APNIC Training

IPV6 Workshop

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ICT Leadership and Management Academy

Introduction

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  - Geoff Huston of APNIC

Overview

IPv6 Workshop

- IPv6 Protocol Architecture Overview
- IPV6 Addressing and Sub-netting
- IPv6 Host Configuration
- Training ISP Network Topology Overview
- Deployment of IPV6 in Interior Gateway
- IPv4 to IPv6 Transition technologies
- Planning & Implementation of IPv6 on Exterior Gateway (BGP)
- Connecting ISP network to an IXP

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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 excremental use
- IPv6 was also called IPng in the early days of IPv6 protocol development stage

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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 (RFC1719 and RFC1726, Dec 1994)

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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

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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

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

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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

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

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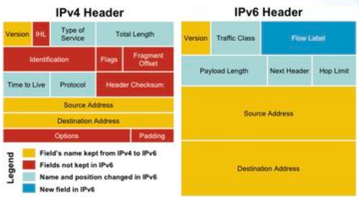
Protocol Header Comparison



- 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

Diagram Source: www.cisco.com

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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 4-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 24-bit field. It tags a flow for the IP packets. It can be used for multilayer switching techniques and faster packet-switching performance

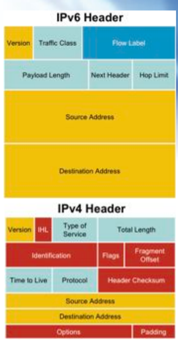

Diagram Source: www.cisco.com

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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.
- 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.

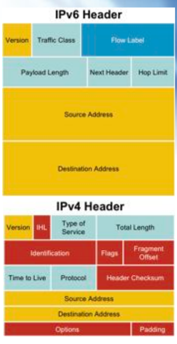

Diagram Source: www.cisco.com

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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 is 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

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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
- Other code value 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

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Extension Header Type

- Six type of extension header defined:
  1. Hop-by-hop option i.e Router Alert, Jumbogram
  2. Routing Header ie. Source Routing
  3. Fragment header
  4. Authentication header
  5. Encrypted security payload
  6. Destination option header

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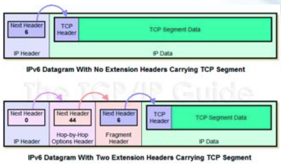
Link listed Extension Header



- 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

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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

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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.

Source: www.cisco.com

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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

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Size of The IPv6 Datagram

- The maximum size of IPv6 datagram will be determined by two factor:
  - Maximum Transmission Unit (MTU) of intermediate nodes [L2 link technology can support i.e HDLC]
  - Payload length of IPv6 header which is 16 bit so normal payload can not be larger then 64k octets.
  - Jumbogram can increase IPv6 datagram size larger then 64k octets. But they need special processing on each hop since they are oversize.
  - One of two uses of hop-by-hop option header is Jumbogram

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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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Questions?

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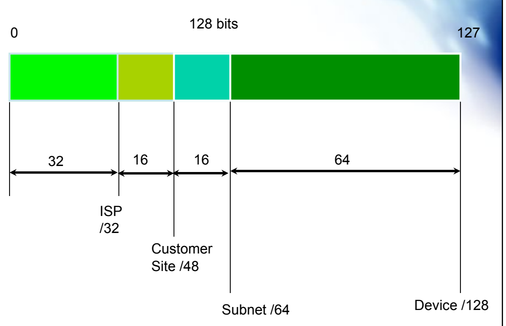
Size of the IPv6 address space

- An IPv6 address is 16 octets (128 bits)
- This would allow every person on the planet to have their own internet as large as the current Internet
- It is difficult to foresee running out of IPv6 addresses

IPv6 addressing

- 128 bits of address space
- 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 address prefix

- When you do IPv6 sub-netting, you need to think in binary values not in hexadecimal value
- 2001:1::/32
  =2001:0001::/32
  Hex 2001 = Binary 0010 0000 0000 0001
  Hex 0001 = Binary 0000 0000 0000 0001
- 2001:2:3::/48
  =2001:0002:0003::/48
  Hex 2001 = Binary 0010 0000 0000 0001
  Hex 0002 = Binary 0000 0000 0000 0010
  Hex 0003 = Binary 0000 0000 0000 0011

IPv6 address prefix

- /64s in 2001:2:3::/48 are
  - 2001:0002:0003:0001::/64
  - 2001:0002:0003:0002::/64
  - 2001:0002:0003:0003::/64
  - Etc.
  - 16 bits of address space
    - You can have 65536 /64s in one /48 IPv6 address
    - Note:: indicates the remaining 64 bits are all zeros and can then be used to identify hosts::

IPv6 address prefix

- Another example:
- 2001:1::/32
  =2001:0001::/32
  Hex 2001 = Binary 0010 0000 0000 0001
  Hex 0001 = Binary 0000 0000 0000 0001
- How about /47s in 2001:1::/32?

IPv6 address prefix

- How about /47s in 2001:1::/32?
  Hex 2001 = Binary 0010 0000 0000 0001 = 16 bits
  Hex 0001 = Binary 0000 0000 0000 0001 = 32
  Hex 0000 = Binary 0000 0000 0000 0000 = 47 (32 bits in prefix – "fixed", 15 bits in subnet)
  So the 15 subnet bits (red) are used to identify the /47s: Subnets numbered using these bits
  Binary 0000 0000 0000 0000 = Hex 0000
  The first /47 is 2001:0001:0000::/47

  Binary 0000 0000 0000 0010 = Hex 0002
  So the second /47 is 2001:0001:0002::/47

  Binary 0000 0000 0000 0100 = Hex 0004
  So the third /47 is 2001:0001:0004::/47

  Binary 0000 0000 0000 0110 = Hex 0006
  So the fourth /47 is 2001:0001:0006::/47

  Binary 0000 0000 0000 1000 = Hex 0008
  So the fifth /47 is 2001:0001:0008 ::/47

Exercise 1

IPv6 Sub-netting

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Exercise 1.1: IPv6 subnetting

1. Identify the first four /64 address blocks out of 2001:AA:2000::/48
   1. ____________________
   2. ____________________
   3. ____________________
   4. ____________________

Exercise 1.2: IPv6 subnetting

1. Identify the fist four /36 address blocks out of 2001:ABC::/32
   1. ____________
   2. ____________
   3. ____________
   4. ____________

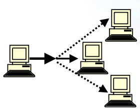
Exercise 1.3: IPv6 subnetting

3. Identify the first six /37 address blocks out of 2001:AA::/32
   1. ____________
   2. ____________
   3. ____________
   4. ____________
   5. ____________
   6. ____________

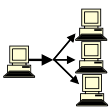
IPv6 addressing model

- **IPv6 Address type** RFC 4291
  - Unicast
    - An identifier for a single interface

  - Anycast
    - An identifier for a set of interfaces



  - Multicast
    - An identifier for a group of nodes



IPv6 Address Range

- Unspecified Address ::/128
- Loopback ::1/128
- Global Unicast 0010 2000::/3
- Link Local 1111 1110 10 FE80::/10
- Multicast Address 1111 1111 FF00::/8

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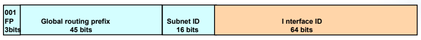
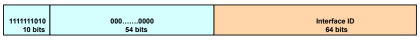
Unicast address

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



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



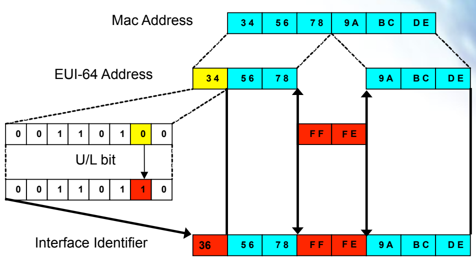
Special addresses

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

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

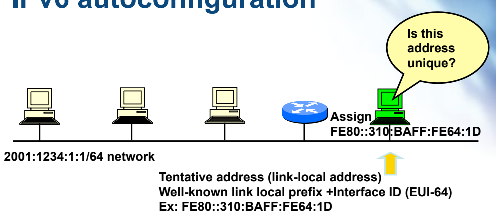
RFC 2462

- 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

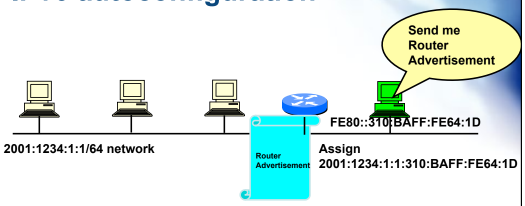
- IPv6 link local address
  - Even if no servers/routers exist to assign an IP address to a device, the device can still auto-generate an IP address
    - Allows interfaces on the same link to communicate with each other
- Stateless
  - No control over information belongs to the interface with an assigned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

IPv6 autoconfiguration



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

IPv6 autoconfiguration



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

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Workshop Exercises

- **Exercise 1: IPv6 Host Configuration**

Exercise 1: IPv6 Host Configuration

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

- Windows XP
- **ipv6 install**

Exercise 1: IPv6 Host Configuration

Verify your Configuration

- c:\>ipconfig

Exercise 1: IPv6 Host Configuration

Testing your configuration

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

- **Note: the Zone id is YOUR interface index**

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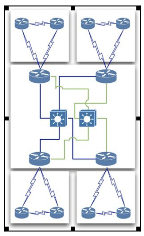
Training ISP Network Topology

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

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Training ISP Network Topology

Transport Link:

- Inter-connection between regional core router
- Higher data transmission capacity then access link
- Training ISP has 2 transport link for link redundancy
- 2 Transport link i.e Purple link & Green link are connected to two L3 switch

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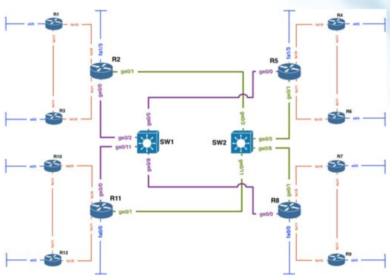
Training ISP Network Topology



Training ISP Topology Diagram

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Training ISP Network Topology

Design Consideration:

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

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Training ISP Network Topology

Design Consideration:

- Conservation will get high preference for IPv4 address planning and aggregation will get high preference for IPv6 address planning.

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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 network

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Training ISP Network Topology

Design Consideration:

- Training ISP is already in production with IPv4 protocol
- Need to implement IPv6 within the same infrastructure
- Down time need to minimize as less as possible
- There has to be a smooth migration plan from IPv4 to IPv6

Training ISP IPV4 Addressing Pan

Current IPv4 Addressing Plan:

Summary parent block IPV4

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

Training ISP IPV4 Addressing Pan

Current IPv4 Addressing Plan:

Detail DC infrastructure block IPV4

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

Training ISP IPV4 Addressing Pan

Current IPv4 Addressing Plan:

Detail infrastructure WAN block IPV4

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

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Training ISP IPV4 Addressing Pan

Current IPv4 Addressing Plan:

Detail infrastructure block Transport & Loopback IPV4

25	172.16.12.0	/24	Transit link BLUE	No	
26	172.16.13.0	/24	Transit link GREEN	No	
27	172.16.15.0	/24	Loopback	No	

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Training ISP IPV4 Addressing Pan

Current IPv4 Addressing Plan:

Detail customer block IPV4

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

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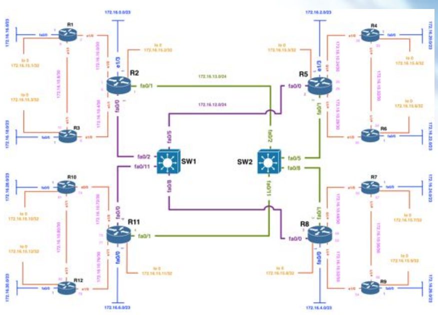
Training ISP IPV4 Addressing Pan



Training ISP IPv4 Address Plan

Training ISP IPV6 Addressing Pan

IPv6 address plan consideration:

- Big IPv6 address space can cause very very large routing table size
- Most transit service provider apply IPv6 prefix filter on anything other then /32 & /48 prefix size
- Prefix announcement need to send to Internet should be either /32 or /48 bit boundary

Training ISP IPV6 Addressing Pan

IPv6 address plan consideration (RFC3177):

- WAN link can be used on /64 bit boundary
- End site/Customer sub allocation can be made on /56 bit boundary
- Utilization/HD ratio will be calculated based on /56 end site assignment/sub-allocation

Training ISP IPV6 Addressing Pan

IPv6 Address Plan:

Summary Parent Block & Regional Network (256x/40)

Block#	Prefix	Description
	2406:6400::/32	***Parent Block***
	2406:6400:0000:0000::/40	Infrastructure
	2406:6400:0100:0000::/40	Customer network Region 1
	2406:6400:0200:0000::/40	Customer network Region 2
	2406:6400:0300:0000::/40	Customer network Region 3
	2406:6400:0400:0000::/40	Customer network Region 4
	2406:6400:0500:0000::/40	
	2406:6400:0600:0000::/40	
	2406:6400:0700:0000::/40	
	2406:6400:0800:0000::/40	
	2406:6400:0900:0000::/40	
	2406:6400:0A00:0000::/40	
	2406:6400:0B00:0000::/40	
	2406:6400:0C00:0000::/40	
	2406:6400:0D00:0000::/40	
	2406:6400:0E00:0000::/40	
	2406:6400:0F00:0000::/40	

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Training ISP IPV6 Addressing Pan

IPv6 Address Plan:

Summary Infrastructure Prefix (256x/48)

Block#	Prefix	Description
	2406:6400:0000:0000::/40	***Infrastructure***
	2406:6400:0000:0000::/48	Loopback
	2406:6400:0001:0000::/48	R2 DC Summary
	2406:6400:0002:0000::/48	R5 DC Summary
	2406:6400:0003:0000::/48	R8 DC Summary
	2406:6400:0004:0000::/48	R11 DC Summary
	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	Purple Transport
	2406:6400:000E:0000::/48	Green Transport
	2406:6400:000F:0000::/48	WAN Prefix

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Training ISP IPV6 Addressing Pan

IPv6 Address Plan WAN Prefix:

2406:6400:000F:0000::/48	***WAN Prefix (65535x/64)***

2406:6400:000F:0000::/64	R2-R1
2406:6400:000F:0001::/64	R2-R3
2406:6400:000F:0002::/64	R1-R3
2406:6400:000F:0003::/64	
2406:6400:000F:0004::/64	
2406:6400:000F:0005::/64	
2406:6400:000F:0006::/64	
2406:6400:000F:0007::/64	
2406:6400:000F:0008::/64	
2406:6400:000F:0009::/64	
2406:6400:000F:000A::/64	
2406:6400:000F:000B::/64	
2406:6400:000F:000C::/64	
2406:6400:000F:000D::/64	
2406:6400:000F:000E::/64	
2406:6400:000F:000F::/64	

2406:6400:000F:0010::/64	R5-R4
2406:6400:000F:0011::/64	R5-R6
2406:6400:000F:0012::/64	R4-R6
2406:6400:000F:0013::/64	
2406:6400:000F:0014::/64	
2406:6400:000F:0015::/64	
2406:6400:000F:0016::/64	
2406:6400:000F:0017::/64	
2406:6400:000F:0018::/64	
2406:6400:000F:0019::/64	
2406:6400:000F:001A::/64	
2406:6400:000F:001B::/64	
2406:6400:000F:001C::/64	
2406:6400:000F:001D::/64	
2406:6400:000F:001E::/64	
2406:6400:000F:001F::/64	

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Training ISP IPV6 Addressing Pan

IPv6 Address Plan:

2406:6400:000F:0000::/48	*WAN Prefix (65535x/64)*

2406:6400:000F:0030::/64	R11-R10		2406:6400:000F:0020::/64	R8-R7
2406:6400:000F:0031::/64	R11-R12		2406:6400:000F:0021::/64	R8-R9
2406:6400:000F:0032::/64	R10-R12		2406:6400:000F:0022::/64	R7-R9
2406:6400:000F:0033::/64			2406:6400:000F:0023::/64	
2406:6400:000F:0034::/64			2406:6400:000F:0024::/64	
2406:6400:000F:0035::/64			2406:6400:000F:0025::/64	
2406:6400:000F:0036::/64			2406:6400:000F:0026::/64	
2406:6400:000F:0037::/64			2406:6400:000F:0027::/64	
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2406:6400:000F:0039::/64			2406:6400:000F:0029::/64	
2406:6400:000F:003A::/64			2406:6400:000F:002A::/64	
2406:6400:000F:003B::/64			2406:6400:000F:002B::/64	
2406:6400:000F:003C::/64			2406:6400:000F:002C::/64	
2406:6400:000F:003D::/64			2406:6400:000F:002D::/64	
2406:6400:000F:003E::/64			2406:6400:000F:002E::/64	
2406:6400:000F:003F::/64			2406:6400:000F:002F::/64	

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Training ISP IPV6 Addressing Pan

IPv6 Address Plan:

Summary Customer net Region 1 (256x/48)

Block#	Prefix	Description
	2406:6400:0100:0000::/40	Customer network Region 1
	2406:6400:0100:0000::/48	***R1 Cust Net***
	2406:6400:0101:0000::/48	
	2406:6400:0102:0000::/48	
	2406:6400:0103:0000::/48	
	2406:6400:0104:0000::/48	
	2406:6400:0105:0000::/48	
	2406:6400:0106:0000::/48	
	2406:6400:0107:0000::/48	
	2406:6400:0108:0000::/48	***R3 Cust Net***
	2406:6400:0109:0000::/48	
	2406:6400:010A:0000::/48	
	2406:6400:010B:0000::/48	
	2406:6400:010C:0000::/48	
	2406:6400:010D:0000::/48	
	2406:6400:010E:0000::/48	
	2406:6400:010F:0000::/48	

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Training ISP IPV6 Addressing Pan

Future IPv6 Address Plan:

Summary Customer net Region 2 (256x/48)

Block#	Prefix	Description
	2406:6400:0200:0000::/40	Customer network Region 2
	2406:6400:0200:0000::/48	***R4 Cust Net***
	2406:6400:0201:0000::/48	
	2406:6400:0202:0000::/48	
	2406:6400:0203:0000::/48	
	2406:6400:0204:0000::/48	
	2406:6400:0205:0000::/48	
	2406:6400:0206:0000::/48	
	2406:6400:0207:0000::/48	
	2406:6400:0208:0000::/48	***R6 Cust Net***
	2406:6400:0209:0000::/48	
	2406:6400:020A:0000::/48	
	2406:6400:020B:0000::/48	
	2406:6400:020C:0000::/48	
	2406:6400:020D:0000::/48	
	2406:6400:020E:0000::/48	
	2406:6400:020F:0000::/48	

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Training ISP IPV6 Addressing Pan

IPv6 Address Plan:

Summary Customer net Region 3 (256x/48)

Block#	Prefix	Description
	2406:6400:0300:0000::/40	Customer network Region 3
	2406:6400:0300:0000::/48	***R7 Cust Net***
	2406:6400:0301:0000::/48	
	2406:6400:0302:0000::/48	
	2406:6400:0303:0000::/48	
	2406:6400:0304:0000::/48	
	2406:6400:0305:0000::/48	
	2406:6400:0306:0000::/48	
	2406:6400:0307:0000::/48	
	2406:6400:0308:0000::/48	***R9 Cust Net***
	2406:6400:0309:0000::/48	
	2406:6400:030A:0000::/48	
	2406:6400:030B:0000::/48	
	2406:6400:030C:0000::/48	
	2406:6400:030D:0000::/48	
	2406:6400:030E:0000::/48	
	2406:6400:030F:0000::/48	

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Training ISP IPV6 Addressing Pan

IPv6 Address Plan:

Summary Customer net Region 4 (256x/48)

Block#	Prefix	Description
	2406:6400:0400:0000::/40	Customer network Region 4
	2406:6400:0400:0000::/48	***R10 Cust Net***
	2406:6400:0401:0000::/48	
	2406:6400:0402:0000::/48	
	2406:6400:0403:0000::/48	
	2406:6400:0404:0000::/48	
	2406:6400:0405:0000::/48	
	2406:6400:0406:0000::/48	
	2406:6400:0407:0000::/48	
	2406:6400:0408:0000::/48	***R12 Cust Net***
	2406:6400:0409:0000::/48	
	2406:6400:040A:0000::/48	
	2406:6400:040B:0000::/48	
	2406:6400:040C:0000::/48	
	2406:6400:040D:0000::/48	
	2406:6400:040E:0000::/48	
	2406:6400:040F:0000::/48	

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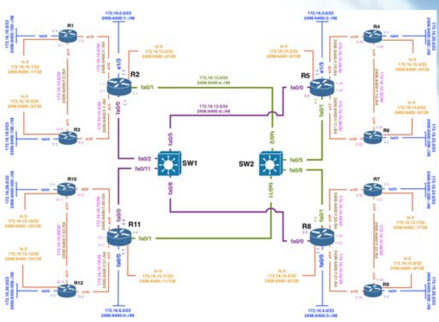
Training ISP IPV6 Addressing Pan



Training ISP IPv6 Address Plan

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Questions?

Overview

IPv6 Workshop

- IPv6 Protocol Architecture Overview
- IPV6 Addressing and Sub-netting
- IPv6 Host Configuration
- Training ISP Network Topology Overview
- **Deployment of IPV6 in Interior Gateway**
- IPv4 to IPv6 Transition technologies
- Planning & Implementation of IPv6 on Exterior Gateway (BGP)
- Connecting ISP network to an IXP

Configuration of OSPF as IGP

Scenario:

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

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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 unreachables
ip address 172.16.15.1 255.255.255.255
no shutdown
interface e1/0
description WAN R1-R2
no ip redirects
no ip directed-broadcast
no ip unreachables
ip address 172.16.10.2 255.255.255.252
no shutdown
interface e1/1
description WAN R1-R3
no ip redirects
no ip directed-broadcast
no ip unreachables
ip address 172.16.10.9 255.255.255.252
no shutdown
interface fa0/0
description Router1 customer network
no ip redirects
no ip directed-broadcast
no ip unreachables
no cdp enable
ip address 172.16.16.1 255.255.255.0
no shutdown
```


Configuration of OSPF as IGP

IPv6 Interface configuration for Router1:

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

Configuration of OSPF as IGP

OSPF Configuration for IPv4:

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

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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

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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
```

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Configuration of OSPF as IGP

OSPF for IPv6 Configuration Command:

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


Configuration of OSPF as IGP

Verify OSPF configuration:

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


Configuration of OSPF as IGP

Example OSPF configuration for Router1:

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

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

OSPF Packet Type

Five OSPF Packet Type:

```
t: Specifies the OSPF packet type:
  1: hello [every 10 sec]
  2: DBD   [Database Descriptor Packet]
  3: LSR   [Link State Request Packet]
  4: LSU   [Link State Update Packet]
  5: LSAck [Link State Ack Packet]

debug ip ospf packet
debug ipv6 ospf packet
```

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Deployment IPV6 in IGP

OSPFv3 or OSPF for IPv6 Overview:

- OSPFv3 is described in RFC 2740
- Most of OSPF3 functions are same as OSPFv2
- In OSPFv3 routing process does not need to be explicitly created. Simply enabling OSPF on an interface will create routing process on a router

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Deployment IPV6 in IGP

OSPFv3 or OSPF for IPv6 Overview:

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

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Deployment IPV6 in IGP

OSPFv3 or OSPF for IPv6 Overview:

- OSPFv3 require IPSec to enable authentication. Crypto images are required to use adjacency authentication
- To use IPSec AH you must use `IPv6 OSPF authentication` command
- To use IPSec ESP you must enable `IPv6 OSPF encryption` command

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Deployment IPV6 in IGP

OSPFv3 or OSPF for IPv6 Overview:

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

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Deployment IPV6 in IGP

- OSPFv3 or OSPF for IPv6 Overview:
  - The Hello packet now contains no address information at all, and includes an Interface ID which the originating router has assigned to uniquely identify (among its own interfaces) its interface to the link.
  - This Interface ID becomes the Netowrk-LSA's Link State ID, obviously when the router become Designated-Router on the link.

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Questions?

Overview

IPv6 Workshop

- IPv6 Protocol Architecture Overview
- IPV6 Addressing and Sub-netting
- IPv6 Host Configuration
- Training ISP Network Topology Overview
- Deployment of IPV6 in Interior Gateway
- **IPv4 to IPv6 Transition technologies**
- Planning & Implementation of IPv6 on Exterior Gateway (BGP)
- Connecting ISP network to an IXP

Transition overview

- How to get connectivity from an IPv6 host to the global IPv6 Internet?
  - Via an native connectivity
  - Via IPv6-in-IPv4 tunnelling techniques
- IPv6-only deployments are rare
- Practical reality
  - Sites deploying IPv6 will not transit to IPv6 -only, but transit to a state where they support both IPv4 and IPv6 (dual-stack)

http://www.6net.org/book/deployment-guide.pdf p59

IPv4 to IPv6 transition

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

Transition overview

- Three basic ways of transition
  - Dual stack
  - Deploying IPv6 and then implementing IPv6-in-IPv4 tunnelling
  - IPv6 only networking
- Different demands of hosts and networks to be connected to IPv6 networks will determine the best way of transition

Transition overview

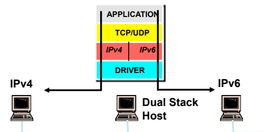
- Dual stack
  - Allow IPv4 and IPv6 to coexist in the same devices and networks
- Tunnelling
  - Allow the transport of IPv6 traffic over the existing IPv4 infrastructure
- Translation
  - Allow IPv6 only nodes to communicate with IPv4 only nodes

IPv6 essentials by Silvia Hagen, p255

Dual stack transition

RFC 4213

- Dual stack = TCP/IP protocol stack running both IPv4 and IPv6 protocol stacks simultaneously
  - Application can talk to both
- Useful at the early phase of transition



Dual stack

- A host or a router runs both IPv4 and IPv6 in the protocol TCP/IP stack.
- Each dual stack node is configured with both IPv4 and IPv6 addresses
- Therefore it can both send and receive datagrams belonging to both protocols
- The simplest and the most desirable way for IPv4 and IPv6 to coexist

http://www.6net.org/book/deployment-guide.pdf p60

Dual stack

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

Dual stack and DNS

- DNS is used with both protocol versions to resolve names and IP addresses
  - An dual stack node needs a DNS resolver that is capable of resolving both types of DNS address records
    - DSN A record to resolve IPv4 addresses
    - DNS AAAA record to resolve IPv6 addresses
- Dual stack network
  - Is an infrastructure in which both IPv4 and Ipv6 forwarding is enabled on routers

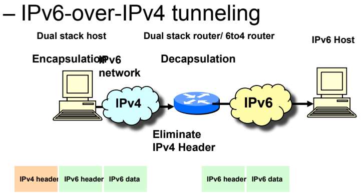
IPv6 essentials by Silvia Hagen, p256

Tunnels

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

Tunneling – general concept

- Tunneling can be used by routers and hosts
  - IPv6-over-IPv4 tunneling



Tunnelling – general concept

- A tunnel can be configured in four different ways:
  - Router to router
    - Spans one hop of the end-to-end path between two hosts. Probably the most common method
  - Host to router
    - Spans the first hop of the end-to-end path between two hosts. Found in the tunnel broker model
  - Host to host
    - Spans the entire end-to-end path between two hosts
  - Router to host
    - Spans the last hop of the end-to-end path between two hosts

Tunnel encapsulation

- The steps for the encapsulation of the IPv6 packet
  - The entry point of the tunnel decrements the IPv6 hop limit by one
  - Encapsulates the packet in an IPv4 header
  - Transmits the encapsulated packet through the tunnel
  - The exit point of tunnel receives the encapsulated packet
    - If necessary, the IPv4 packet is fragmented

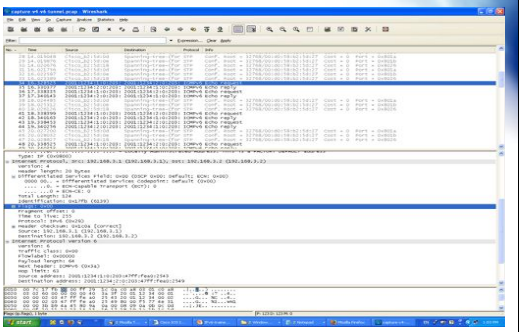
IPv6 essentials by Silvia Hagen, p258

Tunnel encapsulation (Cont)

- It checks whether the source of the packet (tunnel entry point) is an acceptable source (according to its configuration)
  - If the packet is fragmented, the exit point reassembles it
- The exit point removes the IPv4 header
- Then it forwards the IPv6 packet to its original destination

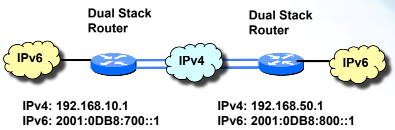
IPv6 essentials by Silvia Hagen, p258

Encapsulated IPv6 packets in IPv4



Manual configuration

RFC 4213



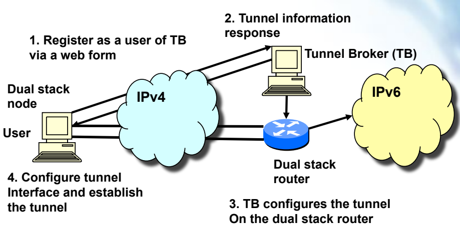
Manually configured tunnels require:

- Dual stack end points
- Explicit configuration with both IPv4 and IPv6 addresses at each end

Concept is borrowed from Cisco. Training material "Ipv6 Seminar" delivered at South Asian IPv6 Summit, Jan 2004

Tunnel broker

RFC 3053



Questions?

Overview

IPv6 Workshop

- IPv6 Protocol Architecture Overview
- IPV6 Addressing and Sub-netting
- IPv6 Host Configuration
- Training ISP Network Topology Overview
- Deployment of IPV6 in Interior Gateway
- IPv4 to IPv6 Transition technologies
- **Planning & Implementation of IPv6 on Exterior Gateway (BGP)**
- Connecting ISP network to an IXP

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.

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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/Static
- Training ISP is having one native IPv6 transit and one tunnel IPv6 transit with AS45192 & AS131107 (2.35 as dot)

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Case study- Deployment IPv6 in EGP

Basic BGP Configuration:

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

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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

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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
```

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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
```

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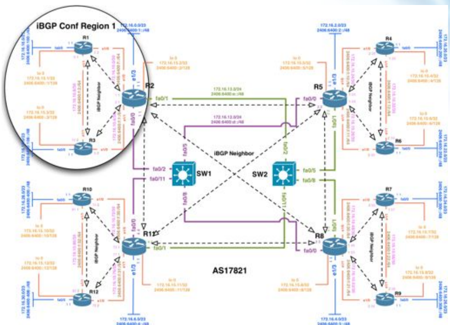
iBGP Peering For Region 1



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IPv4 iBGP Conf POP Router

- Router1

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


IPv4 iBGP Configuration Verification

- POP Router

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


IPv6 iBGP Conf POP Router

- Router1

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

IPv6 iBGP Configuration Verification

- POP Router

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

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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
```

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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]
```

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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
```

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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]
```

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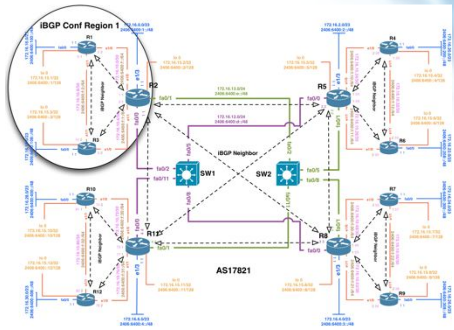
iBGP Full Mesh Issue



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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
```

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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::/32 ge 32 le 32
ipv6 prefix-list IPV6-CUST-IN seq 10 permit cust::/32 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
```

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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

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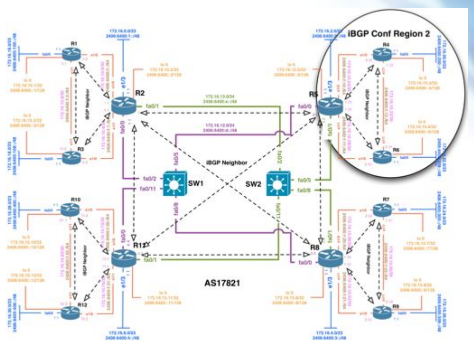
iBGP Peering For Region 2



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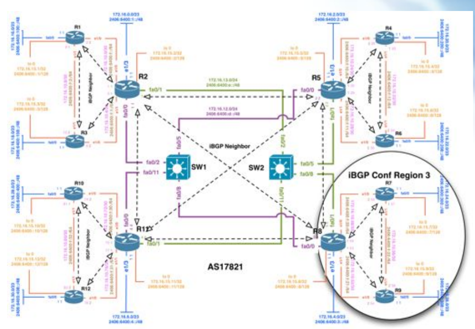
iBGP Peering For Region 3



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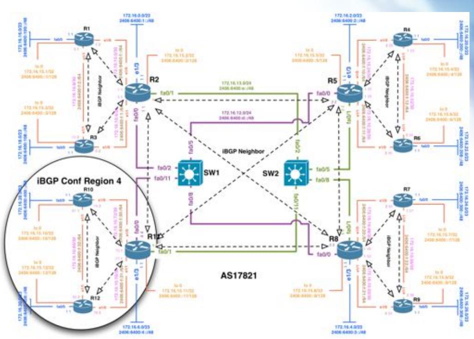
iBGP Peering For Region 4



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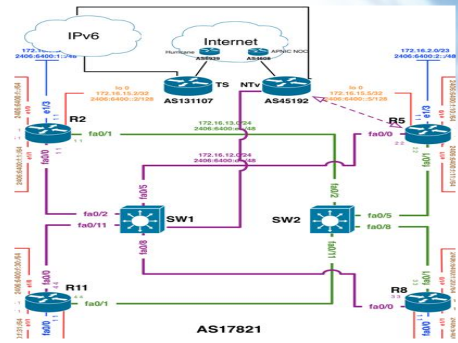
IPv6 Native Transit Conf Plan



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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

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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
```

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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
```

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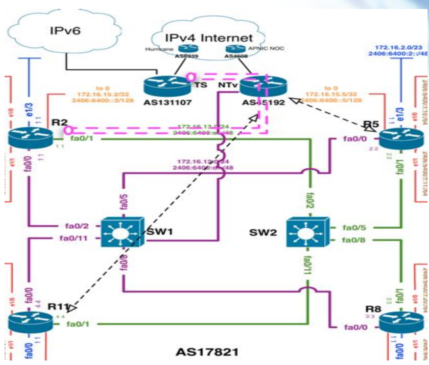
IPv6 Tunnel Transit Conf Plan



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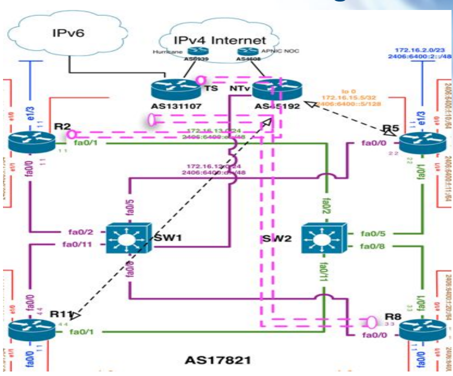
IPv6 Tunnel Transit Configuration



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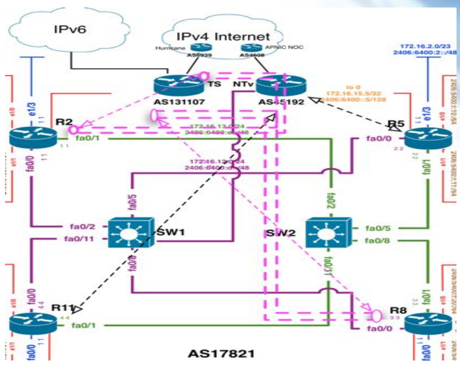
IPv6 Tunnel Transit Configuration



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6 to 4 Tunnel Configuration

IOS Command for Tunnel Interface:

Router2

```
config t
interface Tunnel0
tunnel source 172.16.12.1
tunnel destination 192.168.1.1
tunnel mode ipv6ip
ipv6 address 2406:6400:F:40::2/64
ipv6 enable
```

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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
```

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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
```

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AS Numbers

- Two Ranges:
  - [0 – 65535] are the original 16 bit
  - [65536 – 4294967295] are the new 32 bit
- Usages
  - 0 and 65535 Reserved
  - 1 to 64495 Public Internet
  - 64496 to 64511 Documentation –RFC5398
  - 64512 to 65534 Private use
  - 23456 represent 32 Bit range in 16 bit world
  - 65536 to 65551 Documentation – RFC 5398
  - 65552 to 4294967295 Public Internet

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32 bit AS number representation

- AS DOT
  - Based upon 2-Byte AS representation
  - <Higher2bytes in decimal> . <Lower2bytes in decimal>
  - For example: AS 65546 is represented as 1.10
  - Easy to read, however hard for regular expressions
  - There is a meta character "." in regular expression
  - i.e For example, a.c matches "*abc*", etc., but [a.c] matches only "*a*", ".", or "*c*".
- AS PLAIN
  - ASPLAIN IETF preferred notation
  - Continuation on how a 2-Byte AS number has been represented historically
  - Notation: The 32 bit binary AS number is translated into a Single decimal value Example: AS 65546
  - Total AS Plain range (0 – 65535 - 65,536 - 4,294,967,295)

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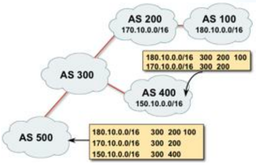
4 Byte AS number

- 32 Bit range representation specified in RFC5396
- APNIC resource range:
  - In AS DOT: 2.0 ~ 2.1023
  - In AS PLAIN: 131072 ~ 132095
- AS number converter

http://submit.apnic.net/cgi-bin/convert-asn.pl

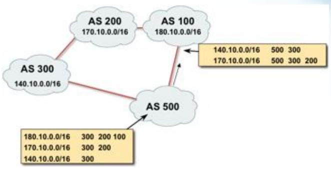
AS Path Attribute



- Sequence of ASes a route has traversed
- Used for
  - Loop detection
  - Path metrics where the length of the AS Path is used as in path selection

Source: www.cisco.com

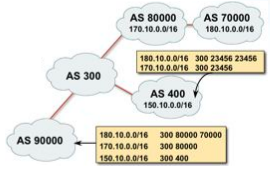
AS Path Loop Detection



- 180.10.0.0/16 is not accepted by AS100 as the prefix has AS100 in its AS-PATH
- This is loop detection in action

Source: www.cisco.com

AS Path Attribute (2 byte and 4 byte)



- Internet with 16-bit and 32-bit ASNs
  - 32-bit ASNs are 65536 and above
  - AS-PATH length maintained

Source: www.cisco.com

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32-bit AS Transition

- Think about this space as a set of NEW / OLD boundaries
- Define the NEW / OLD and the OLD / NEW transitions
- Preserve all BGP information at the transition interfaces
  - **Translate** 32-bit AS Path information into a 16-bit representation
  - **Tunnel** 32-bit AS Path information through 16-bit AS domain as an update attribute

32-bit AS Transition

- Think about this space as a set of NEW / OLD boundaries
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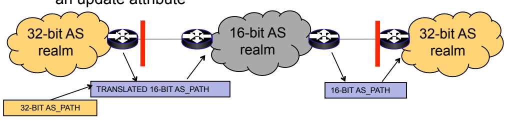
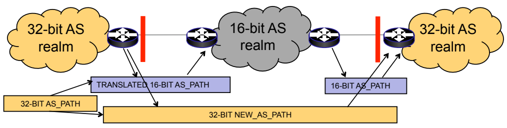


TRANSLATE all 32-bit-only AS numbers to **AS23456**

32-bit AS Transition

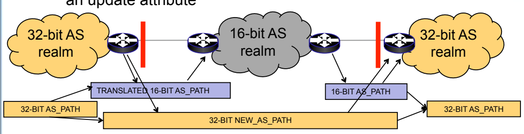
- Think about this space as a set of NEW / OLD boundaries
- Define the NEW / OLD and the OLD / NEW transitions
- Preserve all BGP information at the transition interfaces
  - **Translate** 32-bit AS Path information into a 16-bit representation
  - **Tunnel** 32-bit AS Path information through 16-bit AS domain as an update attribute



COPY 32-bit AS_PATH to NEW_AS_PATH

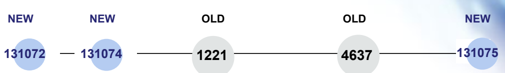
32-bit AS Transition

- Think about this space as a set of NEW / OLD boundaries
- Define the NEW / OLD and the OLD / NEW transitions
- Preserve all BGP information at the transition interfaces
  - **Translate** 32-bit AS Path information into a 16-bit representation
  - **Tunnel** 32-bit AS Path information through 16-bit AS domain as an update attribute

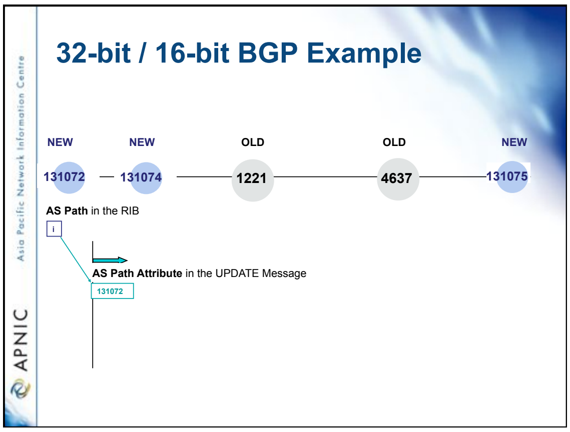


REASSEMBLE 32-bit AS_PATH

32-bit / 16-bit BGP Example



AS Path in the RIB


32-bit / 16-bit BGP Example
NEW
NEW
OLD
OLD
NEW
131072
131074
1221
4637
131075
AS Path in the RIB
i
AS Path Attribute in the UPDATE Message
131072
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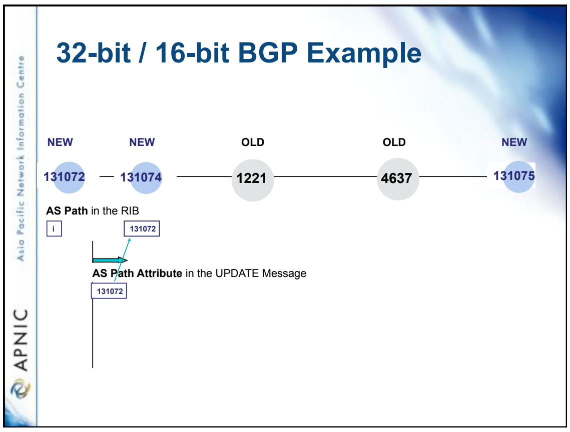
32-bit / 16-bit BGP Example
NEW
NEW
OLD
OLD
NEW
131072
131074
1221
4637
131075
AS Path in the RIB
i
131072
AS Path Attribute in the UPDATE Message
131072
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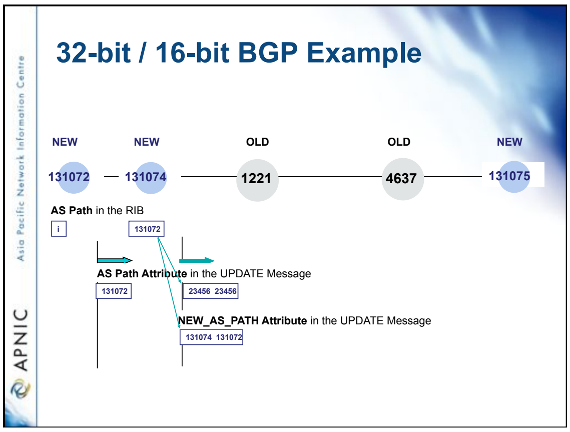
32-bit / 16-bit BGP Example
NEW
NEW
OLD
OLD
NEW
131072
131074
1221
4637
131075
AS Path in the RIB
i
131072
AS Path Attribute in the UPDATE Message
131072
23456 23456
NEW_AS_PATH Attribute in the UPDATE Message
131074 131072
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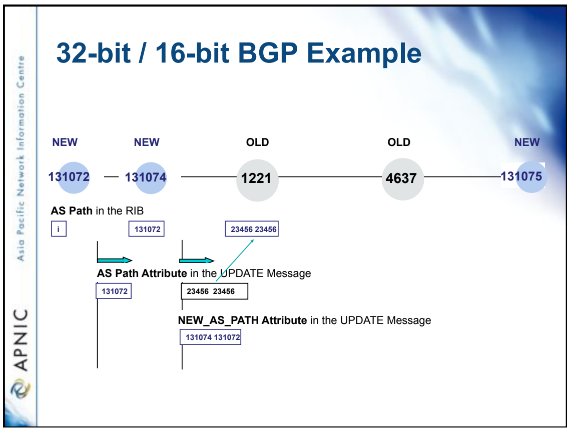

32-bit / 16-bit BGP Example
NEW
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OLD
OLD
NEW
131072
131074
1221
4637
131075
AS Path in the RIB
i
131072
23456 23456
AS Path Attribute in the UPDATE Message
131072
23456 23456
NEW_AS_PATH Attribute in the UPDATE Message
131074 131072
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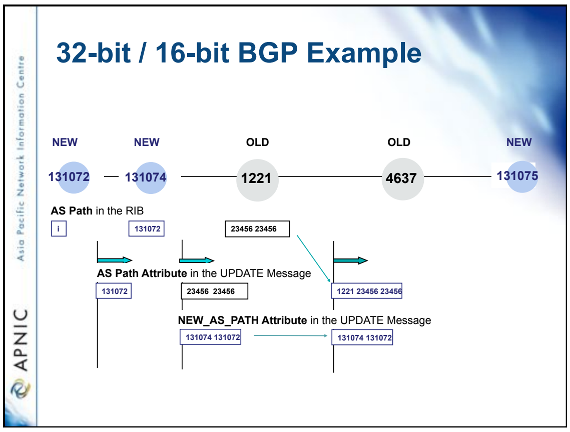

32-bit / 16-bit BGP Example
NEW
NEW
OLD
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131072
131074
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AS Path in the RIB
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23456 23456
AS Path Attribute in the UPDATE Message
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23456 23456
1221 23456 23456
NEW_AS_PATH Attribute in the UPDATE Message
131074 131072
131074 131072
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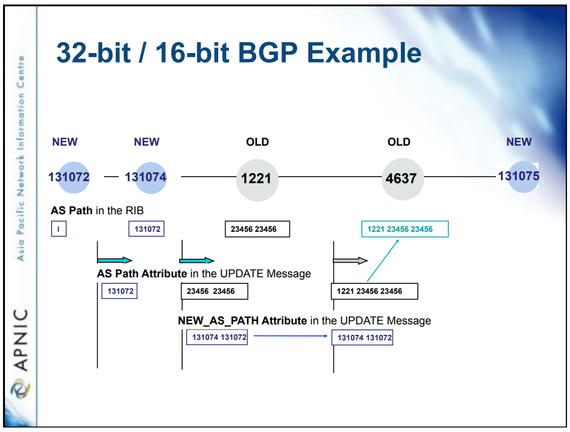

32-bit / 16-bit BGP Example
NEW
NEW
OLD
OLD
NEW
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131074
1221
4637
131075
AS Path in the RIB
i
131072
23456 23456
1221 23456 23456
AS Path Attribute in the UPDATE Message
131072
23456 23456
1221 23456 23456
NEW_AS_PATH Attribute in the UPDATE Message
131074 131072
131074 131072
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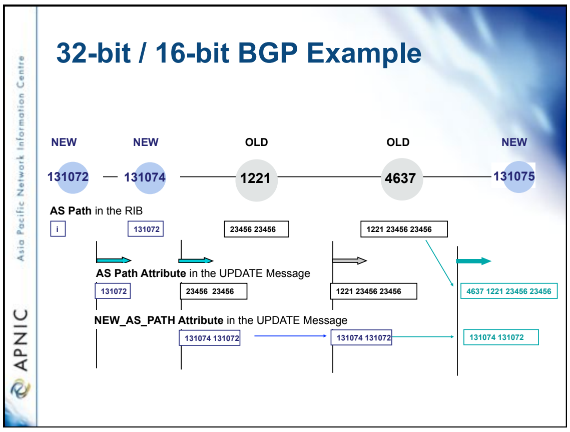
32-bit / 16-bit BGP Example
NEW
NEW
OLD
OLD
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131072
131074
1221
4637
131075
AS Path in the RIB
i
131072
23456 23456
1221 23456 23456
AS Path Attribute in the UPDATE Message
131072
23456 23456
1221 23456 23456
4637 1221 23456 23456
NEW_AS_PATH Attribute in the UPDATE Message
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131074 131072
APNIC
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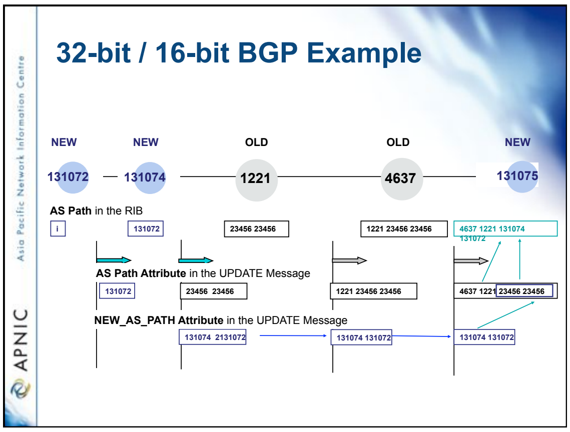
32-bit / 16-bit BGP Example
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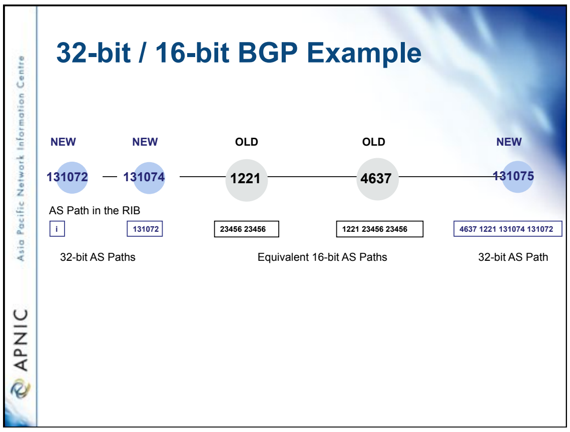
32-bit / 16-bit BGP Example
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32-bit AS Paths
Equivalent 16-bit AS Paths
32-bit AS Path
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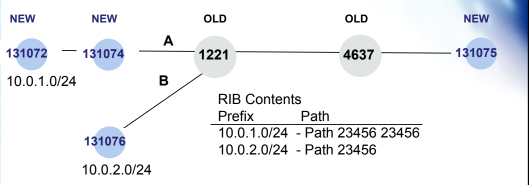
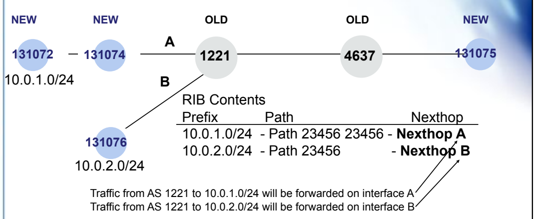
Can old-BGP get Confused?



NO! BGP Nexthop is the key!



This is standard BGP behaviour – nothing changes here for BGP as it is used today

NEW_AS_PATH Attribute

- BGP speakers in 16-bit AS domains should support **NEW_AS_PATH** as a transitive optional attribute in UPDATE messages
  - because that's where the 32-bit path is hiding
  - That's a "SHOULD" not a "MUST",
  - Its better if you do, but nothing fatally breaks if you don't
  - Mixed 2 / 4 Byte loops will get detected in the 16-bit world as a fallback
- Default BGP configurations will do the right thing here

NEW_AGGREGATOR Attribute

- BGP speakers in 16-bit AS domains should support **NEW_AGGREGATOR** as a transitive optional attribute in UPDATE messages
  - because that's where the 32-bit Aggregator AS is hiding
  - That's a "SHOULD" not a "MUST", by the way
  - Its better if you do, but nothing fatally breaks if you don't
- Default BGP configurations should do the right thing here

AS 23456

- **AS 23456** is going to appear in many 16-bit AS paths – both origin and transit
- This is not an error – it's a 16-bit token holder for a 32-bit AS number

AS Path and AS4 Path Example

Router5:

```
Network  Next Hop Metric LocPrf Weight Path
*> 2001::/32 2406:6400:F:41::1
                              0 23456 38610 6939 i
* i  2406:6400:D::5 0 100   0 45192 4608 4826 6939 i

*> 2001:200::/32    2406:6400:F:41::1
                          0 23456 38610 6939 2500 i
* i   2406:6400:D::5 0 100 0 45192 4608 4826 6939
   2500 i
```

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Questions?

Overview

IPv6 Workshop

- IPv6 Protocol Architecture Overview
- IPV6 Addressing and Sub-netting
- IPv6 Host Configuration
- Training ISP Network Topology Overview
- Deployment of IPV6 in Interior Gateway
- IPv4 to IPv6 Transition technologies
- Planning & Implementation of IPv6 on Exterior Gateway (BGP)
- **Connecting ISP network to an IXP**

Case study- IXP Configuration

Two type of traffic exchange between ISPs

- Transit
  - Where ISP will pay to send/receive traffic
  - Downstream ISP will pay upstream ISP for transit service
- Peering
  - ISPs will not pay each other to interchange traffic
  - Works well if win win for both
  - Reduce cost on expensive transit link

IX Peering Model

- **BLPA (Bi-Lateral Peering Agreement)**
  - IX will only provide layer two connection/switch port to ISPs
  - Every ISPs will arrange necessary peering arrangement with others by their mutual business understanding.
- **MLPA (Multi-Lateral Peering Agreement)**
  - IX will provide layer two connection/switch port to ISPs
  - Each ISP will peer with a **route server** on the IX.
  - Route server will collect and distribute directly connected routes to every peers.

IXP Peering Policy

- BLPA is applicable where different categories of ISPs are connected in an IX
  - Large ISPs can choose to peer with large ISPs (base on their traffic volume)
  - Small ISPs will arrange peering with small ISPs
- Would be preferable for large ISPs
  - They will peer with selected large ISPs (Equal traffic interchange)
  - Will not loose business by peering with small ISP

IX Peering Policy

- MLPA model works well to widen the IX scope of operation (i.e national IX).
- Easy to manage peering
  - Peer with the **route server** and get all available local routes.
  - Do not need to arrange peering with every ISPs connected to the IX.
- Unequal traffic condition can create not intersected situation to peer with route server

IX peering Policy

- Both peering model can be available in an IX.
- Member will select peering model i.e either BLPA or MLPA (Route Server Peering)
- IX will provide switch port
- **Mandatory MLPA** model some time not preferred by large ISP (Business Interest)
  - Can create not interested situation to connect to an IX

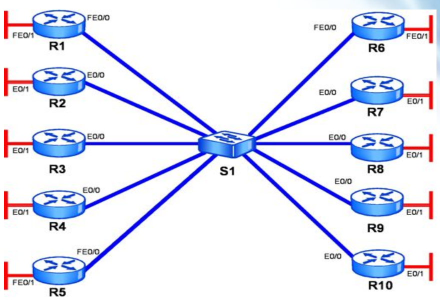
IX Operating Cost

- Access link
- Link maintenance
- Utility
- Administration

Cost Model

- Not for profit
- Cost sharing
- Membership based
- Commercial IX

IX Network Diagram



Case study- IXP Configuration

Required **global & interface** commands to enable IPv6

Router(Config)#ipv6 unicast-routing
Router(Config)#ipv6 cef (optional)

- Configure IPv6 address on interface

Router(Config-if)#ipv6 address *2001:0df0:00aa::1/64*
Router(Config-if)#ipv6 enable

- Verify IPv6 configuration

Router#sh ipv6 interface fa0/0

- Verify connectivity

Router#ping *2001:0df0:00aa::1*

Case study- IXP Configuration

- Required **BGP** commands to enable IPv6 routing

Router(config)# router bgp 1
Router2(config-router)#bgp router-id 10.0.0.1 (if no 32 bit address on any interface)

Router(config-router)# address-family ipv6
Router(config-router-af)# no synchronization
Router(config-router-af)# neighbor 2001:0df0:00aa::1 remote-as 2 (EBGP)
Router(config-router-af)#neighbor 2001:0df0:00aa::1 activate
Router(config-router-af)# network 2001:0df0:00aa::/48

- Verify BGP IPv6 configuration

Router#sh bgp ipv6 unicast summary (summarized neighbor list)
Router#sh bgp ipv6 unicast (BGP database)
Router#sh ipv6 route bgp (BGP routing table)

Case study- IXP Configuration

Required command to add IX prefix filter

- Create prefix filter in global mode

Router(config)#ipv6 prefix-list AS1 seq 2 permit 2001:0df0:aa::/48

- Apply prefix filter in BGP router configuration mode

Router(config-router)# address-family ipv6

Router(config-router-af)#neighbor 2001:0df0:aa::1 prefix-list AS1 in

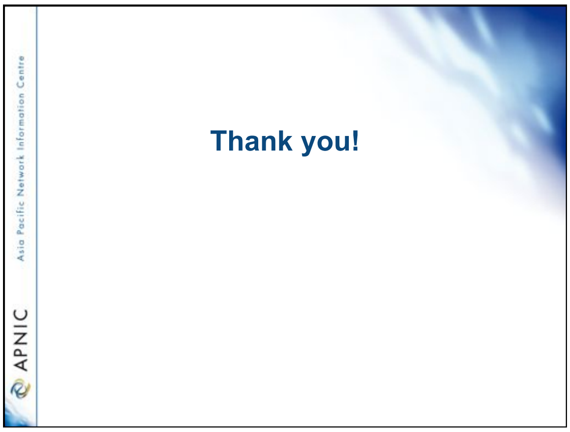
Router(config-router-af)#neighbor 2001:0df0:aa::1 prefix-list AS1 out

Case study- IXP Configuration

Controlling routing update traffic (Not data traffic)

1. Incoming routing update (Will control outgoing data traffic)
2. Outgoing routing update (Will control incoming data traffic)

Questions?


Thank you!
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