Internet Protocol Version 6 (IPv6)

IPv4

Internet Protocol Version 6 (IPv6)

IPv6

Internet Protocol Version 6 (IPv6)

IETF

iana

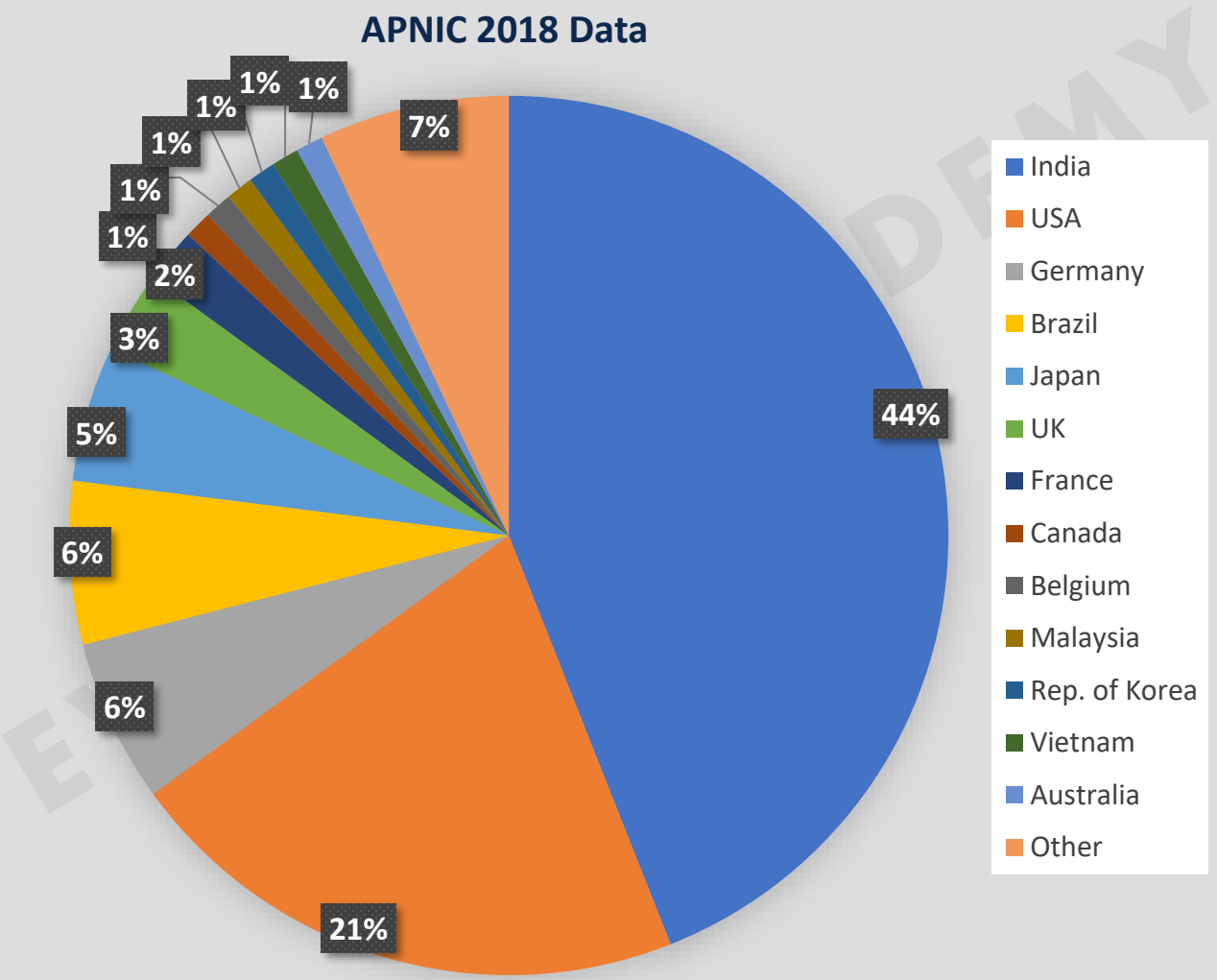
Reginal Internet Registry (RIP)	
AFRINIC	Africa Region
APNIC	Asia/Pacific Region
ARIN	Canada, USA, and some Caribbean Islands
LACNIC	Latin America and some Caribbean Islands
RIPE NCC	Europe, the Middle East, and Central Asia

Internet Protocol Version 6 (IPv6)

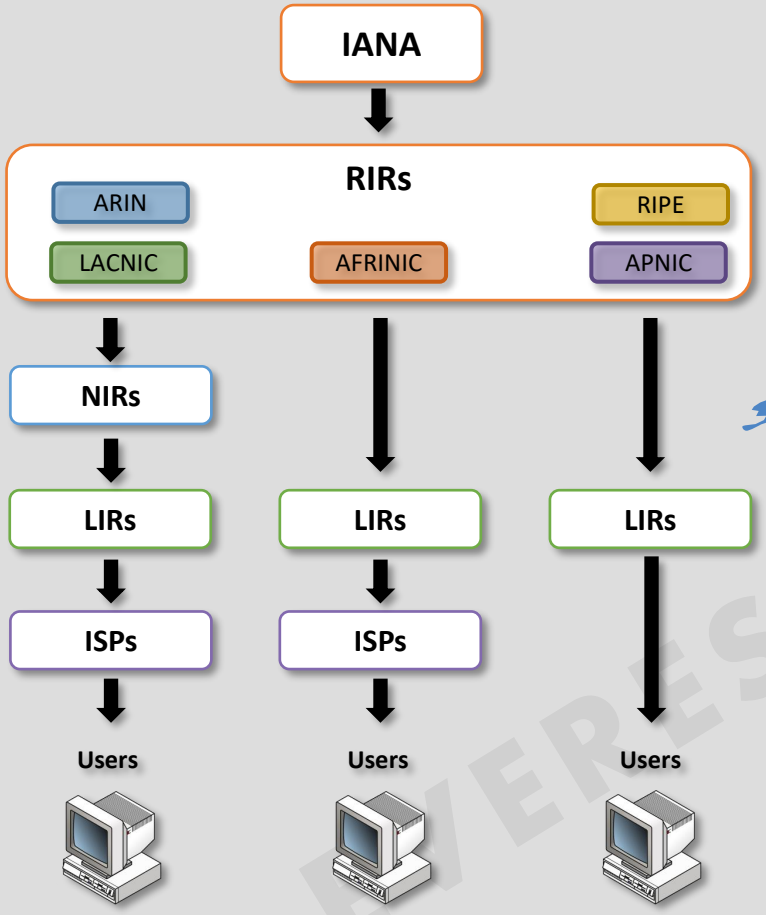
2017 — On **14 July 2017**, IPv6 became an Internet Standard for the **IETF**.

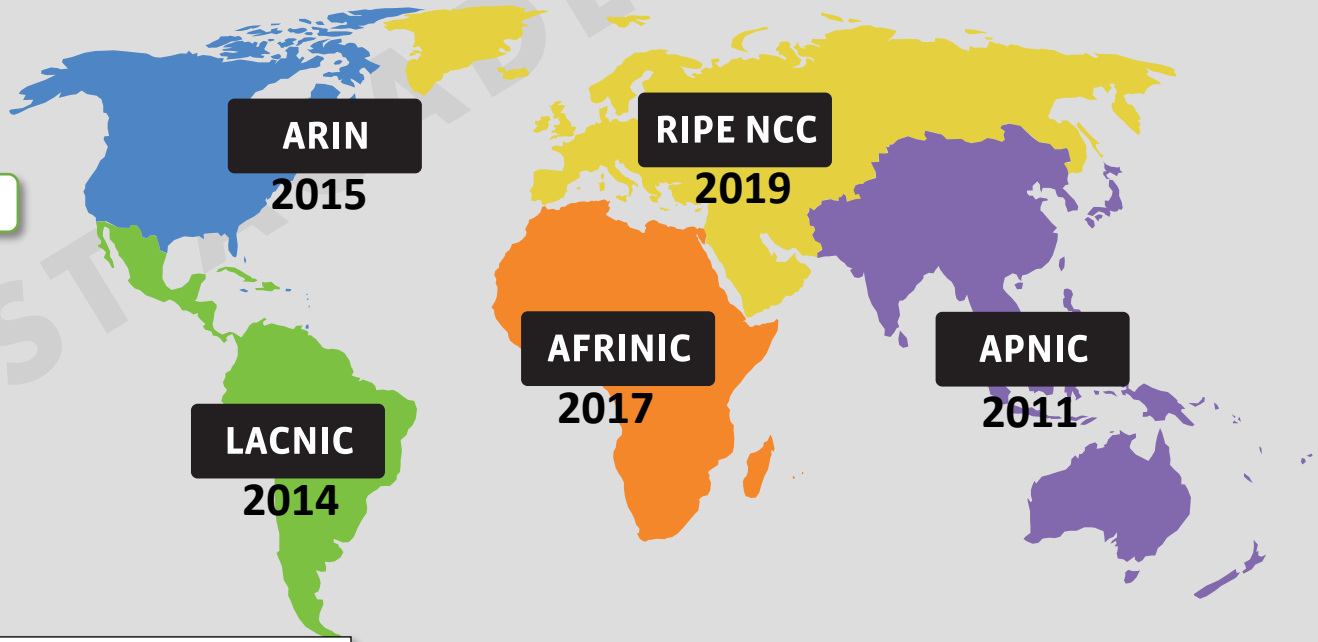
1998 — In **December 1998**, IPv6 became a Draft Standard for the **IETF**.

Internet Protocol Version 6 (IPv6)



Why Do We Need IPv6 ?





- ❖ RIR (Regional Internet Registry)
- ❖ LIR (Local Internet Registry)
- ❖ NIR (National Internet Registry)
- ❖ ISP (Internet Service Provider)

IPv4 Address Exhaustion

1

- **Mobile devices:**
  IPv4 increasingly became the *de facto* standard for networked digital communication, mobile phones have become viable Internet hosts.

2

- **Always-on connections:**
  Broadband connections are always active, as the gateway devices (routers, broadband modems) are rarely turned off.

3

- **More Internet Users:**
  The many new Internet users in countries such as China and India has joined the Internet.

4

- **Inefficient Address Use:**
  Organizations that obtained IP addresses in the 1980s were often allocated far more addresses than they actually required.

Efforts To Delay Address Space Exhaustion

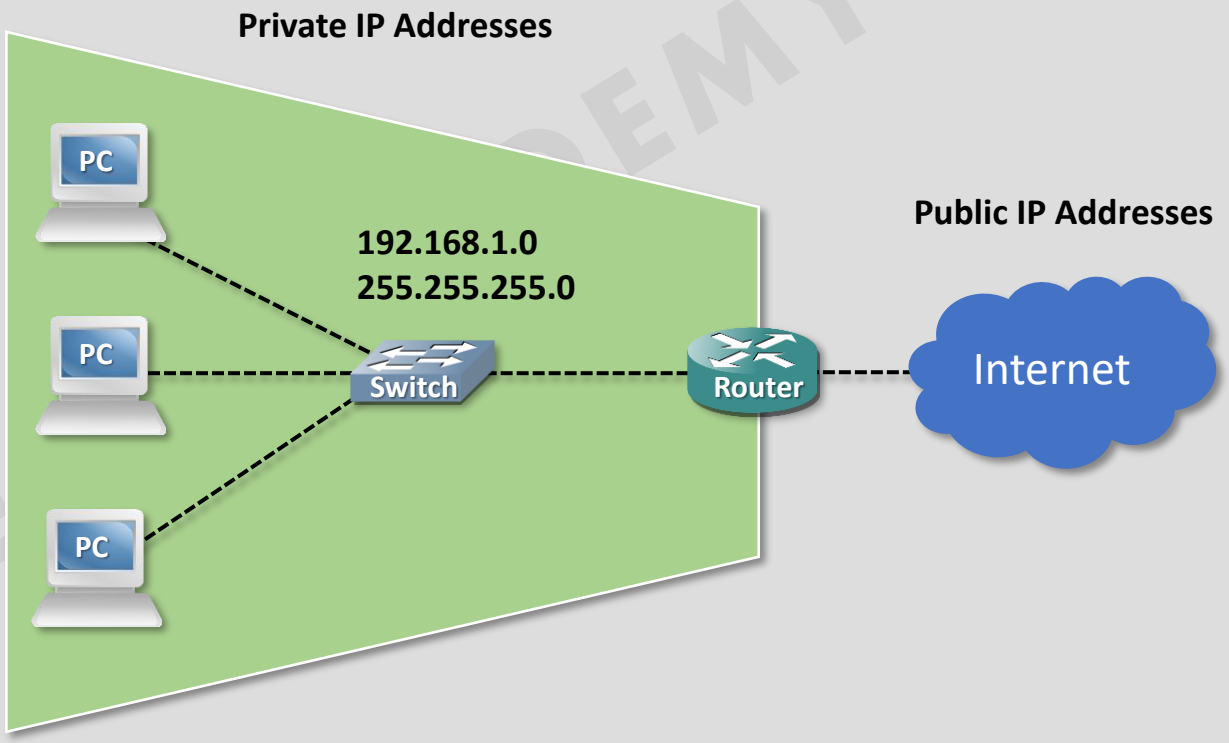
01 Private Addresses

Private IP Addresses Space		
Class	From	To
A	**10.0.0.0**	**10.255.255.255**
B	**172.16.0.0**	**172.31.255.255**
C	**192.168.0.0**	**192.168.255.255**

Efforts To Delay Address Space Exhaustion

01 Private Addresses

02 NAT and PAT

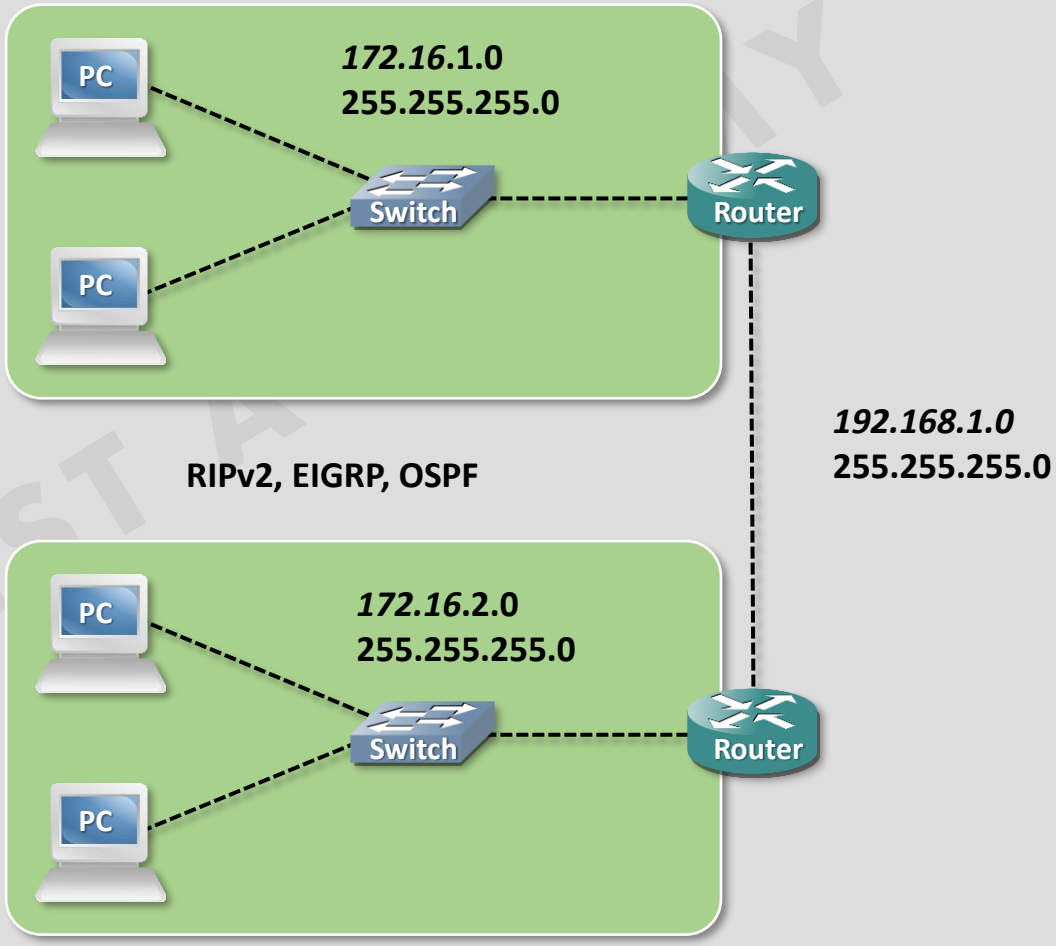


Efforts To Delay Address Space Exhaustion

01 Private Addresses

02 NAT and PAT

03 Classless Routing



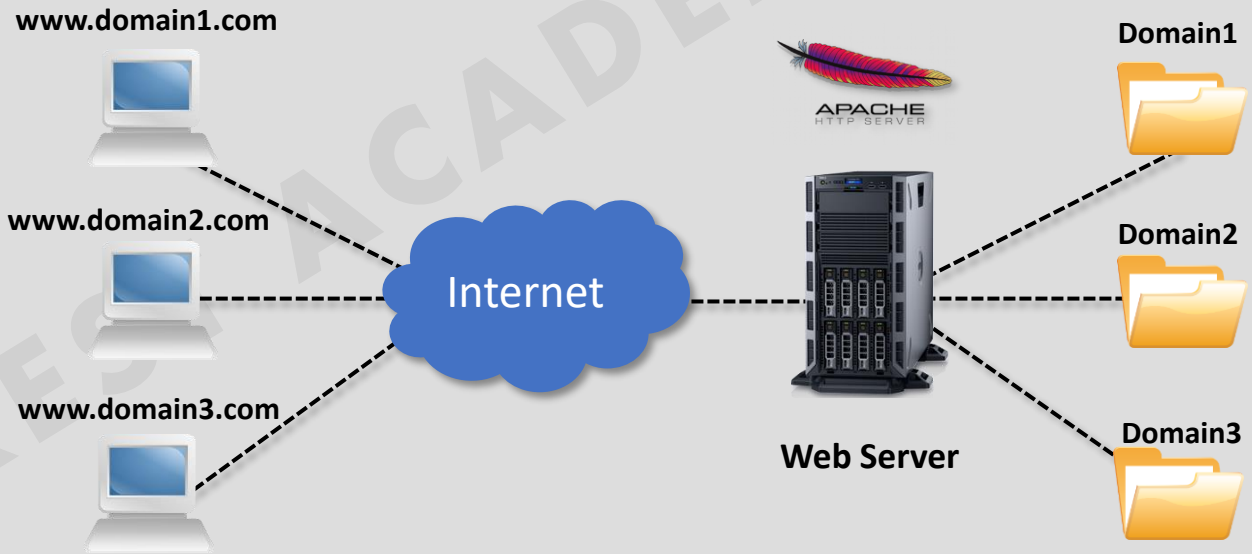
Efforts To Delay Address Space Exhaustion

01 Private Addresses

02 NAT and PAT

03 Classless Routing

04 Virtual Hosting



IPv6 Features

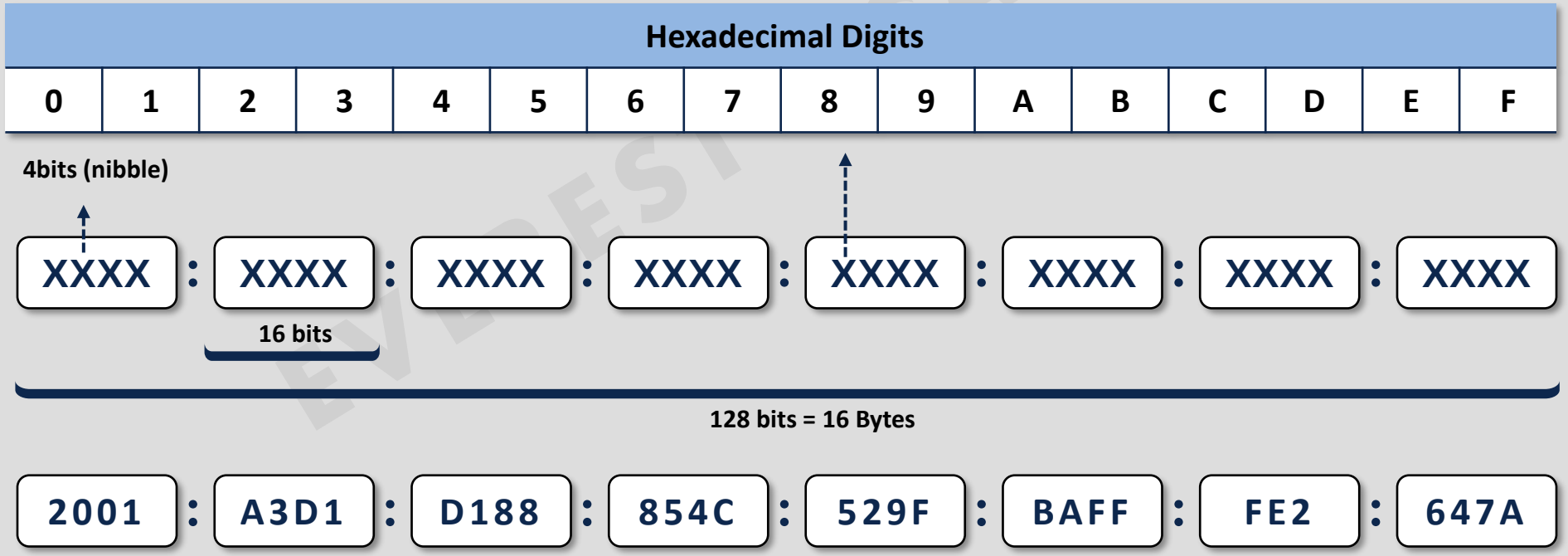
01 Large Address Space	▪ 2^{128}, or approximately 3.4×10^{38} addresses.
02 Simplified Header	▪ 8 Fields , 40 Bytes.
03 Auto Configuration	▪ Support stateless and stateful auto configuration.
04 More Efficient Routing	▪ The packet header in IPv6 is simpler than the IPv4 header. ▪ IPv6 header does not include a checksum field. ▪ IPv6 routers do not perform IP fragmentation.
05 Extension Headers	▪ Options are implemented as extensions.
06 Built-in Security	▪ The IPsec Authentication Header (AH) and the Encapsulating Security Payload header (ESP) are implemented as IPv6 extension headers
07 Multicasting	▪ Broadcasts are replaced by multicasts and anycasts.
08 Mobility	▪ A host can move between different links without changing its IP address.

IPv6 Address

❖ **An Internet Protocol Version 6 Address (IPv6 Address)** is a **numerical label** that is used to identify a network interface of a computer or a device in an IPv6 computer network.

❖ **An IPv6 Address is represented as eight groups of four hexadecimal digits separated by colons (:)**

2001:A3D1:D188:854C:529F:BAFF:FE23:647A



Shortening IPv6 Addresses

1

- Leading zeros can be removed.

2

- A hextet with 4 zeros can be replaced with only a single zero.

3

- Consecutive sections of zeros are replaced with double colon (::).
- This may only be used once in an address.

- The longest string of all-0s .

- If the strings are of equal length, the first string should use the double colon (::) notation.

Shortening IPv6 Addresses

1

- Leading zeros can be removed.

0F58 : 0052 : 000F : FA80 : 8200 : F000 : 600A : D0E0

0F58 : 0052 : 000F : FA80 : 8200 : F000 : 600A : D0E0

F58 : 52 : F : FA80 : 8200 : F000 : 600A : D0E0

000A : 0042 : 000F : 0A00 : 8000 : 0009 : 000A : 00E0

000A : 0042 : 000F : 0A00 : 8000 : 0009 : 000A : 00E0

A : 42 : F : A00 : 8000 : 9 : A : E0

Shortening IPv6 Addresses

2

- A hextet with 4 zeros can be replaced with only a single zero.

0000 : 6AAB : 0000 : 687D : 0000 : AA1D : 0000 : 63D5

0 : 6AAB : 0 : 687D : 0 : AA1D : 0 : 63D5

Shortening IPv6 Addresses

3

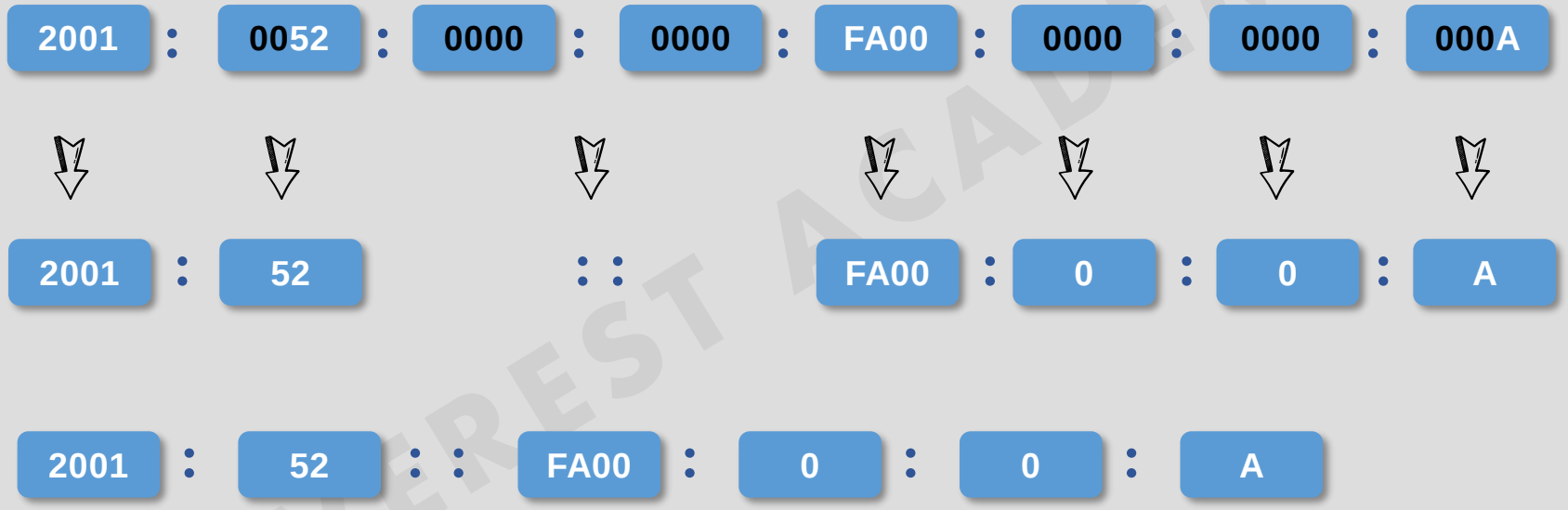
- Consecutive sections of zeros are replaced with two colons (::).
- This may only be used once in an address.

- The longest string of all-0s .
- If the strings are of equal length, the first string should use the double colon (::) notation.

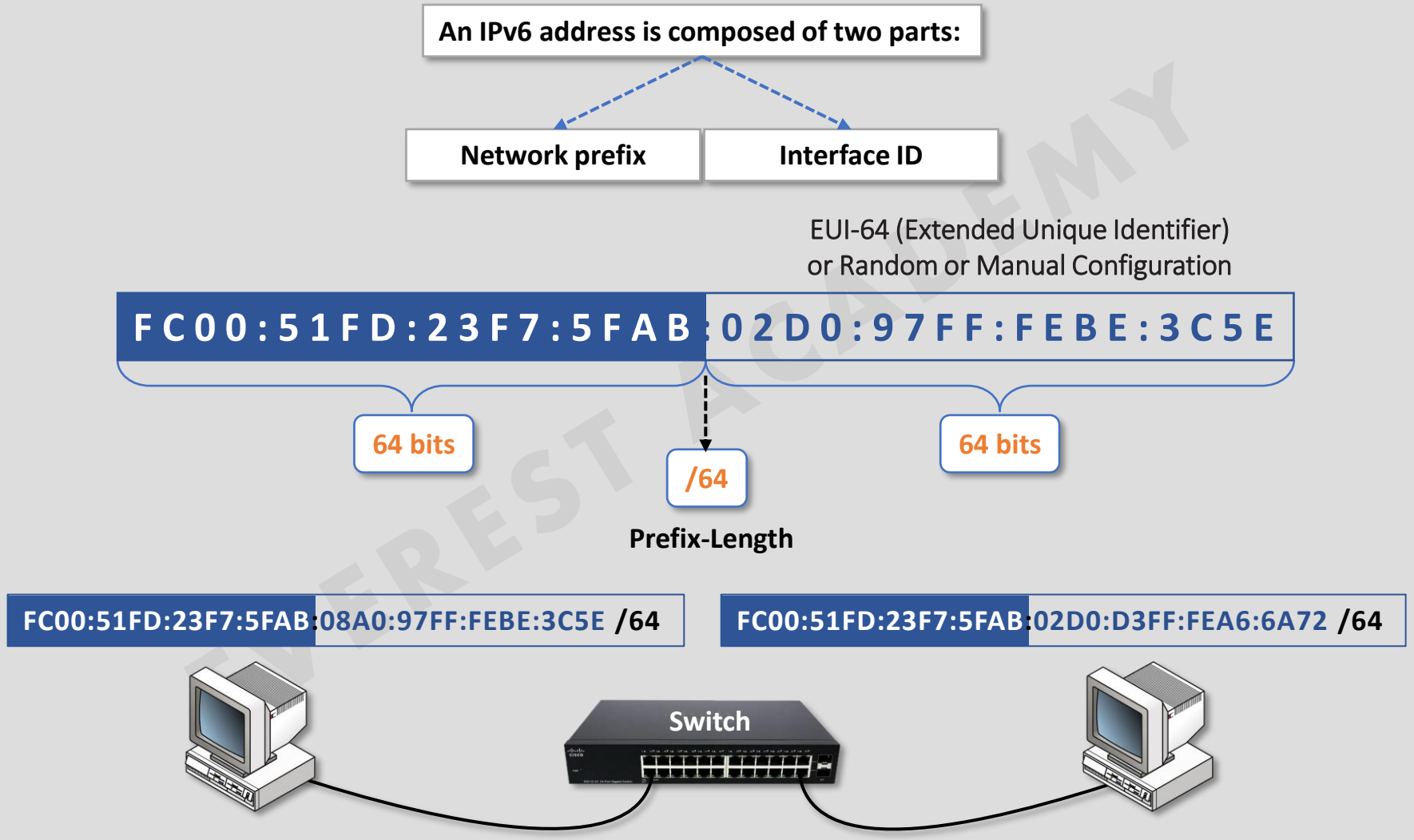
1DE2	0000	0000	0000	82DF	0000	0000	0000

1DE2	0	0	0	82DF	0	0	0
1DE2	0	0	0	82DF	0	0	0

Example of Shortening an IPv6 Address



IPv6 Address Structure

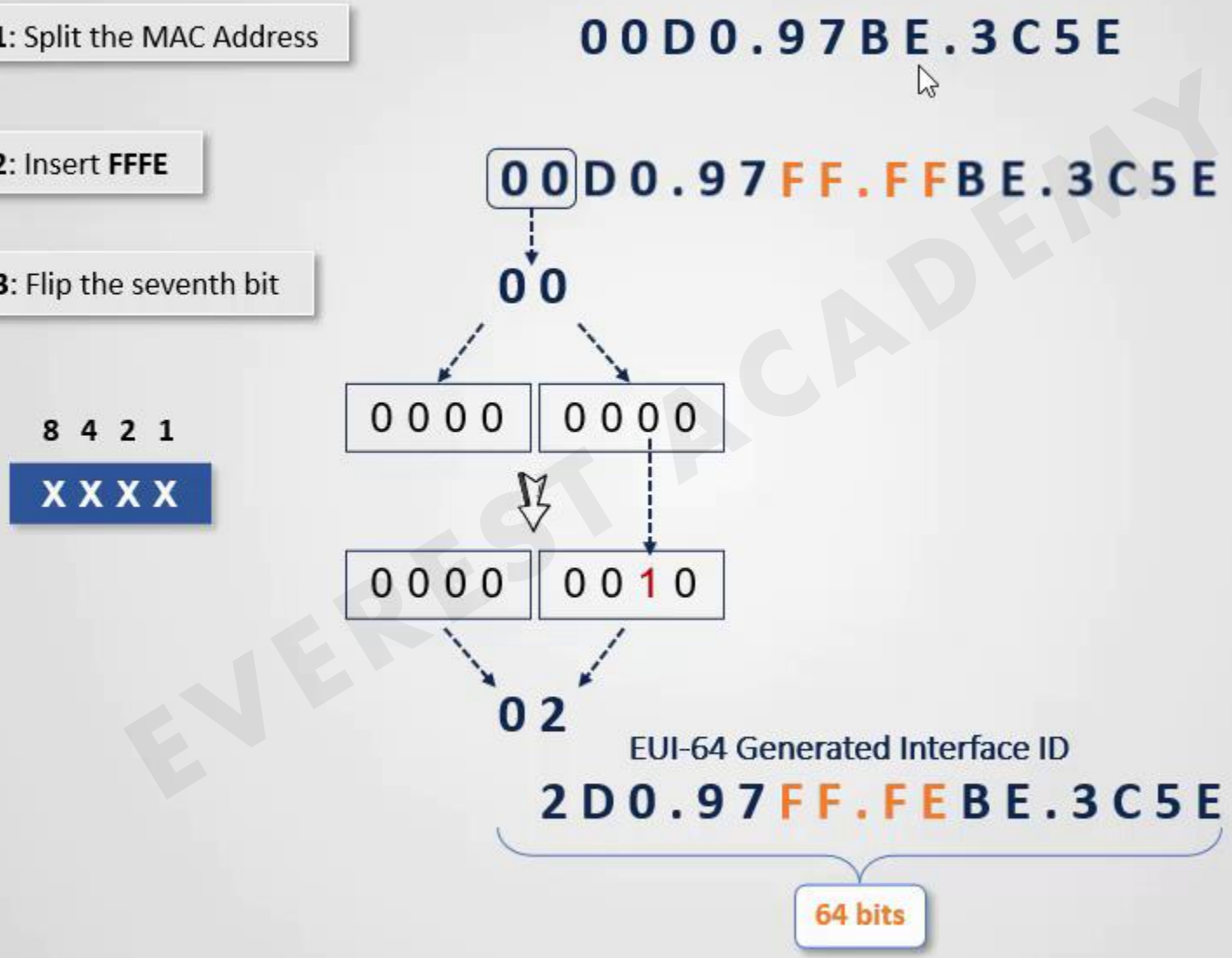


EUI-64 Generated Interface ID

Step 1: Split the MAC Address

Step 2: Insert **FFFE**

Step 3: Flip the seventh bit



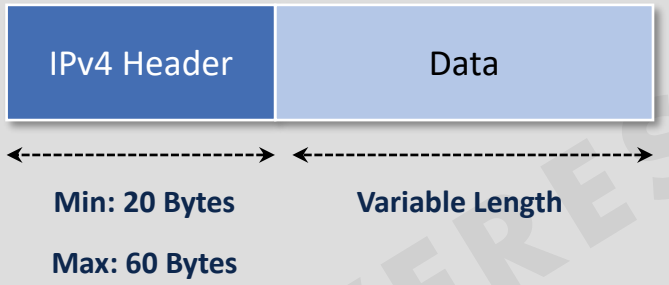
IPv4 and IPv6 Comparison

IPv4 (Deployed 1989)		IPv6 (Deployed 1999)
32 bits	Address Size	128 bits
Dotted Decimal Notation 192.168.1.0	Address Format	Hexadecimal Notation FC00:51FD:23F7:5FAB:02D0:97FF:FEBE:3C5E
192.168.1.0/24	Prefix Notation	FC00:51FD:23F7:5FAB::/64
2^{32}= 4,294,967,296	Number of Addresses	2^{128} = 340,282,366,920,938,463,463,374,607,431,768,211,456

IPv4 and IPv6 Headers Comparison

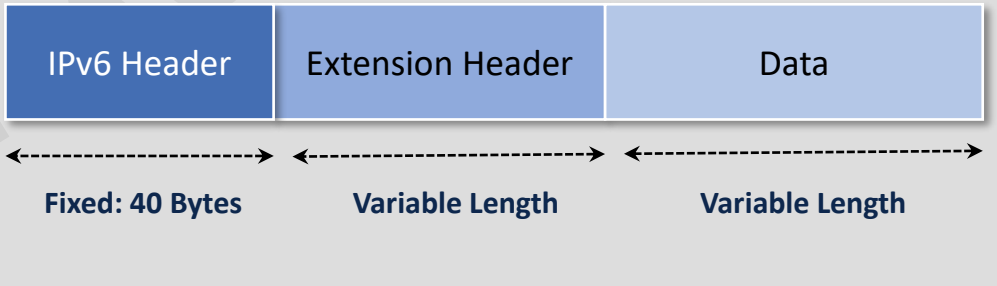
IPv4

Packet

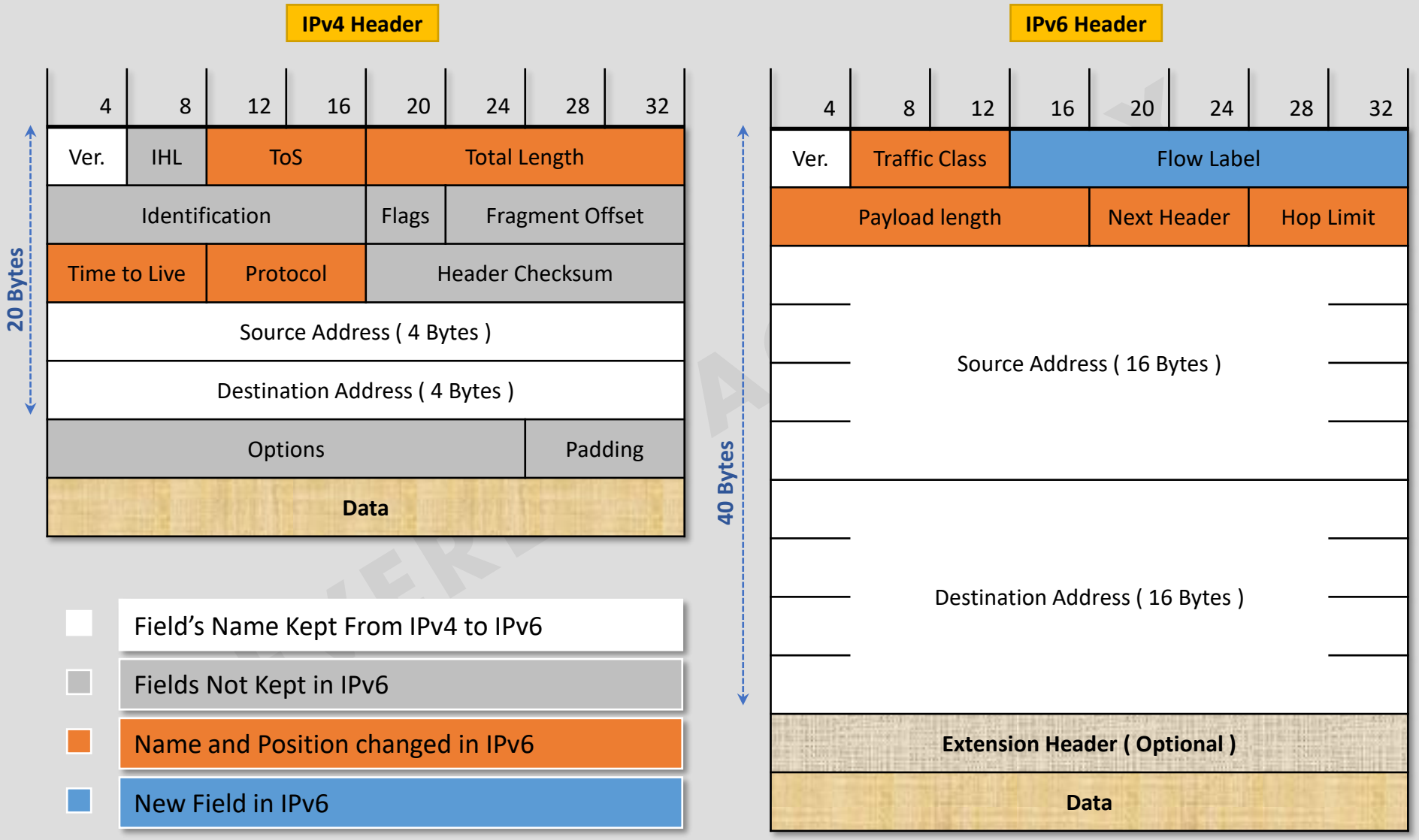


IPv6

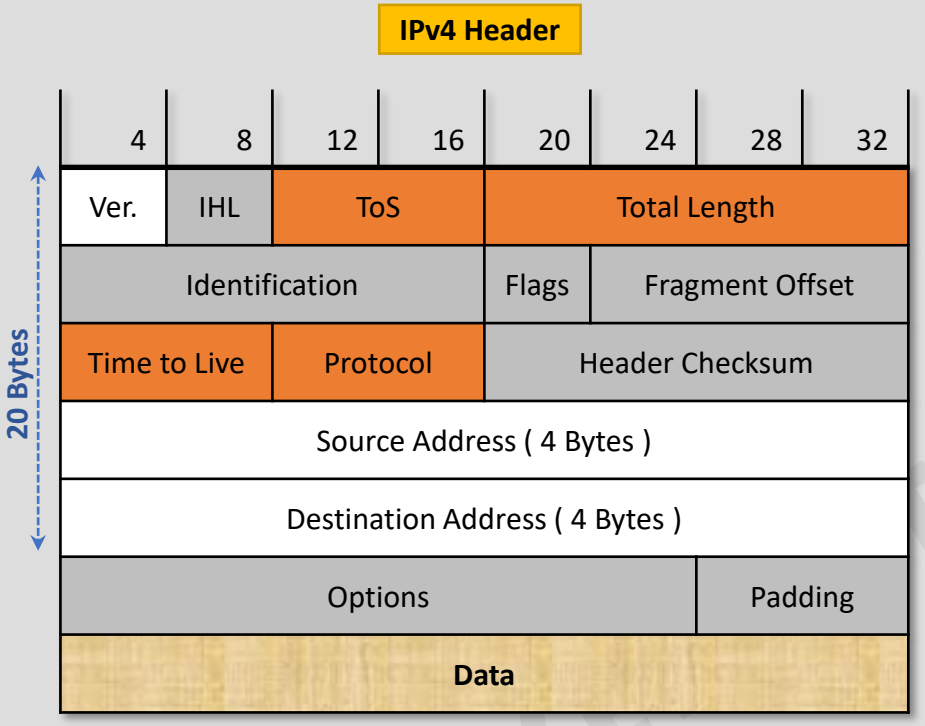
Packet



IPv4 and IPv6 Headers Comparison



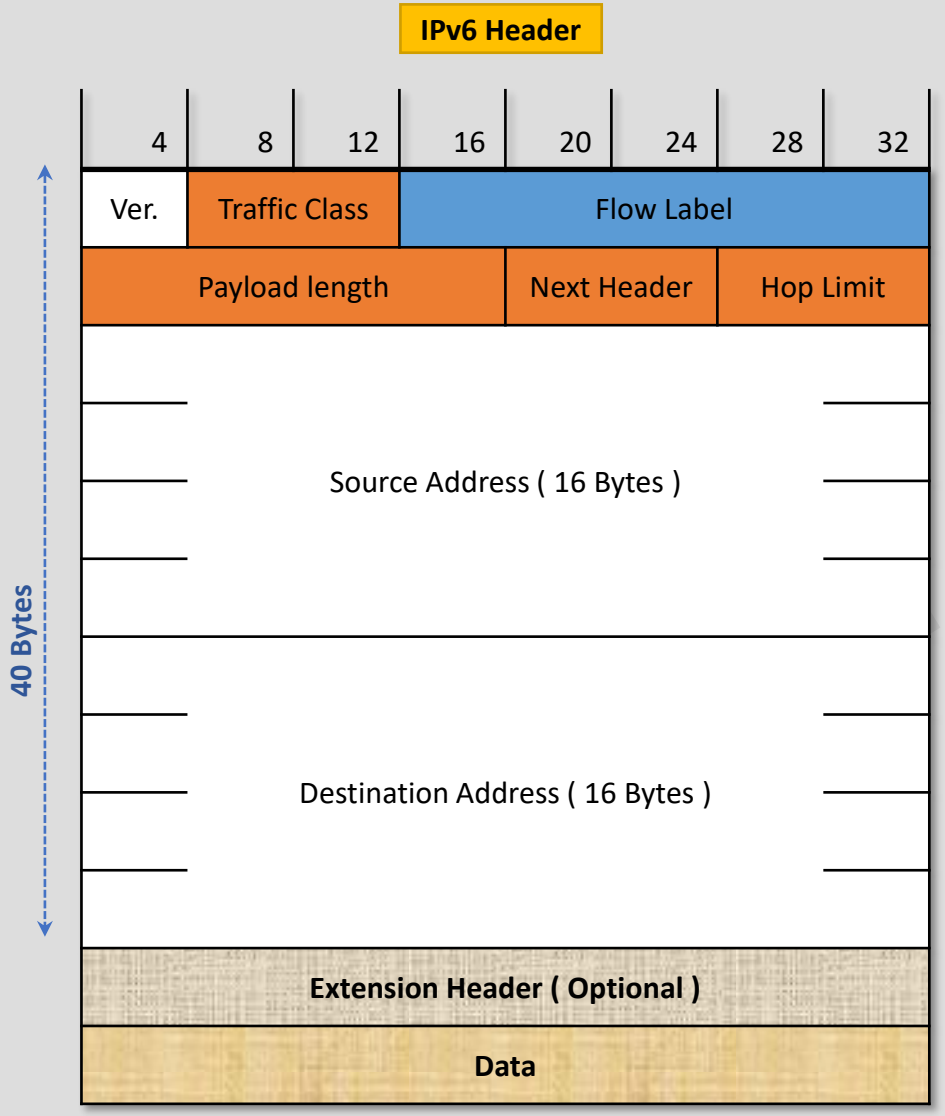
IPv4 and IPv6 Headers Comparison



❖ **ping -l 1000 -n 1 8.8.8.8**

```
Internet Protocol Version 4, Src: 192.168.1.4, Dst: 8.8.8.8
    0100 .... = Version: 4
    .... 0101 = Header Length: 20 bytes (5)
  > Differentiated Services Field: 0x00 (DSCP: CS0, ECN: Not-ECT)
    Total Length: 1028
    Identification: 0xbaa9 (47785)
  > Flags: 0x00
    Fragment Offset: 0
    Time to Live: 128
    Protocol: ICMP (1)
    Header Checksum: 0x0000 [validation disabled]
    [Header checksum status: Unverified]
    Source Address: 192.168.1.4
    Destination Address: 8.8.8.8
> Internet Control Message Protocol
```

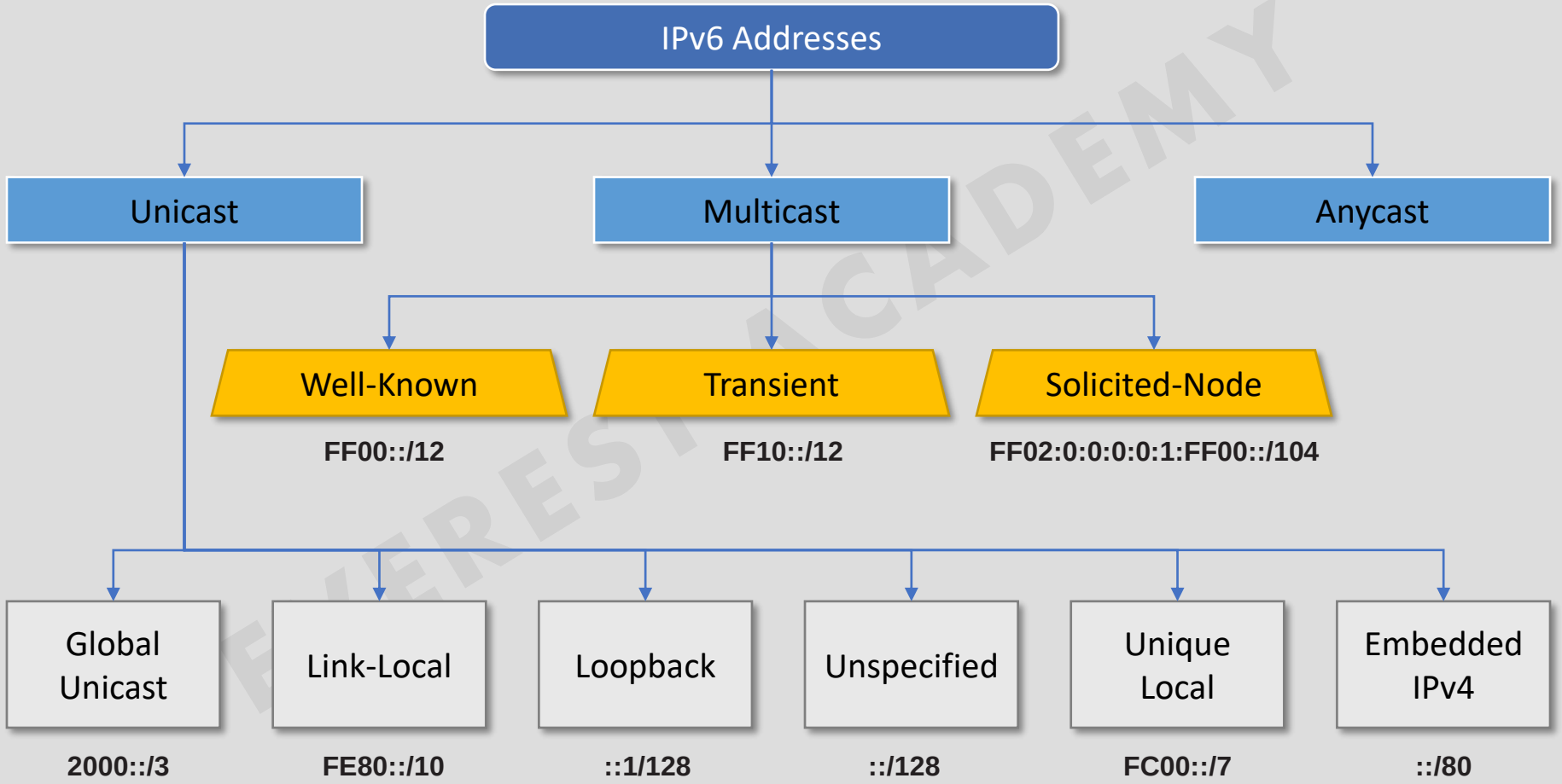
IPv4 and IPv6 Headers Comparison



❖ **ping -l 1000 -n 1 ff80::1**

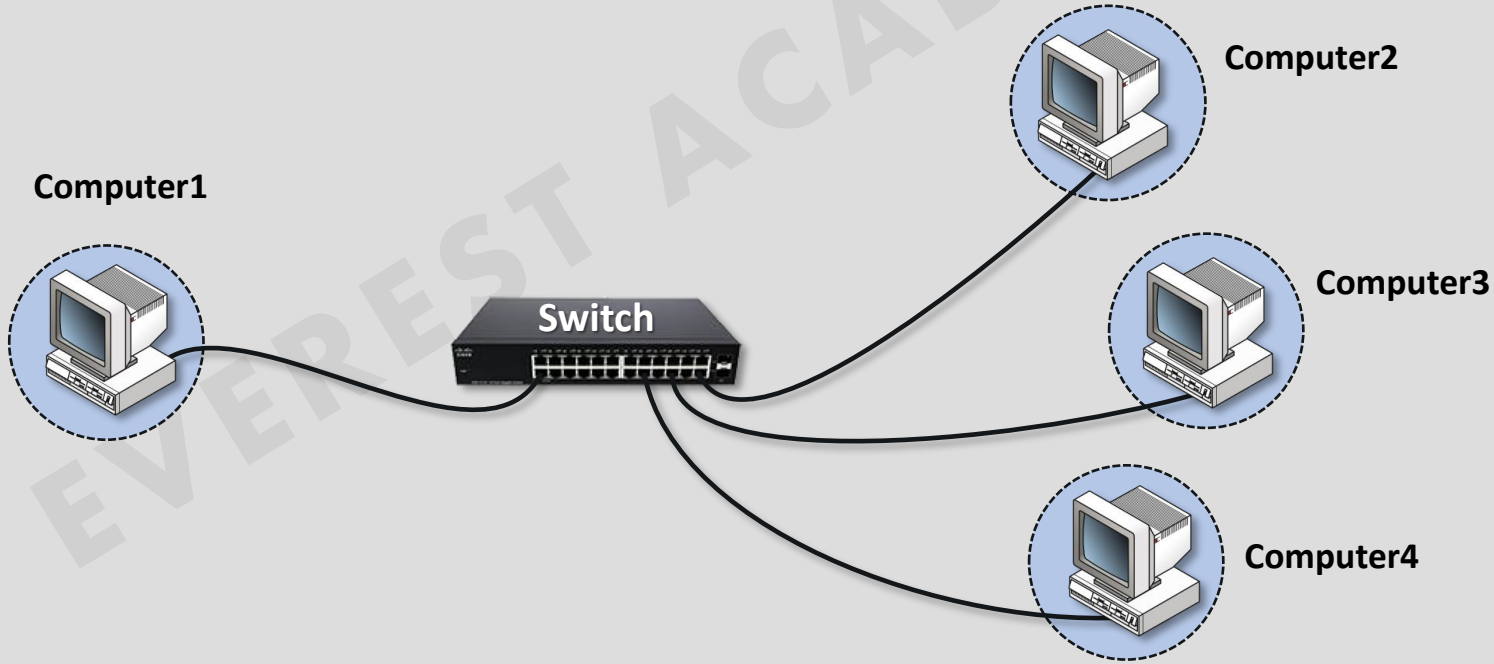
```
Internet Protocol Version 6, Src: fe80::3a60:77ff:febd:2d31, Dst:
    0110 .... = Version: 6
  > .... 0000 0000 .... .... .... .... .... = Traffic Class: 0x00
    .... .... .... 0000 0000 0000 0000 0000 = Flow Label: 0x00000
    Payload Length: 1008
    Next Header: ICMPv6 (58)
    Hop Limit: 128
    Source Address: fe80::3a60:77ff:febd:2d31
    Destination Address: ff80::1
    [Source SA MAC: Pegatron_bd:2d:31 (38:60:77:bd:2d:31)]
> Internet Control Message Protocol v6
```

IPv6 Address Types



Unicast Addresses

- **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. Similar to IPv4, a source IPv6 addresses must be a unicast address.



Unicast Addresses

01	Global unicast: **2000::/3**	A routable address in the IPv6 Internet, similar to a public IPv4 address.
02	Link-local: **FE80::/10**	Used only to communicate with devices on the same local link.
03	Loopback: **::1/128**	An address not assigned to any physical interface that can be used for a host to send an IPv6 packet to itself.
04	Unspecified address: **::/128**	Used only as a source address and indicates the absence of an IPv6 address.
05	Unique local: **FC00::/7**	Similar to a private address in IPv4 and not intended to be routable in the IPv6 Internet.
06	IPv4 embedded: **::/80**	An IPv6 address that carries an IPv4 address in the low-order 32 bits of the address.

Unicast Addresses

01 Global Unicast Addresses (GUAs)

❖ **Global unicast addresses (GUAs),** also known as aggregatable global unicast addresses, are globally routable and reachable in the IPv6 Internet.

⟷ **Public IPv4 Addresses**

Generic Structure of a GUA

- **Global Routing Prefix**: The Global Routing Prefix is the prefix or network portion of the address assigned by the provider, such as an ISP, to the customer site.
- **Subnet ID:** The Subnet ID is a separate field for allocating subnets within the customer site.
- **Interface ID:** The Interface ID identifies the interface on the subnet, equivalent to the host portion of an IPv4 address. The Interface ID in most cases is 64 bits.

<---------- 128 bits ---------->

<---------- n bits ----------> <--- m bits ---> <---------- 128 - n - m bits ---------->

0 0 1	Global Routing Prefix	Subnet ID	Interface ID

2000::/3

Unicast Addresses

01 | Global Unicast Addresses (GUAs)

Configuration

- Manually configured.
- Stateless Address Autoconfiguration.
- Stateful DHCPv6.

Unicast Addresses

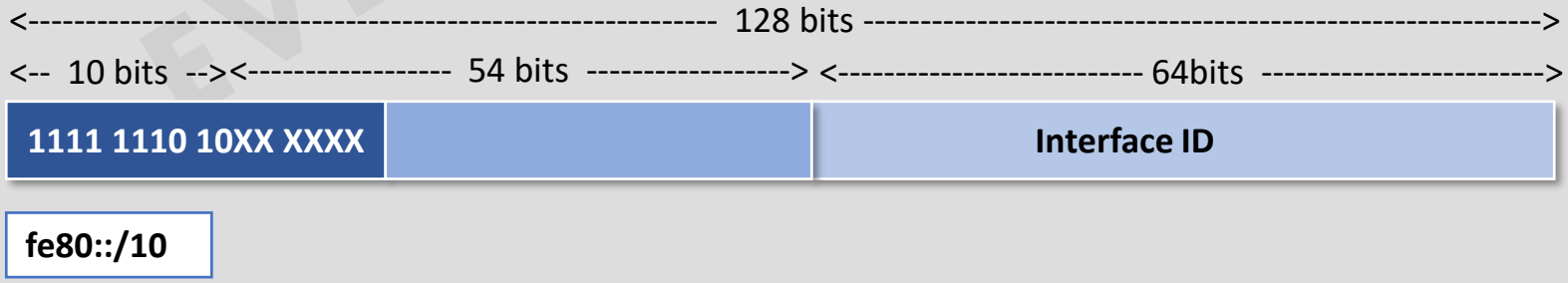
02 Link-Local Unicast Address

- **A link-local address is a** unicast address that is confined to a single link, a single subnet.

⟷ **169.254.0.0/16**

Configuration

- **Manually configured**
- **Automatically**



1111 1110 10XX XXXX		Interface ID

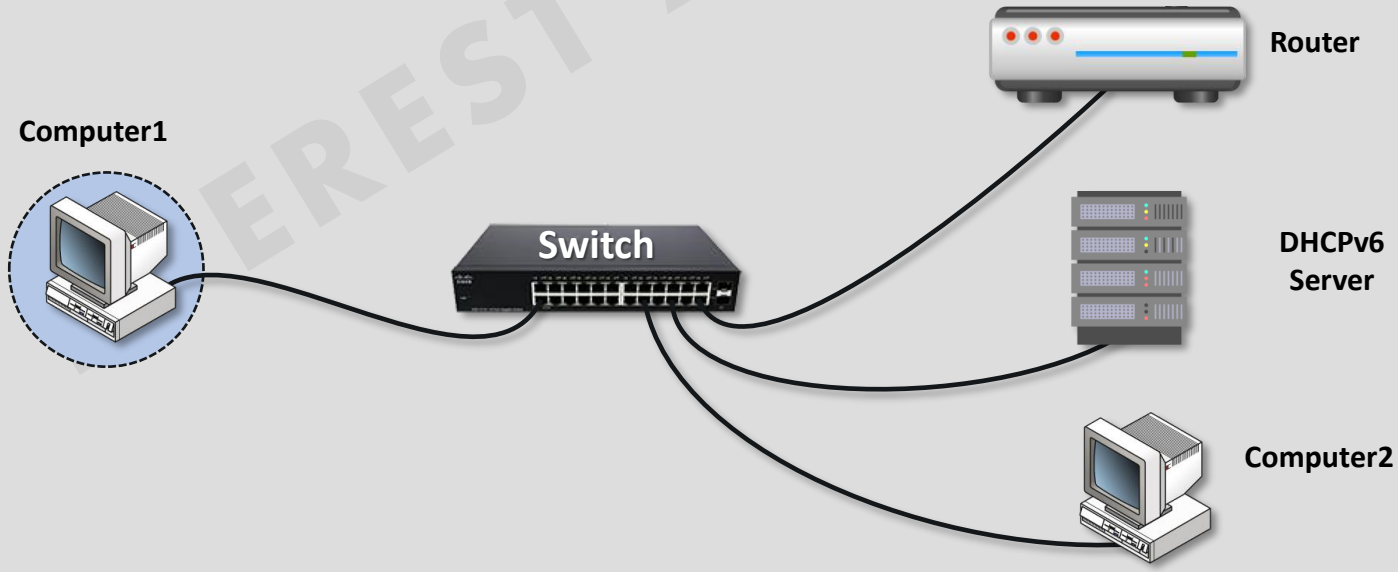
fe80::/10

Unicast Addresses

02 Link-Local Unicast Address

- **Devices dynamically (automatically)** create their own link-local IPv6 address upon startup. This is the default on most operating systems, including Cisco IOS, Windows, Mac OS, and Linux.

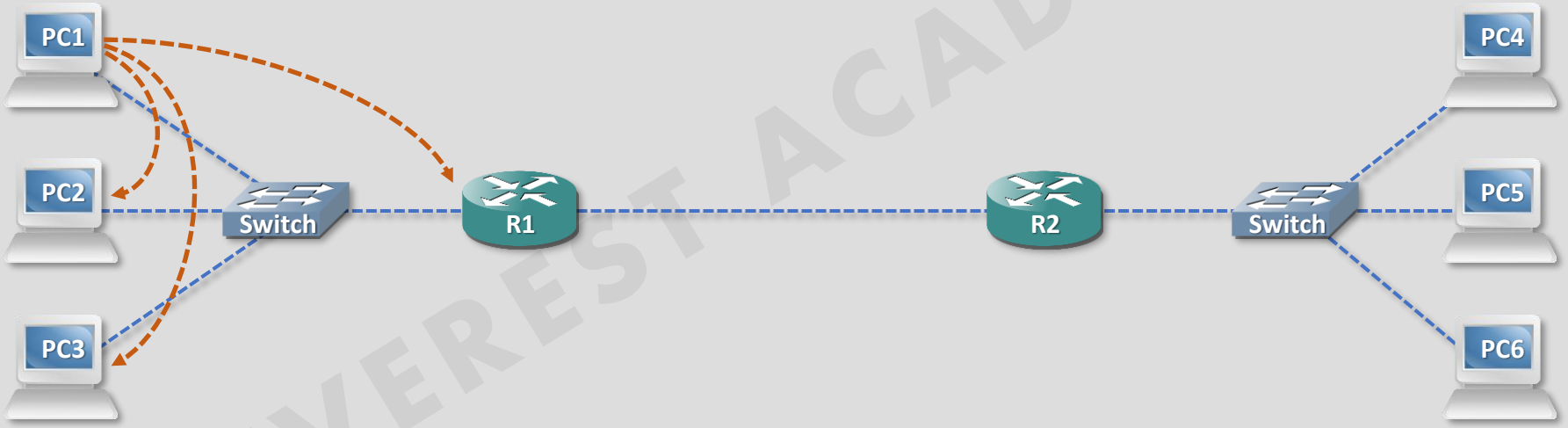
- **Devices** can use its link-local address to communicate with a device where it can obtain information for getting or creating a global unicast address, such as an IPv6 router or a DHCPv6 server. The device can then use this information to communicate with devices on other networks.



Unicast Addresses

02 Link-Local Unicast Address

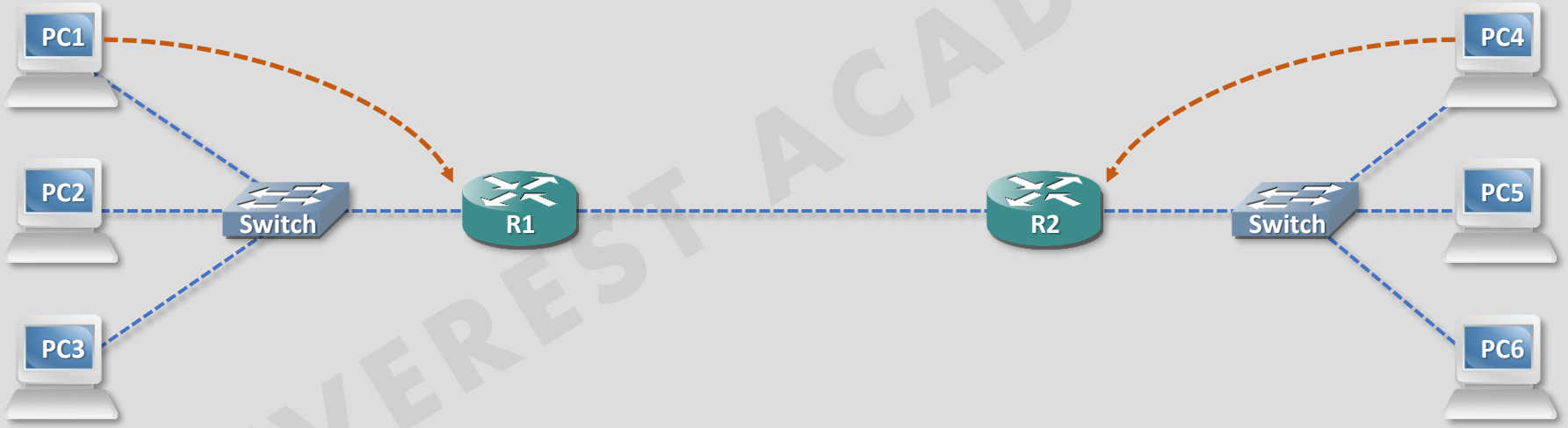
- When a device starts up, before it obtains a GUA address, the device uses its IPv6 link-local address as its source address to communicate with other devices on the network, including the local router.



Unicast Addresses

02 Link-Local Unicast Address

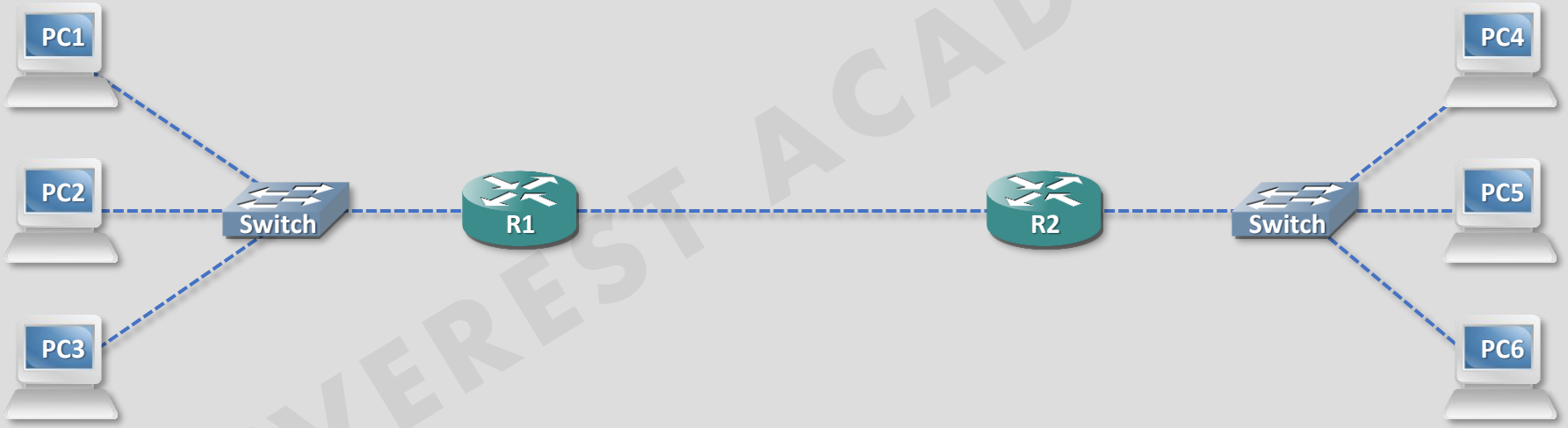
- Devices use the router's link-local address as their default gateway address.



Unicast Addresses

02 Link-Local Unicast Address

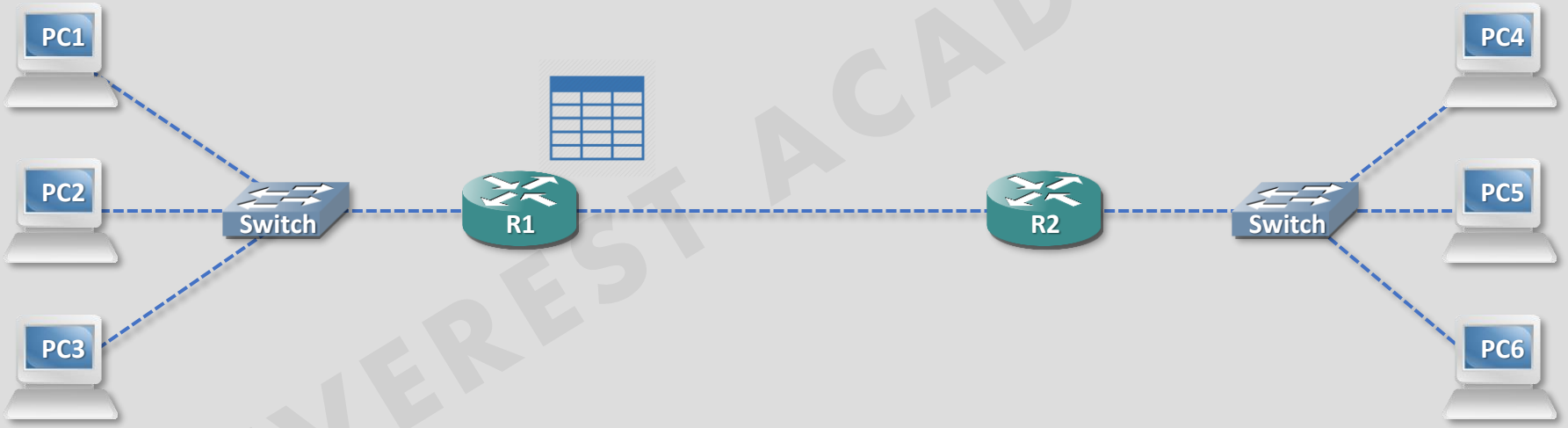
- Routers exchange IPv6 dynamic routing protocol (OSPFv3, EIGRP for IPv6, RIPng) messages from their IPv6 link-local address.



Unicast Addresses

02 Link-Local Unicast Address

- IPv6 routing table entries populated from dynamic routing protocols use the IPv6 link-local address as the next-hop address.



Unicast Addresses

03 Loopback Address

❖ **An IPv6 loopback address** is ::1, an all-0s address except for the last bit, which is set to 1.

⟺ **127.0.0.0/8**

<---------- 128 bits ---------->

::1

0000 : 0000 : 0000 : 0000 : 0000 : 0000 : 0000 : 0001

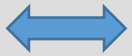
Characteristics

- loopback address cannot be assigned to a physical interface.
- A packet with a loopback address, source address, or destination address should never be sent beyond the device.
- A router can never forward a packet with a destination address that is a loopback address.
- The device must drop a packet received on an interface if the destination address is a loopback address.

Unicast Addresses

03 Loopback Address

❖ **An IPv6 loopback address** is ::1, an all-0s address except for the last bit, which is set to 1.



127.0.0.0/8

<---------- 128 bits ---------->

::1

0000 : 0000 : 0000 : 0000 : 0000 : 0000 : 0000 : 0001

```
C:\>ping ::1

Pinging ::1 with 32 bytes of data:
Reply from ::1: time<1ms
Reply from ::1: time<1ms
Reply from ::1: time<1ms
Reply from ::1: time<1ms

Ping statistics for ::1:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 0ms, Maximum = 0ms, Average = 0ms
```

Unicast Addresses

04 Unspecified Address

- **An unspecified unicast address** is an all-0s address . An unspecified unicast address is used as a source address to indicate the absence of an address.
- One example where an unspecified address can be used by a computer is as a source address in ICMPv6 message to ensure that its link local address is unique.

<---------- 128 bits ---------->

::

0000 : 0000 : 0000 : 0000 : 0000 : 0000 : 0000 : 0000

Characteristics

- An unspecified source address indicates the absence of an address.
- An unspecified address cannot be assigned to a physical interface.
- An unspecified address cannot be used as a destination address.
- A router will never forward a packet that has an unspecified source address.

Unicast Addresses

04 Unspecified Address

No.	Source	Destination	Protocol	Length	Info
12	::	ff02::1:ff22:2222	ICMPv6	78	Neighbor Solicitation for fe80::3a60:77ff:fe22:2222
13	::	ff02::1:ff22:2222	ICMPv6	78	Neighbor Solicitation for fe80::3a60:77ff:fe22:2222

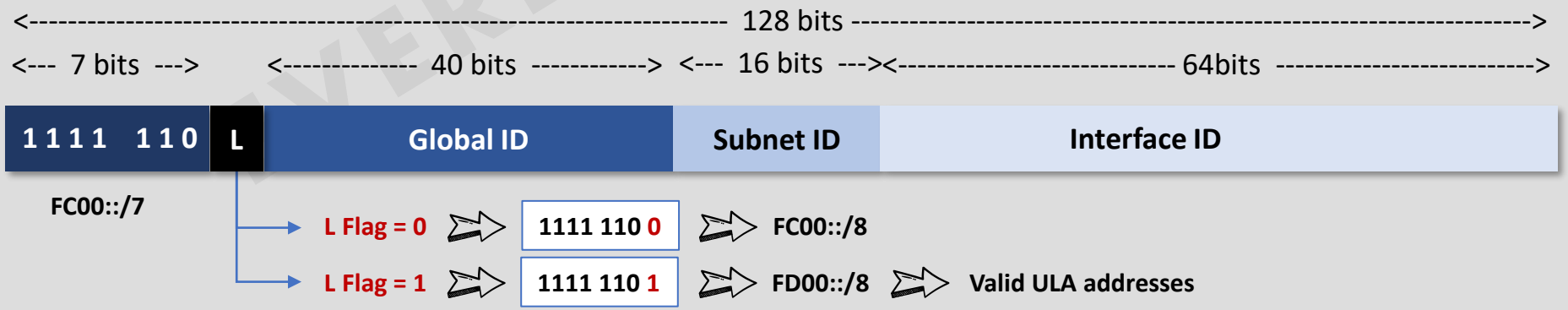
```
> Frame 13: 78 bytes on wire (624 bits), 78 bytes captured (624 bits) on interface \Device\NPF_{2B408050-607E
v Ethernet II, Src: Pegatron_22:22:22 (38:60:77:22:22:22), Dst: IPv6mcast_ff:22:22:22 (33:33:ff:22:22:22)
  > Destination: IPv6mcast_ff:22:22:22 (33:33:ff:22:22:22)
  > Source: Pegatron_22:22:22 (38:60:77:22:22:22)
    Type: IPv6 (0x86dd)
v Internet Protocol Version 6, Src: ::, Dst: ff02::1:ff22:2222
    0110 .... = Version: 6
  > .... 0000 0000 .... .... .... .... .... = Traffic Class: 0x00 (DSCP: CS0, ECN: Not-ECT)
    .... .... .... 0000 0000 0000 0000 0000 = Flow Label: 0x00000
    Payload Length: 24
    Next Header: ICMPv6 (58)
    Hop Limit: 255
    Source Address: ::
    Destination Address: ff02::1:ff22:2222
v Internet Control Message Protocol v6
    Type: Neighbor Solicitation (135)
    Code: 0
    Checksum: 0x873e [correct]
    [Checksum Status: Good]
    Reserved: 00000000
    Target Address: fe80::3a60:77ff:fe22:2222
```

Unicast Addresses

05 Unique Local Addresses (ULA)

- **Unique local addresses (ULAs)** are similar to Global Unicast Addresses but they are for private use and should not be routed in the global Internet.
- **Unique local** addresses are routable only within the scope of such private networks, but not in the global IPv6 Internet.
- **Unique local addresses** may be used freely, without centralized registration, inside a single organization or multiple organizations.
- The range of **Unique local addresses** is FC00::/7 which can be divided into two parts : FC00::/8 and FD00::/8

- **FC00::/8** (1111 1100): When the L flag is set to 0, may be defined in the future.
- **FD00::/8** (1111 1101): When the L flag is set to 1, the address is locally assigned.



Unicast Addresses

05 Unique Local Addresses (ULA)

- **Global IDs** can be generated using a pseudorandom algorithm that gives them a very high probability of being unique.
- **Sample Code for Pseudo-Random Global ID Algorithm** can be used to create a locally assigned local IPv6 address prefix..

Characteristics

- They can be used just like global unicast addresses.
- They can be used for devices that never need access to or from the global Internet.
- They allow sites to be combined or privately interconnected.
- They are independent of any ISP and can be used within a site even without having Internet connectivity.

Unicast Addresses

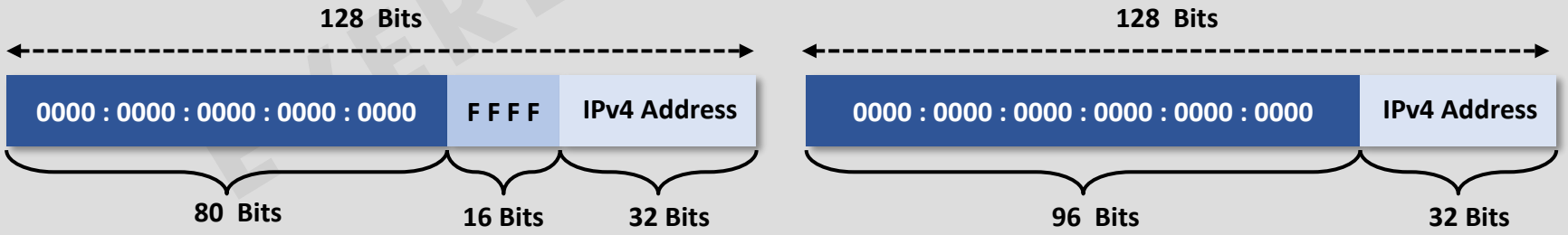
06 IPv4 Embedded Address

- **IPv4 Embedded** Addresses are IPv6 addresses used to aid the transition from IPv4 to IPv6.

- **IPv4 Embedded Addresses** can carry an IPv4 address in the low-order 32 bits and used to represent an IPv4 address inside an IPv6 address.

Types of IPv4 Embedded Addresses

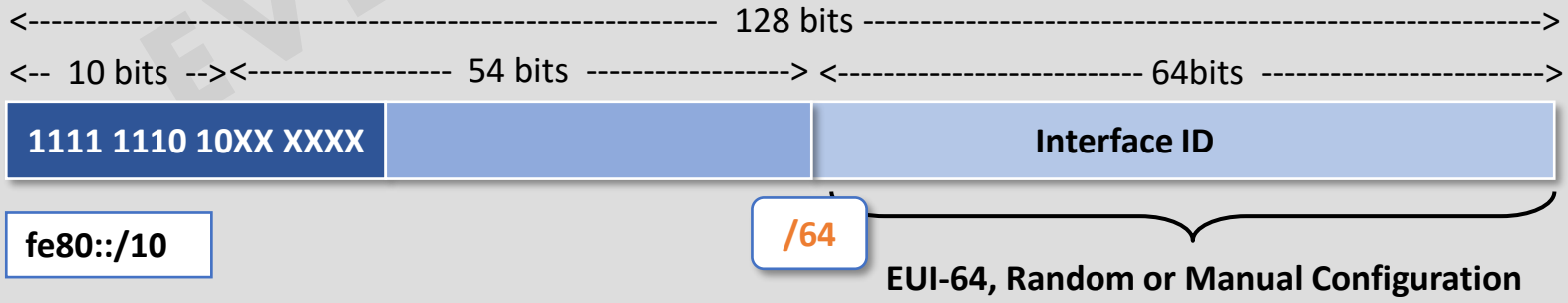
- IPv4-mapped IPv6 addresses
- IPv4-compatible IPv6 addresses (deprecated)



Link-Local Address (LLA)

- A Link-local address (LLA) is a unicast address that is confined to a single interface. The term link refers to a network segment .
- A Link-local address only have to be unique on the link.
- There can be only one link-local address per interface.
- A Link-local address is not routable off the link. This means routers can not forward any packets that has a link-local address.
- IPv6 link-local addresses are equivalent to IPv4 link-local addresses 169.254.0.0/16 (APIPA)
- Devices can use **Duplicate Address Detection (DAD)** to determine whether or not the link-local address is unique.

Structure of a Link-Local Unicast Address



<-- 10 bits --><---------- 54 bits ----------> <---------- 64bits ---------->

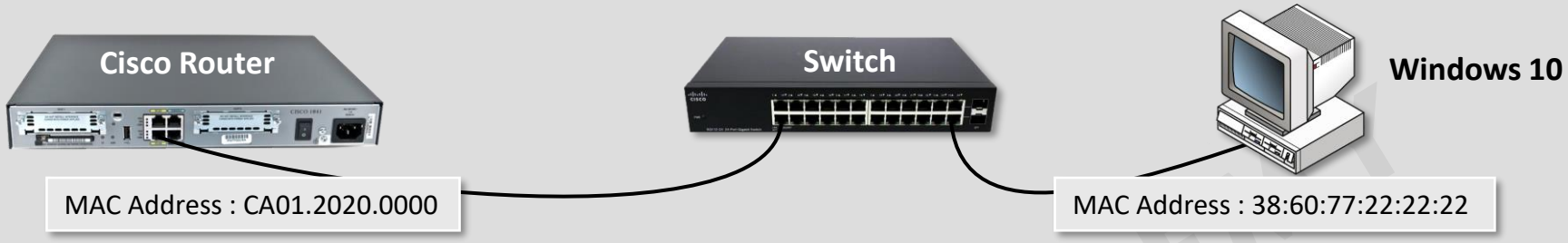
1111 1110 10XX XXXX		Interface ID

fe80::/10

/64

EUI-64, Random or Manual Configuration

Example of Link-Local Addresses



8 4 2 1

X X X X

10 ---> A
11 ---> B
12 ---> C
13 ---> D
14 ---> E
15 ---> F

CA01:2020:0000

CA 01:20FF:FE20:0000

1100 1010

1100 1000

FE80:0000:0000:0000:C8 01:20 FF:FE 20:0000

Link-Local Address : FE80::C801:20FF:FE20:0

38:60:77:22:22:22

38:60:77FF:FE22:22:22

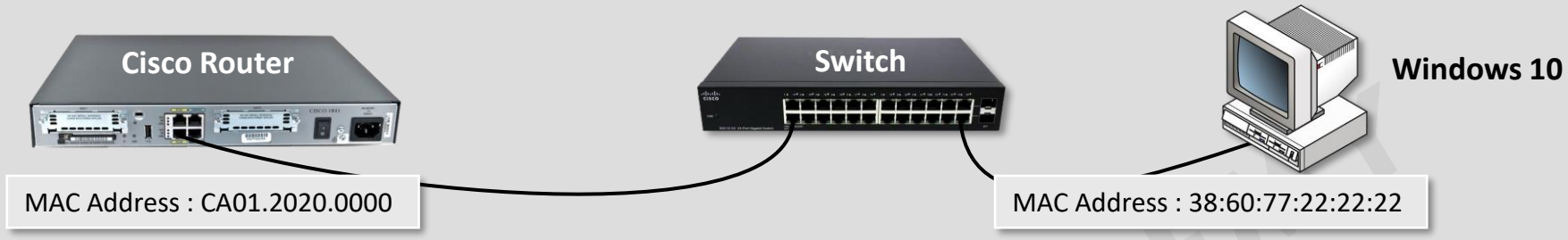
0011 1000

0011 1010

FE80:0000:0000:0000:3A60:77 FF:FE 22:22:22

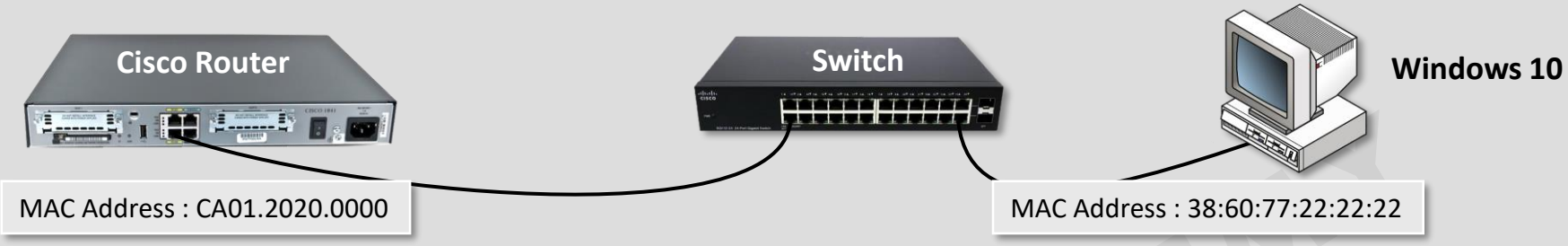
Link-Local Address : FE80::3A60:77FF:FE22:2222

Manual Configuration of a Link-Local Address




```
Router#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
Router(config)#
Router(config)#interface fastethernet 0/0
Router(config-if)#
Router(config-if)#ipv6 address  FE80::C801:20FF:FE20:0 link-local
Router(config-if)#
Router(config-if)#end
Router#
Router#show ipv6 interface brief
*Oct 12 05:30:54.119: %SYS-5-CONFIG_I: Configured from console by console
Router#
Router#
Router#show ipv6 interface brief
FastEthernet0/0        [up/up]
    FE80::C801:20FF:FE20:0
Router#
Router#
```

Example of Link-Local Addresses



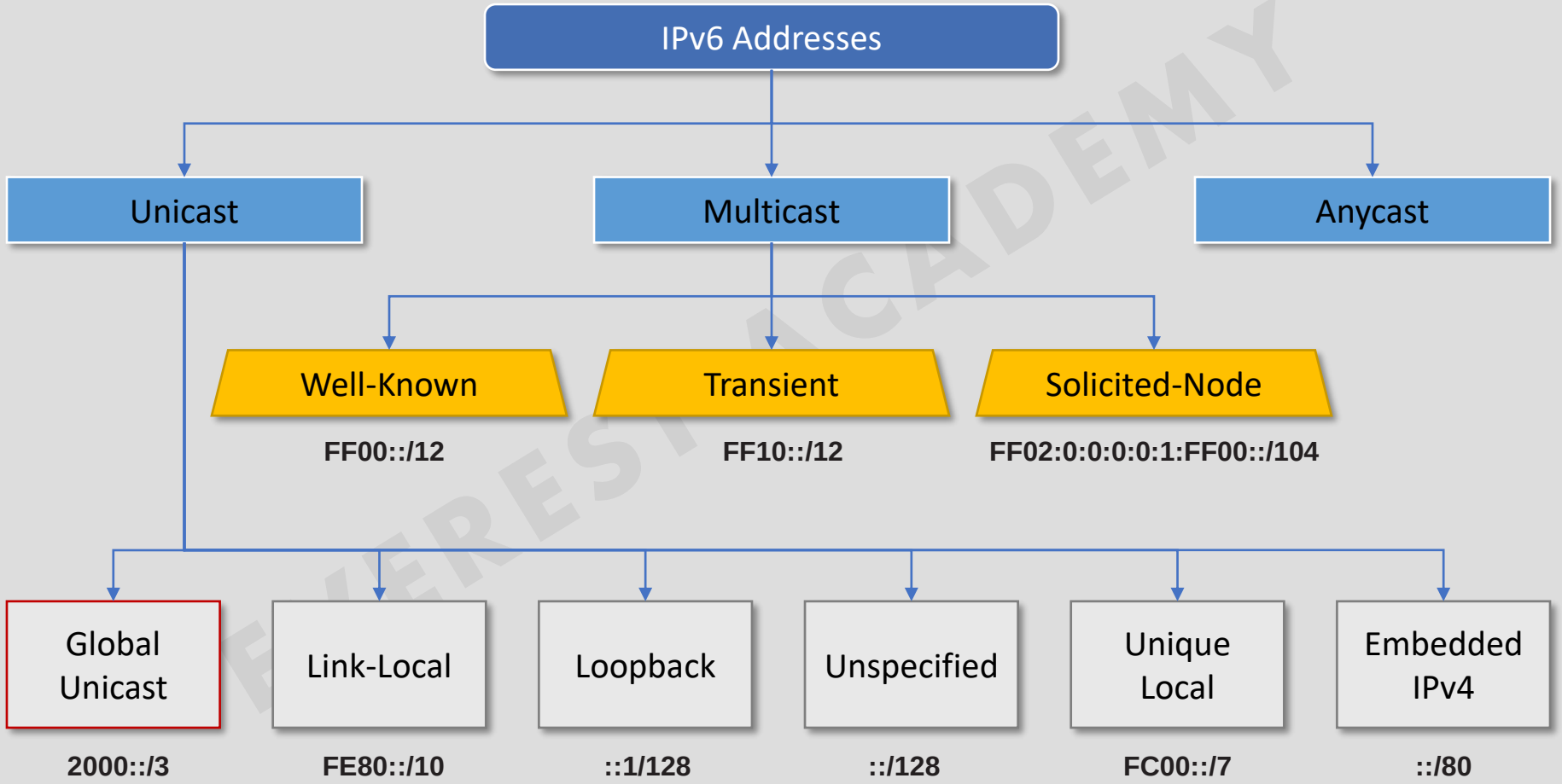

```
C:\> netsh interface ipv6 set global randomizeidentifiers=disabled store=active
```

```
C:\> netsh interface ipv6 set global randomizeidentifiers=disabled store=persistent
```

Administrator: Command Prompt

```
C:\>ipconfig /all

Windows IP Configuration

   Host Name . . . . . . . . . . . . : PC2
   Primary Dns Suffix  . . . . . . . :
   Node Type . . . . . . . . . . . . : Hybrid
   IP Routing Enabled. . . . . . . . : No
   WINS Proxy Enabled. . . . . . . . : No

Ethernet adapter Ethernet0:

   Connection-specific DNS Suffix  . :
   Description . . . . . . . . . . . : Intel(R) 82574L Gigabit Network Connection
   Physical Address. . . . . . . . . : 38-60-77-22-22-22
   DHCP Enabled. . . . . . . . . . . : No
   Autoconfiguration Enabled . . . . : Yes
   Link-local IPv6 Address . . . . . : fe80::3a60:77ff:fe22:2222%4(Preferred)
```

Global Unicast Addresses (GUAs)



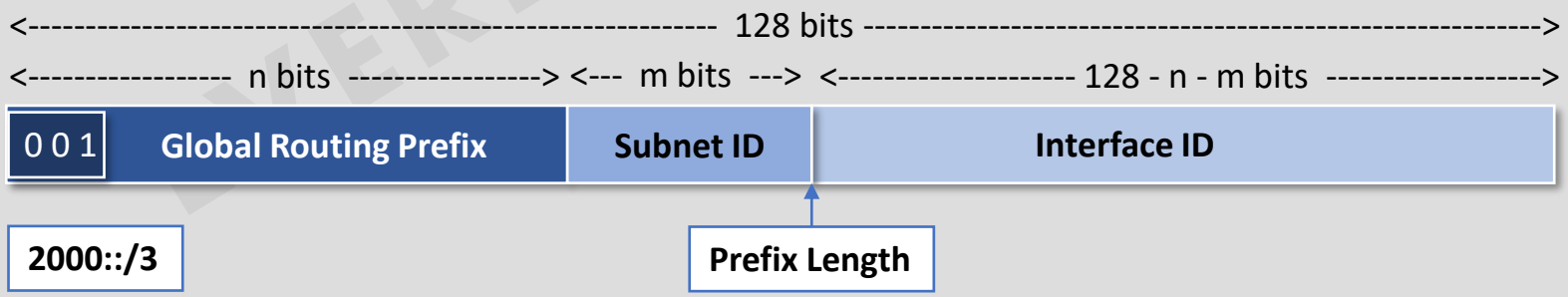
Global Unicast Addresses (GUAs)

- **Global unicast addresses (GUAs),** also known as **aggregatable global unicast addresses**, are globally routable and reachable in the IPv6 Internet.

⟺ **Public IPv4 Addresses**

Generic Structure of a GUA

- **Global Routing Prefix**: The Global Routing Prefix is the prefix or network portion of the address assigned by the provider, such as an ISP, to the customer site.
- **Subnet ID:** The Subnet ID is a **separate field** for allocating subnets within the customer site.
- **Interface ID:** The Interface ID identifies the interface on the subnet, equivalent to the **host portion** of an IPv4 address. The Interface ID in most cases is 64 bits.



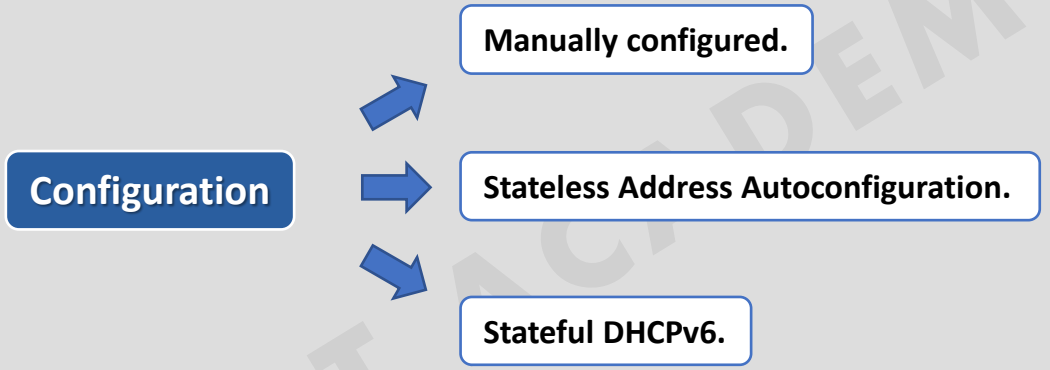
<----------- n bits -----------> <--- m bits ---> <---------- 128 - n - m bits ---------->

0 0 1	Global Routing Prefix	Subnet ID	Interface ID

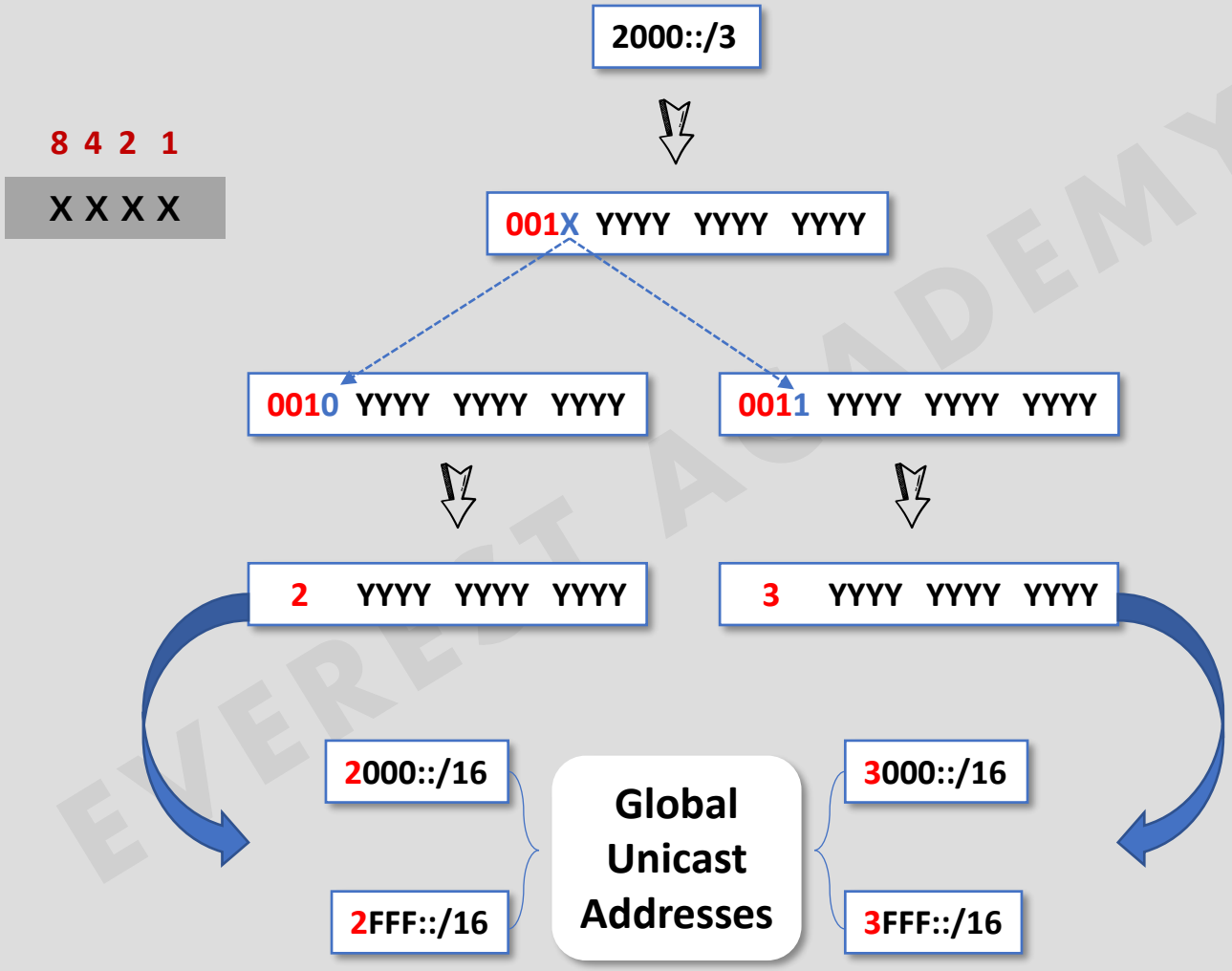
2000::/3

Prefix Length

Global Unicast Addresses (GUAs)



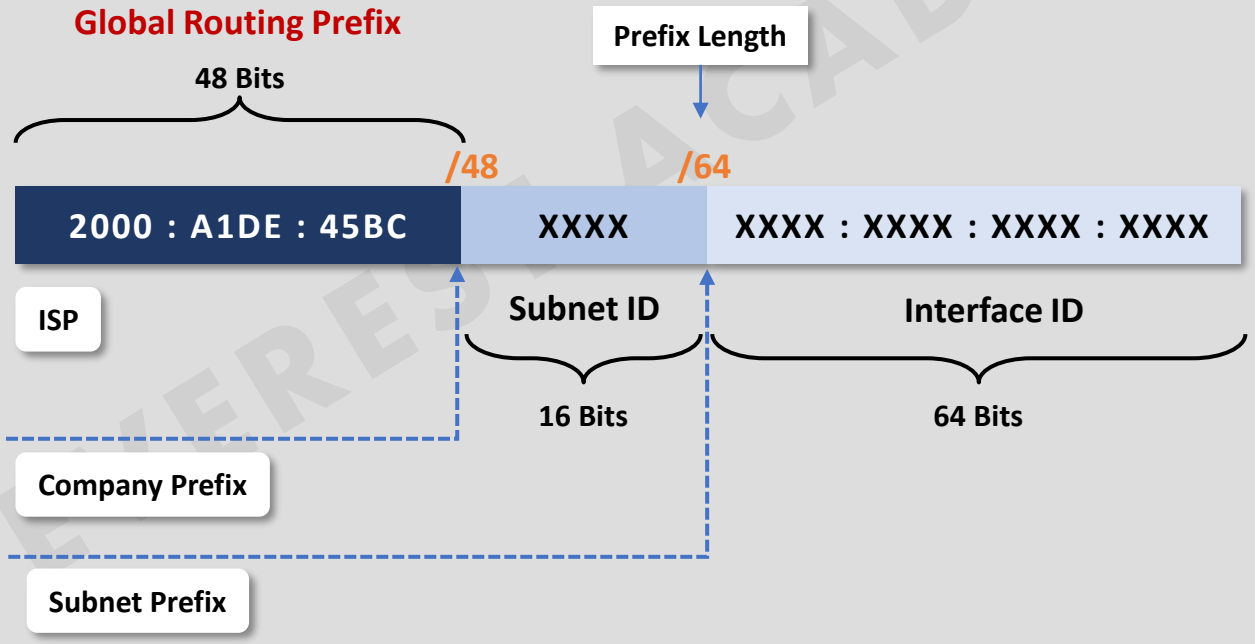
The Range of Global Unicast Addresses



Global Routing Prefix

- **The global routing prefix** is the prefix or network portion of the address assigned by the provider, such as an ISP, to a customer or site.

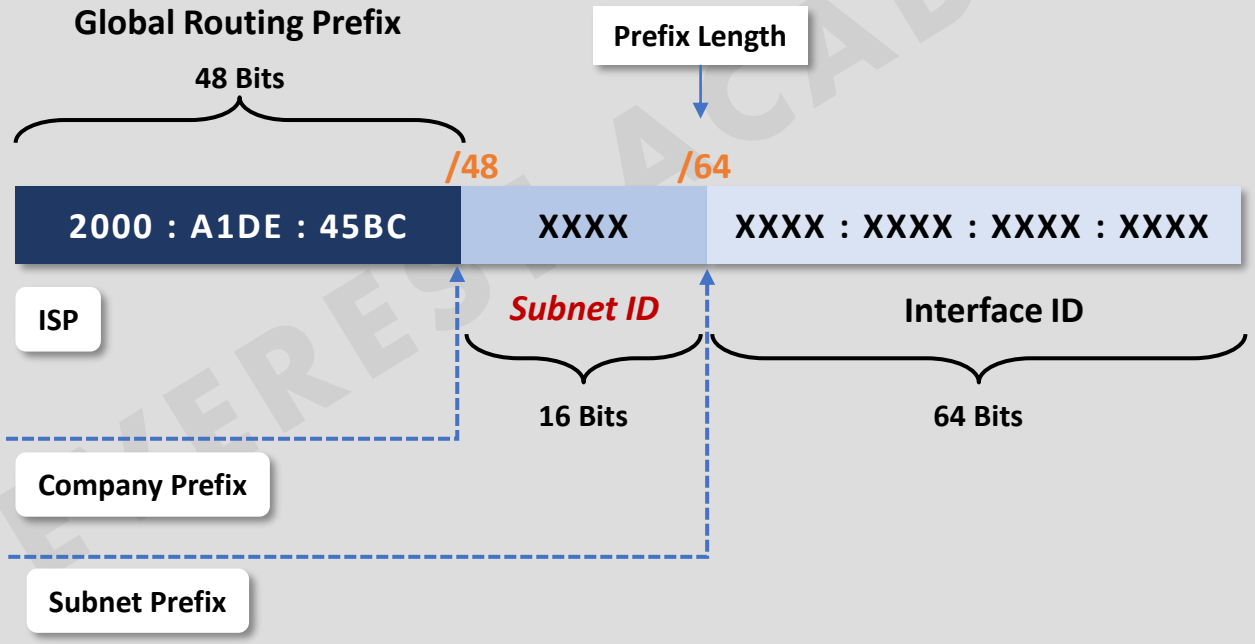
- There is no a specific prefix length for global routing prefix, the most common global routing prefix length is (/48).



Subnet ID

- **In IPv4,** you have to borrow bits from the host portion of the address to create subnets. There are no bits designated for the subnet portion of the address.

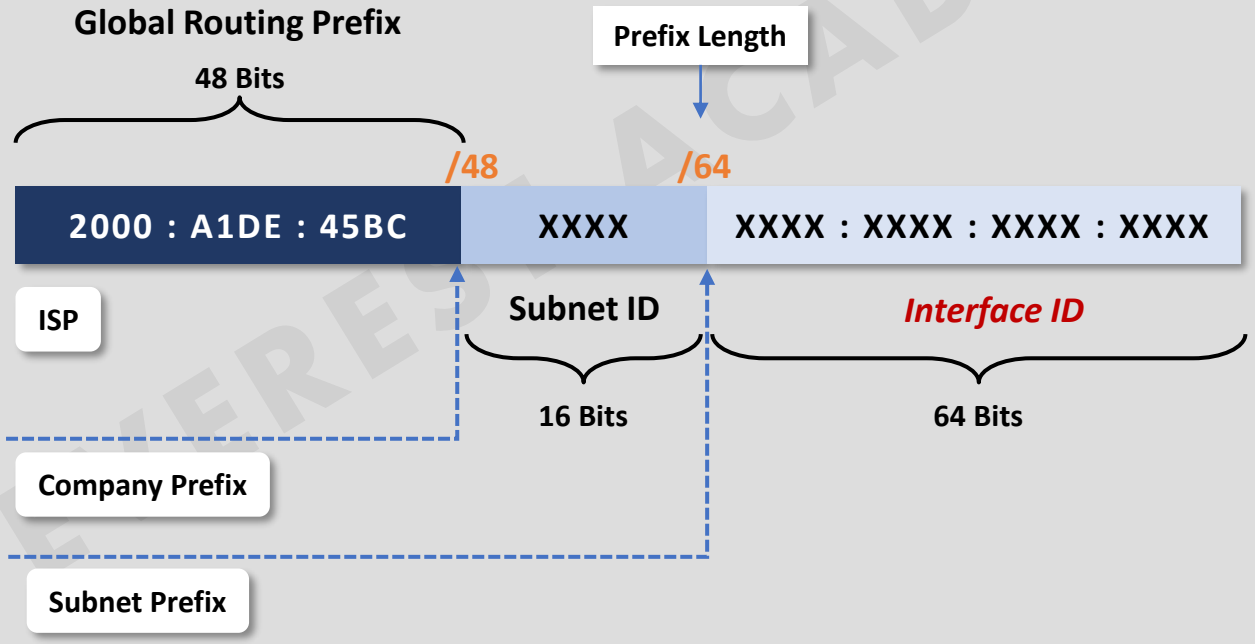
- **In IPv6, the Subnet ID** is a separate field, apart from the host portion of the address.
- **The prefix length** is the total length of the **Global Routing Prefix** and **Subnet ID**.



Interface ID

- **The Interface ID** uniquely identifies the interface on the subnet.
- In most cases, a 64-bit Interface ID should be used for LANs .

- **The term Interface ID** is used rather than **Host ID** because a single host can have multiple interfaces, each having one or more IPv6 addresses.



IPv6 Subnetting Using Global Unicast Addresses

Global Routing Prefix | ***Subnet ID*** | **Interface ID**

/48 /64

2001 : A1DE : 45BC : X X X X : 0000 : 0000 : 0000 : 0000

ISP

0 0 0 0	2001 : A1DE : 45BC : 0 ::/64
0 0 0 1	2001 : A1DE : 45BC : 1 ::/64
0 0 0 2	2001 : A1DE : 45BC : 2 ::/64
↓	↓
0 0 0 F	2001 : A1DE : 45BC : F ::/64
0 0 1 0	2001 : A1DE : 45BC : 10 ::/64
0 0 1 1	2001 : A1DE : 45BC : 11 ::/64
0 0 1 2	2001 : A1DE : 45BC : 12 ::/64
↓	↓
0 0 1 F	2001 : A1DE : 45BC : 1F ::/64
F F F 0	2001 : A1DE : 45BC : FFF0 ::/64
F F F 1	2001 : A1DE : 45BC : FFF1 ::/64
F F F 2	2001 : A1DE : 45BC : FFF2 ::/64
↓	↓
F F F F	2001 : A1DE : 45BC : FFFF ::/64

$2^{16} =$ 65,536 total subnets

IPv6 Subnetting Using Global Unicast Addresses

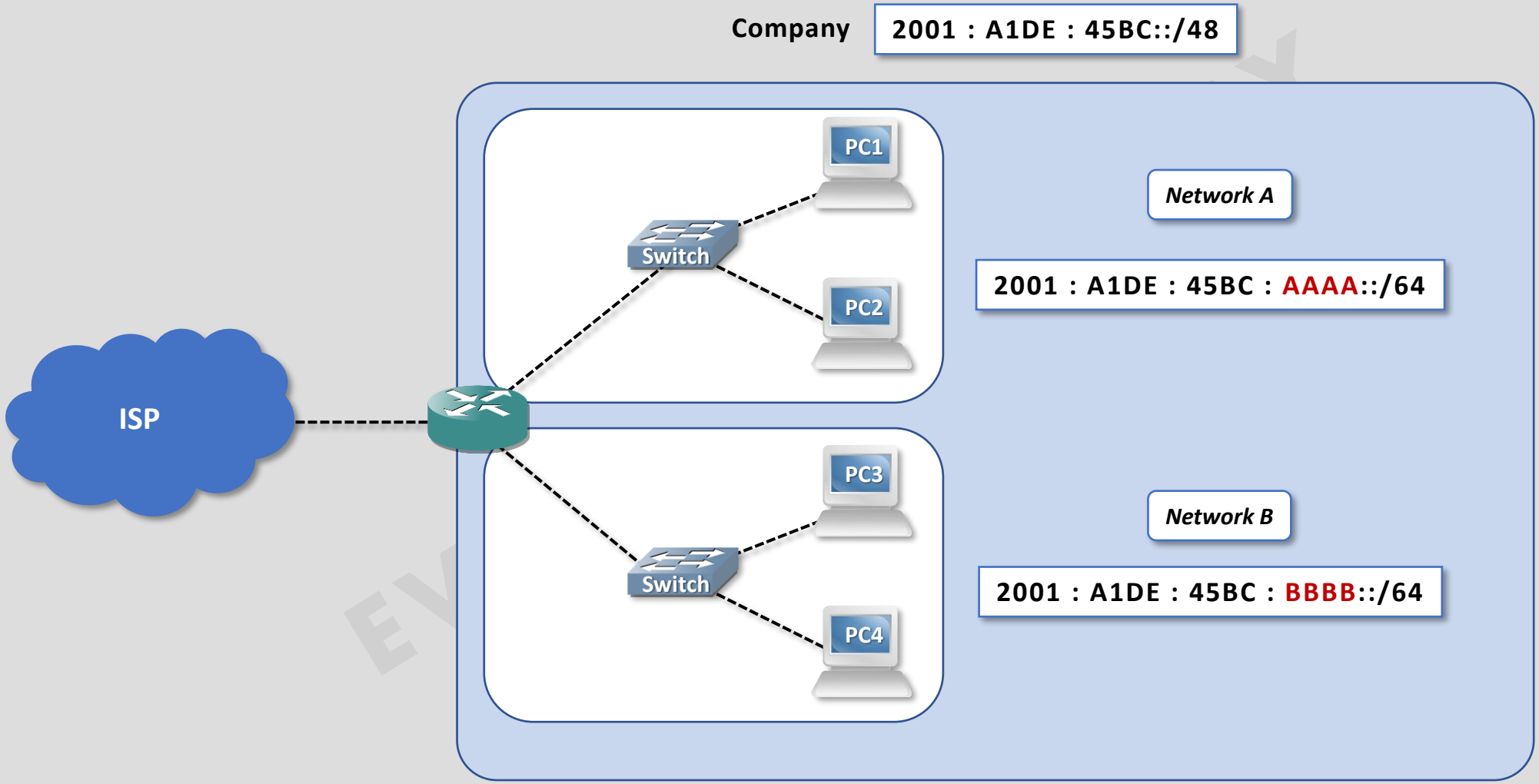
Global Routing Prefix	*Subnet ID*	Interface ID
/48		/64
2001 : A1DE : 45BC :	X X X X	: 0000 : 0000 : 0000 : 0000

ISP

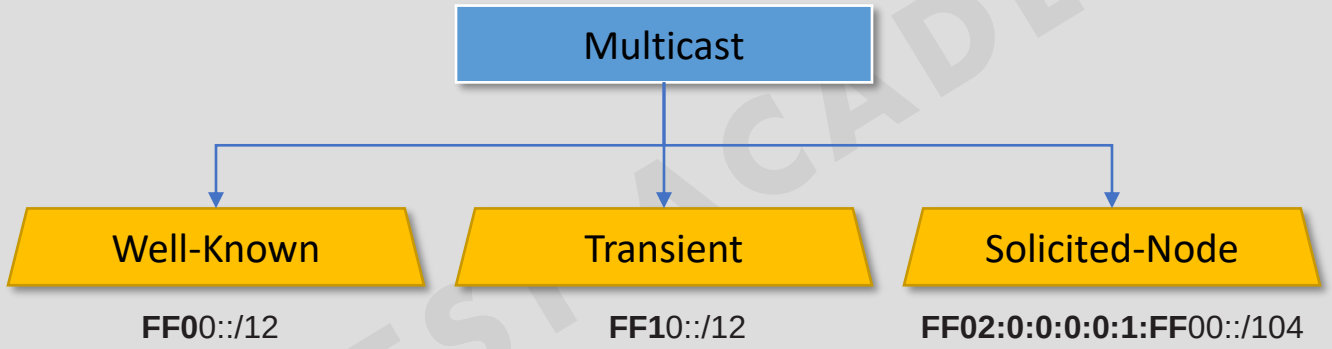
Subnet ID	
0 0 0 0	2001 : A1DE : 45BC : 0 ::/64
0 0 0 1	2001 : A1DE : 45BC : 1 ::/64
0 0 0 2	2001 : A1DE : 45BC : 2 ::/64
↓	↓
0 0 0 F	2001 : A1DE : 45BC : F ::/64
0 0 1 0	2001 : A1DE : 45BC : 10 ::/64
0 0 1 1	2001 : A1DE : 45BC : 11 ::/64
0 0 1 2	2001 : A1DE : 45BC : 12 ::/64
↓	↓
0 0 1 F	2001 : A1DE : 45BC : 1F ::/64
F F F 0	2001 : A1DE : 45BC : FFF0 ::/64
F F F 1	2001 : A1DE : 45BC : FFF1 ::/64
F F F 2	2001 : A1DE : 45BC : FFF2 ::/64
↓	↓
F F F F	2001 : A1DE : 45BC : FFFF ::/64

2^{16}
65,536
Total subnets

IPv6 Prefix Assignment Example



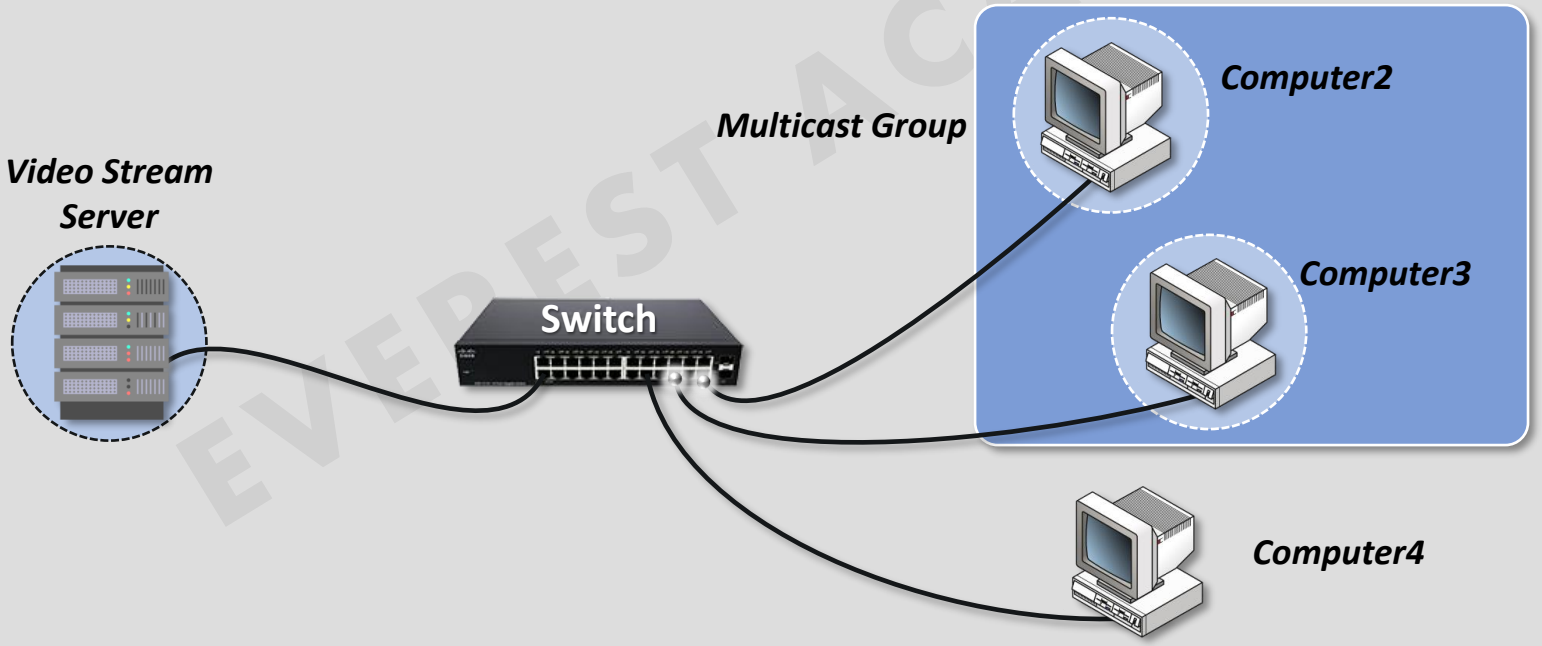
Multicast Addresses



Multicast Addresses

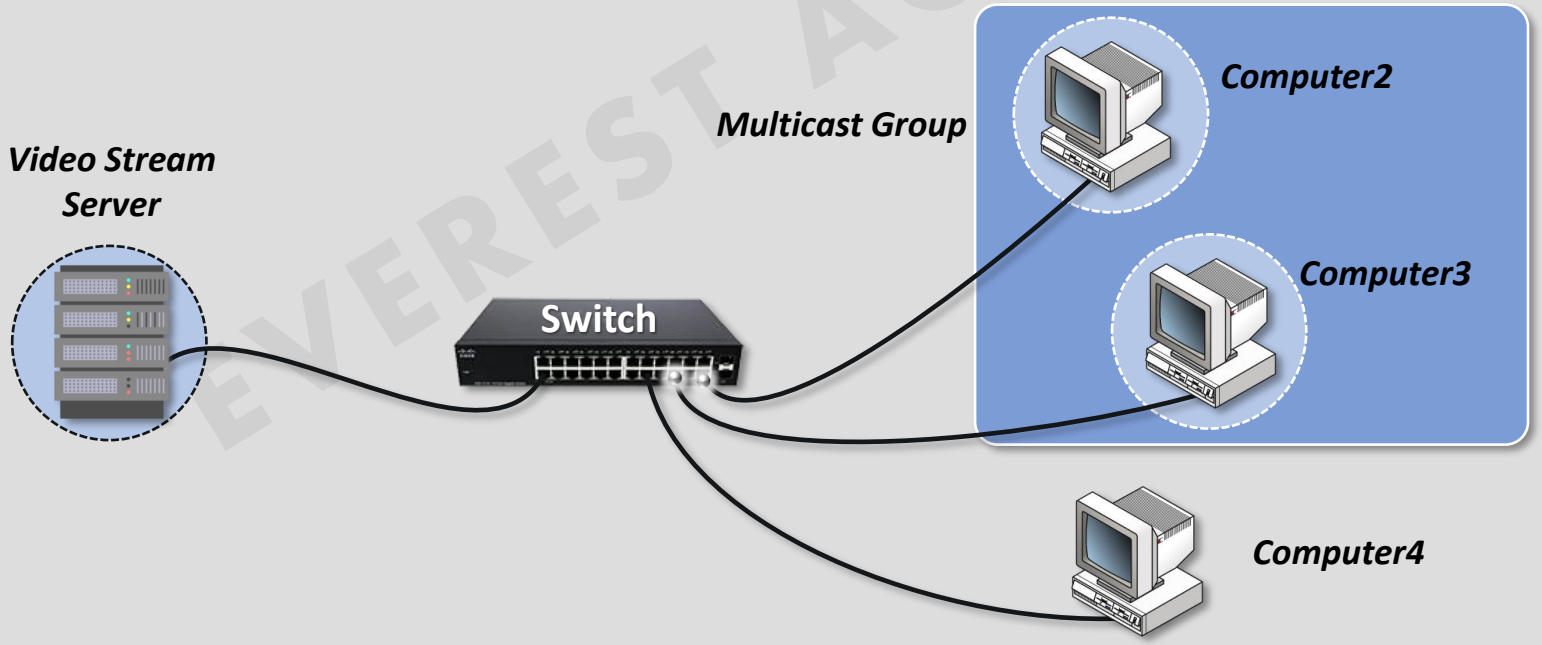
- **Multicast** is a technique in which a device sends a single packet or a single stream of packets to multiple destinations simultaneously (one-to-many).

- **Unicast is** a technique in which a device sends a single packet to a single destinations (one-to-one).



Multicast Addresses

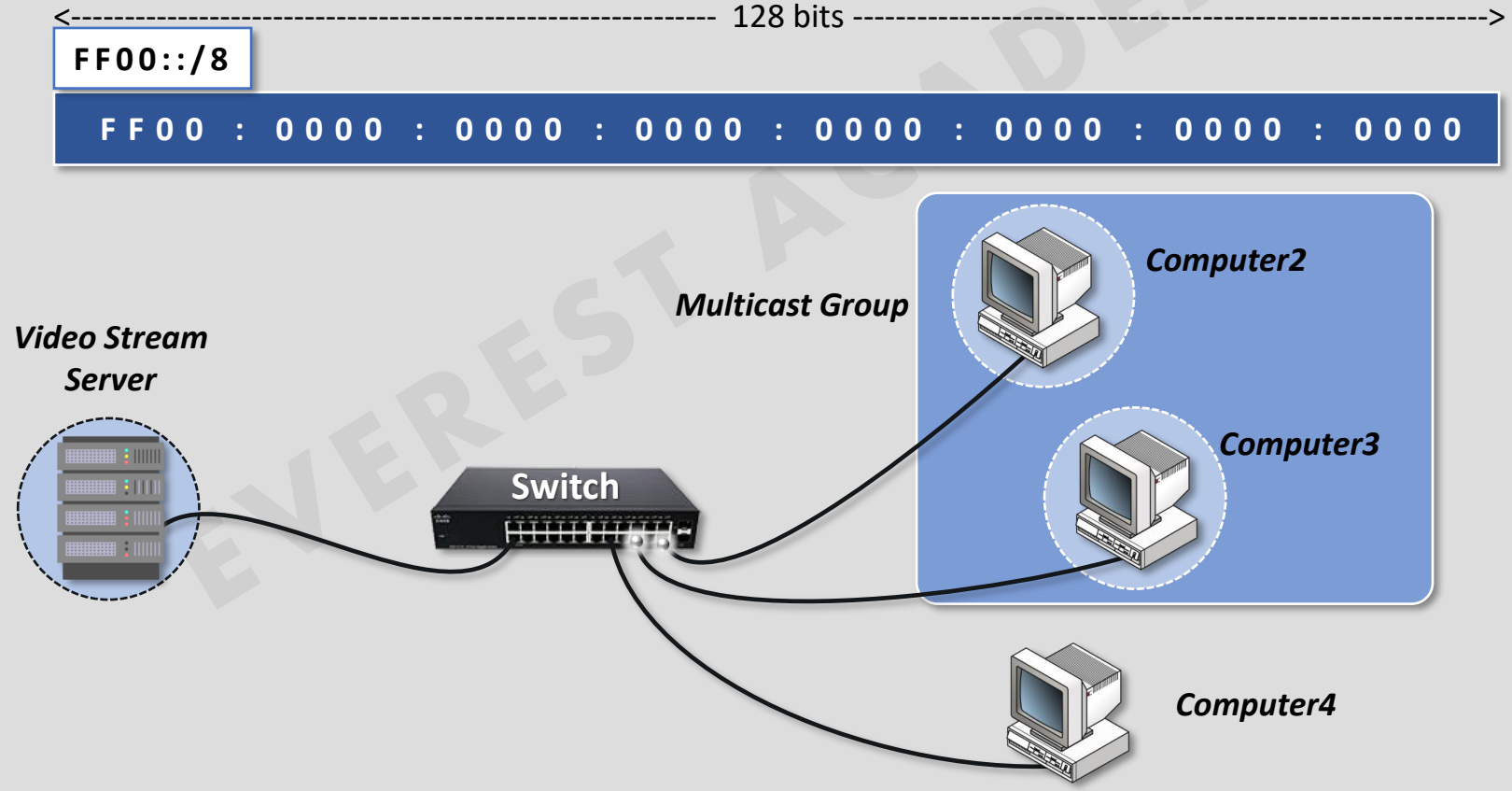
- IP multicast packets can be filtered by the Ethernet switch and the NIC (Network Interface card).
- Filtering multicast frames at the switch can be accomplished by implementing either of the following : **IGMP snooping** or **MLD snooping.**
- IGMP (Internet Group Management Protocol) snooping for **IPv4 multicasting**
- MLD (Multicast Listener Discovery) snooping for **IPv6 multicasting**



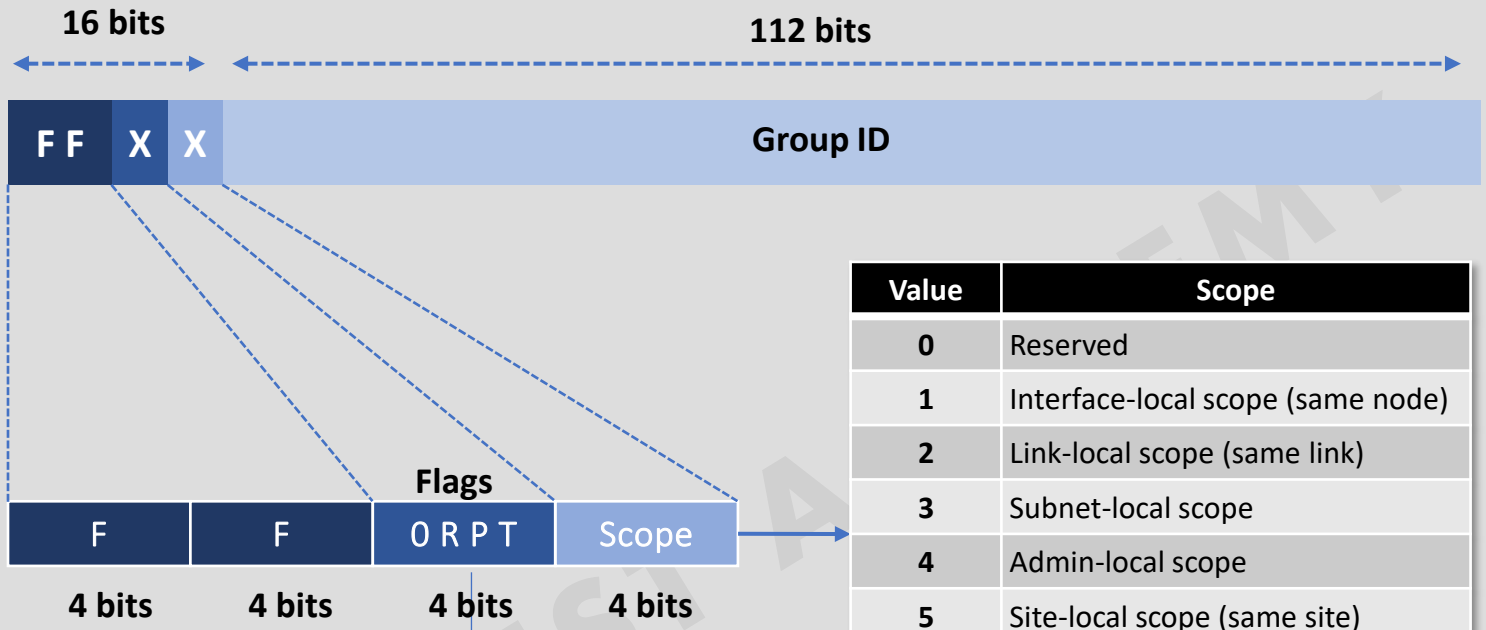
Multicast Addresses

- An IPv6 multicast address has the **prefix FF**00::/8, which defines a group of devices known as a **multicast group**. It is the IPv4 equivalent of **224.0.0.0/4.**

- A packet sent to a multicast group always has a unicast source address. A multicast address can only be a destination address and can never be a source address.



Multicast Address Format



Value	Scope
0	Reserved
1	Interface-local scope (same node)
2	Link-local scope (same link)
3	Subnet-local scope
4	Admin-local scope
5	Site-local scope (same site)
8	Organization-local scope
E	Global scope
F	Reserved

Flags
0 (reserved)
R (rendezvous point)
P (network prefix)
T (transient)

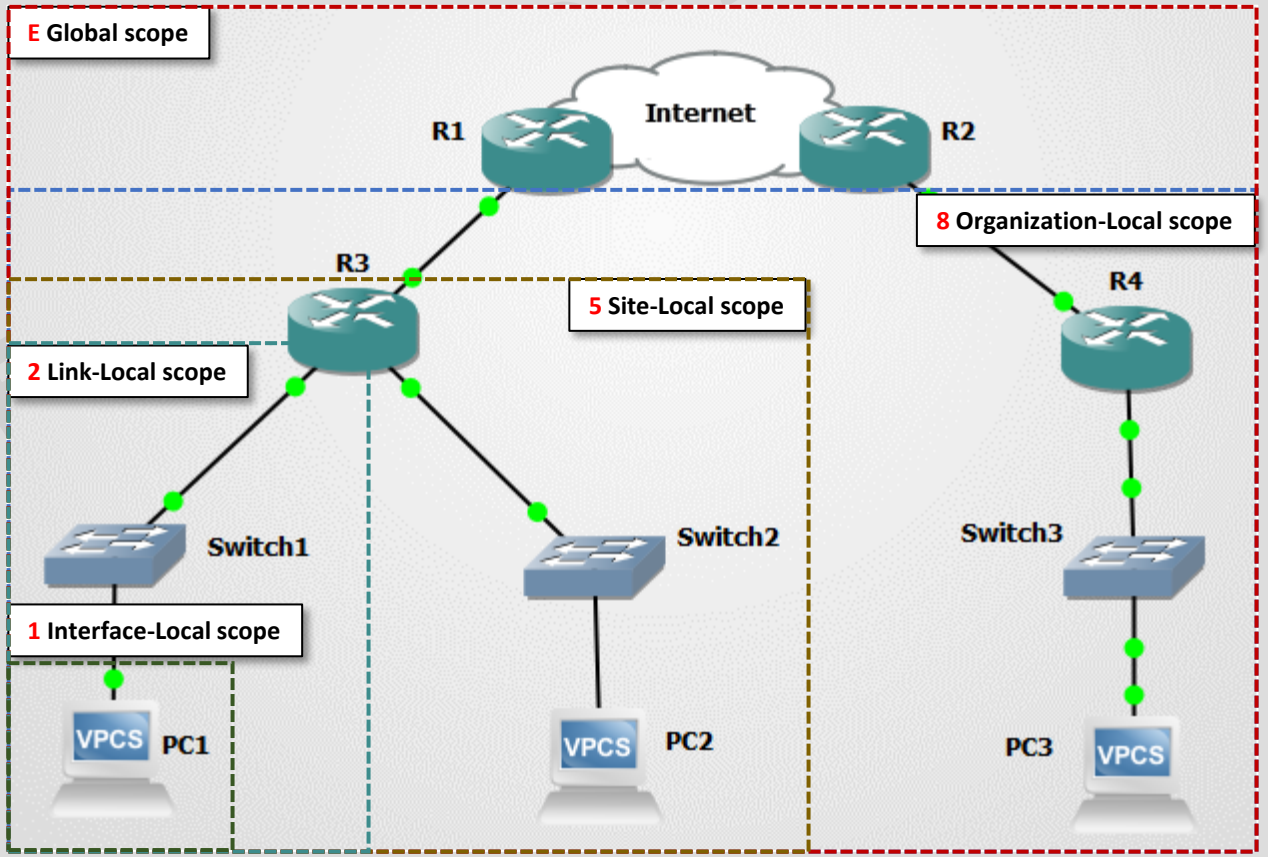
Value	T Flag
0	These addresses, known as **predefined multicast addresses**, are assigned by **IANA** and include both **well-known and solicited multicast**.
1	**Nonpermanent Multicast Addresses** are dynamically assigned by the multicast applications and include **transient** multicast.

Multicast Address Scope

- **The scope field** indicates the scope of the IPv6 internetwork for which the multicast traffic is intended. In addition to information provided by multicast routing protocols, routers use multicast scope to determine whether multicast traffic can be forwarded.

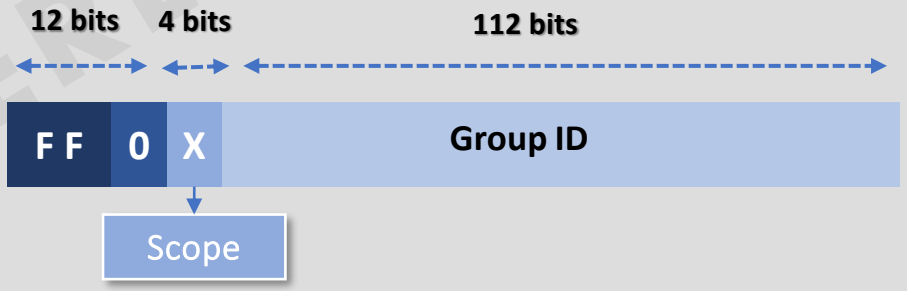
4 bits	4 bits	4 bits	4 bits
F	F	0	Scope

	Value	Scope
	0	Reserved
FF01	1	Interface-local scope (same node)
FF02	2	Link-local scope (same link)
	3	Subnet-local scope
	4	Admin-local scope
FF05	5	Site-local scope (same site)
FF08	8	Organization-local scope (WAN)
FF0E	E	Global scope (Internet)
	F	Reserved



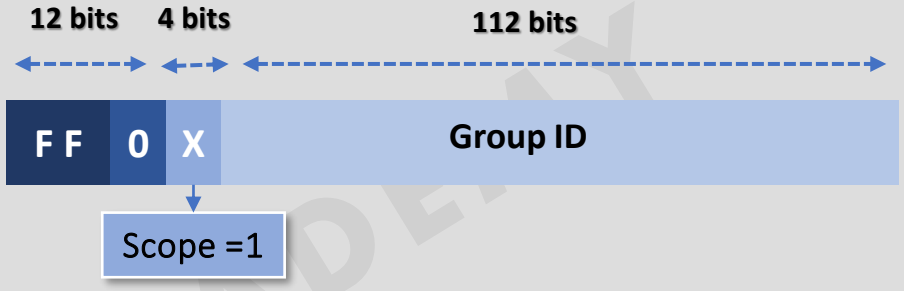
Well-Known Multicast Addresses

- **Well-known multicast addresses** are predefined or reserved multicast addresses for assigned multicast groups.
- **This address type** is typically used for neighbor discovery and routing protocol messages.
- **These addresses** are equivalent to IPv4 well-known multicast addresses in the range **224.0.0.0** to **239.255.255.255.**
- **Well-known multicast addresses** have the prefix **FF0**0::/12, this means that the third hexadecimal digit is always set to **0**.

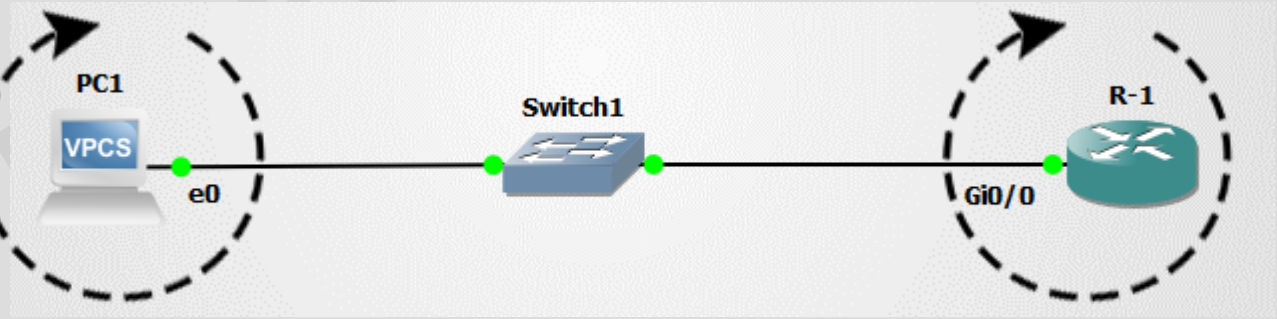


Interface-Local Scope Multicast Groups

- **Interface-Local Scope** spans only a single interface on a node, and is useful only for loopback tests of multicast.

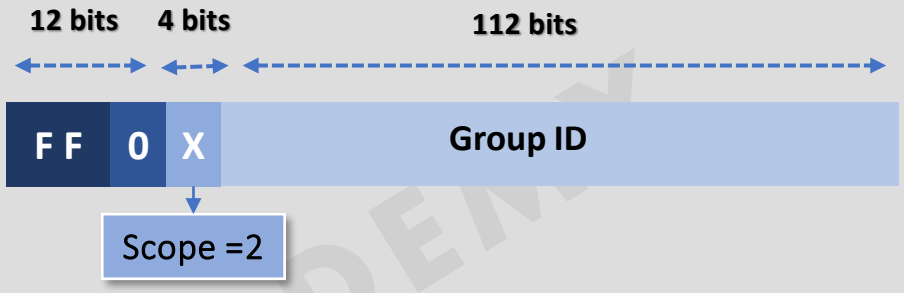


/8 Prefix	Flag	Scope	Predefined Group ID	Compressed Format	Description
FF	0	**1**	0:0:0:0:0:0:1	FF0**1**::1	All-nodes
FF	0	**1**	0:0:0:0:0:0:2	FF0**1**::2	All-routers



Link-Local Scope Multicast Groups

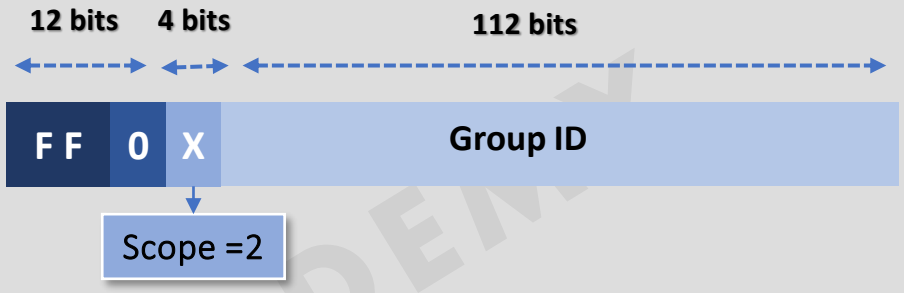
- **Link-Local Scope** have the same scope as link-local unicast addresses (limited to one link, one physical network).



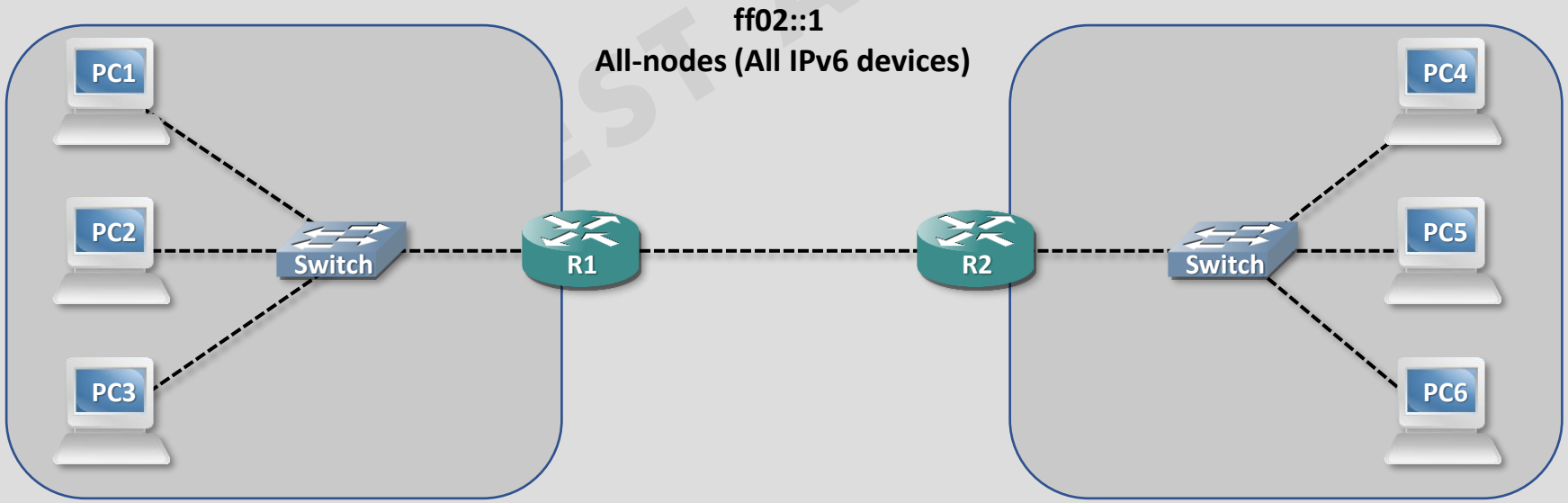
/8 Prefix	Flag	Scope	Predefined Group ID	Compressed Format	Description
FF	0	**2**	0:0:0:0:0:0:1	FF0**2**::1	All-nodes (all-IPv6 devices)
FF	0	**2**	0:0:0:0:0:0:2	FF0**2**::2	All-routers (single link)
FF	0	**2**	0:0:0:0:0:0:5	FF0**2**::5	OSPF routers
FF	0	**2**	0:0:0:0:0:0:6	FF0**2**::6	OSPF designated routers
FF	0	**2**	0:0:0:0:0:0:9	FF0**2**::9	RIP routers
FF	0	**2**	0:0:0:0:0:0:A	FF0**2**::A	EIGRP routers
FF	0	**2**	0:0:0:0:0:1:2	FF0**2**::1:2	All-DHCP servers and relay agents

Link-Local Scope Multicast Groups

- **Link-Local Scope** have the same scope as link-local unicast addresses (limited to one link, one physical network).

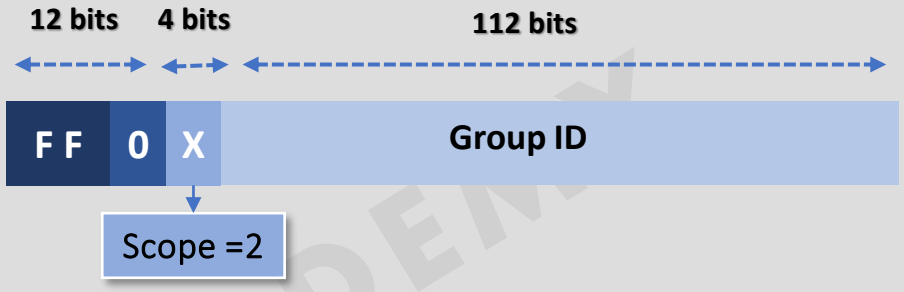


- IPv6 does not have a broadcast address, but there is an **all-nodes or all-IPv6 devices** multicast address, **ff02::1**, which has a similar effect.

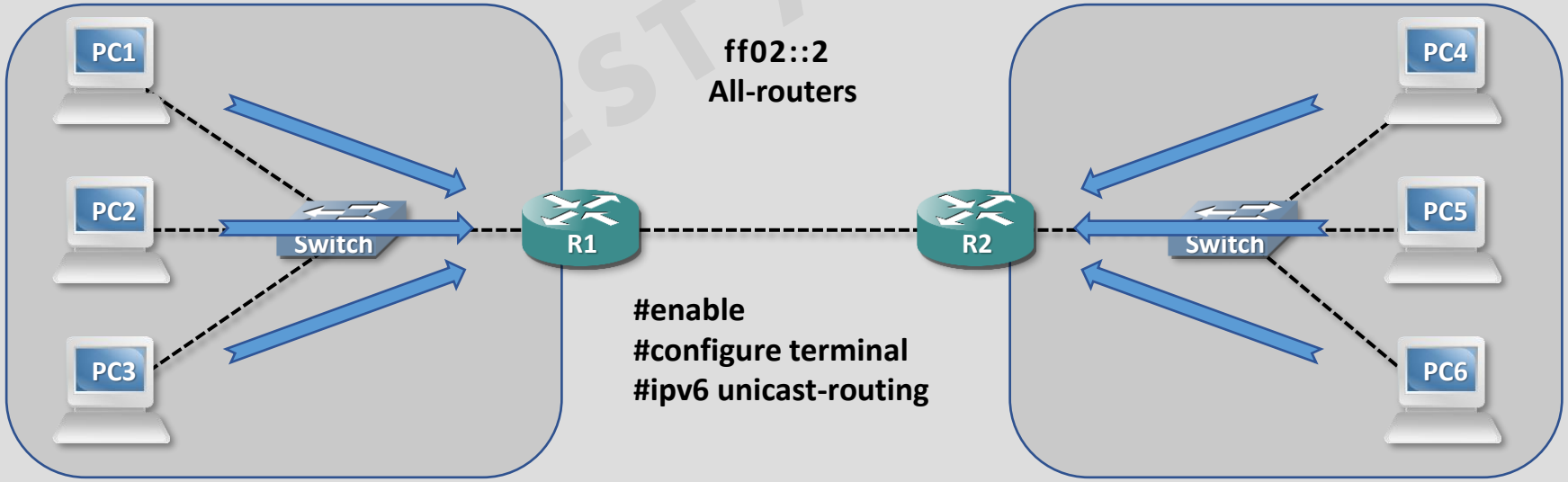


Link-Local Scope Multicast Groups

- **Link-Local Scope** have the same scope as link-local unicast addresses (limited to one link, one physical network).

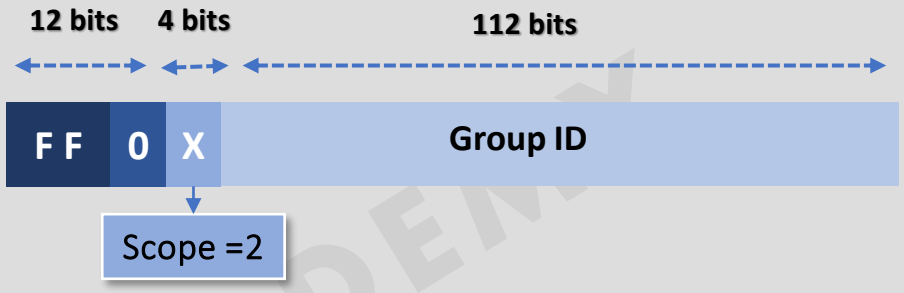


- **All-routers ff02::2**, All routers that are configured with **ipv6 unicast-routing** global configuration command are members of this link-local scope multicast group. All nodes use this multicast address to communicate with routers on their link.

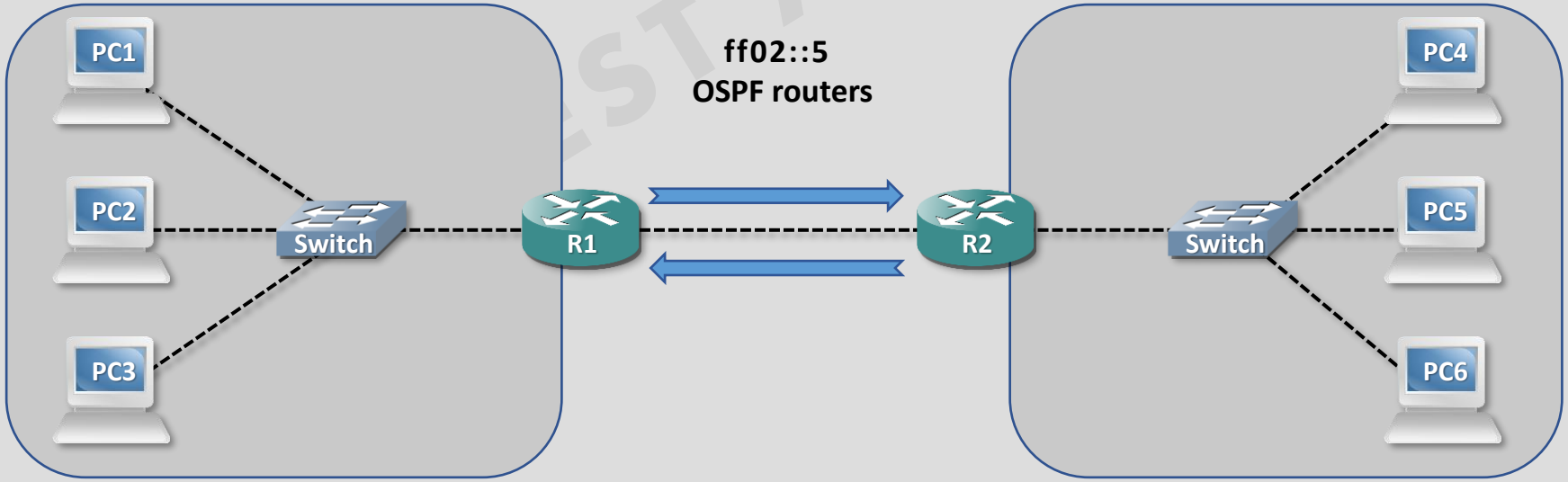


Link-Local Scope Multicast Groups

- **Link-Local Scope** have the same scope as link-local unicast addresses (limited to one link, one physical network).

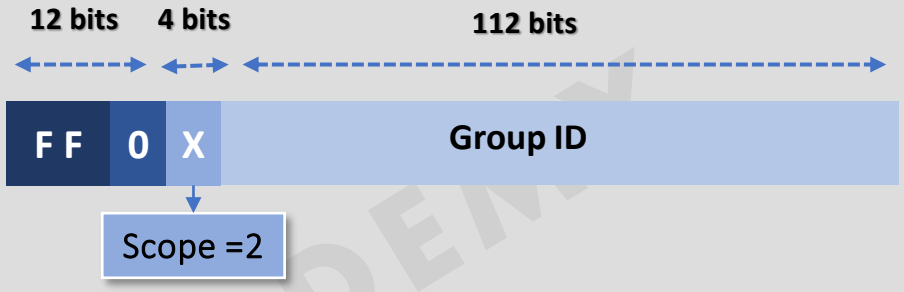


- **OSPF routers FF02::5** , All routers that are running **OSPFv3 protocol** are members of this link-local scope multicast group. Its used to exchange Hello packets and other routing information.

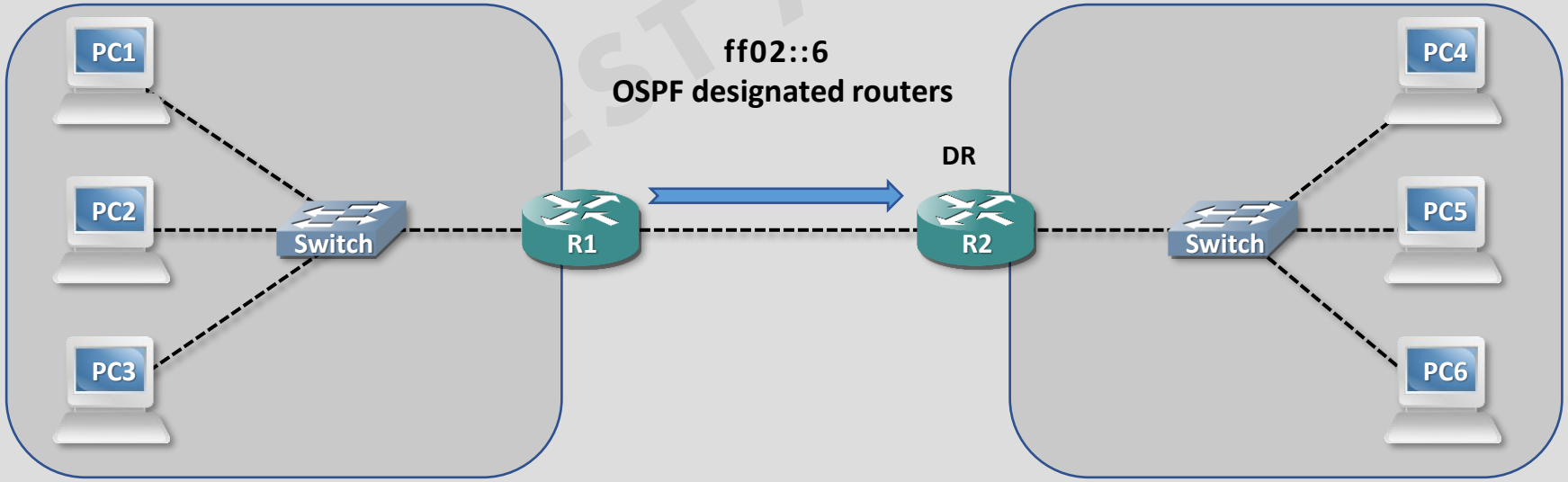


Link-Local Scope Multicast Groups

- **Link-Local Scope** have the same scope as link-local unicast addresses (limited to one link, one physical network).

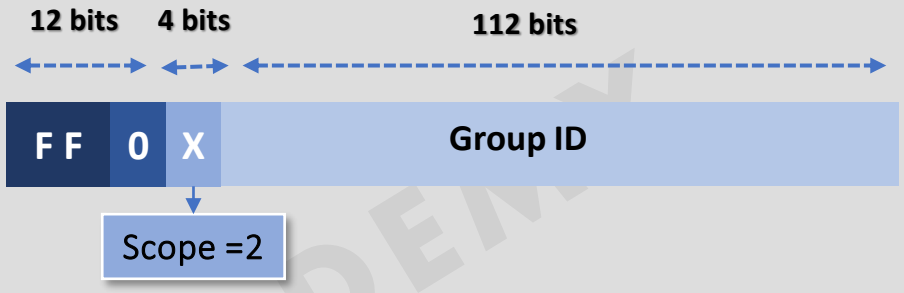


- **OSPF designated routers FF02::6** , the routers that is running **OSPFv3 protocol** and is being elected as a **designated router (DR)** is member of this link-local scope multicast group.

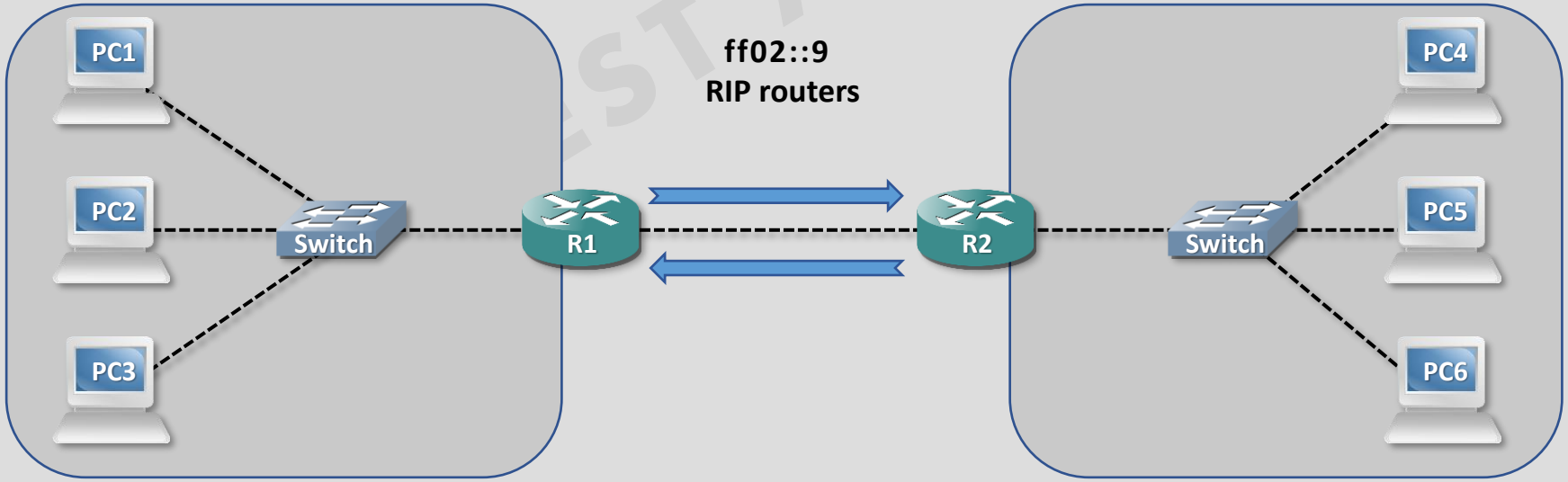


Link-Local Scope Multicast Groups

- **Link-Local Scope** have the same scope as link-local unicast addresses (limited to one link, one physical network).

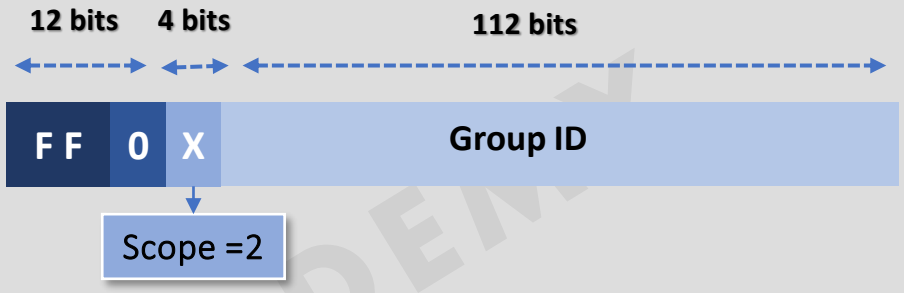


- **RIP routers FF02::9** , All routers that are running **RIPng protocol** are members of this link-local scope multicast group. Its used to exchange routing information.

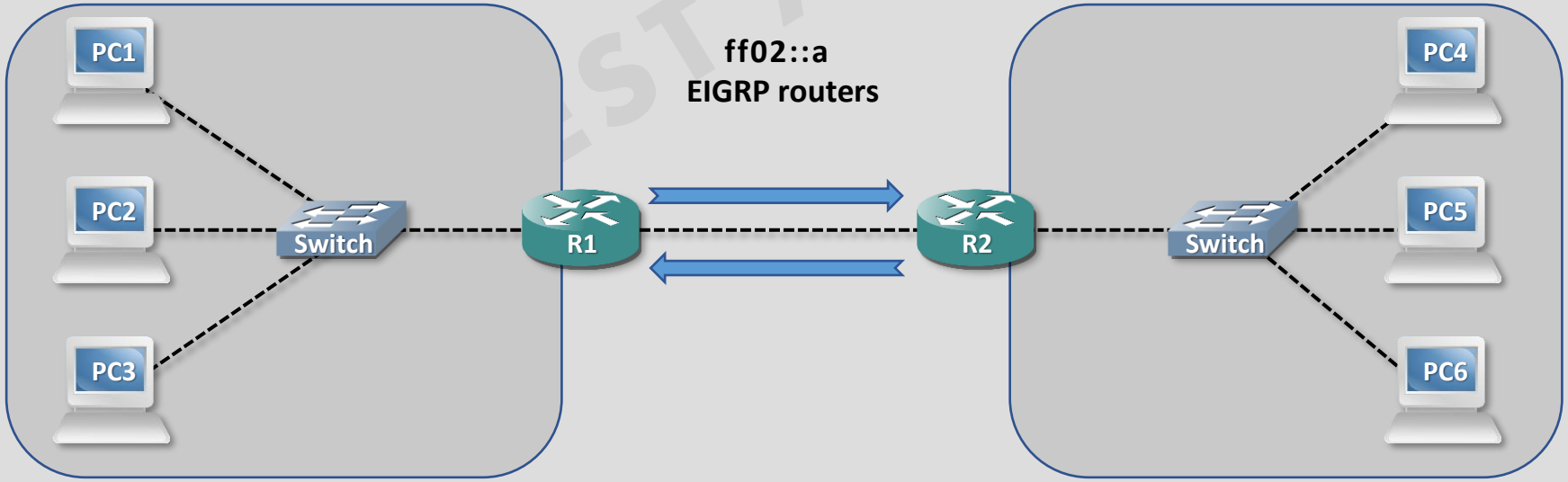


Link-Local Scope Multicast Groups

- **Link-Local Scope** have the same scope as link-local unicast addresses (limited to one link, one physical network).



- **EIGRP routers FF02::A** , All routers that are running **EIGRP for IPv6 protocol** are members of this link-local scope multicast group. Its used to exchange Hello packets and other routing information.



Link-Local Scope Multicast Groups

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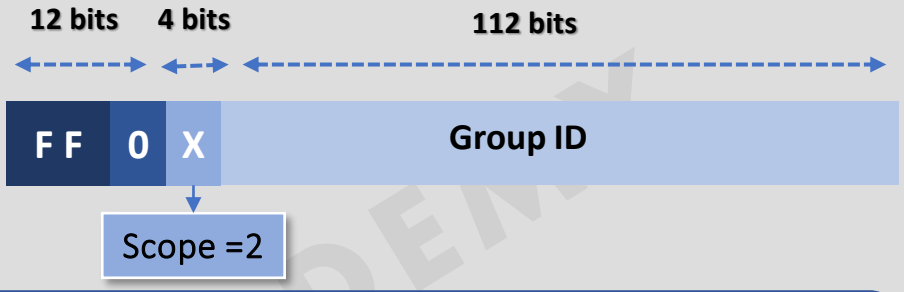
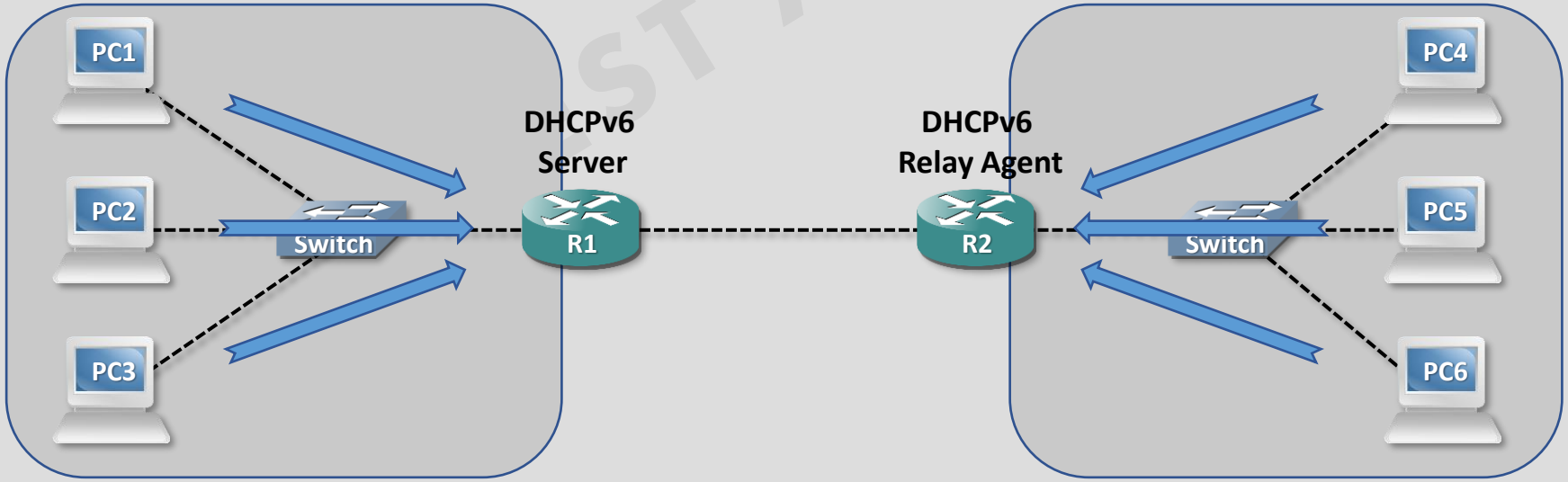
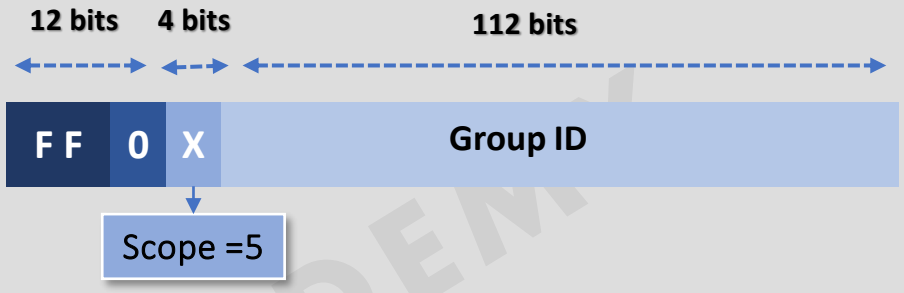


- **All_DHCP_Relay_Agents_and_Servers (ff02::1:2):** All DHCPv6 servers and relay agents are members of this link-local scope multicast group. Clients use this multicast address to communicate with DHCPv6 servers and relay agents on their link.



Site-Local Scope Multicast Groups

- **Site-Local Scope** spans a single site belonging to an organization (limited to the organization).



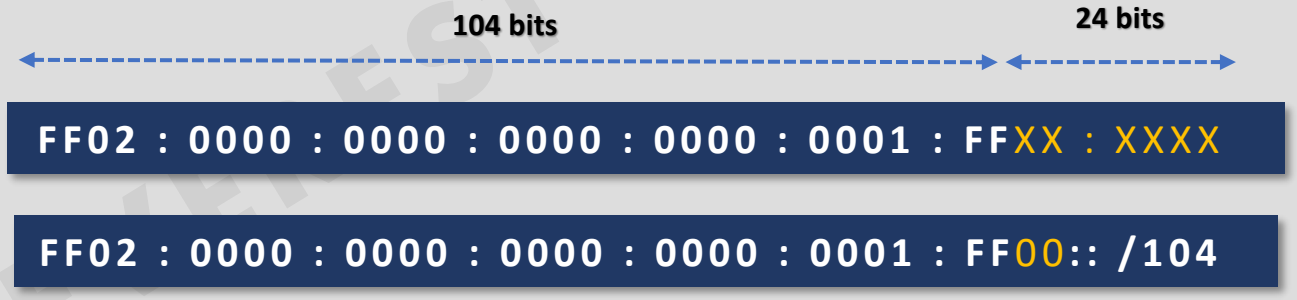
- When implementing **site-local scope** or any scope requiring multicast packets to be routed, IPv6 multicast routing must be enabled using the **ipv6 multicast-routing** global configuration command.

- **All_DHCP_Servers (ff05::1:3):** All DHCPv6 servers are members of this site-local multicast group. Relay agents use this multicast address to send messages to all DHCPv6 servers within a site or when they do not know the unicast address of the server.

/8 Prefix	Flag	Scope	Predefined Group ID	Compressed Format	Description
FF	0	5	0:0:0:0:0:0:2	FF05::2	All-routers (all routers on the LAN)
FF	0	5	0:0:0:0:0:1:3	FF05::1:3	All-DHCP servers

Solicited-Node Multicast Address

- **A solicited-node multicast address** is automatically created and assigned to an interface for every ***global unicast address, unique local address***, and ***link-local address*** on that interface.
- These multicast addresses are automatically generated using a special **mapping** of the device's **unicast address** with the solicited-node multicast prefix **FF02:0:0:0:0:1:FF**00::/**104**.
- The solicited-node multicast prefix **FF02:0:0:0:0:1:FF**00::/**104** is **prepended** to the low order ***24 bits*** of the **unicast address**.
- **Solicited-node multicast addresses** are used in ***Neighbor Solicitation (NS) messages*** for ***Address resolution*** and ***Duplicate Address Detection (DAD)*** .



Solicited-Node Multicast Address

Mapping Unicast Address to Solicited-Node Multicast Address

Mapping Solicited-Node Multicast to Ethernet MAC Addresses

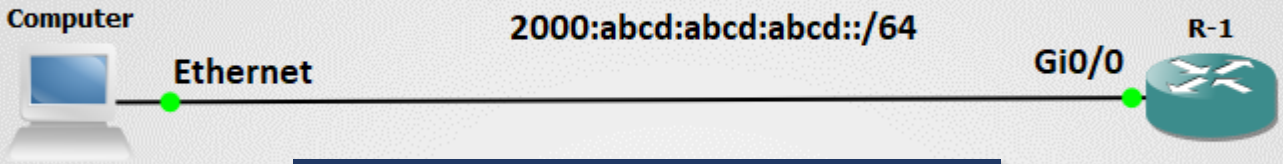
Source	Destination	Type
::	ff02::1:ffa9:7b00	Neighbor Solicitation
fe80::e8c:d4ff:fea9:7b00	ff02::1	Neighbor Advertisement

Link-Local Address — FE80 : : 0E8C : D4FF : FEA9 : 7B00

Solicited-Node Multicast Address — FF02 : : 1 : FFA9 : 7B00

Ethernet MAC Addresses — 33:33:FF:A9:7B:00

Solicited-Node Multicast Address



FF02 : : 1 : FFXX : XXXX/104

Source	Destination	Type
::	ff02::1:ff11:1111	Neighbor Solicitation
2000:abcd:abcd:abcd:1111:11…	ff02::1	Neighbor Advertisement

Global Unicast Address

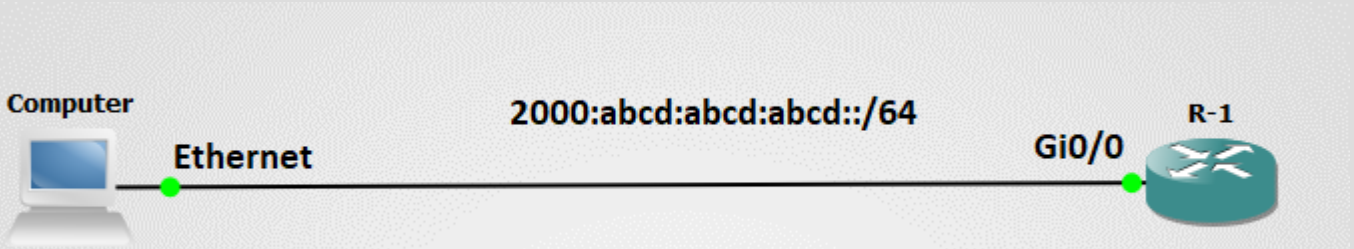
2000 : abcd : abcd : abcd : 1111 : 1111 : 1111 : 1111

Solicited-Node Multicast Address — **FF02 : : 1 : FF11 : 1111**

Ethernet MAC Addresses — **33:33:FF:11:11:11**

The benefit of using this mapping over using a broadcast address is that it allows the Ethernet NIC to examine the destination multicast MAC address and determine whether to pass the encapsulated data to an upper-layer protocol for processing.

Solicited-Node Multicast Address



FE80::E8D:4FF:FEA9:7B00

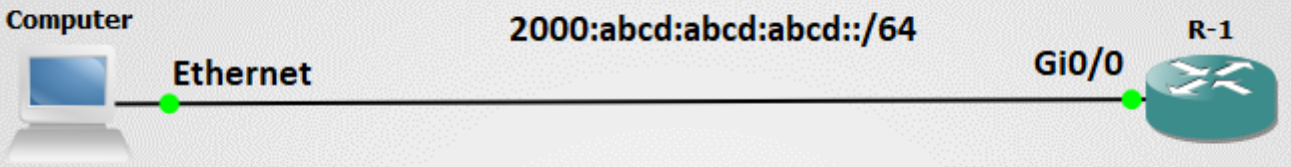
```
Router#
Router#show ipv6 interface gigabitEthernet 0/0
GigabitEthernet0/0 is up, line protocol is up
  IPv6 is enabled, link-local address is FE80::E8C:D4FF:FEA9:7B00
  No Virtual link-local address(es):
  Global unicast address(es):
    2000:ABCD:ABCD:ABCD:1111:1111:1111:1111, subnet is 2000:ABCD:ABCD:ABCD::/64
  Joined group address(es):
    FF02::1
    FF02::2
    FF02::1:FF11:1111
    FF02::1:FFA9:7B00
```

33:33:ff:a9:7b:00

33:33:ff:11:11:11

Ethernet MAC Addresses

Solicited-Node Multicast Address



- ❖ GUA: 2000:abcd:abcd:abcd:2222:2222:2222:2222
- ❖ MAC : 00:50:79:66:68:00
- ❖ GUA: 2000:abcd:abcd:abcd:1111:1111:1111:1111
- ❖ MAC 0c:8c:d4:a9:7b:00

```
C:\>ping    2000:abcd:abcd:abcd:1111:1111:1111:1111
```

Neighbor Solicitation

2000:abcd:abcd:abcd:2222:2222:2222:2222 ---> **FF02::1:FF11:1111**
00:50:79:66:68:00 ---> **33:33:ff:11:11:11**

Equivalent to ARP request

Neighbor Advertisement

Equivalent to ARP Reply

2000:abcd:abcd:abcd:2222:2222:2222:2222 <--- 2000:abcd:abcd:abcd:1111:1111:1111:1111
00:50:79:66:68:00 <--- 0c:8c:d4:a9:7b:00

Echo (ping) request

2000:abcd:abcd:abcd:2222:2222:2222:2222 ---> 2000:abcd:abcd:abcd:1111:1111:1111:1111
00:50:79:66:68:00 ---> **0c:8c:d4:a9:7b:00**

Echo (ping) reply

2000:abcd:abcd:abcd:2222:2222:2222:2222 <--- 2000:abcd:abcd:abcd:1111:1111:1111:1111
00:50:79:66:68:00 <--- 0c:8c:d4:a9:7b:00

Solicited-Node Multicast Address

Mapping Well-Known Multicast to Ethernet MAC Addresses

Description	Well-Known Multicast	Mapped Ethernet MAC Address
All-nodes	FF02::1	33:33:ff:00:00:01
All-routers	FF02::2	33:33:ff:00:00:02
All-OSPF Routers	FF02::5	33:33:ff:00:00:05
All-EIGRP Routers	ff02::a	33:33:ff:00:00:0a

Anycast Addresses