Decimal	Binary	Hexadecimal
0	0000	0
1	0001	1
2	0010	2
3	0011	3
4	0100	4
5	0101	5
6	0110	6
7	0111	7
8	1000	8
9	1001	9
10	1010	A
11	1011	B
12	1100	C
13	1101	D
14	1110	E
15	1111	F

HEXADECIMAL CONVERSION

- Binary / Base 2 / 0b
  0, 1

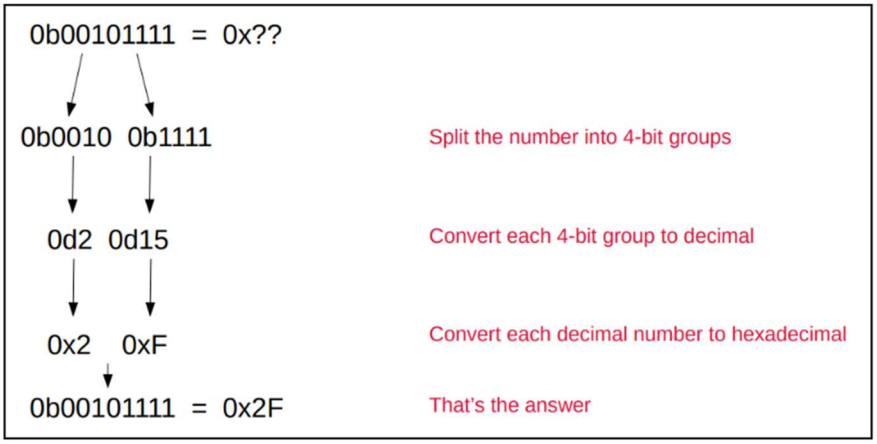
10 ← Is that decimal 10?
Or binary 10 (=decimal 2)?
Or hexadecimal 10 (=decimal 16)?

0b10

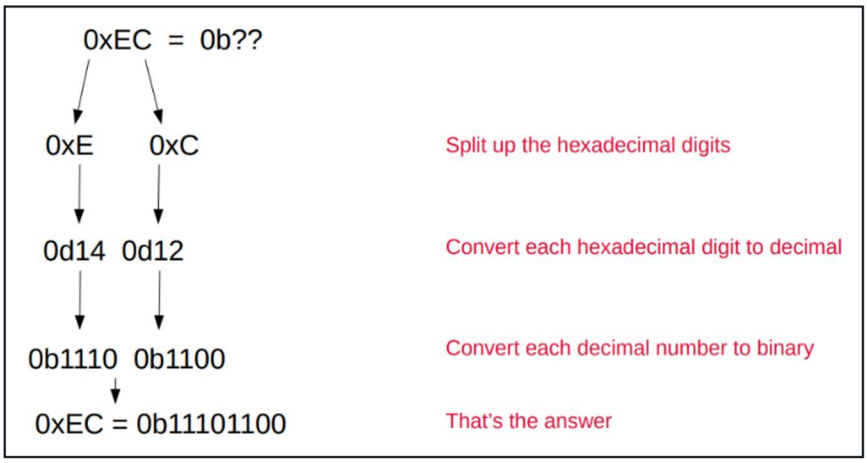
- Decimal / Base 10 / 0d
  0, 1, 2, 3, 4, 5, 6, 7, 8, 9

- Hexadecimal / Base 16 / 0x
  0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F

Binary → Hexadecimal



Hexadecimal → Binary



FIND THE EUI-64 IPv6 ADDRESS

R1's G0/1 interface has a MAC address of `0D2A.4FA3.00B1`.
What will G0/1's IPv6 address be after issuing the following command?
R1(config-if)# **ipv6 address 2001:db8:0:1::/64 eui-64**

a) `2001:db8:0:1:0B2A:4FFF:FFA3:B1`

b) `2001:db8:0:1:C2A:4FFF:FEA3:B1`

c) `2001:db8:0:1:0F2A:4FFF:FFA3:B1`

d) `2001:db8:0:1:F2A:4FFF:FEA3:B1`

1. Divide the MAC:

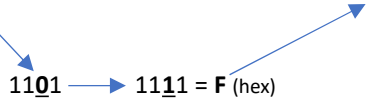
   0D2A 4F | A3 00B1

2. Insert FFEE in middle:

   0D2A 4F**FF FE**A3 00B1

3. Invert 7th bit:

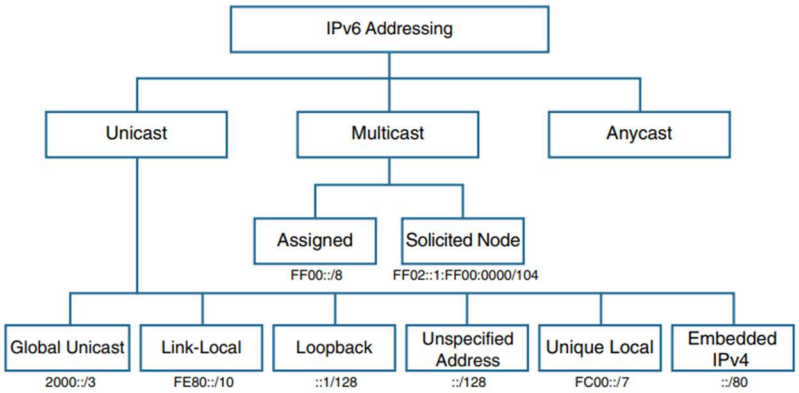
   0**D**2A 4F**FF FE**A3 00B1 ⟶ 0**F**2A 4FFFF FEA3 00B1

4. Insert new EUI-64 MAC as the last 64-bits of the IPv6 address:

   2001:db8:0:1:: ⟶ 2001:db8:0:1:**F2A:4FFF:FEA3:B1**

IPv6 Address Types

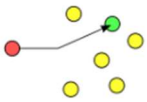


global unicast	internet routable with global routing prefix 2000::/3
multicast address	prefix FF00::/8 (send to group members)
unique local address	private global address, not internet routable, starts with FD00::/8
link-local address	mandatory, auto-configured, local subnet only, used for routing adjacency, prefix FE80::/10
loopback address	universal address, assigned to every interface, prefix ::1/128
modified eui-64	IPv6 host portion identifier, derived from MAC address
unspecified address	source address for initializing host, :1/128

Enable IPv6 routing: **(config)#ipv6 unicast-routing**

Setting up IPv6 address on interface: **(config-if)#ipv6 address [IPv6]/[prefix length]**

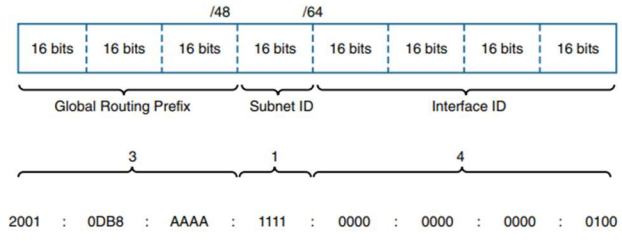
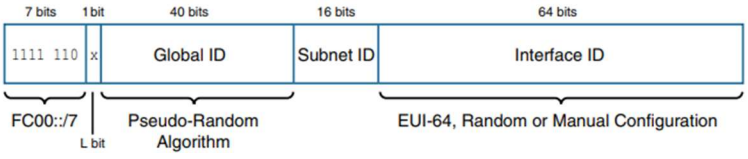
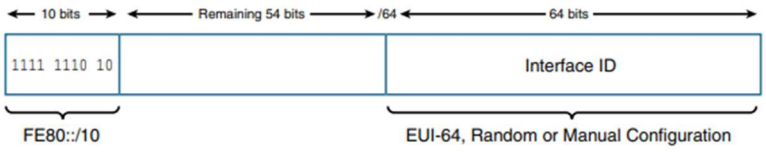
Unicast



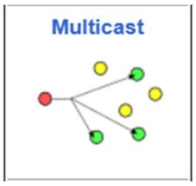
FROM THE SOURCE TO ONE SPECIFIC DESTINATION

A UNICAST ADDRESS UNIQUELY IDENTIFIES AN INTERFACE ON AN IPV6 DEVICE.

A PACKET SENT TO A UNICAST ADDRESS IS RECEIVED BY THE INTERFACE THAT IS ASSIGNED TO THAT ADDRESS.

IPV6 ADDRESS TYPE	STRUCTURE	DESCRIPTION
Global unicast	 **3-1-4** Rule **3** = hextets for global routing prefix **1** = hextet for the subnet ID **4** = hextets for the interface ID	IPv6 public addresses which can be used over the Internet. Must register and be globally unique. Orig 2000::/3 block; now defined as all addresses which aren't reserved for other purposes.
Unique local FC00: :/7 (old) FD00: :/8 (new)		In the block FC00: :/7 (old) and FD00::/8. It is the approximate IPv6 counterpart of the IPv4 private address. Can use freely within internal network and no need to register. It is **not routable on the global Internet**.
Link-local FE80: :/10	 Link local addresses are automatically generated on IPv6-enabled interfaces. By defaut, Cisco devices' interfaces have IPv6 enabled. However, we may need to manually do that by the command: **(config-if)#ipv6 enable**	Only used for communications within the local subnetwork (automatic address configuration, neighbor discovery, router discovery and routing adjacency protocols). It is only valid on the current subnet. **Not routable outside subnet**. It is usually created dynamically using a link-local prefix of FE80: :/10 and a 64-bit interface identifier (based on 48-bit MAC address [EUI-64]).

Multicast addresses

	IPv6 Address Type	Example	Description	IPv4 Equivalent
	Multicast ff00::/8	ff01:0:0:0:0:0:0:2	Multicast addresses are one-to-many. One source to multiple destinations. (there is no 'broadcast address' in IPv6!)	24.0.0.0/4

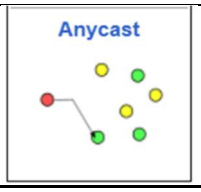
Multicast addresses scopes

- IPv6 defines multiple multicast 'scopes' which indicate how far the packet should be forwarded.
- The addresses in the previous slide all use the 'link-local' scope (FF02), which stays in the local subnet.
- IPv6 multicast scopes:
  - ↳ **Interface-local** (FF01): The packet doesn't leave the local device. Can be used to send traffic to a service within the local device.
  - ↳ **Link-local** (FF02): The packet remains in the local subnet. Routers will not route the packet between subnets. ***Not routable outside subnet***
  - ↳ **Site-local** (FF05): The packet can be forwarded by routers. Should be limited to a single physical location (not forwarded over a WAN)
  - ↳ **Organization-local** (FF08): Wider in scope than site-local (an entire company/organization).
  - ↳ **Global** (FF0E): No boundaries. Possible to be routed over the Internet.

IPv6 addresses join the **FF02::1** and **FF02::2** multicast groups by default.

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

Anycast addresses

	IPv6 Address Type	Example	Description
	Anycast *(No specific range)*	R1(config-if)# ipv6 address 2001:db8:1:1::99/128 **anycast**	From the source to one of multiple possible destinations.

Anycast is a new feature of IPv6, functions as 'one-to-one-of-many' IP connection. Here, multiple routers are configured with the same IPv6 address, routers will forward traffic to the nearest (based on routing metric) router with that address. There is no specific address range for anycast. Use a regular unicast address and specify it as anycast:

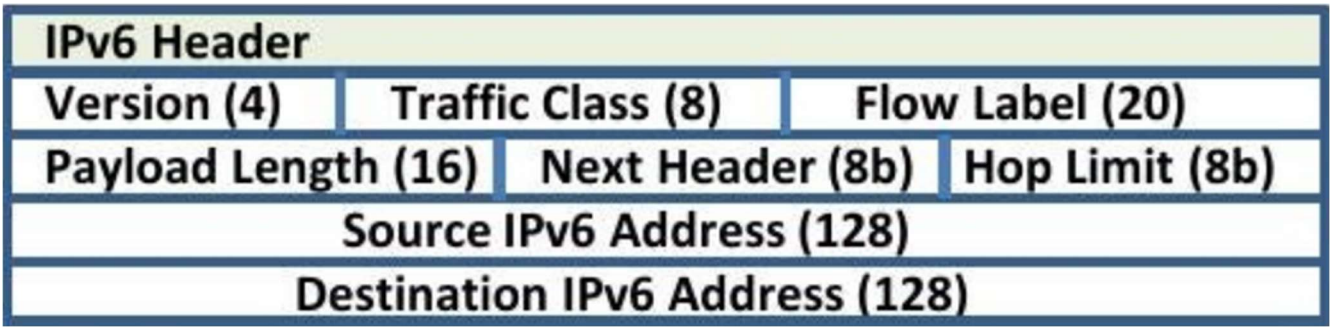
(config-if)#ipv6 address [ipv6 address]/[prefix-length] anycast

Other IPv6 addresses

- `::` = The *unspecified* IPv6 address
  ↳ Can be used when a device doesn't yet know its IPv6 address.
  ↳ IPv6 default routes are configured to `::/0`
  ↳ IPv4 equivalent: `0.0.0.0`

- `::1` = The loopback address
  ↳ Used to test the protocol stack on the local device.
  ↳ Messages sent to this address are processed within the local device, but not sent to other devices.
  ↳ IPv4 equivalent: `127.0.0.0/8` address range

IPv6 Header



Version (4bits):	Indicates the version of IP that is used. Fixed value of 6 (0b0110) to indicate IPv6.
Traffic Class (8bits):	Used for QoS (Quality of Service), to indicate high-priority traffic. For example IP phone traffic, live video calls, etc, will have a Traffic Class value which gives them priority over other traffic.
Flow Label (20bits):	Used to identify specific traffic 'flows' (communications between a specific source and destination).
Payload Length (16bits):	Indicates the length of the payload (the encapsulated Layer 4 segment) in bytes. The length of the IPv6 header itself isn't included, because it's always 40 bytes.
Next Header (8bits):	Indicates the type of the 'next header' (header of the encapsulated segment), for example TCP or UDP. Same function as the IPv4 header's 'Protocol' field.
Hop Limit (8bits):	The value in this field is decremented by 1 by each router that forwards it. If it reaches 0, the packet is discarded. Same function as the IPv4 header's 'TTL' field.
Source/Destination Address (128bits each):	These fields contain the IPv6 addresses of the packet's source and the packet's intended destination.

NDP

Neighbor Discovery Protocol (NDP) is a protocol used with IPv6.

It has various functions, and one of those functions is to replace ARP, which is no longer used in IPv6.

The ARP-like function of NDP uses ICMPv6 and solicited-node multicast addresses to learn the MAC address of other hosts.
*(ARP in IPv4 uses broadcast messages)

Two message types are used:

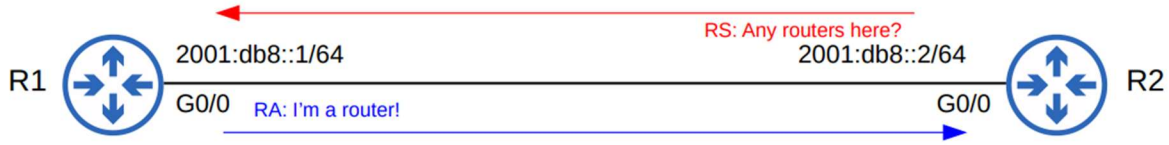
1) Neighbor Solicitation (NS) = ICMPv6 Type 135 * ARP Bcast
2) Neighbor Advertisement (NA) = ICMPv6 Type 136 * ARP Reply

Another function of NDP allows hosts to automatically discover routers on the local network.

Two messages are used for this process:

1) Router Solicitation (RS) = ICMPv6 Type 133
→ Sent to multicast address FF02::2 (all routers).
→ Asks all routers on the local link to identify themselves.
→ Sent when an interface is enabled/host is connected to the network.

2) Router Advertisement (RA) = ICMPv6 Type 134
→ Sent to multicast address FF02::1 (all nodes).
→ The router announces its presence, as well as other information about the link.
→ These messages are sent in response to RS messages.
→ They are also sent periodically, even if the router hasn't received an RS.



One final point about NDP!

Duplicate Address Detection (DAD) allows hosts to check if other devices on the local link are using the same IPv6 address.

Any time an IPv6-enabled interface initializes (**`no shutdown`** command), or an IPv6 address is configured on an interface (by any method: manual, SLAAC, etc.), it performs DAD.

DAD uses two messages you learned earlier: NS and NA.

The host will send an NS to its own IPv6 address. If it doesn't get a reply, it knows the address is unique.

If it gets a reply, it means another host on the network is already using the address.

IPv6 Static Routing

```
ipv6 route destination/prefix-length {next-hop | exit-interface [next-hop]} [ad]
```

Directly attached static route: Only the exit interface is specified.

```
ipv6 route destination/prefix-length exit-interface
  R1(config)# ipv6 route 2001:db8:0:3::/64 g0/0
```

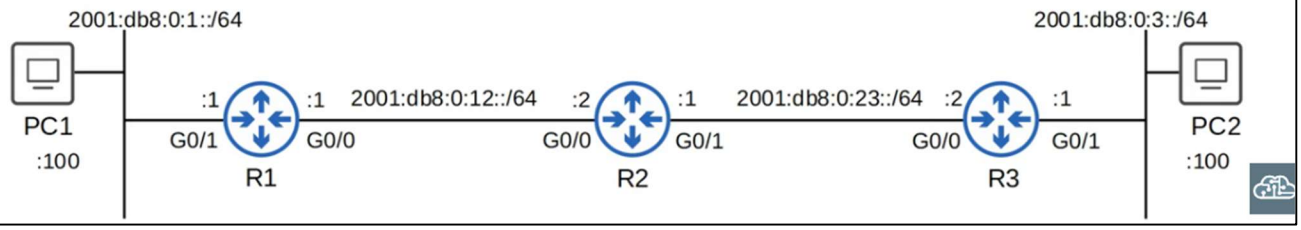
In IPv6, you CAN'T use directly attached static routes if the interface is an Ethernet interface.

Recursive static route: Only the next hop is specified.

```
ipv6 route destination/prefix-length next-hop
  R1(config)# ipv6 route 2001:db8:0:3::/64 2001:db8:0:12::2
```

Fully specified static route: Both the exit interface and next hop are specified.

```
ipv6 route destination/prefix-length exit-interface next-hop
  R1(config)# ipv6 route 2001:db8:0:3::/64 g0/0 2001:db8:0:12::2
```




```
ipv6 route destination/prefix-length {next-hop | exit-interface [next-hop]} [ad]
```

Network route:

```
R1(config)# ipv6 route 2001:db8:0:3::/64 2001:db8:0:12::2
```

Host route:

```
R2(config)# ipv6 route 2001:db8:0:1::100/128 2001:db8:0:12::1
R2(config)# ipv6 route 2001:db8:0:3::100/128 2001:db8:0:23::2
```

Default route:

```
R3(config)# ipv6 route ::/0 2001:db8:0:23::1
```