

IPv6 Design and Deployment Workshop

NPIX and ISOC Nepal Chapter

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APNIC



Introduction

- Presenters

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Supported by:

Overview

IPv6 Deployment Workshop [Module One]

- Introduction to IPv6
- IPv6 Protocol Architecture
- IPv6 Security Features
- IPv6 Addressing and Sub-netting
- IPv6 Host Configuration

Overview

IPv6 Deployment Workshop [Module Two]

- IPv6 Deployment IP address Plan- Case Study
- IPv6 Deployment in IGP- Case Study
- IPv4 to IPv6 Transition Technologies

Overview

IPv6 Deployment Workshop [Module Three]

- IPv6 Deployment in EGP- Case Study
- Basic Internet Service Delivery using IPv6 Transport

Overview

IPv6 Deployment Workshop [Module One]

- Introduction to IPv6
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IPv6 Deployment Workshop

- **Introduction to IPv6**
- IPv6 Protocol Architecture
- IPv6 Security Features
- IPv6 Addressing and Sub-netting
- IPv6 Host Configuration

What Is IPv6?

- IP stands for **I**nternet **P**rotocol 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

- During the late 1980s (88-89) Internet has started to grow exponentially
- The ability to scale Internet for future demands requires a limitless supply of IP addresses and improved mobility
- In 1991 IETF decided that the current version of IP (IPv4) had outlived its design and need to develop a new protocol for Internet
- In 1994 IETF gave a clear direction of IPng or IPv6 after a long process of discussion

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]
- December 1994
 - 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

- New generation Internet need:
 - Plenty of address space (PDA, Mobile Phones, Tablet PC, Car, TV etc etc ☺)
 - Solution of very complex hierarchical addressing need, which IPv4 is unable 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

New Functional Improvement In IPv6

- 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 sizes (40 byte) and 64-bit header alignment mean better performance from routers and bridges/switches
- No hop-by-hop segmentation
 - Path MTU discovery

New Functional Improvement In IPv6

- 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

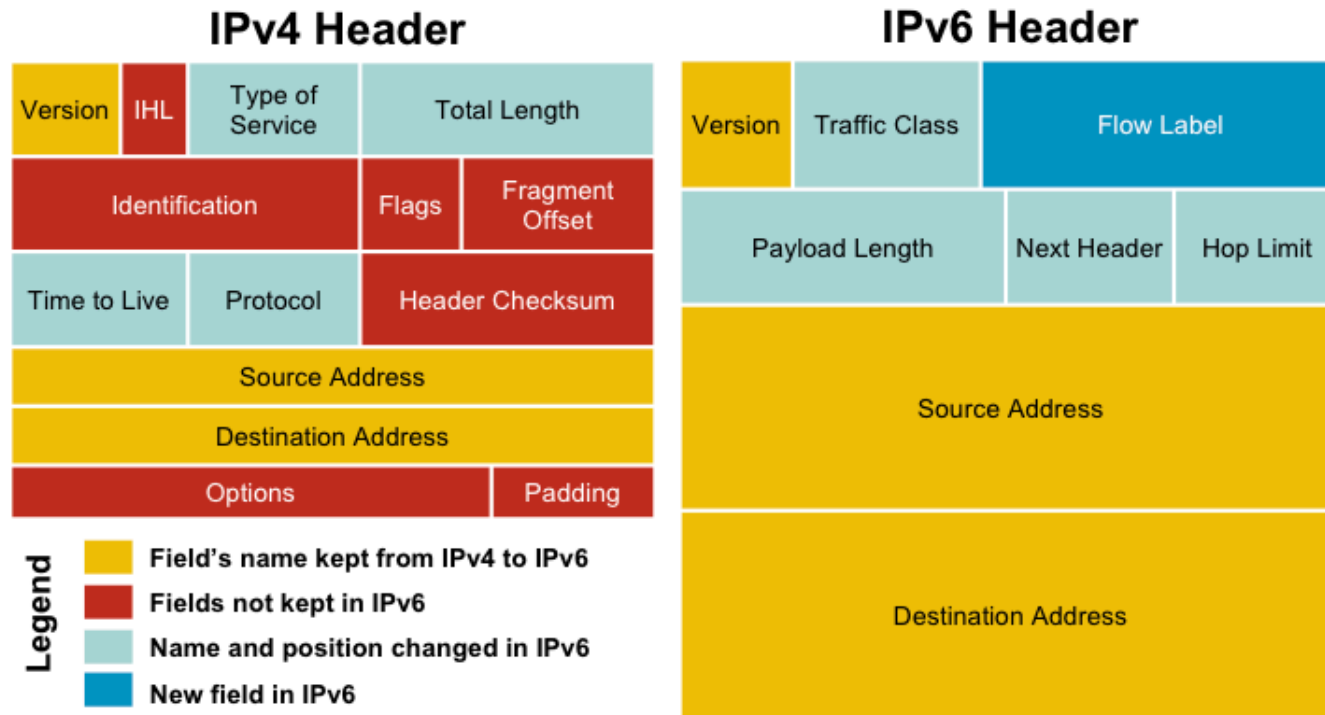
Questions?

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IPv6 Deployment Workshop

- Introduction to IPv6
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Protocol Header Comparison

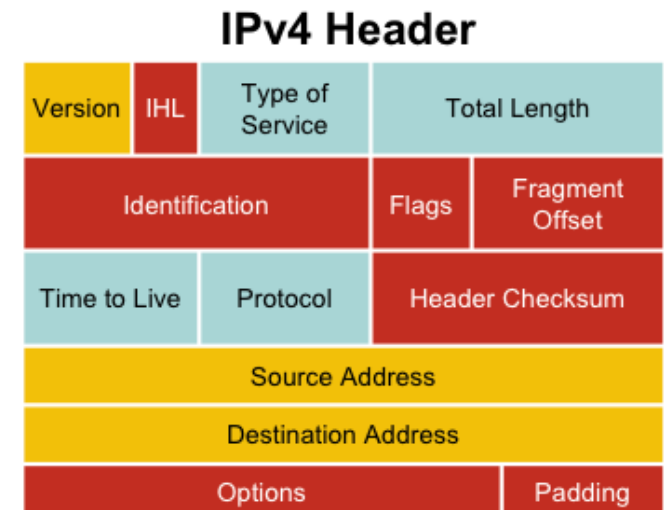
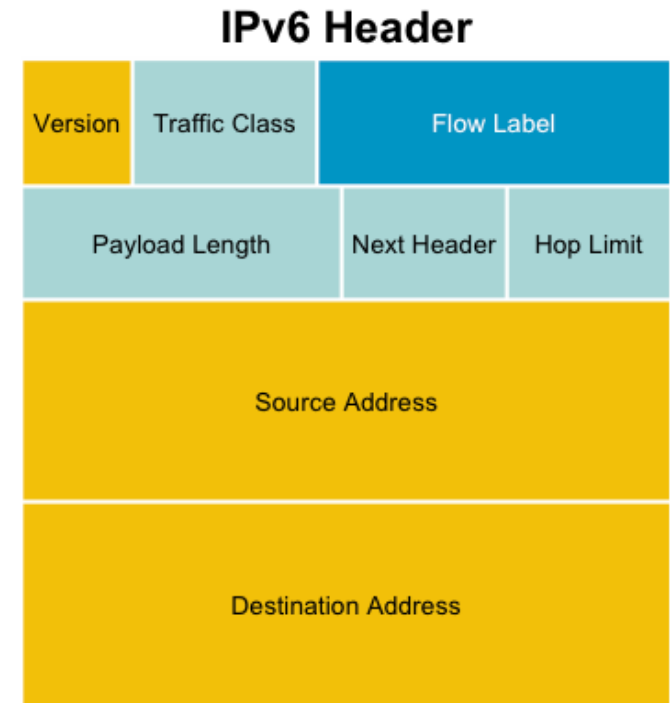


- IPv4 contain 10 basic header field
- IPv6 contain 6 basic header field
- IPv6 header has 40 octets in contrast to the 20 octets in IPv4
- So a smaller number of header fields and the header is 64-bit aligned to enable fast processing by current processors

IPv6 Protocol Header Format

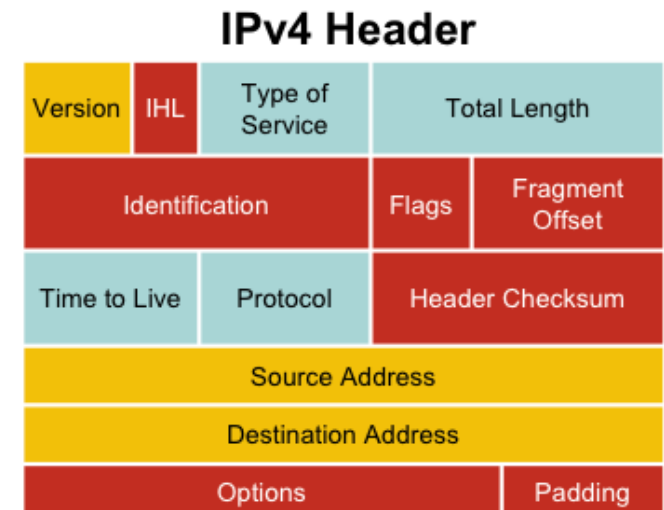
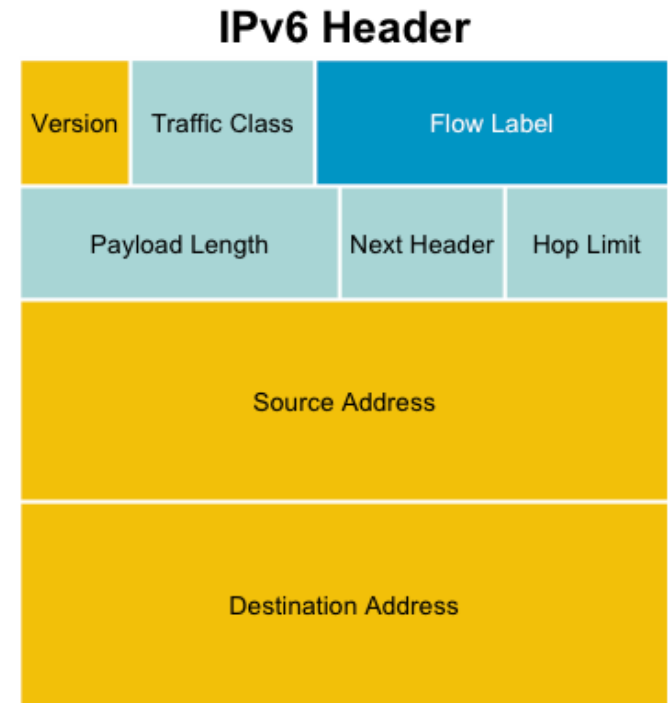
The IPv6 header fields:

- **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 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. $2^{16} = 65536$ 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 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 IPv6 packet

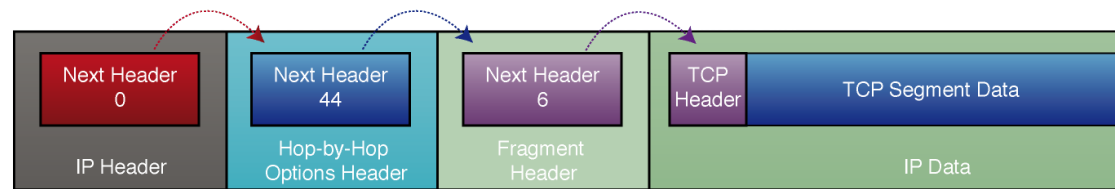
IPv6 Extension Header

- If the Next Header field value (code) is 6 it determine 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-hope 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 then 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

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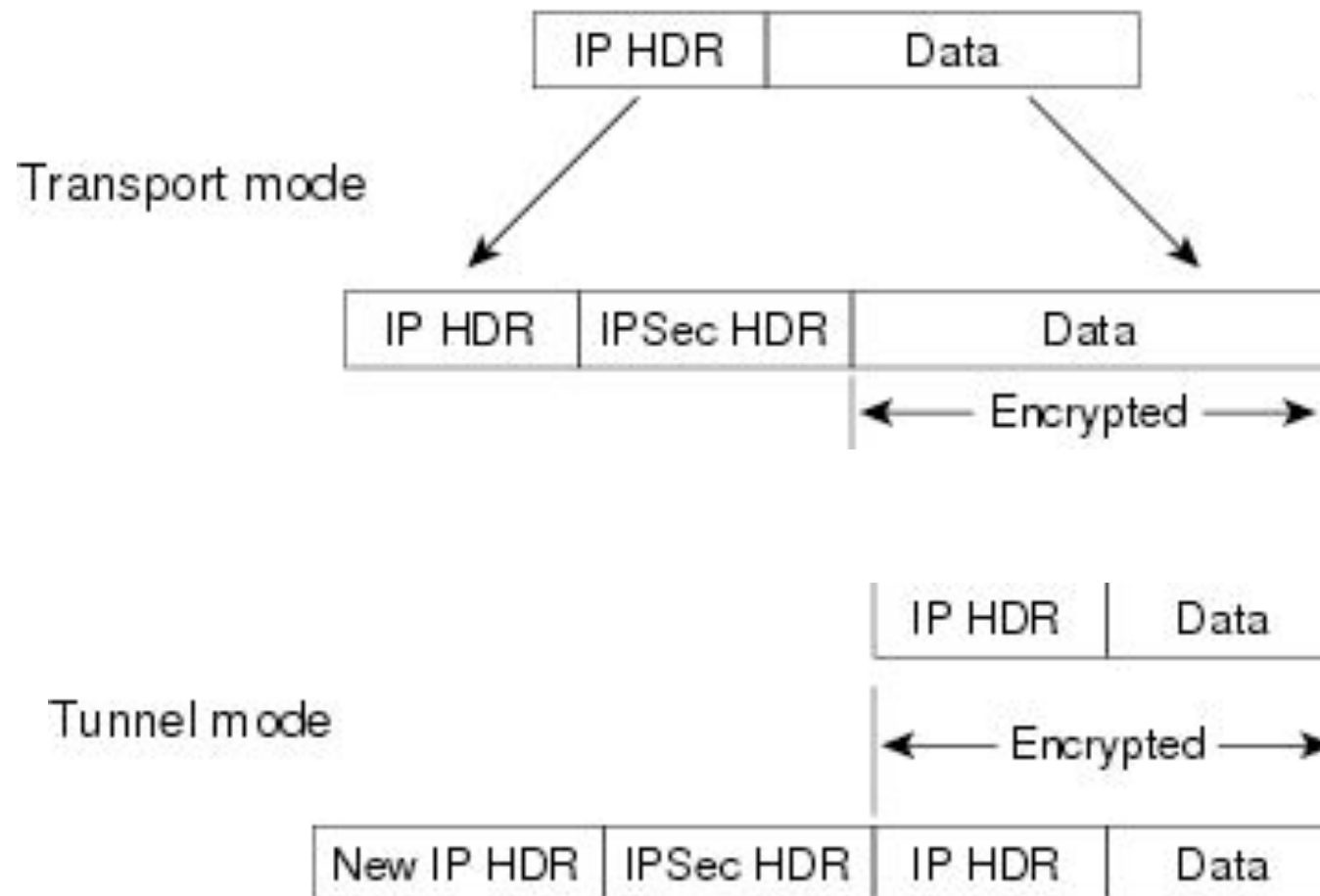
IPv6 Security Features

- 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



IPsec Pre-establish Security Association

- IPsec peer need a pre-establish security association before they start sending packets
- This involves standard key exchange and cryptographic algorithm
- Standard IKE (Internet Key Exchange) protocol is used for IPsec of IPv6

Symmetric and Asymmetric Keying

- There are two basic types of keying solutions:
 - Symmetric
 - Same key will be used to encrypt and decrypt data packet. Since same key is used for encryption and decryption its simple and faster. Key need to share out of band. Tunnel mode symmetric key
 - Asymmetric
 - Asymmetric keying use public key and private key for encryption and decryption. Key can be share in band. Transport mode use asymmetric key

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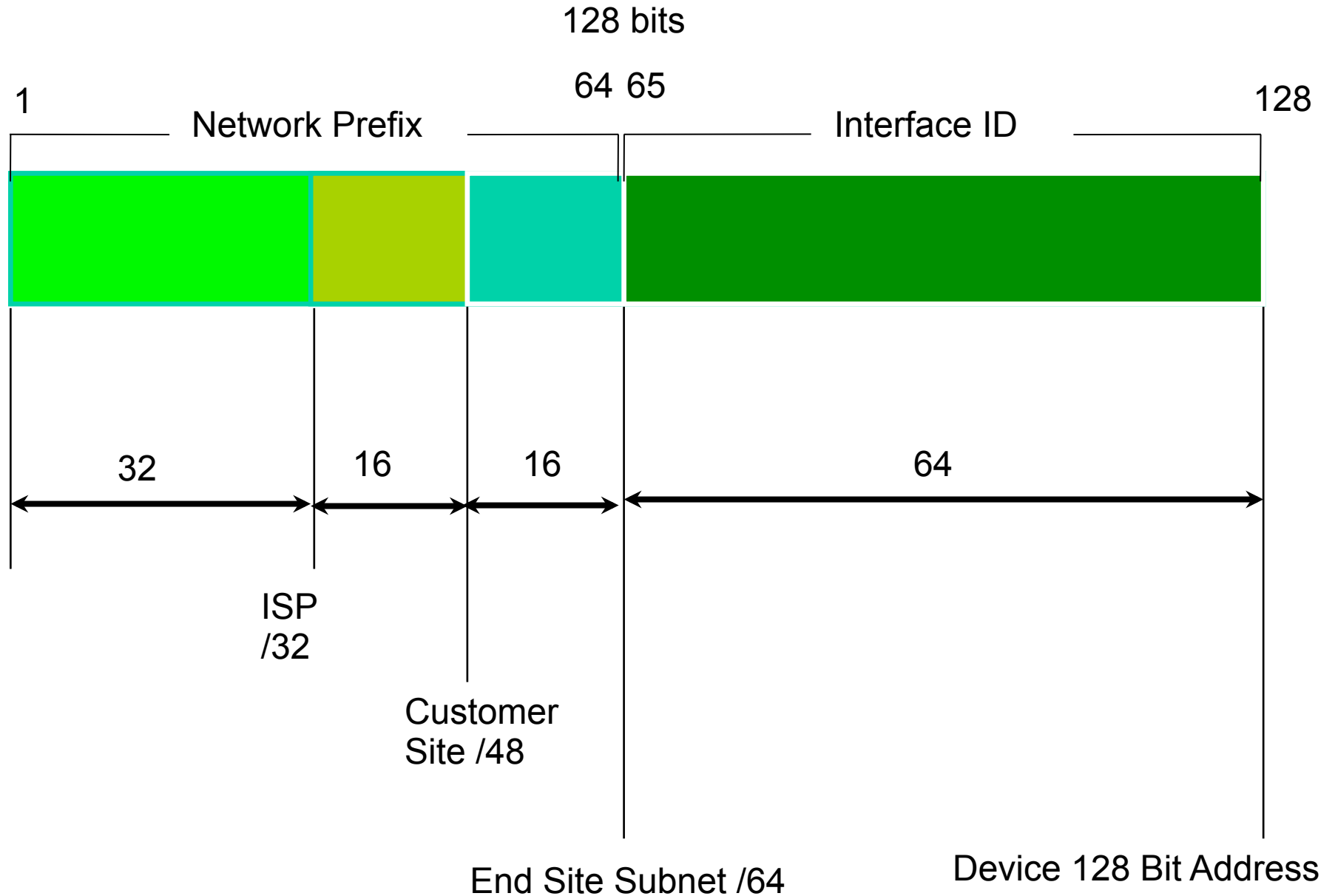
IPv6 Addressing

- An IPv6 address is 128 bits long
- So the number of addresses are 2^{128}
=340282366920938463463374607431768211455
(39 decimal digits)
=0xffffffffffffffffffffffffffffffff (32 hexadecimal digits)
- In hex 4 bit (nibble) is represented by a hex digit
- So 128 bit is reduced down to 32 hex digit

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
- Example:
 - FE38:DCE3:124C:C1A2:BA03:6735:EF1C:683D
 - Abbreviated form of address
 - 4EED:0023:0000:0000:0000:036E:1250:2B00
 - →4EED:23:0:0:0:36E:1250:2B00
 - →4EED:23::36E:1250:2B00
 - (Null value can be used only once)

IPv6 addressing structure



IPv6 addressing model

- **IPv6 Address type**



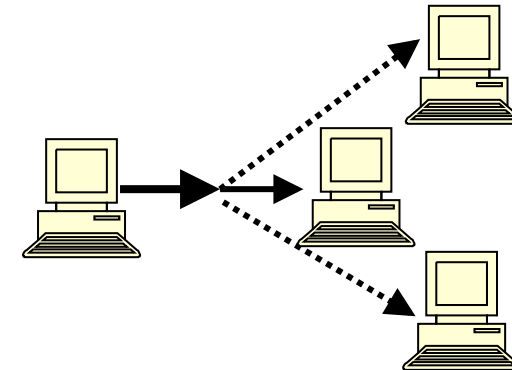
- Unicast

- An identifier for a single interface



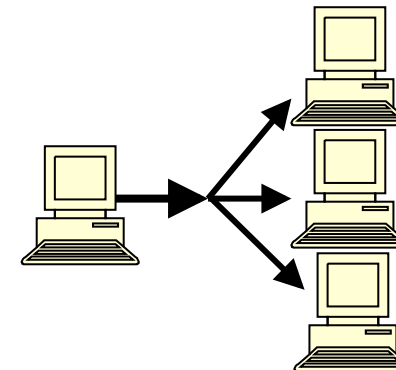
- Anycast

- An identifier for a set of interfaces



- Multicast

- An identifier for a group of nodes



Addresses Without a Network Prefix

- Localhost ::1/128
- Unspecified Address ::/128

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
 - This address in packet destination that packet would never pass through a router
 - fe80::/10

Local Addresses With Network Prefix

- Unique Local IPv6 Unicast Address
 - Addresses similar to the RFC 1918 / private address like in IPv4 but will ensure 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>

Global Addresses With Network Prefix

- IPV6 Global Unicast Address
 - Global Unicast Range: 0010 2000::/3
0011 3000::/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

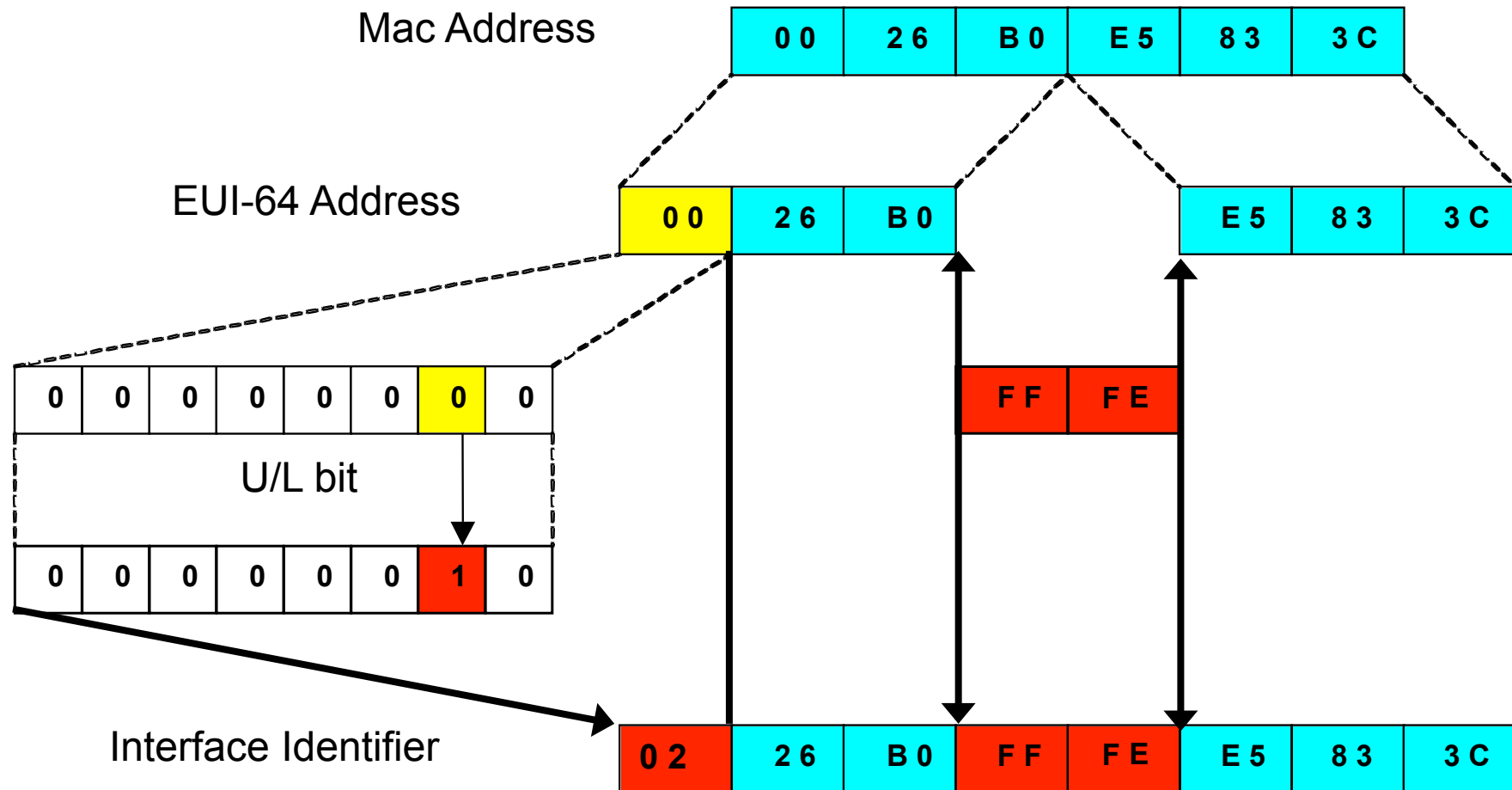
Examples and Documentation Prefix

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

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



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.

IPv6 autoconfiguration



- 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 DHCP server
 - DHCPv6

Plug and Play

- IPv6 link local address
 - Even if no servers/routers exist to assign an IP address to a device, the device can still auto-generate an IP address
 - Allows interfaces on the same link to communicate with each other
- Stateless
 - No control over information belongs to the interface with an assigned IP address
 - Possible security issues
- Stateful
 - Remember information about interfaces that are assigned IP addresses

IPv6 Neighbor Discovery (ND)

- IPv6 use 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 ICMP6 as transport
 - Compared to IPv4 ARP no need to write different ARP for different L2 protocol i.e. Ethernet etc.

IPv6 Neighbor Discovery (ND)

- 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:ff**00:0010**
- All host listen to its solicited node multicast address corresponding to its unicast and anycast address (If defined)

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 Host A will create L2 frame for Host B?

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

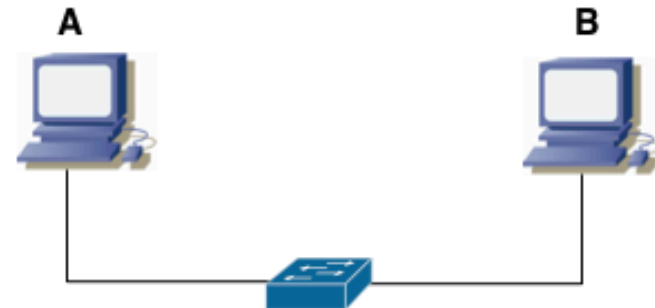
S: 2406:6400::0010 D:2406:6400::0020

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

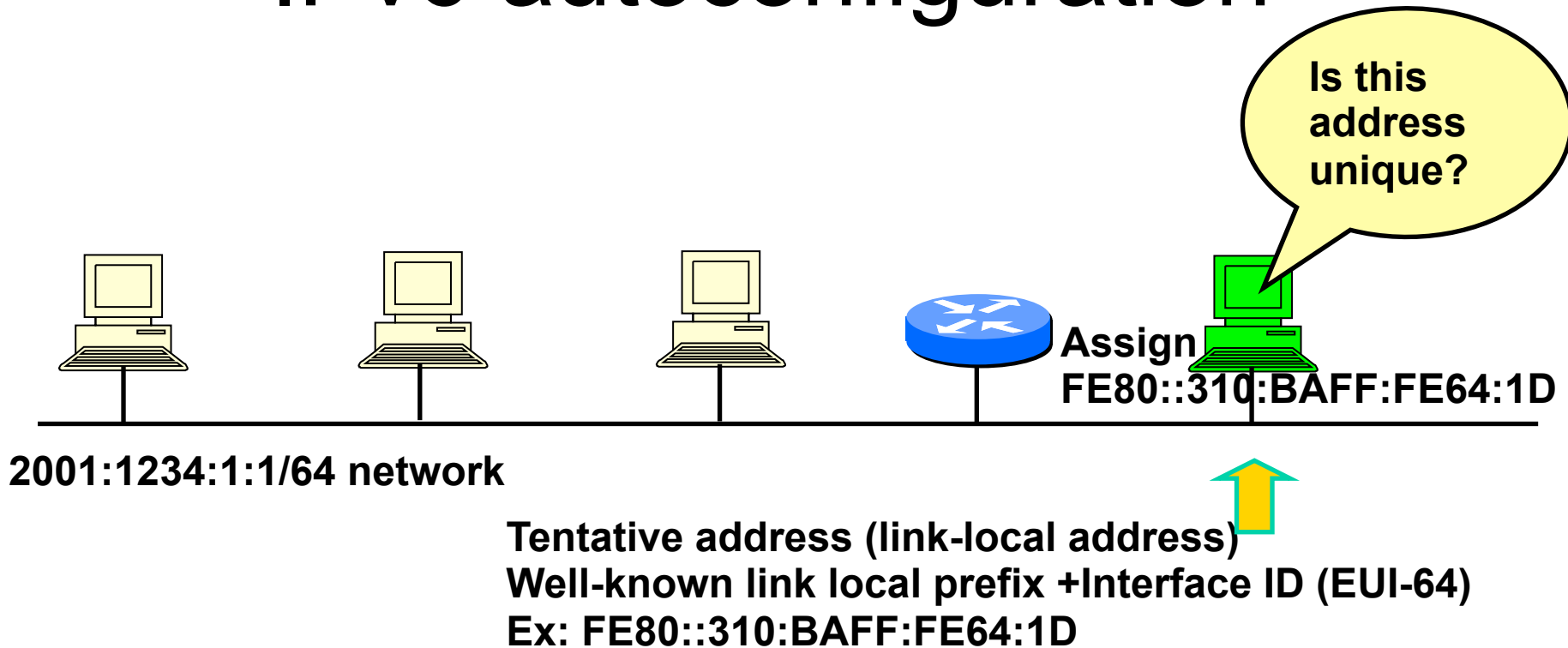
ICMP6 NA Type 136

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

Frame

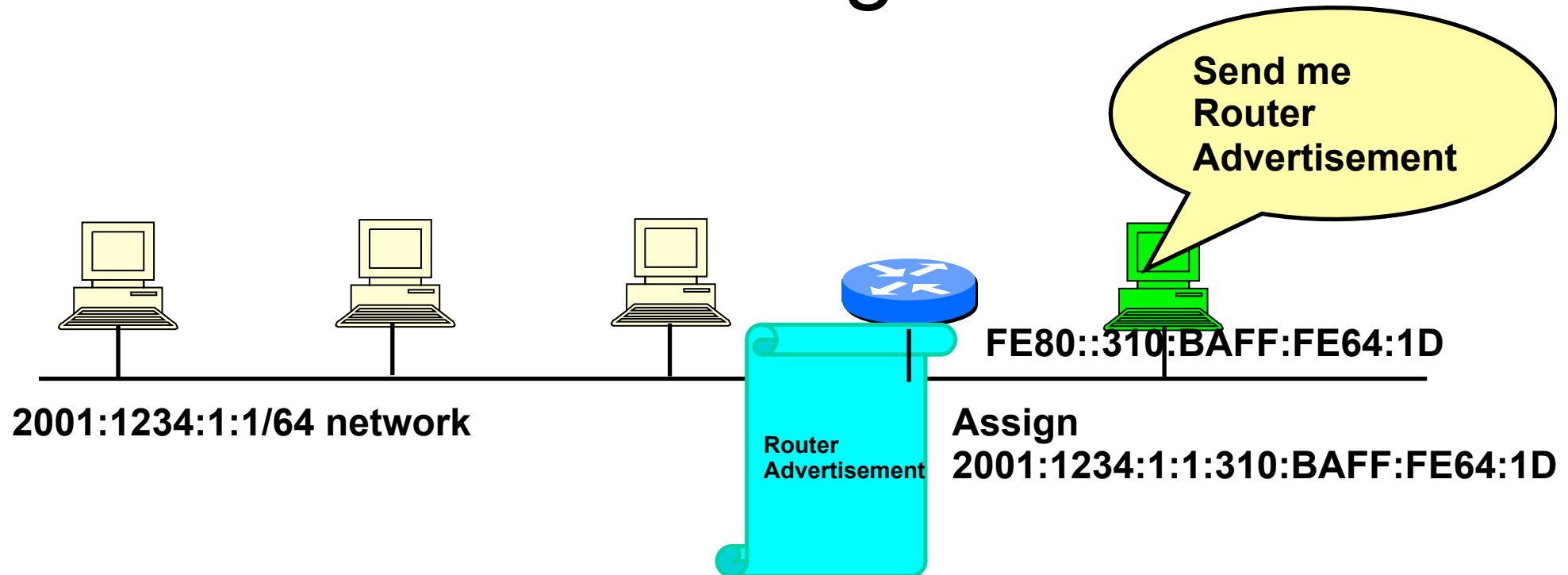
S: 00:26:bb:06:ff:82 D 00:26:bb:06:ff:81

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 the solicited node multicast address (FF02::1:FF64:001D) corresponding to its to be used address
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

Questions?

Exercise 1

IPv6 Sub-netting

Exercise 1.1: IPv6 subnetting

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

1. _____
2. _____
3. _____
4. _____

Exercise 1.2: IPv6 subnetting

1. Identify the first four /35 address blocks out of 2406:6400::/32

1. _____
2. _____
3. _____
4. _____

Questions?

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- **IPv6 Host Configuration**

Configuration of IPv6 Node Address

- There are 3 ways to configure IPv6 address on an IPv6 node:
 - Static address configuration
 - DHCPv6 assigned node address
 - Auto-configuration [New feature in IPv6]

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

Exercise 1: IPv6 Host Configuration

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

Exercise 1: IPv6 Host Configuration

- Configuring an interface
 - *netsh interface ipv6 add address “Local Area Connection” 2406:6400::1*
- Prefix length is not specified with address which will force a /64 on the interface

Exercise 1: IPv6 Host Configuration

Verify your Configuration

- `c:\>ipconfig`

Verify your neighbor table

- `c:\>netsh interface ipv6 show neighbors`
- `# ip -6 neigh show [Linux]`
- `#ndp -a [Mac OS]`

Exercise 1: IPv6 Host Configuration

- Disable privacy state variable

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

OR

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

Exercise 1: IPv6 Host Configuration

Testing your configuration

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

Note: the Zone id is YOUR interface index

Exercise 1: IPv6 Host Configuration

- 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
```


Exercise 1: IPv6 Host Configuration

- Configuring 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
```

```
Interface eth1 {  
    advSendAdvert on;  
    prefix 2406:6400::/64 {  
        AdvOnLink on; };  
    };
```

Exercise 1: IPv6 Host Configuration

- 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`

Exercise 1: IPv6 Host Configuration

- Configuring RA on FreeBSD

- Set IPv6 address forwarding on

- ```
sysctl -w net.inet6.ip6.forwarding=1
```

- Assign IPv6 address on an interface

- ```
# ifconfig en1 inet6 2001:07F9:0400:010E::1 prefixlen 64
```

- RA on an interface

- ```
rtadvd en1
```

# Exercise 1: IPv6 Host Configuration

- Configure RA on Cisco

Config t

Interface e0/1

Ipv6 nd prefix-advertisement 2406:6400::/64

# Questions?

# Overview

## IPv6 Deployment Workshop [Module Two]

- IPv6 Deployment IP address Plan- Case Study
- IPv6 Deployment in IGP- Case Study
- IPv4 to IPv6 Transition Technologies

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## IPv6 Deployment Workshop

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- IPv6 Deployment in IGP- Case Study
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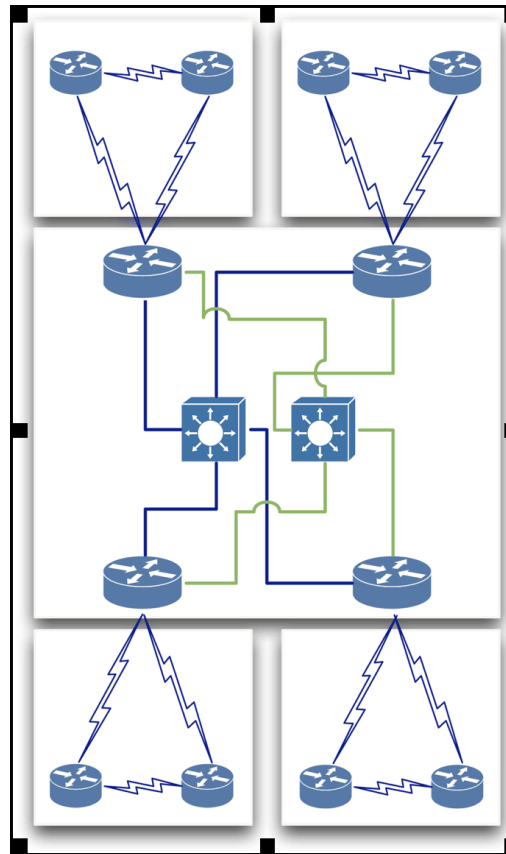
# Training ISP Network Topology

## 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:

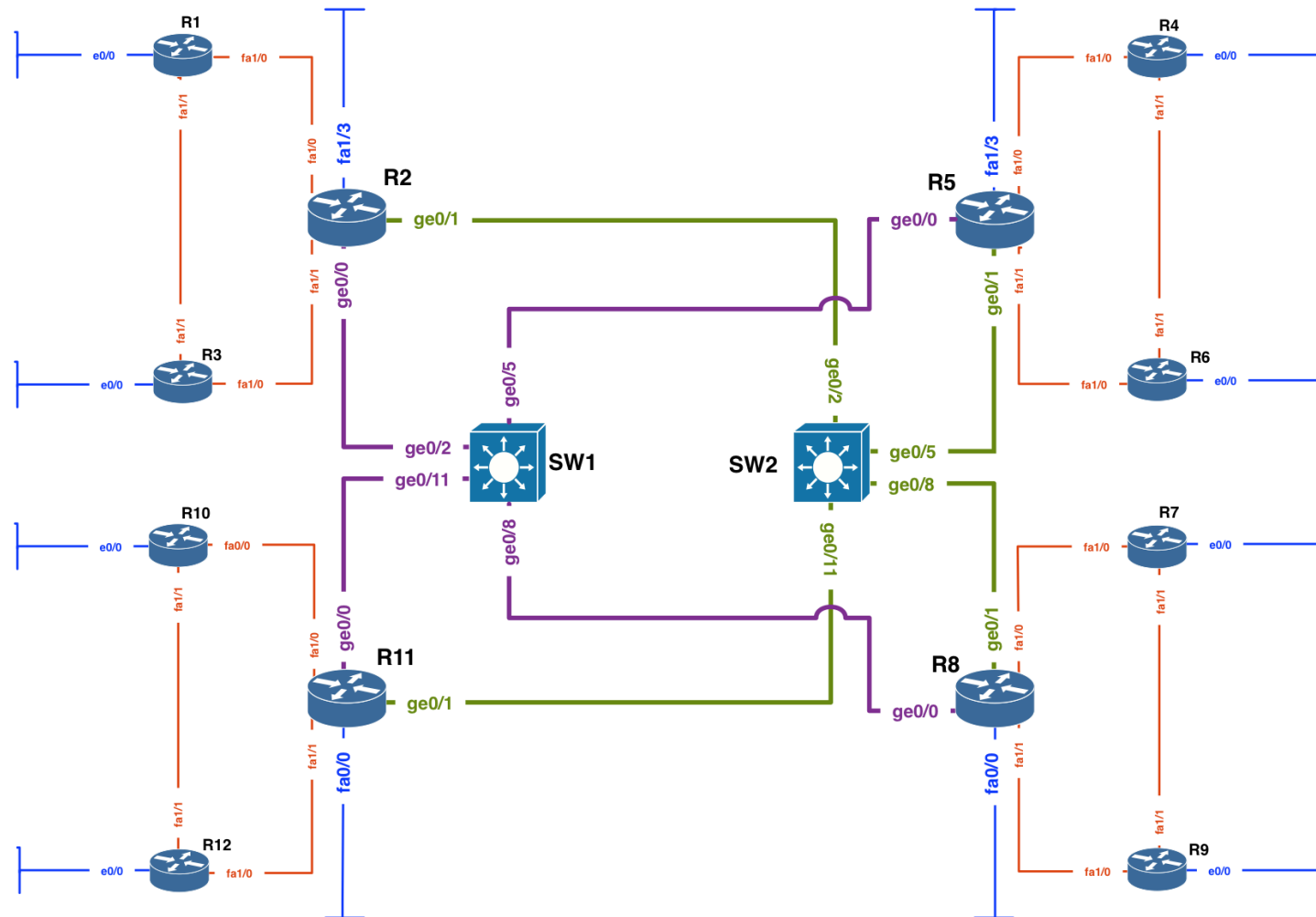
- Connection between customer network & Edge router
- Usually 10 to 100 MBPS link
- Separate routing policy from most of ISP
- Training ISP will connect them on edge router with separate customer IP prefix

# 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 career 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:

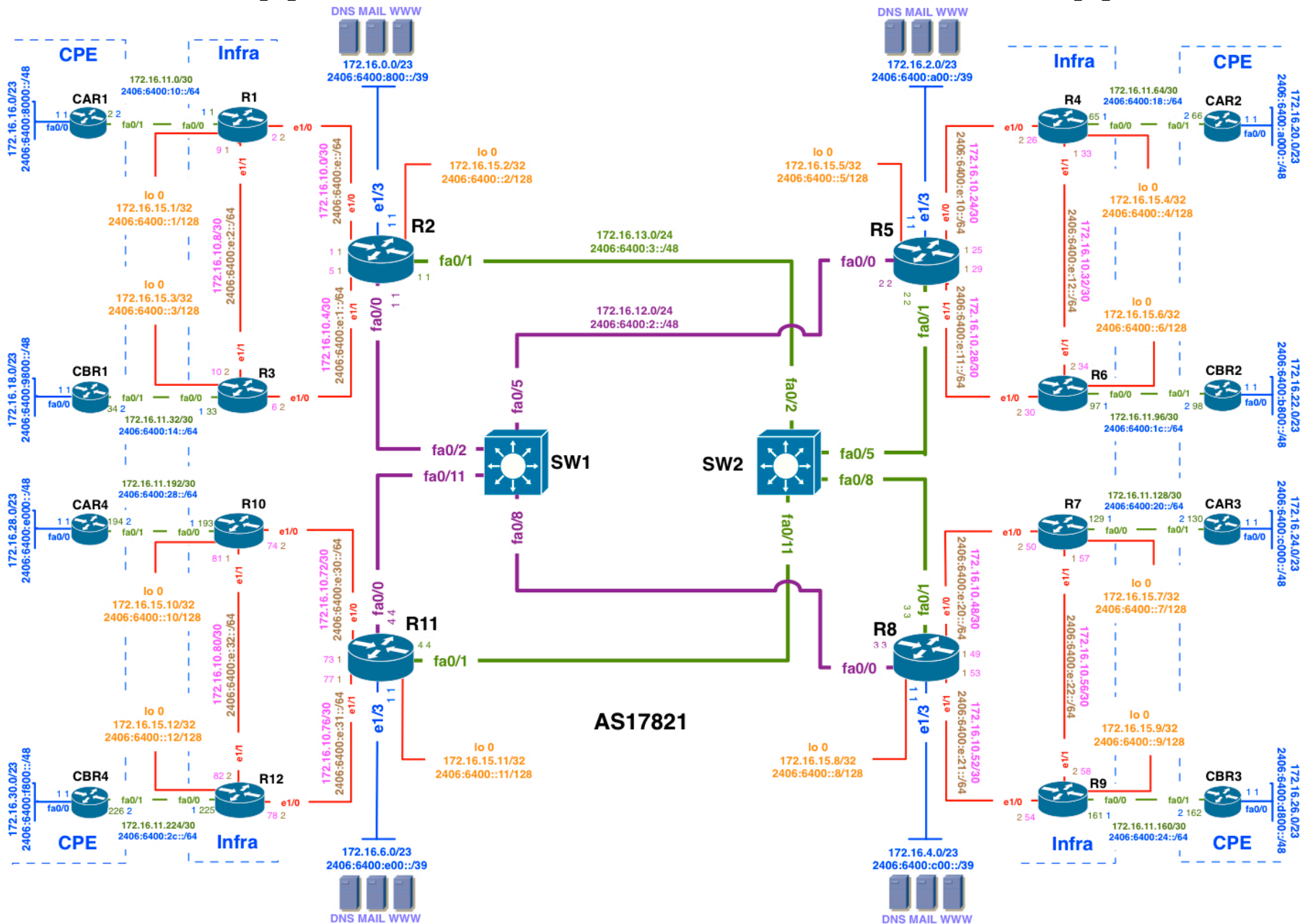
- Big IPv6 address space can cause very very large routing table size
- Most transit service provider apply IPv6 aggregation prefix filter (i.e. anything other than /48 &  $\leq$  /32 prefix size
- Prefix announcement need to send to Internet should be either /32 or /48 bit boundary

# Training ISP IPV6 Addressing Plan

IPv6 address plan consideration (RFC3177):

- 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

# Training ISP IPV6 Addressing Plan



# 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

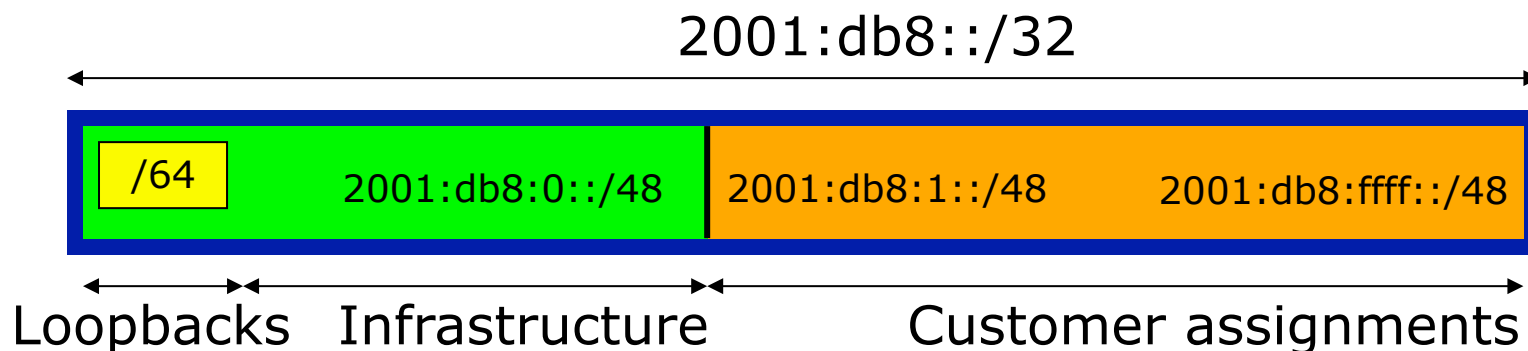
# Addressing Plans Planning

- 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

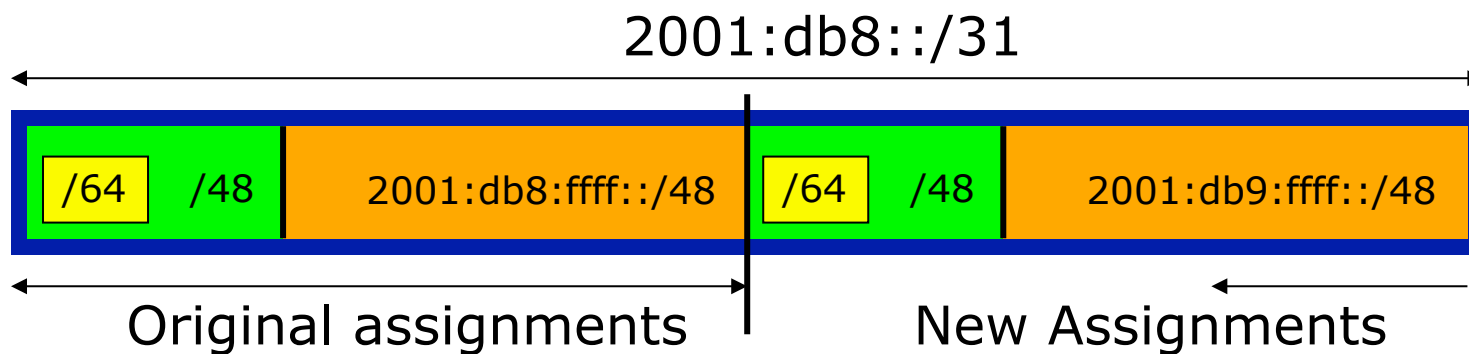


# Addressing Plans – ISP Infrastructure

## □ 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

**Table 1: Top level distribution infrastructure & customer**

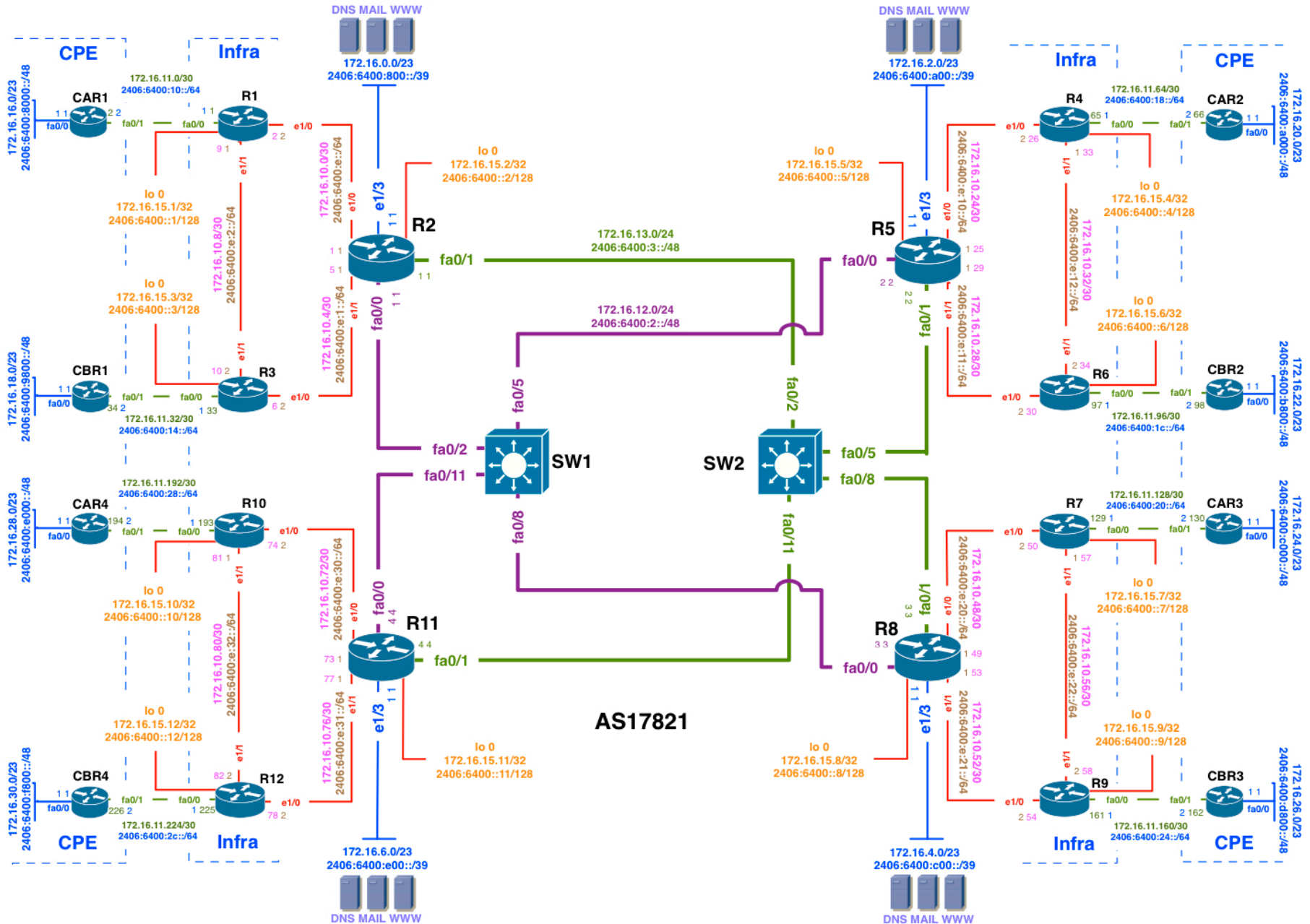
| Block# | Prefix                   | Description                | Reverse Domain              | SOR     | Registration |
|--------|--------------------------|----------------------------|-----------------------------|---------|--------------|
| 1      | <b>2406:6400::/32</b>    | <b><i>Parent Block</i></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

**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

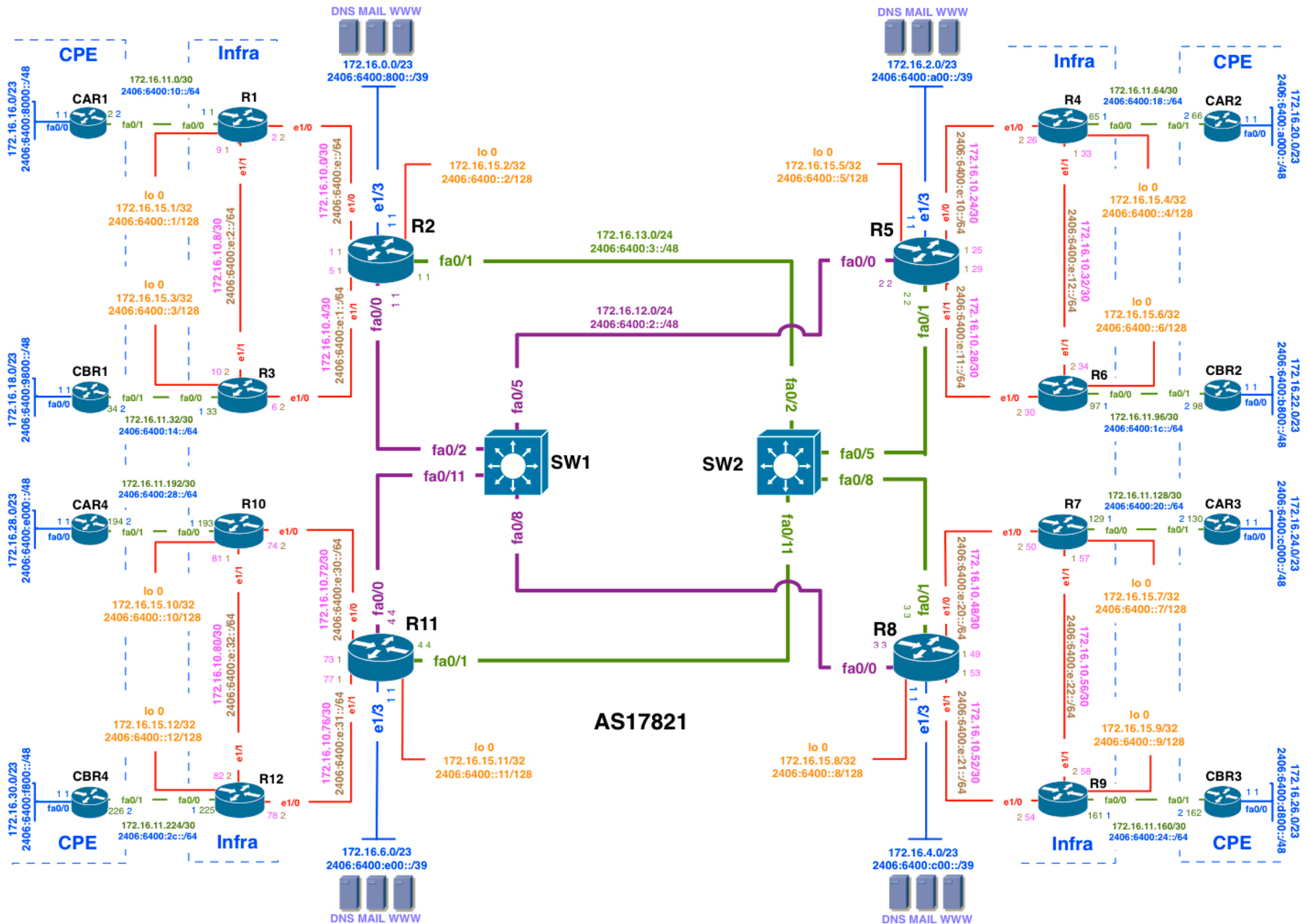
| Table 3: Detail distribution infrastructure |                                 |                                      |                               |     |              |
|---------------------------------------------|---------------------------------|--------------------------------------|-------------------------------|-----|--------------|
| 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

**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 4 DC Summary [R11] |                |

# Training ISP IPV6 Addressing Plan





# Training ISP IPV6 Addressing Plan

**Table 5: Further detail loopback, transport & infrastructure WAN**

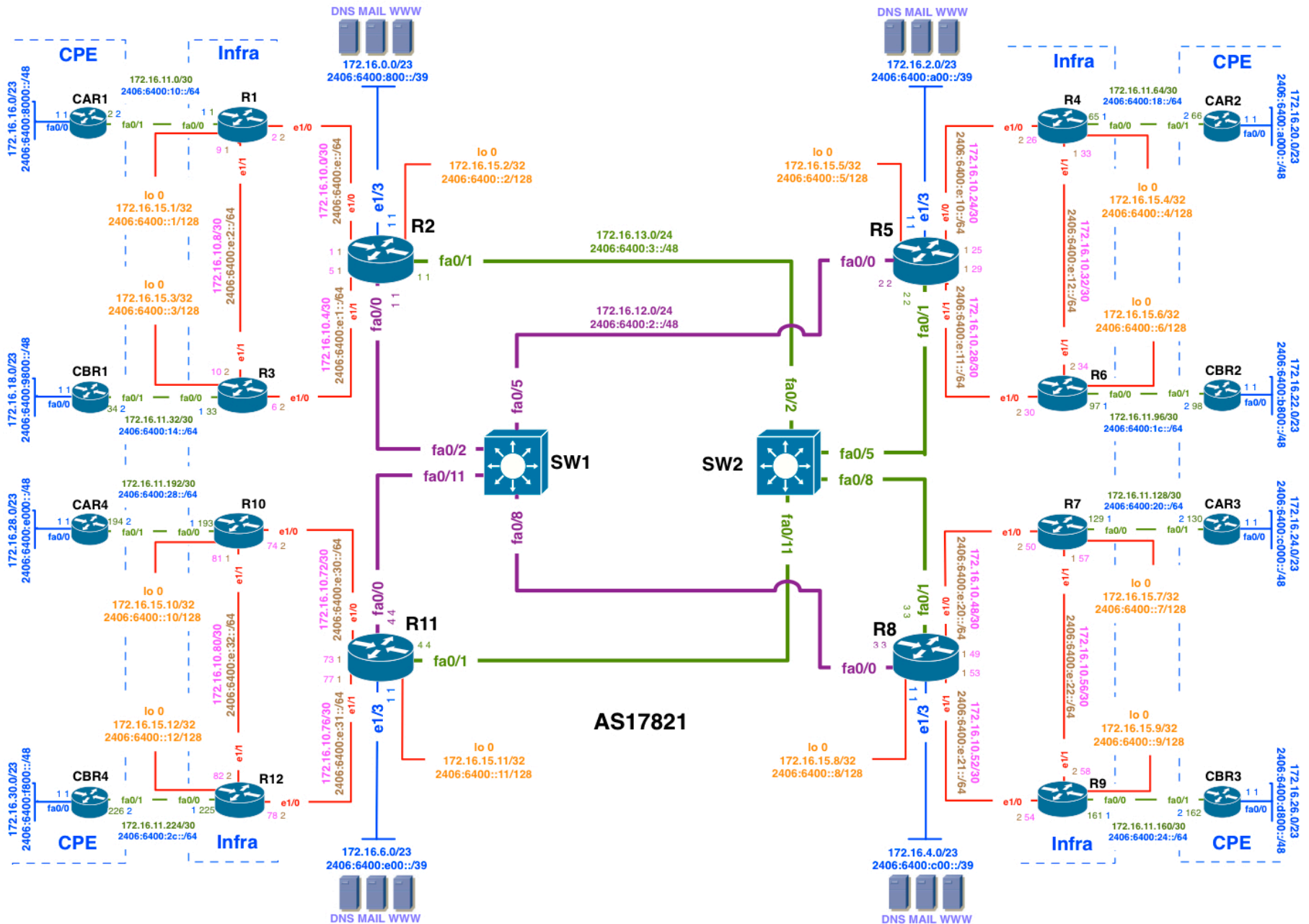
| Block#    | Prefix                          | Description                                | Reverse Domain                       | SOR | Registration |
|-----------|---------------------------------|--------------------------------------------|--------------------------------------|-----|--------------|
| <b>11</b> | <b>2406:6400:0000:0000::/40</b> | <b>Loopback, Transport &amp; Infra WAN</b> | <b>0.0.0.0.4.6.6.0.4.2.ip6.arpa.</b> |     |              |
| 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

| 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

| 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

| 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

| 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

| 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 |                       |            |     |              |
|                                    | 2406:6400:000E:0028::/64 |                       |            |     |              |
|                                    | 2406:6400:000E:0029::/64 |                       |            |     |              |
|                                    | 2406:6400:000E:002A::/64 |                       |            |     |              |
|                                    | 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 |                       |            |     |              |





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| 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           |





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| 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           |



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| 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           |

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| Table 14: Detail CS link WAN Region 4 |                          |                                |            |     |              |
|---------------------------------------|--------------------------|--------------------------------|------------|-----|--------------|
| Block#                                | Prefix                   | Description                    | PTR Record | SOR | Registration |
| 42                                    | 2406:6400:0028:0000::/48 | WAN Prefix CS Link R10 Region4 |            | No  | Recommended  |
|                                       | 2406:6400:0028:0000::/64 | R10[::1]-CAR4[::2]             | Yes        | No  | No           |
|                                       | 2406:6400:0028:0001::/64 |                                | Yes        | No  | No           |
|                                       | 2406:6400:0028:0002::/64 |                                | Yes        | No  | No           |
|                                       | 2406:6400:0028:0003::/64 |                                | Yes        | No  | No           |
|                                       | 2406:6400:0028:0004::/64 |                                | Yes        | No  | No           |
|                                       | 2406:6400:0028:0005::/64 |                                | Yes        | No  | No           |
|                                       | 2406:6400:0028:0006::/64 |                                | Yes        | No  | No           |
|                                       | 2406:6400:0028:0007::/64 |                                | Yes        | No  | No           |
|                                       | 2406:6400:0028:0008::/64 |                                | Yes        | No  | No           |
|                                       | 2406:6400:0028:0009::/64 |                                | Yes        | No  | No           |
|                                       | 2406:6400:0028:000A::/64 |                                | Yes        | No  | No           |
|                                       | 2406:6400:0028:000B::/64 |                                | Yes        | No  | No           |
|                                       | 2406:6400:0028:000C::/64 |                                | Yes        | No  | No           |
|                                       | 2406:6400:0028:000D::/64 |                                | Yes        | No  | No           |
|                                       | 2406:6400:0028:000E::/64 |                                | Yes        | No  | No           |
|                                       | 2406:6400:0028:000F::/64 |                                | Yes        | No  | No           |
| Block#                                | Prefix                   | Description                    | PTR Record | SOR | Registration |
| 43                                    | 2406:6400:002C:0000::/48 | WAN Prefix CS Link R12 Region4 |            | No  | Recommended  |
|                                       | 2406:6400:002C:0000::/64 | R12[::1]-CBR4[::2]             | Yes        | No  | No           |
|                                       | 2406:6400:002C:0001::/64 |                                | Yes        | No  | No           |
|                                       | 2406:6400:002C:0002::/64 |                                | Yes        | No  | No           |
|                                       | 2406:6400:002C:0003::/64 |                                | Yes        | No  | No           |
|                                       | 2406:6400:002C:0004::/64 |                                | Yes        | No  | No           |
|                                       | 2406:6400:002C:0005::/64 |                                | Yes        | No  | No           |
|                                       | 2406:6400:002C:0006::/64 |                                | Yes        | No  | No           |
|                                       | 2406:6400:002C:0007::/64 |                                | Yes        | No  | No           |
|                                       | 2406:6400:002C:0008::/64 |                                | Yes        | No  | No           |
|                                       | 2406:6400:002C:0009::/64 |                                | Yes        | No  | No           |
|                                       | 2406:6400:002C:000A::/64 |                                | Yes        | No  | No           |
|                                       | 2406:6400:002C:000B::/64 |                                | Yes        | No  | No           |
|                                       | 2406:6400:002C:000C::/64 |                                | Yes        | No  | No           |
|                                       | 2406:6400:002C:000D::/64 |                                | Yes        | No  | No           |
|                                       | 2406:6400:002C:000E::/64 |                                | Yes        | No  | No           |
|                                       | 2406:6400:002C:000F::/64 |                                | Yes        | No  | No           |

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| 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 |                               |             |            |              |

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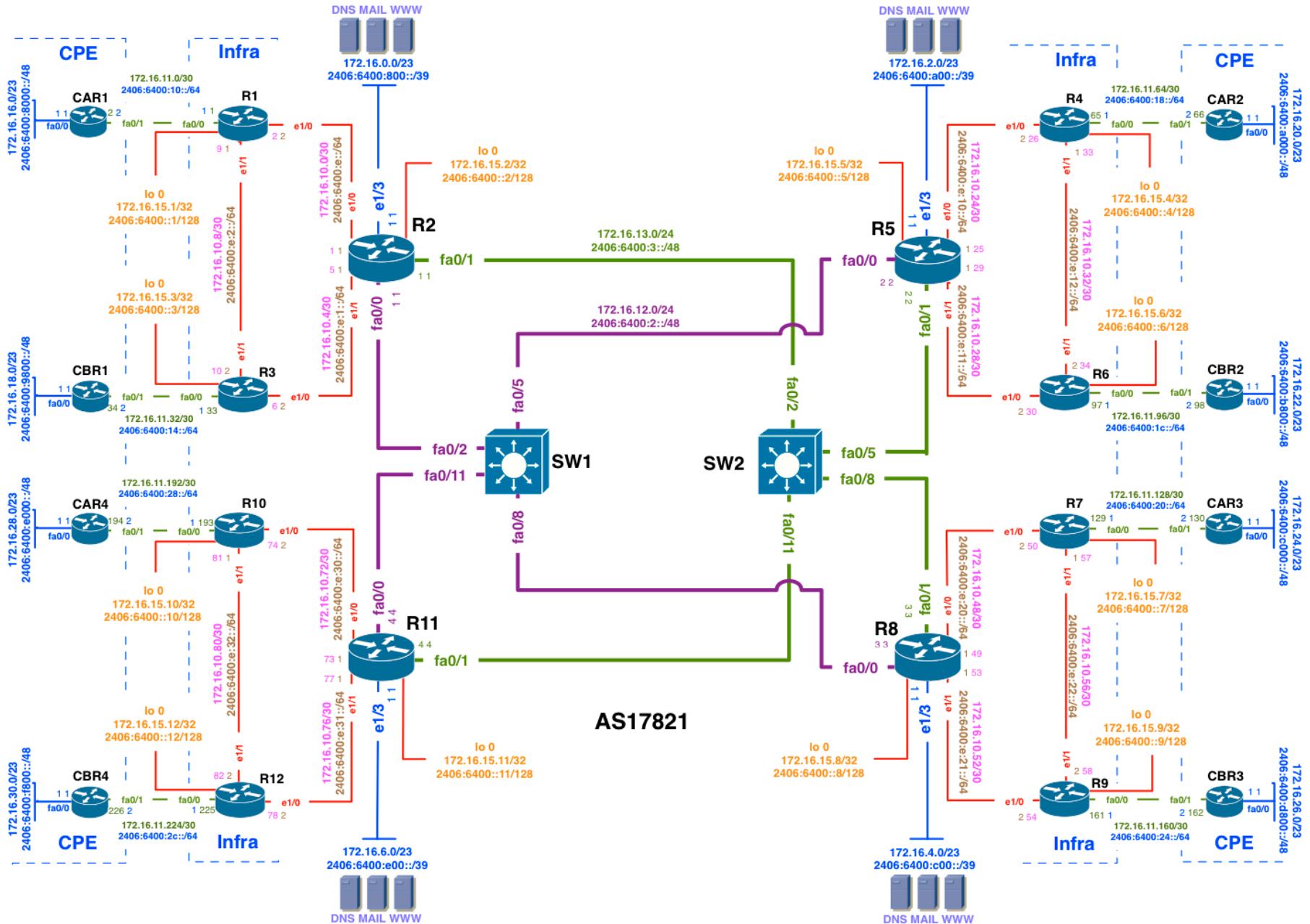
| Table 16: Summarization oprions customer block Region 1 |                          |                               |                |
|---------------------------------------------------------|--------------------------|-------------------------------|----------------|
| Block#                                                  | 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]      |                |

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| 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 |                               |             |     |              |



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| 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

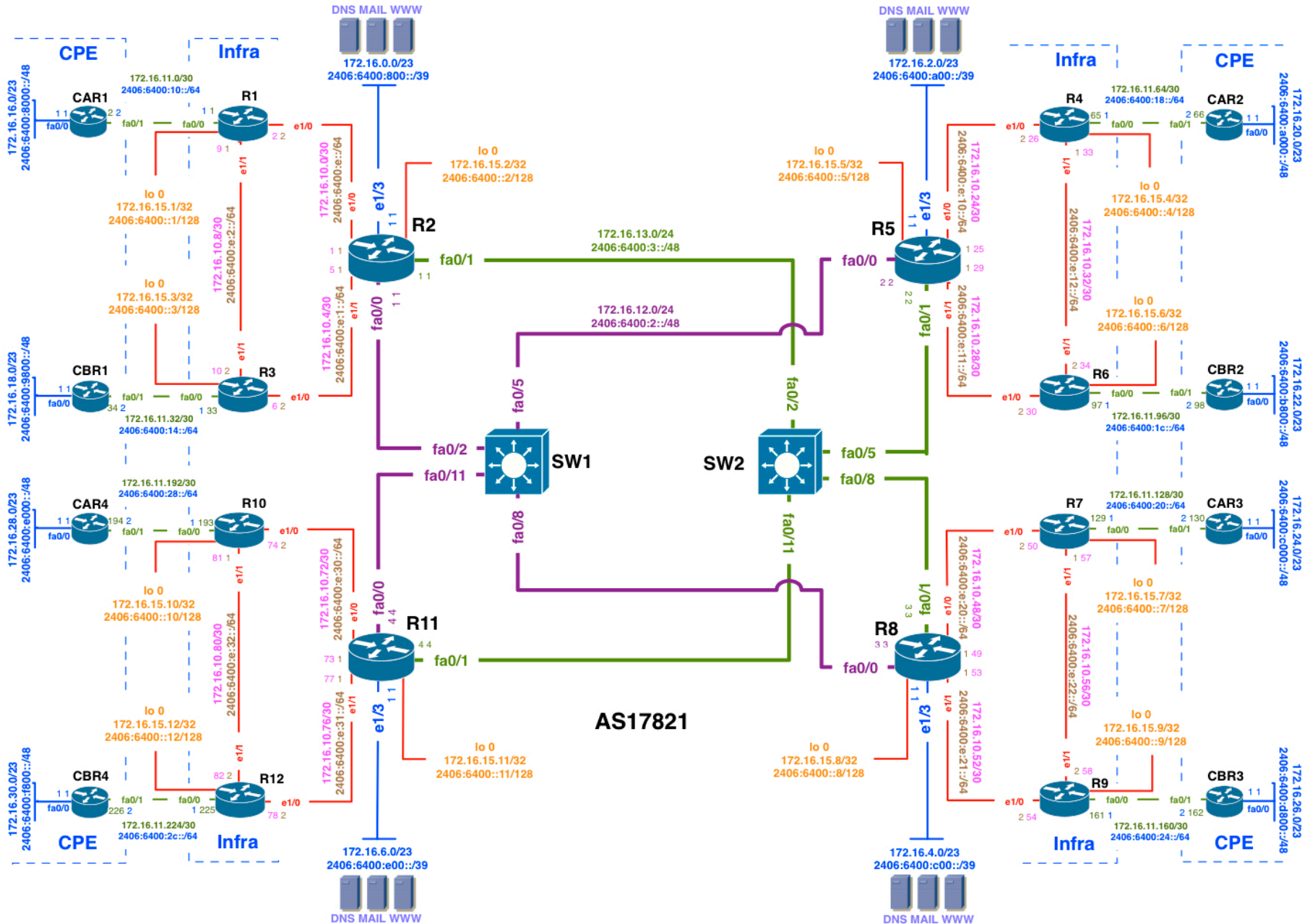
| Table 19: Summarization oprions customer block Region 2 |                          |                               |                |
|---------------------------------------------------------|--------------------------|-------------------------------|----------------|
| Block#                                                  | 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

**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



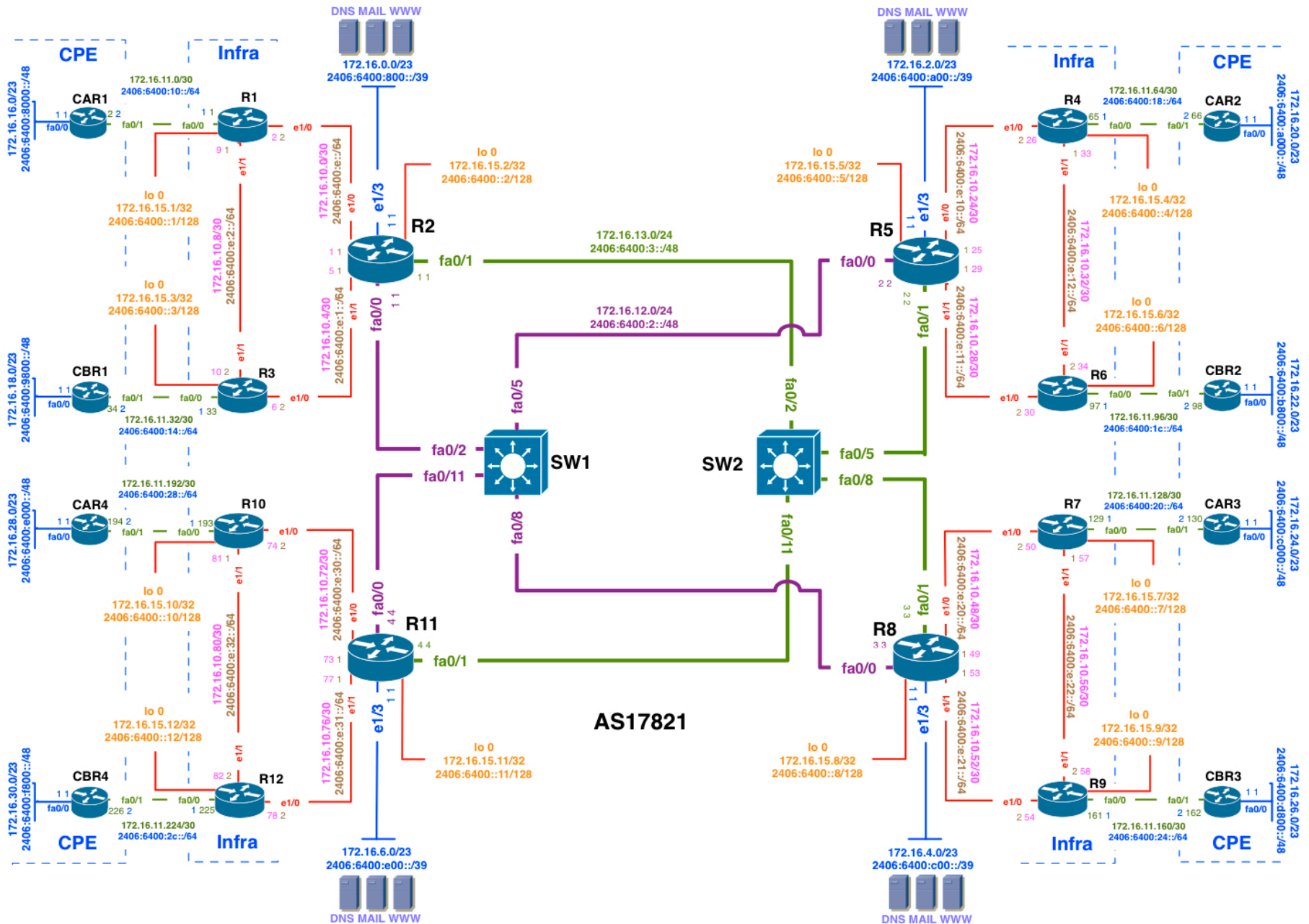
# Training ISP IPV6 Addressing Plan

# Training ISP IPV6 Addressing 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

| 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

| 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

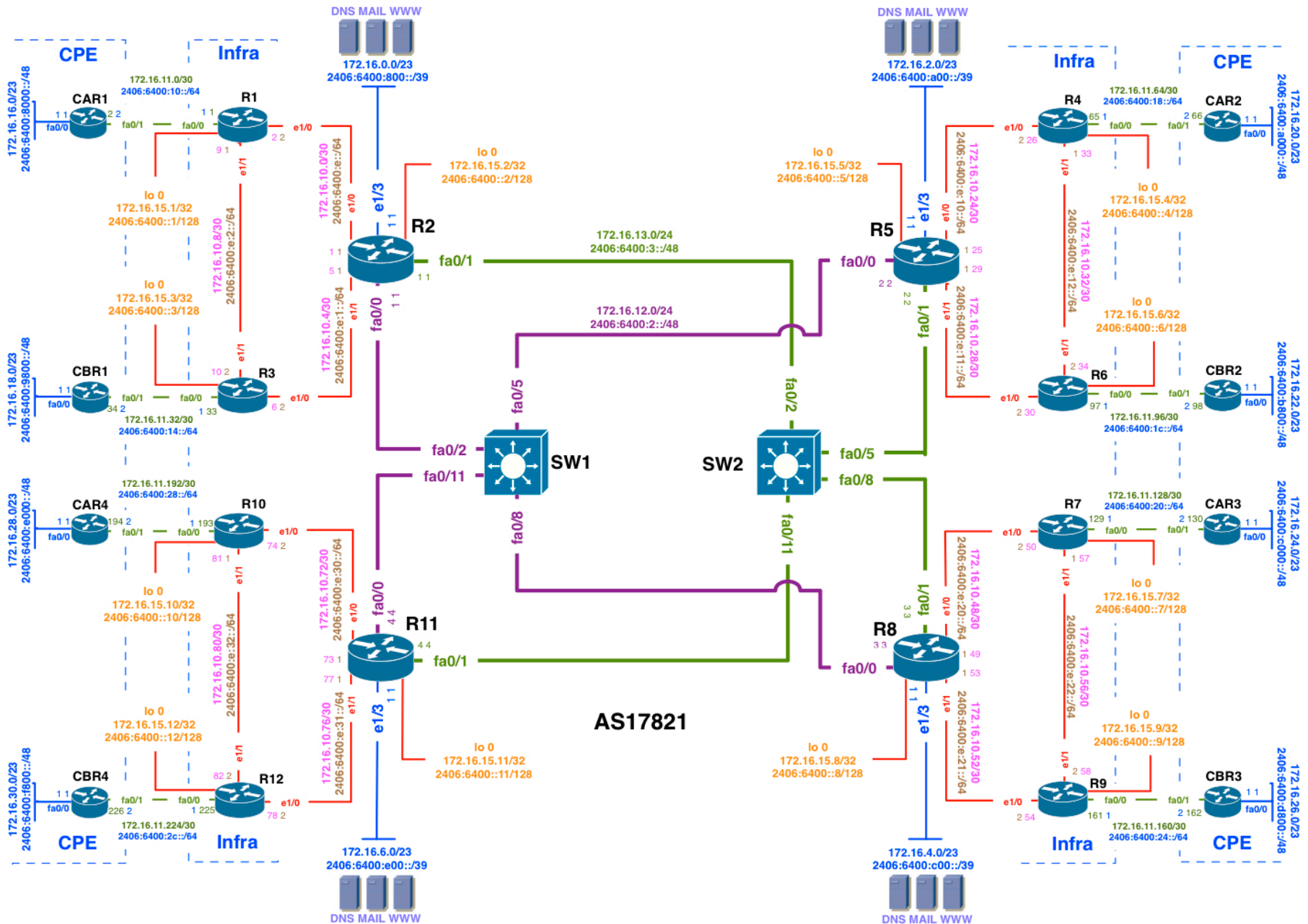
| Table 25: Summarization oprions customer block Region 4 |                          |                               |                |
|---------------------------------------------------------|--------------------------|-------------------------------|----------------|
| Block#                                                  | 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

**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 |                                |             |     |              |

# Training ISP IPV6 Addressing Plan



# Training ISP 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

## 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

## 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

## Detail customer link WAN block

| Block# | Prefix        | Size | Description            | SOR | Register |
|--------|---------------|------|------------------------|-----|----------|
|        | 172.16.11.0   | /26  | WAN CS Link Region1    |     |          |
|        | 172.16.11.0   | /27  | WAN CS Link POP1 [R1]  |     |          |
|        | 172.16.11.0   | /30  | R1[::1]-CAR1[::2]      | No  | No       |
|        | 172.16.11.4   | /30  |                        |     |          |
|        | 172.16.11.32  | /27  | WAN CS Link POP2 [R3]  |     |          |
|        | 172.16.11.32  | /30  | R3[::33]-CBR1[::34]    | No  | No       |
|        | 172.16.11.36  | /30  |                        |     |          |
|        |               |      |                        |     |          |
|        | 172.16.11.64  | /26  | WAN CS Link Region2    |     |          |
|        | 172.16.11.64  | /27  | WAN CS Link POP1 [R4]  |     |          |
|        | 172.16.11.64  | /30  | R4[::65]-CAR2[::66]    | No  | No       |
|        | 172.16.11.68  | /30  |                        |     |          |
|        | 172.16.11.96  | /27  | WAN CS Link POP2 [R6]  |     |          |
|        | 172.16.11.96  | /30  | R6[::97]-CBR2[::98]    | No  | No       |
|        | 172.16.11.100 | /30  |                        |     |          |
|        |               |      |                        |     |          |
|        | 172.16.11.128 | /26  | WAN CS Link Region3    |     |          |
|        | 172.16.11.128 | /27  | WAN CS Link POP1 [R7]  |     |          |
|        | 172.16.11.128 | /30  | R7[::129]-CAR3[::130]  | No  | No       |
|        | 172.16.11.132 | /30  |                        |     |          |
|        | 172.16.11.160 | /27  | WAN CS Link POP2 [R9]  |     |          |
|        | 172.16.11.160 | /30  | R9[::161]-CBR3[::162]  | No  | No       |
|        | 172.16.11.164 | /30  |                        |     |          |
|        |               |      |                        |     |          |
|        | 172.16.11.192 | /26  | WAN CS Link Region4    |     |          |
|        | 172.16.11.192 | /27  | WAN CS Link POP1 [R10] |     |          |
|        | 172.16.11.192 | /30  | R10[::193]-CAR4[::194] | No  | No       |
|        | 172.16.11.196 | /30  |                        |     |          |
|        | 172.16.11.224 | /27  | WAN CS Link POP2 [R12] |     |          |
|        | 172.16.11.224 | /30  | R12[::225]-CBR4[::226] | No  | No       |
|        | 172.16.11.228 | /30  |                        |     |          |

# Training ISP 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 |  |

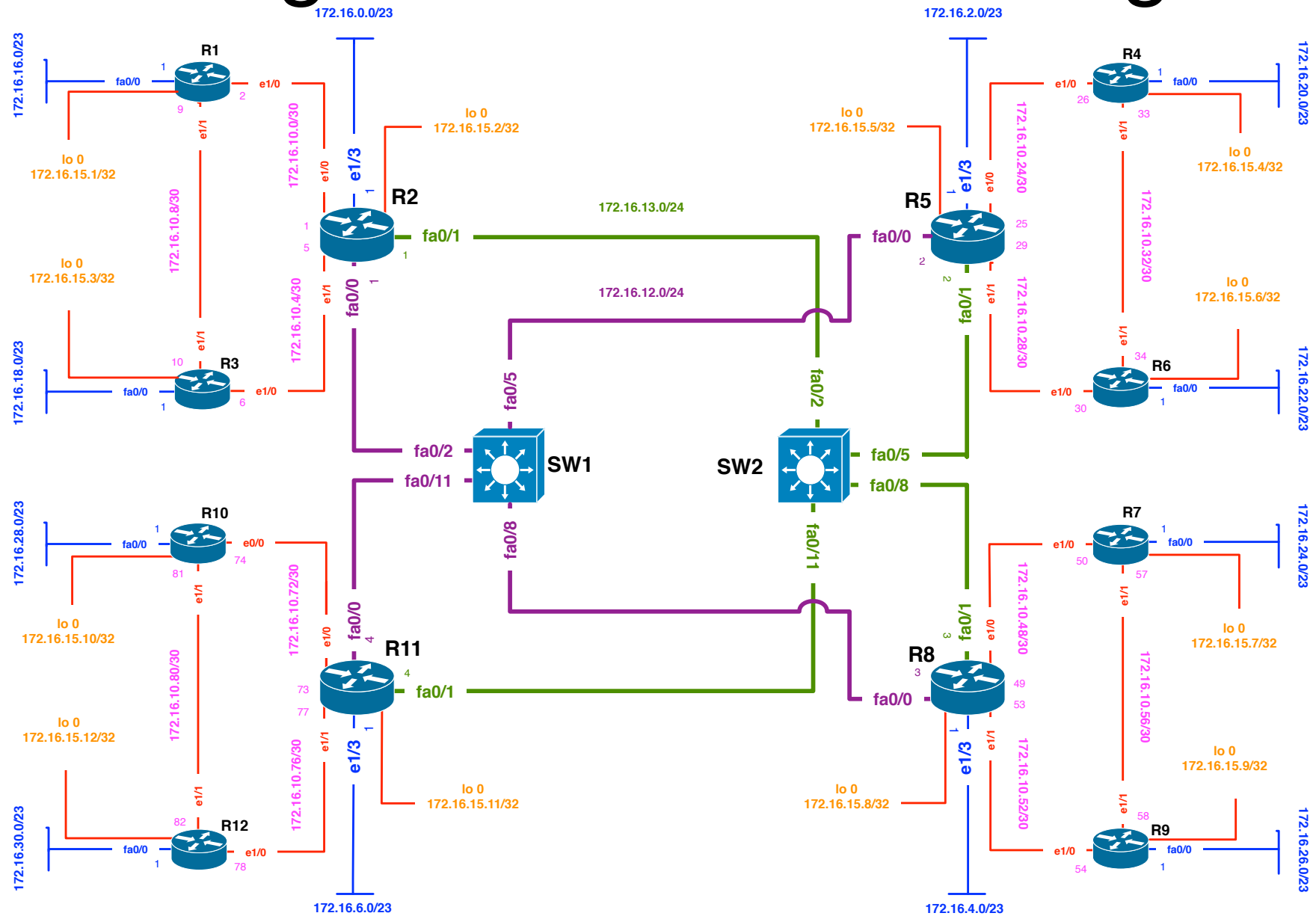


# Training ISP IPV4 Addressing Plan

## 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



Training ISP IPv4 Address Plan



# Questions?

# Overview

## IPv6 Deployment Workshop

- IPv6 Deployment IP address Plan- Case Study
- **IPv6 Deployment in IGP- Case Study**
- IPv4 to IPv6 Transition Technologies

# Configuration of OSPF as IGP

Minimum Router OS require for OSPF3:

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 OSPF3 on an Interface following steps must be done on a Router:

- Enable IPv6 unicast routing
- Enable IPv6 CEF

```
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 unreachables
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 unreachable
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 unreachable
ip address 172.16.10.2 255.255.255.252
no shutdown
```

# Configuration of OSPF as IGP

## IPv4 Interface configuration for Router1:

```
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
```

142

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
```

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# 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
```

# Configuration of OSPF as IGP

Example OSPF configuration for Router1:

```
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
```

# Questions?

# Overview

## IPv6 Deployment Workshop

- IPv6 Deployment IP address Plan- Case Study
- IPv6 Deployment in IGP- Case Study
- **IPv4 to IPv6 Transition Technologies**

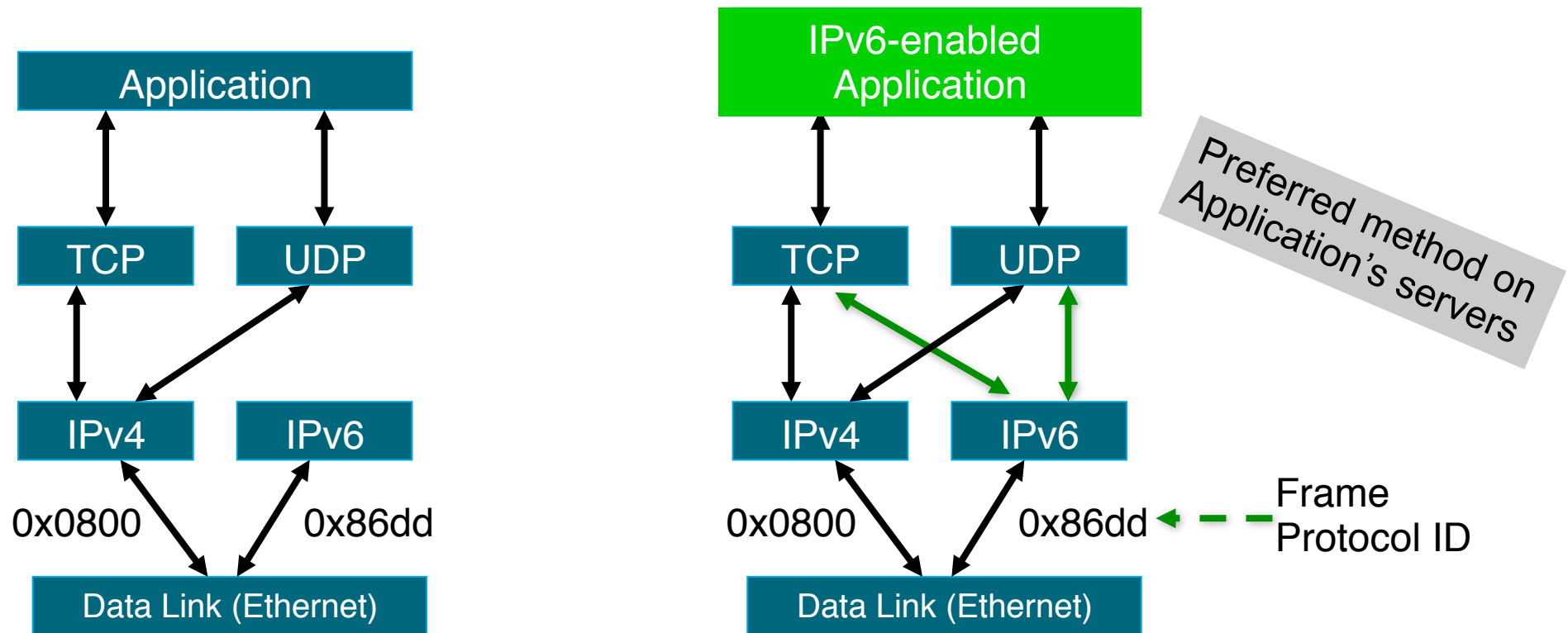
# IETF Working Groups

- “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)

# IPv4-IPv6 Co-existence/Transition

- A wide range of techniques have been identified and implemented, basically falling into three categories:
  - **Dual-stack** techniques, to allow IPv4 and IPv6 to co-exist in the same devices and networks
  - **Tunneling** techniques, to avoid order dependencies when upgrading hosts, routers, or regions
  - **Translation** techniques, to allow IPv6-only devices to communicate with IPv4-only devices
- Expect all of these to be used, in combination

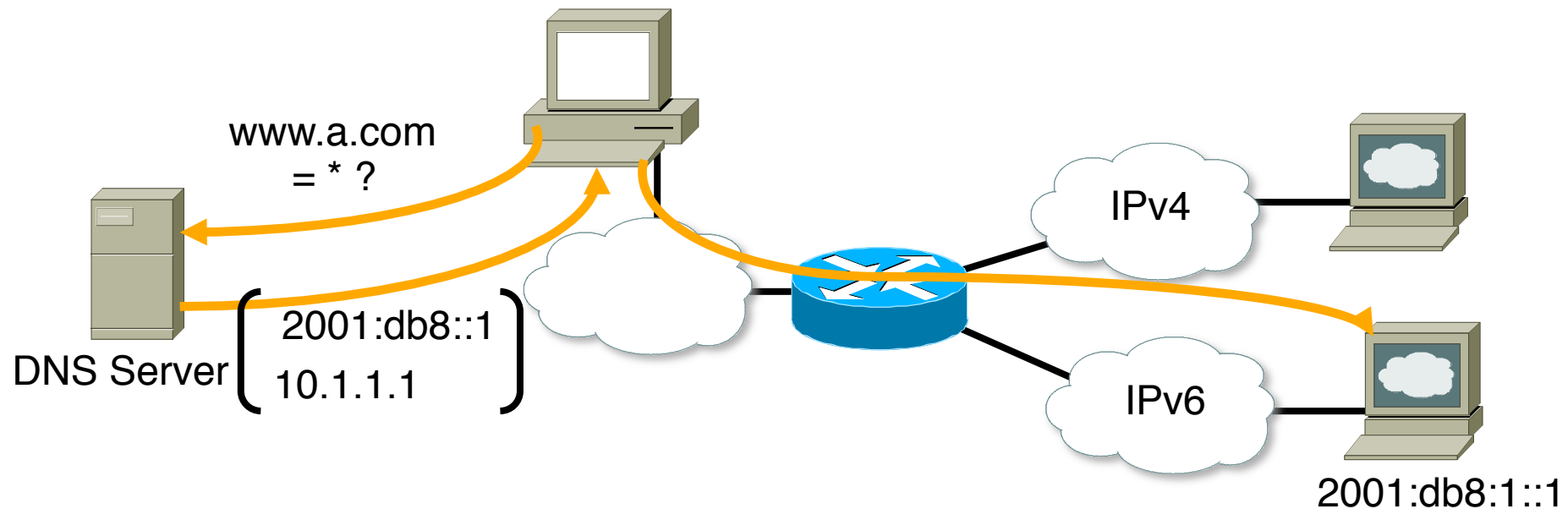
# Dual Stack Approach



- 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

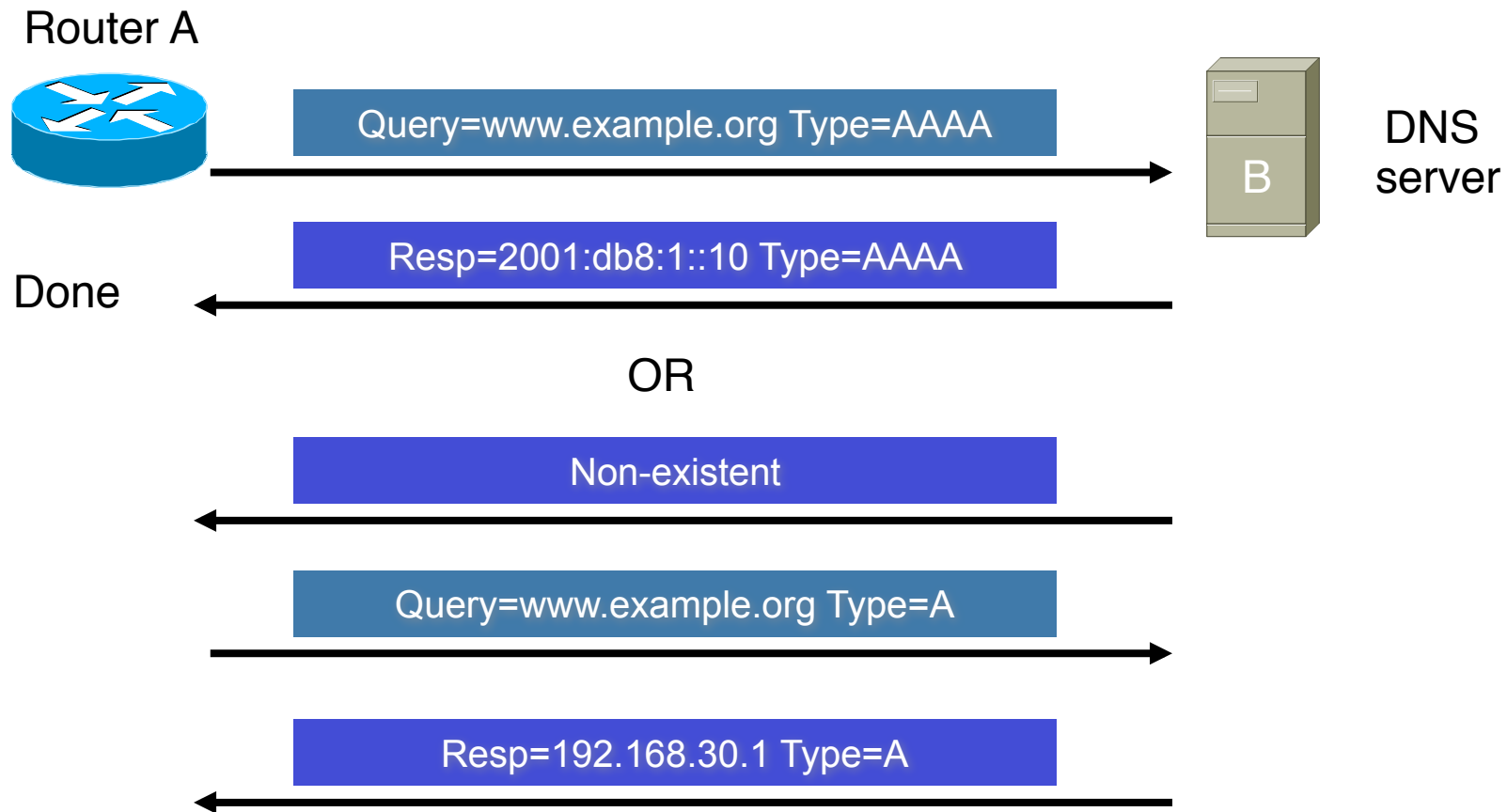


# Dual Stack Approach & DNS



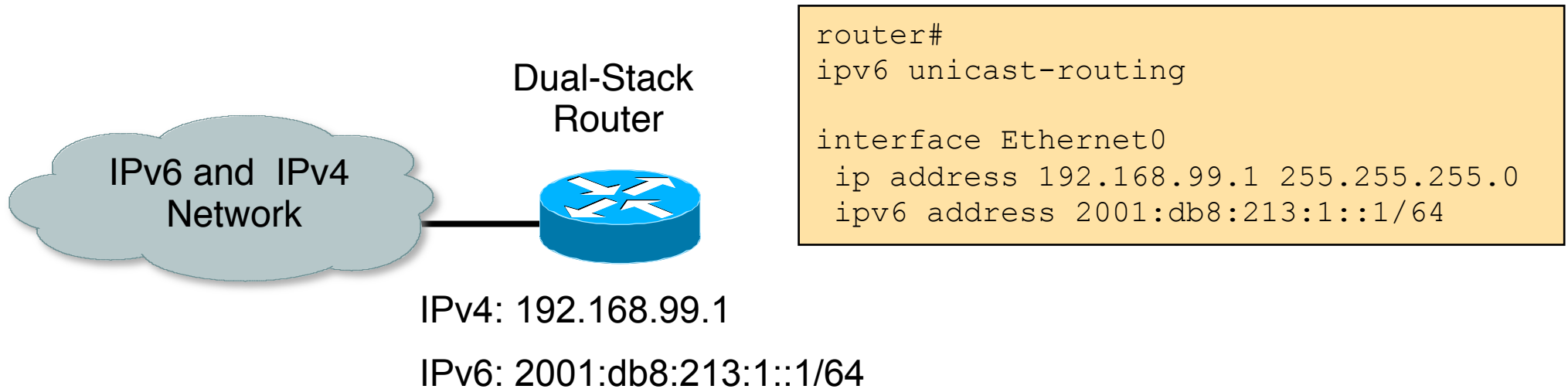
- In a dual stack case, an application that:
  - Is IPv4 and IPv6-enabled
  - Asks the DNS for all types of addresses
  - Chooses one address and, for example, connects to the IPv6 address

# Example of DNS query



- DNS resolver picks IPv6 AAAA record first

# A Dual Stack Configuration

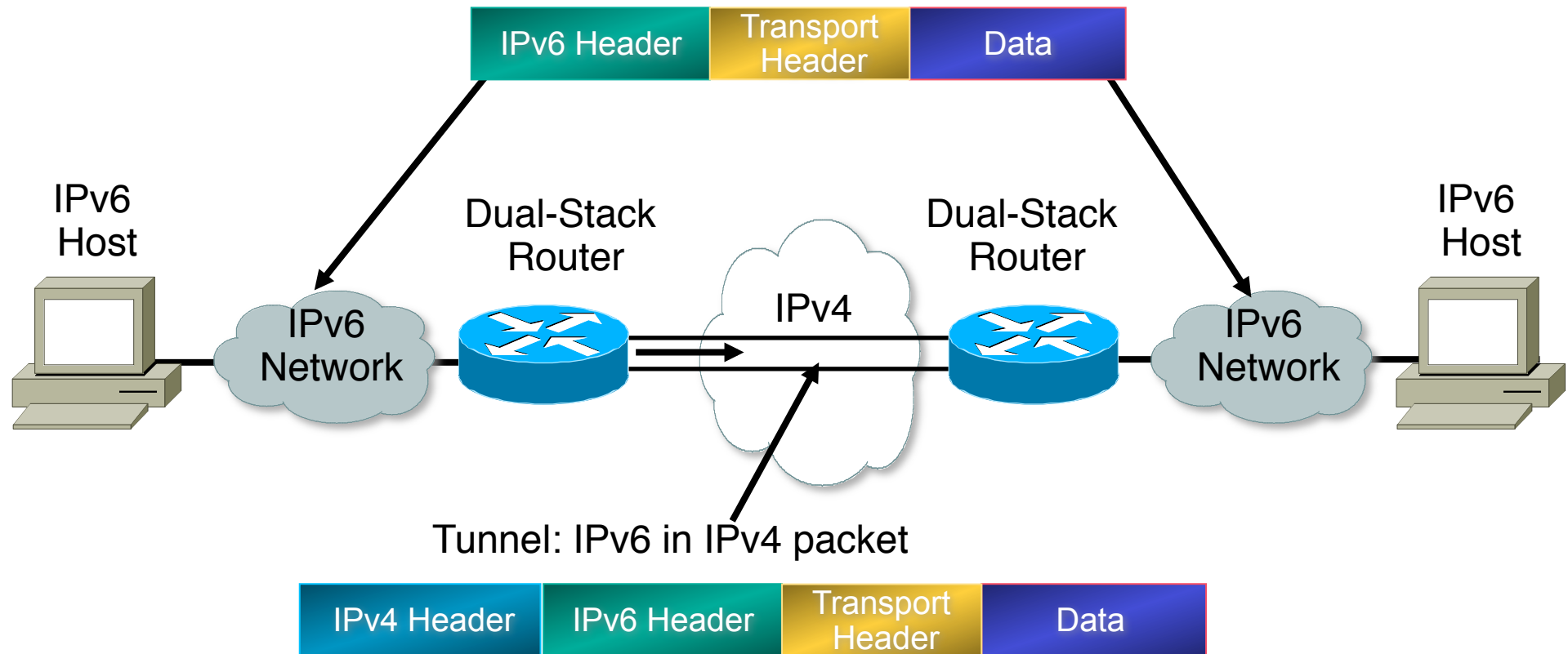


- IPv6-enabled router
  - If IPv4 and IPv6 are configured on one interface, the router is dual-stacked
  - Telnet, Ping, Traceroute, SSH, DNS client, TFTP,...

# Using Tunnels for IPv6 Deployment

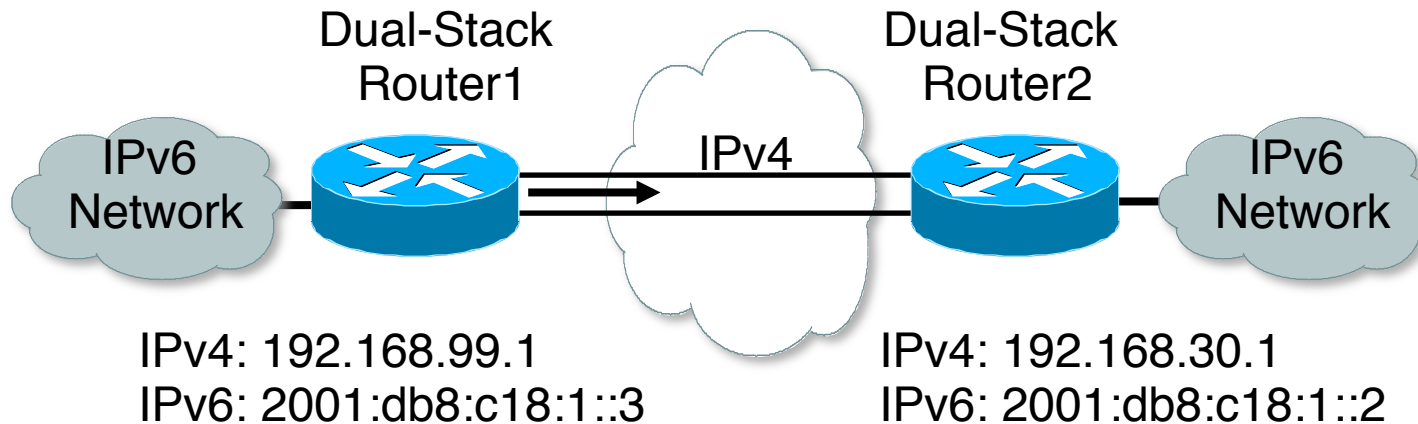
- Many techniques are available to establish a tunnel:
  - Manually configured
    - Manual Tunnel (RFC 2893)
    - GRE (RFC 2473)
  - Semi-automated
    - Tunnel broker
  - Automatic
    - 6to4 (RFC 3056)
    - 6rd

# 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#

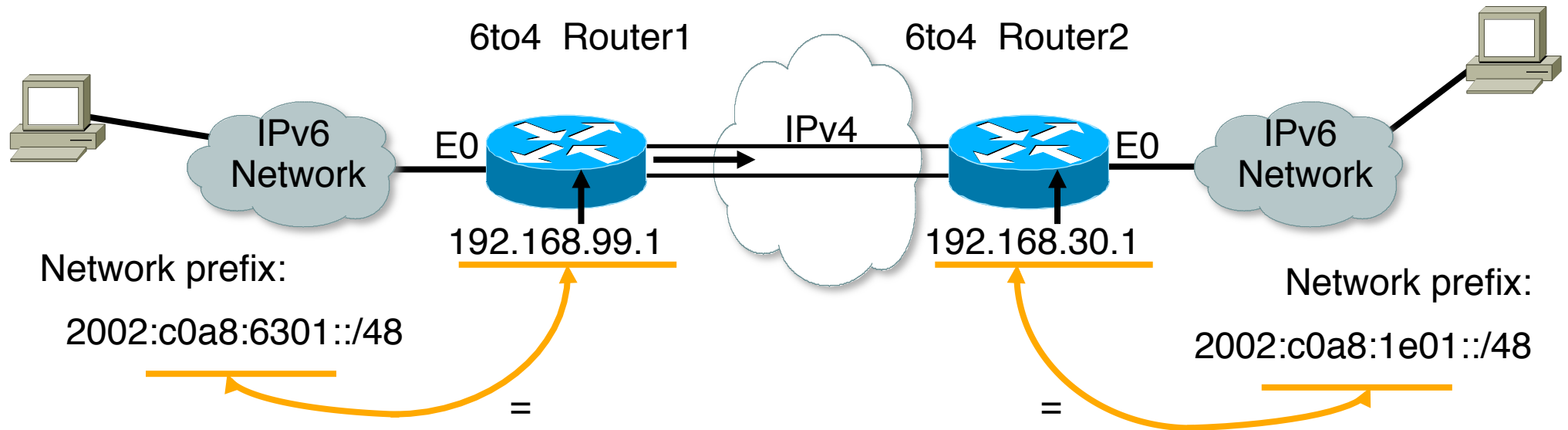
interface Tunnel0
 ipv6 address 2001:db8:c18:1::3/64
 tunnel source 192.168.99.1
 tunnel destination 192.168.30.1
 tunnel mode ipv6ip
```

```
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

# 6to4 Tunnel (RFC 3056)

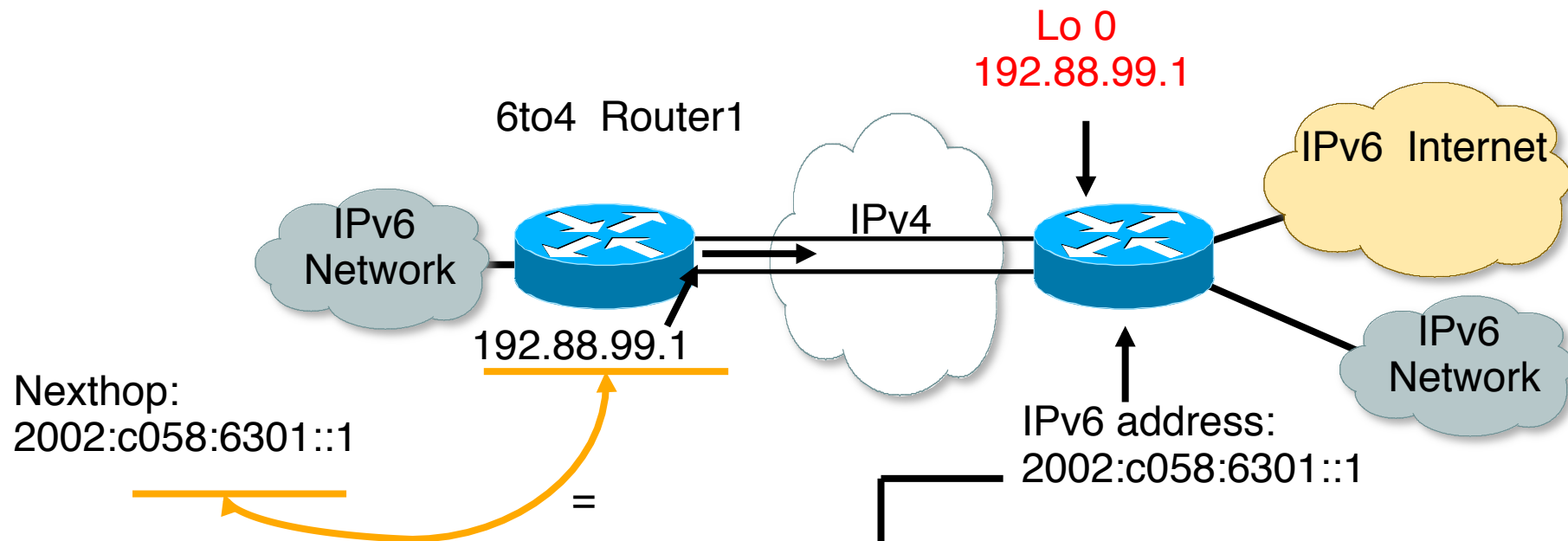


- 6to4 Tunnel:
  - Is an automatic tunnel method
  - Gives a prefix to the attached IPv6 network
  - 2002::/16 assigned to 6to4
  - Requires one global IPv4 address on each Ingress/Egress site

```
router2#
interface Loopback0
 ip address 192.168.30.1 255.255.255.0
 ipv6 address 2002:C0A8:1E01:0000::1/64
interface Tunnel0
 no ip address
 ipv6 address 2002:C0A8:1E01:0010::1/64
 tunnel source 192.168.30.1
 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::1/64
interface Tunnel0
 no ip address
 ipv6 unnumbered Ethernet0
 tunnel source Loopback0
 tunnel mode ipv6ip 6to4

ipv6 route 2002::/16 Tunnel0
ipv6 route ::/0 2002:c058:6301::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

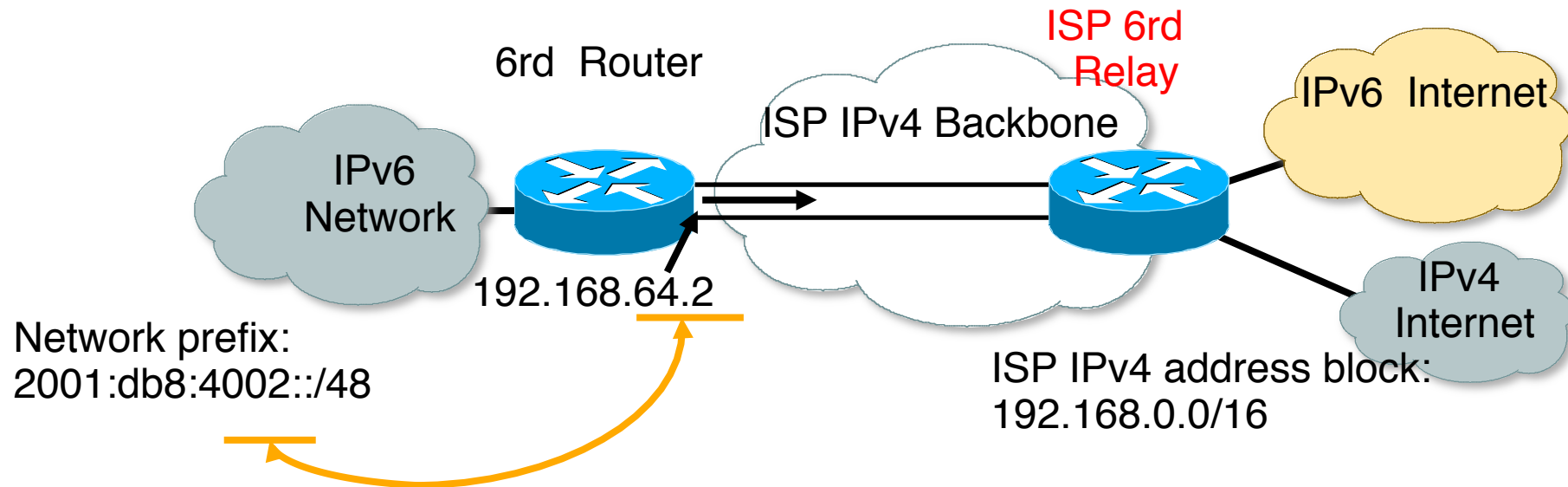
- 6to4 prefix is 2002::/16
- 192.88.99.0/24 is the IPv4 anycast network for 6to4 routers
- 6to4 relay service
  - An ISP who provides a facility to provide connectivity over the IPv4 Internet between IPv6 islands
    - Is connected to the IPv6 Internet and announces 2002::/16 by BGP to the IPv6 Internet
    - 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

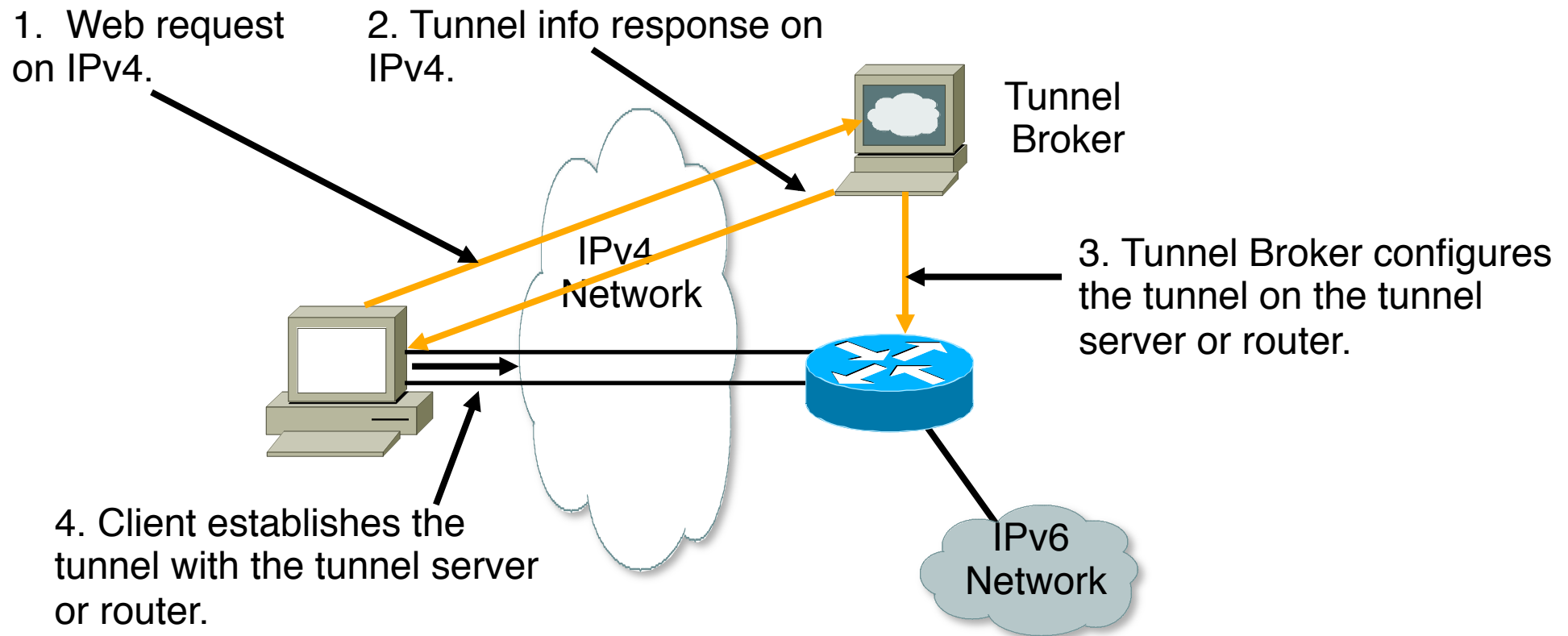
```
interface loopback0
 ip address 192.88.99.1 255.255.255.255
 ipv6 address 2002:c058:6301::1/128
!
interface tunnel 2002
 no ip address
 ipv6 unnumbered Loopback0
 tunnel source Loopback0
 tunnel mode ipv6ip 6to4
 tunnel path-mtu-discovery
!
interface FastEthernet0/0
 ip address 105.3.37.1 255.255.255.0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

# Questions?

# Overview

## IPv6 Deployment Workshop [Module Three]

- IPv6 Deployment in EGP- Case Study
- Basic Internet Service Delivery using IPv6 Transport

# Overview

## IPv6 Deployment Workshop

- **IPv6 Deployment in EGP- Case Study**
- Basic Internet Service Delivery using IPv6 Transport

# Case study- Deployment IPv6 in EGP

## 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.



# Case study- Deployment IPv6 in EGP

## Scenario:

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

# Case study- Deployment IPv6 in EGP

## Basic BGP Configuration:

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

# Case study- Deployment IPv6 in EGP

## 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

# Case study- Deployment IPv6 in EGP

## 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
```

# Case study- Deployment IPv6 in EGP

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
```

```
!
```

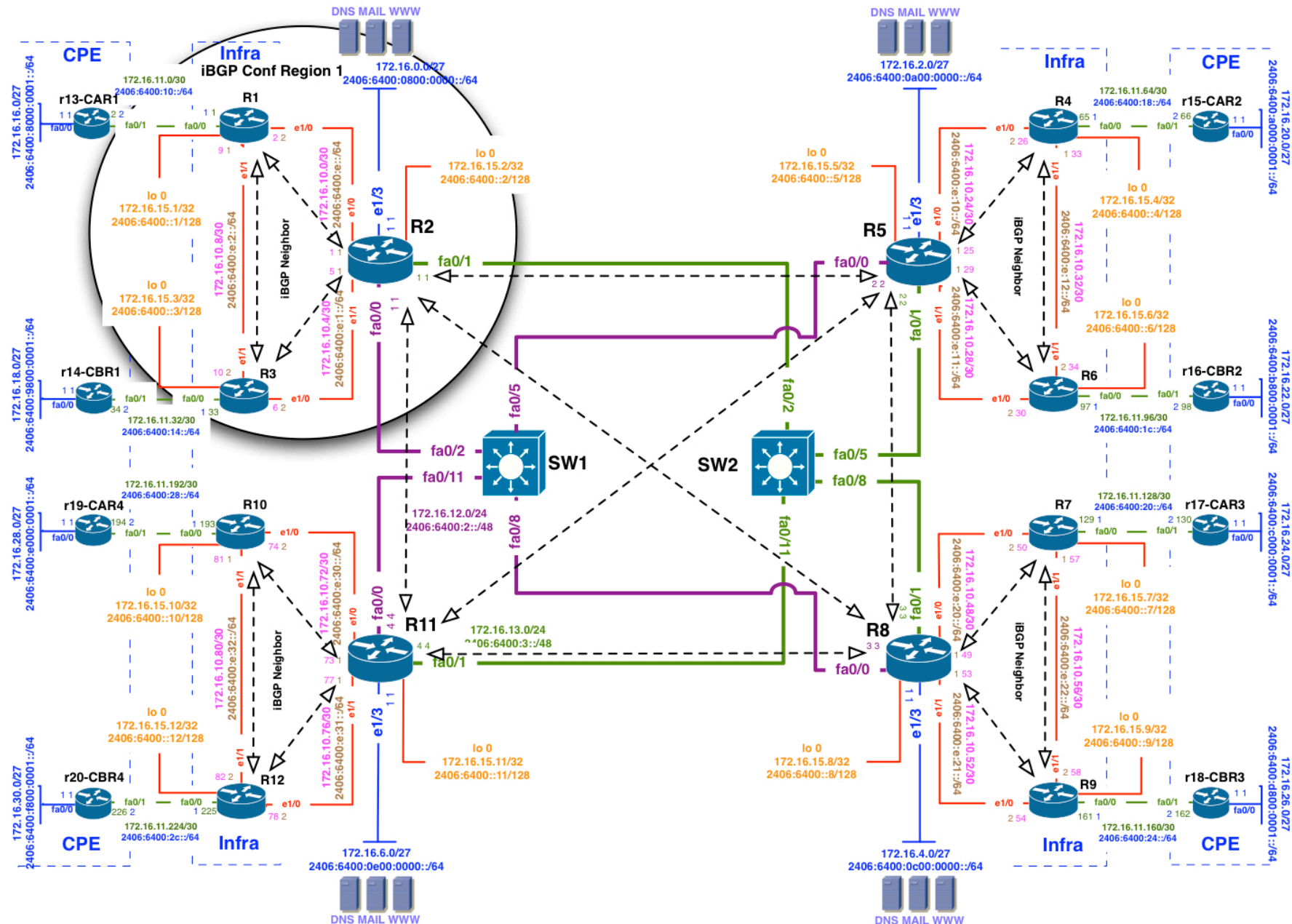
```
network 2406:6400:0100:0000::/48
```

```
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
```

# 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 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
```

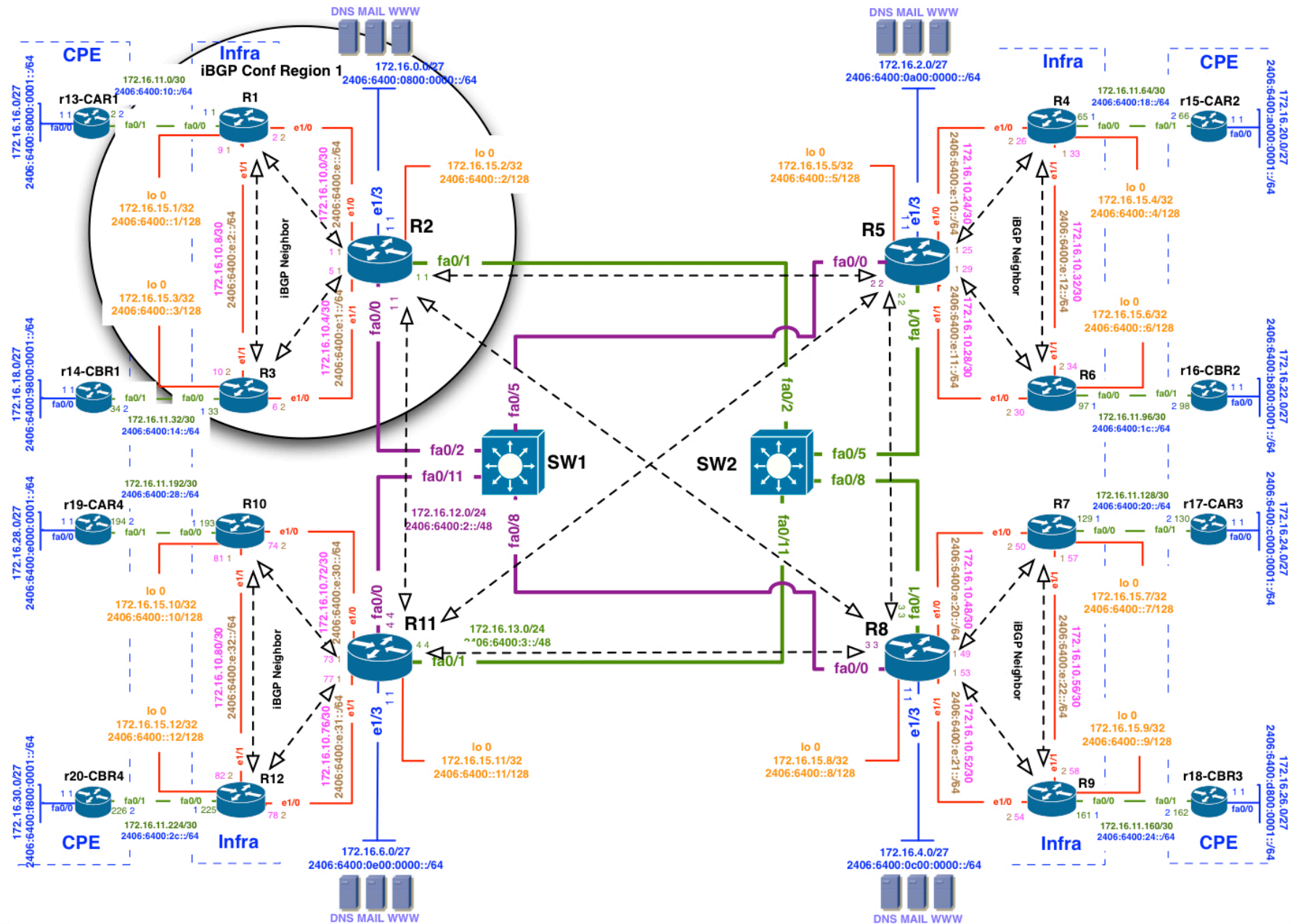
```
sh ipv6 route bgp
```

```
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

The diagram illustrates a complex network topology for a multi-region BGP configuration. It features a central core with two switches (SW1, SW2) and several routers (R1-R12, R13-CAR1, R14-CBR1, R19-CAR4, R20-CBR4, R3, R4, R5, R6, R7, R8, R9, R10, R11, R12, R13-CAR1, R14-CBR1, R19-CAR4, R20-CBR4). The network is divided into three main regions: Region 1 (left), Region 2 (top right), and Region 3 (bottom right). Each region has its own BGP configuration and inter-region connections. The diagram includes IP addresses, interface names, and BGP neighbor relationships. The network is connected to the Internet via DNS, MAIL, and WWW services.

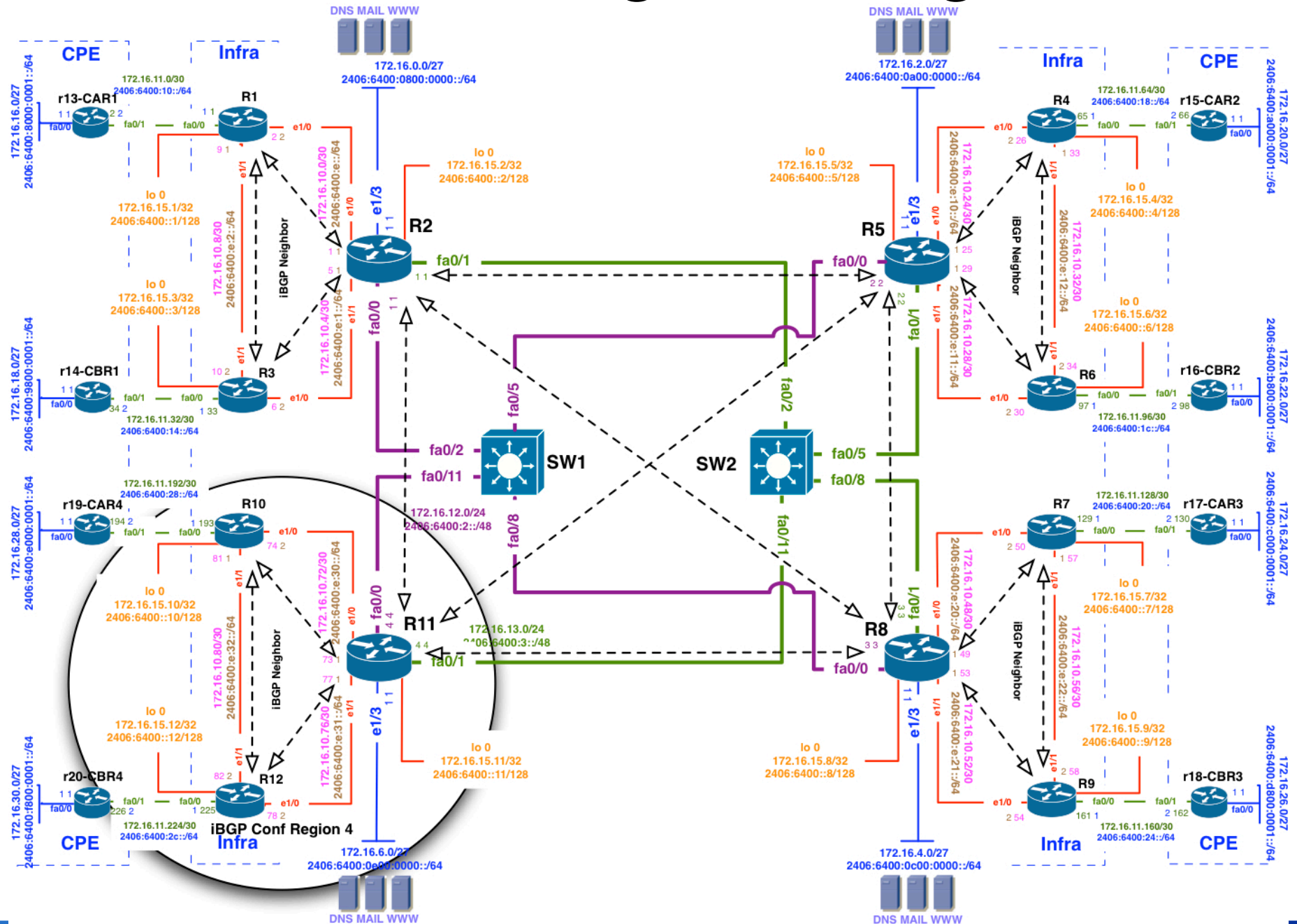
The diagram illustrates a complex network topology for a multi-region BGP configuration. It features a central core with two switches (SW1, SW2) and eight routers (R1-R8). The routers are connected to various external networks, including CPE (Customer Premises Equipment), Infra (Infrastructure), and DNS MAIL WWW. The diagram shows IP addresses for interfaces and loops, and BGP neighbor relationships. A specific region, 'IBGP Conf Region 3', is highlighted with a circle around routers R7, R8, and R9.

**Key Components and Connections:**

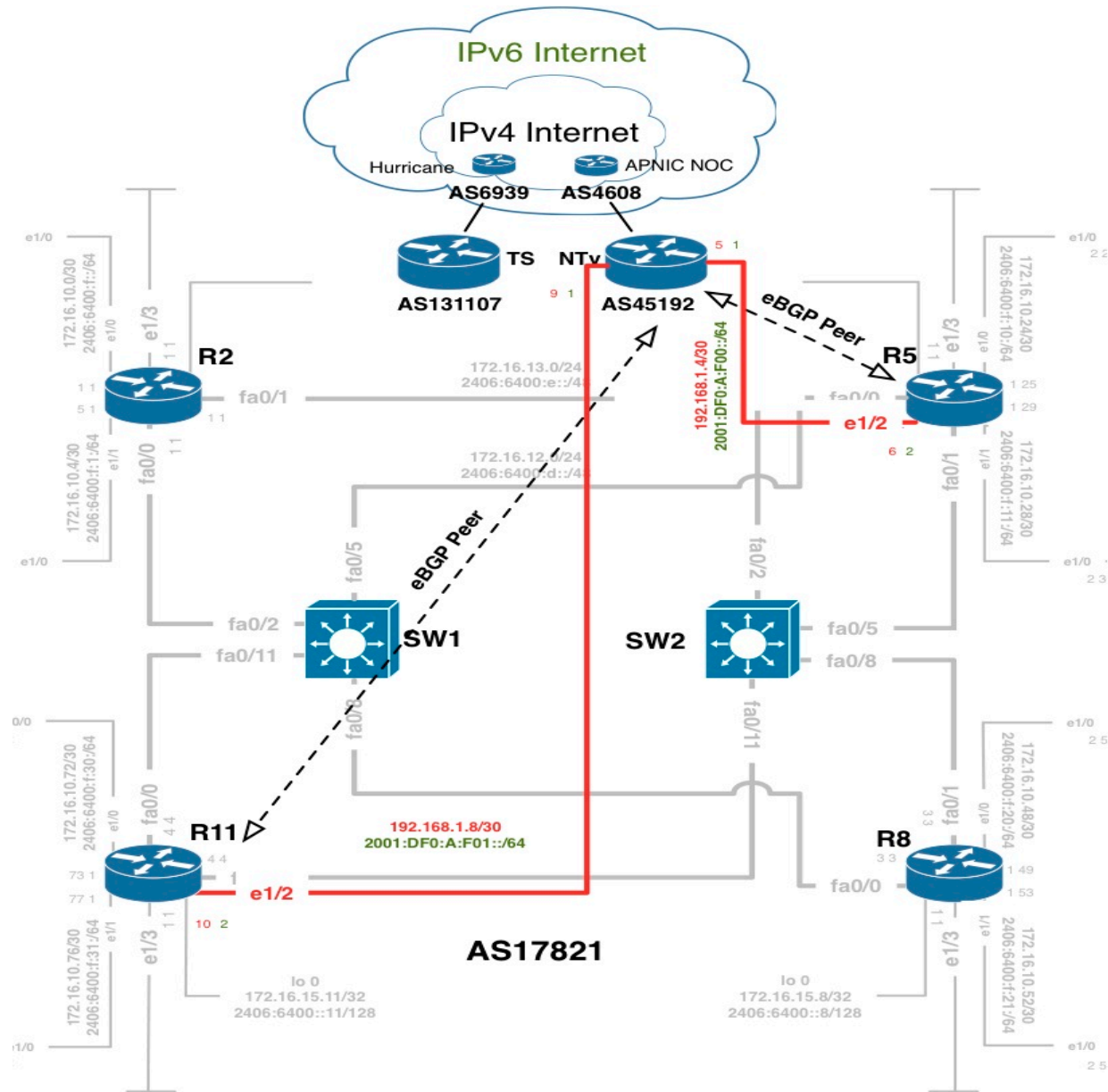
- Core Routers:** R1, R2, R3, R4, R5, R6, R7, R8, R9, R10, R11, R12, R13, R14, R15, R16, R17, R18, R19, R20.
- Switches:** SW1, SW2.
- External Networks:** CPE, Infra, DNS MAIL WWW.
- IP Addresses:** Various IP addresses are assigned to interfaces and loops, including 172.16.0.0/27, 2406:6400:0000::/64, 172.16.10.0/30, 172.16.15.0/32, 172.16.12.0/24, 172.16.13.0/24, 172.16.10.80/30, 172.16.10.70/30, 172.16.10.60/30, 172.16.10.50/30, 172.16.10.40/30, 172.16.10.30/30, 172.16.10.20/30, 172.16.10.10/30, 172.16.10.0/30, 172.16.15.8/32, 172.16.15.7/32, 172.16.15.6/32, 172.16.15.5/32, 172.16.15.4/32, 172.16.15.3/32, 172.16.15.2/32, 172.16.15.1/32, 172.16.15.0/32, 172.16.12.0/24, 172.16.13.0/24, 172.16.10.80/30, 172.16.10.70/30, 172.16.10.60/30, 172.16.10.50/30, 172.16.10.40/30, 172.16.10.30/30, 172.16.10.20/30, 172.16.10.10/30, 172.16.10.0/30, 172.16.15.8/32, 172.16.15.7/32, 172.16.15.6/32, 172.16.15.5/32, 172.16.15.4/32, 172.16.15.3/32, 172.16.15.2/32, 172.16.15.1/32, 172.16.15.0/32.
- BGP Neighbor Relationships:** Indicated by dashed lines between routers.
- IBGP Conf Region 3:** A circle highlighting routers R7, R8, and R9.



# 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:

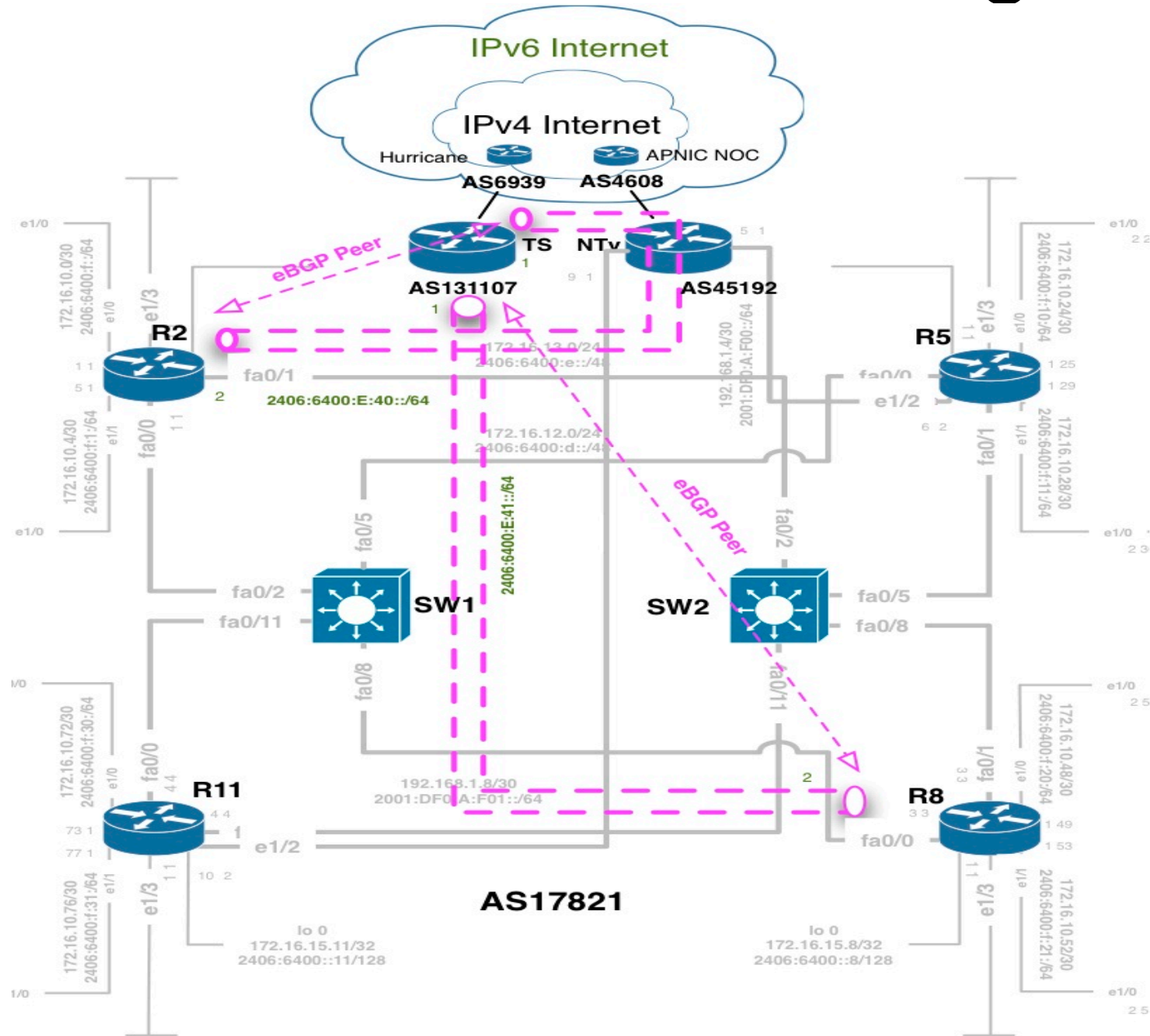
```
config t
ipv6 prefix-list IPV6-GLOBAL-IN seq 5 permit ::/0 ge 32 le 32
ipv6 prefix-list IPV6-GLOBAL-IN seq 10 permit ::/0 ge 48 le 48
!
ipv6 prefix-list IPV6-GLOBAL-OUT seq 5 permit ::/0 ge 32 le 32
ipv6 prefix-list IPV6-GLOBAL-OUT seq 10 permit ::/0 ge 48 le 48

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 Tunnel Transit Configuration



# 6 to 4 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
```

# 6 to 4 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
```

# Questions?

# Overview

## IPv6 Deployment Workshop

- IPv6 Deployment in EGP- Case Study
- **Basic Internet Service Delivery using IPv6 Transport**



# 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
```

# Creating the reverse zone file

- [illegible]

# Creating the reverse zone file

- Major task is filling up the zone file with entries such as
  - 1.0.0.0.1.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.8.d.b.  
0.1.0.0.2.ip6.arpa
- Strategy needed!
  - Otherwise serious errors would result, reverse DNS wouldn't function,
  - Missing out a single "0" will have consequences
- Possible strategies:
  - Delegate infrastructure /48 to a separate zone file
  - Delegate PtP link /48 to a separate zone file
  - Each customer /48 is delegated to a separate zone file
  - Etc...

# 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 PTR cr1.pop1.isp.net.
```

- And we still would have to count zeroes!
- 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

# Example Infrastructure Reverse Zone

```
; Point to Point links
;
$ORIGIN 0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.1.1.0.0.0.0.0.8.b.d.0.1.0.0.2.ip6.arpa.
1 PTR ge0-1.cr1.pop1.isp.net.
2 PTR ge0-0.br1.pop1.isp.net.
$ORIGIN 0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.1.1.1.0.0.0.0.0.8.b.d.0.1.0.0.2.ip6.arpa.
1 PTR ge0-1.cr1.pop1.isp.net.
2 PTR ge0-1.br2.pop1.isp.net.
$ORIGIN 0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.2.1.1.0.0.0.0.0.8.b.d.0.1.0.0.2.ip6.arpa.
1 PTR ge0-1.cr2.pop1.isp.net.
2 PTR ge0-1.br1.pop1.isp.net.
$ORIGIN 0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.3.1.1.0.0.0.0.0.8.b.d.0.1.0.0.2.ip6.arpa.
1 PTR ge0-1.cr2.pop1.isp.net.
2 PTR ge0-0.br2.pop1.isp.net.
```

- Note the use of \$ORIGIN and how it keeps the actual line with the PTR value simple

# Example Loopback Reverse Zone

```
; PoP1
;
$ORIGIN 0.0.1.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.8.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, 255.255.255.255 ip4.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.

[illegible][illegible]

# 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>
```



# Questions?

Need any help?

Thank You! 😊