

Lecture 03

IP Address and subnetting

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Lecture

03

LEARNING OUTCOMES

- Understand the structure of IP address v4.0 (IPv4) and IP address v6.0 (IPv6)
- Understand the subnet mask for IPv4.
- Calculate the number of hosts for a given network.
- Recognize the IPv4 classes.
- Understand how an IP address v4.0 or v6.0 is assigned to the host.
- Differentiate between unicast, multicast, broadcast, and anycast.
- Understand the different types of unicast addresses of IPv6.
- Understand the meaning of Classless Inter-Domain Routing (CIDR).
- Understand how to perform subnetting for IPv4 addresses.
- Understand how to perform subnetting for IPv6 addresses.

An overview of binary numeral system

What is a numeral system?

A numeral system is a mathematical notation for representing numbers of a given set, there are four common numeral systems, they are **Binary**, **Octal**, **Decimal**, and **Hexadecimal** numeral system. There are five basic elements that identify each numeral system, and they are:

- **Digits**; The numbers used to express the numeral system.
- **Base**; The count of the numbers used in the numeral system.
- **Order**; The position (order) of the number within a given set of numbers for certain numeral system.
- **Weight**; Equals the base power the order (position) of the number within a given set of numbers **$(\text{Base})^{\text{Order}}$** .
- **Value**; The decimal value of each position within a given set of numbers and it equals ***the number that exist in this position multiply by the weight of this position.***

An overview of binary numeral system

Binary numeral system:

Binary system consists of only two numbers, Zero and One (0 and 1), Thus:

- **Digits;** 0,1.
- **Base;** two (2), since there are only two digits to represent this numeral system.

Binary	1	0	1	1
Order	3	2	1	0
Weight	$(2^3) = 8$	$(2^2) = 4$	$(2^1) = 2$	$(2^0) = 1$
Values	$8 \times 1 = 8$	$4 \times 0 = 0$	$2 \times 1 = 2$	$1 \times 1 = 1$

The decimal value of this binary number equals the summation of all values for each position within the number set $(1011)_2 = 1+2+0+8 = (11)_{10}$

An overview of binary numeral system

Conversion from binary to decimal:

Conversion from binary to decimal system can be performed as the following example:

1 1 1 0 1
← 4 3 2 1 0 →

Order from right to left

$$\begin{aligned}\text{Decimal value} &= [1 \times (2^4)] + [1 \times (2^3)] + [1 \times (2^2)] + [0 \times (2^1)] + [1 \times (2^0)] \\ &= 16 + 8 + 4 + 0 + 1 = (29)_{10}\end{aligned}$$

An overview of binary numeral system

Conversion from decimal to binary:

Conversion from decimal to binary system can be performed as the following example:

Binary base = 2	decimal number = 13	division remaining
2	6	1
2	3	0
2	1	1
2	0	1

The diagram illustrates the conversion of the decimal number 13 to its binary equivalent. It consists of a table with three columns: 'Binary base = 2', 'decimal number = 13', and 'division remaining'. The rows show the successive division of 13 by 2, resulting in remainders 1, 0, 1, and 1. Red arrows indicate the division process, and black arrows point from the remainders to the final binary result.

Result; $(13)_{10} = (1101)_2$

An overview of binary numeral system

One bit = 0 or 1, One Byte = 8 bits (*equals to 255 in decimal*) and is used to express the size of documents and other files, programs, ...etc.

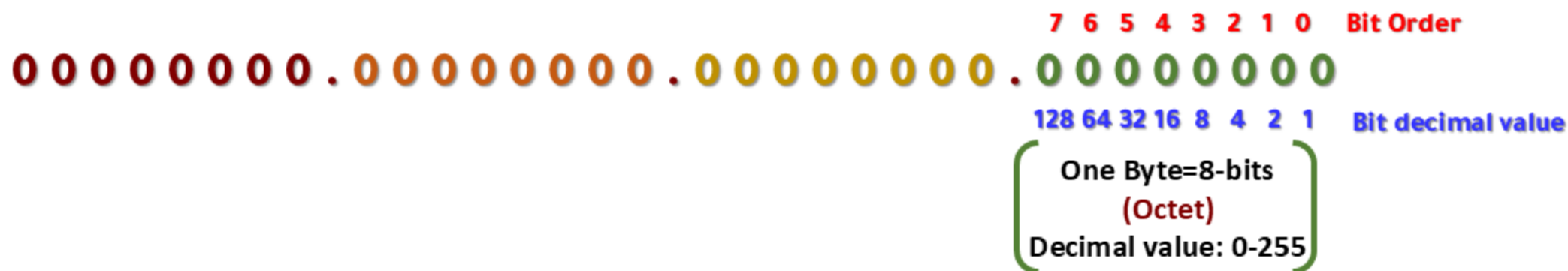
One Byte = 8 Bits

Bit No. 7	Bit No. 6	Bit No. 5	Bit No. 4	Bit No. 3	Bit No. 2	Bit No. 1	Bit No. 0							
1	0	0	0	1	0	1	1							
Bit Value $2^7 = 128$	Bit Value $2^6 = 64$	Bit Value $2^5 = 32$	Bit Value $2^4 = 16$	Bit Value $2^3 = 8$	Bit Value $2^2 = 4$	Bit Value $2^1 = 2$	Bit Value $2^0 = 1$							
128	+	0	+	0	+	0	+	8	+	0	+	2	+	1

The decimal value of binary byte is = 139

What is an IP Address v4.0?

Internet Protocol Address version 4.0 (IP Address v4.0) is a 32-bit Dotted Decimal Notation assigned to each device connected to a computer network that uses Transmission Control Protocol (TCP) / Internet Protocol(IP) for communication, each device in the same network should has a unique IP Address.



Example of IP Address v4.0:

192.168.10.5

human-readable IP Address

192 . 168 . 10 . 5

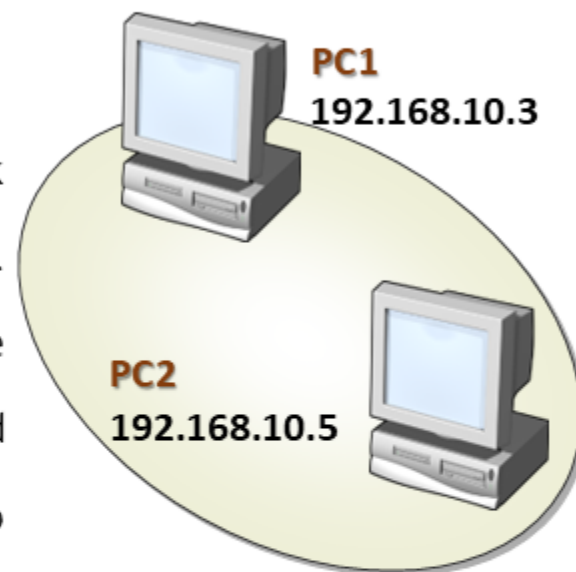
Device-readable IP Number

128 64 32 16 8 4 2 1 128 64 32 16 8 4 2 1 128 64 32 16 8 4 2 1 128 64 32 16 8 4 2 1

Each IP address has an IP number that is written in binary for it to be read and transmitted by computers across a network. This binary number is translated into an IP address, which is displayed in a decimal format that is human-readable.

Subnet Mask:

IP address v4.0 is consisting to two portions, **network ID** portion that identify the network where the computer sets, and **host ID** portion that identify the computer on its network. **Subnet Mask** is used to identify the two portions by indicating the network ID within the IP address. A subnet mask is a 32-bit number created by setting **host bits to all 0s** and setting **network bits to all 1s**. In this way, the subnet mask separates the IP address into the network and host addresses, for example:



Host	IP address	Subnet mask	Network ID	Shortcut IP/Mask
PC1	192.168.10.3	255.255.0.0	192.168.0.0	192.168.10.3/16
PC2	192.168.10.5	255.255.255.0	192.168.10.0	192.168.10.5/24

How does the subnet mask work?

IP Address: 192.168.10.5 11000000.10101000.00001010.00000101

Subnet mask: 255.255.255.0 11111111.11111111.11111111.00000000

X	Y	Z
0	0	0
1	0	0
0	1	0
1	1	1



Network ID: 192.168.10.0 11000000.10101000.00001010.00000000

Number of hosts of a given network:

No. of hosts of a given network = (base of binary numeral system)^{no. of bits of the host portion} - 2

= 2^{no. of bits of the host portion} - 2

Example:

A network has an ID 172.16.10.0 calculate the number of hosts that this network can hold.

OR

A host of an IP address of 172.16.10.9 and the subnet mask is 255.255.255.0 calculate the number of hosts that this network can hold.

The number of bits of the host portion for this network = 8-bits.

The number of hosts of this network = $2^8 - 2 = 254$ hosts

IP Address is classified into five classes depending on the number of hosts and uses as follows:

Class A IP address:

Class A IP address is for networks with large number of total hosts. Class A allows for 126 networks by using the first octet for the network ID. The first bit in this octet is always zero. The remaining seven bits in this octet complete the network ID. The 24 bits in the remaining three octets represent the hosts ID and allows for 16,777,214 million hosts per network. Class B network number values begin at 1 and end at 126.

<u>Rule</u>	<u>Minimums and maximums</u>	<u>Decimal range</u>
Class A: First bit is always 0.	00000000 = 0 01111111 = 127	1 - 126* * 0 and 127 are reserved.

Network ID	Host	Host	Host
------------	------	------	------

Public IP Range: 1.0.0.1 to 126.255.255.254

First octet value range from 1 to 126*

Private IP Range: 10.0.0.1 to 10.255.255.254

Subnet Mask: 255.0.0.0 (8 bits)

Number of Networks: 126

Number of Hosts per Network: 16,777,214

** 127.0.0.1 to 127.255.255.255 are network testing addresses (also referred to as loop-back addresses). These are virtual IP address; they cannot be assigned to a device.*

Class B IP address:

Class B addresses are for medium to large sized networks allows for 16,384 networks by using the first two octets for the network ID. The first two bits in the first octet are always 1 0. The remaining six bits, together with the second octet, complete the network ID. The 16 bits in the third and fourth octet represent host ID and allows for 65,534 hosts per network. Class B network number values begin at 128 and end at 191.

<u>Rule</u>	<u>Minimums and maximums</u>	<u>Decimal range</u>
Class B: First two bits are always 10.	10000000 = 128 10111111 = 191	128 - 191

Network ID	Network ID	Host	Host
------------	------------	------	------

Public IP Range: 128.0.0.1 to 191.255.255.254

First octet value range from 128 to 191

Private IP Range: 172.16.0.1 to 172.31.255.254

Subnet Mask: 255.255.0.0 (16 bits)

Number of Networks: 16,384

Number of Hosts per Network: 65,534

Class C IP address:

Class C addresses are used in small local area networks (LANs) allows for 2,097,152 million networks by using the first three octets for the network ID. In a class C IP address, the first three bits of the first octet are always 1 1 0. And the remaining 21 bits of first three octets complete the network ID. The last octet (8 bits) represent the host ID and allows for 254 hosts per network. Class C network number values begins at 192 and end at 223.

<u>Rule</u>	<u>Minimums and maximums</u>	<u>Decimal range</u>
Class C: First three bits are always 110.	11000000 = 192 11011111 = 223	192 - 223

Network ID	Network ID	Network ID	Host
------------	------------	------------	------

Public IP Range: 192.0.0.1 to 223.255.255.254

First octet value range from 192 to 223

Private IP Range: 192.168.0.1 to 192.168.255.254

Subnet Mask: 255.255.255.0 (8 bits)

Number of Networks: 2,097,152

Number of Hosts per Network: 254

Class D IP address:

Class D IP addresses are not allocated to hosts and are used for multicasting. Multicasting allows a single host to send a single stream of data to thousands of hosts across the Internet at the same time. It is often used for audio and video streaming, such as IP-based cable TV networks.

<u>Rule</u>	<u>Minimums and maximums</u>	<u>Decimal range</u>
Class D: First four bits are always 1110.	11100000 = 224 11101111 = 239	224 - 239
IP Range: 224.0.0.1 to 239.255.255.255		
First octet value range from 224 to 239		
Subnet Mask: N/A, no host bits within the Class D		
Number of Networks: N/A		
Number of Hosts per Network: Multicasting		

Class E IP address:

Class E IP addresses are not allocated to hosts and are not available for general use. These are reserved for research purposes.

<u>Rule</u>	<u>Minimums and maximums</u>	<u>Decimal range</u>
Class E:	11110000=240	240-255
First Four bits are always 1111	11111111=255	

IP Range: 240.0.0.1 to 255.255.255.255

First octet value range from 240 to 255

Subnet Mask: N/A

Number of Networks: N/A

Number of Hosts per Network: Research/Experimental

Private IP Addresses:

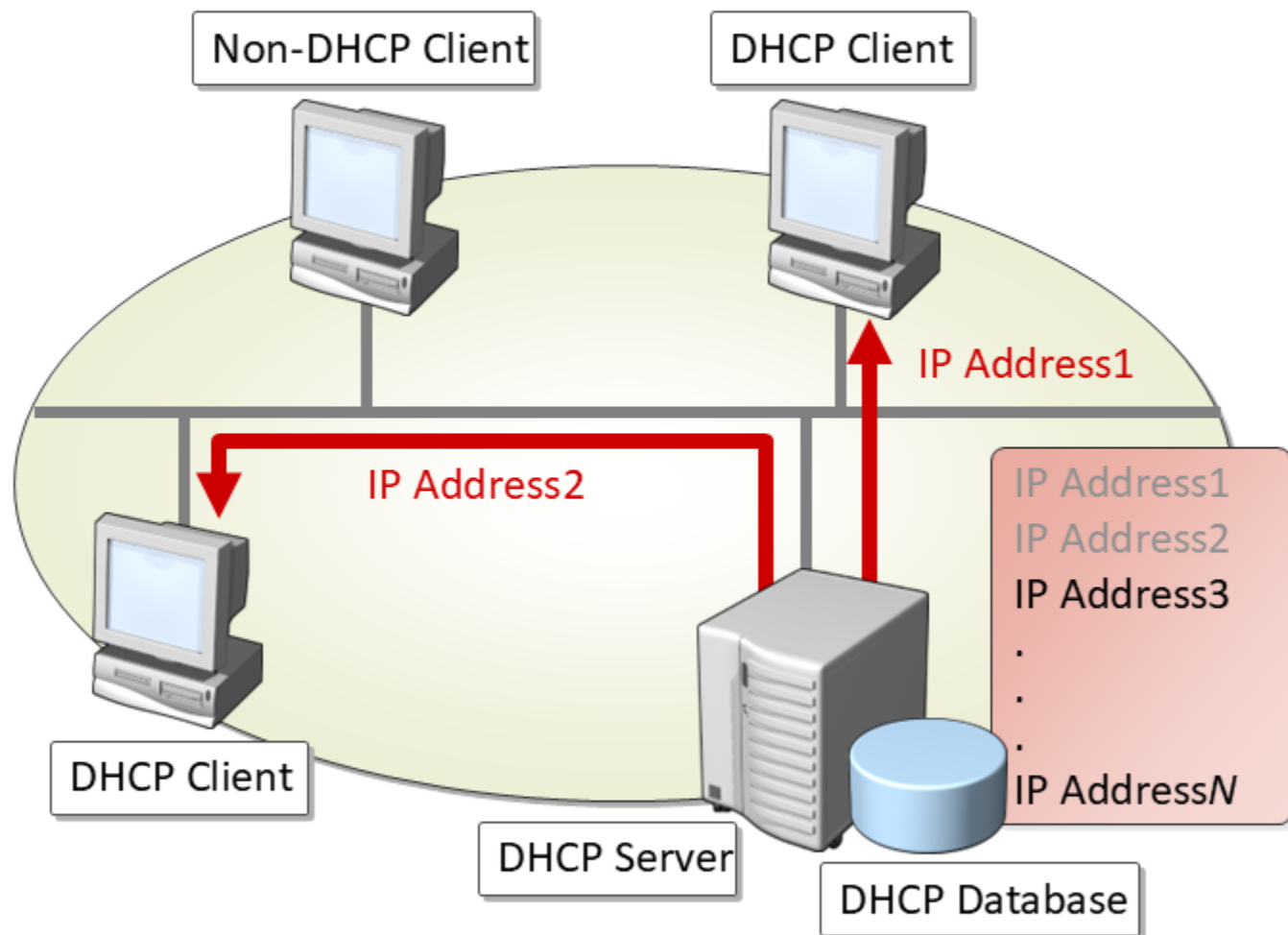
Within each network class, there are designated IP address that is reserved specifically for private/internal use only. This IP address **cannot be used on Internet-facing devices** as that are **non-routable**. However, within your own home or business network, private IP addresses are assigned to your devices (such as workstations, printers, and file servers).

Class A	Private Range: 10.0.0.1 to 10.255.255.254
Class B	Private Range: 172.16.0.1 to 172.31.255.254
	APIPA Range: 169.254.0.1 to 169.254.255.254 <i>Automatic Private IP Addressing (APIPA) is a feature with Microsoft Windows-based computers to automatically assign itself an IP address within this range if a Dynamic Host Configuration Protocol (DHCP) server is not available on the network.</i>
Class C	Private Range: 192.168.0.1 to 192.168.255.254

IP Address and subnetting

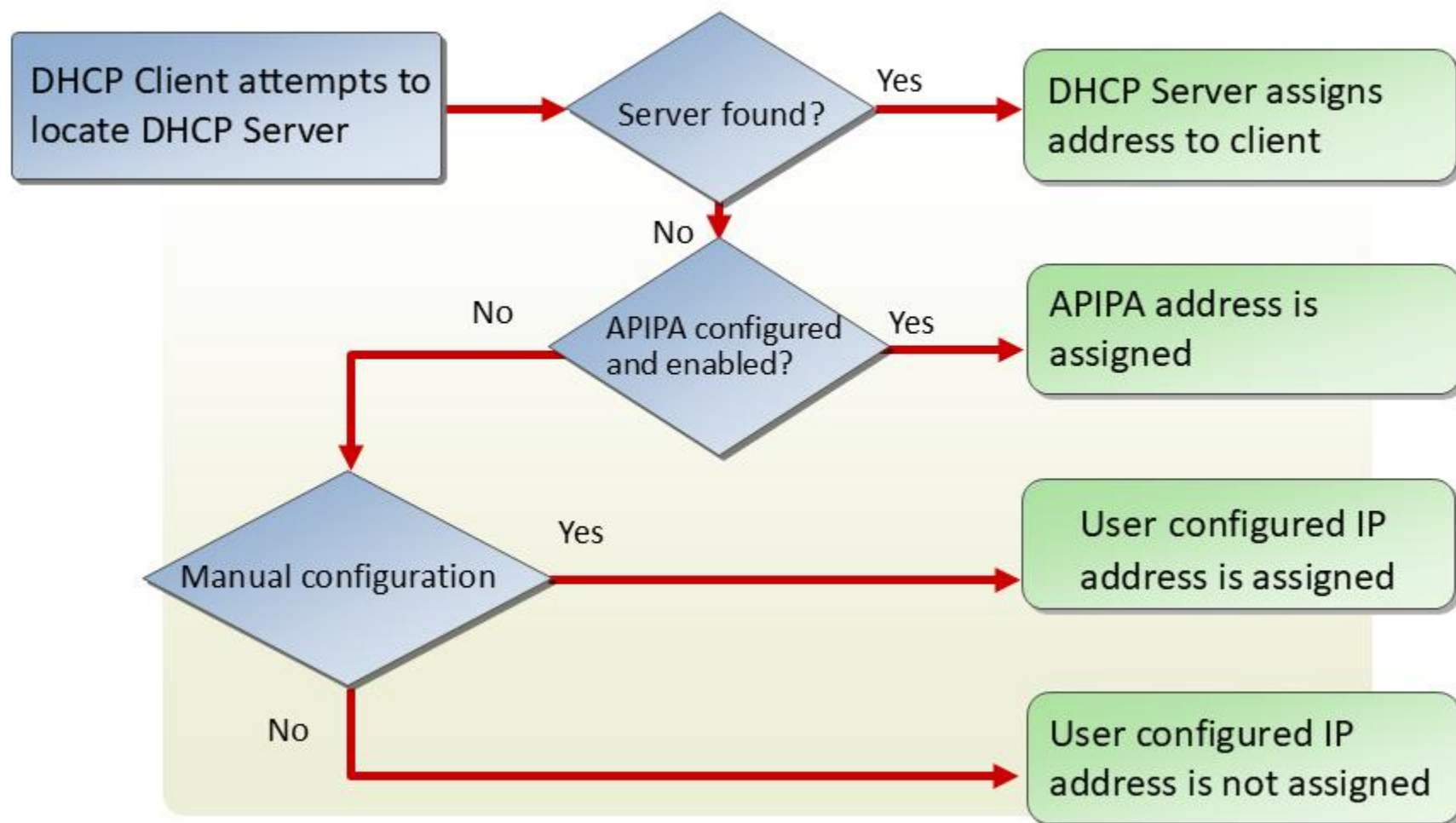
DHCP is a mechanism that automates the assignment of IP addresses to fixed and mobile hosts that are connected wired or wirelessly.

The device sends a request for an IP address that is picked up by a **DHCP** server. The server responds by delivering an IP address to the device, and it may take it back after a specified time to be **reassigned** to another device as it seeks access to the network.



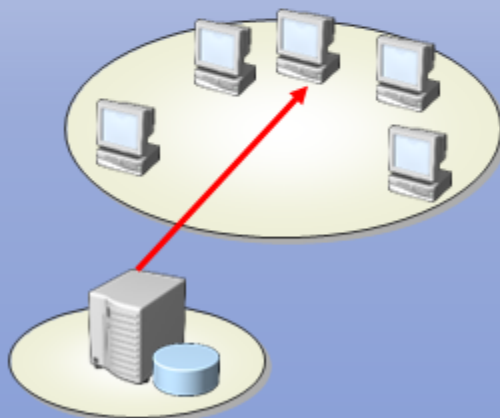
How a host get an IP Address v4.0?

- **Statically**; Where a user assign an IP address in the IP configuration window statically.
- **Dynamic Host Configuration Protocol (DHCP)**; DHCP assigns dynamic IP addresses to devices on a network. With dynamic addressing, a device can have a different IP address every time it connects to the network.
- **Automatic Private IP Addressing (APIPA)**; APIPA is a feature of later Windows operating systems that allows DHCP clients to automatically self-configure an IP address and subnet mask when a DHCP server isn't available.

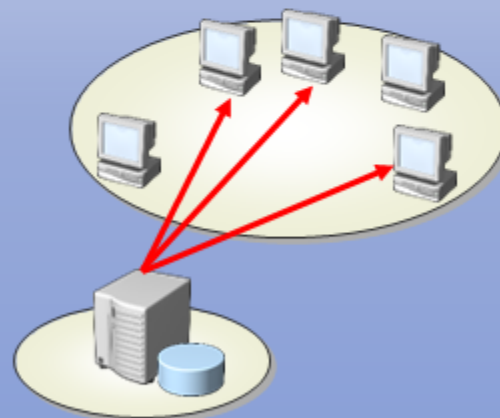


IP Address v4.0 Types**Unicast**

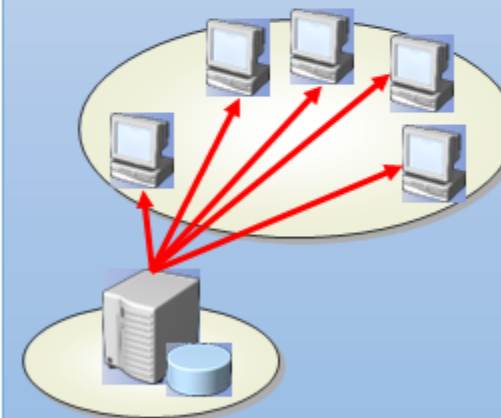
One to One

**Multicast**

One to Many

**Broadcast**

One to All

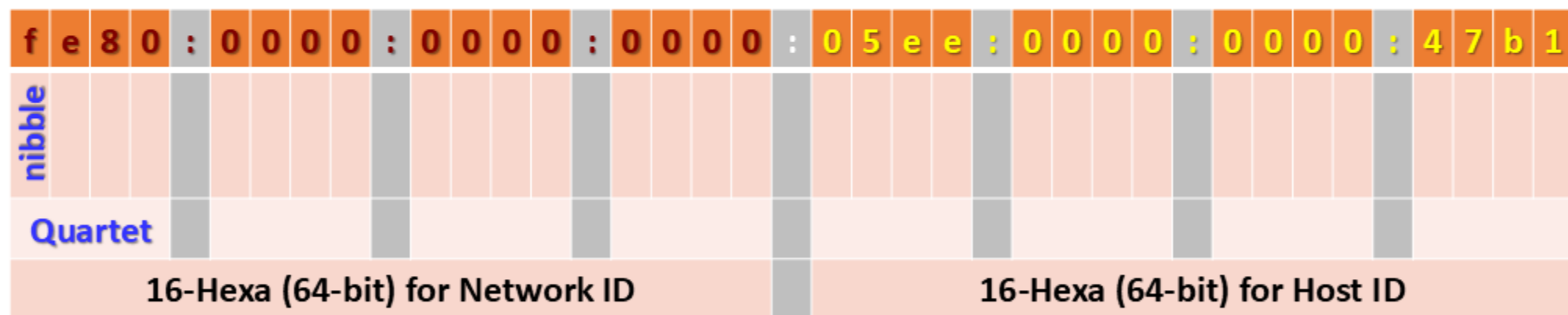


Summary of IP address v4.0

- Each four numbers in an IP address v4.0 is called an Octet (8 bits) and Each Octet can only has a number from 0 (00000000) to 255 (11111111). It is consisting of two portions, network ID portion, and host ID portion.
- Subnet mask is used to identify the two portions of IP address v4.0.
- No. of hosts of a given network = $2^{\text{no. of bits of the host portion}} - 2$. Since the host ID can not be all zeros or all "255", All zeros represent network ID, and All "255" represent broadcast address.
- There are five classes of IP address v4.0; **Class A** (1-126), **Class B** (128-191), **Class C** (192-223), **Class D** (224-239) for multicasting only , **Class E** (240-255) for experimental and research purposes.
- In private network Use **private IP range** which have been reserved from public internet use. (10.0.0.0, 172.16.0.0, 192.168.0.0, and 169.254.0.0).

What is an IP Address v6.0?

Internet Protocol Address version 6.0 (IP Address v6.0) is a **128-bit Hexadecimal Notation** (each 4-bit called nibble) divided into eight blocks (each block called quartet) separated by colons; each block is displayed in four hexadecimal number (16-bit).



IP Address v6.0 simplified:

Simplify by suppressing the leading 0's.

f e 8 0 : 0 0 0 0 : 0 0 0 0 : 0 0 0 0 : 0 5 e e : 0 0 0 0 : 0 0 0 0 : 4 7 b 1

f e 8 0 : 0 : 0 : 0 : 5 e e : 0 : 0 : 4 7 b 1

Express a single contiguous set of 0 block into "::".

f e 8 0 : 0 : 0 : 0 : 5 e e : 0 : 0 : 4 7 b 1

f e 8 0 :: 5 e e : 0 : 0 : 4 7 b 1

OR

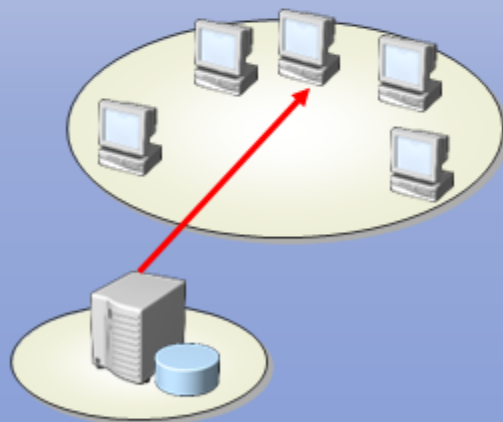
f e 8 0 : 0 : 0 : 0 : 5 e e :: 4 7 b 1

NOT f e 8 0 :: 5 e e :: 4 7 b 1

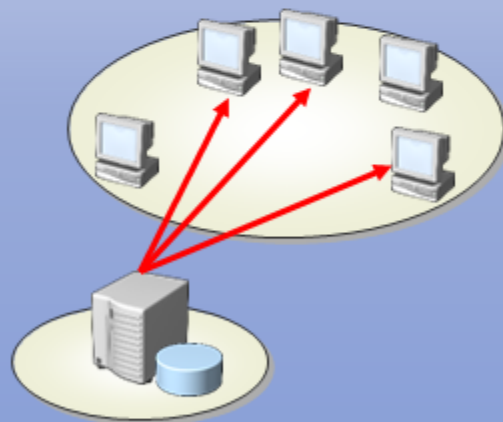


IP Address v6.0 Types**Unicast**

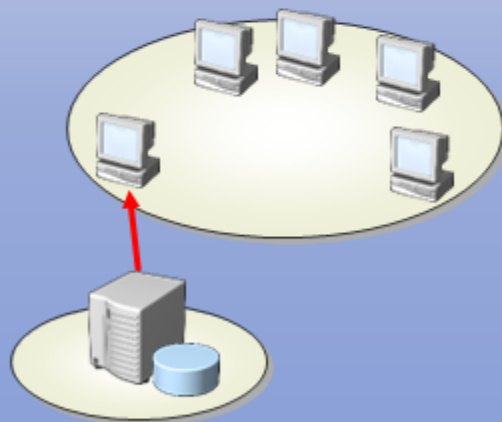
One to One

**Multicast**

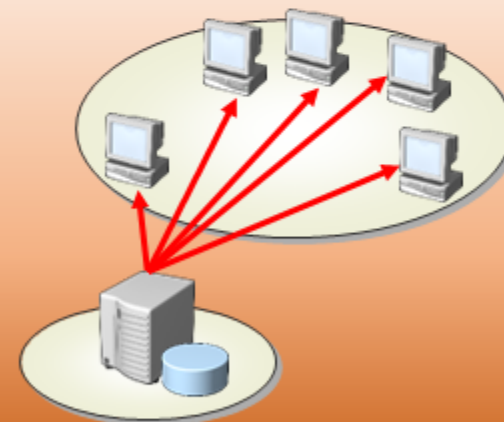
One to Many

**Anycast**

One to Closest node

**Broadcast**

One to All

**Not available in IPv6
replaced by Multicast**

Unicast

Global Unicast Address

Globally routable on the Internet equivalent to public IP address v4.0

First quartet = 2000-3fff

Unique Local Address

Assigned by the administrator equivalent to Private IP address v4.0

Always start with fd

Link-Local Address

Communicates with neighboring nodes on the same link equivalent to APIPA IP address v4.0

Always start with fe80

Loopback Address

Used for troubleshooting and testing equivalent to 127.0.0.1 in IP address V4.0.

0.0.0.0.0.0:0:1 or ::1

Compatibility Address

Used for migration from IP address v4.0 to IP address v6.0

First quartet = 2002

Global Unicast Address

2	0 0 1 : 0 d b 8 : 0 c a d :	0 8 0 0	: 0 0 0 0 : 0 0 0 0 : 5 8 e 0 : 3 0 0 a
3-bits Address Prefix	Global routing prefix Assigned by IANA	16-bits for subnet ID Assigned by organization	Controlled by the organization They could be manually assigned or using DHCP
always start with 001 (0010 or 0011) in hexa = 2 or 3	Assigned by local registry the whole 48-bits (including address prefix) referred to site prefix	Used by Organization for subnetting The ISP May use part of Subnet ID	
16-Hexa (64-bit) for Network ID			16-Hexa (64-bit) for Interface ID

Unique Local Address

f d	0 1 : 0 d b 8 : 0 c a d :	0 8 0 0	: 0 0 0 0 : 0 0 0 0 : 5 1 e 0 : 3 0 0 b
8-bits Address Prefix always start with (fd)	40-bits assigned and configured by network administrator	16-bits for subnet ID assigned by admin	Controlled by the administrator They could be manually assigned or using DHCP
	16-Hexa (64-bit) for Network ID	16-Hexa (64-bit) for Interface ID	

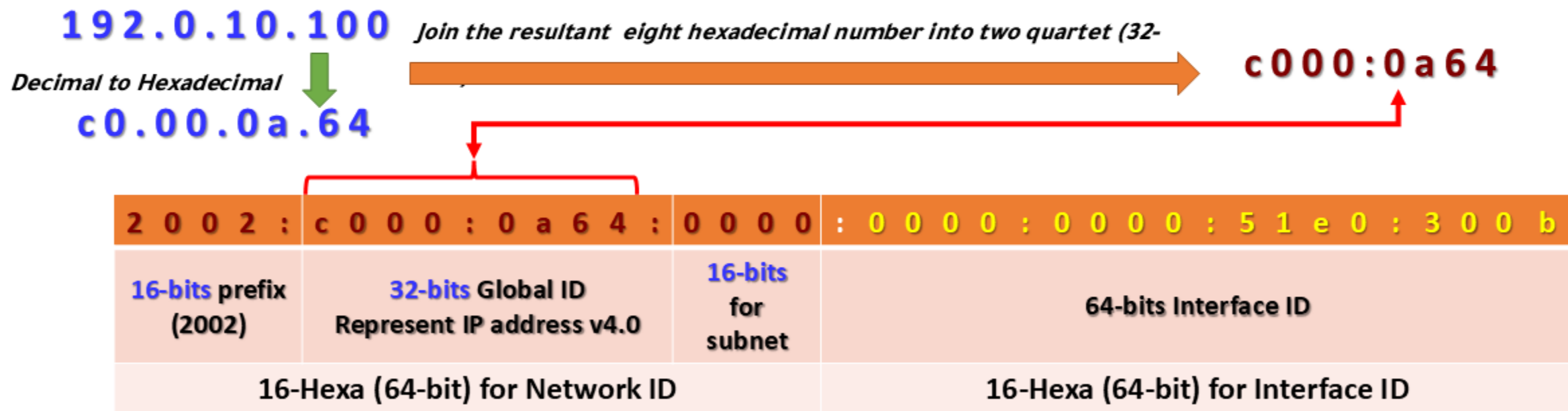
Link-Local Address

f e 8	0 : 0 0 0 0 : 0 0 0 0 : 0 0 0 0	: 0 0 0 0 : 0 0 0 0 : 6 7 e 0 : 3 0 a b
10-bits Address Prefix always start with (fe80)	54-bits all zeros	Randomized Interface ID
	16-Hexa (64-bit) for Network ID	16-Hexa (64-bit) for Interface ID

Every node will receive a Link-Local address

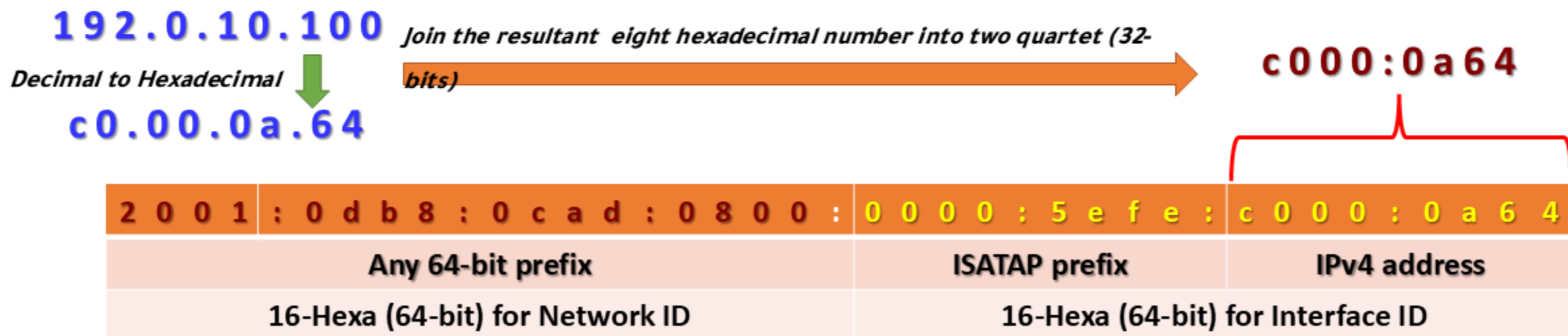
Compatibility Address

Using **6to4** method where IPv4 is encapsulated into IPv6, **for example**; IPv4= 192.0.10.100. First convert each octet to hexadecimal number where each octet equals two hexadecimal as following:



Compatibility Address

Using **Intra-Site Automatic Tunnel Addressing Protocol (ISATAP)** method where IPv4 is encapsulated into Interface ID portion of IPv6. This method is used for Intranet only. It starts with **0:5efe**, from the previous example;



Multicast

All nodes multicasting : ff02::1

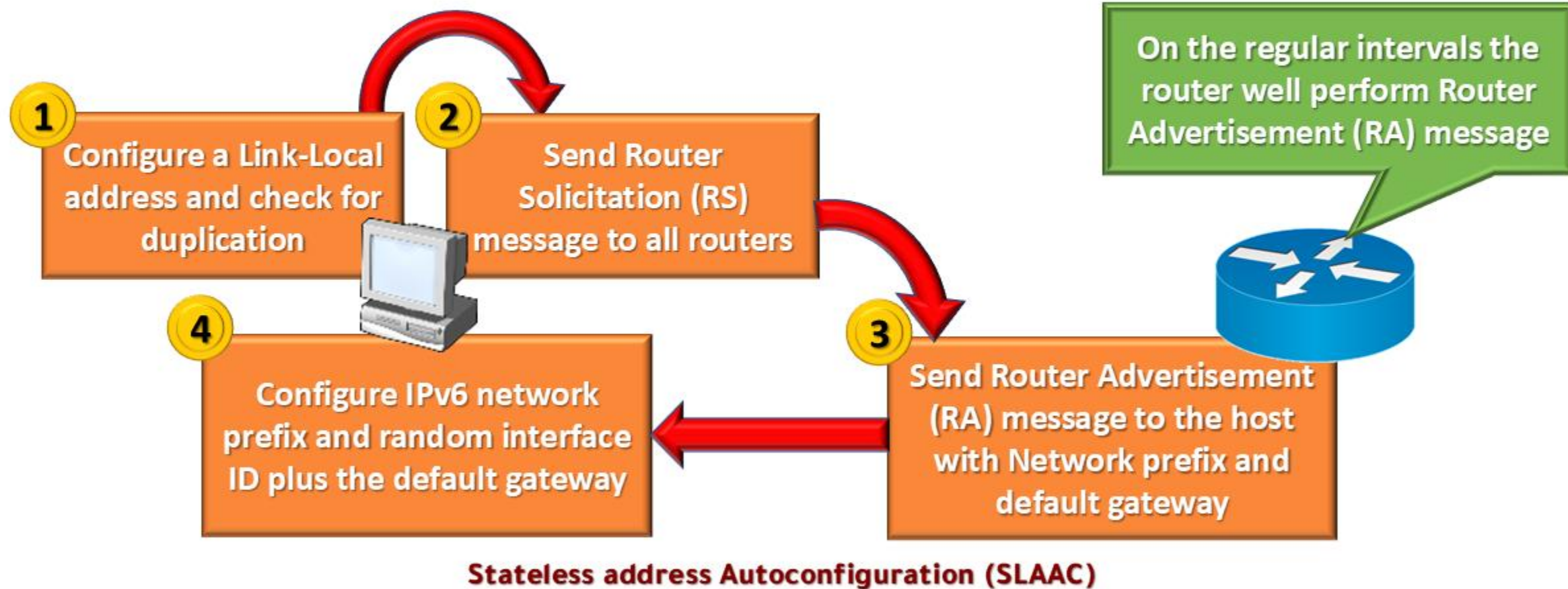
All Routers multicasting : ff02::2

Used for neighbor discovery.

f f	0	2	:	0 0 0 0 : 0 0 0 0 : 0 0 0 0 : 0 0 0 0 : 0 0 0 0 : 0 0 0 0 : 0 0 0 2
8-bit prefix	Flag	Scop		112-bits Group ID

How a host get an IP Address v6.0?

- **Stateful Address Autoconfiguration;** refers to a host ability to get address information using DHCP v6.0 or manually configured.
- **Stateless address Autoconfiguration (SLAAC);** refers to a host ability to get address information (Basic configuration) by using **neighbor discovering protocol**, no **DHCP** required but it could be used to provide additional configuration such as **DNS**.

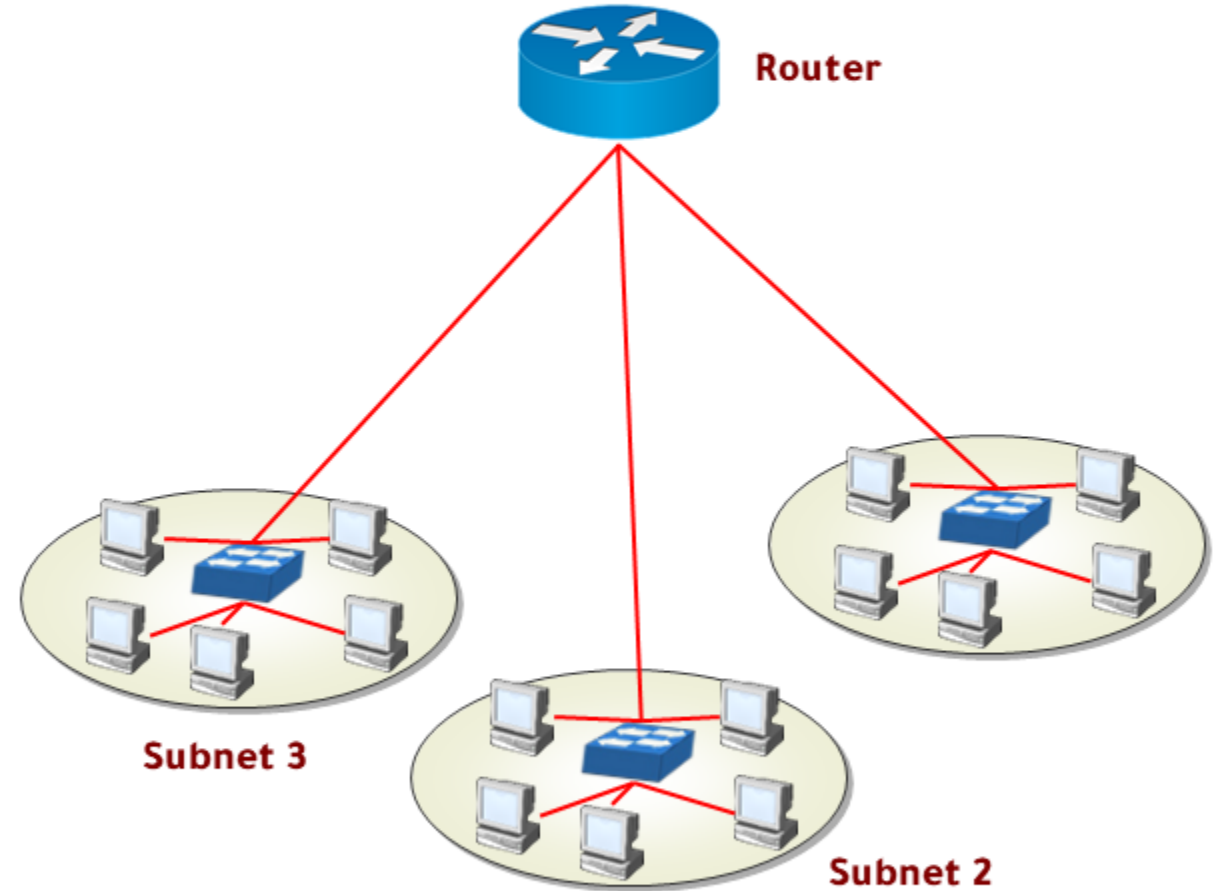


Summary of IP address v6.0

- IP address v6.0 consists of 32 hexadecimal number (128-bits) in eight quartet each quartet is four hexadecimals (16-bits) each decimal number called nibble.
- Global unified address starts from **2000 to 3fff** routable on the Internet.
- Link-Local address starts with **fe80** and used for local network only (it is not routable on the Internet).
- Unique local address starts with **fd** and used in private network only (it is not routable on the Internet).
- Compatibility Address used for migration from IPv4 to IPv6, in **6to4** method IPv4 is encapsulated into IPv6 in the network ID portion which starts with 2002 where in **ISATAP** method the IPv4 is encapsulated into Interface ID portion of IPv6 which starts with **0:5efe**.
- Multicast address starts with **ff** and used for neighbor discovery.

Subnetting:

Subnetting is the process of dividing a network into two or more networks (subnets) by taking one-bit or more from the host ID as a subnet ID. **Subnetting** narrows down the IP address to usage within a range of devices. Therefore, network traffic can travel a shorter distance without passing through unnecessary routers to reach its destination making networks more efficient.



Classless Inter-Domain Routing (CIDR):

CIDR is based on **subnetting**; Taking a single class of IP addresses and chopping it up into multiple smaller groups. It replaces the old system based on classes A, B, and C. This scheme also helped greatly extend the life of **IPv4** as well as slow the growth of routing tables. **CIDR** and **subnetting** are virtually the same thing. **Subnetting** is done by an organization and **CIDR** is done by an **ISP**.

*The problem would occur when an organization required more than 254 host machines and therefore would no longer fall into **class C** but rather **class B**. This means that the organization would use a **class B license** even though they had far less than 65,535 hosts. Therefore, if an organization only required 2,500 hosts, they would be wasting about 63,000 hosts by holding a **class B license** which would greatly **decrease the availability of IPv4 addresses unnecessarily**.*

How does CIDR work?

CIDR is based on **variable-length subnet masking (VLSM)**. This allows it to define prefixes of arbitrary lengths making it much more efficient than the old system. CIDR is an alternate method of representing a subnet mask. It is simply a count of the number of network bits and preceded by a slash "/" and follows the IP address. *For example*, an IP address v4.0 of 131.10.55.70 with a subnet mask of 255.255.0.0 (which has 8 network bits) would be represented as **131.10.55.70 /16**.

CIDR	Dotted Decimal		CIDR	Dotted Decimal
/1	128.0.0.0		/17	255.255.128.0
/2	192.0.0.0		/18	255.255.192.0
/3	224.0.0.0		/19	255.255.224.0
/4	240.0.0.0		/20	255.255.240.0
/5	248.0.0.0		/21	255.255.248.0
/6	252.0.0.0		/22	255.255.252.0
/7	254.0.0.0		/23	255.255.254.0
/8	255.0.0.0		/24	255.255.255.0
/9	255.128.0.0		/25	255.255.255.128
/10	255.192.0.0		/26	255.255.255.192
/11	255.224.0.0		/27	255.255.255.224
/12	255.240.0.0		/28	255.255.255.240
/13	255.248.0.0		/29	255.255.255.248
/14	255.252.0.0		/30	255.255.255.252
/15	255.254.0.0		/31	255.255.255.254
/16	255.255.0.0		/32	255.255.255.255

Subnetting of IPv4:

A network ID of class C IPv4; 192.168.150.0 /24. Divide this network into 4 subnet and determine The following for each subnet:

- The subnet ID.
- The broadcast ID.
- Maximum hosts per subnet.
- The host ID range (first IP address and last IP address).
- The new subnet mask.

192 . 168 . 150 . 0
 11000000.10101000.10010110.00000000
 128 64 32 16 8 4 2 1 128 64 32 16 8 4 2 1 128 64 32 16 8 4 2 1 128 64 32 16 8 4 2 1
 255 . 255 . 255 . 0

Number of bits	Power of 2 (the base of binary number)	Decimal value
0	2^0	1
1	2^1	2
2	2^2	4
3	2^3	8
4	2^4	16
5	2^5	32
6	2^6	64
7	2^7	128

Q: How many bits should be taken from host ID portion?

We need **four subnets**, so from the right table four subnets need **2-bits** from the host ID portion.

	192	.	168	.	150	.	0		
	11000000	.	10101000	.	10010110	.	00	000000	
	Network ID						Subnet ID	Host ID	Maximum hosts
Subnet 1	11000000	.	10101000	.	10010110	.	00	000000 - 111111	$2^6 - 2 = 62$
Subnet 2	11000000	.	10101000	.	10010110	.	01	000000 - 111111	$2^6 - 2 = 62$
Subnet 3	11000000	.	10101000	.	10010110	.	10	000000 - 111111	$2^6 - 2 = 62$
Subnet 4	11000000	.	10101000	.	10010110	.	11	000000 - 111111	$2^6 - 2 = 62$
Subnet Mask	11111111	.	11111111	.	11111111	.	11	000000	
	255		255		255	.	192		

Subnet 1							
Network ID	192	.	168	.	150	.	0 /26
	11000000	.	10101000	.	10010110	.	00 000000
Broadcast	192	.	168	.	150	.	63 /26
	11000000	.	10101000	.	10010110	.	00 111111
First IP address	192	.	168	.	150	.	1 /26
	11000000	.	10101000	.	10010110	.	00 000001
Last IP address	192	.	168	.	150	.	62 /26
	11000000	.	10101000	.	10010110	.	00 111110

Subnet 2							
Network ID	192	.	168	.	150	.	64 /26
	11000000	.	10101000	.	10010110	.	01 000000
Broadcast	192	.	168	.	150	.	127 /26
	11000000	.	10101000	.	10010110	.	01 111111
First IP address	192	.	168	.	150	.	65 /26
	11000000	.	10101000	.	10010110	.	01 000001
Last IP address	192	.	168	.	150	.	126 /26
	11000000	.	10101000	.	10010110	.	01 111110

Subnet 3							
Network ID	192	.	168	.	150	.	128 /26
	11000000	.	10101000	.	10010110	.	10 000000
Broadcast	192	.	168	.	150	.	191 /26
	11000000	.	10101000	.	10010110	.	10 111111
First IP address	192	.	168	.	150	.	129 /26
	11000000	.	10101000	.	10010110	.	10 000001
Last IP address	192	.	168	.	150	.	190 /26
	11000000	.	10101000	.	10010110	.	10 111110

Subnet 4							
Network ID	192	.	168	.	150	.	192 /26
	11000000	.	10101000	.	10010110	.	11 000000
Broadcast	192	.	168	.	150	.	255 /26
	11000000	.	10101000	.	10010110	.	11 111111
First IP address	192	.	168	.	150	.	193 /26
	11000000	.	10101000	.	10010110	.	11 000001
Last IP address	192	.	168	.	150	.	254 /26
	11000000	.	10101000	.	10010110	.	11 111110

Subnetting of IPv6:

An international car maintenance company wants to open branches in three countries (Egypt, Saudi Arabia, and UAE). Each country has 60 different locations, and each location has ten workshops.

The ISP has assigned the following public IPv6 address (**2001:db8:cad:: /48**) to the company. **Perform subnetting to the previous IPv6 address to create three networks for the countries, 60 networks for the locations within each country, and ten networks for workshops within each location.**

Egypt

Country dedicated subnet

↳ 60 locations
 ↳ 10 workshops

**Saudi Arabia**

Country dedicated subnet

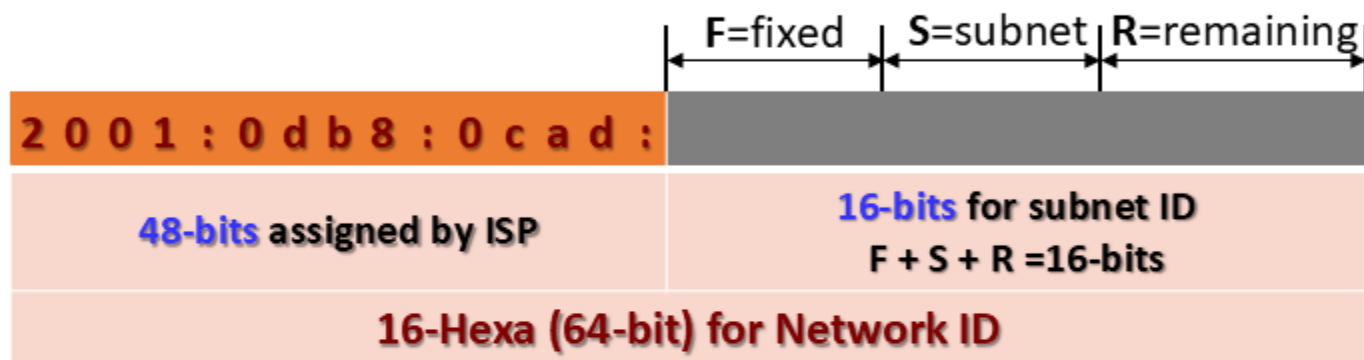
↳ 60 locations
 ↳ 10 workshops

**United Arab Emirates**

Country dedicated subnet

↳ 60 locations
 ↳ 10 workshops

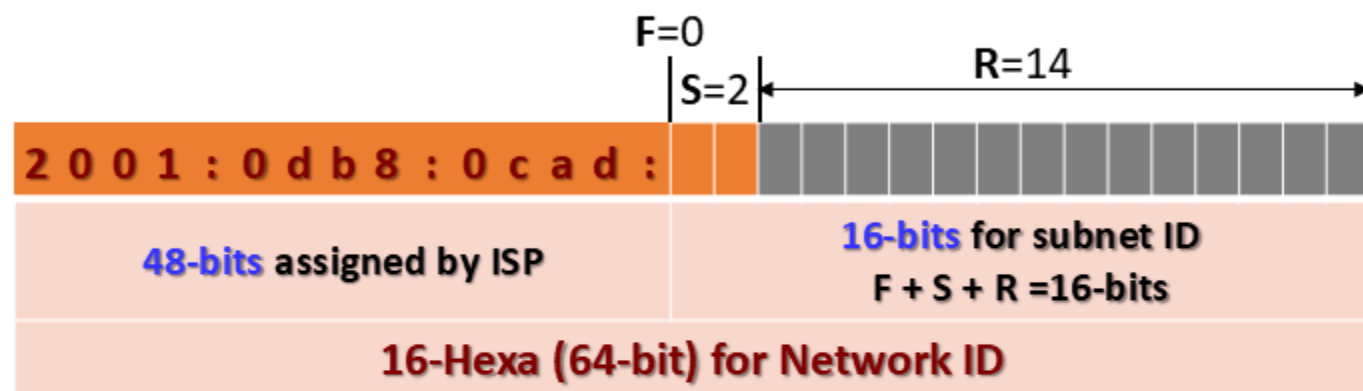




Q; How many bits should be taken from subnet ID portion for countries networks?

We need **three subnets**, so from the right table there is no three decimal value, thus take the closest upper value (four). Subnets need **2-bits** from the subnet ID portion.

Number of bits	Power of 2	Decimal value
1	2^1	2
2	2^2	4
3	2^3	8
4	2^4	16
5	2^5	32
6	2^6	64
7	2^7	128
8	2^8	256
9	2^9	512
10	2^{10}	1024
11	2^{11}	2028
12	2^{12}	4096
13	2^{13}	8192
14	2^{14}	16384
15	2^{15}	32769
16	2^{16}	653536

**Calculation of the incremental value****(I) to obtain four subnets:**

$$I = 2^{16-F-S}$$

$$I = 2^{16-0-2}$$

$$I = 2^{14} = (16384)_{10} = (4000)_{16}$$

*Increment the subnet ID of the
IPv6 by the value of (I)*

The first level of subnet;`2001:db8:cad:0000:: /50``2001:db8:cad:4000:: /50``2001:db8:cad:8000:: /50``2001:db8:cad:c000:: /50`

Assign three subnets to each main branch of each country



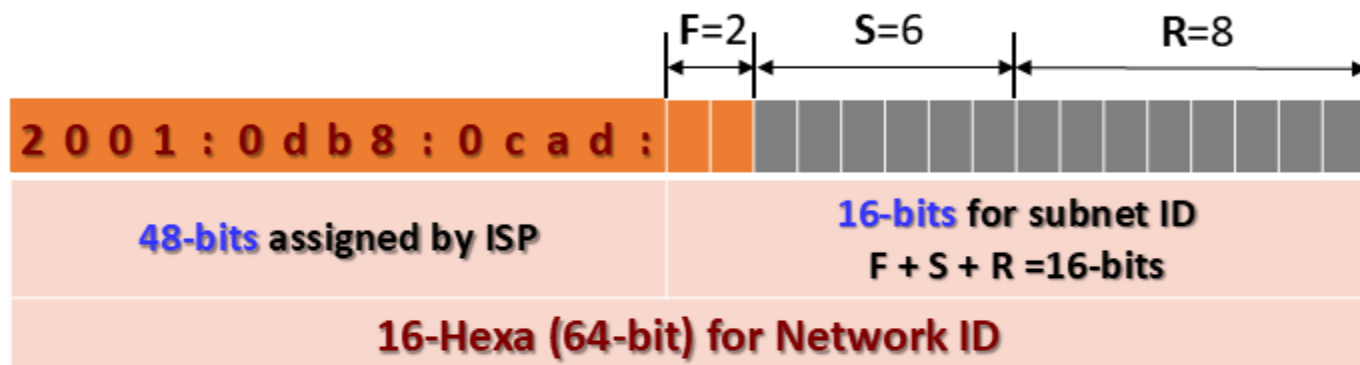
2001:db8:cad:0000:: /50



2001:db8:cad:4000:: /50



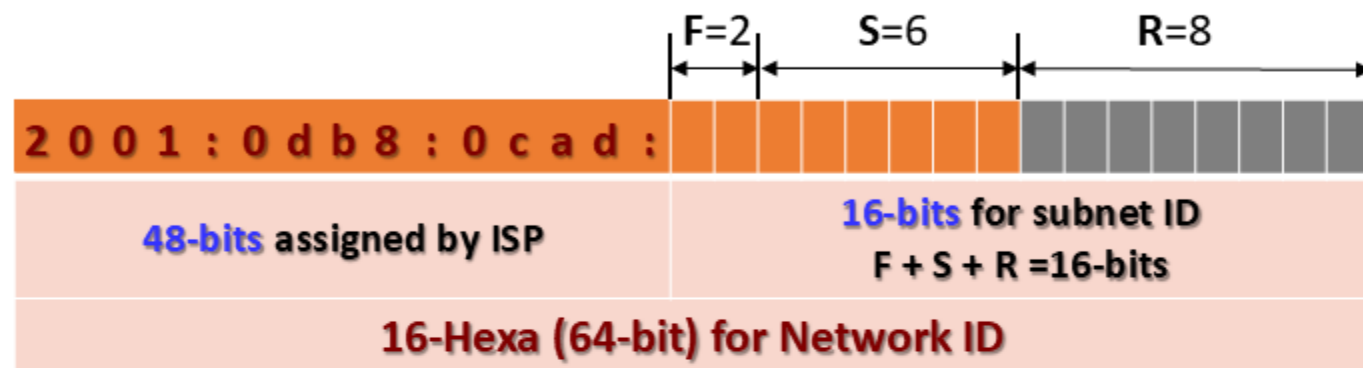
2001:db8:cad:8000:: /50



Q; How many bits should be taken from subnet ID portion for 60 locations subnets?

We need **60 subnets**, so from the right table there is no 60 decimal value, thus take the closest upper value (64). Subnets need **6-bits** from the subnet ID portion.

Number of bits	Power of 2	Decimal value
1	2^1	2
2	2^2	4
3	2^3	8
4	2^4	16
5	2^5	32
6	2^6	64
7	2^7	128
8	2^8	256
9	2^9	512
10	2^{10}	1024
11	2^{11}	2028
12	2^{12}	4096
13	2^{13}	8192
14	2^{14}	16384
15	2^{15}	32769
16	2^{16}	653536



Calculation of the incremental value

(I) to obtain 60 subnets:

$$I = 2^{16-F-S}$$

$$I = 2^{16-2-6}$$

$$I = 2^8 = (256)_{10} = (100)_{16}$$

Increment the subnet ID of the
IPv6 by the value of (I)

The second level of subnet (e.g., Saudi Arabia);

2001:db8:cad:4000:: /56

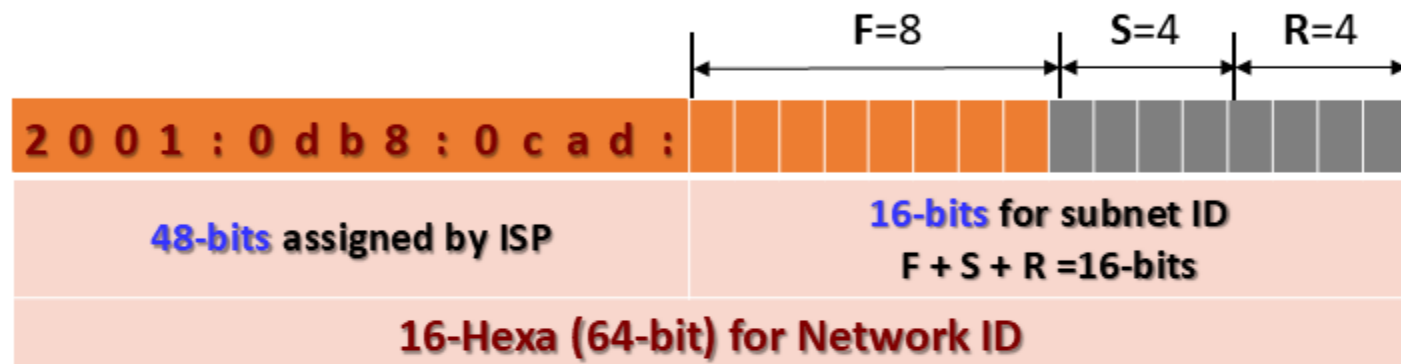
2001:db8:cad:4100:: /56

2001:db8:cad:4200:: /56

⋮

2001:db8:cad:7b00:: /56

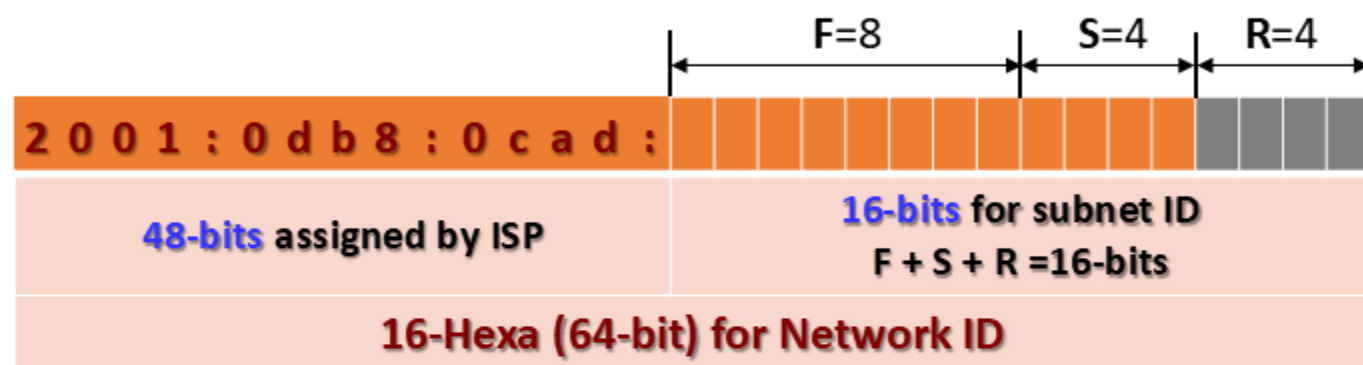
56 = 48 + 2 + 6 where 2 is the F value and 6 is the S value.



Q; How many bits should be taken from subnet ID portion for 10 workshops subnets?

We need **10 subnets**, so from the right table there is no 10 decimal value, thus take the closest upper value (16). Subnets need **4-bits** from the subnet ID portion.

Number of bits	Power of 2	Decimal value
1	2^1	2
2	2^2	4
3	2^3	8
4	2^4	16
5	2^5	32
6	2^6	64
7	2^7	128
8	2^8	256
9	2^9	512
10	2^{10}	1024
11	2^{11}	2028
12	2^{12}	4096
13	2^{13}	8192
14	2^{14}	16384
15	2^{15}	32769
16	2^{16}	653536



Calculation of the incremental value

(I) to obtain 10 subnets:

$$I = 2^{16-F-S}$$

$$I = 2^{16-8-4}$$

$$I = 2^4 = (16)_{10} = (10)_{16}$$

Increment the subnet ID of the
IPv6 by the value of (I)

The Third level of subnet (e.g., Saudi Arabia);

2001:db8:cad:4100:: /60

2001:db8:cad:4110:: /60

2001:db8:cad:4120:: /60

⋮

2001:db8:cad:4190:: /60

60 = 48 + 8 + 4 where 8 is the F value and 4 is the S value.

