IP ADDRESSES :

Every host and router on the Internet has an IP address, which encodes its network number and host number. The combination is unique : in principle, no two machines on the Internet have the same IP address. All IP addresses are 32 bits long and are used in the Source address and Destination address fields of IP packets. It is important to note that an IP address does not actually refer to a host. It really refers to a network interface, so if a host is on two networks, it must have two IP addresses. However, in practice, most hosts are on one network and thus have one IP address.

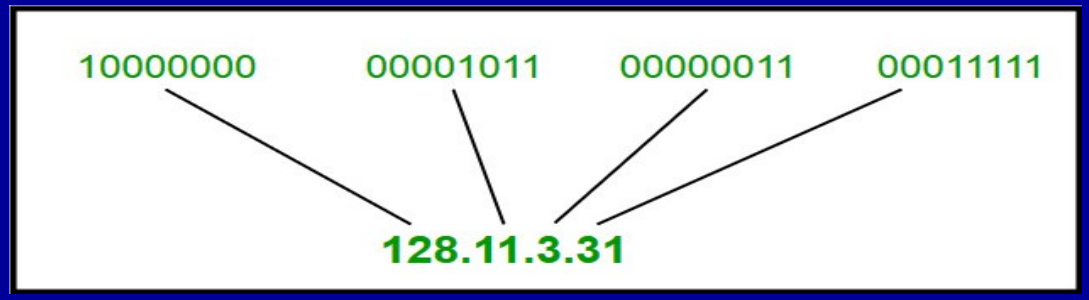
For several decades, IP addresses were divided into the five categories listed in Fig. A . This allocation has come to be called classful addressing. It is no longer used, but references to it in the literature are still common.

IP ADDRESS

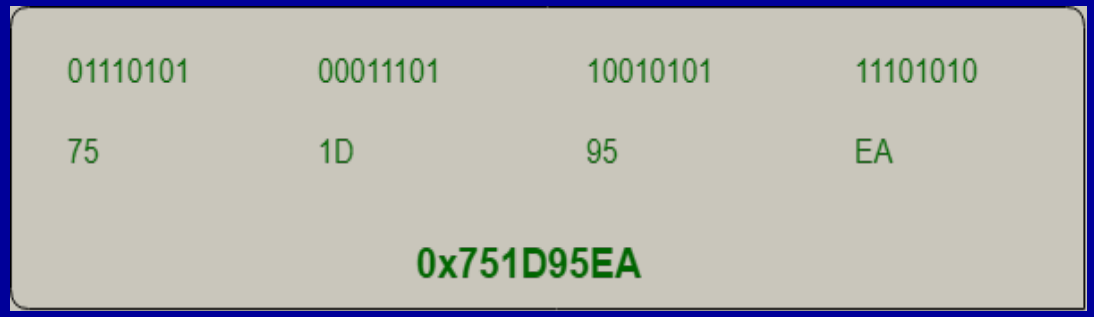
IP address is an address having information about how to reach a specific host, especially outside the LAN. An IP address is a 32 bit unique address having an address space of 2^{32}.

Generally, there are two notations in which IP address is written, dotted decimal notation and hexadecimal notation.

Dotted Decimal Notation



Hexadecinal Notation



IP ADDRESS

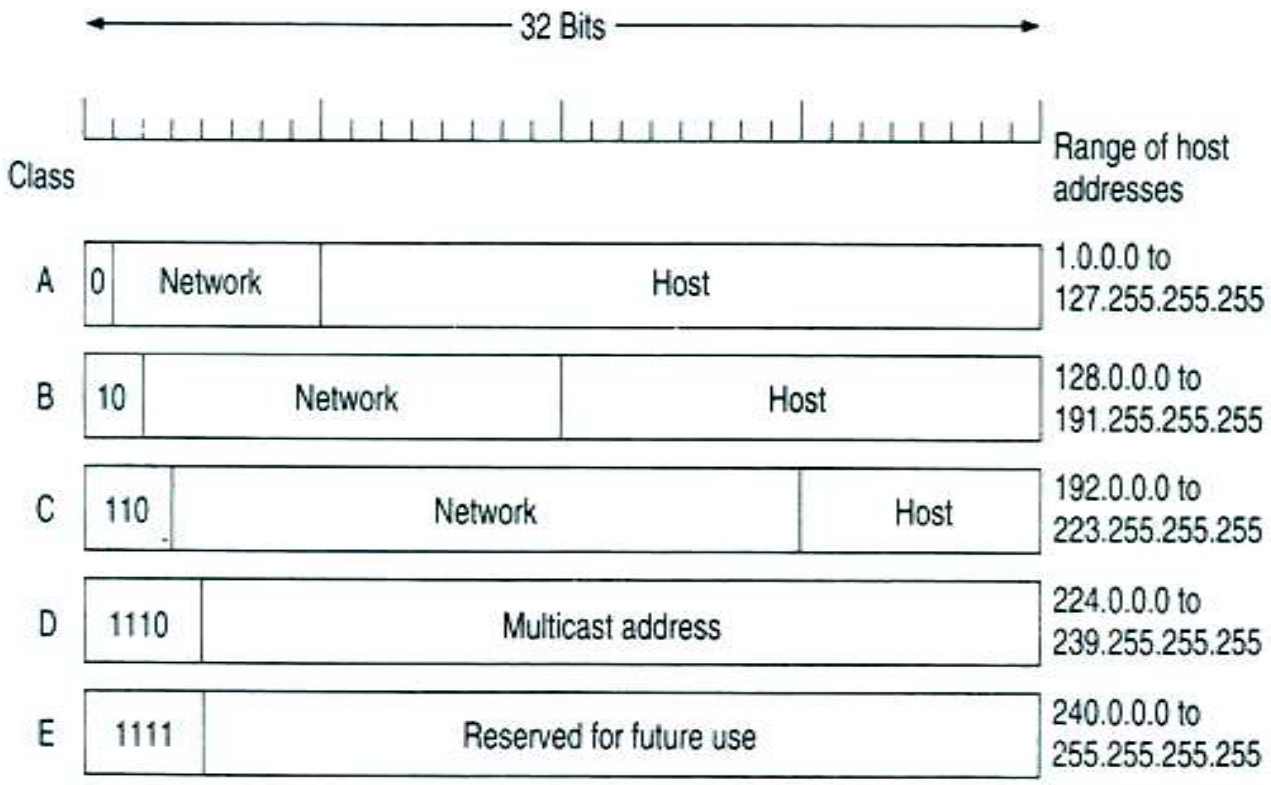


Figure - A IP address formats.

IP ADDRESS

The class A, B, C, and D formats allow for up to 128 networks with 16 million hosts each, 16,384 networks with up to 64K hosts, and 2 million networks (e.g., LANs) with up to 256 hosts each (although a few of these are special). Also supported is multicast, in which a datagram is directed to multiple hosts. Addresses beginning with 1111 are reserved for future use. Over 500,000 networks are now connected to the Internet, and the number grows every year. Network numbers are managed by a nonprofit corporation called ICANN (Internet Corporation for Assigned Names and Numbers) to avoid conflicts. In turn, ICANN has delegated parts of the address space to various regional authorities, which then dole out IP addresses to ISPs and other companies.

IP ADDRESS

Network addresses, which are 32-bit numbers, are usually written in dotted decimal notation. In this format, each of the 4 bytes is written in decimal, from 0 to 255. For example, the 32-bit hexadecimal address C0290614 is written as 192.41.6.20. The lowest IP address is 0.0.0.0 and the highest is 255.255.255.255.

The values 0 and -1 (all 1 s) have special meanings, as shown in Fig. B. The value 0 means this network or this host. The value of -1 is used as a broadcast address to mean all hosts on the indicated network.

IP ADDRESS

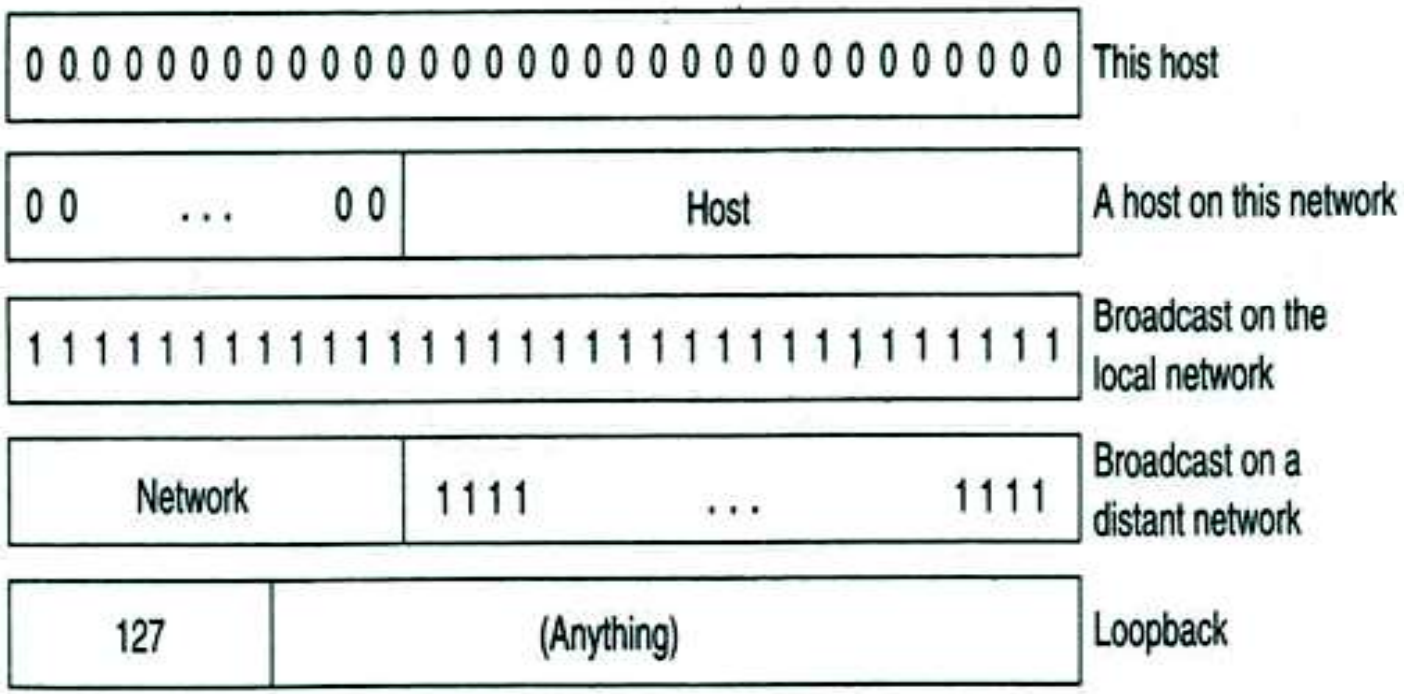


Figure - B Special IP addresses.

IP ADDRESS

The IP address 0.0.0.0 is used by hosts when they are being booted. IP addresses with 0 as network number refer to the current network. These addresses allow machines to refer to their own network without knowing its number (but they have to know its class to know how many Os to include). The address consisting of all 1s allows broadcasting on the local network, typically a LAN.

IP ADDRESS

The addresses with a proper network number and all 1s in the host field allow machines to send broadcast packets to distant LANs anywhere in the Internet (although many network administrators disable this feature). Finally, all addresses of the form 127.xx.yy.zz are reserved for loopback testing. Packets sent to that address are not put out onto the wire; they are processed locally and treated as incoming packets. This allows packets to be sent to the local network without the sender knowing its number.

Subnets :

As we have seen, all the hosts in a network must have the same network number. This property of IP addressing can cause problems as networks grow. For example, consider a university that started out with one class B network used by the Computer Science Dept. for the computers on its Ethernet. A year later, the Electrical Engineering Dept. wanted to get on the Internet, so they bought a repeater to extend the CS Ethernet to their building. As time went on, many other departments acquired computers and the limit of four repeaters per Ethernet was quickly reached. A different organization was required.

IP ADDRESS

Getting a second network address would be hard to do since network addresses are scarce and the university already had enough addresses for over 60,000 hosts. The problem is the rule that a single class A, B, or C address refers to one network, not to a collection of LANs. As more and more organizations ran into this situation, a small change was made to the addressing system to deal with it.

IP ADDRESS

The solution is to allow a network to be split into several parts for internal use but still act like a single network to the outside world. A typical campus network nowadays might look like that of Fig. C, with a main router connected to an ISP or regional network and numerous Ethernets spread around campus in different departments. Each of the Ethernets has its own router connected to the main router (possibly via a backbone LAN, but the nature of the interrouter connection is not relevant here).

IP ADDRESS

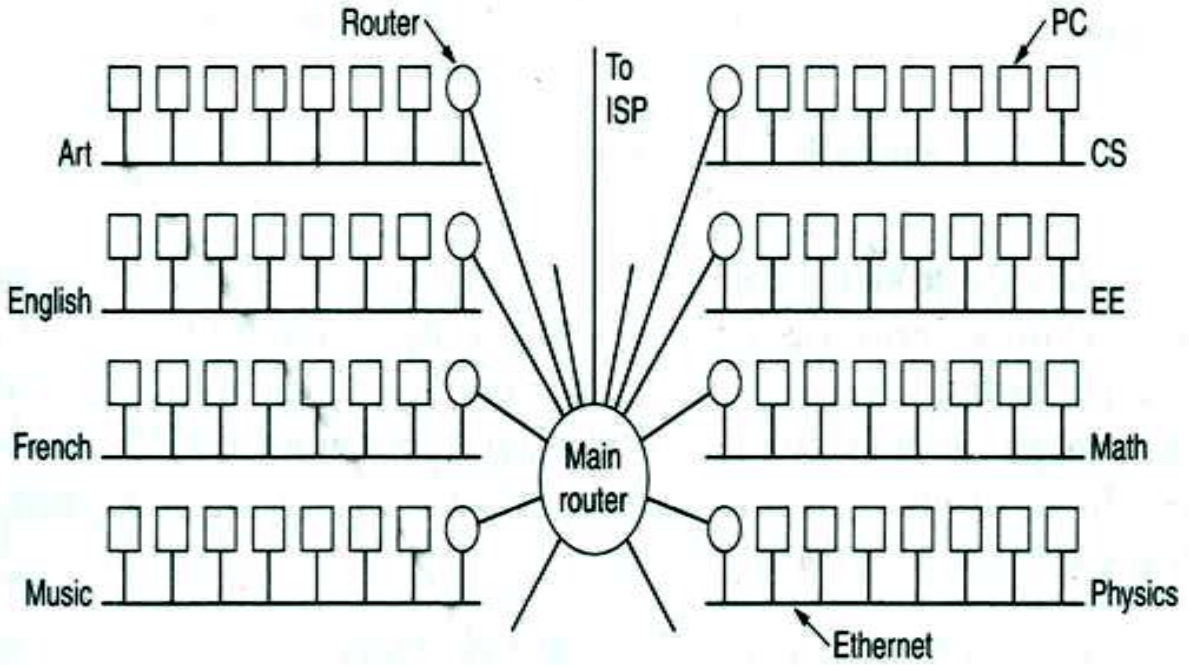


Figure - C campus network consisting of LANs for various departments.

IP ADDRESS

In the Internet literature, the parts of the network (in this case, Ethernets) are called subnets. As we mentioned earlier, this usage conflicts with "subnet" to mean the set of all routers and communication lines in a network. Hopefully, it will be clear from the context which meaning is intended. In this section and the next one, the new definition will be the one used exclusively.

IP ADDRESS

When a packet comes into the main router, how does it know which subnet (Ethernet) to give it to? One way would be to have a table with 65,536 entries in the main router telling which router to use for each host on campus. This idea would work, but it would require a very large table in the main router and a lot of manual maintenance as hosts were added, moved, or taken out of service.

IP ADDRESS

Instead, a different scheme was invented. Basically, instead of having a single class B address with 14 bits for the network number and 16 bits for the host number, some bits are taken away from the host number to create a subnet number. For example, if the university has 35 departments, it could use a 6-bit subnet number and a 10-bit host number, allowing for up to 64 Ethernets, each with a maximum of 1022 hosts (0 and -1 are not available). This split could be changed later if it turns out to be the wrong one.

IP ADDRESS

To implement subnetting, the main router needs a subnet mask that indicates the split between network + subnet number and host, as shown in Fig. D. Subnet masks are also written in dotted decimal notation, with the addition of a slash followed by the number of bits in the network + subnet part. For the example of Fig. D, the sub net mask can be written as 255.255.252.0. An alternative notation is /22 to indicate that the subnet mask is 22 bits long.

IP ADDRESS

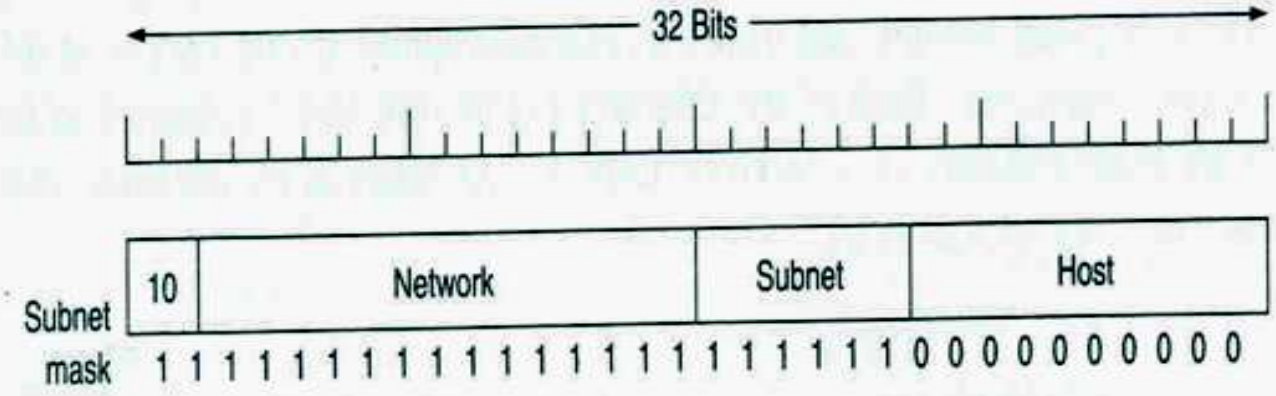


Figure - D A class B network subnetted into 64 subnets.

IP ADDRESS

Outside the network, the subnetting is not visible, so allocating a new subnet does not require contacting ICANN or changing any external databases. In this example, the first subnet might use IP addresses starting at 130.50.4.1; the second subnet might start at 130.50.8.1; the third subnet might start at 130.50.12.1; and so on. To see why the subnets are counting by fours, note that the corresponding binary addresses are as follows:

Subnet 1: 10000010 00110010 000001|00 00000001
Subnet 2: 10000010 00110010 000010|00 00000001
Subnet 3: 10000010 00110010 000011|00 00000001

Here the vertical bar (|) shows the boundary between the subnet number and the host number. To its left is the 6-bit subnet number; to its right is the 10-bit host number. .

IP ADDRESS

To see how subnets work, it is necessary to explain how IP packets are processed at a router. Each router has a table listing some number of (network, 0) IP addresses and some number of (this network, host) IP addresses. The first kind tells how to get to distant networks. The second kind tells how to get to local hosts. Associated with each table is the network interface to use to reach the destination, and certain other information.

IP ADDRESS

When an IP packet arrives, its destination address is looked up in the routing table. If the packet is for a distant network, it is forwarded to the next router on the interface given in the table. If it is a local host (e.g., on the router's LAN), it is sent directly to the destination. If the network is not present, the packet is forwarded to a default router with more extensive tables. This algorithm means that each router only has to keep track of other networks and local hosts, not (network, host) pairs, greatly reducing the size of the routing table.

IP ADDRESS

When subnetting is introduced, the routing tables are changed, adding entries of the form (this-network, subnet, 0) and (this-network, this-subnet, host). Thus, a router on subnet k knows how to get to all the other subnets and also how to get to all the hosts on subnet k. It does not have to know the details about hosts on other subnets. In fact, all that needs to be changed is to have each router do a Boolean AND with the network's subnet mask to get rid of the host number and look up the resulting address in its tables (after determining which network class it is).