



Ecole Supérieure  
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COLLEGE OF ENGINEERING & ARCHITECTURE

# Routing and Switching

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## *Evaluation*



Lab Report+ Quiz:**10%**

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# Chapter 5 : IPv6

## Topics:

- **IPv6 Addressing scheme**
- **IPv6 Address Plan**
- **IPv6 Address Types**
- **IPv6 Address Scopes**
- **IPv6 and Subnetting**

# IPv6 Addressing Rules

- **128 bits (or 16 bytes) long:** four times as long as its predecessor.
- $2^{128}$  : about 340 billion billion billion billion different addresses
- **Colon hexadecimal notation:**
  - addresses are written using 32 hexadecimal digits.
  - digits are arranged into 8 groups of four to improve the readability.
  - Groups are separated by colons
- **2001:0718:1c01:0016:020d:56ff:fe77:52a3**
- Note:
  - DNS plays an important role in the IPv6 world
    - manual typing of IPv6 addresses is not an easy thing,
    - Some **zero suppression rules** are allowed to lighten this task at least a little.

# IPv6 Address Notation: Example

128.91.45.157.220.40.0.0.0.252.87.212.200.31.255

Binary  
100000000010110110010110110011101110000101000000000000000000  
000000000000000011111100010101111101010011001000000111111111111

Dotted Decimal  
128 91 45 157 220 40 0 0 0 0 252 87 212 200 31 255

Hexadecimal	0	32	64	96	128
Straight Hex	805B	2D9D	DC28	0000	0000
Leading-Zero Suppressed	805B	2D9D	DC28	0	0
Zero-Compressed	805B	2D9D	DC28	..	FC57
Mixed Notation	805B	2D9D	DC28	..	FC57 212 200 31 255

# Rule 1- IPv6 Zero Suppression

- ✓ Some types of addresses contain long sequences of zeros.
- ✓ To further simplify the representation of IPv6 addresses, a contiguous sequence of 16-bit blocks set to 0 in the colon hexadecimal format can be compressed to “::”, known as **double-colon**.

- ✓ For example:

## **link-local address**

FE80:0:0:0:2AA:FF:FE9A:4CA2 → FE80::2AA:FF:FE9A:4CA2.

## **multicast address**

FF02:0:0:0:0:0:2 → FF02::2

## **loopback address**

0:0:0:0:0:0:1 → ::1

## Rule 1- IPv6 Zero Suppression

- ✓ Zero compression can only be used to compress a single contiguous series of 16-bit blocks expressed in colon hexadecimal notation.
- ✓ You cannot use zero compression to include part of a 16-bit block.

For example,

cannot express FF02:30:0:0:0:0:5 as FF02:3::5

correct representation = FF02:30::5

Leading zeroes in every group can be omitted.

**2001:718:1c01:16:20d:56ff:fe77:52a3**

# Rule 1- IPv6 Zero Suppression

**To determine the number of 0 bits represented by the “::”**

1. count the number of blocks in the compressed address
2. (-) subtract this number from 8
3. (\*) multiply the result by 16.

**For example**

1. FF02::2
2. two blocks - “FF02” block and “2” block.
3. The number of bits expressed by the “::” is 96 ( $96 = (8 - 2) \times 16$ ).

**Zero compression can only be used once in a given address.**

Otherwise, you could not determine the number of 0 bits represented by each instance of “::”.

# IPv6 Prefixes

- ✓ The prefix is the part of the address that indicates the bits that have fixed values or are the bits of the subnet prefix.
- ✓ Prefixes for IPv6 subnets, routes, and address ranges are expressed in the same way as Classless Inter-Domain Routing (CIDR) notation for IPv4.
- ✓ An IPv6 prefix is written in *address/prefix-length* notation.  
For example, **21DA:D3::/48** and **21DA:D3:0:2F3B::/64** are IPv6 address prefixes.
- ✓ **Note** IPv4 implementations commonly use a dotted decimal representation of the network prefix known as the subnet mask. A subnet mask is not used for IPv6. Only the prefix length notation is supported.

# IPv6 Prefixes

- When writing both a node address and a prefix of that node address (e.g., the node's subnet prefix), the two can be combined as follows:

- The node address:

12AB:0:0:CD30:123:4567:89AB:CDEF

- And its subnet number:

{12AB:0:0:CD30::/60}

- Can be represented as

[12AB:0:0:CD30:]123:4567:89AB:CDEF/60]

## IPv6 Addresses: Types and scopes

- IPv6 addresses come in different **types** (Unicast, multicast, anycast) and different **scopes** (link, global, and so on).
- The **type** of the address determines if packets are destined for one or for many machines.
- The **scope** of the address determines which contexts the address makes sense in.
- IPv6 addresses are assigned to interfaces on nodes, not to the nodes themselves. This is a big change from IPv4, where very often the address associated with a machine's interface is that machine. Instead, IPv6 interfaces commonly and usefully have more than one IPv6 address.

# IPv6 Address Categories

**There are 3 categories of addresses in IPv6:**

- **Unicast**

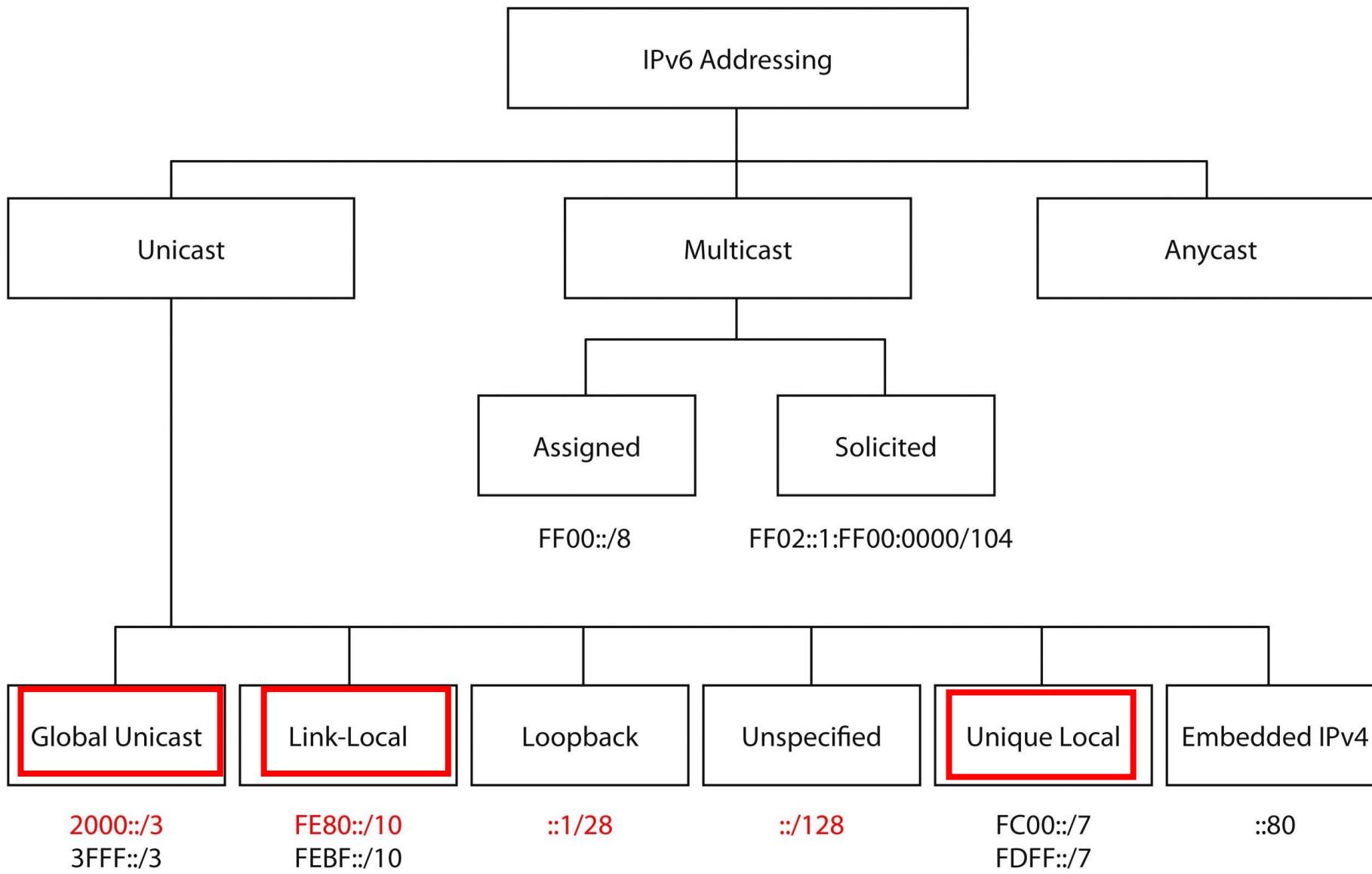
A unicast address uniquely identifies an interface of an IPv6 node. A packet sent to a unicast address is delivered to the interface identified by that address.

- **Multicast**

A multicast address identifies a group of IPv6 interfaces. A packet sent to a multicast address is processed by all members of the multicast group.

- **Anycast**

An anycast address is assigned to multiple interfaces (usually on multiple nodes). A packet sent to an anycast address is delivered to only one of these interfaces, usually the nearest one.



# IPv6 Addresses scopes



## Address Types and Scope

**Global Unicast Address** --Scope Internet- Routed on Internet

**Unique Local** -- Scope Internal Network or VPN -Internally routable but Not routed on Internet

**Link Local** - Scope network link- Not Routed internally or externally.

# IPv6 Unicast Address Scopes

Three types of scopes:

- 1. Link-local scope**

Identifies all hosts within a single layer 2 domain.

Called as **link-local addresses**

- 2. Unique-local scope**

Identifies all devices reachable within an administrative site or domain typically contains multiple distinct links.

Called as **unique-local addresses (ULAs)**

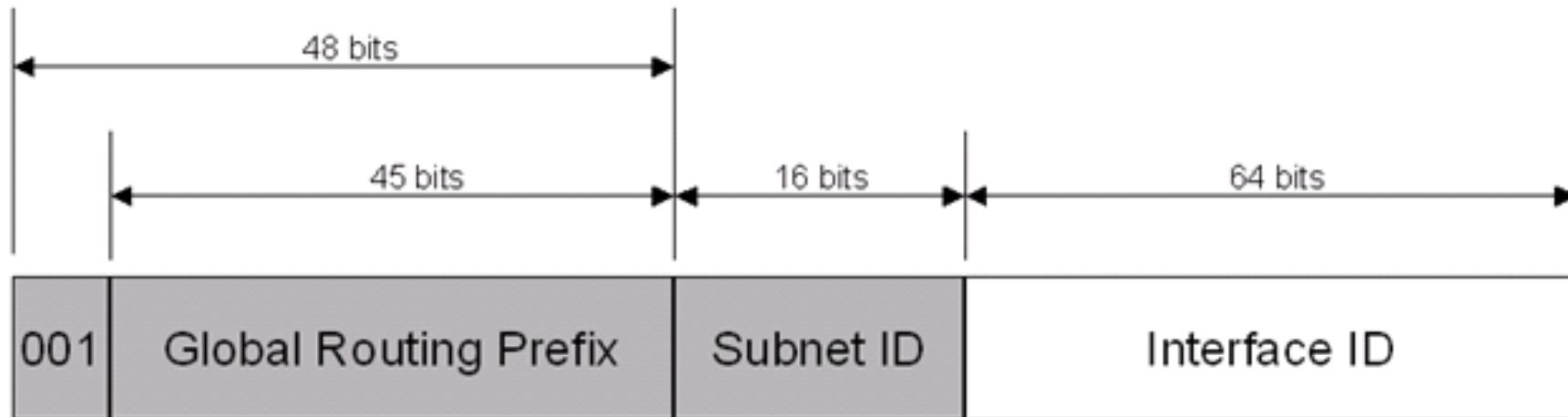
- 3. Global scope**

Identifies all devices reachable across the Internet.

Called as **global unicast addresses (GUAs)**

# Global Unicast addresses

- Equivalent to public IPv4 addresses.
- Globally routable and reachable on the IPv6 portion of the Internet.
- The scope of a global unicast address is the entire IPv6 Internet.
- Global scoped communication are identified by high-level 3 bits set to 001 (2000::/3)



# Global Unicast addresses

Each aggregatable global unicast IPv6 address has three parts:

Fixed portion set to 001 – The three high-order bits are set to 001. The address prefix for currently assigned global addresses is 2000::/3.

## Global Routing Prefix – Site Prefix

Site prefix assigned to an organization (leaf site) by a provider should be at least a /48 prefix  
= 45 + high-order bits (001).

/48 prefix represents the high-order 48-bit of the network prefix.  
prefix assigned to the organization is part of the provider's prefix.

## Subnet-id - Site

With one /48 prefix allocated to an organization by a provider, it is possible for that organization to enable up to 65,535 subnets (assignment of 64-bit's prefix to subnets).

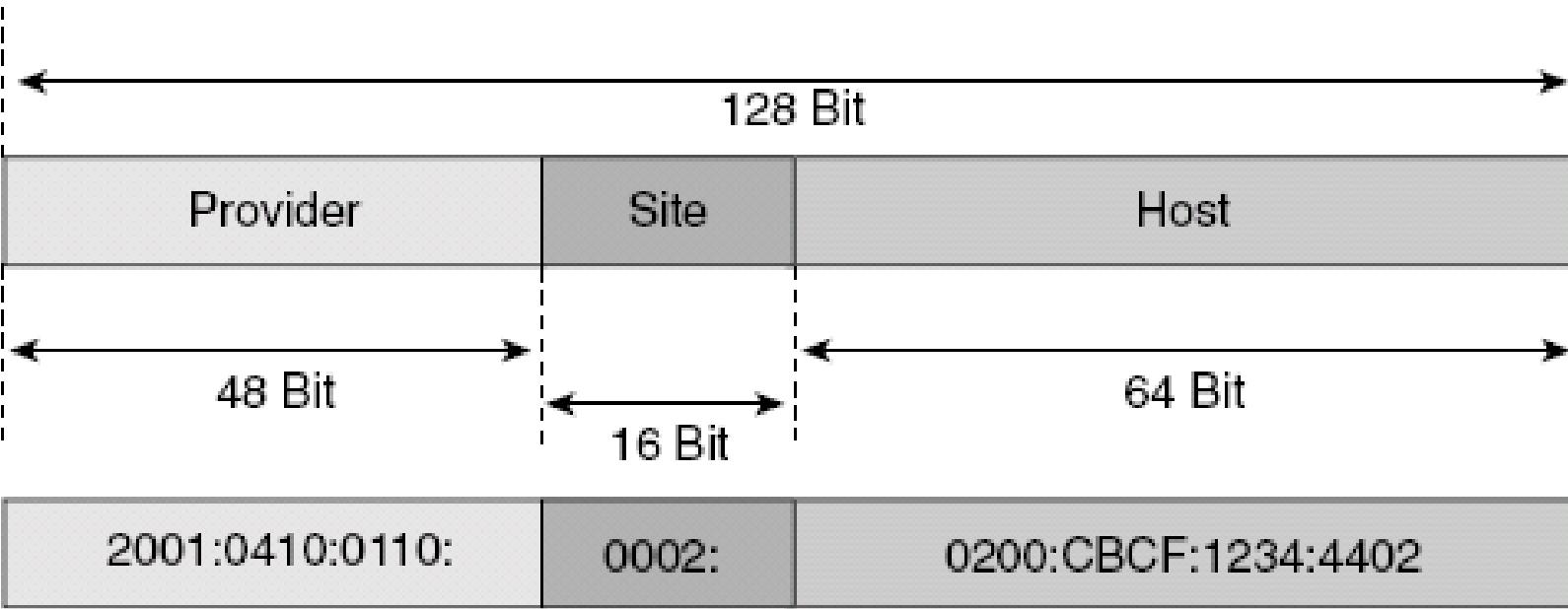
The organization can use bits 49 to 64 (16-bit) of the prefix received for subnetting.

## Interface-id – Host

The host part uses each node's interface identifier.

This part of the IPv6 address, which represents the address's low-order 64-bit, is called the *interface ID*.

# Global Unicast addresses



**2001:0410:0110::/48 is assigned by a provider**

**2001:0410:0110:0002::/64 network subnet within the organization**

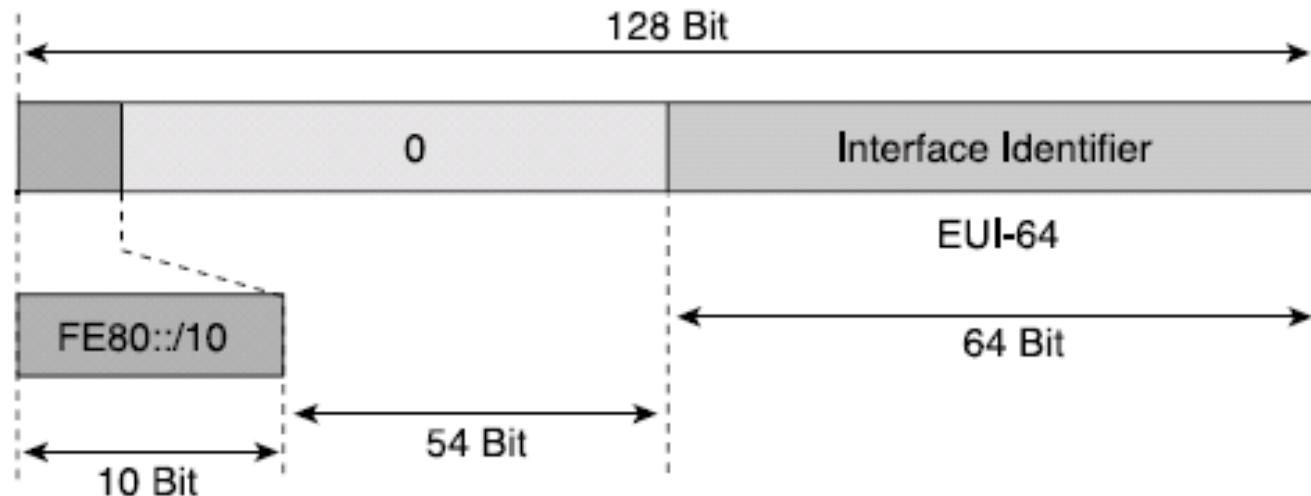
**2001:0410:0110:0002:0200:CBCE:1234:4402 – node address  
within the subnet**

## Link-local Unicast Address

- IPv6 link-local addresses are equivalent to IPv4 link-local addresses defined in RFC 3927 that use the 169.254.0.0/16 prefix.
- The scope of a link-local address is the local link.
- A link-local address is required for Neighbor Discovery (NDP) processes and is always automatically configured, even in the absence of all other unicast addresses.

# Link-local Unicast Address

- ✓ Used only between nodes connected on the same local link.
- ✓ When an IPv6 stack is enabled on a node, one link-local address is automatically assigned to each interface of the node at boot time.
- ✓ IPv6 **link-local prefix FE80::/10** is used and the **interface identifier in Extended Unique Identifier 64 (EUI-64)** format is appended as the address's low-order 64-bit.
- ✓ Bits 11 through 64 are set to 0 (54-bit).
- ✓ Link-local addresses are only for local-link scope and must never be routed between subnets within a site.



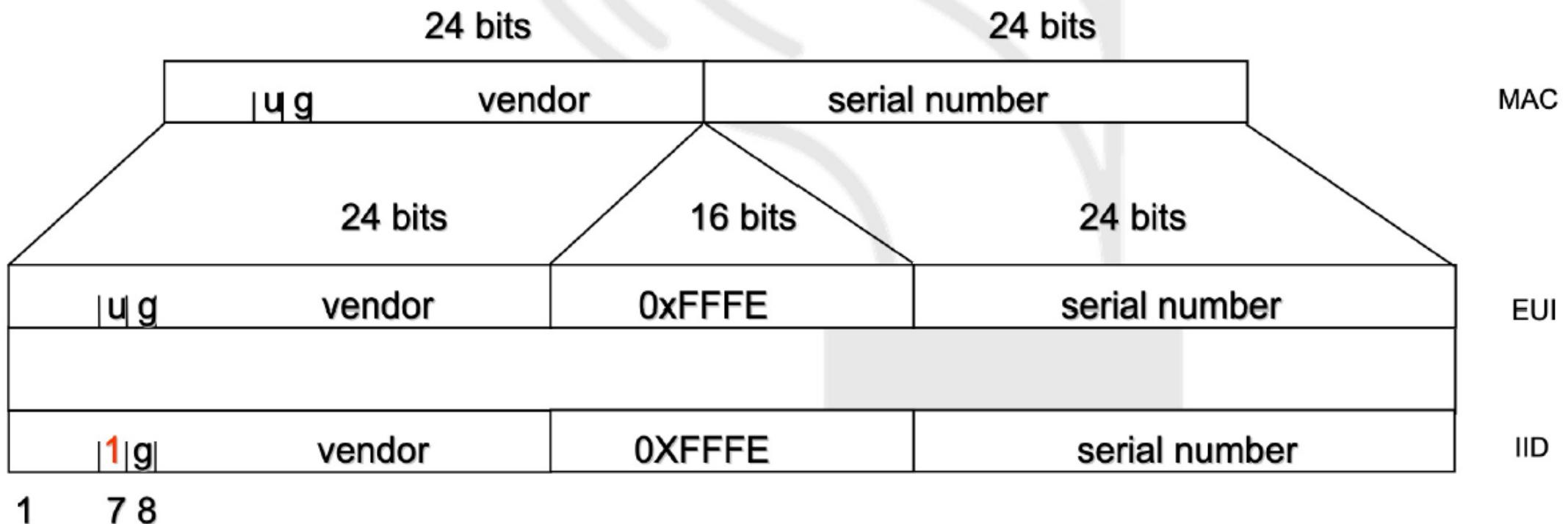
## EUI-64 Identifier

- The interface identifiers for IPv6 unicast addresses are used to **identify interfaces on a given link**.  
Therefore, this identifier must be **unique within a given subnet**, and in some cases, it can also be **unique on a larger scale**, even **globally** (across the Internet).
- In some cases, the identifier is **directly derived from the MAC address** (Layer 2) of the interface

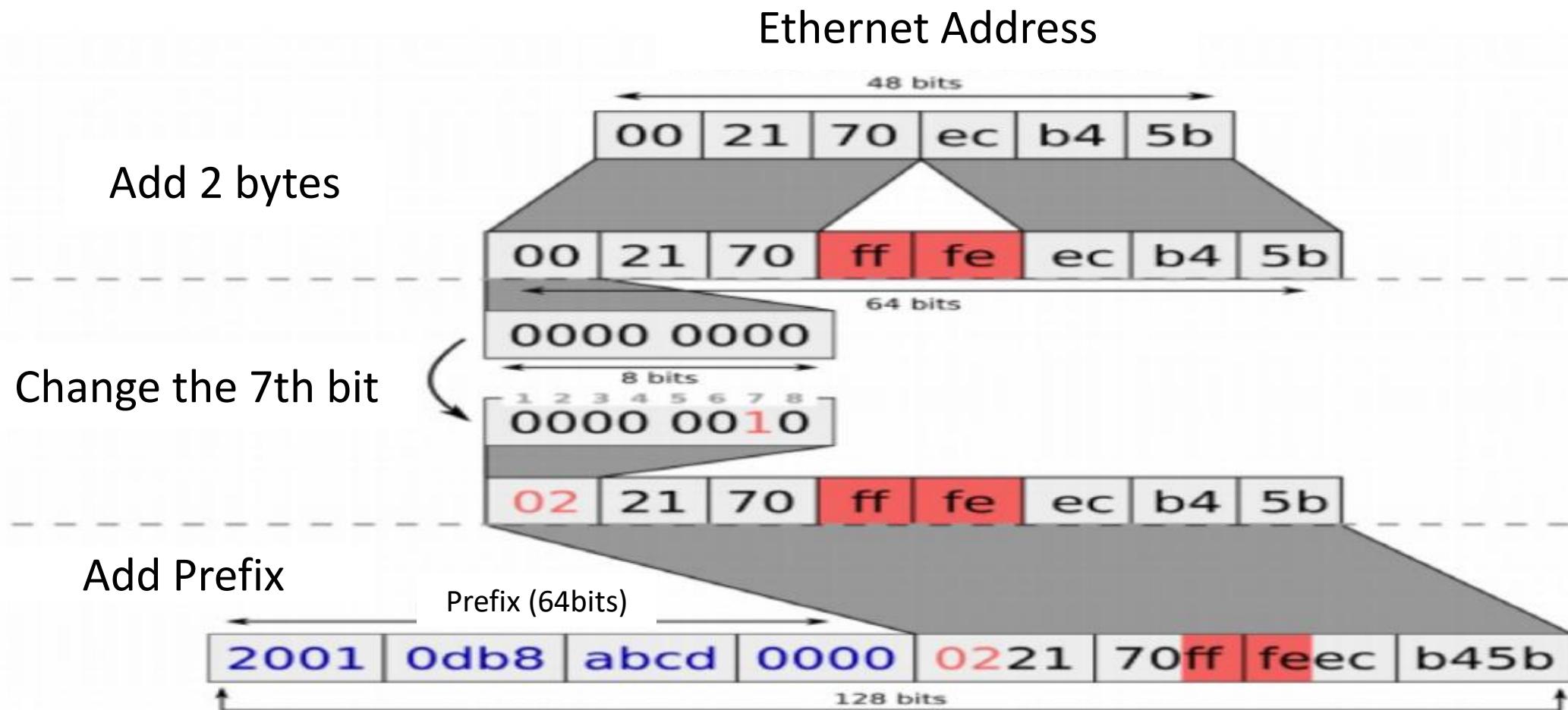
## EUI-64 Identifier

```
eth0      Link encap:Ethernet  HWaddr 08:00:27:78:fc:dc
          inet addr:172.16.40.2  Bcast:172.16.255.255  Mask:255.255.0.0
          inet6 addr: 2001:db8:46:0:a00:27ff:fe78:fcdc/64 Scope:Global
          inet6 addr: fe80::a00:27ff:fe78:fcdc/64 Scope:Link
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:0 errors:0 dropped:0 overruns:0 queueing discipline:0
          TX packets:0 errors:0 dropped:0 overruns:0 queueing discipline:0
```

# EUI-64 Identifier



# EUI-64 Identifier



	0	8	16	24	32	40	48	
48-bit IEEE 802 MAC Address	39	A7	94	07	CB	D0		
	00111001	10100111	10010100	00000111	11001011	11010000		
Organizationally Unique Identifier (OUI)								Device Identifier
1. Split MAC Address	00111001	10100111	10010100			00000111	11001011	11010000
2. Add "FFFE" Bit Pattern To Middle 16 Bits	00111001	10100111	10010100	11111111	11111110	00000111	11001011	11010000
3. Change Bit 7 To "1"	001110 <b>11</b>	10100111	10010100	11111111	11111110	00000111	11001011	11010000
Modified EUI-64 Identifier In Hexadecimal Notation	3B	A7	94	FF	FE	07	CB	D0
IPv6 Identifier In Colon Hexadecimal Notation	3B:A7:94:FF:FE:07:CB:D0							

64-Bit IPv6 Modified EUI-64 Interface Identifier

# Special IPv6 Addresses

The following are special IPv6 addresses:

## Unspecified address

- ✓ unspecified address (0:0:0:0:0:0:0 or ::) is only used to indicate the absence of an address.
- ✓ equivalent to the IPv4 unspecified address of 0.0.0.0.
- ✓ used as a source address for packets attempting to verify the uniqueness of a tentative address.
- ✓ never assigned to an interface or used as a destination address.

## Loopback address

- ✓ The loopback address (0:0:0:0:0:0:1 or ::1) is used to identify a loopback interface, enabling a node to send packets to itself.
- ✓ It is equivalent to the IPv4 loopback address of 127.0.0.1.
- ✓ Packets addressed to the loopback address must never be sent on a link or forwarded by an IPv6 router.



**NO BROADCAST IN IPV6**

# Multicast Address

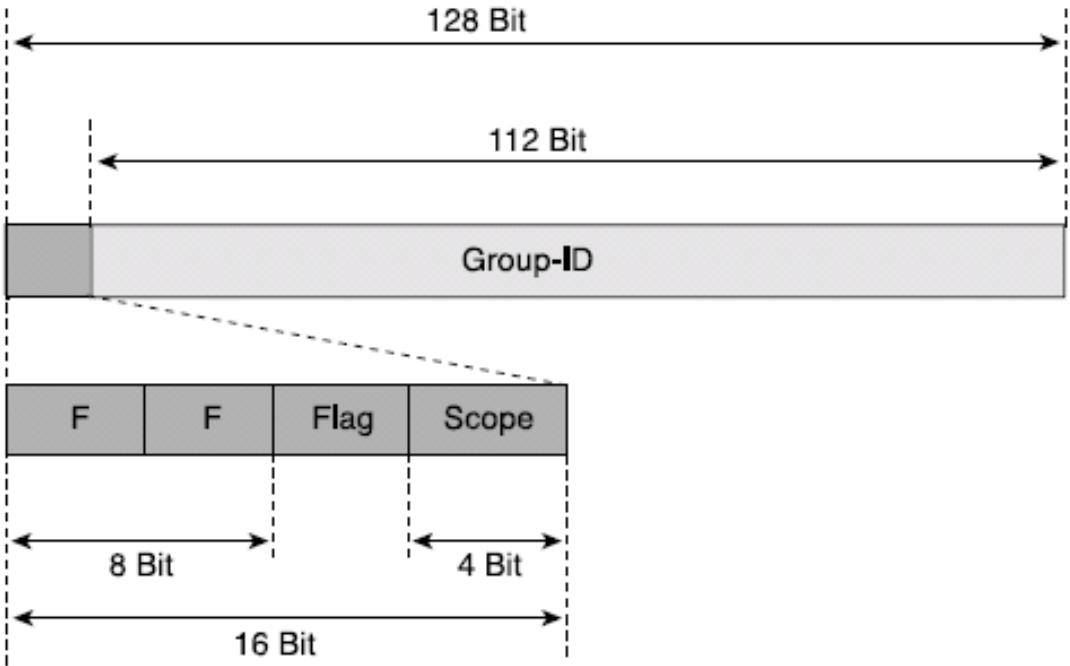
- ✓ In IPv6, multicast traffic operates in the same way that it does in IPv4.
- ✓ Nodes can join or leave a multicast group at any time.
- ✓ IPv6 multicast addresses have the **first eight bits set to 1111 1111**.
- ✓ An IPv6 address is easy to classify as multicast because it always begins with “FF”.
- ✓ Multicast addresses cannot be used as source addresses or as intermediate destinations in a Routing extension header.
- ✓ Beyond the first eight bits, multicast addresses include additional structure to identify their flags, scope, and multicast group.

# Multicast Address

- ✓ Main goal of multicasting is having an efficient network to save bandwidth on links by optimizing the number of packets exchanged between nodes
- ✓ In IPv4:  
224.0.0.0/3, where the high-order 3-bit of the IPv4 address is set to 111
- ✓ In IPv6:

Representation	Value
Preferred format	FF00:0000:0000:0000:0000:0000:0000:0000/8
Compressed format <sup>1</sup>	FF00:0:0:0:0:0:0:0/8
Compressed format	FF00::/8
Binary format	High-order 8-bit is set to 1111 1111

# Multicast Address



- ✓ High-order 3-bit of the Flag field is reserved and must be initialized using 0 values.
- ✓ Remaining bit indicates the type of multicast address.

# Multicast Address



- ✓ The prefix associated with multicast addresses is **FF00::/8**, meaning addresses range from **FF00** to **FFFF**.

The **Scope field** defines a state associated with the multicast address over **4 bits**:

**ORTP**

**T (1 or 0)** → *Temporary flag*: specifies whether the address is **temporary (1)** or **permanent (0)**

**P (1 or 0)** → *Prefix flag*: specifies whether the address is **based on a network prefix (1)** or **not (0)**

**R (1 or 0)** → *R flag*: specifies whether the address is **constructed from a network, router, or server address**

## Scope

- ✓ 0: Reserved
- ✓ 1: Interface local
- ✓ 2: Link-local
- ✓ 3: Subnet-local
- ✓ 4: Admin-local
- ✓ 5: Site-local
- ✓ 8: Organization-local
- ✓ E: Global
- ✓ F: Reserved

# Anycast Address

- ✓ Anycast addresses can be considered a conceptual cross between unicast and multicast addressing.

**Unicast → send to this one address**

**Multicast → send to every member of this group**

**Anycast → send to any one member of this group**

- ✓ In choosing which member to send to, for efficiency reasons normally send to the closest one - closest in routing terms.

So, anycast mean “**send to the closest member of this group**”.

- ✓ The network itself plays the key role in anycast by routing the packet to the nearest destination by measuring network distance.
- ✓ Anycast addresses use aggregatable global unicast addresses.
- ✓ They can also use site-local or link-local addresses.
- ✓ Note that it is impossible to distinguish an anycast address from a unicast address.

# Anycast Address

Representation	Reserved anycast address
Preferred format	<i>UNICAST_PREFIX</i> :0000:0000:0000:0000, where <i>UNICAST_PREFIX</i> is a 64-bit value
Binary format	Bits 65 through 128 are set to 0

- Also called the **subnet-router anycast address**.
- All IPv6 routers are required to support subnet-router anycast addresses for each of their subnet interfaces.

# IPv6 Addresses for a Host

Typical IPv6 hosts are **logically multihomed** because they have at least two addresses with which they can receive packets

1. a link-local address for local link traffic
2. a routable site-local or global address.

# IPv6 Addresses for a Router

An IPv6 router is assigned the following unicast addresses:

- A link-local address for each interface
- Unicast addresses for each interface (which one or multiple global unicast addresses)
- A Subnet-Router anycast address
- Additional anycast addresses (optional)
- The loopback address (::1) for the loopback interface