# IPv6 Addressing

## Awareness Objective

- IPv6 Address Format & Basic Rules

- Understanding the IPv6 Address Components

- Understanding & Identifying Various Types of IPv6 Addresses

# IPv6 ADDRESS FORMAT

# IPv4 Address SYNTAX

W  .  X  .  Y  .  Z

192  .  168  .  5  .  1

W,X,Y,Z represent 8 bits converted to Decimal

# IPv6 Address SYNTAX

XXXX : XXXX : XXXX : XXXX : XXXX  : XXXX : XXXX : XXXX

Where each X represent a 4 bits hexadecimal field

2001:0DB8:1234:0000:0000:C1C0:ABCD:0876

# FROM 128 bit BINARY TO 8 BLOCK OF 'HEXTETS'

- **The following is an IPv6 address in binary form:**

00100000000000010000110110111000000000000000000000000000101110111011
00000010101010100000000011111111111111100010100010011100010110110

- The 128-bit address is divided along **16-bit** blocks:

0010000000000001   0000110110111000   0000000000000000   0010111100111011
0000001010101010   0000000011111111   1111111000101000   1001110001011010

- Each 16-bit block is converted to **hexadecimal – taking 4 bits as one block-** and delimited with **colons**. The result is :

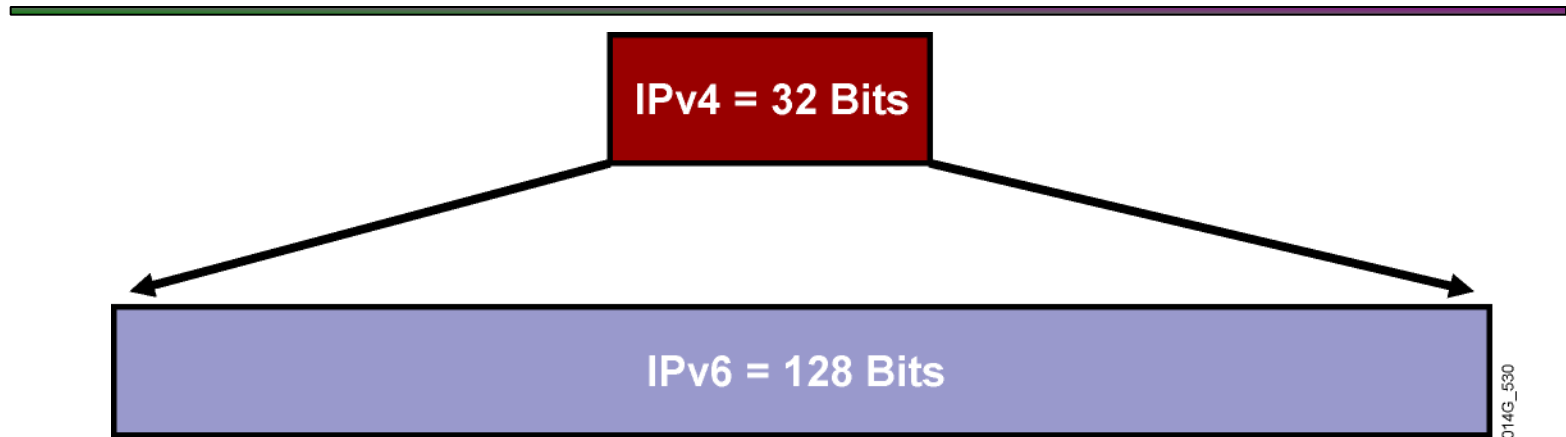Second 16 bits block is          0000          1101     1011          1000

                                   ↓             ↓        ↓             ↓

                                   0             D        B             8

Thus, the 8 blocks are represented as :

## 2001:0DB8:0000:2F3B:02AA:00FF:FE28:9C5A

# IPv6 Address Capacity



IPv4 = 32 Bits

IPv6 = 128 Bits

014G_530

- **IPv4: 32 bits or 4 bytes long**
    - **4.2 billion possible IP addresses**

- **IPv6: 128 bits or 16 bytes**
    - **$340 * 10^{36}$ possible IP addresses**
    - **340 undecillion or 340 trillion trillion trillion**
    - **340 lakh lakh lakh crores !!**

# IPv6 ADDRESS RULES

# Address Rules

Written in Case Insensitive colon 'hextet' notation

2001:0DB8:0000:003B:02AA:00FF:FE28:0C5A

2001:0Db8:0000:003B:02aa:00ff:FE28:0C5A

# Rule 2

The leading zeros within each 16-bit block can be removed. However, each block must have at least a single digit

2001:0Db8:0000:003B:02aa:00ff:FE28:0C5A

2001:0Db8:0000:003B:02aa:00ff:FE28:0C5A

2001:Db8:0:3B:2aa:ff:FE28:C5A

# SUPPRESSION OF CONTIGUOUS SEQUENCE OF '0'

**A contiguous sequence of 16-bit blocks set to 0 in the colon hexadecimal format can be compressed to "::", *double-colon***

- FF02:0:0:0:0:0:0:1 ➡ FF02::1

- FE80:0:0:0:2AA:FF:FE9A:4CA2 ➡ FE80::2AA:FF:FE9A:4CA2

Zero compression can only be used once in a given address

2001:0:0:1234:0:0:0:C1C0

2001::1234::C1C0

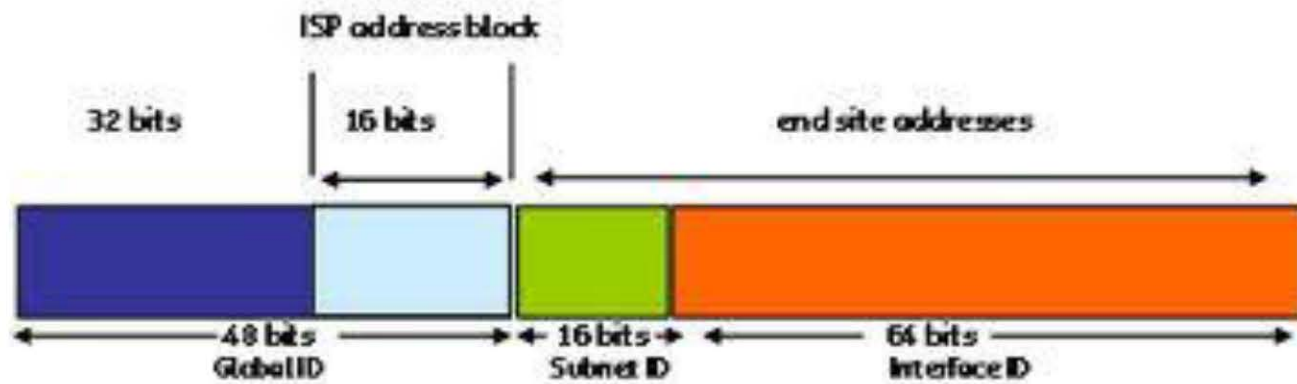# IPv6 Addresses in URL

In a URL, it is enclosed in brackets

http://[2001:1:4F3A::206:AE14]

If writing Domain name in the URL, Should use Fully Qualified Domain Names (FQDN)

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# IPv6 ADDRESS COMPONENTS

# IPv6 ADDRESS HAS TWO PARTS

## 'ROUTING PREFIX'
## AND
## 'INTERFACE IDENTIFIER'

# IPv6 Prefix & Interface ID

2001:0A3C:5437:ABCD:0:0:0:0/**64**

Prefix

Interface ID

| Global Routing Prefix | Subnet | Interface Address |
|---|---|---|
| 48 bits | 16 bits | 64 bits |
| Identifies provider | local subnet | identifies host |

# IPv6 Prefixes

- Certain fixed numbers of high-order bits of an IPv6 address may specify an ISP Network, a site within an organisation or a subnet

- Prefixes for IPv6 Addresses are expressed in the same way as CIDR notation in IPv4.

- An IPv6 prefix is written in /*N-length* notation; N -Decimal

-  For example, 21DA:D3::/48 and 21DA:D3:0:2F3B::/64 ; /48 AND /64 are IPv6 address prefixes.
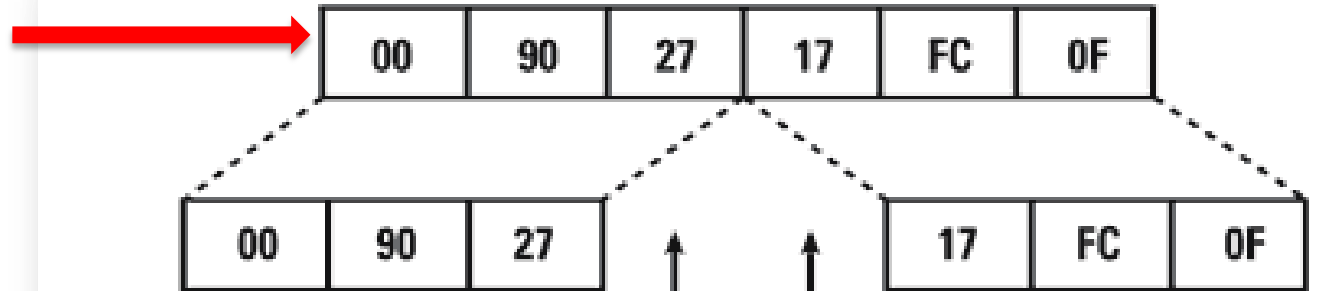
# IPv6 INTERFACE ID
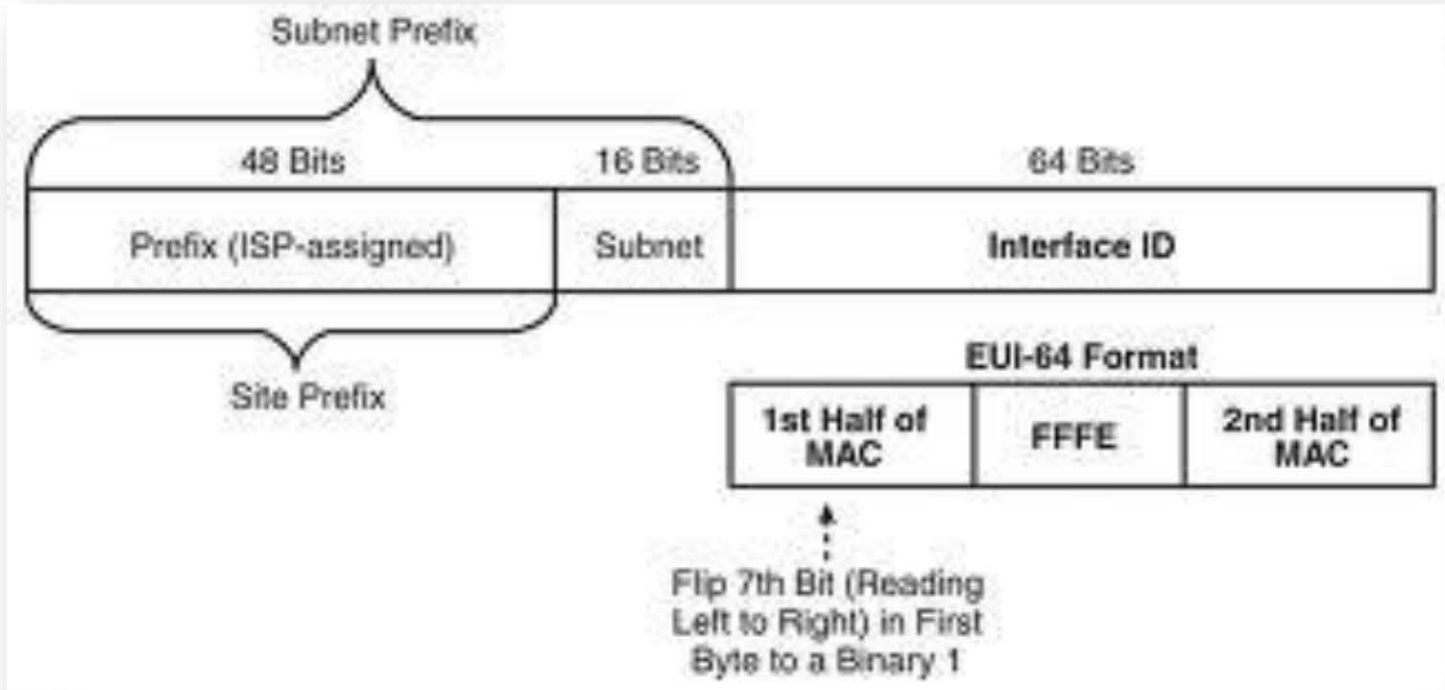
# IPv6 Interface Identifiers

- **Fixed** Sixty-four LSB bits of IPv6 address. Guaranteed unique on the subnet

- In IPv4, hosts ID are of variable length depending upon the sub netting scheme whereas in IPv6 Interface ID is of fixed length  as 64 bits

- Mapping IEEE 802 48 bit MAC address  into 64 bit Interface ID (EUI-64)

- In IPV6, nodes can generate its Interface ID automatically

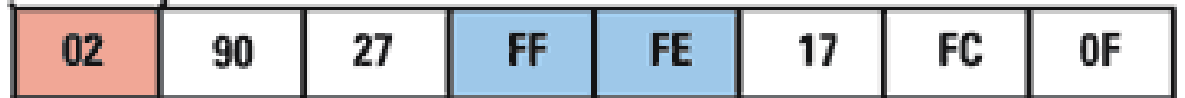# Mapping IEEE 802 MAC address into interface identifier (EUI-64)

48 bit MAC ID

| 00 | 90 | 27 | 17 | FC | 0F |

| 00 | 90 | 27 | | | 17 | FC | 0F |

Insert FF FE

| FF | FE |

| 00 | 90 | 27 | FF | FE | 17 | FC | 0F |

Invert the 7th bit

000000U0

U = 1

Where U = { 1 = Unique, 0 = Not Unique }

| 02 | 90 | 27 | FF | FE | 17 | FC | 0F |

# AWARENESS OBJECTIVES

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# IPv6 Address Scope

- **Link-local**: The scope is the local link (nodes on the same subnet)

- **Site-local**: The scope is the site of an organization (private site addressing) – Now Deprecated

- **Unique – Local** : Scope is the organization ; Similar to Private IPv4 addresses

- **Global**: The scope is global (IPv6 public addresses)

# Unicast IPv6 Addresses
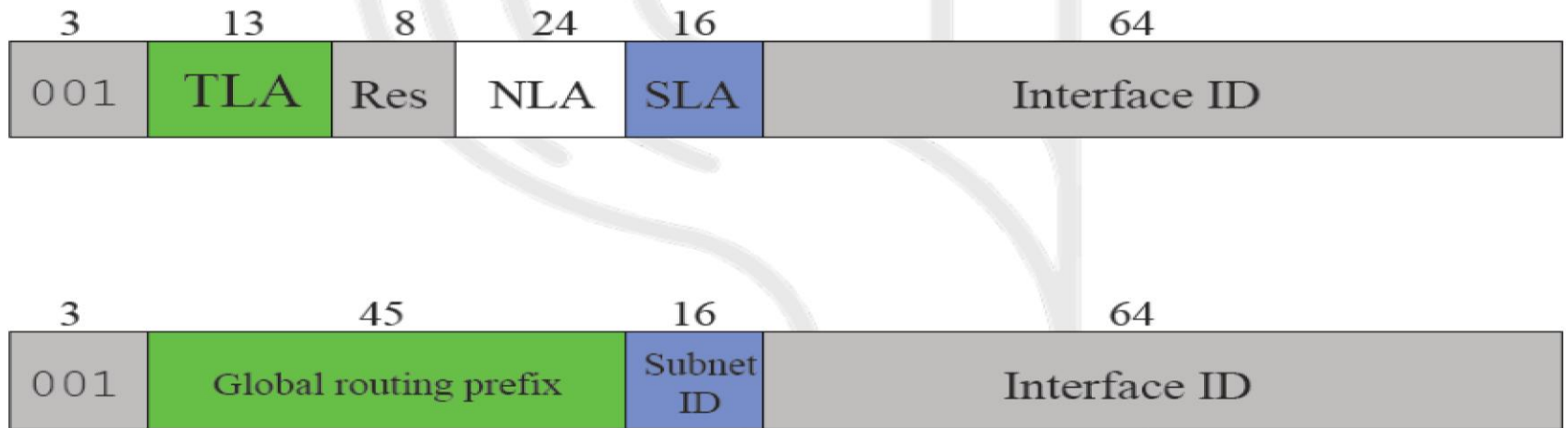
- **Global**

- **Link-local**

- **Unique-Local**

**Figure 2-3    IPv6 Address Scopes**

**Global**    **Unique Local**    **Link Local**

251399
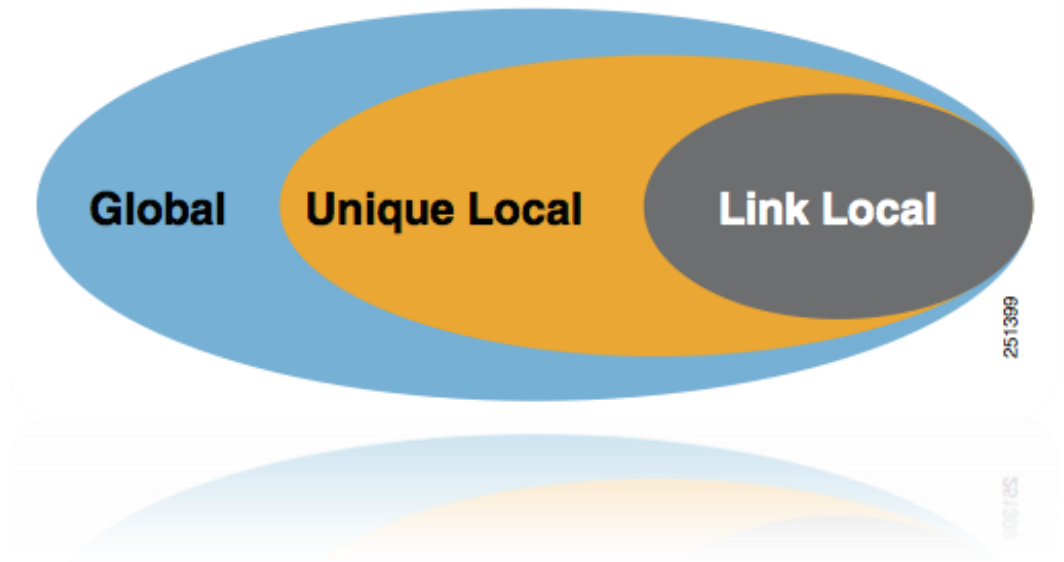
# Global Unicast Addresses

Global unicast addresses are equivalent to public IPv4 addresses. They are globally routable and reachable on the IPv6 portion of the Internet

**Format Prefix 2000::/3**

| 3 | 13 | 8 | 24 | 16 | 64 |
|---|---|---|---|---|---|
| 001 | TLA | Res | NLA | SLA | Interface ID |

| 3 | 45 | 16 | 64 |
|---|---|---|---|
| 001 | Global routing prefix | Subnet ID | Interface ID |

First 3 bits (001) are fixed; next 45 bit prefix- collection of larger and smaller ISPs that provide access to the IPv6 Internet

Next 16 bits- Collection of subnets within an organization's site

The **interface ID** 64 bit- identifies a specific interface on a subnet within an organization's site

# 001 – First 3 bits are Reserved

- IANA has only released 1/8$^{th}$ of the entire IPv6 addresses

- For this, first 3 MSB are fixed as 001

- The entire global-unicast IPv6 address range is from 2000::/128 to 3FFF:FFFF:FFFF:FFFF:FFFF:FFFF:FFFF/128, which is only 1/8th of the entire IPv6 address space!

# IPv6 Address Allocation
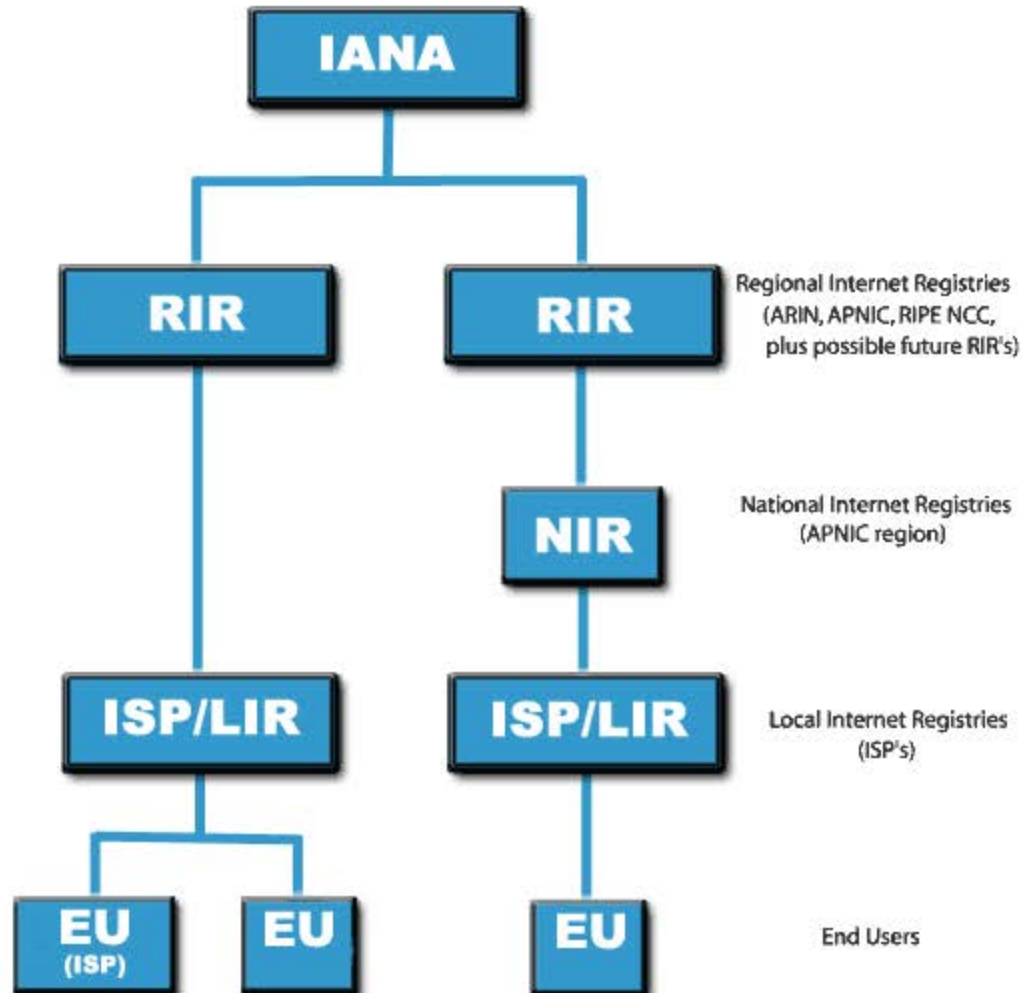
# REGIONAL INTERNET REGISTRY (RIRs)

# Global Unicast Address Allocation

- IETF RFC 3177 recommended /48 block to end sites

- However, RIRs adopted /56 or /64 blocks

- Now IETF released RFC 6177, which allows flexibility to the RIRs in allocation of address block to end sites

- But it recommends blocks larger than /64 so that end sites may grow into multiple subnet.

- Top level ISP gets /30 or /32

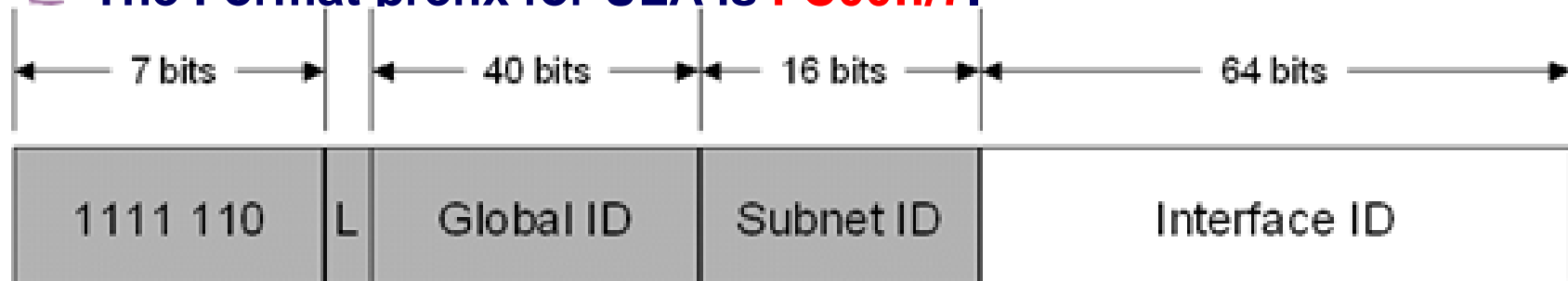# OTHER TYPES OF IPv6 ADDRESSES

## LLA   SLA   ULA

# IPv6 Link Local Unicast Address (LLA)

- **Hosts on the same link (the same subnet) use these automatically configured addresses to communicate with each other.**

- **Must for the Neighbor Discovery protocol**

- **The prefix Format for LLA is FE80::/64.**

- **The prefix Format for LLA**

| 1111 1110 10 (10 bits) | 000 ...000 (54 bits) | Interface ID (64 bits) |
|---|---|---|

# IPv6 Unique Local Address (ULA)

- **Replaces Site Local Addresses**

- **Equivalent to Private IP addresses in IPv4**

- **Provides unique Private IPv6 addresses across all sites of an organization**

- **Removes The ambiguity of non- unique site-local addresses in an organization**

- **The Format prefix for ULA is FC00::/7.**

| ← 7 bits → | | ← 40 bits → | ← 16 bits → | ← 64 bits → |
|---|---|---|---|---|
| 1111 110 | L | Global ID | Subnet ID | Interface ID |

# SPECIAL IPv6 ADDRESSES

**Loopback   Unspecified**

# Special Unicast Addresses

- **Unspecified address**

  - 0:0:0:0:0:0:0:0 or **::**          (0.0.0.0 in IPv4)
  - is only used to indicate the absence of an address
  - The unspecified address is typically used by the node to know its address when plugged into the network.
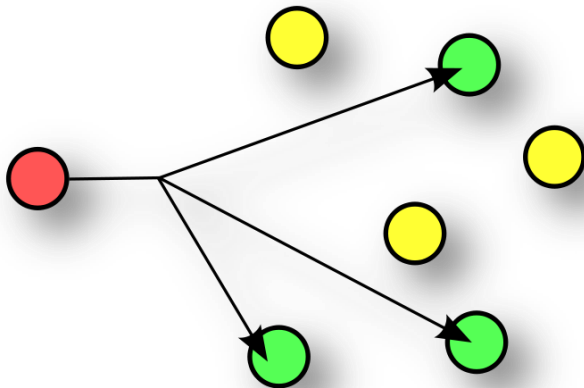

- **Loopback address**

  - 0:0:0:0:0:0:0:0:1 or **::1**          ( 127.0.0.1 in IPv4)
  - used to identify a loopback interface, enabling a node to send packets to itself
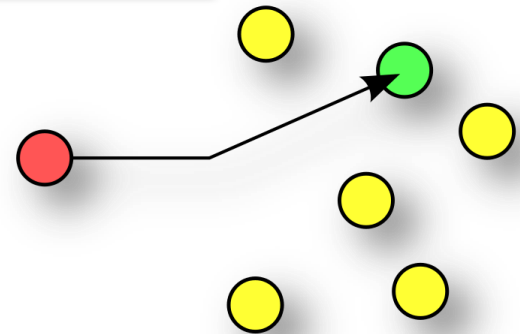
# IPv4-mapped IPv6 addresses

- IPv4-mapped address

    - 0:0:0:0:0:ffff:*w.x.y.z*          or                    ::**ffff:*w.x.y.z***

    - used to represent the addresses of IPv4 nodes as IPv6 addresses
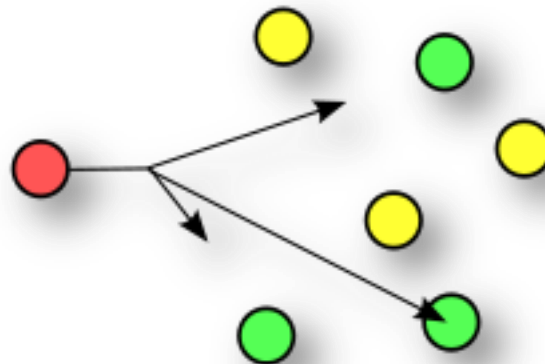    - Used in Hybrid dual-stack IPv6/IPv4 implementations
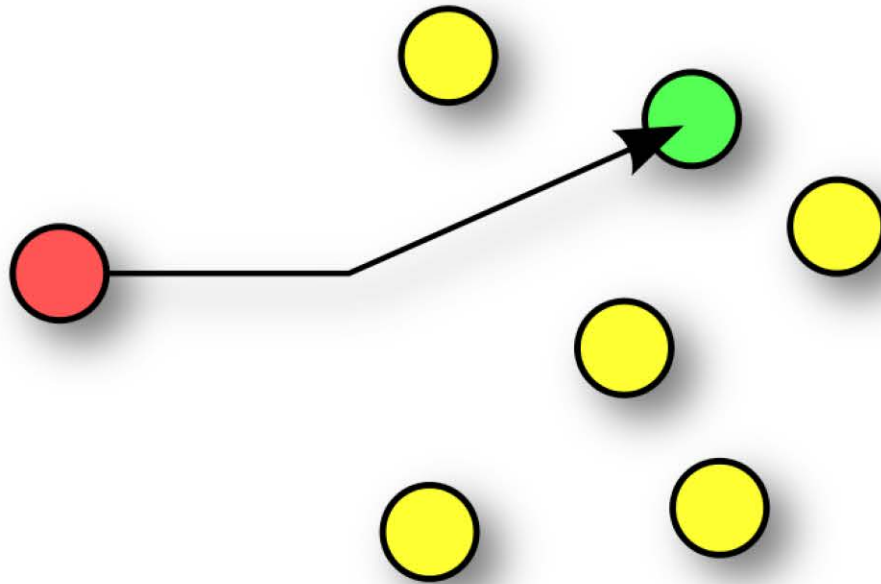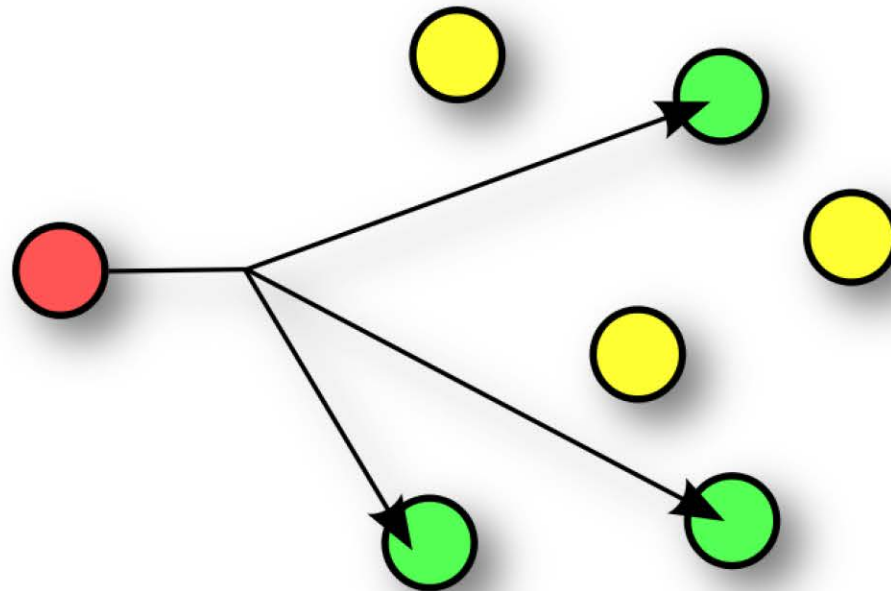
# IPv6 ADDRESS TYPES

MULTICAST
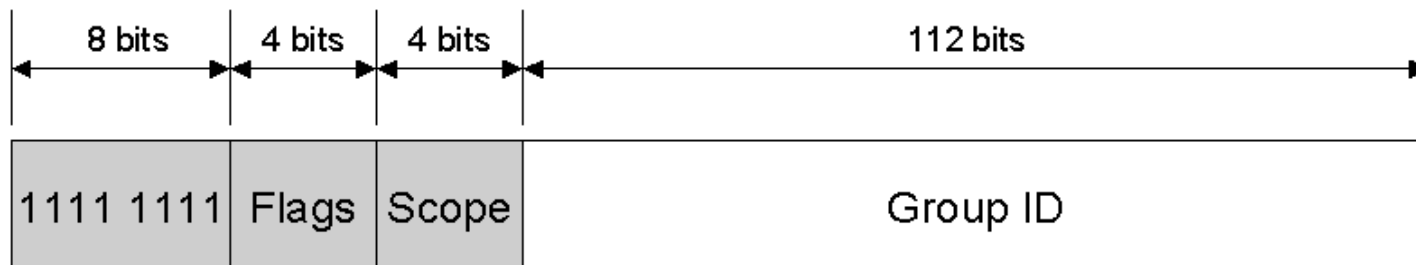
UNICAST

ANYCAST

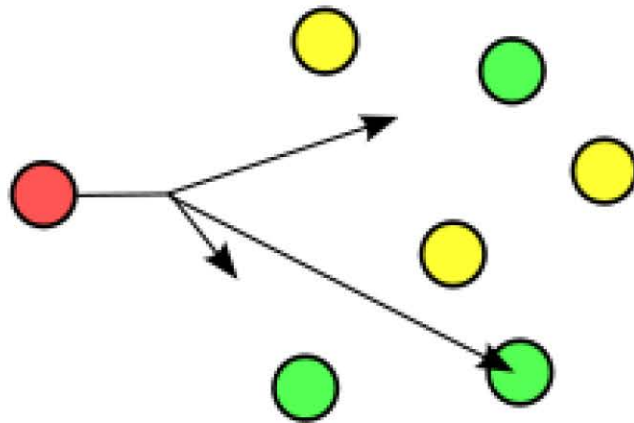# UNICAST IPv6 ADDRESS

# Multicast IPv6 ADDRESS

# MULTICAST ADDRESS

- One to many communication

- IPv6 nodes can listen to multiple multicast addresses at the same time

- **No Broadcast Address in IPv6**

IPv6 Multicast address  **Format Prefix**          **FF00::/8**

| 8 bits | 4 bits | 4 bits | 112 bits |
|--------|--------|--------|----------|
| 1111 1111 | Flags | Scope | Group ID |

# Anycast  IPv6 Addresses

- One-to-nearest

- Anycast addresses allow packet to be **routed to one of a number** of different nodes all responding to the same address

- are allocated from the unicast address space

- It cannot be distinguished from a Unicast address

- **Used only as Destination Address and may be assigned to an IPv6 router only**

# Anycast IPv6 Address Uses

- Multiple Router on a remote subnet
- Multi Homing
- Multiple DNS server on a subnet
- Content delivery Networks
- IPv4 to IPv6 transition
  - 6 to4 networks
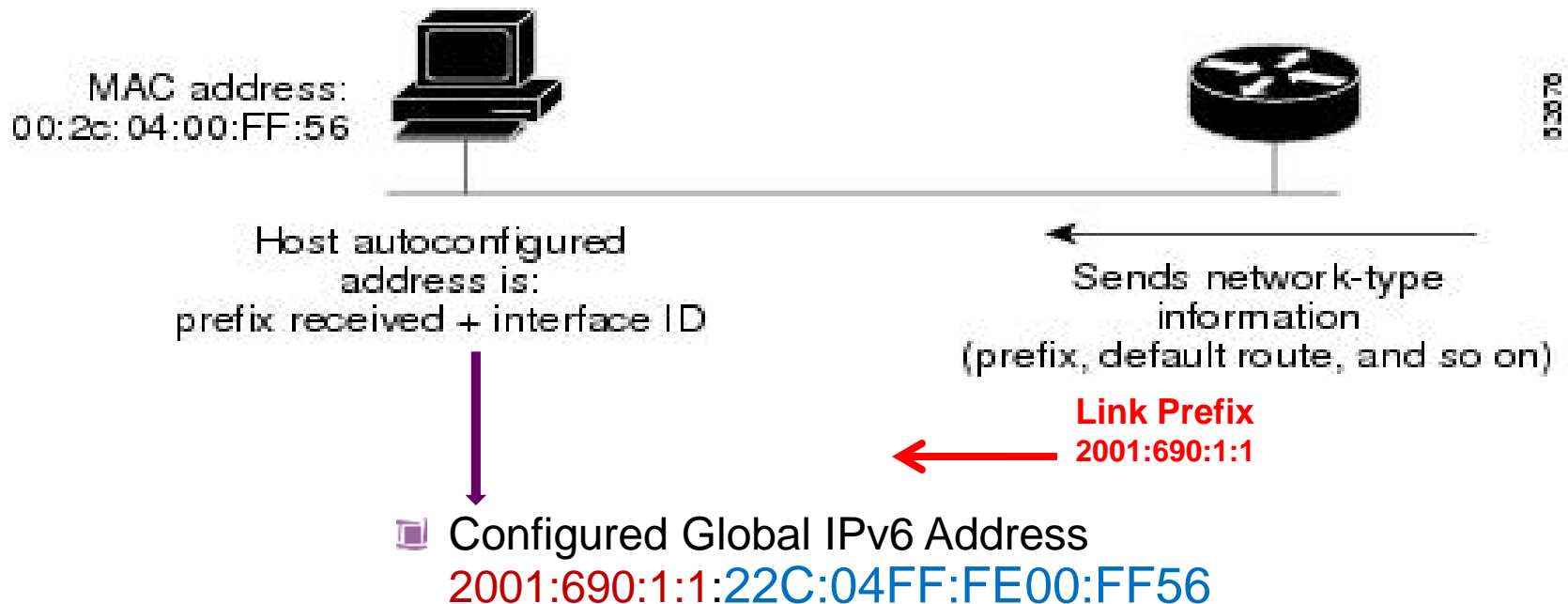
# IPv6 Address Auto-configuration
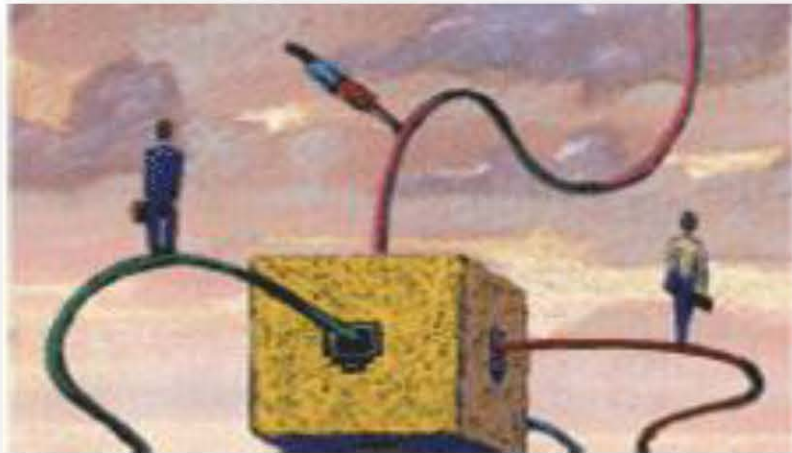
# Address Auto Configuration

- Unique feature of IPv6 enabling automatic configuration of various types of IPv6 address by the IPv6 host

- By default IPv6 host can configure Link local address
  - FE80::EUI-64 Interface ID

- Site local and Global IPv6 address can also be configured automatically without the help of DHCP server

# Stateless Autoconfiguration Example

- MAC address  : 00:2C:04:00:FF:56

- EUI 64 Address: 0**2**2C:04FF:FE00:FF56

- Auto configured Link Local Address : FE80::22C:04FF:FE00:FF56

MAC address:
00:2c:04:00:FF:56

Host autoconfigured
address is:
prefix received + interface ID

Sends network-type
information
(prefix, default route, and so on)

**Link Prefix**
**2001:690:1:1**

- Configured Global IPv6 Address
2001:690:1:1:22C:04FF:FE00:FF56

# Why does this matter?

- Manual configuration of individual machines before connecting them to the network may not be required.
  - Only the Router & Server require Manual configuration

- Provide **Plug-and-play** communication

- A large site with multiple networks and routers should not require the presence of a statefull address configuration server.

- Enables small sensors to work in IPv6 network

- It may be one of the **killer feature** of IPv6

# Hence, to Summarise

- IPv6 address is 128 bit long written in eight block of hexadecimal field

- Almost Infinite numbers of IPv6 addresses

- IPv6 address has two parts – Routing prefix and Interface Identifier

- Unicast, Multicast, Anycast IPv6 Addresses with specific format prefix

- Nodes can auto configure IPv6 addresses