Exam Topic 1.9: IPv6 Address Types

- Focus on learning the various IPv6 address types.
- In Day 31, Global unicast and Link-local IPv6 addresses were briefly introduced.
- In this lesson, we will go more in-depth on those and also learn about the other types.

Lesson Overview

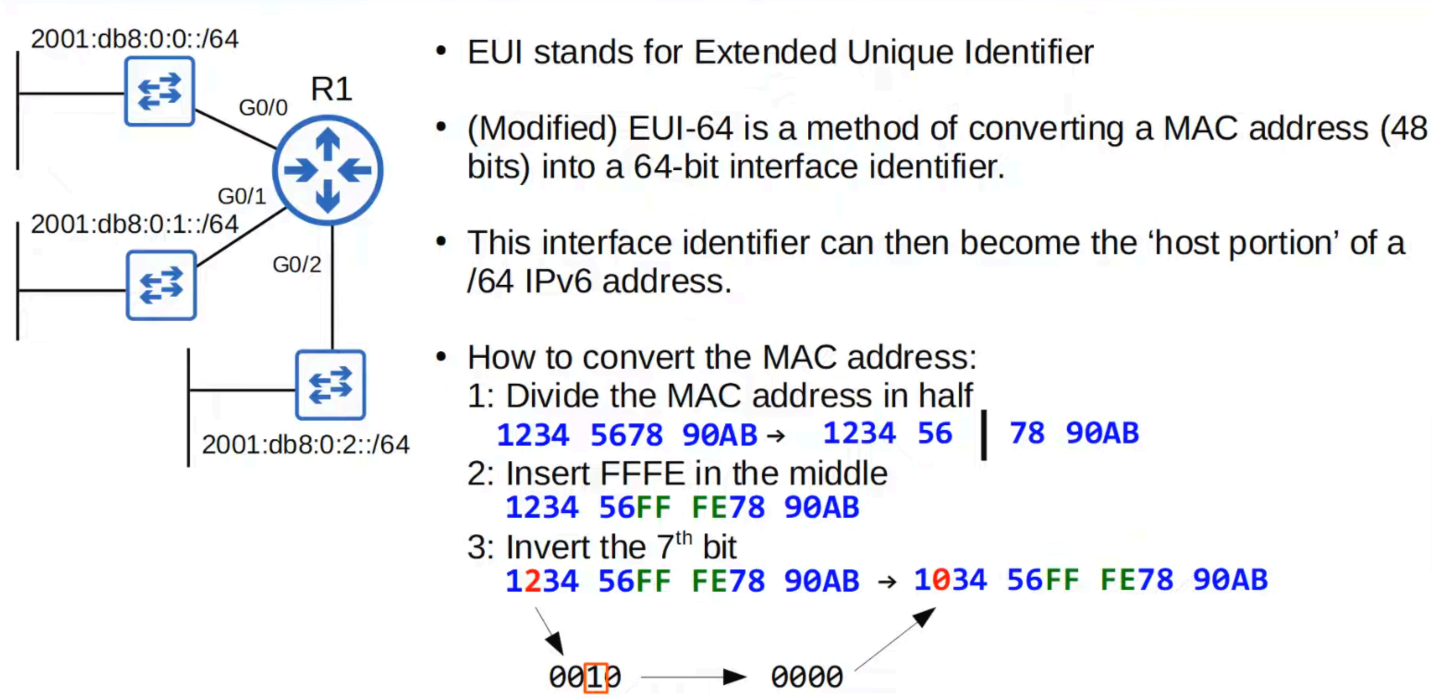
- **IPv6 Address Configuration**: Another way to configure an IPv6 address on an interface using 'modified EUI-64' (exam topic 1.9.f).
- **IPv6 Address Types**: An overview of Global unicast, unique local, link local, multicast, and other types.

IPv6 Address Configuration with EUI-64

- **EUI-64** stands for Extended Unique Identifier.
- The technically correct term is **modified EUI-64**, but it's usually just called EUI-64. For the CCNA, they are considered the same.
- It is a method for converting a 48-bit MAC address into a 64-bit interface identifier.
- This 64-bit identifier becomes the host portion of a /64 IPv6 address.
    - A /64 prefix means 64 bits are for the network portion and 64 bits are for the host portion.

Steps to Convert a MAC Address to an EUI-64 Interface ID

- The router performs this process automatically, but you need to know the steps.



- **Example:** Converting MAC address `1234.5678.90AB`.
- **Step 1:** Divide the MAC address in half.
    - Example: The MAC address is split between `5678`
        - 56 | 78
- **Step 2:** Insert the hexadecimal value `FFFE` in the middle.
    - Example: The address becomes `1234.56 FF.FE 78.90AB`.
        - 56 FF | FE 78

- **Step 3:** Invert the 7th bit of the address.
    - If the 7th bit is a 0, change it to a 1.
    - If the 7th bit is a 1, change it to a 0.
    - Example:
        - The 7th bit is the 3rd bit of the second hexadecimal digit (`2`).
        - The first hex digit `1` represents bits 1, 2, 3, and 4.
        - The second hex digit `2` (binary `0010`) represents bits 5, 6, 7, and 8.
        - The 3rd bit of `2` is a `1`. Inverting it changes it to `0`.
            - 0010 --> 0000
        - The binary for the first two digits becomes `0010 --> 0000`.
        - Converting `0010` back to hex is `1`, and `0000` is `0`.
        - The final modified start of the address is `1034`.
    - The final 64-bit interface identifier is `1034.56FF.FE78.90AB`.

EUI-64 Conversion Practice

MAC Address	EUI-64 Interface Identifier
782B CBAC 0867	7A2B CBFF FEAC 0867
0200 4C4F 4F50	0000 4CFF FE4F 4F50
0050 56C0 0001	0250 56FF FEC0 0001
00FF 6BA6 F456	02FF 6BFF FEA6 F456
96AB 6D6B 98AE	94AB 6DFF FE6B 98AE

- Here are some practice questions to convert MAC addresses to EUI-64 interface identifiers.
- Remember the three steps:
    1. Split the MAC address in half.
    2. Insert `FFFE` in the middle.
    3. Invert the 7th bit.
- The video provides the answers. For more practice, try writing out some random MAC addresses and finding the EUI-64 interface identifier.

Why the 7th Bit is Inverted (U/L Bit)

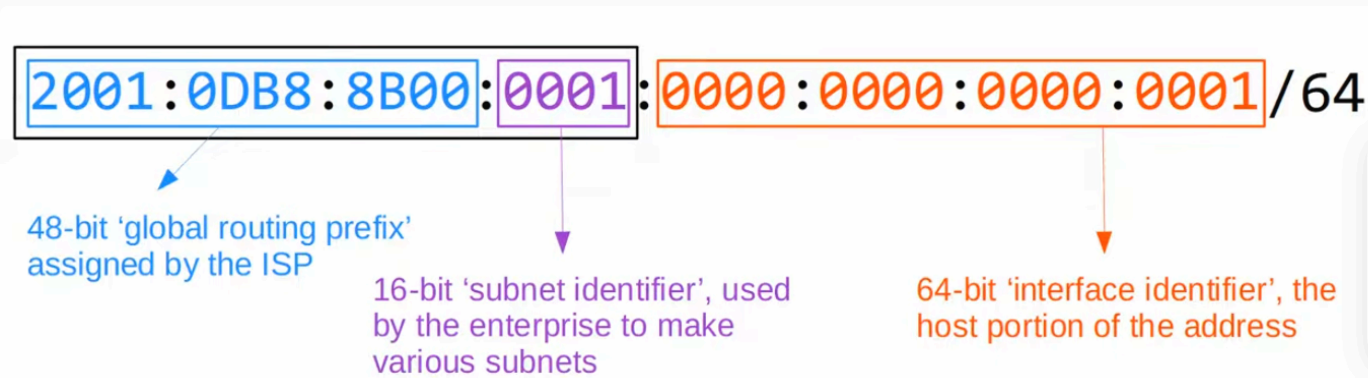
- **Note:** This is likely not required for the CCNA exam.

- **MAC Address Types**:
  - **UAA (Universally Administered Address)**: Unique MAC addresses assigned by the manufacturer.
  - **LAA (Locally Administered Address)**: MAC addresses manually assigned by an admin or protocol.
    - You can manually configure a MAC address on an interface using the `MAC-ADDRESS` command. These do not need to be globally unique.
- **The U/L Bit**:
  - The 7th bit of the MAC address is called the U/L bit (Universal/Local bit).
  - If the U/L bit is `0`, it's a UAA.
  - If the U/L bit is `1`, it's an LAA.
- **Meaning in IPv6 EUI-64**:
  - The meaning of the U/L bit is reversed in the context of IPv6 EUI-64.
  - If the U/L bit is `0`, it means the original MAC address was an LAA.
  - If the U/L bit is `1`, it means the original MAC address was a UAA.
  - This reversal does not affect the function of the IPv6 address itself; it does not mean the IPv6 address is universal or local.

Global Unicast Addresses

- **Definition**: Global unicast IPv6 addresses are public addresses that can be used over the Internet.
- **Registration**: You must register to use global unicast addresses.
- **Uniqueness**: They are expected to be globally unique. Using the same range as another company will cause problems.

- **Address Range**:
  - Originally defined as `2000::/3` (from `2000:0000:0000:0000:0000:0000:0000:0000` to `3FFF:FFFF:FFFF:FFFF:FFFF:FFFF:FFFF:FFFF`).
  - Later updated so that all addresses not reserved for other purposes are considered global unicast addresses.
- **Structure**: A global unicast address has three parts.
  - **Global routing prefix**: A 48-bit prefix assigned to the company by their ISP.
  - **Subnet identifier**: The remaining 16 bits of the prefix (since a /64 prefix is standard), allowing for over 65,000 subnets.
  - **Interface identifier**: The last 64 bits of the address (the "host portion" in IPv4 terms). This can be generated with EUI-64 or manually configured.
- **Example:**



  - A company is assigned the /48 prefix `2001:0DB8:0000::` by their ISP.
  - They use the next 16 bits for the subnet identifier, for example, `0001` for subnet 1.
  - The first 64 bits (`2001:0DB8:0000:0001::/64`) form the network prefix.
  - The last 64 bits are the interface identifier, which could be `0000:0000:0000:0001` or generated via EUI-64.

Unique Local Addresses

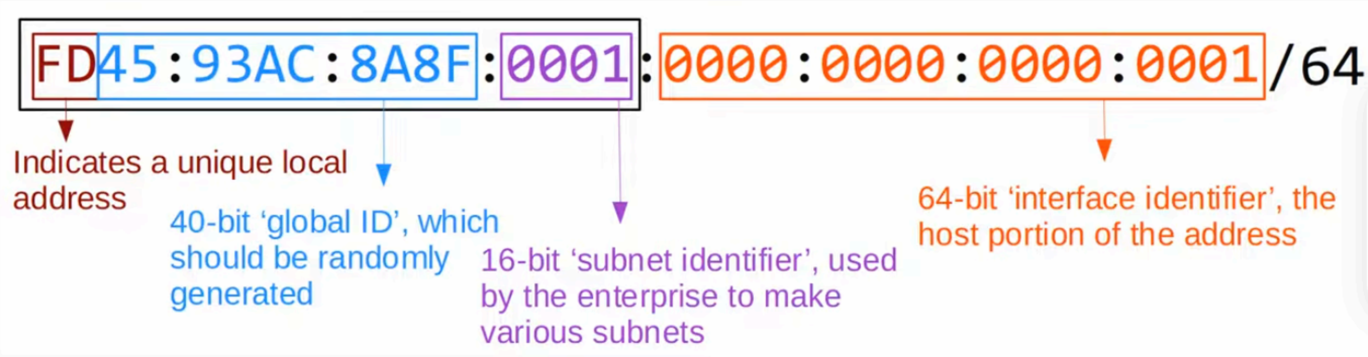
- **Definition**: Unique local IPv6 addresses are private addresses which cannot be used over the Internet (similar to private IPv4 addresses).

- **Registration**: You do not need to register to use them.
- **Uniqueness**: They can be used freely within internal networks and don't need to be globally unique, but you should still try to make them unique.
- **Routing**: These addresses cannot be routed over the Internet; your ISP will drop packets destined for unique local addresses.
- **Address Range**:

  - Uses the address block `FC00::/7` (`FC00::` to `FDFF:FFFF:FFFF:FFFF:FFFF:FFFF:FFFF:FFF`
  - However, a later update requires the 8th bit to be set to 1, so the first two digits must be `FD`.

  - The address block `FC00::/7` is reserved for unique local addresses.
  - A later update requires the 8th bit to be set to `1`, so all unique local addresses will begin with `FD`.
- **Structure**:
  - **FD**: Indicates the address is in the unique local address range.
  - **Global ID**: The next 40 bits.
    - It is recommended that this part be randomly generated.
    - **Reason**: To ensure the global ID is unique so that addresses don't overlap when companies merge. If all companies use a simple global ID (e.g., all 0s), merging networks could cause duplicate subnets and significant problems. Randomly generating the global ID makes duplicate subnets highly unlikely.
  - **Subnet identifier**: Similar to global unicast addresses, used to create subnets.
  - The first 64 bits make up the network prefix. While a /64 prefix length is not required, it is the standard for IPv6.
  - **Interface ID**: The last 64 bits, just like in global unicast addresses.

- **Example:**

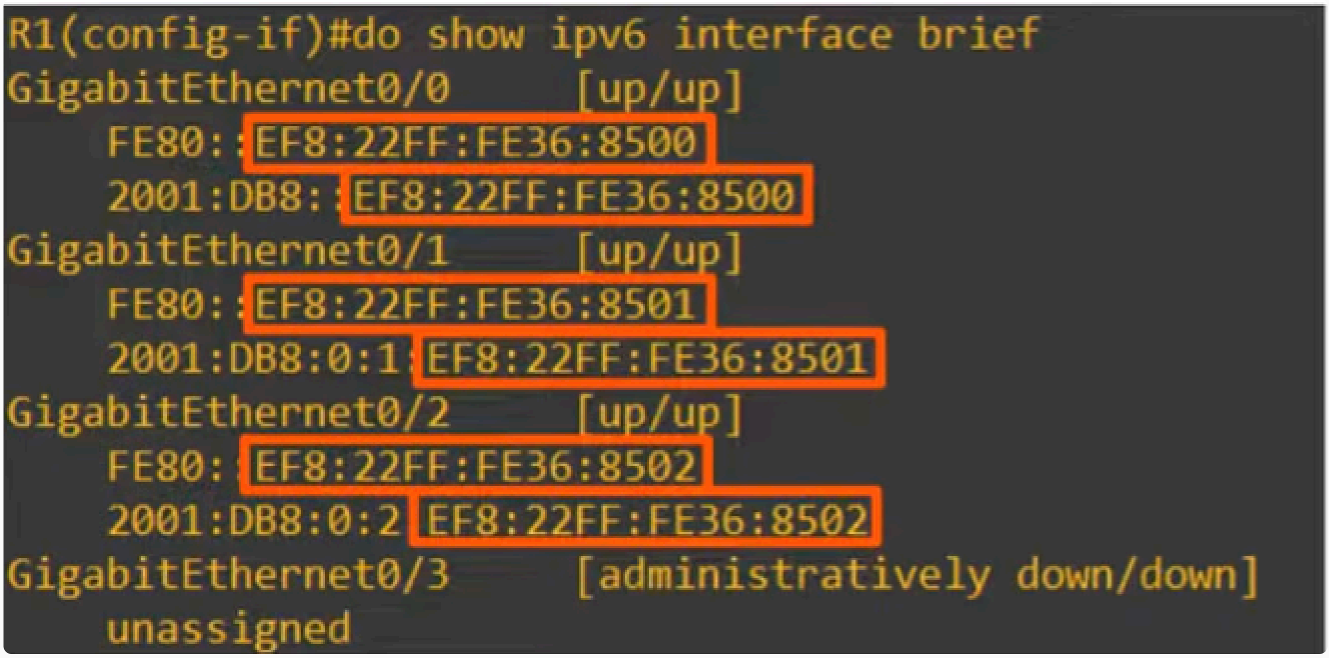


  - `FD` indicates the unique local range.
  - The next 40 bits are the global ID (recommended to be randomly generated).
  - The next 16 bits are the subnet identifier.
  - The final 64 bits are the interface ID.

Link-Local Addresses

- **Definition**: Link-local IPv6 addresses are automatically generated on IPv6-enabled interfaces.
- **Configuration**: You can use the command `IPV6 ENABLE` to enable IPv6 on an interface without configuring an address; it will automatically generate a link-local address as the only IPv6 address on that interface.
- **Address Range**:
  - Uses the address block `FE80::/10`.
  - The standard states that the 54 bits after the first 10 bits should all be `0`, so you will only see link-local addresses beginning with `FE8` (not `FE9`, `FEA`, or `FEB`).

- **Interface ID**: Generated using EUI-64 rules.

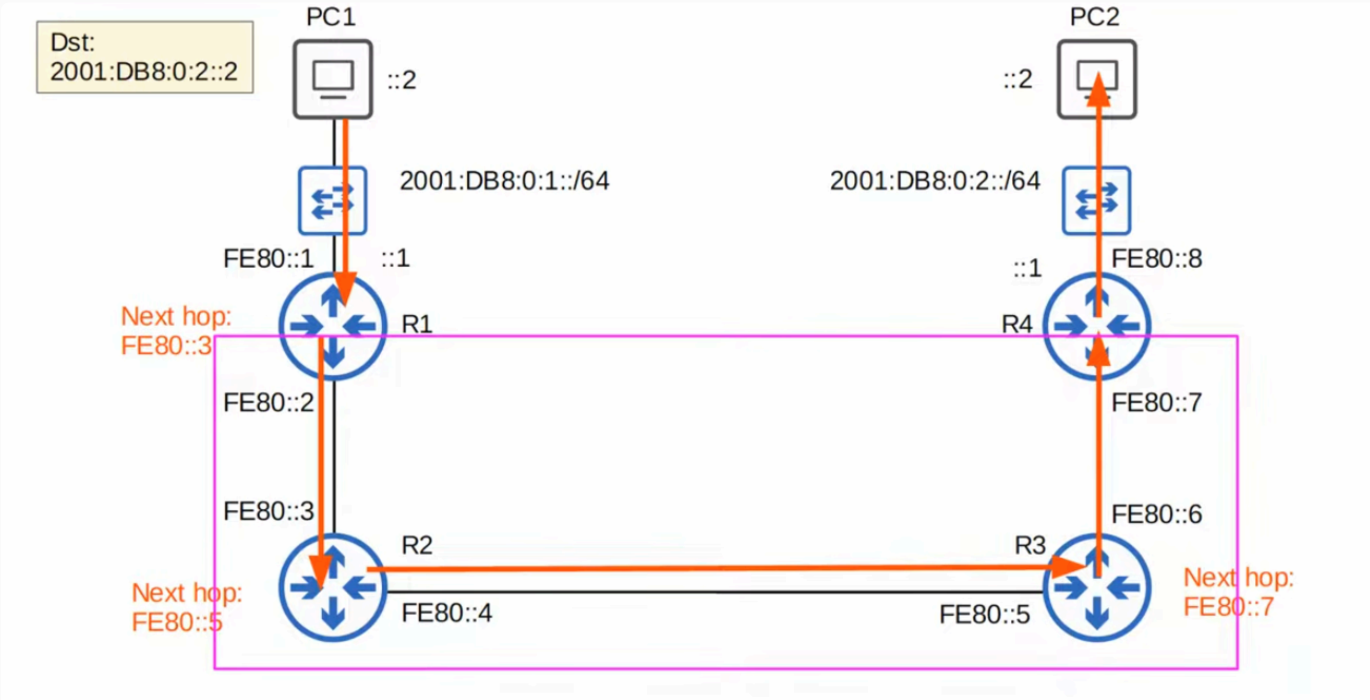


```
R1(config-if)#do show ipv6 interface brief
GigabitEthernet0/0     [up/up]
    FE80::EF8:22FF:FE36:8500
    2001:DB8::EF8:22FF:FE36:8500
GigabitEthernet0/1     [up/up]
    FE80::EF8:22FF:FE36:8501
    2001:DB8:0:1:EF8:22FF:FE36:8501
GigabitEthernet0/2     [up/up]
    FE80::EF8:22FF:FE36:8502
    2001:DB8:0:2:EF8:22FF:FE36:8502
GigabitEthernet0/3     [administratively down/down]
    unassigned
```

    - **Example:** Using `show ipv6 interface brief`, each link-local address uses the same interface ID as the global unicast address configured earlier because both used EUI-64.
- **Scope**: Used for communication within a single link (a single subnet).
- **Routing**: Routers will not route packets with a link-local destination IPv6 address; they will not forward the packets between subnets.
- **Uses**:
    - Routing protocol peerings (e.g., OSPFv3 uses link-local addresses for neighbor adjacencies and sending LSAs).
    - Next-hop address for static routes.
    - Neighbor Discovery Protocol (NDP), which is IPv6's replacement for ARP, uses link-local addresses to function.

Example of Link-Local Address Usage (Routing)

- **Scenario**:



  - PC1 (Subnet `2001:DB8:0:1::/64`) sends a packet to PC2 (Subnet `2001:DB8:0:2::/64`).
  - PC1 forwards the packet to its default gateway R1 (`2001:DB8:0:1::1`).
  - R1 looks up the destination `2001:DB8:0:2::2` and forwards it to the next hop R2 at link-local address `FE80::3`.
  - R2 looks up the destination and forwards it to next hop R3 at `FE80::5`.
  - R3 looks up the destination and forwards it to next hop R4 at `FE80::7`.
  - R4 forwards the packet to PC2.
- **Key Observation**: In the transit portion of the network between R1 and R4, the routers only use link-local addresses for next-hop routing.
- **Limitation**:
  - Routers cannot ping each other using these link-local addresses (e.g., R1 cannot ping R3 at `FE80::5`).
  - If R1 tries to ping a link-local address, the packet is dropped because routers do not route packets destined for link-local addresses.

- **Conclusion**: While link-local addresses cannot be used as destination addresses for routed traffic, they function perfectly fine as **next-hop addresses** in routing tables.

IPv6 Multicast Addresses (Topic 1.9.e)

- **Communication Types Review**:
  - **Unicast**: One-to-one communication (from one source to one destination).
  - **Broadcast**: One-to-all communication (from one source to ALL destinations within the subnet).
  - **Multicast**: One-to-many communication (from one source to multiple destinations that have joined the specific group).
- **Multicast Range**: `FF00::/8`.
- **Broadcast in IPv6**:
  - IPv6 does **not** use broadcast. There is no "broadcast address" in IPv6.
  - Multicast is used to send messages to all hosts in a subnet instead.

Important IPv6 Multicast Addresses

- **Exam Requirement**: You should know these multicast addresses for the CCNA.

- **Memory Aid**: The IPv4 and IPv6 versions of these multicast addresses often share the same last digit.
  - **Example**:

Purpose	IPv6 Address	IPv4 Address
All nodes/hosts (functions like broadcast)	FF02::1	224.0.0.1
All routers	FF02::2	224.0.0.2
All OSPF routers	FF02::5	224.0.0.5
All OSPF DRs/BDRs	FF02::6	224.0.0.6
All RIP routers	FF02::9	224.0.0.9
All EIGRP routers	FF02::A	224.0.0.10

    - All OSPF Routers: `FF02::5` (IPv6) and `224.0.0.5` (IPv4).
    - All EIGRP Routers: `FF02::A` (IPv6, where A = 10 in hex) and `224.0.0.10` (IPv4).

- **All Nodes Multicast Address**:

Purpose	IPv6 Address	IPv4 Address
All nodes/hosts (functions like broadcast)	FF02::1	224.0.0.1
All routers	FF02::2	224.0.0.2
All OSPF routers	FF02::5	224.0.0.5
All OSPF DRs/BDRs	FF02::6	224.0.0.6
All RIP routers	FF02::9	224.0.0.9
All EIGRP routers	FF02::A	224.0.0.10

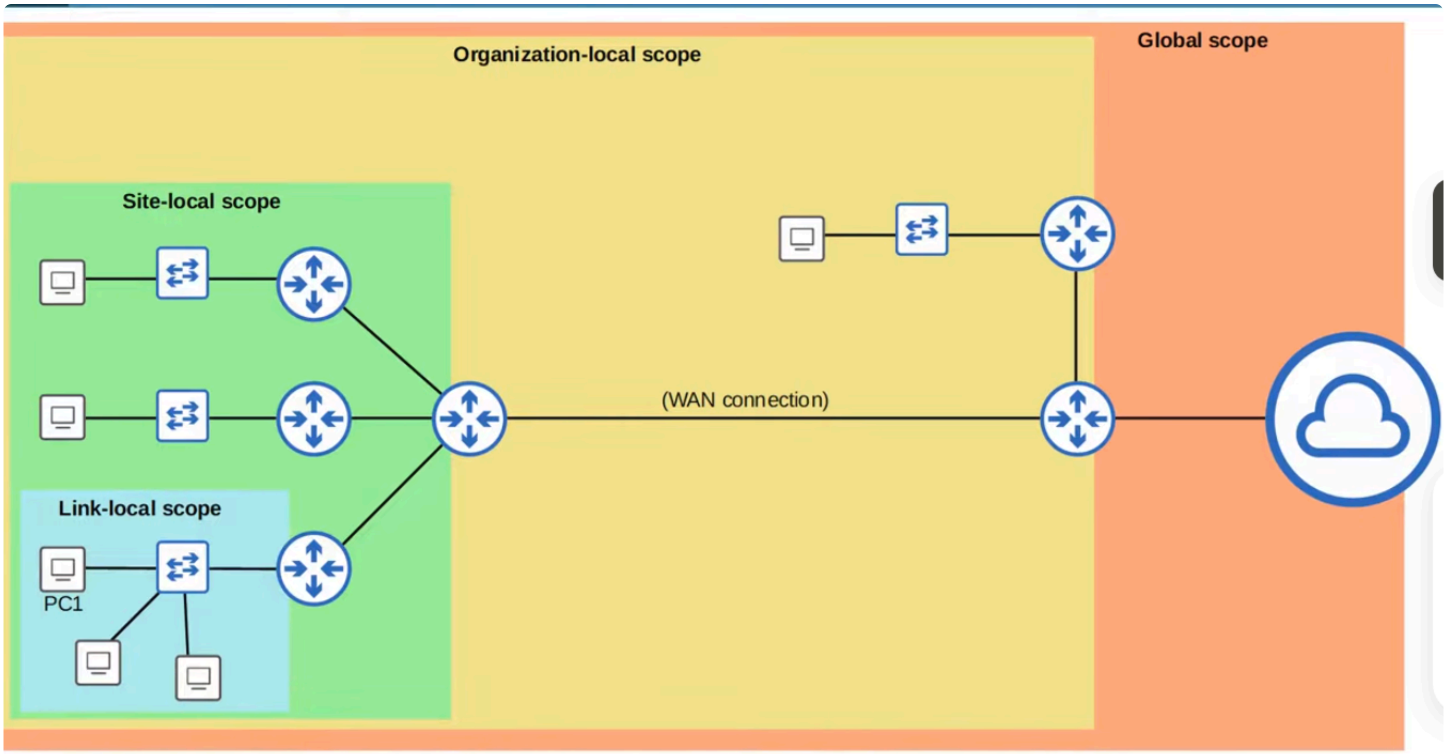
  - Also called the "all hosts" multicast address.
  - Functions like a broadcast because it is destined for all hosts.
  - This is how IPv6 replaces broadcast traffic: by sending traffic to this multicast address.

IPv6 Multicast Scopes

- IPv6 defines multiple multicast "scopes" which indicate how far the multicast packet should be forwarded.
- The addresses discussed previously (e.g., OSPF, EIGRP, All Nodes) use the **link-local** scope, staying in the local subnet.
  - *Note:* This is a different concept than an IPv6 link-local unicast address (FE80).
- **Interface-Local (`FF01`)**:
  - Multicast messages do not leave the local device.
  - Can be used to send traffic to a service running within the local device.
  - Also known as "node-local."

- **Link-Local (`FF02`):**
    - These multicast addresses stay within the local subnet and are not routed between subnets.
- **Site-Local (`FF05`):**
    - Can be forwarded by routers.
    - By definition, should be limited to a single physical location and not forwarded over a WAN.
    - The network engineer must configure the actual boundaries of the scope.
- **Organization-Local (`FF08`):**
    - Intended to be wider in scope than site-local multicasts (e.g., reaching all subnets in a company).
    - The network engineer must configure the boundaries of the scope.
- **Global (`FF0E`):**
    - A wider scope than organization-local.
    - These multicast messages can even be routed over the public Internet.
    - Defined as having "no boundaries."

Visualization of Multicast Scopes



- **Link-Local Multicast**: From PC1's perspective, a link-local multicast reaches devices on the local subnet only.
- **Site-Local Multicast**: A site-local multicast has a wider range than link-local, but does not cross the WAN to another company site.
- **Organization-Local Multicast**: An organization-local multicast can reach devices in another office connected with a WAN link.
- **Global Multicast**: The global scope can reach beyond the organization itself.
- **Configuration Note**: Aside from interface-local and link-local, the actual boundaries of each scope need to be defined by the network engineer. Multicast configuration is beyond the scope of the CCNA.

Verification: Joined Multicast Groups

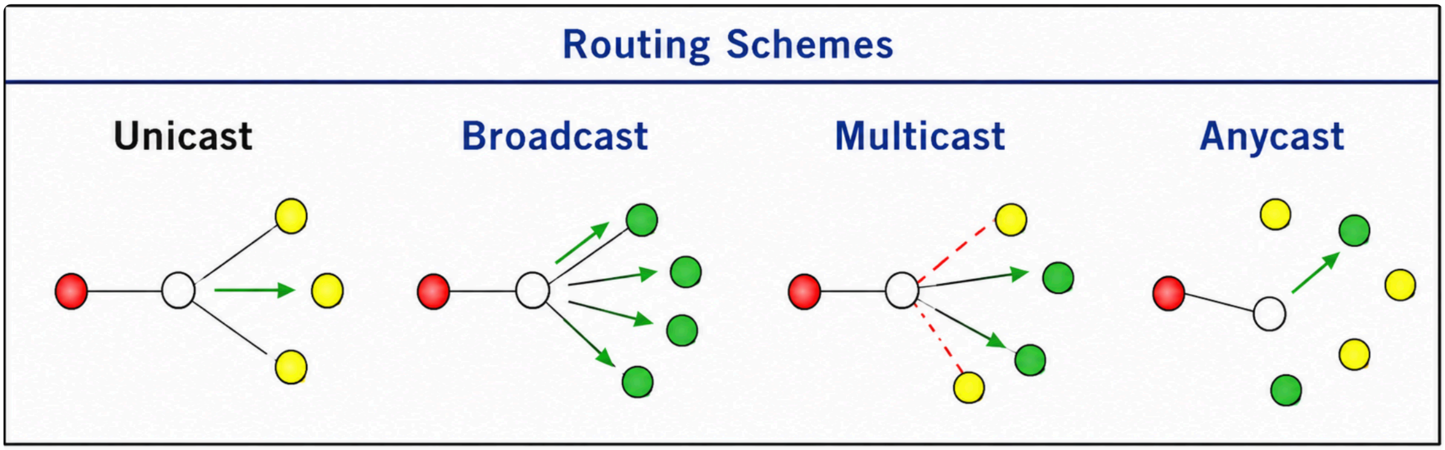
- **Verification:** Use `show ipv6 interface` to view the joined multicast groups on an interface.
  - The output displays a 'joined group addresses' section.

- **Example:**

```
R1#sh ipv6 int g0/0
GigabitEthernet0/0 is up, line protocol is up
  IPv6 is enabled, link-local address is FE80::EF8:22FF:FE36:8500
  No Virtual link-local address(es):
  Global unicast address(es):
    2001:DB8::EF8:22FF:FE36:8500, subnet is 2001:DB8::/64 [EUI]
  Joined group address(es):
    FF02::1
    FF02::2
    FF02::1:FF36:8500
  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.
```

  - R1's G0/0 interface automatically joins the `FF02::1` (all nodes/all hosts) multicast group because it is a host in that subnet.
  - It also joins the `FF02::2` (all routers) multicast group because it is a router.
  - It also joins a solicited-node multicast address (to be discussed in Day 33).

Anycast Addresses



- **Definition**: Anycast messaging is 'one-to-one-of-many' (one-of-multiple). There are multiple possible destinations, but the traffic is only sent to the nearest one.
- **Function**:
  - Multiple routers are configured with the exact same IPv6 address.
  - They use a routing protocol to advertise the address.
  - When hosts send packets to that address, other routers forward it to the 'nearest' router configured with that IP address.
  - 'Nearest' is determined by the smallest routing protocol metric.
- **Address Range**: There is no specified range for anycast addresses.
  - You use a regular unicast address (global unicast or unique local) and specify it as an anycast address.

Configuring Anycast Addresses

- Anycast addresses are configured just like regular IPv6 addresses, but with the keyword `anycast` added to the end of the command.
- An example uses a `/128` prefix length (similar to a `/32` in IPv4), which advertises a host route.

Configuration Example:

```
R1(config)# interface G0/0
R1(config-if)# ipv6 address 2001:DB8::1/128 anycast
```

Verification of Anycast Addresses

- **Verification:** Use `show ipv6 interface` to view the configured addresses.
- The output will list the anycast address under 'global unicast addresses', but it is identified by the `ANY` tag at the end of the line.

Verification Example:

```
R1# show ipv6 interface G0/0
```

```
R1(config)#int g0/0
R1(config-if)#ipv6 address 2001:db8:1:1::99/128 anycast
R1(config-if)#
R1(config-if)#do show ipv6 interface g0/0
GigabitEthernet0/0 is up, line protocol is up
  IPv6 is enabled, link-local address is FE80::EF8:22FF:FE36:8500
  No Virtual link-local address(es):
  Global unicast address(es):
    2001:DB8::EF8:22FF:FE36:8500, subnet is 2001:DB8::/64 [EUI]
    2001:DB8:1:1::99, subnet is 2001:DB8:1:1::99/128 [ANY]
  Joined group address(es):
    FF02::1
    FF02::2
    FF02::1:FF00:99
    FF02::1:FF36:8500
  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)
```

Unspecified IPv6 Address

- **Address**: `::` (all 0s).
- **Usage**: Used when a device doesn't know its IPv6 address yet.
- **Default Routes**: IPv6 default routes are configured to `::/0`.
- **IPv4 Equivalent**: `0.0.0.0`.

IPv6 Loopback Address

- **Address**: `::1` (127 bits of 0 followed by a single 1).
- **Usage**: Used to test the protocol stack on the local device.
- **Scope**: Messages sent to this address are processed within the local device, but not sent to other devices.

- **IPv4 Equivalent**: The `127.0.0.0/8` address range.
  - IPv6 uses just a single address (`::1`) instead of a large block, which is much more efficient.

Lesson Summary

- **EUI-64 Configuration**: Configured IPv6 addresses by making the router automatically generate an interface ID using EUI-64.
- **Global Unicast Addresses**: Public IPv6 addresses that can be routed over the Internet.
  - Remember the three sections: Global routing prefix, subnet identifier, and interface identifier.
- **Unique Local Addresses**: Private addresses where no registration is needed.
  - Free to use in internal networks, but not routed over the Internet.
- **Link-Local Addresses**: Automatically configured when you enable IPv6 on an interface.
  - This happens when configuring another IPv6 address or by using the `IPV6 ENABLE` command.
- **Multicast Addresses**: Included common reserved multicast addresses for OSPF, RIP, and EIGRP.
  - Covered different multicast scopes (be familiar with the concept).
- **Other Types**:
  - **Anycast**: Used to send traffic to one destination out of multiple possible destinations.
  - **Unspecified**: All 0s, usually written as `::`.
  - **Loopback**: Written as `::1`.
