CSE 306

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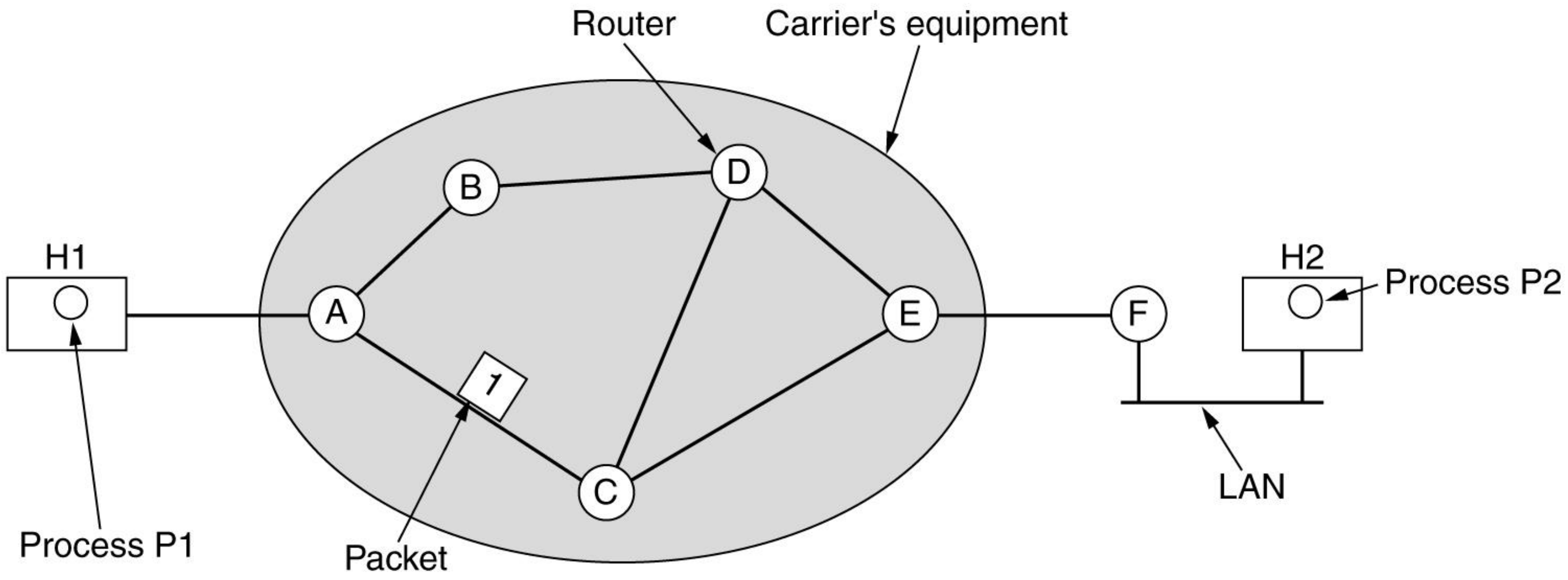
Network Layer Design Issues

- Store-and-Forward Packet Switching
- Services Provided to the Transport Layer
- Implementation of Connectionless Service
- Implementation of Connection-Oriented Service
- Comparison of Virtual-Circuit and Datagram Subnets

Store-and-Forward Packet Switching

The environment of the network layer protocols.



Services provided to Transport layer

The services need to be carefully designed with the following goals in mind:

1. The **services** should be **independent of the router** technology.
2. The transport layer should be **shielded** from the **number, type, and topology** of the routers present.
3. The network addresses made available to the transport layer should use a **uniform numbering plan**, even across LANs and WANs.

Packet Switching

- Datagram Approach: Connectionless Service

- Virtual Circuit Approach: Connection Oriented Service

POLL 1

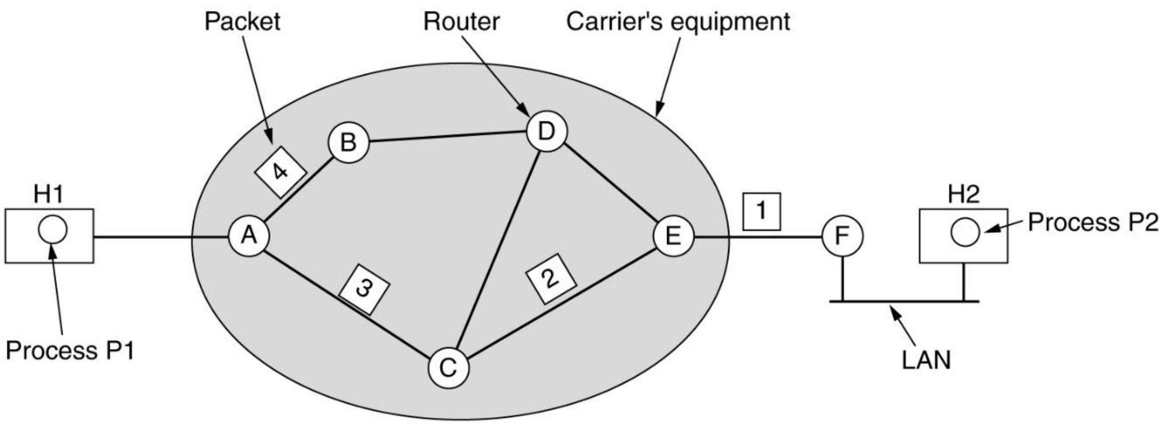
- Datagram approach is

a) Connection oriented service

b) Connectionless service

Implementation of Connectionless Service

Routing within a diagram subnet.



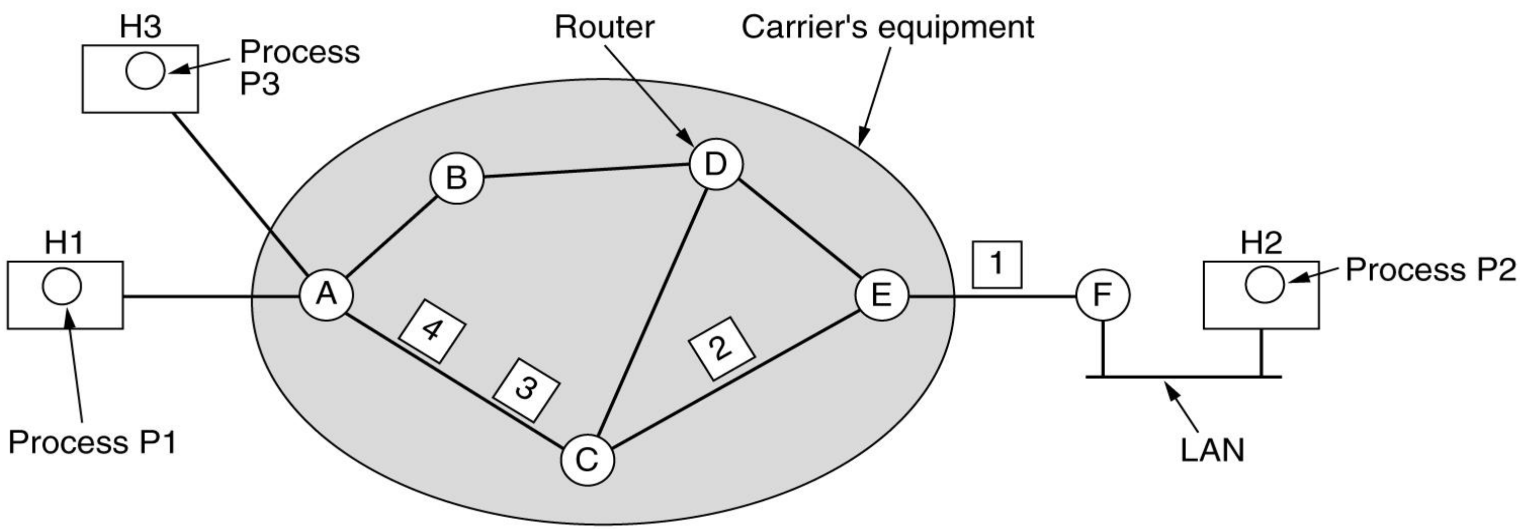
A's table (initially | later), C's table, E's table

Dest.	A's table initially (Line)	A's table later (Line)	C's table (Line)	E's table (Line)
A	–	–	A	C
B	B	B	A	D
C	C	C	–	C
D	B	B	D	D
E	C	B	E	–
F	C	B	E	F

Dest. Line

Implementation of Connection-Oriented Service

Routing within a virtual-circuit subnet.



A's table

In		Out	
H1	1	C	1
H3	1	C	2

C's table

A	1	E	1
A	2	E	2

E's table

C	1	F	1
C	2	F	2

POLL 2

- Connection identifier is linked with

a) Connectionless service

b) Connection oriented Service

c) None

Comparison of Virtual-Circuit and Datagram Subnets

Issue	Datagram subnet	Virtual-circuit subnet
Circuit setup	Not needed	Required
Addressing	Each packet contains the full source and destination address	Each packet contains a short VC number
State information	Routers do not hold state information about connections	Each VC requires router table space per connection
Routing	Each packet is routed independently	Route chosen when VC is set up; all packets follow it
Effect of router failures	None, except for packets lost during the crash	All VCs that passed through the failed router are terminated
Quality of service	Difficult	Easy if enough resources can be allocated in advance for each VC
Congestion control	Difficult	Easy if enough resources can be allocated in advance for each VC

POLL 3

- Which one of the following deals with transaction processing system
- Datagram Approach
- Virtual Connection Approach

Network Layer Services

- Packetizing: encapsulating the payload(data received from upper layer) at source and decapsulating at the destination.

- Routing: To find the best path from source to destination using routing protocols.

- Forwarding: Action applied by each router when packet arrives at one of its interface using routing or forwarding table.

- Routing and Forwarding are related to each other.

NETWORK-LAYER PERFORMANCE

The performance of a network can be measured in terms of:

- *Delay*
- *Throughput*
- *Packet loss*

POLL 4

- Is Delay a parameter for network Performance

a) Yes

b) No

c) Don’t Know

d) Didn’t understood the question

Delay

The delays in a network can be divided into four types:

- Transmission delay
- Propagation delay
- Processing delay
- Queuing delay.

- *Transmission Delay*

  Delaytr = (Packet length) / (Transmission rate).

- *Propagation Delay*

  Delaypg = (Distance) / (Propagation speed).

- *Processing Delay*

  Delaypr = Time required to process a packet in a router or a destination host

- *Queuing Delay*

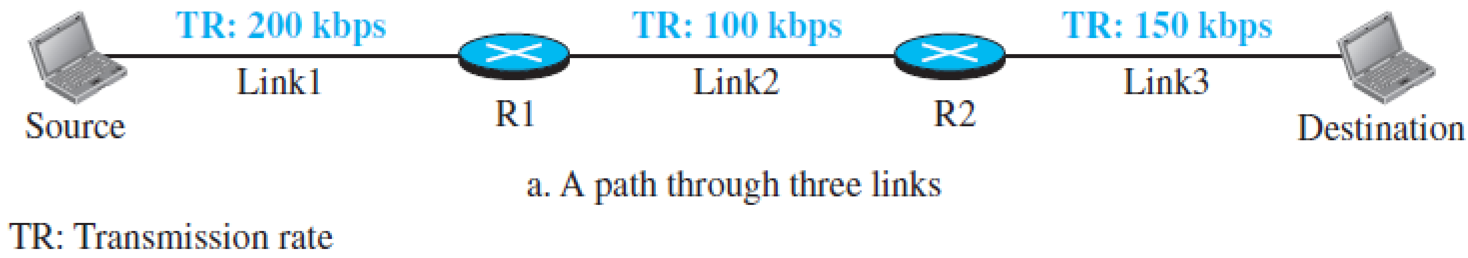
  Delayqu = The time a packet waits in input and output queues in a router

- *Total Delay*

  Total delay = (*n + 1) (Delaytr + Delaypg + Delaypr) + (n) (Delayqu)*

Throughput

- **Throughput = minimum {TR1, TR2, . . . TRn}.**



Packet Loss

- When a router receives a packet while processing another packet, the received packet needs to be stored in the input buffer waiting for its turn.

- A router, however, has an input buffer with a limited size. A time may come when the buffer is full and the next packet needs to be dropped.

- The effect of packet loss on the Internet network layer is that the packet needs to be resent, which in turn may create overflow and cause more packet loss.

IPv4 Address

Note

An IPv4 address is 32 bits long.

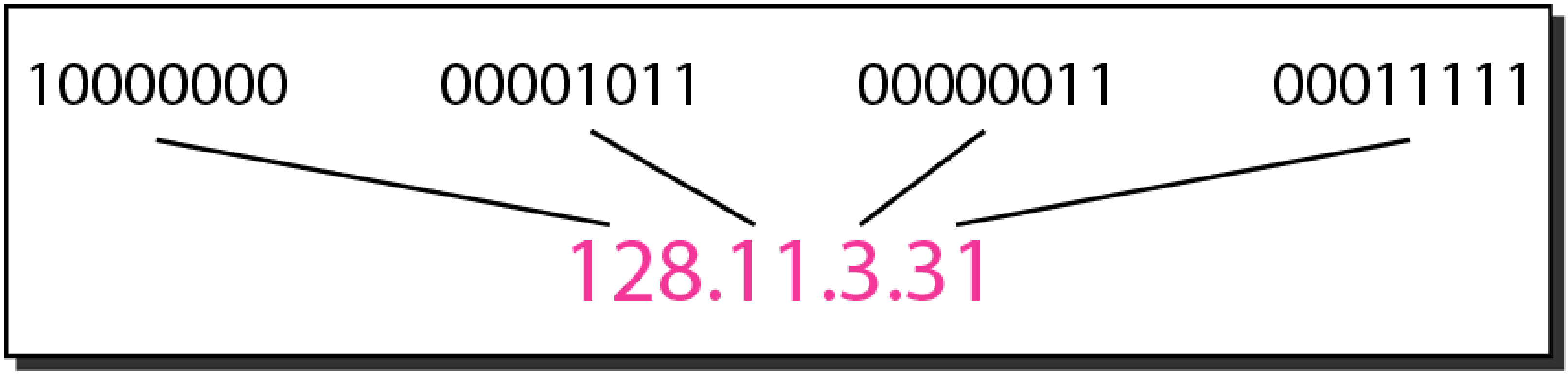
Note

The IPv4 addresses are unique and universal.

The address space of IPv4 is

2^{32} or 4,294,967,296.

Figure Dotted-decimal notation and binary notation for an IPv4 address



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

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

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

Note

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

Figure Finding the classes in binary and dotted-decimal notation

	First byte	Second byte	Third byte	Fourth byte
Class A	0			
Class B	10			
Class C	110			
Class D	1110			
Class E	1111			

a. Binary notation

	First byte	Second byte	Third byte	Fourth byte
Class A	0–127			
Class B	128–191			
Class C	192–223			
Class D	224–239			
Class E	240–255			

b. Dotted-decimal notation

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

Table 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

Note

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

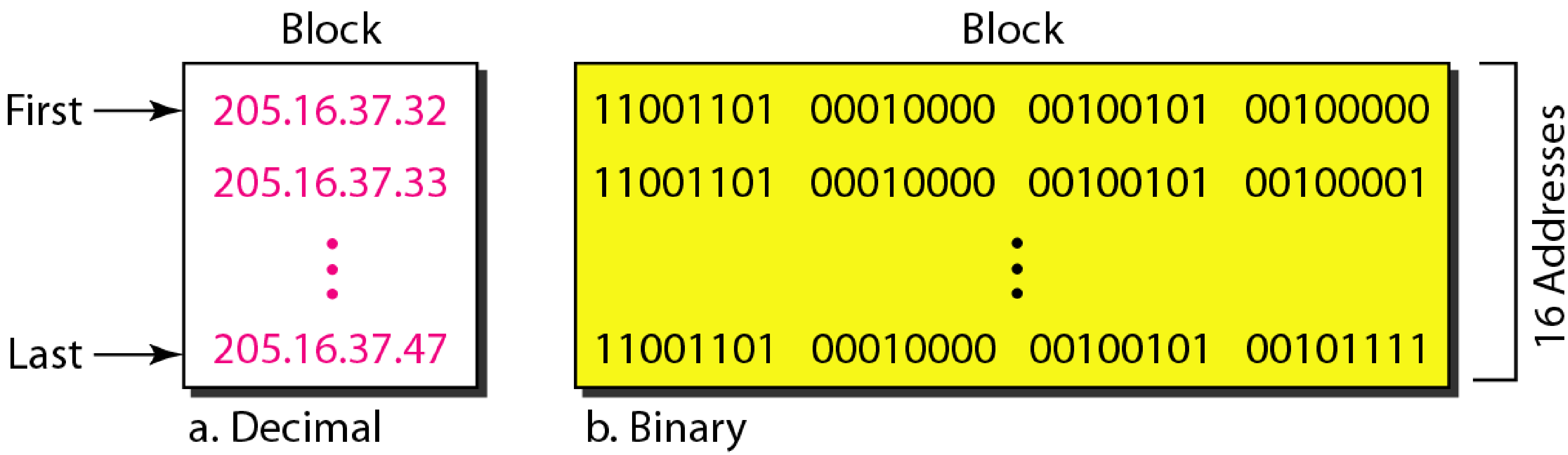
Table Default masks for classful addressing

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

Note

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

Figure A block of 16 addresses granted to a small organization



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.

Note

The first address in the block can be found by setting the rightmost $32 - n$ bits to 0s.

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 in the block?

Solution

The binary representation of the given address is 11001101 00010000 00100101 00100111

If we set 32−28 rightmost bits to 0, we get

11001101 00010000 00100101 0010000

or 205.16.37.32.

Note

The last address in the block can be found by setting the rightmost $32 - n$ bits to 1s.

Find the last address for the block in Last Example

Solution

The binary representation of the given address is

11001101 00010000 00100101 00100111

If we set 32 − 28 rightmost bits to 1, we get 11001101 00010000 00100101 00101111

or 205.16.37.47

Note

The number of addresses in the block can be found by using the formula 2^{32-n}.

Find the number of addresses in last example

Solution

The value of n is 28, which mean the number of addresses is 2^{32-28} or 16.

Another way to find the first address, the last address, and

the number of addresses is to represent the mask as a 32-bit binary (or 8-digit hexadecimal) number. This is particularly useful when we are writing a program to find these pieces of information. In Example the /28 can be represented as

11111111 11111111 11111111 11110000

(twenty-eight 1s and four 0s).

Find

a. The first address

b. The last address

c. The number of addresses.

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 1s; the result is 0 otherwise.*

Address:	11001101	00010000	00100101	00100111
Mask:	**11111111**	**11111111**	**11111111**	**11110000**
First address:	11001101	00010000	00100101	00100000

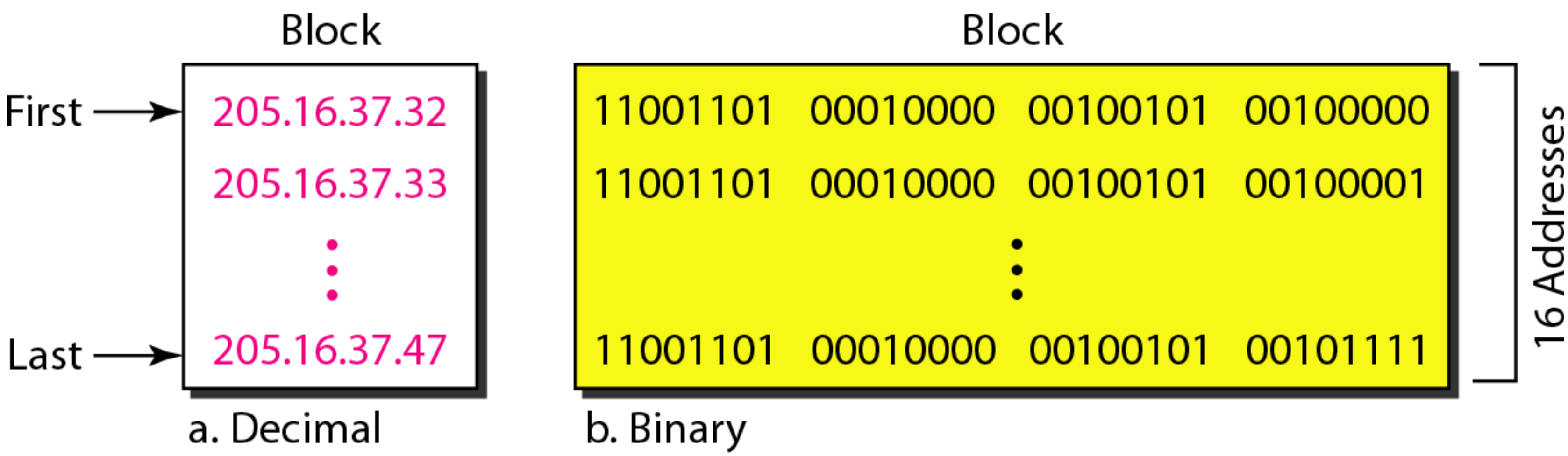
b. *The last address can be found by ORing the given addresses with the complement of the mask. ORing here is done bit by bit. The result of ORing 2 bits is 0 if both bits are 0s; the result is 1 otherwise. The complement of a number is found by changing each 1 to 0 and each 0 to 1.*

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

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

Figure *A network configuration for the block 205.16.37.32/28*



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

Figure *Two levels of hierarchy in an IPv4 address*

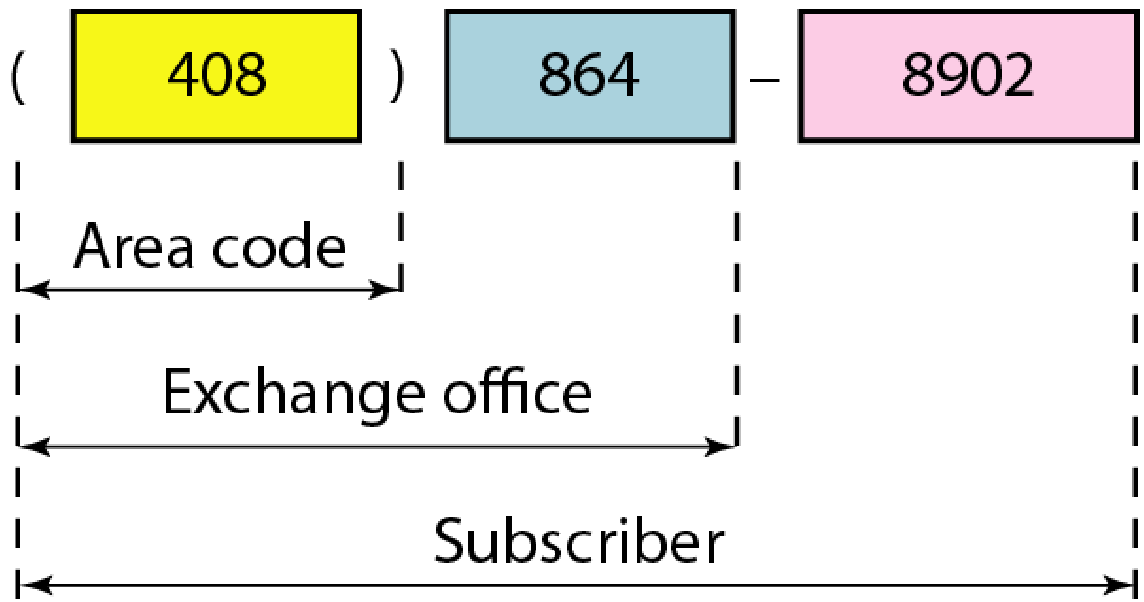
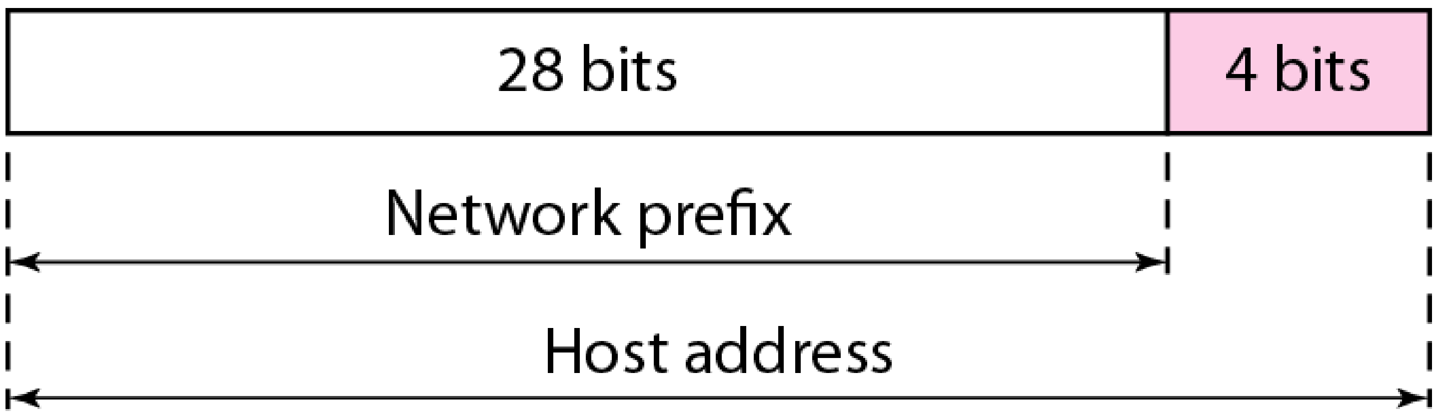
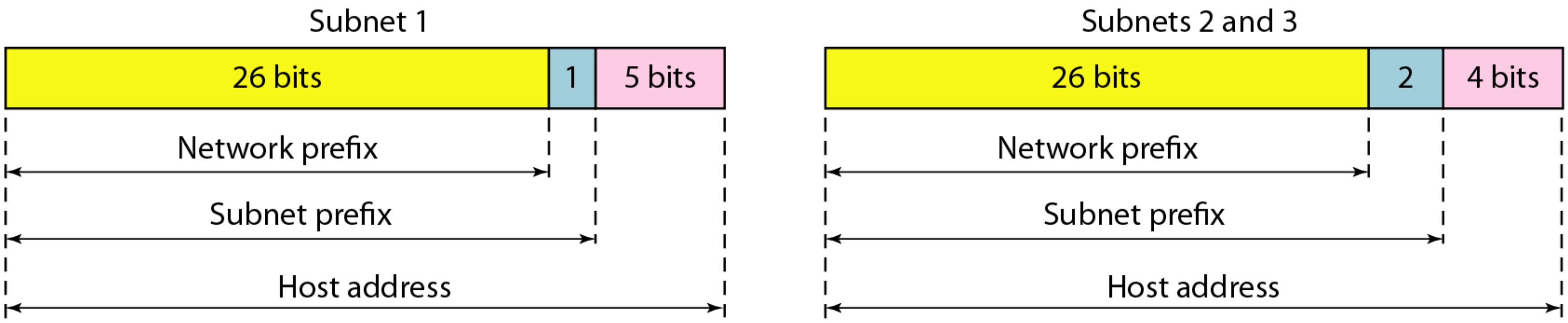


Figure *A frame in a character-oriented protocol*



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

Figure *Three-level hierarchy in an IPv4 address*



- *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.

Group 1

For 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		

Group2

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		

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

Figure *An example of address allocation and distribution by an ISP*