



RIPE NCC
RIPE NETWORK COORDINATION CENTRE

Basic IPv6

Training Course

August 2016

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
- Deploying
- Transition Mechanisms
- Exercise: Configuring IPv6
- Real Life IPv6 Deployment
- Deployment Challenges
- Tips



IPv4?

Section 1

Reaching the next billion



- Around 3,61 billion Internet users now
 - around 49,2 % 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

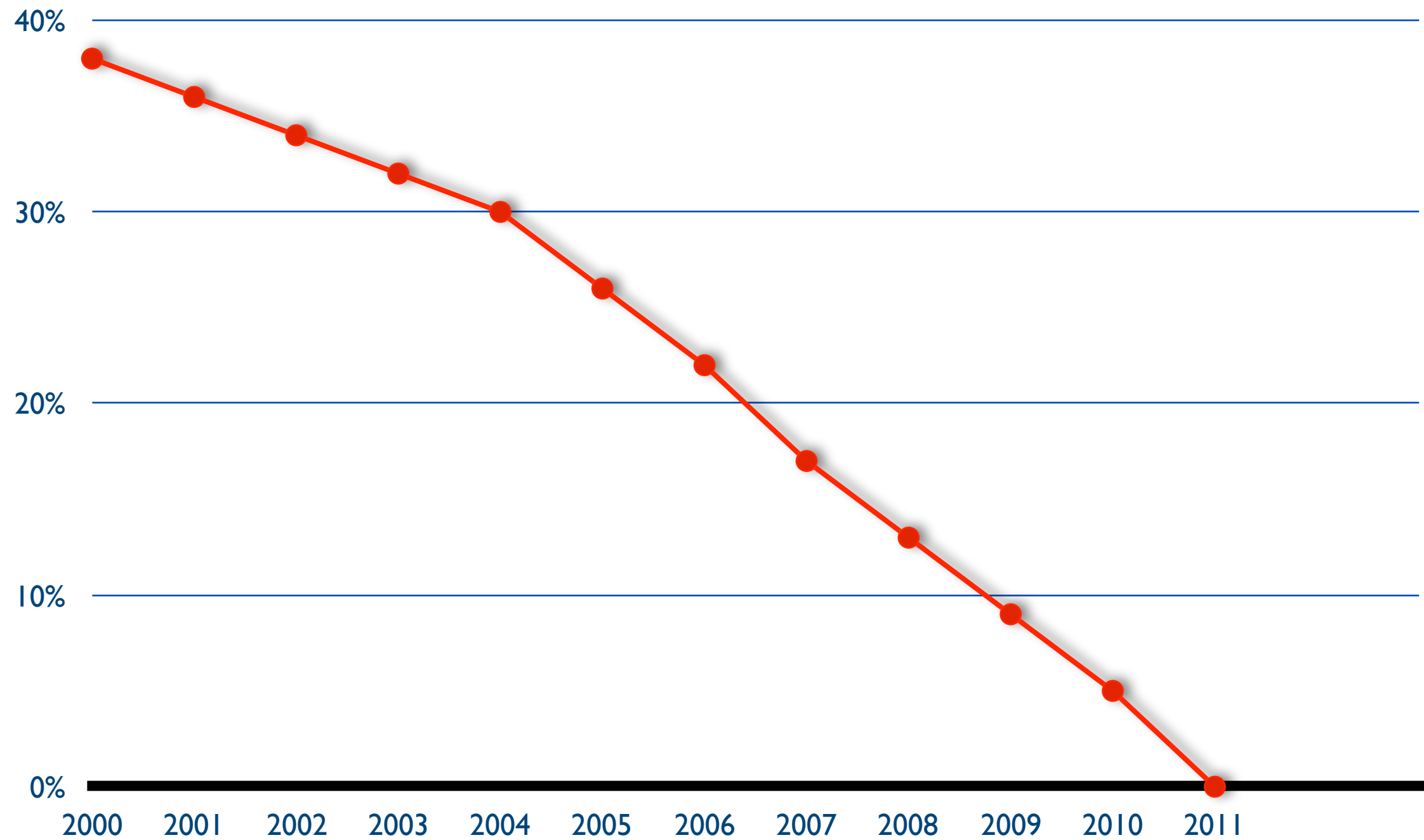


Libelium Smart World



http://www.libelium.com/top_50_iot_sensor_applications_ranking
© Libelium Comunicaciones Distribuidas S.L.

IANA IPv4 Pool



IPv4 Exhaustion



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

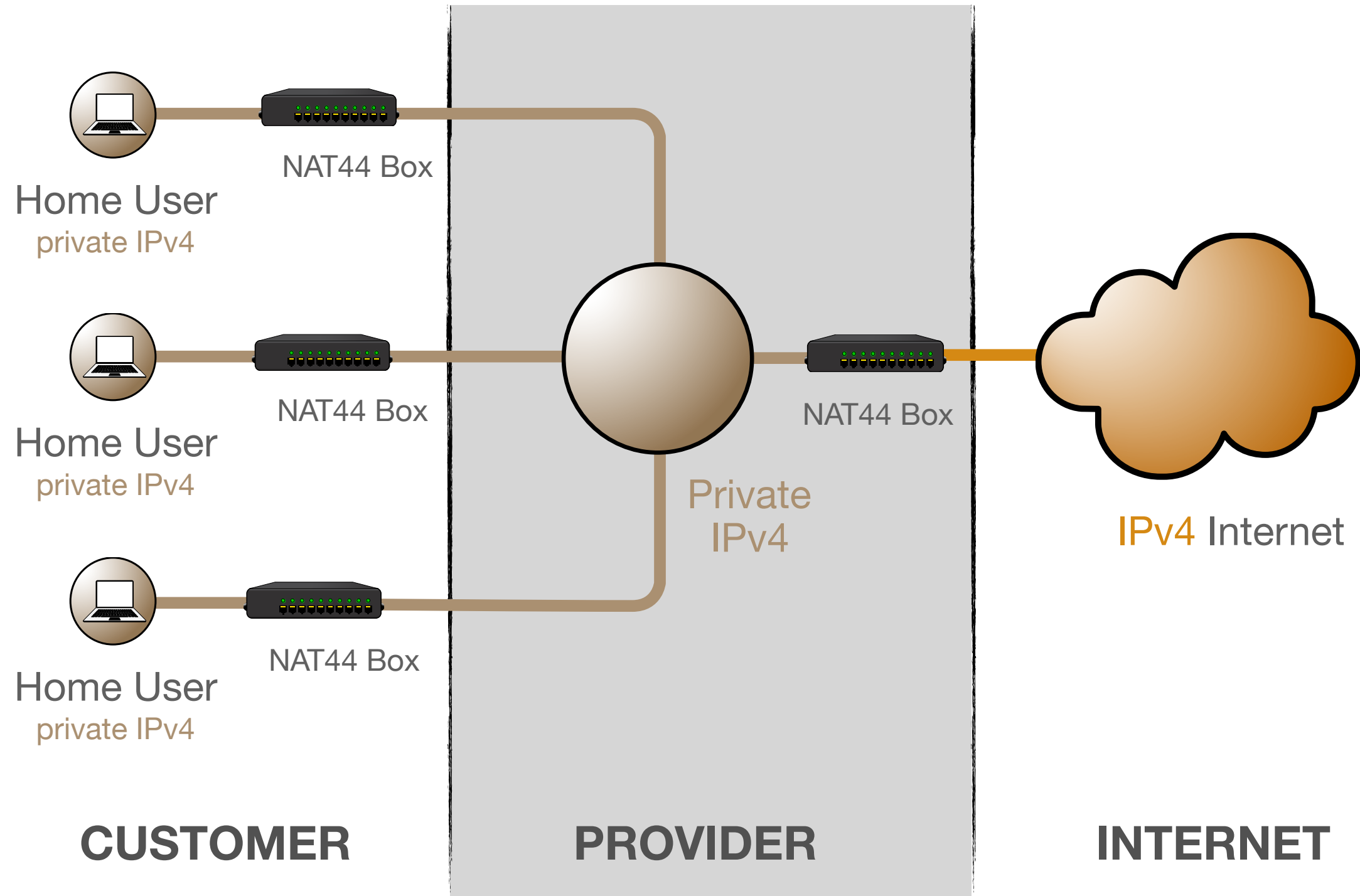


Network Address Translation



- 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

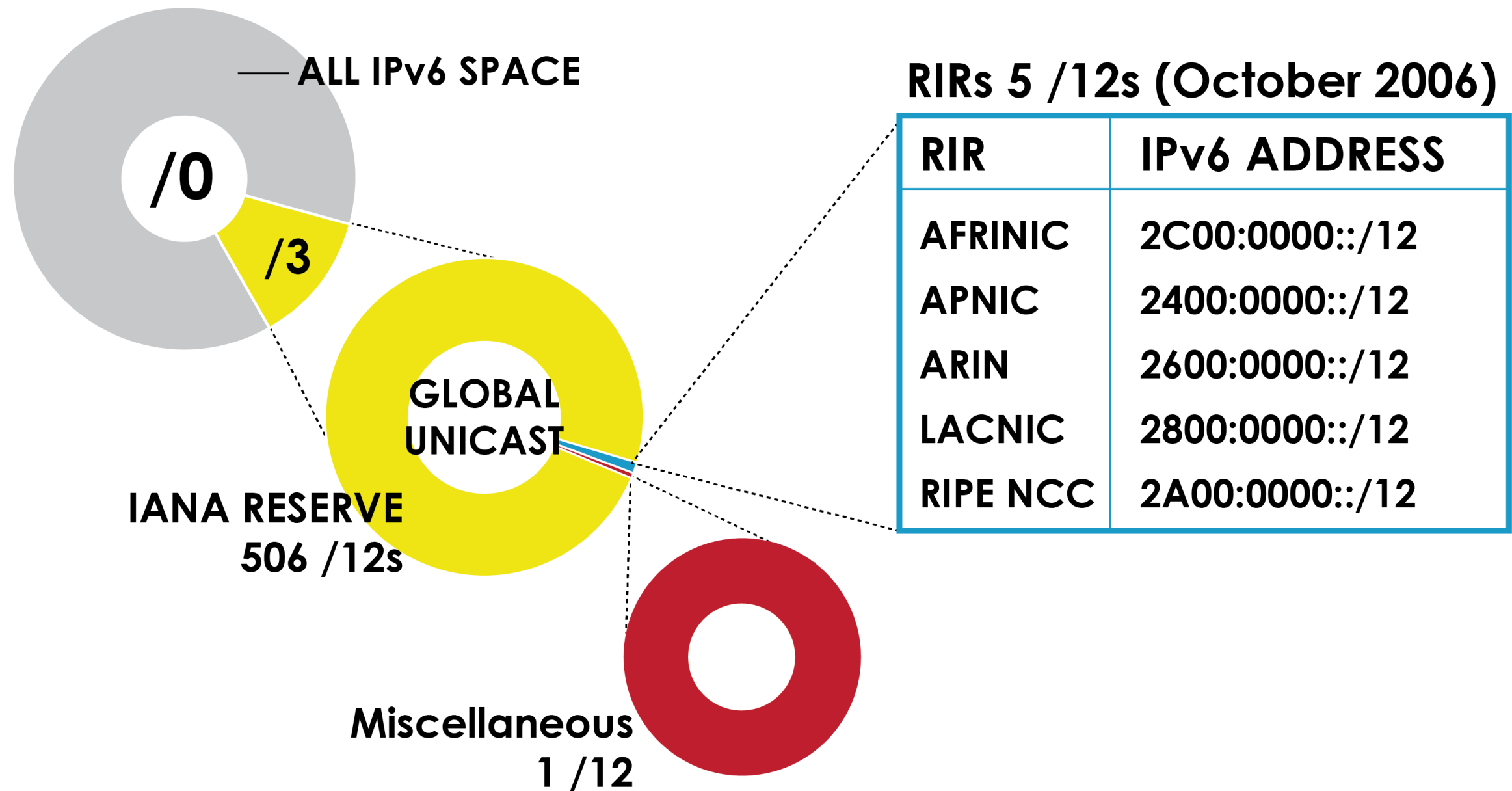




IPv6 Address Basics

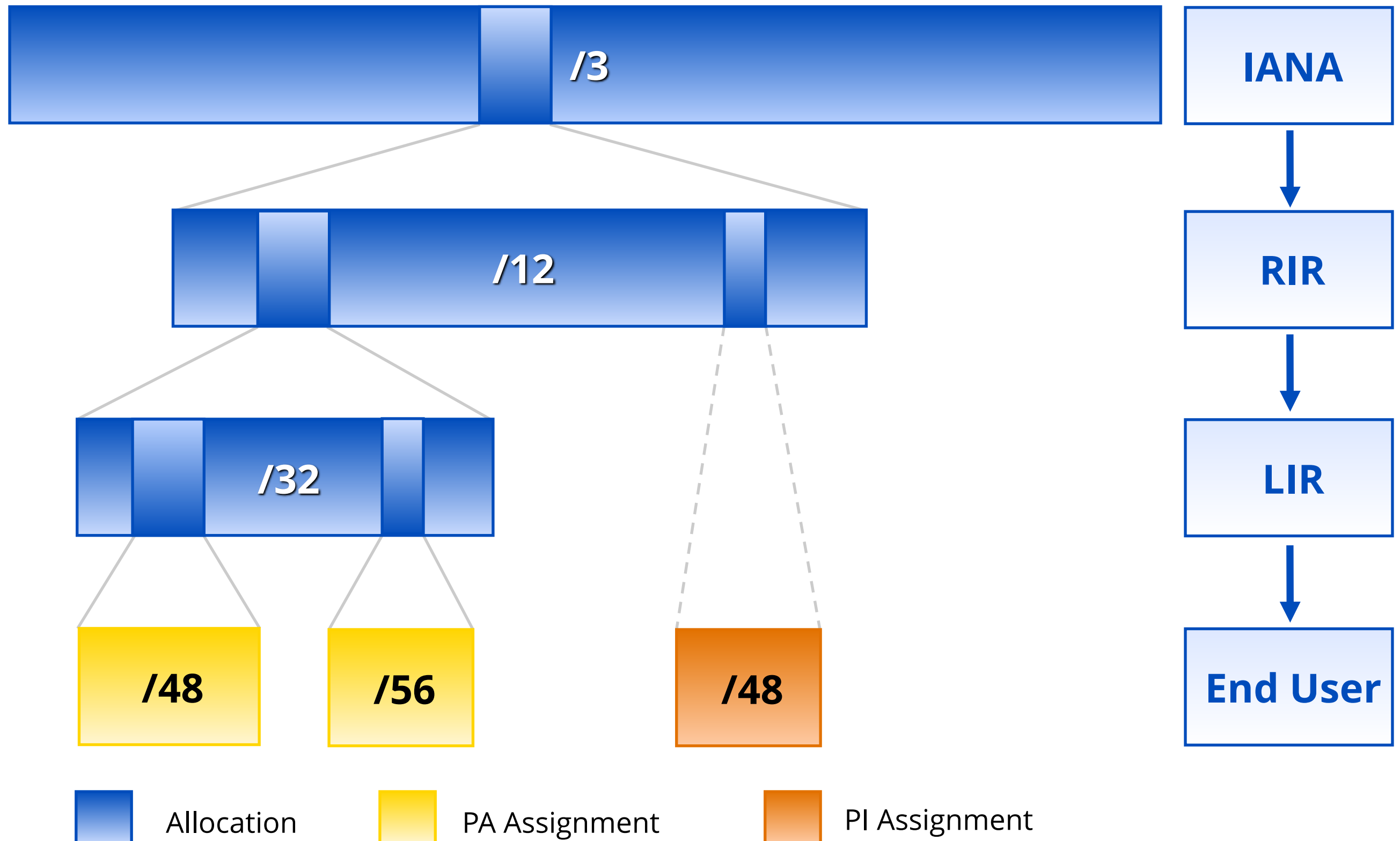
Section 2

IP Address Distribution



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

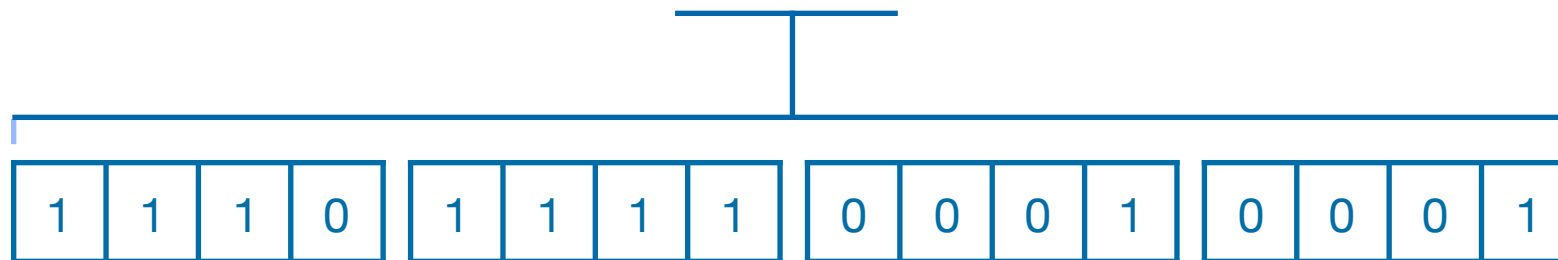
Address Notation



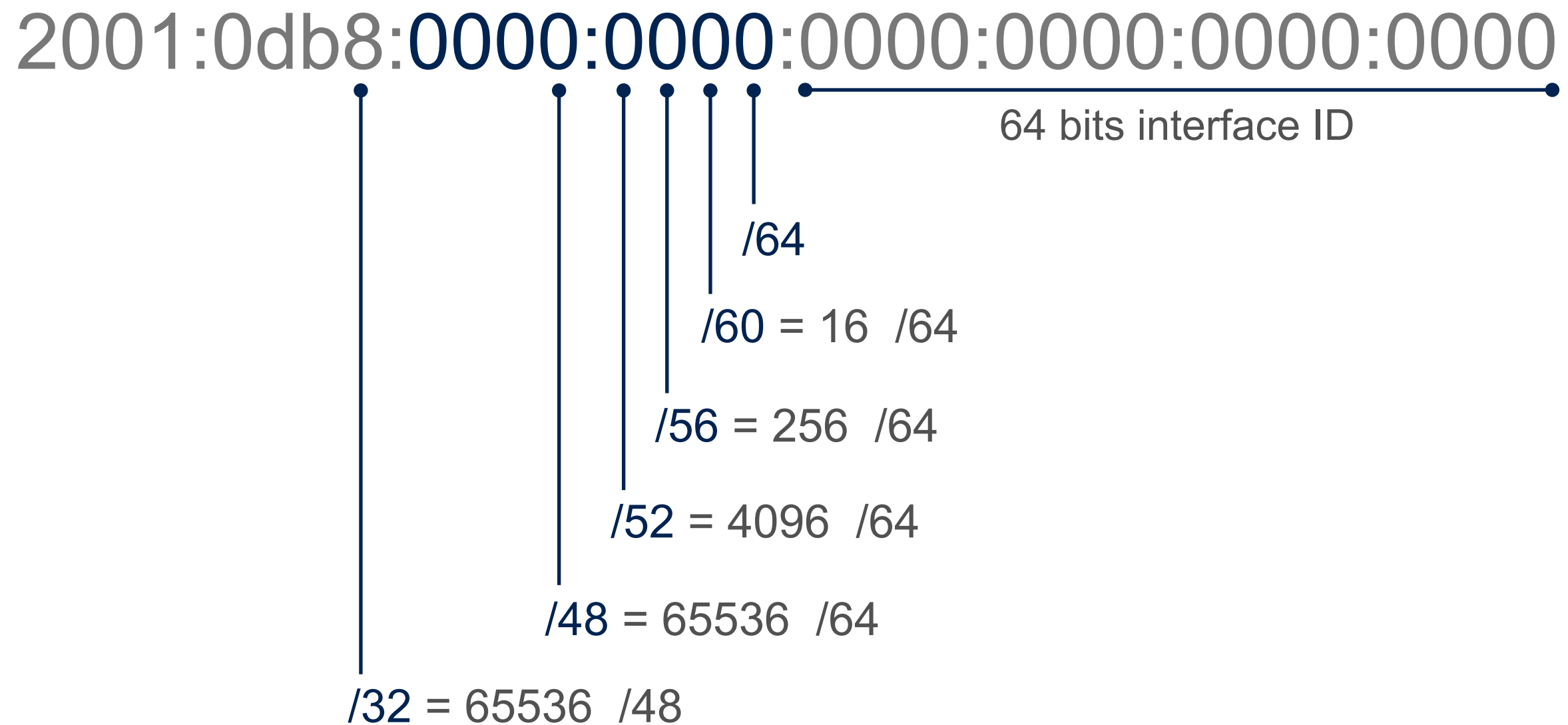
2001:0db8:003e:ef11:0000:0000:c100:004d

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 Notation

Exercise



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



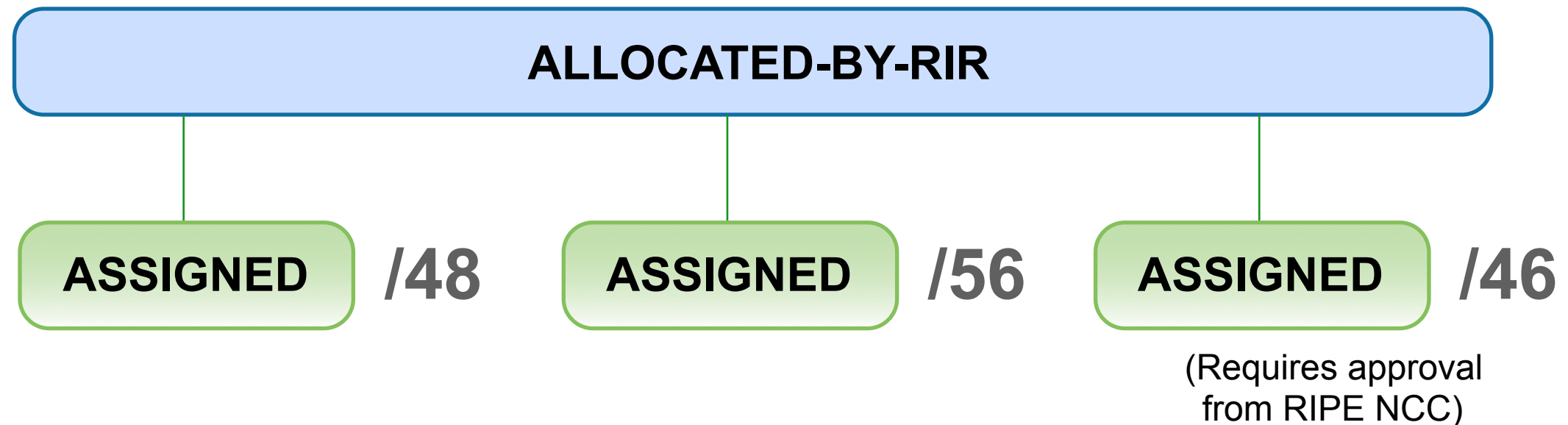
- Give your customers enough addresses
 - Minimum /64
 - Up to /48
- More than /48, send in request form
 - alternatively, make a sub-allocation
- Every assignment must be registered in the RIPE Database

Comparison IPv4 and IPv6 status



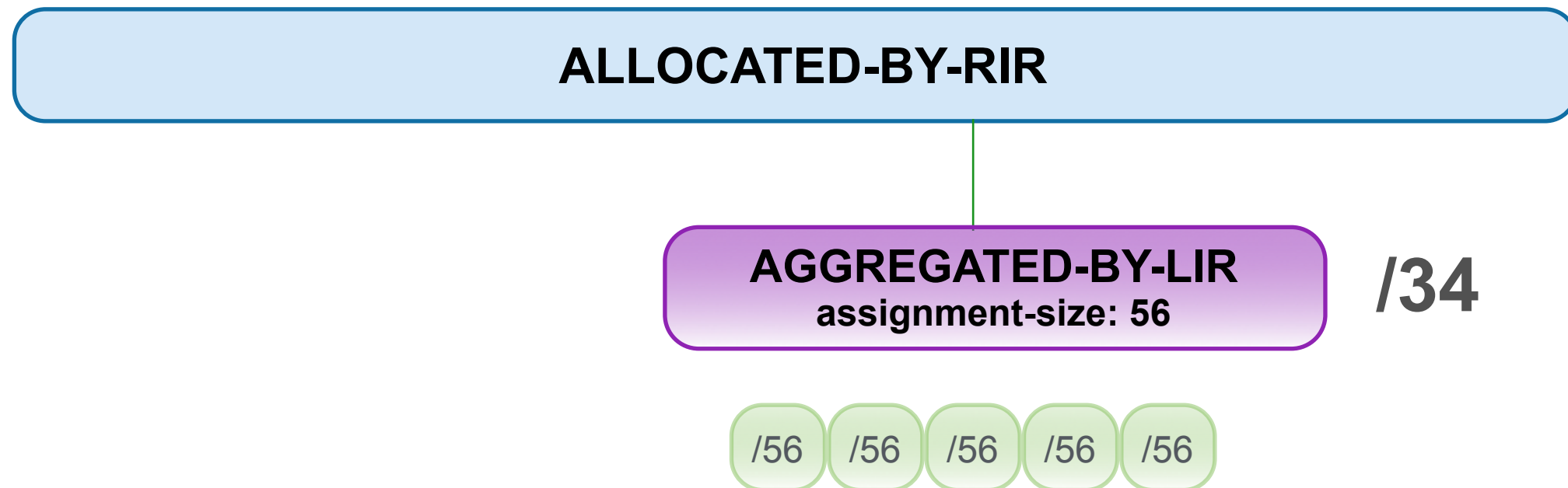
IPv4		IPv6
ALLOCATED PA	Allocation	ALLOCATED-BY-RIR
ASSIGNED PA	Assignment	ASSIGNED
	Group of Assignments	AGGREGATED-BY-LIR
SUB-ALLOCATED PA	Sub-Allocation	ALLOCATED-BY-LIR
ASSIGNED PI	PI Assignment	ASSIGNED PI

Using ASSIGNED



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

Using AGGREGATED-BY-LIR



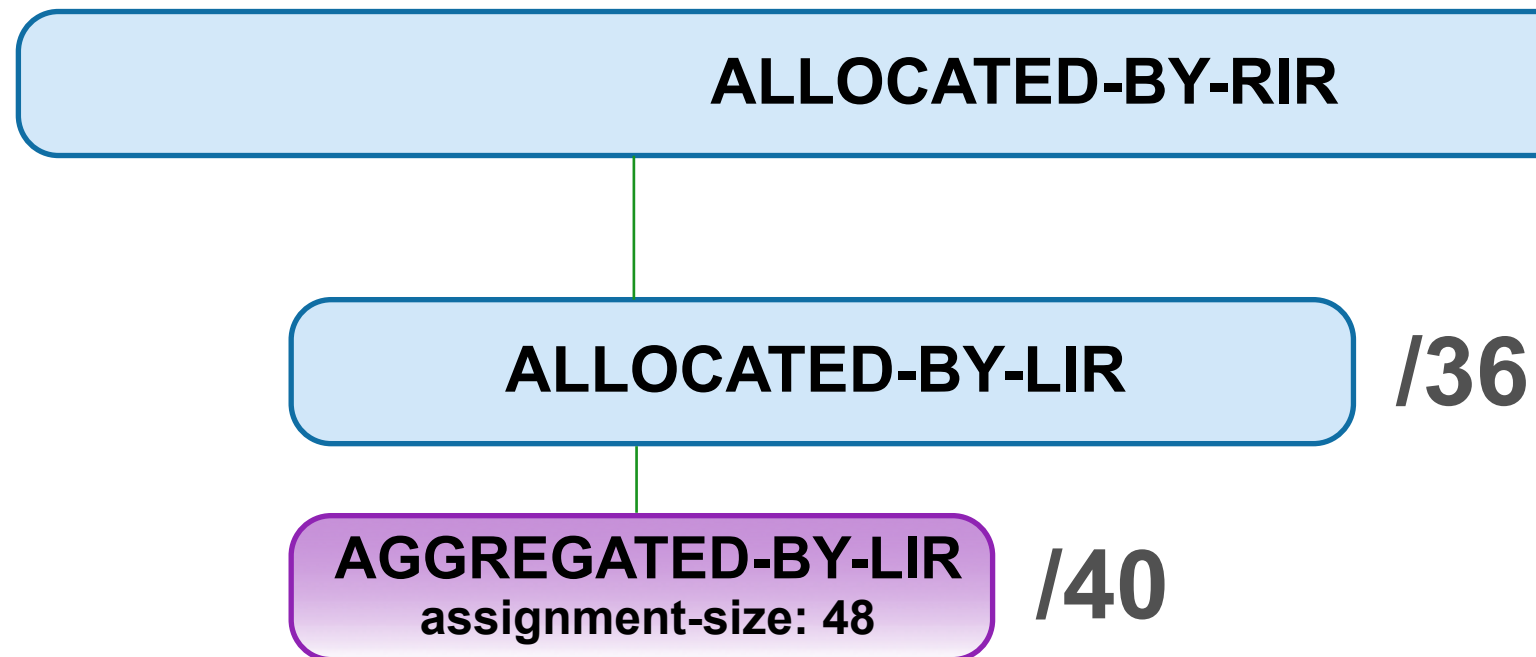
- Can be used to group customers
 - example: residential broadband customers
- “assignment size:” = assignment of each customer

AGGREGATED-BY-LIR in the RIPE DB



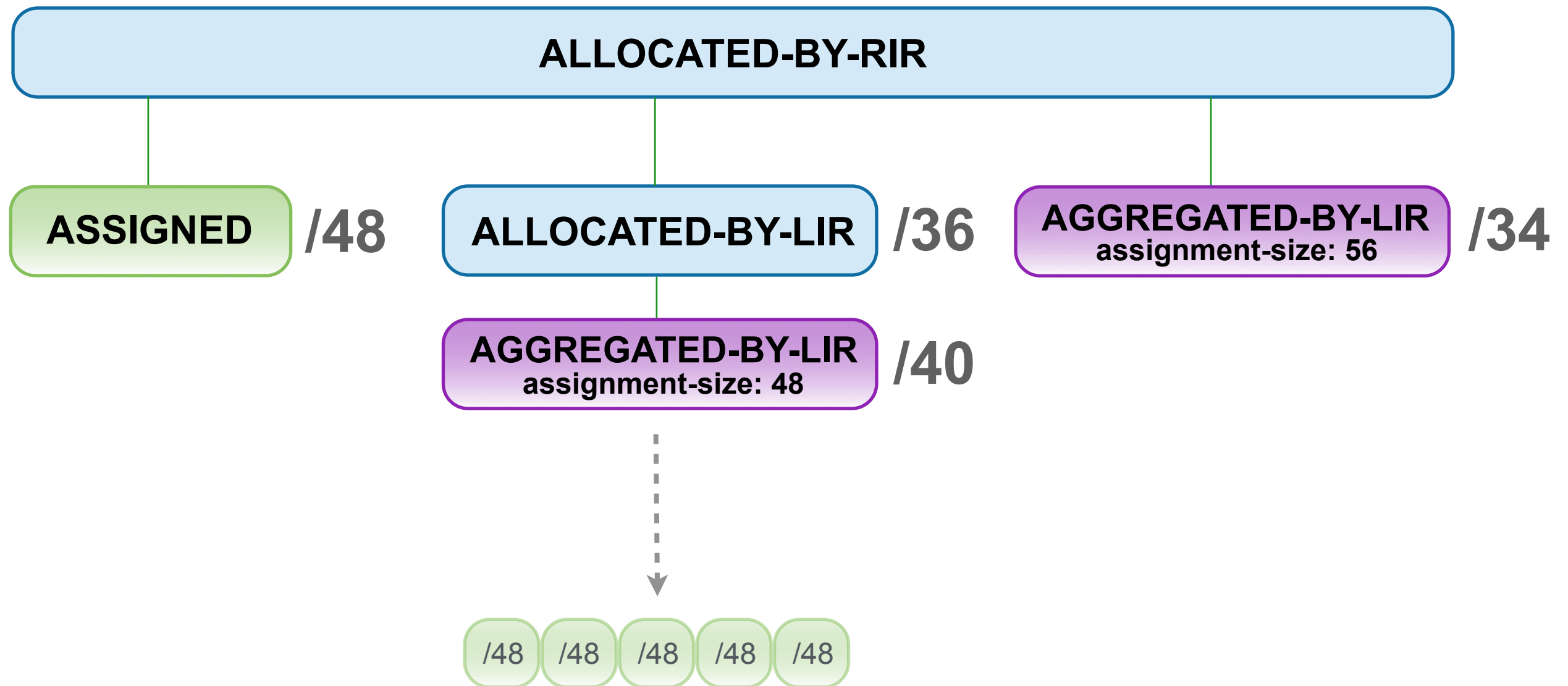
inet6num:	2001:db8:1000::/36
netname:	Brightlife
descr:	Broadband services
country:	NL
admin-c:	BN649-RIPE
tech-c:	BN649-RIPE
status:	AGGREGATED-BY-LIR
assignment-size:	48
mnt-by:	BRIGHTLIFE-MNT
notify:	noc@example.net
created:	2015-05-31T12:34:01Z
last-modified:	2015-05-31T12:34:01Z
source:	RIPE

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

Overview



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: fd**da:2415:4e1d**::/48



Making Assignments

Exercise

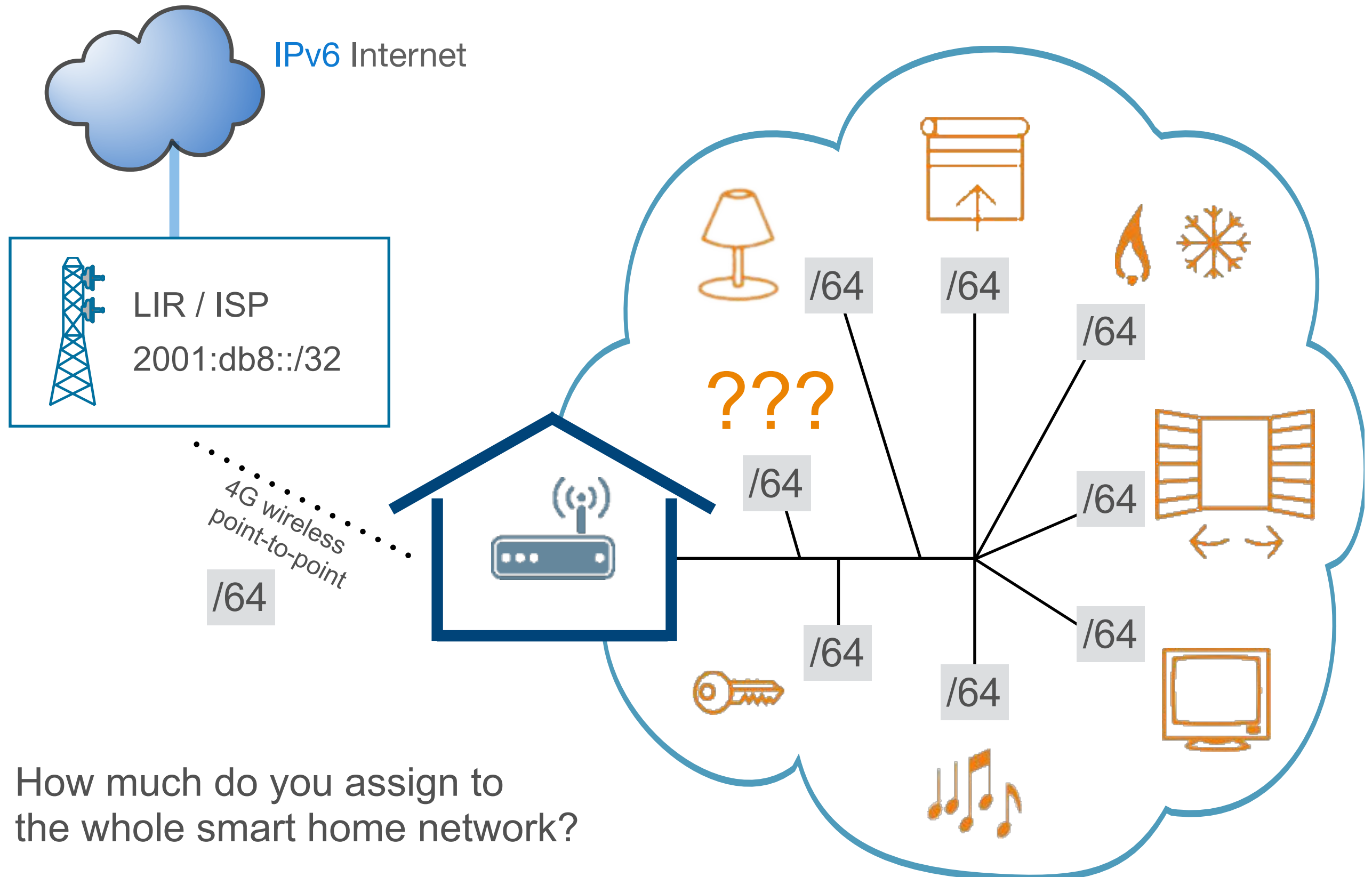
Making Assignments Exercise



Smart Home 6!

- 20 minutes preparation time
- 10 minutes discussion

Smart Home 6 Network Diagram



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

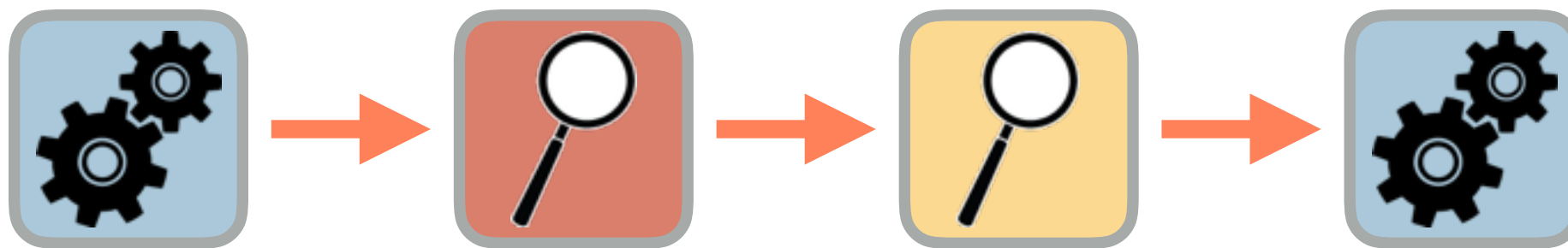


- Address Autoconfiguration
 - Supported by Neighbor Discovery
 - Stateless - with SLAAC
 - Stateful - with DHCPv6
- Neighbor Discovery Protocol
 - Replaces ARP from IPv4
 - Uses ICMPv6 and Multicast
 - Finds the other IPv6 devices on the link
 - Keeps track of reachability

The Autoconfiguration Process



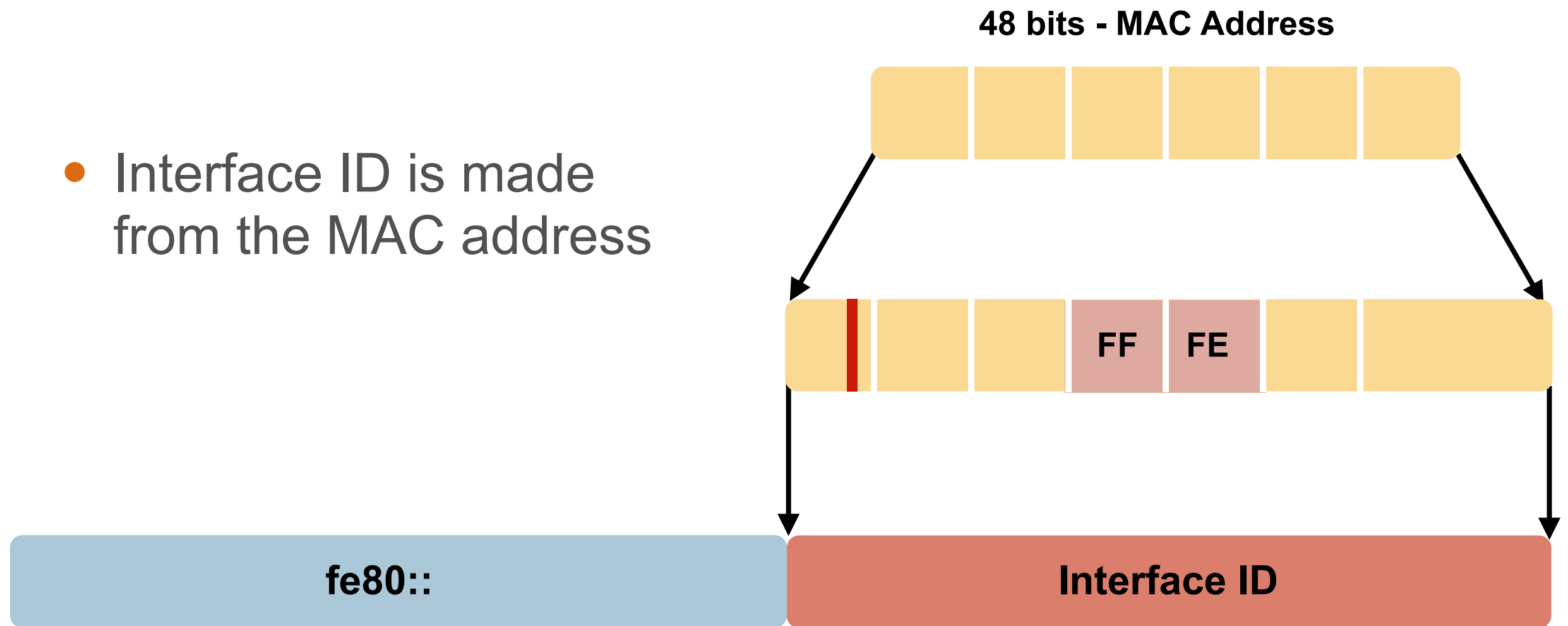
1. Make a Link-Local address
2. Check for duplicates on the link
3. Search for a router
4. Make a Global Unicast address



Making a Link-Local Address



- Interface ID is made from the MAC address



- $\text{fe80::} + \text{Interface ID} = \text{Link-Local address for the host}$

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

IPv6 unicast address



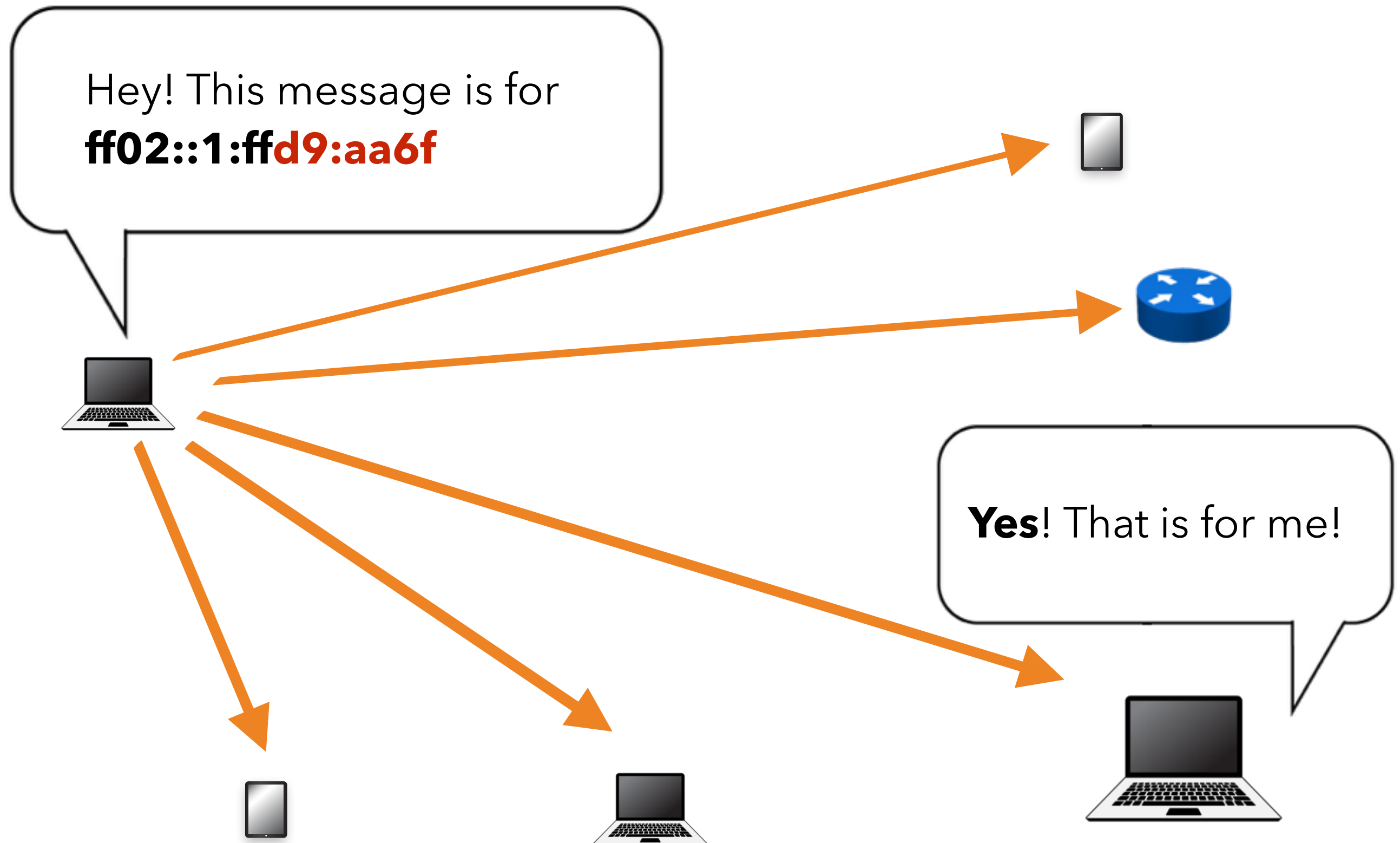
Solicited-node multicast address



128 bits



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)

Link Prefix

Interface ID

Global Unicast IPv6 Address

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

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





Deploying IPv6

Section 6

Privacy Extensions for SLAAC



- Provides privacy for users
- Changes the interface ID over time
- Duplicate Address Detection ensures uniqueness
- In case of collision, a new random address is generated

64 bits stay the same

64 bits change over period of time

Link Prefix

Random Interface ID

Global Unicast IPv6 Address

DHCPv6



- Used to give additional information like DNS servers or to manage the address pool
- Router Advertisement message contains hints
 - If “managed config” flag is set to ‘1’, the host can use DHCPv6 to get an address
 - Optionally the address of a DNS server (RFC 6106)
- Using additional flags, the network admin can disable SLAAC and force DHCPv6

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.4.0.0.0.1.c.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.4.0.0.0.1.c.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

IPv6 in the Routing Registry



Route6 object:

```
route6:      2001:db8::/32
origin:      AS65550
```

Aut-num object:

```
aut-num:     AS65550
mp-import:   afi ipv6.unicast from AS64496 accept ANY
mp-export:   afi ipv6.unicast to AS64496 announce AS65550
```

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



Transition Mechanisms

Section 7

Transitioning: Solving Two Problems



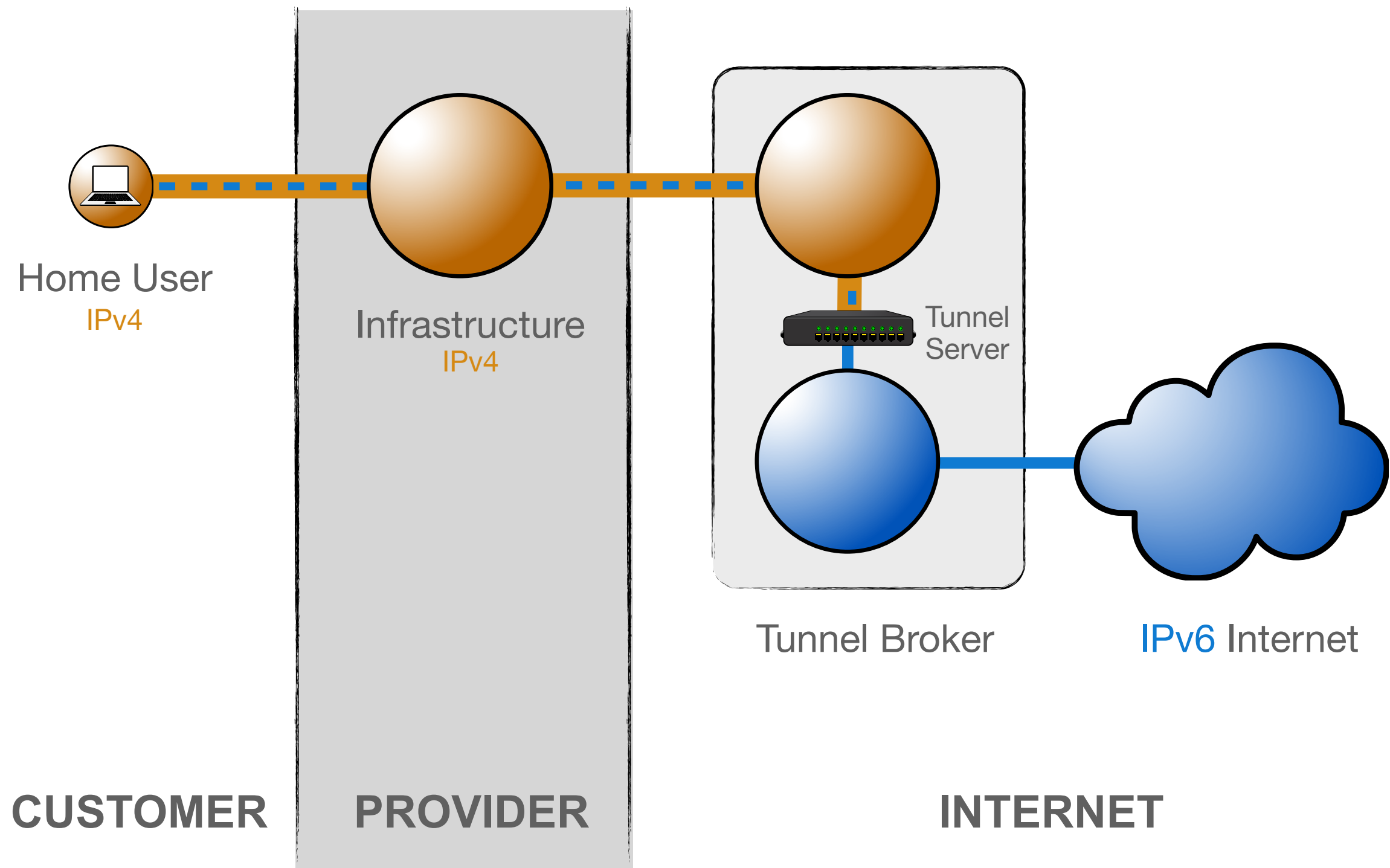
- Maintaining connectivity to IPv4 hosts by sharing IPv4 addresses between clients
 - Extending the address space with NAT/CGN/LSN
 - Translating between IPv6 and IPv4
- Provide a mechanism to connect to the emerging IPv6-only networks
 - Tunnelling IPv6 packets over IPv4-only networks

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

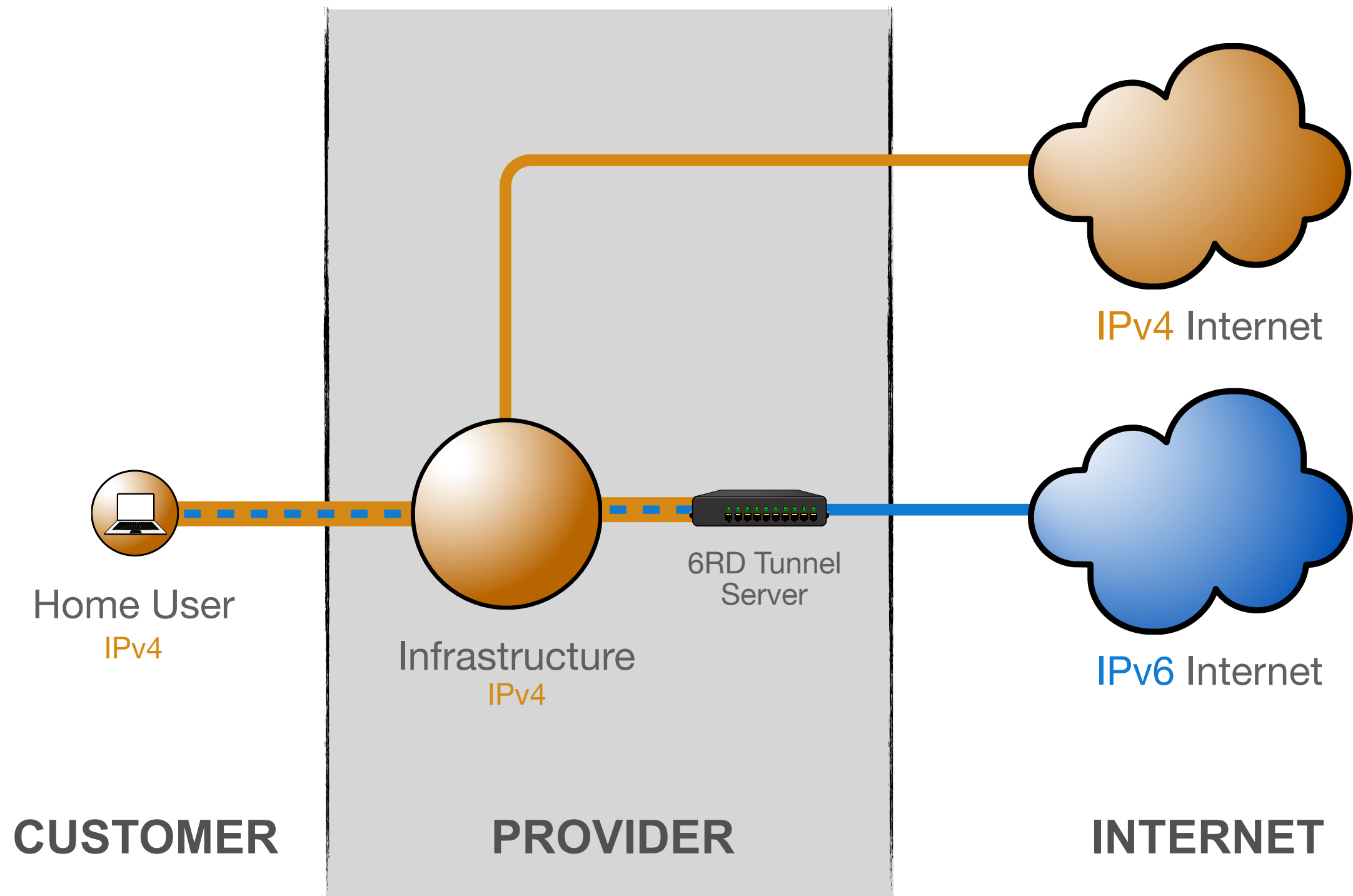


6RD



- 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

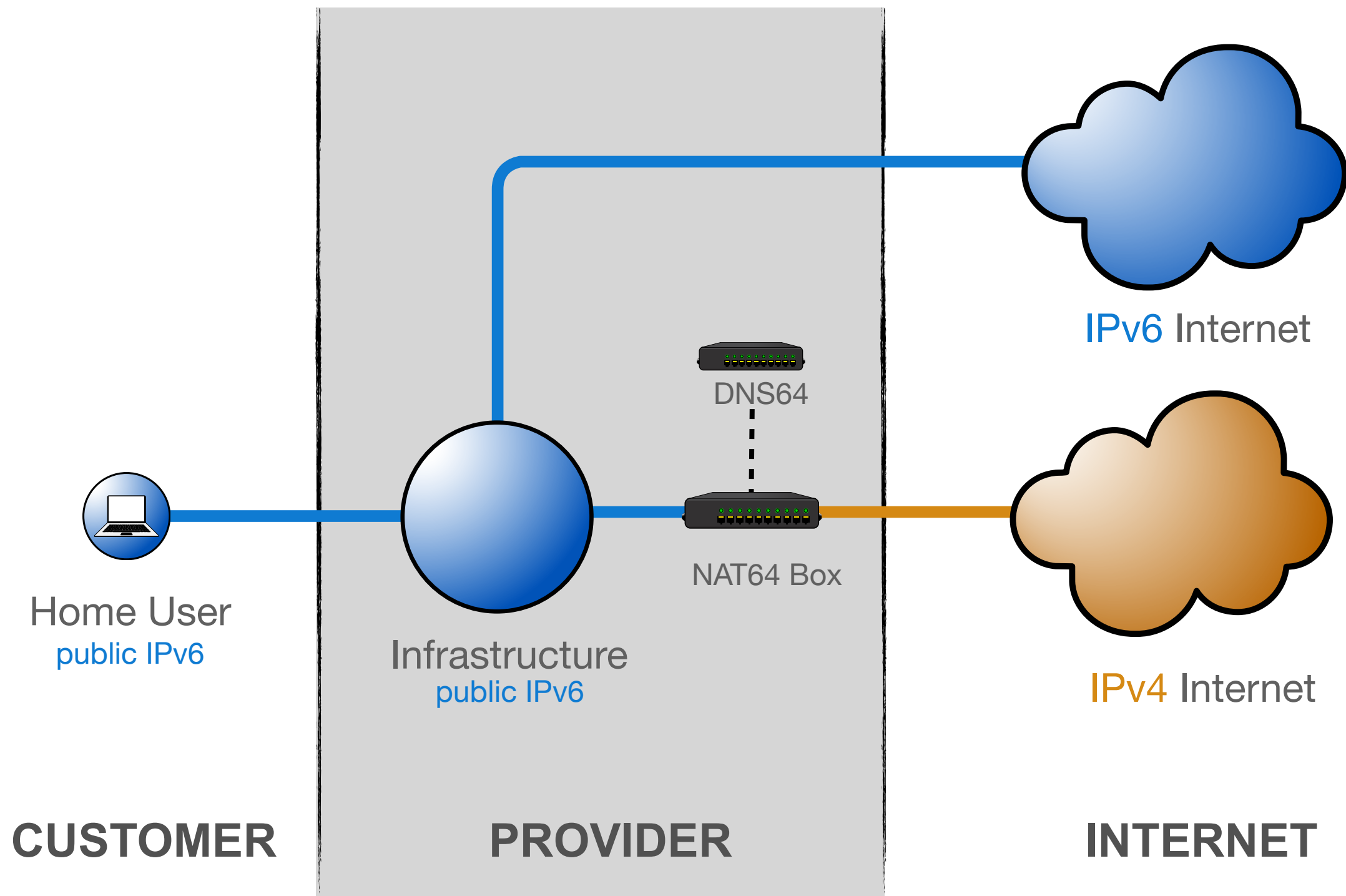


NAT64 / DNS64



- 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

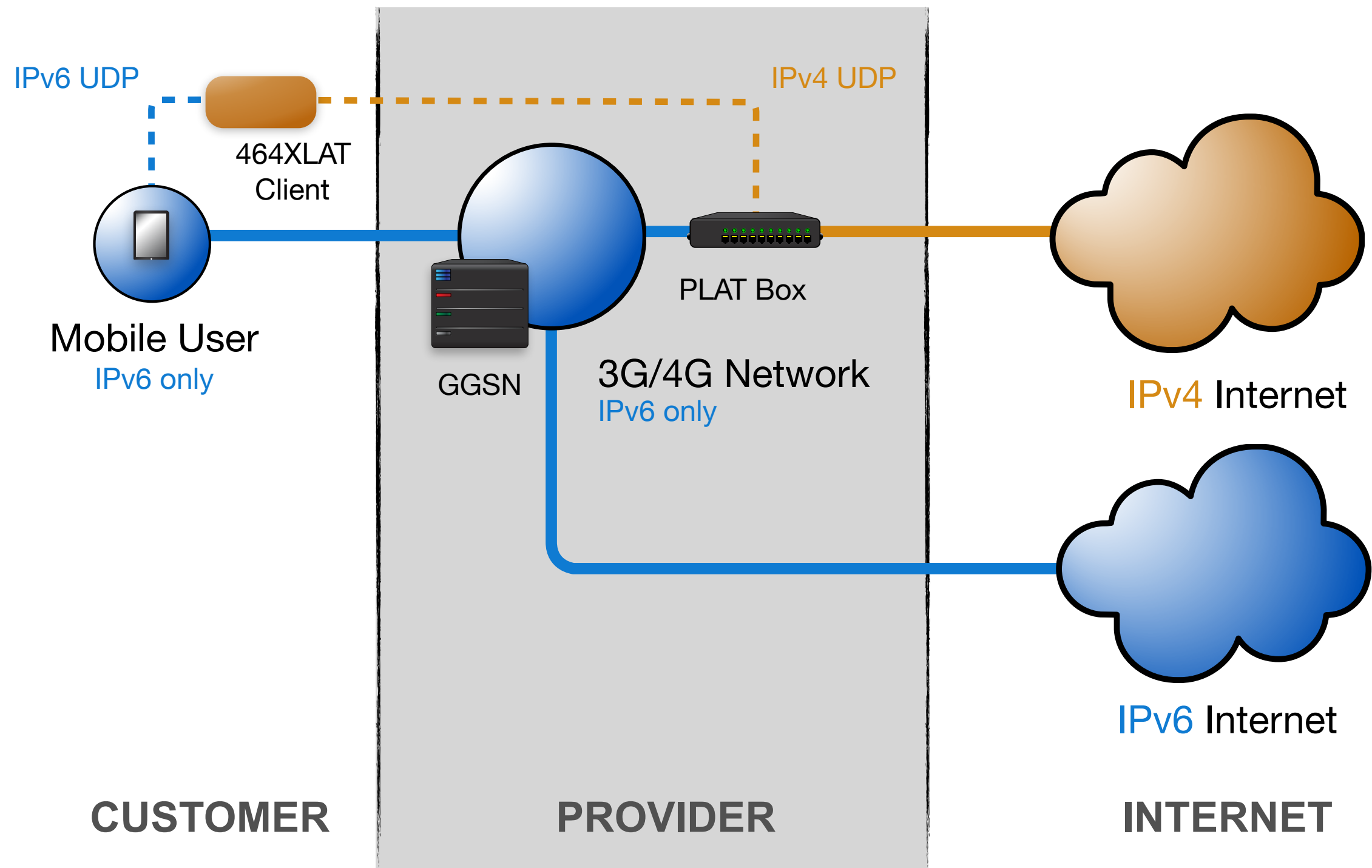


464XLAT



- 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

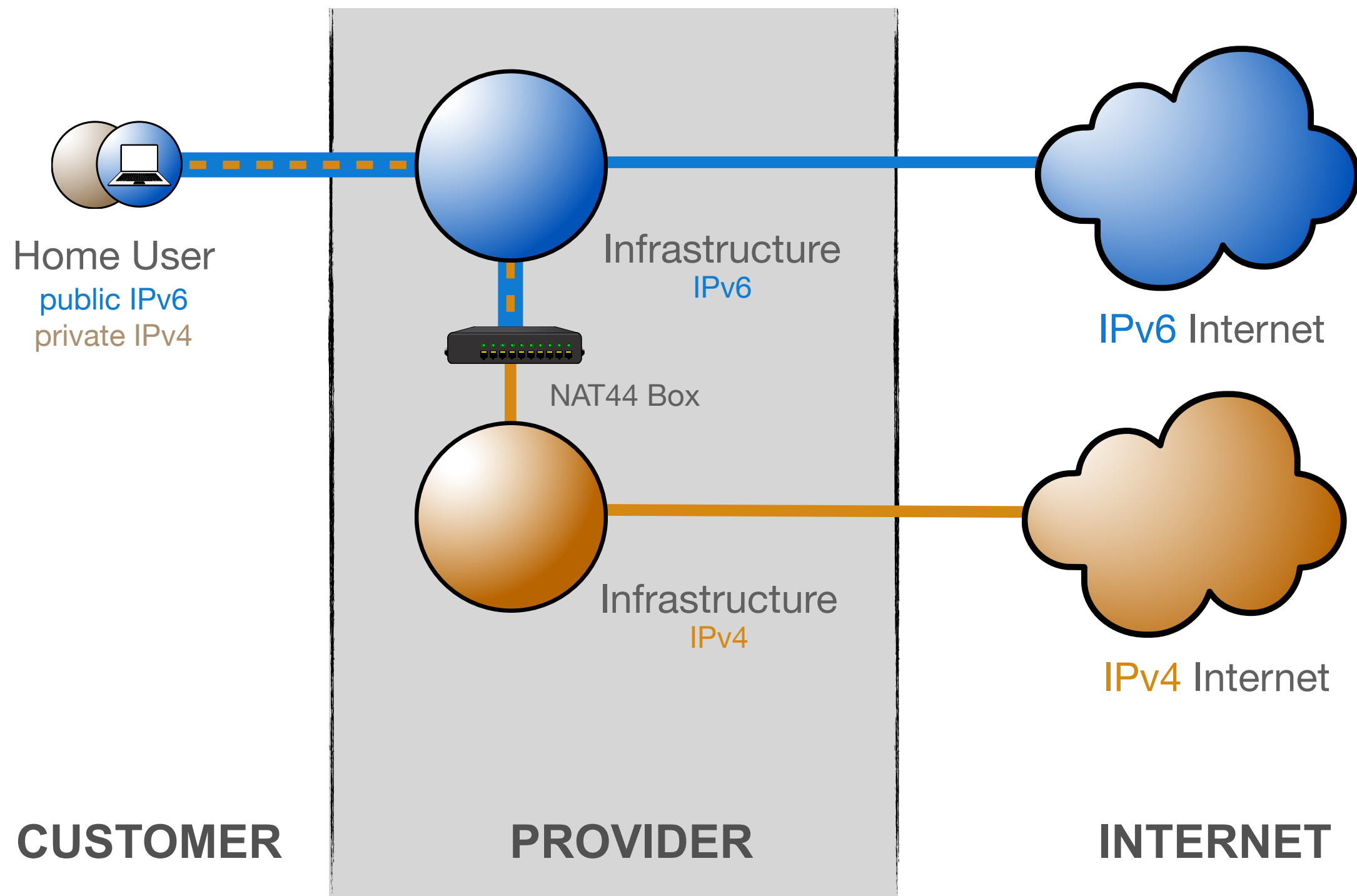


DS-lite



- 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

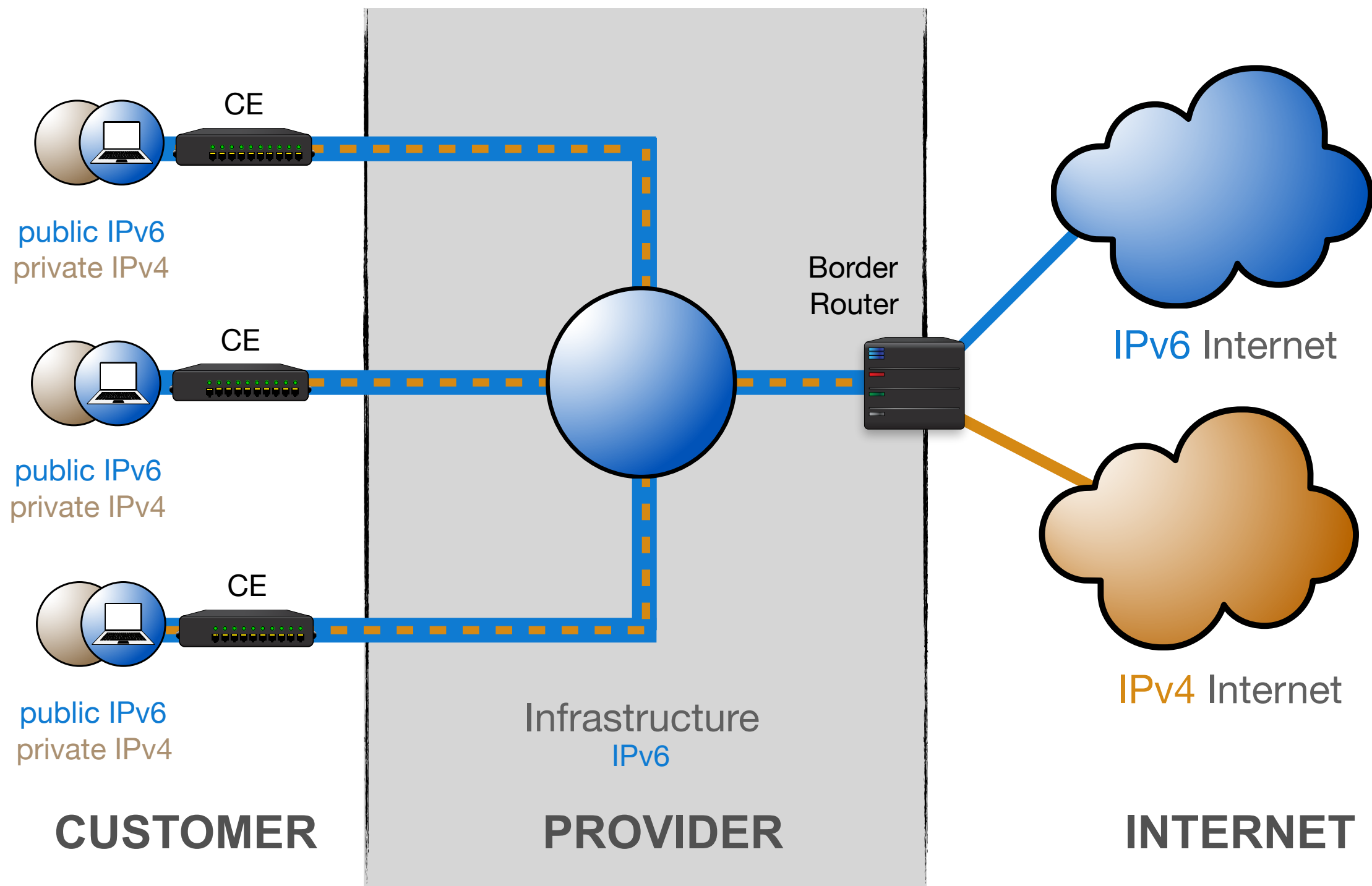


MAP-E / MAP-T



- 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

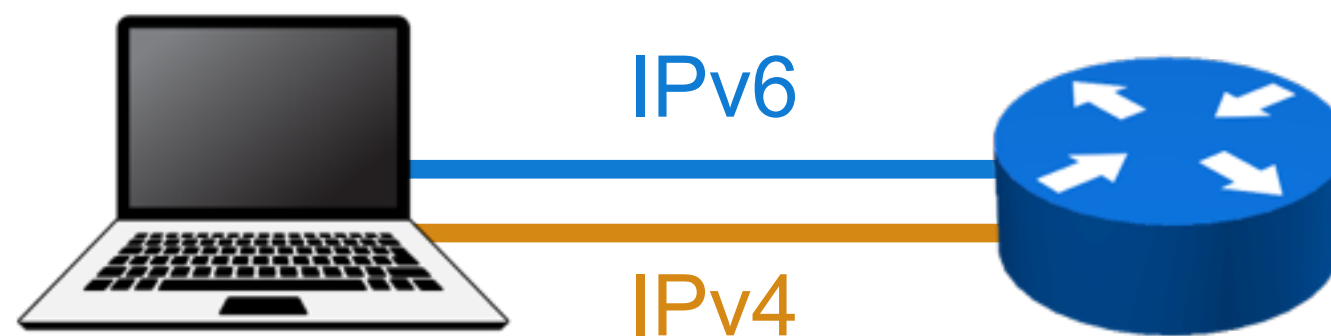
MAP-E / MAP-T



Best Transition Mechanism?



Dual Stack





Configuring a 6in4 Tunnel

Exercise

Exercise: Configuring a 6in4 tunnel



- Make sure you have connectivity
- Go to: workbench.ripe.net
- Your login is your number on participants list

Login: **X**
Password: **ipv6**

Choose “Tunnelling IPv6: 6in4” from the menu

Exercise: Configuring a 6in4 tunnel



- Login to the routers

Login: basicipv6_uX_r1
Password: ipv6

Login: basicipv6_uX_r2
Password: ipv6

Exercise: Configuring a 6in4 tunnel



- On both routers, execute:

```
configure terminal  
ipv6 unicast-routing  
ipv6 cef
```

Exercise: Configuring a 6in4 tunnel



- On router 1:

```
interface tunnel0  
no ip address  
ipv6 address 2001:db8:X::1/64  
tunnel source FastEthernet0/0  
tunnel mode ipv6ip  
tunnel destination 192.168.X.1
```

Exercise: Configuring a 6in4 tunnel



- On router 2:

```
interface tunnel0  
no ip address  
ipv6 address 2001:db8:X::2/64  
tunnel source FastEthernet0/0  
tunnel mode ipv6ip  
tunnel destination 10.0.X.1
```


Exercise: Configuring a 6in4 tunnel



- Testing the configuration

```
ping ipv6 2001:db8:X::1
```

and

```
ping ipv6 2001:db8:X::2
```



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



Deployment Challenges

Discussion

Deployment Challenges



- Think of a challenge/problem your organisation could have when you deploy IPv6
- Let's see if you can find solutions!



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>

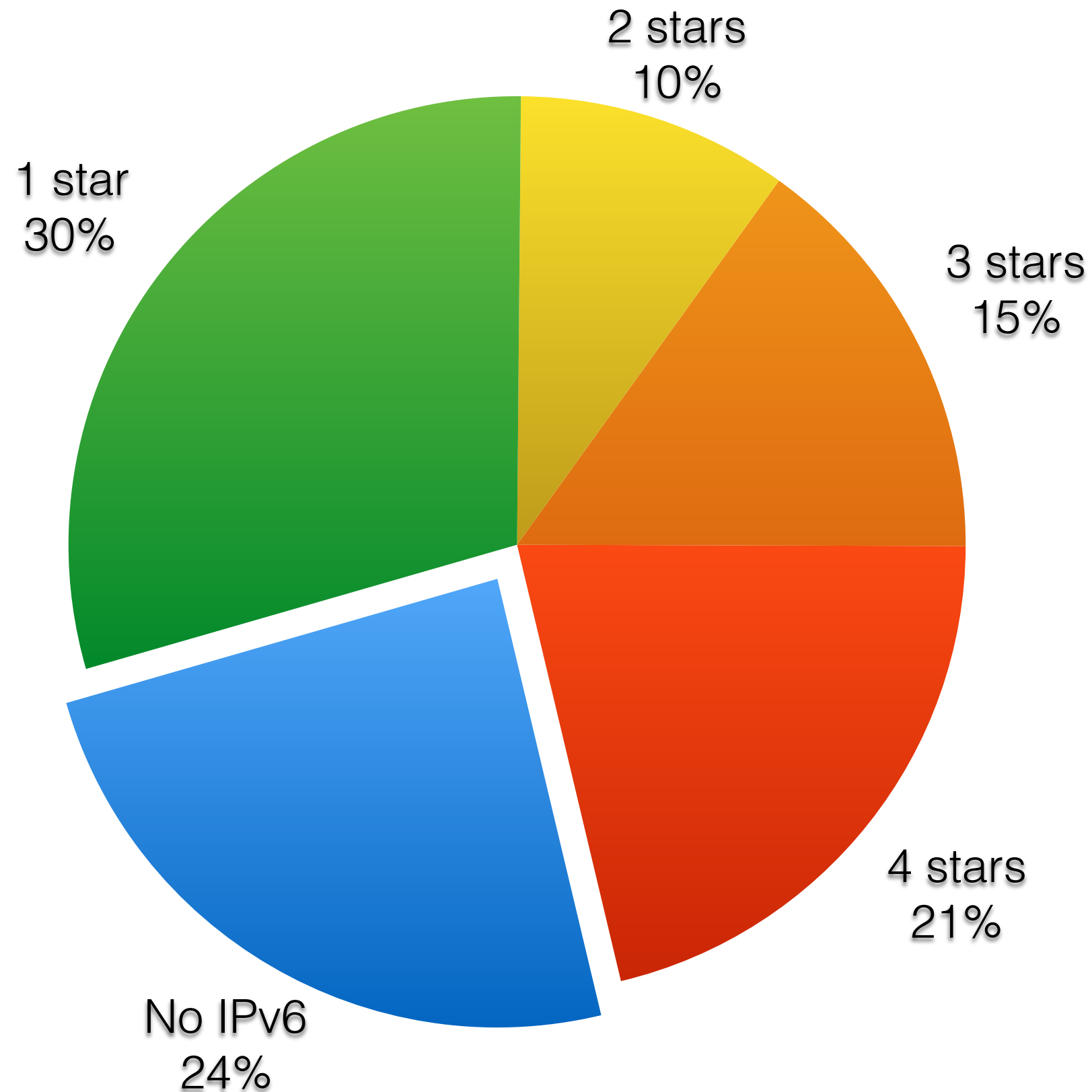


IPv6 Ripeness



- 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: 14273 LIRs



IPv6 RIPv6ness: 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
- New 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/basic-ipv6-training-course/Basic-IPv6-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





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Feedback!



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

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Konec Kraj Ěnn Fund پایان
Lõpp Beigas Vége Son An Críoch Kraj
Fine 𐤒𐤍𐤔𐤁 Endir Sfârșit Fin Τέλος
Einde Конец Slut Slutt
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