

# APNIC IPv6 Workshop

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# Overview

- Introduction to IPv6 and Protocol Architecture
- IPv6 Addressing and Subnetting
- IPv6 Host Configuration
- IPv6 Deployment Plan – Case Study
- IPv6 Deployment in IGP – Case Study
- IPv4 to IPv6 Transition Technologies
- IPv6 Deployment in EGP – Case Study
- IPv6 DNS

# Overview

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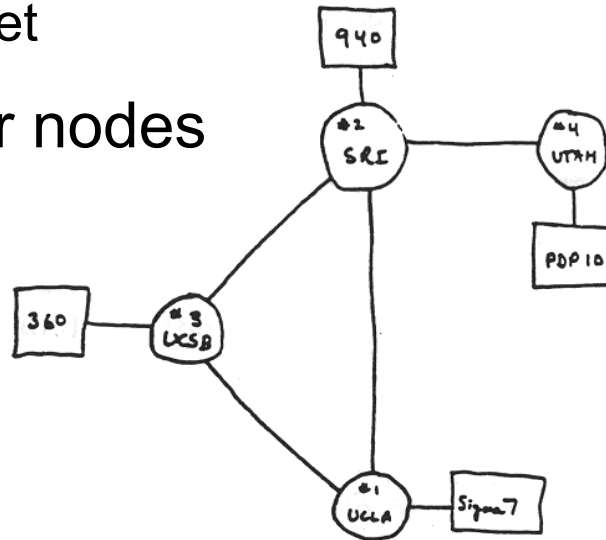
# Before IPv6



# In the beginning...

- 1968 - DARPA
  - (Defense Advanced Research Projects Agency) contracts with BBN to create ARPAnet

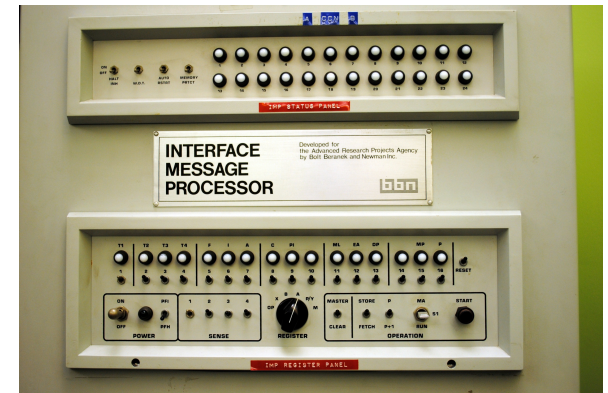
- 1969 – First four nodes



THE ARPA NETWORK

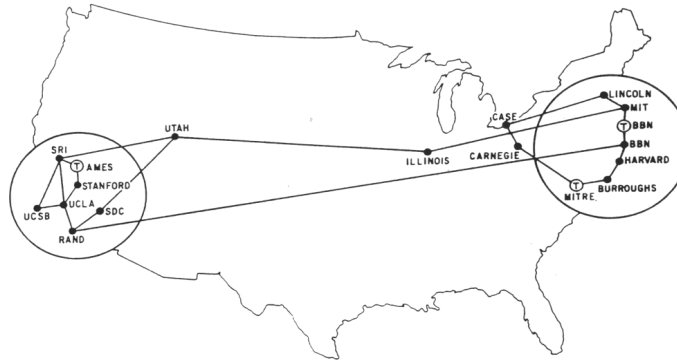
DEC 1969

4 NODES



# The Internet is born...

- 1970 - Five nodes:
  - UCLA – Stanford - UC Santa Barbara - U of Utah – BBN
- 1971 – 15 nodes, 23 hosts connected



- 1974 – TCP specification by Vint Cerf & Bob Kahn
- 1983 – TCP/IP
  - On January 1, the Internet with its 1000 hosts converts en masse to using TCP/IP for its messaging

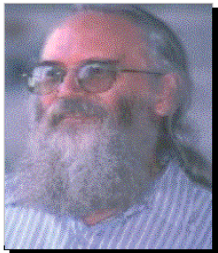
# Pre 1992

RFC 1020  
1987

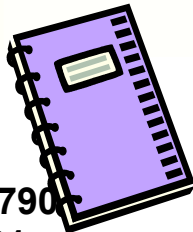
DDNIC



RFC 1261  
1991



RFC 790  
1981



“The assignment of numbers is also handled by Jon. If you are developing a protocol or application that will require the use of a link, socket, port, protocol, or network number **please contact Jon to receive a number assignment.**”

# Address Architecture - History

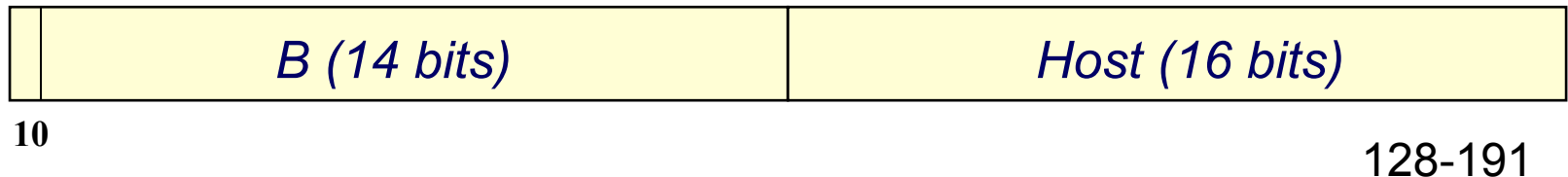
- Initially, only 256 networks in the Internet!
- Then, network “classes” introduced:
  - Class A (128 networks x 16M hosts)
  - Class B (16,384 x 65K hosts)
  - Class C (2M x 254 hosts)

# Address Architecture - Classful

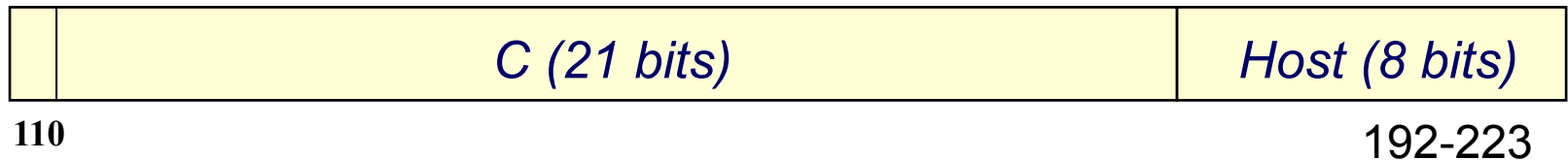
Class A: 128 networks x 16M hosts (50% of all address space)



Class B: 16K networks x 64K hosts (25%)



Class C: 2M networks x 254 hosts (12.5%)



# Internet Challenges 1992

- Address space depletion
  - IPv4 address space is finite
  - Historically, many wasteful allocations
- Routing chaos
  - Legacy routing structure, router overload
  - CIDR & aggregation are now vital
- Inequitable management
  - Unstructured and wasteful address space distribution

# Classless & Classful addressing

Best Current Practice

## Classful



Obsolete

- *inefficient*
- *depletion of B space*
- *too many routes from C space*

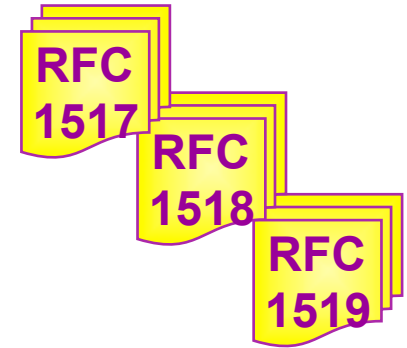
## Classless

Addresses	Prefix	Classful	Net Mask
...	...	...	...
8	/29		255.255.255.248
16	/28		255.255.255.240
32	/27		255.255.255.224
64	/26		255.255.255.192
128	/25		255.255.255.128
256	/24	1 C	255.255.255.0
...	...	...	...
4096	/20	16 C's	255.255.240.0
8192	/19	32 C's	255.255.224
16384	/18	64 C's	255.255.192
32768	/17	128 C's	255.255.128
65536	/16	1 B	255.255.0.0
...	...	...	...

- Network boundaries may occur at *any* bit

# Evolution of Internet Resource Management

- 1993: Development of “CIDR”
  - addressed both technical problems



Address depletion

→ Through more accurate assignment

- variable-length network address

Routing table overload

→ Through address space aggregation

- “supernetting”



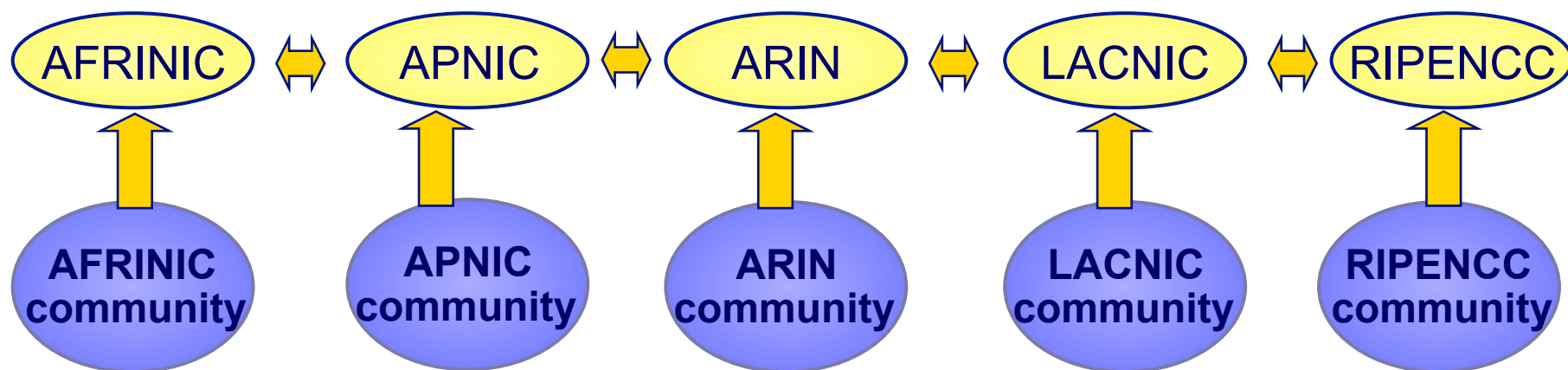
# Evolution of Internet Resource Management

- Administrative problems remained
  - Increasing complexity of CIDR-based allocations
  - Increasing awareness of conservation and aggregation
  - Need for fairness and consistency
- RFC 1366 (1992)
  - Described the “growth of the Internet and its increasing globalization”
  - Additional complexity of address management
  - Set out the basis for a regionally distributed Internet registry system



# Evolution of Address Policy

- Establishment of RIRs
  - Regional open processes
  - Cooperative policy development
  - Industry self-regulatory model
    - bottom up



# Intro to IPv6

# What is IPv6?

- **IP** stands for Internet Protocol which is one of the main pillars that supports the Internet today
- Current version of IP protocol is IPv4
- The new version of IP protocol is IPv6
- There is a version of IPv5 but it was assigned for experimental use [RFC1190]
- IPv6 was also called IPng in the early days of IPv6 protocol development stage

# Background of IPv6 Protocol

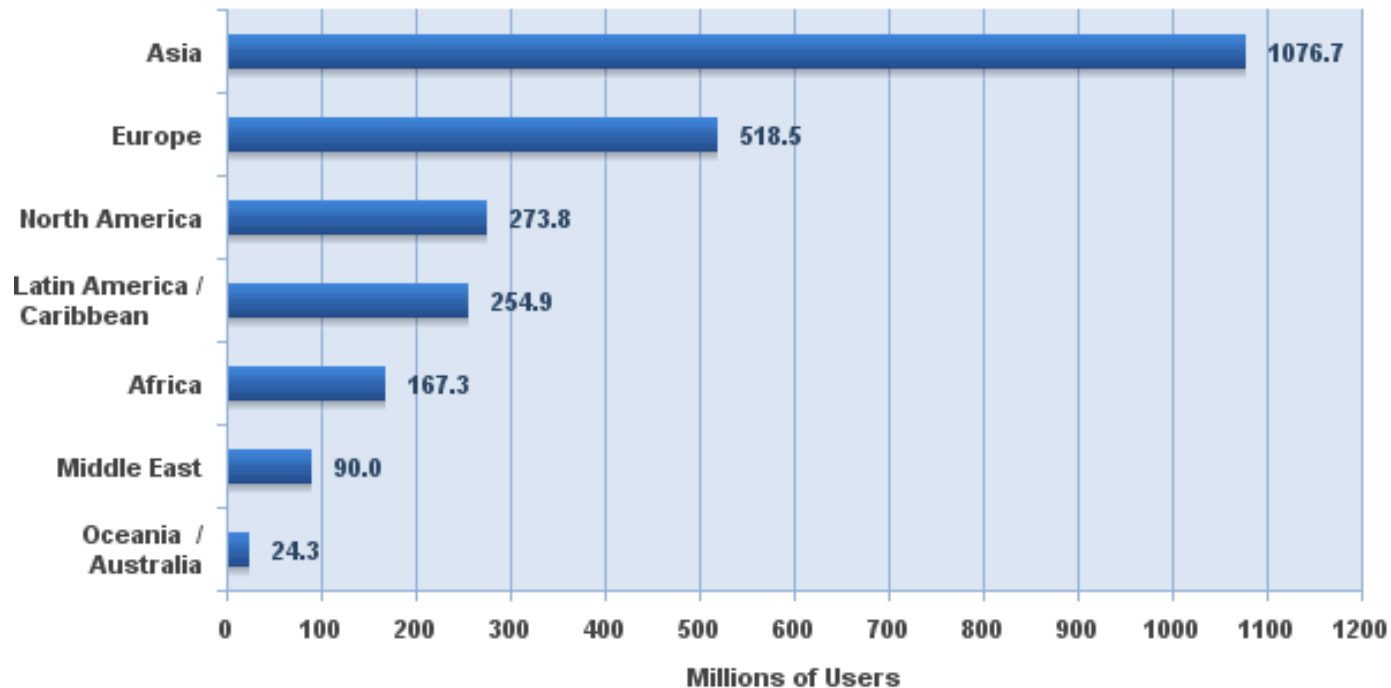
- August 1990
  - First wakeup call by Solensky in IETF on IPv4 address exhaustion
- December 1994
  - IPng area were formed within IETF to manage IPng effort [RFC1719]
  - List of technical criteria was defined to choose IPng [RFC1726]
- January 1995
  - IPng director recommendation to use 128 bit address [RFC1752]
- December 1995
  - First version of IPv6 address specification [RFC1883]
- December 1998
  - Updated version changing header format from 1st version [RFC2460]

# Motivation Behind IPv6 Protocol

- Plenty of address space (Mobile Phones, Tablet Computers, Car Parts, etc. 😊 )
- Solution of very complex hierarchical addressing need, which IPv4 is unable to provide
- End to end communication without the need of NAT for some real time application (i.e online transaction)
- Ensure security, reliability of data and faster processing of protocol overhead
- Stable service for mobile network (i.e Internet in airline, trains)

# World Internet Users Today

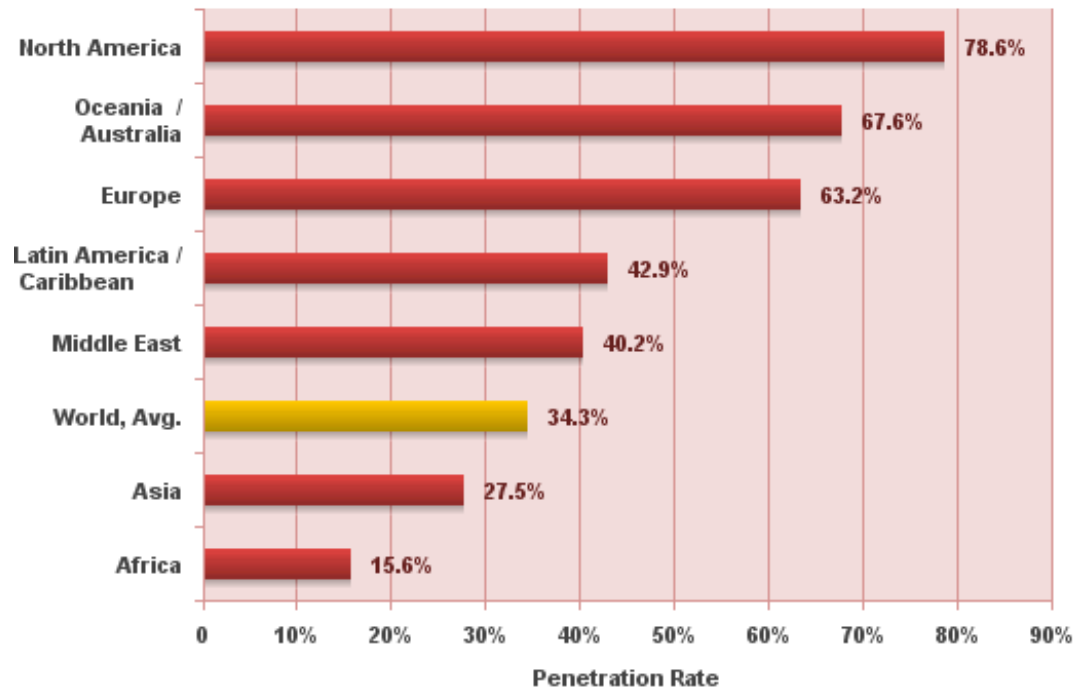
**Internet Users in the World  
by Geographic Regions - 2012 Q2**



Source: Internet World Stats - [www.internetworldstats.com/stats.htm](http://www.internetworldstats.com/stats.htm)  
2,405,518,376 Internet users estimated for June 30, 2012  
Copyright © 2012, Miniwatts Marketing Group

# World Internet Penetration Today

**World Internet Penetration Rates  
by Geographic Regions - 2012 Q2**

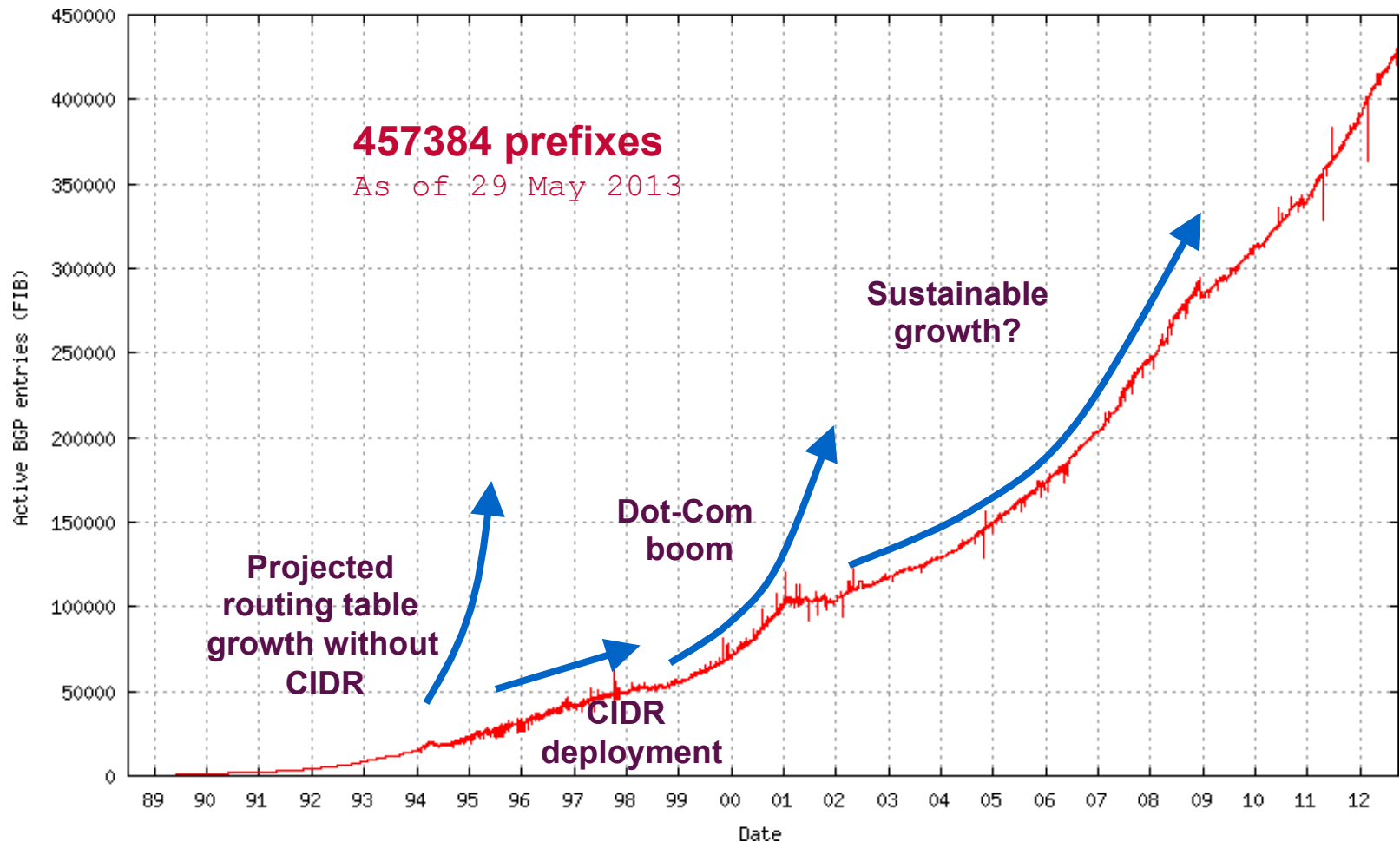


Source: Internet World Stats - [www.internetworldstats.com/stats.htm](http://www.internetworldstats.com/stats.htm)  
Penetration Rates are based on a world population of 7,017,846,922  
and 2,405,518,376 estimated Internet users on June 30, 2012.  
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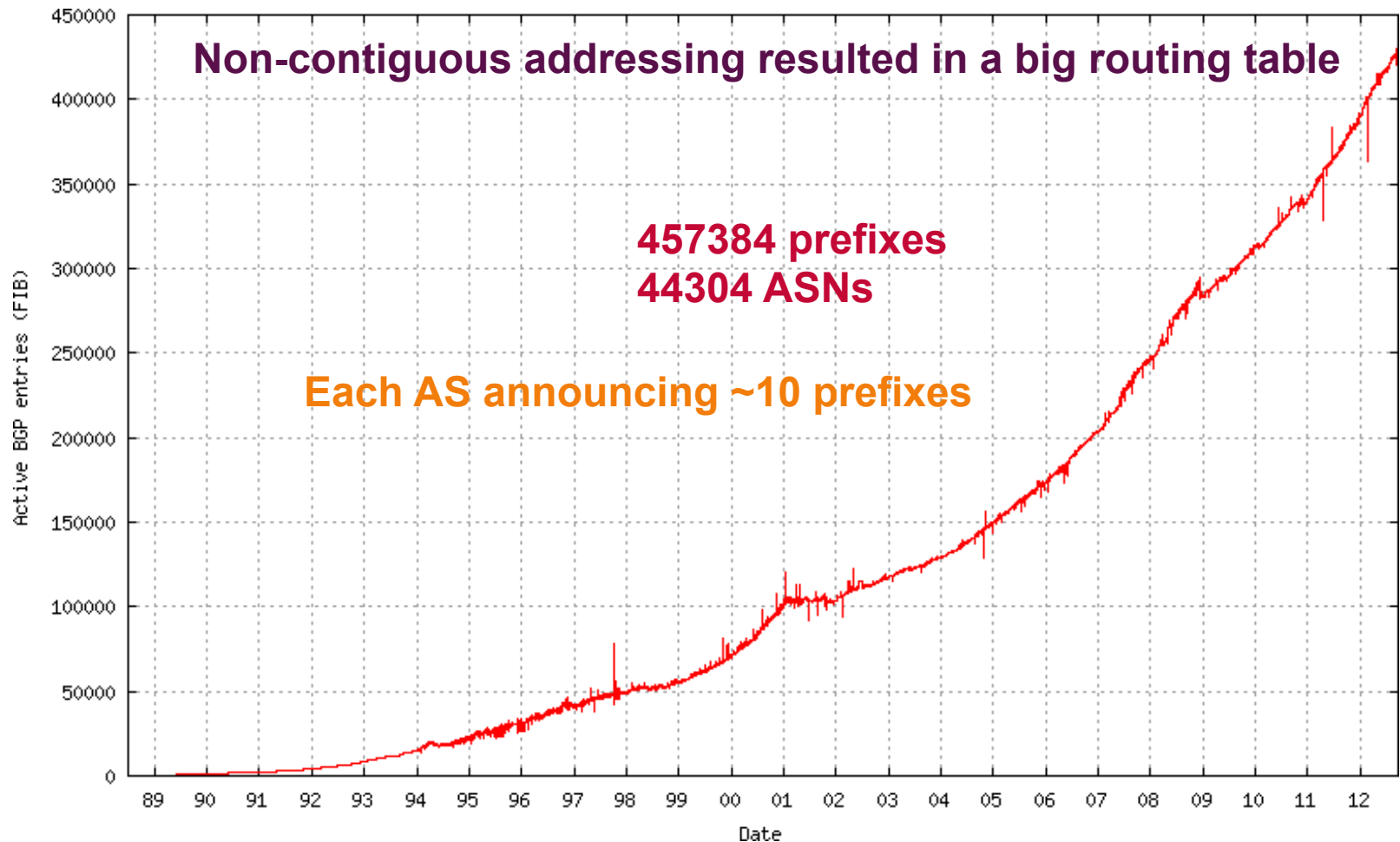


# Growth of the Global Routing Table

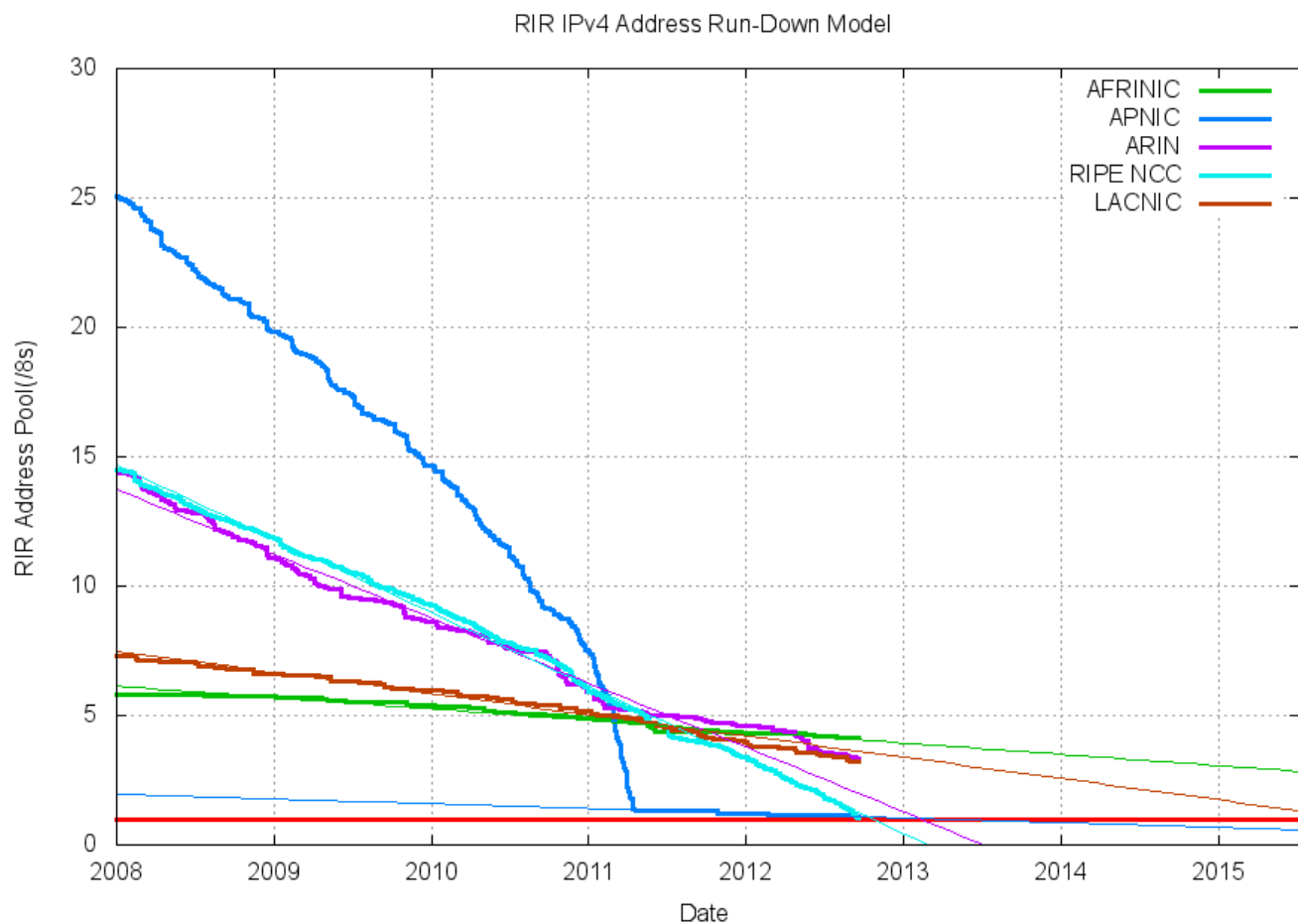
<http://bgp.potaroo.net/as1221/bgp-active.html>



# IPv4 BGP Table



# IPv4 Exhaustion



# New Functional Improvement

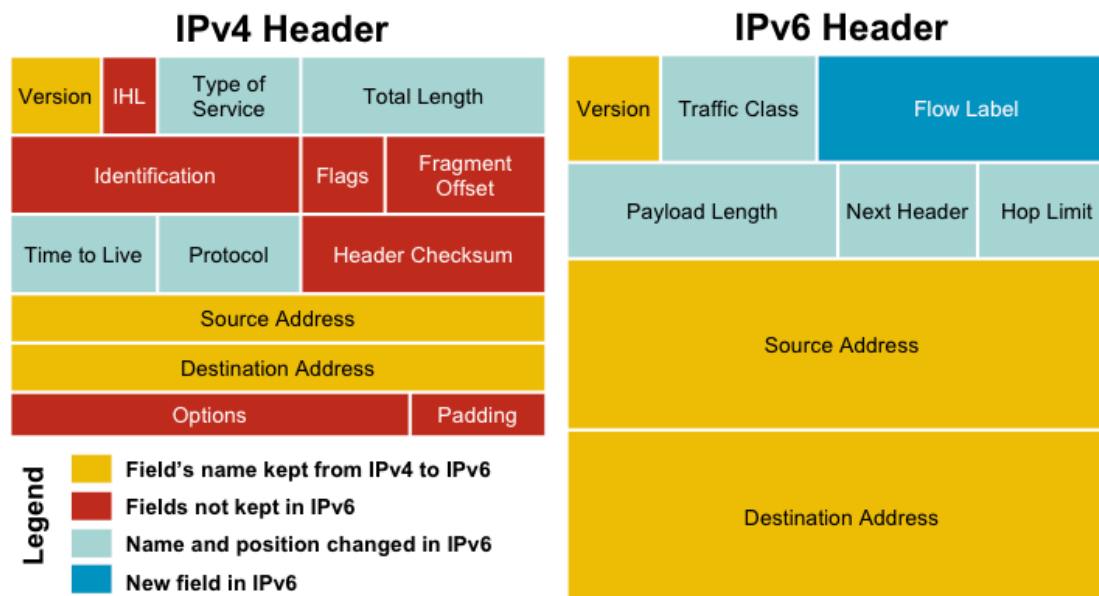
- Address Space
  - Increase from 32-bit to 128-bit address space
- Management
  - Stateless autoconfiguration means no more need to configure IP addresses for end systems, even via DHCP
- Performance
  - Fixed header size (40 bytes) and 64-bit header alignment mean better performance from routers and bridges/switches
- No hop-by-hop segmentation
  - Path MTU discovery

Source: <http://www.opus1.com/ipv6/whatisipv6.html>

# New Functional Improvement

- Multicast/Multimedia
  - Built-in features for multicast groups, management, and new "anycast" groups
- Mobile IP
  - Eliminate triangular routing and simplify deployment of mobile IP-based systems
- Virtual Private Networks
  - Built-in support for ESP/AH encrypted/ authenticated virtual private network protocols;
- Built-in support for QoS tagging
- No more broadcast

# Protocol Header Comparison



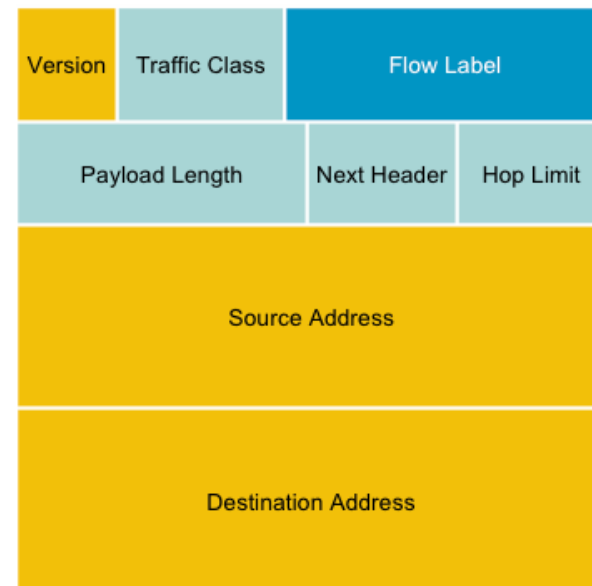
- IPv4 contains 10 basic header field
- IPv6 contains 6 basic header field
- IPv6 header has 40 octets in contrast to the 20 octets in IPv4
- So a smaller number of header fields and the header is 64-bit aligned to enable fast processing by current processors

Diagram Source: [www.cisco.com](http://www.cisco.com)

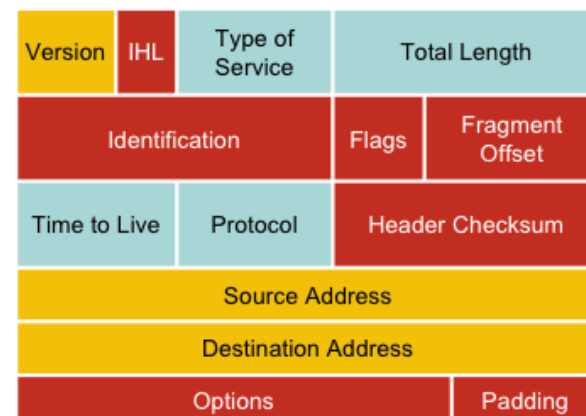
# IPv6 Protocol Header Format

- The IPv6 header fields:
- **Version**
  - A 4-bit field, same as in IPv4. It contains the number 6 instead of the number 4 for IPv4
- **Traffic class**
  - A 8-bit field similar to the type of service (ToS) field in IPv4. It tags packet with a traffic class that it uses in differentiated services (DiffServ). These functionalities are the same for IPv6 and IPv4.
- **Flow label**
  - A completely new 20-bit field. It tags a flow for the IP packets. It can be used for multilayer switching techniques and faster packet-switching performance

IPv6 Header



IPv4 Header



# IPv6 Protocol Header Format

- **Payload length**

- This 16-bit field is similar to the IPv4 Total Length Field, except that with IPv6 the Payload Length field is the length of the data carried after the header, whereas with IPv4 the Total Length Field included the header. 216 = 65536 Octets.

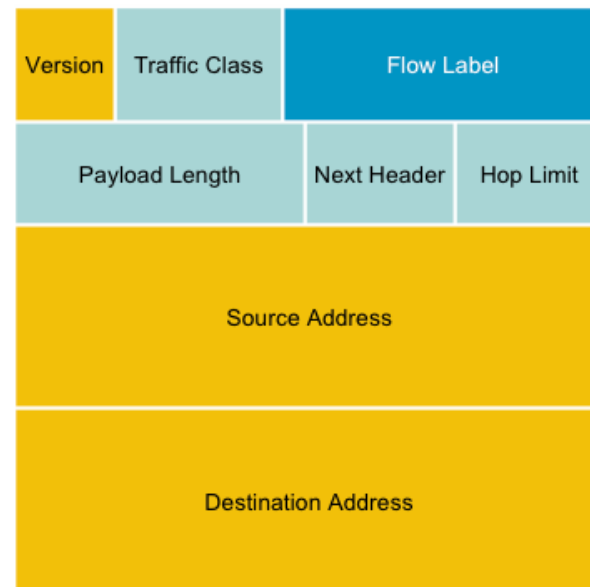
- **Next header**

- The 8-bit value of this field determines the type of information that follows the basic IPv6 header. It can be a transport-layer packet, such as TCP or UDP, or it can be an extension header. The next header field is similar to the protocol field of IPv4.

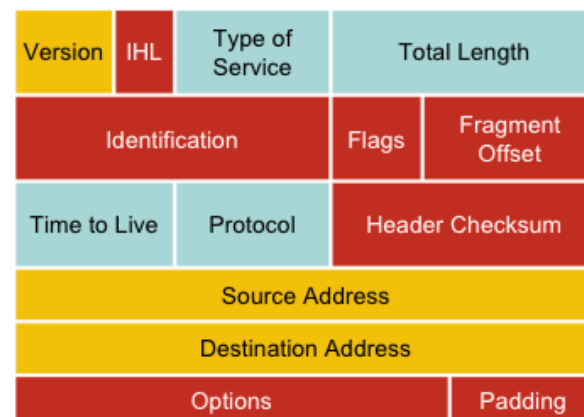
- **Hop limit**

- This 8-bit field defines by a number which count the maximum hops that a packet can remain in the network before it is destroyed. With the IPv4 TLV field this was expressed in seconds and was typically a theoretical value and not very easy to estimate.

IPv6 Header



IPv4 Header





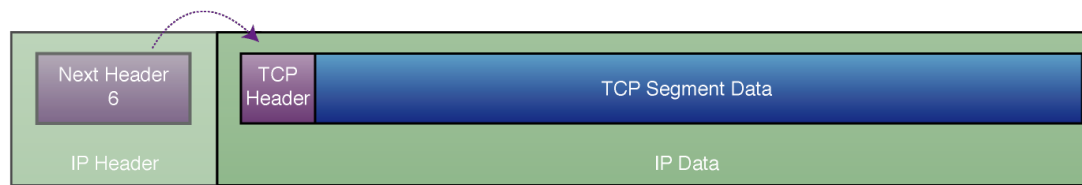
# IPv6 Extension Header

- Adding an optional Extension Header in IPv6 makes it simple to add new features in IP protocol in future without a major re-engineering of IP routers everywhere
- The number of extension headers are not fixed, so the total length of the extension header chain is variable
- The extension header will be placed in between main header and payload in an IPv6 packet

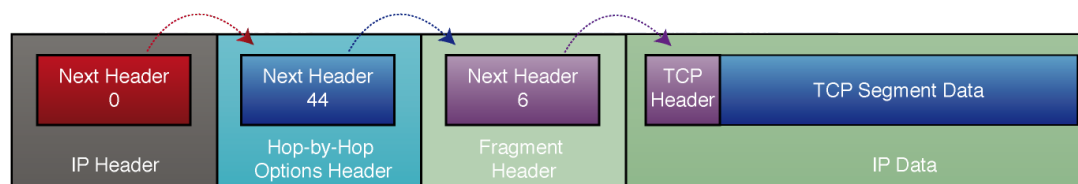
# IPv6 Extension Header

- If the Next Header field value (code) is 6, it determines that there is no extension header and the next header field is pointing to TCP header which is the payload of this IPv6 packet
- Code values of Next Header field:
  - 0 Hop-by-hop option
  - 2 ICMP
  - 6 TCP
  - 17 UDP
  - 43 Source routing
  - 44 Fragmentation
  - 50 Encrypted security payload
  - 51 Authentication
  - 59 Null (No next header)
  - 60 Destination option

# Link listed Extension Header



IPv6 Datagram With No Extension Headers Carrying TCP Segment



IPv6 Datagram With Two Extension Headers Carrying TCP Segment

- Link listed extension header can be used by simply using next header code value
- Above example use multiple extension header creating link list by using next header code value i.e 0 44 6
- The link list will end when the next header point to transport header i.e next header code 6

# Order Of Extension Header

- Source node follow the order:
  - 1. Hop-by-hop
  - 2. Routing
  - 3. Fragment
  - 4. Authentication
  - 5. Encapsulating security payload
  - 6. Destination option
  - 7. Upper-layer
- Order is important because:
  - Only hop-by-hop has to be processed by every intermediate nodes
  - Routing header need to be processed by intermediate routers
  - At the destination fragmentation has to be processed before others
  - This is how it is easy to implement using hardware and make faster processing engine

# Fragmentation Handling In IPv6

- Routers handle fragmentation in IPv4 which cause variety of processing performance issues
- IPv6 routers no longer perform fragmentation. IPv6 host use a discovery process [Path MTU Discovery] to determine most optimum MTU size before creating end to end session
- In this discovery process, the source IPv6 device attempts to send a packet at the size specified by the upper IP layers [i.e TCP/Application].
- If the device receives an ICMP packet too big message, it informs the upper layer to discard the packet and to use the new MTU.
- The ICMP packet too big message contains the proper MTU size for the pathway.
- Each source device needs to track the MTU size for each session.

# MTU Size Guideline

- MTU for IPv4 and IPv6
  - MTU is the largest size datagram that a given link layer technology can support [i.e HDLC]
  - Minimum MTU 68 Octet [IPv4] 1280 Octet [IPV6]
  - Most efficient MTU 576 [IPv4] 1500 [IPv6]
- Important things to remember:
  - Minimum MTU for IPv6 is 1280
  - Most efficient MTU is 1500
  - Maximum datagram size 64k
  - With IPv6 in IPv4 tunnel 1560 [Tunnel Source Only]

# IPv6 Header Compression

- IPv6 header size is double than IPv4
- Some time it becomes an issue on limited bandwidth link i.e Radio
- **Robust Header Compression [RoHC]** standard can be used to minimize IPv6 overhead transmission in limited bandwidth link
- RoHC is IETF standard for IPv6 header compression

# IPv6 Security Features

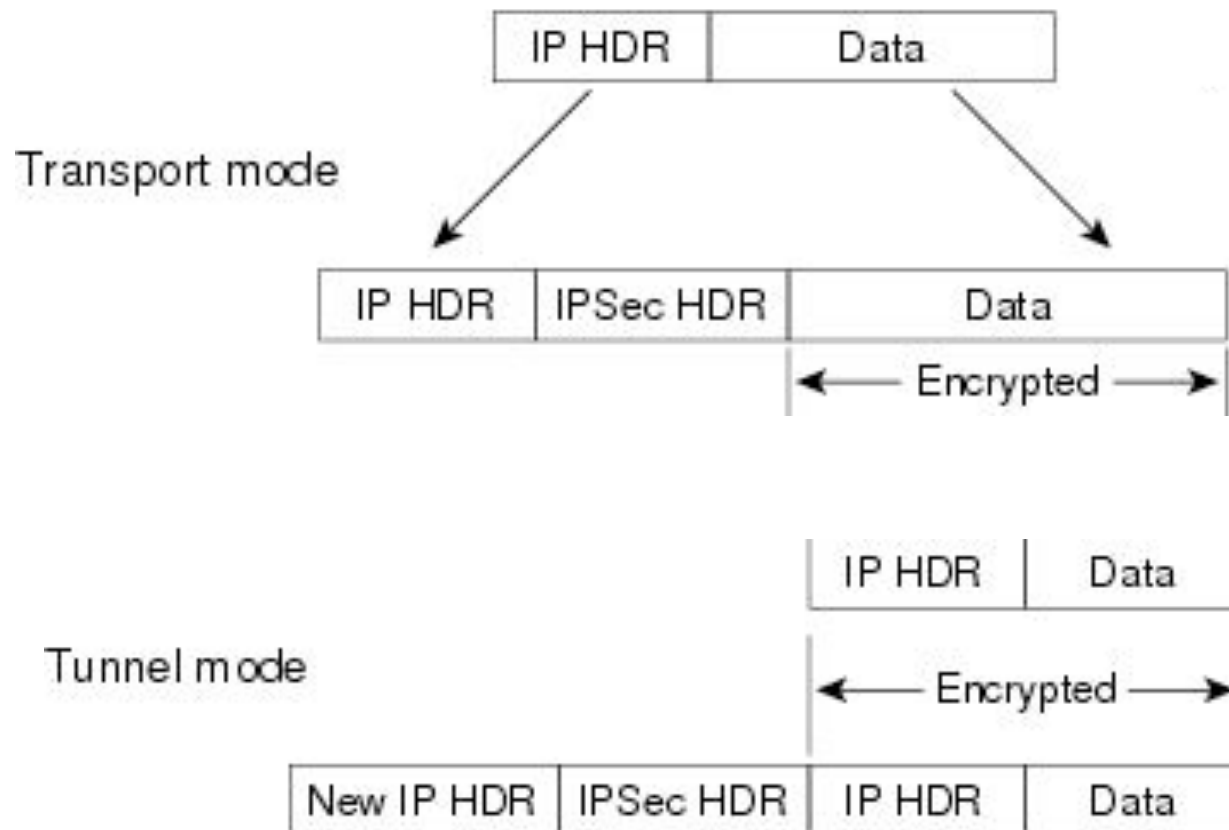
- IPsec is mandatory in IPv6
- Since IPsec become part of the IPv6 protocol all node can secure their IP traffic if they have required keying infrastructure
- In build IPsec does not replace standard network security requirement but introduce added layer of security with existing IP network



# IPsec Transport and Tunnel Mode

- IPsec has two mode of encapsulation
  - Transport mode  
Provide end to end security between two end station
  - Tunnel mode  
Provide secure connection between two gateway (router).  
Unencrypted data from end system go through encrypted tunnel provided by the source and destination gateways

# IPsec Transport and Tunnel Mode



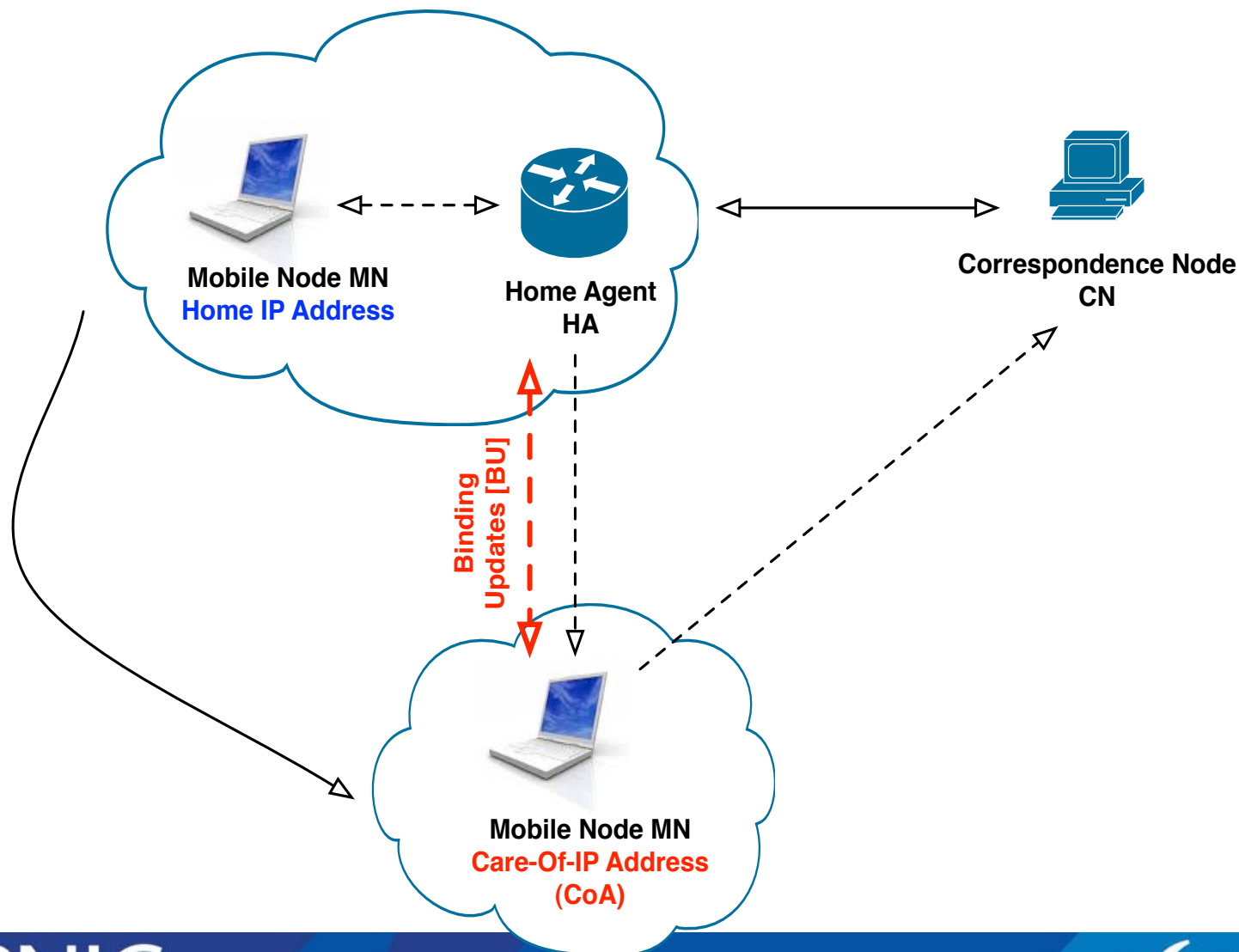
# IP Address Mobility

- IP address mobility is a mechanism that will sustain the IP connection even when the IP address change if the device move from one location to other location (subnet)
- IP address mobility is achieved by using Mobile IP
- Mobile IP is designed to work with both IPv4 [RFC3344] and IPv6 [RFC3775]
- Mobile IP operation is optimized for IPv6

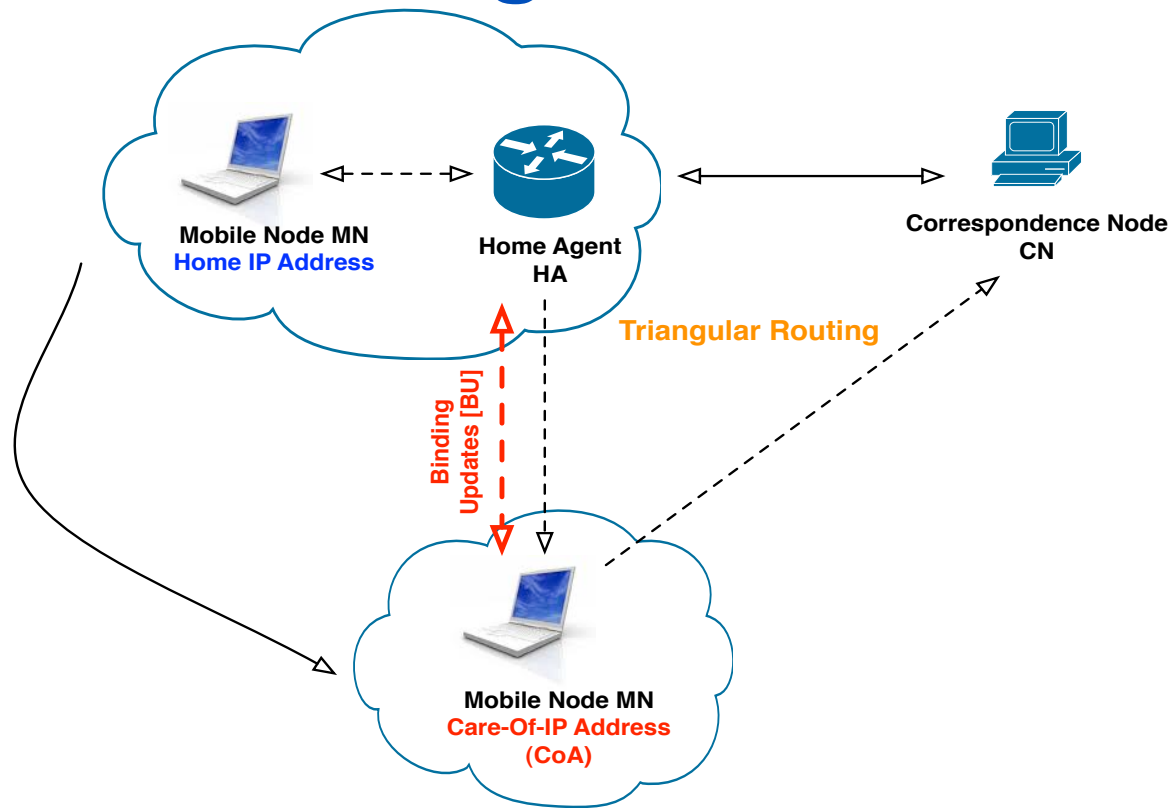
# IP Address Mobility Terminology

- Mobile Node [MN]
  - Is the mobile user
- Correspondent Node [CN]
  - Fixed [or may be mobile] user
- Home Agent [HA]
  - Usually a router in home representing MN
- Home IP Address
  - Primary (fixed) IP address of MN
- Care-Of-Address [CoA]
  - Secondary (variable) IP address of MN
- Binding Update [BU]
  - Process to register new IP address to HA [some time CN]

# Basic Mobile IP Operation

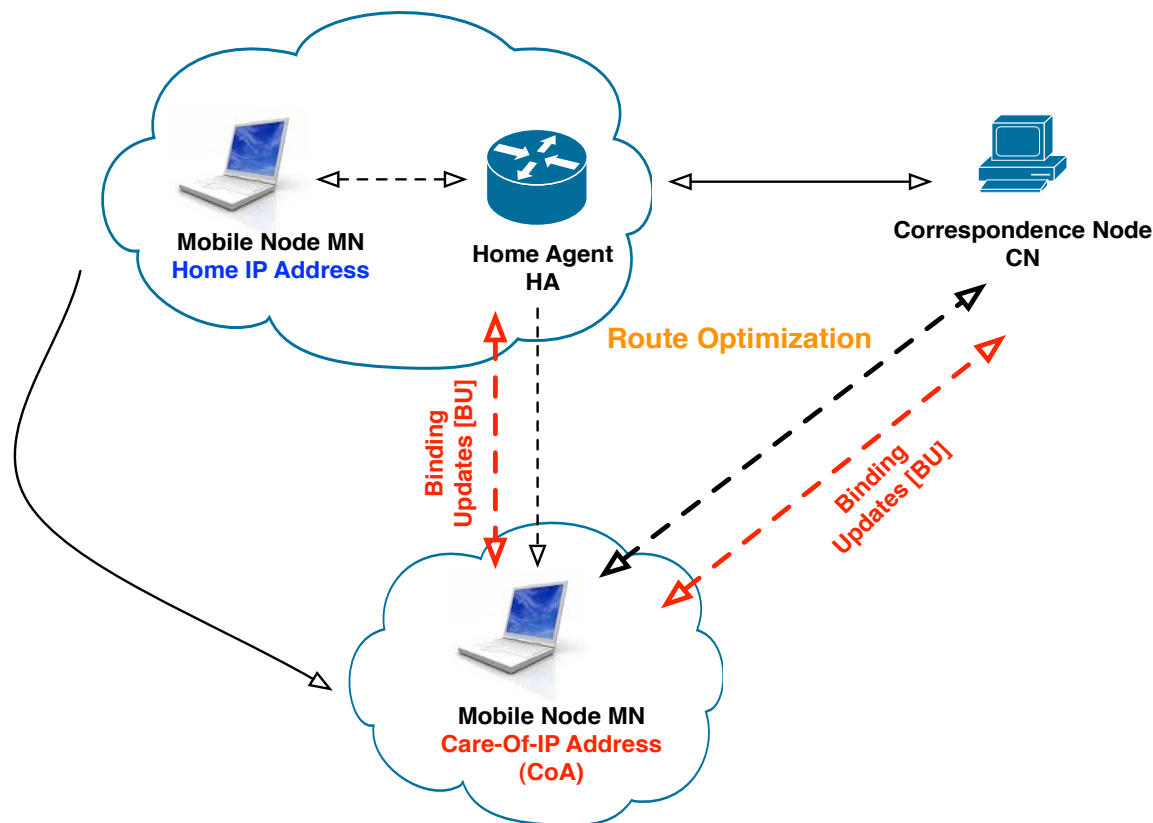


# Triangular Routing Issue



- Triangular routing creates delay which affects real time application i.e VoIP, streaming etc

# Route Optimization



- MN send BU to CN informing its CoA
- Direct data communication will start between MN and CN

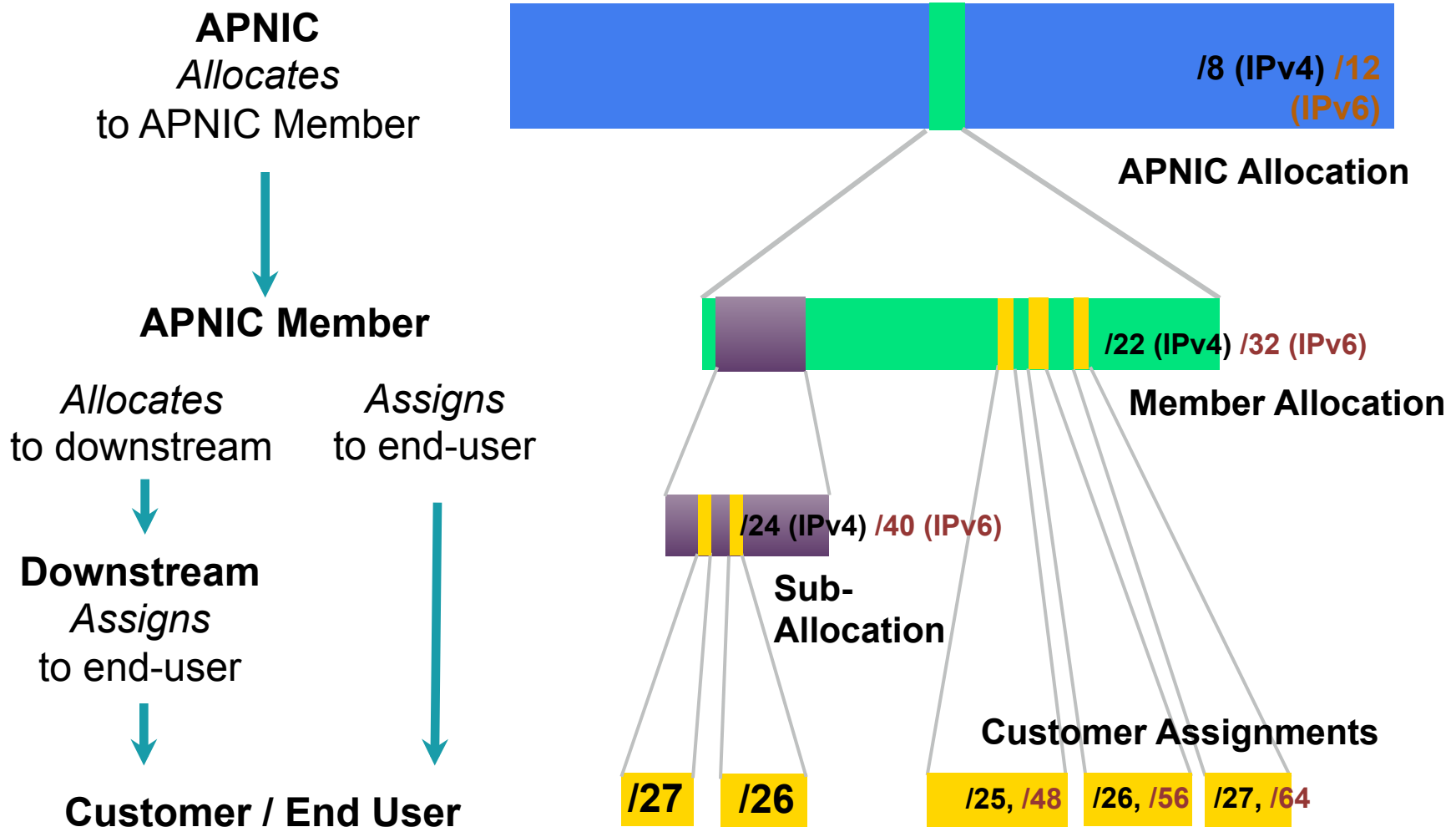
# IPv6 Resource Management



# Allocation And Assignment

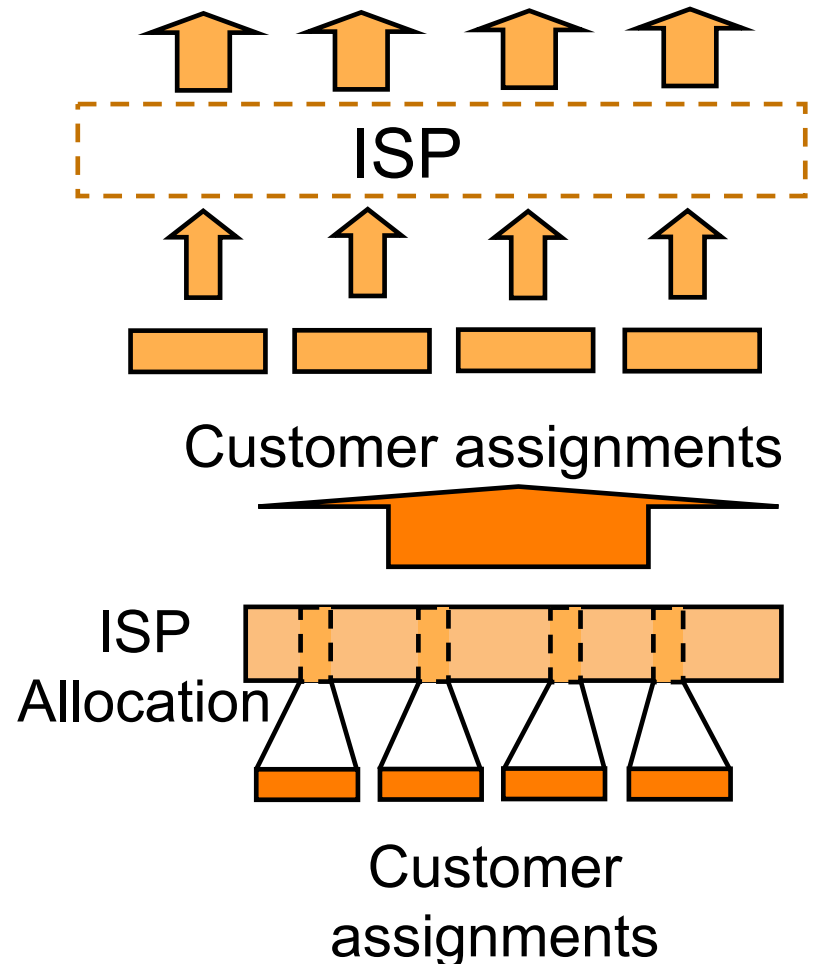
- Allocation
  - “A block of address space held by an IR (or downstream ISP) for subsequent allocation or assignment”
    - Not yet used to address any networks
- Assignment
  - “A block of address space used to address an operational network”
    - May be provided to ISP customers, or used for an ISP’s infrastructure (‘self-assignment’)

# Allocation and Assignment

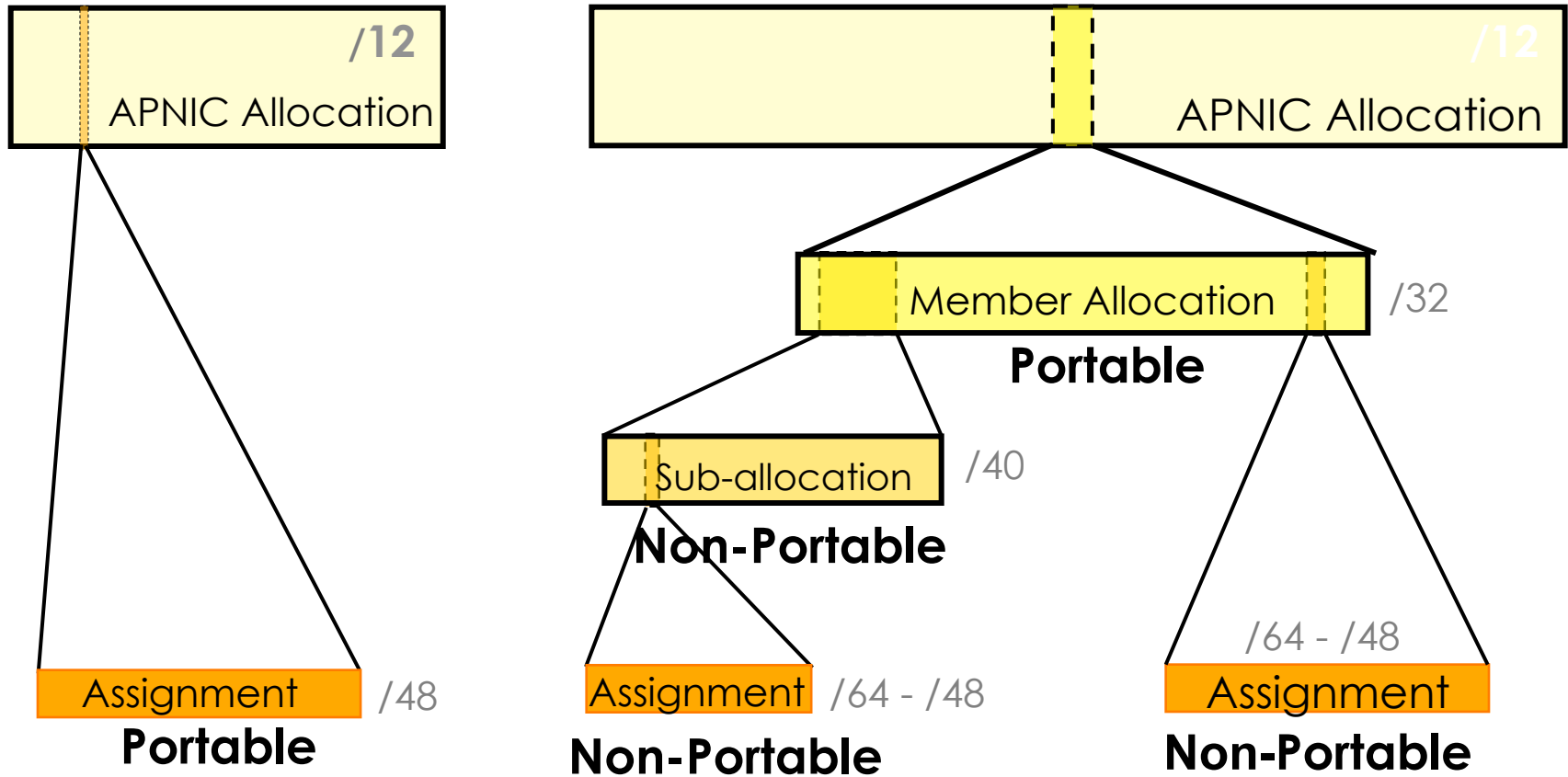


# Portable & non-portable

- Portable Assignments
  - Customer addresses independent from ISP
    - Keeps addresses when changing ISP
  - Bad for size of routing tables
  - Bad for QoS: routes may be filtered, flap-dampened
- Non-portable Assignments
  - Customer uses ISP's address space
    - Must renumber if changing ISP
  - Only way to effectively scale the Internet
- Portable allocations
  - Allocations made by APNIC/NIRs



# Address Management Hierarchy



Describes “portability” of the address space

# Internet Resource Management Objectives

## Conservation

- Efficient use of resources
- Based on demonstrated need

## Aggregation

- Limit routing table growth
- Support provider-based routing

## Registration

- Ensure uniqueness
- Facilitate trouble shooting

Uniqueness, fairness and consistency

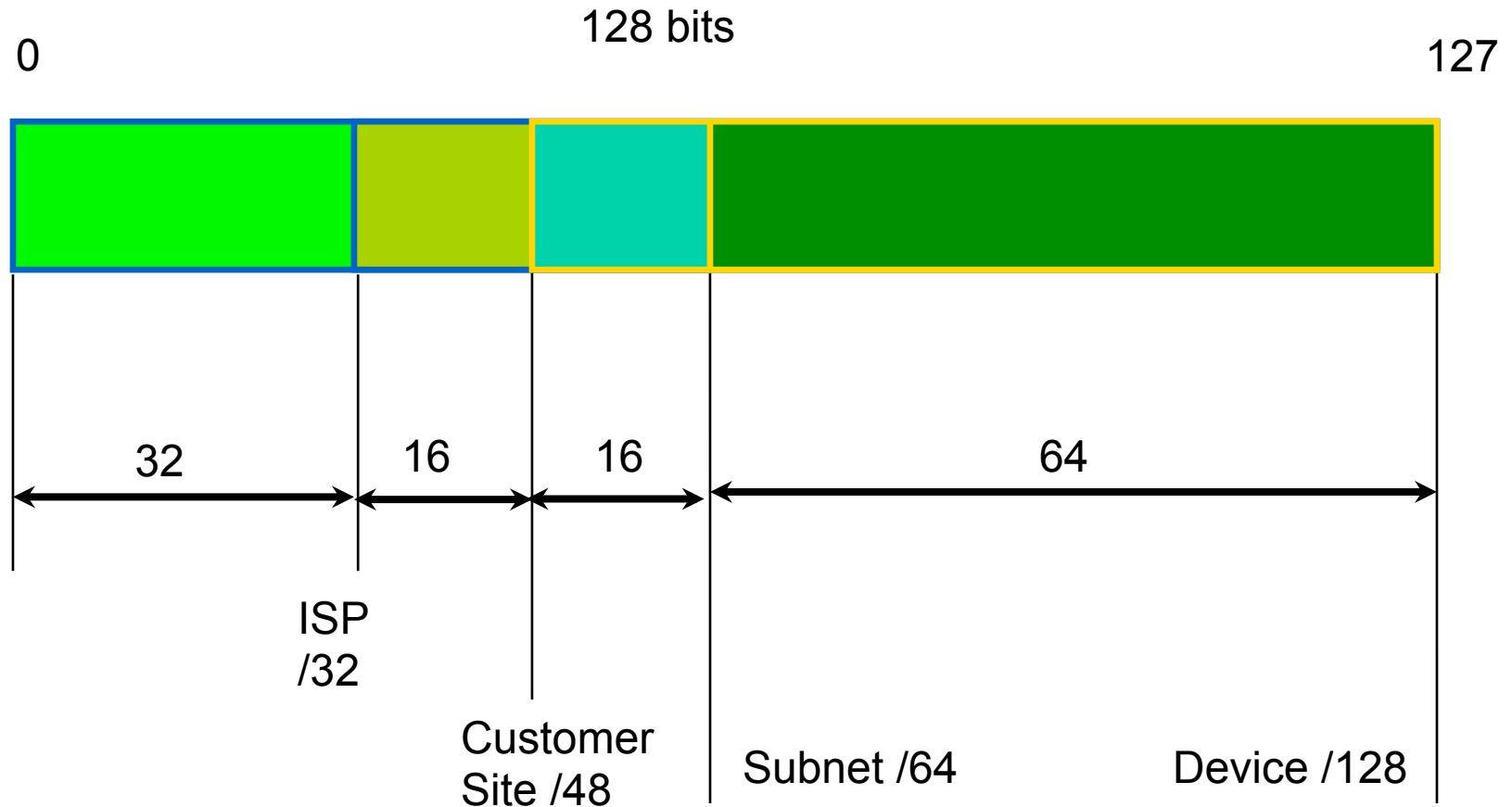
# Initial IPv6 Allocation

- To qualify for an initial allocation of IPv6 address space, an organization must:
  - Not be an end site (must provide downstream services)
  - Plan to provide IPv6 connectivity to organizations to which it will make assignments
- Meet one of the two following criteria:
  - Have a plan for making at least 200 assignments to other organizations within two years OR
  - Be an existing ISP with IPv4 allocations from an APNIC or an NIR, which will make IPv6 assignments or sub-allocations to other organizations and announce the allocation in the inter-domain routing system within two years

# “One Click” IPv6 Policy

- Members with IPv4 holdings can click the button in MyAPNIC to instantly receive their IPv6 block
  - No forms to fill out!
  - “Get your IPv6 addresses” icon in the main landing page at MyAPNIC
- A Member that has an IPv4 allocation is eligible for a /32
- A Member that has an IPv4 assignment is eligible for a /48

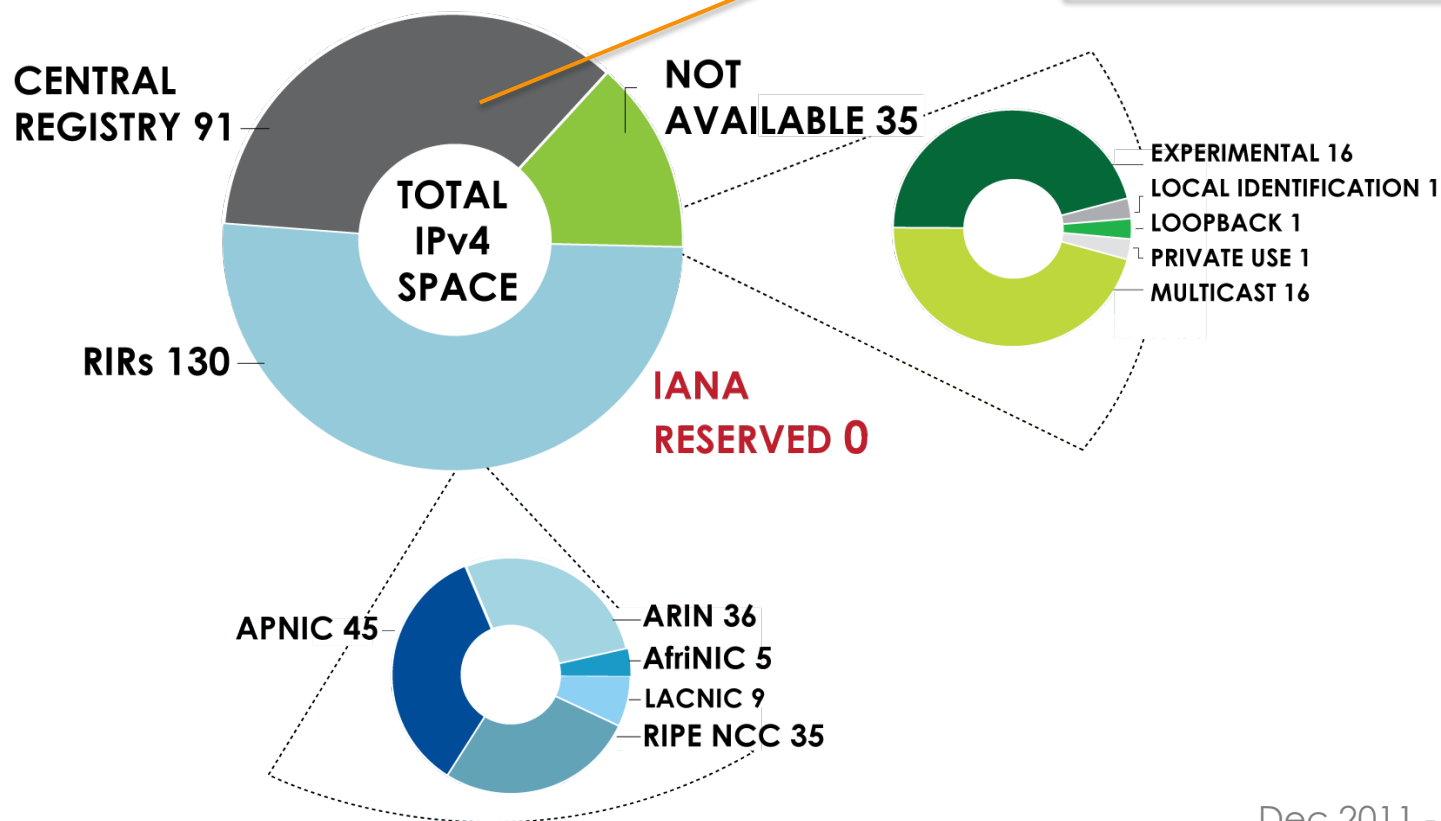
# IPv6 Addressing Structure





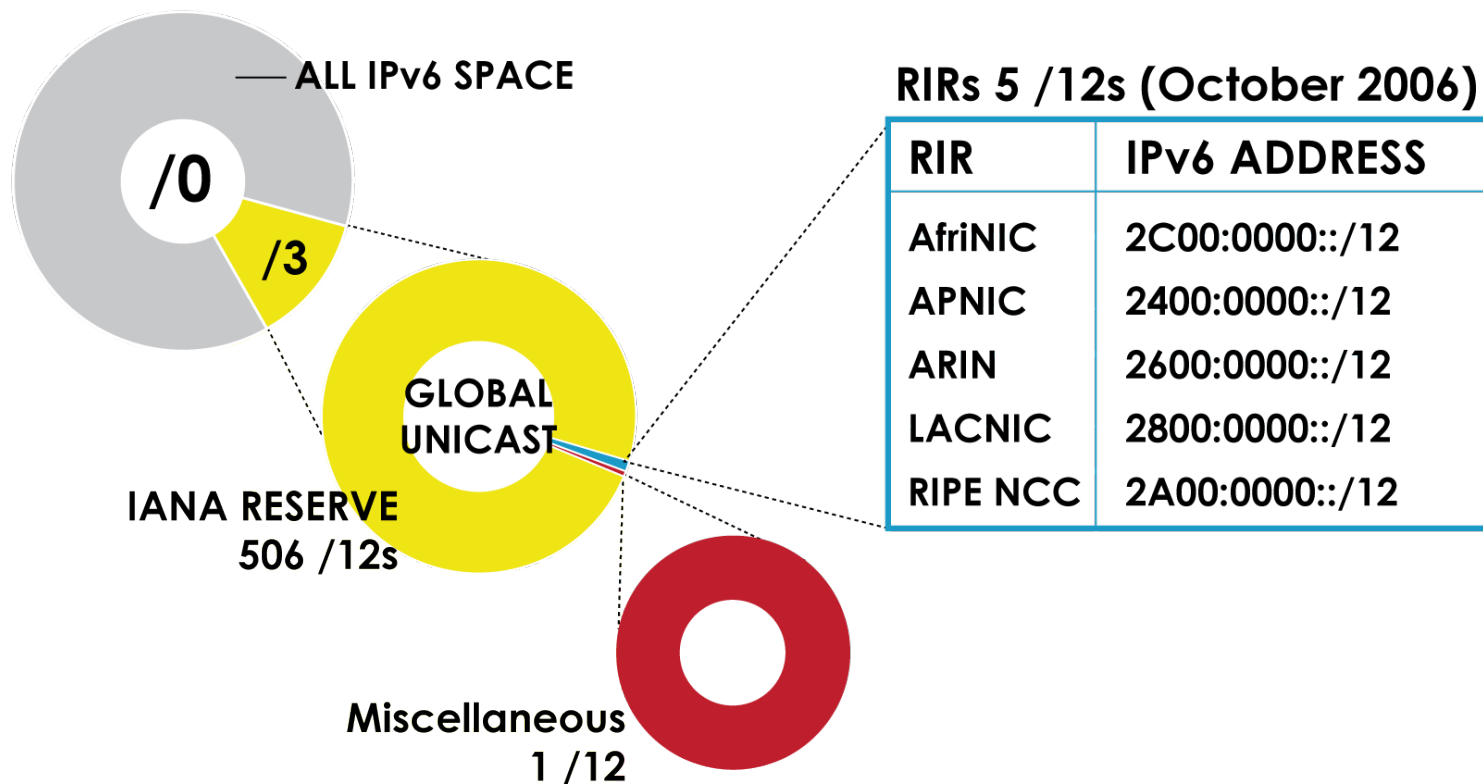
# Historical Resources

## STATUS OF 256 /8s IPv4 ADDRESS SPACE



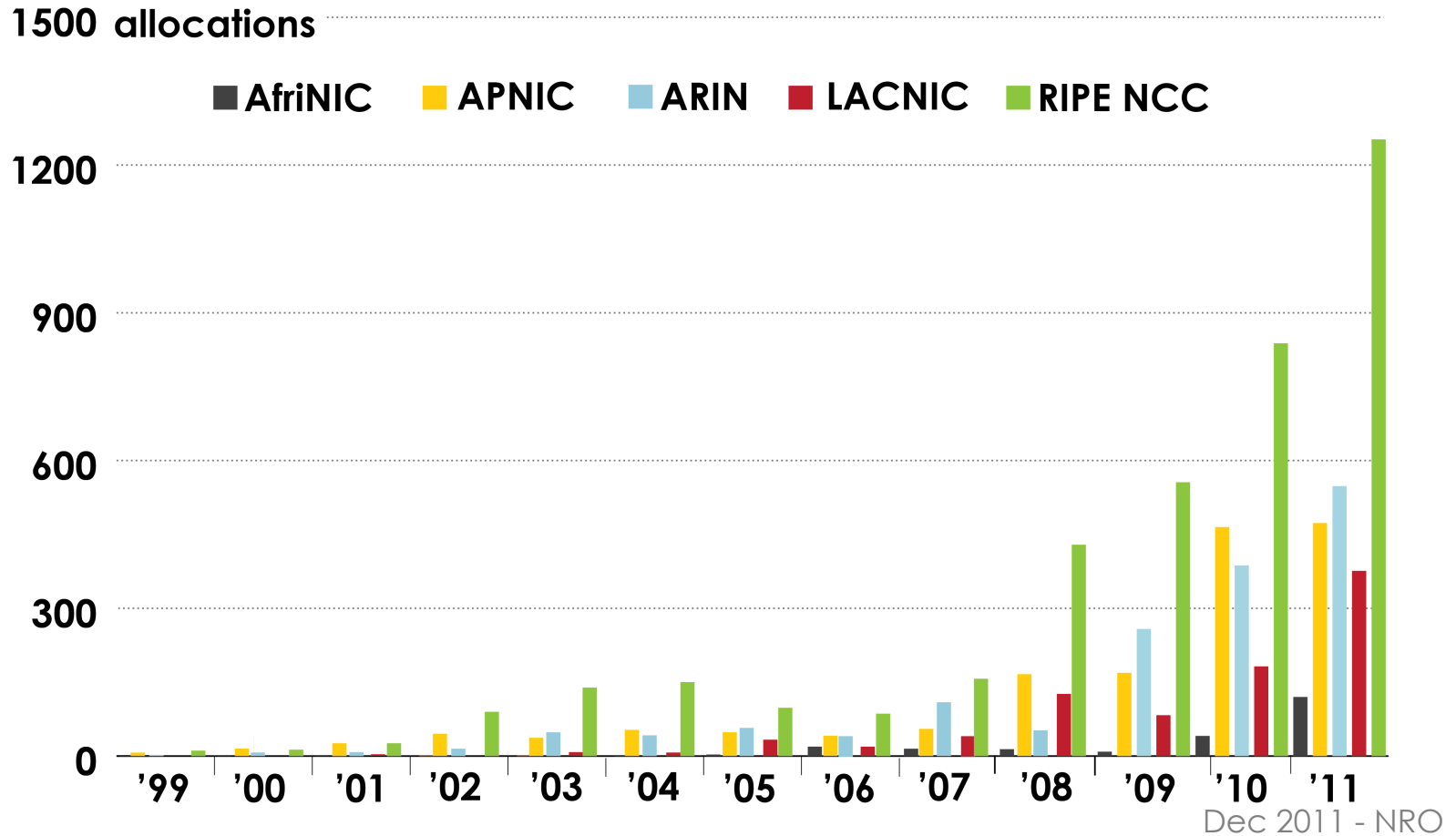
Dec 2011 - NRO

# IPv6 Address Space

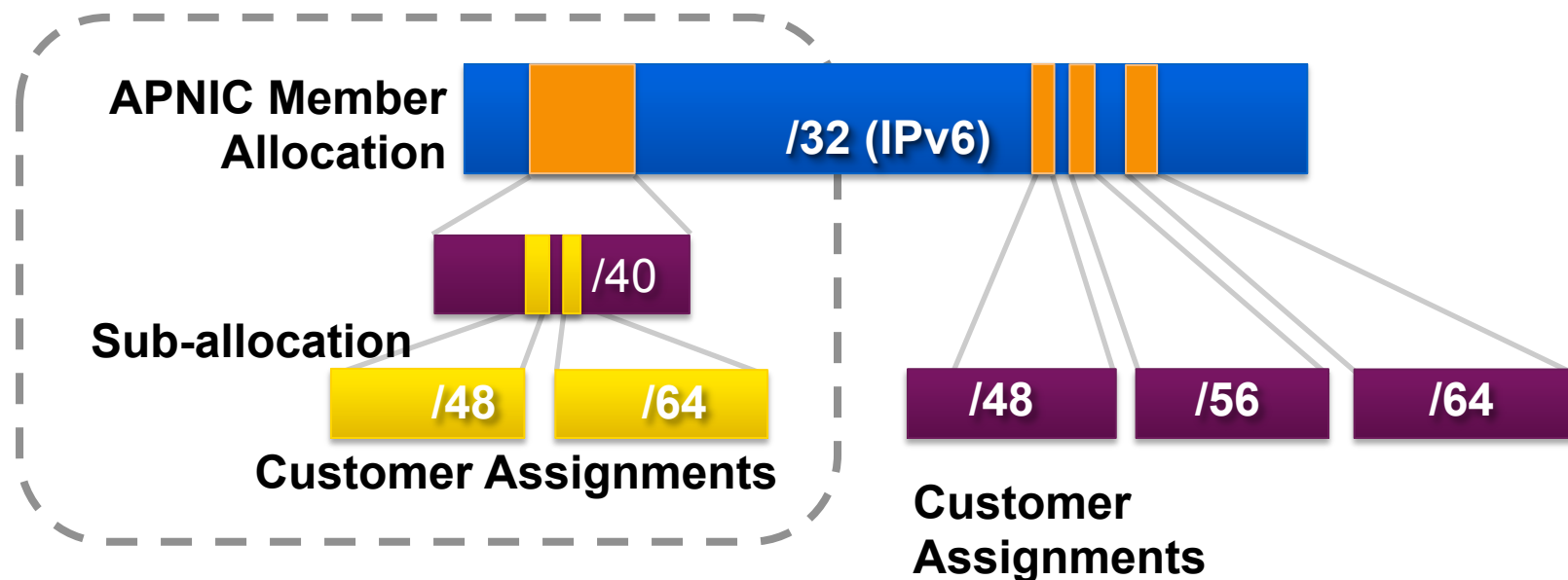


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# IPv6 Allocations RIRs to LIRs



# Sub-allocations



- No specific policy for LIRs to allocate space to subordinate ISPs
- All /48 assignments to end sites must be registered
- Second Opinion applies
  - Must submit a second opinion request for assignments more than /48

# Sub-allocation Guidelines

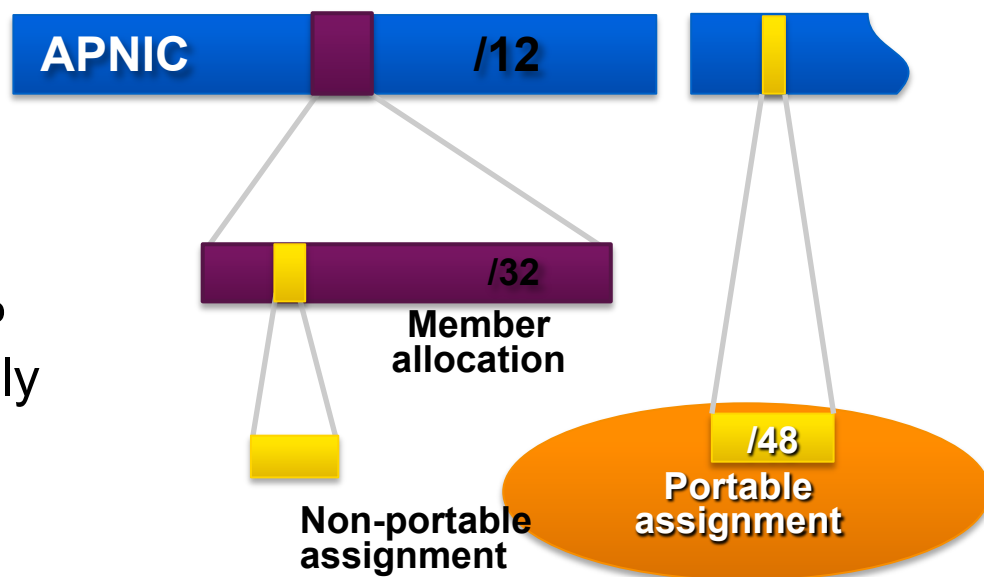
- Sub-allocate cautiously
  - Only allocate or assign what the customer has demonstrated a need for
  - Seek APNIC advice if in doubt
- Efficient assignments
  - Member is responsible for overall utilisation
- Database registration (WHOIS Db)
  - Sub-allocations & assignments must be registered in the whois db

# IPv6 Assignment Policy

- Assignment address space size
  - Minimum of /64 (only 1 subnet), Normal maximum of /48, Larger end-site assignment can be justified
- In typical deployments today
  - Several ISPs gives small customers a /56 or a /60 and Single LAN end sites a /64, e.g.,
    - /64 if end-site will ever only be a LAN
    - /60 for small end-sites (e.g. consumer)
    - /56 for medium end-sites (e.g. small business)
    - /48 for large end-sites
- Assignment of multiple /48s to a single end site
  - Documentation must be provided
  - Will be reviewed at the RIR/NIR level
- Assignment to operator's infrastructure
  - /48 per PoP as the service infrastructure of an IPv6 service operator

# Portable Assignments for IPv6

- For (small) organisations who require a portable assignment for multi-homing purposes
  - The current policy allows for IPv6 portable assignment to end-sites
  - Size: /48, or a shorter prefix if the end site can justify it
  - To be multi-homed within 1 month
  - Demonstrate need to use 25% of requested space immediately and 50% within a year



# IXP IPv6 Assignment Policy

- Criteria
  - Demonstrate ‘open peering policy’
  - 3 or more peers
- Portable assignment size: /48
  - All other needs should be met through normal processes
  - /64 holders can “upgrade” to /48
    - Through NIRs/ APNIC
    - Need to return /64





# Portable Critical Infrastructure Assignments

- What is Critical Internet Infrastructure?
  - Domain Registry Infrastructure
    - Operators of Root DNS, gTLD, and ccTLD
  - Address Registry Infrastructure
    - IANA, RIRs & NIRs
- Why a specific policy ?
  - Protect stability of core Internet function
- Assignment sizes:
  - IPv6: /32

# IPv6 Utilisation

- Utilisation determined from end site assignments
  - ISP responsible for registration of all /48 assignments
  - Intermediate allocation hierarchy not considered
- Utilisation of IPv6 address space is measured differently from IPv4
  - Use HD ratio to measure
- Subsequent allocation may be requested when IPv6 utilisation requirement is met

# Subsequent Allocation

- Must meet **HD = 0.94** utilisation requirement of previous allocation (subject to change)
- Other criteria to be met
  - Correct registrations (all /48s registered)
  - Correct assignment practices etc
- Subsequent allocation results in a doubling of the address space allocated to it
  - Resulting in total IPv6 prefix is 1 bit shorter
  - Or sufficient for 2 years requirement

# HD Ratio

- The HD ratio threshold is
  - $HD = \log (/56 \text{ units assigned}) / \log (16,777,216)$
  - $0.94 = 6,183,533 \times /56 \text{ units}$
- Calculation of the HD ratio
  - Convert the assignment size into equivalent /56 units
    - Each /48 end site =  $256 \times /56 \text{ units}$
    - Each /52 end site =  $16 \times /56 \text{ units}$
    - Each /56 end site =  $1 \times /56 \text{ units}$
    - Each /60 end site =  $1/16 \times /56 \text{ units}$
    - Each /64 end site =  $1/256 \times /56 \text{ units}$

# IPv6 utilisation (HD = 0.94)

- Percentage utilisation calculation

IPv6 Prefix	Site Address Bits	Total site address in /56s	Threshold (HD ratio 0.94)	Utilisation %
/42	14	16,384	9,153	55.9%
/36	20	1,048,576	456,419	43.5%
/35	21	2,097,152	875,653	41.8 %
<b>/32</b>	<b>24</b>	<b>16,777,216</b>	<b>6,185,533</b>	<b>36.9%</b>
/29	27	134,217,728	43,665,787	32.5 %
/24	32	4,294,967,296	1,134,964,479	26.4 %
/16	40	1,099,511,627,776	208,318,498,661	18.9 %

RFC 3194: “In a hierarchical address plan, as the size of the allocation increases, the density of assignments will decrease.”

# Agenda

- Introduction to IPv6 and Protocol Architecture
- **IPv6 Addressing and Sub-netting**
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- IPv4 to IPv6 Transition Technologies
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- IPv6 DNS

# IPv6 Addressing

- An IPv6 address is 128 bits long
- So the number of addresses are  $2^{128} = 340282366920938463463374607431768211455$
- In hex, 4 bits (also called a 'nibble') is represented by a hex digit

2001:DC0:A910::

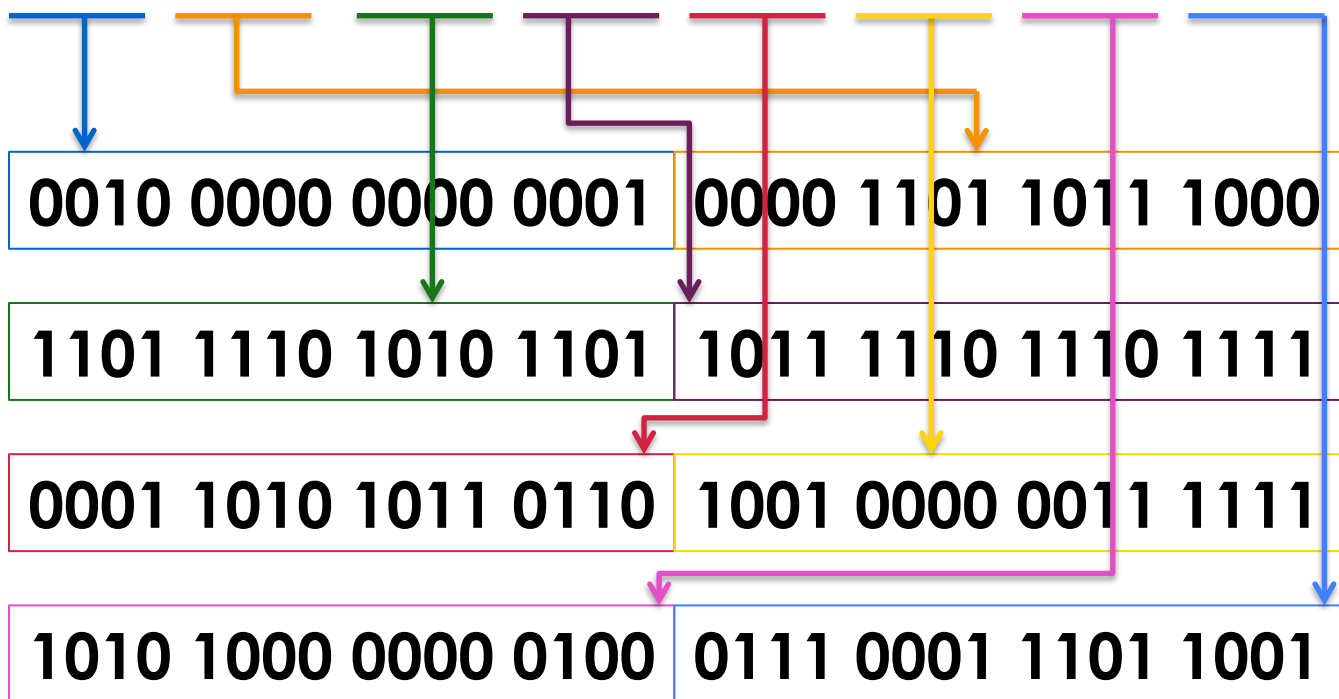


nibbles

1010|1001|0001|0000

# IPv6 Addressing

**2001:0DB8:DEAD:BEEF:1AB6:503F:A804:71D9**



128 bits is reduced down to 32 hex digits



# IPv6 Address Representation



- Hexadecimal values of eight 16 bit fields
  - X:X:X:X:X:X:X:X (X=16 bit number, ex: A2FE)
  - 16 bit number is converted to a 4 digit hexadecimal number
  - Case insensitive
- Example:
  - FE38:DCE3:124C:C1A2:BA03:6735:EF1C:683D
  - Abbreviated form of address
    - FE80:0023:**0000:0000:0000**:036E:1250:2B00 **Leading zeroes**
    - FE80:23:**0:0:0**:36E:1250:2B00 **Groups of zeroes**
    - FE80:23::**36E:1250:2B00** **Double colons**
  - (Null value can be used only once)

# IPv6 Address Representation (2)

- Double colons (::) representation
  - RFC5952 recommends that the rightmost set of :0: be replaced with :: for consistency
    - 2001:db8:0:2f::5 rather than 2001:db8::2f:0:0:0:5
- In a URL, it is enclosed in brackets (RFC3986)
  - [http://\[2001:db8:4f3a::206:ae14\]:8080/index.html](http://[2001:db8:4f3a::206:ae14]:8080/index.html)
  - Cumbersome for users, mostly for diagnostic purposes
  - Use fully qualified domain names (FQDN)
- Prefix Representation
  - Representation of prefix is just like IPv4 CIDR
  - In this representation, you attach the prefix length
  - IPv6 address is represented as:
    - 2001:db8:12::/40

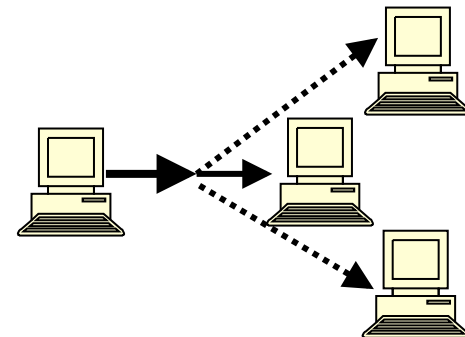
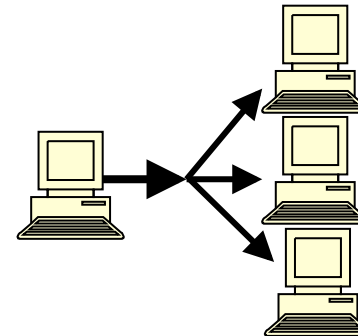
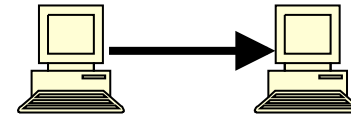
# Exercise

1. 2001:0db8:0000:0000:0000:0000:0000:0000
2. 2001:0db8:0000:0000:d170:0000:1000:0ba8
3. 2001:0db8:0000:0000:00a0:0000:0000:10bc
4. 2001:0db8:0fc5:007b:ab70:0210:0000:00bb

# IPv6 Addressing Model

RFC  
4291

- Unicast
  - An identifier for a single interface
- Multicast
  - An identifier for a group of nodes
- Anycast
  - An identifier for a set of interfaces



# Unicast address

- Address given to interface for communication between host and router
  - Global unicast address currently delegated by IANA



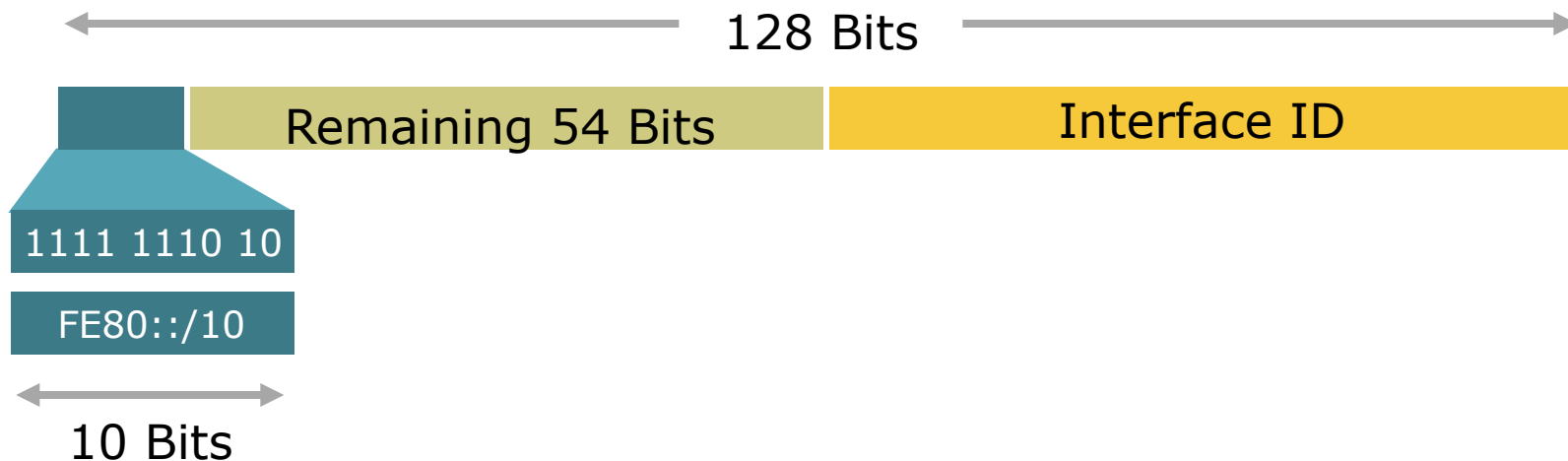
- Local use unicast address
  - Link-local address (starting with FE80::)



# Local Addresses With Network Prefix

- Link Local Address
  - A special address used to communicate within the local link of an interface (i.e. anyone on the link as host or router)
  - The address in the packet destination would never pass through a router (local scope)
  - Mandatory address - automatically assigned as soon as IPv6 is enabled
  - **fe80::/10**

# Local Addresses With Network Prefix



- Remaining 54 bits could be Zero or any manual configured value

# Local Addresses With Network Prefix

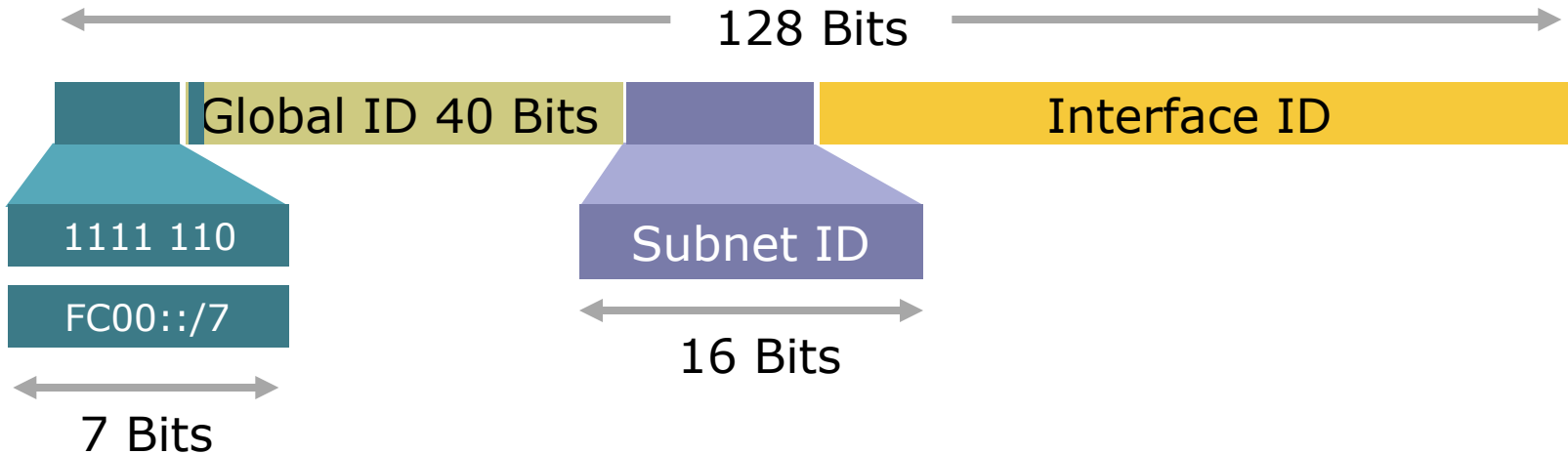
- Site Local Address
  - Addresses similar to the RFC 1918 / private address like in IPv4
  - **fec0::/10**
- This address type is now deprecated by RFC 3879 because of lack of uniqueness
- Still used in test lab



# Local Addresses With Network Prefix

- Unique Local IPv6 Unicast Address
  - Addresses similar to the RFC 1918 (private address) in IPv4
  - Ensures uniqueness
  - A part of the prefix (40 bits) are generated using a pseudo-random algorithm and it's improbable that two generated ones are equal
  - **fc00::/7**
  - Example webtools to generate ULA prefix
    - <http://www.sixxs.net/tools/grh/ula/>
    - <http://www.goebel-consult.de/ipv6/createLULA>
  - RFC 4193

# Local Addresses With Network Prefix



- Unique-Local Addresses Used For:
  - Local communications & inter-site VPNs
  - Local devices such as printers, telephones, etc
  - Site Network Management systems connectivity
- Not routable on the Internet

# Global Addresses With Network Prefix

- **IPV6 Global Unicast Address**

- Global Unicast Range: 0010 2000::/3  
0011 3FFF:FFF:....:FFFF/3
- All five RIRs are given a /12 from the /3 to further distribute within the RIR region

APNIC 2400:0000::/12

ARIN 2600:0000::/12

AfrinIC 2C00:0000::/12

LACNIC 2800:0000::/12

Ripe NCC 2A00:0000::/12

# Global Addresses With Network Prefix

- 6to4 Addresses
  - **2002::/16**
  - Designed for a special tunneling mechanism [RFC 3056] to connect IPv6 Domains via IPv4 Clouds
  - Automatic tunnel transition Mechanisms for IPv6 Hosts and Routers
  - Need 6to4 relay routers in ISP network

# Examples and Documentation Prefix

- Two address ranges are reserved for examples and documentation purpose by RFC 3849
  - For example 3fff:ffff::/32
  - For documentation 2001:0DB8::/32

# Special addresses

- The unspecified address
  - A value of 0:0:0:0:0:0:0:0 (::)
  - It is comparable to 0.0.0.0 in IPv4
- The loopback address
  - It is represented as 0:0:0:0:0:0:0:1 (::1)
  - Similar to 127.0.0.1 in IPv4

# Addresses Without a Network Prefix

- Loopback `::1/128`
- Unspecified Address `::/128`
- IPv4-mapped IPv6 address `::ffff/96 [a.b.c.d]`
- IPv4-compatible IPv6 address `::/96 [a.b.c.d]`

# IPv6 Address Space

---

IPv6 Prefix	Allocation	RFC
0000::/8	Reserved by IETF	RFC 4291
2000::/3	Global Unicast	RFC 4291
FC00::/7	Unique Local Address	RFC 4193
FE80::/10	Link Local Unicast	RFC 4291
FEC0::/10	Reserved by IETF	RFC 3879
FF00::/8	Multicast	RFC 4291
2002::/16	6to4	RFC3056

---

<http://www.iana.org/assignments/ipv6-address-space/ipv6-address-space.xml>



# Subnetting

- Network engineers must have a solid understanding of subnetting
  - Important for address planning
- IPv6 subnetting is similar (if not exactly the same) as IPv4 subnetting
- Note that you are working on hexadecimal digits rather than binary
  - 0 in hex = 0000 in binary
  - 1 in hex = 0001 in binary

# Subnetting (Example)

- Provider A has been allocated an IPv6 block  
**2001:DB8::/32**
- Provider A will delegate /48 blocks to its customers
- Find the blocks provided to the first 4 customers

# Subnetting (Example)

Original block: **2001:0DB8::/32**

Rewrite as a /48 block: **2001:0DB8:0000:/48**

**This is your  
network prefix!**

How many /48 blocks are there in a /32?

$$\frac{/32}{/48} = \frac{2^{128-32}}{2^{128-48}} = \frac{2^{96}}{2^{80}} = 2^{16}$$

Find only the first 4 /48 blocks...

# Subnetting (Example)

Start by manipulating the LSB of your network prefix – write in BITS

**2001:0DB8:0000::/48**



2001:0DB8:	0000 0000 0000 0000	::/48	➡	2001:0DB8:0000::/48
2001:0DB8:	0000 0000 0000 0001	::/48	➡	2001:0DB8:0001::/48
2001:0DB8:	0000 0000 0000 0010	::/48	➡	2001:0DB8:0002::/48
2001:0DB8:	0000 0000 0000 0011	::/48	➡	2001:0DB8:0003::/48

Then write back into hex digits

# Exercise 1.1: IPv6 subnetting

- Identify the first four /64 address blocks out of 2001:DB8:0::/48

1. \_\_\_\_\_
2. \_\_\_\_\_
3. \_\_\_\_\_
4. \_\_\_\_\_

## Exercise 1.2: IPv6 subnetting

- Identify the first four /36 address blocks out of 2406:6400::/32

1. \_\_\_\_\_

2. \_\_\_\_\_

3. \_\_\_\_\_

4. \_\_\_\_\_

## Exercise 1.3: IPv6 subnetting

- Identify the first six /35 address blocks out of 2406:6400::/32

1. \_\_\_\_\_
2. \_\_\_\_\_
3. \_\_\_\_\_
4. \_\_\_\_\_
5. \_\_\_\_\_
6. \_\_\_\_\_

# Agenda

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# Configuration of IPv6 Nodes

- There are 3 ways to configure IPv6 address on an IPv6 node:
  - Static address configuration
  - DHCPv6 assigned node address
  - Autoconfiguration (New feature in IPv6)

# Configuration of IPv6 Nodes

- Stateless mechanism
  - For a site not concerned with the exact addresses
  - No manual configuration required
  - Minimal configuration of routers
  - No additional servers
- Stateful mechanism
  - For a site that requires tighter control over exact address assignments
  - Needs a DHCPv6 server

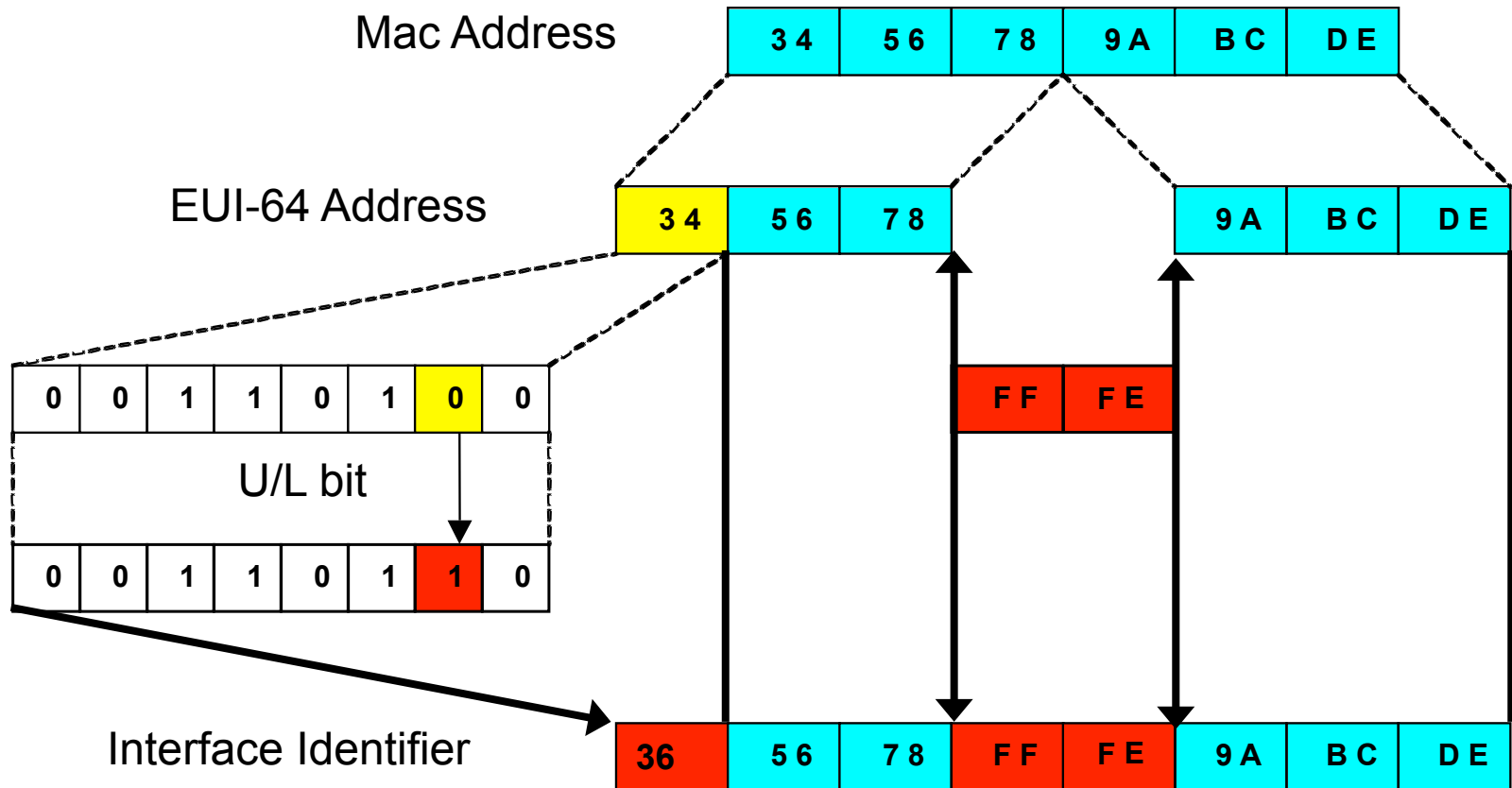
# IPv6 Autoconfiguration

- IPv6 **S**tateless **A**ddress **A**utoconfiguration (SLACC)
- Allow a host to obtain or create unique addresses for its interface/s
  - Manual configuration should not be required
  - Even if no servers/routers exist to assign an IP address to a device, the device can still auto-generate an IP address
- Small sites should not require DHCPv6 server to communicate
  - Plug and play
  - Allows interfaces on the same link to communicate with each other
- Facilitate the renumbering of a site's machines

# Interface ID

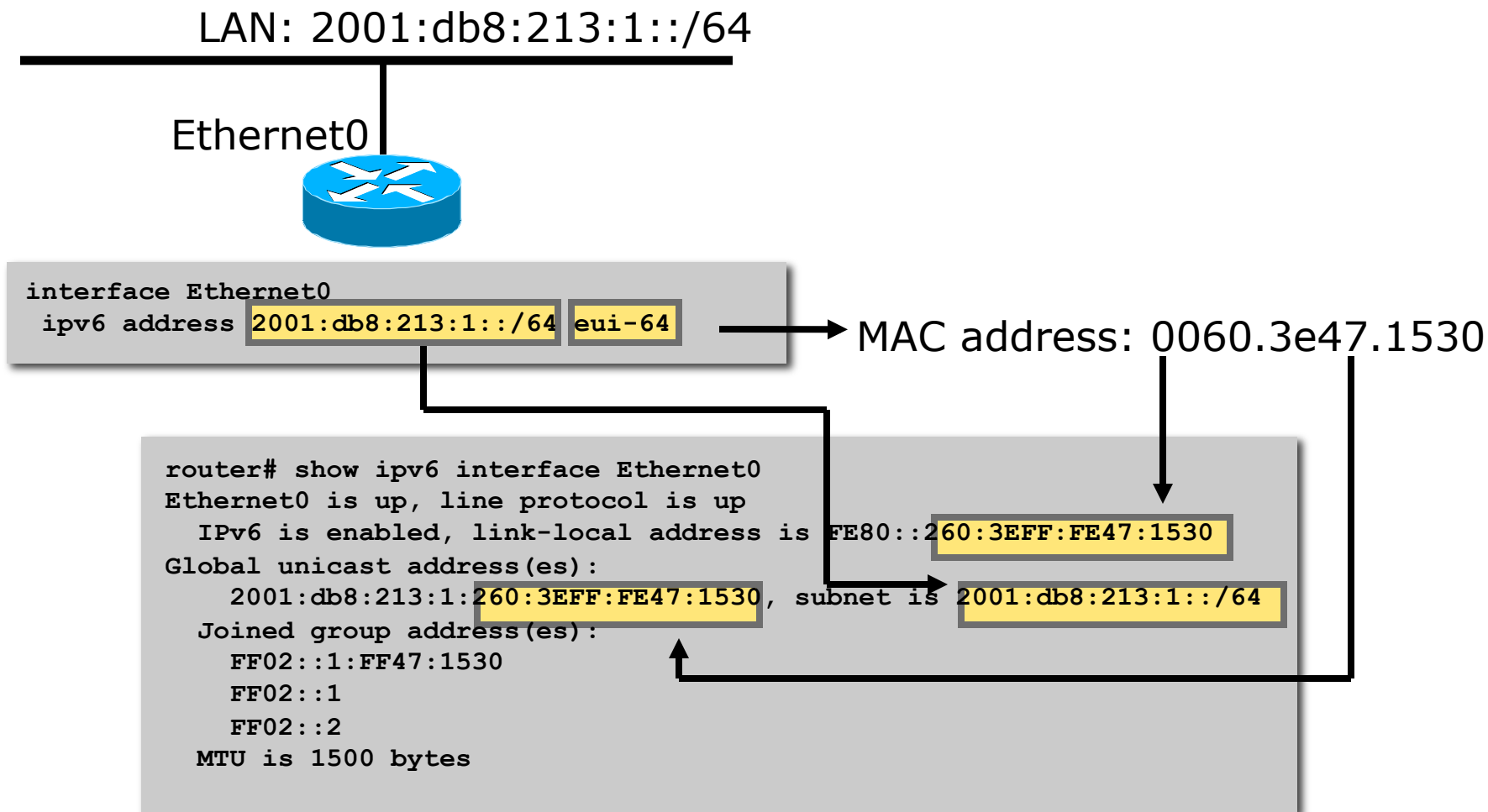
- The lowest-order 64-bit field addresses
- May be assigned in several different ways:
  - auto-configured from a 48-bit MAC address expanded into a 64-bit EUI-64
  - assigned via DHCP
  - manually configured
  - auto-generated pseudo-random number
  - possibly other methods in the future

# EUI-64

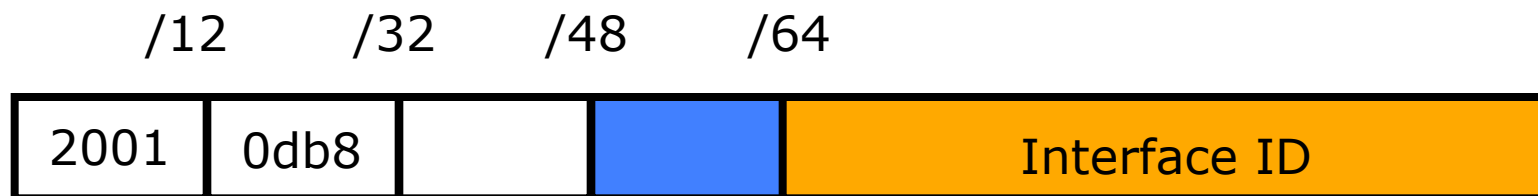


EUI-64 address is formed by inserting FFFE and OR'ing a bit identifying the uniqueness of the MAC address

# IPv6 Addressing Examples



# IPv6 Address Privacy



- Temporary addresses for IPv6 host client application, e.g. Web browser
- Intended to inhibit device/user tracking but is also a potential issue
  - More difficult to scan all IP addresses on a subnet
  - But port scan is identical when an address is known
- Random 64 bit interface ID, run DAD before using it
- Rate of change based on local policy
- Implemented on Microsoft Windows XP/Vista/7
  - Can be activated on FreeBSD/Linux/MacOS with a system call

# IPv6 Neighbor Discovery (ND)

- IPv6 uses multicast (L2) instead of broadcast to find out target host MAC address
- It increases network efficiency by eliminating broadcast from L2 network
- IPv6 ND use ICMPv6 as transport
  - Compared to IPv4 ARP no need to write different ARP for different L2 protocol i.e. Ethernet etc.



# Solicited-Node Multicast

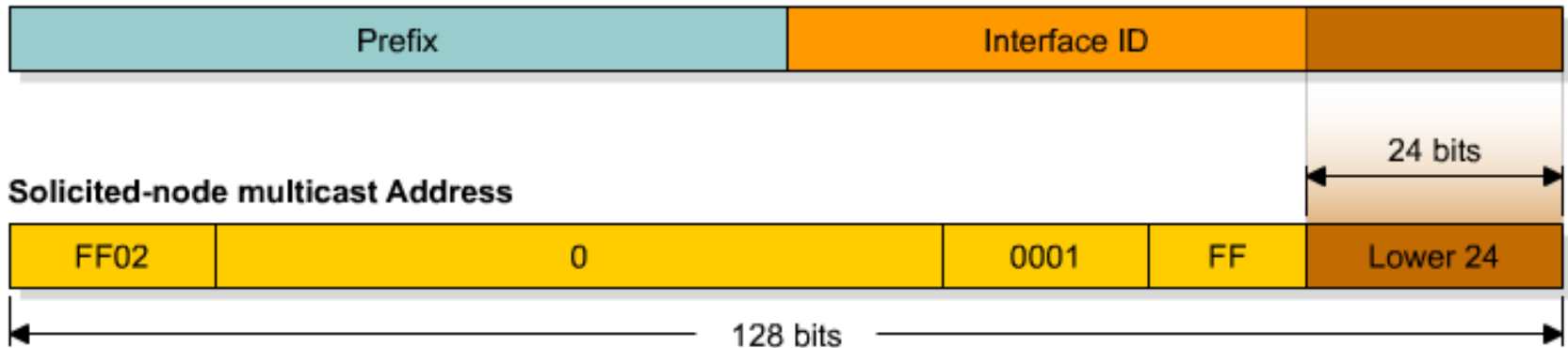
- Solicited-Node Multicast is used for Duplicate Address Detection
  - Part of the Neighbour Discovery process
  - Replaces ARP
  - Duplicate IPv6 Addresses are rare, but still have to be tested for
- For each unicast and anycast address configured there is a corresponding solicited-node multicast address
  - This address is only significant for the local link

# Solicited-Node Multicast

- Solicited Node Multicast Address
  - Start with FF02:0:0:0:0:1:ff::/104
  - Last 24 bit from the interface IPV6 address
- Example Solicited Node Multicast Address
  - IPV6 Address 2406:6400:0:0:0:0:0000:0010
  - Solicited Node Multicast Address is FF02:0:0:0:0:1:ff00:0010
- All hosts listen to its solicited node multicast address corresponding to its unicast and anycast address (If defined)

# Solicited-Node Multicast Address

IPv6 Address



- Solicited-node multicast address consists of FF02:0:0:0:0:1:FF::/104 prefix joined with the lower 24 bits from the unicast or anycast IPv6 address

# Solicited-Node Multicast

```
R1#sh ipv6 int e0
Ethernet0 is up, line protocol is up
  IPv6 is enabled, link-local address is FE80::200:CFF:FE3A:8B18
  No global unicast address is configured
  Joined group address(es):
    FF02::1
    FF02::2
    FF02::1:FF3A:8B18
  MTU is 1500 bytes
  ICMP error messages limited to one every 100 milliseconds
  ICMP redirects are enabled
  ND DAD is enabled, number of DAD attempts: 1
  ND reachable time is 30000 milliseconds
  ND advertised reachable time is 0 milliseconds
  ND advertised retransmit interval is 0 milliseconds
  ND router advertisements are sent every 200 seconds
  ND router advertisements live for 1800 seconds
  Hosts use stateless autoconfig for addresses.
R1#
```

↑

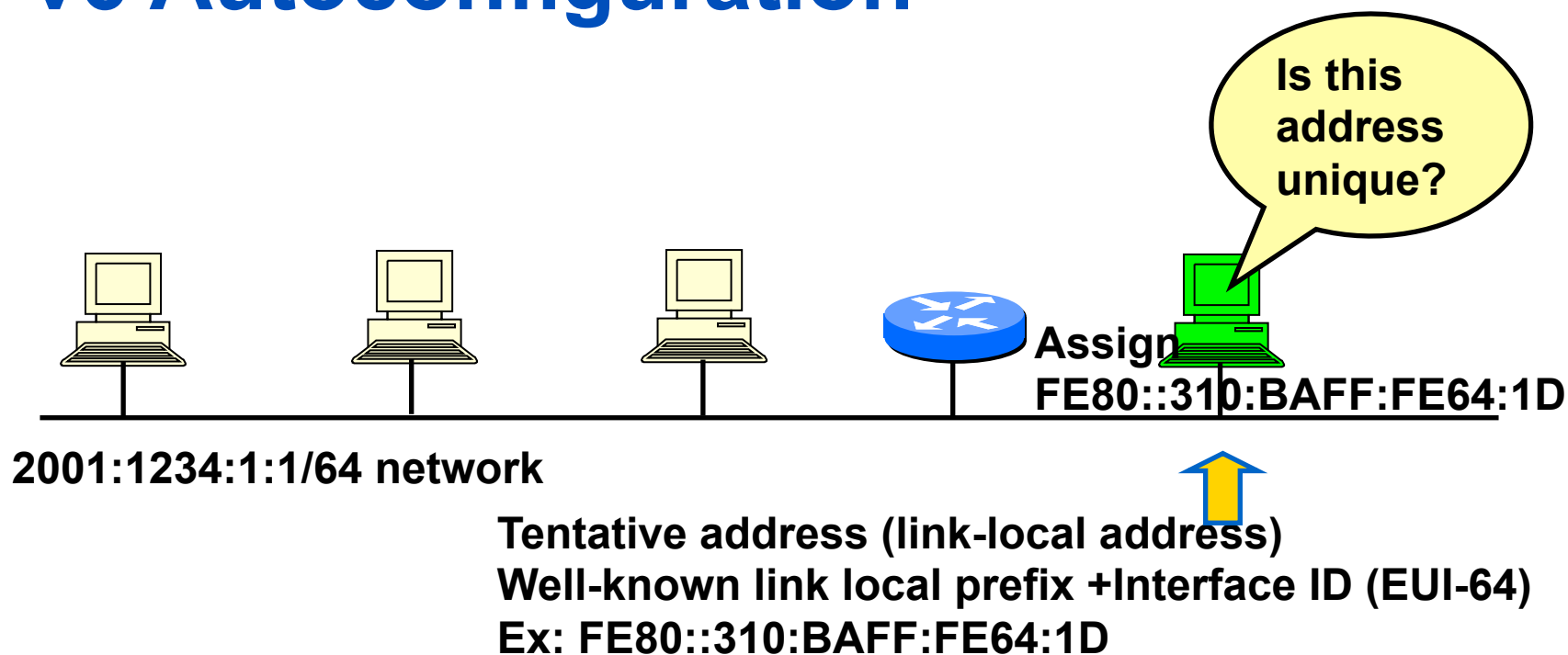
Solicited-Node Multicast Address

←

# IPv6 Neighbor Discovery (ND)

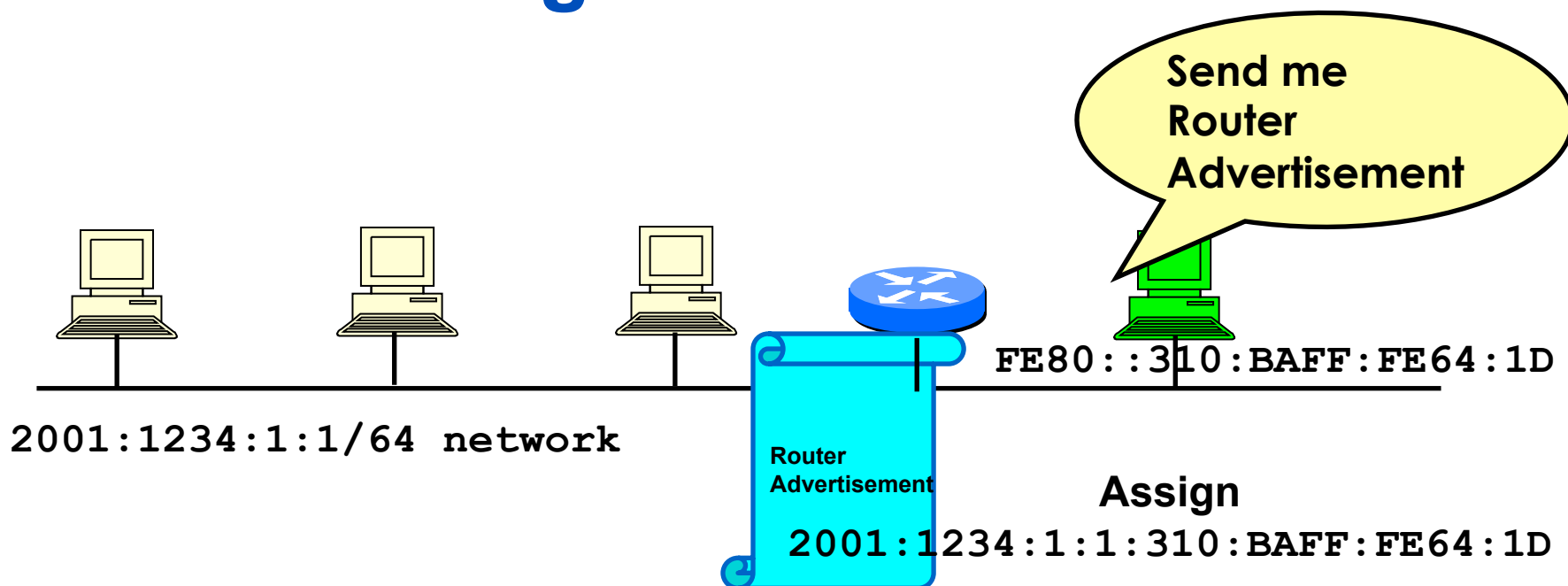
- Host A would like to communicate with Host B
  - Host A IPv6 global address **2406:6400::10**
  - Host A IPv6 link local address **fe80::226:bbff:fe06:ff81**
  - Host A MAC address **00:26:bb:06:ff:81**
- Host B IPv6 global address **2406:6400::20**
  - Host B Link local **UNKNOWN** [Gateway if outside the link]
  - Host B MAC address **UNKNOWN**
- How will Host A create L2 frame for Host B?

# IPv6 Autoconfiguration



1. A new host is turned on.
2. Tentative address will be assigned to the new host.
3. Duplicate Address Detection (DAD) is performed. First the host transmit
  - a Neighbor Solicitation (NS) message to all-nodes multicast address (FF02::1)
5. If no Neighbor Advertisement (NA) message comes back then the address is unique.
6. FE80::310:BAFF:FE64:1D will be assigned to the new host.

# IPv6 Autoconfiguration



1. The new host will send Router Solicitation (RS) request to the all-routers multicast group (FF02::2).
2. The router will reply Routing Advertisement (RA).
3. The new host will learn the network prefix. E.g, `2001:1234:1:1/64`
4. The new host will assigned a new address Network prefix+Interface ID  
E.g, `2001:1234:1:1:310:BAFF:FE64:1D`

# IPv6 Neighbor Discovery (ND)

## Host A

IPv6 global address: **2406:6400::0010**

IPv6 Link local: **fe80::0226:bbff:fe06:ff81**

MAC address: 00:26:bb:06:ff:81

Listen to other then above:

FF02::1 [All node multicast]  
FF02:0:0:0:0:1:ff00:0010 [Solicited node m.cast unicast]  
FF02:0:0:0:0:1:ff06:ff81 [Solicited node m.cast link local]

### Packet

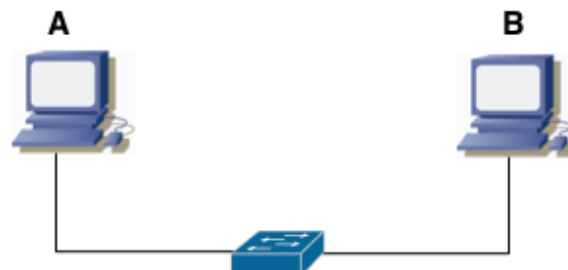
S: 2406:6400::0010 D:2406:6400::0020

### ICMP6 NS Type 135

S: fe80::0226:bbff:fe06:ff81  
D:FF02:0:0:0:0:1:ff00:0020

### Frame

S: 00:26:bb:06:ff:81 D 33:33:ff:00:00:20  
Ethernet reserved IPv6 m.cast: 33:33:xx:xx:xx:xx



Multicast enable switch: Unicast by IGMP snooping  
Non multicast enable switch: broadcast, PC LAN card filter or discard

## Host B

IPv6 global address: **2406:6400::0020**

IPv6 Link local: **fe80::0226:bbff:fe06:ff82** [Unknown to A]

MAC address: 00:26:bb:06:ff:82 [Unknown to A]

Listen to other then above:

FF02::1 [All node multicast]  
FF02:0:0:0:0:1:ff00:0020 [Solicited node m.cast unicast]  
FF02:0:0:0:0:1:ff06:ff82 [Solicited node m.cast link local]

### Packet

S: 2406:6400::0020 D:2406:6400::0010

### ICMP6 NA Type 136

S: fe80::0226:bbff:fe06:ff82  
D:fe80::0226:bbff:fe06:ff81

### Frame

S: 00:26:bb:06:ff:82 D 00:26:bb:06:ff:81

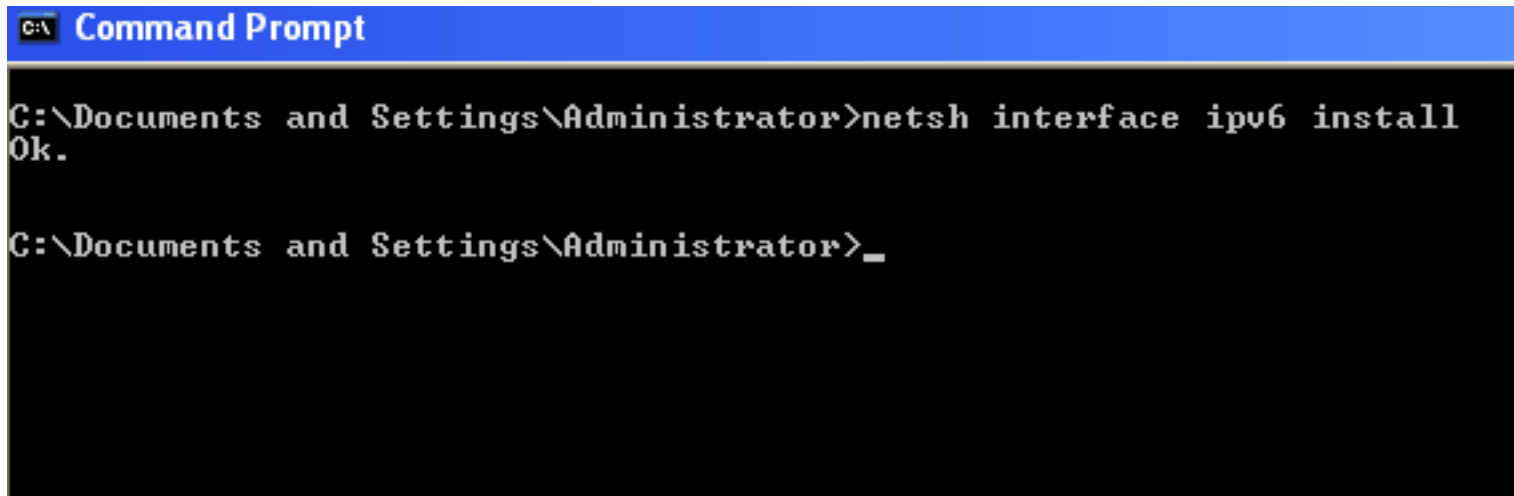


# ICMPv6 Messages for Autoconfiguration

- 133 Router Solicitation
  - Prompts a router to send a Router Advertisement.
- 134 Router Advertisement
  - Sent by routers to tell hosts on the local network the router exists and describe its capabilities.
- 135 Neighbor Solicitation
  - Sent by a device to request the layer two address of another device while providing its own as well.
- 136 Neighbor Advertisement
  - Provides information about a host to other devices on the network

# IPv6 Host Configuration (Windows)

- Windows XP SP2
  - `netsh interface ipv6 install`
- Windows XP
  - `ipv6 install`



```
Command Prompt
C:\Documents and Settings\Administrator>netsh interface ipv6 install
Ok.
C:\Documents and Settings\Administrator>_
```

# IPv6 Host Configuration (Windows)

- Configuring an interface

```
netsh interface ipv6 add address "Local  
Area Connection" 2406:6400::1
```

- Note: Prefix length is not specified with address which will force a /64 on the interface

- Verify your Configuration

```
c:\>ipconfig
```

- Verify your neighbour table

```
– C:\> netsh interface ipv6 show neighbors
```

# IPv6 Host Configuration (Windows)

- Disable privacy state variable

```
C:\> netsh interface ipv6 set privacy state=disable
```

OR

```
C:\> netsh interface ipv6 set global  
randomizeidentifiers=disabled
```

# IPv6 Host Configuration (Windows)

- Testing your configuration

- `ping fe80::260:97ff:fe02:6ea5%4`



Zone ID

- Note: the Zone ID is your interface index

# IPv6 Host Configuration (Linux)

- Enabling IPv6 on Linux
  - Set the NETWORKING\_IPV6 variable to yes in /etc/sysconfig/network

```
# vi /etc/sysconfig/network
NETWORKING_IPV6=yes
# service network restart
```

- Adding IPv6 address on an interface

```
# ifconfig eth0 add inet6 2406:6400::1/64 (OR)
# ifconfig eth0 add 2406:6400::1/64
```

# IPv6 Host Configuration (Linux)

- Configuring Router Advertisement (RA) on Linux
  - Set IPv6 address forwarding on

```
# echo "1" /proc/sys/net/ipv6/conf/all/forward
```
  - Need radvd-0.7.1-3.i386.rpm installed
  - On the demon conf file /etc/radvd.conf

```
# vi /etc/radvd.conf
```

# IPv6 Host Configuration (FreeBSD)

- Enabling IPv6 on FreeBSD
  - Set the `ipv6_enable` variable to `yes` in the `/etc/rc.conf`

```
# vi /etc/rc.conf
ipv6_enable=yes
```
- Adding IPv6 address on an interface

```
# ifconfig fxp0 inet6 2406:6400::1/64
```



# Zone IDs for Local-Use Addresses

- In Windows XP for example:
- Host A:
  - fe80::2abc:d0ff:fee9:4121%4
- Host B:
  - fe80::3123:e0ff:fe12:3001%3
- Ping from Host A to Host B
  - ping fe80::3123:e0ff:fe12:3001%4 (not %3)
    - identifies the interface zone ID on the host which is connected to that segment.

# Configuration of IPv6 Node Address

Quantity	Address	Requirement	Context
One	Loopback [::1]	Must define	Each node
One	Link-local	Must define	Each Interface
Zero to many	Unicast	Optional	Each interface
Zero to many	Unique-local	Optional	Each interface
One	All-nodes multicast [ff02::1]	Must listen	Each interface
One	Solicited-node multicast ff02:0:0:0:0:1:ff/104	Must listen	Each unicast and anycast define
Any	Multicast Group	Optional listen	Each interface

ULA are unicast address globally unique but used locally within sites. Any sites can have /48 for private use. Each /48 is globally unique so no Collision of identical address in future when they connect together

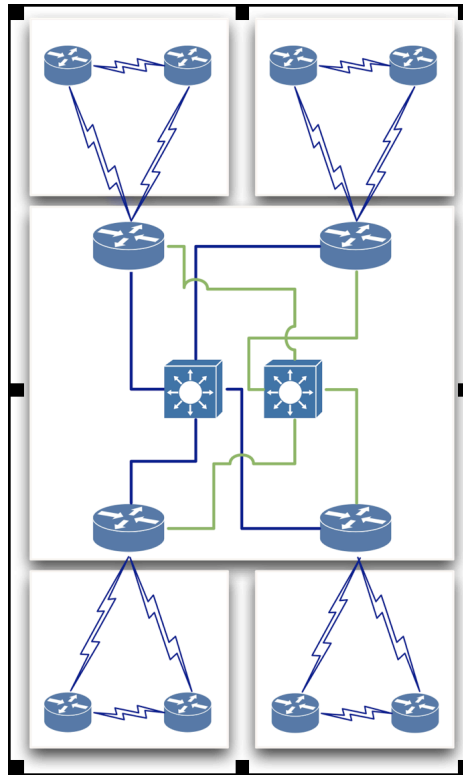
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# Training ISP Network Topology

- Scenario:
  - Training ISP has 4 main operating area or region
  - Each region has 2 small POP
  - Each region will have one datacenter to host content
  - Regional network are inter-connected with multiple link

# Training ISP Network Topology



Training ISP Topology Diagram

# Training ISP Network Topology

- Regional Network:
  - Each regional network will have 3 routers
  - 1 Core & 2 Edge Routers
  - 2 Point of Presence (POP) for every region
  - POP will use a router to terminate customer network i.e Edge Router
  - Each POP is an aggregation point of ISP customer

# Training ISP Network Topology

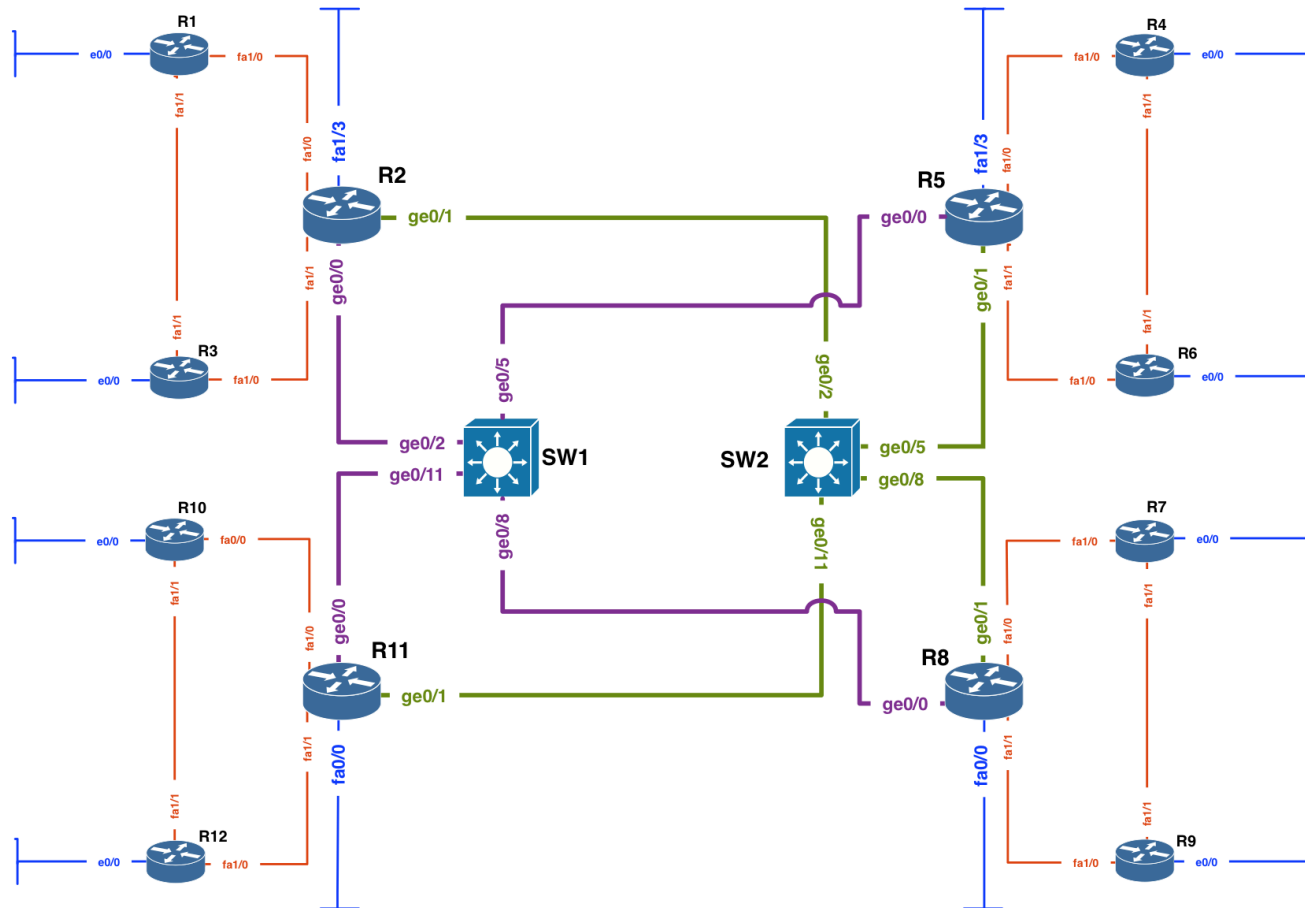
- Access Network:
  - Connection between customer network & Edge router
  - Usually 10 to 100 MBPS link
  - Separate routing policy from most of ISP
  - Training ISP will connect them on edge router with separate customer IP prefix

# Training ISP Network Topology

- Transport Link:
  - Inter-connection between regional core router
  - Higher data transmission capacity than access link
  - Training ISP has 2 transport link for link redundancy
  - 2 Transport link i.e Purple link & Green link are connected to two carrier grade switch



# Training ISP Network Topology



Training ISP Core IP Backbone

# Training ISP Network Topology

- Design Consideration:
  - Each regional network should have address summarization capability for customer block and CS link WAN.
  - Prefix planning should have scalability option for next couple of years for both customer block and infrastructure
  - No Summarization require for infrastructure WAN and loopback address

# Training ISP Network Topology

- Design Consideration:
  - All WAN link should be ICMP reachable for link monitoring purpose (At least from designated host)
  - Conservation will get high preference for IPv4 address planning and aggregation will get high preference for IPv6 address planning.

# Training ISP Network Topology

- Design Consideration:
  - OSPF is running in ISP network to carry infrastructure IP prefix
  - Each region is a separate OSPF area
  - Transport core is in OSPF area 0
  - Customer will connect on either static or eBGP (Not OSPF)
  - iBGP will carry external prefix within ISP core IP network

# Training ISP IPv6 Addressing Plan

- IPv6 address plan consideration:
  - Big IPv6 address space can cause very very large routing table size
  - Most transit service provider apply IPv6 aggregation prefix filter (i.e. anything other than /48 &  $\leq$  /32 prefix size
  - Prefix announcement need to send to Internet should be either /32 or /48 bit boundary

# Training ISP IPv6 Addressing Plan

- IPv6 address plan consideration (RFC6177):
  - WAN link can be used on /64 bit boundary
  - End site/Customer sub allocation can be made between /48~ /64 bit boundary
  - APNIC Utilization/HD ratio will be calculated based on /56 end site assignment/sub-allocation

# Addressing Plans – ISP Infrastructure

- What about LANs?
  - /64 per LAN
- What about Point-to-Point links?
  - Protocol design expectation is that /64 is used
  - /127 now recommended/standardised
    - <http://www.rfc-editor.org/rfc/rfc6164.txt>
    - (reserve /64 for the link, but address it as a /127)
  - Other options:
    - /126s are being used (mirrors IPv4 /30)
    - /112s are being used
      - Leaves final 16 bits free for node IDs
    - Some discussion about /80s, /96s and /120s too

# Addressing Plans – ISP Infrastructure

- ISPs should receive /32 from their RIR
- Address block for router loop-back interfaces
  - Generally number all loopbacks out of **one** /48
  - /128 per loopback
- Address block for infrastructure
  - /48 allows 65k subnets
  - /48 per region (for the largest international networks)
  - /48 for whole backbone (for the majority of networks)
  - Summarise between sites if it makes sense



# Addressing Plans – Customer

- Customers get **one** /48
  - Unless they have more than 65k subnets in which case they get a second /48 (and so on)
- In typical deployments today:
  - Several ISPs give small customers a /56 or single LAN end-sites a /64, e.g.:
    - /64 if end-site will only ever be a LAN
    - /56 for medium end-sites (e.g. small business)
    - /48 for large end-sites
    - (This is another very active discussion area)

# Addressing Plans – Advice

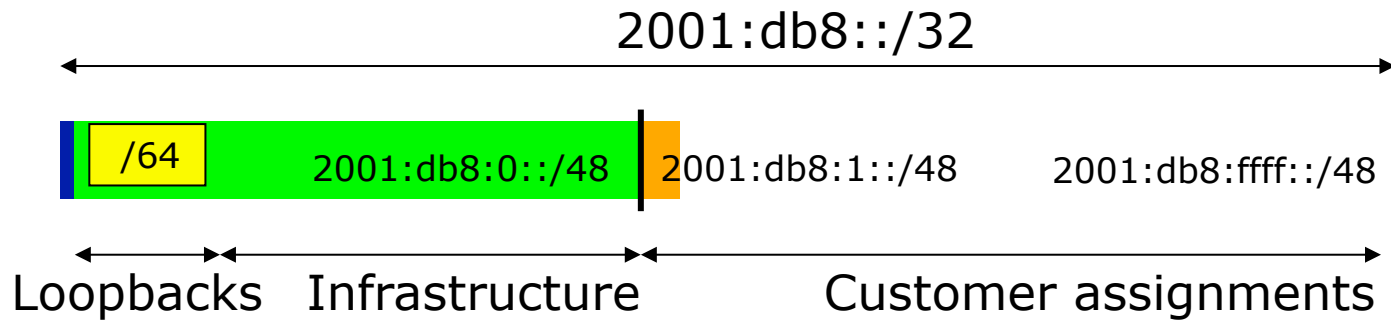
- Customer address assignments should not be reserved or assigned on a per PoP basis
  - Same principle as for IPv4
  - ISP iBGP carries customer nets
  - Aggregation within the iBGP not required and usually not desirable
  - Aggregation in eBGP is very necessary
- Backbone infrastructure assignments:
  - Number out of a **single** /48
    - Operational simplicity and security
  - Aggregate to minimise size of the IGP

# Addressing Plans Planning

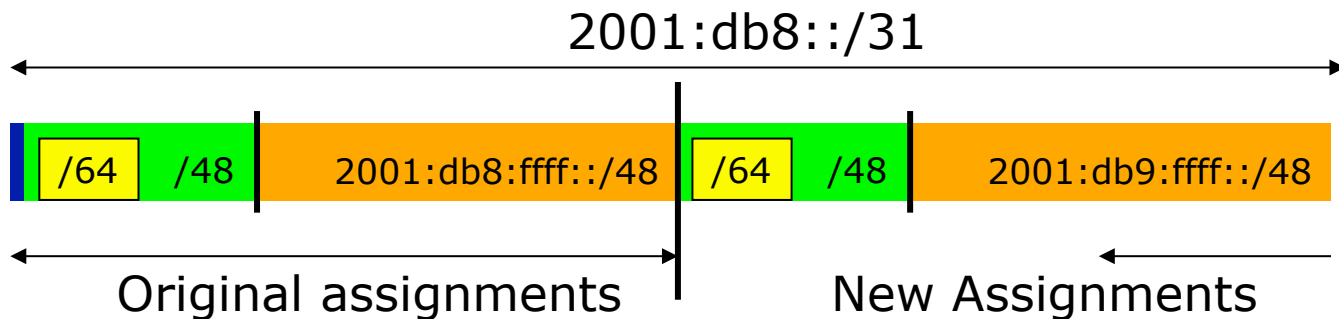
- Registries will usually allocate the next block to be contiguous with the first allocation
  - Minimum allocation is /32
  - Very likely that subsequent allocation will make this up to a /31
  - So plan accordingly

# Addressing Plans – ISP Infrastructure

## Phase One



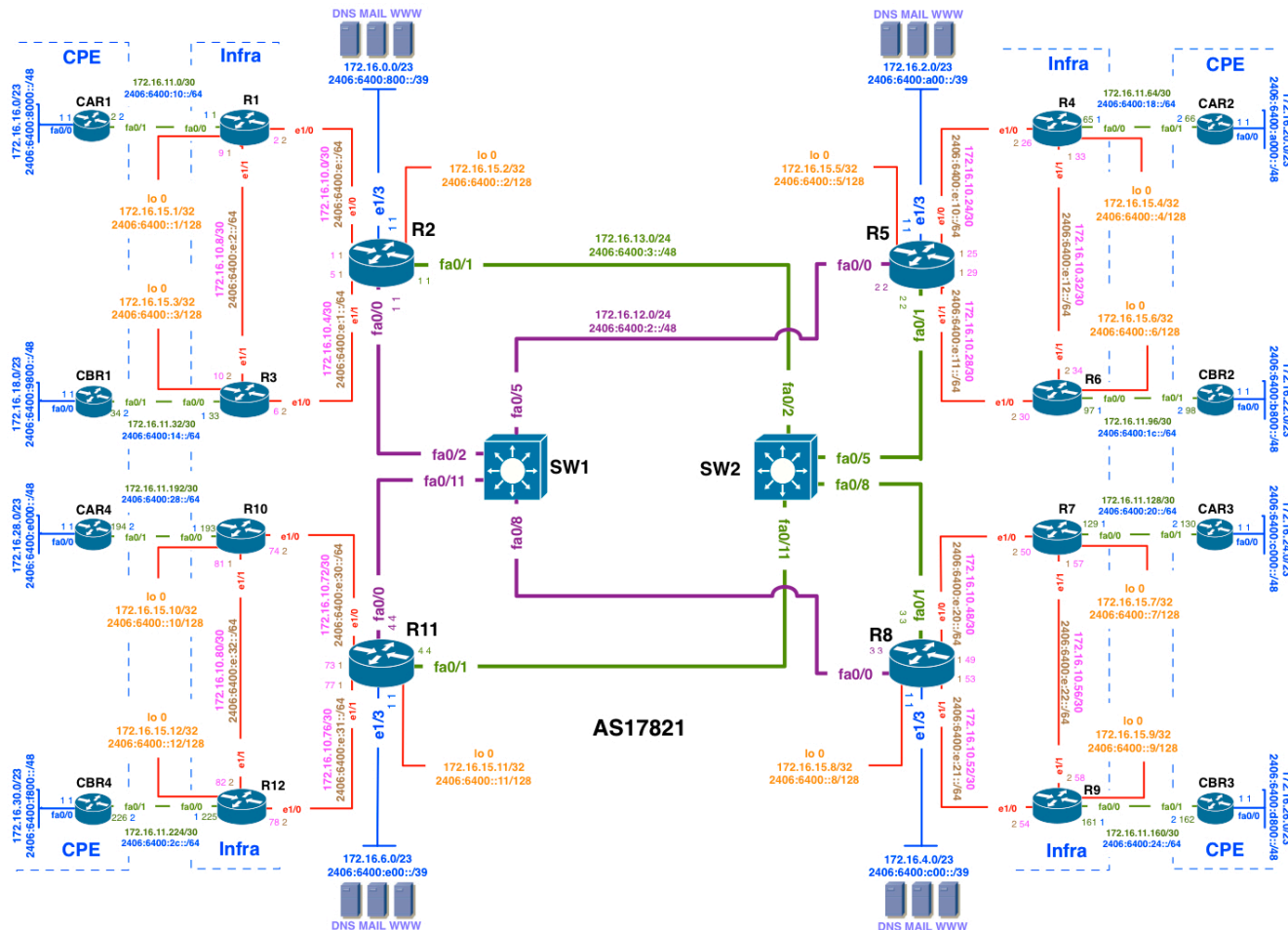
## Phase Two – Second /32



# Example Address Plan

- IPv6 Allocation From Registry is
  - 2406:6400::/32
- IPv4 Allocation From Registry is
  - 172.16.0.0/19

# Training ISP IPv6 Addressing Plan



# Training ISP IPV6 Addressing Plan

- IPv6 Address Plan:

Table 1: Top level distribution infrastructure & customer					
Block#	Prefix	Description	Reverse Domain	SOR	Registration
1	<b>2406:6400::/32</b>	<b>Parent Block</b>	0.0.4.6.6.0.4.2.ip6.arpa.	N/A	APNIC
2	2406:6400:0000:0000::/36	Infrastructure	0.0.0.4.6.6.0.4.2.ip6.arpa.	No	Optional
	2406:6400:1000:0000::/36				
	2406:6400:2000:0000::/36				
	2406:6400:3000:0000::/36				
	2406:6400:4000:0000::/36				
	2406:6400:5000:0000::/36				
	2406:6400:6000:0000::/36				
	2406:6400:7000:0000::/36				
3	2406:6400:8000:0000::/36	Customer network Region 1	8.0.0.4.6.6.0.4.2.ip6.arpa.	Not yet	Optional
	2406:6400:9000:0000::/36				
4	2406:6400:a000:0000::/36	Customer network Region 2	a.0.0.4.6.6.0.4.2.ip6.arpa.	Not yet	Optional
	2406:6400:b000:0000::/36				
5	2406:6400:c000:0000::/36	Customer network Region 3	c.0.0.4.6.6.0.4.2.ip6.arpa.	Not yet	Optional
	2406:6400:d000:0000::/36				
6	2406:6400:e000:0000::/36	Customer network Region 4	e.0.0.4.6.6.0.4.2.ip6.arpa.	Not yet	Optional
	2406:6400:f000:0000::/36				

# Training ISP IPV6 Addressing Plan

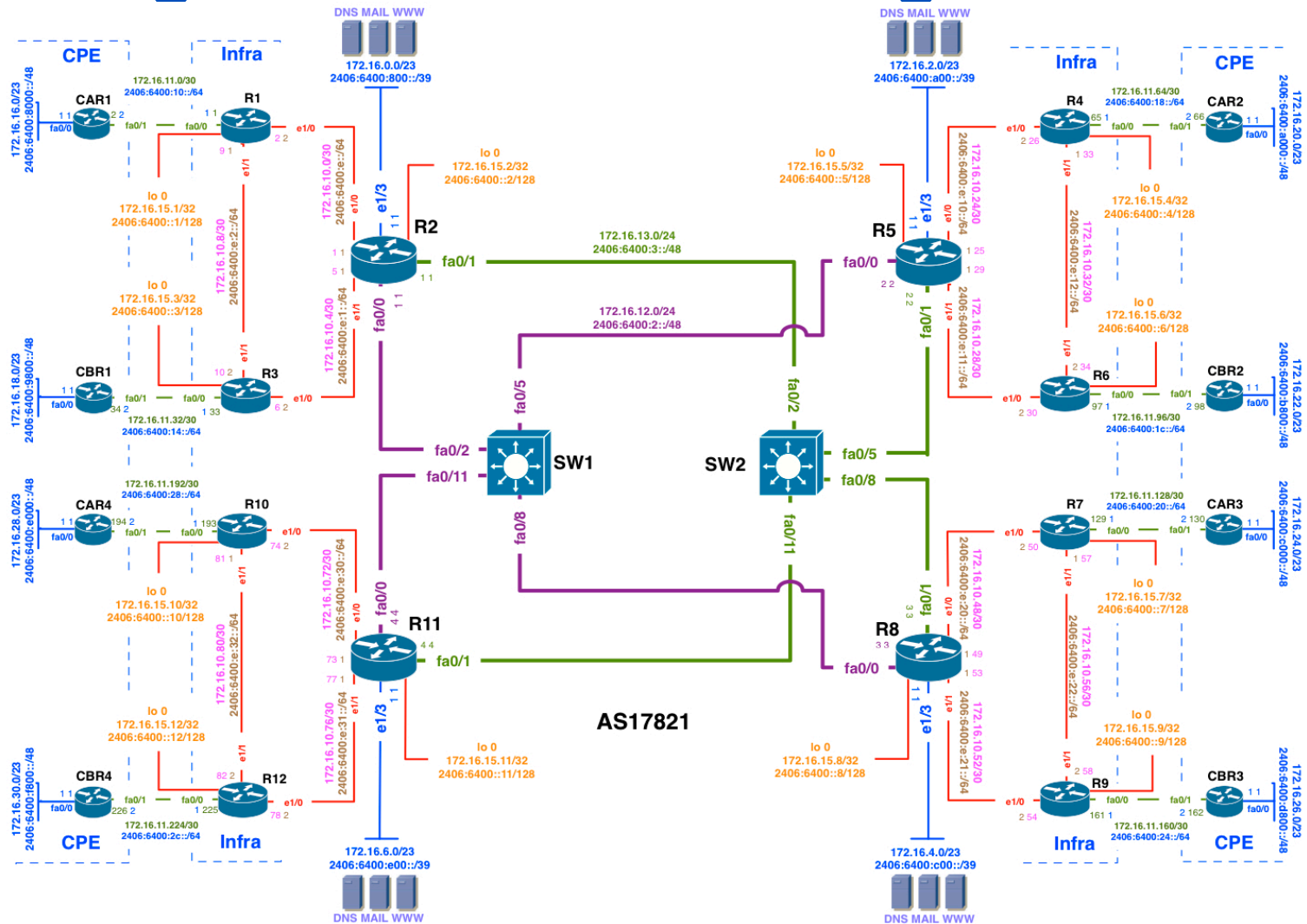
- IPv6 Address Plan:

**Table 2: Top level summarization option infrastructure & customer**

Block#	Prefix	Description	Reverse Domain
7	2406:6400:8000:0000::/35	CS net summary region1 [R2]	2x/36 arpa domain
8	2406:6400:a000:0000::/35	CS net summary region2 [R5]	2x/36 arpa domain
9	2406:6400:c000:0000::/35	CS net summary region3 [R8]	2x/36 arpa domain
10	2406:6400:e000:0000::/35	CS net summary region4 [R11]	2x/36 arpa domain



# Training ISP IPV6 Addressing Plan



# Training ISP IPV6 Addressing Plan

- IPv6 Address Plan:

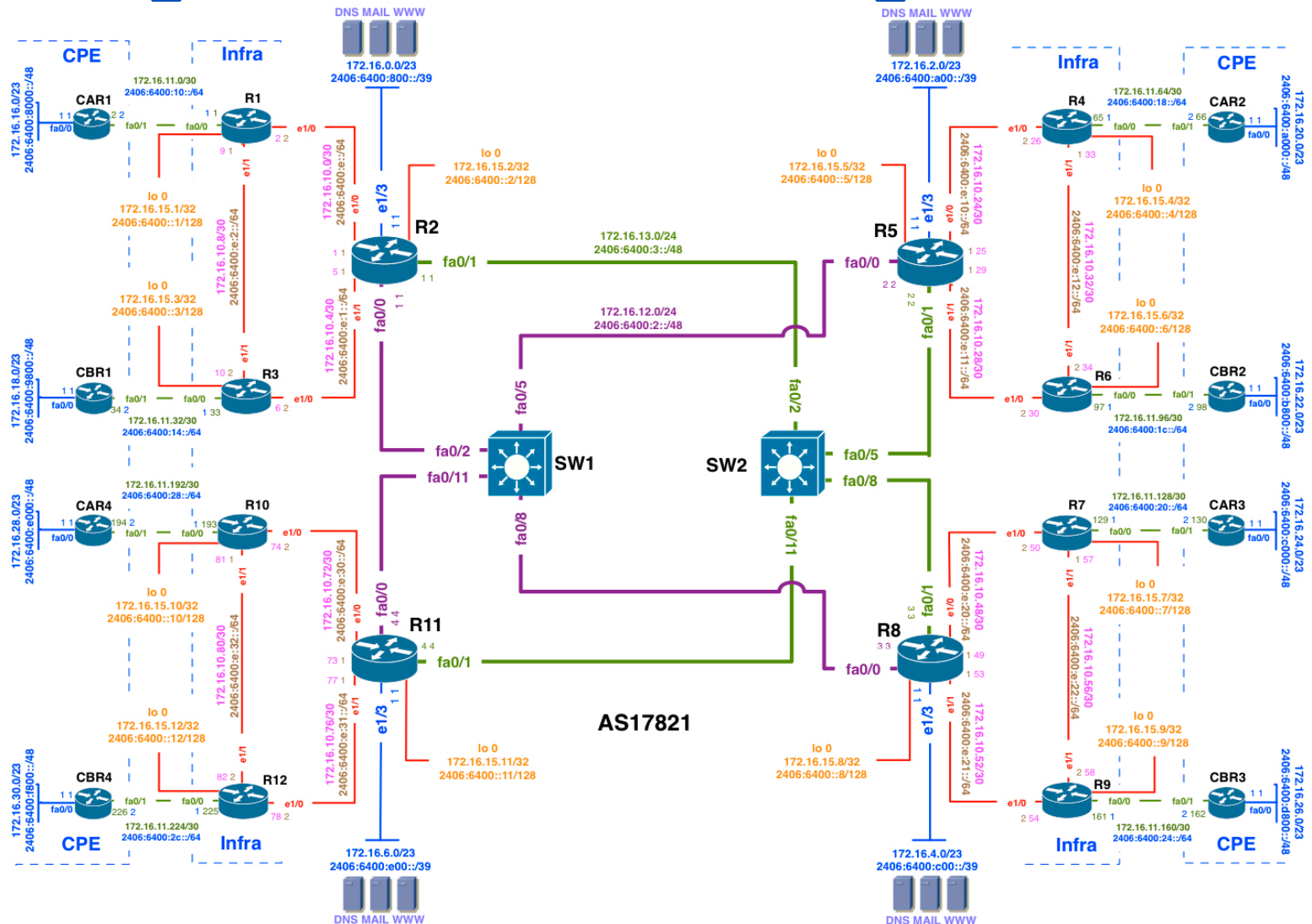
Table 3: Detail distribution infrastructure					
Block#	Prefix	Description	Reverse Domain	SOR	Registration
2	<b>2406:6400:0000:0000::/36</b>	<b>Infrastructure</b>	0.0.0.4.6.6.0.4.2.ip6.arpa.	No	Optional
11	2406:6400:0000:0000::/40	Loopback, Transport & WAN [Infra+CS]	0.0.0.0.4.6.6.0.4.2.ip6.arpa.	No	Optional
	2406:6400:0100:0000::/40				
	2406:6400:0200:0000::/40				
	2406:6400:0300:0000::/40				
	2406:6400:0400:0000::/40				
	2406:6400:0500:0000::/40				
	2406:6400:0600:0000::/40				
	2406:6400:0700:0000::/40				
16	2406:6400:0800:0000::/40	R2 DC	8.0.0.0.4.6.6.0.4.2.ip6.arpa.	No	Recommended
	2406:6400:0900:0000::/40				
17	2406:6400:0a00:0000::/40	R5 DC	a.0.0.0.4.6.6.0.4.2.ip6.arpa.	No	Recommended
	2406:6400:0b00:0000::/40				
18	2406:6400:0c00:0000::/40	R8 DC	c.0.0.0.4.6.6.0.4.2.ip6.arpa.	No	Recommended
	2406:6400:0d00:0000::/40				
19	2406:6400:0e00:0000::/40	R11 DC	e.0.0.0.4.6.6.0.4.2.ip6.arpa.	No	Recommended
	2406:6400:0f00:0000::/40				

# Training ISP IPV6 Addressing Plan

- IPv6 Address Plan:

Table 4: Datacenter prefix summarization options			
Block#	Prefix	Description	Reverse Domain
12	2406:6400:0800:0000::/39	Region 1 DC Summary [R2]	
13	2406:6400:0a00:0000::/39	Region 2 DC Summary [R5]	
14	2406:6400:0c00:0000::/39	Region 3 DC Summary [R8]	
15	2406:6400:0e00:0000::/39	Region 3 DC Summary [R8]	

# Training ISP IPV6 Addressing Plan



# Training ISP IPV6 Addressing Plan

- IPv6 Address Plan:

Table 5: Further detail loopback, transport & infrastructure WAN					
Block#	Prefix	Description	Reverse Domain	SOR	Registration
11	2406:6400:0000:0000::/40	Loopback, Transport & Infra WAN	0.0.0.0.4.6.6.0.4.2.ip6.arpa.		
20	2406:6400:0000:0000::/48	Loopback		No	Recommended
	2406:6400:0001:0000::/48				
21	2406:6400:0002:0000::/48	Purple Transport		No	Recommended
22	2406:6400:0003:0000::/48	Green Transport		No	Recommended
	2406:6400:0004:0000::/48				
	2406:6400:0005:0000::/48				
	2406:6400:0006:0000::/48				
	2406:6400:0007:0000::/48				
	2406:6400:0008:0000::/48				
	2406:6400:0009:0000::/48				
	2406:6400:000A:0000::/48				
	2406:6400:000B:0000::/48				
	2406:6400:000C:0000::/48				
	2406:6400:000D:0000::/48				
23	2406:6400:000E:0000::/48	WAN Prefix Infra Link		No	Recommended
	2406:6400:000F:0000::/48				

# Training ISP IPV6 Addressing Plan

- IPv6 Address Plan:

Table 6: Further detail CS link WAN					
Block#	Prefix	Description	Reverse Domain	SOR	Registration
27	2406:6400:0010:0000::/48	WAN Prefix CS Link R1 Region1		No	Recommended
	2406:6400:0011:0000::/48				
	2406:6400:0012:0000::/48				
	2406:6400:0013:0000::/48				
28	2406:6400:0014:0000::/48	WAN Prefix CS Link R3 Region1		No	Recommended
	2406:6400:0015:0000::/48				
	2406:6400:0016:0000::/48				
	2406:6400:0017:0000::/48				
32	2406:6400:0018:0000::/48	WAN Prefix CS Link R4 Region2		No	Recommended
	2406:6400:0019:0000::/48				
	2406:6400:001A:0000::/48				
	2406:6400:001B:0000::/48				
33	2406:6400:001C:0000::/48	WAN Prefix CS Link R6 Region2		No	Recommended
	2406:6400:001D:0000::/48				
	2406:6400:001E:0000::/48				
	2406:6400:001F:0000::/48				
37	2406:6400:0020:0000::/48	WAN Prefix CS Link R7 Region3		No	Recommended
	2406:6400:0021:0000::/48				
	2406:6400:0022:0000::/48				
	2406:6400:0023:0000::/48				
38	2406:6400:0024:0000::/48	WAN Prefix CS Link R9 Region3		No	Recommended
	2406:6400:0025:0000::/48				
	2406:6400:0026:0000::/48				
	2406:6400:0027:0000::/48				
42	2406:6400:0028:0000::/48	WAN Prefix CS Link R10 Region4		No	Recommended
	2406:6400:0029:0000::/48				
	2406:6400:002A:0000::/48				
	2406:6400:002B:0000::/48				
43	2406:6400:002C:0000::/48	WAN Prefix CS Link R12 Region4		No	Recommended
	2406:6400:002D:0000::/48				
	2406:6400:002E:0000::/48				
	2406:6400:002F:0000::/48				

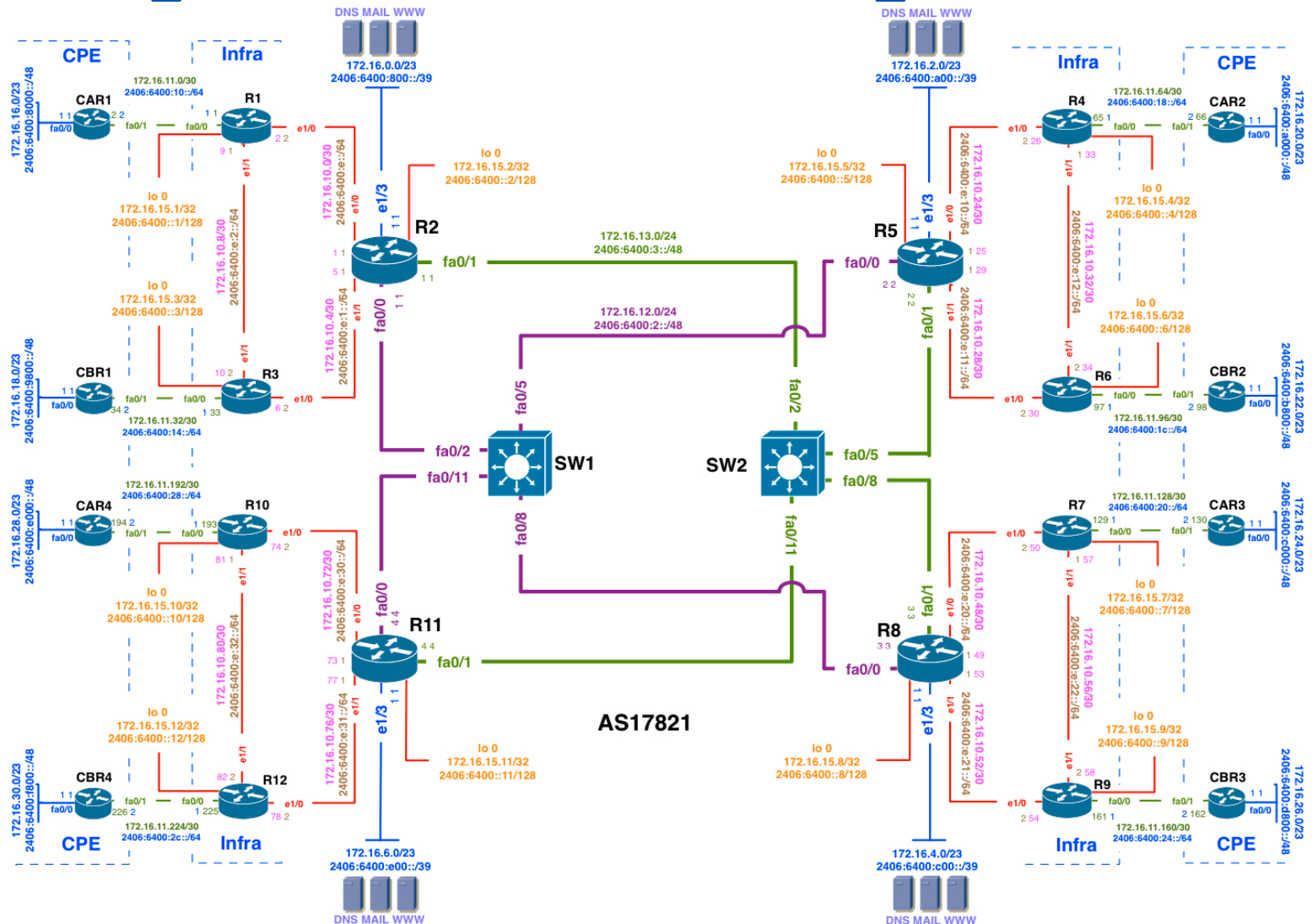
# Training ISP IPV6 Addressing Plan

- IPv6 Address Plan:

Table 7: CS link WAN summarization options			
Block#	Prefix	Description	Reverse Domain
24	2406:6400:0010:0000::/45	WAN CS Link Region1 Summary [R2]	
25	2406:6400:0010:0000::/46	WAN CS Link Region1 POP1 Summary [R1]	
26	2406:6400:0014:0000::/46	WAN CS Link Region1 POP2 Summary [R3]	
Block#	Prefix	Description	Reverse Domain
29	2406:6400:0018:0000::/45	WAN Prefix CS Link Region2 Summary [R5]	
30	2406:6400:0018:0000::/46	WAN CS Link Region2 POP1 Summary [R4]	
31	2406:6400:001C:0000::/46	WAN CS Link Region2 POP2 Summary [R6]	
Block#	Prefix	Description	Reverse Domain
34	2406:6400:0020:0000::/45	WAN Prefix CS Link Region3 Summary [R8]	
35	2406:6400:0020:0000::/46	WAN CS Link Region3 POP1 Summary [R7]	
36	2406:6400:0024:0000::/46	WAN CS Link Region3 POP2 Summary [R9]	
Block#	Prefix	Description	Reverse Domain
39	2406:6400:0028:0000::/45	WAN Prefix CS Link Region4 Summary [R11]	
40	2406:6400:0028:0000::/46	WAN CS Link Region4 POP1 Summary [R10]	
41	2406:6400:002C:0000::/46	WAN CS Link Region4 POP2 Summary [R12]	



# Training ISP IPV6 Addressing Plan





# Training ISP IPV6 Addressing Plan

- IPv6 Address Plan:

Table 8: Further detail loopback					
Block#	Prefix	Description	PTR Record	SOR	Registration
20	2406:6400:0000:0000::/48	Loopback		No	Recommeded
			YES		
43	2406:6400:0000:0000::1/128	Router1 loopback 0	YES	No	No
44	2406:6400:0000:0000::2/128	Router2 loopback 0	YES	No	No
45	2406:6400:0000:0000::3/128	Router3 loopback 0	YES	No	No
46	2406:6400:0000:0000::4/128	Router4 loopback 0	YES	No	No
47	2406:6400:0000:0000::5/128	Router5 loopback 0	YES	No	No
48	2406:6400:0000:0000::6/128	Router6 loopback 0	YES	No	No
49	2406:6400:0000:0000::7/128	Router7 loopback 0	YES	No	No
50	2406:6400:0000:0000::8/128	Router8 loopback 0	YES	No	No
51	2406:6400:0000:0000::9/128	Router9 loopback 0	YES	No	No
52	2406:6400:0000:0000::10/128	Router10 loopback 0	YES	No	No
53	2406:6400:0000:0000::11/128	Router11 loopback 0	YES	No	No
54	2406:6400:0000:0000::12/128	Router12 loopback 0	YES	No	No

# Training ISP IPV6 Addressing Plan

- IPv6 Address Plan:

Table 9: Further detail transport					
Block#	Prefix	Description	PTR Record	SOR	Registration
21	2406:6400:0002:0000::/48	Purple Transport		No	Recommended
	2406:6400:0002:0000::1/48	Router2 fa0/0	YES	No	No
	2406:6400:0002:0000::2/48	Router5 fa0/0	YES	No	No
	2406:6400:0002:0000::3/48	Router8 fa0/0	YES	No	No
	2406:6400:0002:0000::4/48	Router11 fa0/0	YES	No	No
Block#	Prefix	Description	PTR Record	SOR	Registration
22	2406:6400:0003:0000::/48	Green Transport		No	Recommended
	2406:6400:0003:0000::1/48	Router2 fa0/1	YES	No	No
	2406:6400:0003:0000::2/48	Router5 fa0/1	YES	No	No
	2406:6400:0003:0000::3/48	Router8 fa0/1	YES	No	No
	2406:6400:0003:0000::4/48	Router11 fa0/1	YES	No	No

# Training ISP IPV6 Addressing Plan

- IPv6 Address Plan:

Table 10: Further detail Infra WAN					
Block#	Prefix	Description	PTR Record	SOR	Registration
23	2406:6400:000E:0000::/48	WAN Prefix Infra Link		No	Recommended
55	2406:6400:000E:0000::/64	R2[::1]-R1[::2]	YES	No	No
56	2406:6400:000E:0001::/64	R2[::1]-R3[::2]	YES	No	No
57	2406:6400:000E:0002::/64	R1[::1]-R3[::2]	YES	No	No
	2406:6400:000E:0003::/64				
	2406:6400:000E:0004::/64				
	2406:6400:000E:0005::/64				
	2406:6400:000E:0006::/64				
	2406:6400:000E:0007::/64				
	2406:6400:000E:0008::/64				
	2406:6400:000E:0009::/64				
	2406:6400:000E:000A::/64				
	2406:6400:000E:000B::/64				
	2406:6400:000E:000C::/64				
	2406:6400:000E:000D::/64				
	2406:6400:000E:000E::/64				
	2406:6400:000E:000F::/64				
58	2406:6400:000E:0010::/64	R5[::1]-R4[::2]	YES	No	No
59	2406:6400:000E:0011::/64	R5[::1]-R6[::2]	YES	No	No
60	2406:6400:000E:0012::/64	R4[::1]-R6[::2]	YES	No	No
	2406:6400:000E:0013::/64				
	2406:6400:000E:0014::/64				
	2406:6400:000E:0015::/64				
	2406:6400:000E:0016::/64				
	2406:6400:000E:0017::/64				
	2406:6400:000E:0018::/64				
	2406:6400:000E:0019::/64				
	2406:6400:000E:001A::/64				
	2406:6400:000E:001B::/64				
	2406:6400:000E:001C::/64				
	2406:6400:000E:001D::/64				
	2406:6400:000E:001E::/64				
	2406:6400:000E:001F::/64				
61	2406:6400:000E:0020::/64	R8[::1]-R7[::2]	YES	No	No
62	2406:6400:000E:0021::/64	R8[::1]-R9[::2]	YES	No	No
63	2406:6400:000E:0022::/64	R7[::1]-R9[::2]	YES	No	No
	2406:6400:000E:0023::/64				
	2406:6400:000E:0024::/64				
	2406:6400:000E:0025::/64				
	2406:6400:000E:0026::/64				
	2406:6400:000E:0027::/64				
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	2406:6400:000E:002B::/64				
	2406:6400:000E:002C::/64				
	2406:6400:000E:002D::/64				
	2406:6400:000E:002E::/64				
	2406:6400:000E:002F::/64				
64	2406:6400:000E:0030::/64	R11[::1]-R10[::2]	YES	No	No
65	2406:6400:000E:0031::/64	R11[::1]-R12[::2]	YES	No	No
66	2406:6400:000E:0032::/64	R10[::1]-R12[::2]	YES	No	No
	2406:6400:000E:0033::/64				
	2406:6400:000E:0034::/64				
	2406:6400:000E:0035::/64				
	2406:6400:000E:0036::/64				
	2406:6400:000E:0037::/64				
	2406:6400:000E:0038::/64				
	2406:6400:000E:0039::/64				
	2406:6400:000E:003A::/64				

# Training ISP IPV6 Addressing Plan

- IPv6 Address Plan:

Table 11: Detail CS link WAN Region 1					
Block#	Prefix	Description	PTR Record	SOR	Registration
27	2406:6400:0010:0000::/48	WAN Prefix CS Link R1 Region1		No	Recommended
	2406:6400:0010:0000::/64	R1[::1]-CAR1[::2]	Yes	No	No
	2406:6400:0010:0001::/64		Yes	No	No
	2406:6400:0010:0002::/64		Yes	No	No
	2406:6400:0010:0003::/64		Yes	No	No
	2406:6400:0010:0004::/64		Yes	No	No
	2406:6400:0010:0005::/64		Yes	No	No
	2406:6400:0010:0006::/64		Yes	No	No
	2406:6400:0010:0007::/64		Yes	No	No
	2406:6400:0010:0008::/64		Yes	No	No
	2406:6400:0010:0009::/64		Yes	No	No
	2406:6400:0010:000A::/64		Yes	No	No
	2406:6400:0010:000B::/64		Yes	No	No
	2406:6400:0010:000C::/64		Yes	No	No
	2406:6400:0010:000D::/64		Yes	No	No
	2406:6400:0010:000E::/64		Yes	No	No
	2406:6400:0010:000F::/64		Yes	No	No
Block#	Prefix	Description	PTR Record	SOR	Registration
28	2406:6400:0014:0000::/48	WAN Prefix CS Link R3 Region1		No	Recommended
	2406:6400:0014:0000::/64	R3[::1]-CBR1[::2]	Yes	No	No
	2406:6400:0014:0001::/64		Yes	No	No
	2406:6400:0014:0002::/64		Yes	No	No
	2406:6400:0014:0003::/64		Yes	No	No
	2406:6400:0014:0004::/64		Yes	No	No
	2406:6400:0014:0005::/64		Yes	No	No
	2406:6400:0014:0006::/64		Yes	No	No
	2406:6400:0014:0007::/64		Yes	No	No
	2406:6400:0014:0008::/64		Yes	No	No
	2406:6400:0014:0009::/64		Yes	No	No
	2406:6400:0014:000A::/64		Yes	No	No
	2406:6400:0014:000B::/64		Yes	No	No
	2406:6400:0014:000C::/64		Yes	No	No
	2406:6400:0014:000D::/64		Yes	No	No
	2406:6400:0014:000E::/64		Yes	No	No
	2406:6400:0014:000F::/64		Yes	No	No

# Training ISP IPV6 Addressing Plan

- IPv6 Address Plan:

Table 12: Detail CS link WAN Region 2					
Block#	Prefix	Description	PTR Record	SOR	Registration
32	2406:6400:0018:0000::/48	WAN Prefix CS Link R4 Region2		No	Recommended
	2406:6400:0018:0000::/64	R4[::1]-CAR2[::2]	Yes	No	No
	2406:6400:0018:0001::/64		Yes	No	No
	2406:6400:0018:0002::/64		Yes	No	No
	2406:6400:0018:0003::/64		Yes	No	No
	2406:6400:0018:0004::/64		Yes	No	No
	2406:6400:0018:0005::/64		Yes	No	No
	2406:6400:0018:0006::/64		Yes	No	No
	2406:6400:0018:0007::/64		Yes	No	No
	2406:6400:0018:0008::/64		Yes	No	No
	2406:6400:0018:0009::/64		Yes	No	No
	2406:6400:0018:000A::/64		Yes	No	No
	2406:6400:0018:000B::/64		Yes	No	No
	2406:6400:0018:000C::/64		Yes	No	No
	2406:6400:0018:000D::/64		Yes	No	No
	2406:6400:0018:000E::/64		Yes	No	No
	2406:6400:0018:000F::/64		Yes	No	No
Block#	Prefix	Description	PTR Record	SOR	Registration
33	2406:6400:001C:0000::/48	WAN Prefix CS Link R6 Region2		No	Recommended
	2406:6400:001C:0000::/64	R6[::1]-CBR2[::2]	Yes	No	No
	2406:6400:001C:0001::/64		Yes	No	No
	2406:6400:001C:0002::/64		Yes	No	No
	2406:6400:001C:0003::/64		Yes	No	No
	2406:6400:001C:0004::/64		Yes	No	No
	2406:6400:001C:0005::/64		Yes	No	No
	2406:6400:001C:0006::/64		Yes	No	No
	2406:6400:001C:0007::/64		Yes	No	No
	2406:6400:001C:0008::/64		Yes	No	No
	2406:6400:001C:0009::/64		Yes	No	No
	2406:6400:001C:000A::/64		Yes	No	No
	2406:6400:001C:000B::/64		Yes	No	No
	2406:6400:001C:000C::/64		Yes	No	No
	2406:6400:001C:000D::/64		Yes	No	No
	2406:6400:001C:000E::/64		Yes	No	No
	2406:6400:001C:000F::/64		Yes	No	No

# Training ISP IPV6 Addressing Plan

- IPv6 Address Plan:

Table 13: Detail CS link WAN Region3					
Block#	Prefix	Description	PTR Record	SOR	Registration
37	2406:6400:0020:0000::/48	WAN Prefix CS Link R7 Region3		No	Recommended
	2406:6400:0020:0000::/64	R7[::1]-CAR3[::2]	Yes	No	No
	2406:6400:0020:0001::/64		Yes	No	No
	2406:6400:0020:0002::/64		Yes	No	No
	2406:6400:0020:0003::/64		Yes	No	No
	2406:6400:0020:0004::/64		Yes	No	No
	2406:6400:0020:0005::/64		Yes	No	No
	2406:6400:0020:0006::/64		Yes	No	No
	2406:6400:0020:0007::/64		Yes	No	No
	2406:6400:0020:0008::/64		Yes	No	No
	2406:6400:0020:0009::/64		Yes	No	No
	2406:6400:0020:000A::/64		Yes	No	No
	2406:6400:0020:000B::/64		Yes	No	No
	2406:6400:0020:000C::/64		Yes	No	No
	2406:6400:0020:000D::/64		Yes	No	No
	2406:6400:0020:000E::/64		Yes	No	No
	2406:6400:0020:000F::/64		Yes	No	No
Block#	Prefix	Description	PTR Record	SOR	Registration
38	2406:6400:0024:0000::/48	WAN Prefix CS Link R9 Region3		No	Recommended
	2406:6400:0024:0000::/64	R9[::1]-CBR3[::2]	Yes	No	No
	2406:6400:0024:0001::/64		Yes	No	No
	2406:6400:0024:0002::/64		Yes	No	No
	2406:6400:0024:0003::/64		Yes	No	No
	2406:6400:0024:0004::/64		Yes	No	No
	2406:6400:0024:0005::/64		Yes	No	No
	2406:6400:0024:0006::/64		Yes	No	No
	2406:6400:0024:0007::/64		Yes	No	No
	2406:6400:0024:0008::/64		Yes	No	No
	2406:6400:0024:0009::/64		Yes	No	No
	2406:6400:0024:000A::/64		Yes	No	No
	2406:6400:0024:000B::/64		Yes	No	No
	2406:6400:0024:000C::/64		Yes	No	No
	2406:6400:0024:000D::/64		Yes	No	No
	2406:6400:0024:000E::/64		Yes	No	No
	2406:6400:0024:000F::/64		Yes	No	No

# Training ISP IPV6 Addressing Plan

- IPv6 Address Plan:

Table 15: Customer block Region 1					
Block#	Prefix	Description	Reverse DNS	SOR	Registration
7	2406:6400:8000:0000::/35	Customer block Region 1			
	2406:6400:8000:0000::/40	Customer block POP1 [R1]		>= /48 Yes	Yes
	2406:6400:8100:0000::/40				
	2406:6400:8200:0000::/40				
	2406:6400:8300:0000::/40				
	2406:6400:8400:0000::/40				
	2406:6400:8500:0000::/40				
	2406:6400:8600:0000::/40				
	2406:6400:8700:0000::/40				
	2406:6400:8800:0000::/40	Customer block future use/POP		>= /48 Yes	Yes
	2406:6400:8900:0000::/40				
	2406:6400:8A00:0000::/40				
	2406:6400:8B00:0000::/40				
	2406:6400:8C00:0000::/40				
	2406:6400:8D00:0000::/40				
	2406:6400:8E00:0000::/40				
	2406:6400:8F00:0000::/40				
	2406:6400:9000:0000::/40	Customer block future use/POP		>= /48 Yes	Yes
	2406:6400:9100:0000::/40				
	2406:6400:9200:0000::/40				
	2406:6400:9300:0000::/40				
	2406:6400:9400:0000::/40				
	2406:6400:9500:0000::/40				
	2406:6400:9600:0000::/40				
	2406:6400:9700:0000::/40				
	2406:6400:9800:0000::/40	Customer block POP2 [R3]		>= /48 Yes	Yes
	2406:6400:9900:0000::/40				
	2406:6400:9A00:0000::/40				
	2406:6400:9B00:0000::/40				
	2406:6400:9C00:0000::/40				
	2406:6400:9D00:0000::/40				
	2406:6400:9E00:0000::/40				
	2406:6400:9F00:0000::/40				

# Training ISP IPV6 Addressing Plan

- IPv6 Address Plan:

Table 16: Summarization oprions customer block Region 1			
Block#	Prefix	Description	Reverse Domain
	2406:6400:8000:0000::/35	Customer block Region 1 [R2]	
	2406:6400:8000:0000::/37	Customer block POP1 [R1]	
	2406:6400:8800:0000::/37	Customer block future use/POP	
	2406:6400:9000:0000::/37	Customer block future use/POP	
	2406:6400:9800:0000::/37	Customer block POP2 [R3]	

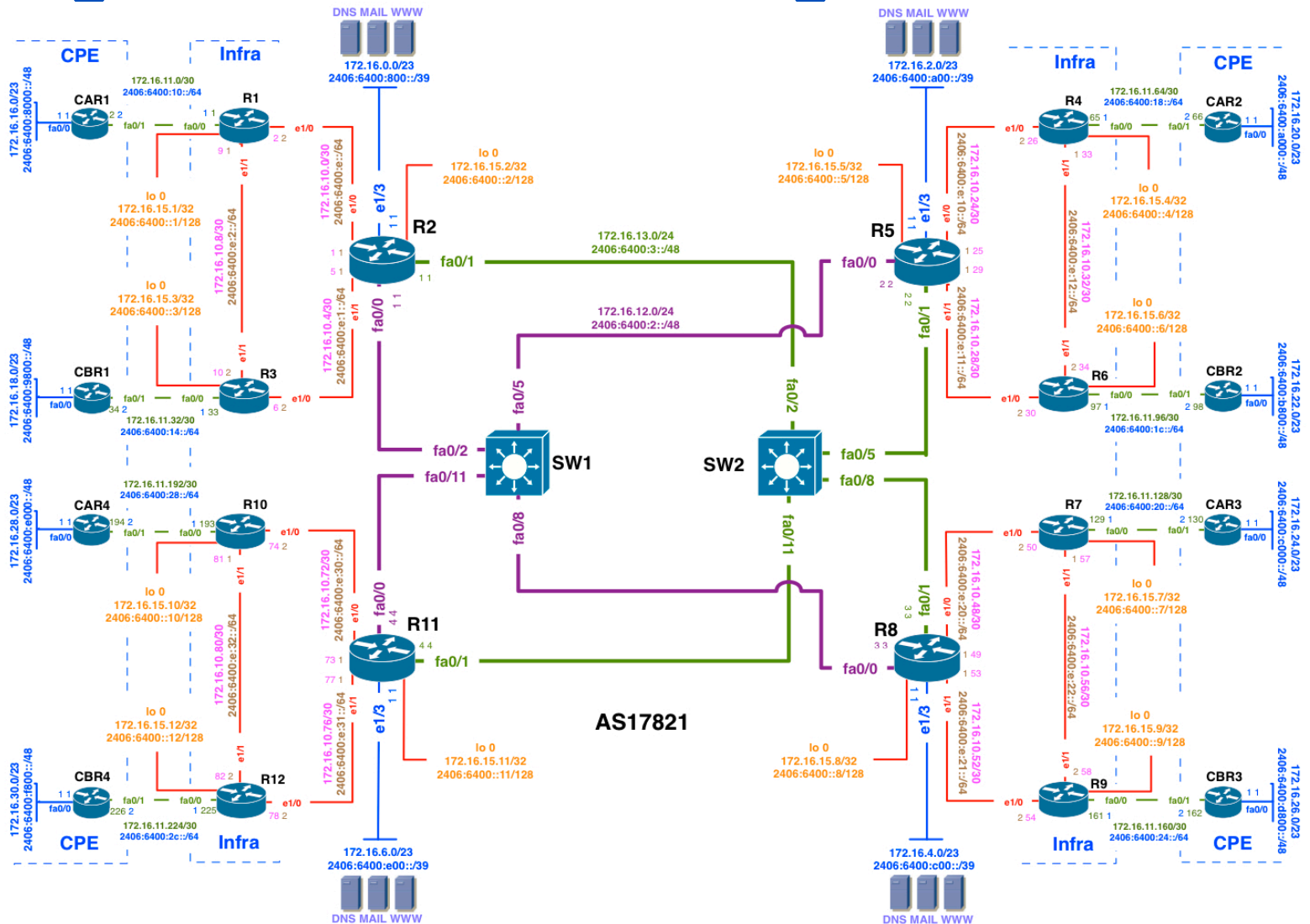


# Training ISP IPV6 Addressing Plan

- IPv6 Address Plan:

Table 17: Detail customer block Region 1					
Block#	Prefix	Description	Reverse DNS	SOR	Registration
	2406:6400:8000:0000::/40	1st Customer block POP1 [R1]			
	2406:6400:8000:0000::/48	1st Customer prefix POP1 [R1]		Yes	Yes
	2406:6400:8001:0000::/48				
	2406:6400:8002:0000::/48				
	2406:6400:8003:0000::/48				
	2406:6400:8004:0000::/48				
	2406:6400:8005:0000::/48				
	2406:6400:8006:0000::/48				
	2406:6400:8007:0000::/48				
	2406:6400:9800:0000::/40	1st Customer block POP2 [R3]			
	2406:6400:9800:0000::/48	1st Customer prefix POP2 [R3]		Yes	Yes
	2406:6400:9801:0000::/48				
	2406:6400:9802:0000::/48				
	2406:6400:9803:0000::/48				
	2406:6400:9804:0000::/48				
	2406:6400:9805:0000::/48				
	2406:6400:9806:0000::/48				
	2406:6400:9807:0000::/48				

# Training ISP IPV6 Addressing Plan



# Training ISP IPV6 Addressing Plan

- IPv6 Address Plan:

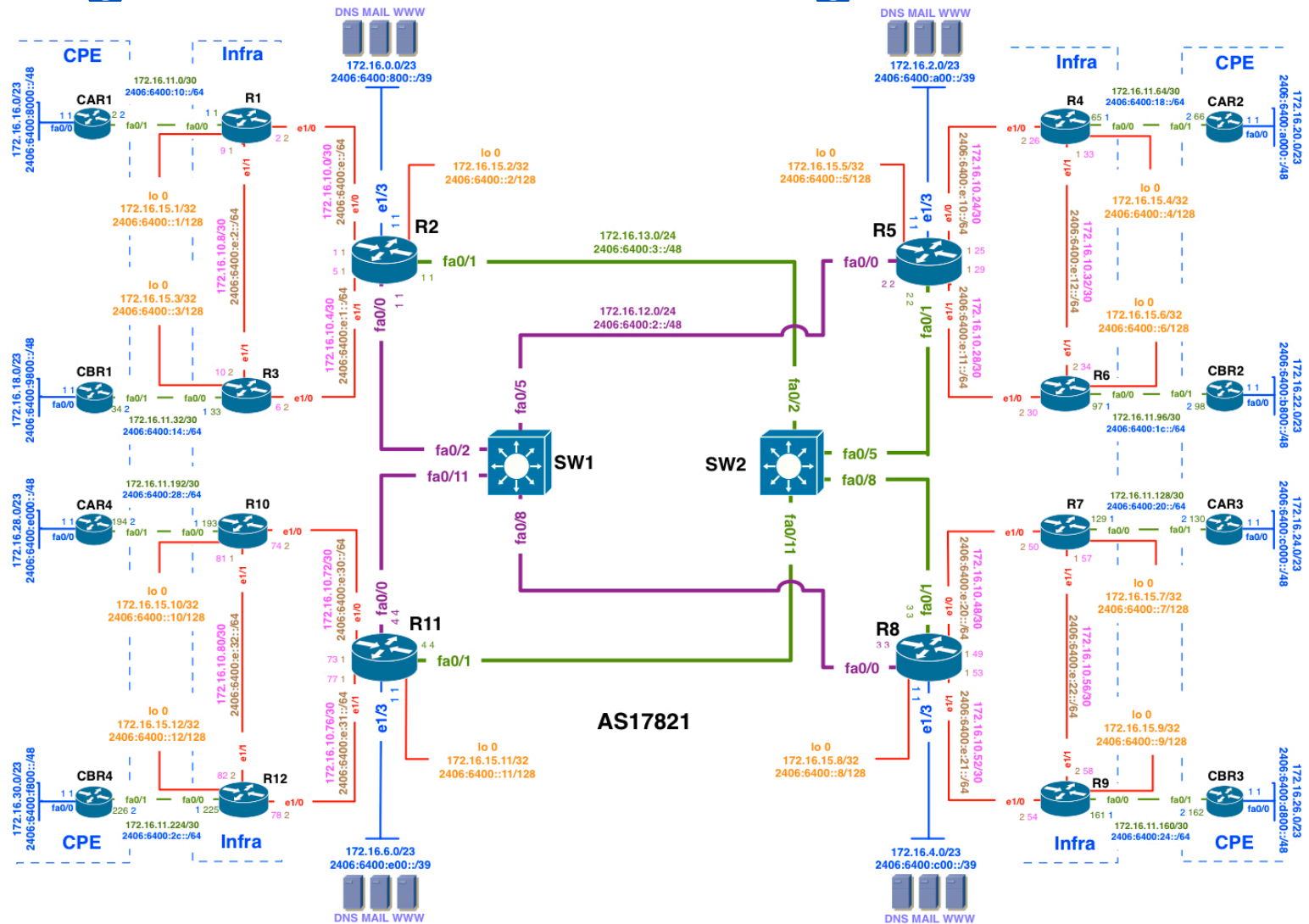
Table 18: Customer block Region 2					
Block#	Prefix	Description	Reverse DNS	SOR	Registration
8	2406:6400:a000:0000::/35	Customer block Region 2			
	2406:6400:A000:0000::/40	Customer block POP1 [R4]		>= /48 Yes	Yes
	2406:6400:A100:0000::/40				
	2406:6400:A200:0000::/40				
	2406:6400:A300:0000::/40				
	2406:6400:A400:0000::/40				
	2406:6400:A500:0000::/40				
	2406:6400:A600:0000::/40				
	2406:6400:A700:0000::/40				
	2406:6400:A800:0000::/40	Customer block future use/POP		>= /48 Yes	Yes
	2406:6400:A900:0000::/40				
	2406:6400:AA00:0000::/40				
	2406:6400:AB00:0000::/40				
	2406:6400:AC00:0000::/40				
	2406:6400:AD00:0000::/40				
	2406:6400:AE00:0000::/40				
	2406:6400:AF00:0000::/40				
	2406:6400:B000:0000::/40	Customer block future use/POP		>= /48 Yes	Yes
	2406:6400:B100:0000::/40				
	2406:6400:B200:0000::/40				
	2406:6400:B300:0000::/40				
	2406:6400:B400:0000::/40				
	2406:6400:B500:0000::/40				
	2406:6400:B600:0000::/40				
	2406:6400:B700:0000::/40				
	2406:6400:B800:0000::/40	Customer block POP2 [R6]		>= /48 Yes	Yes
	2406:6400:B900:0000::/40				
	2406:6400:BA00:0000::/40				
	2406:6400:BB00:0000::/40				
	2406:6400:BC00:0000::/40				
	2406:6400:BD00:0000::/40				
	2406:6400:BE00:0000::/40				
	2406:6400:BF00:0000::/40				

# Training ISP IPV6 Addressing Plan

- IPv6 Address Plan:

Table 19: Summarization oprions customer block Region 2			
Block#	Prefix	Description	Reverse Domain
	2406:6400:A000:0000::/35	Customer block Region 2 [R5]	
	2406:6400:A000:0000::/37	Customer block POP1 [R4]	
	2406:6400:A800:0000::/37	Customer block future use/POP	
	2406:6400:B000:0000::/37	Customer block future use/POP	
	2406:6400:B800:0000::/37	Customer block POP2 [R6]	

# Training ISP IPV6 Addressing Plan



# Training ISP IPV6 Addressing Plan

- IPv6 Address Plan:

Table 20: Detail customer block Region 2					
Block#	Prefix	Description	Reverse DNS	SOR	Registration
	2406:6400:A000:0000::/40	1st Customer block POP1 [R4]			
	2406:6400:A000:0000::/48	1st Customer prefix POP1 [R4]		Yes	Yes
	2406:6400:A001:0000::/48				
	2406:6400:A002:0000::/48				
	2406:6400:A003:0000::/48				
	2406:6400:A004:0000::/48				
	2406:6400:A005:0000::/48				
	2406:6400:A006:0000::/48				
	2406:6400:A007:0000::/48				
	2406:6400:B800:0000::/40	1st Customer block POP2 [R6]			
	2406:6400:B800:0000::/48	1st Customer prefix POP2 [R6]		Yes	Yes
	2406:6400:B801:0000::/48				
	2406:6400:B802:0000::/48				
	2406:6400:B803:0000::/48				
	2406:6400:B804:0000::/48				
	2406:6400:B805:0000::/48				
	2406:6400:B806:0000::/48				
	2406:6400:B807:0000::/48				

# Training ISP IPV6 Addressing Plan

Table 21: Customer block Region 3					
Block#	Prefix	Description	Reverse DNS	SOR	Registration
9	2406:6400:c000:0000::/35	Customer block Region 3			
	2406:6400:C000:0000::/40	Customer block POP1 [R7]		>= /48 Yes	Yes
	2406:6400:C100:0000::/40				
	2406:6400:C200:0000::/40				
	2406:6400:C300:0000::/40				
	2406:6400:C400:0000::/40				
	2406:6400:C500:0000::/40				
	2406:6400:C600:0000::/40				
	2406:6400:C700:0000::/40				
	2406:6400:C800:0000::/40	Customer block future use/POP		>= /48 Yes	Yes
	2406:6400:C900:0000::/40				
	2406:6400:CA00:0000::/40				
	2406:6400:CB00:0000::/40				
	2406:6400:CC00:0000::/40				
	2406:6400:CD00:0000::/40				
	2406:6400:CE00:0000::/40				
	2406:6400:CF00:0000::/40				
	2406:6400:D000:0000::/40	Customer block future use/POP		>= /48 Yes	Yes
	2406:6400:D100:0000::/40				
	2406:6400:D200:0000::/40				
	2406:6400:D300:0000::/40				
	2406:6400:D400:0000::/40				
	2406:6400:D500:0000::/40				
	2406:6400:D600:0000::/40				
	2406:6400:D700:0000::/40				
	2406:6400:D800:0000::/40	Customer block POP2 [R9]		>= /48 Yes	Yes
	2406:6400:D900:0000::/40				
	2406:6400:DA00:0000::/40				
	2406:6400:DB00:0000::/40				
	2406:6400:DC00:0000::/40				
	2406:6400:DD00:0000::/40				
	2406:6400:DE00:0000::/40				
	2406:6400:DF00:0000::/40				

# Training ISP IPV6 Addressing Plan

- IPv6 Address Plan:

Table 22: Summarization oprions customer block Region 3			
Block#	Prefix	Description	Reverse Domain
	2406:6400:c000:0000::/35	Customer block Region 3 [R8]	
	2406:6400:C000:0000::/37	Customer block POP1 [R7]	
	2406:6400:C800:0000::/37	Customer block future use/POP	
	2406:6400:D000:0000::/37	Customer block future use/POP	
	2406:6400:D800:0000::/37	Customer block POP2 [R9]	

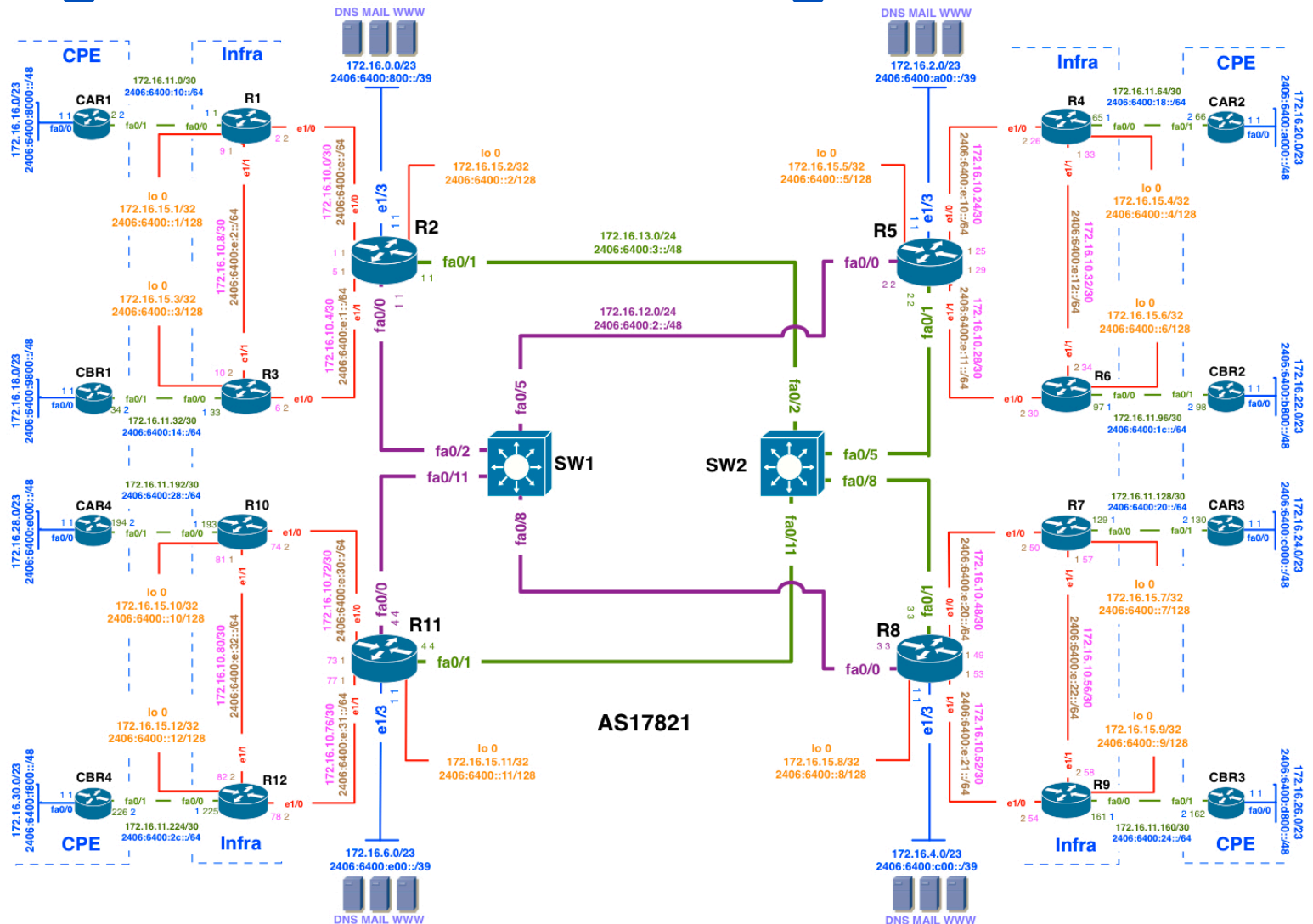


# Training ISP IPV6 Addressing Plan

- IPv6 Address Plan:

Table 23: Detail customer block Region 3					
Block#	Prefix	Description	Reverse DNS	SOR	Registration
	2406:6400:C000:0000::/40	1st Customer block POP1 [R7]			
	2406:6400:C000:0000::/48	1st Customer prefix POP1 [R7]		Yes	Yes
	2406:6400:C001:0000::/48				
	2406:6400:C002:0000::/48				
	2406:6400:C003:0000::/48				
	2406:6400:C004:0000::/48				
	2406:6400:C005:0000::/48				
	2406:6400:C006:0000::/48				
	2406:6400:C007:0000::/48				
	2406:6400:D800:0000::/40	1st Customer block POP2 [R9]			
	2406:6400:D800:0000::/48	1st Customer prefix POP2 [R9]		Yes	Yes
	2406:6400:D801:0000::/48				
	2406:6400:D802:0000::/48				
	2406:6400:D803:0000::/48				
	2406:6400:D804:0000::/48				
	2406:6400:D805:0000::/48				
	2406:6400:D806:0000::/48				
	2406:6400:D807:0000::/48				

# Training ISP IPV6 Addressing Plan



# Training ISP IPV6 Addressing Plan

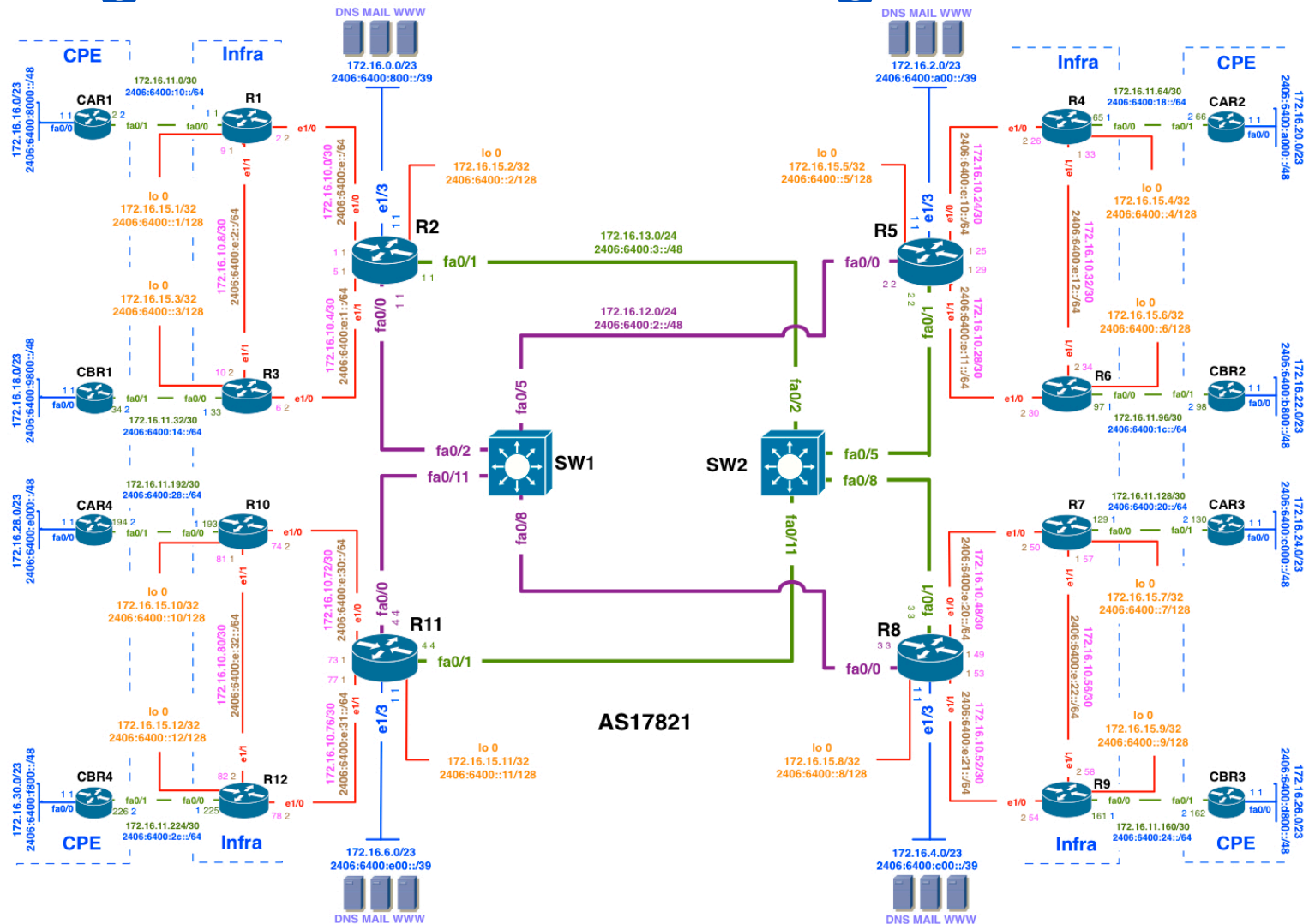
Table 24: Customer block Region 4					
Block#	Prefix	Description	Reverse DNS	SOR	Registration
10	2406:6400:e000:0000::/35	Customer block Region 4			
	2406:6400:E000:0000::/40	Customer block POP1 [R10]		>= /48 Yes	Yes
	2406:6400:E100:0000::/40				
	2406:6400:E200:0000::/40				
	2406:6400:E300:0000::/40				
	2406:6400:E400:0000::/40				
	2406:6400:E500:0000::/40				
	2406:6400:E600:0000::/40				
	2406:6400:E700:0000::/40				
	2406:6400:E800:0000::/40	Customer block future use/POP		>= /48 Yes	Yes
	2406:6400:E900:0000::/40				
	2406:6400:EA00:0000::/40				
	2406:6400:EB00:0000::/40				
	2406:6400:EC00:0000::/40				
	2406:6400:ED00:0000::/40				
	2406:6400:EE00:0000::/40				
	2406:6400:EF00:0000::/40				
	2406:6400:F000:0000::/40	Customer block future use/POP		>= /48 Yes	Yes
	2406:6400:F100:0000::/40				
	2406:6400:F200:0000::/40				
	2406:6400:F300:0000::/40				
	2406:6400:F400:0000::/40				
	2406:6400:F500:0000::/40				
	2406:6400:F600:0000::/40				
	2406:6400:F700:0000::/40				
	2406:6400:F800:0000::/40	Customer block POP2 [R12]		>= /48 Yes	Yes
	2406:6400:F900:0000::/40				
	2406:6400:FA00:0000::/40				
	2406:6400:FB00:0000::/40				
	2406:6400:FC00:0000::/40				
	2406:6400:FD00:0000::/40				
	2406:6400:FE00:0000::/40				
	2406:6400:FF00:0000::/40				

# Training ISP IPV6 Addressing Plan

- IPv6 Address Plan:

Table 25: Summarization oprions customer block Region 4			
Block#	Prefix	Description	Reverse Domain
	2406:6400:e000:0000::/35	Customer block Region 4 [R11]	
	2406:6400:E000:0000::/37	Customer block POP1 [R10]	
	2406:6400:E800:0000::/37	Customer block future use/POP	
	2406:6400:F000:0000::/37	Customer block future use/POP	
	2406:6400:F800:0000::/37	Customer block POP2 [R12]	

# Training ISP IPV6 Addressing Plan



# Training ISP IPV6 Addressing Plan

- IPv6 Address Plan:

Table 26: Detail customer block Region 4					
Block#	Prefix	Description	Reverse DNS	SOR	Registration
	2406:6400:E000:0000::/40	1st Customer block POP1 [R10]			
	2406:6400:E000:0000::/48	1st Customer prefix POP1 [R10]		Yes	Yes
	2406:6400:E001:0000::/48				
	2406:6400:E002:0000::/48				
	2406:6400:E003:0000::/48				
	2406:6400:E004:0000::/48				
	2406:6400:E005:0000::/48				
	2406:6400:E006:0000::/48				
	2406:6400:E007:0000::/48				
	2406:6400:F800:0000::/40	1st Customer block POP2 [R10]			
	2406:6400:F800:0000::/48	1st Customer prefix POP2 [R10]		Yes	Yes
	2406:6400:F801:0000::/48				
	2406:6400:F802:0000::/48				
	2406:6400:F803:0000::/48				
	2406:6400:F804:0000::/48				
	2406:6400:F805:0000::/48				
	2406:6400:F806:0000::/48				
	2406:6400:F807:0000::/48				

# APNIC



# Training ISP IPv4 Addressing Plan

- Current IPv4 Addressing Plan:

Summary parent block IPV4

Block#	Prefix	Size	Description
1	172.16.0.0	/19	Parent block
2	172.16.0.0	/20	Infrastructure
3	172.16.16.0	/20	Customer network



# Training ISP IPv4 Addressing Plan

- Current IPv4 Addressing Plan:

## Detail DC infrastructure block IPV4

Block#	Prefix	Size	Description	SOR	Register
2	172.16.0.0	/20	Infrastructure		
4	172.16.0.0	/23	Router2 DC summary net		
5	172.16.0.0	/24	Router2 DC	No	Recommended
6	172.16.2.0	/23	Router5 DC summary net		
7	172.16.2.0	/24	Router5 DC	No	Recommended
8	172.16.4.0	/23	Router8 DC summary net		
9	172.16.4.0	/24	Router8 DC	No	Recommended
10	172.16.6.0	/23	Router11 DC summary net		
11	172.16.6.0	/24	Router11 DC	No	Recommended

# Training ISP IPv4 Addressing Plan

- Current IPv4 Addressing Plan:

**Detail infrastructure WAN block IPV4**

12	172.16.10.0	/24	WAN prefix		Optional
13	172.16.10.0	/30	Router2-1 WAN	No	
14	172.16.10.4	/30	Router2-3 WAN	No	
15	172.16.10.8	/30	Router1-3 WAN	No	
16	172.16.10.24	/30	Router5-4 WAN	No	
17	172.16.10.28	/30	Router5-6 WAN	No	
18	172.16.10.32	/30	Router4-6 WAN	No	
19	172.16.10.48	/30	Router8-7 WAN	No	
20	172.16.10.52	/30	Router8-9 WAN	No	
21	172.16.10.56	/30	Router7-9 WAN	No	
22	172.16.10.72	/30	Router11-10 WAN	No	
23	172.16.10.76	/30	Router11-12 WAN	No	
24	172.16.10.80	/30	Router10-12 WAN	No	

# Training ISP IPv4 Addressing Plan

- Current IPv4 Addressing Plan:

## Detail infrastructure block Transport & Loopback IPV4

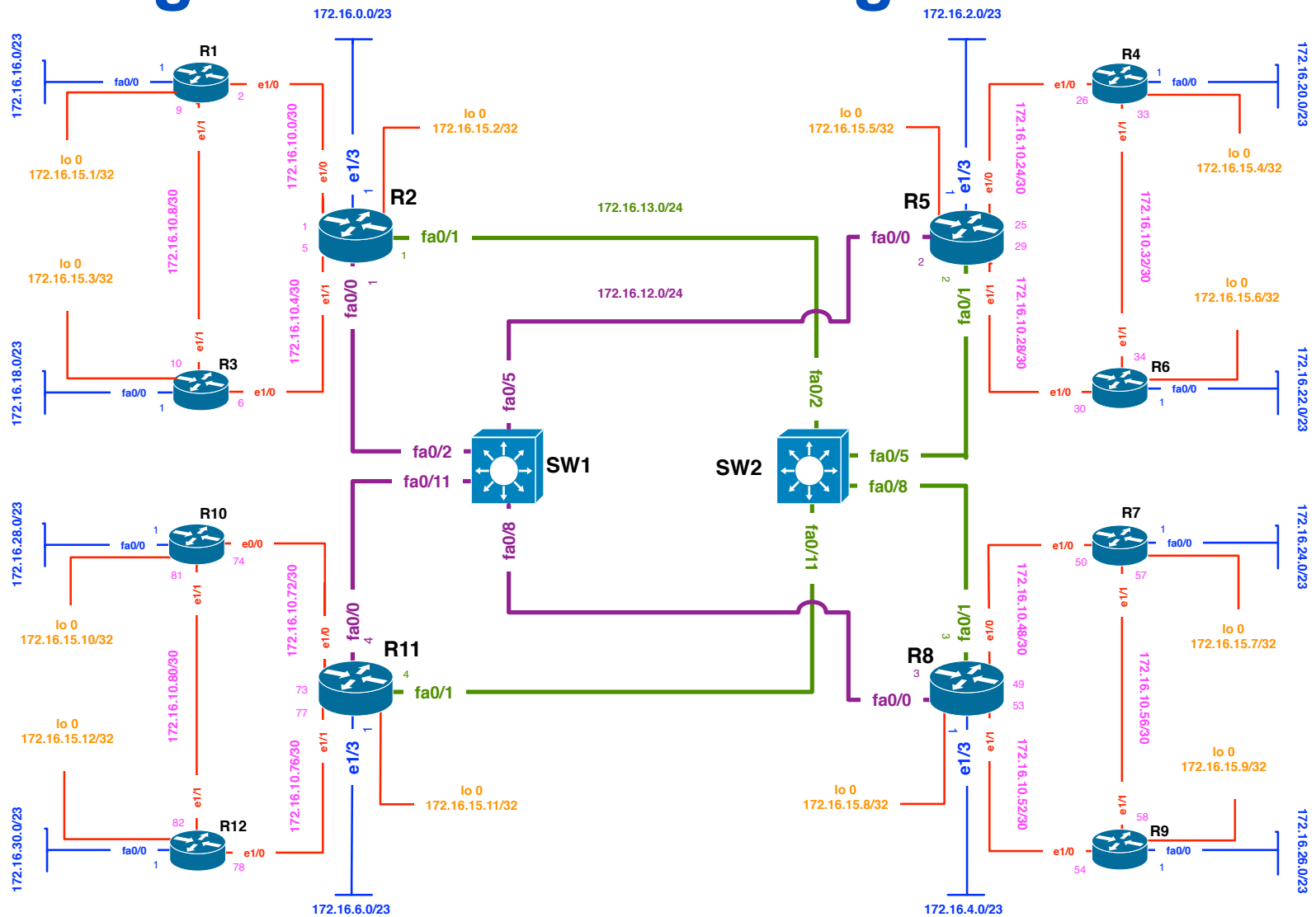
25	172.16.12.0	/24	Transport link PURPLE	No	
26	172.16.13.0	/24	Transport link GREEN	No	
27	172.16.15.0	/24	Loopback	No	

# Training ISP IPv4 Addressing Plan

## Detail customer block

Block#	Prefix	Size	Description	SOR	Register
28	172.16.6.0	/20	Customer network		
29	172.16.16.0	/22	Router2 summary net		
30	172.16.16.0	/23	Router1 CS network	Yes	Must
31	172.16.18.0	/23	Router3 CS network	Yes	Must
32	172.16.20.0	/22	Router5 summary net		
33	172.16.20.0	/23	Router4 CS network	Yes	Must
34	172.16.22.0	/23	Router6 CS network	Yes	Must
35	172.16.24.0	/22	Router8 summary net		
36	172.16.24.0	/23	Router7 CS network	Yes	Must
37	172.16.26.0	/23	Router9 CS network	Yes	Must
38	172.16.28.0	/22	Router11 summary net		
39	172.16.28.0	/23	Router10 CS network	Yes	Must
40	172.16.30.0	/23	Router12 CS network	Yes	Must

# Training ISP IPv4 Addressing Plan



# Agenda

- Introduction to IPv6 and Protocol Architecture
- IPv6 Addressing and Sub-netting
- IPv6 Host Configuration
- IPv6 Deployment Plan – Case Study
- **IPv6 Deployment in IGP – Case Study**
- IPv4 to IPv6 Transition Technologies
- IPv6 Deployment in EGP – Case Study
- IPv6 DNS

# Configuration of OSPF as IGP

- Scenario:
  - Training ISP need to configure OSPF as IGP for both IPv4 and IPv6
  - Dual stack mechanism will be used to ensure both IPv4 and IPv6 operation
  - OSPFv3 supports IPv6 routed protocol
  - IGP is used to carry next hop only for BGP

# Configuration of OSPF as IGP

- Minimum Router OS require for OSPFv3:
  - Cisco IOS
    - 12.2(15)T or later (For OSPFv3)
    - 12.2(2)T or later (For IPv6 support)
  - Jun OS
    - JunOS 8.4 or later



# Configuration of OSPF as IGP

- Before enabling OSPFv3 on an interface, the following steps must be done on a Router:
  - Enable IPv6 unicast routing
  - Enable IPv6 CEF (forwarding table)

```
config t
ipv6 unicast-routing
ipv6 cef (distributed cef)
```

# Configuration of OSPF as IGP

- Configure interface for both IPv4 and IPv6:

```
interface e1/0
description WAN R1-R2
no ip redirects
no ip directed-broadcast
no ip unreachable
ip address 172.16.10.2 255.255.255.252
no shutdown
```

```
interface e1/0
ipv6 address 2406:6400:000F:0000::2/64
ipv6 enable
```

# Configuration of OSPF as IGP

- Verify Interface configuration:

```
sh ip interface e0/0  
ping 172.16.10.1
```

```
sh ipv6 interface e0/0  
ping 2406:6400:000F:0000::2
```

# Configuration of OSPF as IGP

## IPv4 Interface configuration for Router1:

```
interface loopback 0
description Router1 Loopback
no ip redirects
no ip directed-broadcast
no ip unreachables
ip address 172.16.15.1
255.255.255.255
no shutdown
interface e1/0
description WAN R1-R2
no ip redirects
no ip directed-broadcast
no ip unreachables
ip address 172.16.10.2
255.255.255.252
no shutdown
```

```
interface e1/1
description WAN R1-R3
no ip redirects
no ip directed-broadcast
no ip unreachables
ip address 172.16.10.9
255.255.255.252
no shutdown
interface fa0/0
description Router1 customer
network
no ip redirects
no ip directed-broadcast
no ip unreachables
no cdp enable
ip address 172.16.16.1
255.255.255.0
no shutdown
```

# Configuration of OSPF as IGP

- IPv6 Interface configuration for Router1:

```
interface loopback 0
ipv6 address 2406:6400:0000:0000::1/128
ipv6 enable
interface e1/0
ipv6 address 2406:6400:000F:0000::2/64
ipv6 enable
interface e1/1
ipv6 address 2406:6400:000F:0002::1/64
ipv6 enable
interface fa0/0
ipv6 address 2406:6400:0100:0000::1/48
ipv6 enable
```

# Configuration of OSPF as IGP

- OSPF Configuration for IPv4:
  - OSPF for IPv4 can be configured from global configuration mode
  - Interface mode configuration will also activate OSPF process on your running config

# Configuration of OSPF as IGP

- OSPF Configuration for IPv6:
  - OSPF for IPv6 need to configure from Interface configuration mode
  - Interface mode configuration will automatically activate OSPF process on your running config

# Configuration of OSPF as IGP

- OSPF for IPv6 Configuration Command:

```
router ospf 17821
log-adjacency-changes
passive-interface default
network 172.16.15.1 0.0.0.0 area 1
no passive-interface e1/0
network 172.16.10.0 0.0.0.3 area 1
no passive-interface e1/1
network 172.16.10.8 0.0.0.3 area 1
```



# Configuration of OSPF as IGP

- OSPF for IPv6 Configuration Command:

```
interface loopback 0
ipv6 ospf 17821 area 1
interface e1/0
ipv6 ospf 17821 area 1
interface e1/1
ipv6 ospf 17821 area 1
```

# Configuration of OSPF as IGP

- Verify OSPF configuration:

```
sh run
!  
interface Ethernet1/0  
  description WAN R1-R2  
  ip address 172.16.10.2 255.255.255.252  
  no ip redirects  
  no ip unreachable  
  half-duplex  
  ipv6 address 2406:6400:F::2/64  
  ipv6 enable  
  ipv6 ospf 17821 area 1
```

# Configuration of OSPF as IGP

- Example OSPF configuration for Router1:

```
router ospf 17821
log-adjacency-changes
passive-interface default
network 172.16.15.1 0.0.0.0
area 1

no passive-interface e1/0
network 172.16.10.0 0.0.0.3
area 1

no passive-interface e1/1
network 172.16.10.8 0.0.0.3
area 1
```

```
interface loopback 0
ipv6 ospf 17821 area 1

interface e1/0
ipv6 ospf 17821 area 1

interface e1/1
ipv6 ospf 17821 area 1
```

# OSPF Packet Type

- Five OSPF Packet Type:
- t: Specifies the OSPF packet type:
  - 1: hello [every 10 sec]
  - 2: DBD [Database Descriptor Packet]
  - 3: LSR [Link State Request Packet]
  - 4: LSU [Link State Update Packet]
  - 5: LSAck [Link State Ack Packet]
- debug ip ospf packet
- debug ipv6 ospf packet

# IPv6 Deployment in IGP

- OSPFv3 or OSPF for IPv6 Overview:
  - OSPFv3 is described in RFC 2740
  - Most of OSPFv3 functions are same as OSPFv2
  - In OSPFv3 routing process does not need to be explicitly created. Simply enabling OSPF on an interface will create routing process on a router

# IPv6 Deployment in IGP

- OSPFv3 or OSPF for IPv6 Overview:
  - Multiple instances of OSPFv3 can be run on a link which is unlike in OSPFv2
  - OSPFv3 still use 32 bit address as router ID. If no IPv4 address is configured on any interface need to use router-id command to set 32 bit router-id.

# IPv6 Deployment in IGP

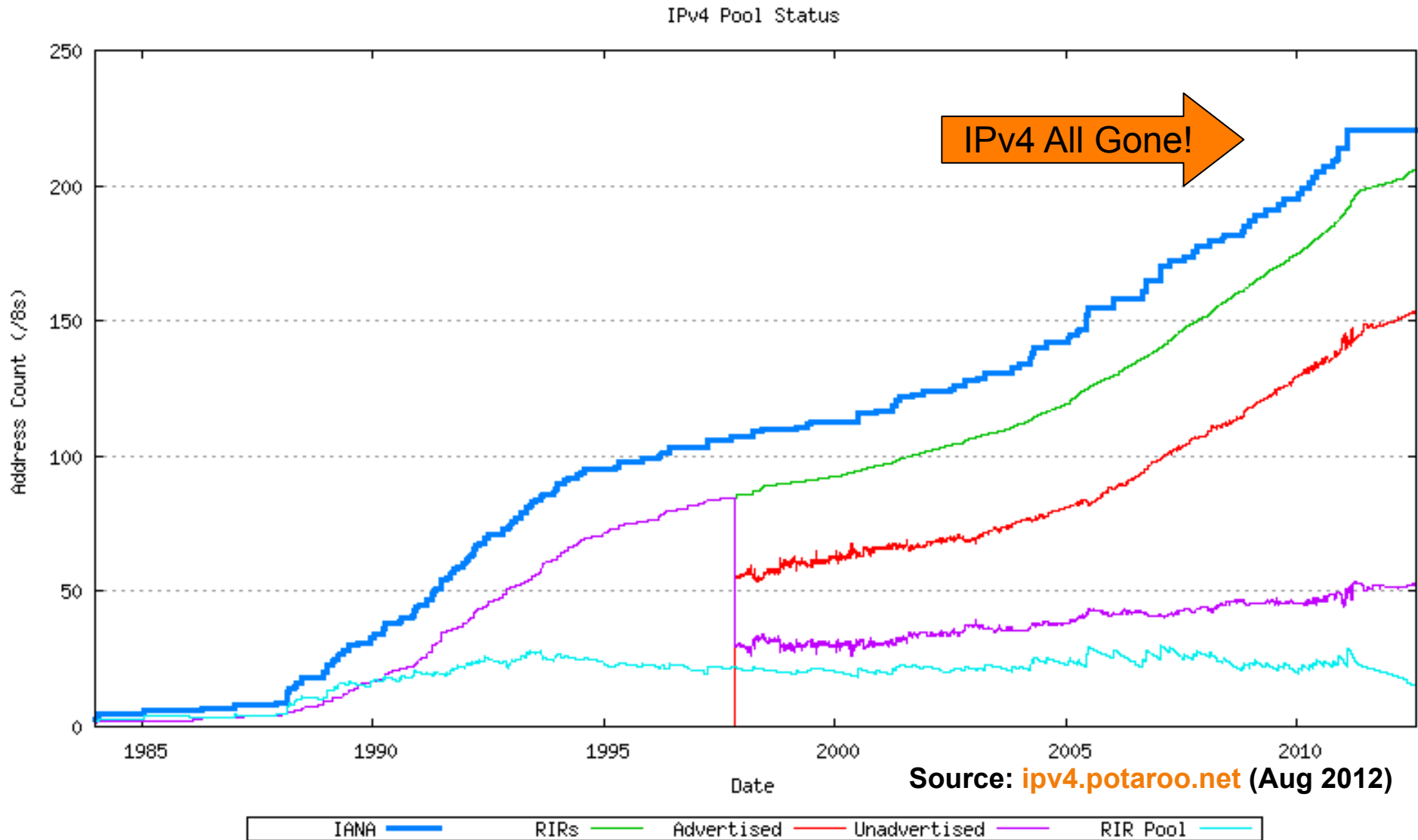
- OSPFv3 or OSPF for IPv6 Overview:
  - LSA types and functions in OSPF3 are same as OSPF2
  - OSPFv3 use IPv6 address FF02::5 for AllSPF router multicast and IPv6 address FF02::6 for AllD router multicast
  - DR/BDR concepts for Broadcast Multi-access network are same in OSPFv3 as OSPFv2

# Agenda

- Introduction to IPv6 and Protocol Architecture
- IPv6 Addressing and Sub-netting
- IPv6 Host Configuration
- IPv6 Deployment Plan – Case Study
- IPv6 Deployment in IGP – Case Study
- **IPv4 to IPv6 Transition Technologies**
- IPv6 Deployment in EGP – Case Study
- IPv6 DNS



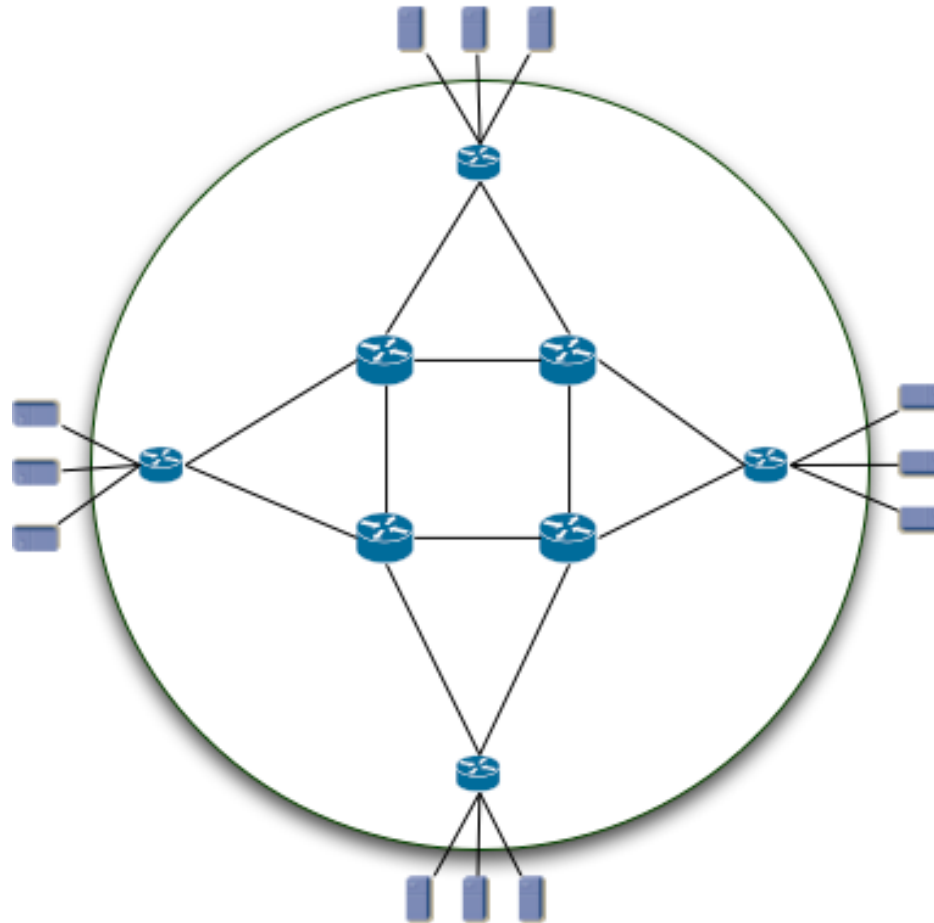
# “The times, They are a’ changin’”



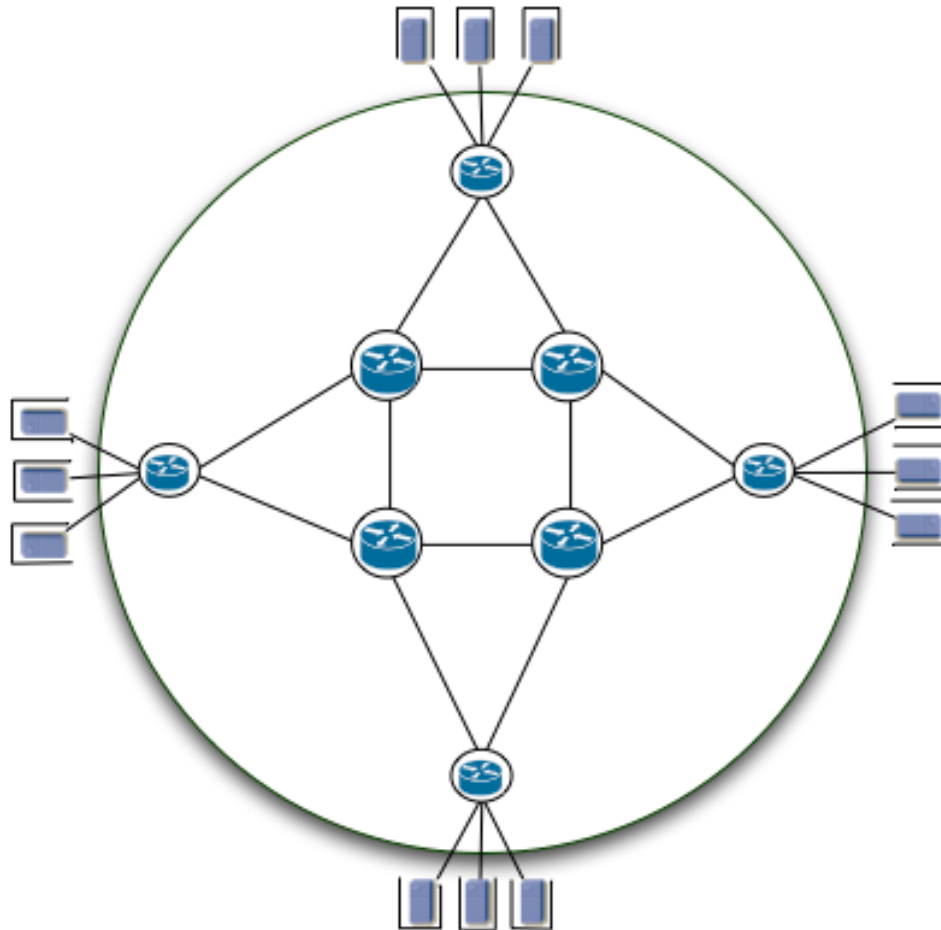
# IETF Working Groups

- “v6ops”
  - Define the processes by which networks can be transitioned from IPv4 to IPv6
  - [www.ietf.org/dyn/wg/charter/v6ops-charter.html](http://www.ietf.org/dyn/wg/charter/v6ops-charter.html)
- “behave”
  - Designs solutions for the IPv4 to IPv6 translations scenarios
  - [www.ietf.org/dyn/wg/charter/behave-charter.html](http://www.ietf.org/dyn/wg/charter/behave-charter.html)
- “softwires”
  - Specifies the standardisation of discovery, control and encapsulation methods for connecting IPv4 networks across IPv6 networks and IPv6 networks across IPv4 networks in a way that will encourage multiple, inter-operable implementations
  - [www.ietf.org/dyn/wg/charter/softwire-charter.html](http://www.ietf.org/dyn/wg/charter/softwire-charter.html)

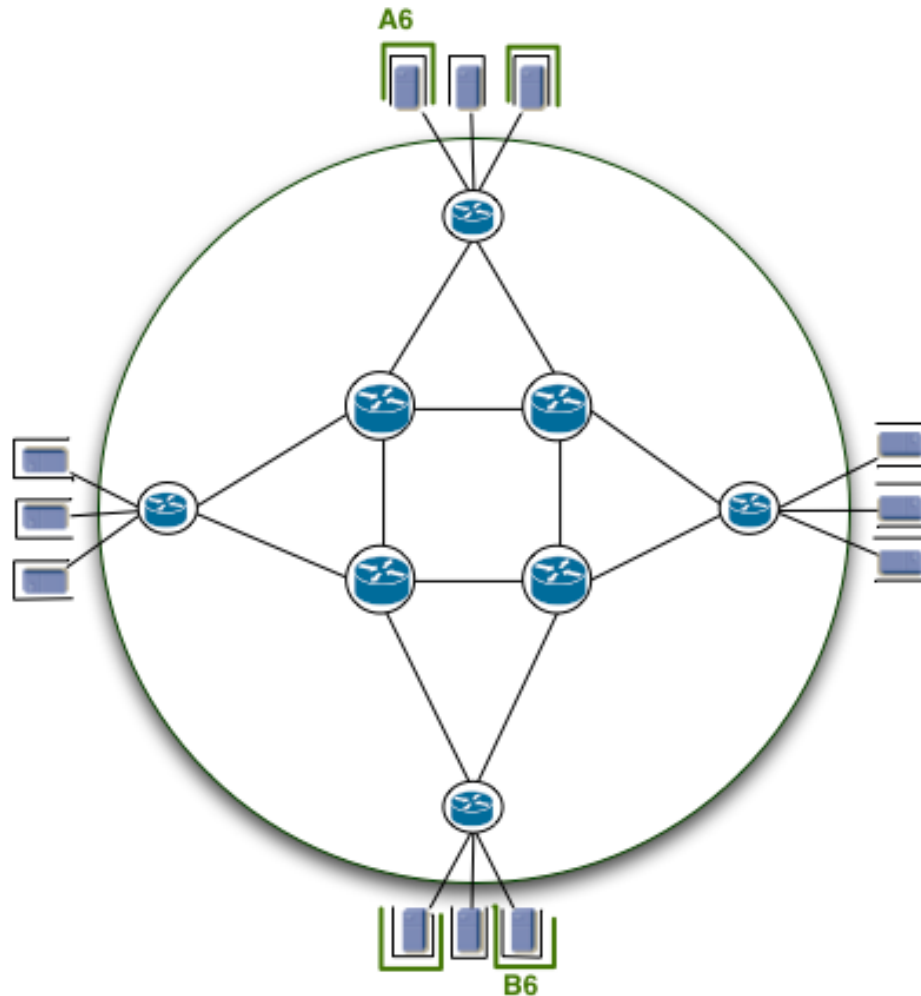
# Transition Concept



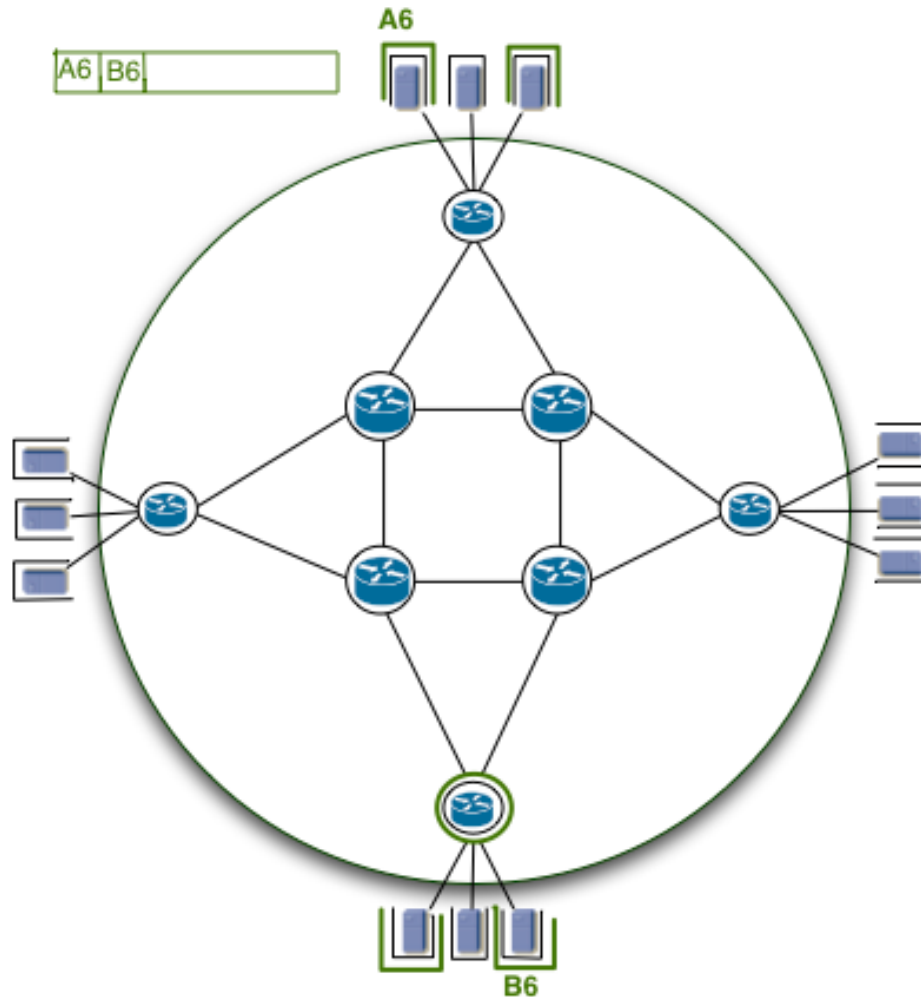
# Transition Concept



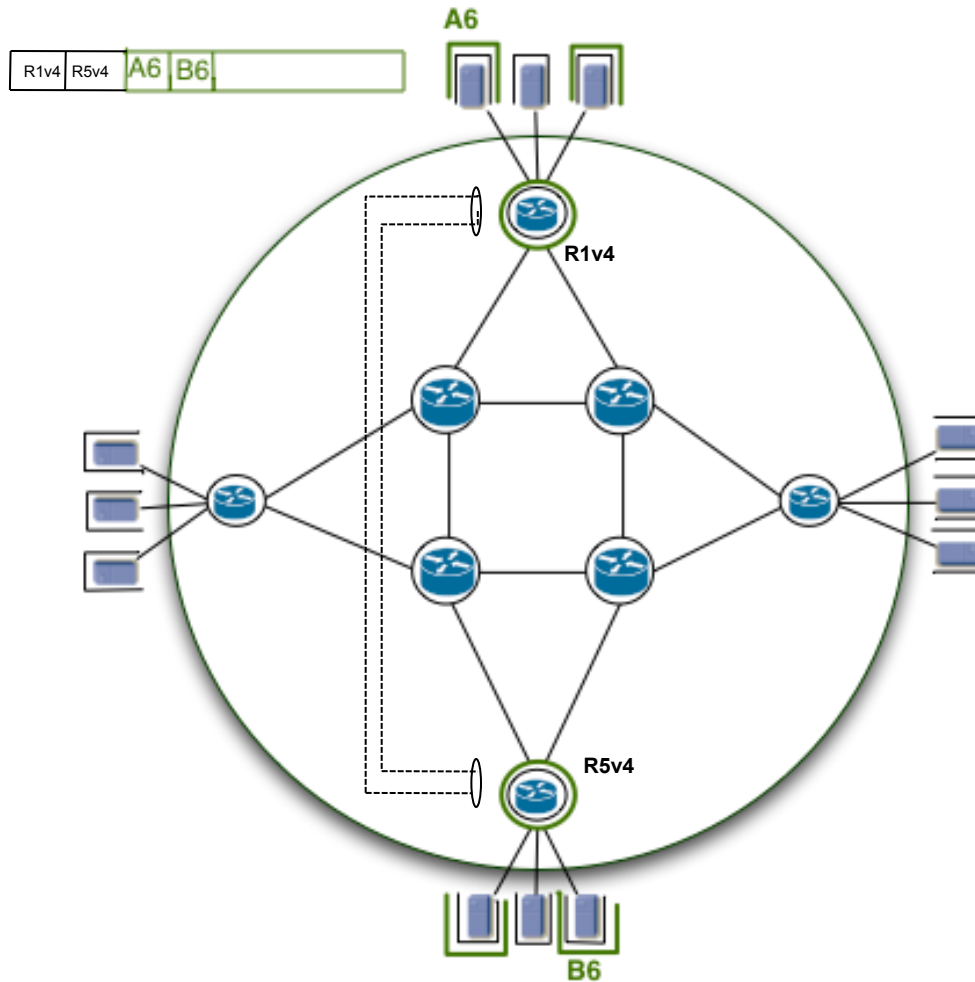
# Transition Concept



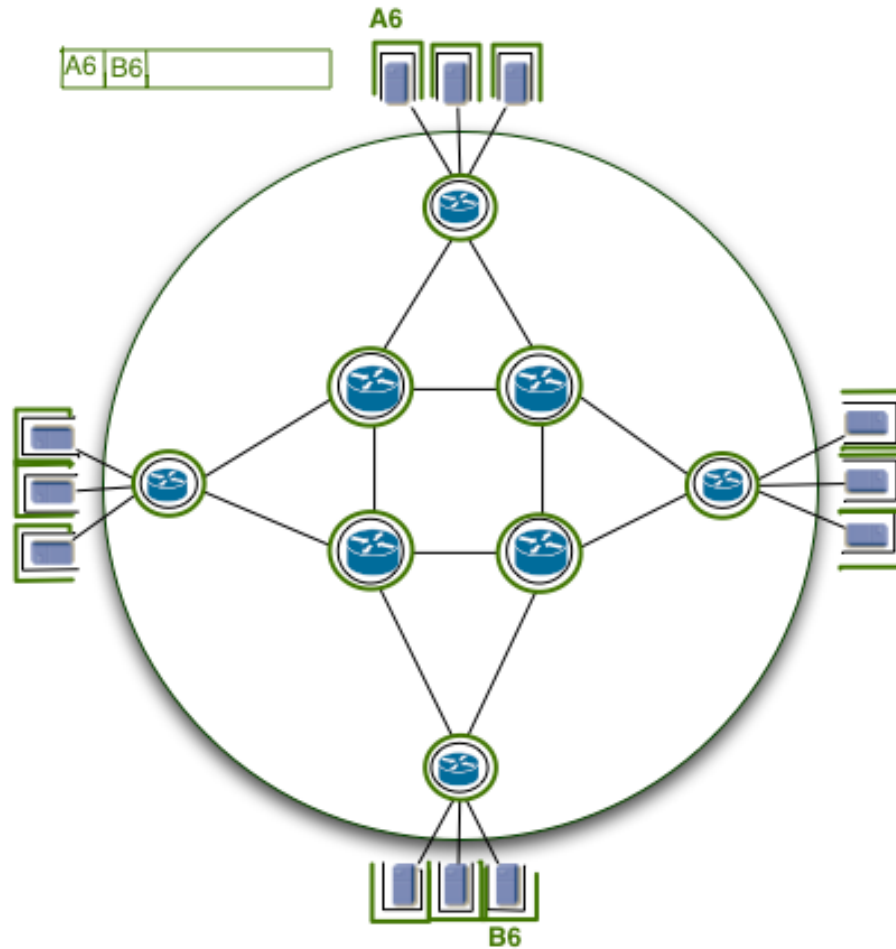
# Transition Concept



# Transition Concept



# Transition Concept





# IPv4 to IPv6 Transition

- Implementation rather than transition
  - No fixed day to convert
- The key to successful IPv6 transition
  - Maintaining compatibility with IPv4 hosts and routers while deploying IPv6
    - Millions of IPv4 nodes already exist
    - Upgrading every IPv4 nodes to IPv6 is not feasible
    - No need to convert all at once
    - Transition process will be gradual

# Strategies available for Service Providers

- Do nothing
  - Wait and see what competitors do
  - Business not growing, so don't care what happens
- Extend life of IPv4
  - Force customers to NAT
  - Buy IPv4 address space on the marketplace
- Deploy IPv6
  - Dual-stack infrastructure
  - IPv6 and NATed IPv4 for customers
  - 6rd (Rapid Deploy) with native or NATed IPv4 for customers
  - Or various other combinations of IPv6, IPv4 and NAT

# Dual-Stack Networks

- Both IPv4 and IPv6 have been fully deployed across all the infrastructure
  - Routing protocols handle IPv4 and IPv6
  - Content, application, and services available on IPv4 and IPv6
- End-users use dual-stack network transparently:
  - If DNS returns IPv6 address for domain name query, IPv6 transport is used
  - If no IPv6 address returned, DNS is queried for IPv4 address, and IPv4 transport is used instead
- It is envisaged that the Internet will operate dual-stack for many years to come

# IP in IP Tunnels

- A mechanism whereby an IP packet from one address family is encapsulated in an IP packet from another address family
  - Enables the original packet to be transported over network of another address family
- Allows ISP to provide dual-stack service prior to completing infrastructure deployment
- Tunnelling techniques include:
  - IPinIP, GRE, 6to4, Teredo, ISATAP, 6rd, MPLS

# Address Family Translation (AFT)

- Refers to translation of an IP address from one address family into another address family
  - e.g. IPv6 to IPv4 translation (sometimes called NAT64)
  - Or IPv4 to IPv6 translation (sometimes called NAT46)

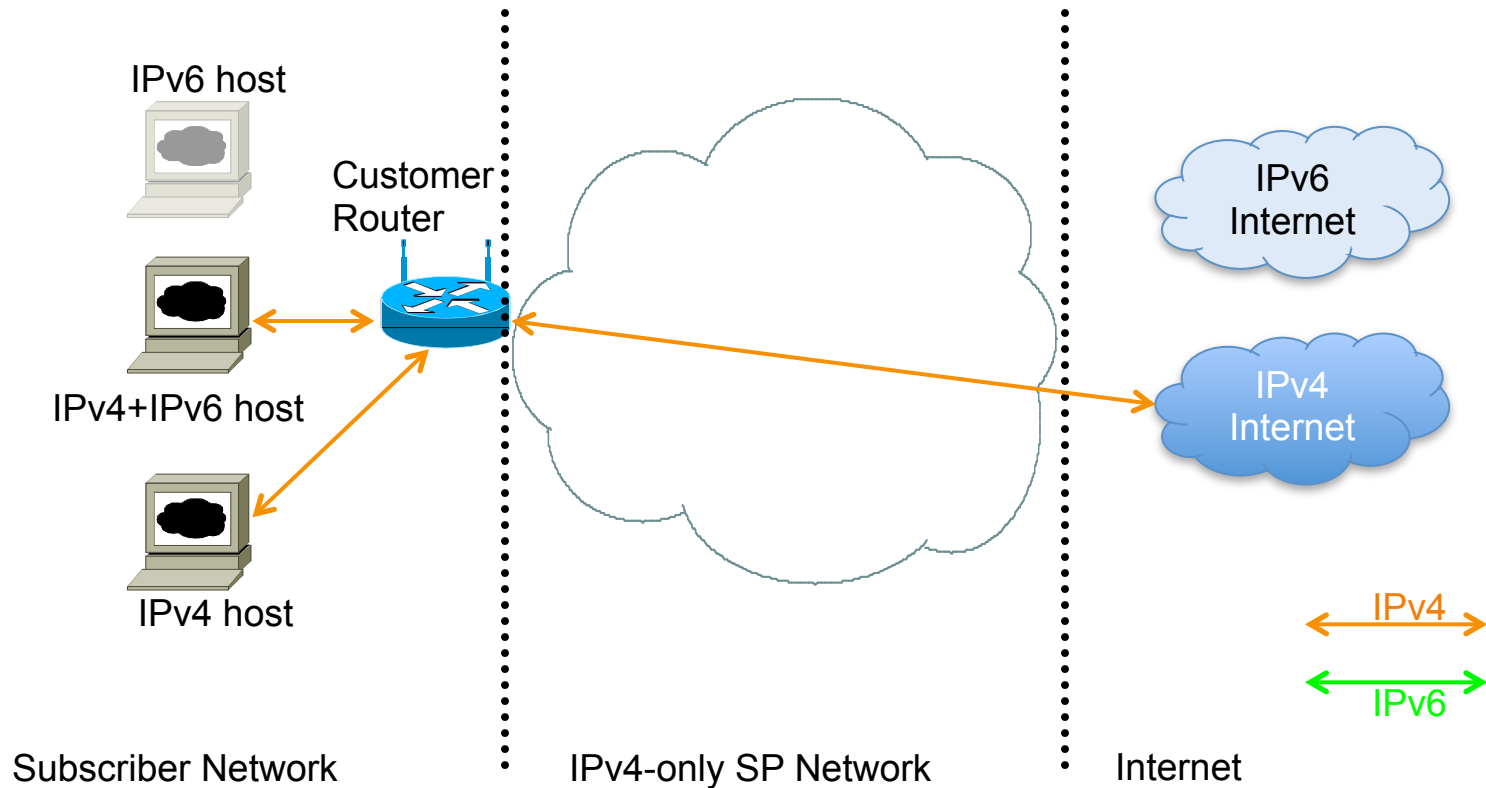
# Network Address Translation (NAT)

- NAT is translation of one IP address into another IP address
- NAPT (Network Address & Port Translation) translates multiple IP addresses into one other IP address
  - TCP/UDP port distinguishes different packet flows
- NAT-PT (NAT – Protocol Translation) is a particular technology which does protocol translation in addition to address translation
  - NAT-PT is has now been made obsolete by the IETF
  - <http://tools.ietf.org/html/rfc4966>

# Carrier Grade NAT (CGN)

- ISP version of subscriber NAT
  - Subscriber NAT can handle only hundreds of translations
  - ISP NAT can handle millions of translations
- Not limited to just translation within one address family, but does address family translation as well
- Often referred to as Large Scale NAT (LSN)

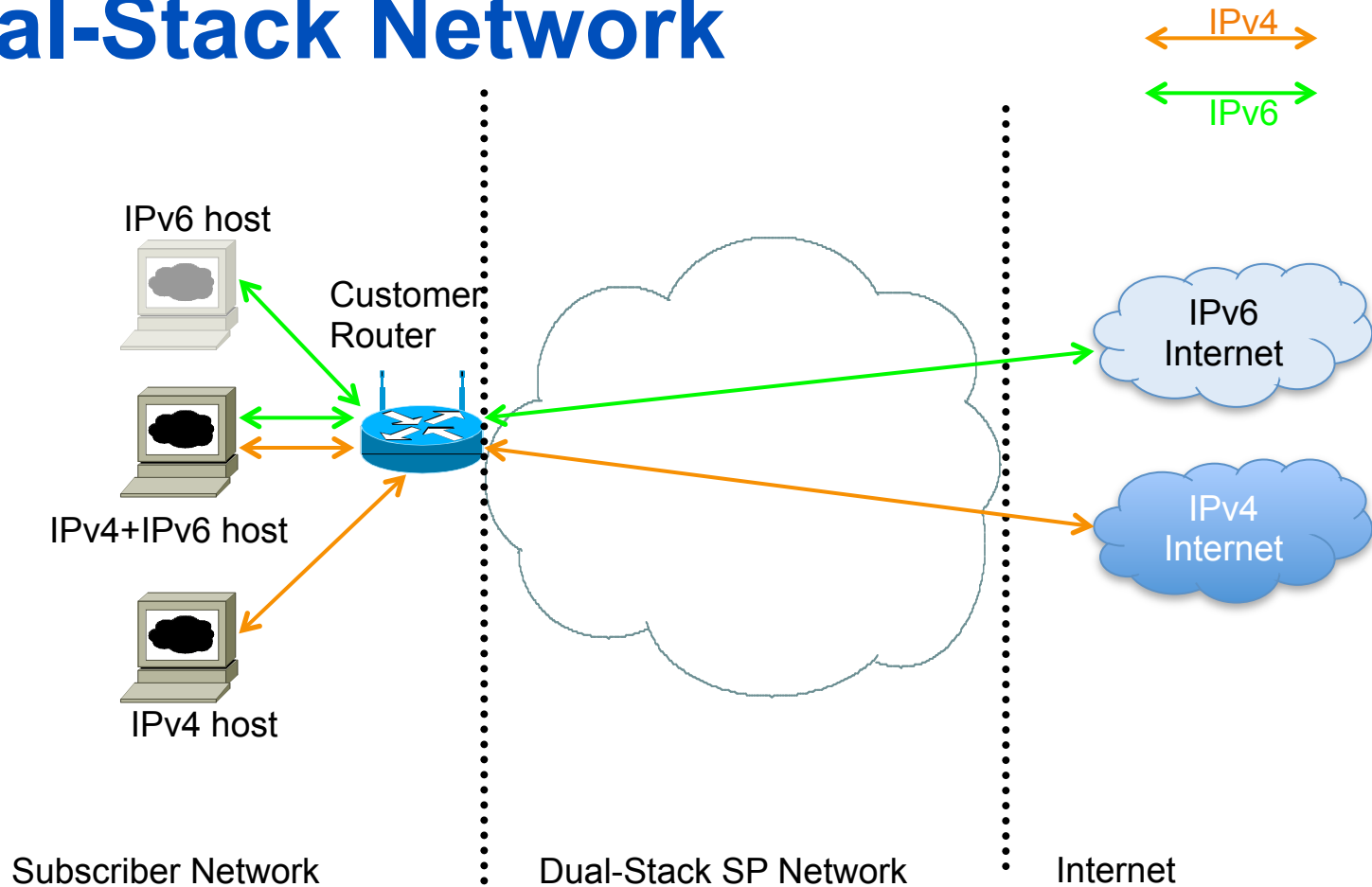
# IPv4 only Network



- The situation for many SPs today:
  - No IPv6 for consumer
  - IPv4 scaling lasts as long as IPv4 addresses are available

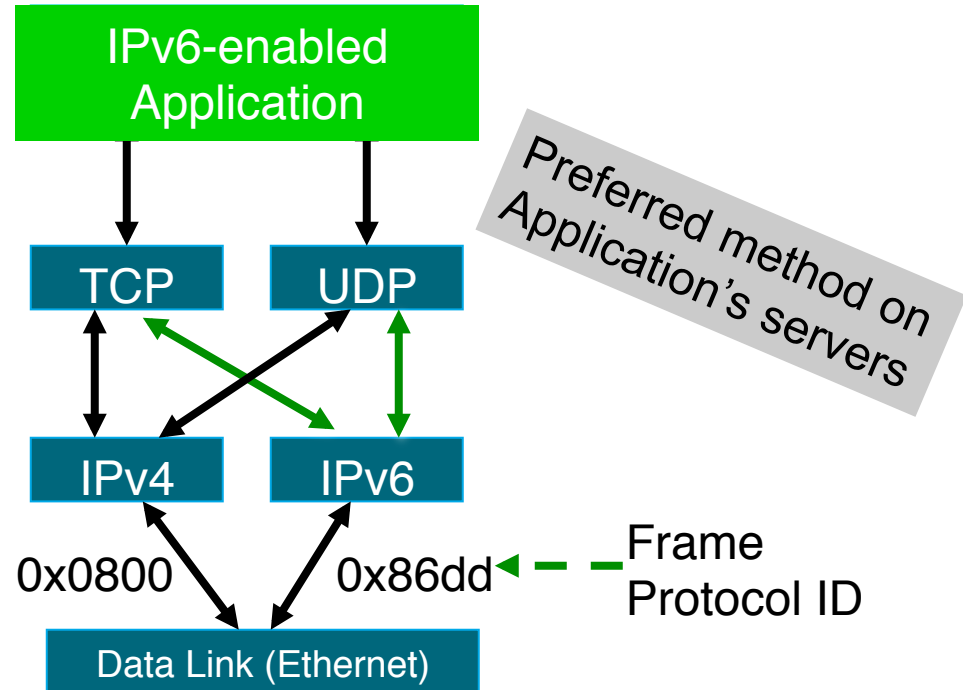
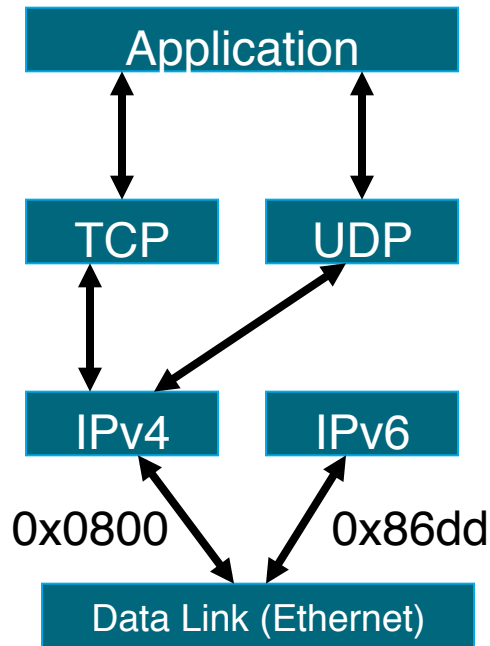


# Dual-Stack Network



- The original transition scenario, but dependent on:
  - IPv6 being available all the way to the consumer
  - Sufficient IPv4 address space for the consumer and SP core

# Dual Stack Approach

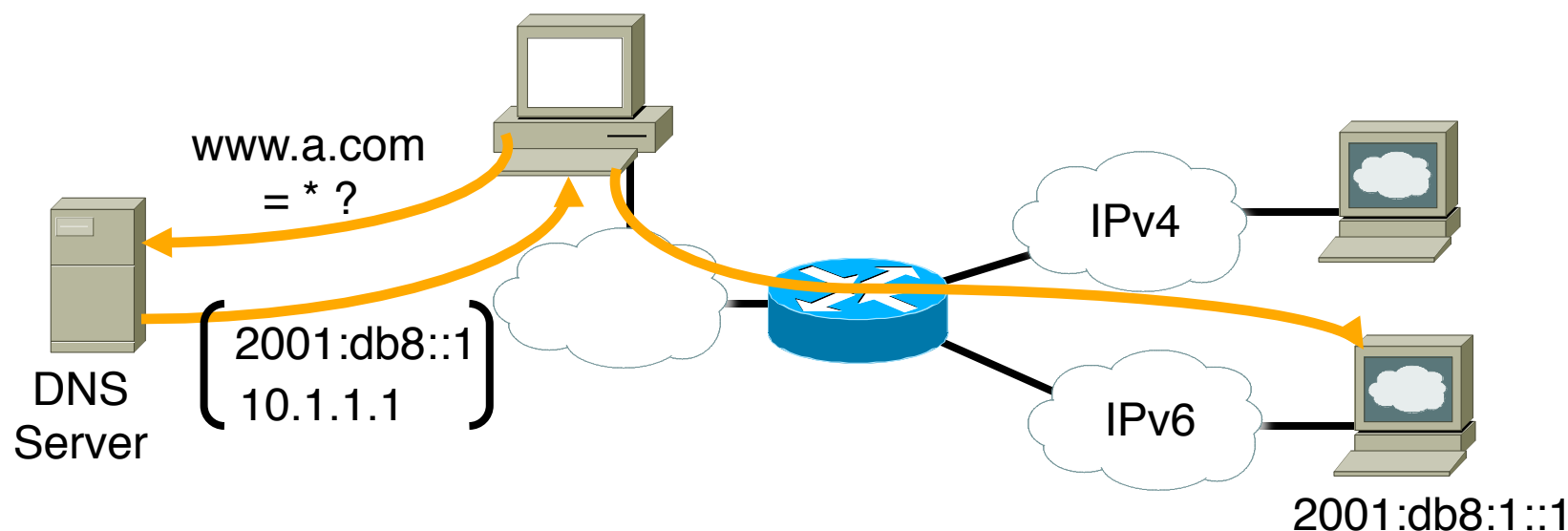


- Dual stack node means:
  - Both IPv4 and IPv6 stacks enabled
  - Applications can talk to both
  - Choice of the IP version is based on name lookup and application preference

# Dual Stack Challenges

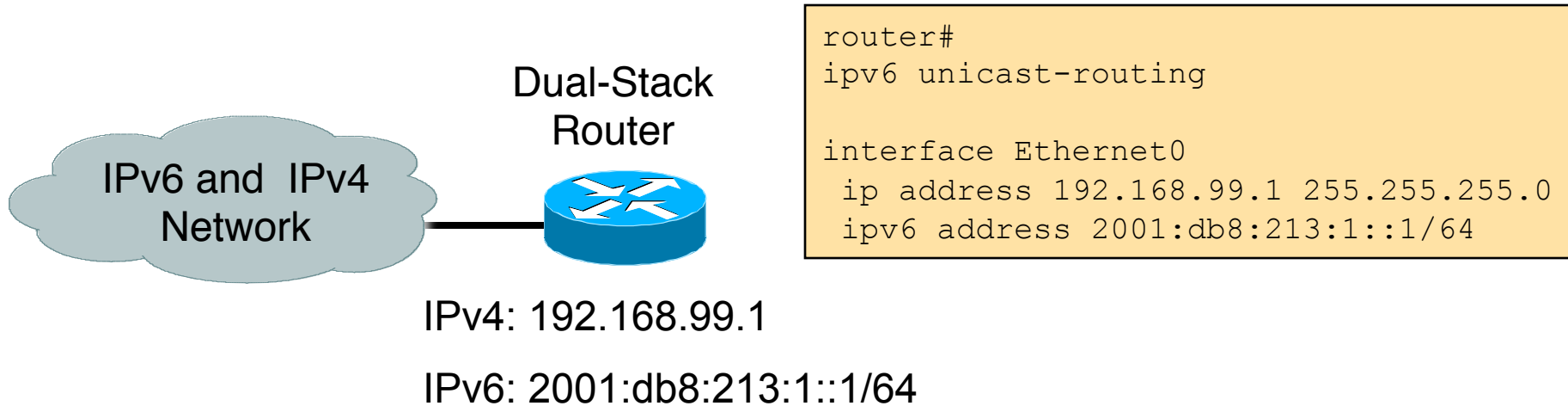
- Compatible software
  - Eg. If you use OSPFv2 for your IPv4 network you need to run OSPFv3 in addition to OPSFv2
- Transparent availability of services
- Deployment of servers and services
- Content provision
- Business processes
- Traffic monitoring
- End user deployment

# Dual Stack Approach & DNS



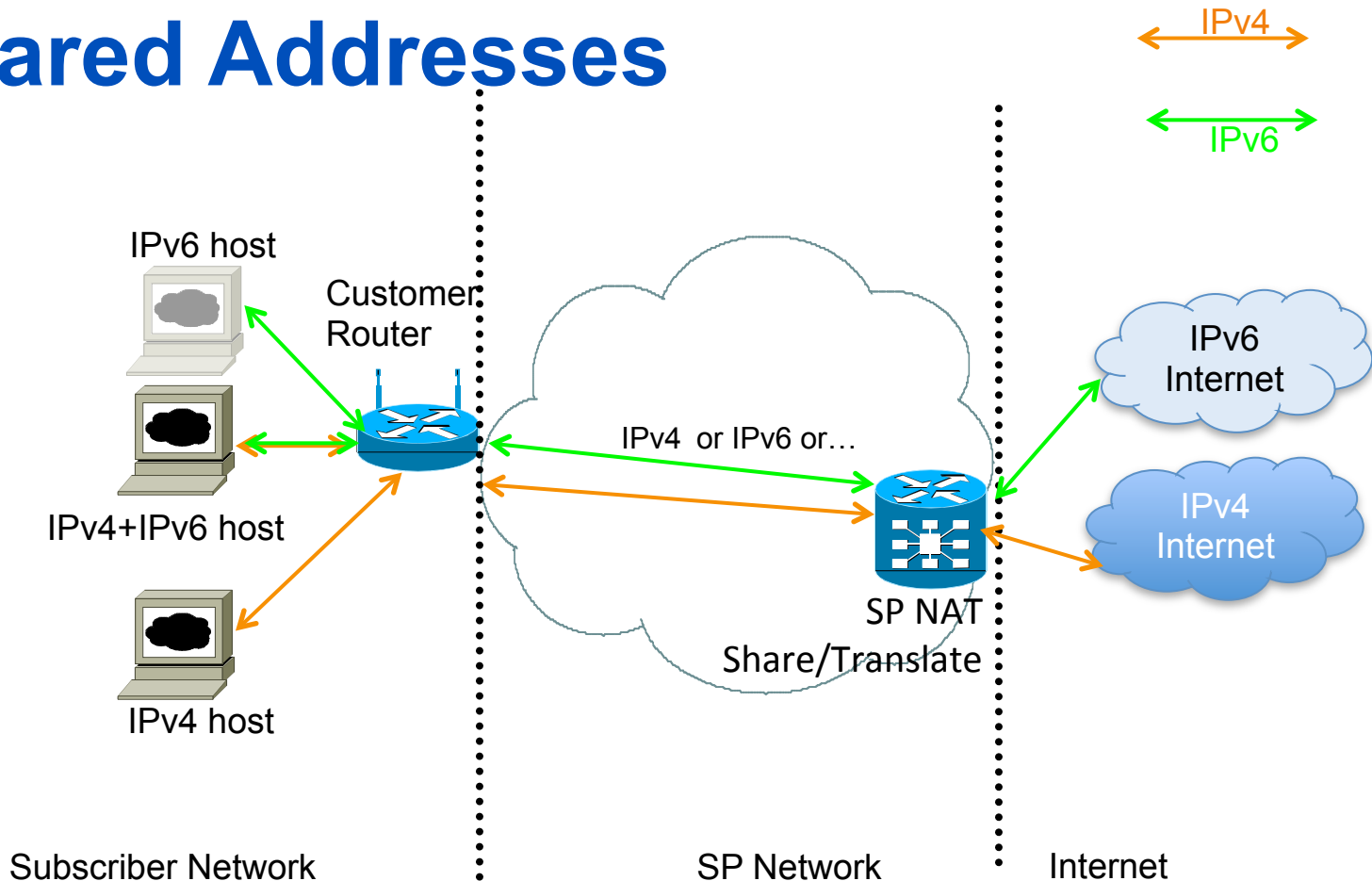
- In a dual stack case, an application that:
  - Is IPv4 and IPv6-enabled
  - Asks the DNS for all types of addresses
  - Chooses one address and, for example, connects to the IPv6 address

# A Dual Stack Configuration



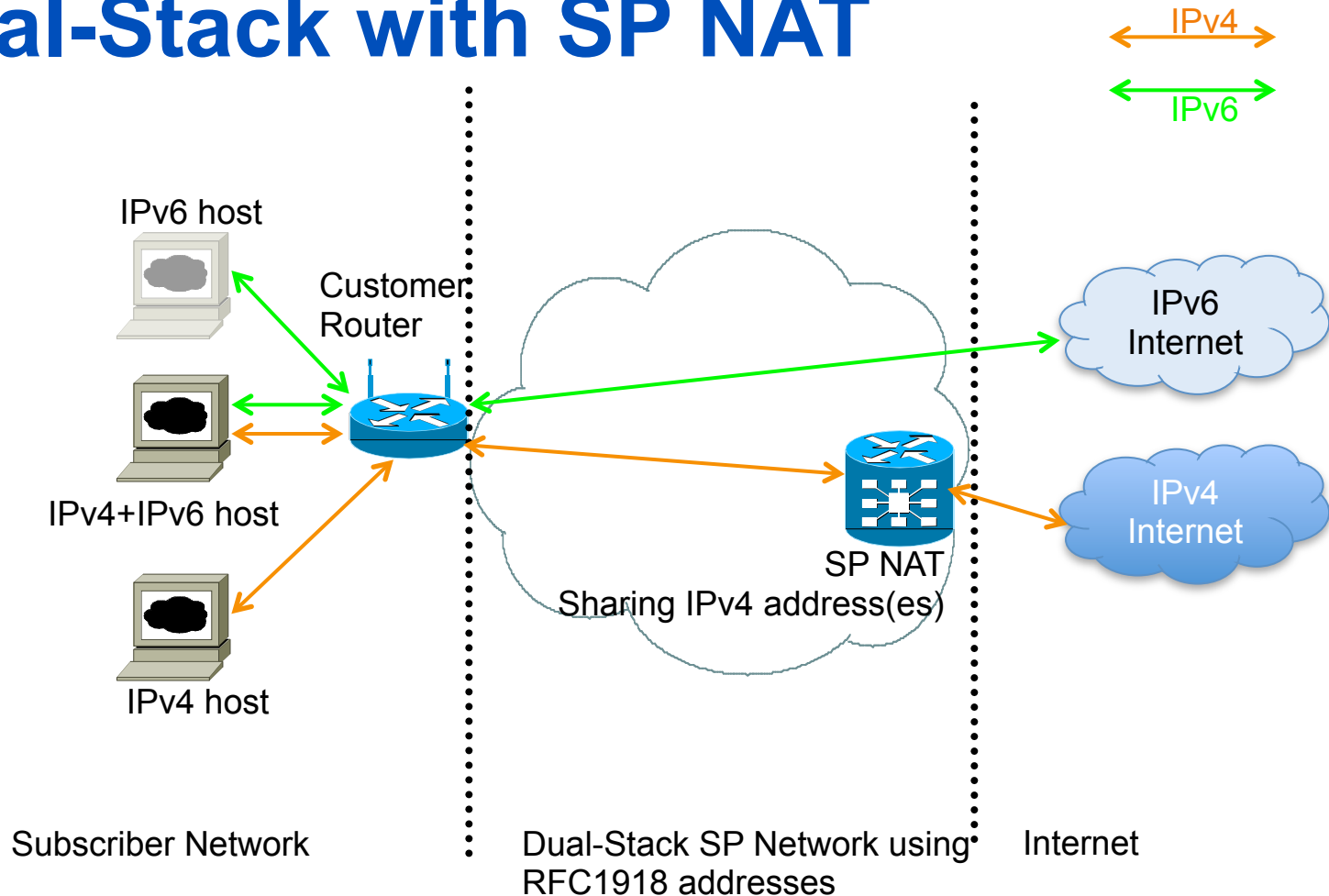
- IPv6-enabled router
  - If IPv4 and IPv6 are configured on one interface, the router is dual-stacked
  - Telnet, Ping, Traceroute, SSH, DNS client, TFTP,...

# Shared Addresses



- SP shares globally routable IPv4 addresses amongst customers:
  - Customer could have IPv6, or IPv4, or a mixture
  - SP NAT device does necessary sharing and translation to access IPv4 and IPv6 Internets

# Dual-Stack with SP NAT



- More likely scenario:
  - IPv6 being available all the way to the consumer
  - SP core and customer has to use IPv4 NAT due to v4 depletion

# Using Tunnels for IPv6 Deployment

- Many techniques are available to establish a tunnel:
  - Manually configured
    - Manual Tunnel (RFC 2893)
    - GRE (RFC 2473)
  - Semi-automated
    - Tunnel broker
  - Automatic
    - 6to4 (RFC 3056)
    - 6rd

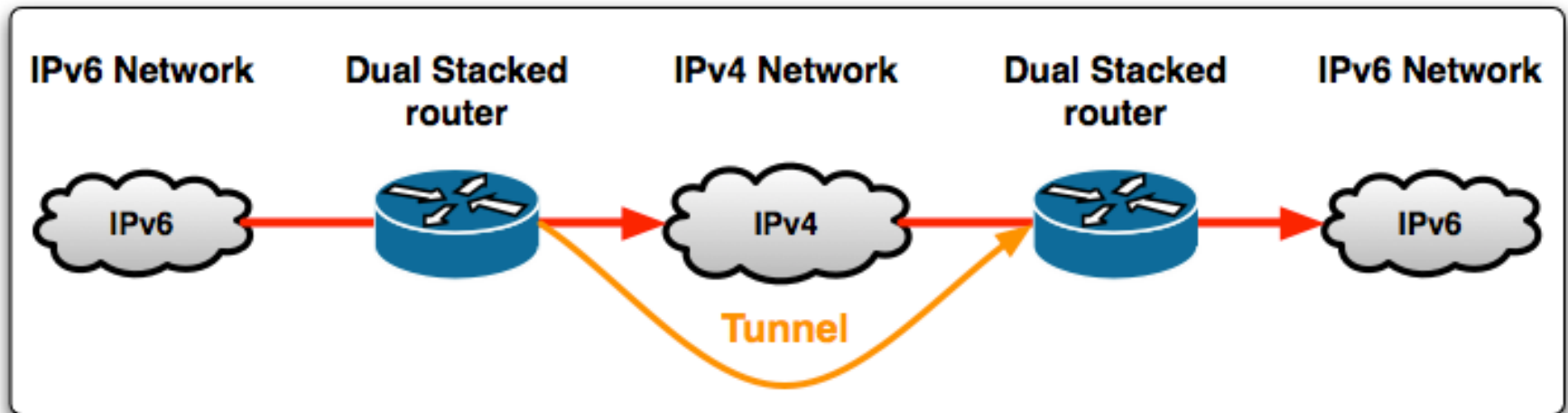


# Tunnels

- Part of a network is IPv6 enabled
  - Tunnelling techniques are used on top of an existing IPv4 infrastructure and uses IPv4 to route the IPv6 packets between IPv6 networks by transporting these encapsulated in IPv4
  - Tunnelling is used by networks not yet capable of offering native IPv6 functionality
  - It is the main mechanism currently being deployed to create global IPv6 connectivity
- Manual, automatic, semi-automatic configured tunnels are available

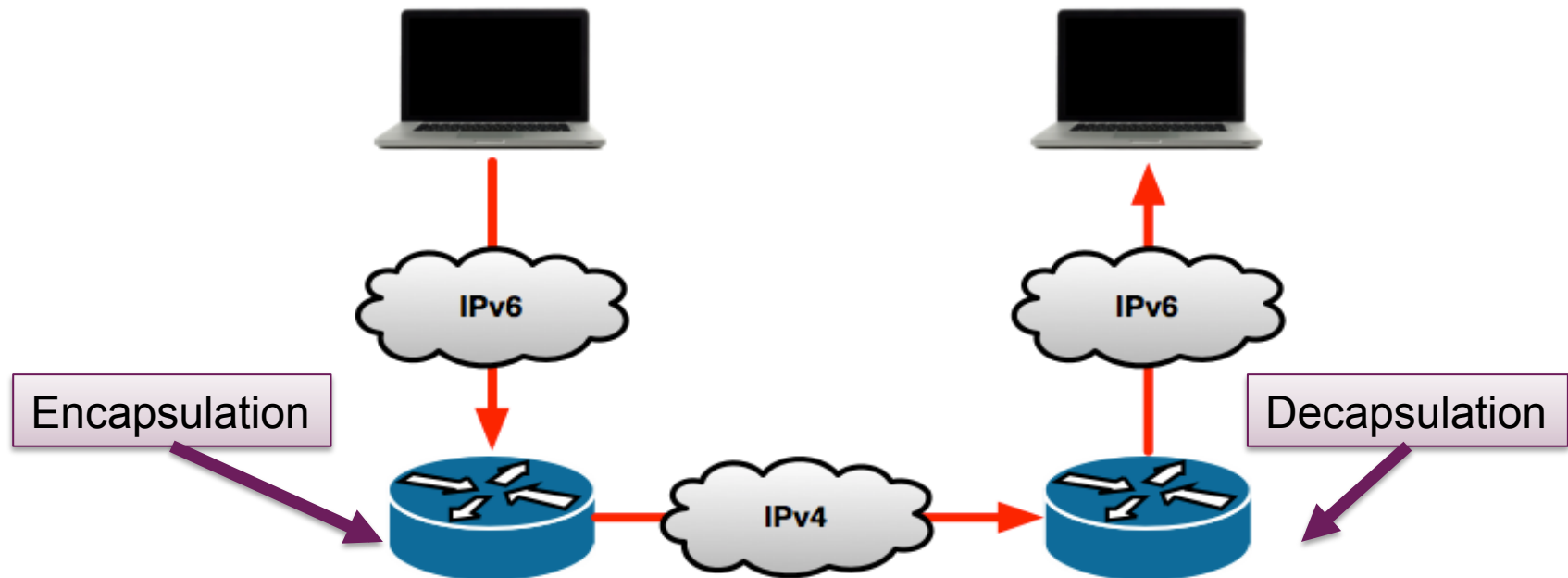
# Tunneling – General Concept

- Tunneling can be used by routers and hosts
  - Tunneling is a technique by which one transport protocol is encapsulated as the payload of another.

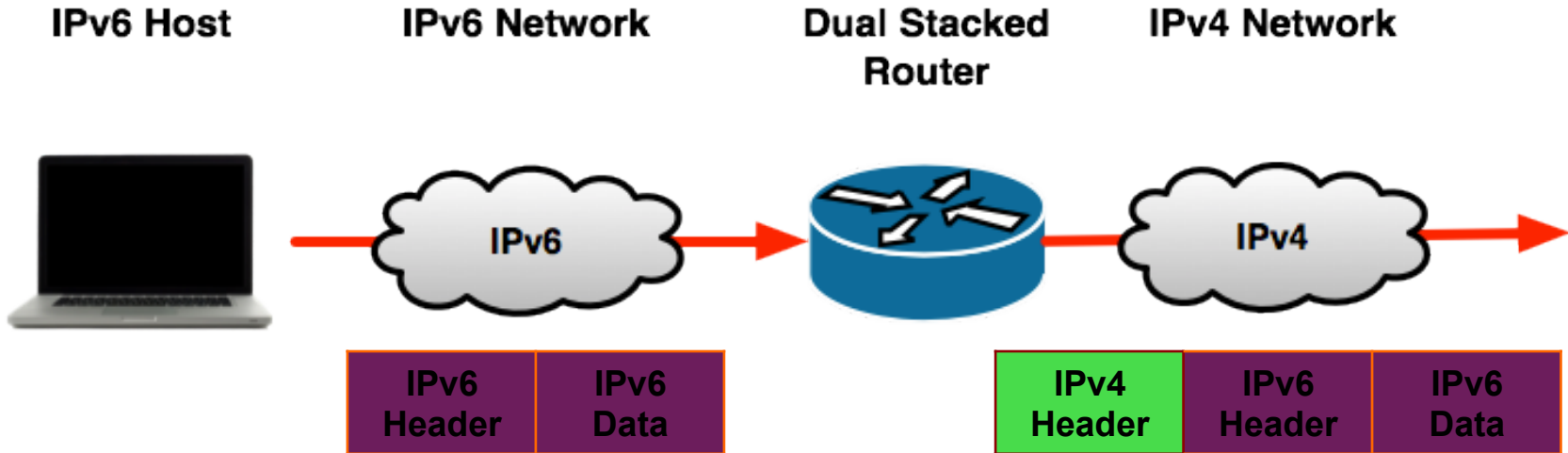


# Tunneling – General Concept

- Two stepped process
  - Encapsulation of IPv6 packets to IPv4 packets
  - Decapsulation of IPv4 packets to IPv6 packets

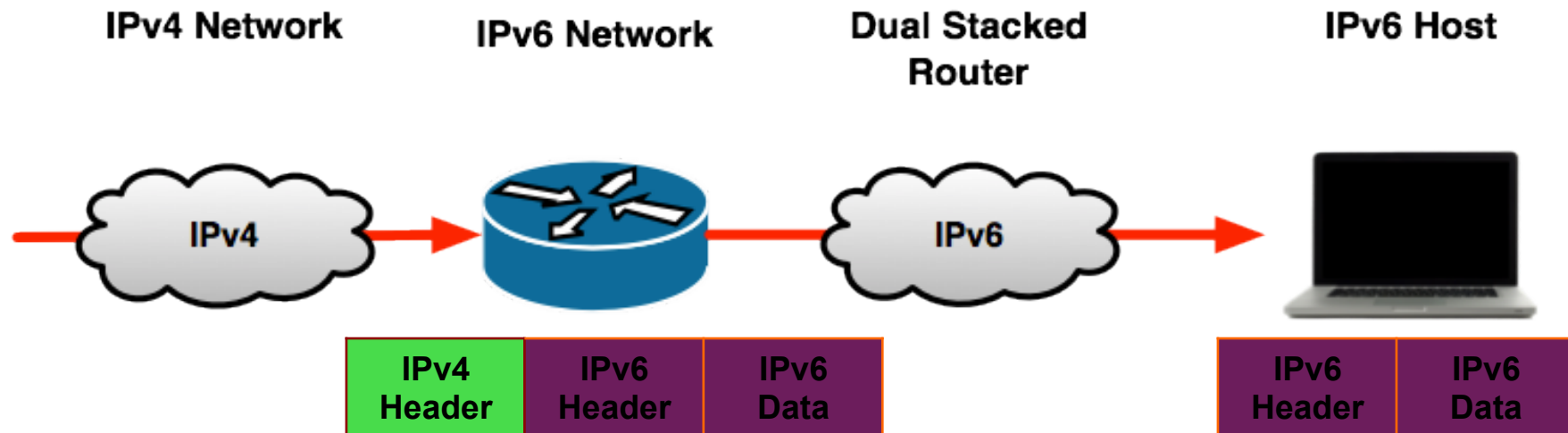


# Tunnel Encapsulation



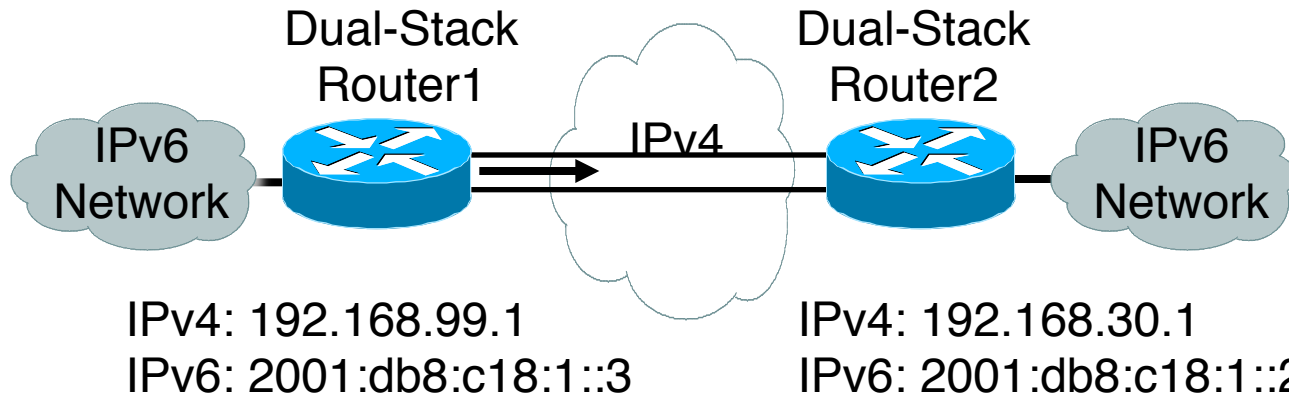
IPv6 essentials by Silvia Hagen, p258

# Tunnel Decapsulation



IPv6 essentials by Silvia Hagen, p258

# Manually Configured Tunnel (RFC4213)

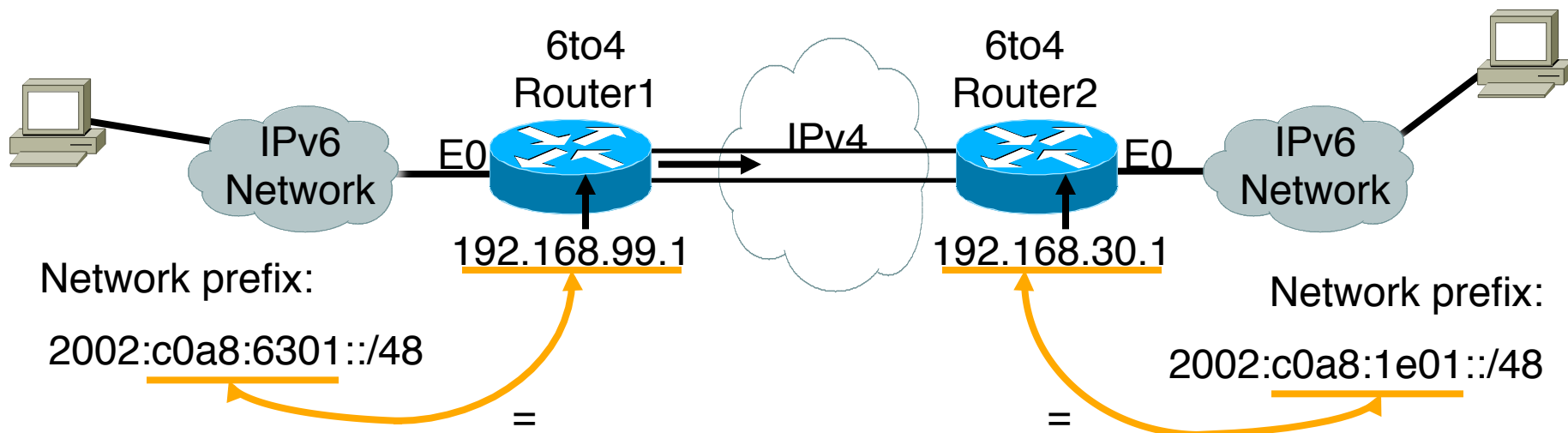


```
router1#  
  
interface Tunnel0  
  ipv6 address 2001:db8:c18:1::3/64  
  tunnel source 192.168.99.1  
  tunnel destination 192.168.30.1  
  tunnel mode ipv6ip
```

```
router2#  
  
interface Tunnel0  
  ipv6 address 2001:db8:c18:1::2/64  
  tunnel source 192.168.30.1  
  tunnel destination 192.168.99.1  
  tunnel mode ipv6ip
```

- Manually Configured tunnels require:
  - Dual stack end points
  - Both IPv4 and IPv6 addresses configured at each end

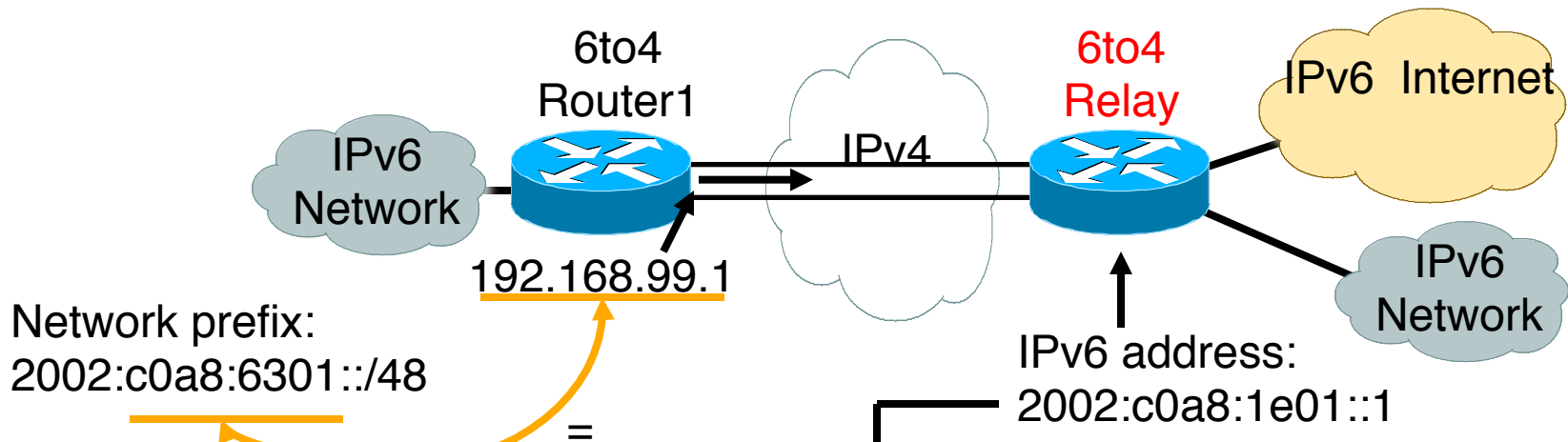
# 6to4 Tunnel (RFC 3056)



- 6to4 Tunnel:
  - Is an automatic tunnel method
  - Gives a prefix to the attached IPv6 network
  - 2002::/16 assigned to 6to4
  - Requires one global IPv4 address on each Ingress/Egress site

```
router2#  
interface Loopback0  
 ip address 192.168.30.1 255.255.255.0  
 ipv6 address 2002:c0a8:1e01:1::/64 eui-64  
interface Tunnel0  
 no ip address  
 ipv6 unnumbered Ethernet0  
 tunnel source Loopback0  
 tunnel mode ipv6ip 6to4  
  
ipv6 route 2002::/16 Tunnel0
```

# 6to4 Relay



```
router1#  
interface Loopback0  
 ip address 192.168.99.1 255.255.255.0  
 ipv6 address 2002:c0a8:6301:1::/64 eui-64  
interface Tunnel0  
 no ip address  
 ipv6 unnumbered Ethernet0  
 tunnel source Loopback0  
 tunnel mode ipv6ip 6to4  
  
ipv6 route 2002::/16 Tunnel0  
ipv6 route ::/0 2002:c0a8:1e01::1
```

- 6to4 relay:
  - Is a gateway to the rest of the IPv6 Internet
  - Default router
  - Anycast address (RFC 3068) for multiple 6to4 Relay



# 6to4 in the Internet

- 6to4 prefix is 2002::/16
- 192.88.99.0/24 is the IPv4 anycast network for 6to4 routers
- 6to4 relay service
  - An ISP who provides a facility to provide connectivity over the IPv4 Internet between IPv6 islands
    - Is connected to the IPv6 Internet and announces 2002::/16 by BGP to the IPv6 Internet
    - Is connected to the IPv4 Internet and announces 192.88.99.0/24 by BGP to the IPv4 Internet
  - Their router is configured with local IPv4 address of 192.88.99.1 and local IPv6 address of 2002:c058:6301::1

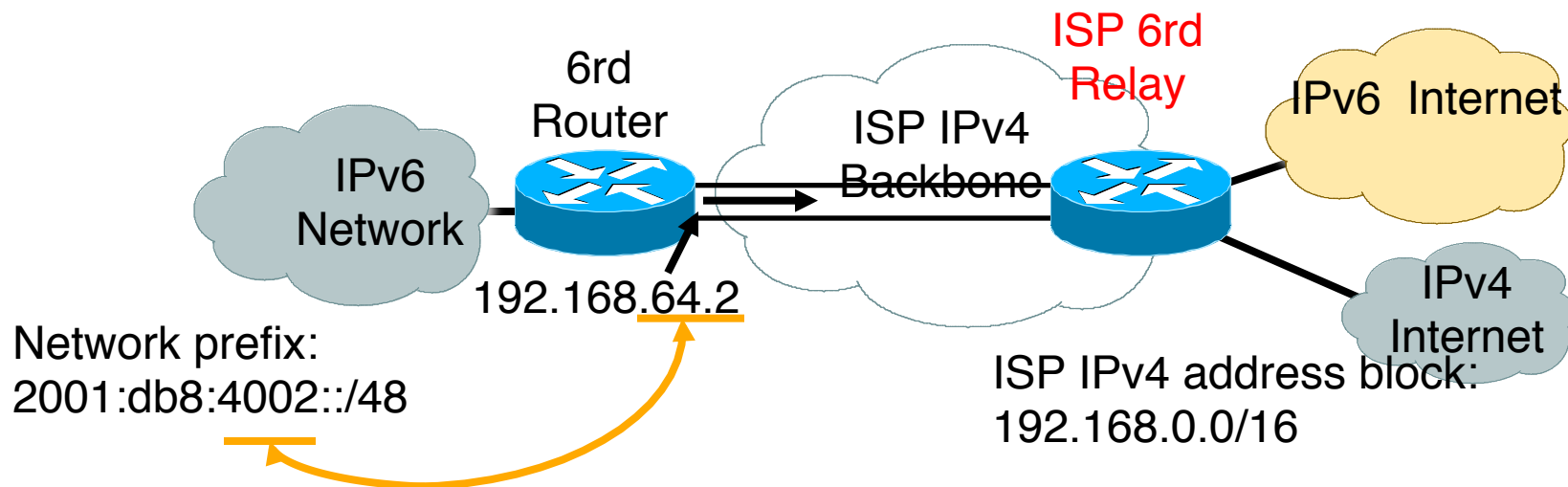
# 6to4 in the Internet

## Relay Router Configuration

```
interface loopback0
    ip address 192.88.99.1 255.255.255.255
    ipv6 address 2002:c058:6301::1/128
!
interface tunnel 2002
    no ip address
    ipv6 unnumbered Loopback0
    tunnel source Loopback0
    tunnel mode ipv6ip 6to4
    tunnel path-mtu-discovery
!
interface FastEthernet0/0
    ip address 105.3.37.1 255.255.255.0
    ipv6 address 2001:db8::1/64
```

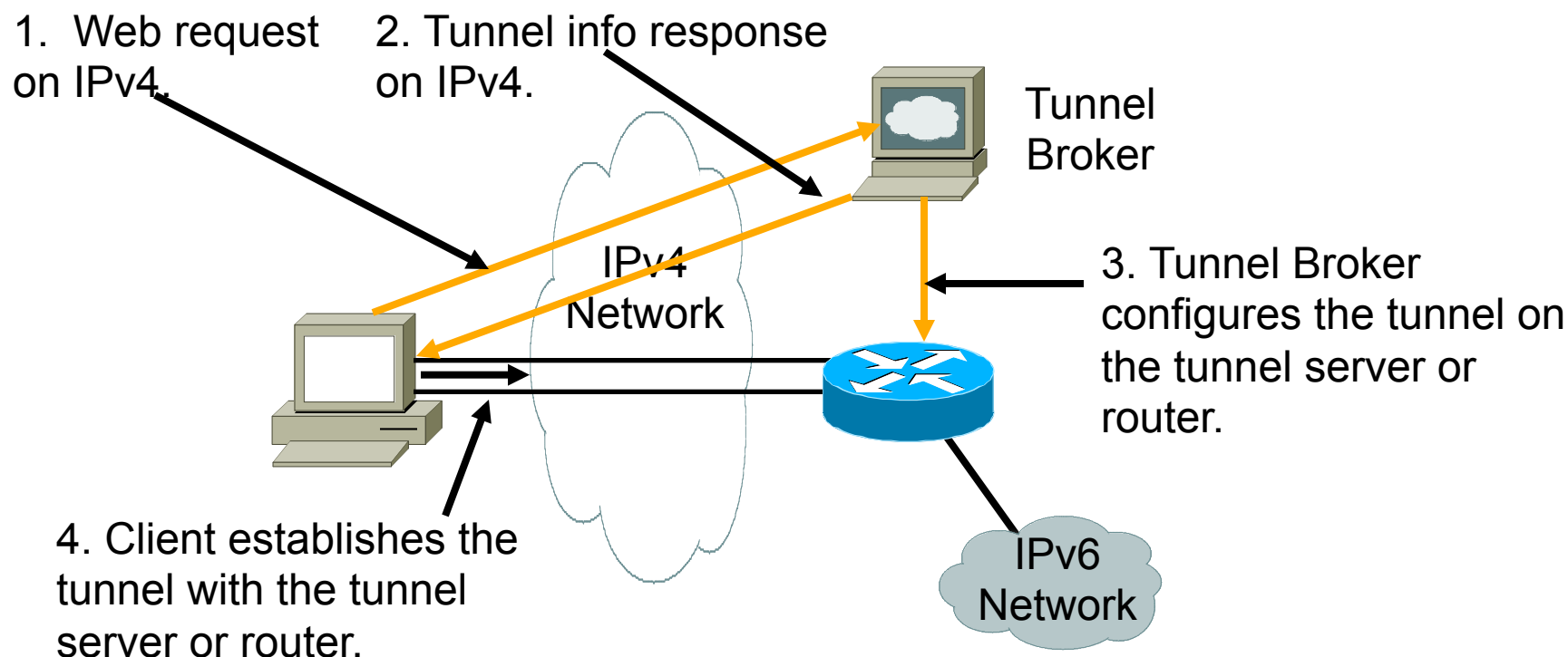
```
!
router bgp 100
    address-family ipv4
        neighbor <v4-transit> remote-as 101
        network 192.88.99.0 mask 255.255.255.0.
    address-family ipv6
        neighbor <v6-transit> remote-as 102
        network 2002::/16
!
ip route 192.88.99.0 255.255.255.0 null0 254
ipv6 route 2002::/16 tunnel2002
```

# 6rd Tunnel



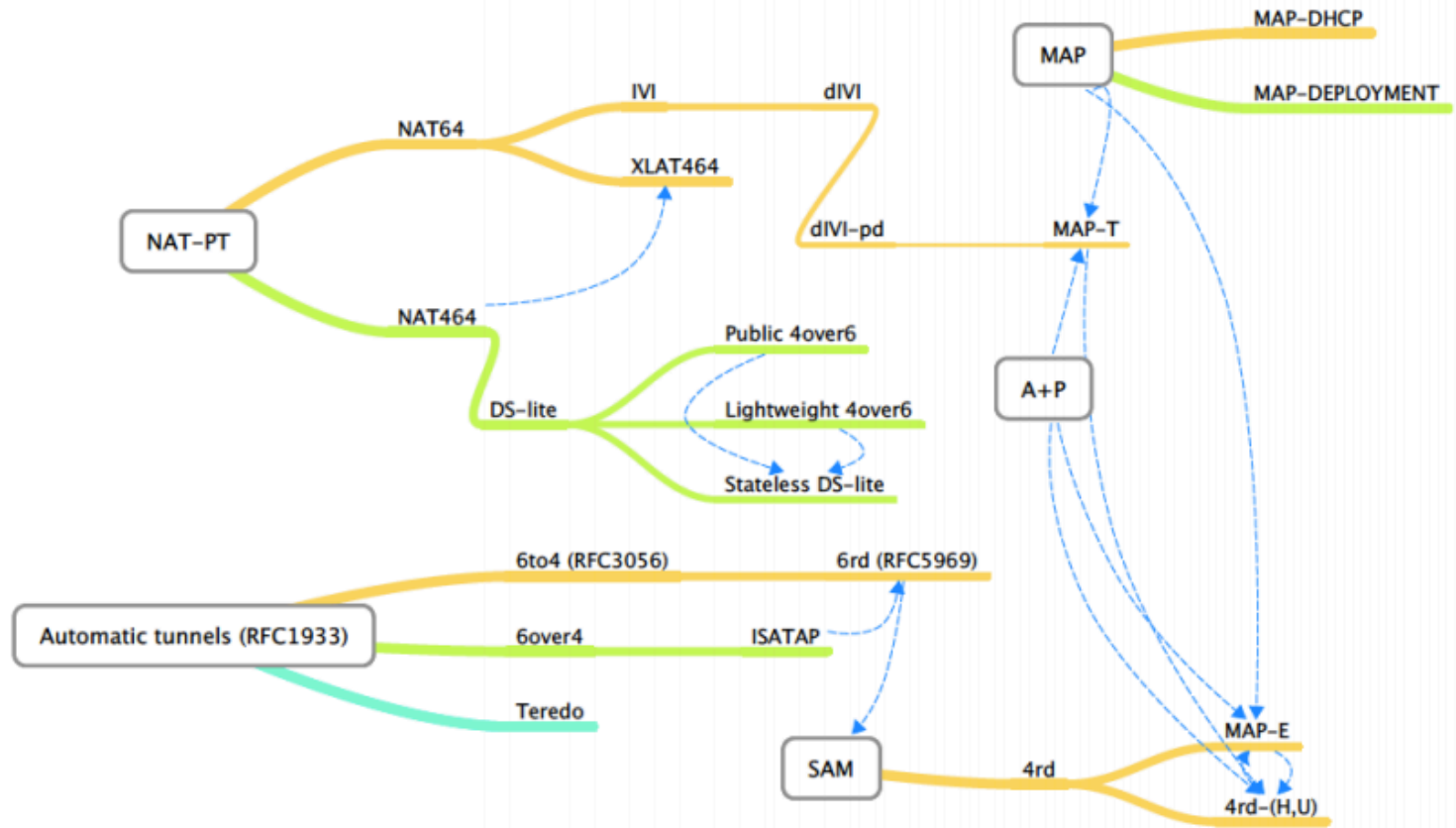
- 6rd (example):
  - ISP has 192.168.0.0/16 IPv4 address block
  - ISP has 2001:db8::/32 IPv6 address block
  - Final 16 bits of IPv4 address used on customer point-to-point link to create customer /48 → customer uses 2001:db8:4002::/48 address space
  - IPv6 tunnel to ISP 6rd relay bypasses infrastructure which cannot handle IPv6

# Tunnel Broker



- Tunnel broker:
  - Tunnel information is sent via http-ipv4

# Evolution of IPv6 Transition Technologies as of March 2013 (IETF83)



Source: IETF 83 Softwires

# Conclusions

## Potential Techniques

Scenario	Potential Techniques
Content and Applications move to IPv6	IPv6 only network; Dual-Stack, 6rd and DS-lite as migration techniques
Content and Applications on IPv4 and IPv6	Dual-Stack (if enough IPv4) or 6rd; SP IPv4-NAT; DS-lite (for greenfield) *
Users are IPv6 only	IPv6 only network; Dual-Stack, 6rd and DS-lite as migration techniques
No change (double NAT)	SP IPv4-NAT *
No change (no double NAT)	Do nothing *

\* Transfer Market applicable

# Recommendations

- Start deploying IPv6 as long term strategy
- Evaluate current addressing usage to understand if IPv4 to IPv4 NAT is sufficient for transition period
- Prepare a translation mechanism from the IPv4 Internet to the IPv6 Internet
- Educate your user base on IPv6 introduction, the use cases and troubleshooting

# Agenda

- Introduction to IPv6 and Protocol Architecture
- IPv6 Addressing and Sub-netting
- IPv6 Host Configuration
- IPv6 Deployment Plan – Case Study
- IPv6 Deployment in IGP – Case Study
- IPv4 to IPv6 Transition Technologies
- **IPv6 Deployment in EGP – Case Study**
- IPv6 DNS
- IPv6 Security



# IPv6 Deployment in EGP – Case Study

- Scenario:
  - BGP4 is used in Training ISP network
  - iBGP is used between internal routers in Training ISP to carry external prefixes (i.e Customer & Global Internet Prefixes)
  - Route Reflector is used to resolve iBGP full mesh scalability issue.

# IPv6 Deployment in EGP – Case Study

- Scenario:
  - Transit service with upstream ASes is configured with eBGP
  - Customer network from downstream can also be configured with eBGP/Static
  - Training ISP is having one native IPv6 transit and one tunnel IPv6 transit with AS45192 & AS131107 (2.35 as dot)

# IPv6 Deployment in EGP – Case Study

- Basic BGP Configuration:

```
router bgp 17821  
address-family ipv6  
no synchronization
```

# IPv6 Deployment in EGP – Case Study

Adding iBGP Neighbor:

```
router bgp 17821
address-family ipv6
!
neighbor 2406:6400:0000:0000::2 remote-as 17821
neighbor 2406:6400:0000:0000::2 update-source loopback
0
neighbor 2406:6400:0000:0000::2 activate
```

iBGP neighbor is always recommended with loopback interface

# IPv6 Deployment in EGP – Case Study

Announcing IPv6 Prefix:

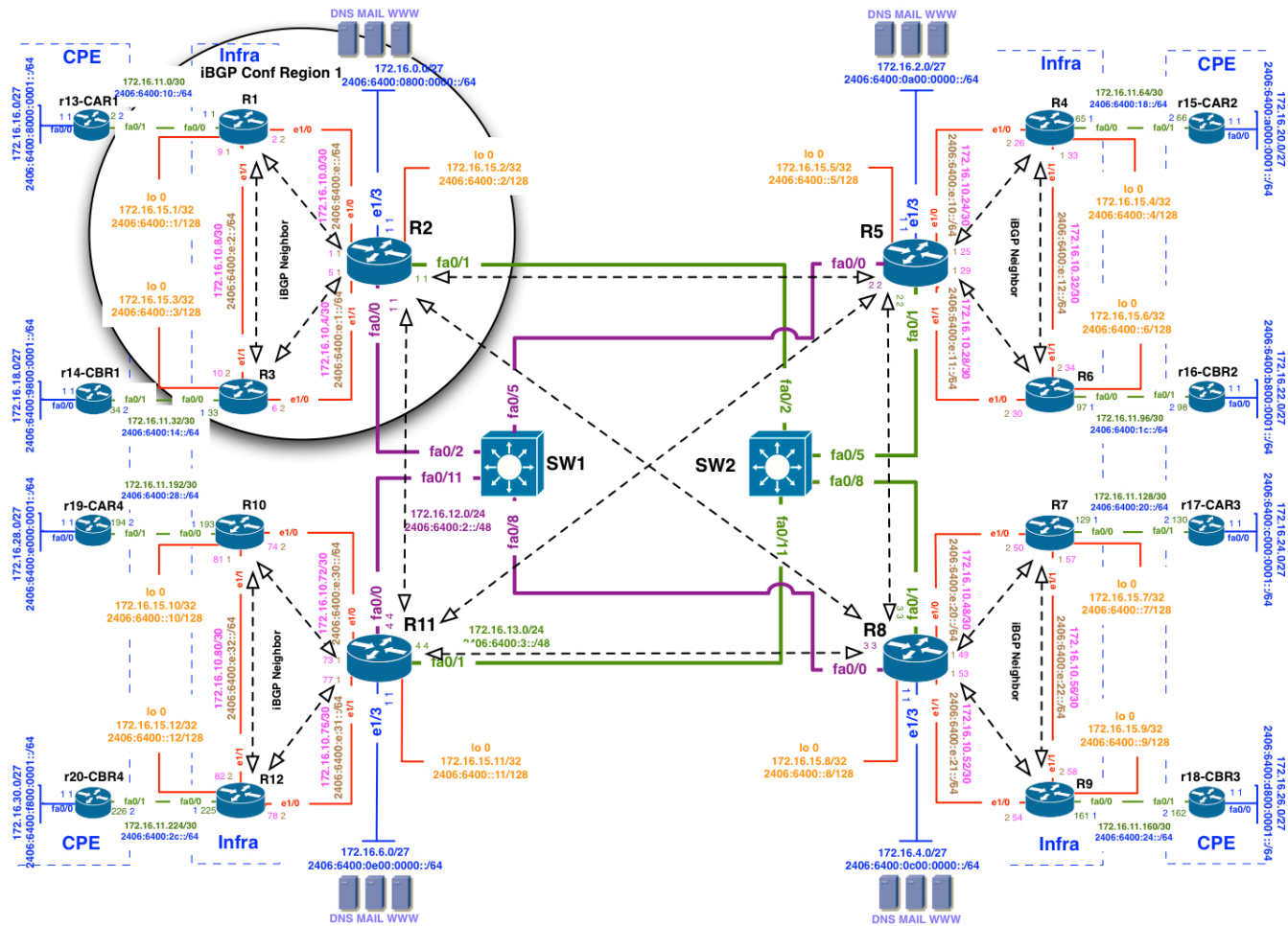
```
router bgp 17821
address-family ipv6
!
neighbor 2406:6400:0000:0000::2 remote-as 17821
neighbor 2406:6400:0000:0000::2 update-source
loopback 0
neighbor 2406:6400:0000:0000::2 activate
!
network 2406:6400:0100:0000::/48
```

# IPv6 Deployment in EGP – Case Study

Add Pull-up route if needed:

```
router bgp 17821
address-family ipv6
!
neighbor 2406:6400:0000:0000::2 remote-as 17821
neighbor 2406:6400:0000:0000::2 update-source loopback 0
neighbor 2406:6400:0000:0000::2 activate
!
network 2406:6400:0100:0000::/48
exit
exit
ipv6 route 2406:6400:0100:0000::/48 null 0
```

# iBGP Peering For Region 1



# IPv4 iBGP Conf POP Router

- Router1

```
config t
router bgp 17821
address-family ipv4
no auto-summary
no synchronization
neighbor 172.16.15.2 remote-as 17821
neighbor 172.16.15.2 update-source loopback 0
neighbor 172.16.15.2 activate
neighbor 172.16.15.3 remote-as 17821
neighbor 172.16.15.3 update-source loopback 0
neighbor 172.16.15.3 activate
network 172.16.16.0 mask 255.255.254.0
exit
exit
ip route 172.16.16.0 255.255.254.0 null 0 permanent
exit
wr
```



# IPv4 iBGP Configuration Verification

- POP Router

```
sh bgp ipv4 unicast summary
sh bgp ipv4 unicast
sh ip route bgp
sh bgp ipv4 unicast neighbors [router 1.....router12
loopback] advertised-routes
sh bgp ipv4 unicast neighbors [router 1.....router12
loopback] received-routes
sh ip route [R2, R5, R8, R11 datacenter prefix]
```

# IPv6 iBGP Conf POP Router

- Router1

```
config t
router bgp 17821
address-family ipv6
no synchronization
neighbor 2406:6400:0000:0000::2 remote-as 17821
neighbor 2406:6400:0000:0000::2 update-source loopback 0
neighbor 2406:6400:0000:0000::2 activate
neighbor 2406:6400:0000:0000::3 remote-as 17821
neighbor 2406:6400:0000:0000::3 update-source loopback 0
neighbor 2406:6400:0000:0000::3 activate
network 2406:6400:0100:0000::/45
exit
exit
ipv6 route 2406:6400:0100:0000::/45 null 0
Exit
wr
```

# IPv6 iBGP Configuration Verification

- POP Router

```
sh bgp ipv6 unicast summary
sh bgp ipv6 unicast
sh ipv6 route bgp
sh bgp ipv6 unicast neighbors [router 1.....router12
loopback] advertised-routes
sh bgp ipv6 unicast neighbors [router 1.....router12
loopback] received-routes
sh ipv6 route [R2, R5, R8, R11 datacenter prefix]
```

# IPv4 iBGP Conf Core Router

- Router2 Configuration

```
config t
router bgp 17821
address-family ipv4
no auto-summary
no synchronization
neighbor 172.16.15.1 remote-as 17821
neighbor 172.16.15.1 update-source loopback 0
neighbor 172.16.15.1 activate
neighbor 172.16.15.3 remote-as 17821
neighbor 172.16.15.3 update-source loopback 0
neighbor 172.16.15.3 activate
neighbor 172.16.15.5 remote-as 17821
neighbor 172.16.15.5 update-source loopback 0
```

```
neighbor 172.16.15.5 activate
neighbor 172.16.15.8 remote-as 17821
neighbor 172.16.15.8 update-source loopback 0
neighbor 172.16.15.8 activate
neighbor 172.16.15.11 remote-as 17821
neighbor 172.16.15.11 update-source loopback 0
neighbor 172.16.15.11 activate
network 172.16.0.0 mask 255.255.254.0
exit
exit
ip route 172.16.0.0 255.255.254.0 null 0 permanent
Exit
wr
```

# IPv4 iBGP Configuration Verification

- Core Router

```
sh bgp ipv4 unicast summary
sh bgp ipv4 unicast
sh ip route bgp
sh bgp ipv4 unicast neighbors [router 1.....router12
loopback] advertised-routes
sh bgp ipv4 unicast neighbors [router 1.....router12
loopback] received-routes
sh ip route [R2, R5, R8, R11 datacenter prefix]
```

# IPv6 iBGP Conf Core Router

- Router2 Configuration

```
config t
router bgp 17821
address-family ipv6
no synchronization
neighbor 2406:6400:0000:0000::1
remote-as 17821
neighbor 2406:6400:0000:0000::1
update-source loopback 0
neighbor 2406:6400:0000:0000::1
activate
neighbor 2406:6400:0000:0000::3
remote-as 17821
neighbor 2406:6400:0000:0000::3
update-source loopback 0
neighbor 2406:6400:0000:0000::3
activate
neighbor 2406:6400:0000:0000::5
remote-as 17821
neighbor 2406:6400:0000:0000::5
update-source loopback 0
neighbor 2406:6400:0000:0000::5
activate
```

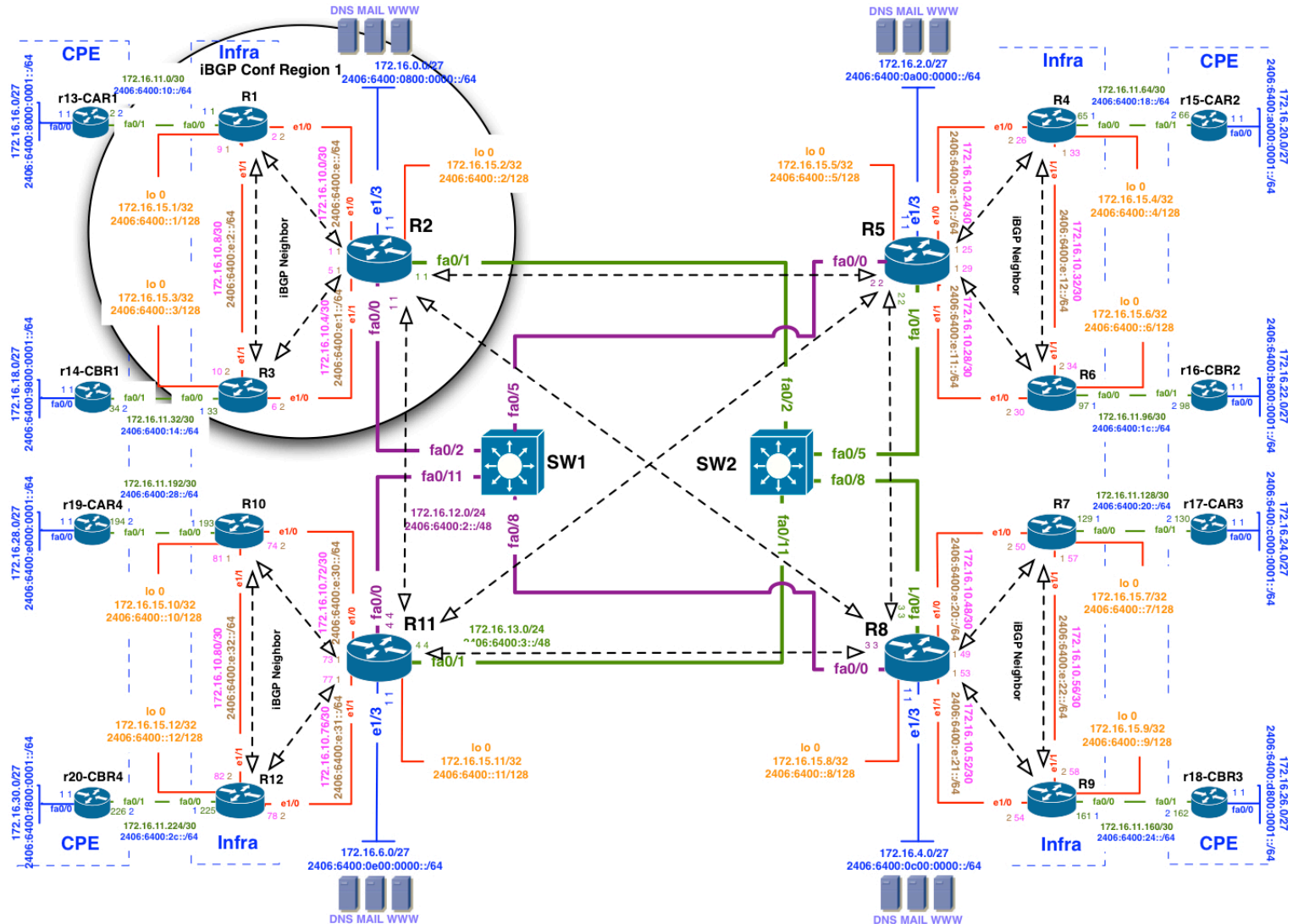
```
neighbor 2406:6400:0000:0000::8
remote-as 17821
neighbor 2406:6400:0000:0000::8
update-source loopback 0
neighbor 2406:6400:0000:0000::8
activate
neighbor 2406:6400:0000:0000::11
remote-as 17821
neighbor 2406:6400:0000:0000::11
update-source loopback 0
neighbor 2406:6400:0000:0000::11
activate
network 2406:6400:0001:0000::/48
exit
exit
ipv6 route 2406:6400:0001:0000::/48
null 0
exit
wr
```

# IPv6 iBGP Configuration Verification

- Core Router

```
sh bgp ipv6 unicast summary
sh bgp ipv6 unicast
sh ipv6 route bgp
sh bgp ipv6 unicast neighbors [router 1.....router12
loopback] advertised-routes
sh bgp ipv6 unicast neighbors [router 1.....router12
loopback] received-routes
sh ipv6 route [R2, R5, R8, R11 datacenter prefix]
```

# iBGP Full Mesh Issue





# iBGP Full Mesh Issue

- Route reflector configuration:

```
router bgp 17821
address-family ipv6
!
neighbor 2406:6400:0000:0000::1 remote-as 17821
neighbor 2406:6400:0000:0000::1 update-source loopback 0
neighbor 2406:6400:0000:0000::1 activate
!
neighbor 2406:6400:0000:0000::1 route-reflector-client
```

# Controlling IPV6 Route Aggregation

- IPv6 prefix filter configuration Customer:

```
config t
ipv6 prefix-list IPV6-CUST-OUT seq 5 permit ::/0 ge 32 le 32
ipv6 prefix-list IPV6-CUST-OUT seq 10 permit ::/0 ge 48 le 48
ipv6 prefix-list IPV6-CUST-IN seq 5 permit cust::/0 ge 32 le
32
ipv6 prefix-list IPV6-CUST-IN seq 10 permit cust::/0 ge 48 le
48

router bgp 17821
address-family ipv6
neighbor cust::2 prefix-list IPV6PREFIX out
exit
exit
exit
clear bgp ipv6 unicast cust::2 soft out
```

# Case Study- Deployment IPv6 in EGP

- IPv6 address summarization:

```
router bgp 17821
address-family ipv6
!
aggregate-address 2406:6400::/32
```

- Need to be very careful when you summarize address

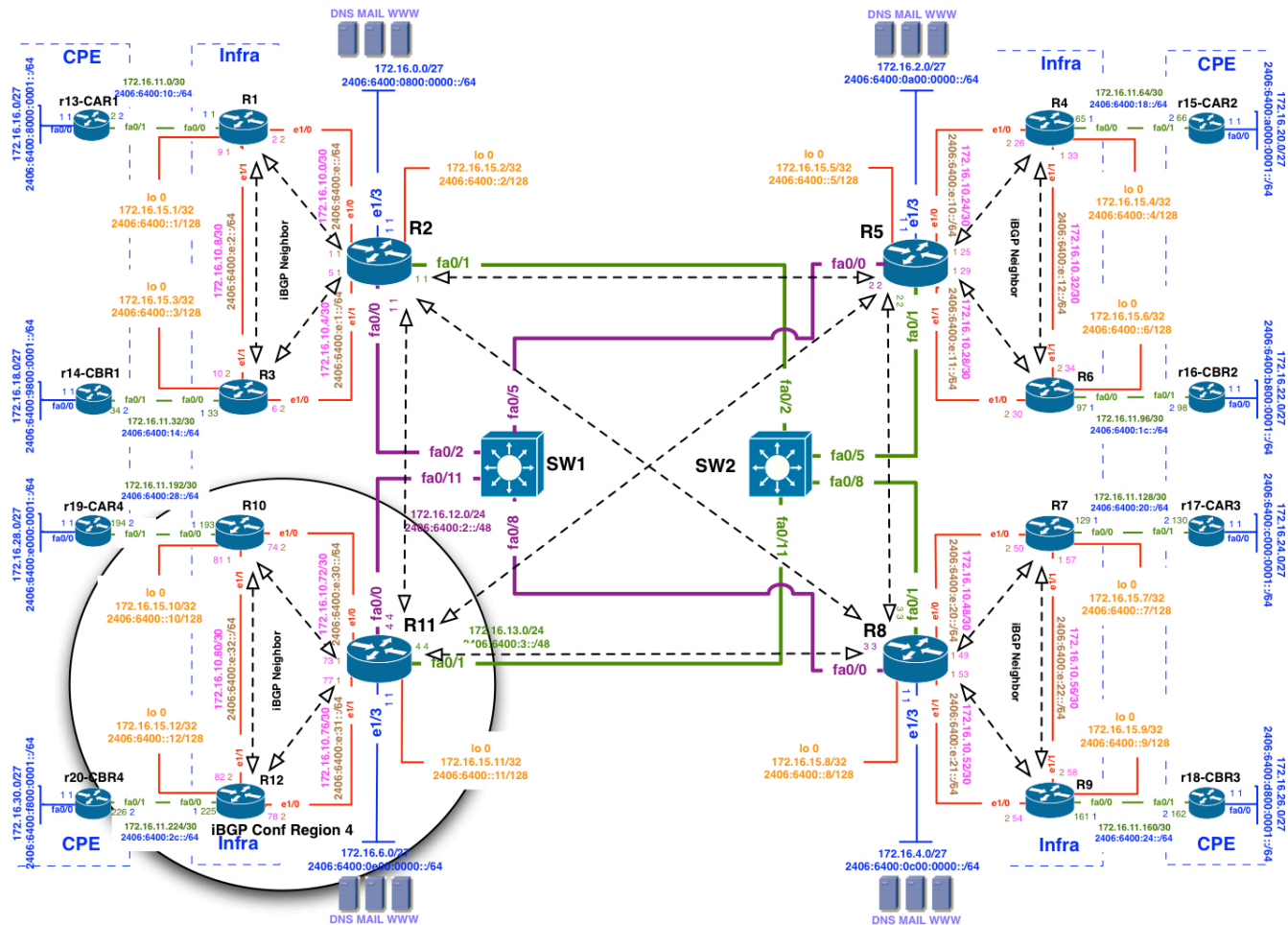
# APNIC



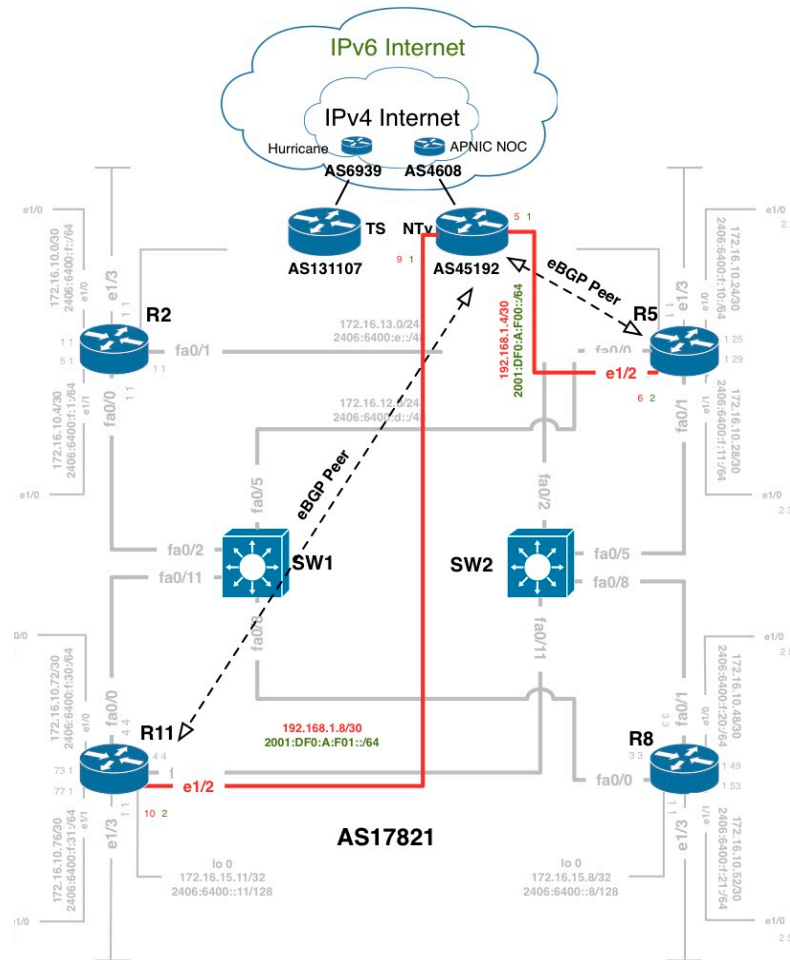
# APNIC



# iBGP Peering For Region 4



# IPv6 Native Transit Conf Plan



# IPv6 IOS Command For eBGP

- Adding eBGP Neighbor:

```
router bgp 17821
address-family ipv6
!
neighbor 2406:6400:000D:0000::5 remote-as 45192
neighbor 2406:6400:000D:0000::5 activate
```

- eBGP neighbor is always recommended with directly connected interface



# IPv6 Native Transit Configuration

- Router5

```
config t
router bgp 17821
address-family ipv6
neighbor 2406:6400:000D:0000::5 remote-as 45192
neighbor 2406:6400:000D:0000::5 activate
neighbor 2406:6400:000E:0000::5 remote-as 45192
neighbor 2406:6400:000E:0000::5 activate
exit
exit
exit
Wr
```

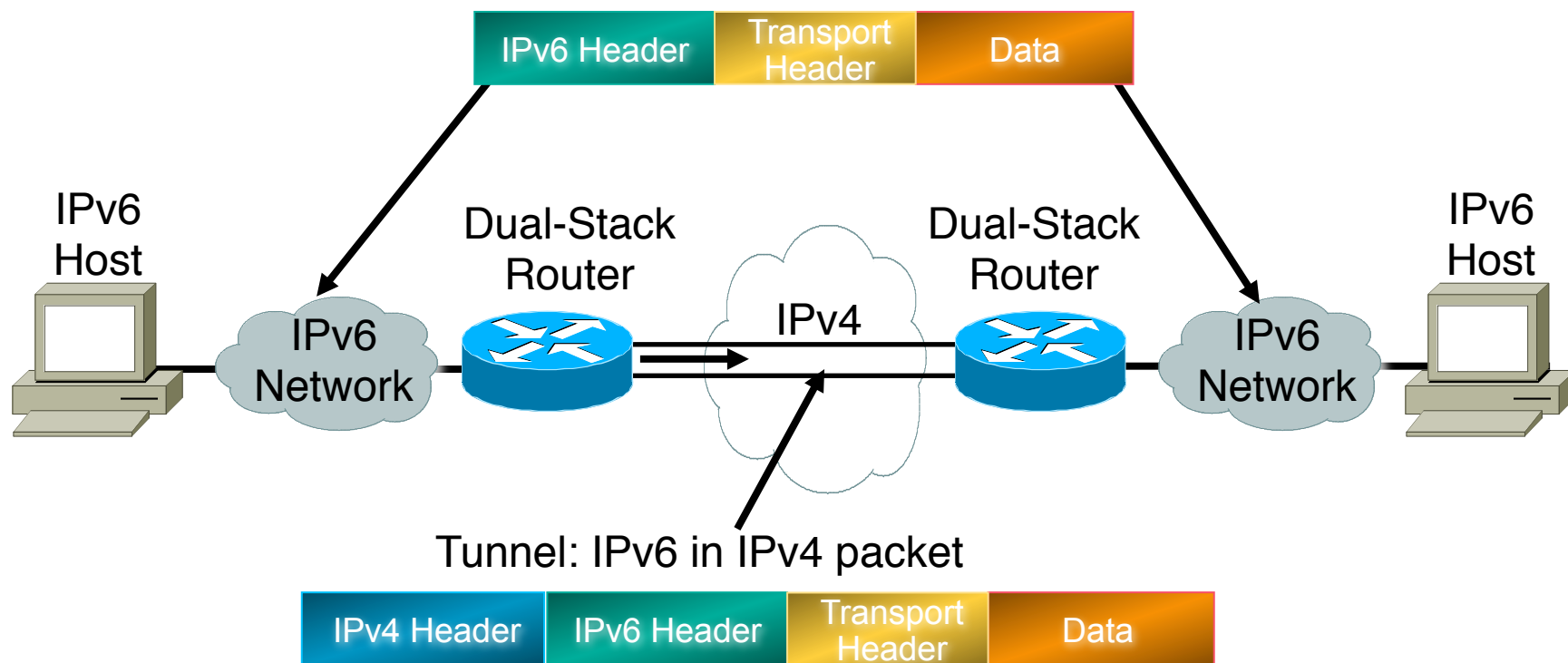
# Controlling IPV6 Route Aggregation

- IPv6 prefix filter configuration Native Transit:

```
config t
ipv6 prefix-list IPV6-GLOBAL-IN seq 5 permit ::/0 ge 32 le 32
ipv6 prefix-list IPV6-GLOBAL-IN seq 10 permit ::/0 ge 48 le 48
!
ipv6 prefix-list IPV6-GLOBAL-OUT seq 5 permit ::/0 ge 32 le 32
ipv6 prefix-list IPV6-GLOBAL-OUT seq 10 permit ::/0 ge 48 le 48

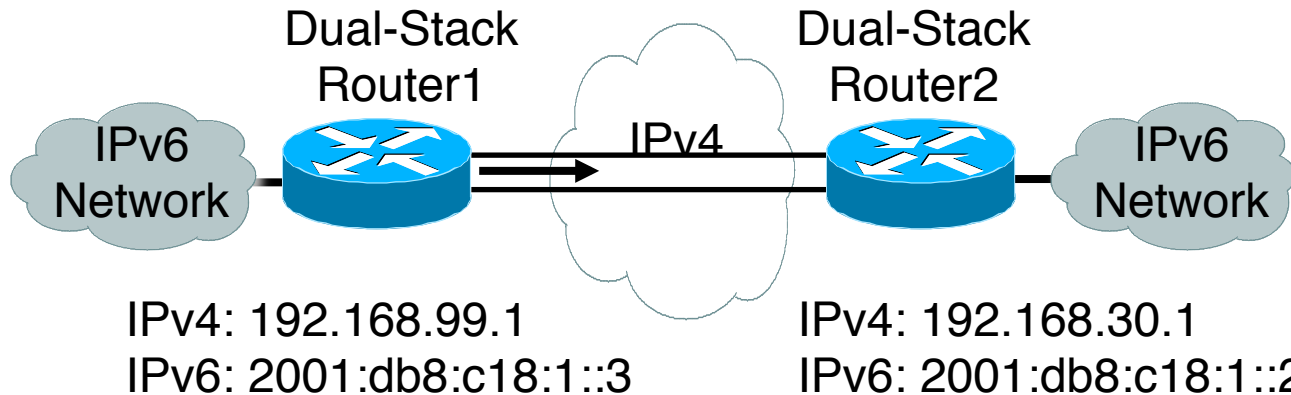
router bgp 17821
address-family ipv6
neighbor 2406:6400:000D:0000::5 prefix-list IPV6-GLOBAL-IN in
neighbor 2406:6400:000D:0000::5 prefix-list IPV6-GLOBAL-OUT out
exit
exit
exit
clear bgp ipv6 unicast 2406:6400:000D:0000::5 soft in
clear bgp ipv6 unicast 2406:6400:000D:0000::5 soft out
```

# IPv6 over IPv4 Tunnels



- Tunneling is encapsulating the IPv6 packet in the IPv4 packet
- Tunneling can be used by routers and hosts

# Manually Configured Tunnel (RFC2893)

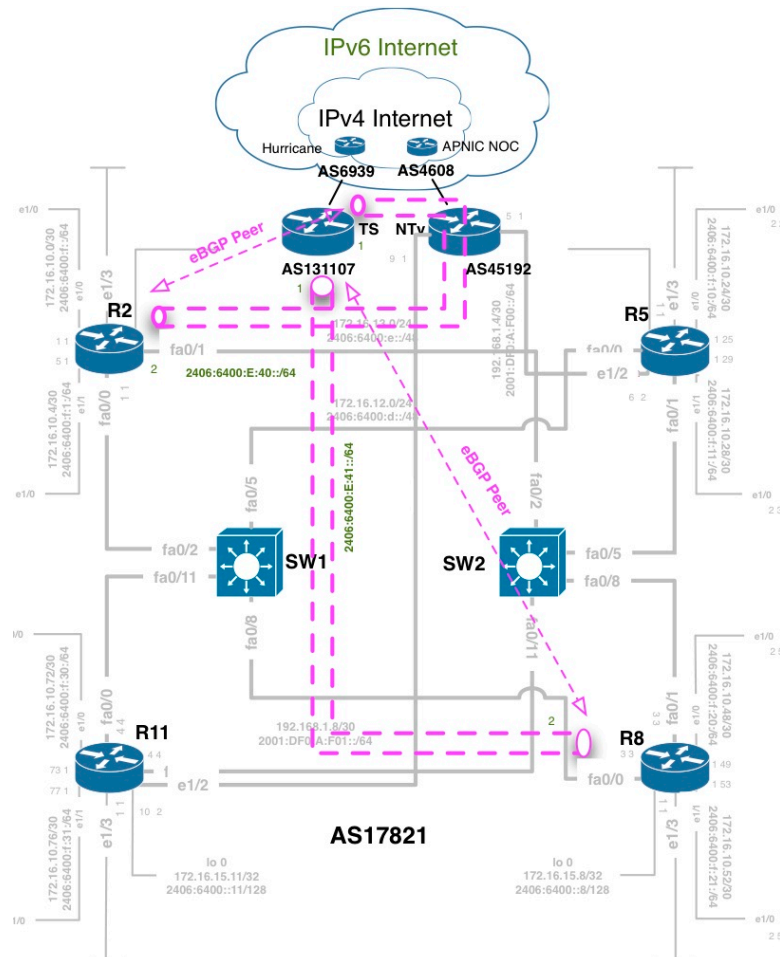


```
router1#  
  
interface Tunnel0  
  ipv6 address 2001:db8:c18:1::3/64  
  tunnel source 192.168.99.1  
  tunnel destination 192.168.30.1  
  tunnel mode ipv6ip
```

```
router2#  
  
interface Tunnel0  
  ipv6 address 2001:db8:c18:1::2/64  
  tunnel source 192.168.30.1  
  tunnel destination 192.168.99.1  
  tunnel mode ipv6ip
```

- Manually Configured tunnels require:
  - Dual stack end points
  - Both IPv4 and IPv6 addresses configured at each end

# IPv6 Tunnel Transit Configuration



# 6to4 Tunnel Configuration

- IOS Command for Tunnel Interface:

- Router2

```
config t
interface Tunnel0
tunnel source 172.16.15.2
tunnel destination 192.168.1.1
tunnel mode ipv6ip
ipv6 address 2406:6400:F:40::2/64
ipv6 enable
```

# 6to4 Tunnel Configuration

- IOS Command for Tunnel Peering:

```
router bgp 17821
address-family ipv6
neighbor 2406:6400:F:40::1 remote-as 23456
neighbor 2406:6400:F:40::1 activate
```

# Controlling IPv6 Route Aggregation

- IPv6 prefix filter configuration Tunnel Transit:

```
config t
ipv6 prefix-list IPV6-GLOBAL-IN seq 5 permit ::/0 ge 32 le 32
ipv6 prefix-list IPV6-GLOBAL-IN seq 10 permit ::/0 ge 48 le 48
!
ipv6 prefix-list IPV6-GLOBAL-OUT seq 5 permit ::/0 ge 32 le 32
ipv6 prefix-list IPV6-GLOBAL-OUT seq 10 permit ::/0 ge 48 le 48

router bgp 17821
address-family ipv6
neighbor 2406:6400:F:40::1 prefix-list IPV6-GLOBAL-IN in
neighbor 2406:6400:F:40::1 prefix-list IPV6-GLOBAL-OUT out
exit
exit
exit
clear bgp ipv6 unicast 2406:6400:F:40::1 soft in
clear bgp ipv6 unicast 2406:6400:F:40::1 soft out
```

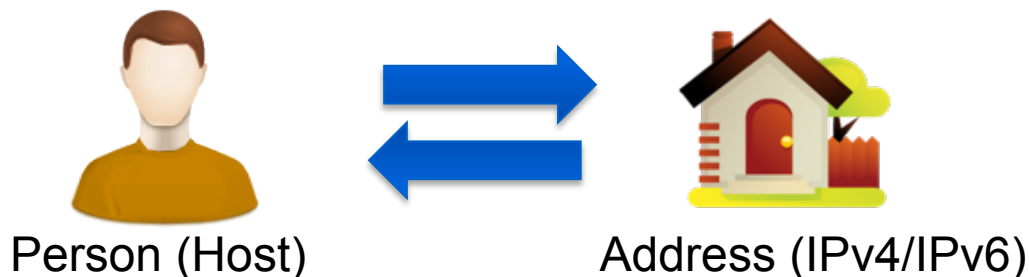


# Agenda

- Introduction to IPv6 and Protocol Architecture
- IPv6 Addressing and Sub-netting
- IPv6 Host Configuration
- IPv6 Deployment Plan – Case Study
- IPv6 Deployment in IGP – Case Study
- IPv4 to IPv6 Transition Technologies
- IPv6 Deployment in EGP – Case Study
- **IPv6 DNS**

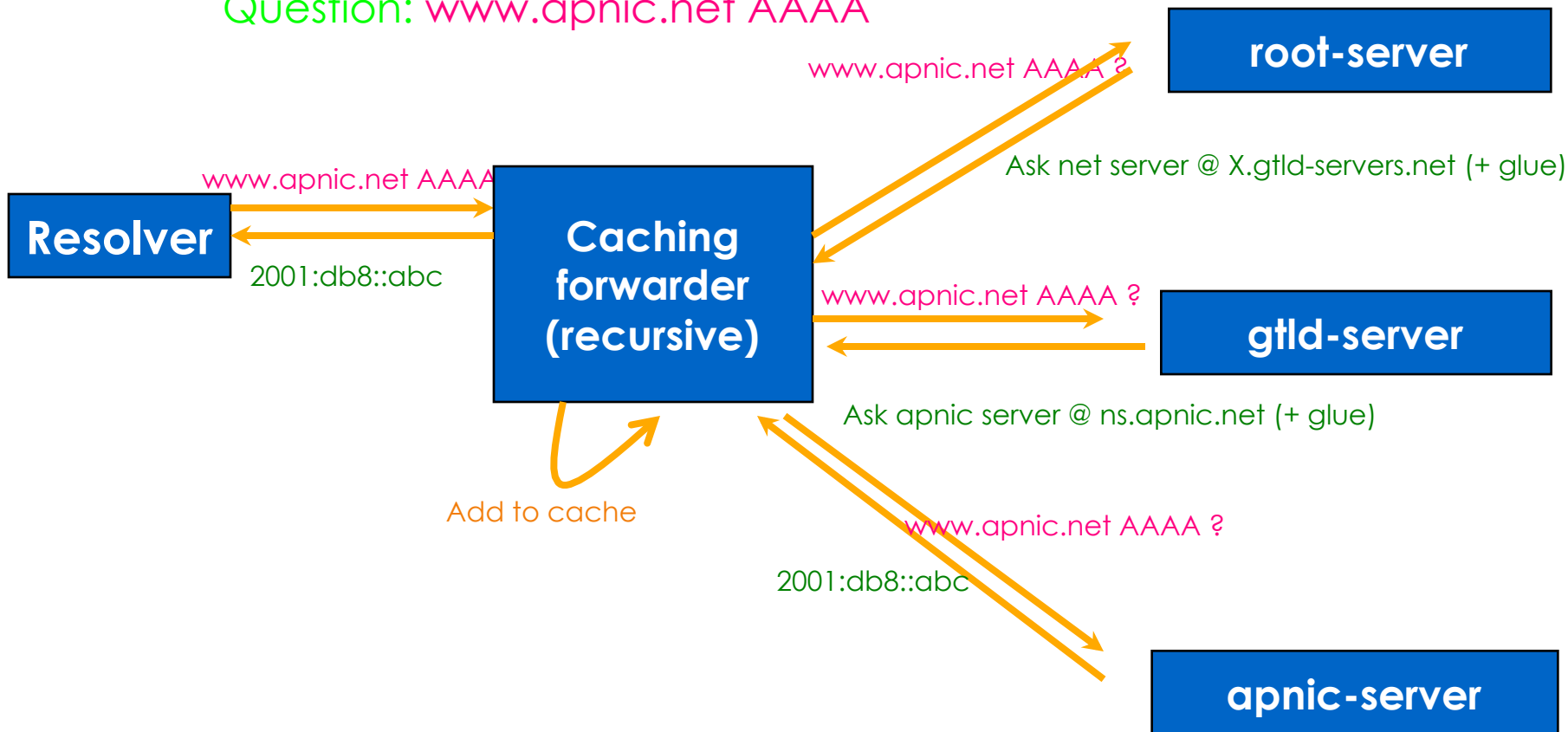
# DNS Basics

- DNS maps one resource to another resource
  - IP address to hostname (and vice versa)
  - Useful for long addresses (such as IPv6)
- Globally distributed, hierarchical tree structure
- Three components: namespace, resolvers, servers
- Resource records are the actual mappings
  - RR Types: A, AAAA, PTR, CNAME, etc



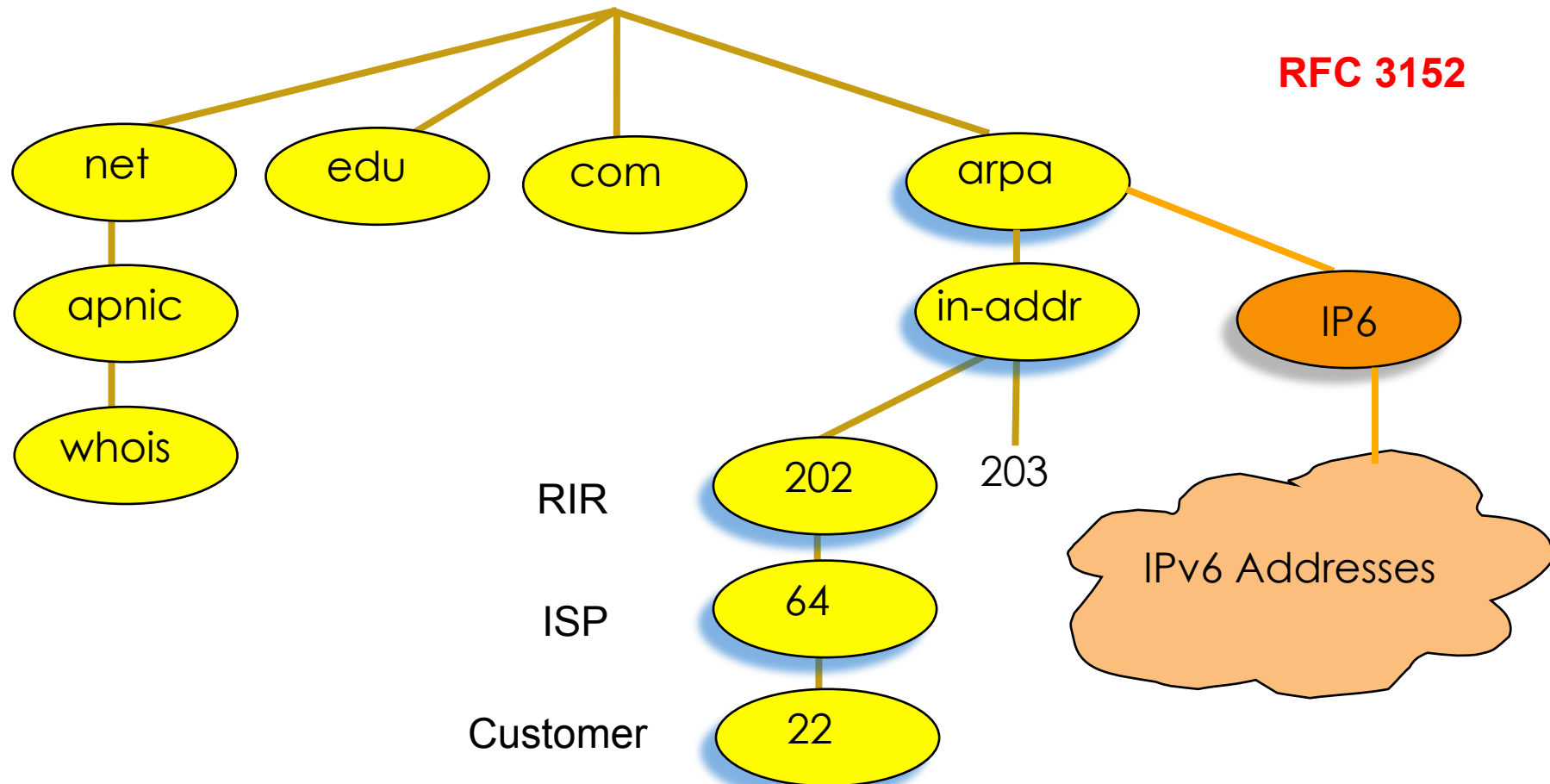
# DNS Overview (Lookup)

Question: **www.apnic.net AAAA**



# IPv6 Reverse DNS tree

## Root DNS



# RFCs

- RFC 3596 – DNS Extensions to Support IPv6
  - Introduced AAAA record
  - IP6.ARPA domain
  - Updates RFC1886 (uses IP6.INT domain)
- RFC 3152 – Delegation of IP6.ARPA
  - Used for reverse mapping
  - IP6.ARPA is analogous to IN-ADDR.ARPA zone for IPv4
- RFC 3901 – DNS IPv6 Transport Operational Guidelines
  - As a Best Common Practice

# IPv6 Representation in the DNS

- Forward lookup support: Multiple RR records for name to number
  - AAAA (Similar to A RR for IPv4 )
- Reverse lookup support:
  - Reverse nibble format for zone ip6.arpa
- Multiple addresses are possible for any given name
  - Ex: in a multi-homed situation
- Can assign A records and AAAA records to a given name/ domain
- Can also assign separate domains for IPv6 and IPv4

# Sample Forward Lookup File

```
apnic.net. 7200 IN      SOA      ns.apnic.net. admin.apnic.net.
(
    2010020901      ; Serial
    12h      ; Refresh 12 hours
    4h      ; Retry 4 hours
    4d      ; Expire 4 days
    2h      ; Negative cache 2 hours )

apnic.net.      7200  IN      NS      ns.apnic.net.
server1.apnic.net. 3600  IN      A      193.0.1.162
                3600  IN      AAAA     2001:0db8:1230::ABC:1
```

# IPv6 Reverse Lookups – PTR records

- Similar to the IPv4 reverse record

```
b.a.9.8.7.6.5.0.4.0.0.0.3.0.0.0.2.0.0.0.1.0.0.0.0.0.0.1.2.3.4.ip6.arpa.
```

```
IN      PTR    test.ip6.example.com.
```

- Example: reverse name lookup for a host with address

3ffe:8050:201:1860:42::1

```
$ORIGIN 0.6.8.1.1.0.2.0.0.5.0.8.e.f.f.3.ip6.arpa.
```

```
1.0.0.0.0.0.0.0.0.0.0.0.0.2.4.0.0 14400 IN PTR host.example.com.
```



# Sample Reverse Lookup File

```
$ORIGIN 0.0.0.0.4.3.2.1.8.B.D.0.1.0.0.2
```

```
apnic.net. 7200 IN      SOA      ns.apnic.net. admin.apnic.net.  
      (  
      2010020901      ; Serial  
      12h  ; Refresh 12 hours  
      4h   ; Retry 4 hours  
      4d   ; Expire 4 days  
      2h   ; Negative cache 2 hours )
```

```
apnic.net.      7200 IN      NS      ns.apnic.net.
```

```
1.C.B.A.0.0.0.0.0.0.0.0.0.0.0 3600 IN      PTR server1.apnic.net.
```

# IPv6 in the Root Servers

- <http://www.internic.net/zones/named.root>
- 9 of 13 root servers have IPv6 AAAA records
  - C, E, G root servers don't have IPv6 capability yet
  - root.hints file contains the IP address of the root servers

# IPv6 in TLDs

- (as of 28 March 2013)
- Total number of TLDs: 317
- TLDs with IPv6: 276 (87%)
- Registered domains with AAAA records: 4,809,569
  - COM: 1,686,543 of 108,698,290 domains
  - NET: 324,983 of 15,040,549 domains

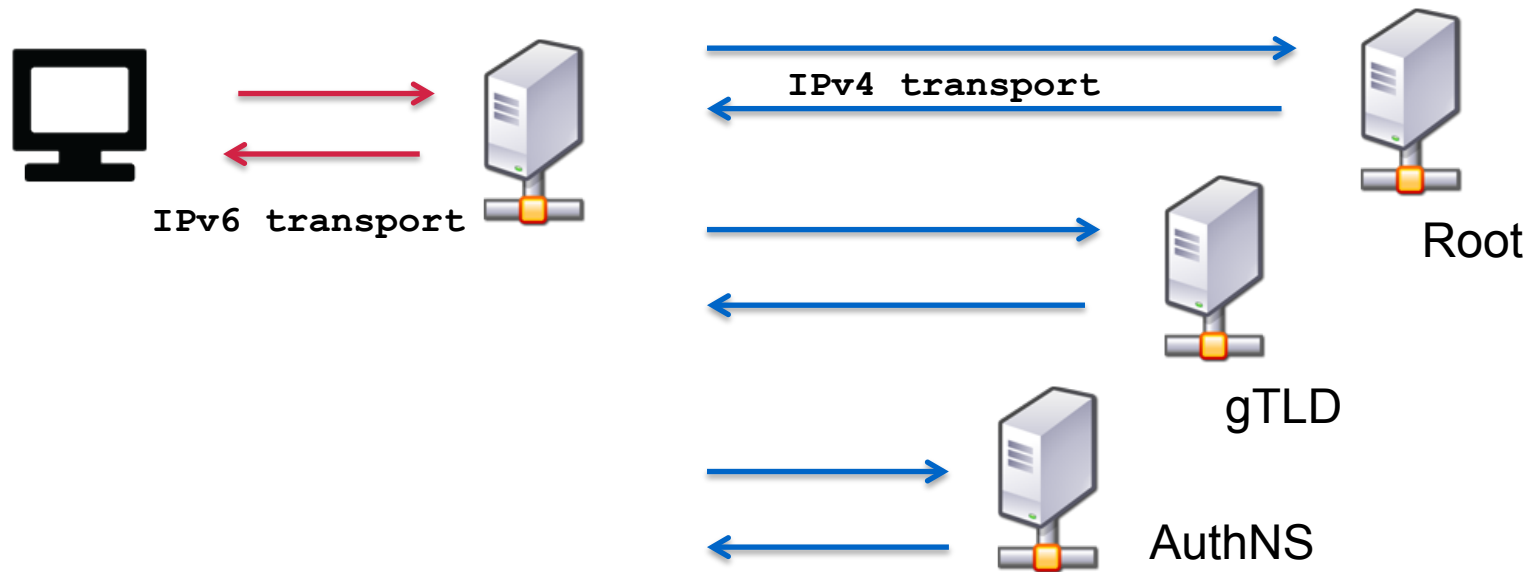
Source: Global IPv6 Deployment Progress Report  
<http://bgp.he.net/ipv6-progress-report.cgi>

# Anycast DNS Servers

- Benefits of Anycast DNS
  - Increased reliability
  - Load balancing
  - Improved performance
  - Enhanced security
  - Localized impact of DoS attacks
  - Simplified client configuration
  - Increased availability

# DNS Infrastructure

- All DNS servers must be dual-stack because not all DNS Infrastructure supports IPv6 yet



# Using BIND with IPv6

- BIND options for IPv6

- Listen-on-v6 { };
- Query-source-v6 { };
- Use-v6-udp-ports or avoid-v6-udp-ports
- Transfer-source-v6

- AAAA records

- PTR records

- In named.conf

```
Zone "1.0.0.0.8.b.d.0.1.0.0.2.ip6.arpa" {  
    Type master;  
    File "ipv6ptr.zone";  
};
```

- In zone file

```
4.3.2.1.0.0.0.1.0.0.0.0. IN PTR www.example.com
```

# Forward and Reverse DNS

- Populating the DNS is an often omitted piece of an ISP operation
  - Unfortunately it is extremely vital, both for connectivity and for troubleshooting purposes
- Forward DNS for IPv6
  - Simply a case of including suitable AAAA records alongside the corresponding A records of a host
- Reverse DNS for IPv6
  - Requires getting the /32 address block delegated from the RIR, and then populating the ip6.arpa fields

# Forward DNS

- Operators typically access the router by connecting to loopback interface address
- Setting up the IPv6 entries means adding a quad-A record beside each A record:

r1.pop1	A	192.168.1.1
	AAAA	2001:db8::1:1
r2.pop1	A	192.168.1.2
	AAAA	2001:db8::1:2
gw1.pop1	A	192.168.1.3
	AAAA	2001:db8::1:10



# Forward DNS

- Completing the infrastructure zone file as per the example is sufficient
  - Update the SOA record
  - Reload the nameserver software
  - All set
- If connecting from an IPv6 enabled client
  - IPv6 transport will be chosen before the IPv4 transport
  - For all connections to IPv6 enabled devices which have entries in the forward DNS zones

# Reverse DNS

- First step is to have the /32 address block delegated by the RIR
- Prepare the local nameservers to handle the reverse zone, for example in BIND:

```
zone "8.b.d.0.1.0.0.2.ip6.arpa" in {  
    type master;  
    file "ip6.arpa-zones/db.2001.0db8;  
    allow-transfer {"External"; "NOC-NET";};  
};
```

- And then “create and populate the zone file”

# Reverse DNS

- The db.2001.0db8 zone file heading:

```
$TTL 86400
```

```
@      IN      SOA      ns1.isp.net. hostmaster.isp.net. (  
                                2008111000      ;serial  
                                43200           ;refresh  
                                3600            ;retry  
                                608400          ;expire  
                                7200)           ;minimum
```

```
                NS      ns1.isp.net.
```

```
                NS      ns2.isp.net.
```

```
;Hosts are list below here
```

**APNIC**

-

# APNIC

-

# Creating the reverse zone file

- Reverse zone for the /32 could read like:

```
; header as previously
;
; Infrastructure /48
0.0.0.0    NS      ns1.isp.net.
0.0.0.0    NS      ns2.isp.net.
; Customer PtP link /48
1.0.0.0    NS      ns1.isp.net.
1.0.0.0    NS      ns2.isp.net.
; Customer One /48
2.0.0.0    NS      ns1.isp.net.
2.0.0.0    NS      ns2.isp.net.
; etc - fill in as we grow
f.f.f.f    NS      ns1.isp.net.
f.f.f.f    NS      ns2.isp.net.
```

# Infrastructure reverse zone

- And now we have a /48 reverse zone delegated for infrastructure
  - How do we populate this file?? Entries could still be like this:

```
1.0.0.0.1.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0 PTR      cr1.pop1.isp.net.
```

- Suggestion 1:
  - Delegate loopbacks to their own /64
  - Keeps the loopback zone file separate, and perhaps easier to manage
- Suggestion 2:
  - Make use of the \$ORIGIN directive

# APNIC





# Example Loopback Reverse Zone

```
; PoP1
;
$ORIGIN 0.0.1.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.8.b.d.0.1.0.0.2.ip6.arpa.
1.0 PTR cr1.pop1.isp.net.
2.0 PTR cr2.pop1.isp.net.
3.0 PTR br1.pop1.isp.net.
4.0 PTR br2.pop1.isp.net.
0.1 PTR gw1.pop1.isp.net.
1.1 PTR gw2.pop1.isp.net.
2.1 PTR gw3.pop1.isp.net.
3.1 PTR gw4.pop1.isp.net.
; etc
```

- Note again the use of \$ORIGIN and how it keeps the actual lines with the PTR value **simple** for each loopback interface in the PoP

# IPv6 DNS

- Previous examples show how to build forward and reverse DNS zone files
  - Forward is easy
  - Reverse can be troublesome unless care is applied and there is a good strategy in place
- There may well be tools out there which help build reverse DNS zone files from IPv6 address databases
  - Long term that will be a better approach!

# Dual Stack DNS Conf

- Both Master & Slave
  - DNS software bind-9.7.3.tar.gz [source <ftp.isc.org/isc/bind9/9.7.3>]
  - BIND root directory [/var/named/chroot] conf file path: /etc/sysconfig/named
  - [named.conf] file path: /var/named/chroot/etc/
  - Zone file path for master zone: /var/named/chroot/var/named/master/
  - Zone file path for slave zone: /var/named/chroot/var/named/slave/
  - Binary executable path: /usr/sbin/
  - Doc file path: /usr/share/doc/bind-9.7\*

# Dual Stack DNS Conf

- #vi named.conf

options

{

directory "/var/named";

dump-file "data/cache\_dump.db";

statistics-file "data/named\_stats.txt";

memstatistics-file "data/named\_mem\_stats.txt";

listen-on-v6 { any; };

};

acl "slave-server-list" {

203.176.189.29; 2001:0df0:a:100::1e;

};

# Dual Stack DNS Conf

- Split DNS configuration:
  - 3 view need to configure
    - View "localhost\_resolver"
    - view "internal"
    - view "external"

# Dual Stack DNS Conf

- View "localhost\_resolver"  
view "localhost\_resolver"

```
{  
match-clients      { localhost; };  
match-destinations { localhost; };  
recursion yes;  
include "/etc/named.root.hints";  
include "/etc/named.rfc1912.zones";  
};
```

- \* rfc1912zones i.e. localhost, localdomain, 0.0.127 in-addr.arpa, ::1 ip6.arpa, 255.in-addr.arpa, 0.in-addr.arpa \*

# Dual Stack DNS Conf

- view "internal"

```
view "internal"
```

```
{
```

```
match-clients      { localnets; };
```

```
match-destinations { localnets; };
```

```
recursion yes;
```

```
include "/etc/named.root.hints";
```

# Dual Stack DNS Conf

- view "internal"

```
zone "romlab.net" {  
    type master;  
    file "master/romlab.net.db";  
    allow-update      { none; };  
    allow-transfer { slave-server-list; };  
};
```



# Dual Stack DNS Conf

- view "internal"

```
zone "189.176.203.in-addr.arpa" {  
    type master;  
    file "master/189.176.203.in-addr.arpa.db";  
    allow-update      { none; };  
    allow-transfer { slave-server-list; };  
};
```

# Dual Stack DNS Conf

- view "internal"

```
zone " a.0.0.0.0.f.d.0.1.0.0.2.ip6.arpa" {  
    type master;  
    file " master/a.0.0.0.0.f.d.0.1.0.0.2.ip6.arpa.db";  
    allow-update      { none; };  
    allow-transfer { slave-server-list; };  
};  
  
};
```

# Dual Stack DNS Conf

- view "external"

view "external"

{

match-clients { any; };

match-destinations { any; };

recursion no;

allow-query-cache { none; };

# Dual Stack DNS Conf

- view "external"

```
zone "romlab.net" {  
    type master;  
    file "master/romlab.net.db";  
    allow-update      { none; };  
    allow-transfer { slave-server-list; };  
};
```

# Dual Stack DNS Conf

- view "external"

```
zone "189.176.203.in-addr.arpa" {  
    type master;  
    file "master/189.176.203.in-addr.arpa.db";  
    allow-update      { none; };  
    allow-transfer { slave-server-list; };  
};
```

# Dual Stack DNS Conf

- view "external"

```
zone " a.0.0.0.0.f.d.0.1.0.0.2.ip6.arpa" {  
type master;  
file " master/a.0.0.0.0.f.d.0.1.0.0.2.ip6.arpa.db";  
allow-update      { none; };  
allow-transfer { slave-server-list; };  
};  
};
```

# Dual Stack DNS Conf

- Zone file "ipv6.arpa"

\$TTL 86400

@ IN SOA ns1.romlab.net. root.romlab.net. (

2011032801 ; serial

3H ; refresh

15M ; retry

1W ; expiry

1D ) ; minimum

IN NS ns1.romlab.net.

IN NS ns2.romlab.net.

f.1.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.1.0

IN PTR ns1.romlab.net.

e.1.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.1.0

IN PTR ns2.romlab.net.

# Configuring DHCPv6 on Linux

- Server Configuration [dhcp6s]
  - First need install DHCPv6 RPM on the server
    - `# yum -y install dhcpv6`
  - Enable IPv6 networking and IPv6 forwarding
    - `# vi /etc/sysconfig/network`  
NETWORKING\_IPV6=yes  
IPV6FORWARDING=yes



# Configuring DHCPv6 on Linux

- Configure IPv6 on interface
  - # vi /etc/sysconfig/network-scripts/ifcfg-eth0  
IPV6INIT=yes  
IPV6ADDR=" 2406:6400:a000::1/64"
- Specify interface for DHCP server
  - # vi /etc/sysconfig/dhcp6s  
DHCP6SIF=eth0  
DHCP6SARGS=

# Configuring DHCPv6 on Linux

- Edit the DHCPv6 server configuration file as follows:

```
# cp /usr/share/doc/dhcpv6-*/dhcp6s.conf /etc/
```

- # vi /etc/dhcp6s.conf

```
interface eth0 {  
    server-preference 255;  
    renew-time 60;  
    rebind-time 90;
```

# Configuring DHCPv6 on Linux

```
option dns_servers 2406:6400:800::2 example.com;
link AAA {
    pool{
        range 2406:6400:800::20 to 2406:6400:800::40/64;
        prefix 2406:6400:800::/64;
    };
};
};
```

Start DHCPv6 server daemon:

```
# service network restart && service dhcp6s start && chkconfig dhcp6s on
```

# Unix Webserver

- Apache 2.x supports IPv6 by default
- Simply edit the **httpd.conf** file
  - HTTPD listens on all IPv4 interfaces on port 80 by default
  - For IPv6 add:

```
Listen [2001:db8:10::1]:80
```

    - So that the webserver will listen to requests coming on the interface configured with 2001:db8:10::1/64

# Unix Sendmail

- Sendmail 8 as part of a distribution is usually built with IPv6 enabled
  - But the configuration file needs to be modified
- Then edit `/etc/mail/sendmail.mc` thus:
  - Remove the line which is for IPv4 only and enable the IPv6 line thus (to support both IPv4 and IPv6):
    - `DAEMON_OPTIONS( 'Name=IPv4, Family=inet' Addr=203.176.189.2' )dnl`
    - `DAEMON_OPTIONS( 'Name=IPv6, Family=inet6, Addr=3ffe:b00:1:1::1' )dnl`
  - configuration files such as mailertable, access, and relay-domains
    - `IPV6:3ffe:b00:1:1::1`
  - Remake `sendmail.cf`, then restart sendmail

# FTP Server

- Vsftpd is discussed here
  - Standard part of many Linux distributions now
- IPv6 is supported, but not enable by default
  - Need to run two vsftpd servers, one for IPv4, the other for IPv6
- IPv4 configuration file: /etc/vsftpd/vsftpd.conf

```
listen=YES
listen_address=<ipv4 addr>
```
- IPv6 configuration file: /etc/vsftpd/vsftpdv6.conf

```
listen=NO
listen_ipv6=YES
listen_address6=<ipv6 addr>
```

# IPv6@APNIC



Your IP address:  
203.119.42.199

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## Community

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- Policy development
- Participate
- Working with the community
- About the Internet community
- IPv6@APNIC**
  - Key IPv6 messages
  - IPv6 data and statistics
  - IPv6 Transition Stories
  - IPv6 Best Current Practices
- IPv4 exhaustion

## IPv6@APNIC



IPv6 is a top issue for the Asia Pacific Internet community. APNIC engages in activities throughout the region to help facilitate a smooth transition. The greater goal is to support the Asia Pacific in deploying IPv6 to maintain a scalable Internet for everyone.

APNIC reached the last /8 of IPv4 addresses in April 2011, and now delegates IPv4 resources according to the "last /8 policy". The scarcity of IPv4 makes IPv6 deployment critical for all networks and organizations in the Asia Pacific. Here's what APNIC is doing to support the community in achieving real and tangible IPv6 deployment:



### Distributing IPv6 addresses

Getting an IPv6 block is the first step in your transition, and the process is very simple.

[Kickstart IPv6 - one click to IPv6](#)



### IPv6 training and education

Is your technical staff ready to deploy IPv6? Gaining technical knowledge does not happen overnight. Plan and implement training for your personnel. APNIC Training is constantly updating our IPv6 content, to reflect the industry's best current practices.

[Upcoming training events](#)

## Related links

[IPv6 news feed](#)

## IPv6 Info

Curated by APNIC



MicroNugget: 3 Basic Tasks For Building an IPv6 Network

[Scoop.it](#)

## IPv4 Exhaustion Counter

▼ Present Status (RIR)

RIR	X-day and Reserved Blocks (Remaining /8)	Date	Value
AfrNIC		Jan 22, 2021	3.03
APNIC		Apr 15, 2011	0.89
ARIN		Jun 13, 2014	5.52
LACNIC		Oct 01, 2014	2.37
RIPE NCC		Sep 14, 2012	1.02

# Wrapping up...

- Readings
  - Enterprise IPv6 Deployment Guidelines
  - <http://tools.ietf.org/html/draft-ietf-v6ops-enterprise-incremental-ipv6-02>
  - IPv6 Guidance for Internet Content Providers and Application Service Providers
  - <http://tools.ietf.org/html/rfc6883>



# APNIC Helpdesk Chat



Your IP address:  
2001:dc0:a000:4:595f:4f90:654f:402c

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## Services

Services APNIC provides

- > Registration services
- > Informing the community
- > Routing Registry
- > Resource certification
- > Training & education
- > Policy development
- ▼ Helpdesk
  - Using VoIP

- ▶ Apply for resources
- ▶ Become a Member
- ▶ Make a payment
- ▶ Manage Internet resources
- ▶ Helpdesk

## Helpdesk

Monday - Friday  
09:00 to 21:00 (UTC +10)

 **Email**  
[helpdesk@apnic.net](mailto:helpdesk@apnic.net)

 **Phone**  
+61 7 3858 3188

 **VoIP**  
[helpdesk@voip.apnic.net](mailto:helpdesk@voip.apnic.net)

 **Fax**  
+ 61 7 3858 3199

**Multi-language phone support**  
Bahasa Indonesia, Bengali, Cantonese, English, Filipino (Tagalog), Hindi, and Mandarin.

 **APNIC Live Chat Online**  
[Click here to chat](#)

## Frequently asked questions

Request Live! Support

[livehelp.apnic.net/request.php?l=apnplive&x=1&deptid=1&pa...](http://livehelp.apnic.net/request.php?l=apnplive&x=1&deptid=1&pa...)

## APNIC Helpdesk Chat

Welcome to our Live Chat.

Name

Email

What is your question?

Powered by PHP Live! v3.3 © OSI Codes Inc.

- ▶ A-Z Glossary
- ▶ Contact APNIC

## Helpdesk queries

**APNIC's Member Services**  
Helpdesk can assist you receive faster responses for:

- Status of requests
- Membership enquiries
- Billing issues
- Database enquiries

**Existing members**  
Please use [MyAPNIC](#) to apply for resources.

## Public holidays

**APNIC offices and Helpdesk**  
are closed for the following

# Questions?

Thank You