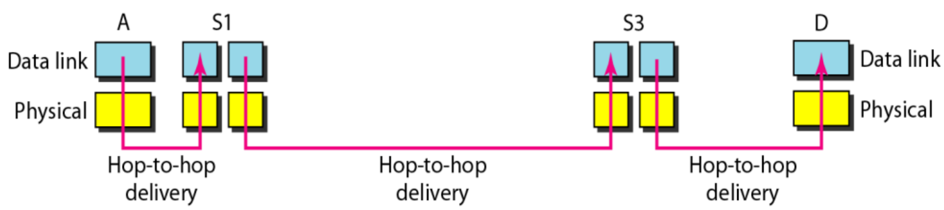
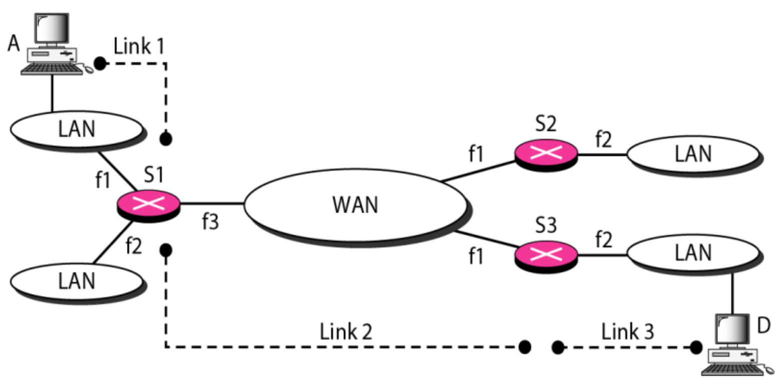
Network Layer: Part 2

Internetworking

Internetworking means connecting networks together to make an internetwork or an internet. This internetwork is made of five networks: four LANs and one WAN. If host A needs to send a data packet to host D, the packet needs to go first from A to Rl (a switch or router), then from Rl to R3, and finally from R3 to host D. We say that the data packet passes through three links. In each link, two physical and two data link layers are involved. However, there is a big problem here. When data arrive at interface flof Rl, how does RI know that interface f3 is the outgoing interface? There is no provision in the data link (or physical) layer to help Rl make the right decision. The frame does not carry any routing information either. The frame contains the MAC address ofA as the source and the MAC address of Rl as the destination. For a LAN or a WAN, delivery means carrying the frame through one link, and not beyond.





Note

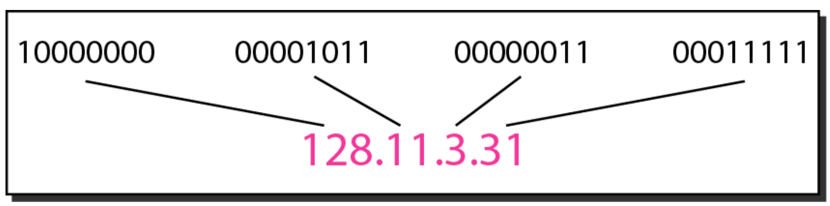
1. **Switching at the network layer in the Internet uses the datagram approach to packet switching.**
2. **Communication at the network layer in the Internet is connectionless.**

IPv4 Address

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.

Address Space

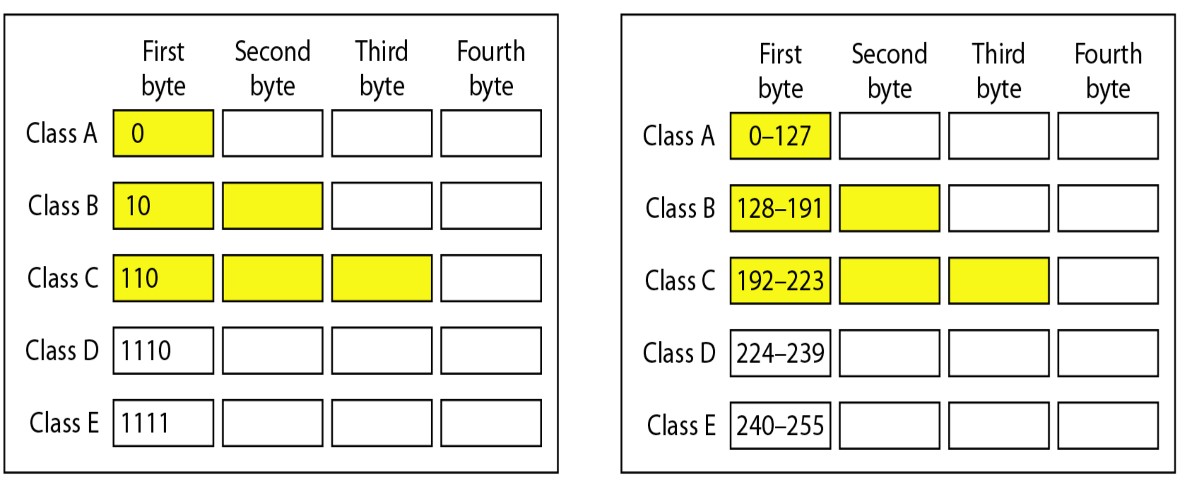
An address space is the total number of addresses used by the protocol. If a protocol uses N bits to define an address, the address space is 2^N because each bit can have two different values (0 or 1) and N bits can have 2^N values.
IPv4 uses 32-bit addresses, which means that the address space is 2^{32} or 4,294,967,296 (more than 4 billion).



Dotted decimal and binary notation

Classful Addressing

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, a large part of the available addresses were wasted.



a. Binary notation

b. Dotted-decimal notation

Quest: 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 O. This is a class A address.
b. The first 2 bits are 1; the third bit is O. This is a class C address.
c. The first byte is 14 (between 0 and 127); the class is A.
d. The first byte is 252 (between 240 and 255); the class is E.

Netid and Hostid

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.

Mask

The length of the netid and hostid (in bits) is predetermined in classful addressing . A mask (also called the default mask), a 32-bit number made of contiguous 1s followed by contiguous as

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

The mask can help us to find the netid and the hostid. For example, the mask for a class A address has eight 1s, which means the first 8 bits of any address in class A define the netid; the next 24 bits define the hostid. The mask in the form /n here *n* can be 8, 16, or 24 in classful addressing. This notation is also called slash notation or Classless Inter domain Routing (CIDR) notation. The notation is used in classless addressing.

Subnetting

If an organization was granted a large block in class A or B, it could divide the addresses into several contiguous groups and assign each group to smaller networks (called subnets) .Subnetting increases the number of 1s in the mask.

Supernetting

In other words, several networks are combined to create a super n/w or supernet. Supernetting decreases the number of 1's in mask. For example if an organization is given four class C address the changes from class /24 to /22.

Classless Addressing

To overcome address depletion and give more organizations access to the Internet, classless addressing was designed and implemented.

Address Blocks

In classless addressing, when an entity, small or large, needs to be connected to the Internet, it is granted a block (range) of addresses. The size of the block (the number of addresses) varies based on the nature and size of the entity. the Internet authorities impose three restrictions on classless address blocks:

1. The addresses in a block must be contiguous, one after another.
2. The number of addresses in a block must be a power of 2 (I, 2, 4, 8, ...).
3. The first address must be evenly divisible by the number of addresses.

Mask

A better way to define a block of addresses is to select any address in the block and the mask. A mask is a 32-bit number in which the *n* leftmost bits are 1s and the 32 - *n* rightmost bits are 0s. In IPv4 addressing, a block of addresses can be defined as **x.y.z.t/n**in which x.y.z.t defines one of the addresses and **the /*n*** defines the mask.

1. The first address in the block can be found by setting the rightmost 32 - *n* bits to 0s.
2. The last address in the block can be found by setting the rightmost 32 - *n* bits to 1s.
3. The number of addresses in the block can be found by using the formula 2^{32-n}

Quest: A block of addresses is granted to a small organization. We know that one of the addresses is 205.16.37.39/28. What is the first address, last address and no. of addresses in the block?

Solution

a. The first address can be found by ANDing the given addresses with the mask. ANDing here is done bit by bit. The result of ANDing 2 bits is 1 if both bits are Is; the result is 0 otherwise.

Address:11001101 00010000 00100101 00100111

Mask:11111111 11111111 11111111 11110000

First address:11001101 00010000 00100101 00100000

b. The last address can be found by ORing the given addresses with the complement of the mask. ORing here is done bit by bit. The result of ORing 2 bits is 0 if both bits are Os; the result is 1 otherwise. The complement of a number is found by changing each 1 to 0 and each 0 to 1.

Address:11001101 00010000 00100101 00100111
Mask complement:00000000 00000000 00000000 00001111
Last address: 11001101 00010000 *00100101 00101111*

c. The number of addresses can be found by complementing the mask, interpreting it as a decimal number, and adding 1 to it.
Mask complement:000000000 00000000 00000000 00001111

Number of addresses:15+1=16

Note:-

1. The first address in a block is normally not assigned to any device; it is used as the network address that represents the organizationto the rest of the world.

2. Each address in the block can be considered as a two-level hierarchical structure: the leftmost *n* bits (prefix) define the network and the rightmost 32-n bits define the host.

Example 19.10

An ISP is granted a block of addresses starting with 190.100.0.0/16 (65,536 addresses). The ISP needs to distribute these addresses to three groups of customers as follows:

a. The first group has 64 customers; each needs 256 addresses.

b. The second group has 128 customers; each needs 128 addresses.

c. The third group has 128 customers; each needs 64 addresses.

Design the subblocks and find out how many addresses are still available after these allocations.

19.1

Group 1For this group, each customer needs 256 addresses. This means that 8 (log2 256) bits are needed to define each host. The prefix length is then 32 − 8 = 24. The addresses are

1st Customer:	*190.100.0.0/24*	*190.100.0.255/24*
2nd Customer:	*190.100.1.0/24*	*190.100.1.255/24*
. . .		
64th Customer:	*190.100.63.0/24*	*190.100.63.255/24*
Total = 64 × 256 = 16,384		

Group 2

For this group, each customer needs 128 addresses. This means that 7 (log2 128) bits are needed to define each host. The prefix length is then 32 − 7 = 25. The addresses are

1st Customer:	*190.100.64.0/25*	*190.100.64.127/25*
2nd Customer:	*190.100.64.128/25*	*190.100.64.255/25*
. . .		
128th Customer:	*190.100.127.128/25*	*190.100.127.255/25*
Total = 128 × 128 = 16,384		

Group 3

For this group, each customer needs 64 addresses. This means that 6 ($\log_2 64$) bits are needed to each host. The prefix length is then 32 − 6 = 26. The addresses are

1st Customer:	*190.100.128.0/26*	*190.100.128.63/26*
2nd Customer:	*190.100.128.64/26*	*190.100.128.127/26*
. . .		
128th Customer:	*190.100.159.192/26*	*190.100.159.255/26*
Total = 128 × 64 = 8192		

Number of granted addresses to the ISP: 65,536

Number of allocated addresses by the ISP: 40,960

Number of available addresses: 24,576