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Computer Network Fundamentals

Chapter Five

IP Addressing

((Network Layer))

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5.1- <u>Introduction</u>

Communication at the network layer is source to destination; a computer somewhere in the world needs to communicate with another computer somewhere else in the world. Usually, computers communicate through the Internet. The packet transmitted by the sending computer may pass through several LANs or WANs before reaching the destination computer.

For this level of communication, we need a **global addressing scheme called logical addressing**. Today, we use the term IP address to mean a logical address in the network layer of the TCP/IP protocol suite.

5.2- <u>What is an IP address?</u>

In the most widely installed level of the Internet Protocol (IP) today, an IP address is a **32-bit number** that that *uniquely* and *universally* defines the connection of a device (for example, a computer or a router) to the Internet. The 32 bits in length gives us a maximum of 2^{32} addresses. These addresses are referred to as **IPv4** (IP version 4) addresses or simply IP addresses if there is no confusion.

An IP address has *two* parts: The first part of an Internet address identifies the network (NetID) on which the host resides, while the second part identifies the particular host on the given network (HostID). This creates the two-level addressing hierarchy as shown in figure below

Network Number	Host Number

Each device must know its own IP address and the IP address of the device with which it needs to communicate (source and destination). To communicate on the Internet, every organization must have at least one valid Internet IP address. The 32-bits IP address is known as IPv4.

5.2.1- Notations

There are two prevalent notations to show an IPv4 address: *<u>binary notation</u>* and *<u>dotted decimal notation</u>*.

Figure below shows an IPv4 address in both binary and dotted-decimal notation. Note that because each byte (octet) is 8 bits, each number in dotted-decimal notation is a value ranging from 0 to 255.

117.149.29.2

01110101 10010101 00011101 00000010

IP addressing can be classified as ***classful*** and ***classless*** addresses.

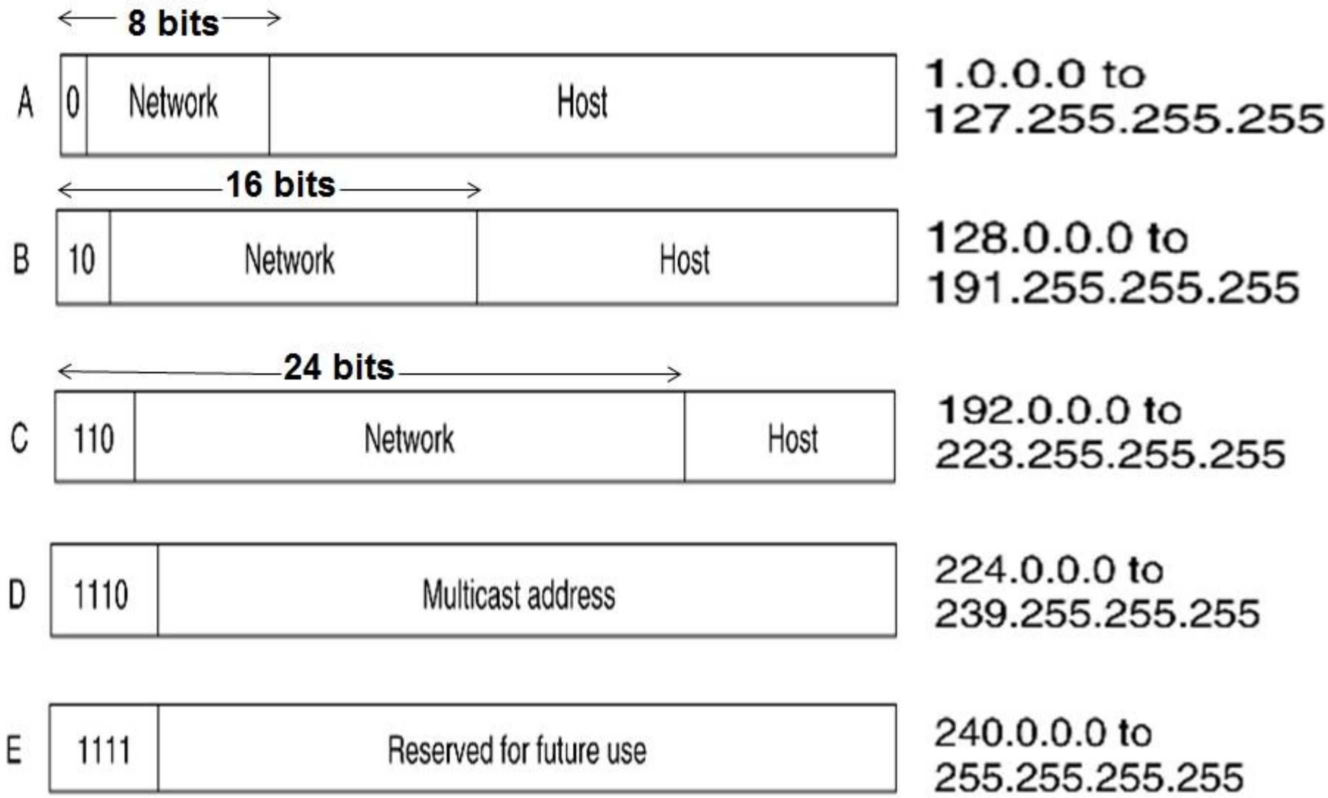
5.3- Classful Addressing

IPv4 addressing, at its inception, used the concept of classes. This architecture is called classful addressing. Although this scheme is becoming obsolete, we briefly discuss it here to show the rationale behind classless addressing.

5.3.1- *Classes*

In classful addressing, the address space is divided into **five classes: A, B, C, D, and E**. Each class occupies some part of the address space.
In classful addressing, an IP address in class A, B, or C is divided into *netid* and *hostid*. These parts are of varying lengths, depending on the class of the address. Figure below shows some *netid* and *hostid* bytes. Note that the concept does not apply to classes D and E.
In class A, one byte defines the netid and three bytes define the hostid. In class B, two bytes define the netid and two bytes define the hostid. In class C, three bytes define the netid and one byte defines the hostid.

Class D addresses were designed for multicasting. Each address in this class is used to define one group of hosts on the Internet. And lastly, the class E addresses were reserved for future use.



Class	High Order Bits	First Octet Range	Number of Network Bits	Number of Host Bits	Number of Networks	Number of Hosts per Network
A	0	0-127	8	24	128	16,777,216
B	10	128-191	16	16	16,384	65,536
C	110	192-223	24	8	2,097,152	256
D	1110	224-239	Used for Multicasting to multiple hosts.			
E	1111	240-255	Reserved for research and development.			

5.3.2- *Reserved IP Addresses*

✓ ***Network address and broadcast address***

For each class there are two addresses which are reserved, these are the first and last address. The first address identifies the *NetID address*, while the last address in the class range is the *broadcast address,* as shown in table below

Class	NetID address	Valid IP addresses	Broadcast address
A	125.0.0.0	125.0.0.1 – 125.255.255.254	125.255.255.255
B	180.20.0.0	180.20.0.1 – 180.20.255.254	180.20.255.255
C	220.100.10.0	220.100.10.1 – 220.100.10.254	220.100.10.255

✓ **Loopback address**

The address **127.0.0.1** is also reserved which is known as a *loopback address* which is used to allow a node to send a test packet to itself without generating a network traffic for the purpose of testing the TCP/IP configuration on a PC.

✓ **Link Local Addresses:**

Address Range (**169.254.0.0 to 169.254.255.255**), these addresses are automatically assigned by the operating system when there is no IP configuration is available and the DHCP server not available.

5.3.3- *Private IP addresses*

These addresses can be used on a private network, but they are *not routable through the internet*. The range for the private IP addresses are given in table below

Range	Prefix
10.0.0.0 – 10.255.255.255	/ 8
172.16.0.0 – 172.31.255.255	/ 12
192.168.0.0 – 192.168.255.255	/ 16

5.3.4- Subnet Mask

Although the length of the netid and hostid (in bits) is predetermined in classful addressing, we can also use a mask (also called the default mask), a 32-bit number made of contiguous 1's followed by contiguous 0's. The masks for classes A, B, and C are shown in Table below; The concept does not apply to classes D and E.

The mask can help us to find the network address (netid) by making a logical AND operation between the IP address and its corresponding mask.

Class	Binary	Dotted Decimal	Prefix
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

The last column in the table shows the mask in the form (/**n**) where *n* can be 8, 16, or 24 in classful addressing. This notation is also called ***prefix notation*** or Classless Interdomain Routing (CIDR) notation. The notation is used in classless addressing. We introduce it here because it can also be applied to classful addressing. We will show later that classful addressing is a special case of classless addressing.

5.4- Classless Addressing

Classful allocation of address space often wasted many addresses, which exhausted the availability of IPv4 addresses. For example, a company that had a network with 260 hosts would need to be given a class B address with more than 65,000 addresses. The system that we currently use is referred to as classless addressing. With the classless system, address blocks appropriate to the number of hosts are assigned to companies or organizations without regard to the unicast class. This is can be achieved using many techniques such as: *Subnetting, Variable Length Subnet Mask (VLSM), and Network Address Translation (NAT)*

5.5- Subnetting

For the purpose of *reducing network traffics* and *simplifying network management*, and also *reducing the waste in IP addresses*; large network can be divided into smaller networks (subnetworks). Subnetting allows for creating multiple logical networks from a single address block.

We create the subnets by using one or more of the host bits as network bits. *This is done by extending the mask to borrow some of the bits from the host portion of the address to create additional network bits.* The more host bits used, the more subnets that can be defined. For each bit borrowed, we double the number of subnetworks available.

Notes:

- *The maximum number of borrowed bits is by leaving 2-bits in the HostID part of the address.*
- To determine the number of subnets or hosts use the following rules:

$$\text{Number of Subnets} = 2^{\text{number\_of\_borrowed\_host\_bits}}$$

$$\underline{\text{Usable}}\ \text{Hosts Per Subnet} = (2^{\text{number\_of\_remaining\_host\_bits}} - 2)$$

Example: What are the number of subnets, hosts, and the valid host addresses given class C IP address 192.168.10.5 and a subnet mask 255.255.255.192 (192.168.10.5 / 26)

Solution:

IP address → 192.168.10.5 → 11000000 . 10101000 . 00001010 . 00000101
Subnet mask → 255.255.255.192 → 11111111 . 11111111 . 11111111 . 11000000

Network address → 192.168.10.0 → 11000000 . 10101000 . 00001010 . 00000000

Subnet mask → 255.255.255.192 → 11111111 . 11111111 . 11111111 . **11** 000000

2 bits are borrowed

The number of subnets = 2^n . (where n = the number of bits borrowed)

$= 2^2 = 4$ subnets

The number of hosts on each subnet = $2^m - 2$. (where m = the number of bits left for hosts).

$= 2^6 - 2 = 62$

shows that each of these subnets can have 62 hosts.

For each subnet, examine the last octet in binary. The values in these octets for the four networks are:

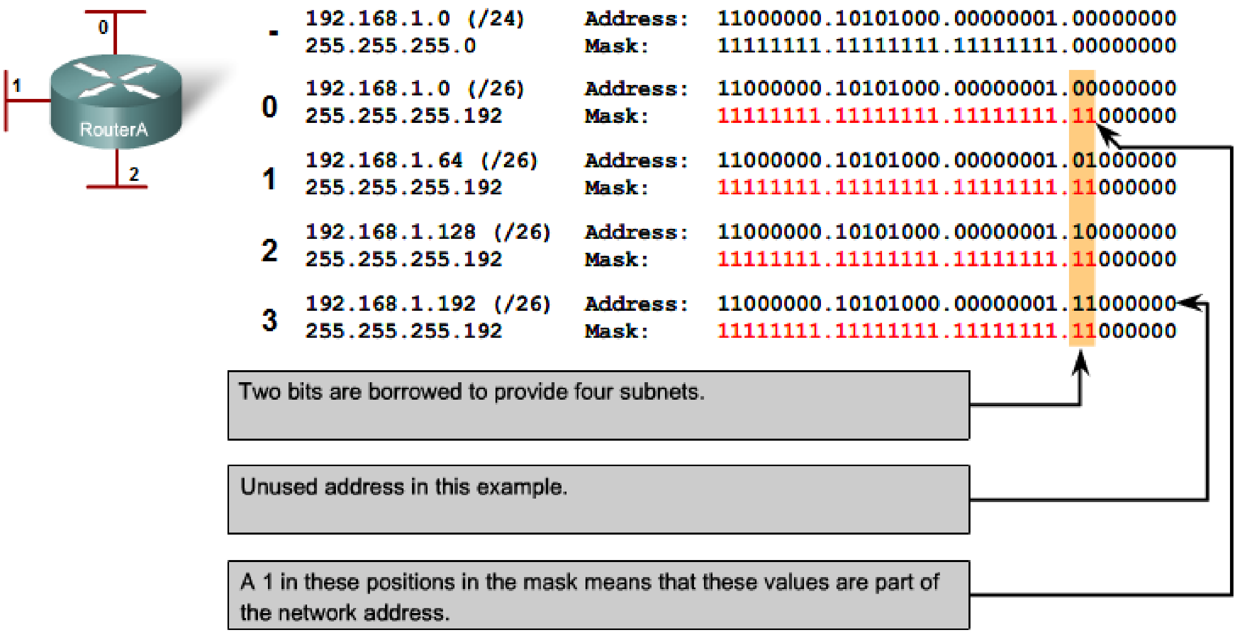
Subnet 1: **00**000000 = 0
Subnet 2: **01**000000 = 64
Subnet 3: **10**000000 = 128
Subnet 4: **11**000000 = 192

Or the subnet block size is = $2^{\text{number-of-host-bits}} = 2^6 = 64$ (*the magic number*)
Therefore, the subnets are = (0, 64, 128, 192)

Table below shows the valid host addresses and the subnet and broadcast addresses for each subnet.

Subnet	Subnet address	Host range	Broadcast address
1	192.168.10.0	192.168.10.**1** → 192.168.10.**62**	192.168.10.63
2	192.168.10.64	192.168.10.**65** → 192.168.10.**126**	192.168.10.127
3	192.168.10.128	192.168.10.**129** → 192.168.10.**190**	192.168.10.191
4	192.168.10.192	192.168.10.**193** → 192.168.10.**254**	192.168.10.255

Figure below illustrate the same process



More subnets are available, but fewer addresses are available per subnet.

A serious limitation of using only a single subnet mask across a given network was that an organization is locked into a fixed-number of fixed-sized subnets. The solution to this problem is to use a VLSM (variable length subnet mask) enables a network number to be configured with different subnet masks on different interfaces.

5.6- IPv6 Addresses

The need for more addresses, in addition to other concerns about the IP layer, motivated a new design of the IP layer called the new generation of IP or IPv6 (lP version 6). In this version, the Internet uses **128-bit addresses** that give much greater flexibility in address allocation. These addresses are referred to as IPv6 (IP version 6) addresses.

An IPv6 address consists of 16 bytes (octets); it is 128 bits long. To make addresses more readable, IPv6 specifies hexadecimal colon notation. In this notation, 128 bits is divided into eight sections, each 2 bytes in length. Two bytes in hexadecimal notation requires four hexadecimal digits. Therefore, the address consists of 32 hexadecimal digits, with every four digits separated by a colon, as shown below

FDEC: 0074 : 0000 : 0000 : 0000 : BOFF : 0000 : FFFO