IP Address in Networking

Overview

- 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.

IPv4 ADDRESSES

An IPv4 address is a 32-bit address that uniquely and universally defines the connection of a device (for example, a computer or a router) to the Internet.

The address space of IPv4 is
2^{32} or 4,294,967,296.

Types of IP Address

Static IP Address

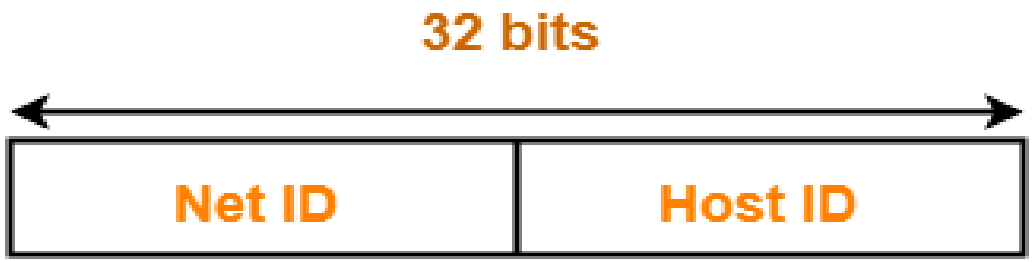
- Static IP Address is an IP Address that once assigned to a network element always remains the same.
- They are configured manually.
- Some ISPs do not provide static IP addresses.
- Static IP Addresses are more costly than dynamic IP Addresses.

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.
- DHCP (Dynamic Host Configuration Protocol) or PPPoE (Point-to-Point Protocol over Ethernet) assigns dynamic IP addresses.

IP Address Format

- 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.



Format of an IP Address

IP Address Format

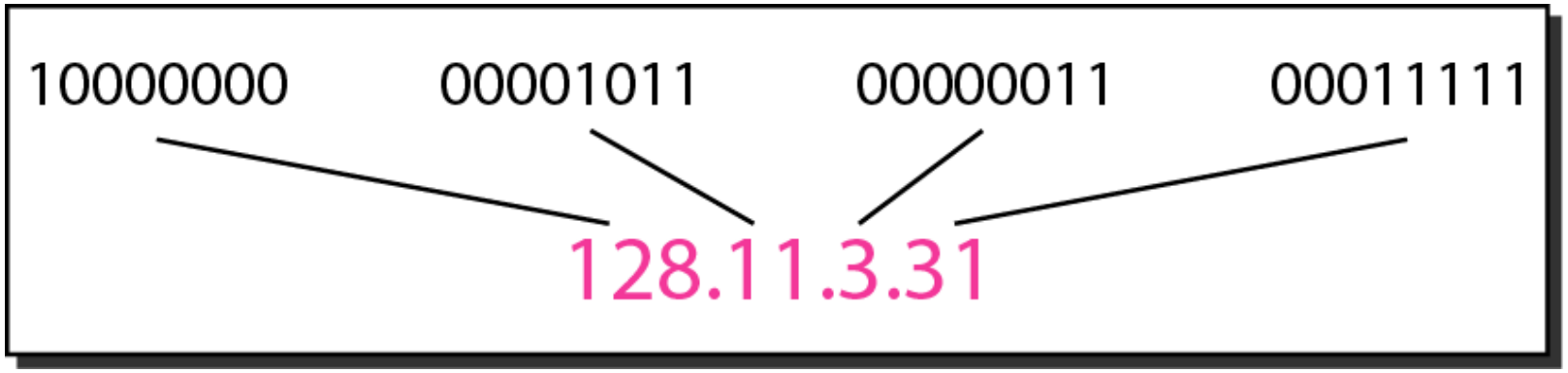
- Network ID represents the IP Address of the network and is used to identify the network.
- Host ID represents the IP Address of the host and is used to identify the host within the network.

IP Address Example

00000001.10100000.00001010.11110000 (Binary Representation)

OR

1.160.10.240 (Decimal Representation)



Dotted Decimal Notation

- Each 8-bit section (known as a byte or octet) of the 32-bit number [IP(v4)] is expressed as a decimal value with periods between them.
- The combination of eight bits can be in $256=2^8$ states, which are expressed as the numbers 0 through 255.
- The range of valid addresses which can be assigned is 0.0.0.0 to 255.255.255.255, which barring various reserved addresses is 4,294,967,296=232

IP Address Example

Change the following IPv4 addresses from binary notation to dotted-decimal notation.

a. 10000001 00001011 00001011 11101111

b. 11000001 10000011 00011011 11111111

Solution

We replace each group of 8 bits with its equivalent decimal number (see Appendix B) and add dots for separation.

a. 129.11.11.239

b. 193.131.27.255

IP Address Example

Change the following IPv4 addresses from dotted-decimal notation to binary notation.

a. 111.56.45.78

b. 221.34.7.82

Solution

We replace each decimal number with its binary equivalent (see Appendix B).

a. 01101111 00111000 00101101 01001110

b. 11011101 00100010 00000111 01010010

IP Address Example

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.

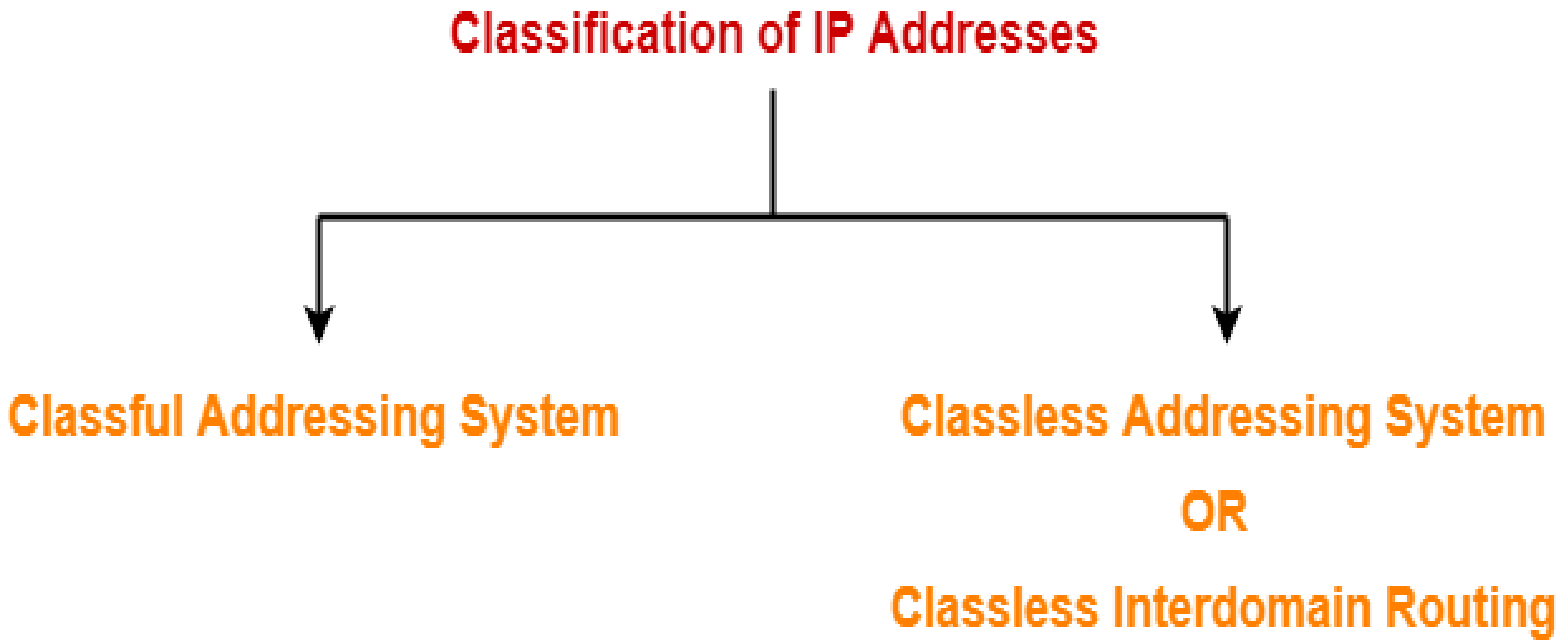
Uniqueness

- Each computer on an internet (or on the Internet) must have a unique address.
  - Two hosts on the same internet can have different network portions and the same node portion.
  - Two hosts on the same internet can have the same network portion and different node portions.
  - Two hosts on the same internet can have different network portions and different node portions.

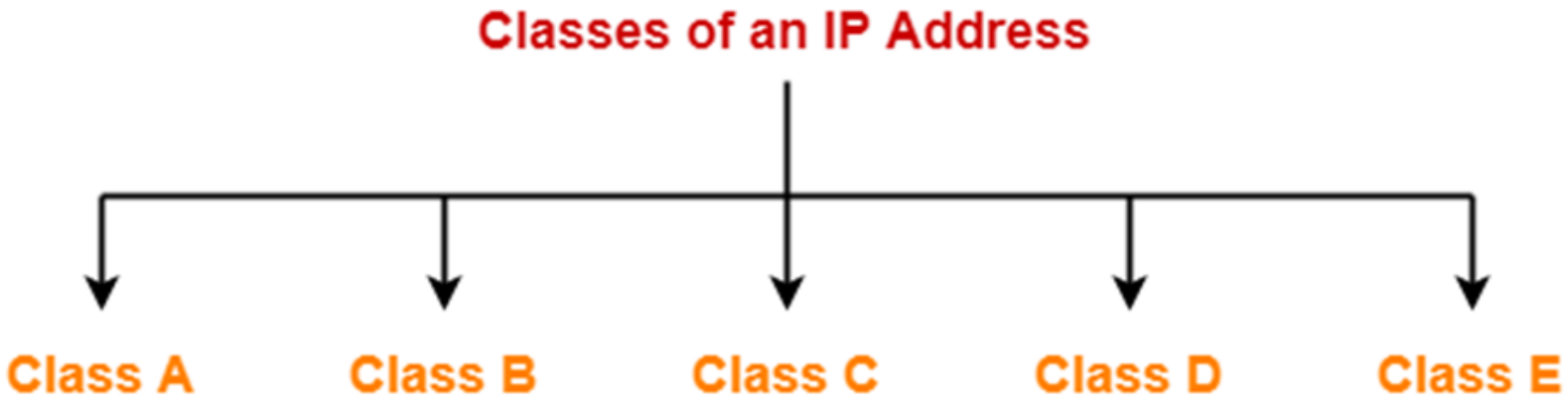
Address Classes

- The IP address is not divided into equal halves with one half for the network portion, the other for the node potion
- The addressing scheme tries to accommodate for the fact that
  - —Some networks (not many) will contain a vast number of hosts
  - —While other networks (very many) will contain a more modest number of hosts
- Thus the IP Class system was developed.

IP Addressing



Classful Addressing

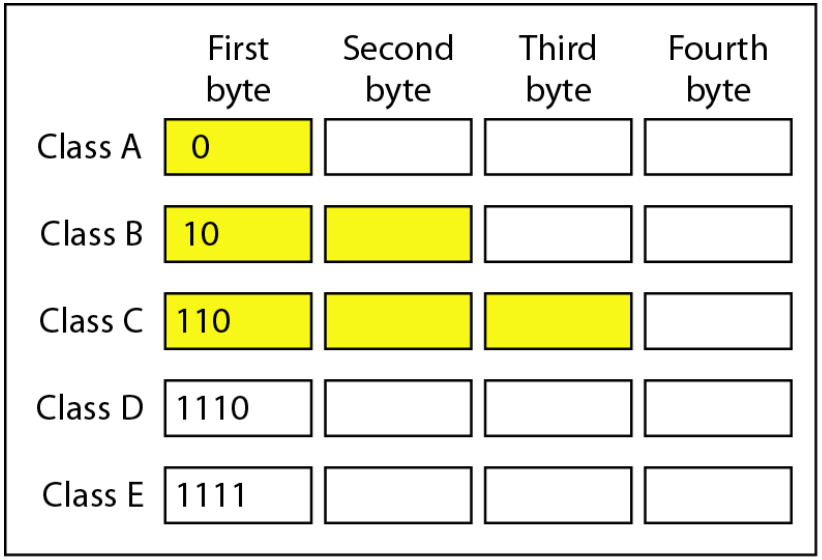


In classful addressing, the address space is divided into five classes: A, B, C, D, and E.

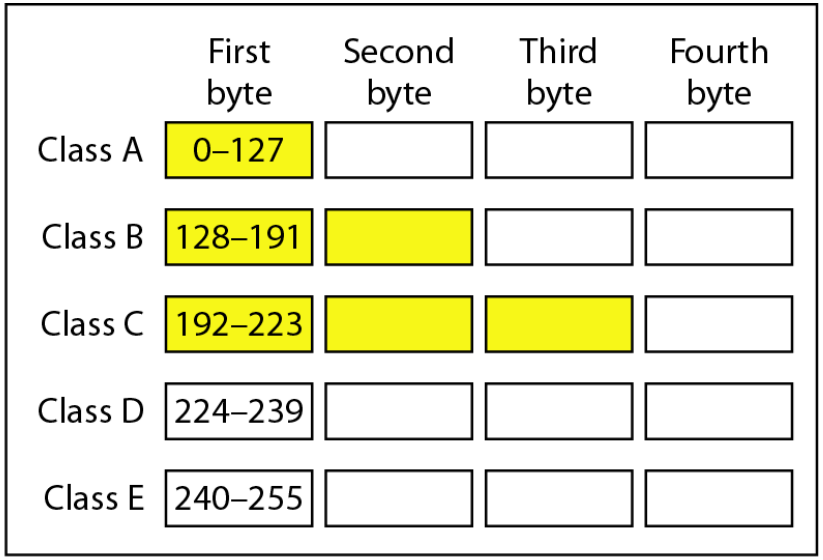
The IP Class System

- Originally the IP(v4) Addresses were broken into 5 classes: A through E.
- The dividing line between network portion and node portion of the IP address differed from class to class.
- The first four bits on the left identify the class to which an address belongs.
- A, B and C are the primary classes for the addressing, D and E were reserved.

Classful Addressing

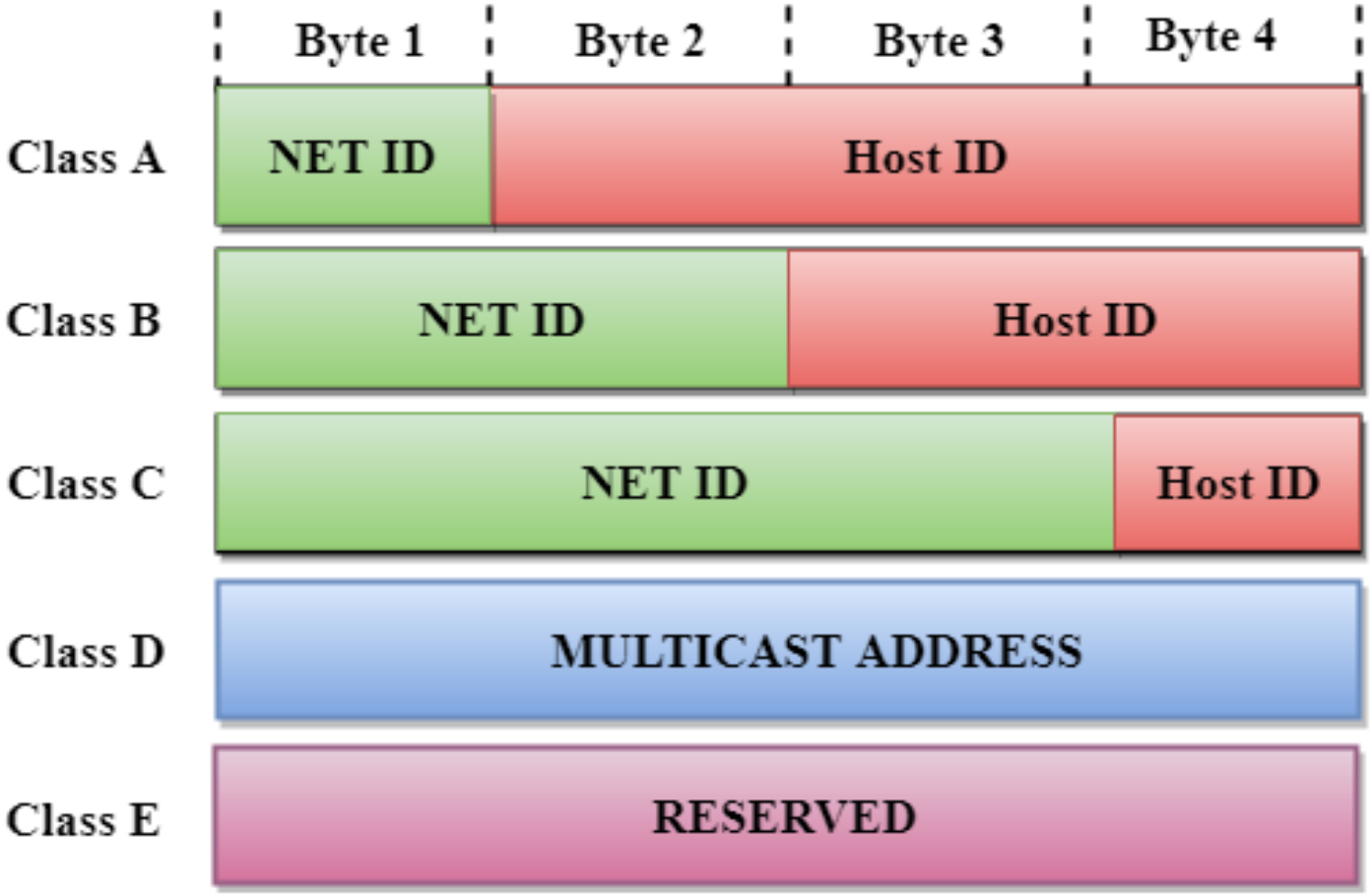


a. Binary notation

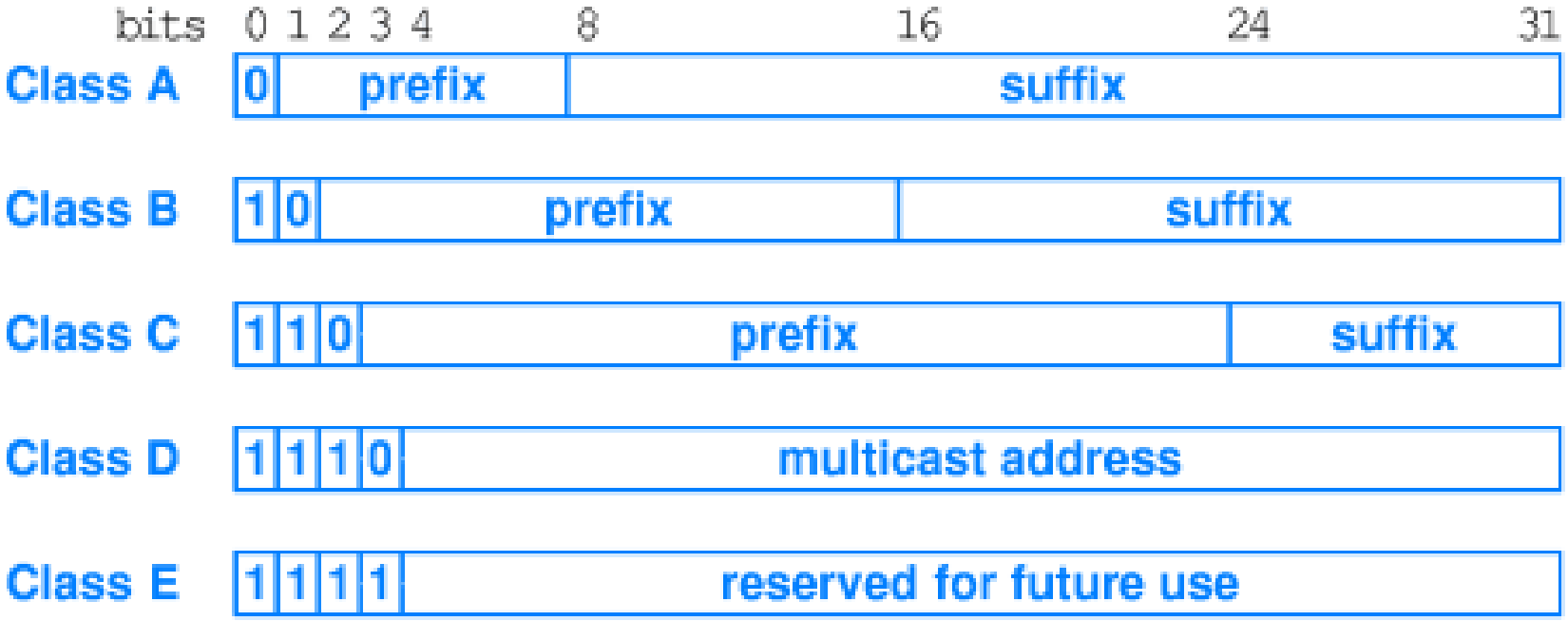


b. Dotted-decimal notation

Classful Addressing



Classful Addressing



Example

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.

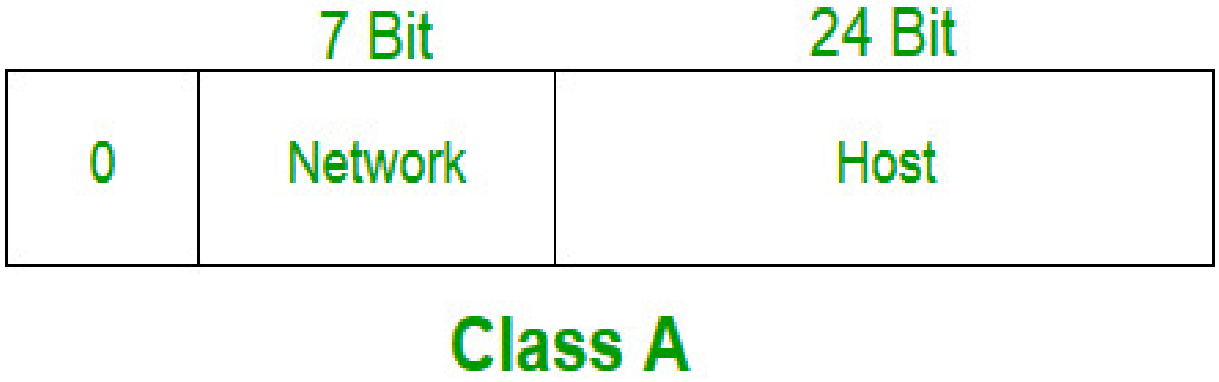
b. The first 2 bits are 1; the third bit is 0. This is a class C address.

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

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

Class A

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



Class A

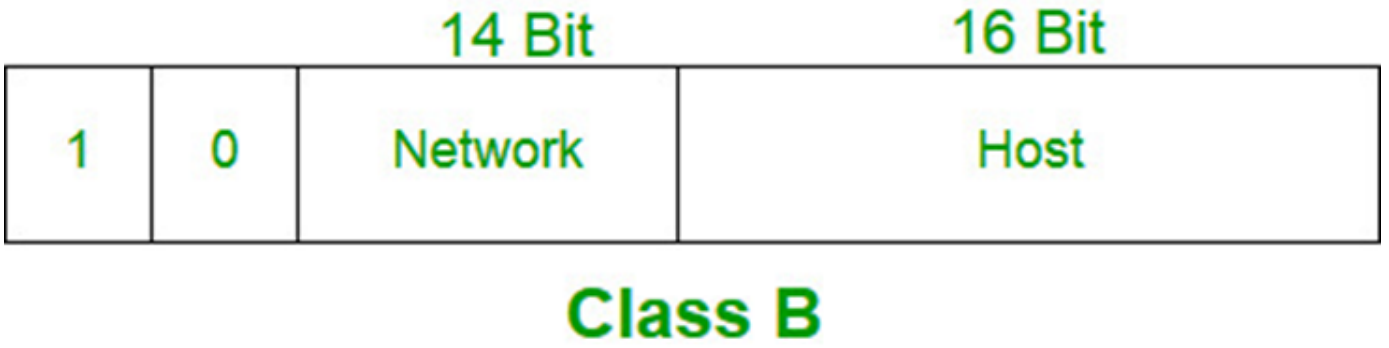
- The remaining 24 bits are used for the Host ID.
- The higher order bit of the first octet in class A is always set to 0.
- The remaining 7 bits in first octet are used to determine network ID.
- The 24 bits of host ID are used to determine the host in any network.
- The default subnet mask for class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

Class A

- IP addresses belonging to class A ranges from 1.x.x.x – 126.x.x.x.
- 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.
- In class B IP Address,
  - The first 16 bits are used for the Network ID.
  - The remaining 16 bits are used for the Host ID.



Class B

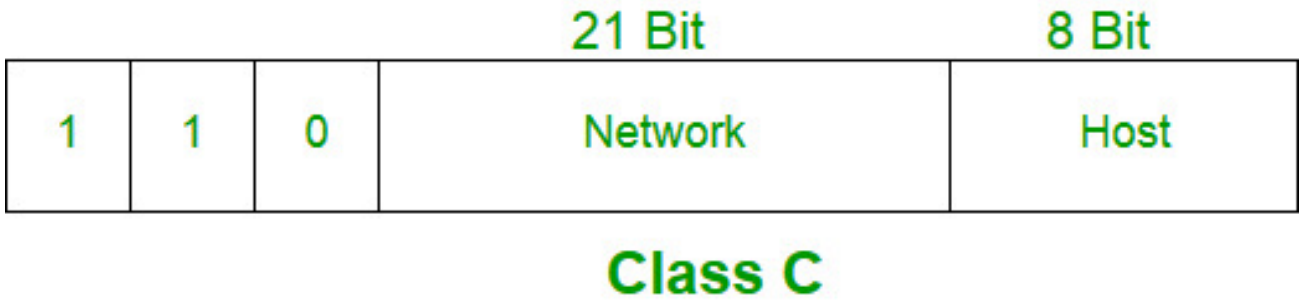
- The higher order bits of the first octet of IP addresses of class B are always set to 10.
- The remaining 14 bits are used to determine network ID.
- The 16 bits of host ID is used to determine the host in any network.
- The default sub-net mask for class B is 255.255.x.x.
- Class B has a total of:
  - 2^14 = 16384 network address
  - 2^16 – 2 = 65534 host address

Class B

- IP addresses belonging to class B ranges from 128.0.x.x – 191.255.x.x.
- 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.
- In class C IP Address,
  - The first 24 bits are used for the Network ID.
  - The remaining 8 bits are used for the Host ID.



Class C

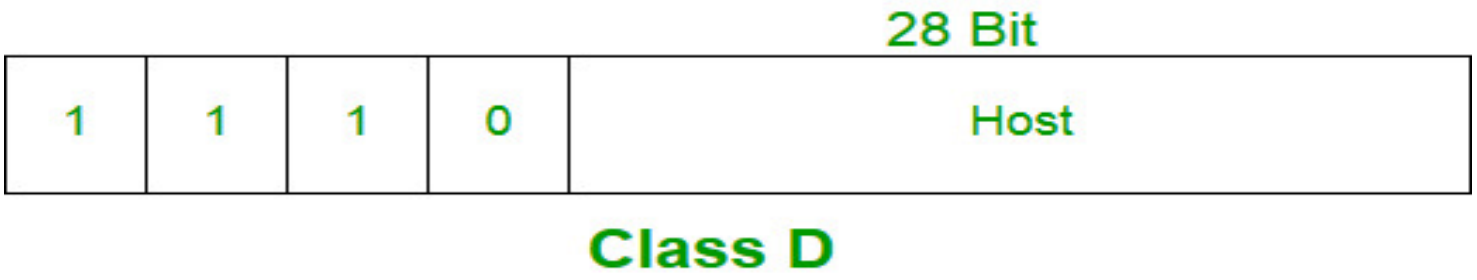
- The higher order bits of the first octet of IP addresses of class C are always set to 110.
- The remaining 21 bits are used to determine network ID.
- The 8 bits of host ID is used to determine the host in any network.
- The default sub-net mask for class C is 255.255.255.x.
- Class C has a total of:
  - 2^21 = 2097152 network address
  - 2^8 – 2 = 254 host address

Class C

- IP addresses belonging to class C ranges from 192.0.0.x – 223.255.255.x.
- Class C is used by organizations requiring small to medium size networks.
- For example- engineering colleges, small universities, small offices etc.

Class D

- If the 32-bit binary address starts with bits 1110, then IP Address belongs to class D.
- **Class D is not divided into Network ID and Host ID.**



Class D

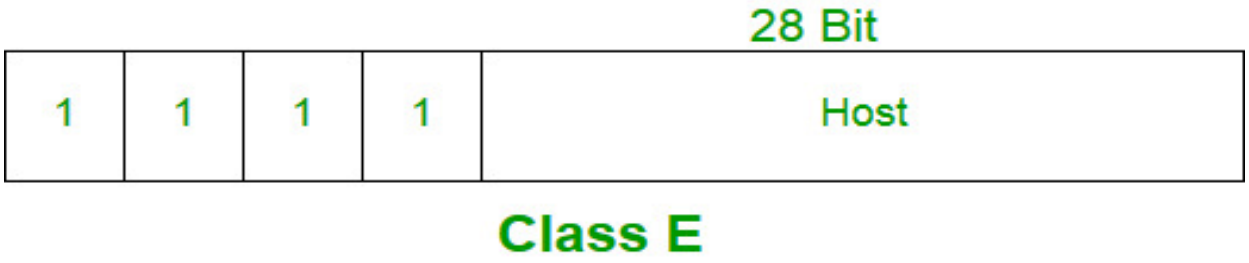
- The higher order bits of the first octet of IP addresses belonging to class D are always set to 1110. The remaining bits are for the address that interested hosts recognize.
- Class D does not posses any sub-net mask.
- IP addresses belonging to class D ranges from 224.0.0.0 – 239.255.255.255.

Class D

- Class D is reserved for multicasting.
- 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

- If the 32-bit binary address starts with bits 1111, then IP Address belongs to class E.
- **Class E is not divided into Network ID and Host ID.**



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 is reserved for future or experimental purposes.

Classes of IP Address

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

Default masks for classful addressing

Class	*Binary*	*Dotted-Decimal*	*CIDR*
A	**11111111** 00000000 00000000 00000000	**255**.0.0.0	/8
B	**11111111 11111111** 00000000 00000000	**255.255**.0.0	/16
C	**11111111 11111111 11111111** 00000000	**255.255.255**.0	/24

Number of blocks and block size in classful IPv4 addressing

Class	*Number of Blocks*	*Block Size*	*Application*
A	128	16,777,216	Unicast
B	16,384	65,536	Unicast
C	2,097,152	256	Unicast
D	1	268,435,456	Multicast
E	1	268,435,456	Reserved

Range of special IP addresses

- 0.0.0.0 – 0.0.0.8 : used to communicate within the current network.
- 127.0.0.0 – 127.0.0.8 : Loop-back addresses
- 169.254.0.0 – 169.254.0.16 : Link local addresses

Important Notes

- All the hosts in a single network always have the same network ID but different Host ID. However, two hosts in two different networks can have the same host ID.
- A single network interface can be associated with more than one IP Address.
- There is no relation between MAC Address and IP Address of a host.
- IP Address of the network called Net ID is obtained by setting all the bits for Host ID to zero.

Important Notes

- Class A Networks accounts for half of the total available IP Addresses.
- In all the classes, total number of hosts that can be configured are 2 less.
- This is to account for the two reserved IP addresses in which all the bits for host ID are either zero or one.
- When all Host ID bits are 0, it represents the Network ID for the network.

Important Notes

- When all Host ID bits are 1, it represents the Broadcast Address.
- Only those devices which have the network layer will have IP Address. So, switches, hubs and repeaters does not have any IP Address.

Summary

- For any given IP Address,
  - If the range of first octet is [1, 126], then IP Address belongs to class A.
  - If the range of first octet is [128, 191], then IP Address belongs to class B.
  - If the range of first octet is [192, 223], then IP Address belongs to class C.
  - If the range of first octet is [224, 239], then IP Address belongs to class D.
  - If the range of first octet is [240, 254], then IP Address belongs to class E.

Summary

- For any given IP Address, IP Address of its network is obtained by setting all its Host ID part bits to 0.
- For any given IP Address, Direct Broadcast Address is obtained by setting all its Host ID part bits to 1.
- For any given IP Address, limited Broadcast Address is obtained by setting all its bits to 1. For any network, its limited broadcast address is always 255.255.255.255.

Summary

- Class D IP Addresses are not divided into Net ID and Host ID parts.
- Class E IP Addresses are not divided into Net ID and Host ID parts.

Problem-01

- For the following IP Addresses-

1.2.3.4, 10.15.20.60, 130.1.2.3, 150.0.150.150, 200.1.10.100, 220.15.1.10, 250.0.1.2, 300.1.2.3

Identify the Class, Network IP Address, Direct broadcast address and Limited broadcast address of each IP Address.

Solution

IP	NID	DBA	LBA
1.2.3.4 (A)	1.0.0.0	1.255.255.255	255.255.255.255
10.15.20.60(A)	10.0.0.0	10.255.255.255	255.255.255.255
130.1.2.3(B)	130.1.0.0	130.1.255.255	255.255.255.255
150.0.150.150(B)	150.0.0.0	150.0.255.255	255.255.255.255
200.1.10.100(C)	200.1.10.0	200.1.10.255	255.255.255.255
220.15.1.10(C)	220.15.1.0	220.15.1.255	255.255.255.255
250.0.1.2(E)	Not available	Not available	Not available
300.1.2.3(Invalid)	Not available	Not available	Not available

Problem-02

- A host with IP Address 200.100.1.1 wants to send a packet to all the hosts in the same network. What will be-
  - Source IP Address
  - Destination IP Address
- **Solution**-
  - Source IP Address = IP Address of the sender = 200.100.1.1
  - Destination IP Address = Limited Broadcast Address = 255.255.255.255

Problem-03

- A host with IP Address 10.100.100.100 wants to use loop back testing. What will be-
  - Source IP Address
  - Destination IP Address
- **Solution**-
  - Source IP Address = 10.100.100.100
  - Destination IP Address = Loopback Testing Address = 127.0.0.1

Problem-04

- How many bits are allocated for Network ID and Host ID in 23.192.157.234 address?

- Solution-
  - Given IP Address belongs to class A. Thus,
  - Number of bits reserved for Network ID = 8
  - Number of bits reserved for Host ID = 24

Problem-05

- What is the network ID of the IP Address 230.100.123.70?

- **Solution**-
  - Given IP Address belongs to class D.
  - Class D IP Addresses are not divided into the Network ID and Host ID parts.
  - Thus, there is no network ID for the given IP Address.

Problem-06

- Suppose that instead of using 16 bits for network part of a class B Address, 20 bits have been used. How many class B networks would have been possible?
- **Solution**-
  - Total 20 bits are used for Network ID of class B.
  - The first two bits are always set to 10.
  - Then, with 18 bits, number of networks possible = 2^{18}

Problem-07

- What is the default mask for 192.0.46.10?

- **Solution**-
  - Given IP Address belongs to class C.
  - For class C, default mask = 255.255.255.0

Classful addressing

In classful addressing, a large part of the available addresses were wasted.

Classful addressing, which is almost obsolete, is replaced with 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.

Rules for Creating CIDR Block

- **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 21, 22, 23, 24, 25 and so on.
- **Rule-03**:
  - First IP Address of the block must be divisible by the size of the block.

CIDR Notation

- CIDR IP Addresses look like-

  a.b.c.d / n

- 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.

Example

- An example of CIDR IP Address is-

  182.0.1.2 / 28

- It suggests-
  - 28 bits are used for the identification of network.
  - Remaining 4 bits are used for the identification of hosts in the network.

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 = 00010100.00001010.00011110.00100000 = 20.10.30.32
- Last IP Address = 00010100.00001010.00011110.00111111 = 20.10.30.63
- Thus, Range of IP Addresses = [20.10.30.32 , 20.10.30.63]

Problem-02

- Consider a block of IP Addresses ranging from 150.10.20.64 to 150.10.20.127. Is it a CIDR block? 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.

Solution

- 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.

Solution

- 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 = 150.10.20.01000000 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.

Solution

- CIDR Representation-
- 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