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Chapter 8
IPv6 Addressing and configuration

by Hadjira BELAIDI

Objectives

After completing this chapter, you will be able to:

- ✓Describe types of IPv6 network addresses.
- ✓Configure global unicast addresses.
- ✓Describe multicast addresses.
- ✓Describe the role of ICMP in an IPv6 network.
- ✓Use ping and traceroute utilities to test network connectivity.

Chap8 Outlines

- Introduction
- IPv6 Unicast Addresses
- Static Configuration of a Global Unicast Address
- Dynamic Configuration of a Global Unicast Address
- EUI-64 Process or Randomly Generated
- Dynamic and Static Link-local Addresses
- Assigned IPv6 Multicast Addresses
- Connectivity Verification

Outlines

IPv6 Address Representation

- 128 bits in length and written as a string of hexadecimal values
- In IPv6, 4 bits represents a single hexadecimal digit, 32 hexadecimal value = IPv6 address

  –2001:0DB8:0000:1111:0000:0000:0000:0200

  –FE80:0000:0000:0000:0123:4567:89AB:CDEF

- Hextet used to refer to a segment of 16 bits or four hexadecimals
- Can be written in either lowercase or uppercase

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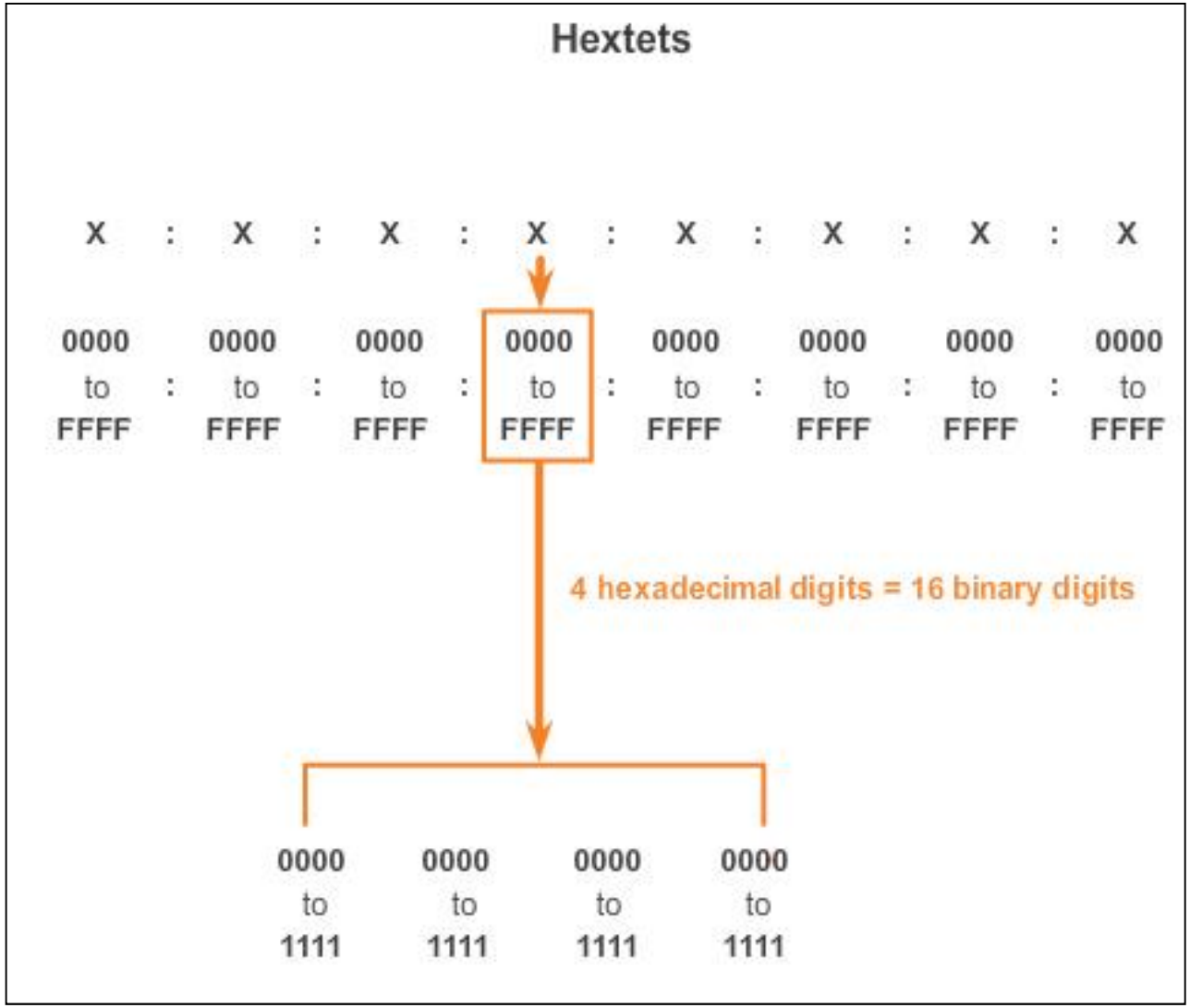


Outlines

Rule 1- Omitting Leading 0s

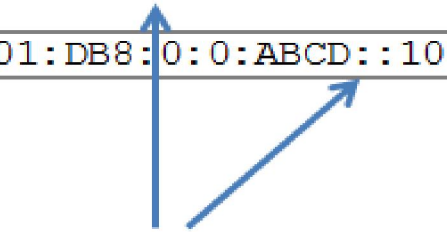
- The first rule to help reduce the notation of IPv6 addresses is any leading 0s (zeros) in any 16-bit section or hextet can be omitted.
- 01AB can be represented as 1AB.
- 09F0 can be represented as 9F0.
- 0A00 can be represented as A00.
- 00AB can be represented as AB.

Preferred	2001:0DB8:000A:1000:0000:0000:0000:0100
No leading 0s	2001: DB8: A:1000: 0: 0: 0: 100
Compressed	2001:DB8:A:1000:0:0:0:100

Rule 2 - Omitting All 0 Segments

- A double colon (::) can replace any single, contiguous string of one or more 16-bit segments (hextets) consisting of all 0's.
- Double colon (::) can only be used once within an address otherwise the address will be ambiguous.
- Known as the *compressed format.*
- Incorrect address - 2001:0DB8::ABCD::1234.

Preferred	2001:0DB8:0000:0000:ABCD:0000:0000:0100
Omit leading 0s	2001: DB8: 0: 0:ABCD: 0: 0: 100
Compressed	2001:DB8::ABCD:0:0:100
OR	
Compressed	2001:DB8:0:0:ABCD::100

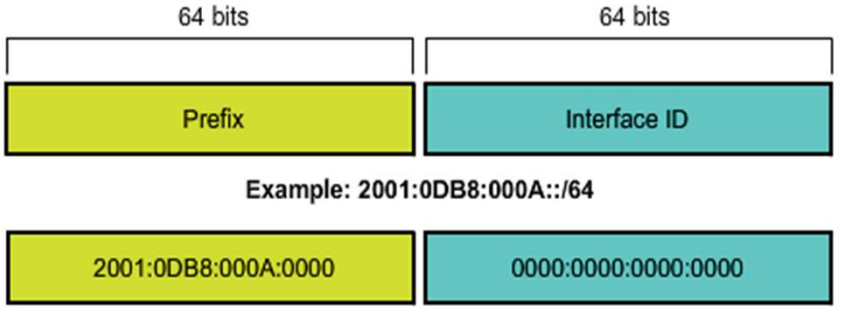


Only one : : may be used.

Preferred	FE80:0000:0000:0000:0123:4567:89AB:CDEF
Omit leading 0s	FE80: 0: 0: 0: 123:4567:89AB:CDEF
Compressed	FE80::123:4567:89AB:CDEF

IPv6 Prefix Length

- IPv6 does not use the dotted-decimal subnet mask notation
- Prefix length indicates the network portion of an IPv6 address using the following format:
  - IPv6 address/prefix length
  - Prefix length can range from 0 to 128
  - Typical prefix length is /64



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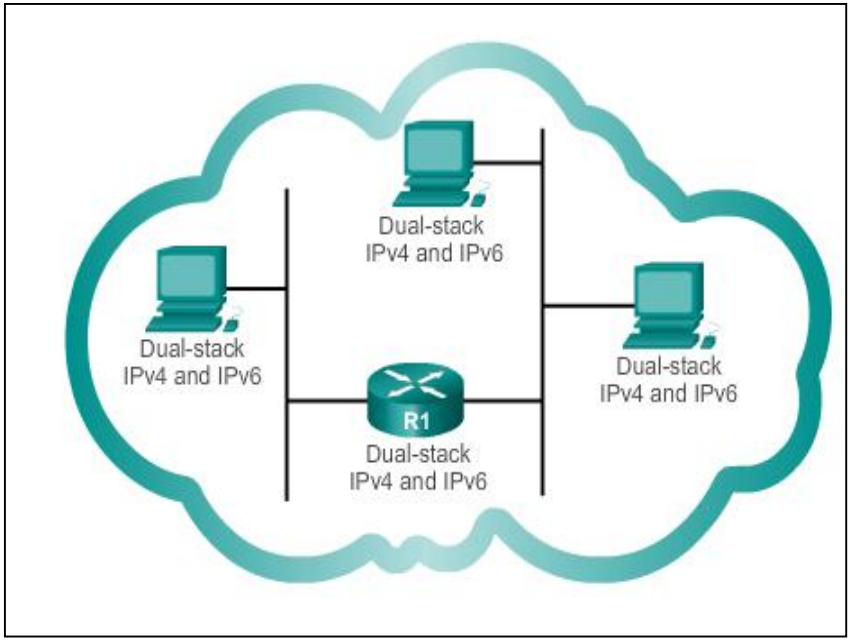
IPv4 and IPv6 Coexistence

The migration techniques can be divided into three categories: Dual-stack, Tunnelling, and Translation.

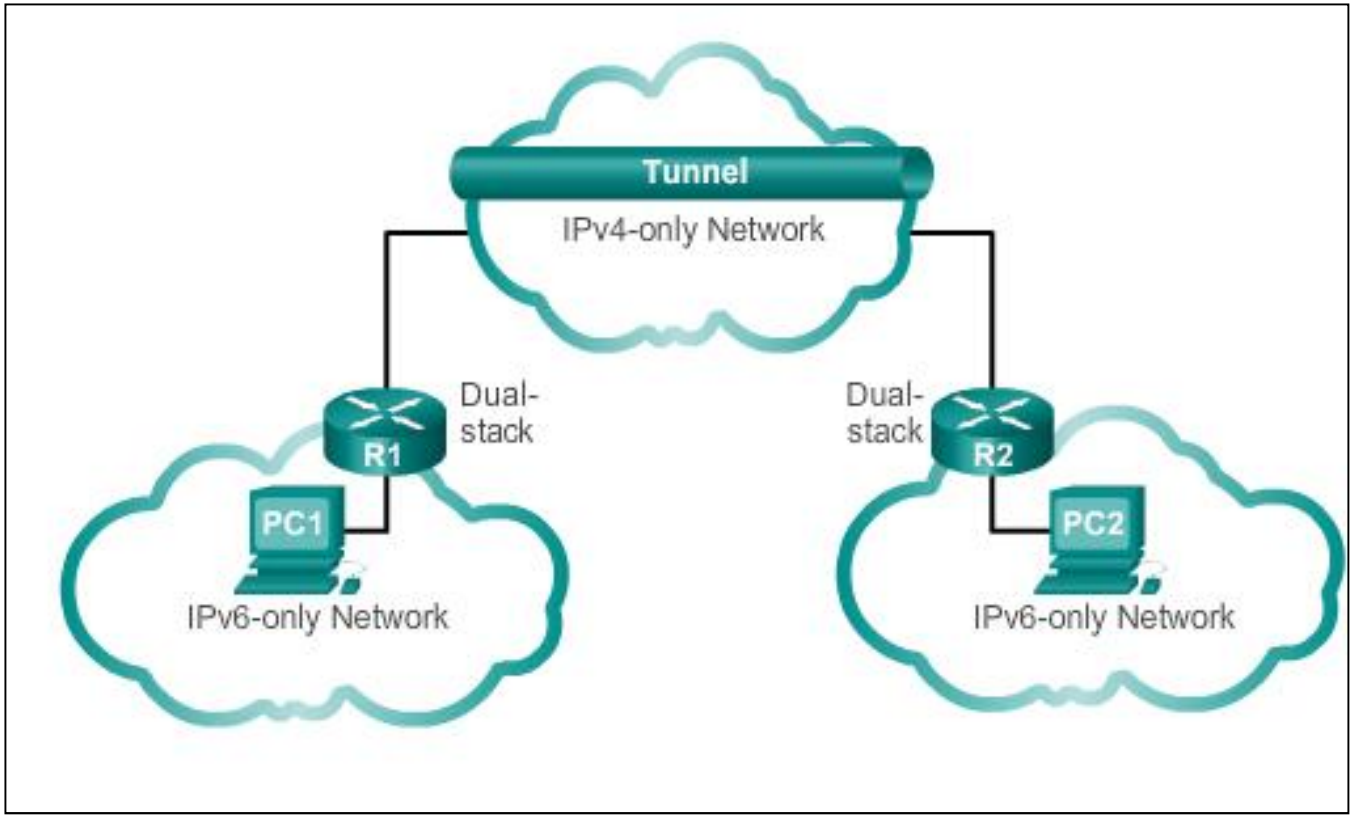
Dual-stack



Dual-stack: Allows IPv4 and IPv6 to coexist on the same network. Devices run both IPv4 and IPv6 protocol stacks simultaneously.

Outlines

Tunnelling



Tunnelling: A method of transporting an IPv6 packet over an IPv4 network. The IPv6 packet is encapsulated inside an IPv4 packet.

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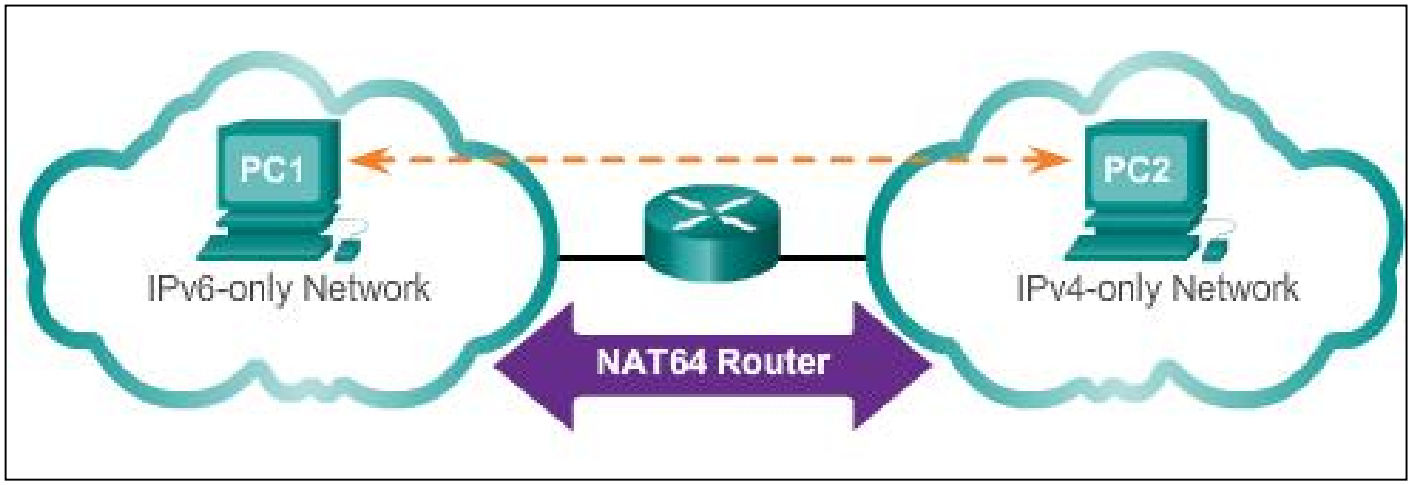
Translation



Translation: The Network Address Translation 64 (NAT64) allows IPv6-enabled devices to communicate with IPv4-enabled devices using a translation technique similar to NAT for IPv4. An IPv6 packet is translated to an IPv4 packet, and vice versa.

Outlines

The Need for IPv6

- IPv6 is designed to be the successor to IPv4.
- Depletion of IPv4 address space has been the motivating factor for moving to IPv6.
- Projections show that all five RIRs will run out of IPv4 addresses between 2015 and 2020.
- With an increasing Internet population, a limited IPv4 address space, issues with NAT and an Internet of things, the time has come to begin the transition to IPv6!
- IPv4 has a theoretical maximum of 4.3 billion addresses, plus private addresses in combination with NAT.
- IPv6 larger 128-bit address space provides for 340 undecillion addresses.
- IPv6 fixes the limitations of IPv4 and includes additional enhancements, such as ICMPv6.

Outlines

IPv6 Address Types

There are three types of IPv6 addresses:

- Unicast
- Multicast
- Anycast.

Note: IPv6 does not have broadcast addresses.

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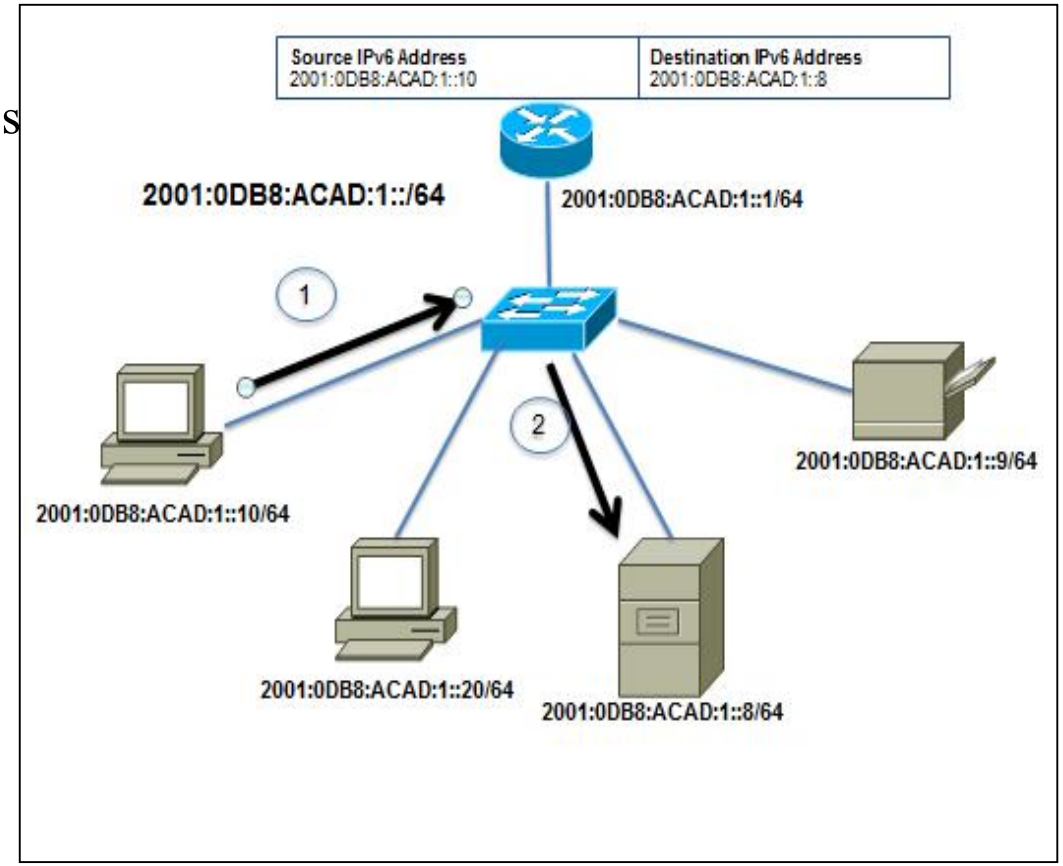
1. IPv6 Unicast Addresses

- Uniquely identifies an interface on an IPv6-enabled device.
- A packet sent to a unicast address is received by the interface that is assigned that address.



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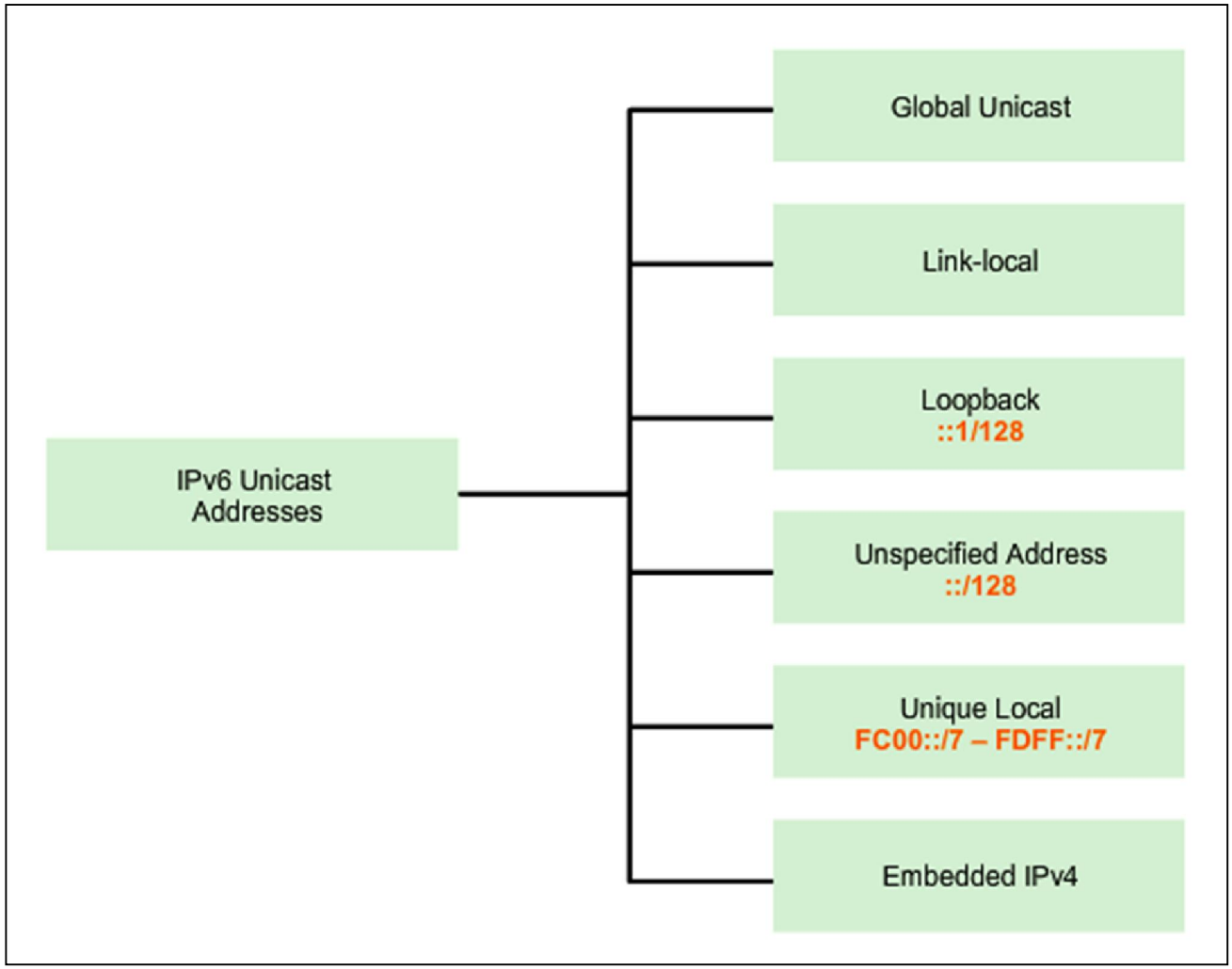
1. IPv6 Unicast Addresses



Outlines

Global Unicast

- Similar to a public IPv4 address
- Globally unique
- Internet routable addresses
- Can be configured statically or assigned dynamically

Link-local

- Used to communicate with other devices on the same local link
- Confined to a single link; not routable beyond the link

Loopback

- Used by a host to send a packet to itself and cannot be assigned to a physical interface.
- Ping an IPv6 loopback address to test the configuration of TCP/IP on the local host.
- All-0s except for the last bit, represented as ::1/128 or just ::1.

Unspecified Address

- All-0's address represented as ::/128 or just ::
- Cannot be assigned to an interface and is only used as a source address.
- An unspecified address is used as a source address when the device does not yet have a permanent IPv6 address or when the source of the packet is irrelevant to the destination.

Unique Local

- Similar to private addresses for IPv4.
- Used for local addressing within a site or between a limited number of sites.
- In the range of FC00::/7 to FDFF::/7.

IPv4 Embedded

- Used to help transition from IPv4 to IPv6.

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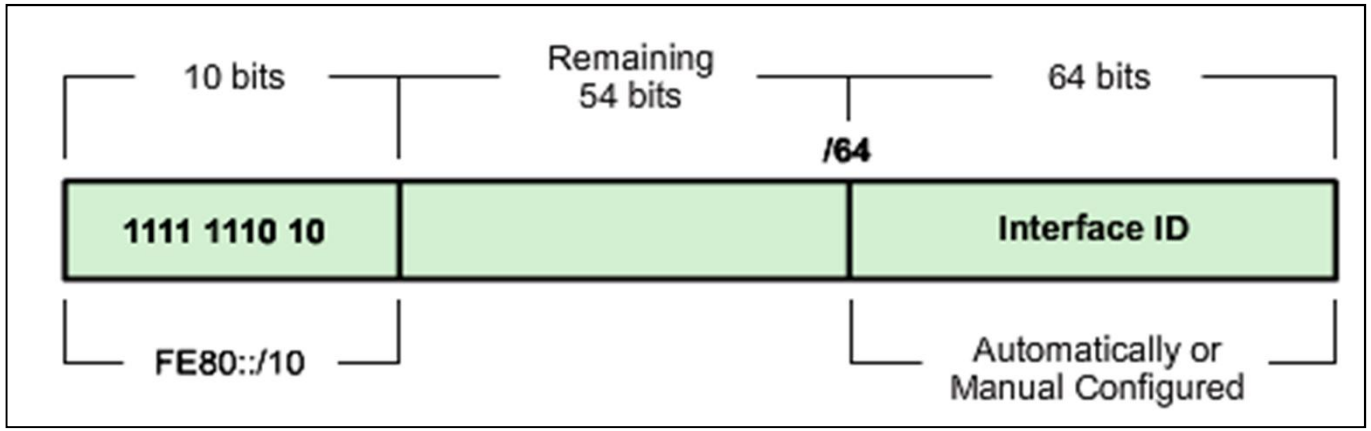
1.1. IPv6 Link-Local Unicast Addresses

- Every IPv6-enabled network interface is REQUIRED to have a link-local address
- Enables a device to communicate with other IPv6-enabled devices on the same link and only on that link (subnet)
- FE80::/10 range, first 10 bits are 1111 1110 10xx xxxx
- 1111 1110 10**00 0000** (FE80) - 1111 1110 10**11 1111** (FEBF)



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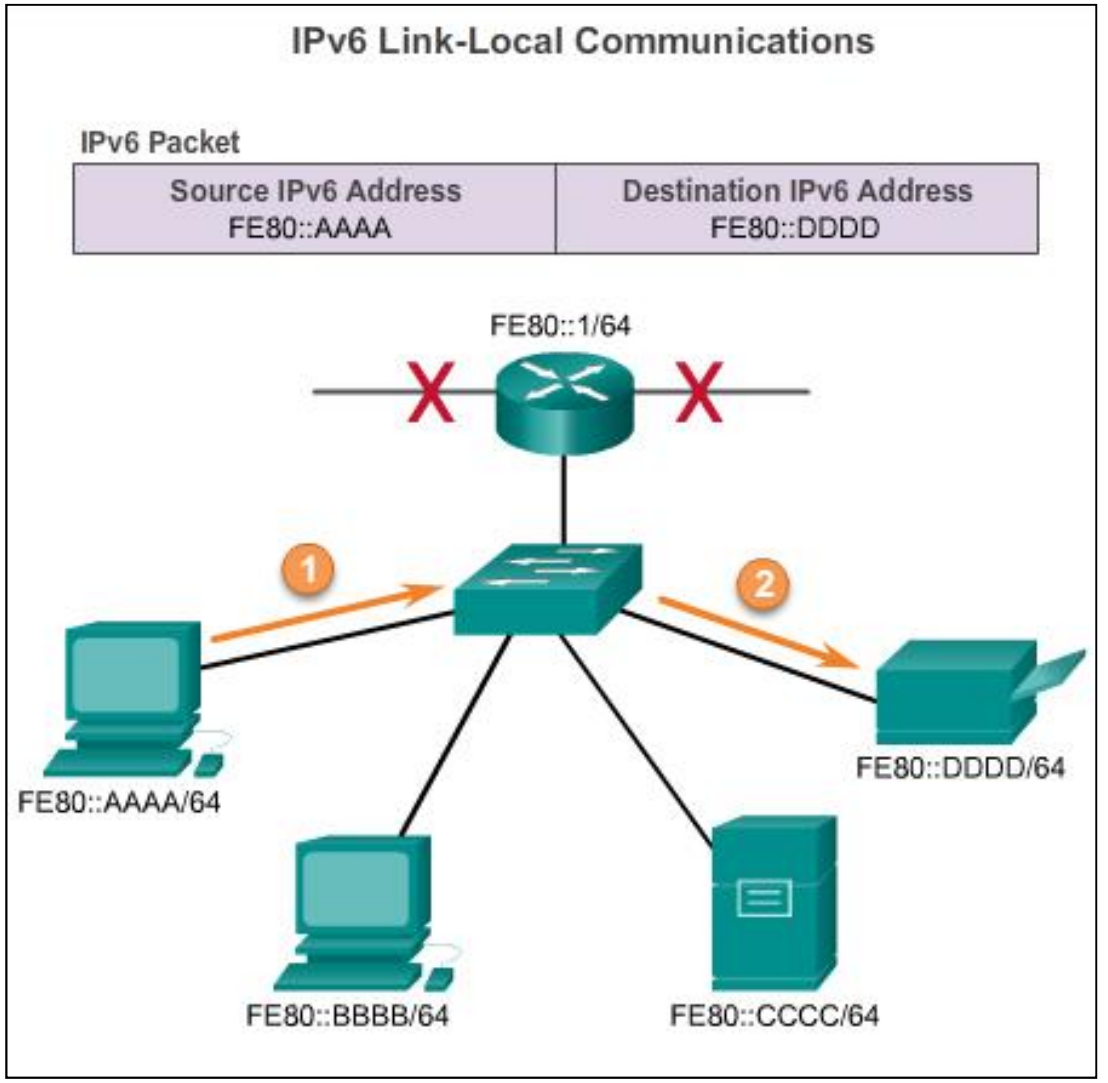
Packets with a source or destination link-local address cannot be routed beyond the link from where the packet originated.



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1.2. IPv6 Global Unicast Address

- IPv6 global unicast addresses are globally unique and routable on the IPv6 Internet
- Equivalent to public IPv4 addresses
- ICANN allocates IPv6 address blocks to the five RIRs (Regional Internet Registry)

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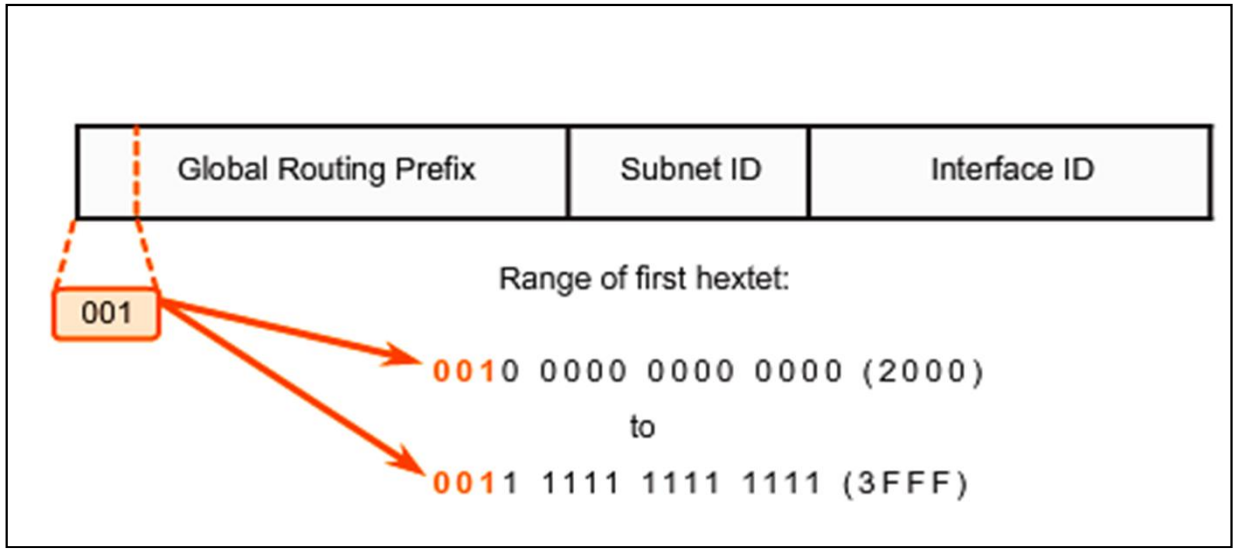
Currently, only global unicast addresses with the first three bits of 001 or 2000::/3 are being assigned



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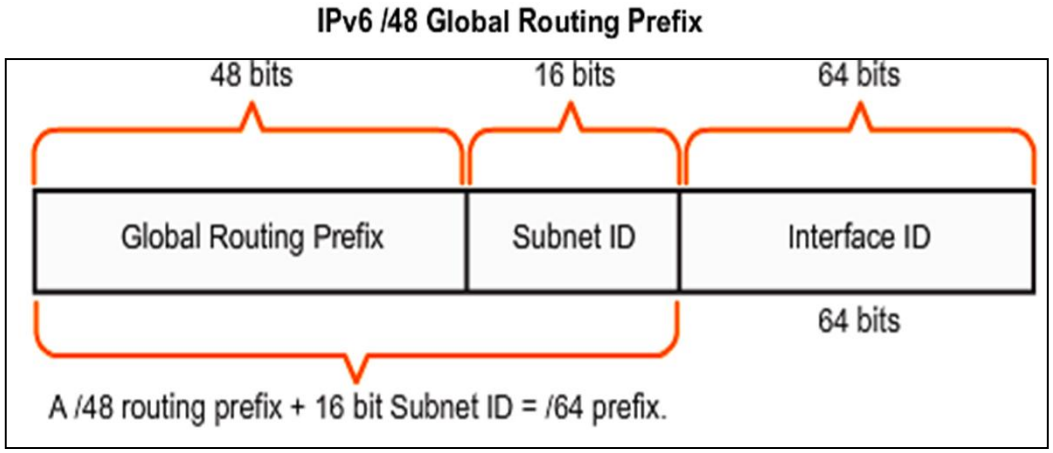
A global unicast address has three parts: Global Routing Prefix, Subnet ID, and Interface ID.

- **Global Routing Prefix** is the prefix or network portion of the address assigned by the provider, such as an ISP, to a customer or site, currently, RIR's assign a /48 global routing prefix to customers.
- 2001:0DB8:ACAD::/48 has a prefix that indicates that the first 48 bits (2001:0DB8:ACAD) is the prefix or network portion.



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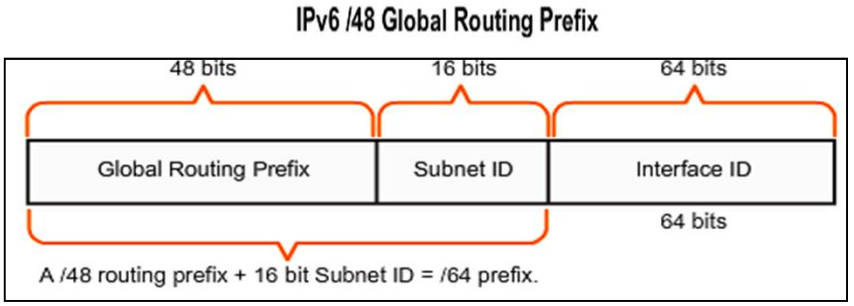
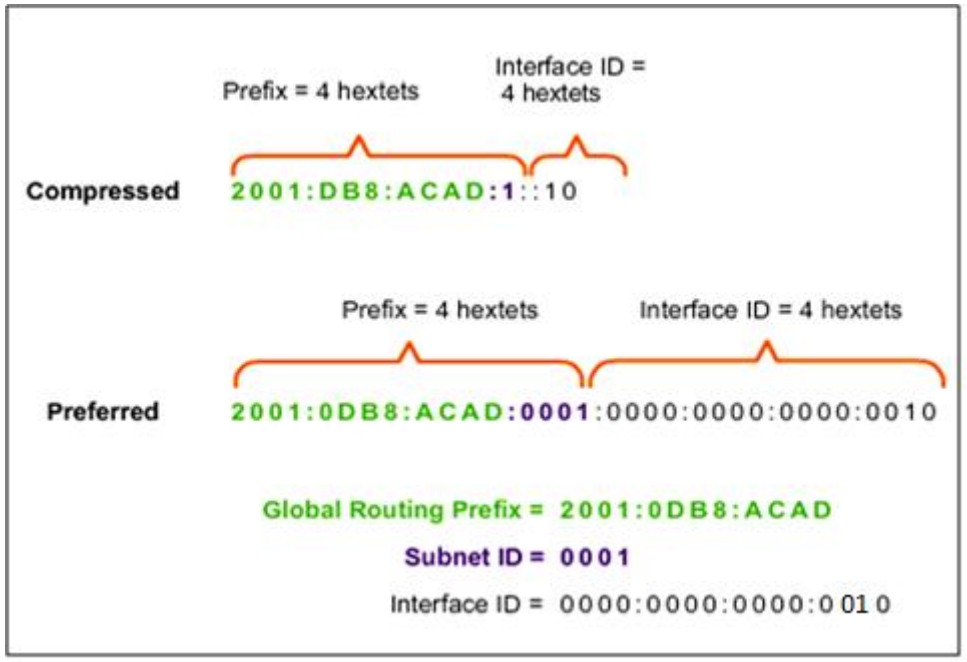


- **Subnet ID** is used by an organization to identify subnets within its site
- **Interface ID**
  - Equivalent to the host portion of an IPv4 address.
  - Used because a single host may have multiple interfaces, each having one or more IPv6 addresses.



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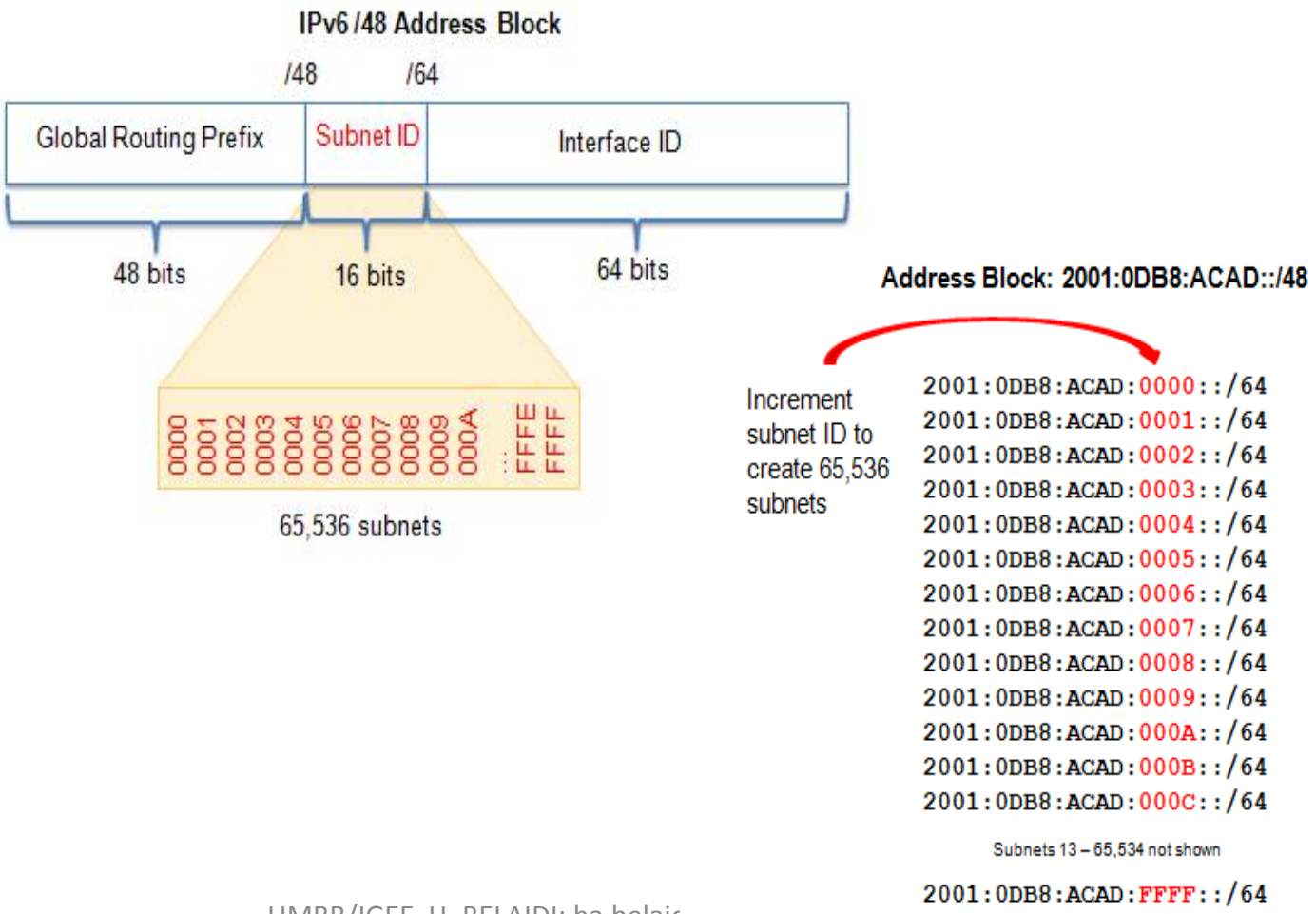
1.3. Subnetting an IPv6 Network

Using the Subnet ID: An IPv6 Network Space is subnetted to support hierarchical, logical design of the network.



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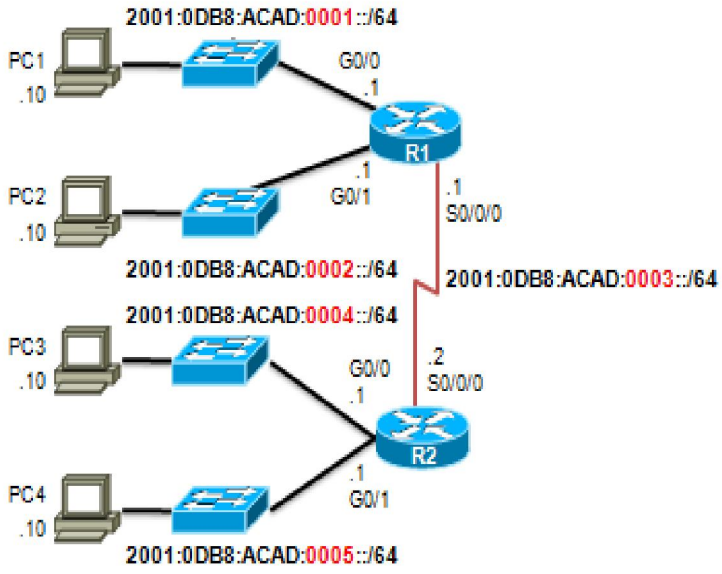
IPv6 Subnetting

Address Block: 2001:0DB8:ACAD::/48

5 subnets allocated from 65,536 available subnets

2001:0DB8:ACAD:0000::/64
2001:0DB8:ACAD:0001::/64
2001:0DB8:ACAD:0002::/64
2001:0DB8:ACAD:0003::/64
2001:0DB8:ACAD:0004::/64
2001:0DB8:ACAD:0005::/64
2001:0DB8:ACAD:0006::/64
2001:0DB8:ACAD:0007::/64
2001:0DB8:ACAD:0008::/64
⋮
2001:0DB8:ACAD:FFFF::/64

IPv6 Subnet Allocation



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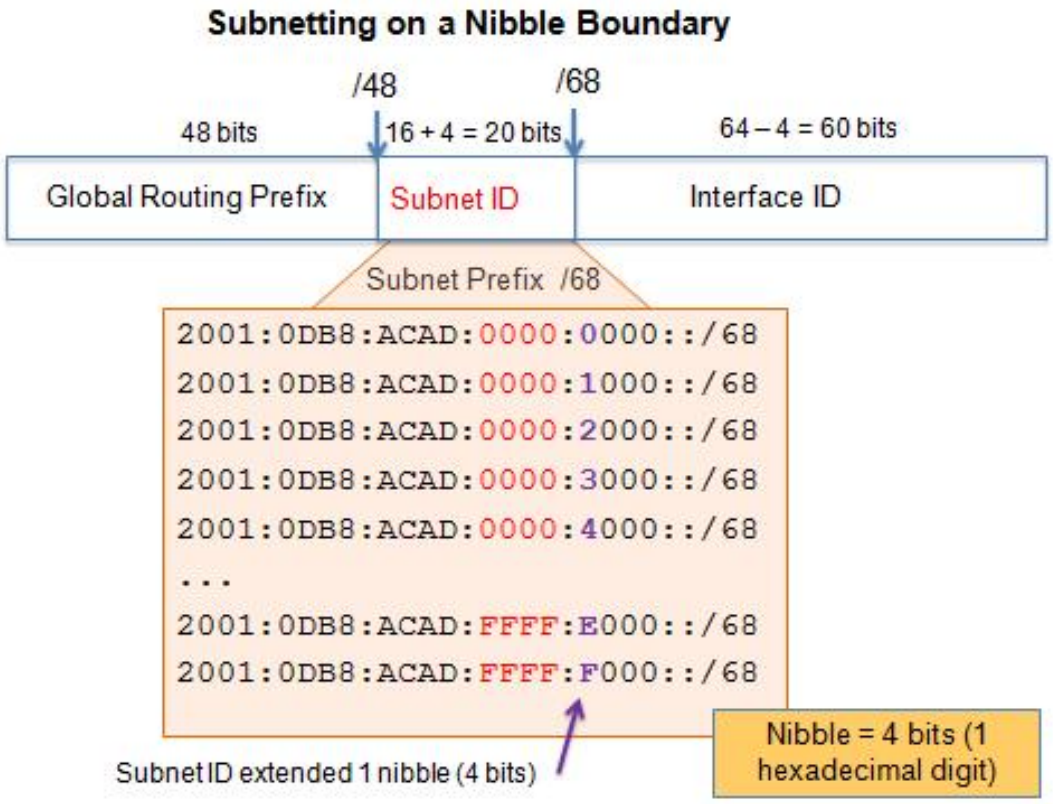
Subnetting into the Interface ID

IPv6 bits can be borrowed from the interface ID to create additional IPv6 subnets.



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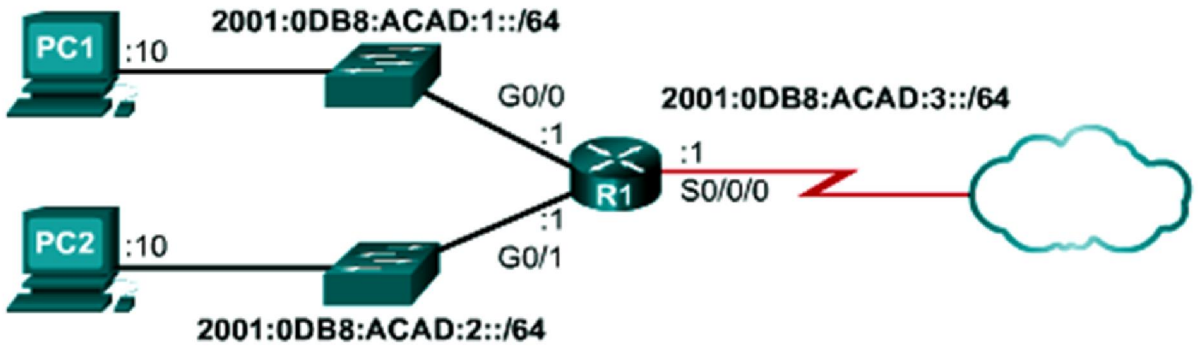
2. Static Configuration of a Global Unicast Address




```
R1(config)#interface gigabitethernet 0/0
R1(config-if)#ipv6 address 2001:db8:acad:1::1/64
R1(config-if)#no shutdown
R1(config-if)#exit
R1(config)#interface gigabitethernet 0/1
R1(config-if)#ipv6 address 2001:db8:acad:2::1/64
R1(config-if)#no shutdown
R1(config-if)#exit
R1(config)#interface serial 0/0/0
R1(config-if)#ipv6 address 2001:db8:acad:3::1/64
R1(config-if)#clock rate 56000
R1(config-if)#no shutdown
```

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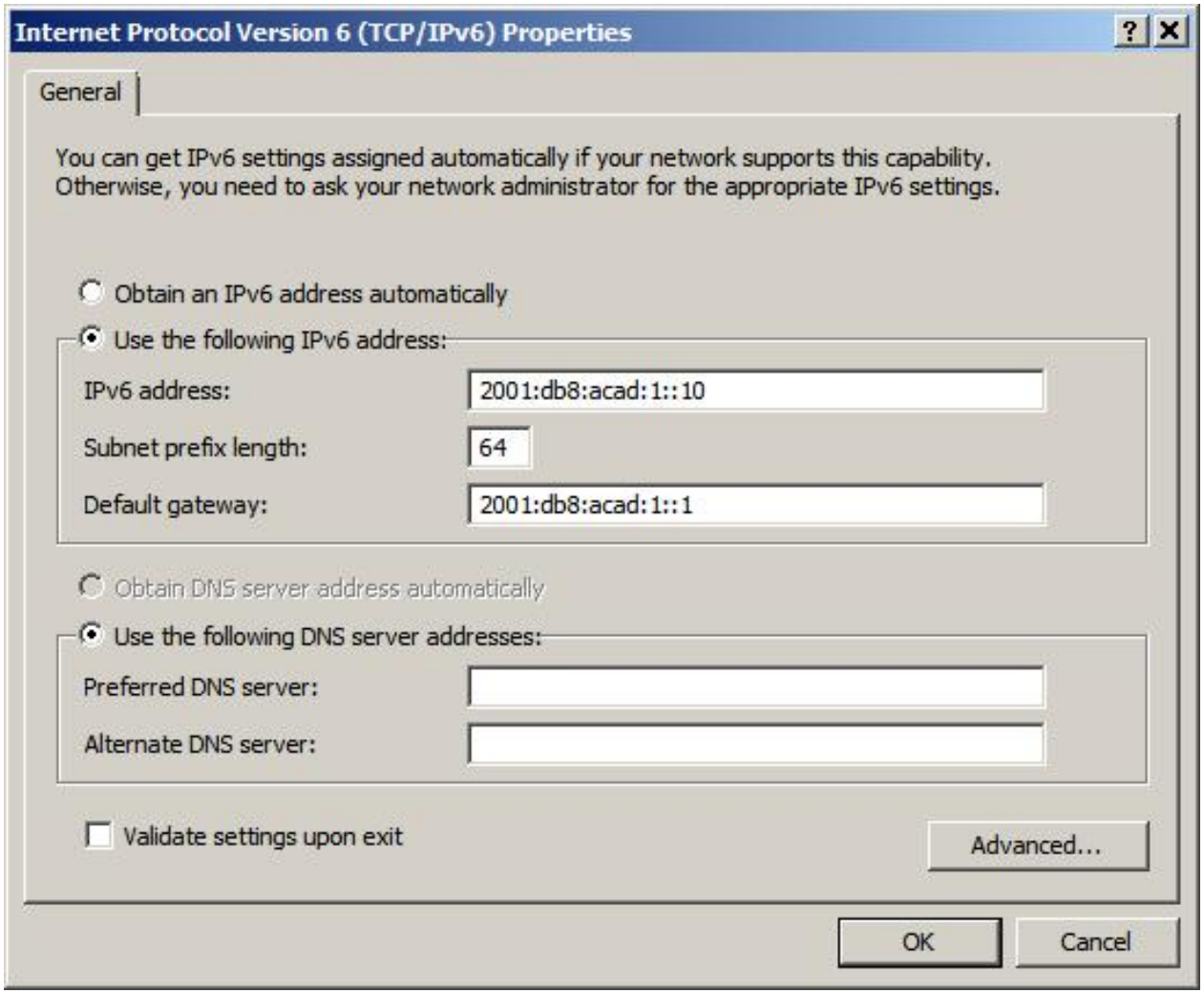
Windows IPv6 Setup



Outlines

3. Dynamic Configuration of a Global Unicast Address

3.1. using SLAAC

Stateless Address Autoconfiguration (SLAAC)

- A method that allows a device to obtain its prefix, prefix length and default gateway from an IPv6 router
- No DHCPv6 server needed
- Rely on ICMPv6 Router Advertisement (RA) messages

IPv6 routers

- Forwards IPv6 packets between networks
- Can be configured with static routes or a dynamic IPv6 routing protocol
- Sends ICMPv6 RA messages

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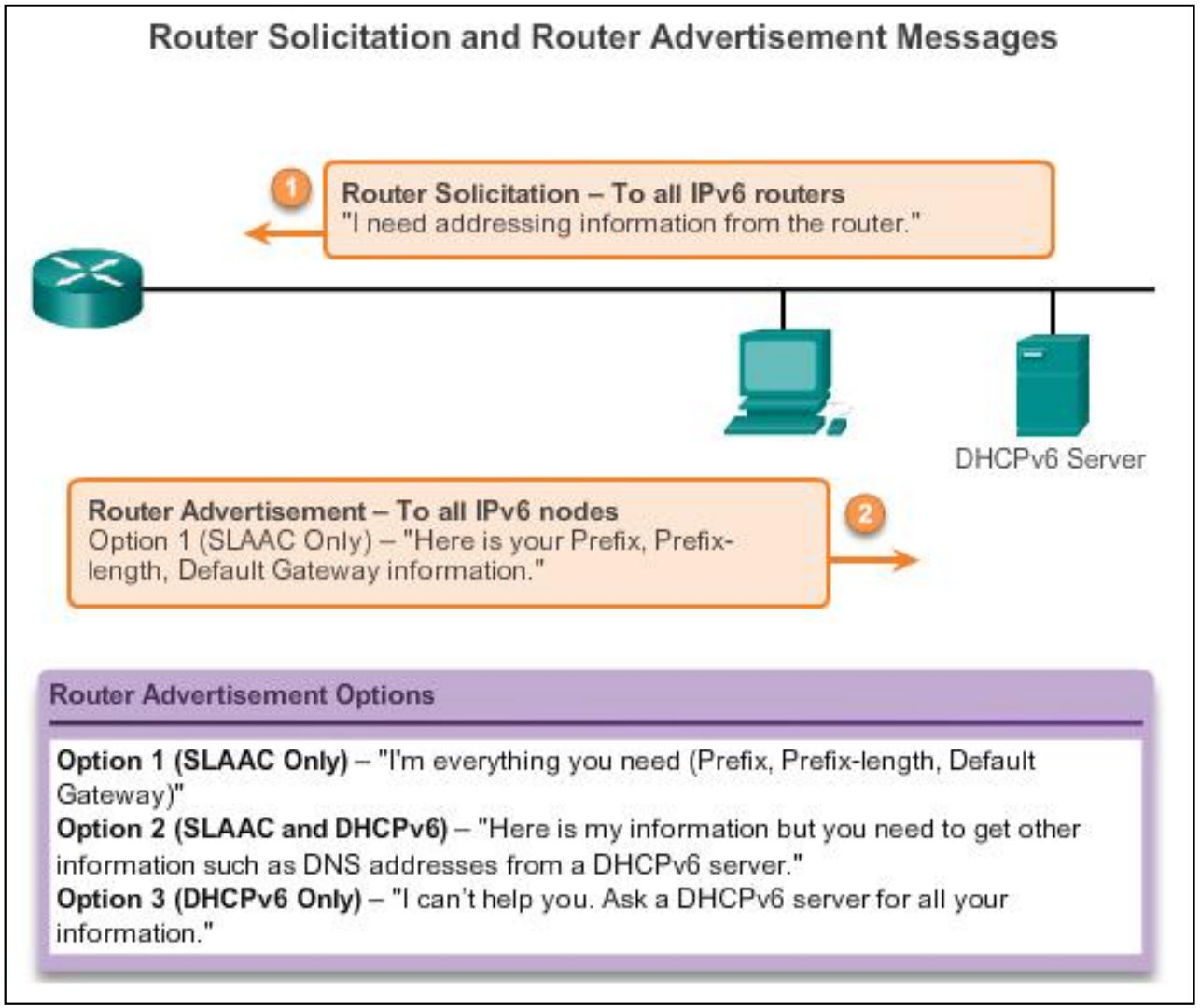

3.2. Using DHCPv6

Dynamic Host Configuration Protocol for IPv6 (DHCPv6)

- Similar to IPv4
- Automatically receives addressing information, including a global unicast address, prefix length, default gateway address and the addresses of DNS servers using the services of a DHCPv6 server.
- Device may receive all or some of its IPv6 addressing information from a DHCPv6 server depending upon whether option 2 (SLAAC and DHCPv6) or option 3 (DHCPv6 only) is specified in the ICMPv6 RA message.
- Host may choose to ignore whatever is in the router's RA message and obtain its IPv6 address and other information directly from a DHCPv6 server.

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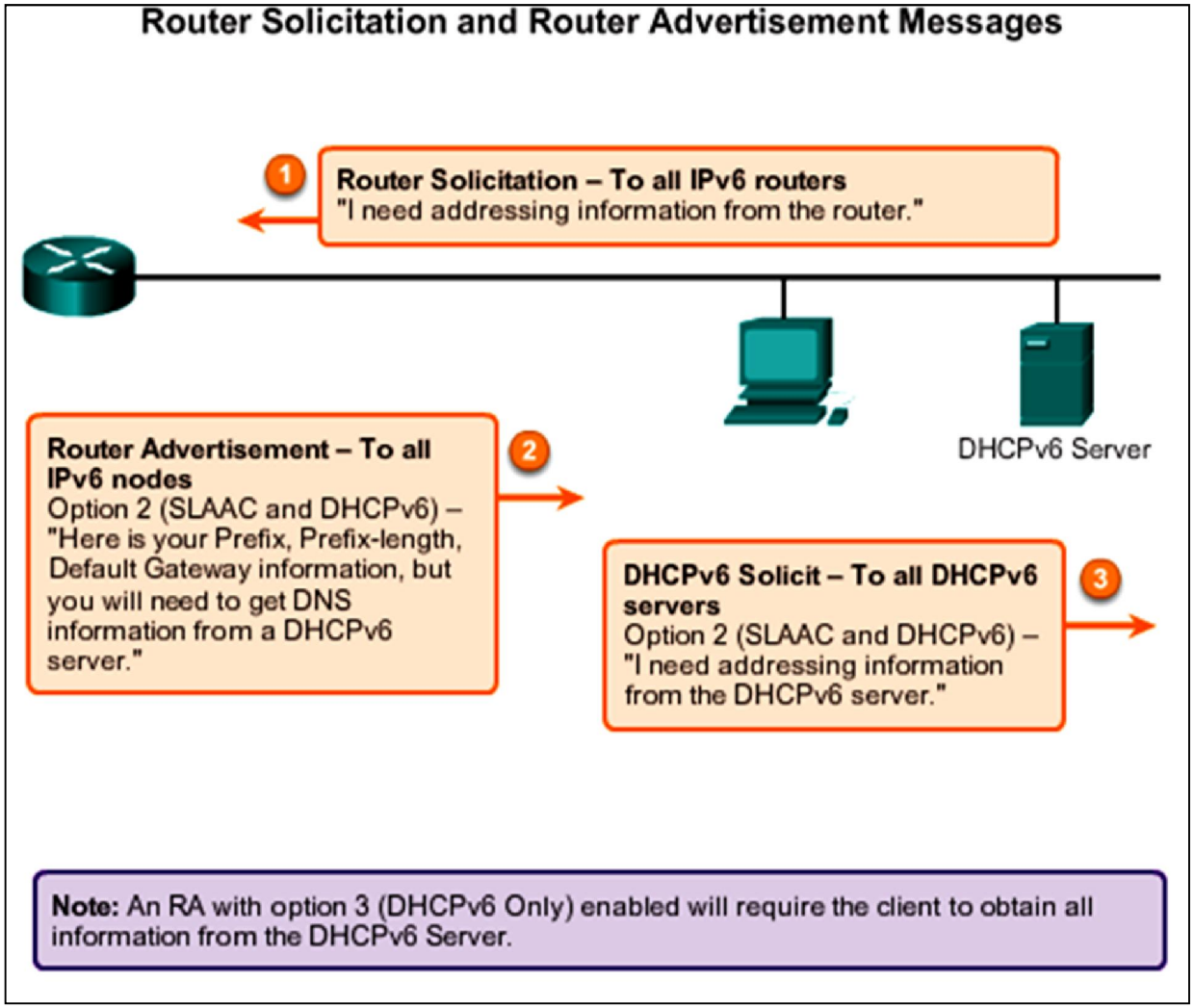

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4. EUI-64 Process or Randomly Generated

EUI-64 Process

- Uses a client's 48-bit Ethernet MAC address and inserts another 16 bits in the middle of the 46-bit MAC address to create a 64-bit Interface ID.
- Advantage is that the Ethernet MAC address can be used to determine the interface; is easily tracked.

EUI-64 Interface ID is represented in binary and comprises three parts:

- 24-bit OUI from the client MAC address, but the 7th bit (the Universally/Locally bit) is reversed (0 becomes a 1).
- Inserted as a 16-bit value FFFE.
- 24-bit device identifier from the client MAC address.

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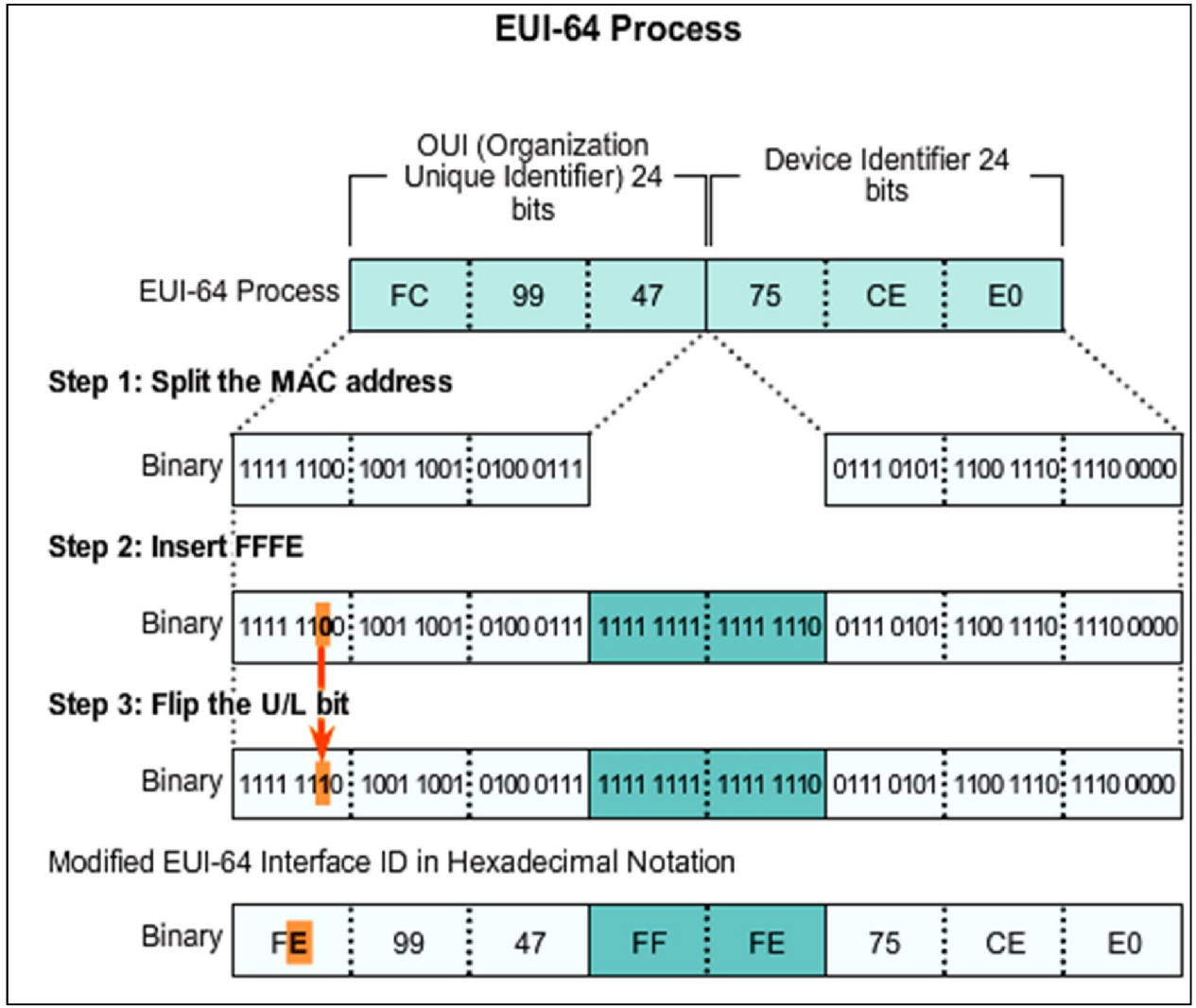

Outlines

Randomly Generated Interface IDs

- Depending upon the operating system, a device can use a randomly generated Interface ID instead of using the MAC address and the EUI-64 process.
- Beginning with Windows Vista, Windows uses a randomly generated Interface ID instead of one created with EUI-64.
- Windows XP (and previous Windows operating systems) used EUI-64.

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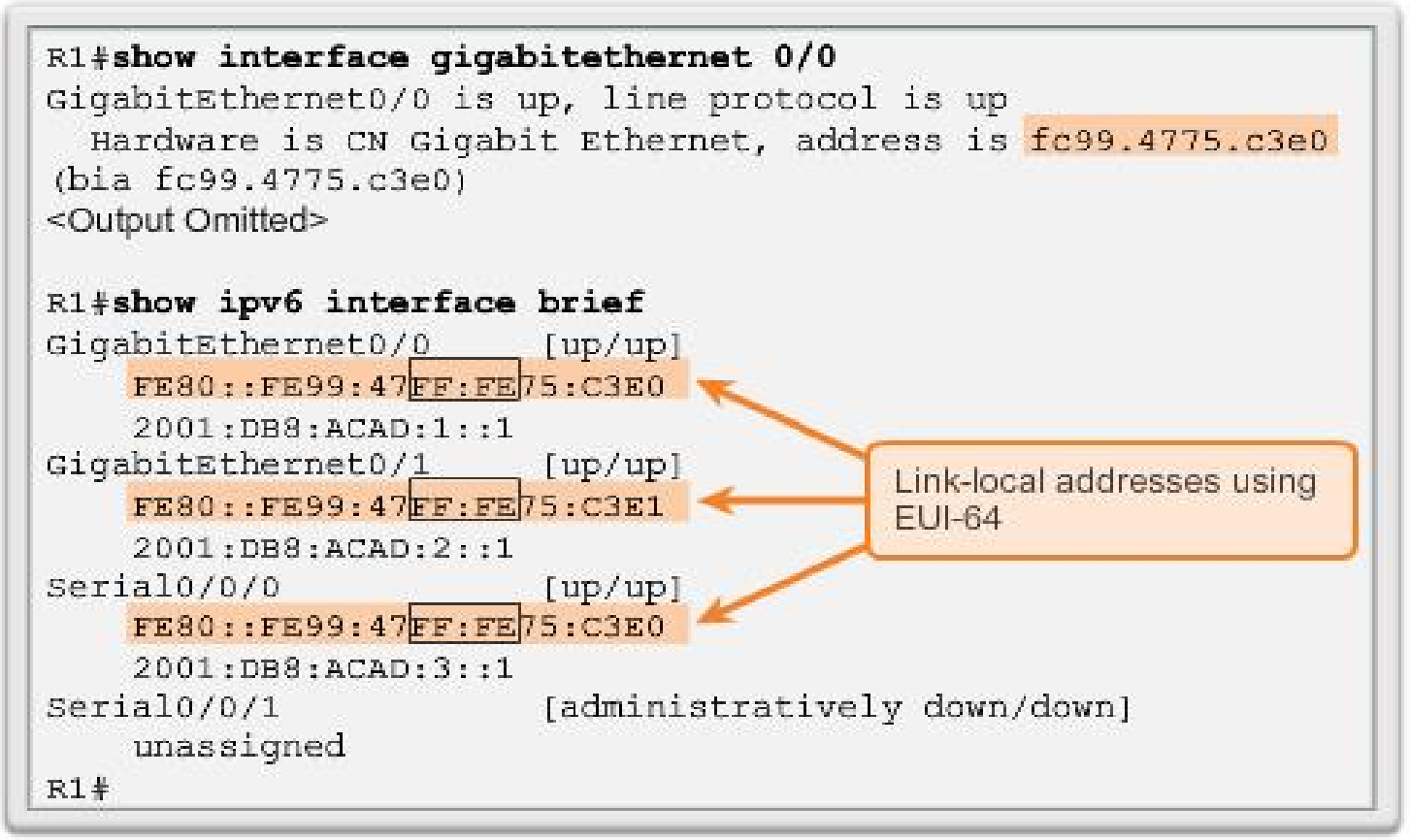

Outlines

5. Dynamic and Static Link-local Addresses

Link-Local Address

- After a global unicast address is assigned to an interface, an IPv6-enabled device automatically generates its link-local address.
- Must have a link-local address that enables a device to communicate with other IPv6-enabled devices on the same subnet.
- Uses the link-local address of the local router for its default gateway IPv6 address.
- Routers exchange dynamic routing protocol messages using link-local addresses.
- Routers' routing tables use the link-local address to identify the next-hop router when forwarding IPv6 packets.

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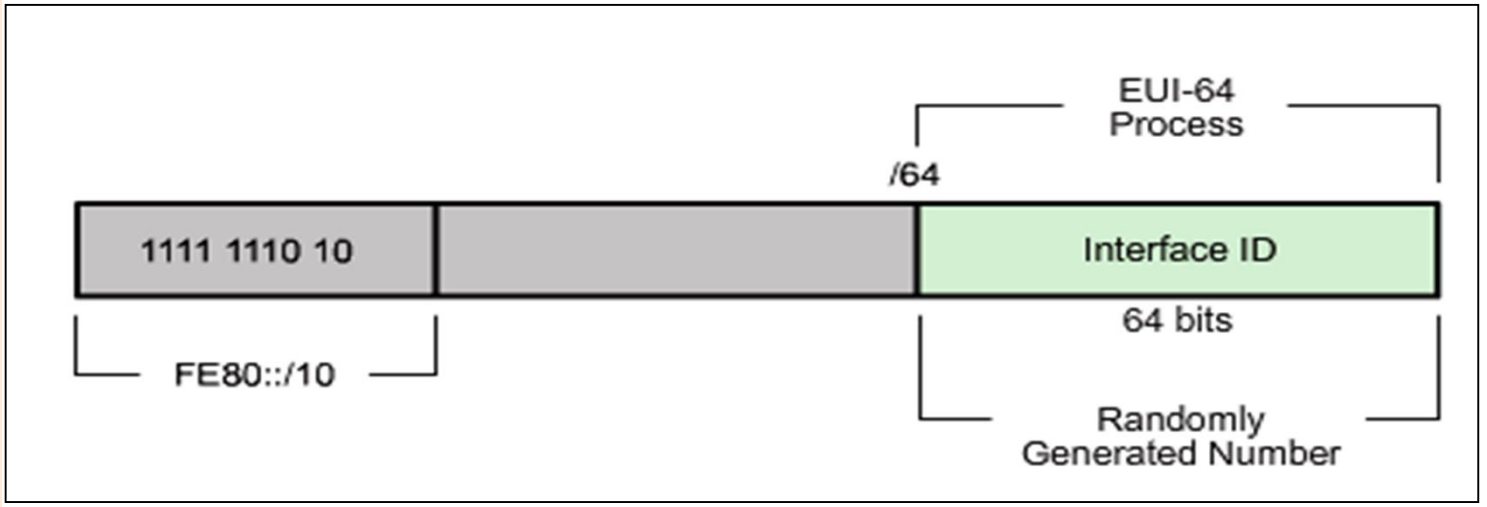
5.1. Dynamically Assigned

The link-local address is dynamically created using the FE80::/10 prefix and the Interface ID.



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- Dynamic and Static Link-local Addresses
- Assigned IPv6 Multicast Addresses
- Connectivity Verification

5.2. Static Link-local Addresses

Configuring Link-local

```
R1(config)#interface gigabitethernet 0/0
R1(config-if)#ipv6 address fe80::1 ?
  link-local  Use link-local address

R1(config-if)#ipv6 address fe80::1 link-local
R1(config-if)#exit
R1(config)#interface gigabitethernet 0/1
R1(config-if)#ipv6 address fe80::1 link-local
R1(config-if)#exit
R1(config)#interface serial 0/0/0
R1(config-if)#ipv6 address fe80::1 link-local
R1(config-if)#
```

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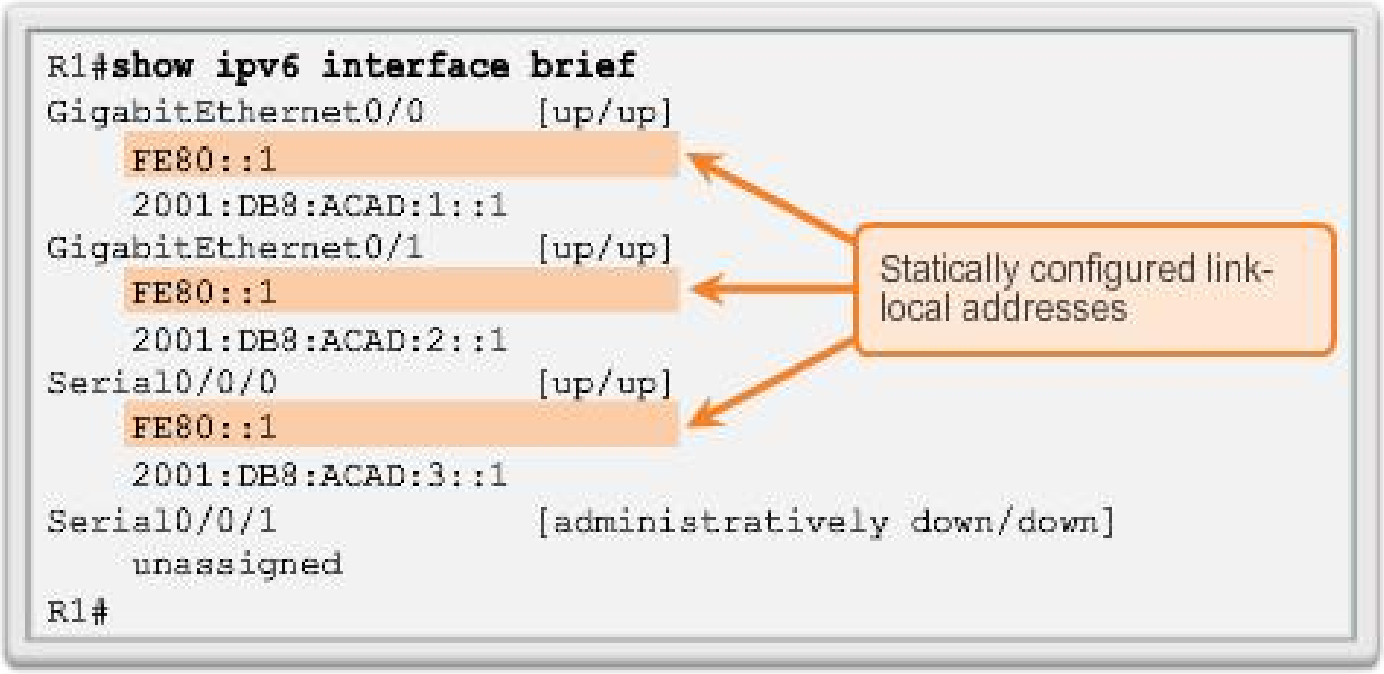
Configuring Link-local



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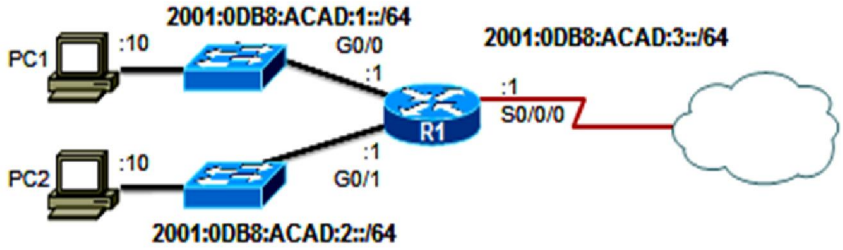
5.3. Verifying IPv6 Address Configuration

Each interface has two IPv6 addresses -

1. global unicast address that was configured
2. one that begins with FE80 is automatically added as a link-local unicast address




```
R1#show ipv6 interface brief
GigabitEthernet0/0      [up/up]
    FE80::FE99:47FF:FE75:C3E0
    2001:DB8:ACAD:1::1
GigabitEthernet0/1      [up/up]
    FE80::FE99:47FF:FE75:C3E1
    2001:DB8:ACAD:2::1
Serial0/0/0             [up/up]
    FE80::FE99:47FF:FE75:C3E0
    2001:DB8:ACAD:3::1
Serial0/0/1             [administratively down/down]
    unassigned
R1#
```

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```
R1#show ipv6 route
IPv6 Routing Table - default - 7 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user
Static

<output omitted>

C   2001:DB8:ACAD:1::/64 [0/0]
     via GigabitEthernet0/0, directly connected
L   2001:DB8:ACAD:1::1/128 [0/0]
     via GigabitEthernet0/0, receive
C   2001:DB8:ACAD:2::/64 [0/0]
     via GigabitEthernet0/1, directly connected
L   2001:DB8:ACAD:2::1/128 [0/0]
     via GigabitEthernet0/1, receive
C   2001:DB8:ACAD:3::/64 [0/0]
     via Serial0/0/0, directly connected
L   2001:DB8:ACAD:3::1/128 [0/0]
     via Serial0/0/0, receive
L   FF00::/8 [0/0]
     via Null0, receive
R1#
```

Outlines

5. Assigned IPv6 Multicast Addresses

- IPv6 multicast addresses have the prefix FF00::/8
- There are two types of IPv6 multicast addresses:
  - Assigned multicast
  - Solicited node multicast

Assigned multicast

Two common IPv6 assigned multicast groups include:

- **FF02::1 All-nodes multicast group** –
  - All IPv6-enabled devices join
  - Same effect as an IPv4 broadcast address
- **FF02::2 All-routers multicast group**
  - All IPv6 routers join
  - A router becomes a member of this group when it is enabled as an IPv6 router with the **ipv6 unicast-routing** global configuration mode command.
  - A packet sent to this group is received and processed by all IPv6 routers on the link or network.

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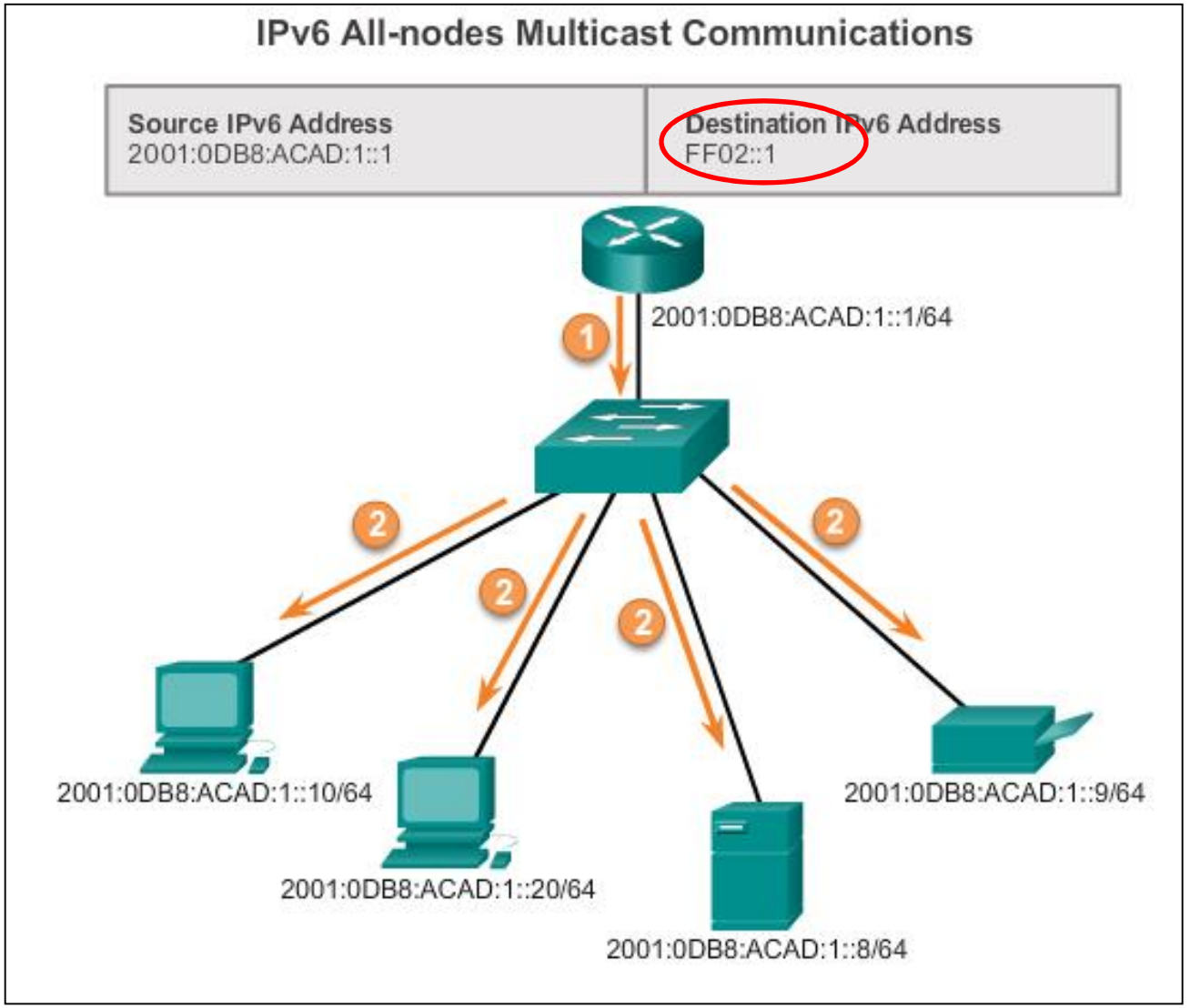

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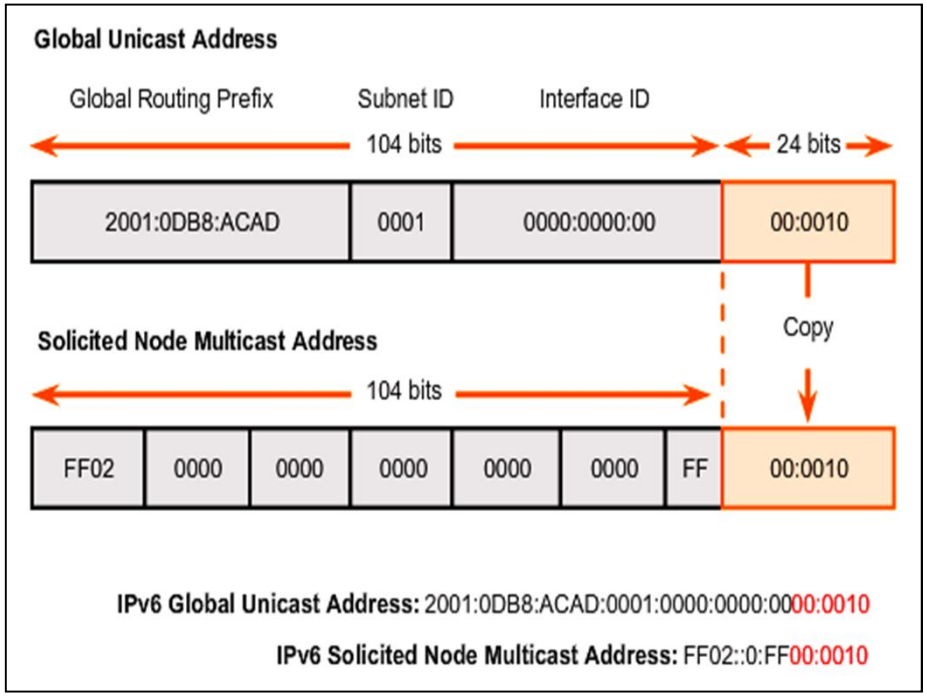
Solicited Node IPv6 Multicast Addresses

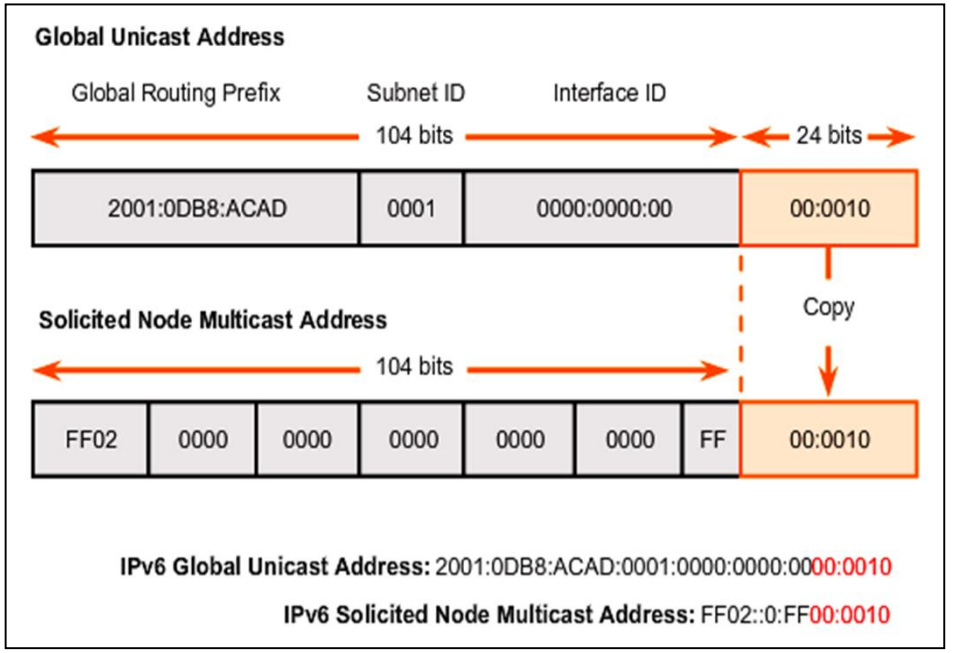
- Similar to the all-nodes multicast address, matches only the last 24 bits of the IPv6 global unicast address of a device
- Automatically created when the global unicast or link-local unicast addresses are assigned
- Created by combining a special FF02:0:0:0:0:0:FF00::/104 prefix with the right-most 24 bits of its unicast address



Outlines

The solicited node multicast address consists of two parts:

- **FF02:0:0:0:0:0:FF00::/104 multicast prefix** – First 104 bits of the all solicited node multicast address
- **Least significant 24-bits** – Copied from the right-most 24 bits of the global unicast or link-local unicast address of the device



Outlines

Multicast Address Examples

- All Nodes Addresses:
  - FF01:0:0:0:0:0:0:1
  - FF02:0:0:0:0:0:0:1
- All Routers Addresses:
  - FF01:0:0:0:0:0:0:2
  - FF02:0:0:0:0:0:0:2
  - FF05:0:0:0:0:0:0:2
- OSPv3:
  - AllSPFRouters : FF02::5
  - AllDRouters : FF02::6
- Solicited-Node Address:
  - FF02:0:0:0:0:1:FFXX:XXXX
  - Concatenation of prefix FF02:0:0:0:0:1:FF00::/104 with the low-order 24 bits of an address (unicast or anycast)

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IPv6 Anycast Addresses

- Anycast addresses can be considered a conceptual cross between unicast and multicast addressing.
  - **Unicast → send to this one address**
  - **Multicast → send to every member of this group**
  - **Anycast → send to any one member of this group**
- In choosing which member to send to, for efficiency reasons normally send to the closest one - closest in routing terms.
- So, anycast mean **"send to the closest member of this group".**
- The network itself plays the key role in anycast by routing the packet to the nearest destination by measuring network distance.
- Anycast addresses use aggregatable global unicast addresses.
- They can also use site-local or link-local addresses.
- Note that it is impossible to distinguish an anycast address from a unicast address.

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Configuring Cisco IOS IPv6 Multicast (examples)

Group mode determines how to forward, compared to interface mode in v4.

By default all interfaces are PIM enabled unless explicitly disabled.

Config for PIM-SSM:

```
!
ipv6 multicast-routing
!
```

Config for PIM-SM:

```
!
ipv6 multicast-routing
ipv6 pim rp-address <v6_address>
!
```

Config for PIM-bidir:

```
!
ipv6 multicast-routing
ipv6 pim rp-address <v6-address> bidir
!
```

Disable PIM on an interface

```
!
interface ethernet 0
 no ipv6 pim
!
```

Outlines

6. Connectivity Verification

6.1. ICMPv4 and ICMPv6 Messages

- ICMP messages common to both ICMPv4 and ICMPv6 include:
  - Host confirmation
  - Destination or Service Unreachable
  - Time exceeded
  - Route redirection
- Although IP is not a reliable protocol, the TCP/IP suite does provide for messages to be sent in the event of certain errors, sent using the services of ICMP.

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6.2. ICMPv6 Router Solicitation and Router Advertisement Messages

- ICMPv6 includes four new protocols as part of the Neighbor Discovery Protocol (ND or NDP):
  - Router Solicitation message
  - Router Advertisement message
  - Neighbor Solicitation message
  - Neighbor Advertisement message
- **Router Solicitation and Router Advertisement Message** – Sent between hosts and routers.
- **Router Solicitation (RS) message** – RS messages are sent as an IPv6 all-routers multicast message.
- **Router Advertisement (RA) message** – RA messages are sent by routers to provide addressing information.

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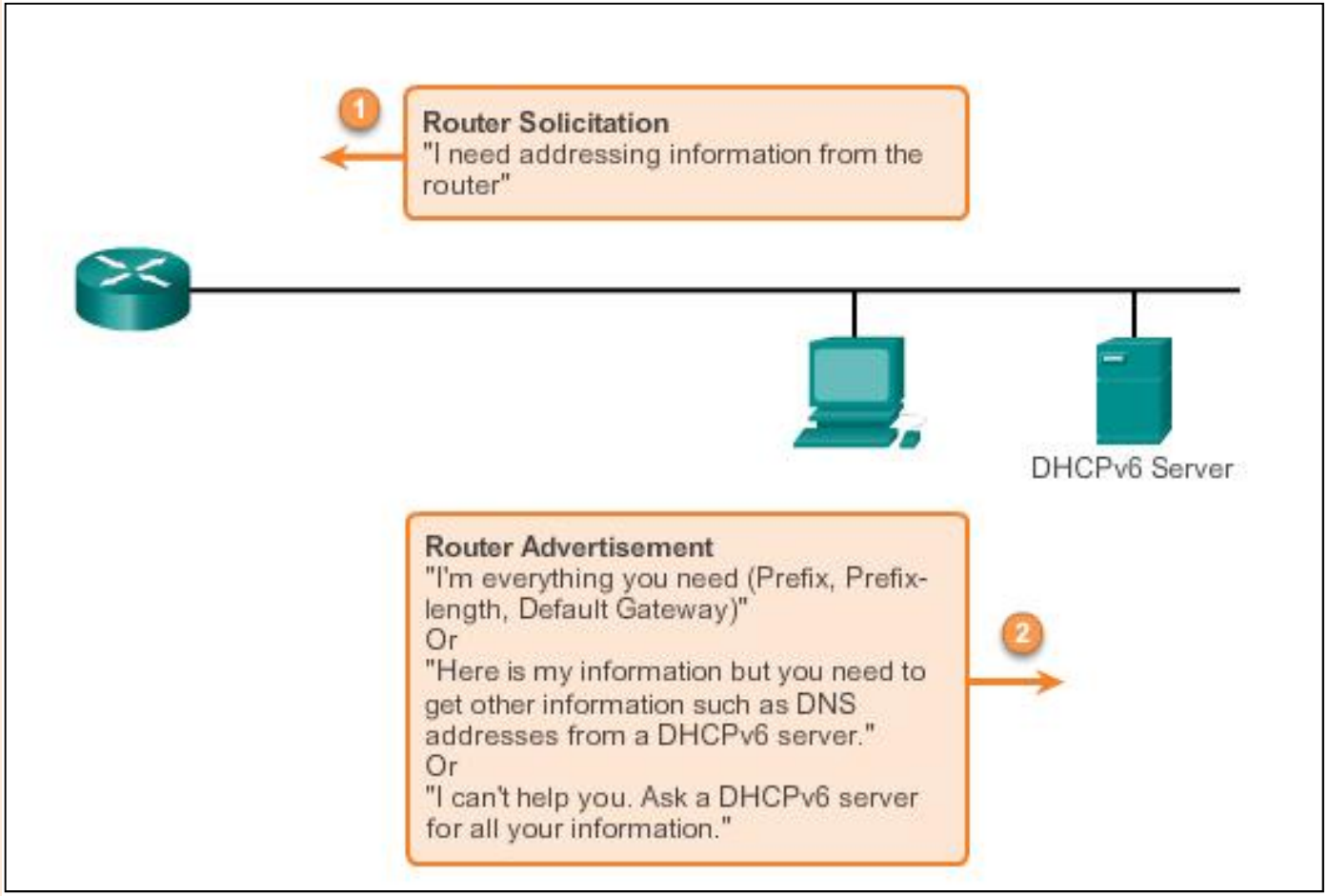

Outlines

- Two additional message types:
  - Neighbor Solicitation (NS)
  - Neighbor Advertisement (NA) messages
- **Used for address resolution** is used when a device on the LAN knows the IPv6 unicast address of a destination, but does not know its Ethernet MAC address.
- **Also used for Duplicate Address Detection (DAD)**
  - Performed on the address to ensure that it is unique.
  - The device sends an NS message with its own IPv6 address as the targeted IPv6 address.

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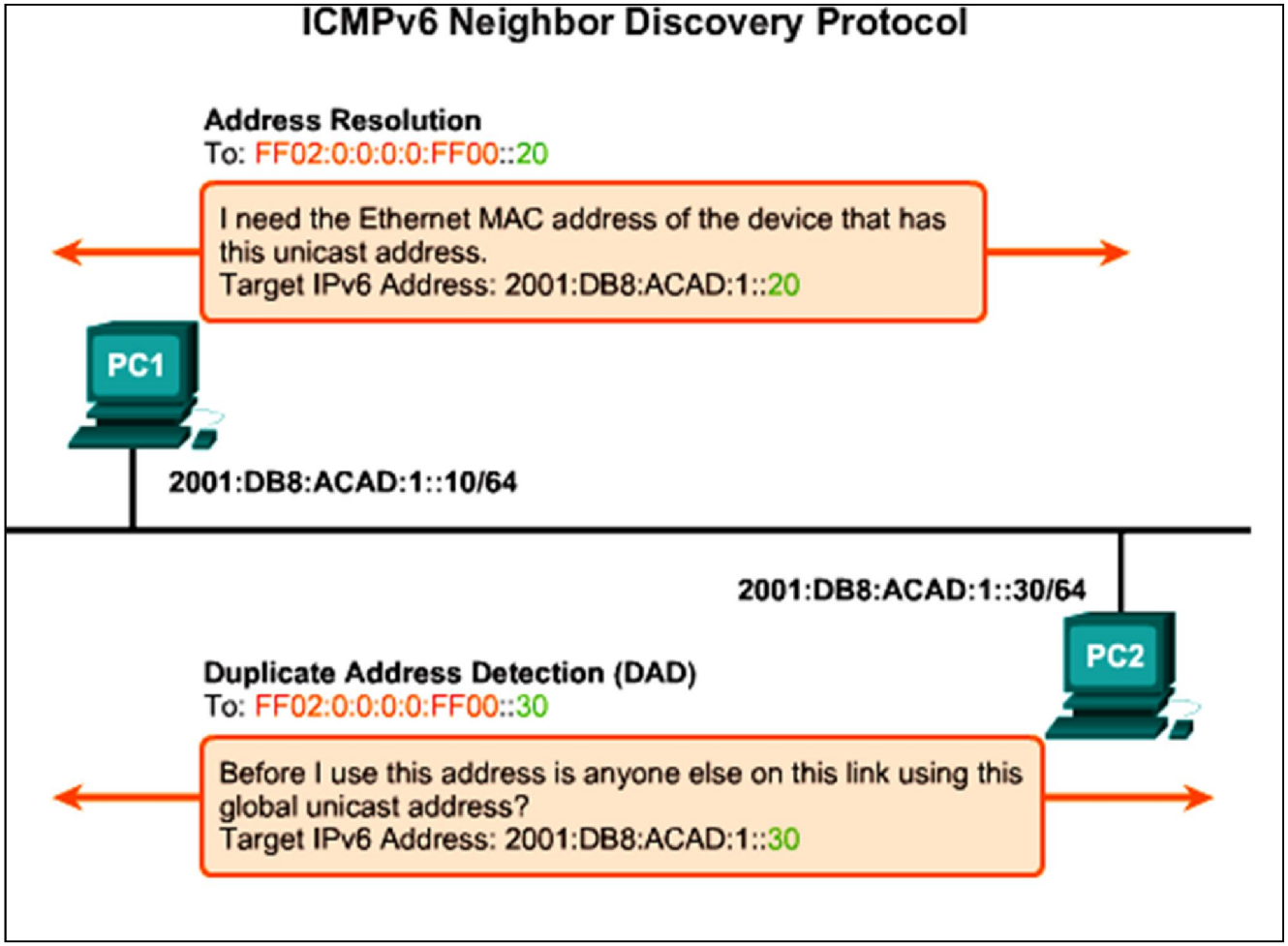

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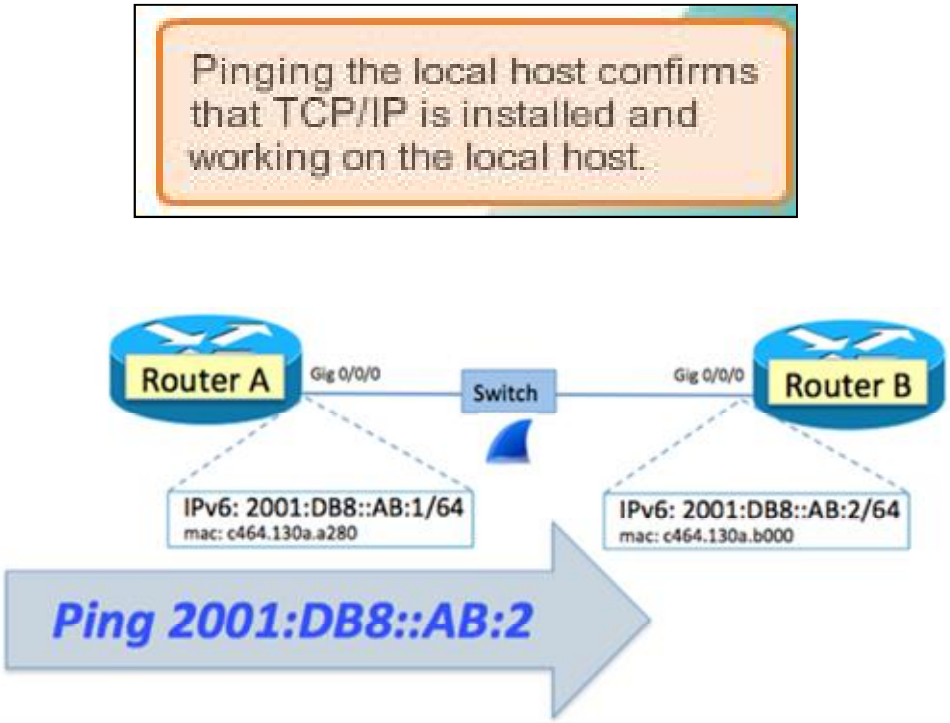
6.3. Ping – Testing the Local Stack



6.4. Traceroute – Testing the Path

Traceroute

- Generates a list of hops that were successfully reached along the path.
- Provides important verification and troubleshooting information.
- If the data reaches the destination, then the trace lists the interface of every router in the path between the hosts.
- If the data fails at some hop along the way, the address of the last router that responded to the trace can provide an indication of where the problem or security restrictions are found.
- Provides round-trip time for each hop along the path and indicates if a hop fails to respond.

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6.5. IPv6 RIP routing protocol

DETAILED STEPS

	Command or Action	Purpose
Step 1	**enable** **Example:** Router> enable	Enables privileged EXEC mode. • Enter your password if prompted.
Step 2	**configure terminal** **Example:** Router# configure terminal	Enters global configuration mode.
Step 3	**ipv6 unicast-routing** **Example:** Router(config)# ipv6 unicast-routing	Enables the forwarding of IPv6 unicast datagrams.
Step 4	**interface** *type number* **Example:** Router(config)# interface gigabitethernet 0/0/0	Specifies the interface type and number, and enters interface configuration mode.
Step 5	**ipv6 rip** *name* **enable** **Example:** Router(config-if)# ipv6 rip process1 enable	Enables the specified IPv6 RIP routing process on an interface.

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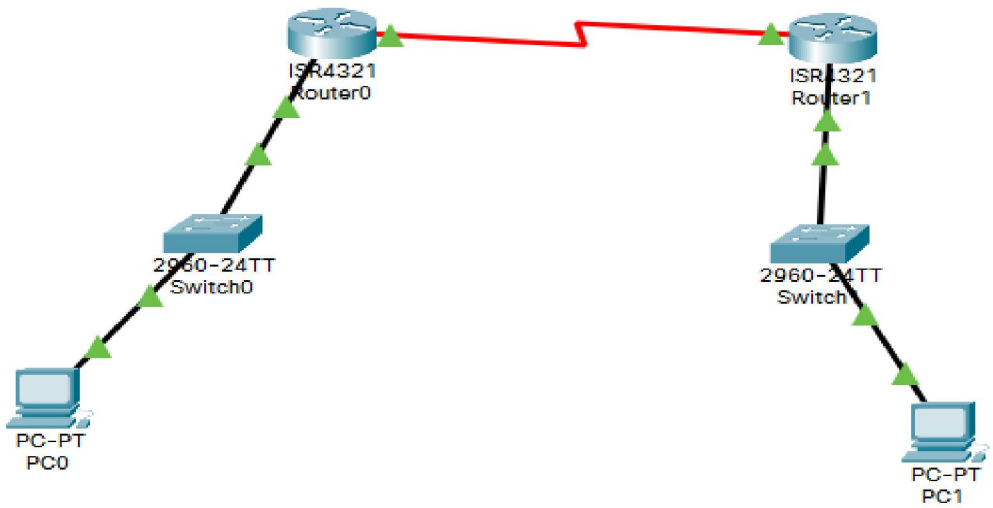
Example




```
Router>en
Router#config ter
Enter configuration commands, one per line.  End with CNTL/Z.
Router(config)#ipv6 unicast-routing
Router(config)#ipv6 router rip R1
Router(config-rtr)#int g0/0/0
Router(config-if)#ipv6 rip R1 enable
Router(config-if)#int s0/1/0
Router(config-if)#ipv6 rip R1 enable
Router(config-if)#end
Router#
%SYS-5-CONFIG_I: Configured from console by console

Router#ping 2001:1:1:3::1

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 2001:1:1:3::1, timeout is 2 second
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/5/16 m

Router#show ipv6 route
IPv6 Routing Table - 6 entries
```