

IP ADDRESSESING

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INTRODUCTION

- ❖ The identifier used in the IP layer of the TCP/IP protocol suite to identify each device connected to the Internet is called the Internet address or IP address.
- ❖ An IP address is a **32-bit address** that uniquely and universally defines the connection of a host or a router to the Internet.
- ❖ **IP addresses are unique**-They are unique in the sense that each address defines one, and only one, connection to the Internet.
- ❖ Two devices on the Internet can never have the same address.



An IP address is a 32-bit address.



The IP addresses are unique which means no two system in the same network can have same IP address



Note:

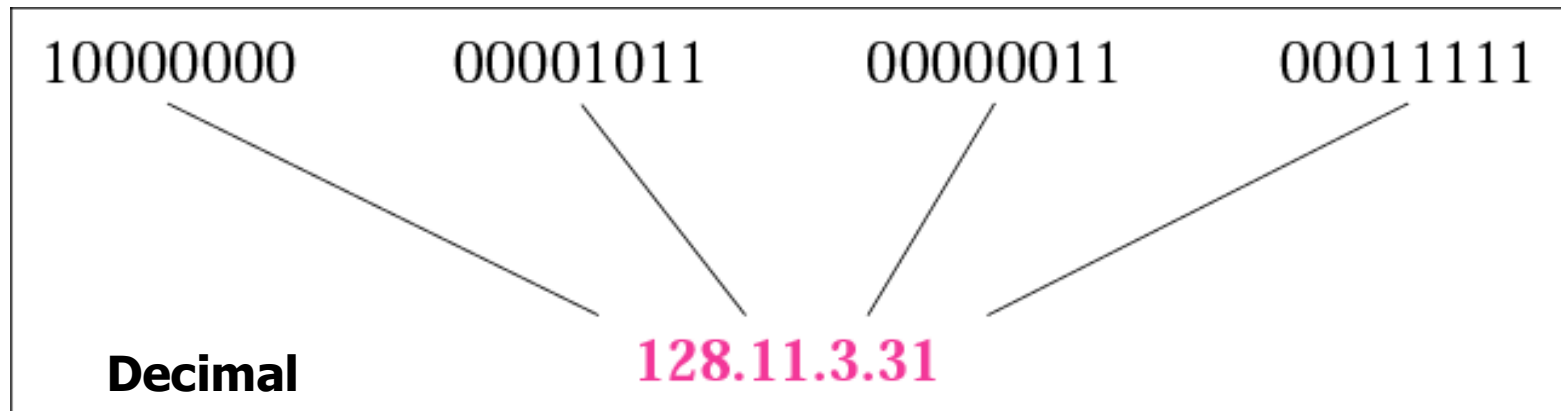
*The address space of IPv4 is
 2^{32} or 4,294,967,296.*



IP address is represented in three notation binary, decimal, and hexadecimal number systems.

Three notations used

Binary



Example 1

Change the following IP addresses from binary notation to dotted-decimal notation.

a. 10000001 00001011 00001011 11101111

b. 11000001 10000011 00011011 11111111

c. 11100111 11011011 10001011 01101111

d. 11111001 10011011 11111011 00001111

Solution

We replace each group of 8 bits with its equivalent decimal number and add dots for separation:

a. 129.11.11.239 b. 193.131.27.255

c. 231.219.139.111 d. 249.155.251.15

Example 2

Change the following IP addresses from dotted-decimal notation to binary notation.

a. 111.56.45.78

b. 221.34.7.82

c. 241.8.56.12

d. 75.45.34.78

Solution

We replace each decimal number with its binary equivalent:

a. 01101111 00111000 00101101 01001110

b. 11011101 00100010 00000111 01010010

c. 11110001 00001000 00111000 00001100

d. 01001011 00101101 00100010 01001110

RULES FOR AN IP ADDRESS

- There should be no leading zeros before any number like 039 is wrong write simply 39.
- An IPv4 IP address can have only four octets.
- The range of one octet is from 0-255.
- An IP address can be either in binary, decimal or hexadecimal notation and not a mixture of all.

Example 3

Find the error, if any, in the following IP addresses:

a. 111.56.045.78

b. 221.34.7.8.20

c. 75.45.301.14

d. 11100010.23.14.67

Solution

a. There are no leading zeroes in dotted-decimal notation (045).

b. We may not have more than four numbers in an IP address.

c. In dotted-decimal notation, each number is less than or equal to 255; 301 is outside this range.

d. A mixture of binary notation and dotted-decimal notation is not allowed.

Example 4

Change the following IP addresses from binary notation to hexadecimal notation.

a. 10000001 00001011 00001011 11101111

b. 11000001 10000011 00011011 11111111

Solution

We replace each group of 4 bits with its hexadecimal equivalent. Note that hexadecimal notation normally has no added spaces or dots; however, 0X (or 0x) is added at the beginning or the subscript 16 at the end to show that the number is in hexadecimal.

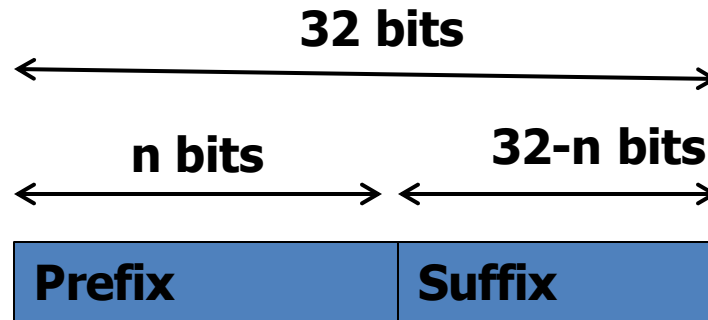
a. 0X810B0BEF or 810B0BEF₁₆

b. 0XC1831BFF or C1831BFF₁₆

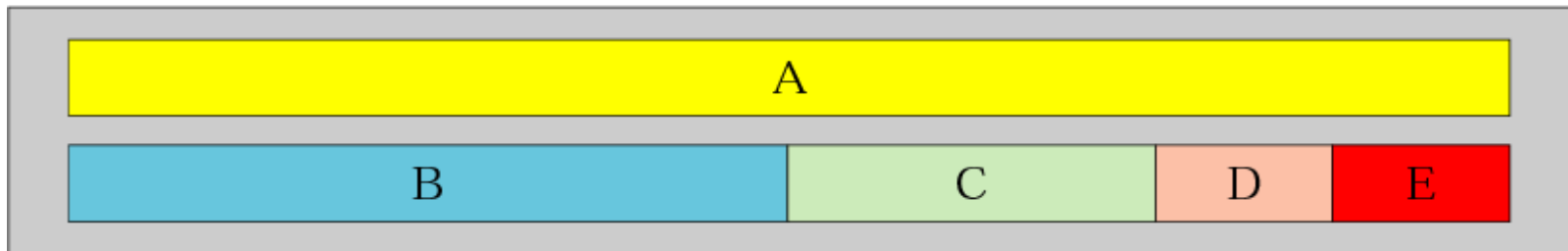
CLASSFUL ADDRESSING

- ❖ IP addresses, when started a few decades ago, used the concept of classes. This architecture is called **classful addressing**.
- ❖ In the mid-1990s, a new architecture, called classless addressing, was introduced and will eventually supersede the original architecture.
- ❖ However, part of the Internet is still using classful addressing, but the migration is very fast.
- ❖ In classful addressing the whole address space is divided in five classes: A,B,C,D,E.

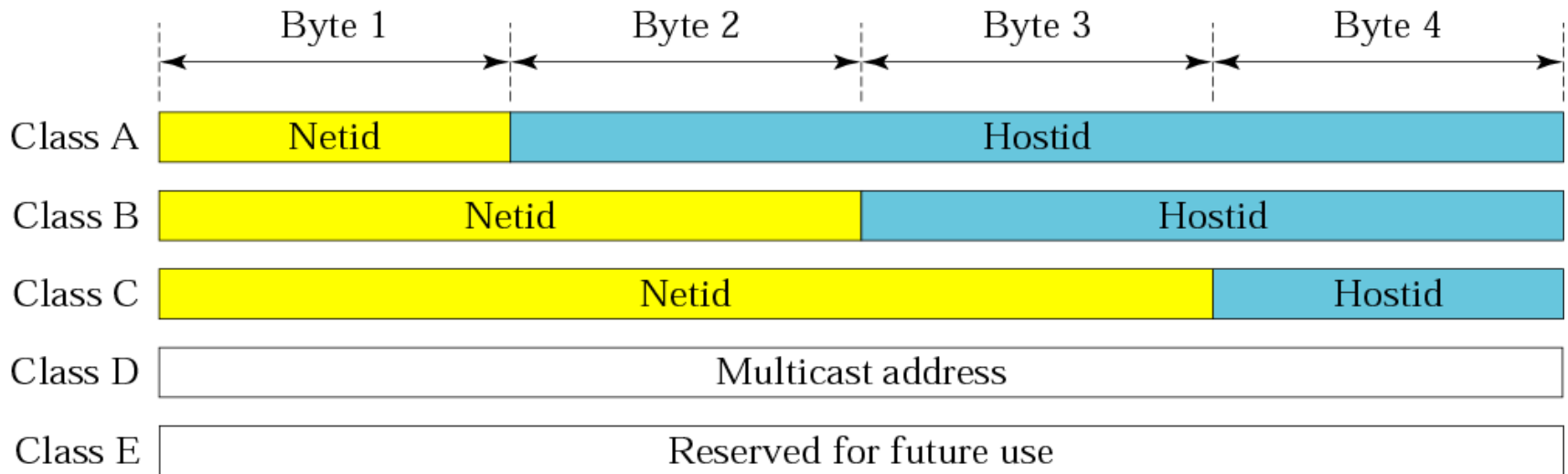
Occupation of the address space



Address space

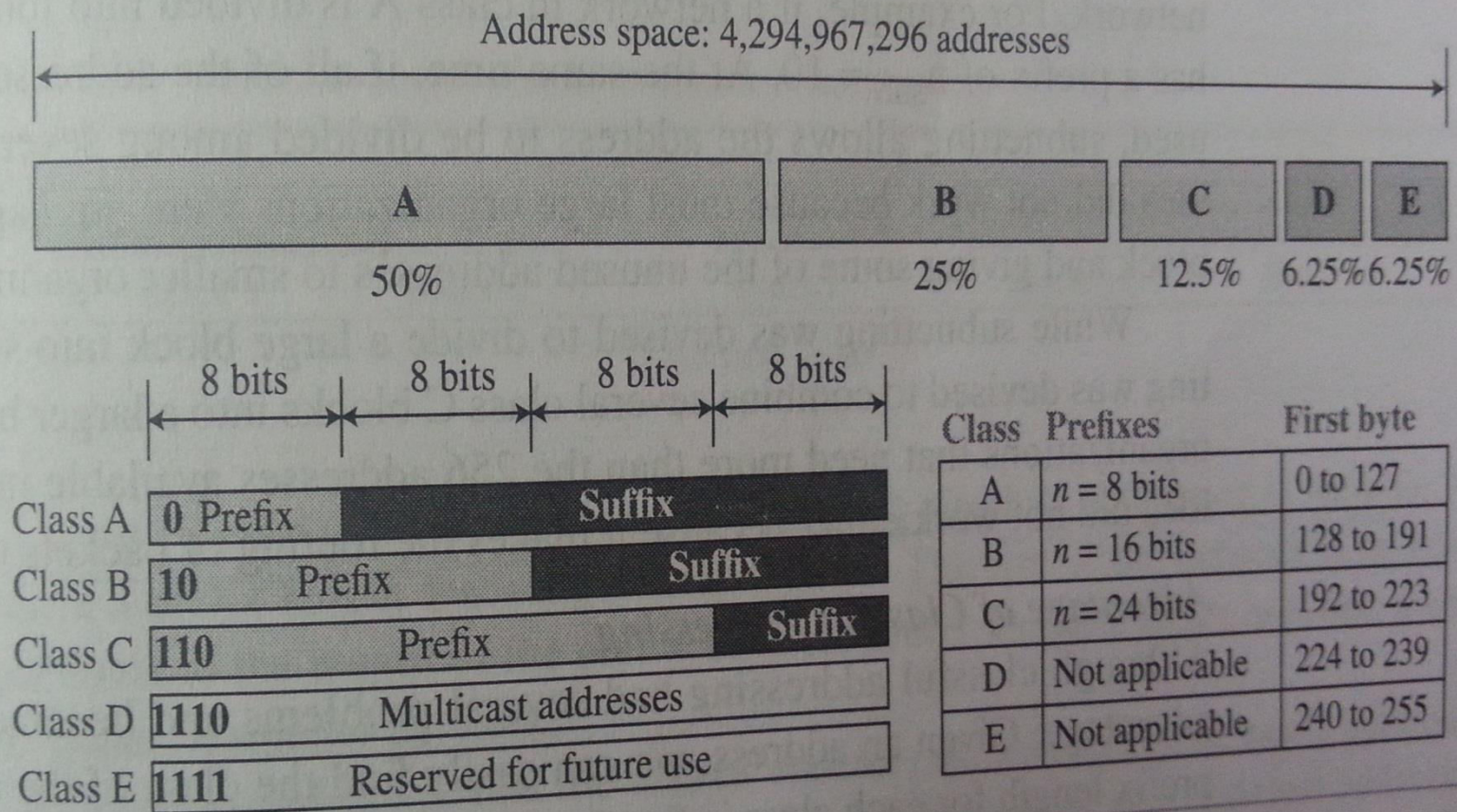


Netid and Hostid

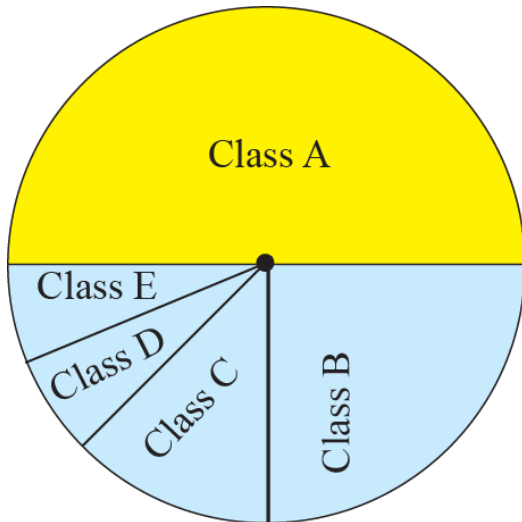


NOTE: Each address is divided into two parts netid and hostid. The netid is used to determine the network address while hostid tells the id of a particular node in a network.

Figure 4.31 Occupation of the address space in classful addressing



Addresses Per Class



<i>Class</i>	<i>Number of Addresses</i>	<i>Percentage</i>
A	$2^{31} = 2,147,483,648$	50%
B	$2^{30} = 1,073,741,824$	25%
C	$2^{29} = 536,870,912$	12.5%
D	$2^{28} = 268,435,456$	6.25%
E	$2^{28} = 268,435,456$	6.25%

Source: TCP/IP Protocol Suite by Forouzan

Finding the class of address

	Octet 1	Octet 2	Octet 3	Octet 4
Class A	0.....			
Class B	10.....			
Class C	110.....			
Class D	1110....			
Class E	1111....			

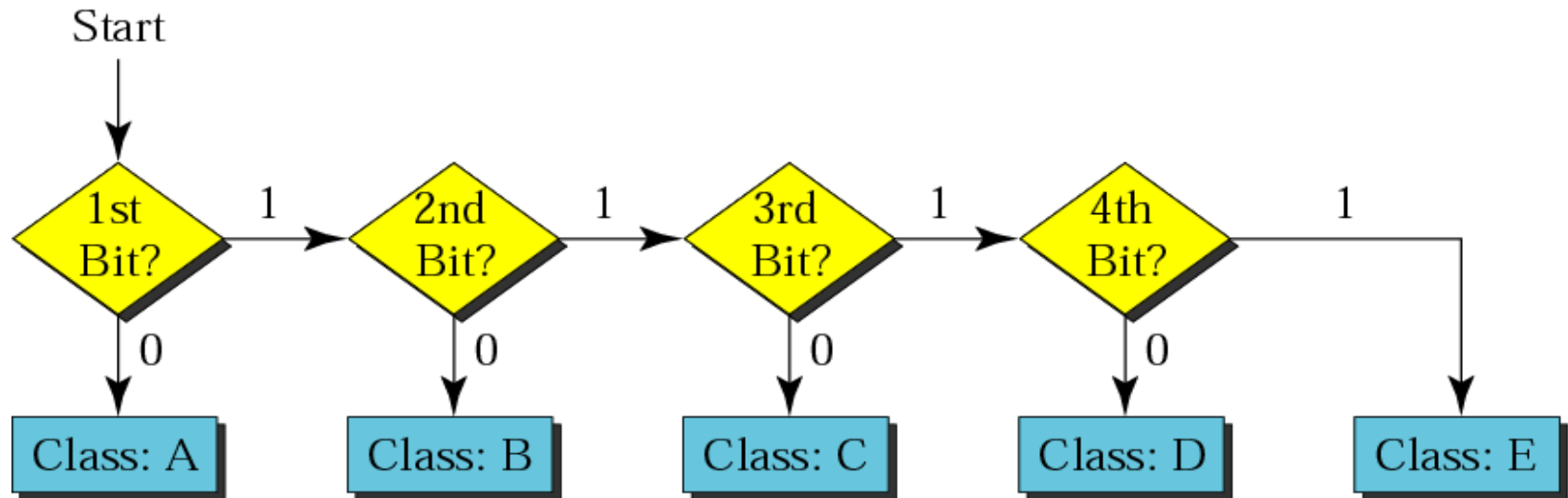
Binary notation

	Byte 1	Byte 2	Byte 3	Byte 4
Class A	0–127			
Class B	128–191			
Class C	192–223			
Class D	224–299			
Class E	240–255			

Dotted-decimal notation

Source: TCP/IP Protocol Suite by Forouzan

Finding the address class



Source: TCP/IP Protocol Suite by Forouzan

Example 6

Find the class of each address:

- a. 00000001 00001011 00001011 11101111*
- b. 11000001 10000011 00011011 11111111*
- c. 10100111 11011011 10001011 01101111*
- d. 11110011 10011011 11111011 00001111*

Solution

See the procedure in Figure 4.4.

- a. The first bit is 0. This is a class A address.*
- b. The first 2 bits are 1; the third bit is 0. This is a class C address.*
- c. The first bit is 0; the second bit is 1. This is a class B address.*
- d. The first 4 bits are 1s. This is a class E address..*

Example 7

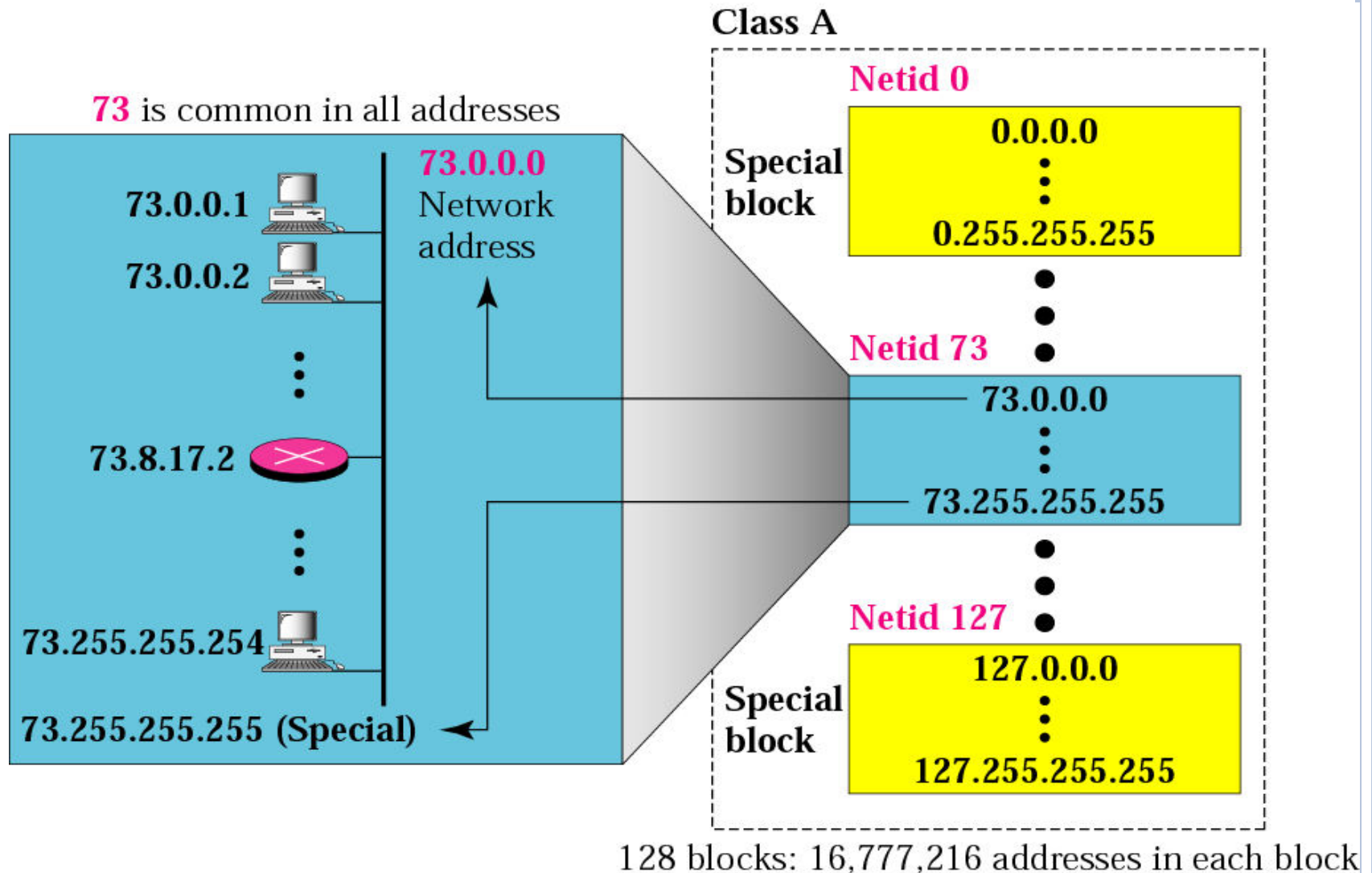
Find the class of each address:

- a. 227.12.14.87 b. 193.14.56.22 c. 14.23.120.8*
d. 252.5.15.111 e. 134.11.78.56

Solution

- a. The first byte is 227 (between 224 and 239); the class is D.*
b. The first byte is 193 (between 192 and 223); the class is C.
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.
e. The first byte is 134 (between 128 and 191); the class is B.

Blocks in class A



Source: TCP/IP Protocol Suite by Forouzan



Note:

Millions of class A addresses are wasted because each netid can have 2^{24} hosts.

CLASS A ADDRESSES

- ❖ Class A IP addresses use the 1st 8 bits (1st Octet) to designate the Network address.
- ❖ The 1st bit which is always a 0, is used to indicate the address as a Class A address & the remaining 7 bits are used to designate the Network.
- ❖ The other 3 octets contain the Host address.
- ❖ There are 128 Class A Network Addresses, but because addresses with all zeros aren't used & address 127 is a special purpose address, 126 Class A Networks are available.

CLASS A ADDRESSES (CONT.)

- ❖ There are 16,777,214 Host addresses available in a Class A address.
- ❖ Rather than remembering this number exactly, you can use the following formula to compute the number of hosts available in any of the class addresses, where “n” represents the number of bits in the host portion:

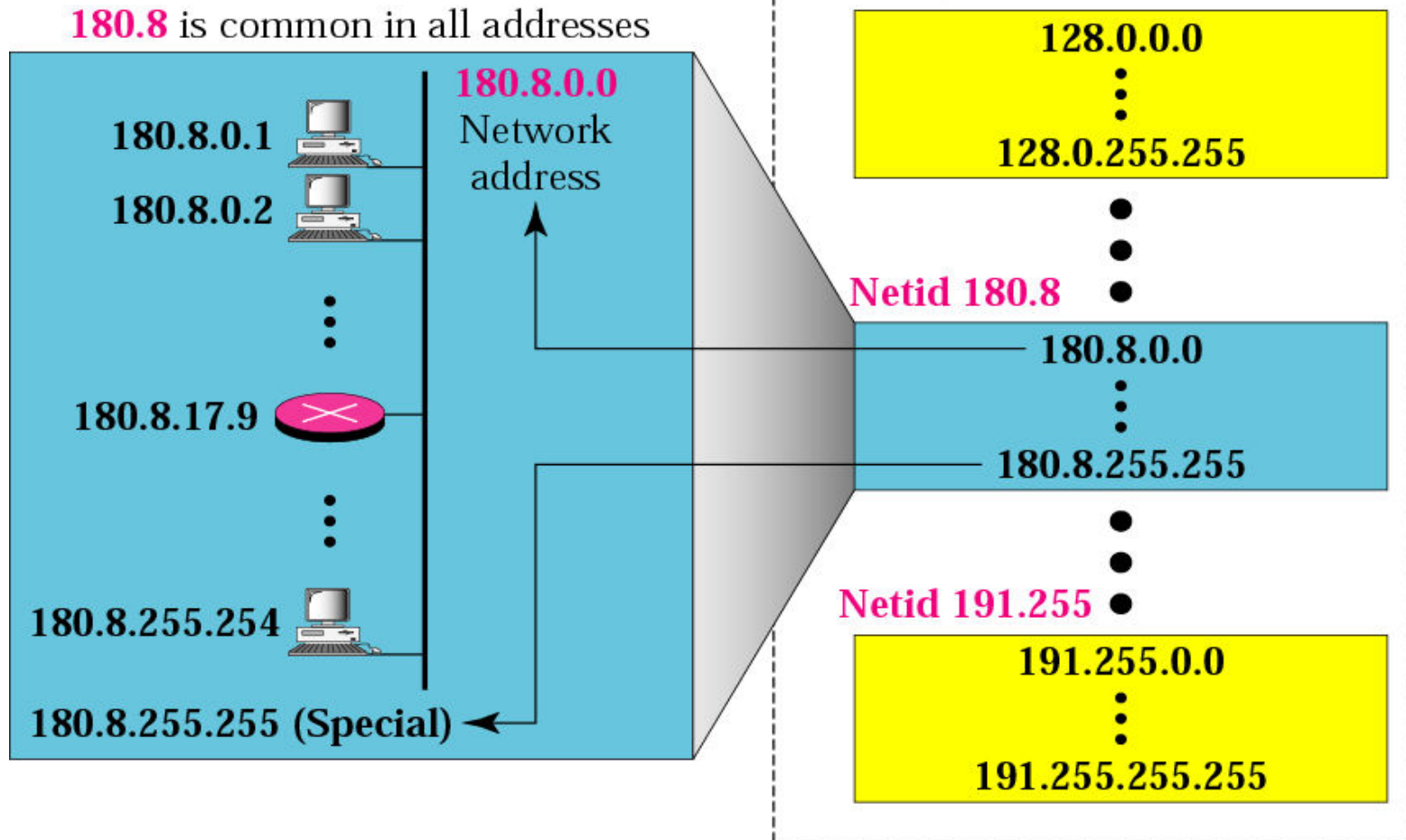
$$(2^n - 2) = \text{Number of available hosts}$$

CLASS A ADDRESSES (CONT.)

- ❖ For a Class A network, there are:
 $2^{24} - 2$ or 16,777,214 hosts.
- ❖ Half of all IP addresses are Class A addresses.
- ❖ You can use the same formula to determine the number of Networks in an address class.
- ❖ Eg., a Class A address uses 7 bits to designate the network, so $(2^7 - 2) = 126$ or there can be 126 Class A Networks.

Blocks in class B

Class B



16,384 blocks: 65,536 addresses in each block

Source: TCP/IP Protocol Suite by Forouzan

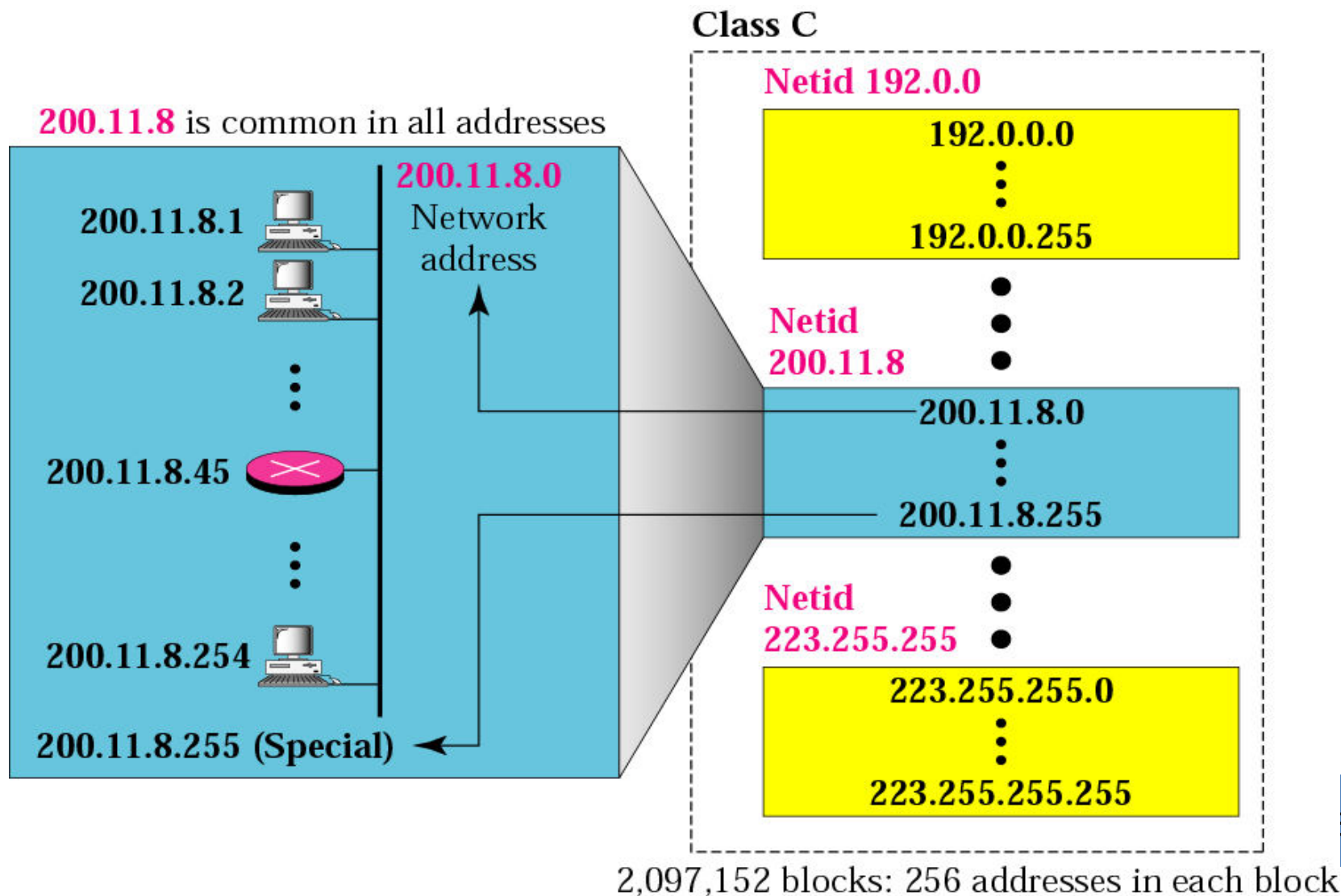
CLASS B IP ADDRESSES

- ❖ Class B addresses use the 1st 16 bits (two octets) for the Network address.
- ❖ The last 2 octets are used for the Host address.
- ❖ The 1st 2 bit, which are always 10, designate the address as a Class B address & 14 bits are used to designate the Network. This leaves 16 bits (two octets) to designate the Hosts.
- ❖ So how many Class B Networks can there be?
- ❖ Using our formula, $(2^{14} - 2)$, there can be 16,382 Class B Networks & each Network can have $(2^{16} - 2)$ Hosts, or 65,534 Hosts.



Many class B addresses are wasted.

Blocks in class C



Source: TCP/IP Protocol Suite by Forouzan

CLASS C IP ADDRESSES

- ❖ Class C addresses use the 1st 24 bits (three octets) for the Network address & only the last octet for Host addresses.
- ❖ The 1st 3 bits of all class C addresses are set to 110, leaving 21 bits for the Network address, which means there can be 2,097,150 ($2^{21} - 2$) Class C Networks, but only 254 ($2^8 - 2$) Hosts per Network.



Note:

The number of addresses in class C is smaller than the needs of most organizations.

Characteristics of the IP Address Classes

Class	Address Range	Identify Bits (binary value)	Bits in Network ID	Number of Networks	Bits in Host ID	Number of Hosts/ Network
A	0 ~ 127	1 (0)	7	126	24	16,777,214
B	128~191	2 (10)	14	16,382	16	5,534
C	192~223	3 (110)	21	2,097,150	8	254



Class D addresses are used for multicasting; there is only one block in this class.



Note:

Class E addresses are reserved for future purposes; most of the block is wasted.



Note:

In classful addressing, the network address (the first address in the block) is the one that is assigned to the organization. The range of addresses can automatically be inferred from the network address.

Example 9

Given the network address 17.0.0.0, find the class, the block, and the range of the addresses.

Solution

The class is A because the first byte is between 0 and 127. The block has a netid of 17. The addresses range from 17.0.0.0 to 17.255.255.255.

Example 10

Given the network address 132.21.0.0, find the class, the block, and the range of the addresses.

Solution

The class is B because the first byte is between 128 and 191. The block has a netid of 132.21. The addresses range from 132.21.0.0 to 132.21.255.255.

Example 11

Given the network address 220.34.76.0, find the class, the block, and the range of the addresses.

Solution

The class is C because the first byte is between 192 and 223. The block has a netid of 220.34.76. The addresses range from 220.34.76.0 to 220.34.76.255.

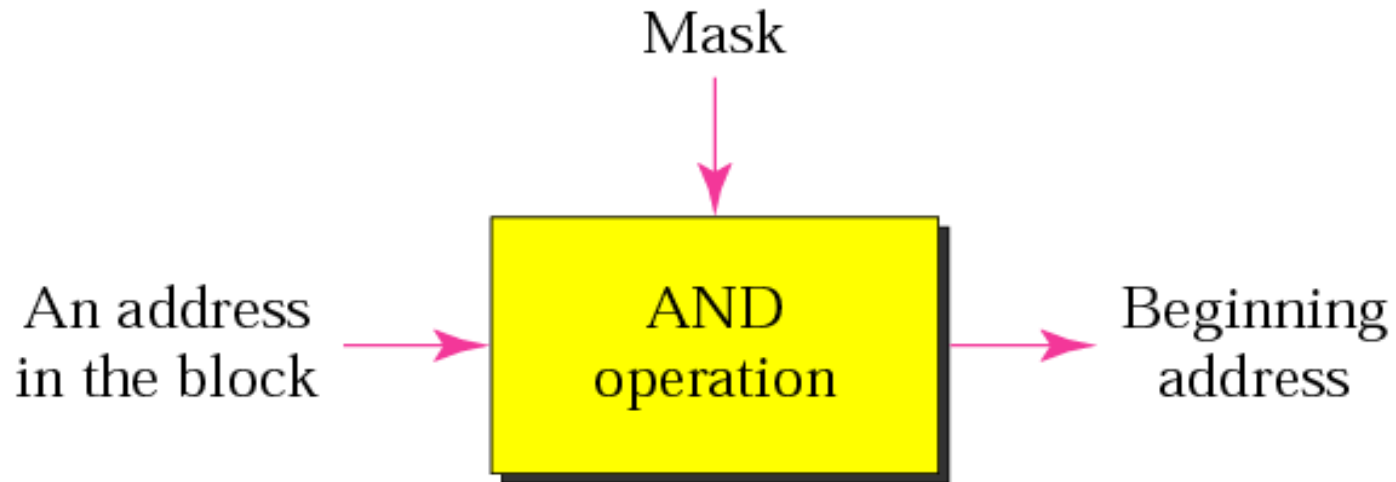
SPECIAL ADDRESSES

- ❖ A few addresses are set aside for specific purposes.
- ❖ Network addresses that are all binary zeros, all binary ones & Network addresses beginning with 127 are special Network addresses.

SPECIAL ADDRESSES (CONT.)

Special IP Addresses			
<i>Network Address</i>	<i>Host Address</i>	<i>Description</i>	<i>Example</i>
0's	0's	Default Cisco Route	0.0.0.0
0's	Host Address	Local Network Hosts	0.0.0.115
1's	1's	Broadcast to Local Network	255.255.255.255
Network Address	1's	Broadcast to Network Address	192.21.12.255
127	Anything	Loopback Testing	127.0.0.1

Masking Concept



The mask is used to find the first address of a block. When the AND operation is applied between the address of a block and default mask of a class it gives us the beginning address of the block.

Default masks{Source:TCP/IP Protocol Suite by Forouzan]

<i>Class</i>	<i>Mask in binary</i>	<i>Mask in dotted-decimal</i>
A	11111111 00000000 00000000 00000000	255.0.0.0
B	11111111 11111111 00000000 00000000	255.255.0.0
C	11111111 11111111 11111111 00000000	255.255.255.0



Note:

The network address is the beginning address of each block. It can be found by applying the default mask to any of the addresses in the block (including itself). It retains the netid of the block and sets the hostid to zero.

Example 12

Given the address 23.56.7.91, find the beginning address (network address).

Solution

*The default mask is 255.0.0.0, which means that only the first byte is preserved and the other 3 bytes are set to 0s. The network address is **23.0.0.0**.*

Example 13

Given the address 132.6.17.85, find the beginning address (network address).

Solution

*The default mask is 255.255.0.0, which means that the first 2 bytes are preserved and the other 2 bytes are set to 0s. The network address is **132.6.0.0**.*

Example 14

Given the address 201.180.56.5, find the beginning address (network address).

Solution

*The default mask is 255.255.255.0, which means that the first 3 bytes are preserved and the last byte is set to 0. The network address is **201.180.56.0**.*



Note that we must not apply the default mask of one class to an address belonging to another class.

SUBNETTING AND SUPERNETTING

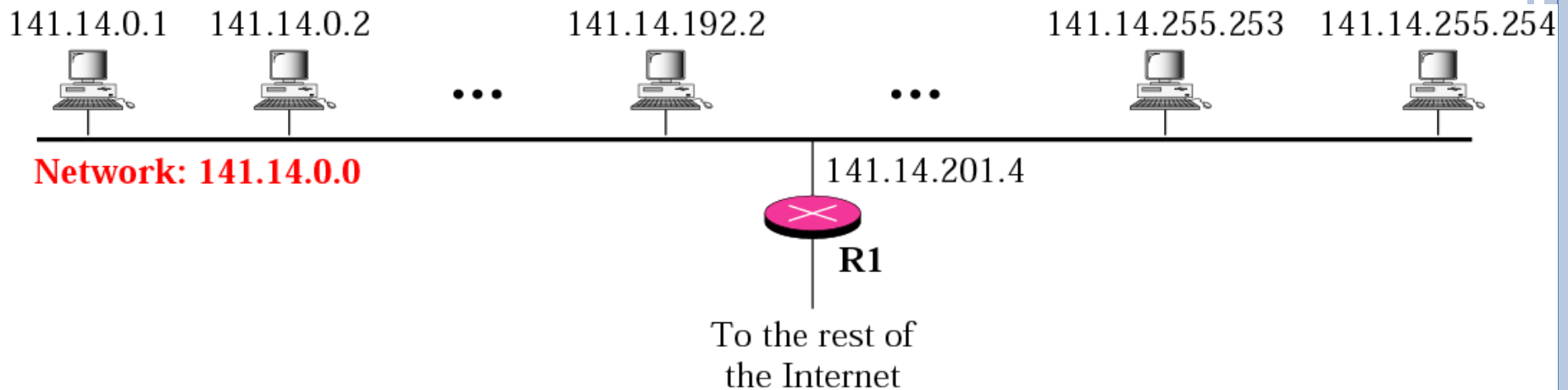
- ❖ In the previous sections we discussed the problems associated with classful addressing.
- ❖ Specifically, the network addresses available for assignment to organizations are close to depletion.
- ❖ This is coupled with the ever-increasing demand for addresses from organizations that want connection to the Internet.
- ❖ In this section we briefly discuss two solutions: subnetting and supernetting.

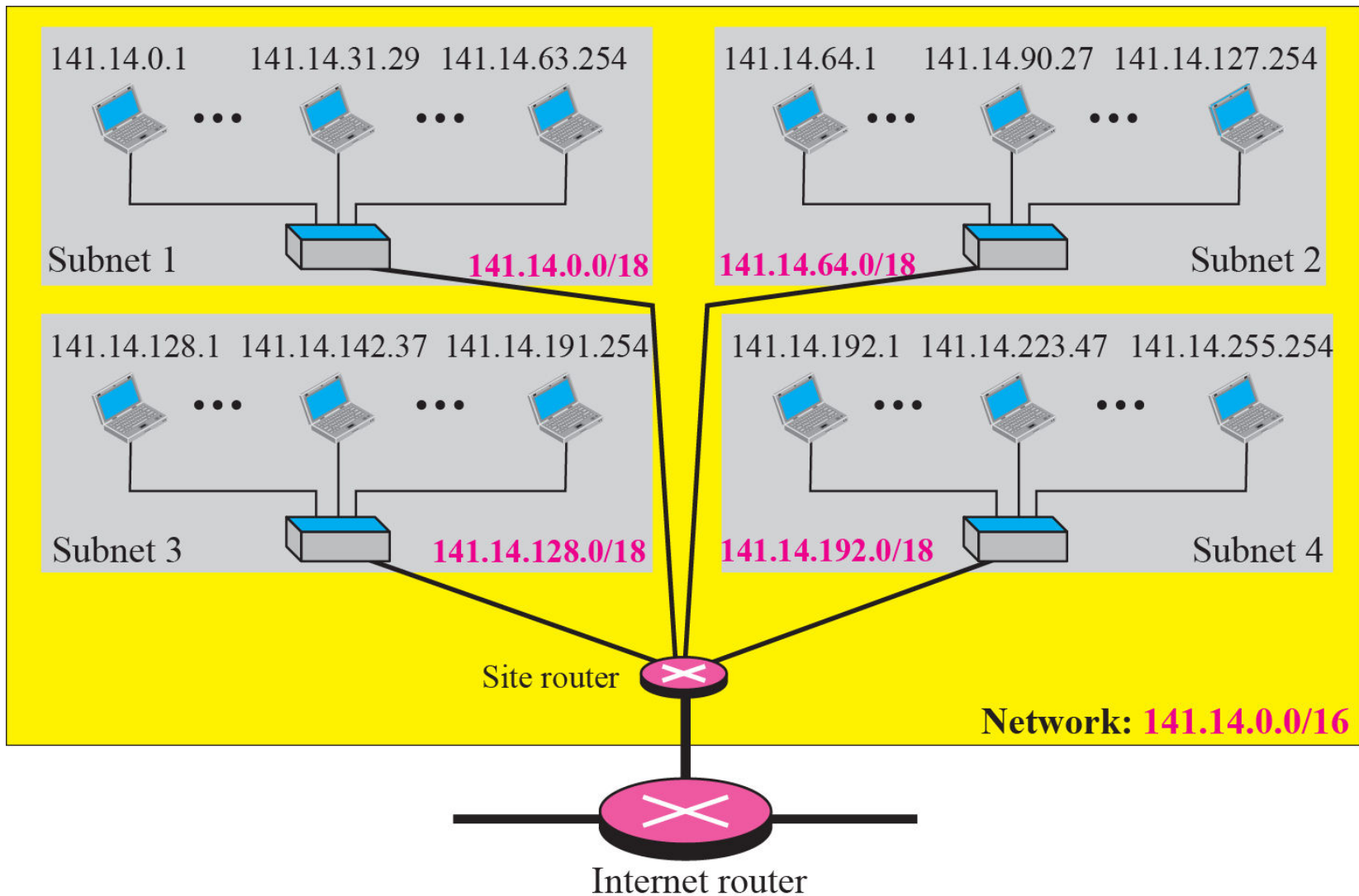


Note:

IP addresses are designed with two levels of hierarchy.

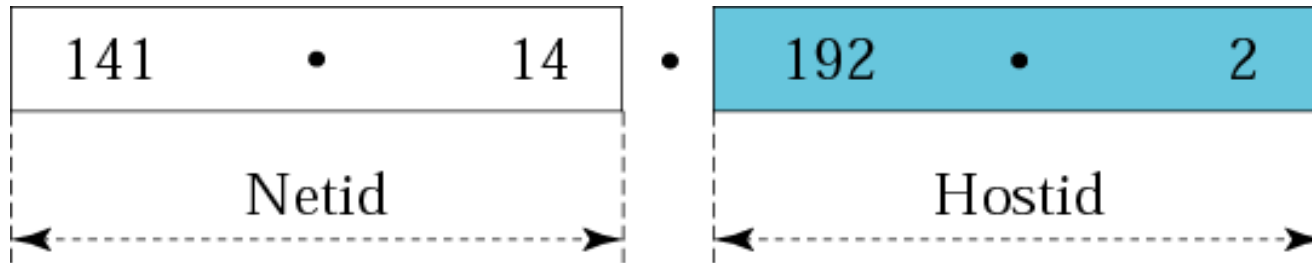
A network with two levels of hierarchy (not subnetted)



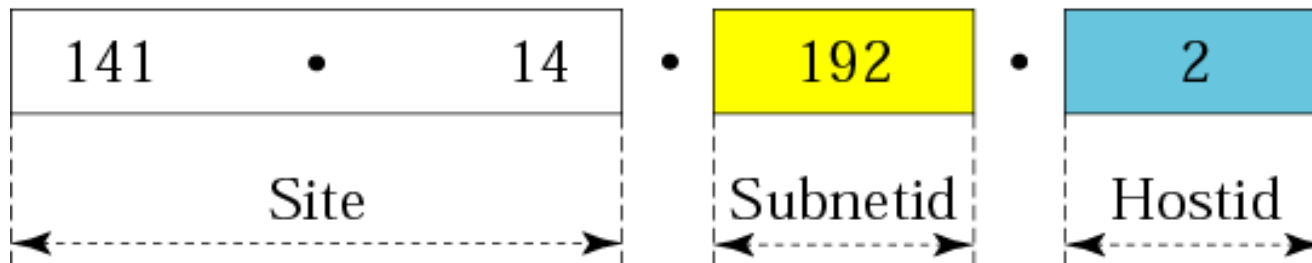


Source: TCP/IP Protocol Suite by Forouzan

Addresses in a network with and without subnetting



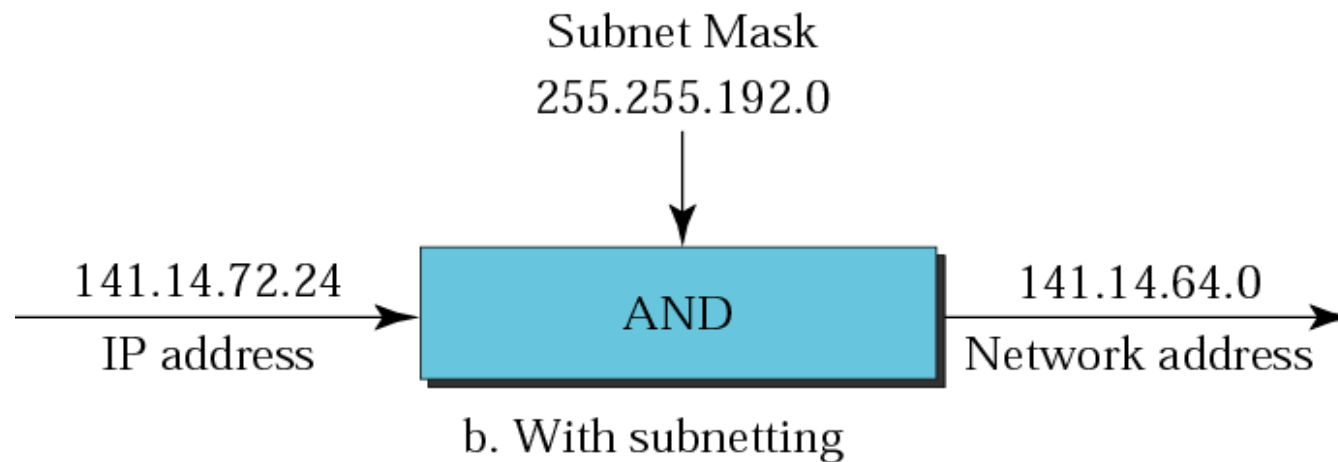
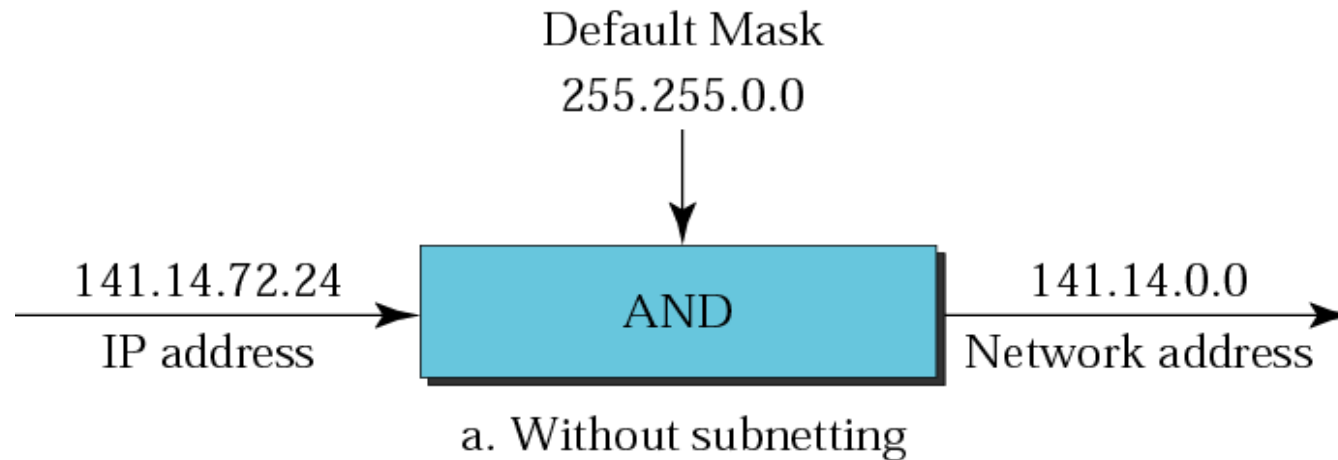
a. Without subnetting



b. With subnetting

Source: TCP/IP Protocol Suite by Forouzan

Default mask and subnet mask



Example 15

What is the subnetwork address if the destination address is 200.45.34.56 and the subnet mask is 255.255.240.0?

Solution

We apply the AND operation on the address and the subnet mask.

Address ➡ *11001000 00101101 00100010 00111000*

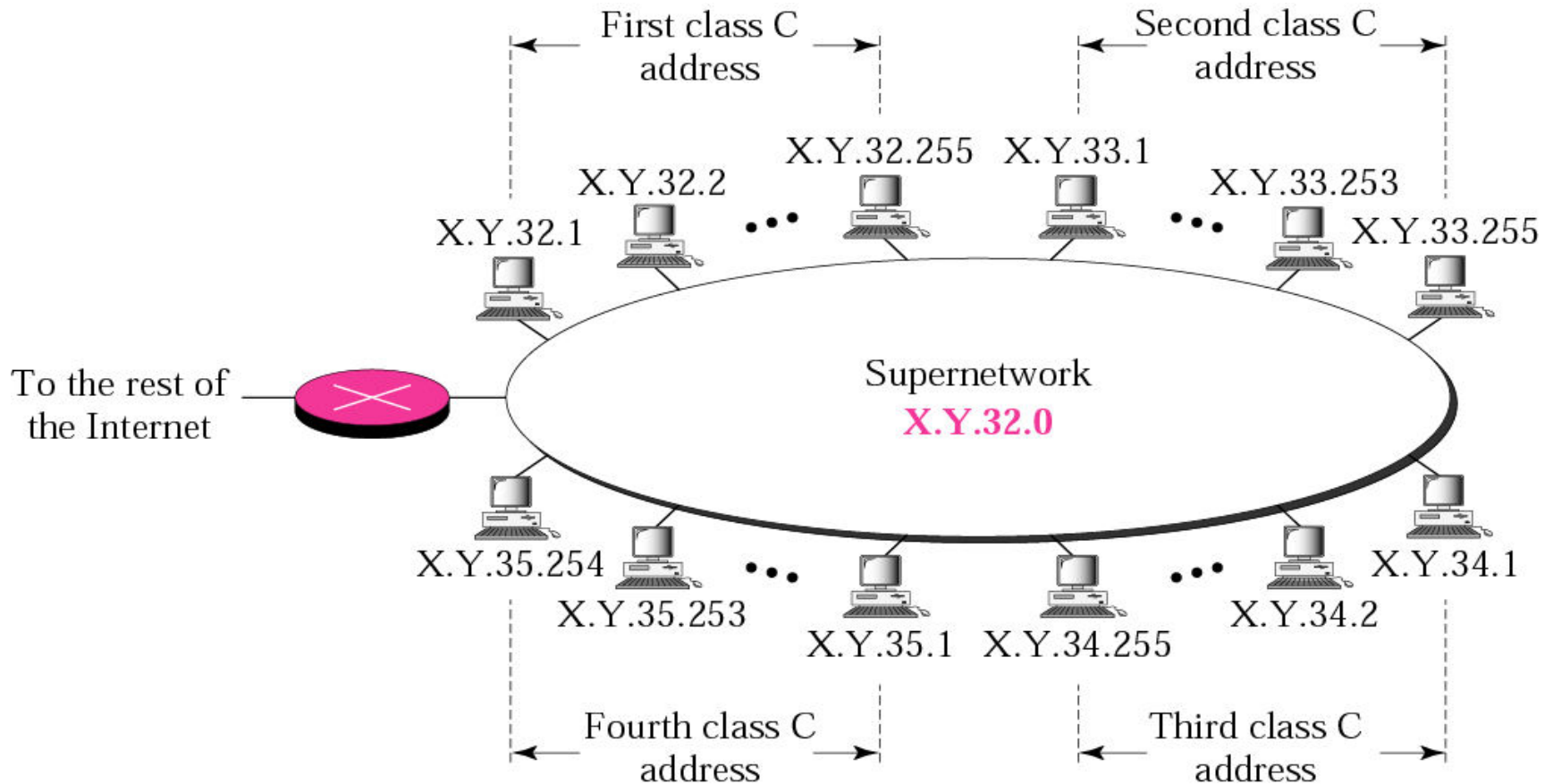
Subnet Mask ➡ *11111111 11111111 11110000 00000000*

Subnetwork Address ➡ *11001000 00101101 00100000 00000000.*

Comparison of a default mask and a subnet mask

	255.255.0.0			
Default Mask	11111111 11111111		00000000 00000000	
			16	
	255.255.224.0			
Subnet Mask	11111111 11111111		111	00000 00000000
			3	13

A Supernetwork



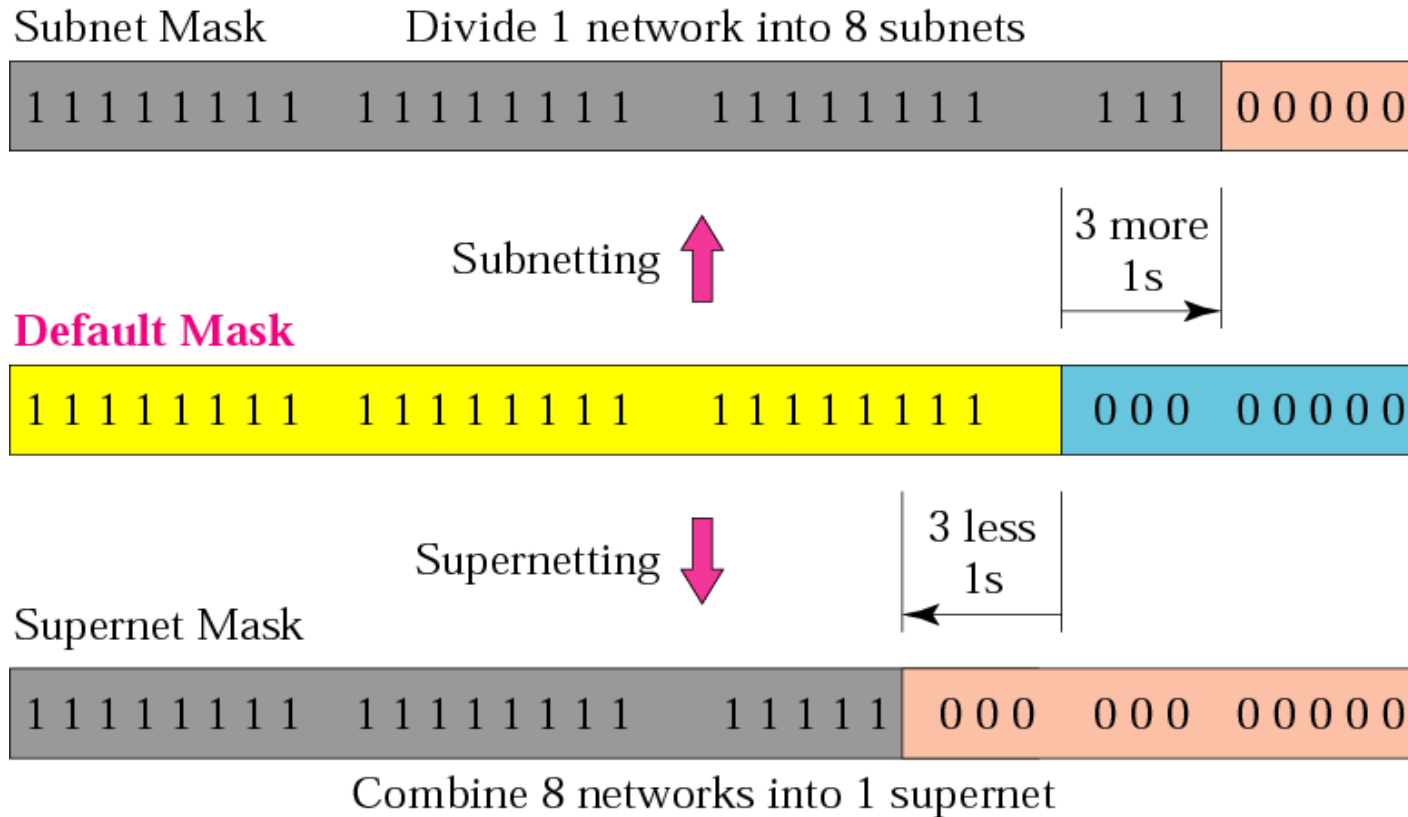
Source: TCP/IP Protocol Suite by Forouzan



In subnetting, we need the first address of the subnet and the subnet mask to define the range of addresses.

In supernetting, we need the first address of the supernet and the supernet mask to define the range of addresses.

Comparison of subnet, default, and supernet masks



Example 3 : A Company is granted a site address 201.70.64.0. The company needs six subnets. Design the subnets.

Solution : Since the given address is a class C network, so the default mask is **255.255.255.0**

- As we need 6 subnets, we need three extra 1 ($2^n = 6$, for $n = 3$, we have 8 subnets from which we can choose any 6).

So the subnet mask is, **255.255.255.200** as shown below :

255	255	255	200
11111111	11111111	11111111	11100000

→ 3 extra 1's for subnets

- We required only 6 subnets among 8 (possible). The six subnets are as –

Combination	Subnet Number
000	Subnet 1
001	Subnet 2
010	Subnet 3
011	Subnet 4
100	Subnet 5
101	Subnet 6

- Remaining unused subnets are created by using 110 & 111
- So, the various address of 6 subnets are shown as –

Subnet No.	Address
1	201.70.64.0 to 201.70.64.31
2	201.70.64.32 to 201.70.64.63
3	201.70.64.64 to 201.70.64.95
4	201.70.64.96 to 201.70.64.127
5	201.70.64.128 to 201.70.64.159
6	201.70.64.160 to 201.70.64.191

EXPLANATION OF PREVIOUS NUMERICAL

- ❖ The first step to solve subnetting problem is to see how many subnets we need to make. For eg if we have to make four subnets then 2 bits from host id is taken($2^2=4$)
- ❖ Now the hierarchy is three level netid, subnetid(2 bits from hostid) and remaining bits showing the hostid.
- ❖ The number of hosts in a network are $2^{\text{no. of hosts bits}}$ (after removing the subnetid bits).
- ❖ Now the next step is to determine the subnet mask.

- ❖ To find subnet mask put the bits of netid and subnetid to one and hostid bits to zero and convert them to dotted decimal form discussed previously.
- ❖ To find the first and last address of each block change the subnetid bits like for 4 subnets we have taken two bits for subnet so 00,01,10,11

CLASSLESS ADDRESSING

Source: TCP/IP Protocol Suite by Forouzan

- ❖ In classful addressing, two-level addressing was provided by dividing an address into netid and hostid.
- ❖ When an organization is granted a block of addresses, the block is actually divided into two parts, the prefix and the suffix.
- ❖ In classless addressing, the prefix defines the network and the suffix defines the host.
- ❖ In classless addressing, the length of the prefix, n , depends on the size of the block; it can be 0, 1, 2, 3, . . . , 32.
- ❖ In classless addressing, the value of n is referred to as prefix length; the value of $32 - n$ is referred to as suffix length.
- ❖ The idea of network mask in classless addressing is the same as the one in classful addressing. A network mask is a 32-bit number with the n leftmost bits all set to 0s and the rest of the bits all set to 1s.

Classless Addressing - CIDR

Classless interdomain routing (CIDR)

byte	.	byte	.	byte	byte	.	/	n
------	---	------	---	------	------	---	---	---

n = no. of bits in netid

Example:

12.24.76.2/8

The slash notation is formally referred to as classless interdomain routing or CIDR (pronounced cider) notation.

- ❖ The following addresses are defined using slash notations.
 - a) In the address 12.23.24.78/8, the network mask is 255.0.0.0. The mask has eight 1s and twenty-four 0s. The prefix length is 8; the suffix length is 24.
 - b) In the address 130.11.232.156/16, the network mask is 255.255.0.0. The mask has sixteen 1s and sixteen 0s. The prefix length is 16; the suffix length is 16.
 - c) In the address 167.199.170.82/27, the network mask is 255.255.255.224. The mask has twenty-seven 1s and five 0s. The prefix length is 27; the suffix length is 5.

Example 16

One of the addresses in a block is 167.199.170.82/27. Find the number of addresses in the network, the first address, and the last address.

Solution

The value of n is 27. The network mask has twenty-seven 1s and five 0s. It is 255.255.255.240.

a. The number of addresses in the network is $2^{(32 - n)} = 2^{(32 - 27)} = 2^5 = 32$.

b. We use the AND operation to find the first address (network address). The first address is 167.199.170.64/27.

- Address in binary: **10100111 11000111 10101010 01010010**
- Network mask: **11111111 11111111 11111111 11100000**
- First address: **10100111 11000111 10101010 01000000**

c. To find the last address, we first find the complement of the network mask and then OR it with the given address: The last address is 167.199.170.95/27.

- Address in binary: **10100111 11000111 10101010 01010010**
- Complement of network mask: **00000000 00000000 00000000 00011111**
- Last address: **10100111 11000111 10101010 01011111**