



Chapter 8.2: IP Version 6



Introduction to Networks

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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
- 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!

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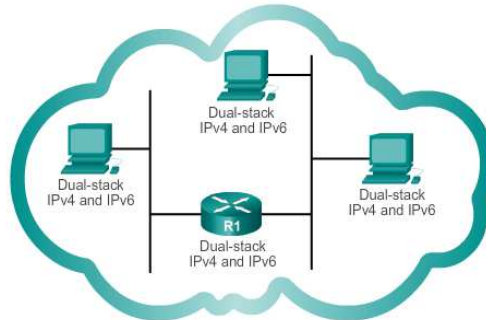
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IPv4 and IPv6 Coexistence

The migration techniques can be divided into three categories:

#1

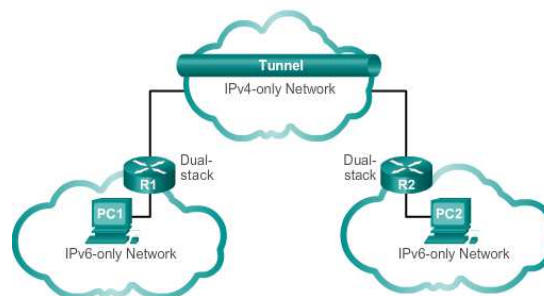


Dual-stack: Allows IPv4 and IPv6 to coexist on the same network. Devices run both IPv4 and IPv6 protocol stacks simultaneously.

IPv4 and IPv6 Coexistence

The migration techniques can be divided into three categories:

#2



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

The migration techniques can be divided into three categories:

#3



Translation: 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 values = 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 hexadecimal
- 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
- 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



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

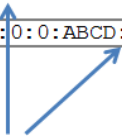
IPv6 Addressing

Rule 2- Omitting All 0 Segments

▪ Examples

#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.

#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

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Types of IPv6 Addresses

IPv6 Address Types

There are three types of IPv6 addresses:

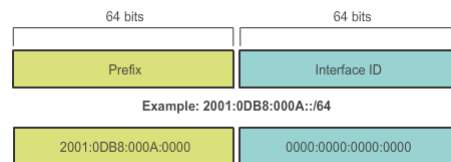
- **Unicast**
- **Multicast**
- **Anycast.**

Note: IPv6 does not have broadcast addresses.

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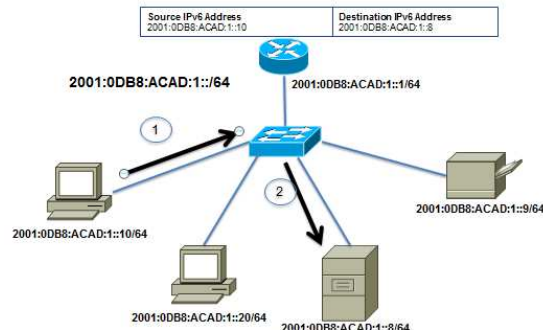
IPv6 Prefix Length

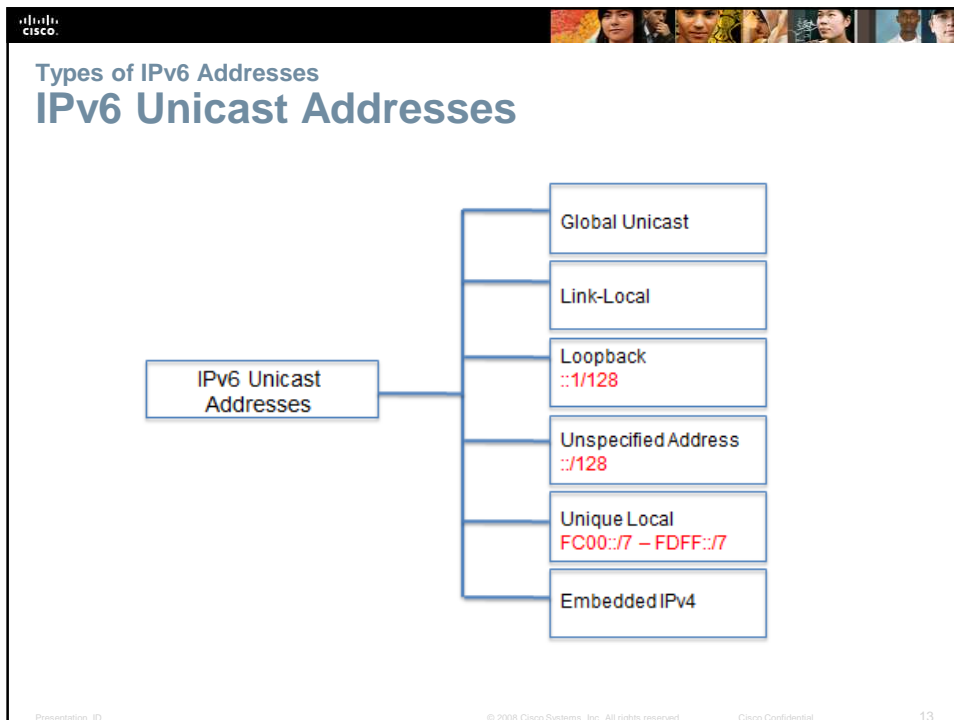
- IPv6 does not use the dotted-decimal subnet mask notation
- Prefix length indicates the network portion of an IPv6 address using the following format:
 - IPv6 address/prefix length
 - Prefix length can range from 0 to 128
 - Typical prefix length is /64





IPv6 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
- **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
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Types of IPv6 Addresses

IPv6 Unicast Addresses

- **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

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Types of IPv6 Addresses

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

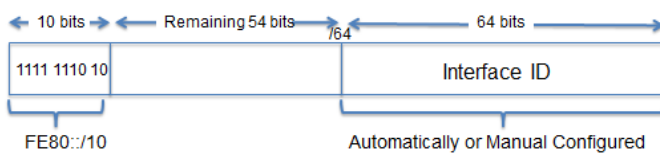
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Types of IPv6 Addresses

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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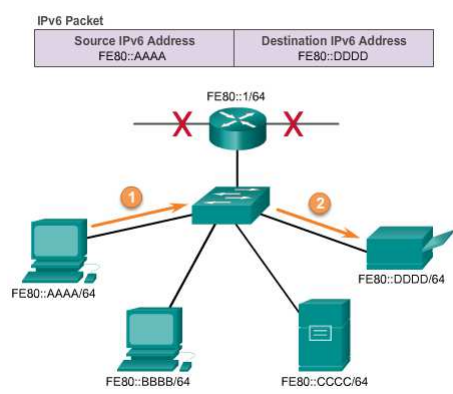



Types of IPv6 Addresses

IPv6 Link-Local Unicast Addresses

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

IPv6 Link-Local Communications



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IPv6 Unicast Addresses

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 (*Internet Corporation for Assigned Names and Numbers*) allocates IPv6 address blocks to the five RIRs (*Regional Internet Registry*)
- Currently, only global unicast addresses with the first three bits of 001 or 2000::/3 are being assigned (2006)

<https://www.iana.org/assignments/ipv6-unicast-address-assignments/ipv6-unicast-address-assignments.xhtml>
[RIR Delegations/IPv6/AT](#)

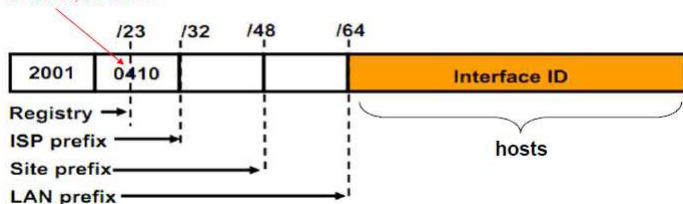
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IPv6 Unicast Addresses

Structure of an IPv6 Global Unicast Address

04-ARIN, 06-RIPE



Global Routing Prefix	Subnet ID	Interface ID
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Range of first hexet:

001 → 0010 0000 0000 0000 (2000)

to

0011 1111 1111 1111 (3FFF)

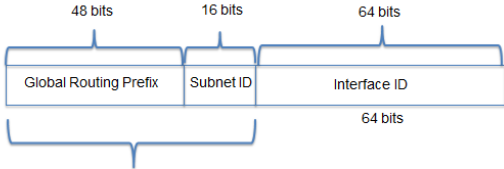
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IPv6 Unicast Addresses

Structure of an IPv6 Global Unicast Address



- A global unicast address has three parts:



A /48 routing prefix + 16 bit Subnet ID = /64 prefix.

- Global Routing Prefix**- 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

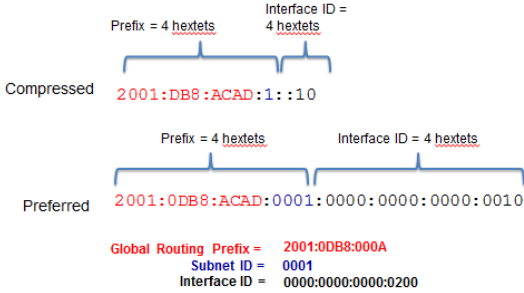
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IPv6 Unicast Addresses

Structure of an IPv6 Global Unicast Address

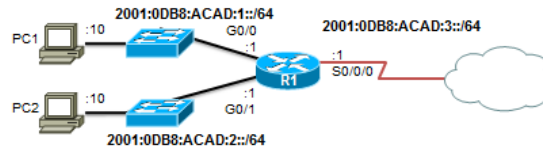
- Subnet ID**
 - Used by an organization to identify subnets within its site
- Interface ID**
 - Equivalent to the host portion of an IPv4 address
 - Used because a single host may have multiple interfaces, each having one or more IPv6 addresses



Global Routing Prefix = 2001:0DB8:000A
Subnet ID = 0001
Interface ID = 0000:0000:0000:0200

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IPv6 Unicast Addresses 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
  
```



IPv6 Unicast Addresses Dynamic Configuration of a Global Unicast Address 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

IPv6 Unicast Addresses

Dynamic Configuration of a Global Unicast Address using SLAAC



Command **IPv6 unicast-routing** enables IPv6 routing

RA message can contain one of the following three options

- SLAAC Only – use the information contained in the RA message
- SLAAC and DHCPv6 – use the information contained in the RA message and get other information from the DHCPv6 server, stateless DHCPv6 (example: DNS)
- DHCPv6 only – 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

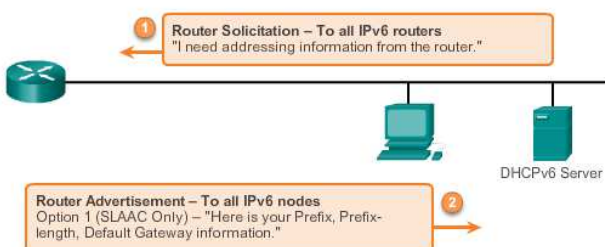
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IPv6 Unicast Addresses

Dynamic Configuration of a Global Unicast Address using SLAAC

Router Solicitation and Router Advertisement Messages



Router Advertisement Options

Option 1 (SLAAC Only) – "I'm everything you need (Prefix, Prefix-length, Default Gateway)"

Option 2 (SLAAC and DHCPv6) – "Here is my information but you need to get other information such as DNS addresses from a DHCPv6 server."

Option 3 (DHCPv6 Only) – "I can't help you. Ask a DHCPv6 server for all your information."

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IPv6 Unicast Addresses

EUI-64 Process or Randomly Generated

EUI-64 Process

- 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 Ethernet MAC address can be used to determine the Interface – easily tracked

EUI-64 Interface ID is represented in binary and is made up of three parts:

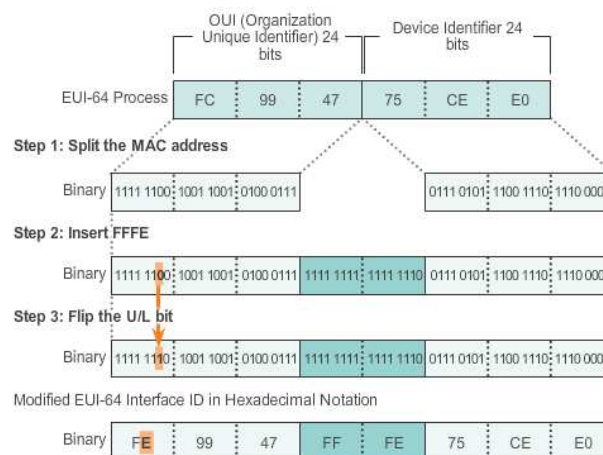
- 24-bit OUI from the client MAC address, but the 7th bit (the Universally/Locally bit) is reversed (0 becomes a 1)
- inserted 16-bit value FFFE
- 24-bit device identifier from the client MAC address





IPv6 Unicast Addresses

EUI-64 Process or Randomly Generated

EUI-64 Process



IPv6 Unicast Addresses EUI-64 Process or Randomly Generated


```

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#

```

Link-local addresses using
EUI-64



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IPv6 Unicast Addresses EUI-64 Process or Randomly Generated

Randomly Generated Interface IDs

- Depending upon the operating system, a device may 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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Dynamic Link-local Addresses

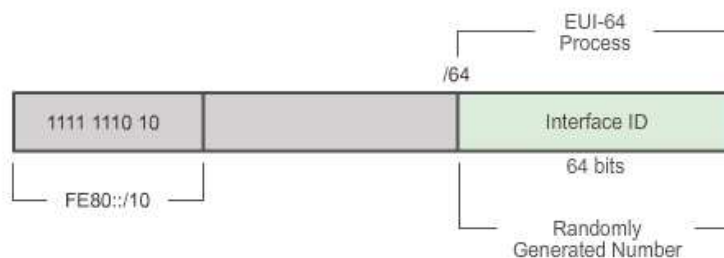
Link-local Address

- After a global unicast address is assigned to an interface, IPv6-enabled device automatically generates its link-local address
- Must have a link-local address which 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

Dynamically Assigned

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



IPv6 Unicast Addresses 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)#
```

IPv6 Unicast Addresses Static Link-local Addresses

Configuring link-local

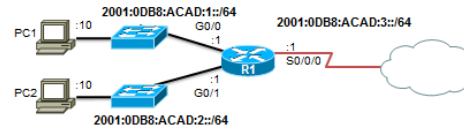
```
R1#show ipv6 interface brief
GigabitEthernet0/0    [up/up]
    FE80::1
    2001:DB8:ACAD:1::1
GigabitEthernet0/1    [up/up]
    FE80::1
    2001:DB8:ACAD:2::1
Serial0/0/0           [up/up]
    FE80::1
    2001:DB8:ACAD:3::1
Serial0/0/1           [administratively down/down]
    unassigned
R1#
```

Statically configured link-local addresses

IPv6 Global Unicast Addresses 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 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#
```

IPv6 Global Unicast Addresses Verifying IPv6 Address Configuration

```
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#
```