# IPv6

Source: Cisco networking

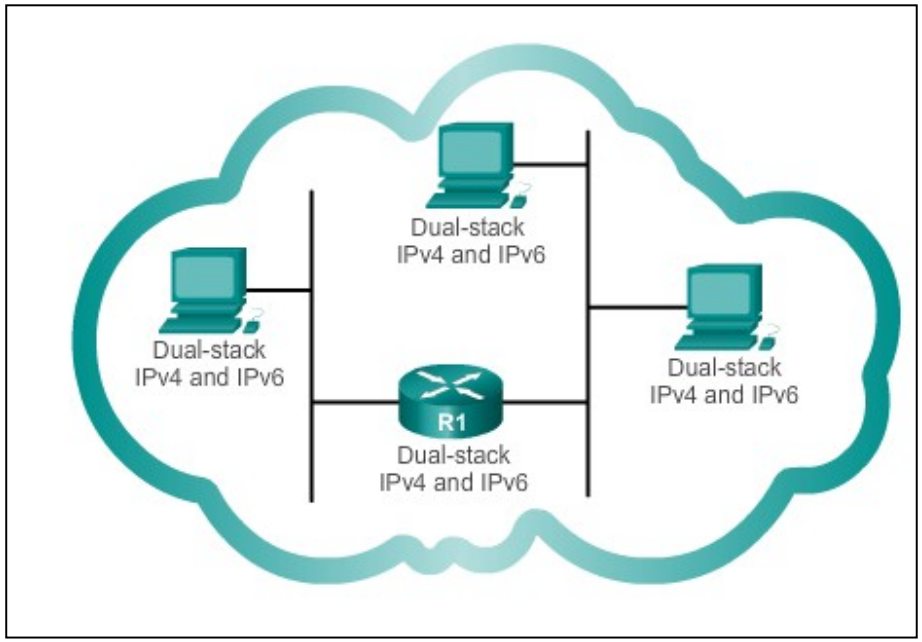
# The Need for IPv6

- 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.

# IPv4 and IPv6 Coexistence

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

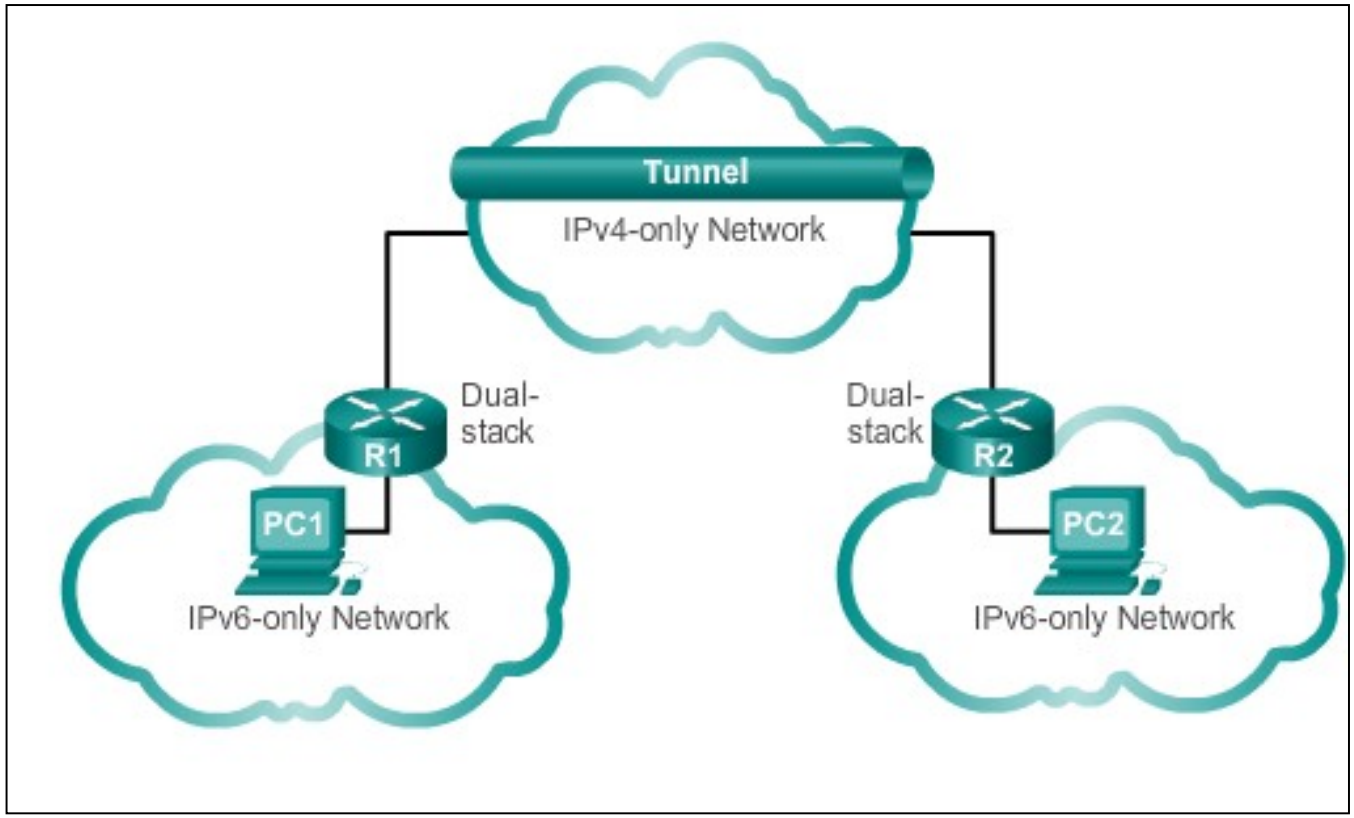
Dual-stack




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

# IPv4 and IPv6 Coexistence (cont.)

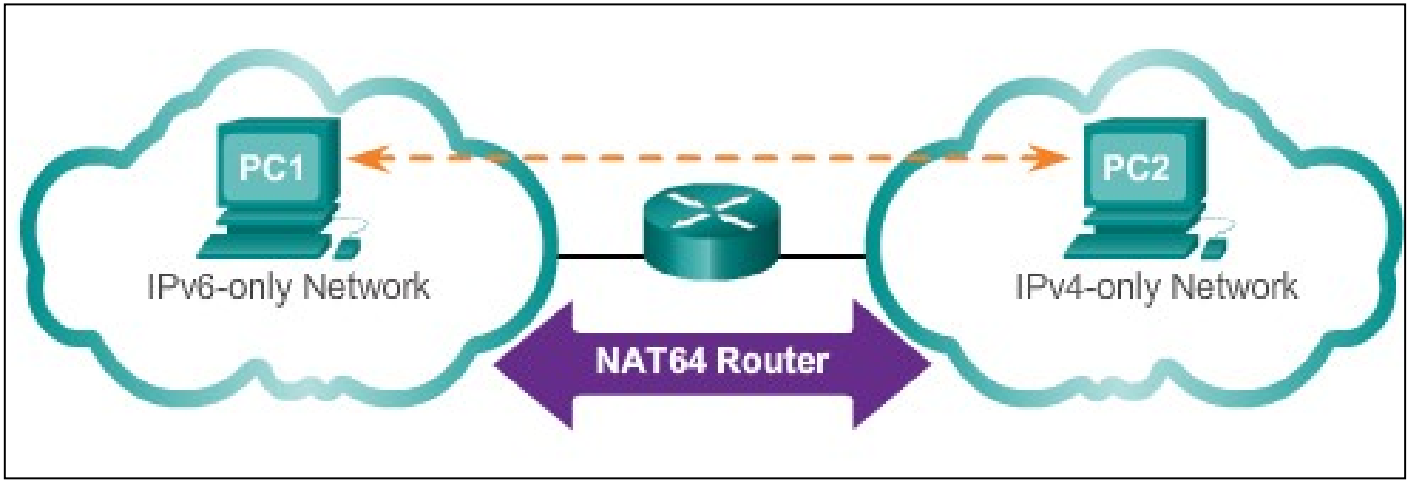
Tunnelling




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

# IPv4 and IPv6 Coexistence (cont.)

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.

# 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

# 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 |

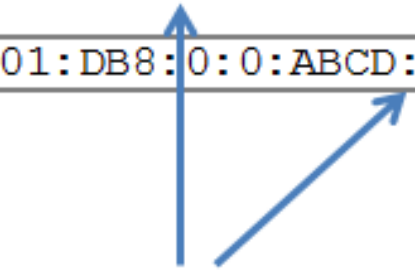
# Rule 2 - Omitting All 0 Segments

- 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.

# Rule 2 - Omitting All 0 Segments (cont.)

## Example #1

| | |
|---|---|
| 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 |



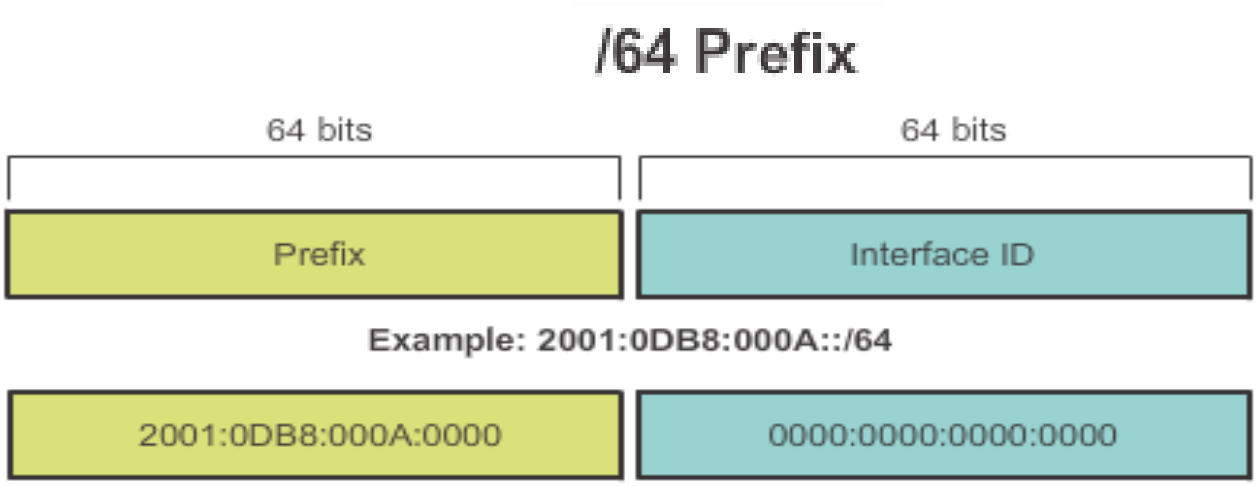
Only one : : may be used.

## Example #2

| | |
|---|---|
| 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



# IPv6 Address Types

There are three types of IPv6 addresses:

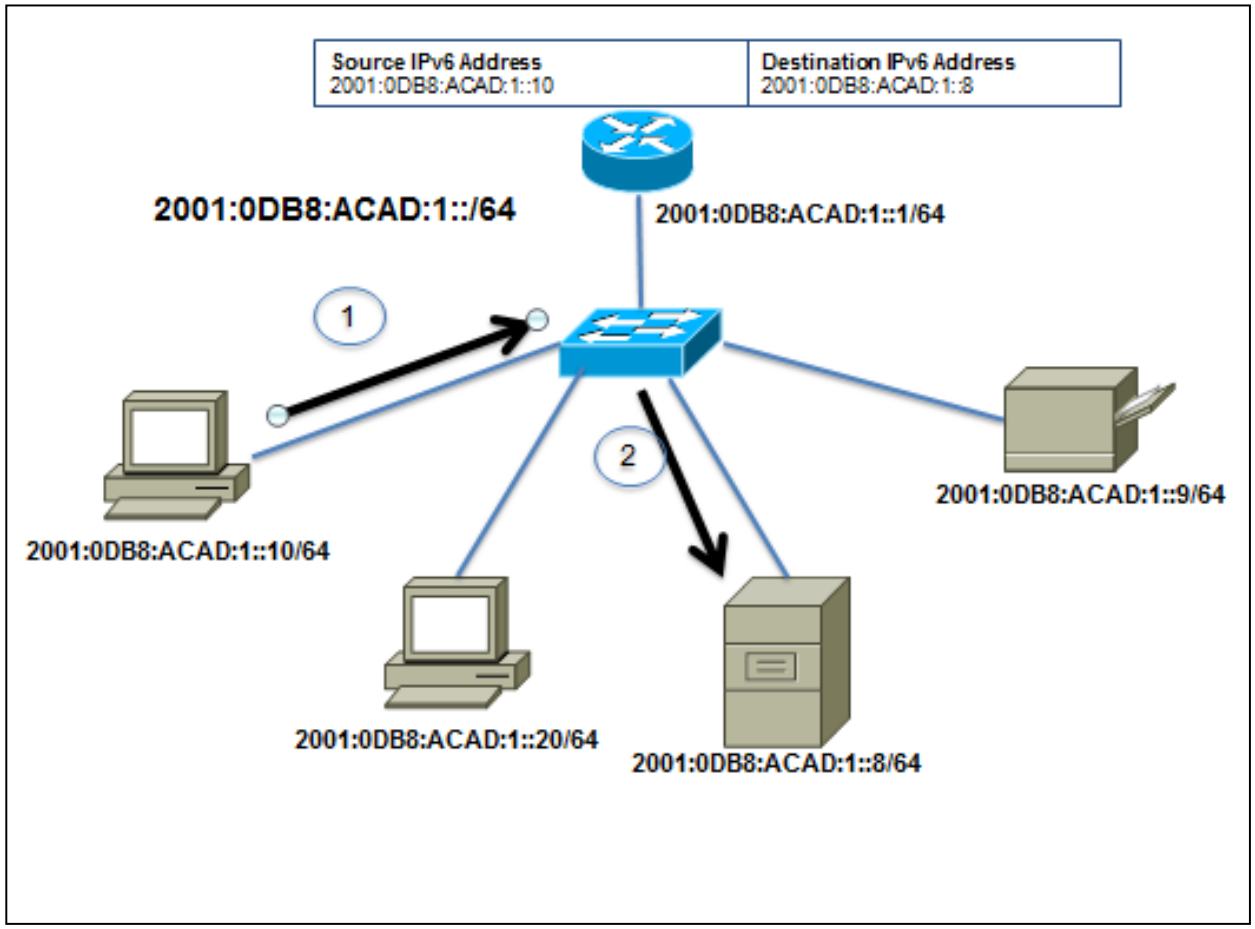
- Unicast
- Multicast
- Anycast.

**Note**: IPv6 does not have broadcast addresses.

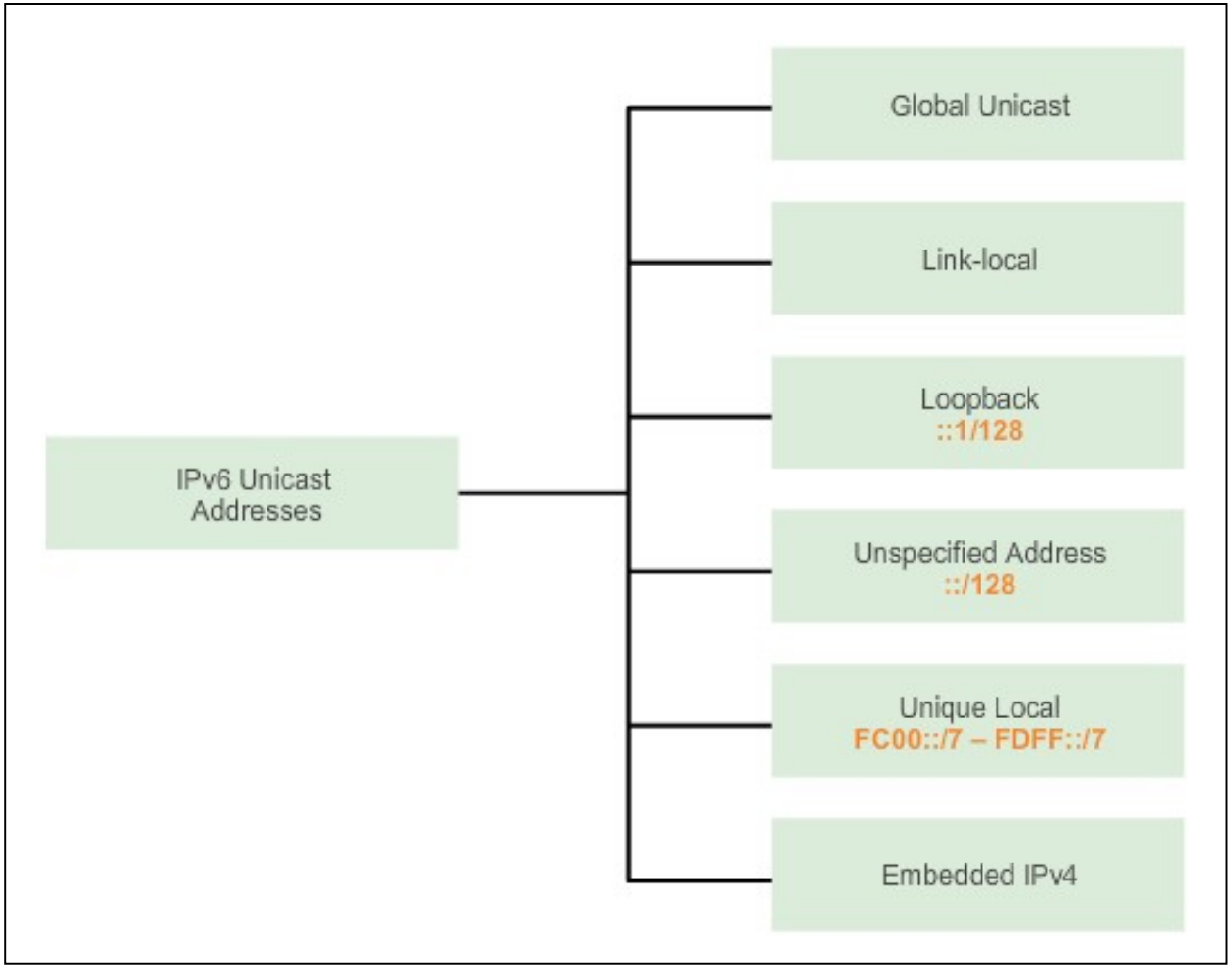
# IPv6 Unicast Addresses

## Unicast

- 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.



# IPv6 Unicast Addresses (cont.)



# IPv6 Unicast Addresses (cont.)

**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

# IPv6 Unicast Addresses (cont.)

**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.

# IPv6 Unicast Addresses

**Unique Local**

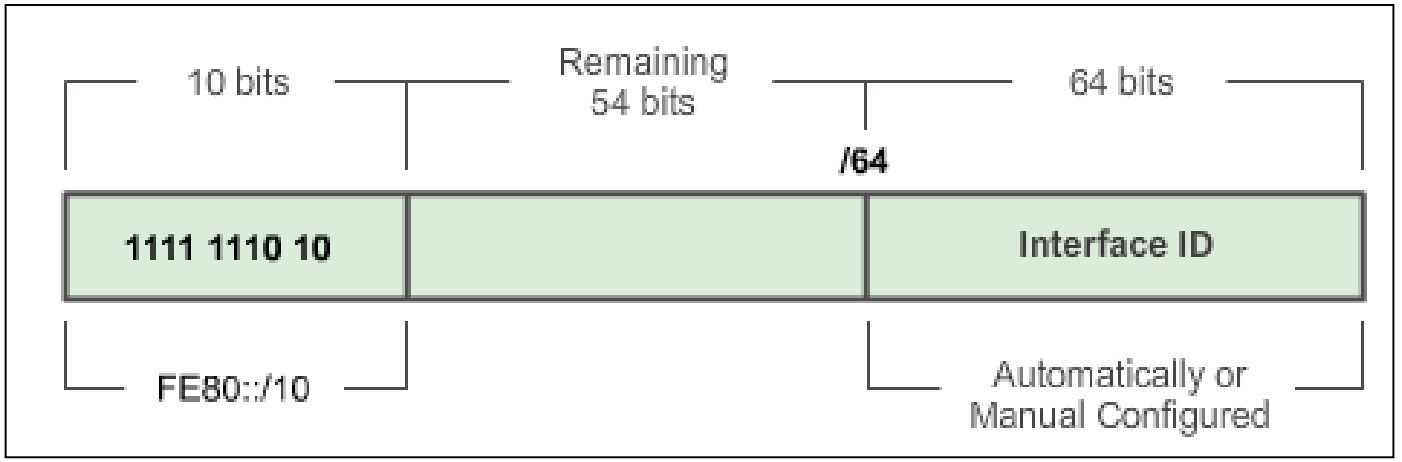
- Similar to private addresses for IPv4.
- Used for local addressing within a site or between a limited number of sites.
- In the range of FC00::/7 to FDFF::/7.

**IPv4 Embedded**

- Used to help transition from IPv4 to IPv6.

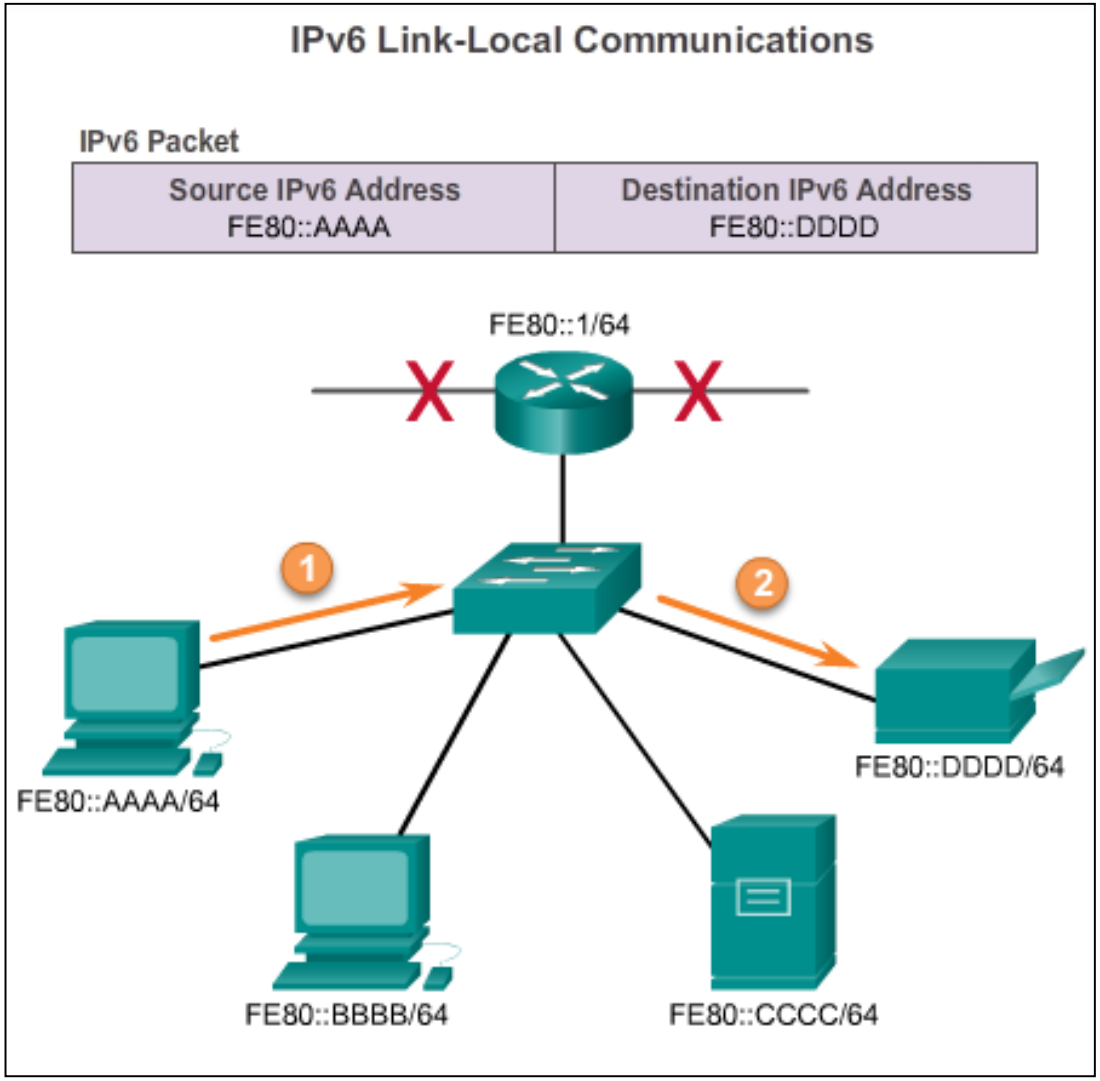
# IPv6 Link-Local Unicast Addresses

- 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)



# IPv6 Link-Local Unicast Addresses (cont.)

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

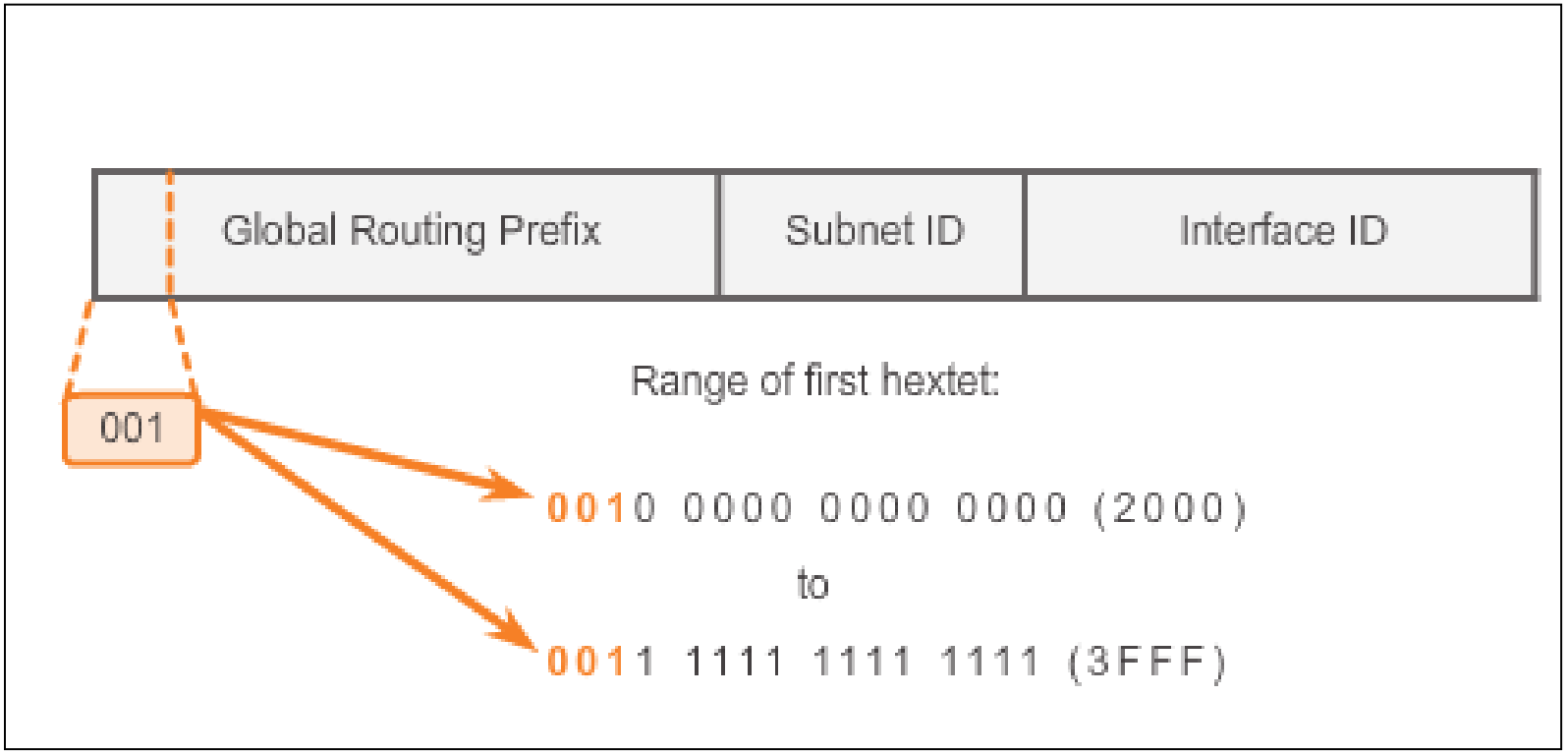


# Structure of an IPv6 Global Unicast Address

- 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

# Structure of an IPv6 Global Unicast Address (cont.)

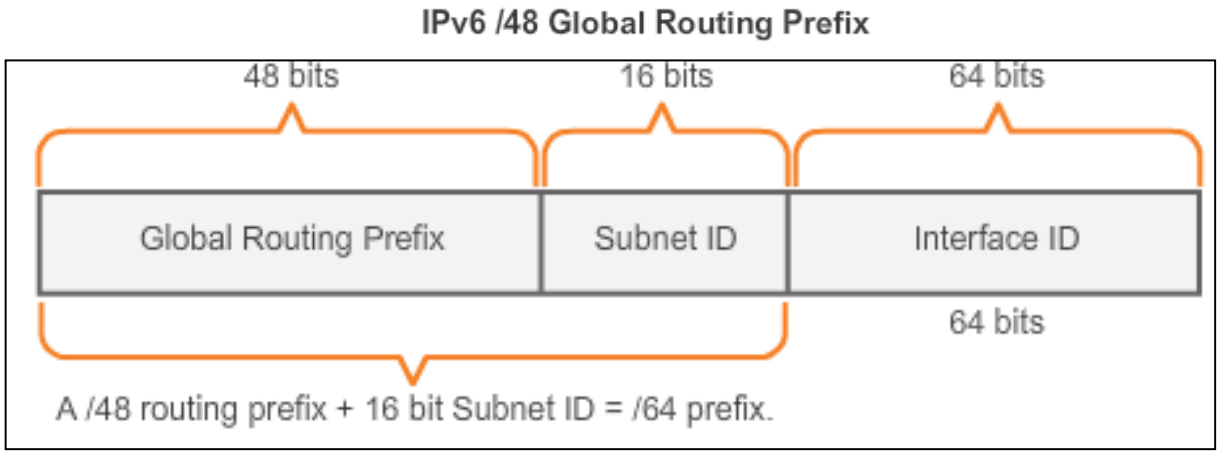
Currently, only global unicast addresses with the first three bits of 001 or 2000::/3 are being assigned



# Structure of an IPv6 Global Unicast Address (cont.)

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

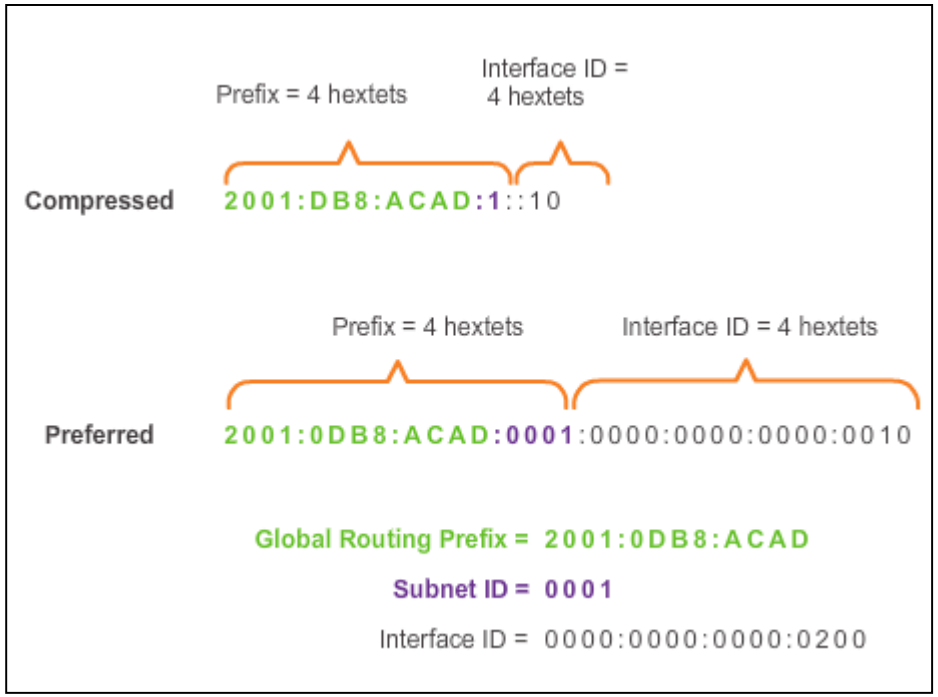
- **Global Routing Prefix** is the prefix or network portion of the address assigned by the provider, such as an ISP, to a customer or site, currently, RIR's assign a /48 global routing prefix to customers.
- 2001:0DB8:ACAD::/48 has a prefix that indicates that the first 48 bits (2001:0DB8:ACAD) is the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



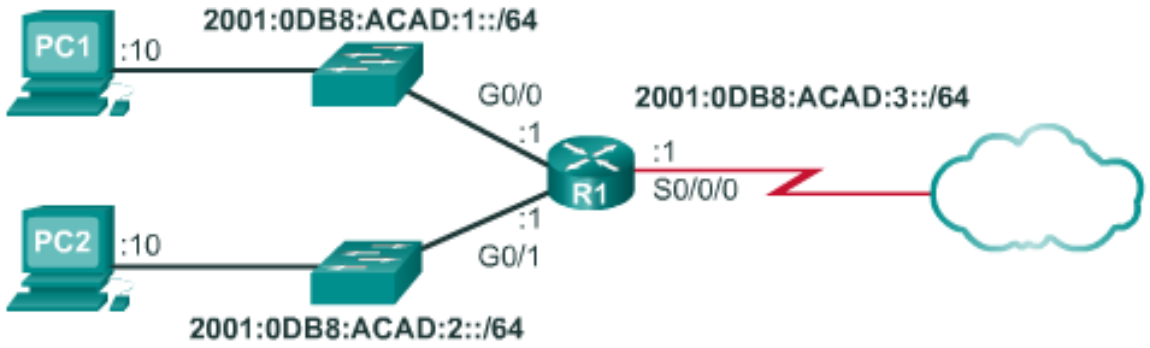
# Structure of an IPv6 Global Unicast Address (cont.)

- **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.

**Reading a Global Unicast Address**



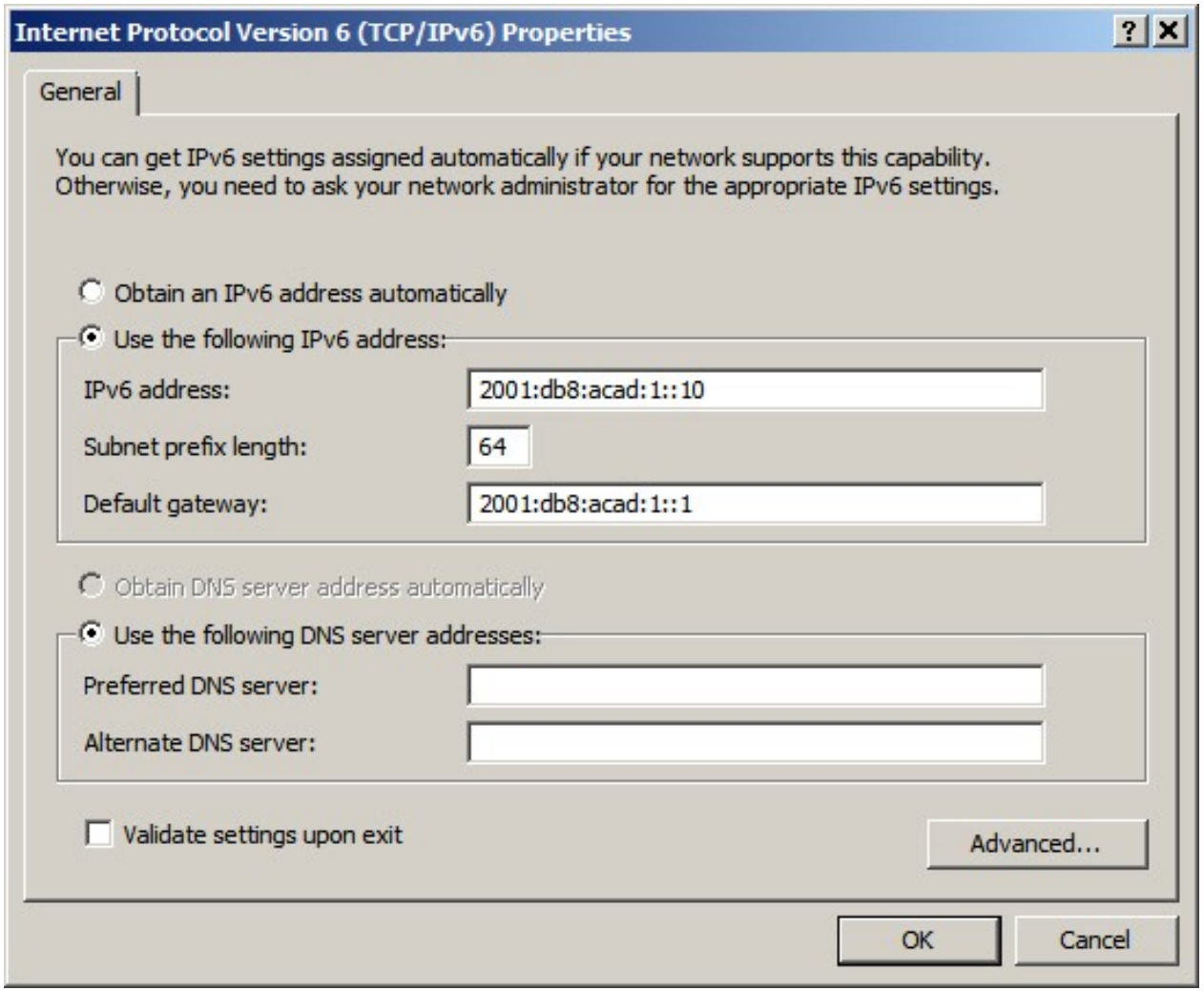
# Static Configuration of a Global Unicast Address




```
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
```

# Static Configuration of an IPv6 Global Unicast Address (cont.)

Windows IPv6 Setup



# Dynamic Configuration of a Global Unicast Address using SLAAC

**Stateless Address Autoconfiguraton (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

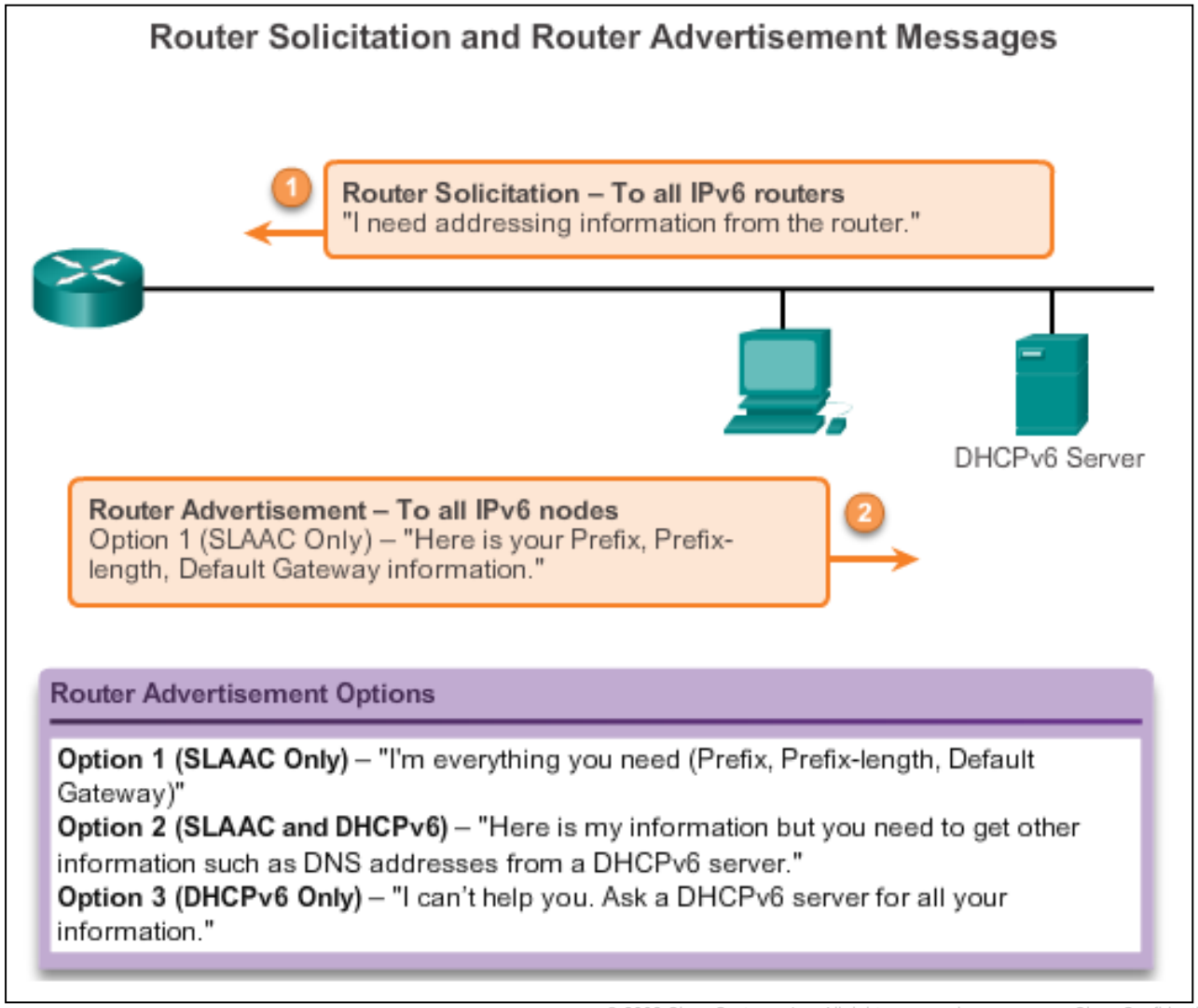
**IPv6 routers**

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

# Dynamic Configuration of a Global Unicast Address using SLAAC (cont.)

- The **`IPv6 unicast-routing`** command enables IPv6 routing.
- RA message can contain one of the following three options:
  - SLAAC Only – Uses the information contained in the RA message.
  - SLAAC and DHCPv6 – Uses the information contained in the RA message and get other information from the DHCPv6 server, stateless DHCPv6 (for example, DNS).
  - DHCPv6 only – The device should not use the information in the RA, stateful DHCPv6.
- Routers send ICMPv6 RA messages using the link-local address as the source IPv6 address

# Dynamic Configuration of a Global Unicast Address using SLAAC (cont.)

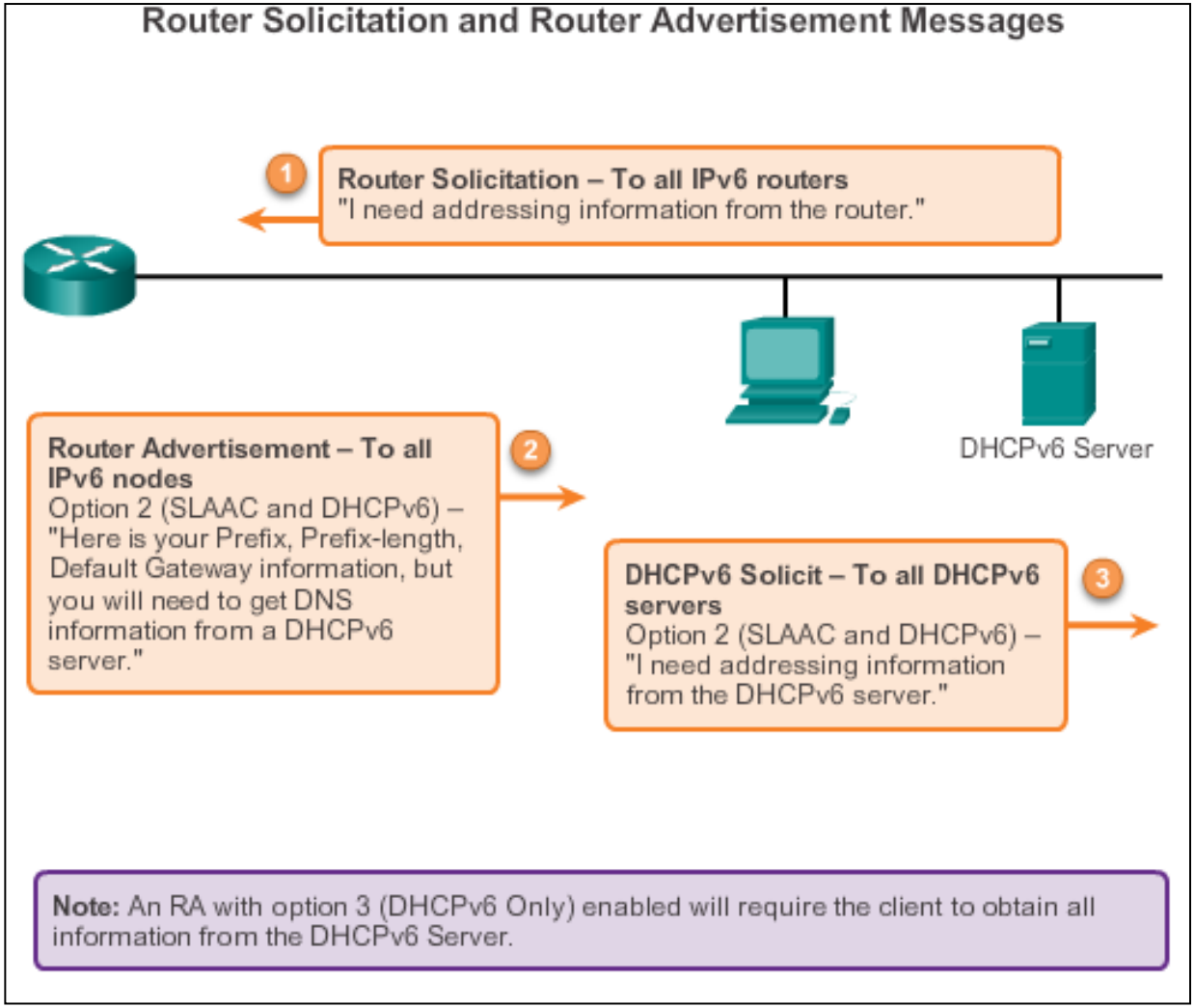


# Dynamic Configuration of a Global Unicast Address using DHCPv6 (cont.)

**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.

# Dynamic Configuration of a Global Unicast Address using DHCPv6 (cont.)



# EUI-64 Process

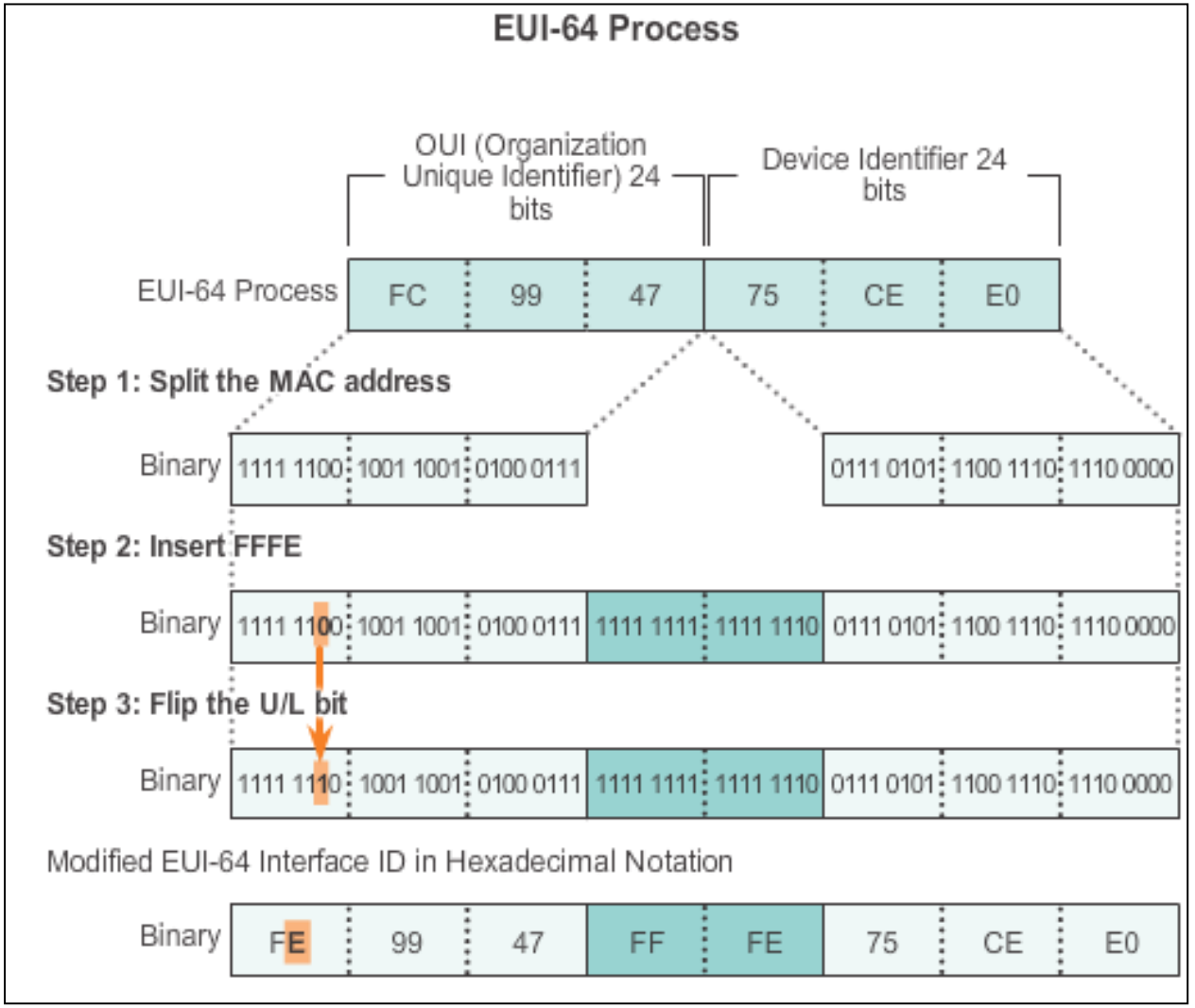
**EUI-64 Process**

- 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.

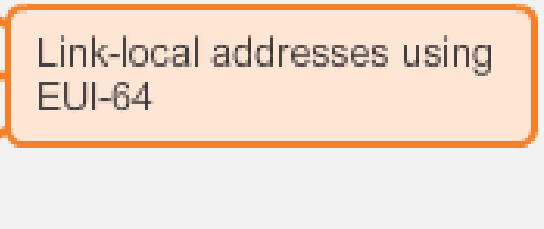
# EUI-64 Process



# EUI-64 Process

```
R1#show interface gigabitethernet 0/0
GigabitEthernet0/0 is up, line protocol is up
  Hardware is CN Gigabit Ethernet, address is fc99.4775.c3e0
(bia fc99.4775.c3e0)
<Output Omitted>

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#
```



# Static Link-local Addresses

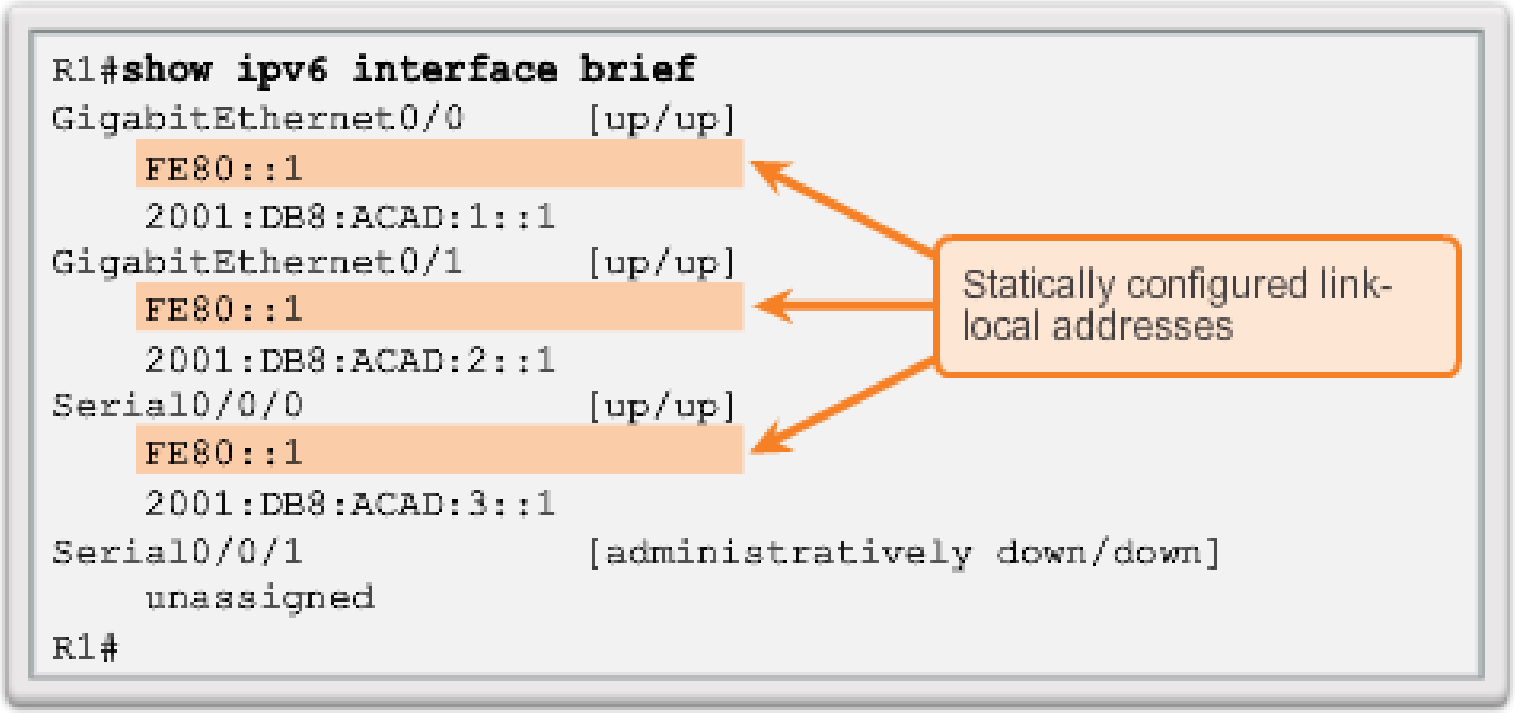
## Configuring Link-local

```
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)#
```

# Static Link-local Addresses (cont.)

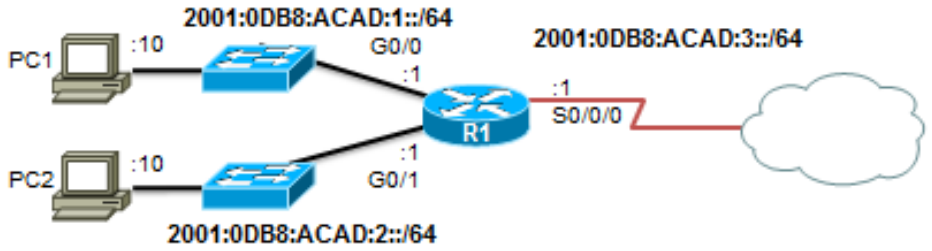
## Configuring Link-local



# 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#
```

# Verifying IPv6 Address Configuration (cont.)

```
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#
```

# 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 IPv6 Multicast Addresses (cont.)

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.

# Assigned IPv6 Multicast Addresses (cont.)