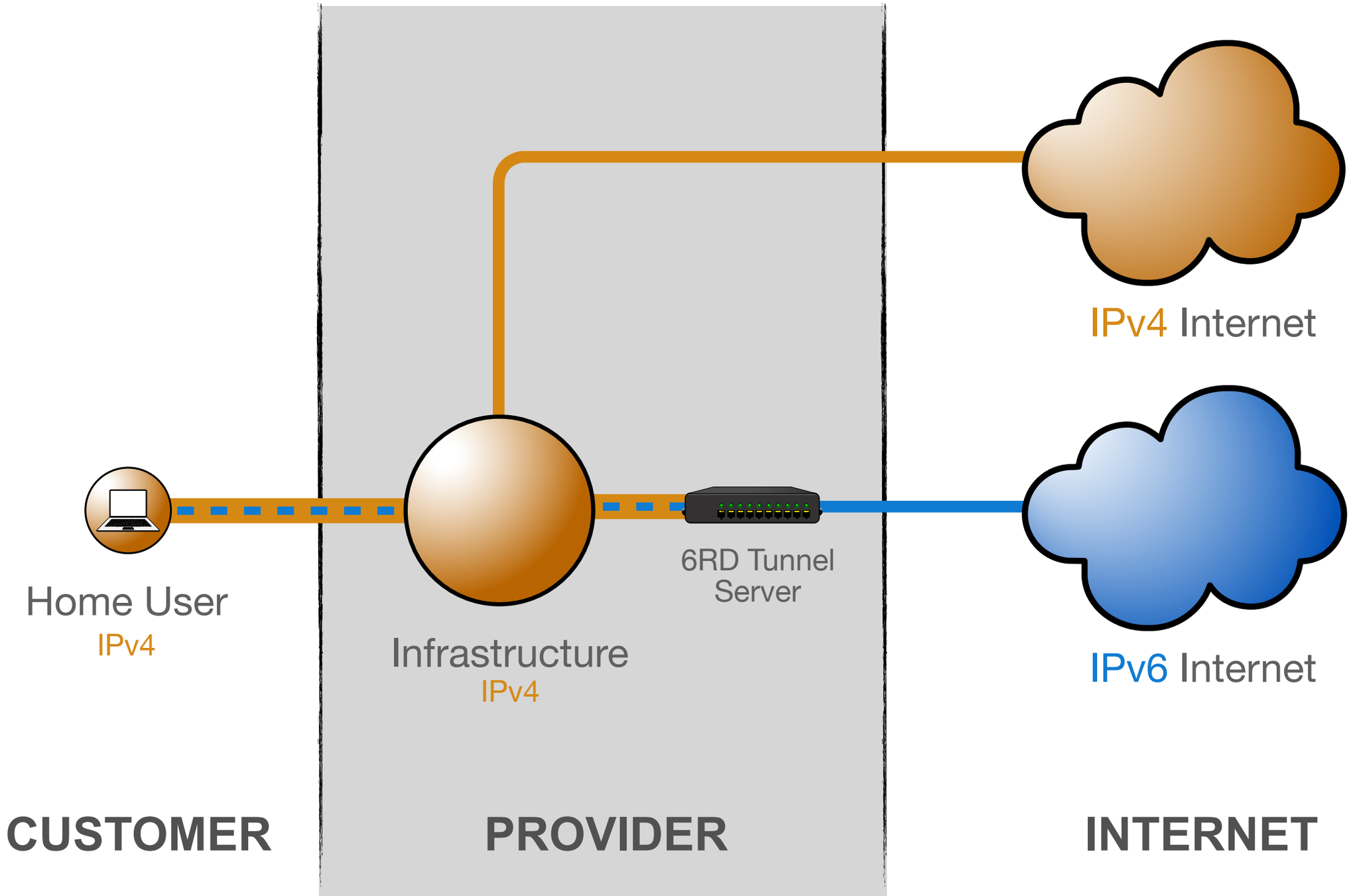
6in4


Home User
IPv4
Infrastructure
IPv4
Tunnel
Server
Tunnel Broker
IPv6 Internet
CUSTOMER
PROVIDER
INTERNET

6RD

- Encodes the IPv4 address in the IPv6 prefix
- Uses address space assigned to the operator
- The operator has full control over the relay
- Traffic is symmetric across a relay
  - Or at least stays in your domain
- Can work with both public and private IPv4 space
- Needs additional software for signalling

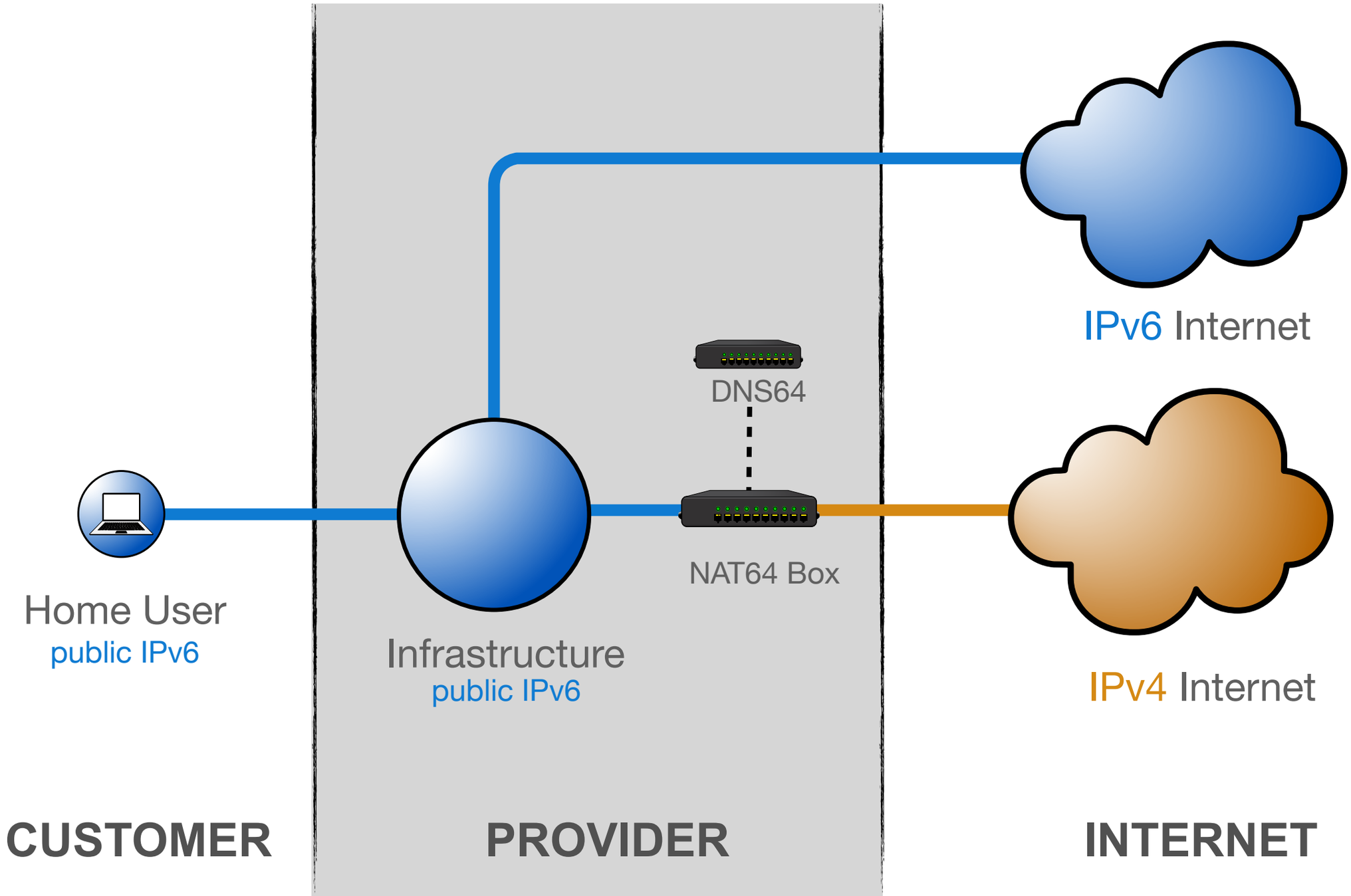
6RD


IPv4 Internet
IPv6 Internet
6RD Tunnel Server
Home User
IPv4
Infrastructure
IPv4
CUSTOMER
PROVIDER
INTERNET

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

NAT64 / DNS64

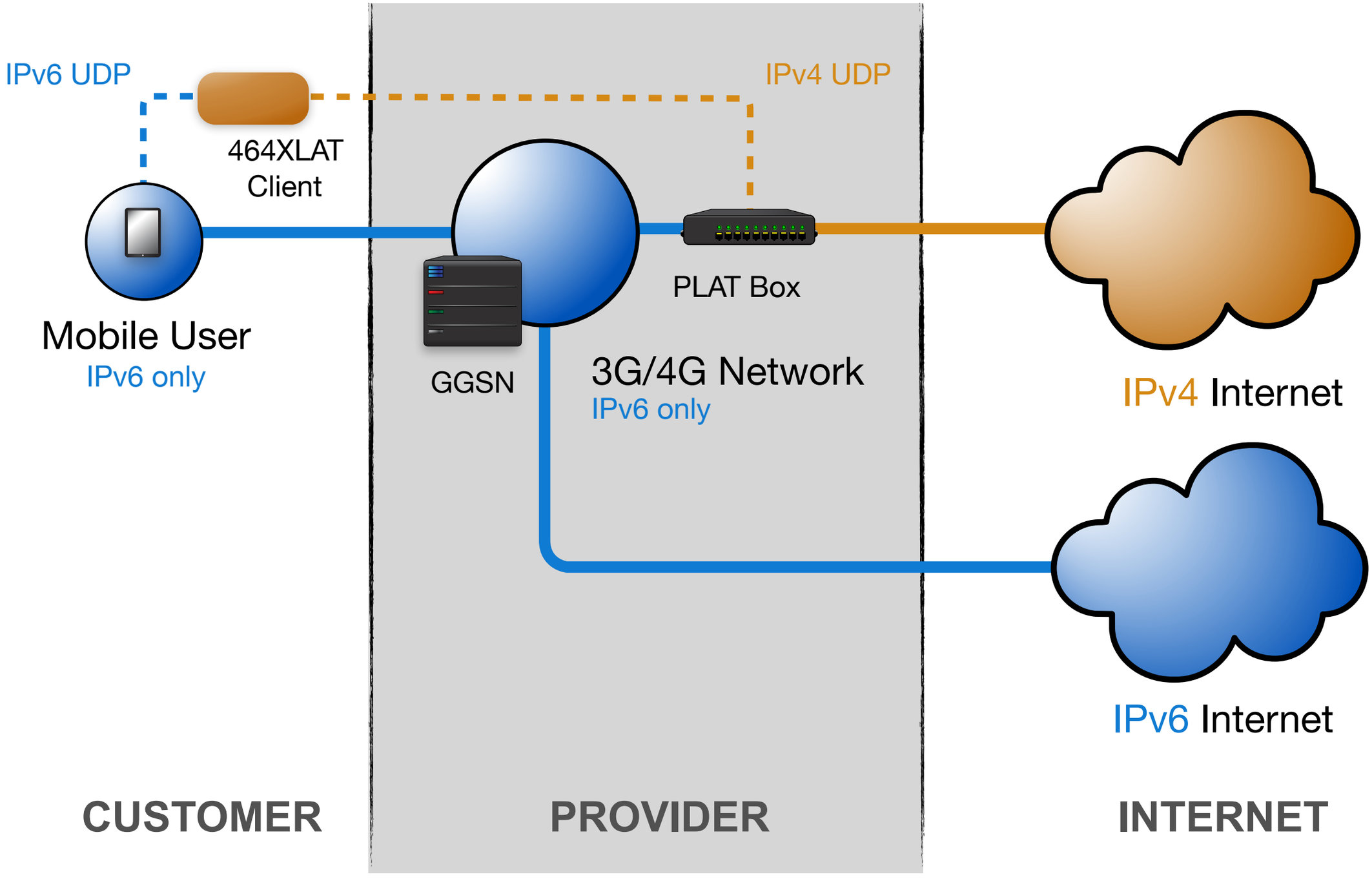

IPv6 Internet
DNS64
NAT64 Box
Home User
public IPv6
Infrastructure
public IPv6
IPv4 Internet
CUSTOMER
PROVIDER
INTERNET

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

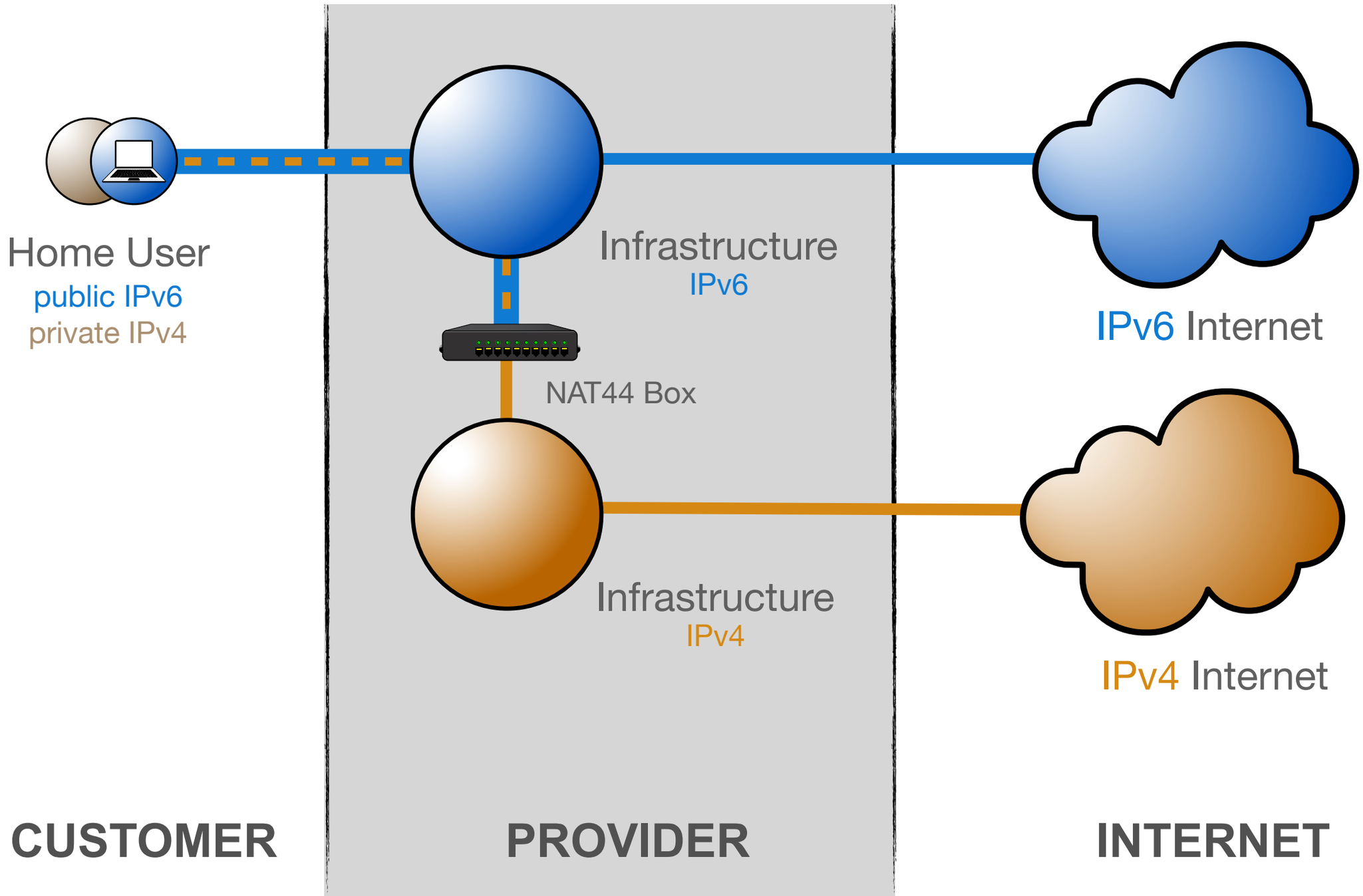
464XLAT


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

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

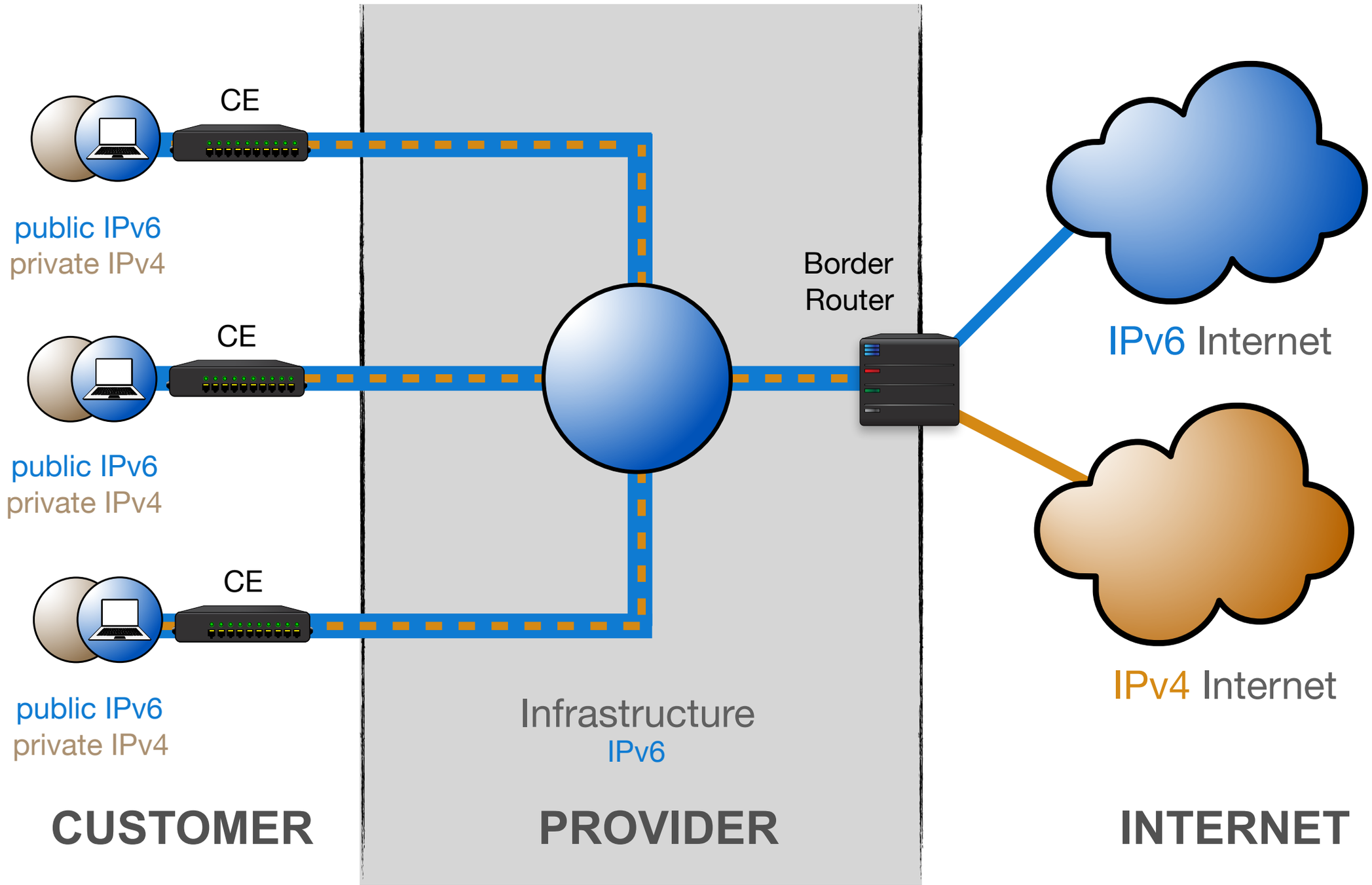
DS-lite


Home User
public IPv6
private IPv4
Infrastructure
IPv6
NAT44 Box
Infrastructure
IPv4
IPv6 Internet
IPv4 Internet
CUSTOMER
PROVIDER
INTERNET

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 NAT44 allows traffic to flow asymmetrically in and out of MAP domain

MAP-E / MAP-T


CE
public IPv6
private IPv4
CE
public IPv6
private IPv4
CE
public IPv6
private IPv4
Border
Router
IPv6 Internet
IPv4 Internet
Infrastructure
IPv6
CUSTOMER
PROVIDER
INTERNET

Best Transition Mechanism?

Dual Stack