30. IPv6 on Routers

EUI-64 INTERFACE ID

EUI-64 is an auto-generated option for the host portion of the addresses. To predict an address:

- Split the interface's MAC address in half (24-bits = 6 hex digits = ½ of a MAC address)
- Insert FFFE into the middle
- Invert the 7th bit—This happens to be the OUI (Organizational Unique Identifier) bit. If the MAC address is legitimate (the OUI portion was assigned to the manufacturer by a central authority, this bit will always be 0, so by inverting it, you're really adding 2 to the second hex digit of the address. On a Cisco exam, this bit might already be set, so make sure you actually invert the bit. Every other hex value has an inverted 7th bit. In a table, this looks like:

0	1		4	5		8	9		C	D
2	3		6	7		A	B		E	F

Simply jump between the top and bottom rows to flip the seventh bit.

LINK-LOCAL ADDRESSES

Link-Local—Valid only on their own link or LAN, i.e. not routable. These unicast addresses are

- Used as next-hop for routing—but need an output interface since they are *link*-local, making it perfectly legitimate to reuse the same address on more than one interface
- Used for default gateway by hosts
- Auto-generated—Cisco uses EUI-64, Microsoft uses random (address varies over time)

Pointless Detail—Prefix is technically FE80::/10, (so FE8…, FE9…,FEA…, FEB…), *but* the next 54 bits must be 0, so only FE80 survives, literally FE80:0000:0000:0000 + host bits.

ROUTER CONFIGURATION

```
R5(config)# ipv6 unicast-routing
```
Without this, router will respond to pings but not route them, like a host instead of a router
```
R5(config)# interface Gi0/0
R5(config-if)# description TO R6
R5(config-if)# ipv6 address 2001:db8:56::5/64
```
You can't have a space before the /64
```
R5(config-if)# ip address 10.56.0.5 255.255.255.0
```
It's OK to have an IPv4 address too; that's called dual-stack
```
R5(config-if)# no shutdown
R5(config-if)# interf lo0
Jan  2 12:21:27.455: %LINEPROTO-5-UPDOWN: Line protocol on Interface Loopback0,
          changed state to up
```
Loopback interfaces are automatically up (not shutdown) as soon as they're created. They're
"imaginary" interfaces that make great pinging targets in prototyping labs.
```
R5(config-if)# description R5 Imaginary LAN
R5(config-if)# ipv6 address 2001:db8:5::/64 eui-64
```
Ask the router to create an EUI-64 address in the given network automatically

! The "show interfaces" command (not "show *ip* interfaces") tells us the IPv4 address of an
. interface, but not the IPv6 address, so it doesn't help us.

```
R5# show interfaces Gi0/0
GigabitEthernet0/0 is up, line protocol is down
  Hardware is MV96340 Ethernet, address is 001e.1321.e3a8 (bia 001e.1321.e3a8)
  Description: TO R6
  Internet address is 10.56.0.5/24
                    …Rest omitted
```

```
R5# show  ipv6 interface brief
GigabitEthernet0/0          [up/down]
    FE80::21E:13FF:FE21:E3A8
```
Cisco automatically creates a link-local address for each interface for its own purposes
```
    2001:DB8:56::5
GigabitEthernet0/1          [administratively down/down]
    unassigned
Serial0/2/0                 [administratively down/down]
    unassigned
Serial0/2/1                 [administratively down/down]
    unassigned
Loopback0                   [up/up]
    FE80::21E:13FF:FE21:E3A8
    2001:DB8:5:0:21E:13FF:FE21:E3A8
```
The EUI-64 address we asked the router to create. Comparing it to the link-local address above

(FE80::), we can tell that when Cisco automatically creates a link-local address, it uses EUI-64

```
R5# show  ipv6 interface gi0/0
GigabitEthernet0/0 is up, line protocol is down
  IPv6 is tentative, link-local address is FE80::21E:13FF:FE21:E3A8 [TEN]
  No Virtual link-local address(es):
  Description: TO R6
  Global unicast address(es):
    2001:DB8:56::5, subnet is 2001:DB8:56::/64 [TEN]
```
Cisco was nice enough to calculate the subnet address for you.
```
  Joined group address(es):
    FF02::1
    FF02::2
  MTU is 1500 bytes
  ICMP error messages limited to one every 100 milliseconds
  ICMP redirects are enabled
  ICMP unreachables are sent
  ND DAD is enabled, number of DAD attempts: 1
  ND reachable time is 30000 milliseconds (using 30000)
  ND advertised reachable time is 0 (unspecified)
  ND advertised retransmit interval is 0 (unspecified)
  ND router advertisements are sent every 200 seconds
  ND router advertisements live for 1800 seconds
  ND advertised default router preference is Medium
  Hosts use stateless autoconfig for addresses.
```

Just like in IPv4, IOS will automatically add directly connected routes to the routing table as soon as those interfaces are configured and the links come up. By putting an address on the interface, you've told the router to reach that subnet out that interface. In fact, you've put that interface in play for IPv6 routing in general.

```
R5# show ipv6 route connected
IPv6 Routing Table - default - 3 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
       B - BGP, HA - Home Agent, MR - Mobile Router, R - RIP
       I1 - ISIS L1, I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary
       D - EIGRP, EX - EIGRP external, ND - Neighbor Discovery, l - LISP
       O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF ext 1, OE2 - OSPF ext 2
       ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2
C   2001:DB8:5::/64 [0/0]
     via Loopback0, directly connected
```

> *Our connected route for Gi0/0 doesn't show up because the link isn't up. We've configured our end and did a "no shutdown," but the other end isn't up. Therefore, our link is up/down (see "show ipv6 interface [brief]" or "show interfaces [Gi0/0]" or even "show ip interface brief").*

MANUAL LINK-LOCAL

You can manually set a link-local address by tacking "link-local" onto the end of an ordinary interface address assignment.

```
R5(config)#interf gi0/0
R5(config-if)# ipv6 address FE80::5 link-local
```

IPv6 happily allows multiple IPv6 addresses on the same interface. Link-local addresses are an exception. Configuring a link-local interface address will replace any earlier link-local address, including an autogenerated one.

As already mentioned, setting a normal IPv6 address on an interface will cause IOS to autogenerate an IPv6 link-local address on that interface. You can also manually create a link-local with no normal IPv6 address, as shown above. If you *really* want IPv6 running on an interface with only an autogenerated link-local address. You can manually enable IPv6 on the interface and let it create its own link-local address

```
R5(config-if)# ipv6 enable
```

This might make sense on a WAN link that needs IPv6 but doesn't need its own address because OSI layer 2 can guarantee delivery across the WAN link and you'll specify the next hop in routes using only the exit interface.

DYNAMIC ADDRESSING

Unfortunately, DHCPv6 and SLAAC aren't explained until chapter 31. Suffice to say that they are two ways that a router interface can configure itself, perhaps for an ISP connection where a static address hasn't been paid for.

```
R6(config)# interface Gi0/0
R6(config-if)# ipv6 address dhcp
R6(config-if)#interface Gi0/1
R6(config-if)# ipv6 address autoconfig
```

> *The autoconfig keyword refers to SLAAC*

IPv6 drops support for broadcasts and relies on multicasts. IPv6 multicast addresses begin with "FF" and can be further limited in their scope.

- FF02::/16 addresses have a link-local (LAN/not routable) scope
- FF08::/16 addresses have an organization-local (intranet-only / non-internet) scope

Some common multicast addresses defined by RFC (or by Cisco, in the case of EIGRP) include

PREFIX	ADDRESS TYPE	DESCRIPTION
FF02::1	All nodes	
FF02::2	All routers	
FF02::5	All OSPF	Hellos
FF02::6	All OSPF DR	Designated routers
FF02::A	All EIGRP	
FF02::1:2	DHCP Relay Agents	

Routers automatically subscribe to FF02::1 (all nodes) and FF02::2 (all routers). You can use "show ipv6 interface" to see which multicast addresses a router is listening to.

```
R5# show  ipv6 interface gi0/0
GigabitEthernet0/0 is up, line protocol is down
  IPv6 is tentative, link-local address is FE80::21E:13FF:FE21:E3A8 [TEN]
  No Virtual link-local address(es):
  Description: TO R6
  Global unicast address(es):
    2001:DB8:56::5, subnet is 2001:DB8:56::/64 [TEN]
  Joined group address(es):
    FF02::1
    FF02::2
```

OTHER ADDRESSES

Solicited-Node Multicast—Every IPv6 interface has an extra link-local "solicited-mode" multicast address that concatenates FF02::1:FF00/104 with the last 6 hex digits (24 bits) of its unicast address. Messages sent to that address will be processed by every host whose last 6 unicast digits match. Literally, the solicited mode multicast address looks like

```
FF02:0000:0000:0000:0000:0001:FFxx:xxxx
FF02::1:FFxx:xxxx
```

It should show up in the "show ipv6 interface [gi0/0]" command under "Joined group address(es)," though perhaps not until the interface is up/up.

Anycast—destination is the nearest participating router, providing load balancing for services. First, this relies on the fact that one interface can have multiple IPv6 addresses. Each participating router has the same address configured as an anycast address & advertises its participation to the other routers. When any router receives a packet to that address, it forwards the package to the nearest participating router. The client is unawares.

```
R5(config)# interf gi0/0
R5(config-if)# ipv6 address 2001:db8:AAAA::A/128 anycast
```

```
R5# show ipv6 interface Gi0/0
GigabitEthernet0/0 is up, line protocol is up
  IPv6 is enabled, link-local address is FE80::21E:13FF:FE21:E3A8
  No Virtual link-local address(es):
  Global unicast address(es):
    2001:DB8:56::5, subnet is 2001:DB8:56::/64
    2001:DB8:AAAA::A, subnet is 2001:DB8:AAAA::A/128 [ANY]
  Joined group address(es):
    FF02::1
    FF02::2
    FF02::1:FF00:5
    FF02::1:FF00:A
    FF02::1:FF21:E3A8
```

> *These last 3 lines are our solicited mode multicasts (the :FF in the middle gives it away). There's one for each address on the interface: first our explicitly entered unicast address 2001:db8:56::5, then our anycast 2001:db8:aaaa::a, and finally the link-local fe80::21e:13ff:fe21:e3a8.*

```
R5# show ipv6 interface brief
GigabitEthernet0/0          [up/up]
    FE80::21E:13FF:FE21:E3A8
    2001:DB8:56::5
    2001:DB8:AAAA::A
```

> *No sign that this is an anycast address when "brief" is used on the command.*

```
GigabitEthernet0/1          [administratively down/down]
    unassigned
```

Two other special addresses—you'll recognize these from the IPv4 DHCP discussion.

- :: (all zeroes)—unknown or unspecified—perhaps a host doesn't know its address yet.
- ::1 (127 zeroes and a one)—loopback

Finally, if your "show ipv6 interface gi0/0" command shows absolutely no result except to return your prompt, maybe ipv6 isn't running on that interface (no ipv6 address yet).

PREFIX REVIEW

Prefix	Address Type	Description
FD00::/8	Unique Local	Nets not officially assigned. See chapter 29.
FE80::/10	link-local	
FF02::1	Multicast—All nodes	
FF02::2	Multicast—All routers	
FF02:: (various)	Multicast—Routing protocols	
FF02::1:FF /104	Solicited Mode Multicast	
(varies)	Global Unicast	World-routable "real" addresses
(any unicast)	Anycast	Declare it as anycast when you put on interface