**IP**- An Internet Protocol is also known as IP address. It is a numerical label which assigned to each device connected to a computer network which uses IP for communication.

IP address act as an identifier for a specific machine on a particular network.

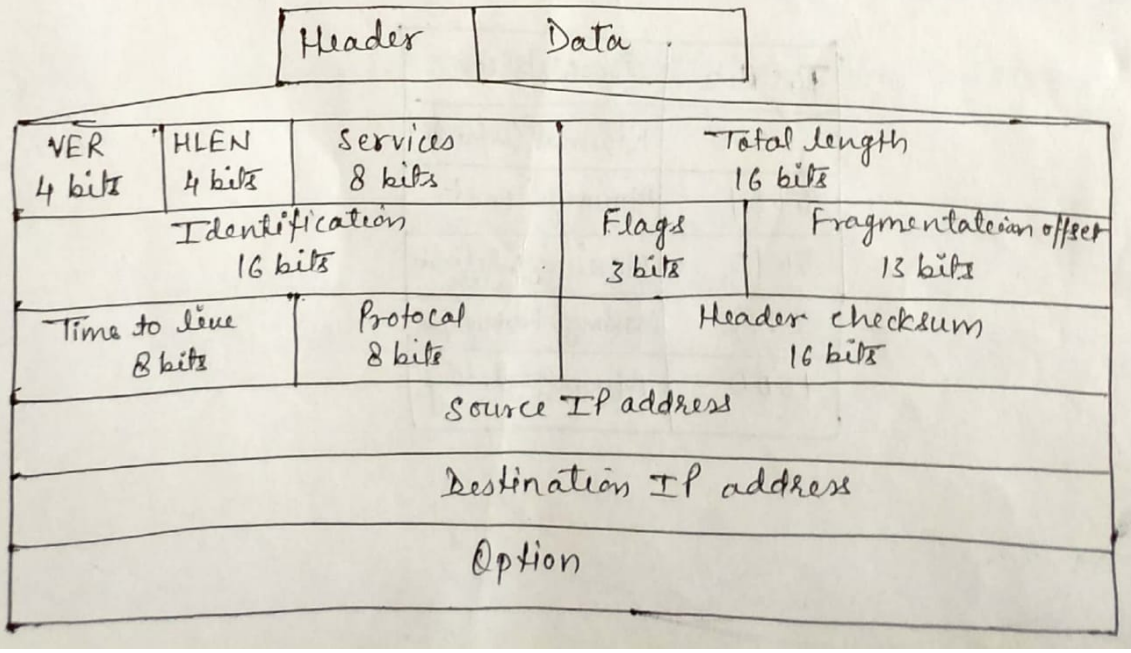
**IPV4**- IPv4 was the first version of IP. The IPv4 uses a 32-bit address scheme allowing to store 2^32 addresses which is more than 4 billion addresses.

The Internet Protocol version 4 (IPv4) is the delivery machenism used by the TCP/IP protocol

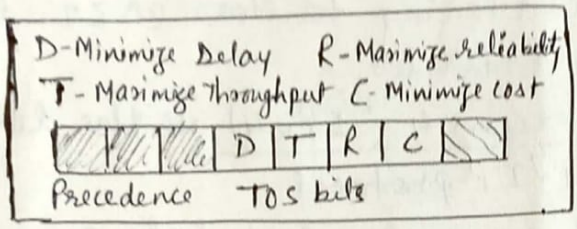
IPv4 is an unreliable & connectionless datagram protokol – a best effort delivery service. The term best effort means that IPv4 provides no error control or flow control. IPv4 assumes the unreliability of the underlaying layers and does its best to get a transmission through to its destination, but with no guarantees.

~~The~~ packets in the IPv4 layer are call datagrams.

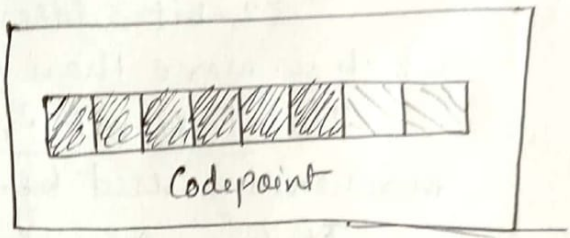
IPv4 datagram formate.



- Version – Version no. of Internet Protocol used.
- HLEN – Length of entire IP header.
- Services – IETF (Internet Engineering Task for) has changed the interpretation & name of this 8 bit field. This field, previously called serice type, is now called differentiated services.




Service Type




Differentiated Services

i) Service type – In this interpretation, the first 3 bits are called precedance bits. The next 4 bits are called type of service (TOS) bits, and the last bit is not used

3 bits precedance defines the priority of the datagram in issues such as congestion control.

TOS bits is a 4 bit subfield with each bit having special meaning. ~~The bit patterns and their~~. One & only one bit can have the value of 1 in each datagram.

| TOS Bits | Description |
|---|---|
| 0000 | Normal (Default) |
| 0001 | Minimize cost |
| 0010 | Maximize reliability |
| 0100 | Maximize throughput |
| 1000 | Minimize delay |

Protocol – This field specifies the final destination protocol to which the IPv4 dalagram ~~can encapsulate data from several~~ is delivered.

In other words, since the IPv4 protocol carries data from different other protocols, the value of this field helps the receiving network layer know to which protocol the data belong.

| Value | Protocol |
|---|---|
| 1 | ICMP |
| 2 | IGMP |
| 6 | TCP |
| 17 | UDP |
| 89 | OSPF |

Checksum – This field is used to keep checksum value of entire header which is then used to check if the packet is received error free.

Source address – 32 bit address of the sender (or source) of the packet.

Destination address – 32 bit address of the receiver of the packet.

Options – This is optional field, which is used if the value of IHL is greater than 5.
These options such as security, Record Route, Time stamp etc.

ii) Differentiated services - In this interpretation, the first 6 bits make up the codepoint subfield, & the last 2 bits are not used. The code point field can be used in two different ways.

a) when the 3 rightmost bits are 0s, the 3 leftmost bits are interpreted the same as the precedance bits in the service type interpretation.

b) when the 3 rightmost bits are not 0s, the 6 bits define 64 services based on the priority assignment by the Internet or Local authorities.

Total length - Length of entire IP packet (including IP header and IP payload).

Identification - If IP packet is fragmented during the transmission, all the fragments contain same identification number to identify original IP packet they belong to.

Flags - As required by the network resources, if IP address is too large to handle, these 'flags' tells if they can be fragmented or not.

fragment offset - This offset tells the exact position of the fragment in the original IP packet.

Time to live - A datagram has a limited lifetime in its travel through an internet. To avoid looping in the network, every packet is sent with some TTL value set, which tells the network how many routers (hops) this packet can cross. At each hop, its value is decremented by one & when the value reaches zero, the packet is discarded.

# IPv4 address classes

The first octet referred here is the left most of all. The octets numbered as follows depicting dotted decimal notation of IP Address:

1st Octet 2nd Octet 3rd Octet 4th Octet

**11000000.10101000.00000001.10011000**

192 . 168 . 1 . 152

The number of networks and the number of hosts per class can be derived by this formula:

Number of networks = 2^network_bits

Number of Hosts/Network = 2^host_bits – 2

When calculating hosts' IP addresses, 2 IP addresses are decreased because they cannot be assigned to hosts, i.e. the first IP of a network is network number and the last IP is reserved for Broadcast IP.

## Class A Address

The first bit of the first octet is always set to 0 (zero). Thus the first octet ranges from 1 – 127, i.e.

**00000001 – 01111111**
1 – 127

Class A addresses only include IP starting from 1.x.x.x to 126.x.x.x only. The IP range 127.x.x.x is reserved for loopback IP addresses.

The default subnet mask for Class A IP address is 255.0.0.0 which implies that Class A addressing can have 126 networks ($2^7$-2) and 16777214 hosts ($2^{24}$-2).

Class A IP address format is thus: **0NNNNNNN**.HHHHHHHH.HHHHHHHH.HHHHHHHH

## Class B Address

An IP address which belongs to class B has the first two bits in the first octet set to 10, i.e.

**10000000 – 10111111**
128 – 191

Class B IP Addresses range from 128.0.x.x to 191.255.x.x. The default subnet mask for Class B is 255.255.x.x.

Class B has 16384 ($2^{14}$) Network addresses and 65534 ($2^{16}$-2) Host addresses.

Class B IP address format is: **10NNNNNN.NNNNNNNN**.HHHHHHHH.HHHHHHHH

## Class C Address

The first octet of Class C IP address has its first 3 bits set to 110, that is:

**11000000 – 11011111**
**192 – 223**

Class C IP addresses range from 192.0.0.x to 223.255.255.x. The default subnet mask for Class C is 255.255.255.x.

Class C gives 2097152 ($2^{21}$) Network addresses and 254 ($2^{8}$-2) Host addresses.

Class C IP address format is: **110NNNNN.NNNNNNNN.NNNNNNNN**.HHHHHHHH

## Class D Address

Very first four bits of the first octet in Class D IP addresses are set to 1110, giving a range of:

**11100000 – 11101111**
**224 – 239**

Class D has IP address range from 224.0.0.0 to 239.255.255.255. Class D is reserved for Multicasting. In multicasting data is not destined for a particular host, that is why there is no need to extract host address from the IP address, and Class D does not have any subnet mask.

## Class E Address

This IP Class is reserved for experimental purposes only for R&D or Study. IP addresses in this class ranges from 240.0.0.0 to 255.255.255.254. Like Class D, this class too is not equipped with any subnet mask.

# IPv4 - Subnetting

Each IP class is equipped with its own default subnet mask which bounds that IP class to have prefixed number of Networks and prefixed number of Hosts per network. Classful IP addressing does not provide any flexibility of having less number of Hosts per Network or more Networks per IP Class.

CIDR or **Classless Inter Domain Routing** provides the flexibility of borrowing bits of Host part of the IP address and using them as Network in Network, called Subnet. By using subnetting, one single Class A IP address can be used to have smaller sub-networks which provides better network management capabilities.

## Class A Subnets

In Class A, only the first octet is used as Network identifier and rest of three octets are used to be assigned to Hosts (i.e. 16777214 Hosts per Network). To make more subnet in Class A, bits from Host part are borrowed and the subnet mask is changed accordingly.

For example, if one MSB (Most Significant Bit) is borrowed from host bits of second octet and added to Network address, it creates two Subnets ($2^1$=2) with ($2^{23}$-2) 8388606 Hosts per Subnet.

The Subnet mask is changed accordingly to reflect subnetting. Given below is a list of all possible combination of Class A subnets:

| Network Bits | Subnet Mask | Bits Borrowed | Subnets | Hosts/Subnet |
|---|---|---|---|---|
| 8 | 255.0.0.0 | 0 | 1 | 16777214 |
| 9 | 255.128.0.0 | 1 | 2 | 8388606 |
| 10 | 255.192.0.0 | 2 | 4 | 4194302 |
| 11 | 255.224.0.0 | 3 | 8 | 2097150 |
| 12 | 255.240.0.0 | 4 | 16 | 1048574 |
| 13 | 255.248.0.0 | 5 | 32 | 524286 |
| 14 | 255.252.0.0 | 6 | 64 | 262142 |
| 15 | 255.254.0.0 | 7 | 128 | 131070 |
| 16 | 255.255.0.0 | 8 | 256 | 65534 |
| 17 | 255.255.128.0 | 9 | 512 | 32766 |
| 18 | 255.255.192.0 | 10 | 1024 | 16382 |
| 19 | 255.255.224.0 | 11 | 2048 | 8190 |
| 20 | 255.255.240.0 | 12 | 4096 | 4094 |
| 21 | 255.255.248.0 | 13 | 8192 | 2046 |
| 22 | 255.255.252.0 | 14 | 16384 | 1022 |
| 23 | 255.255.254.0 | 15 | 32768 | 510 |
| 24 | 255.255.255.0 | 16 | 65536 | 254 |
| 25 | 255.255.255.128 | 17 | 131072 | 126 |
| 26 | 255.255.255.192 | 18 | 262144 | 62 |
| 27 | 255.255.255.224 | 19 | 524288 | 30 |
| 28 | 255.255.255.240 | 20 | 1048576 | 14 |
| 29 | 255.255.255.248 | 21 | 2097152 | 6 |
| 30 | 255.255.255.252 | 22 | 4194304 | 2 |

In case of subnetting too, the very first and last IP address of every subnet is used for Subnet Number and Subnet Broadcast IP address respectively. Because these two IP addresses cannot be assigned to hosts,

sub-netting cannot be implemented by using more than 30 bits as Network Bits, which provides less than two hosts per subnet.

## Class B Subnets

By default, using Classful Networking, 14 bits are used as Network bits providing ($2^{14}$) 16384 Networks and ($2^{16}$-2) 65534 Hosts. Class B IP Addresses can be subnetted the same way as Class A addresses, by borrowing bits from Host bits. Below is given all possible combination of Class B subnetting:

| Network Bits | Subnet Mask | Bits Borrowed | Subnets | Hosts/Subnet |
|---|---|---|---|---|
| 8 | 255.0.0.0 | 0 | 1 | 16777214 |
| 9 | 255.128.0.0 | 1 | 2 | 8388606 |
| 10 | 255.192.0.0 | 2 | 4 | 4194302 |
| 11 | 255.224.0.0 | 3 | 8 | 2097150 |
| 12 | 255.240.0.0 | 4 | 16 | 1048574 |
| 13 | 255.248.0.0 | 5 | 32 | 524286 |
| 14 | 255.252.0.0 | 6 | 64 | 262142 |
| 15 | 255.254.0.0 | 7 | 128 | 131070 |
| 16 | 255.255.0.0 | 8 | 256 | 65534 |
| 17 | 255.255.128.0 | 9 | 512 | 32766 |
| 18 | 255.255.192.0 | 10 | 1024 | 16382 |
| 19 | 255.255.224.0 | 11 | 2048 | 8190 |
| 20 | 255.255.240.0 | 12 | 4096 | 4094 |
| 21 | 255.255.248.0 | 13 | 8192 | 2046 |
| 22 | 255.255.252.0 | 14 | 16384 | 1022 |
| 23 | 255.255.254.0 | 15 | 32768 | 510 |
| 24 | 255.255.255.0 | 16 | 65536 | 254 |
| 25 | 255.255.255.128 | 17 | 131072 | 126 |
| 26 | 255.255.255.192 | 18 | 262144 | 62 |
| 27 | 255.255.255.224 | 19 | 524288 | 30 |
| 28 | 255.255.255.240 | 20 | 1048576 | 14 |
| 29 | 255.255.255.248 | 21 | 2097152 | 6 |
| 30 | 255.255.255.252 | 22 | 4194304 | 2 |

## Class C Subnets

Class C IP addresses are normally assigned to a very small size network because it can only have 254 hosts in a network. Given below is a list of all possible combination of subnetted Class B IP address:

| Network Bits | Subnet Mask | Bits Borrowed | Subnets | Hosts/Subnet |
|---|---|---|---|---|
| 24 | 255.255.255.0 | 0 | 1 | 254 |
| 25 | 255.255.255.128 | 1 | 2 | 126 |
| 26 | 255.255.255.192 | 2 | 4 | 62 |
| 27 | 255.255.255.224 | 3 | 8 | 30 |
| 28 | 255.255.255.240 | 4 | 16 | 14 |
| 29 | 255.255.255.248 | 5 | 32 | 6 |
| 30 | 255.255.255.252 | 6 | 64 | 2 |