IPv6 Addressing

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Objectives

- Migrating to IPv6
- IPv6 Address Representation
- IPv6 Address Types
- ICMPv6
- IPv6 Routing

IPv4 Issues

The Need for IPv6

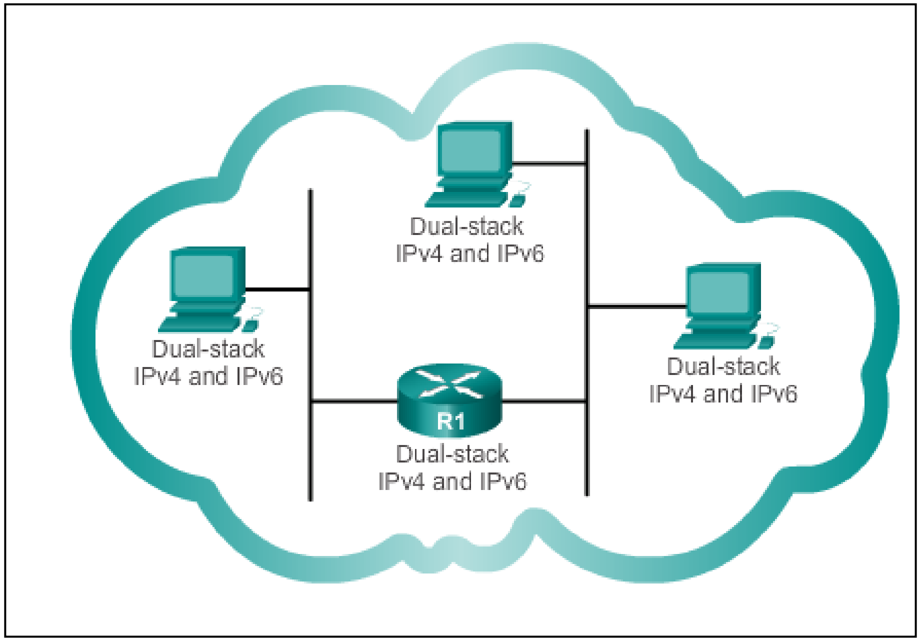
- IPv6 is designed to be the successor to IPv4.
- Depletion of IPv4 address space has been the motivating factor for moving to IPv6.
- With an increasing Internet population, a limited IPv4 address space, issues with NAT and with Internet of things, the time has come to begin the transition to IPv6
- 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.

IPv4 Issues

IPv4 and IPv6 Coexistence

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

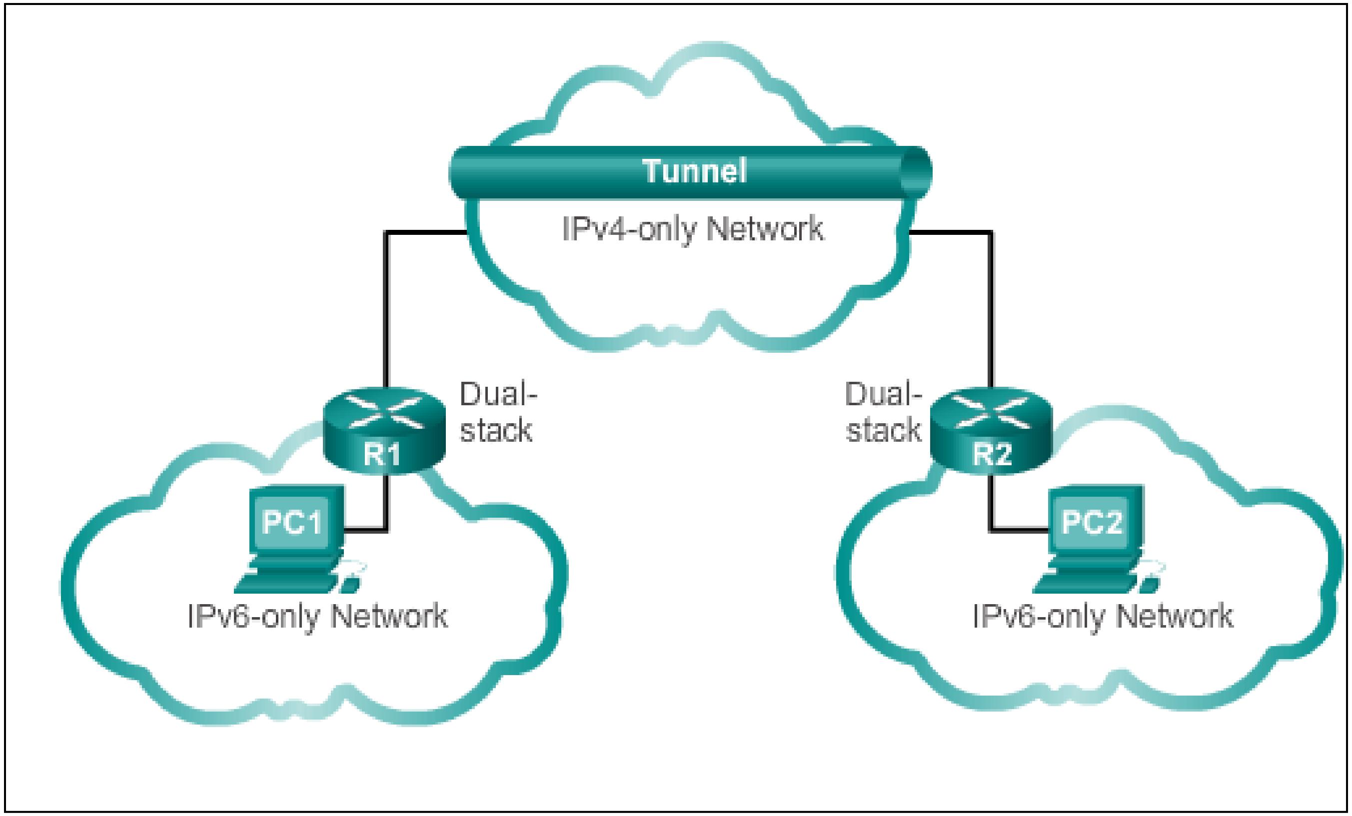
Dual-stack



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.)

Tunneling

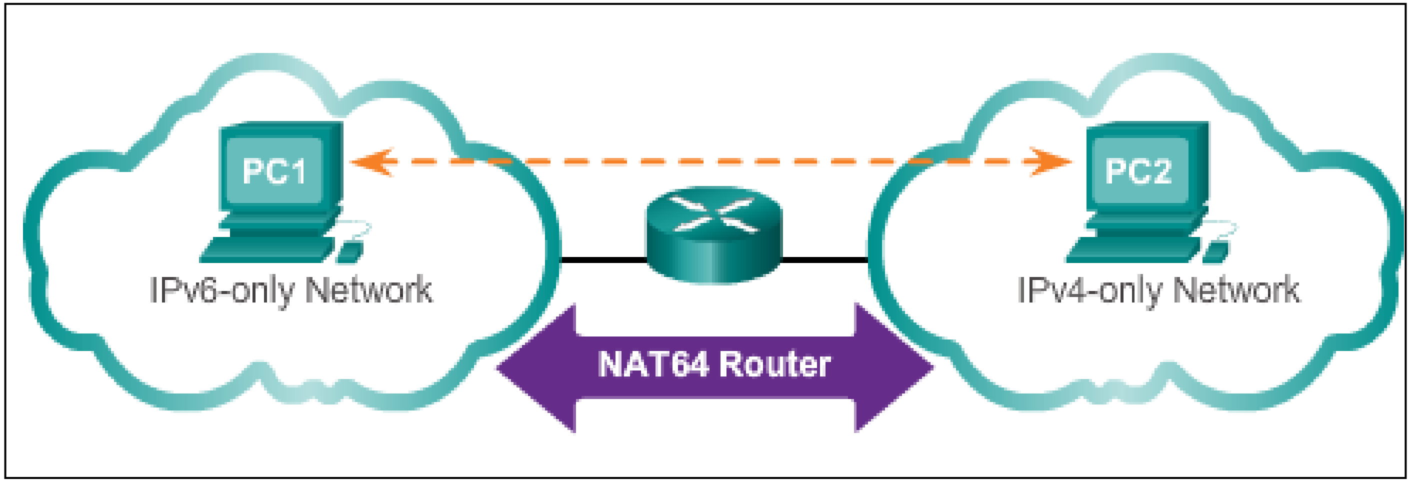


Tunneling: A method of transporting an IPv6 packet over an IPv4 network. The IPv6 packet is encapsulated inside an IPv4 packet.

IPv4 Issues

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

IPv6 Addressing

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.
- 0DB8 can be represented as DB8.
- 000A can be represented as A.
- 0000 can be represented as 0.
- 0100 can be represented as 100.

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

IPv6 Addressing

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.*

IPv6 Addressing

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.

- Incorrect address - 2001:0DB8::ABCD::1234.

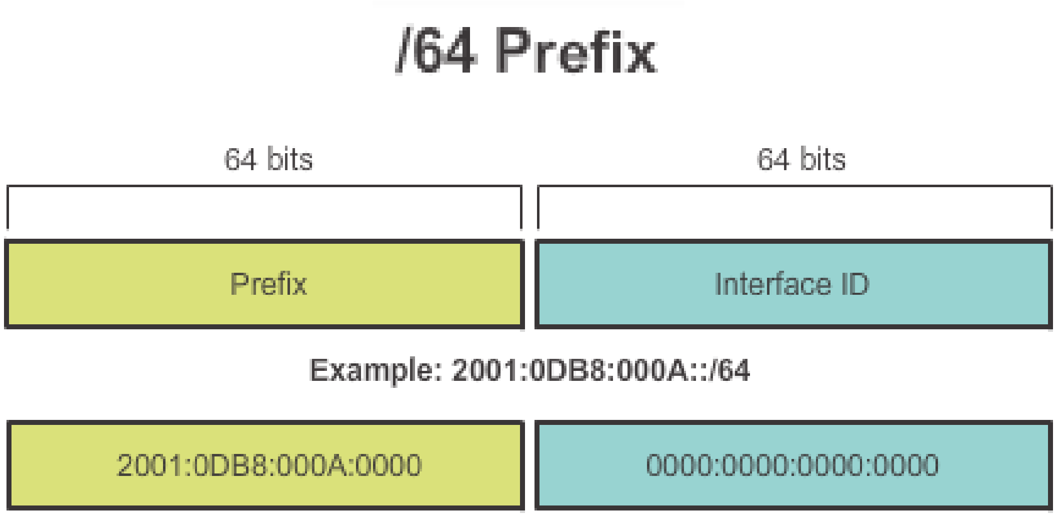
Example #2

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

Types of IPv6 Addresses

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



Types of IPv6 Addresses

IPv6 Address Types

There are three types of IPv6 addresses:

- Unicast
- Multicast
- Anycast.

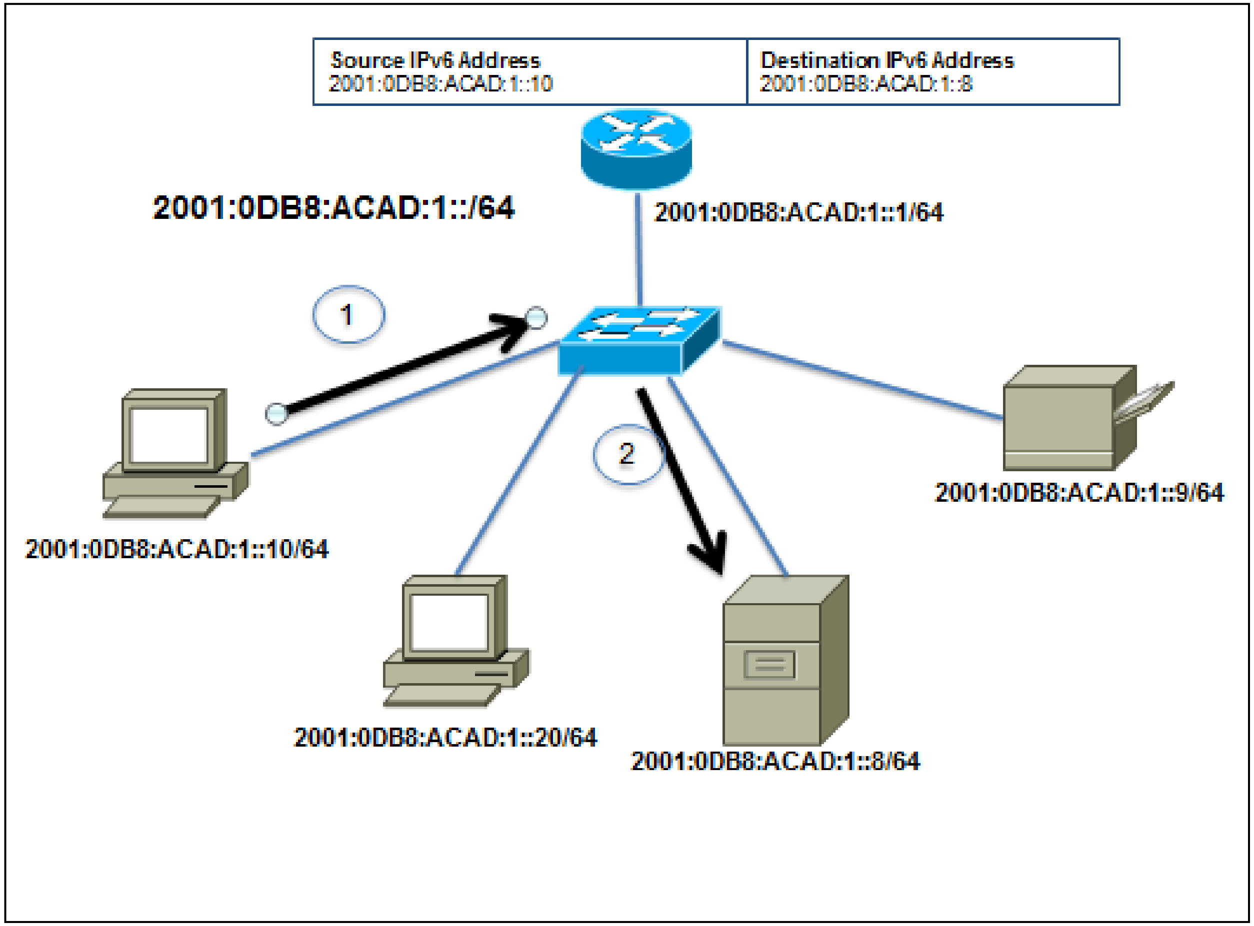
Note: IPv6 does not have broadcast addresses.

Types of IPv6 Addresses

IPv6 Unicast Addresses

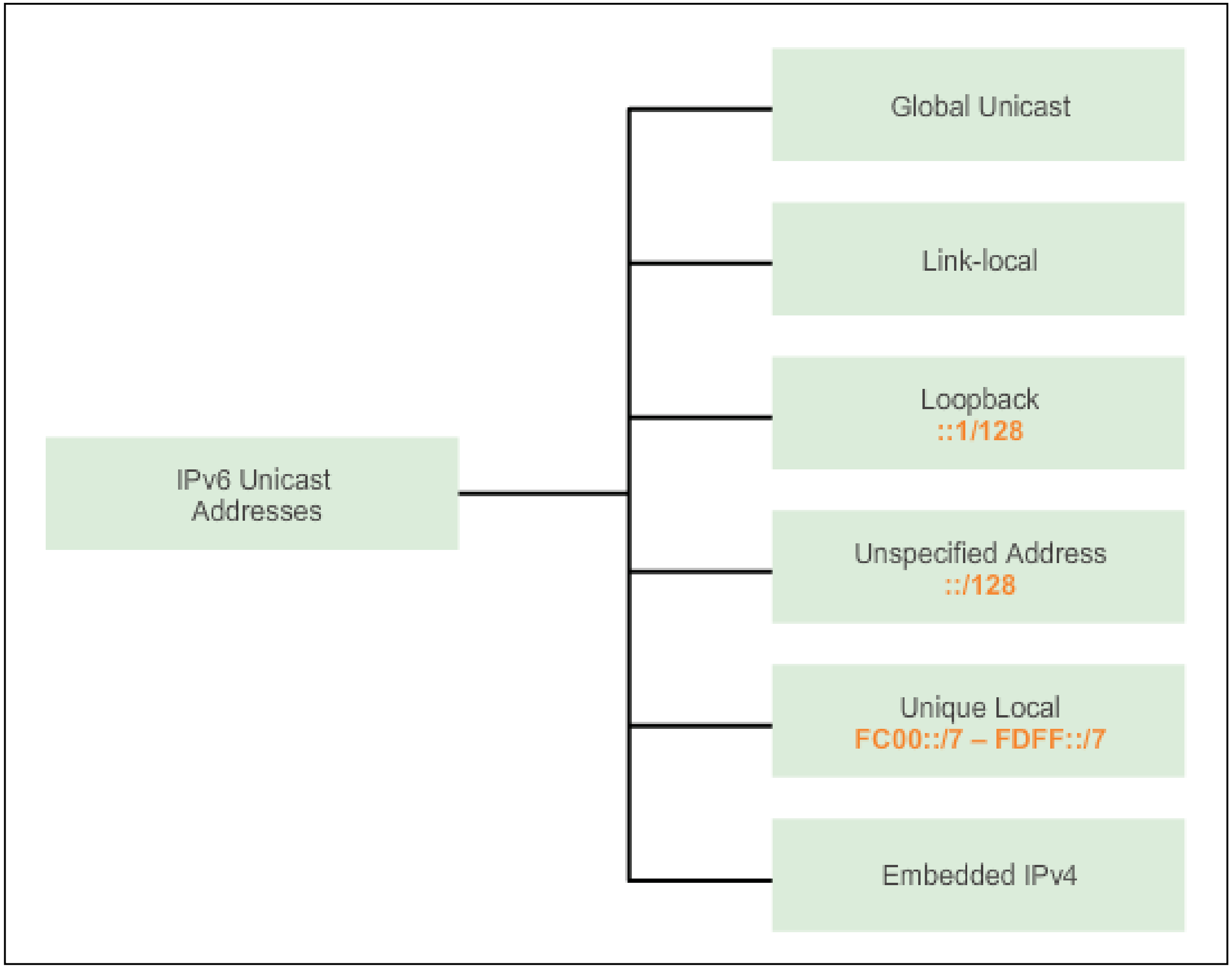
Unicast

- 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.



Types of IPv6 Addresses

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
- ICANN allocates IPv6 address blocks to the five RIRs

Link-local

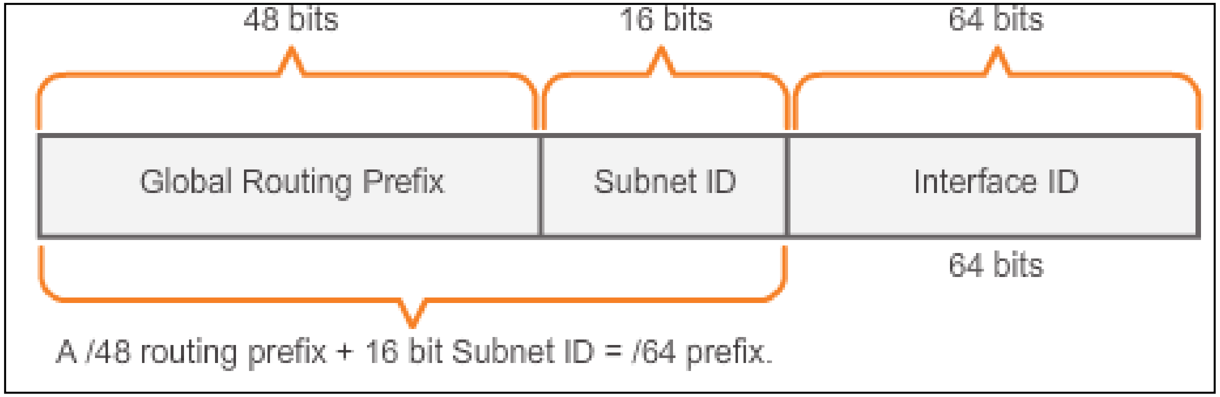
- Used to communicate with other devices on the same local link
- Restricted to a single link; not routable beyond the link

IPv6 Unicast Addresses
Structure of an IPv6 Global Unicast Address

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.

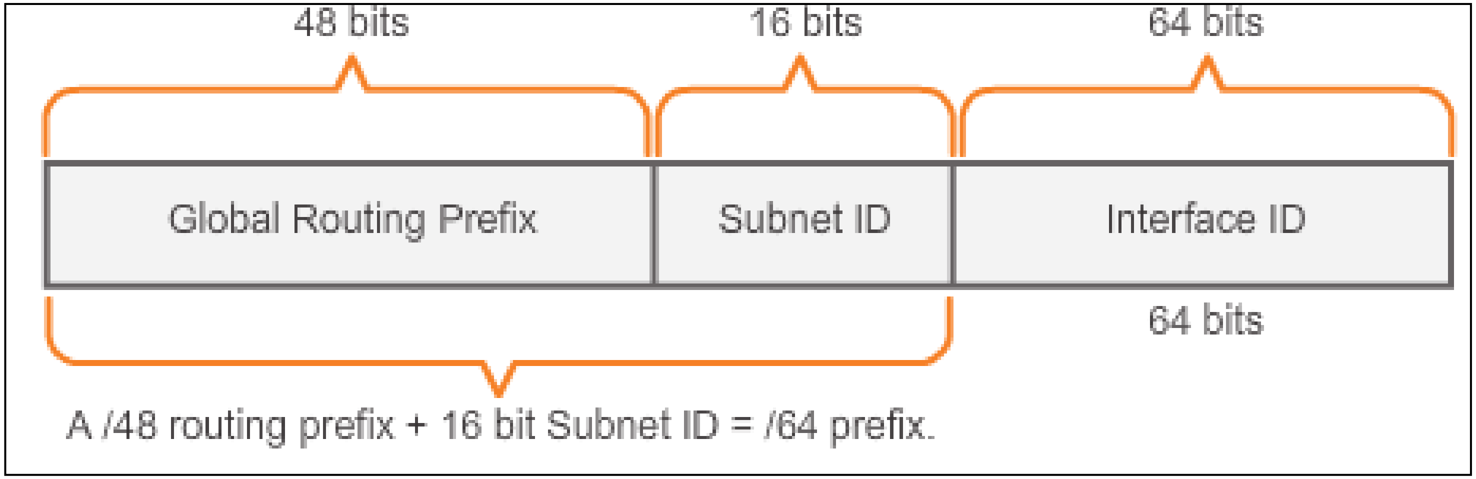
IPv6 /48 Global Routing Prefix



IPv6 Unicast Addresses

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.



Structure of an IPv6 Global Unicast Address (cont.)

Prefix = 4 hextets

Interface ID = 4 hextets

Compressed 2001:DB8:ACAD:1::10

Prefix = 4 hextets

Interface ID = 4 hextets

Reading a Global Unicast Address 2001:0DB8:ACAD:0001:0000:0000:0000:0010

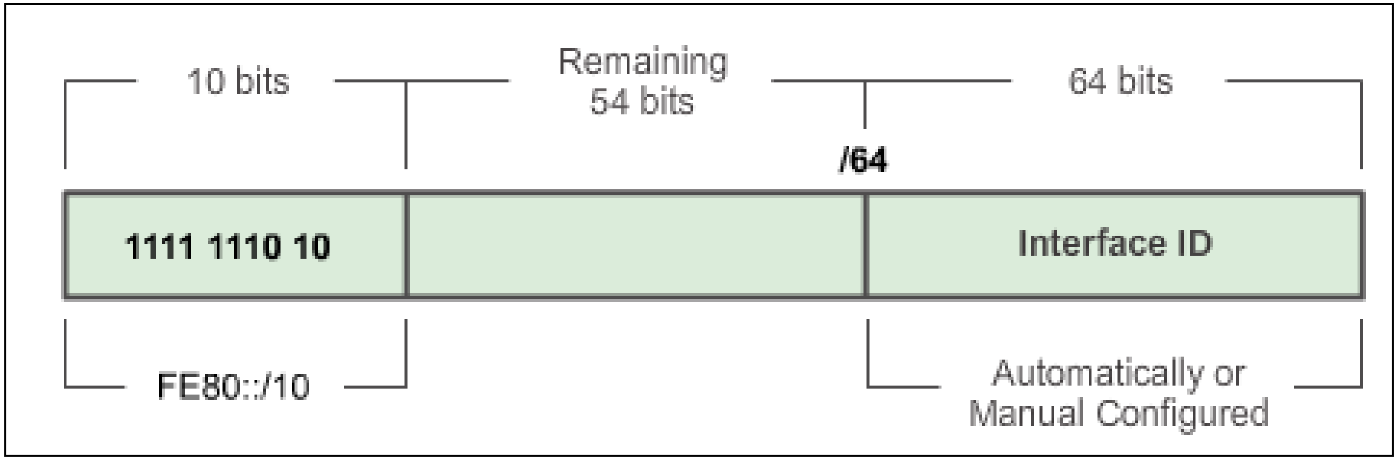
Global Routing Prefix = 2001:0DB8:ACAD

Subnet ID = 0001

Interface ID = 0000:0000:0000:0200

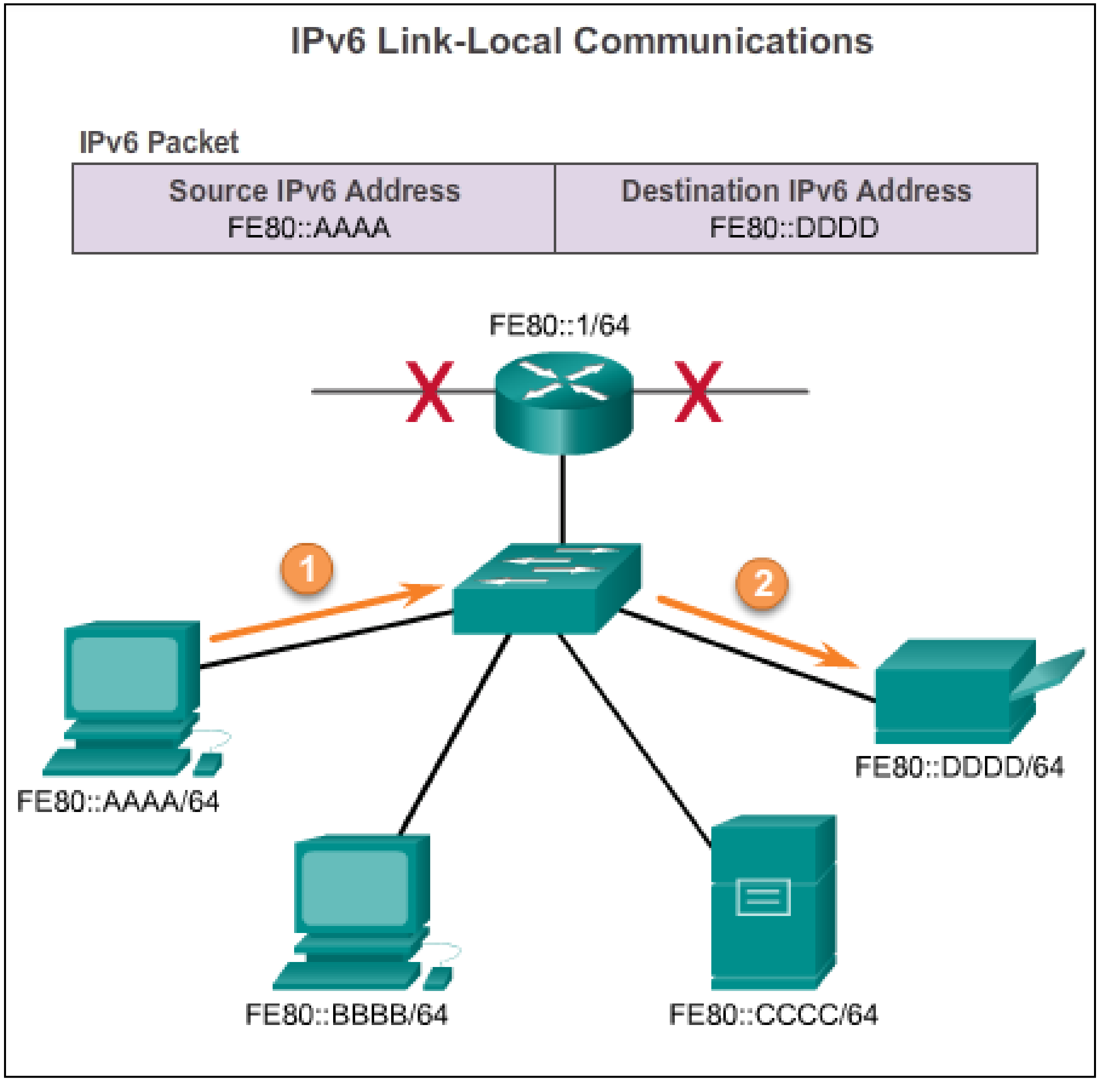
IPv6 Link-Local Unicast Addresses

- 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.



Dynamic Link-local Addresses

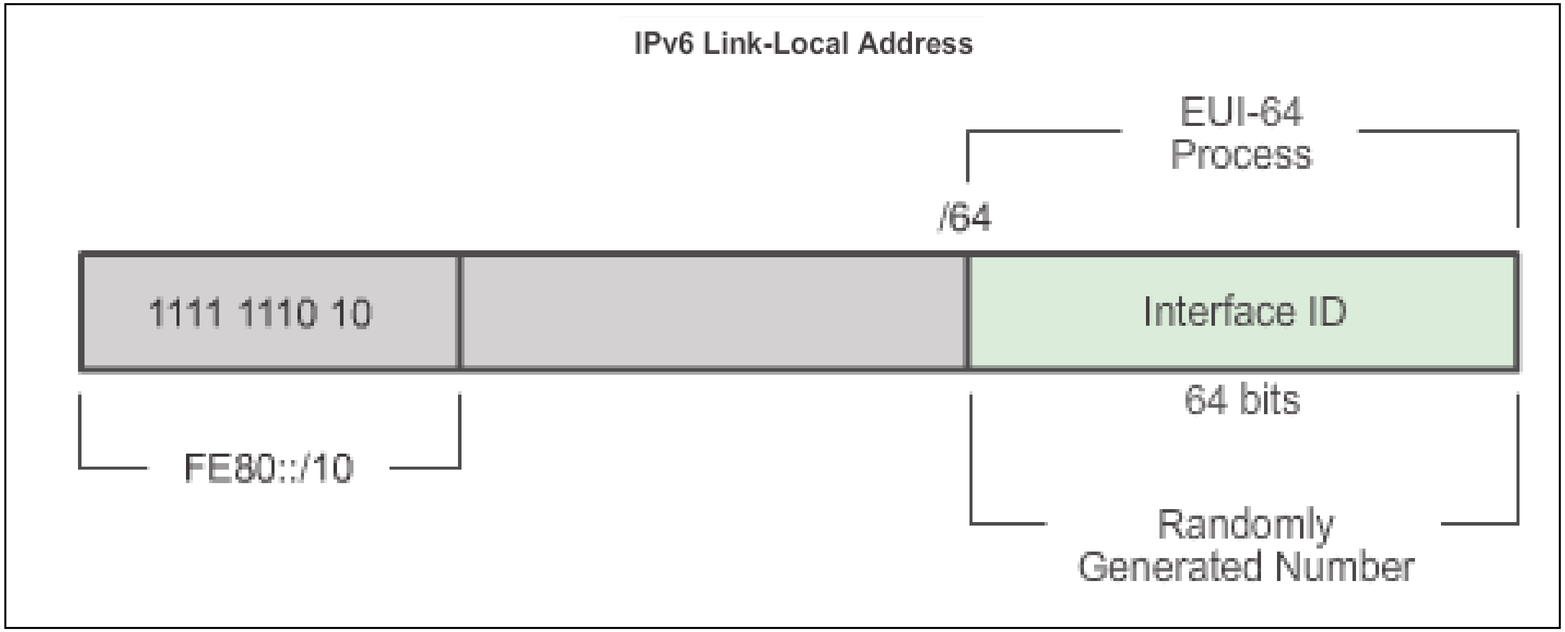
Link-Local Address

- 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.

Dynamic Link-local Addresses (cont.)

Dynamically Assigned

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



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

IPv6 Multicast Addresses

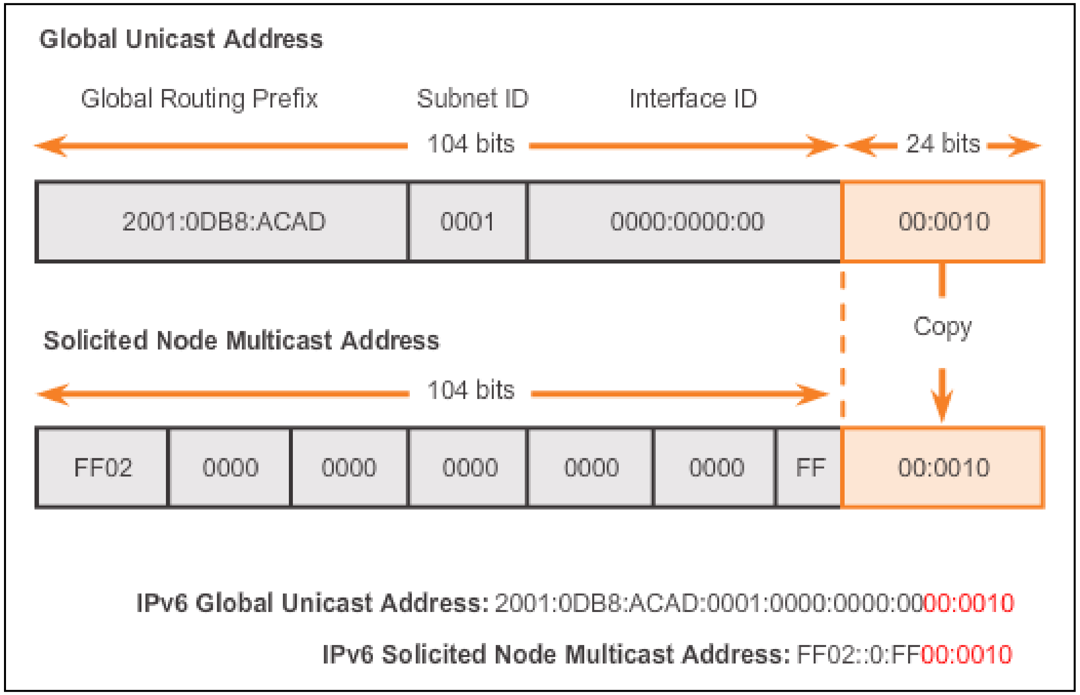
Assigned IPv6 Multicast Addresses (cont.)

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.

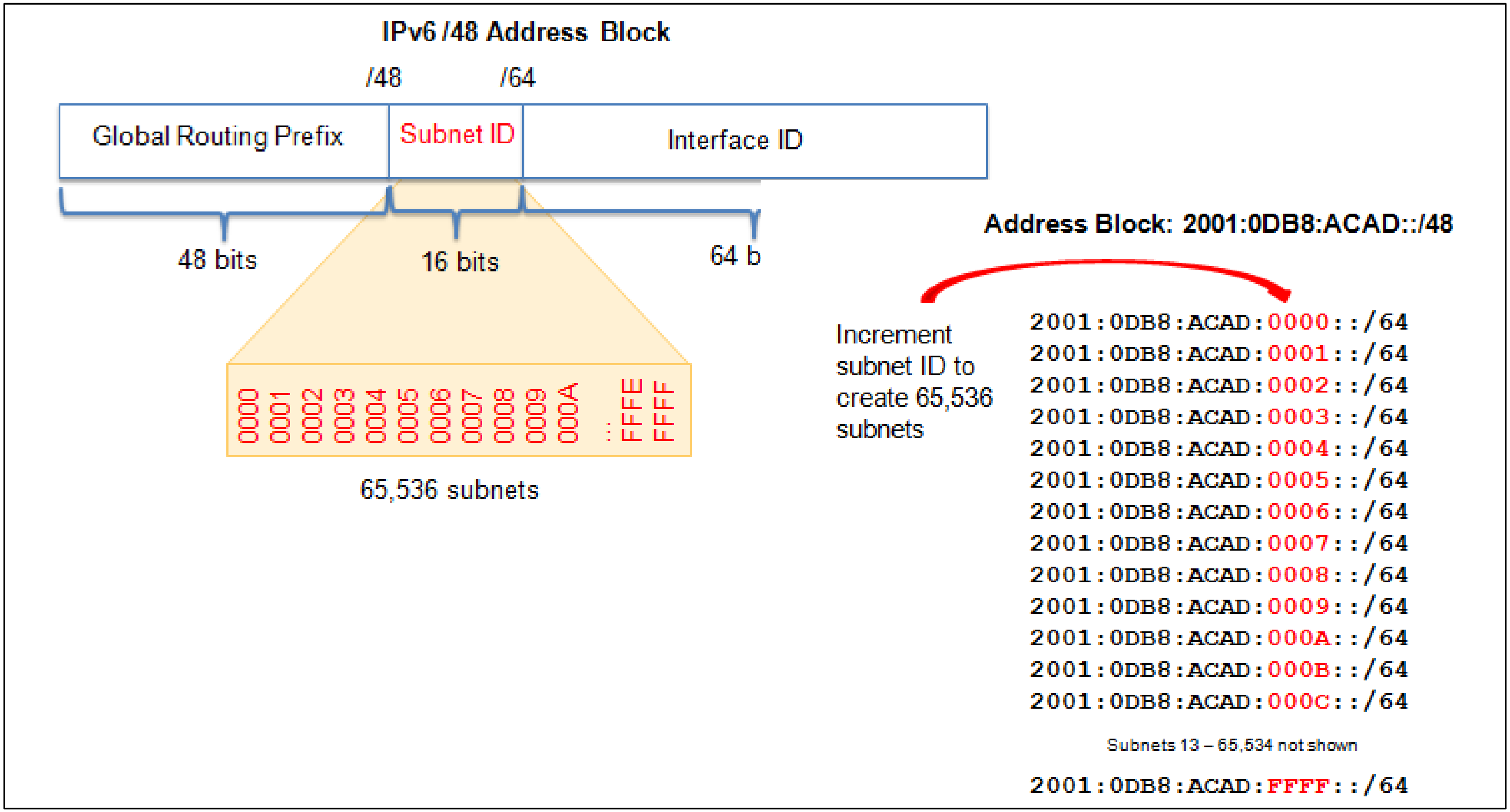
Solicited Node IPv6 Multicast Addresses

- 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



Subnetting Using the Subnet ID

An IPv6 Network Space is subnetted to support hierarchical, logical design of the network



Subnetting an IPv6 Network

IPV6 Subnet Allocation

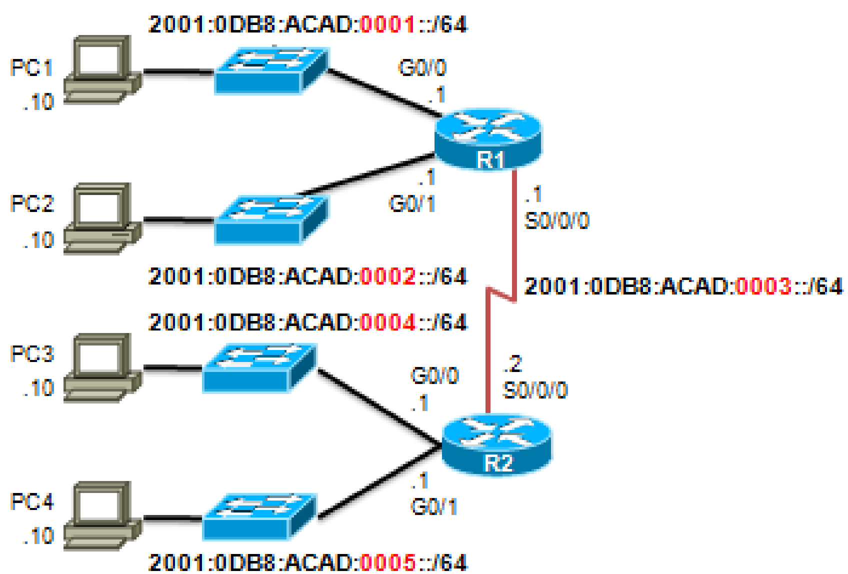
IPv6 Subnetting

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

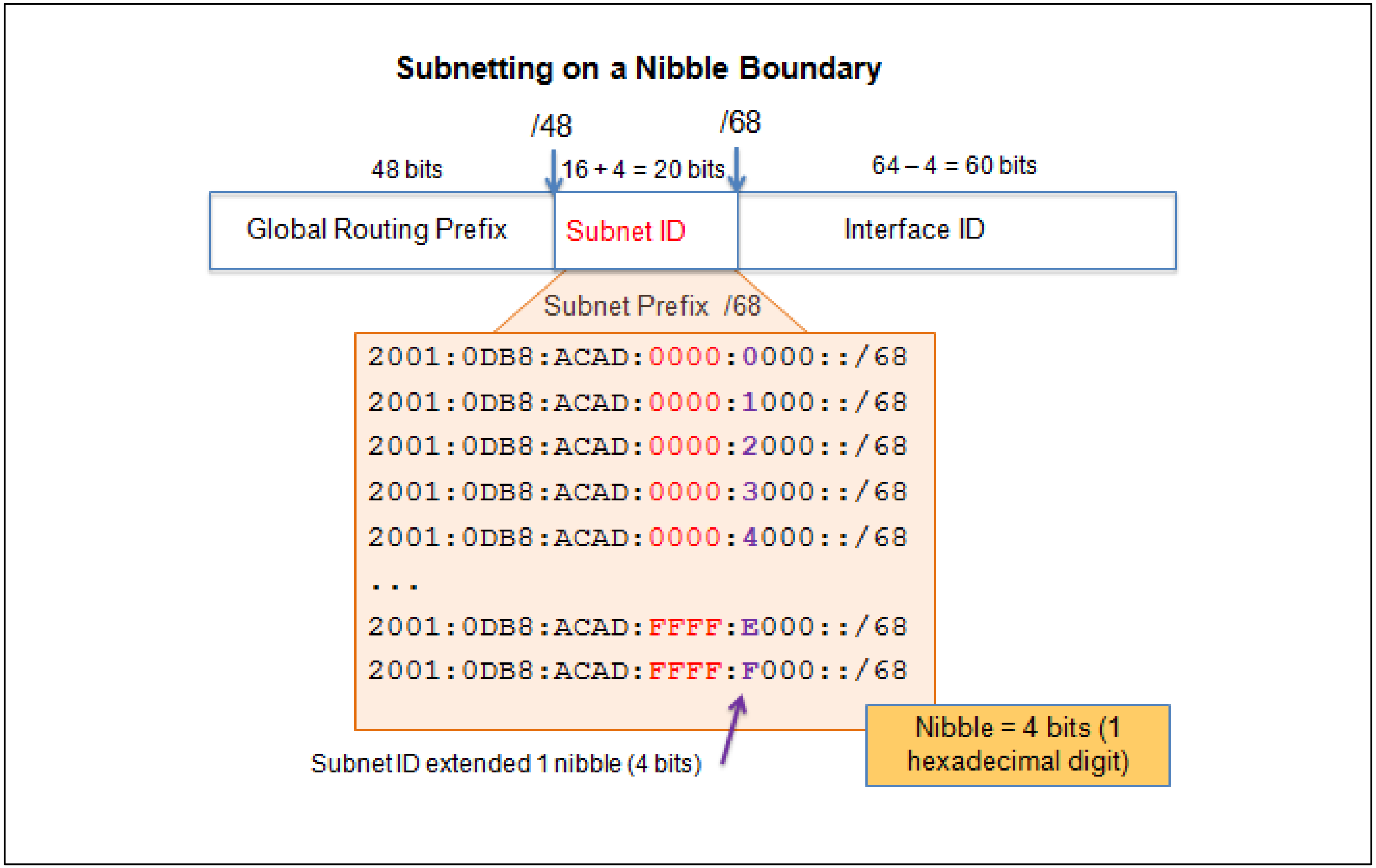
IPv6 Subnet Allocation



Subnetting an IPv6 Network

Subnetting into the Interface ID

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



Obtaining a Provider-Assigned IPv6 Address

The IPv6 address assignment methods are as follows:

- Manual assignment
- Stateless address autoconfiguration (SLAAC)
- Stateless DHCPv6
- Stateful DHCPv6
- DHCPv6 prefix delegation (DHCPv6-PD)

Stateless Address Autoconfiguration

- SLAAC provides the capability for a device to obtain IPv6 addressing information without any intervention from the network administrator.
- This is achieved with the help of RAs, which are sent by routers on the local link.
- RA messages include one or more prefixes, prefix lifetime information, flag information, and default router lifetime information.
- The source IPv6 link-local address of the RA message is used by the host as its IPv6 default router address.
- IPv6 hosts listen for these RAs and use the advertised prefix, which must be 64 bits long.
- The host generates the remaining 64 host bits either by using the IEEE EUI-64 format or by creating a random sequence of bits.
  - The MAC address is split into two 24-bit parts.
  - 0xFFFE is inserted between the two parts, resulting in a 64-bit value.
  - If the generated IPv6 address is unique, it can be applied to the interface.

DHCPv6

In the IPv6 world, there are two types of DHCPv6:

- **Stateless:** Used to supply additional parameters to clients that already have an IPv6 address
  - Stateless DHCPv6 works in combination with SLAAC.
  - An IPv6 host gets its addressing and default router information using SLAAC, from information contained within an RA.
  - However, the IPv6 host also queries a DHCPv6 server for other information it needs, such as the DNS or NTP server addresses.
- **Stateful:** Similar to DHCP for IPv4 (DHCPv4)
  - RAs use the *managed address configuration* flag bit to tell IPv6 hosts to get their addressing and additional information only from the DHCPv6 server (to ignore the prefixes in the RA)
  - The default router address is still received from the RA link-local address

DHCPv6-PD

- An extension to DHCPv6
- Used by an ISP to automate the process of assigning prefixes to a customer for use within the customers network
- The prefix delegation occurs between a provider-edge (PE) device and customer premise equipment (CPE) using the DHCPv6-PD option
- Once the ISP has delegated prefixes to a customer, the customer may further subnet and assign prefixes to the links in their network

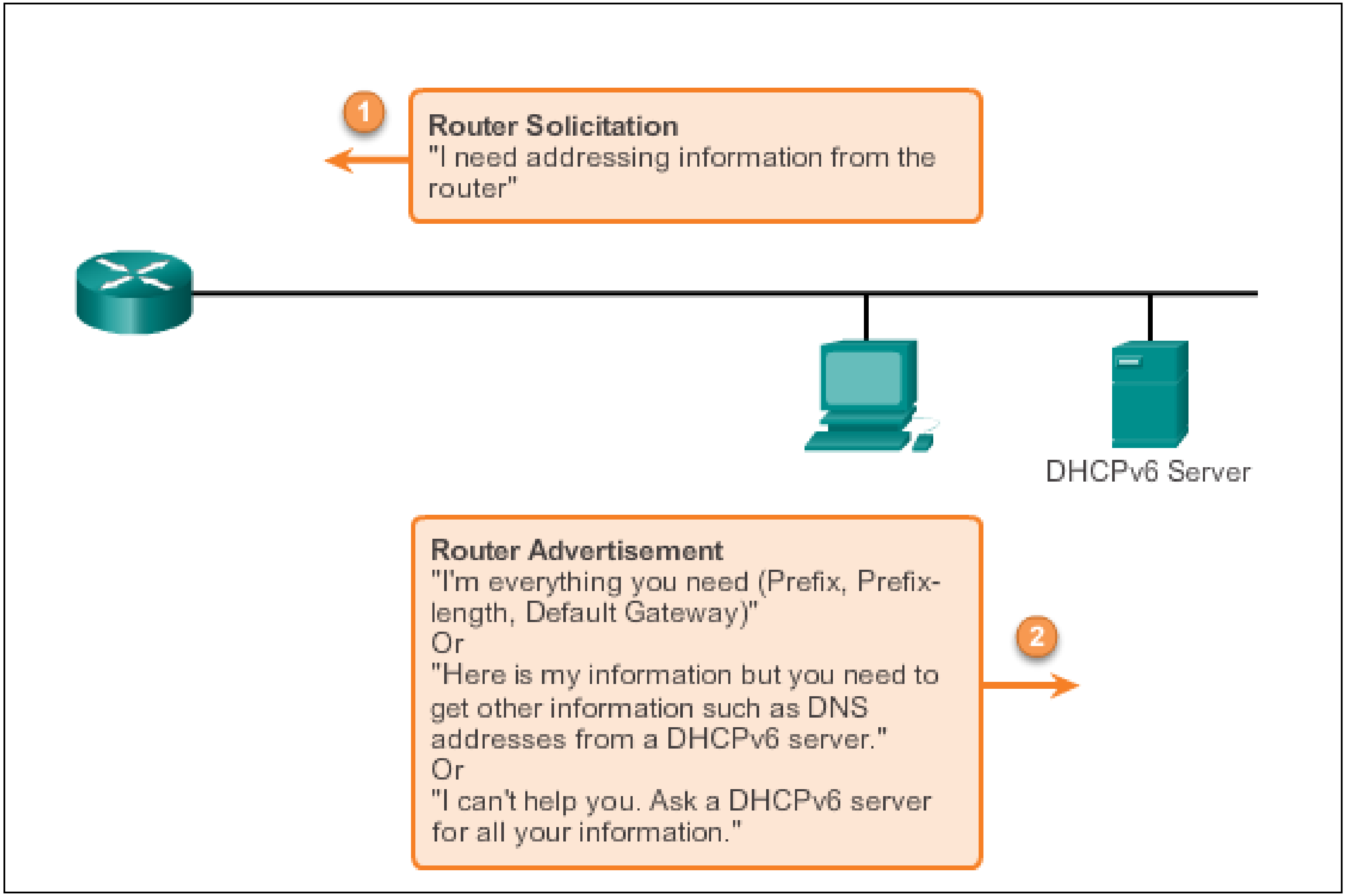
ICMP

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.

ICMP

ICMPv6 Router Solicitation and Router Advertisement Messages (cont.)

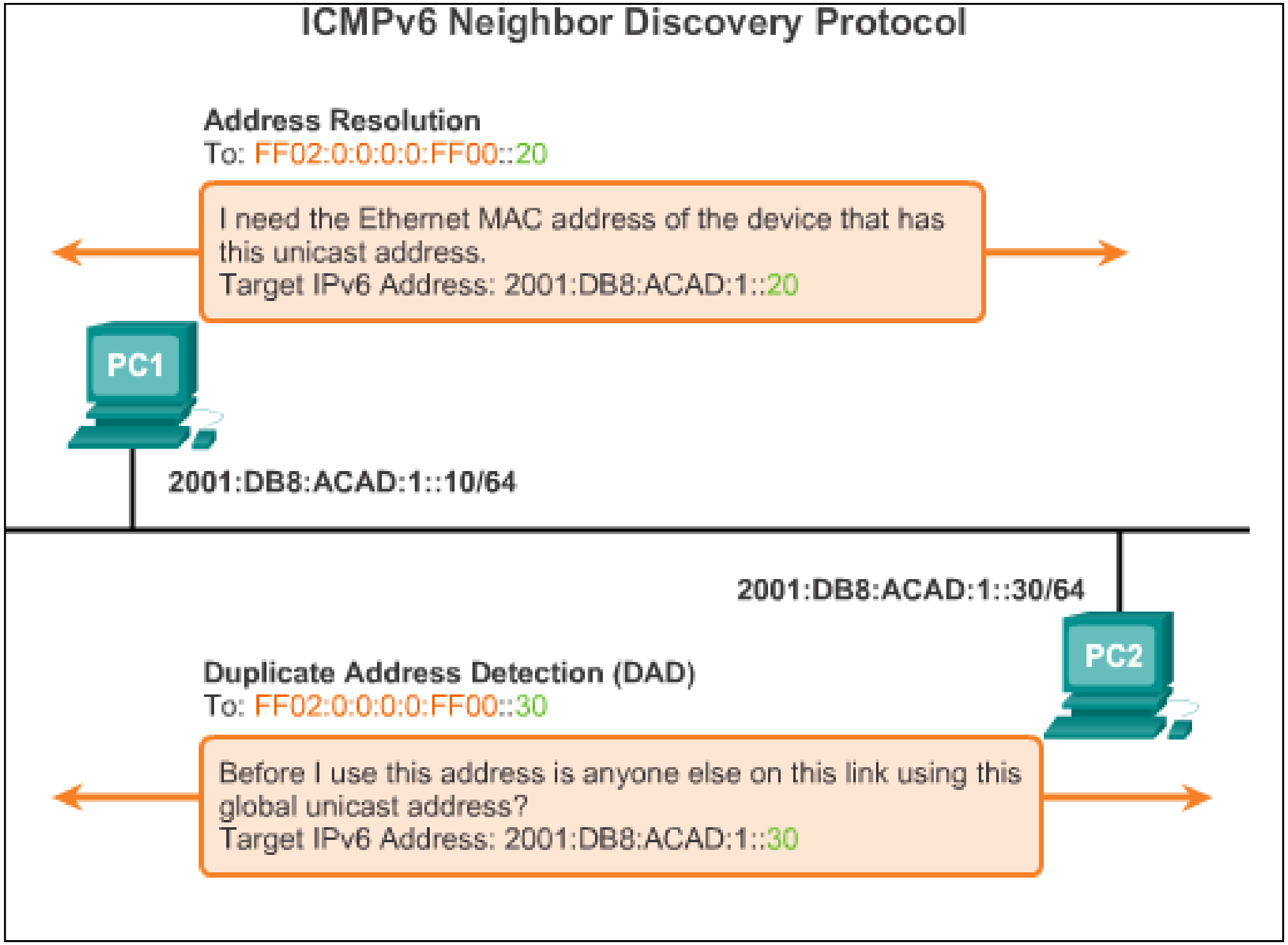


ICMP

ICMPv6 Neighbor Solicitation and Neighbor Advertisement Messages

- **Neighbor Solicitation (NS)** and **Neighbor Advertisement (NA)** messages are:
- **Used for address resolution** 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.

ICMPv6 Neighbor Solicitation and Neighbor Advertisement Messages (cont.)



IPv6 Routing

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IPv6 Routing

- IPv6 supports the following routing:
  - Static Routing
  - RIPng
  - OSPFv3
  - IS-IS for IPv6
  - EIGRP for IPv6
  - Multiprotocol BGP version 4 (MP-BGPv4)
- For each routing option above, the **`ipv6 unicast-routing`** command must be configured to enable the router to:
  - Be configured for static and dynamic IPv6 routing
  - Forward IPv6 packets
  - Send ICMPv6 router advertisement messages

Link-Local Importance for IPv6 Routing

- The link-local address is automatically created (using EUI-64) on an interface when the interface obtains a global IPv6 address, either manually or dynamically.
  - can also be enabled on an interface without assigning a global unicast address using the interface mode command **ipv6 enable**.
- To establish IPv6 neighbor relationship, IPv6 link-local addresses are used.
- Using a global unicast address as a next-hop address with routing is not recommended
- If an IPv4 address is not configured on the router, a router ID is required before it can start running
  - 32-bit router ID

Named EIGRP Configuration and Address Families

- EIGRP named configuration helps eliminate configuration complexity that occurs when configuring EIGRP for both IPv4 and IPv6
  - Enables the configuration of EIGRP for both IPv4 and IPv6 under a single configuration mode
- Named EIGRP configuration organizes specific route types under the same address family
  - Both EIGRP for IPv4 and IPv6 can be configured within this same mode
- IPv6 EIGRP neighbor relationship gets established as soon as you define the IPv6 address family.
- All IPv6-enabled interfaces are automatically included in the EIGRP for IPv6 process.

Named EIGRP Configuration and Address Families

Three different configuration modes:

- **Address family configuration mode**
  - General EIGRP configuration commands for the selected address family are entered under address family configuration mode. Here you can configure the **router ID** and define network statements and also configure the router as an EIGRP stub.
  - Address family configuration mode gives you access to two additional configuration modes: address family interface configuration mode and address family topology configuration mode.
- **Address family interface configuration mode**
  - You should use address family interface configuration mode for all those commands that you have previously configured directly under interfaces. Most common options are setting summarization with the **summary-address** command or marking interfaces as passive using **passive-interface** command. You can also modify default hello and hold-time timers.
- **Address family topology configuration mode**
  - Address family topology configuration mode gathers all configuration options that directly impact the EIGRP topology table. Here you can set load-balancing parameters such as **variance** and **maximum-paths,** or you can redistribute static routes using the **redistribute** command.

OSPFv3 - Renamed LSA

- **Interarea prefix LSAs for ABRs (Type 3):**
  - Type 3 LSAs advertise internal networks to routers in other areas (interarea routes).
  - Type 3 LSAs may represent a single network or a set of networks summarized into one advertisement.
  - Only ABRs generate summary LSAs.
  - In OSPF for IPv6, addresses for these LSAs are expressed as prefix/ prefix length instead of address and mask. The default route is expressed as a prefix with length 0.
- **Interarea router LSAs for ASBRs (Type 4):**
  - Type 4 LSAs advertise the location of an ASBR.
  - Routers that are trying to reach an external network use these advertisements to determine the best path to the next hop.
  - ASBRs generate Type 4 LSAs.

OSPFv3 - New LSA

- **Link LSAs (Type 8):**
  - Type 8 LSAs have local-link flooding scope and are never flooded beyond the link with which they are associated.
  - Link LSAs provide the link-local address of the router to all other routers attached to the link.
  - They inform other routers attached to the link of a list of IPv6 prefixes to associate with the link.
- **Intra-area prefix LSAs (Type 9):**
  - A router can originate multiple intra-area prefix LSAs for each router or transit network, each with a unique link-state ID.
  - The linkstate ID for each intra-area prefix LSA describes its association to either the router LSA or the network LSA.
  - The link-state ID also contains prefixes for stub and transit networks.

OSPFv3 Caveats

- The OSPFv3 address families feature is supported as of Cisco IOS Release 15.1(3)S and Cisco IOS Release 15.2(1)T.
- Cisco devices that run software older than these releases and third-party devices will not form neighbor relationships with devices running the address family feature for the IPv4 address family because they do not set the address family bit.
- Therefore, those devices will not participate in the IPv4 address family SPF calculations and will not install the IPv4 OSPFv3 routes in the IPv6 Routing Information Base (RIB).

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