AMRITA VISHWA VIDYAPEETHAM

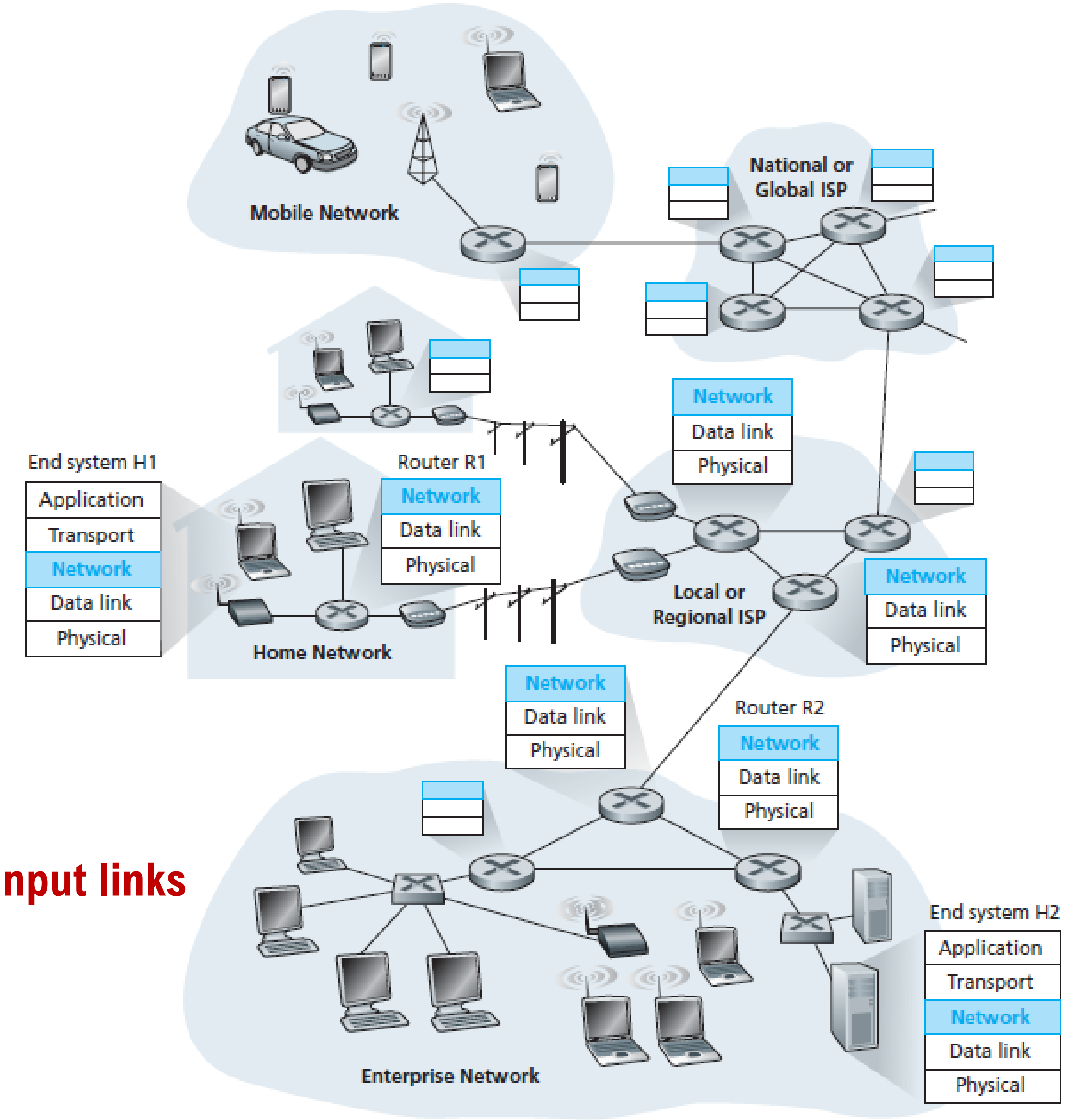
DEEMED TO BE UNIVERSITY

15CSE312
COMPUTER NETWORKS
3-0-0 3

Chapter 4: Network Layer
IP Addressing

Network Layer

The network layer in H1 takes segments from the transport layer in H1, encapsulates each segment into a datagram (that is, a network-layer packet), and then sends the datagrams to its nearby router, R1. At the receiving host, H2, the network layer receives the datagrams from its nearby router R2, extracts the transport-layer segments, and delivers the segments up to the transport layer at H2.



The primary role of the routers is to forward datagrams from input links to output links

Fig shows a simple network with two hosts, H1 and H2, and several routers on the path between H1 and H2

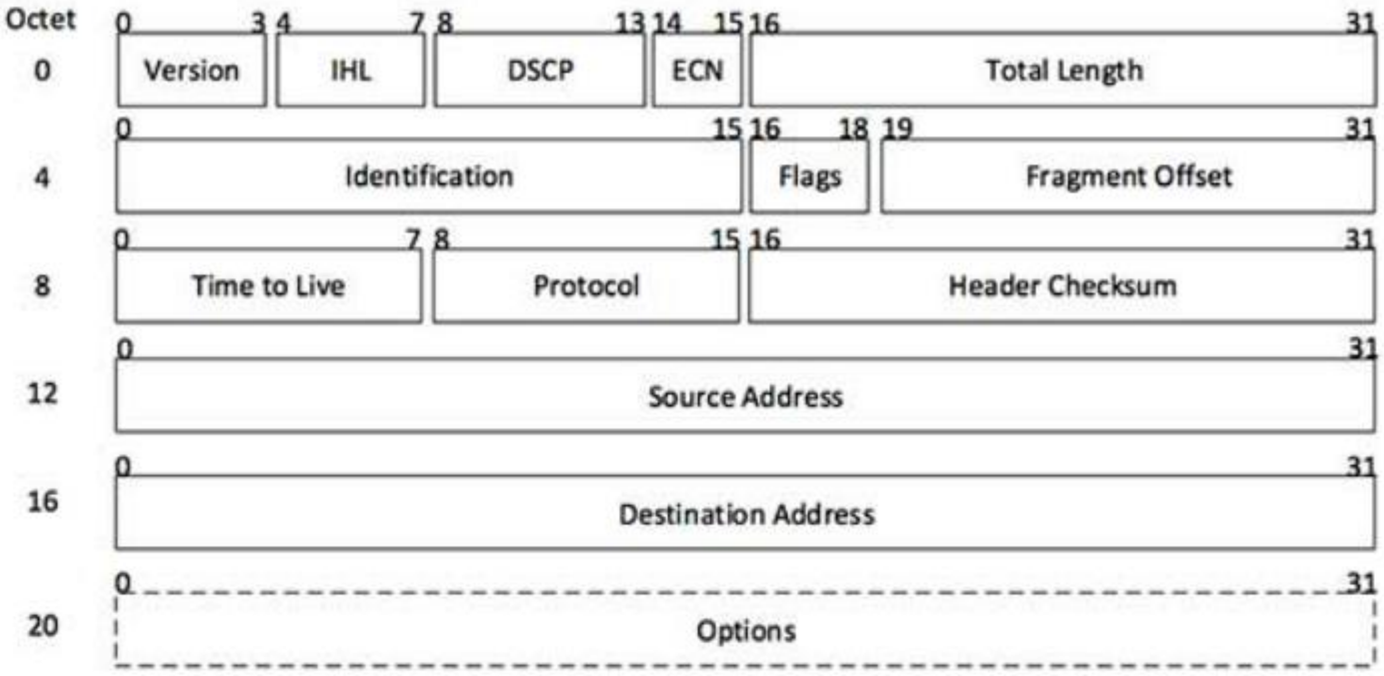
Network Layer- Functionality

- How a machine in a different network can communicate with a machine in another network
  - **Host to Host Delivery** (Source to Destination) using IP addressing
  - **Routing:** which is moving packets (the fundamental unit of data transport on modern computer networks) across the network using the most appropriate paths
  - **Fragmentation** : is done by the network layer when the maximum size of datagram is greater than maximum size of data that can be held in a frame i.e., its Maximum Transmission Unit (MTU). The network layer divides the datagram received from transport layer into fragments so that data flow is not disrupted.

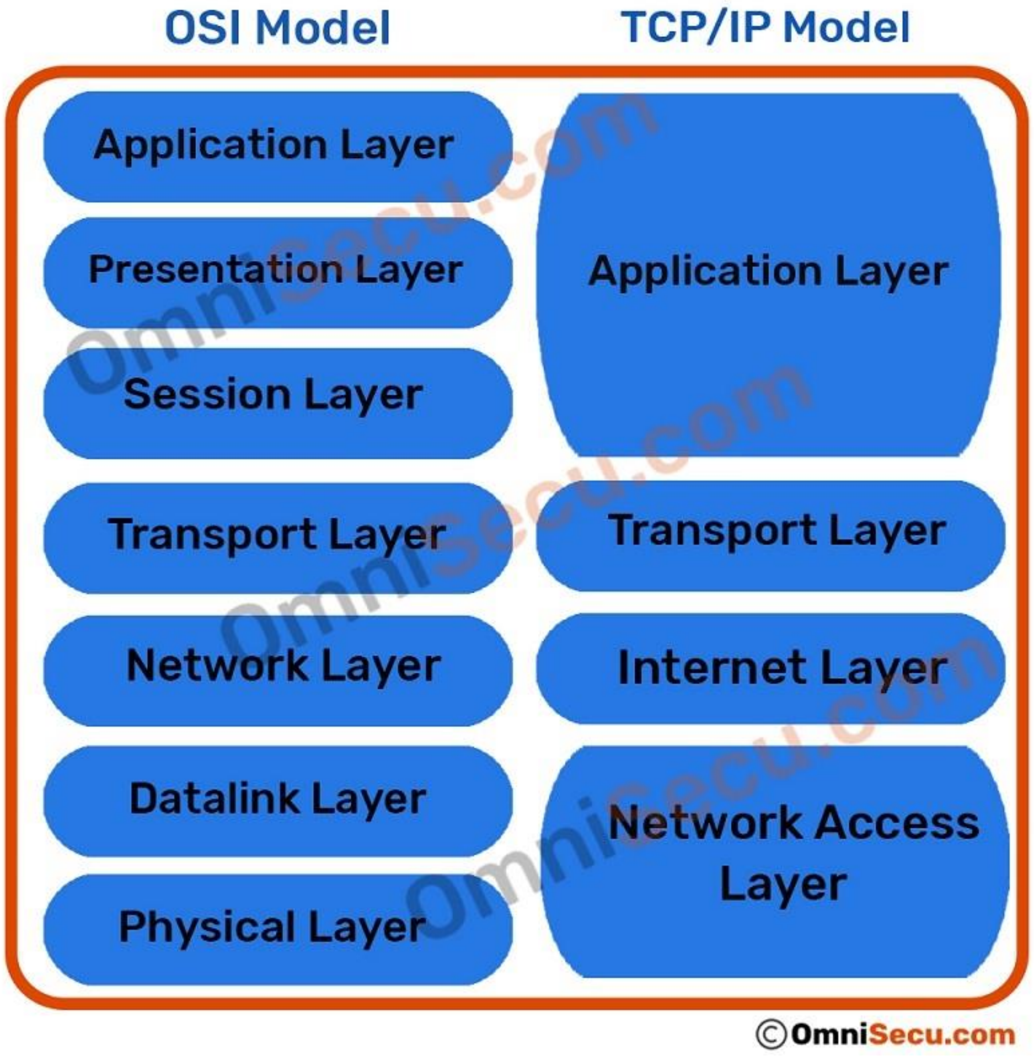
- The network layer is responsible for carrying data from one host to another.
- It provides means to allocate logical addresses to hosts, and identify them uniquely using the same.
- Network layer takes data units from Transport Layer and cuts them in to smaller unit called Data Packet.
- Network layer defines the data path, the packets should follow to reach the destination. Routers work on this layer and provides mechanism to route data to its destination.

IP packet encapsulates data unit received from above layer and add to its own header information.

(IP Encapsulation)



[Image: IP Header]



Internet Protocol version 4 (IPv4)

- Internet Protocol version 4 (IPv4) is the fourth version in the development of the Internet Protocol (IP) and the first version of the protocol to be widely deployed. IPv4 is described in IETF publication RFC 791 (September 1981)

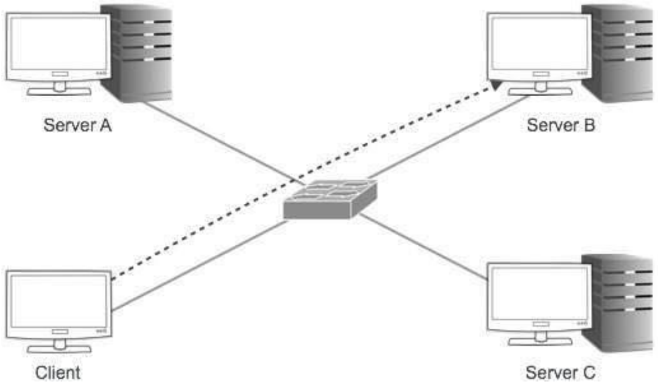
Communication between hosts can happen only if they can identify each other on the network. In a single collision domain (where every packet sent on the segment by one host is heard by every other host) hosts can communicate directly via MAC address. MAC address is a factory coded 48-bits hardware address which can also uniquely identify a host. But if a host wants to communicate with a remote host, i.e. not in the same segment or logically not connected, then some means of addressing is required to identify the remote host uniquely. A logical address is given to all hosts connected to Internet and this logical address is called **Internet Protocol Address**.

IPv6 is the next generation Internet Protocol (IP) standard intended to eventually replace IPv4, the protocol many Internet services still use today.

IPv4 supports three different types of addressing modes. −

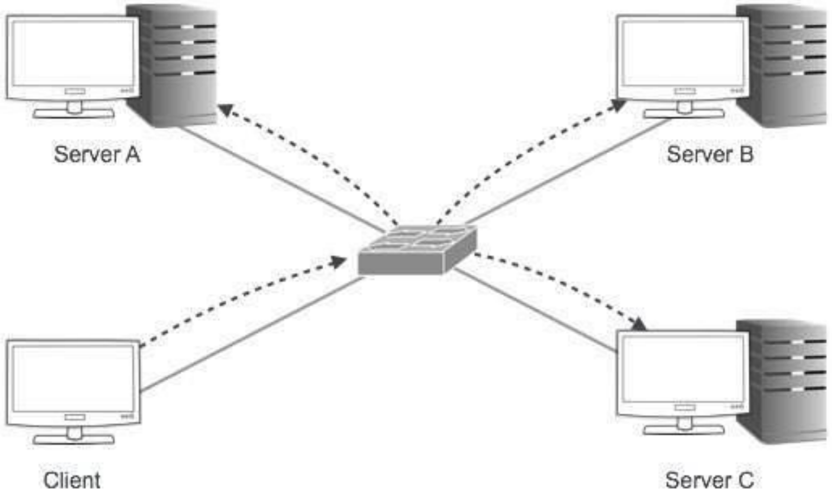
Unicast Addressing Mode

In this mode, data is sent only to one destined host. The Destination Address field contains 32- bit IP address of the destination host. Here the client sends data to the targeted server



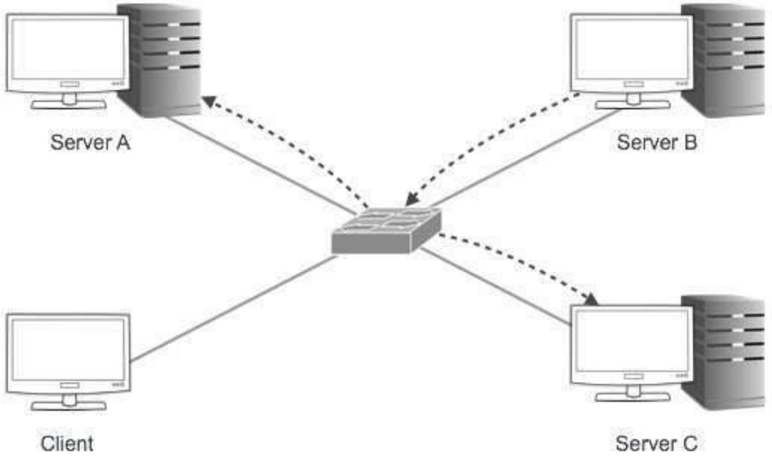
Broadcast Addressing Mode

In this mode, the packet is addressed to all the hosts in a network segment. The Destination Address field contains a special broadcast address, i.e. **255.255.255.255**. When a host sees this packet on the network, it is bound to process it. Here the client sends a packet, which is entertained by all the Servers −



Multicast Addressing Mode

This mode is a mix of the previous two modes, i.e. the packet sent is neither destined to a single host nor all the hosts on the segment. In this packet, the Destination Address contains a special address which starts with 224.x.x.x and can be entertained by more than one host.

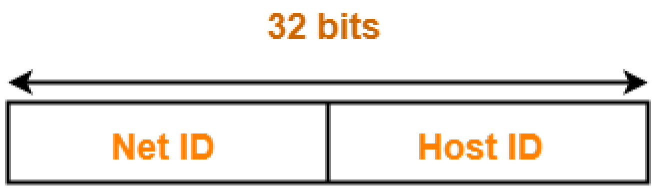


IP Address in Networking-

Internet Corporation for Assigned Names and Numbers is responsible for assigning IP addresses.

An **IP address** consists of two components: a **network ID** and a **host ID**.

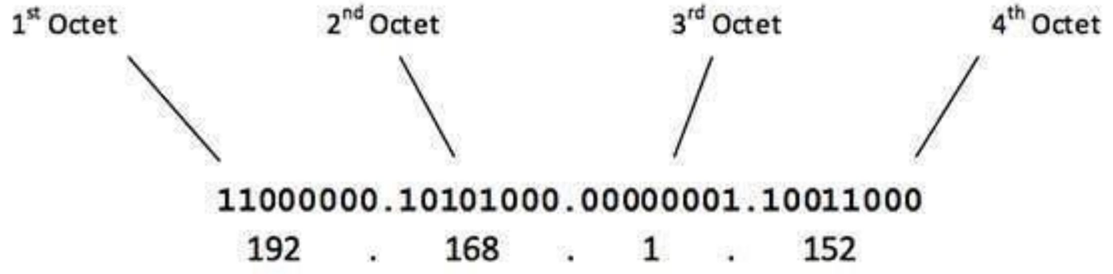
- The **network ID** identifies the **network** segment to which the **host** belongs. The **host ID** identifies an individual **host** on some specific **network** segment. A **host** can communicate directly only with other **hosts** on the same **network** segment.



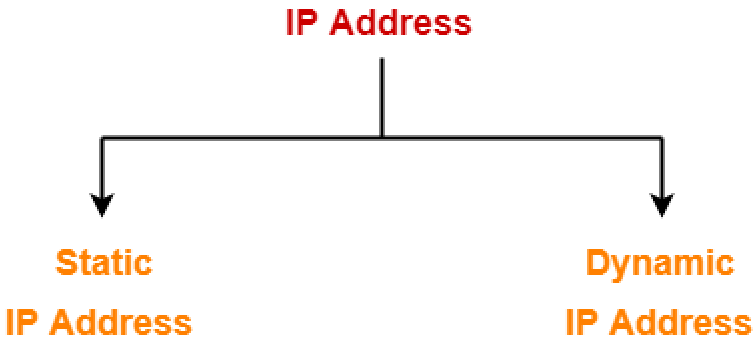
Format of an IP Address

•IP Address is short for **Internet Protocol Address**.
•It is a unique address assigned to each computing device in an IP network.
•ISP assigns IP Address to all the devices present on its network.
•Computing devices use IP Address to identify and communicate with other devices in the IP network.

•IP Address is a 32 bit binary address written as 4 numbers separated by dots.
•The 4 numbers are called as **octets** where each octet has 8 bits.
•The octets are divided into 2 components- Net ID and Host ID.



IP Addresses may be of the following two types-Static and Dynamic



When a device is assigned a **static IP address**, the **address** does not change. Most devices use **dynamic IP addresses**, which are assigned by the network when they connect and change over time.

When static IPs are needed

Most users don't need static IP addresses. Static IP addresses normally matter more when external devices or websites need to remember your IP address. One example is VPN or other remote access solutions that trust (whitelists) certain IPs for security purposes

Static IP Address-

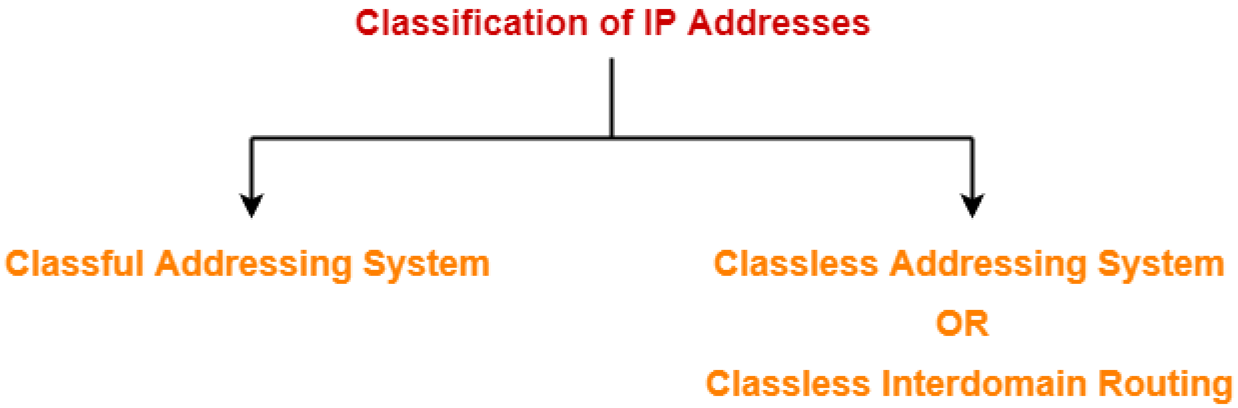
•Static IP Address is an IP Address that once assigned to a network element always remains the same.
•They are configured manually.
•Static IP Addresses are more costly than dynamic IP Addresses.

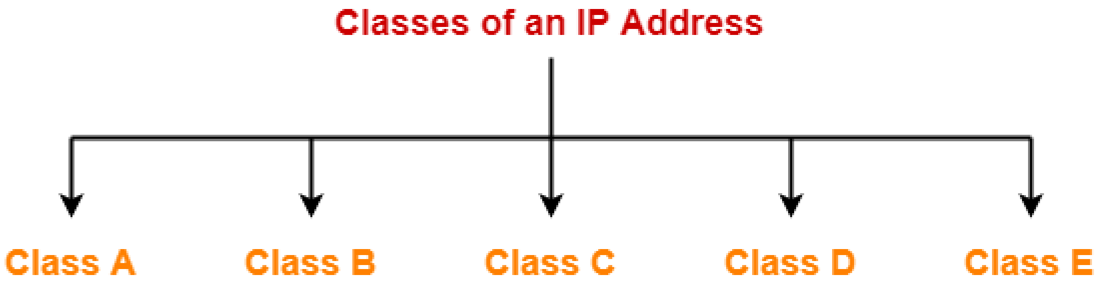
Dynamic IP Address-

•Dynamic IP Address is a temporarily assigned IP Address to a network element.
•It can be assigned to a different device if it is not in use.
•Dynamic Host Configuration Protocol(DHCP) or PPPoE assigns dynamic IP addresses.

Classification of IP address

There are two systems in which IP Addresses are classified-





Classful Addressing:
Introduced in 1981, with classful routing, IP v4 addresses were divided into 5 classes(A to E).

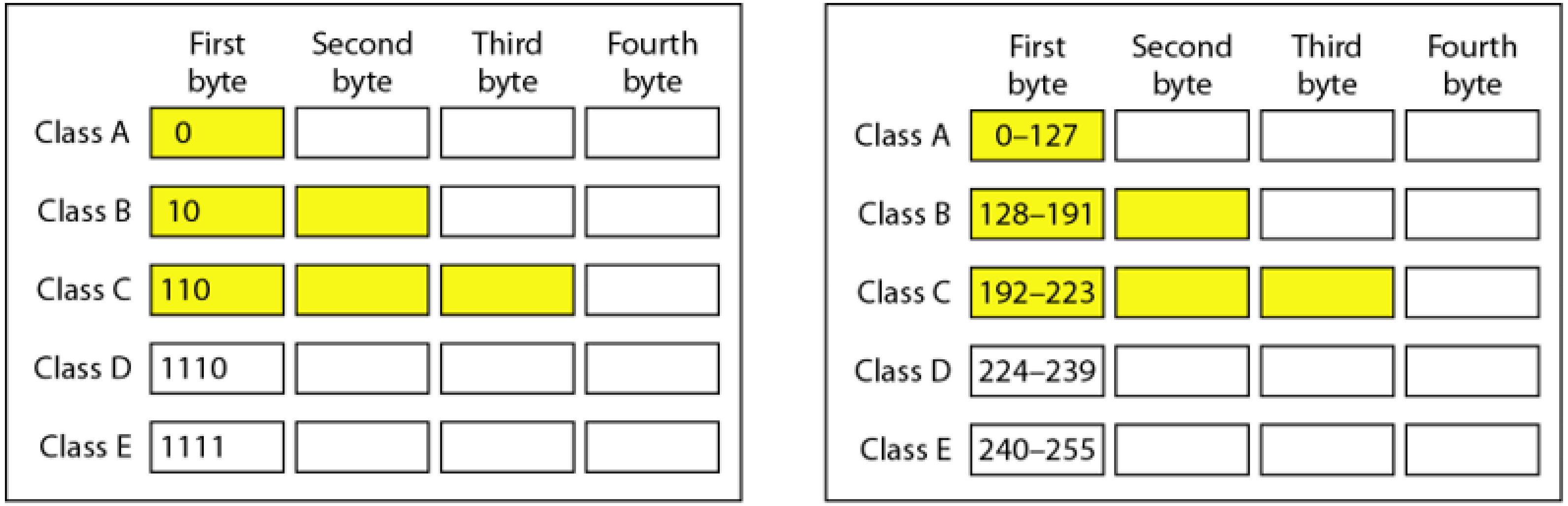
Classes A-C: unicast addresses
Class D: multicast addresses
Class E: reserved for future use

Internet Engineering Task Force introduced Classless addressing in 1993 to replace the previous classful network addressing architecture on the Internet.

Classless Addressing is an improved IP Addressing system. It makes the allocation of IP Addresses more efficient. It replaces the older classful addressing system based on classes. It is also known as **Classless Inter Domain Routing (CIDR).**

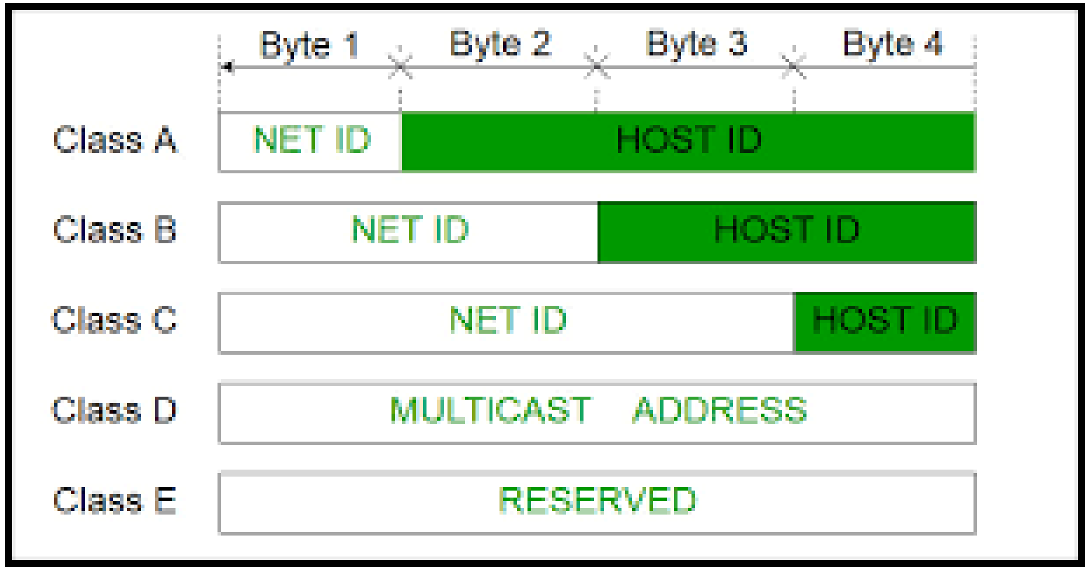
Classful IP addressing

Class	Leading bits	Number of networks	Number of Hosts Per Network
Class A	0	128 (2^7)	**16,777,214**
Class B	10	16,384 (2^{14})	**65,534**
Class C	110	2,097,152 (2^{21})	**254**
Class D (multicast)	1110	**not** defined	



a. Binary notation

b. Dotted-decimal notation



The problem with this classful addressing method is that millions of **class A** address are wasted, many of the **class B** address are wasted, whereas, number of addresses available in **class C** is so small that it cannot cater to the needs of organizations.

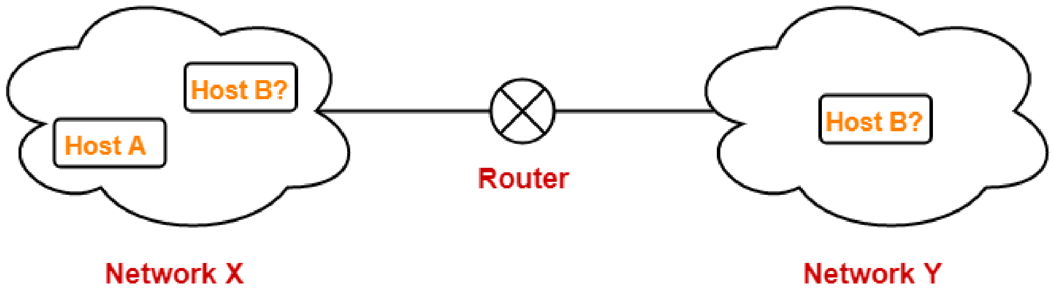
Class D addresses are used for multicast routing and are therefore available as a single block only.

Class E addresses are reserved.

Subnet Mask

Consider-
•There is a host A present in some network X.
•There is a host B.
•Host A wants to send a packet to host B.

Before transmitting the packet, host A determines whether host B is present within the same network or not.



•Host use its subnet mask to determine whether the other host it wants to communicate with is present within the same network or not.
•If the destination host is present within the same network, then source host sends the packet directly to the destination host.
•If the destination host is present in some other network, then source host routes the packet to the default gateway (router).
•Router then sends the packet to the destination host.

Here,
•Host A = Source host
•Host B = Destination host

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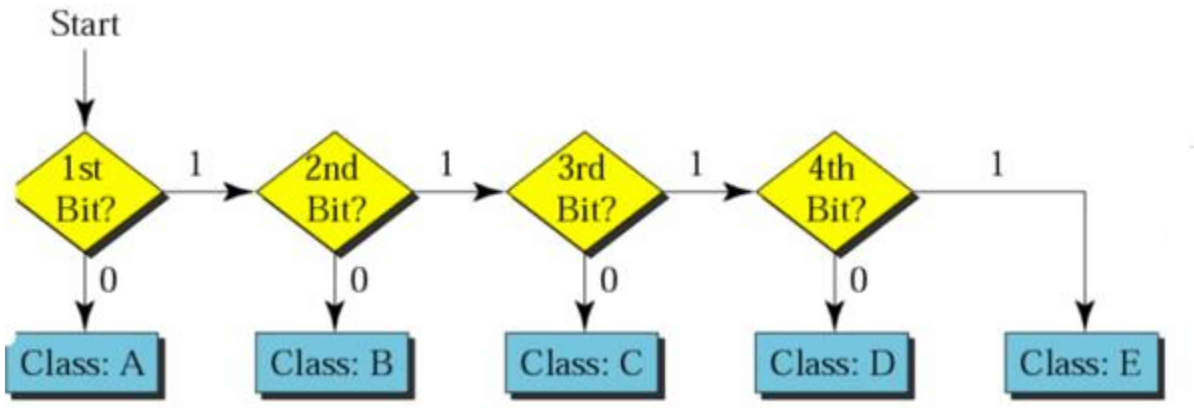
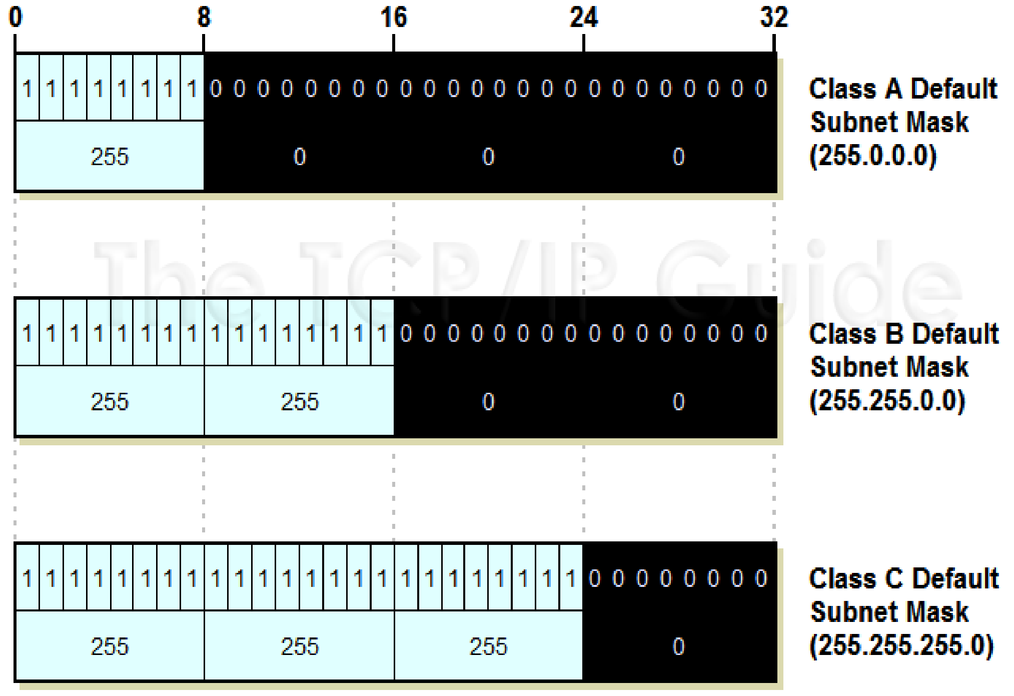
Default Subnet Mask

The subnet mask is used by the router to cover up the network address. It shows which bits are used to identify the subnet.





IP Address 166.75.229.22

mask is 255.255.0.0

IP Address bits	1010 0110 . 0100 1011 . 1110 0101 . 0001 0110
	AND
Masking bits	1111 1111 . 1111 1111 . 0000 0000 . 0000 0000
Network ID	1010 0110 . 0100 1011 . 0000 0000 . 0000 0000
Network ID	166.75.0.0

To determine whether destination host is present within the same network or not, source host follows the following steps

Step-01:

- Source host computes its own network address using its own IP Address and subnet mask.
- After computation, source host obtains its network address with respect to itself.

Step-02:

- Source host computes the network address of destination host using destination IP Address and its own subnet mask.
- After computation, source host obtains the network address of destination host with respect to itself.

Step-03:

Source host compares the two results obtained in the above steps.

Then, following two cases are possible-

Case-01:

If the results are same,
- Source host assumes that the destination host is present within the same network.
- Source host sends the packet directly to the destination host.

Case-02:

If the results are different,
- Source host assumes that the destination host is present in some other network.
- Source host sends the packet via router to the destination host.

Class A- IP addressing.

If the 32 bit binary address starts with a bit 0, then IP Address belongs to class A

1. Class A-

IP address belonging to class A are assigned to the networks that contain a large number of hosts.

In class A IP Address,

•The first 8 bits are used for the Network ID.

•The remaining 24 bits are used for the Host ID.

	7 Bit	24 Bit
0	Network	Host

Class A

Total Number Of IP Addresses-

Total number of IP Addresses available in class A
= Numbers possible due to remaining available 31 bits
= 2^{31}

- The higher order bit of the first octet in class A is always set to 0.
- The remaining 7 bits in first octet are used to determine network ID.
- The 24 bits of host ID are used to determine the host in any network.
- The **default subnet mask** for class A is **255.x.x.x.**

•Therefore, class A has a total of:

•**2^7 -2= 126 network ID**(Here 2 address is subtracted because 0.0.0.0 and 127.x.y.z are special address.)

•**2^{24} – 2 = 16,777,214 host ID**

IP addresses belonging to class A ranges from 1.x.x.x – 126.x.x.x

•Range of 1st octet = [0, 127] binary [**0**0000000,**0**1111111]

•But 2 networks are reserved and unused.

•So, Range of 1st octet = [1, 126]

Class A is used by organizations requiring very large size networks like NASA, Pentagon etc.

Class B

If the 32 bit binary address starts with bits 10, then IP Address belongs to class B.

IP address belonging to class B are assigned to the networks that ranges from medium-sized to large-sized networks.

•The network ID is 16 bits long.

•The host ID is 16 bits long.

		14 Bit	16 Bit
1	0	Network	Host

Class B

Total Number Of IP Addresses-

Total number of IP Addresses available in class B

= Numbers possible due to remaining available 30 bits

= 2^{30}

- The higher order bits of the first octet of IP addresses of class B are always set to 10.
- The remaining 14 bits are used to determine network ID. The 16 bits of host ID is used to determine the host in any network.
- The default sub-net mask for class B is 255.255.x.x.

Class B has a total of:

•2^{14} = 16384 network address

•2^{16} – 2 = 65534 host address

•IP addresses belonging to class B ranges from 128.0.x.x – 191.255.x.x.

Range Of 1st Octet-

We have- Minimum value of 1st octet = **10**000000 = 128

•Maximum value of 1st octet = **10**111111 = 191

So, Range of 1st octet = [128, 191]

Class B is used by organizations requiring medium size networks like IRCTC, banks etc.

Class C

If the 32 bit binary address starts with bits 110, then IP Address belongs to class C.

IP address belonging to class C are assigned to small-sized networks.

- The network ID is 24 bits long.
- The host ID is 8 bits long.

			21 Bit	8 Bit
1	1	0	Network	Host

Class C

Total Number Of IP Addresses-

Total number of IP Addresses available in class C
= Numbers possible due to remaining available 29 bits
= 2^{29}

- The higher order bits of the first octet of IP addresses of class C are always set to 110.
- The remaining 21 bits are used to determine network ID.
- The 8 bits of host ID is used to determine the host in any network.
- The default sub-net mask for class C is 255.255.255.x.

Class C has a total of:

- **2^{21} = 2097152 network address**
- **2^{8} – 2 = 254 host address**

IP addresses belonging to class C ranges from 192.0.0.x – 223.255.255.x.

Range Of 1st Octet-

- Minimum value of 1st octet = **11**000000 = 192
- Maximum value of 1st octet = **110**111111 = 223

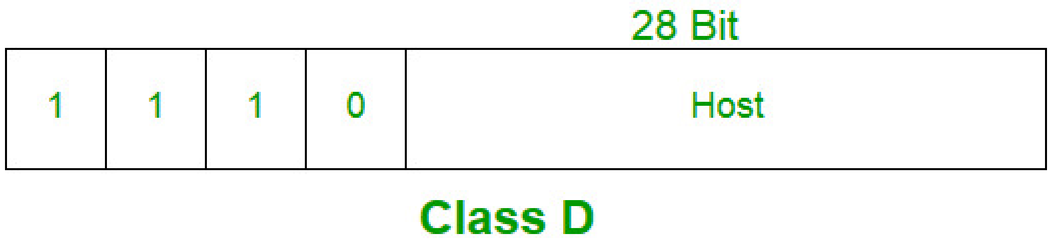
So, Range of 1st octet = [192, 223]

- **Class C is used by organizations requiring small to medium size networks. For example- engineering colleges, small universities, small offices etc.**

Class D (Multicasting)

If the 32 bit binary address starts with bits 1110, then IP Address belongs to class D.

IP address belonging to class D are reserved for multi-casting. The higher order bits of the first octet of IP addresses belonging to class D are always set to 1110. The remaining bits are for the address that interested hosts recognize.
Class D does not posses any sub-net mask. IP addresses belonging to class D ranges from 224.0.0.0 – 239.255.255.255.



Total Number Of IP Addresses-

Total number of IP Addresses available in class D
= Numbers possible due to remaining available 28 bits
= 2^{28}

Range Of 1st Octet-

We have-
- Minimum value of 1st octet = **1110**0000 = 224
- Maximum value of 1st octet = **1110**1111 = 239

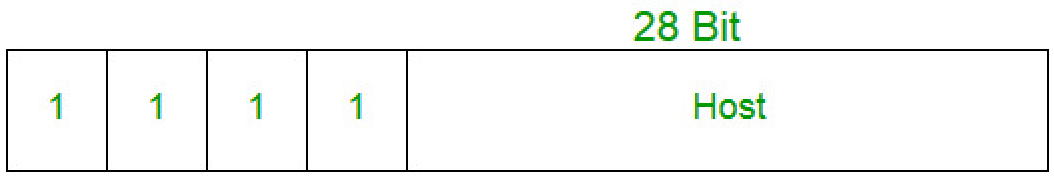
So, Range of 1st octet = [224, 239]

- **Class D is reserved for multicasting-**
  - **sender(s) send data to multiple receivers simultaneously. .**
- **In multicasting, there is no need to extract host address from the IP Address.**
- **This is because data is not destined for a particular host.**

Class E (reserved)

If the 32 bit binary address starts with bits 1111, then IP Address belongs to class E.

IP addresses of class E ranges from 240.0.0.0 – 255.255.255.254.
This class doesn't have any sub-net mask.
The higher order bits of first octet of class E are always set to 1111.



Class E

Total Number Of IP Addresses-

Total number of IP Addresses available in class E
= Numbers possible due to remaining available 28 bits
= 2^{28}

Range Of 1st Octet-

We have-

- Minimum value of 1st octet = **1111**0000 = 240
- Maximum value of 1st octet = **1111**1111 = 255

So, Range of 1st octet = [240, 255]

- **IP addresses belonging to class E are reserved for experimental and research purposes, military purpose**

Summary

CLASS	LEADING BITS	NET ID BITS	HOST ID BITS	NO. OF NETWORKS	ADDRESSES PER NETWORK	START ADDRESS	END ADDRESS
CLASS A	0	8	24	2^7 (128)	2^{24} (16,777,216)	0.0.0.0	127.255.255.255
CLASS B	10	16	16	2^{14} (16,384)	2^{16} (65,536)	128.0.0.0	191.255.255.255
CLASS C	110	24	8	2^{21} (2,097,152)	2^8 (256)	192.0.0.0	223.255.255.255
CLASS D	1110	NOT DEFINED	NOT DEFINED	NOT DEFINED	NOT DEFINED	224.0.0.0	239.255.255.255
CLASS E	1111	NOT DEFINED	NOT DEFINED	NOT DEFINED	NOT DEFINED	240.0.0.0	255.255.255.255

Problem I

Find the error, if any, in the following IPv4 addresses.

a. 111.56.045.78
b. 221.34.7.8.20
c. 75.45.301.14
d. 11100010.23.14.67

Solution

a. There must be no leading zero (045).
b. There can be no more than four numbers.
c. Each number needs to be less than or equal to 255.
d. A mixture of binary notation and dotted-decimal notation is not allowed.

Problem II

Find the class of each address.

a. 00000001 00001011 00001011 11101111

b. 11000001 10000011 00011011 11111111

c. 14.23.120.8

d. 252.5.15.111

Solution

a. ***The first bit is 0. This is a class A address.***

b. ***The first 2 bits are 1; the third bit is 0. This is a class C address.***

c. ***The first byte is 14; the class is A.***

d. ***The first byte is 252; the class is E.***

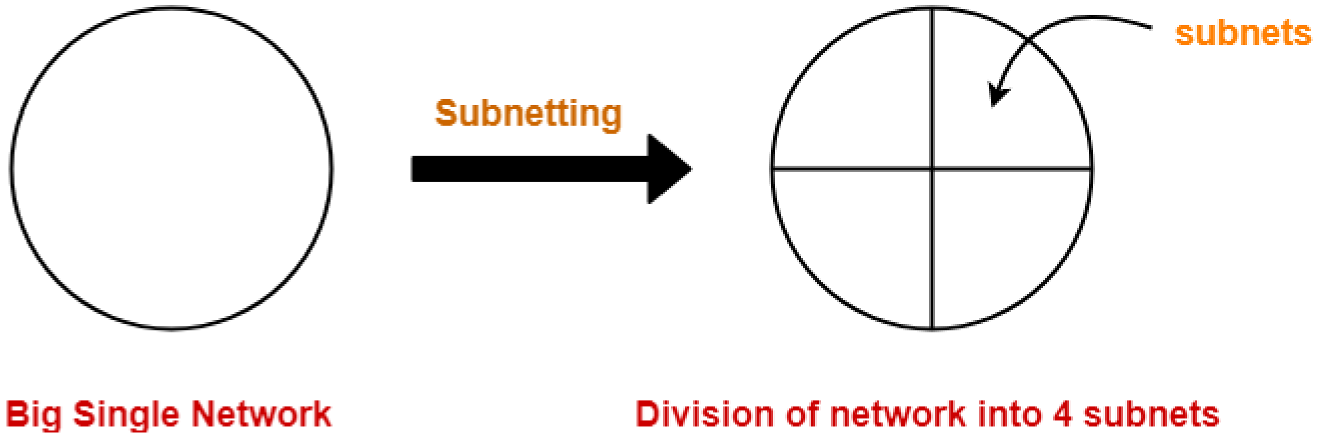
Subnetting in Networking-

- Process of dividing a single network into multiple sub networks is called subnetting
- Sub networks so created are called subnets

Advantages-

The two main advantages of subnetting a network are-

- It improves the security.
- The maintenance and administration of subnets is easy.



Subnet ID-

- Each subnet has its unique network address known as its Subnet ID.
- The subnet ID is created by borrowing some bits from the Host ID part of the IP Address.
- The number of bits borrowed depends on the number of subnets created.

Types of subnetting

1. Fixed Length Subnetting-

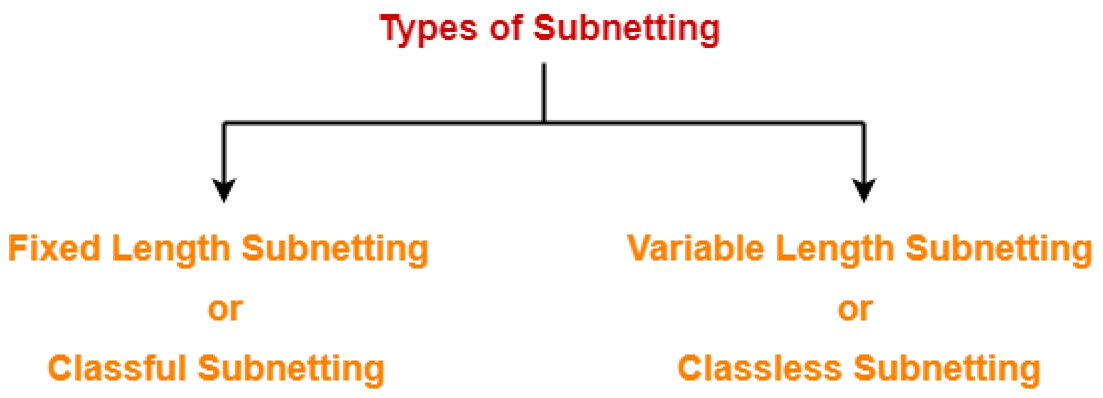
Fixed length subnetting also called as **classful subnetting** divides the network into subnets where-

- All the subnets are of same size.
- All the subnets have equal number of hosts.
- All the subnets have same subnet mask.

2. Variable Length Subnetting-

Variable length subnetting also called as **classless subnetting** divides the network into subnets where-

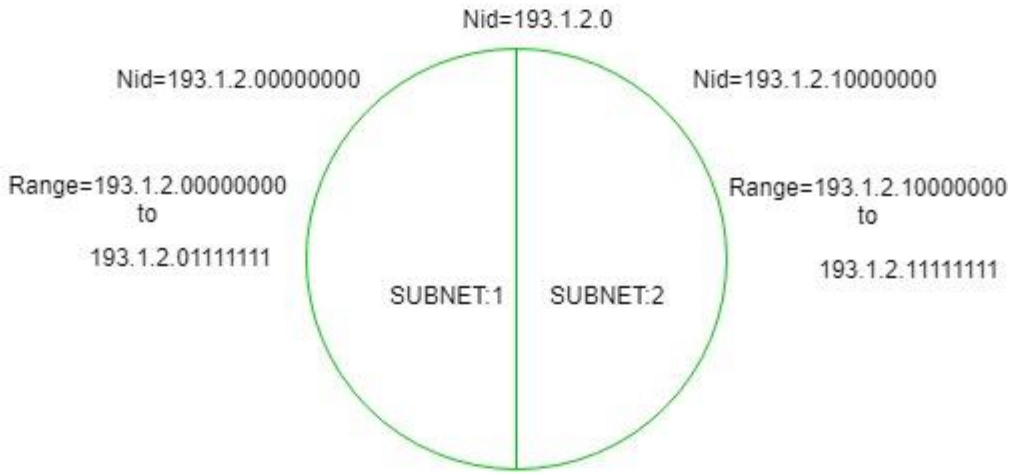
- All the subnets are not of same size.
- All the subnets do not have equal number of hosts.
- All the subnets do not have same subnet mask.



Subnetting in Classful Addressing

When a bigger network is divided into smaller networks, in order to maintain security, then that is known as Subnetting. so, maintenance is easier for smaller networks.

- **How to divide a network into two parts:** To divide a network into two parts, you need to choose one bit for each Subnet from the host ID part.



In the above diagram, there are two Subnets.
Note: It is a class C IP so, there are 24 bits in the network id part and 8 bits in the host id part.

The For Subnet-1:
The first bit which is chosen from the host id part is zero and the range will be from (193.1.2.00000000 till you get all 1's in the host ID part i.e, 193.1.2.01111111) except for the first bit which is chosen zero for subnet id part.
Thus, the range of subnet-1:
193.1.2.0 to 193.1.2.127

For Subnet-2:
The first bit chosen from the host id part is one and the range will be from (193.1.2.100000000 till you get all 1's in the host ID part i.e, 193.1.2.11111111).
Thus, the range of subnet-2:
193.1.2.128 to 193.1.2.255

Note:
1.To divide a network into four (2^2) parts you need to choose two bits from host id part for each subnet i.e, (00, 01, 10, 11).
2.To divide a network into eight (2^3) parts you need to choose three bits from host id part for each subnet i.e, (000, 001, 010, 011, 100, 101, 110, 111) and so on.

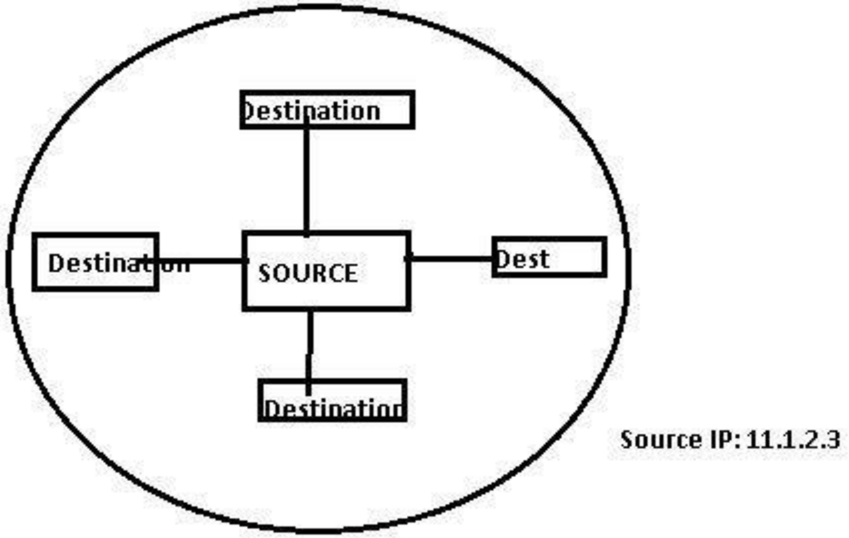
Broadcast

Limited Broadcasting:-

1) In Limited Broadcasting data reaches from source to all the host in a same network.

2) Here source will send message to all the host connected to it

3) Since message covers all host so destination Address would be 255.255.255.255

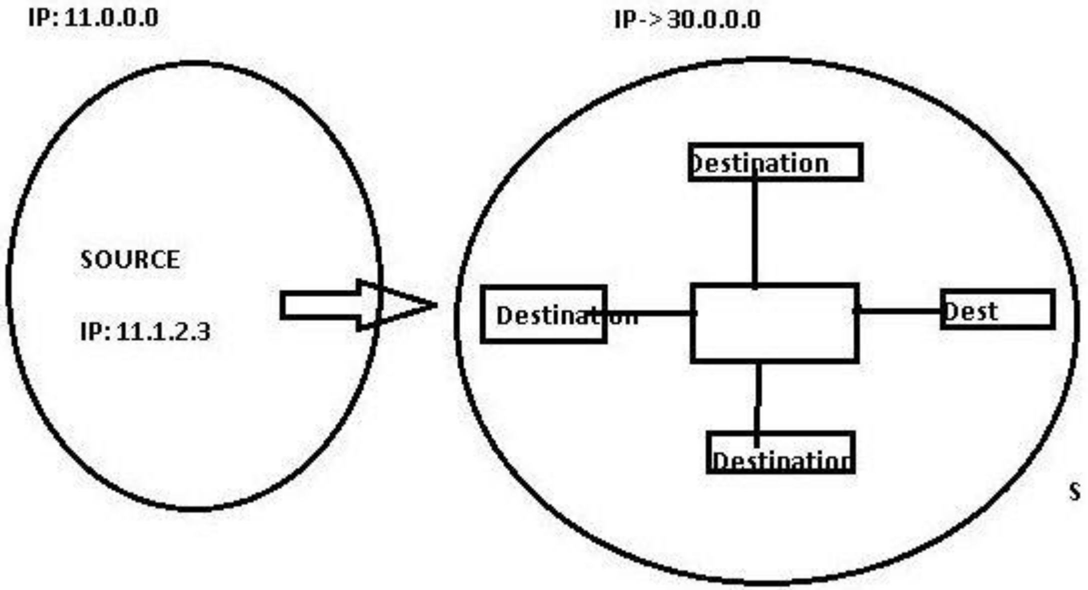


Directed Broadcast:-

1) When host in one network sends message to all host in another network

2) Here source 11.1.2.3 sends data to all the hosts of another network 20.0.0.0

3) Since network is different so we need to tell about network so directed broadcast address is 20.255.255.255



Subnetting Examples- Example-01

Consider-

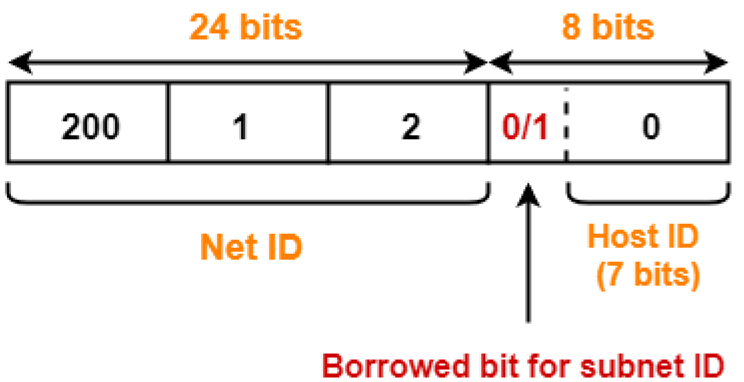
- We have a big single network having IP Address 200.1.2.0.
- We want to do subnetting and divide this network into 2 subnets.

Clearly, the given network belongs to class C.

For creating two subnets and to represent their subnet IDs, we require 1 bit.

So,

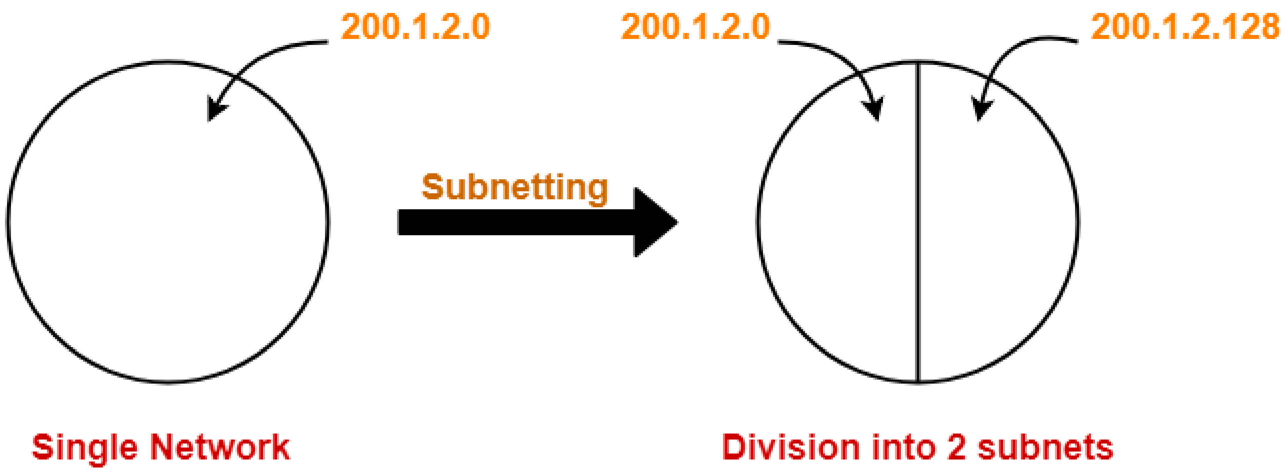
- We borrow one bit from the Host ID part.
- After borrowing one bit, Host ID part remains with only 7 bits.



- If borrowed bit = 0, then it represents the first subnet.
- If borrowed bit = 1, then it represents the second subnet.

IP Address of the two subnets are-

- 200.1.2.**0**0000000 = 200.1.2.0
- 200.1.2.**1**0000000 = 200.1.2.128



Example-01(Continue)

For 1st Subnet-

- IP Address of the subnet = 200.1.2.0
- Total number of IP Addresses = 2^7 = 128
- Total number of hosts that can be configured = 128 – 2 = 126
- Range of IP Addresses = [200.1.2.**0**0000000, 200.1.2.**0**1111111] = [200.1.2.0, 200.1.2.127]
- Direct Broadcast Address = 200.1.2.**0**1111111 = 200.1.2.127
- Limited Broadcast Address = 255.255.255.255

For 2nd Subnet-

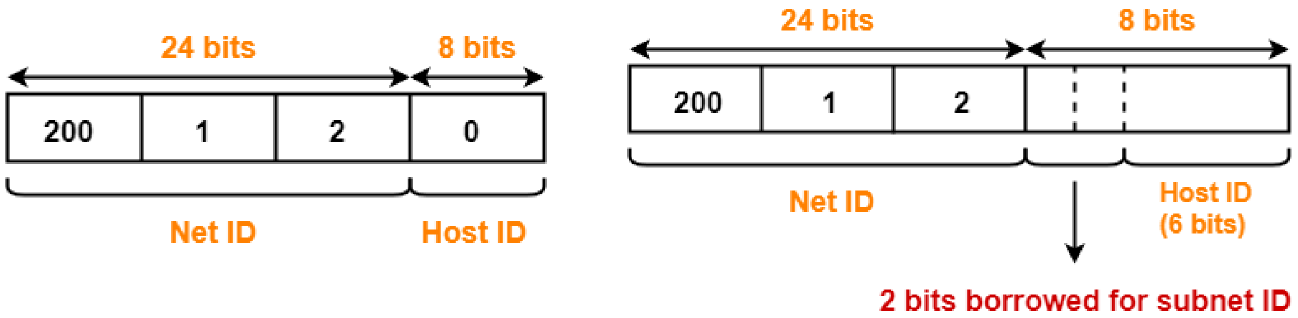
- IP Address of the subnet = 200.1.2.128
- Total number of IP Addresses = 2^7 = 128
- Total number of hosts that can be configured = 128 – 2 = 126
- Range of IP Addresses = [200.1.2.**1**0000000, 200.1.2.**1**1111111] = [200.1.2.128, 200.1.2.255]
- Direct Broadcast Address = 200.1.2.**1**1111111 = 200.1.2.255
- Limited Broadcast Address = 255.255.255.255

Example-02:

Consider-

- We have a big single network having IP Address 200.1.2.0.
- We want to do subnetting and divide this network into 4 subnets.

Clearly, the given network belongs to class C.



For creating four subnets and to represent their subnet IDs, we require 2 bits.

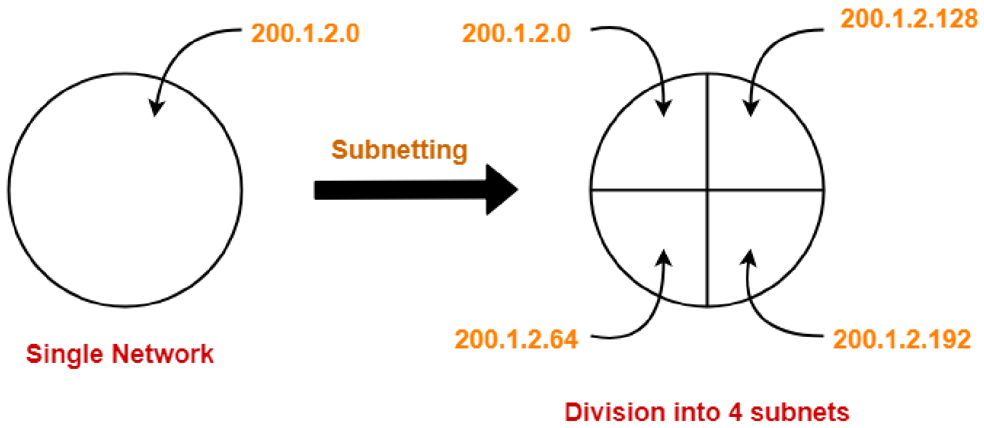
So,

- We borrow two bits from the Host ID part.
- After borrowing two bits, Host ID part remains with only 6 bits.

- If borrowed bits = 00, then it represents the 1st subnet.
- If borrowed bits = 01, then it represents the 2nd subnet.
- If borrowed bits = 10, then it represents the 3rd subnet.
- If borrowed bits = 11, then it represents the 4th subnet.

IP Address of the four subnets are-

- 200.1.2.**00**000000 = 200.1.2.0
- 200.1.2.**01**000000 = 200.1.2.64
- 200.1.2.**10**000000 = 200.1.2.128
- 200.1.2.**11**000000 = 200.1.2.192



Example-02: (continue..)

For 1st Subnet-

- IP Address of the subnet = 200.1.2.0
- Total number of IP Addresses = 2^6 = 64
- Total number of hosts that can be configured = 64 – 2 = 62
- Range of IP Addresses = [200.1.2.**00**000000, 200.1.2.**00**111111] = [200.1.2.0, 200.1.2.63]
- Direct Broadcast Address = 200.1.2.**00**111111 = 200.1.2.63
- Limited Broadcast Address = 255.255.255.255

For 2nd Subnet-

- IP Address of the subnet = 200.1.2.64
- Total number of IP Addresses = 2^6 = 64
- Total number of hosts that can be configured = 64 – 2 = 62
- Range of IP Addresses = [200.1.2.**01**000000, 200.1.2.**01**111111] = [200.1.2.64, 200.1.2.127]
- Direct Broadcast Address = 200.1.2.**01**111111 = 200.1.2.127
- Limited Broadcast Address = 255.255.255.255

For 3rd Subnet-

- IP Address of the subnet = 200.1.2.128
- Total number of IP Addresses = 2^6 = 64
- Total number of hosts that can be configured = 64 – 2 = 62
- Range of IP Addresses = [200.1.2.**10**000000, 200.1.2.**10**111111] = [200.1.2.128, 200.1.2.191]
- Direct Broadcast Address = 200.1.2.**10**111111 = 200.1.2.191
- Limited Broadcast Address = 255.255.255.255

For 4th Subnet-

- IP Address of the subnet = 200.1.2.192
- Total number of IP Addresses = 2^6 = 64
- Total number of hosts that can be configured = 64 – 2 = 62
- Range of IP Addresses = [200.1.2.**11**000000, 200.1.2.**11**111111] = [200.1.2.192, 200.1.2.255]
- Direct Broadcast Address = 200.1.2.**11**111111 = 200.1.2.255
- Limited Broadcast Address = 255.255.255.255

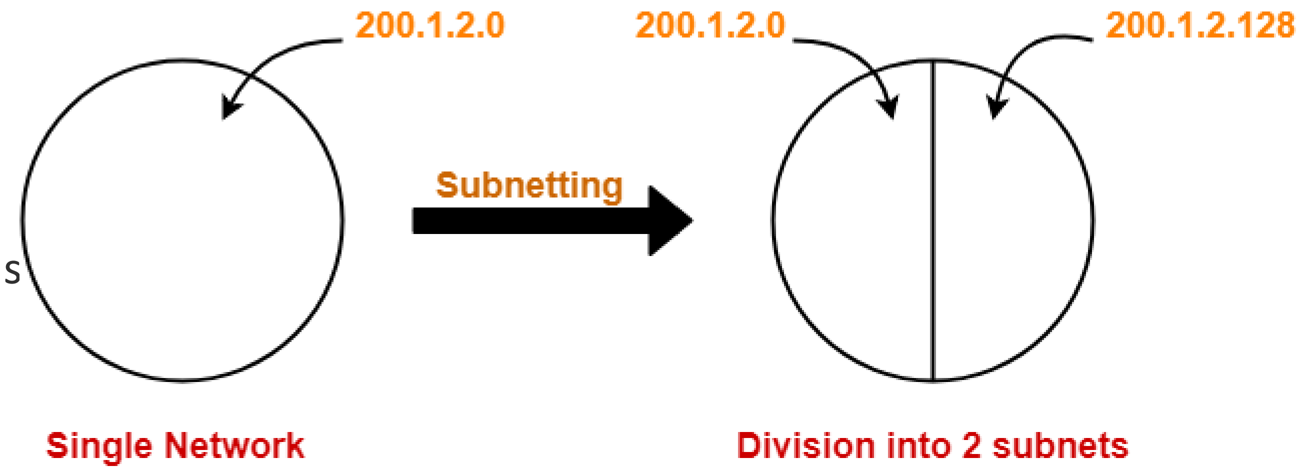
Example-03: Variable length

Consider-

- We have a big single network having IP Address 200.1.2.0.
- We want to do subnetting and divide this network into 3 subnets.

Here, the subnetting will be performed in two steps-

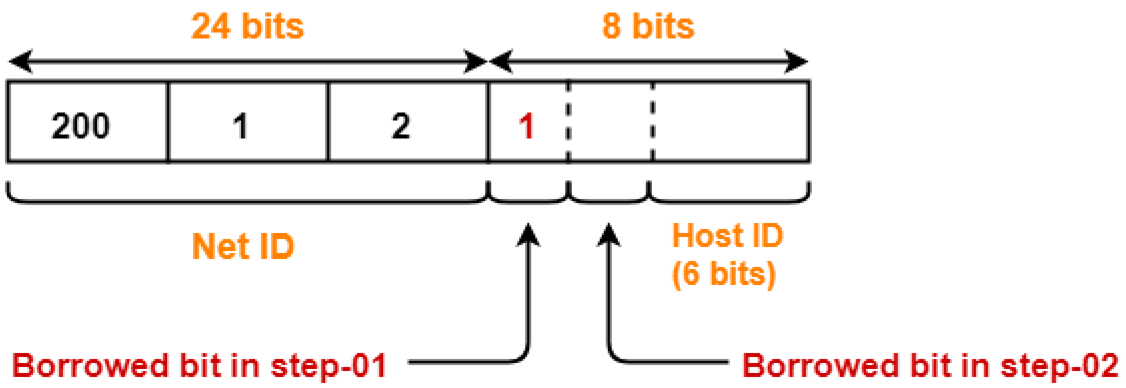
1. Dividing the given network into 2 subnets
2. Dividing one of the subnets further into 2 subnets



Step-01: Dividing Given Network into 2 Subnets-

The subnetting will be performed exactly in the same way as performed in Example-01.
After subnetting, we have-

Example-03(continue.) Variable length



Step-02: Dividing One Subnet into 2 Subnets-

- We perform the subnetting of one of the subnets further into 2 subnets.
- Consider we want to do subnetting of the 2nd subnet having IP Address 200.1.2.128.

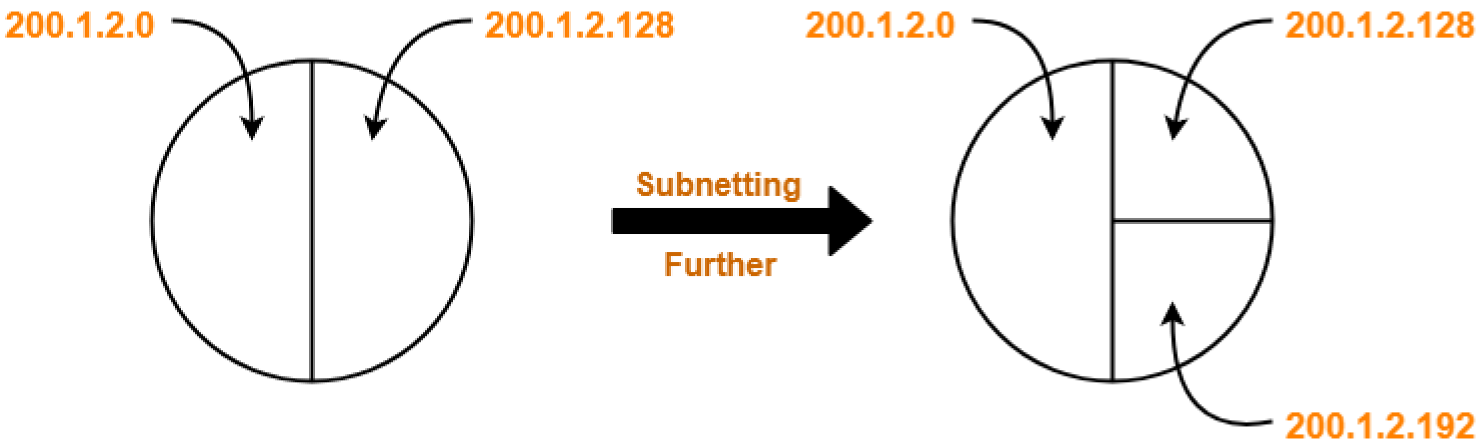
For creating two subnets and to represent their subnet IDs, we require 1 bit.
So,

- We borrow one more bit from the Host ID part.
- After borrowing one bit, Host ID part remains with only 6 bits.

- f 2nd borrowed bit = 0, then it represents one subnet.
- If 2nd borrowed bit = 1, then it represents the other subnet.

IP Address of the two subnets are-

- 200.1.2.**10**000000 = 200.1.2.128
- 200.1.2.**11**000000 = 200.1.2.192



Finally, the given single network is divided into 3 subnets having IP Address-

- 200.1.2.0
- 200.1.2.128
- 200.1.2.192

Example-03(continue.)

For 1st Subnet-

- IP Address of the subnet = 200.1.2.0
- Total number of IP Addresses = 2^7 = 128
- Total number of hosts that can be configured = 128 – 2 = 126
- Range of IP Addresses = [200.1.2.**0**0000000, 200.1.2.**0**1111111] = [200.1.2.0, 200.1.2.127]
- Direct Broadcast Address = 200.1.2.**0**1111111 = 200.1.2.127
- Limited Broadcast Address = 255.255.255.255

For 2nd Subnet-

- IP Address of the subnet = 200.1.2.128
- Total number of IP Addresses = 2^6 = 64
- Total number of hosts that can be configured = 64 – 2 = 62
- Range of IP Addresses = [200.1.2.**10**000000, 200.1.2.**10**111111] = [200.1.2.128, 200.1.2.191]
- Direct Broadcast Address = 200.1.2.**10**111111 = 200.1.2.191
- Limited Broadcast Address = 255.255.255.255

For 3rd Subnet-

- IP Address of the subnet = 200.1.2.192
- Total number of IP Addresses = 2^6 = 64
- Total number of hosts that can be configured = 64 – 2 = 62
- Range of IP Addresses = [200.1.2.**11**000000, 200.1.2.**11**111111] = [200.1.2.192, 200.1.2.255]
- Direct Broadcast Address = 200.1.2.**11**111111 = 200.1.2.255
- Limited Broadcast Address = 255.255.255.255

PRACTICE PROBLEMS BASED ON SUBNETTING

Problem-01:

Suppose a network with IP Address 192.16.0.0. is divided into 2 subnets, find number of hosts per subnet.
Also for the first subnet, find-

1. Subnet Address
2. First Host ID
3. Last Host ID
4. Broadcast Address

Solution-

- Given IP Address belongs to class C.
- So, 24 bits are reserved for the Net ID.
- The given network is divided into 2 subnets.
- So, 1 bit is borrowed from the host ID part for the subnet IDs.
- Then, Number of bits remaining for the Host ID = 7.
- Thus, Number of hosts per subnet = 2^7 = 128.

For 1st Subnet-

- Subnet Address = First IP Address = 192.16.0.**0**0000000 = 172.16.0.0
- First Host ID = 192.16.0.**0**0000001 = 192.16.0.1
- Last Host ID = 192.16.0.**0**1111110 = 192.16.0.126
- Broadcast Address = Last IP Address = 192.16.0.**0**1111111 = 172.16.0.127

Problem-02:

Problem-02:

What is **not true** about subnetting?

1.It is applied for a single network
2.It is used to improve security
3.Bits are borrowed from network portion
4.Bits are borrowed from Host portion

Solution-

Clearly, Option (C) is correct.

Problem-03:

In a class B, network on the internet has a subnet mask of 255.255.240.0. What is the maximum number of hosts per subnet?

1.4096
2.4094
3.4092
4.4090

Solution-

- Number of bits reserved for network ID in the given subnet mask = 20.
- So, Number of bits reserved for Host ID = 32 – 20 = 12 bits.
- Thus, Number of hosts per subnet = $2^{12} - 2 = 4094$.
- In class B, 16 bits are reserved for the network.
- So, Number of bits reserved for subnet ID = 20 – 16 = 4 bits.
- Number of subnets possible = $2^4 = 16$.
- Thus, Option (B) is correct.

Problem III – Subnet mask

Two computers C1 and C2 are configured as follows-

- C1 has IP Address 203.197.2.53 and net mask 255.255.128.0
- C2 has IP Address 203.197.75.201 and net mask 255.255.192.0

Which one of the following statements is true?

1. C1 and C2 both assume they are on the same network
2. C2 assumes C1 is on same network but C1 assumes C2 is on a different network
3. C1 assumes C2 is on same network but C2 assumes C1 is on a different network
4. C1 and C2 both assume they are on different networks

Problem III – Subnet mask (Solution)

Solution-

At Computer C1-

C1 computes its network address using its own IP Address and subnet mask as-
203.197.2.53 AND 255.255.128.0
= 203.197.0.0

C1 computes the network address of C2 using IP Address of C2 and its own subnet mask as-
203.197.75.201 AND 255.255.128.0
= 203.197.0.0

Since both the results are same, so C1 assumes that C2 is on the same network.

At Computer C2-

C2 computes its network address using its own IP Address and subnet mask as-
203.197.75.201 AND 255.255.192.0
= 203.197.64.0

C2 computes the network address of C1 using IP Address of C1 and its own subnet mask as-
203.197.2.53 AND 255.255.192.0
= 203.197.0.0

Since both the results are different, so C2 assumes that C1 is on a different network.
Thus, Option (C) is correct.

The subnet mask for a particular network is 255.255.31.0. Which of the following pairs of IP Addresses could belong to this network?

1. 172.57.88.62 and 172.56.87.233
2. 10.35.28.2 and 10.35.29.4
3. 191.203.31.87 and 191.234.31.88
4. 128.8.129.43 and 128.8.161.55

Solution-

Let the given two IP Addresses belong to Host A and Host B.

Checking Option (A)-

- Host A IP Address = 172.57.88.62
- Host B IP Address = 172.56.87.233

At Host A-

Host A computes its network address using its own IP Address and subnet mask-
172.57.88.62 AND 255.255.31.0
= 172.57.24.0

Host A computes the network address of Host B using IP Address of Host B and its own subnet mask-
172.56.87.233 AND 255.255.31.0
= 172.56.23.0
Since both the results are different, so host A assumes that host B is on a different network.
Thus, both can’t belong to the same network.
Hence, this option gets eliminated.

Checking Option (B)-

- Host A IP Address = 10.35.28.2
- Host B IP Address = 10.35.29.4

At Host A-

Host A computes its network address using its own IP Addres
and subnet mask-
10.35.28.2 AND 255.255.31.0
= 10.35.28.0

Host A computes the network address of Host B using IP Address of Host B and its own subnet mask-
10.35.29.4 AND 255.255.31.0
= 10.35.29.0

Since both the results are different, so host A assumes that h
B is on a different network.
Thus, both can’t belong to the same network.
Hence, this option gets eliminated.

Checking Option (C)-

- Host A IP Address = 191.203.31.87
- Host B IP Address = 191.234.31.88

At Host A-

Host A computes its network address using its own IP Address and subnet mask-
191.203.31.87 AND 255.255.31.0
= 191.203.31.0

Host A computes the network address of Host B using IP Address of Host B and its own subnet mask-
191.234.31.88 AND 255.255.31.0
= 191.234.31.0

Since both the results are same, so host A assumes that host B is on the same network.

At Host B-

Host B computes its network address using its own IP Addre
and subnet mask-
191.234.31.88 AND 255.255.31.0
= 191.234.31.0

Host B computes the network address of Host A using IP Address of Host A and its own subnet mask-
191.203.31.87 AND 255.255.31.0
= 191.203.31.0

Since both the results are different, so host B assumes that A is on a different network.
Thus, both can't belong to the same network.
Hence, this option gets eliminated.

Checking Option (D)-

- Host A IP Address = 128.8.129.43
- Host B IP Address = 128.8.161.55

At Host A-

Host A computes its network address using its own IP Address and subnet mask-
128.8.129.43 AND 255.255.31.0
= 128.8.1.0

Host A computes the network address of Host B using IP Address of Host B and its own subnet mask-
128.8.161.55 AND 255.255.31.0
= 128.8.1.0

Since both the results are same, so host A assumes that host B is on the same network.

At Host B-

Host B computes its network address using its own IP Address and subnet mask-
128.8.161.55 AND 255.255.31.0
= 128.8.1.0

Host B computes the network address of Host A using IP Address of Host A and its own subnet mask-
128.8.129.43 AND 255.255.31.0
= 128.8.1.0

Since both the results are same, so host B assumes that host A is on the same network.
Thus, both the hosts assume that they belong to the same network.

Disadvantages of Subnetting-

- During subnetting,
  - We have to face a loss of IP Addresses.
  - This is because two IP Addresses are wasted for each subnet.
  - One IP address is wasted for its network address.
  - Other IP Address is wasted for its direct broadcasting address.
- After subnetting, the communication process becomes complex involving the following 4 steps-
  1. Identifying the network
  2. Identifying the sub network
  3. Identifying the host
  4. Identifying the process

Classless Addressing- Classless Inter Domain Routing (CIDR)

What happened in classful addressing is that if any company needs more than 254 host machines but far fewer than the 65,533 host addresses then the only option for the company is to take the class B address.
Now suppose company needs only 1000 IP addresses for its host computers then in this (65533-1000=64533) IP addresses get wasted.
For this reason, the Internet was, until the arrival of CIDR, running out of address space much more quickly than necessary. CIDR effectively solved the problem by providing a new and more flexible way to specify network addresses in routers.

In order to reduce the wastage of IP addresses a new concept of Classless Inter-Domain Routing is introduced. Now a days IANA is using this technique to provide the IP addresses. Whenever any user asks for IP addresses, IANA is going to assign that many IP addresses to the User.

Classless Addressing-

Classless Addressing-

- Classless Addressing is an improved IP Addressing system.
- It makes the allocation of IP Addresses more efficient.
- It replaces the older classful addressing system based on classes.
- It is also known as **Classless Inter Domain Routing (CIDR)**.

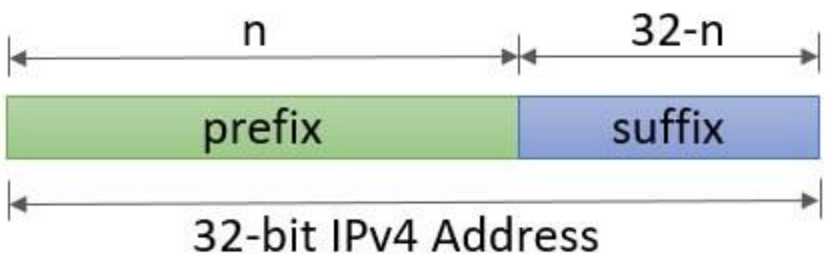
CIDR Block-

When a user asks for specific number of IP Addresses,

- CIDR dynamically assigns a block of IP Addresses based on certain rules.
- This block contains the required number of IP Addresses as demanded by the user.
- This block of IP Addresses is called as a **CIDR block**.

Classless Addressing

the **classless** addressing divides the IPv4 address into two parts referred to as '**prefix**' and '**suffix**'. **Prefix** defines the **network id** whereas **suffix** defines the **host address** in the corresponding network.



Addresses belonging to the **same block** persist the **same prefix** whereas **each host in a block** has a **different suffix**

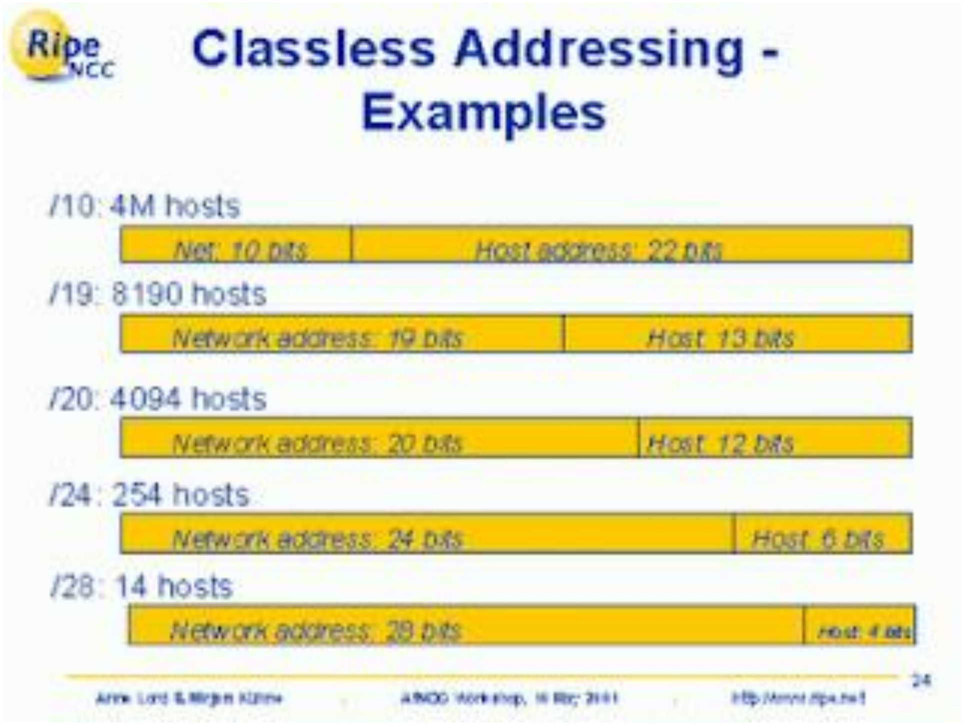
the **length of a prefix (n)** can be **0, 1, 2, 3, ..., 32**. So, the value of **suffix** would automatically be (32- length of the prefix).

In classless addressing, for a given address prefix length, could not be calculated as it can belong to a block of any prefix length. So, here the length of the prefix is included with each address to ease the extraction of block information.

The **length of the prefix (n)** is added to the last of address separated by a **slash**. This is called **slash notation** and more formally it is known as **Classless Inter-Domain Routing (CIDR) notation**.

CIDR notation

Classless addressing uses a variable number of bits for the network and host portions of the address.



CIDR Notation-

CIDR IP Addresses look like-

a.b.c.d / n

167.199.170.82/27

- They end with a slash followed by a number called as IP network prefix.
- IP network prefix tells the number of bits used for the identification of network.
- Remaining bits are used for the identification of hosts in the network.
- Classless addressing treats the IP address as a 32 bit stream of ones and zeroes, where the boundary between network and host portions can fall anywhere between bit 0 and bit 31.

IPv4 address 167.199.170.82/27 have an added value '27 ' which is separated by a slash, is a CIDR notation of classless IPv4 address. The value '**27**' denotes the length of the **prefix**. So, the length of the **suffix** would be '3**2-27= 5**'.

Rules For Creating CIDR Block-

A CIDR block is created based on the following 3 rules-

Rule-01:

- All the IP Addresses in the CIDR block must be contiguous.

Rule-02:

- The size of the block must be presentable as power of 2.
- Size of the block is the total number of IP Addresses contained in the block.
- Size of any CIDR block will always be in the form 2^1, 2^2, 2^3, 2^4, 2^5 and so on.

Rule-03:

- First IP Address of the block must be divisible by the size of the block.

REMEMBER

If any binary pattern consisting of (m + n) bits is divided by 2^n, then-

- Remainder is least significant n bits
- Quotient is most significant m bits

So, any binary pattern is divisible by 2^n, if and only if its least significant n bits are 0.

Examples-

Consider a binary pattern-

01100100.00000001.00000010.01000000

(represented as 100.1.2.64)

- It is divisible by 2^5 since its least significant 5 bits are zero.
- It is divisible by 2^6 since its least significant 6 bits are zero.
- It is not divisible by 2^7 since its least significant 7 bits are not zero.

Problem I

Check whether 100.1.2.32 to 100.1.2.47 is a valid IP address block or not?

Solution

Rule 1 : All the IP addresses are contiguous.

Rule 2 : Total number of IP addresses in the Block = 16 = 2^4.

Rule 3

1st IP address: 100.1.2.00100000

Since, Host Id will contains last 4 bits and all the least significant 4 bits are zero. Hence, first IP address is evenly divisible by the size of the block.

All the three rules are followed by this Block. Hence, it is a valid IP address block.

Rule 1

A block of addresses allocated to an organization must have the contiguous unallocated addresses.

Rule 2

The number of addresses in a block allocated to an organization must be the power of 2.

Rule 3

The first address of every block must be divisible by the length of the block.

Calculations from CIDR

Given address is **192.168.20.166/25**. As we know that the value after the slash in IP address is prefix (n) value=25

No of bits of network ID is 25.
No of bits of host ID is 7 (32-25)

Network ID

11000000. 10101000. 00010100. 10100110
AND
11111111. 1111111. 11111111. 10000000
………………………………………………………………………………
11000000. 10101000. 00010100. 1000000 (Network ID)

192 . 168 . 20 .128 (Network ID)

Network ID :192 . 168 . 20.128
No of bits of network ID is 25**.**
No of bits of host ID is 7
No of Host IDs : 2^7 = 128 (but first and last Host IDs are unusable. First is network ID,Last used as Indirect Broadcast address)
Range of HOST IDs [192. 168 . 20.128 to 192. 168 . 20. 255]
Usable Range: **[**192. 168 . 20.129 to 192. 168 . 20. 254]

First Host ID
192. 168 . 20.129

Last Host ID
192. 168 . 20. 254

Indirect BroadCast ID
192. 168 . 20. 255

Can u do?

- **Ex2: 192.168.30.14/29**

No of bits for network ID: 29
No of bits for Host ID:3

Network ID

11000000. 10101000.000 11110. 00001110

AND

11111111. 1111111. 11111111. 11111000

11000000. 10101000.000 11110. 00001000

92 . 168 . 30 . 8

No of bits of network ID is 29**.**
No of bits of host ID is 3
No of Host IDs : 2^3 =8

Range of HOST IDs
92 . 168 . 30 .8 to 92 . 168 . 30 .15

Range of usable HOST IDs
92 . 168 . 30 .9 to 92 . 168 . 30 .14

First Host ID
92 . 168 . 30 .9
Last Host ID
92 . 168 . 30 .14

Indirect BroadCast ID
92 . 168 . 30 .15

How to calculate IP address subnet information (Network, Broadcast, First IP, Last IP)?

Ex1: 192.168.20.166/25:

166/128 = 1.296875
Network ID: 1*128 = 128 (192.168.20.128)
Broadcast ID: 128+(128-1) = 255 (192.168.20.255)
First Host ID: 128 + 1 = 129 (192.168.20.129)
Last Host ID: 255 - 1 = 254 (192.168.20.254)

Ex2: 192.168.30.14/29:

14/8 = 1.75
Network ID: 1*8 = 8 (192.168.30.8)
Broadcast ID: 8+(8-1) = 15 (192.168.30.15)
First Host ID: 8 + 1 = 9 (192.168.30.9)
Last Host ID: 15 - 1 = 14 (192.168.30.14)

Using Equation:

Network ID: floor(Host Address/Subnet Number of Hosts) * Subnet Number of Hosts
Broadcast ID: (Host ID + (Subnet Number of Hosts-1))
First Host: Network ID + 1
Last Host: Broadcast ID - 1

A short cut

Subnetting in Classless Addressing

Subnetting in Classless addressing

Consider address 195.10.20.128/26

26 bits	6 bits
Network ID	host ID

195.10.20.10000000

$\underbrace{195.10.20.1}_{\text{26 bits (network ID)}}\underbrace{0000000}_{\text{6 bits host ID bits}}$

For subnetting fix 1 MSB of host ID bit to

0 – subnet 1

1 – subnet 2

This creates 2 subnets

195.10.20.100 00000
" 00001
" 00010
⋮
195.10.20.1001 1111

S1	S2
$32 \div 2$	$32 \div 2$

195.10.20.1010 0000
" 00001
" 00010
⋮
195.10.20.1011 1111

195.10.20.128 to 195.10.20.159/27

195.10.20.160 to 195.10.20.191/27

Subnet1- Bit set to 0

Subnet2- Bit set to 1

Subnet1

195.10.20.128/27 to 195.10.20.159/27

195.10.20.10000000 to **195.10.20.100**11111

Subnet2

195.10.20.160/27 to 195.10.20.191/27

195.10.20.10100000 to **195.10.20.101**11111

Why slash 27?

27 bits are now fixed for network address

PRACTICE PROBLEMS BASED ON CLASSLESS INTER DOMAIN ROUTING-

Problem-01:

Given the CIDR representation 20.10.30.35 / 27. Find the range of IP Addresses in the CIDR block.

Solution-

Given CIDR representation is 20.10.30.35 / 27.

It suggests-

- 27 bits are used for the identification of network.
- Remaining 5 bits are used for the identification of hosts in the network.

Given CIDR IP Address may be represented as-

00010100.00001010.00011110.00100011 / 27

So,

- First IP Address = 00010100.00001010.00011110.001**00000** = 20.10.30.32
- Last IP Address = 00010100.00001010.00011110.001**11111** = 20.10.30.63

Thus, Range of IP Addresses = [20.10.30.32 , 20.10.30.63]

Problem-02:

Given the CIDR representation 100.1.2.35 / 20. Find the range of IP Addresses in the CIDR block.

Solution-

Given CIDR representation is 100.1.2.35 / 20.

It suggests-

- 20 bits are used for the identification of network.
- Remaining 12 bits are used for the identification of hosts in the network.

Given CIDR IP Address may be represented as-

01100100.00000001.00000010.00100011 / 20

So,

- First IP Address = 01100100.00000001.0000**0000.00000000** = 100.1.0.0
- Last IP Address = 01100100.00000001.0000**1111.11111111** = 100.1.15.255

Thus, Range of IP Addresses = [100.1.0.0 , 100.1.15.255]

Problem-03:

Consider a block of IP Addresses ranging from 100.1.2.32 to 100.1.2.47.

1. Is it a CIDR block?
2. If yes, give the CIDR representation.

Solution-

For any given block to be a CIDR block, 3 rules must be satisfied-

Rule-01:

- According to Rule-01, all the IP Addresses must be contiguous.
- Clearly, all the given IP Addresses are contiguous.
- So, Rule-01 is satisfied.

Rule-02:

- According to Rule-02, size of the block must be presentable as 2^n.
- Number of IP Addresses in the given block = 47 – 32 + 1 = 16.
- Size of the block = 16 which can be represented as 2^4.
- So, Rule-02 is satisfied.

Rule-03:

- According to Rule-03, first IP Address must be divisible by size of the block.
- So, 100.1.2.32 must be divisible by 2^4.
- 100.1.2.32 = 100.1.2.0010**0000** is divisible by 2^4 since its 4 least significant bits are zero.
- So, Rule-03 is satisfied.

Since all the rules are satisfied, therefore given block is a CIDR block.

CIDR Representation-

We have-
- Size of the block = Total number of IP Addresses = 2^4.
- To have 2^4 total number of IP Addresses, total 4 bits are required in the Host ID part.
- So, Number of bits present in the Network ID part = 32 – 4 = 28.

CIDR Representation = 100.1.2.32 / 28

NOTE-

For writing the CIDR representation,
- We can choose to mention any IP Address from the CIDR block.
- The chosen IP Address is followed by a slash and IP network prefix.
- We generally choose to mention the first IP Address.

Problem-04:

Consider a block of IP Addresses ranging from 150.10.20.64 to 150.10.20.127.

1.Is it a CIDR block?

2.If yes, give the CIDR representation.

Solution-

For any given block to be a CIDR block, 3 rules must be satisfied-

Rule-01:

- According to Rule-01, all the IP Addresses must be contiguous.
- Clearly, all the given IP Addresses are contiguous.
- So, Rule-01 is satisfied.

Rule-02:

- According to Rule-02, size of the block must be presentable as 2^n.
- Number of IP Addresses in given block = 127 – 64 + 1 = 64.
- Size of the block = 64 which can be represented as 2^6.
- So, Rule-02 is satisfied.

Rule-03:

- According to Rule-03, first IP Address must be divisible by size of the block.
- So, 150.10.20.64 must be divisible by 2^6.
- 150.10.20.64 = 150.10.20.01**000000** is divisible by 2^6 since its 6 least significant bits are zero.
- So, Rule-03 is satisfied.

Since all the rules are satisfied, therefore given block is a CIDR block.

CIDR Representation-

We have-

- Size of the block = Total number of IP Addresses = 2^6.
- To have 2^6 total number of IP Addresses, 6 bits are required in the Host ID part.
- So, Number of bits in the Network ID part = 32 – 6 = 26.

Thus,

CIDR Representation = 150.10.20.64 / 26

Problem-05:

Perform CIDR aggregation on the following IP Addresses-

128.56.24.0/24
128.56.25.0/24
128.56.26.0/24
128.56.27.0/24

Solution-

All the 4 given entities represent CIDR block in itself.
We have to now perform the aggregation of these 4 blocks.

Rule-01:

- According to Rule-01, all the IP Addresses must be contiguous.
- Clearly, all the IP Addresses are contiguous.
- So, Rule-01 is satisfied.

Rule-02:

- According to Rule-02, size of the block must be presentable as 2^n.
- Total number of IP Addresses = $2^8 + 2^8 + 2^8 + 2^8 = 2^2 \times 2^8 = 2^{10}$.
- So, Rule-02 is satisfied.

Rule-03:

- According to Rule-03, first IP Address must be divisible by size of the block.
- So, 128.56.24.0 must be divisible by 2^{10}.
- 128.56.24.0 = 128.56.000110**00.00000000** is divisible by 2^{10} since its 10 least significant bits are zero.
- So, Rule-03 is satisfied.

Since all the 3 rules are satisfied, so they can be aggregated.

CIDR Representation-

We have-

- Size of the block = Total number of IP Addresses = 2^{10}.
- To have 2^{10} total number of IP Addresses, 10 bits are required in the Host ID part.
- So, Number of bits in the Network ID part = 32 – 10 = 22.

Thus,

CIDR Representation = 128.56.24.0/22

Problem-06:

Perform CIDR aggregation on the following IP Addresses-
200.96.86.0/24
200.96.87.0/24
200.96.88.0/24
200.96.89.0/24

Solution-

All the 4 given entities represent CIDR block in itself.
We have to now perform the aggregation of these 4 blocks.

Rule-01:

- According to Rule-01, all the IP Addresses must be contiguous.
- Clearly, all the IP Addresses are contiguous.
- So, Rule-01 is satisfied.

Rule-02:

- According to Rule-02, size of the block must be presentable as 2^n.
- Total number of IP Addresses = $2^8 + 2^8 + 2^8 + 2^8 = 2^2 \times 2^8 = 2^{10}$.
- So, Rule-02 is satisfied.

Rule-03:

- According to Rule-03, first IP Address must be divisible by size of the block.
- So, 200.96.86.0 must be divisible by 2^{10}.
- 200.96.86.0 = 200.96.010101**10.00000000** is not divisible by 2^{10} since its 10 least significant bits are not zero.
- So, Rule-03 is unsatisfied.

Since all the 3 rules are not satisfied, so they can not be aggregated.

Classless interdomain routing (CIDR) receive a packet with address 131.23.151.76. The Router's routing table has following entities:

Prefix	output Interface
131.16.0.0/12	3
131.28.0.0/14	5
131.19.0.0/16	2
131.22.0.0/15	1

Packet will be forwarded to which interface ______

Namah Shivaya