Introducing IPv6

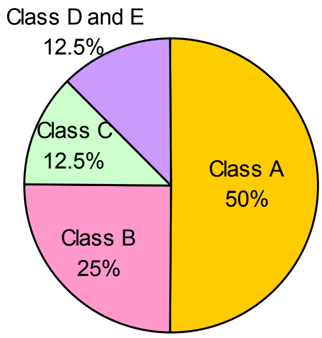
BSCI Module 8 Lessons 1 and 2

Why Do We Need a Larger Address Space?

- Internet population
  - Approximately 973 million users in November 2005
  - Emerging population and geopolitical and address space
- Mobile users
  - PDA, pen-tablet, notepad, and so on
  - Approximately 20 million in 2004
- Mobile phones
  - Already 1 billion mobile phones delivered by the industry
- Transportation
  - 1 billion automobiles forecast for 2008
  - Internet access in planes – Example: Lufthansa
- Consumer devices
  - Sony mandated that all its products be IPv6-enabled by 2005
  - Billions of home and industrial appliances

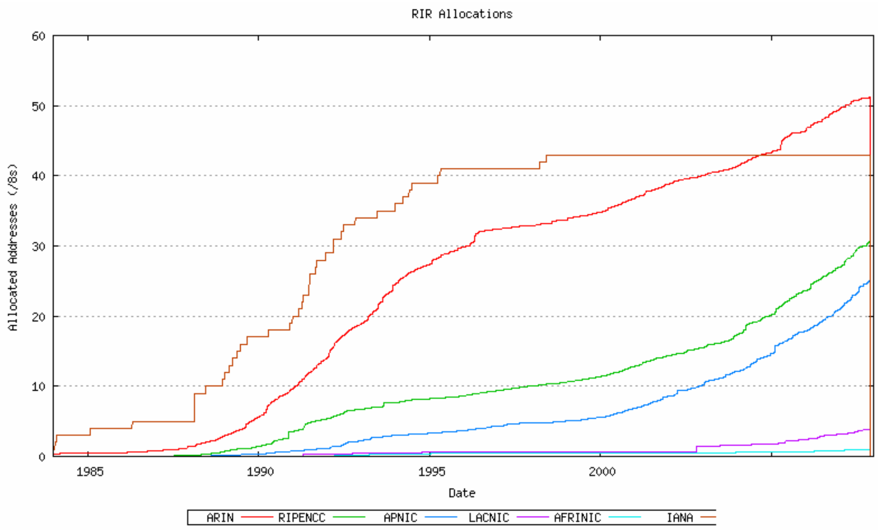
Problems with IPv4 Addressing

- Twenty-five years ago (1981), IP version 4, (IPv4) offered an addressing strategy
  - Address Depletion
  - Internet Routing Table Explosion



http://www.iana.org/assignments/ipv4-address-space

IPv4 assignment by region

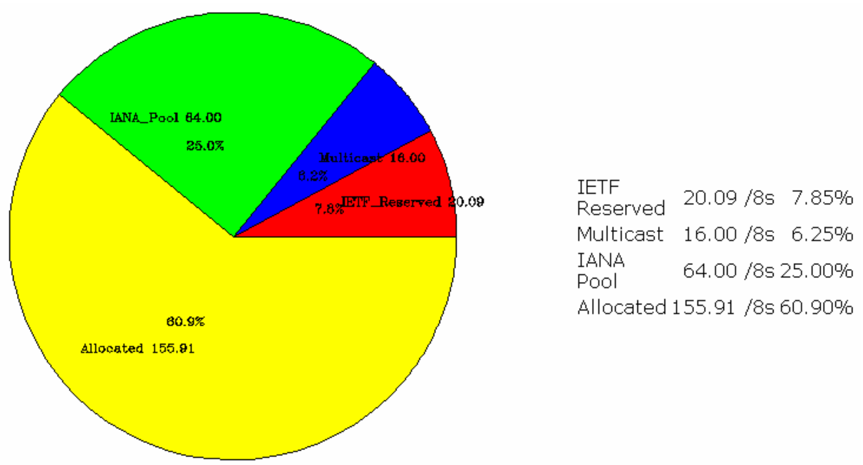


IANA IPv4 Address Registry

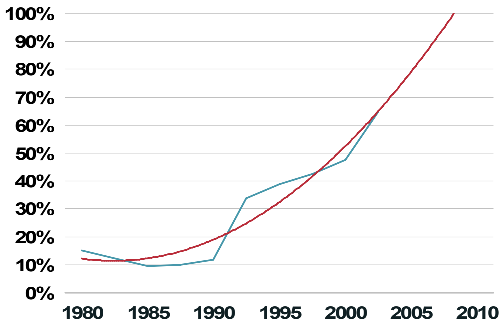
- The address block from **224.0.0.0 through to 239.255.255.255** is reserved for **Multicast** use (16 /8 blocks).
- The address block from **240.0.0.0 through to 255.255.255.255** is **reserved** for future definition (16 /8 blocks).
- The address blocks **0.0.0.0/8, 14.0.0.0/8**, and **127.0.0.0/8** are **reserved**, as are the **address ranges used for private networks** and other reserved uses.
- The remaining addresses, the equivalent of 219.92 /8 address blocks form the pool of unicast addresses which are used for the Internet.
- The IPv4 Unicast Address Pool is divided into 2 parts:
  - Those addresses held in the "**IANA Reserved**" pool, **or** "**UnAllocated**" addresses.

    This pool is used to meet future address requirements
  - Those addresses that have been allocated to the RIRs or directly to end users, or "**Allocated**" addresses.
- IANA IPv4 Address Registry

IANA IPv4 Address Registry

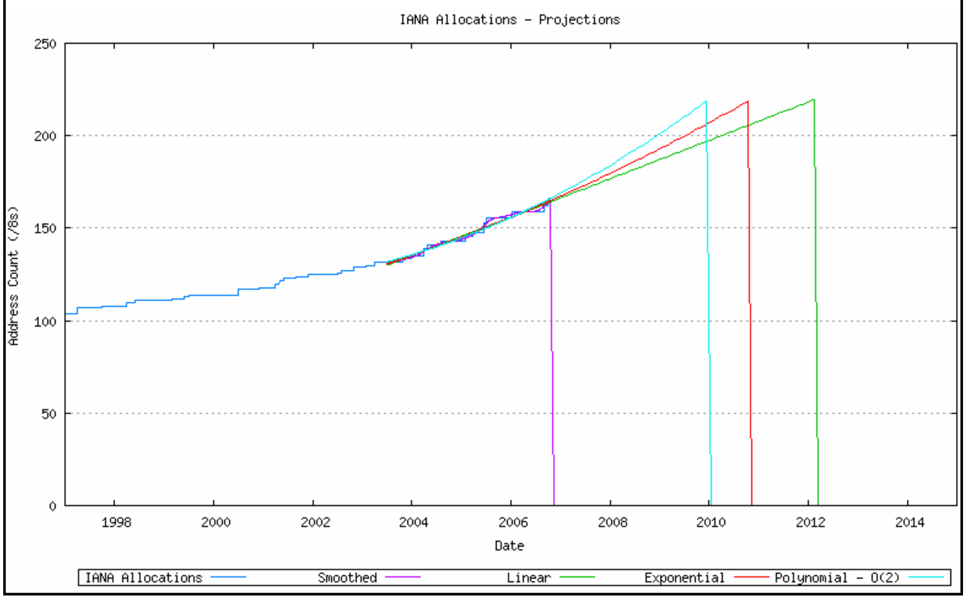


IP Address Allocation History



- In 1981, IPv4 Protocol was published.
- In 1985, about 1/16 of the total IPv4 address space was in use.
- By mid-2001, about 2/3 of the total IPv4 address space was in use.

IPv4 address depletion



IPv4 address depletion

- Exhaustion of the IPv4 Unallocated Address Pool

  June 2011 (dades de Octubre 2006)

  November 2010 (dades de Novembre 2007)

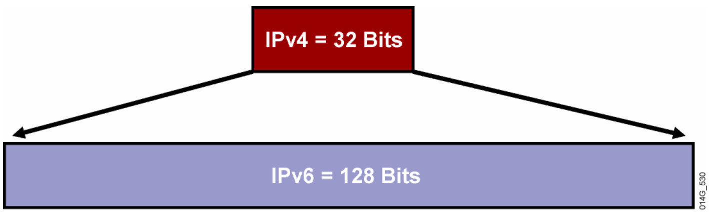
- Complete Exhaustion of all available IPv4 Address Space:

  October 2015 (dades de Octubre 2006)

  August 2011 (dades de Novembre 2007)

http://bgp.potaroo.net/index-ale.html

Larger Address Space



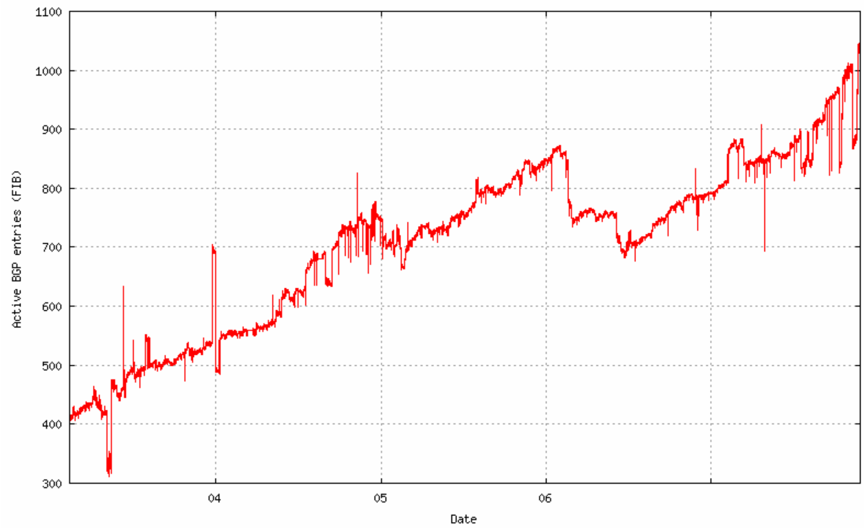
IPv4

- 32 bits or 4 bytes long
  - ≅ 4,200,000,000 possible addressable nodes

IPv6

- 128 bits or 16 bytes: four times the bits of IPv4
  - ≅ 3.4 * 10^{38} possible addressable nodes
  - ≅ 340,282,366,920,938,463,374,607,432,768,211,456
  - ≅ 5 * 10^{28} addresses per person

The “new” protocol: IPv6



The new protocol: IPv6

- IPv6 is compatible with IPv4 since the beginning

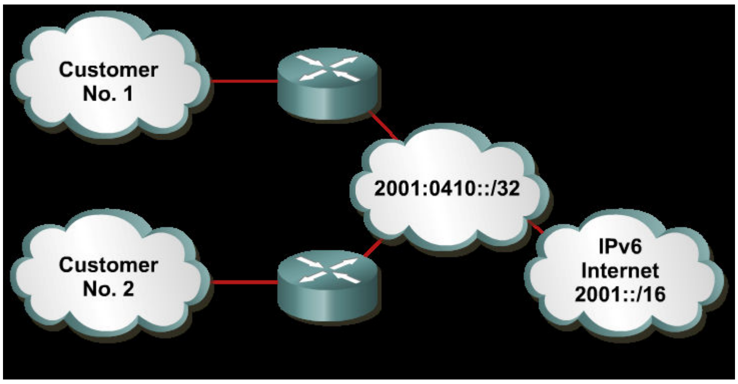
¿Who supports IPv6?

- Worldwide network: 6BONE
- Asia: Main driver
  - The most important groups of investigation are Asian
    - WIDE project: KAME, TAHI and USAGI
  - Japan: The administration networks MUST be IPv6 by 2005 (law enforcement)
- USA: The DoD will not buy any equipment that does not support IPv6. January 2004.
- Europe: Mobile Telephony 3G

IPv6 competitive advantages

- Cost savings with IP address let.
  - IPv4: One address for one end user (and dynamic!)
  - IPv6: A 64 bits range for one end user
- Features that provide advantages…
  - Autoconfiguration
  - Security
  - QoS
  - VoIPv6
  - Mobility

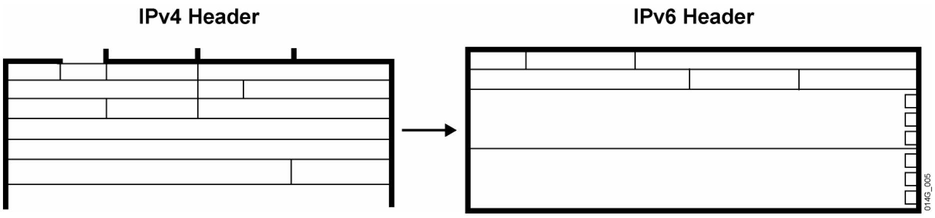
Larger Address Space Enables Address Aggregation



- Aggregation of prefixes announced in the global routing table
- Efficient and scalable routing
- Improved bandwidth and functionality for user traffic

Defining IPv6 Addressing

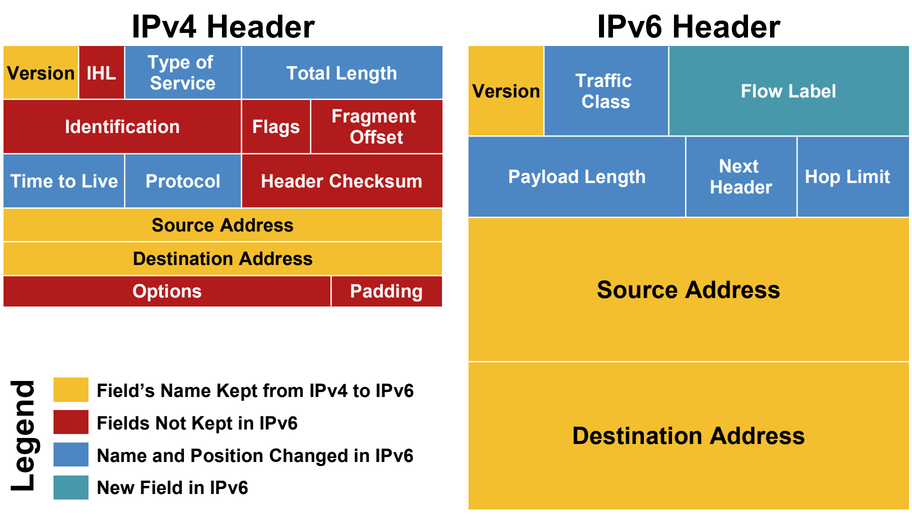
Simple and Efficient Header



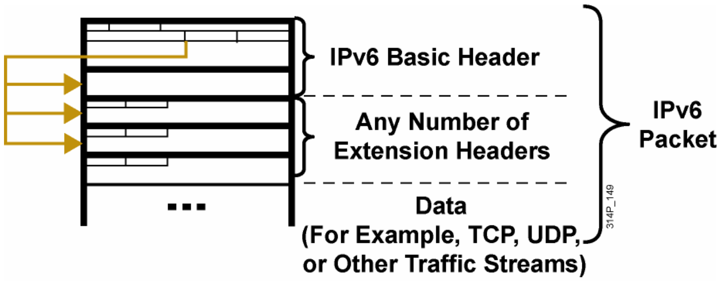
A simpler and more efficient header means:

- 64-bit aligned fields and fewer fields
- Hardware-based, efficient processing
- Improved routing efficiency and performance
- Faster forwarding rate with better scalability

IPv4 and IPv6 Header Comparison



IPv6 Extension Headers



Simpler and more efficient header means:

- IPv6 has extension headers.
- IPv6 handles the options more efficiently.
- IPv6 enables faster forwarding rate and end nodes processing.

IPv6 Address Representation

- ***x*:*x*:*x*:*x*:*x*:*x*:*x*:*x*,** where ***x*** is a 16-bit hexadecimal field
- Leading zeros in a field are optional:

  2031:0:130F:0:0:9C0:876A:130B

- Successive fields of 0 can be represented as ::, but only once per address.

Examples:

2031:0000:130F:0000:0000:09C0:876A:130B

2031:0:130f::9c0:876a:130b

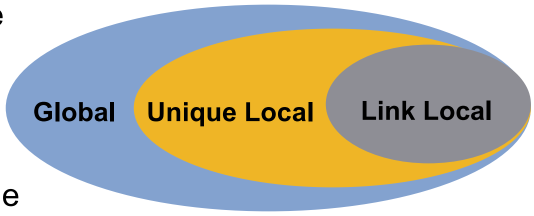
FF01:0:0:0:0:0:0:1 >>> FF01::1

0:0:0:0:0:0:0:1 >>> ::1

2001::2288::2A89 ???

IPv6 - Addressing Model

- Addresses are assigned to interfaces
  - Change from IPv4 mode:
- Interface “expected” to have multiple addresses
- Addresses have scope
  - Link Local
  - Unique Local
  - Global

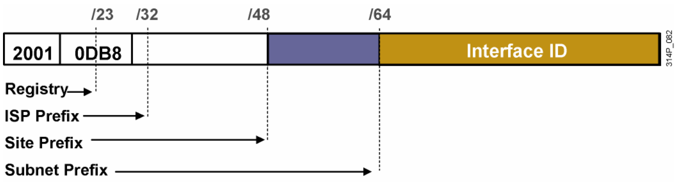


- Addresses have lifetime
  - Valid and preferred lifetime

IPv6 Address Types

- Unicast
  - Address is for a single interface.
  - IPv6 has several types (for example, global and IPv4 mapped).
- Multicast
  - One-to-many
  - Enables more efficient use of the network
  - Uses a larger address range
- Anycast
  - One-to-nearest (allocated from unicast address space).
  - Multiple devices share the same address.
  - All anycast nodes should provide uniform service.
  - Source devices send packets to anycast address.
  - Routers decide on closest device to reach that destination.
  - Suitable for load balancing and content delivery services.

IPv6 Global Unicast (and Anycast) Addresses



- Global unicast and anycast addresses are defined by a global routing prefix, a subnet ID, and an interface ID.

IPv6 Unicast Addressing

- IPv6 addressing rules are covered by multiple RFCs.
  - Architecture defined by RFC 4291.
- Unicast: One to one
  - Global
  - Link local (FE80::/10)
- A single interface may be assigned multiple IPv6 addresses of any type: unicast, anycast, or multicast.

Implementing Dynamic IPv6 Addresses

BSCI Module 8 Lesson 3

IPv6 address format

IPv6 address has three levels of hierarchy

Number of Bits

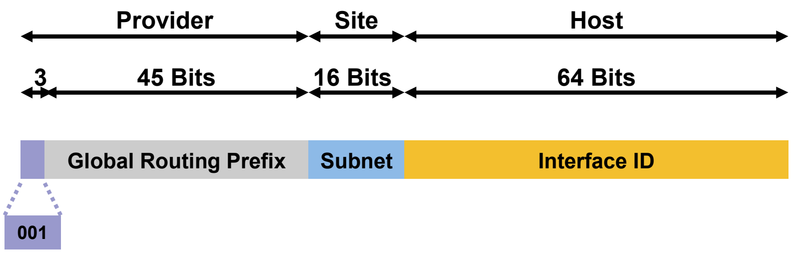
3	13	8	24	16	64
FP	TLA ID	Res	NLA ID	SLA ID	Interface ID
Public Topology				**Site Topology**	**Interface Identifier**

RFC 2374 obsoleta!!!

(RFC 3587)

```
|         n bits          | 64-n bits |          64 bits            |
+-------------------------+-----------+-----------------------------+
|  global routing prefix  | subnet ID |        interface ID         |
+-------------------------+-----------+-----------------------------+
```


Aggregatable Global Unicast Addresses

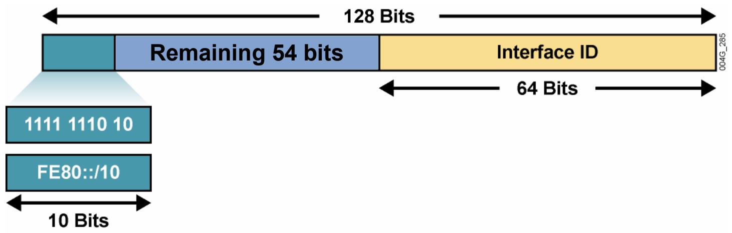


Aggregatable Global Unicast Addresses Are:

- Addresses for generic use of IPv6
- Structured as a hierarchy to keep the aggregation

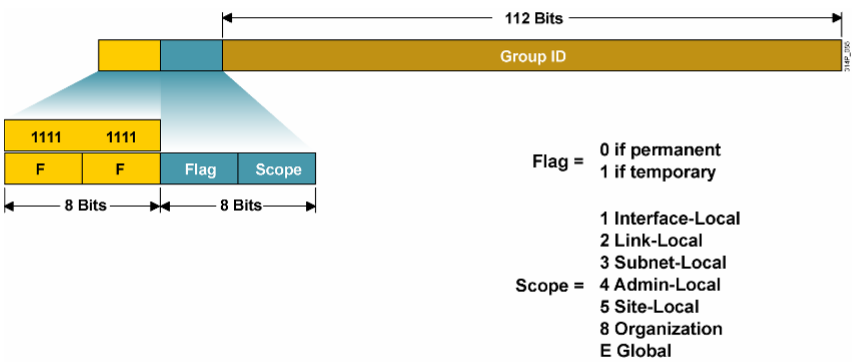
MAC Address to EUI-64

Link-Local Address



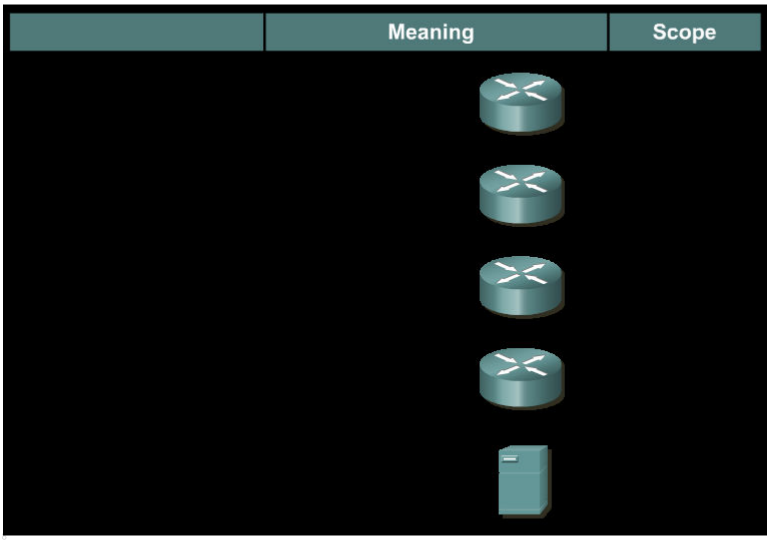
- Mandatory address for communication between two IPv6 devices (similar to ARP but at Layer 3)
- Automatically assigned by router as soon as IPv6 is enabled
- Also used for next-hop calculation in routing protocols
- Only link specific scope
- Remaining 54 bits could be zero or any manual configured value

Multicasting

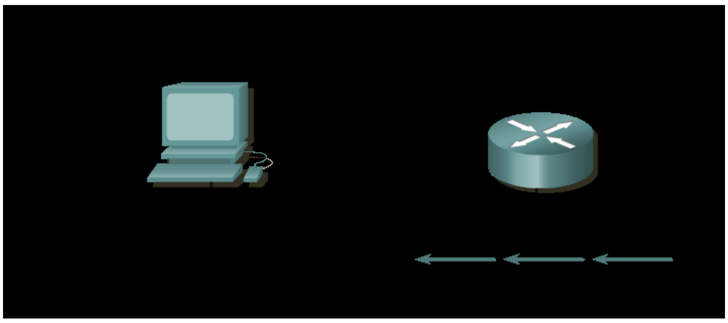


- Multicast is frequently used in IPv6 and replaces broadcast.

Examples of Permanent Multicast Addresses

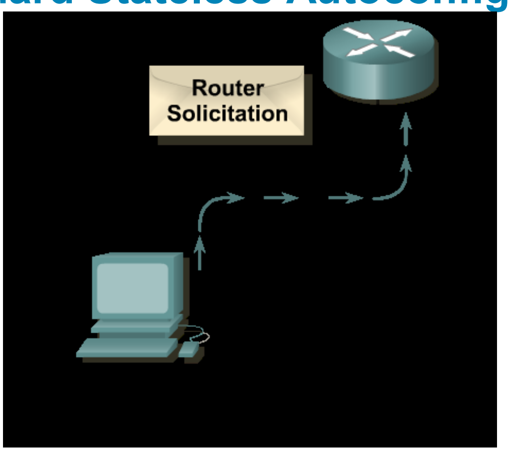


Stateless Autoconfiguration



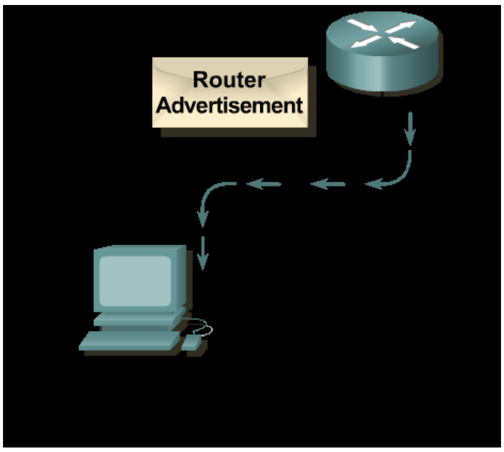
- A router sends network information to all the nodes on the local link.
- A host can autoconfigure itself by appending its IPv6 interface identifier (64-bit format) to the local link prefix (64 bits).
- The result is a full 128-bit address that is usable and guaranteed to be globally unique.

A Standard Stateless Autoconfiguration



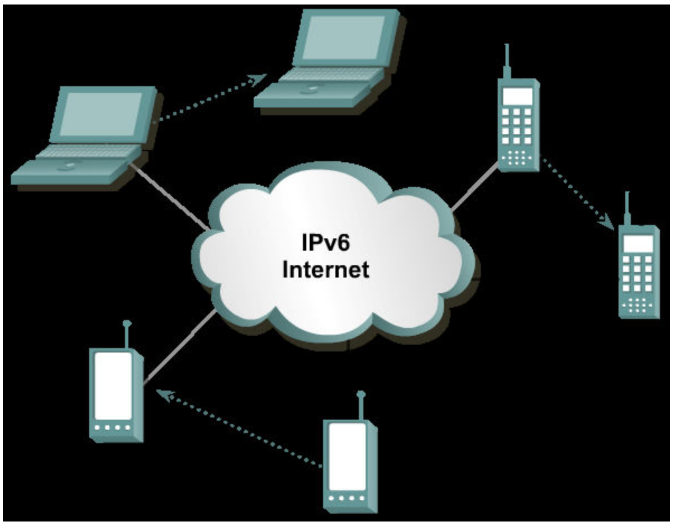
- Stage 1: The PC sends a router solicitation to request a prefix for stateless autoconfiguration.

A Standard Stateless Autoconfiguration (Cont.)



- Stage 2: The router replies with a router advertisement.

IPv6 Mobility

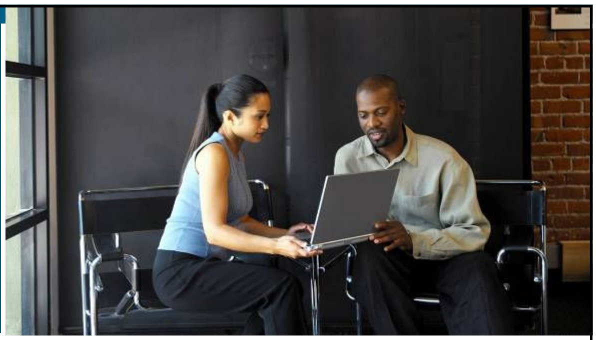


cisco

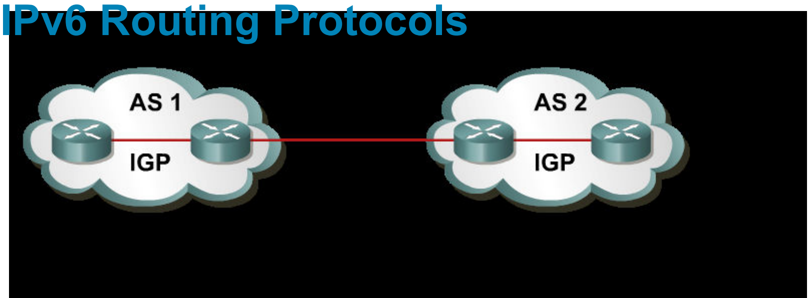
Implementing IPv6 with OSPF and Other Routing Protocols

BSCI Module 8 – Lesson 4

IPv6 Routing Protocols

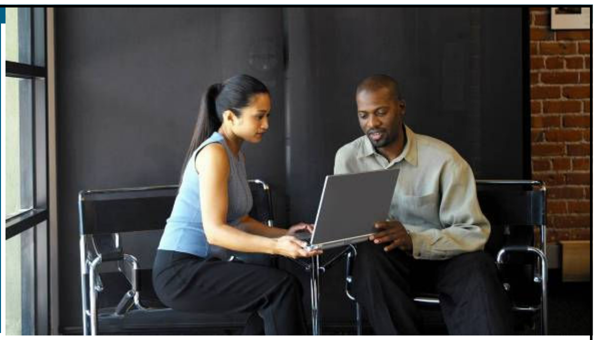


IPv6 Routing Protocols



- IPv6 routing types:
  - Static
  - RIPng (RFC 2080)
  - OSPFv3 (RFC 2740)
  - IS-IS for IPv6
  - MP-BGP4 (RFC 2545/2858)
  - EIGRP for IPv6
- **`ipv6 unicast-routing`** command is required to enable IPv6 before any routing protocol configured.

OSPFv3



OSPFv3-Similarities with OSPFv2

- OSPFv3 is OSPF for IPv6 (RFC 2740):
  - Based on OSPFv2, with enhancements
  - Distributes IPv6 prefixes
  - Runs directly over IPv6
- OSPFv3 & v2 can be run concurrently, because each address family has a separate SPF.
- OSPFv3 uses the same basic packet types as OSPFv2:
  - Hello
  - Database description blocks (DDB)
  - Link state request (LSR)
  - Link state update (LSU)
  - Link state acknowledgement (ACK)

OSPFv3-Similarities with OSPFv2

- Neighbor discovery and adjacency formation mechanism are identical.
- RFC compliant NBMA and point-to-multipoint topology modes are supported. Also supports other modes from Cisco such as point-to-point and broadcast, including the interface.
- LSA flooding and aging mechanisms are identical.

Enhanced Routing Protocol Support Differences from OSPFv2

- OSPFv3 has the same five packet types, but some fields have been changed.

Packet Type	Description
1	Hello
2	Database Description
3	Link State Request
4	Link State Update
5	Link State Acknowledgement

- All OSPFv3 packets have a 16-byte header verses the 24-byte header in OSPFv2.

Version	Type	Packet Length
Router ID		
Area ID		
Checksum	Autype	
Authentication		
Authentication		

Version	Type	Packet Length	
Router ID			
Area ID			
Checksum	Instance ID	0	

OSPFv3-Differences from OSPFv2

OSPFv3 protocol processing per-link, not per-subnet:

- IPv6 connects interfaces to links.
- Multiple IPv6 subnets can be assigned to a single link.
- Two nodes can talk directly over a single link, even though they do not share a common subnet.
- The terms “network” and “subnet” are being replaced with “link”.
- An OSPF interface now connects to a link instead of a subnet.

OSPFv3-Differences from OSPFv2

Multiple OSPFv3 protocol instances can now run over a single link:

- This allows for separate autonomous systems, each running OSPF, to use a common link. A single link could belong to multiple areas.
- Instance ID is a new field that is used to have multiple OSPFv3 protocol instances per link.
- In order to have two instances talk to each other, they need to have the same instance ID. By default it is 0, and for any additional instance it is increased.

OSPFv3-Differences from OSPFv2

- Multicast addresses:

  FF02::5 – Represents all SPF routers on the link local scope; equivalent to 224.0.0.5 in OSPFv2.

  FF02::6 – Represents all DR routers on the link local scope; equivalent to 224.0.0.6 in OSPFv2.

- Removal of address semantics:

  IPv6 addresses are no longer present in OSPF packet header (part of payload information).

  Router LSA and network LSA do not carry IPv6 addresses.

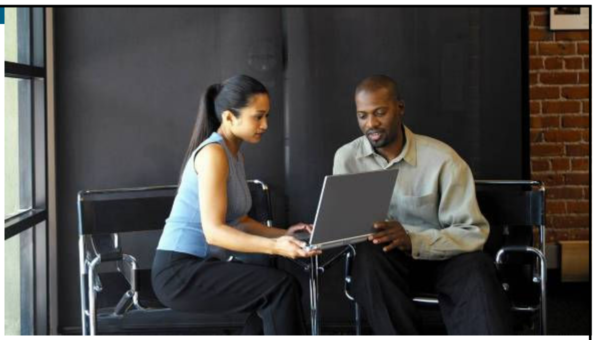
  Router ID, area ID, and link-state ID remains at 32 bits.

  DR and BDR are now identified by their router ID and no longer by their IP address.

- Security:

  OSPFv3 uses IPv6 AH and ESP extension headers instead of variety of mechanisms defined in OSPFv2.

OSPFv3 Configuration



Configuring OSPFv3 in Cisco IOS Software

- Similar to OSPFv2:

  Prefixing existing Interface and exec mode commands with "ipv6"

- Interfaces configured directly:

  Replaces **`network`** command

- "Native" IPv6 router mode:

  Not a submode of **`router ospf`** command

IPv6 and OSPFv3 Commands

Command	Description
`Router(config)#`**`ipv6 unicast-routing`**	Enables the forwarding of IPv6 unicast datagrams.
`Router(config)#`**`ipv6 router ospf`** *`process-id`*	Enables an OSPF process on the router. The process-id parameter identifies a unique OSPFv3 process. This command is used on a global basis.
Example: `Router(config)#ipv6 router ospf 1`	Enables the OSPFv3 process number 1 on the router.
`Router (config-router)# router-id` *`router-id`*	For an IPv6-only router, a **router-id** parameter must be defined in the OSPFv3 configuration as an IPv4 address using the **router-id** *router-id* command. You can use any IPv4 address as the router-id value.
Example: `Router (config-router)# router-id 2.2.2.2`	Identifies 2.2.2.2 as the router-id for this router. It must be unique on each router

Enabling OSPFv3 Globally

Tera Term - COM1 VT

File Edit Setup Control Window Help

```
router#
router# configure terminal
router(config)# ipv6 unicast-routing
router(config)# ipv6 router ospf 1
router(config-router)# router-id 2.2.2.2
```


Steps for Enabling IPv6 and OSPFv3 on an Interface

Step	Command or Action	Purpose
1	`Router(config)#interface` *`type number`*	Specifies an interface type and number, and places the router in interface configuration mode.
2	`Router(config-if)#ipv6 address` *`address/prefix-length`* `[eui-64]`	Configures an IPv6 address for an interface and enables IPv6 processing on the interface. The **eui-64** parameter forces the router to complete the addresses' low-order 64-bits by using an EUI-64 interface ID.
3	`Router(config-if)#ipv6 ospf` *`process-id`* `area` *`area-id`* `[instance` *`instance-id`*`]`	Enables OSPF for IPv6 on an interface.
4	`Router(config-if)#router ospf priority` *`priority number`*	Priority number is used in the designated router election.
5	`Router(config-if)#router ospf cost` *`cost`*	The cost of sending a packet on the interface, expressed in the link state metric.

Enabling OSPFv3 on an Interface

Tera Term - COM1 VT

File Edit Setup Control Window Help

```
router(config)# interface FastEthernet0/0
router(config-if)# ipv6 address 3FFE:FFFF:1::1/64
router(config-if)# ipv6 ospf 1 area 0
router(config-if)# ipv6 ospf priority 20
router(config-if)# ipv6 ospf cost 20
```


Cisco IOS OSPFv3 Specific Attributes

- Configuring area range:

  area area-id range prefix/prefix length
  [advertise | not-advertise] [cost cost]

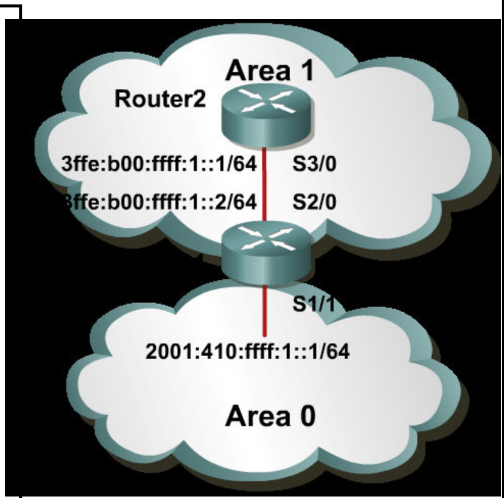
- Showing new LSAs:

  show ipv6 ospf [process-id] database link

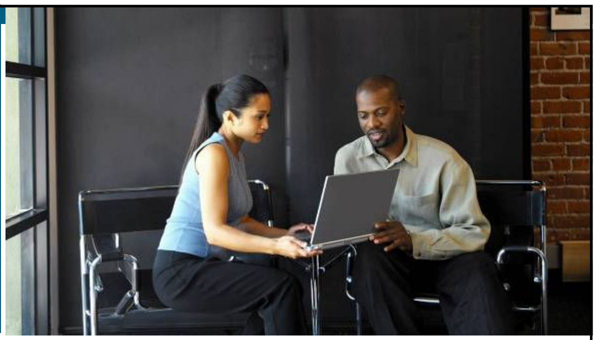
  show ipv6 ospf [process-id] database prefix

OSPFv3 Configuration Example

```
Router2#
interface S3/0
 ipv6 address 3FFE:B00:FFFF:1::1/64
 ipv6 ospf 100 area 1

ipv6 router ospf 100
   router-id 10.1.1.4


Router1#
interface S1/1
 ipv6 address 2001:410:FFFF:1::1/64
 ipv6 ospf 100 area 0

interface S2/0
 ipv6 address 3FFE:B00:FFFF:1::2/64
 ipv6 ospf 100 area 1

 ipv6 router ospf 100
   router-id 10.1.1.3
```



OSPFv3 Verification



Verifying Cisco IOS OSPFv3

```
Router2#show ipv6 ospf int s 3/0
S3/0 is up, line protocol is up
  Link Local Address 3FFE:B00:FFFF:1::1, Interface ID 7
  Area 1, Process ID 100, Instance ID 0, Router ID 10.1.1.4
  Network Type POINT_TO_POINT, Cost: 1
  Transmit Delay is 1 sec, State POINT_TO_POINT,
  Timer intervals configured, Hello 10, Dead 40, Wait 40,
Retransmit 5
    Hello due in 00:00:02
  Index 1/1/1, flood queue length 0
  Next 0x0(0)/0x0(0)/0x0(0)
  Last flood scan length is 3, maximum is 3
  Last flood scan time is 0 msec, maximum is 0 msec
  Neighbor Count is 1, Adjacent neighbor count is 1
    Adjacent with neighbor 10.1.1.3
  Suppress hello for 0 neighbor(s)
```


show ipv6 ospf

```
R7#show ipv6 ospf
Routing Process "ospfv3 1" with ID 75.0.7.1
It is an area border and autonomous system boundary router
Redistributing External Routes from, connected
SPF schedule delay 5 secs, Hold time between two SPFs 10 secs
Minimum LSA interval 5 secs. Minimum LSA arrival 1 secs
LSA group pacing timer 240 secs
Interface floor pacing timer 33 msecs
Retransmission pacing timer 33 msecs
Number of external LSA 3. Checksum Sum 0x12B75
```

show ipv6 ospf (Cont.)

```
Number of areas in this router is 2. 1 normal 0 stub 1 nssa
     Area BACKBONE(0)
         Number of interfaces in this area is 1
         SPF algorithm executed 23 times
         Number of LSA 14. Checksum Sum 0x760AA
         Number of DCbitless LSA 0
         Number of Indication LSA 0
         Number of DoNotAge LSA 0
         Flood list length 0
    Area 2
        Number of interfaces in this area is 1
        It is a NSSA area
        Perform type-7/type-5 LSA translation
        SPF algorithm executed 17 times
        Number of LSA 25. Checksum Sum 0xE3BF0
        Number of DCbitless LSA 0
        Number of Indication LSA 0
        Number of DoNotAge LSA 0
```


show ipv6 ospf neighbor detail

```
Router2#show ipv6 ospf neighbor detail
 Neighbor 10.1.1.3
    In the area 0 via interface S2/0
    Neighbor: interface-id 14, link-local address 3FFE:B00:FFFF:1::2
    Neighbor priority is 1, State is FULL, 6 state changes
    Options is 0x63AD1B0D
    Dead timer due in 00:00:33
    Neighbor is up for 00:48:56
    Index 1/1/1, retransmission queue length 0, number of retransmission 1
    First 0x0(0)/0x0(0)/0x0(0) Next 0x0(0)/0x0(0)/0x0(0)
    Last retransmission scan length is 1, maximum is 1
    Last retransmission scan time is 0 msec, maximum is 0 msec
```

show ipv6 ospf database

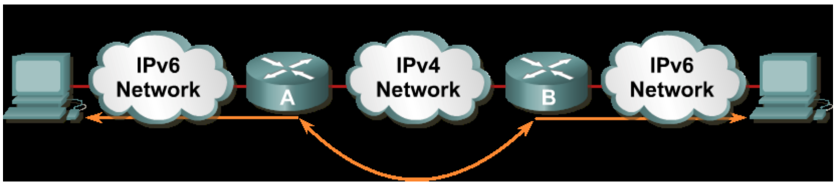
```
        Router Link States (Area 1)
ADV Router     Age     Seq#          Fragment ID   Link count Bits
26.50.0.1      1812    0x80000048    0          1   None
26.50.0.2      1901    0x80000006    0          1   B
        Net Link States (Area 1)
ADV Router     Age     Seq#          Link   ID     Rtr count
26.50.0.1      57      0x8000003B     3            4

        Inter Area Prefix Link States (Area 1)
ADV Router     Age     Seq#          Prefix
26.50.0.2      139     0x80000003    3FFE:FFFF:26::/64
26.50.0.2      719     0x80000001    3FFE:FFF:26::/64

        Inter Area Router Link States (Area 1)
ADV Router     Age     Seq#          Link ID       Dest RtrID
26.50.0.2      772     0x80000001    1207959556    72.0.0.4
26.50.0.4        5     0x80000003    1258292993    75.0.7.1
```


Using IPv6 with IPv4

BSCI Module 8 – Lesson 5

IPv4-to-IPv6 Transition

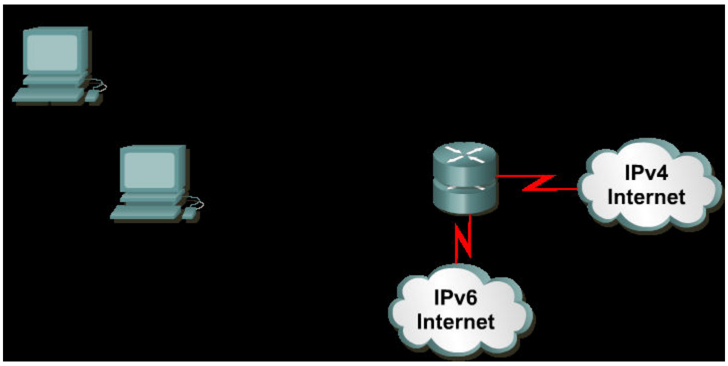
IPv4-to-IPv6 Transition



Transition richness means:

- No fixed day to convert; no need to convert all at once.
- Different transition mechanisms are available:
  - Smooth integration of IPv4 and IPv6
  - Use of dual stack or 6-to-4 tunnels
- Different compatibility mechanisms:
  - IPv4 and IPv6 nodes can communicate

Dual Stack

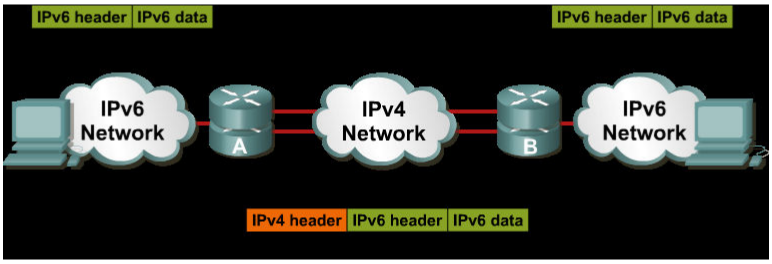


- Dual stack is an integration method where a node has “implementation and connectivity” to both an IPv4 and IPv6 network.

Cisco IOS Software is IPv6-Ready: Cisco IOS Dual Stack

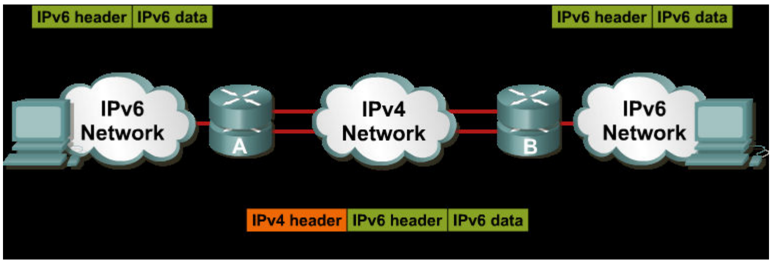
- If both IPv4 and IPv6 are configured on an interface, this interface is dual-stacked.

Tunneling



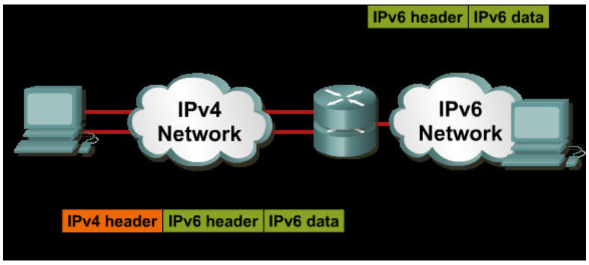
- Tunneling is an integration method where an IPv6 packet is encapsulated within another protocol, such as IPv4. This method of encapsulation is IPv4 protocol 41:
  - This includes a 20-byte IPv4 header with no options and an IPv6 header and payload.
  - This is considered dual stacking.

Cisco IOS Software is IPv6-Ready: Overlay Tunnels



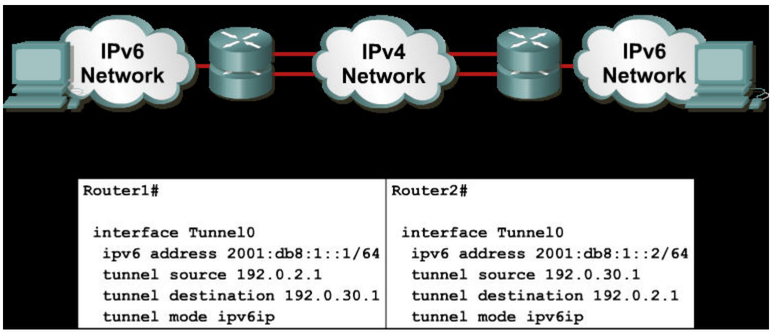
- Tunneling encapsulates the IPv6 packet in the IPv4 packet.

“Isolated” Dual-Stack Host

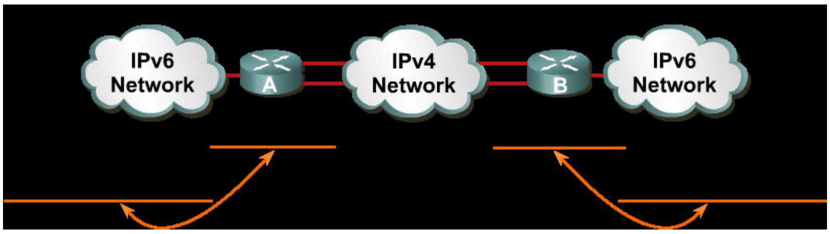


- Encapsulation can be done by edge routers between hosts or between a host and a router.

Example: Cisco IOS Tunnel Configuration

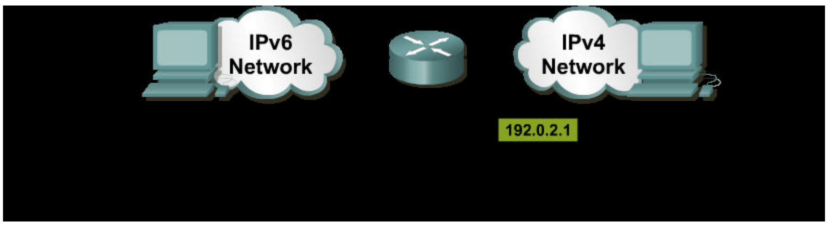


Cisco IOS Software is IPv6-Ready: 6-to-4 Tunneling



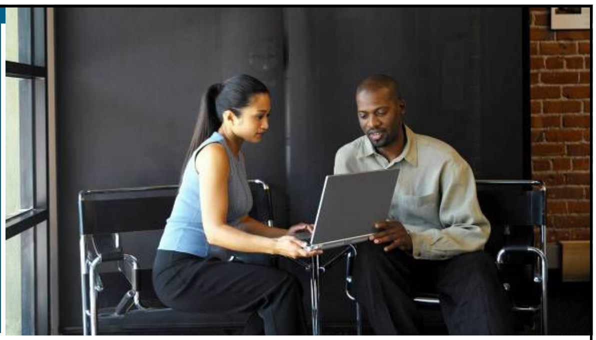
- 6-to-4:
  - Is an automatic tunnel method
  - Gives a prefix to the attached IPv6 network

Translation – NAT-PT



- NAT-Protocol Translation (NAT-PT) is a translation mechanism that sits between an IPv6 network and an IPv4 network.
- The job of the translator is to translate IPv6 packets into IPv4 packets and vice versa.

Q and A



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