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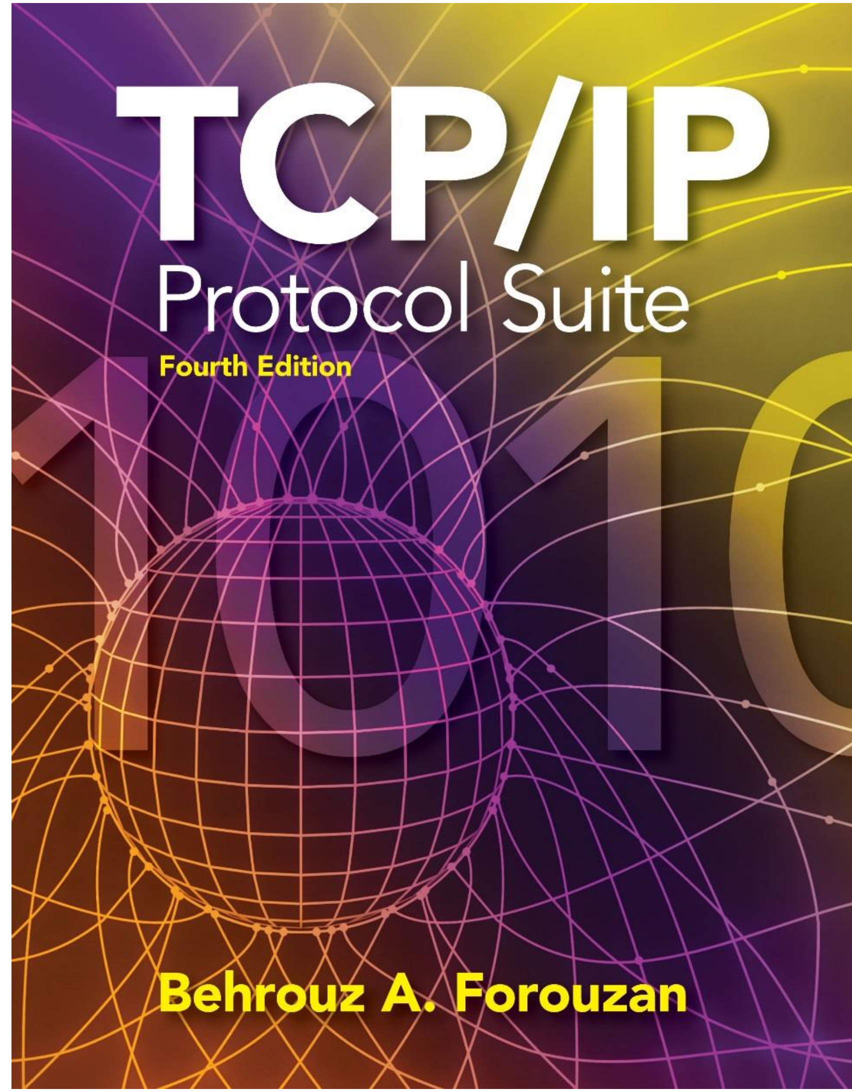
Chapter 5

IPv4 Addresses



5-1 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 IPv4 address is a 32-bit address that uniquely and universally defines the connection of a host or a router to the Internet; an IP address is the address of the interface.

Note

An IPv4 address is 32 bits long.

Note

The IPv4 addresses are unique and universal.

Example 5.3

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

Solution

a. There should be no leading zeroes (045).

b. We may not have more than 4 bytes in an IPv4 address.

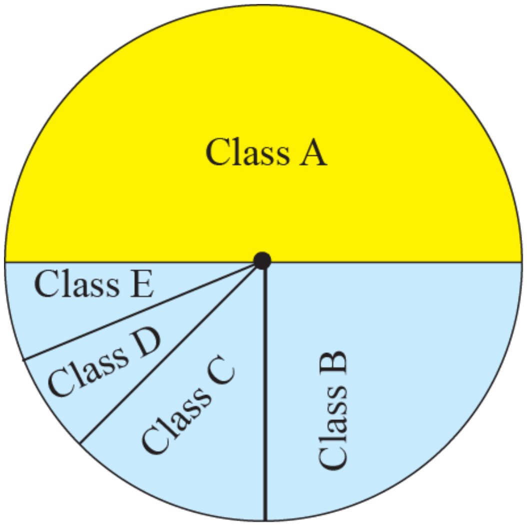
c. Each byte should be less than or equal to 255.

d. A mixture of binary notation and dotted-decimal notation.

5-2 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 that supersedes the original architecture. In this section, we introduce classful addressing because it paves the way for understanding classless addressing and justifies the rationale for moving to the new architecture. Classless addressing is discussed in the next section.

Figure 5.5 *Occupation of address space*



Class A: 2^{31} = 2,147,483,648 addresses, 50%

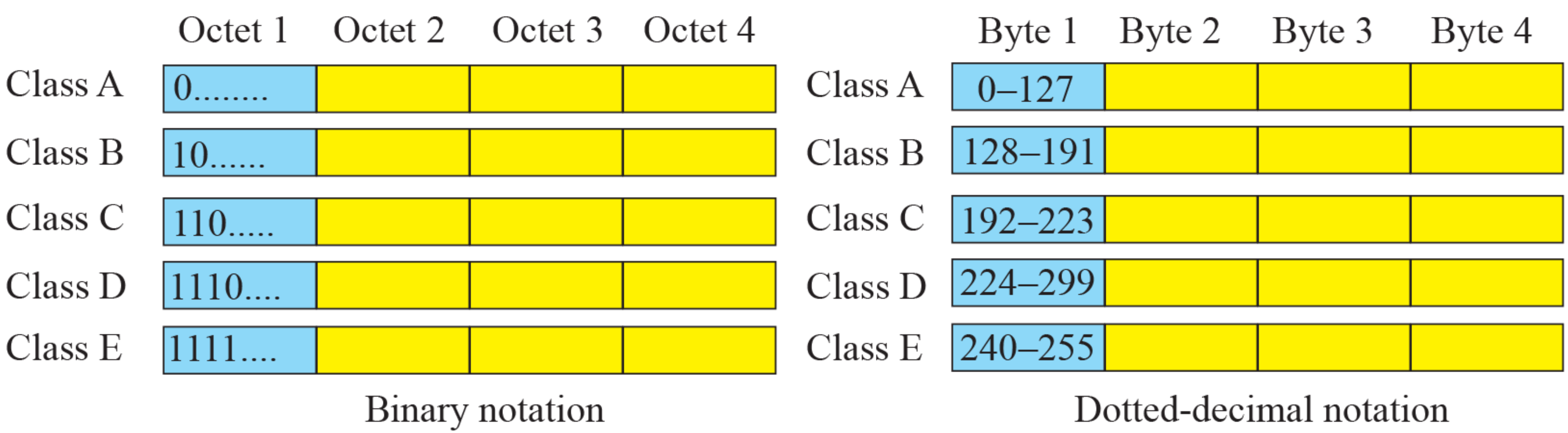
Class B: 2^{30} = 1,073,741,824 addresses, 25%

Class C: 2^{29} = 536,870,912 addresses, 12.5%

Class D: 2^{28} = 268,435,456 addresses, 6.25%

Class E: 2^{28} = 268,435,456 addresses, 6.25%

Figure 5.6 *Finding the class of address*



Example 5.11

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

Solution

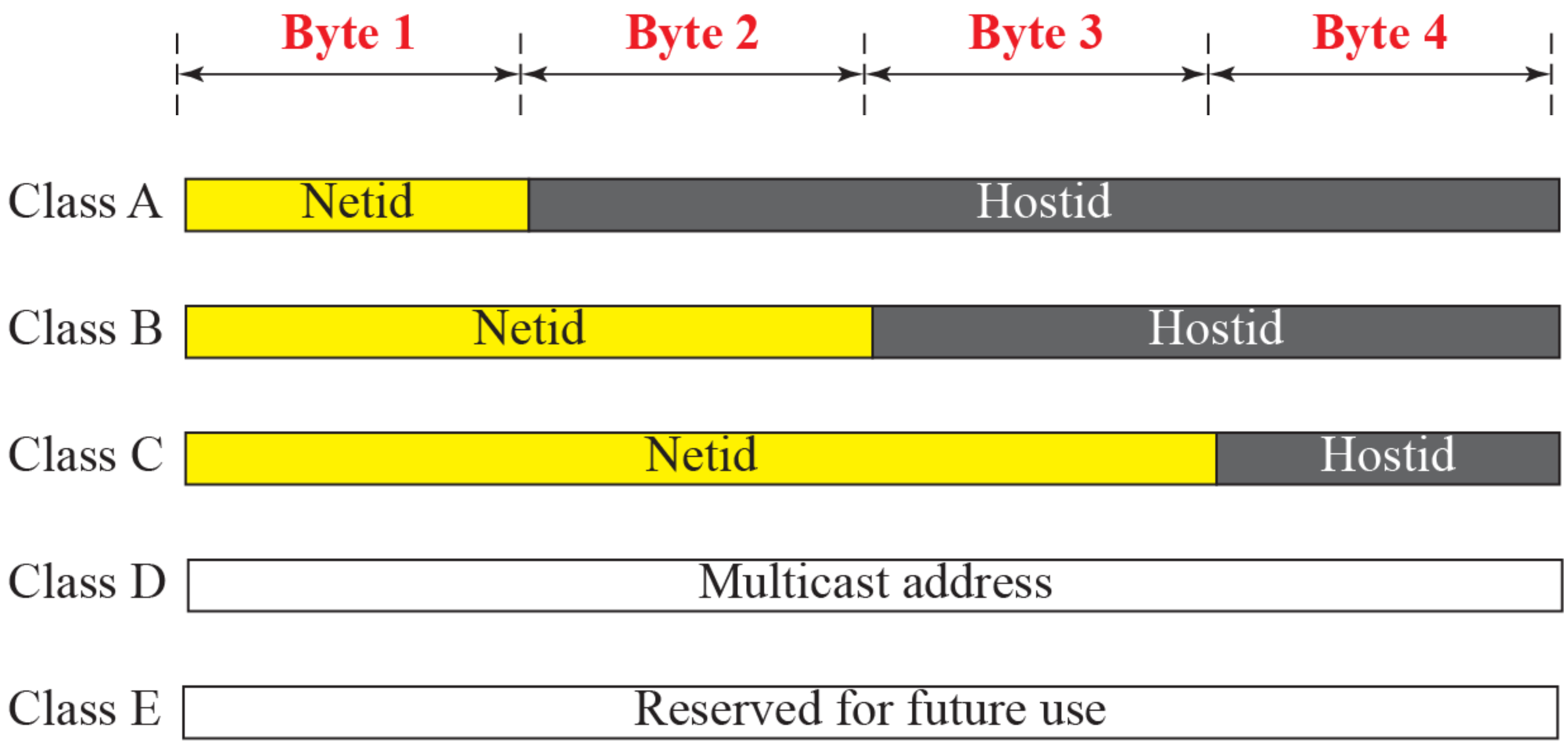
a. The first byte is 227 (between 224 and 239); the class is D.

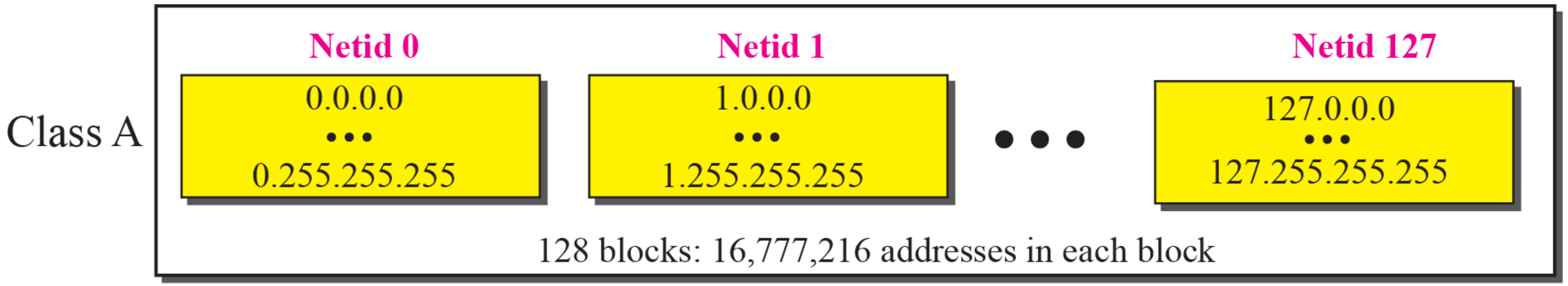
b. The first byte is 193 (between 192 and 223); the class is C.

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.

Figure 5.8 *Netid and hostid*

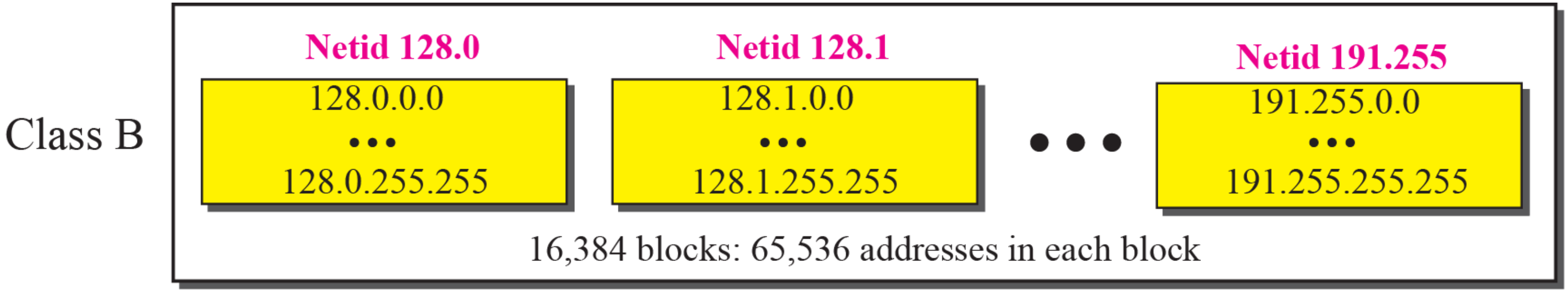



Class A
Netid 0
0.0.0.0
0.255.255.255
Netid 1
1.0.0.0
1.255.255.255
Netid 127
127.0.0.0
127.255.255.255
128 blocks: 16,777,216 addresses in each block

Note

Millions of class A addresses are wasted.

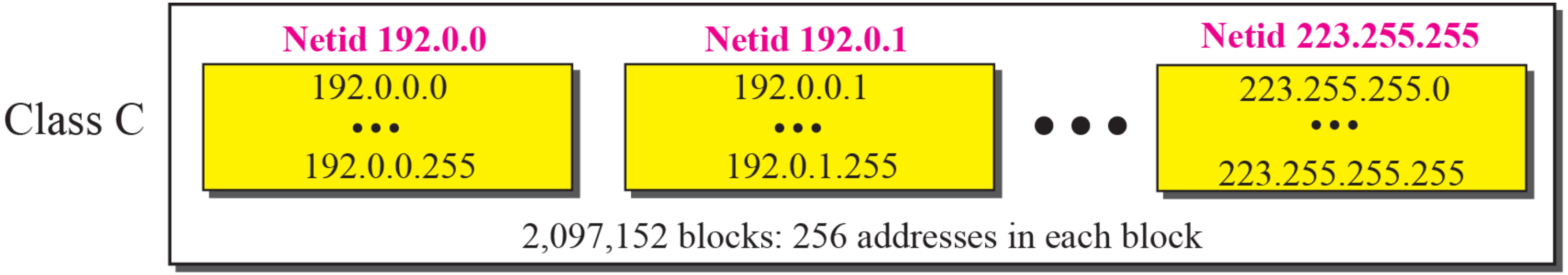
Figure 5.10 *Blocks in Class B*



Note

Many class B addresses are wasted.

Figure 5.11 *Blocks in Class C*



Note

Not so many organizations are so small to have a class C block.

Note

Class D addresses are made of one block, used for multicasting.

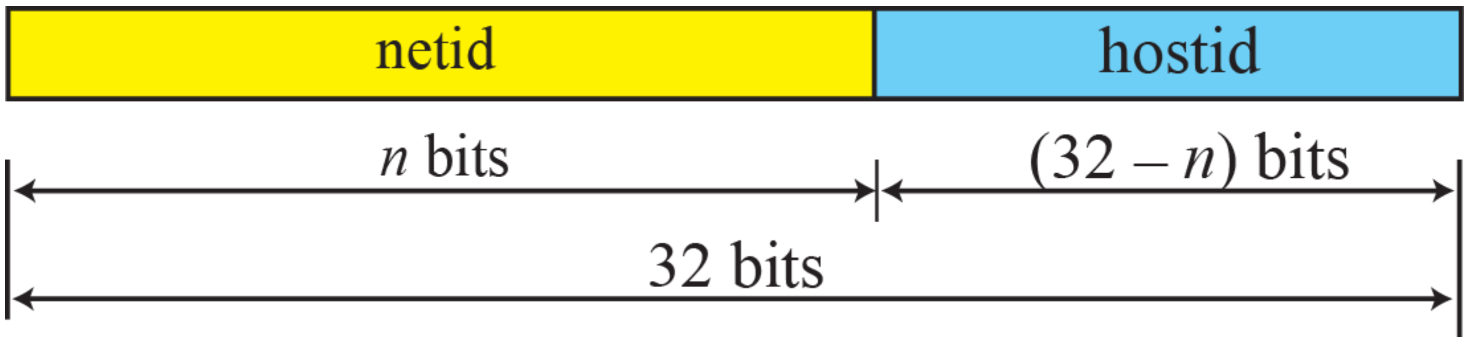
Note

The only block of class E addresses was reserved for future purposes.

Note

The range of addresses allocated to an organization in classful addressing was a block of addresses in Class A, B, or C.

Figure 5.14 *Two-level addressing in classful addressing*



Class A: $n = 8$

Class B: $n = 16$

Class C: $n = 24$

Example 5.13

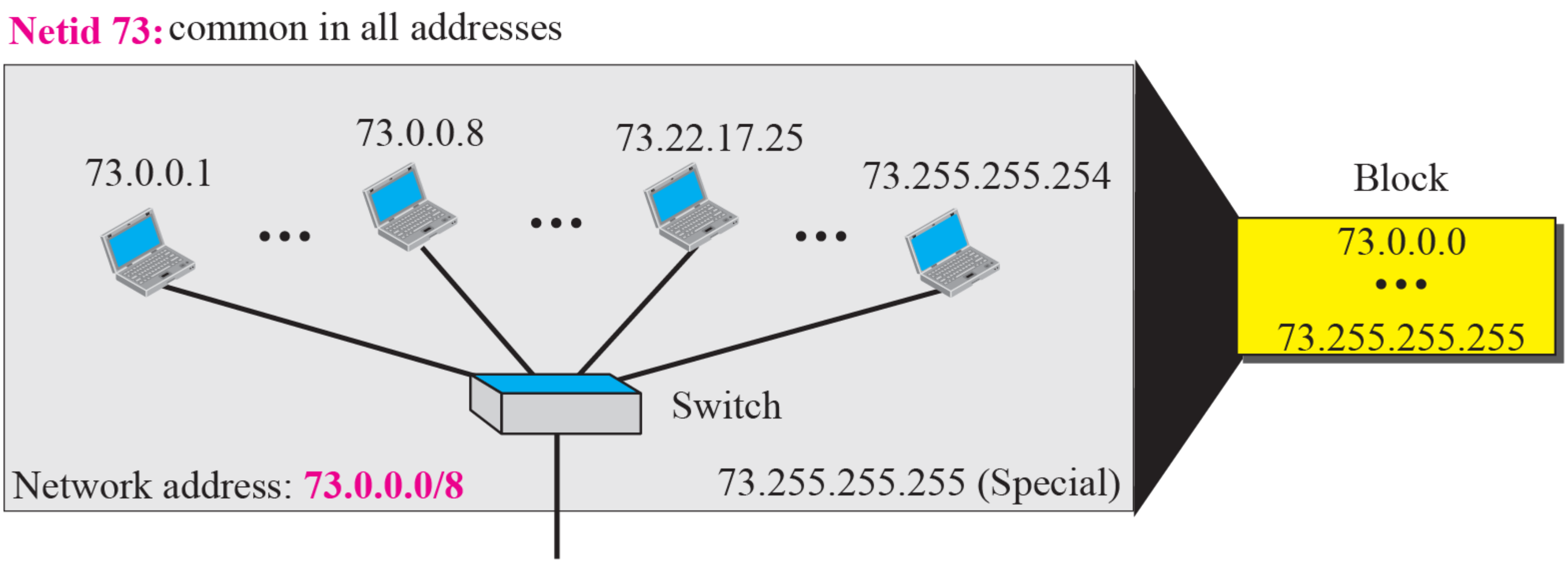
An address in a block is given as 73.22.17.25. Find the number of addresses in the block, the first address, and the last address.

Solution

Figure 5.16 shows a possible configuration of the network that uses this block.

1. The number of addresses in this block is $N = 2^{32-n} = 16,777,216$.
2. To find the first address, we keep the leftmost 8 bits and set the rightmost 24 bits all to 0s. The first address is 73.0.0.0/8, in which 8 is the value of *n*.
3. To find the last address, we keep the leftmost 8 bits and set the rightmost 24 bits all to 1s. The last address is 73.255.255.255.

Figure 5.16 *Solution to Example 5.13*



Example 5.14

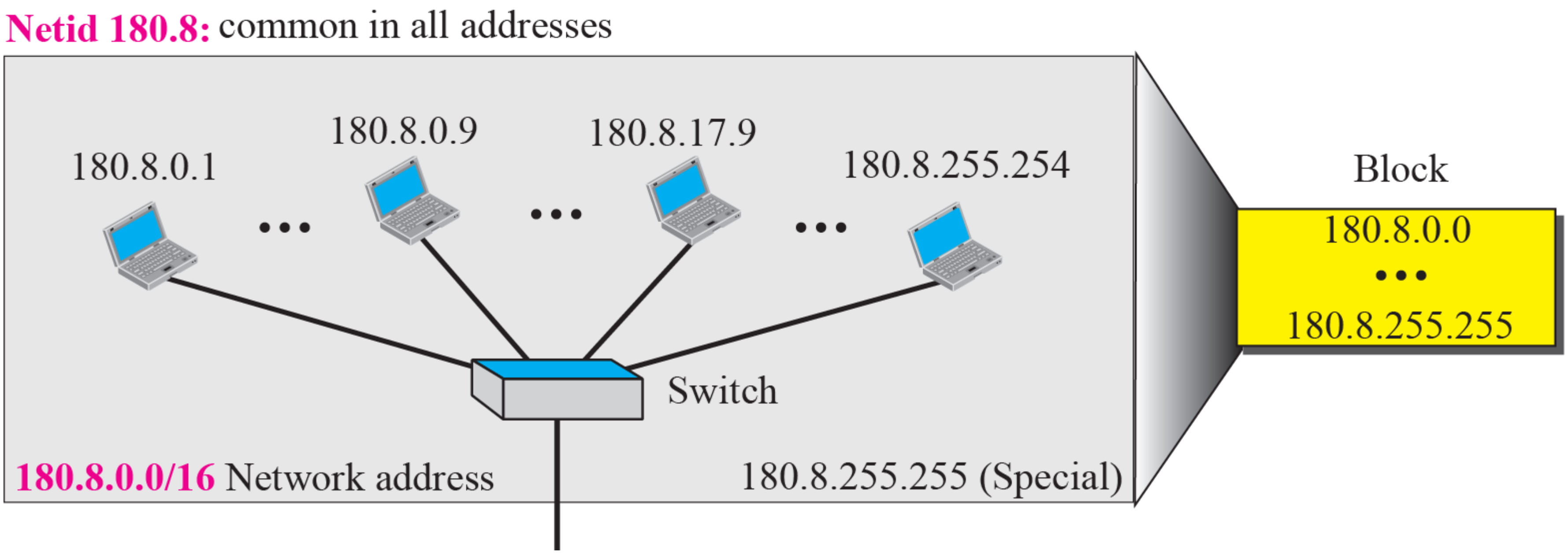
An address in a block is given as 180.8.17.9. Find the number of addresses in the block, the first address, and the last address.

Solution

Figure 5.17 shows a possible configuration of the network that uses this block.

1. The number of addresses in this block is $N = 2^{32-n} = 65{,}536$.
2. To find the first address, we keep the leftmost 16 bits and set the rightmost 16 bits all to 0s. The first address is 18.8.0.0/16, in which 16 is the value of *n*.
3. To find the last address, we keep the leftmost 16 bits and set the rightmost 16 bits all to 1s. The last address is 18.8.255.255.

Figure 5.17 *Solution to Example 5.14*



Example 5.15

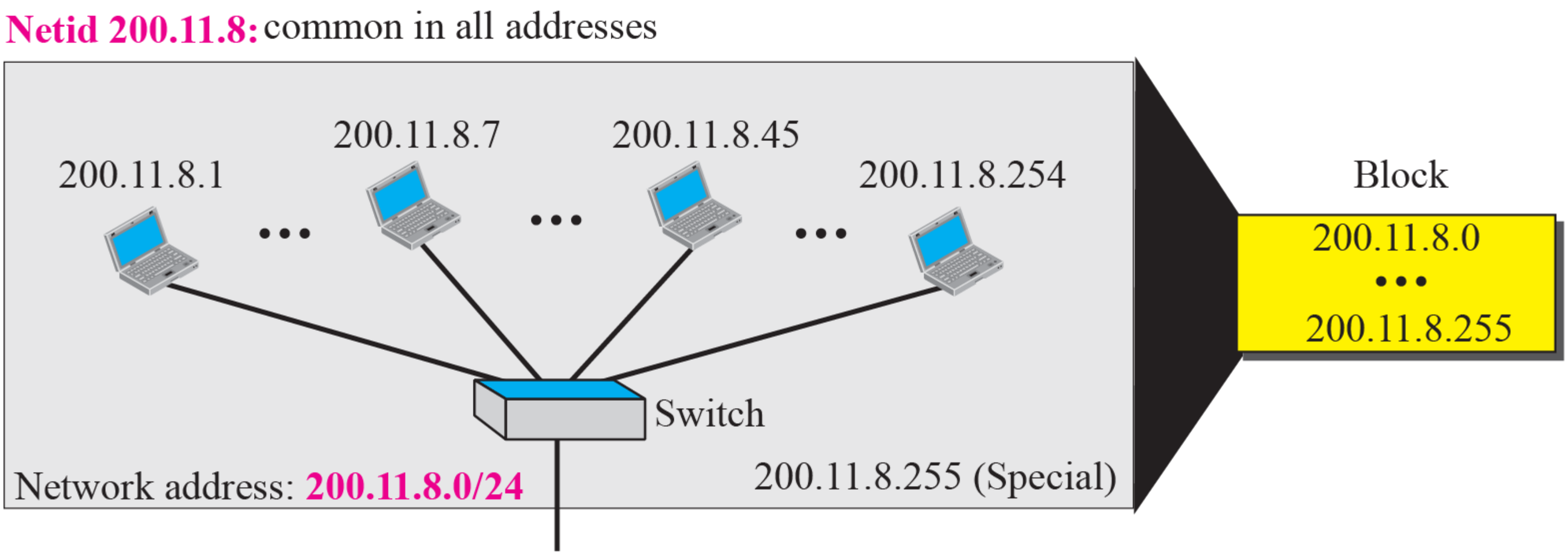
An address in a block is given as 200.11.8.45. Find the number of addresses in the block, the first address, and the last address.

Solution

Figure 5.17 shows a possible configuration of the network that uses this block.

1. The number of addresses in this block is $N = 2^{32-n} = 256$.
2. To find the first address, we keep the leftmost 24 bits and set the rightmost 8 bits all to 0s. The first address is 200.11.8.0/16, in which 24 is the value of *n*.
3. To find the last address, we keep the leftmost 24 bits and set the rightmost 8 bits all to 1s. The last address is 200.11.8.255/16.

Figure 5.18 *Solution to Example 5.15*



Note

The network address is the identifier of a network.

Figure 5.20 *Network addresses*

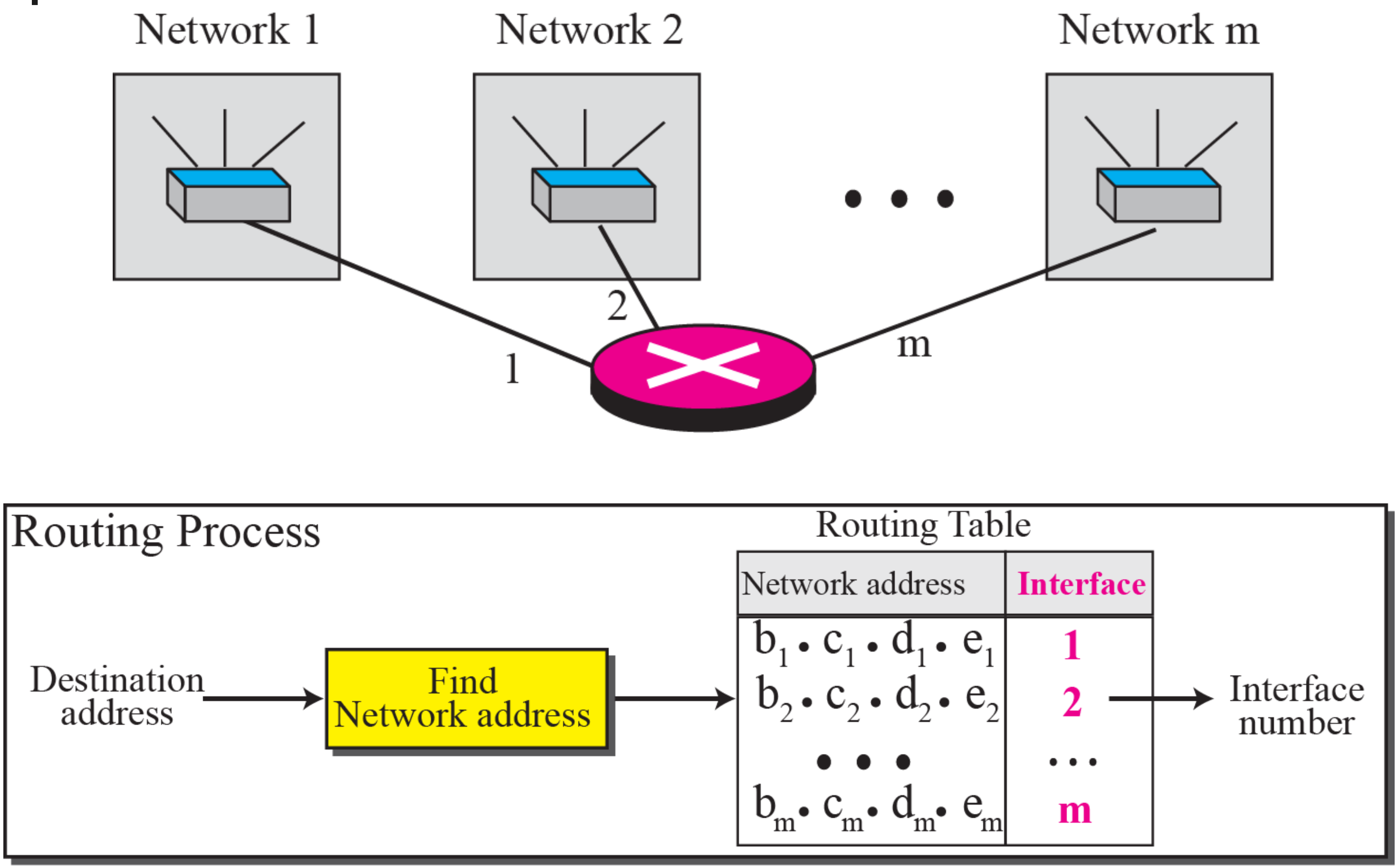


Figure 5.21 *Network mask*

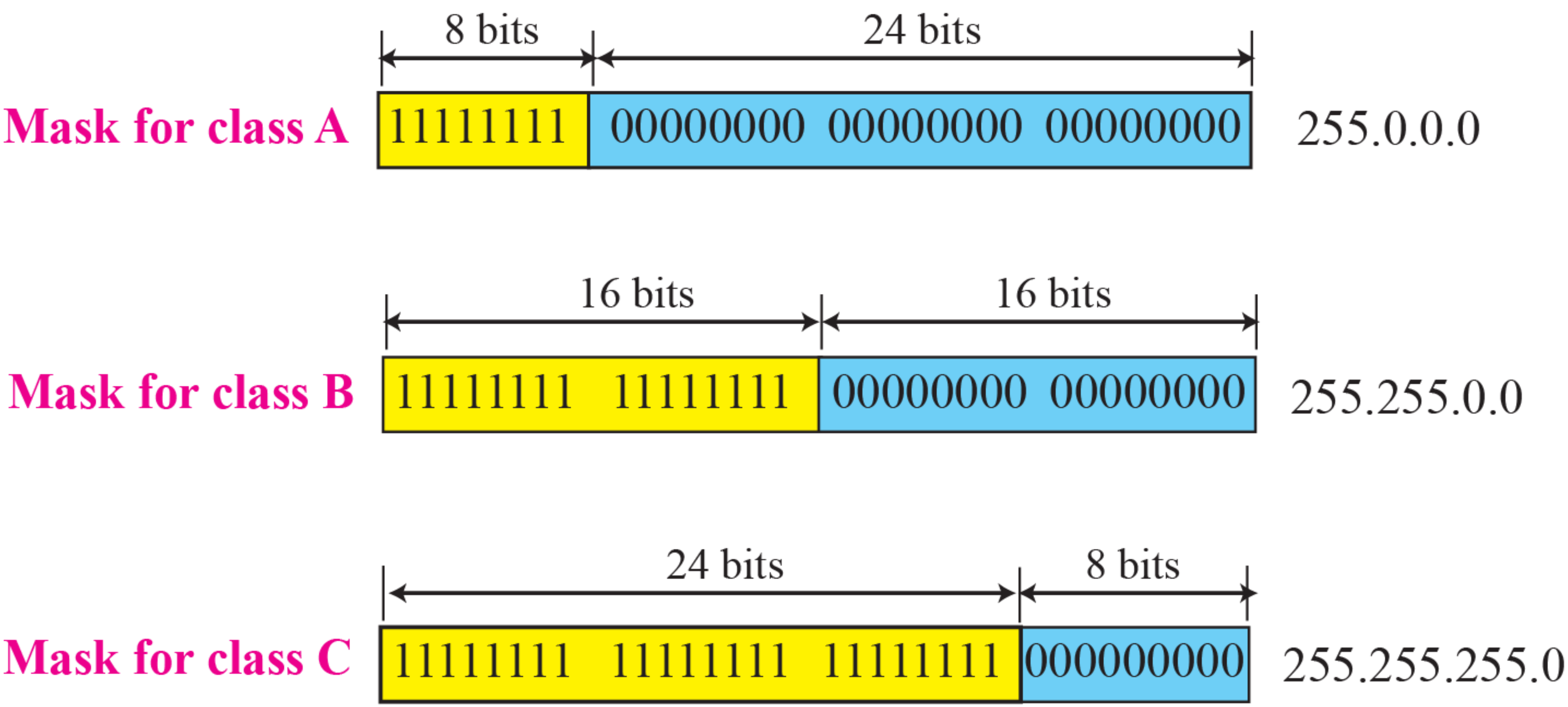
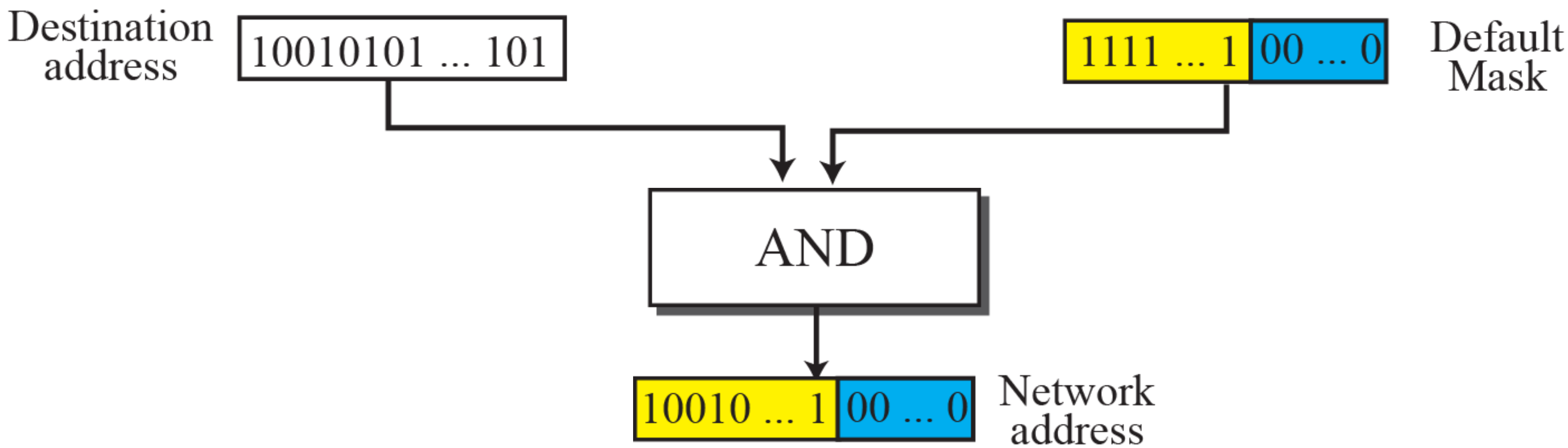


Figure 5.22 *Finding a network address using the default mask*



Example 5.16

A router receives a packet with the destination address 201.24.67.32. Show how the router finds the network address of the packet.

Solution

Since the class of the address is B, we assume that the router applies the default mask for class B, 255.255.0.0 to find the network address.

Destination address	→	201	.	24	.	67	.	32
Default mask	→	255	.	255	.	0	.	0
Network address	→	201	.	24	.	0	.	0

Example 5.19

Figure 5.24 shows the same network in Figure 5.23 after subnetting. The whole network is still connected to the Internet through the same router. However, the network has used a private router to divide the network into four subnetworks. The rest of the Internet still sees only one network; internally the network is made of four subnetworks. Each subnetwork can now have almost 2^{14} hosts. The network can belong to a university campus with four different schools (buildings). After subnetting, each school has its own subnetworks, but still the whole campus is one network for the rest of the Internet. Note that /16 and /18 show the length of the netid and subnetids.

Figure 5.24 *Example 5.19*

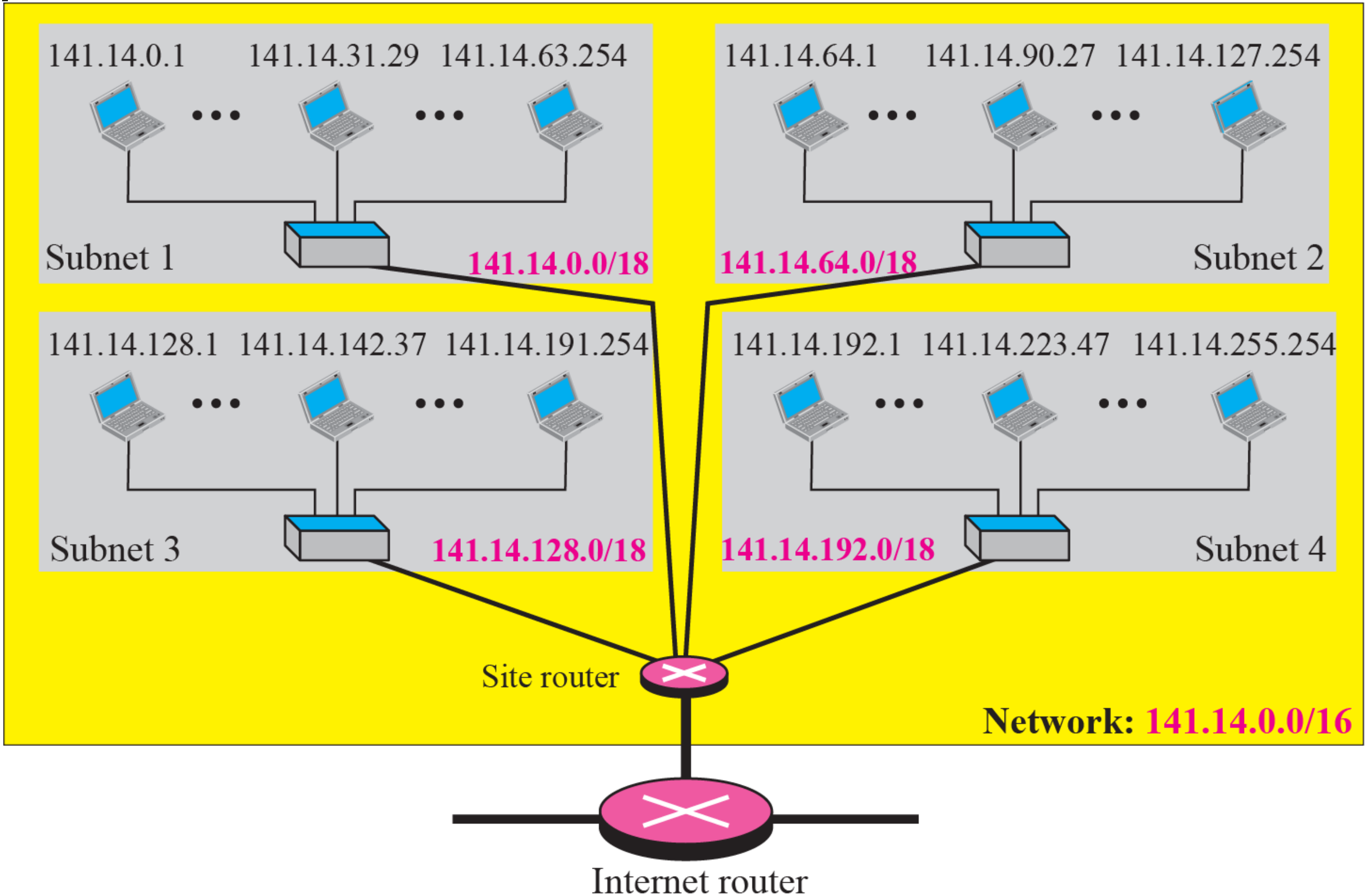
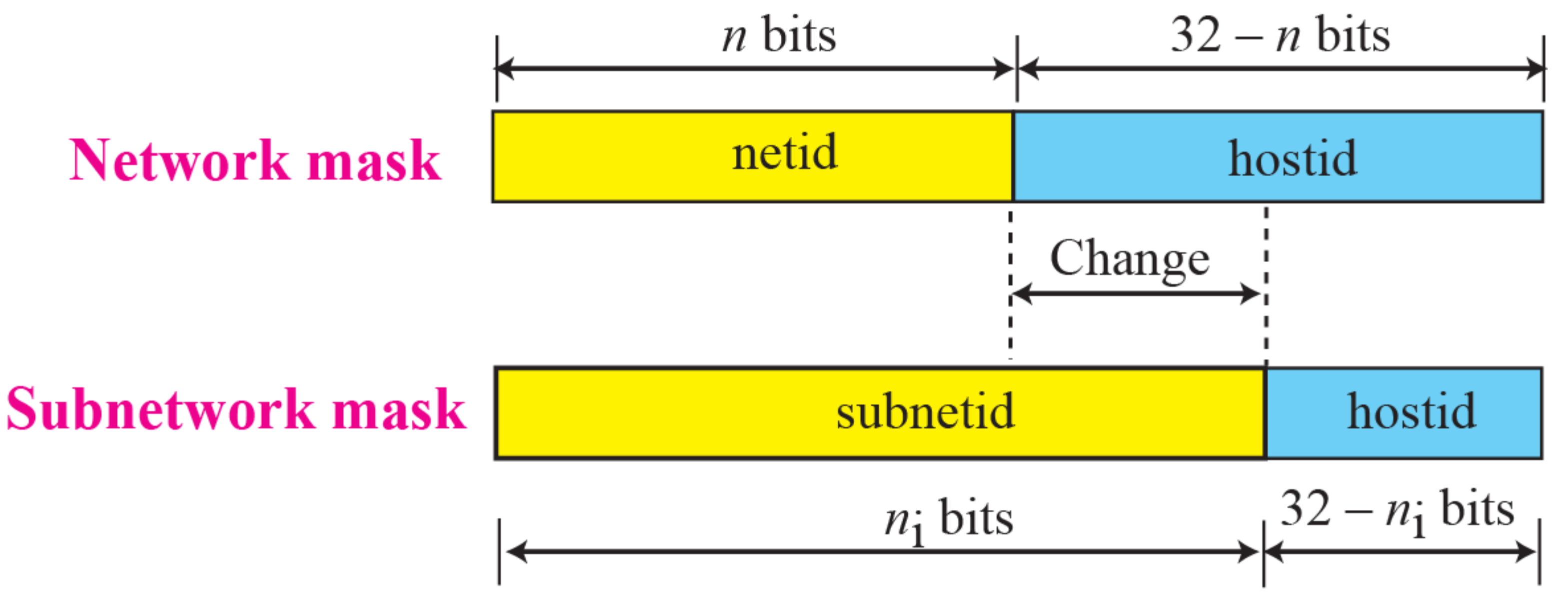


Figure 5.25 *Network mask and subnetwork mask*



Example 5.20

In Example 5.19, we divided a class B network into four subnetworks. The value of n = 16 and the value of

$$n_1 = n_2 = n_3 = n_4 = 16 + \log_2 4 = 18.$$

This means that the subnet mask has eighteen 1s and fourteen 0s. In other words, the subnet mask is 255.255.192.0 which is different from the network mask for class B (255.255.0.0).

Example 5.21

In Example 5.19, we show that a network is divided into four subnets. Since one of the addresses in subnet 2 is 141.14.120.77, we can find the subnet address as:

Address	→	141	.	14	.	120	.	77
Mask	→	255	.	255	.	192	.	0
Subnet Address	→	141	.	14	.	64	.	0

The values of the first, second, and fourth bytes are calculated using the first short cut for AND operation. The value of the third byte is calculated using the second short cut for the AND operation.

Address (120)	0	+	64	+	32	+	16	+	8	+	0	+	0	+	0
Mask (192)	128	+	64	+	0	+	0	+	0	+	0	+	0	+	0
Result (64)	0	+	64	+	0	+	0	+	0	+	0	+	0	+	0

Figure 5.26 *Comparison of subnet, default, and supernet mask*