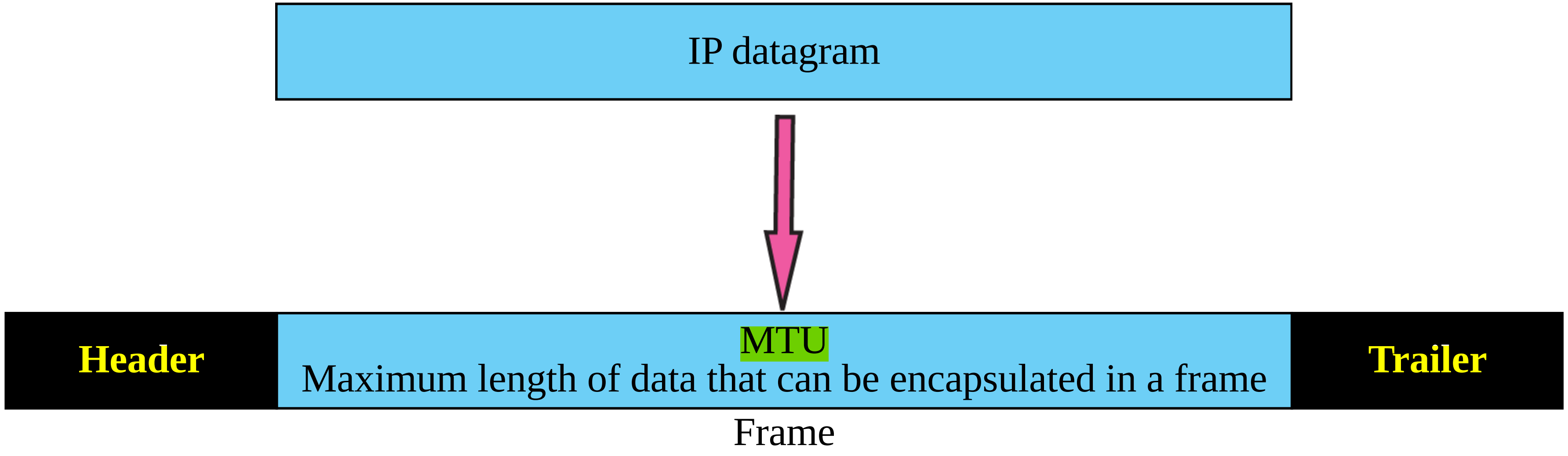
Fragmentation

- A datagram can travel through different networks. Each router decapsulates the IP datagram from the frame it receives, processes it, and then encapsulates it in another frame.
- The format and size of the received frame depend on the protocol used by the physical network through which the frame has just traveled.
- The format and size of the sent frame depend on the protocol used by the physical network through which the frame is going to travel.

✓ **Maximum Transfer Unit (MTU)**

✓ **Fields Related to Fragmentation**

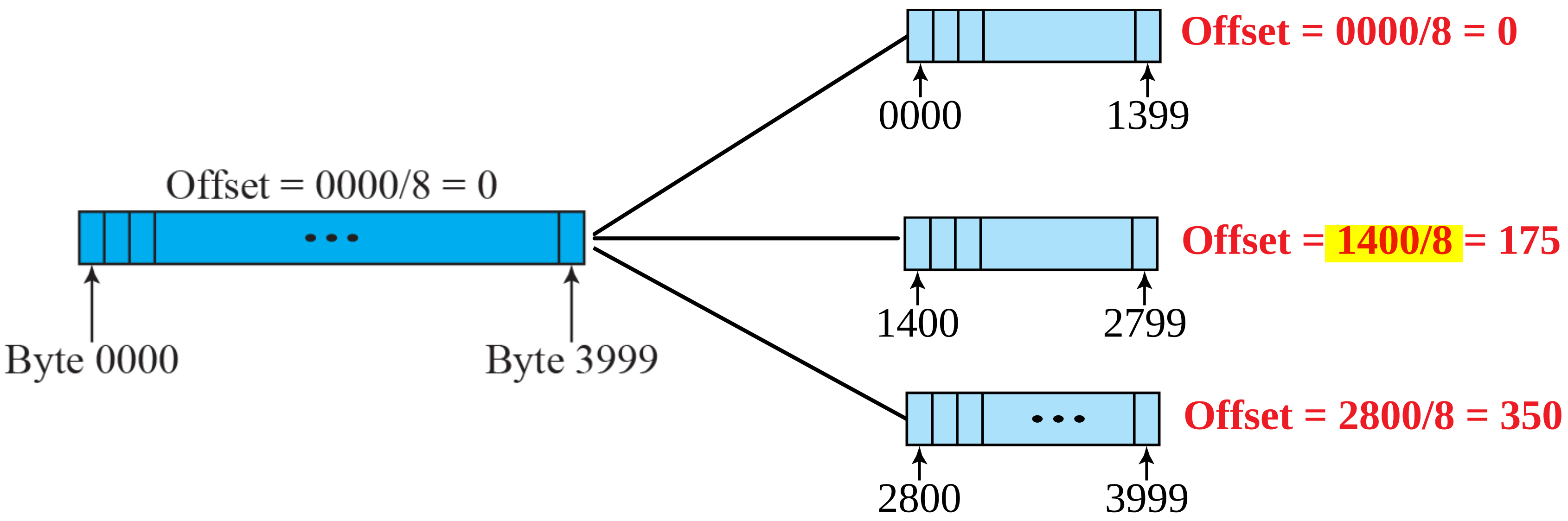
MTU


IP datagram
Header
MTU
Maximum length of data that can be encapsulated in a frame
Trailer
Frame

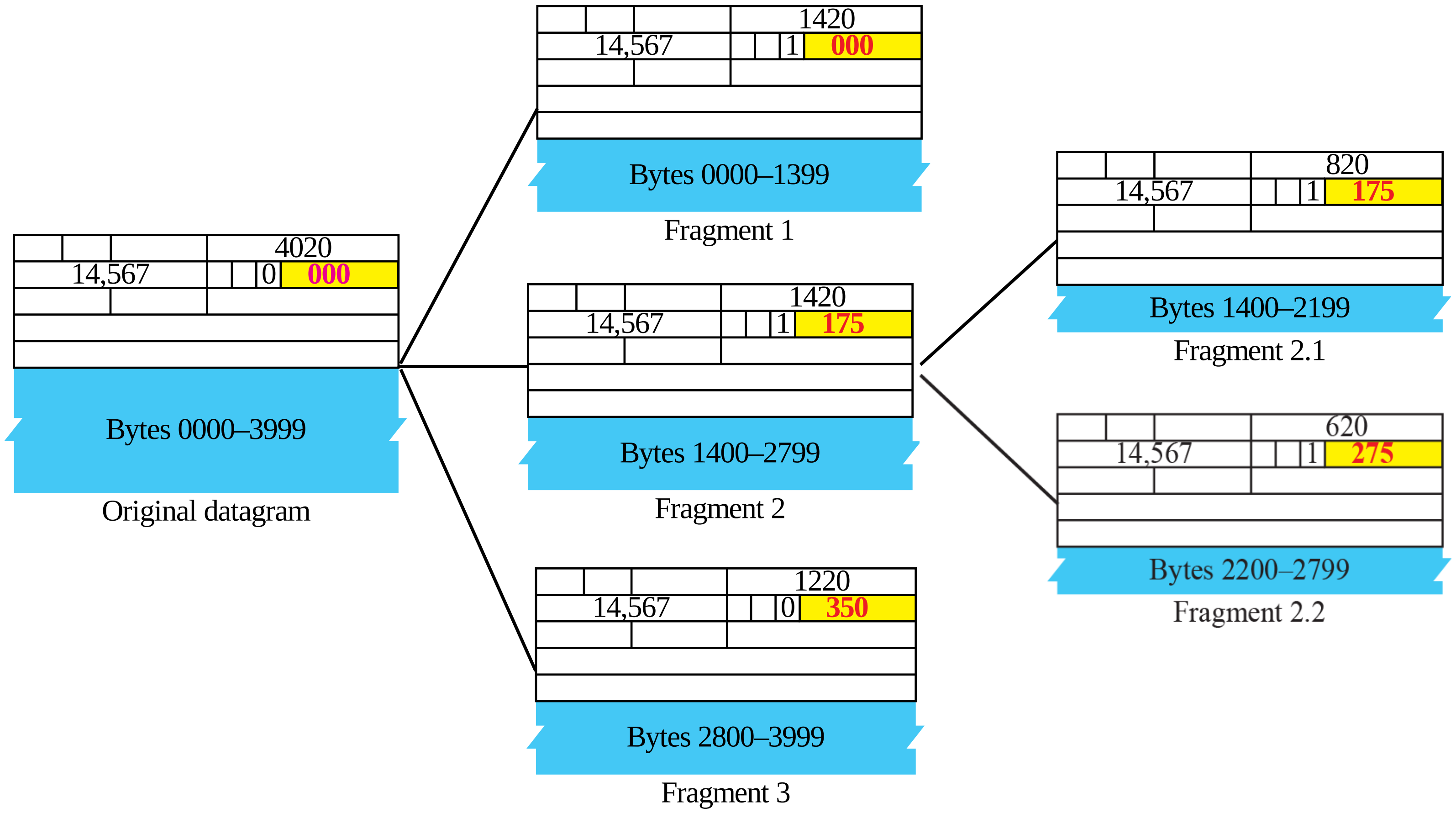
Flags field

D: Do not fragment
M: More fragments

Fragmentation example



Detailed fragmentation example



Example

A packet has arrived with an M bit value of 0. Is this the first fragment, the last fragment, or a middle fragment? Do we know if the packet was fragmented?

Solution

If the M bit is 0, it means that there are no more fragments; the fragment is the last one. However, we cannot say if the original packet was fragmented or not. A nonfragmented packet is considered the last fragment.

Example

A packet has arrived with an M bit value of 1. Is this the first fragment, the last fragment, or a middle fragment? Do we know if the packet was fragmented?

Solution

If the M bit is 1, it means that there is at least one more fragment. This fragment can be the first one or a middle one, but not the last one. We don't know if it is the first one or a middle one; we need more information (the value of the fragmentation offset). See also the next example.

Example

A packet has arrived with an M bit value of 1 and a fragmentation offset value of zero. Is this the first fragment, the last fragment, or a middle fragment?

Solution

Because the M bit is 1, it is either the first fragment or a middle one. Because the offset value is 0, it is the first fragment.

Example

A packet has arrived in which the offset value is 100. What is the number of the first byte? Do we know the number of the last byte?

Solution

To find the number of the first byte, we multiply the offset value by 8. This means that the first byte number is 800. We cannot determine the number of the last byte unless we know the length of the data.

Example

A packet has arrived in which the offset value is 100, the value of HLEN is 5 and the value of the total length field is 100. What is the number of the first byte and the last byte?

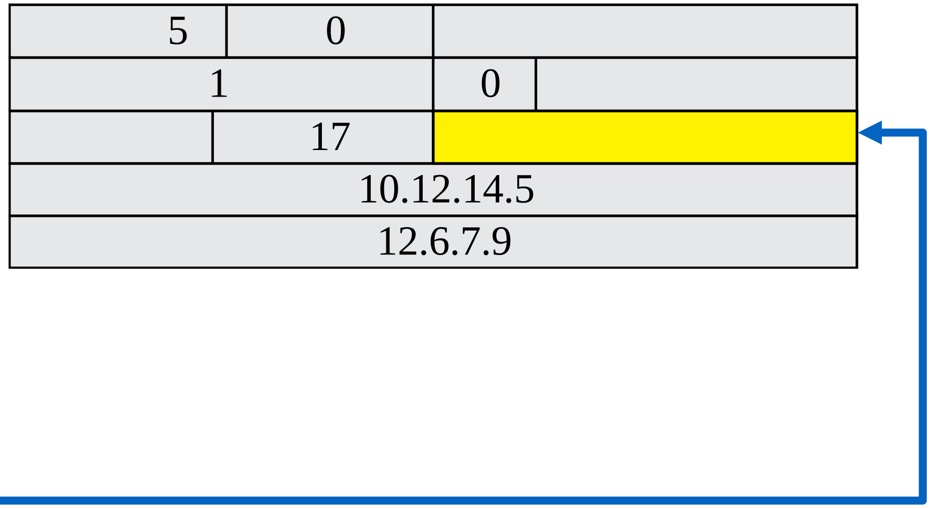
Solution

The first byte number is 100 $\times$ 8 = 800. The total length is 100 bytes and the header length is 20 bytes (5 $\times$ 4), which means that there are 80 bytes in this datagram. If the first byte number is 800, the last byte number must be 879.

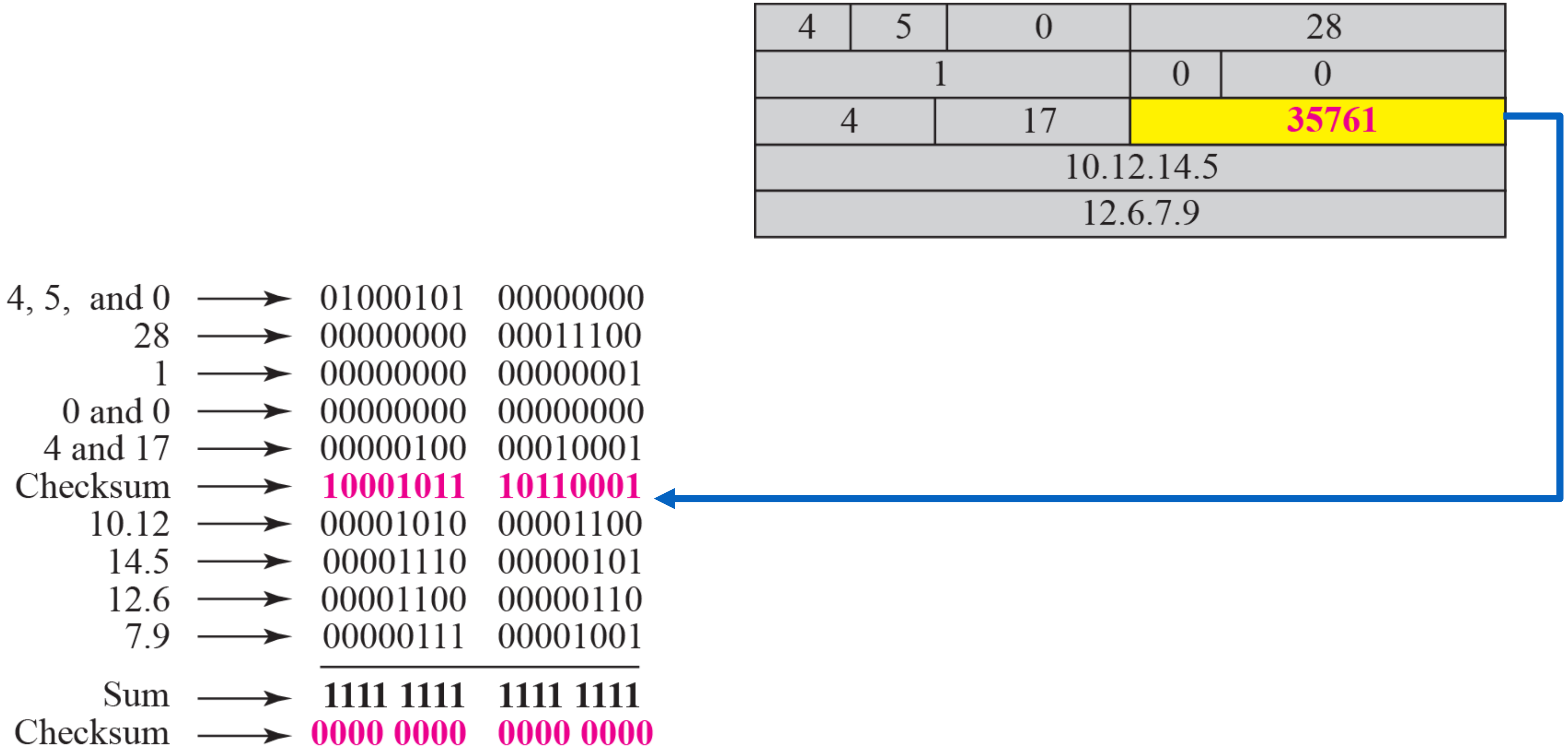
Checksum

- Sender Side: The header is divided into 16-bit sections. All the sections are added and the sum is complemented. The result is inserted in the checksum field.

4, 5, and 0	→	01000101	00000000
28	→	00000000	00011100
1	→	00000000	00000001
0 and 0	→	00000000	00000000
4 and 17	→	00000100	00010001
0	→	00000000	00000000
10.12	→	00001010	00001100
14.5	→	00001110	00000101
12.6	→	00001100	00000110
7.9	→	00000111	00001001
Sum	→	**01110100**	**01001110**
Checksum	→	**10001011**	**10110001**



- Receiver Side: Figure shows the checking of checksum calculation at the receiver site (or intermediate router) assuming that no errors occurred in the header. The header is divided into 16-bit sections. All the sections are added and the sum is complemented. Since the result is 16 0s, the packet is accepted.

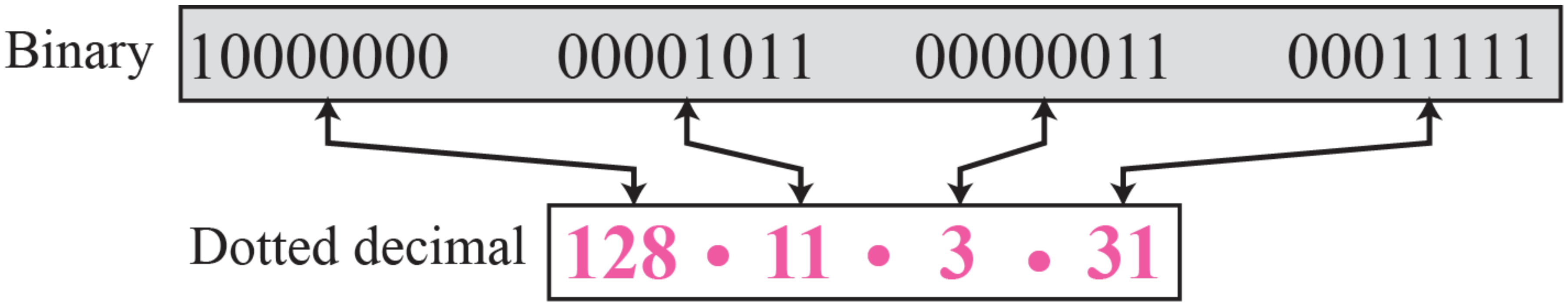


IPv4 Addresses

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

Dotted-decimal notation

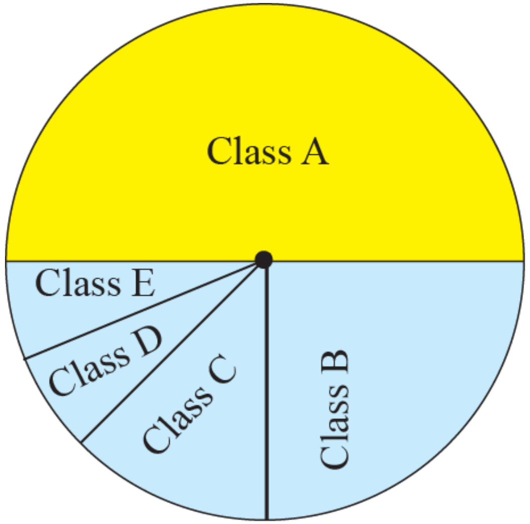


binary notation to dotted-decimal notation.

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.

Address space



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

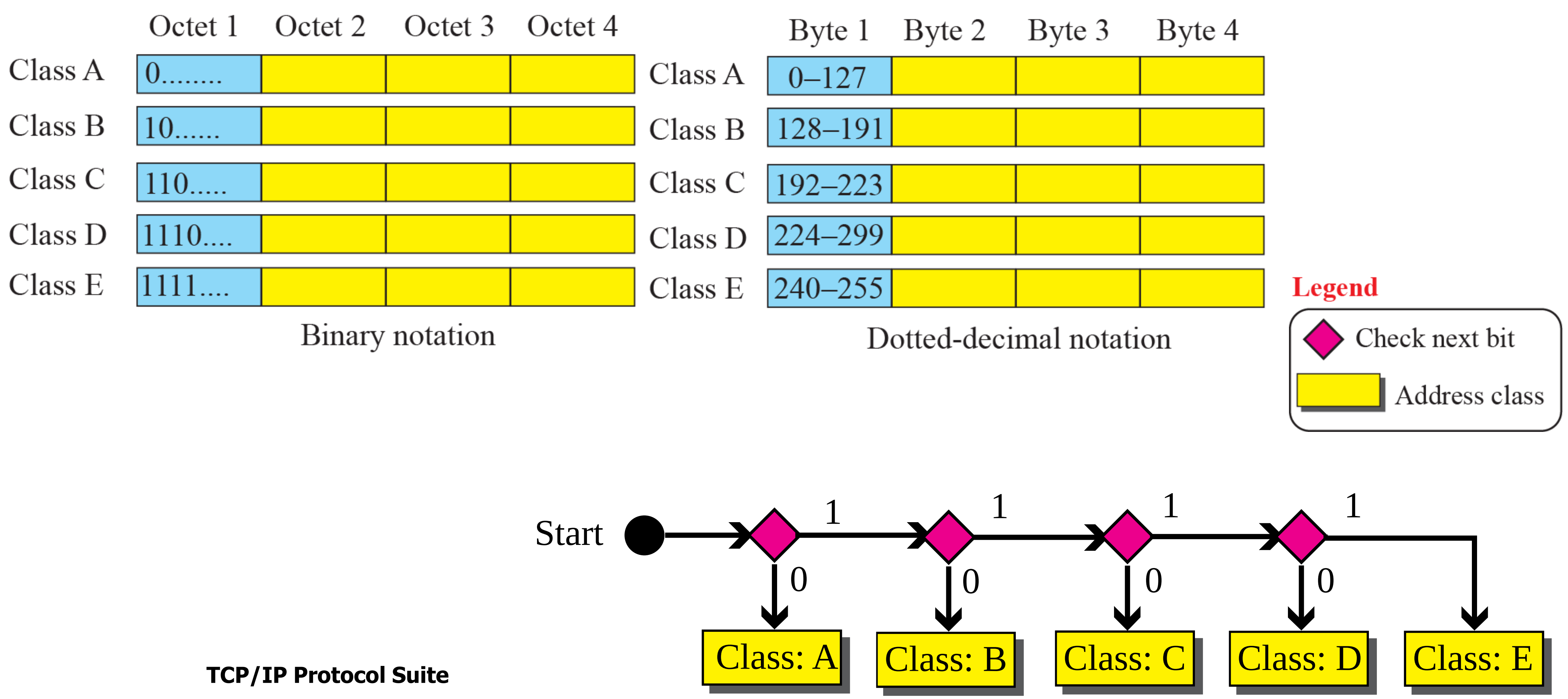
Class B: 2^{30} = 1,073,741,824 addresses, 25%

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%

Finding the class of address



Example

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

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 1; the second bit is 0. This is a class B address.

d. The first 4 bits are 1s. This is a class E address.

Example

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

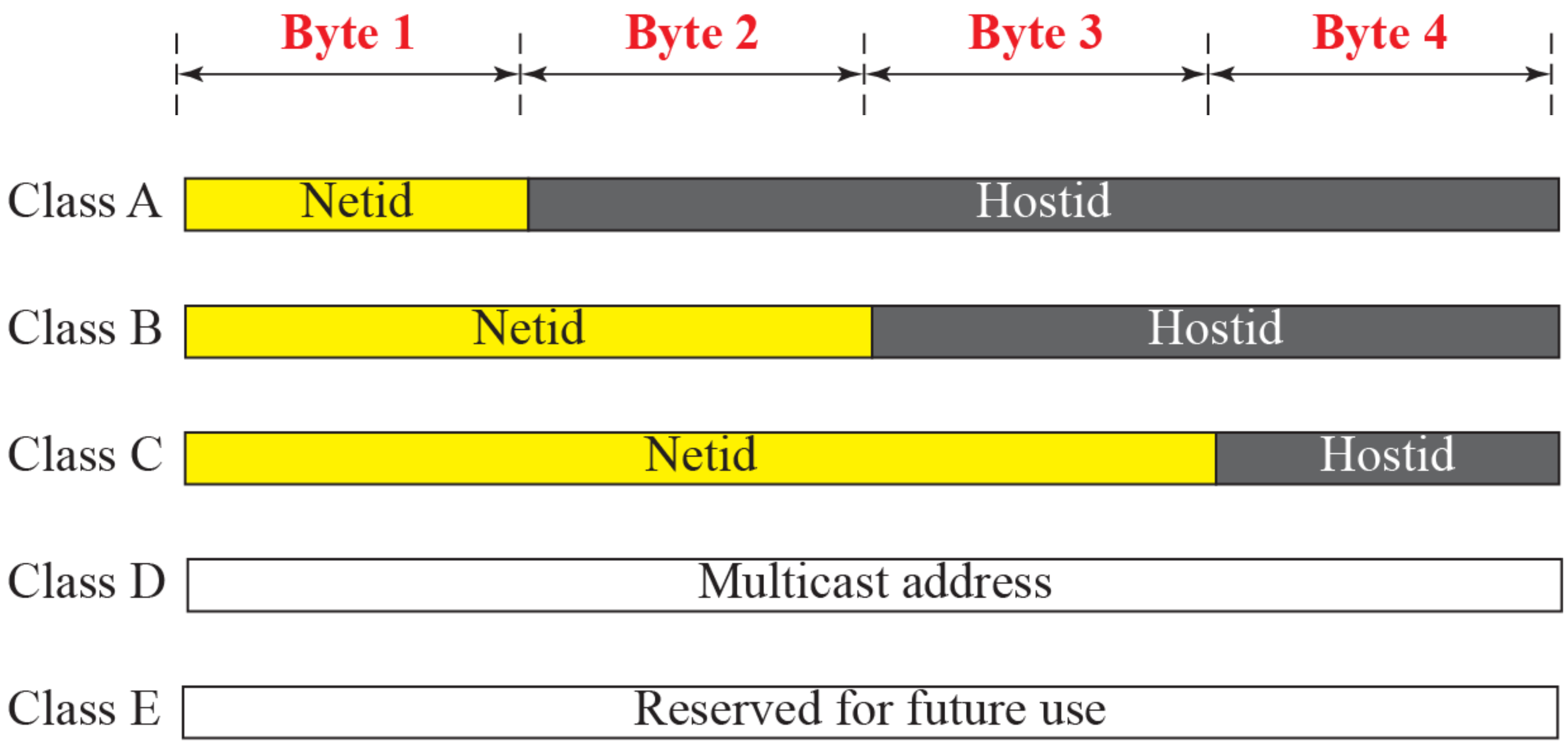
a. The first byte is 227 (between 224 and 239); the class is D.

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

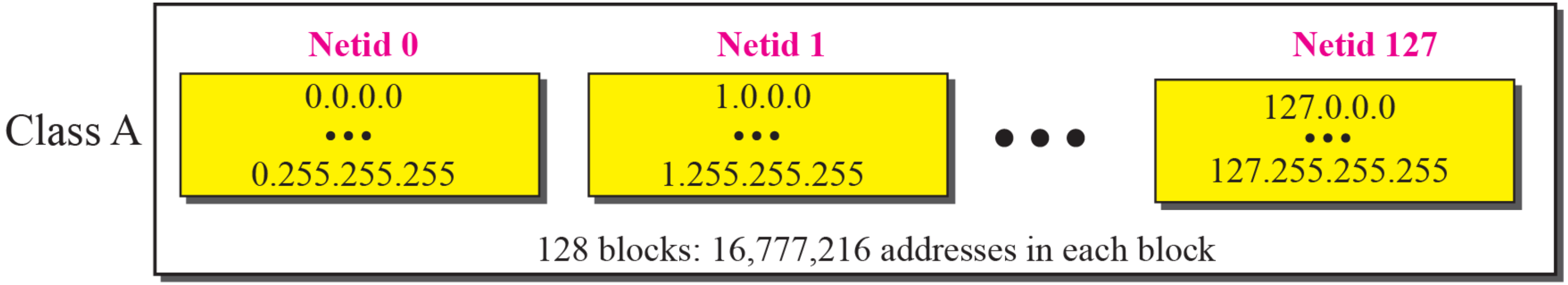
c. The first byte is 14 (between 0 and 127); the class is A.

d. The first byte is 252 (between 240 and 255); the class is E.

Netid and hostid

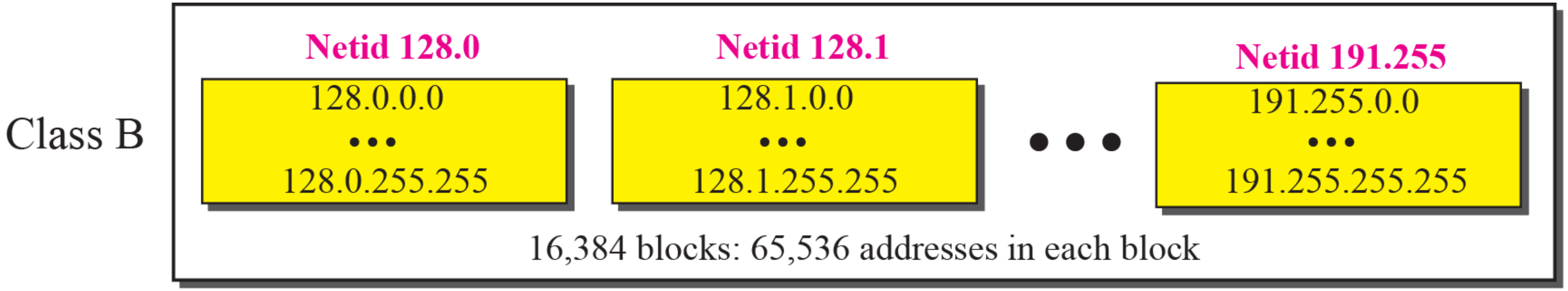


Blocks in Class A



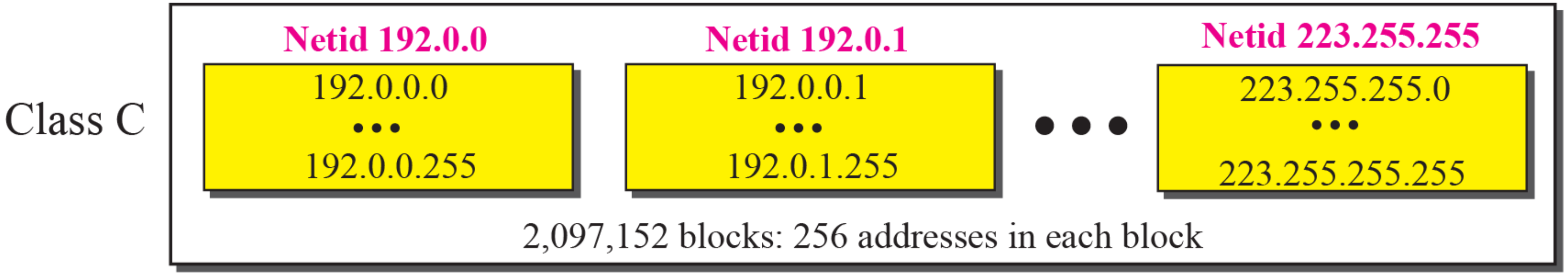
Millions of class A addresses are wasted.

Blocks in Class B



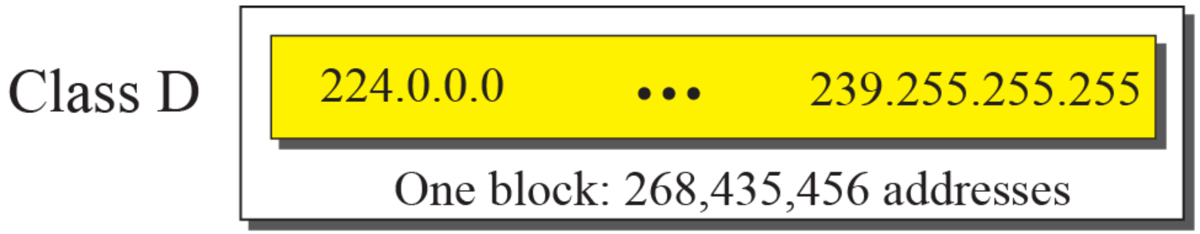
Many class B addresses are wasted.

Blocks in Class C



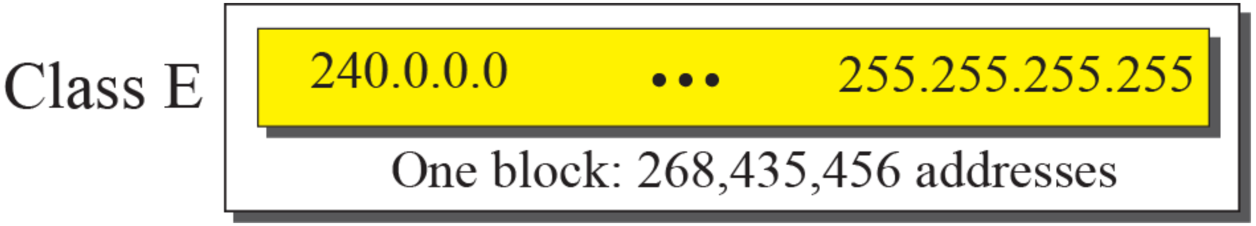
Not so many organizations are so small to have a class C block.

The single block in Class D



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

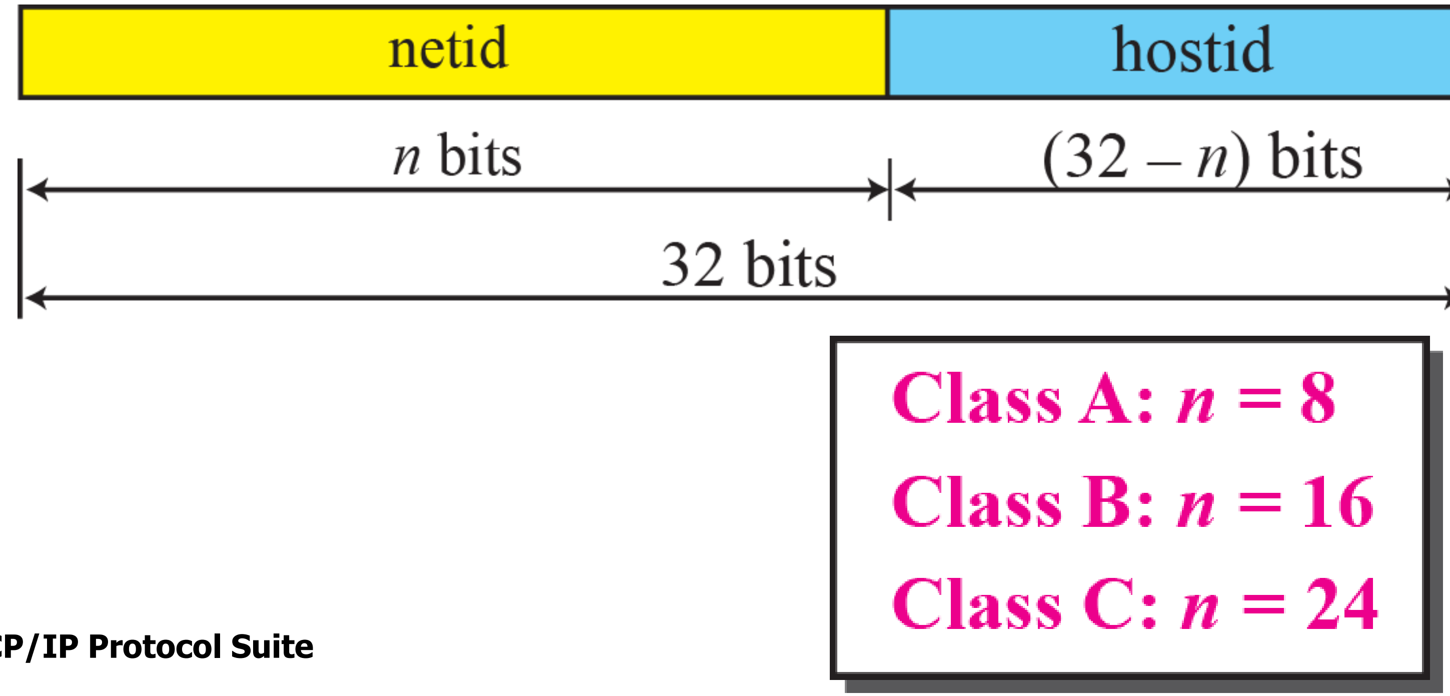
The single block in Class E



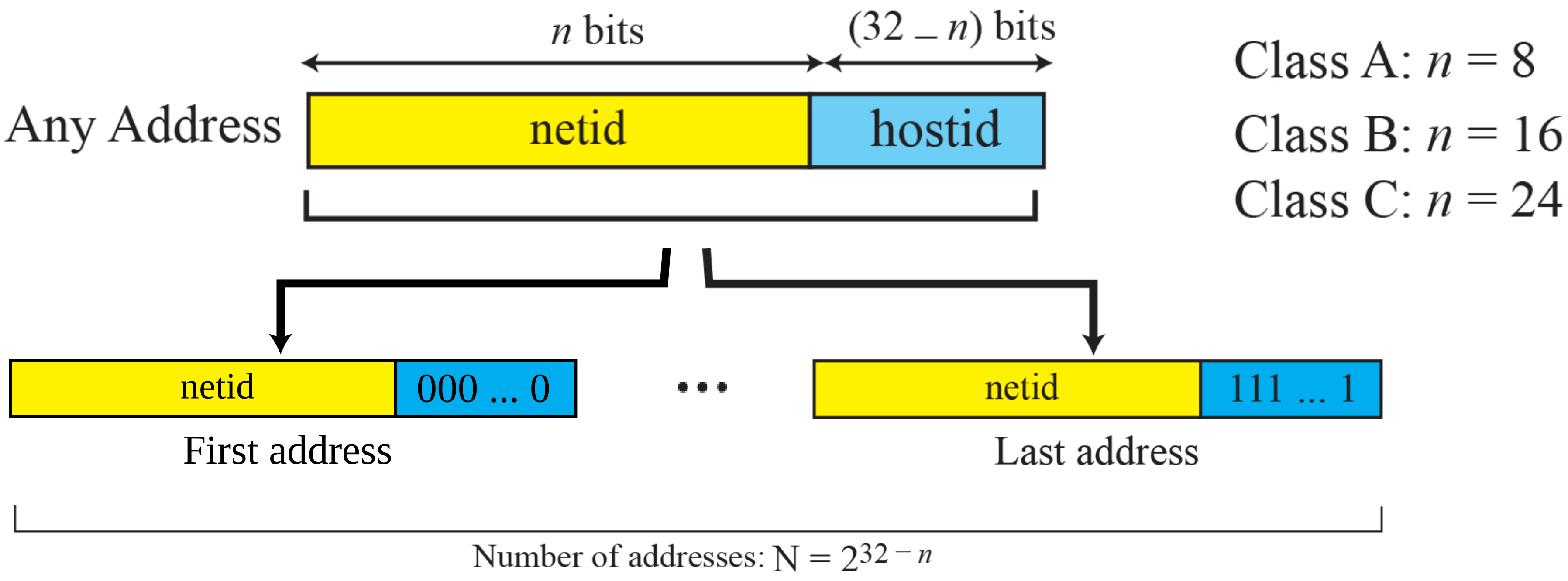
The only block of class E addresses was reserved for future purposes.

Point to Note

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



Information extraction in classful addressing



Example

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

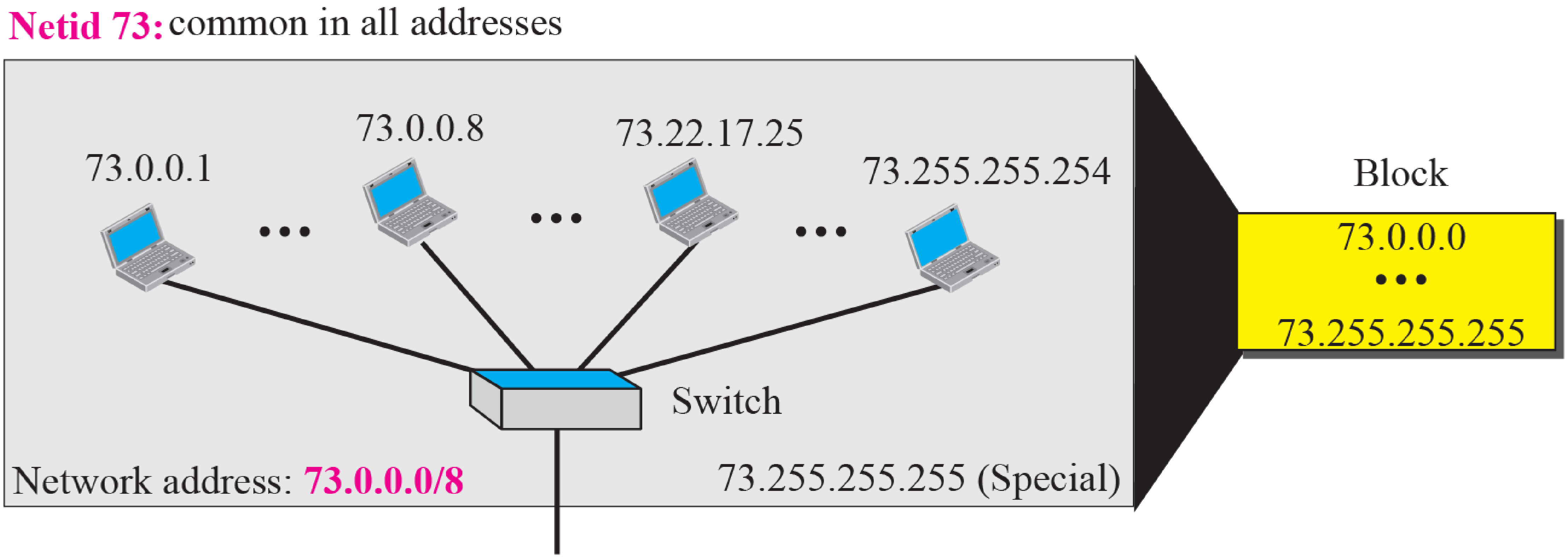
Figure shows a possible configuration of the network that uses this block.

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.

Solution


Netid 73: common in all addresses
73.0.0.1
73.0.0.8
73.22.17.25
73.255.255.254
Block
73.0.0.0
73.255.255.255
Switch
Network address: 73.0.0.0/8
73.255.255.255 (Special)

Example 2

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

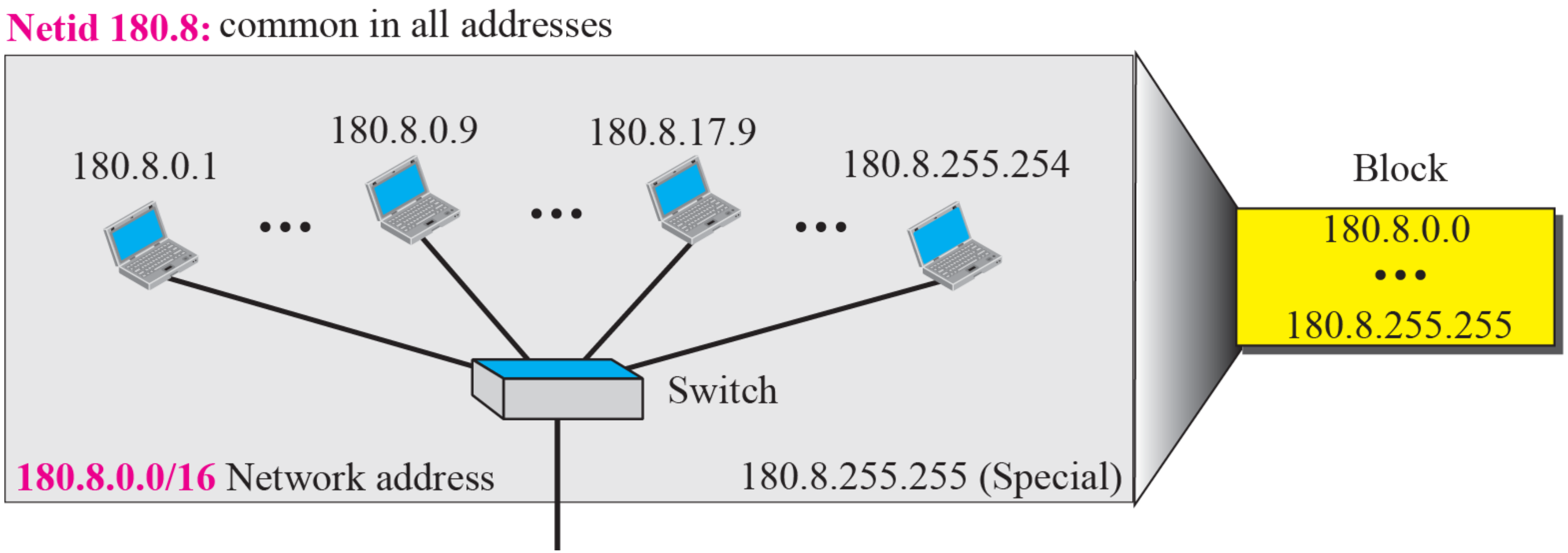
Figure shows a possible configuration of the network that uses this block.

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 180.8.0.0/16, 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 180.8.255.255.

Solution


Netid 180.8: common in all addresses
180.8.0.1
180.8.0.9
180.8.17.9
180.8.255.254
Switch
180.8.0.0/16 Network address
180.8.255.255 (Special)
Block
180.8.0.0
180.8.255.255

Example 3

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

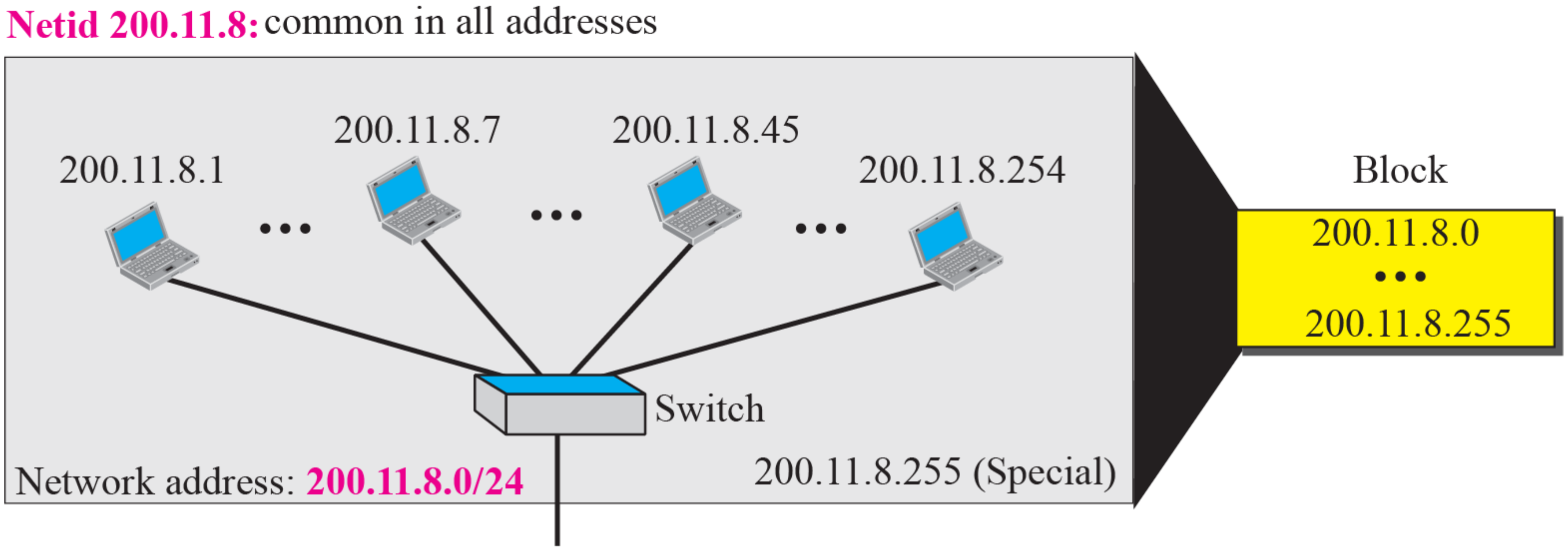
Figure shows a possible configuration of the network that uses this block.

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 200.11.8.0/24, in which 24 is the value of *n*.

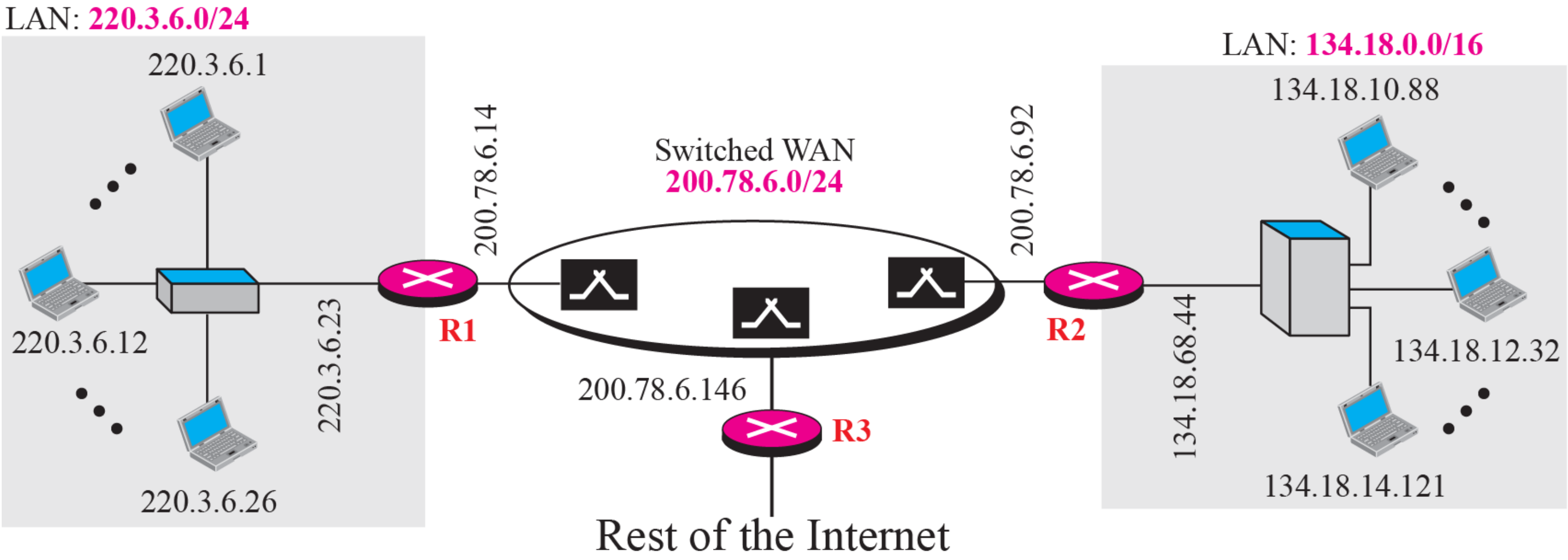
3. To find the last address, we keep the leftmost 24 bits and set the rightmost 8 bits all to 1s. The last address is 200.11.8.255/24.

Solution



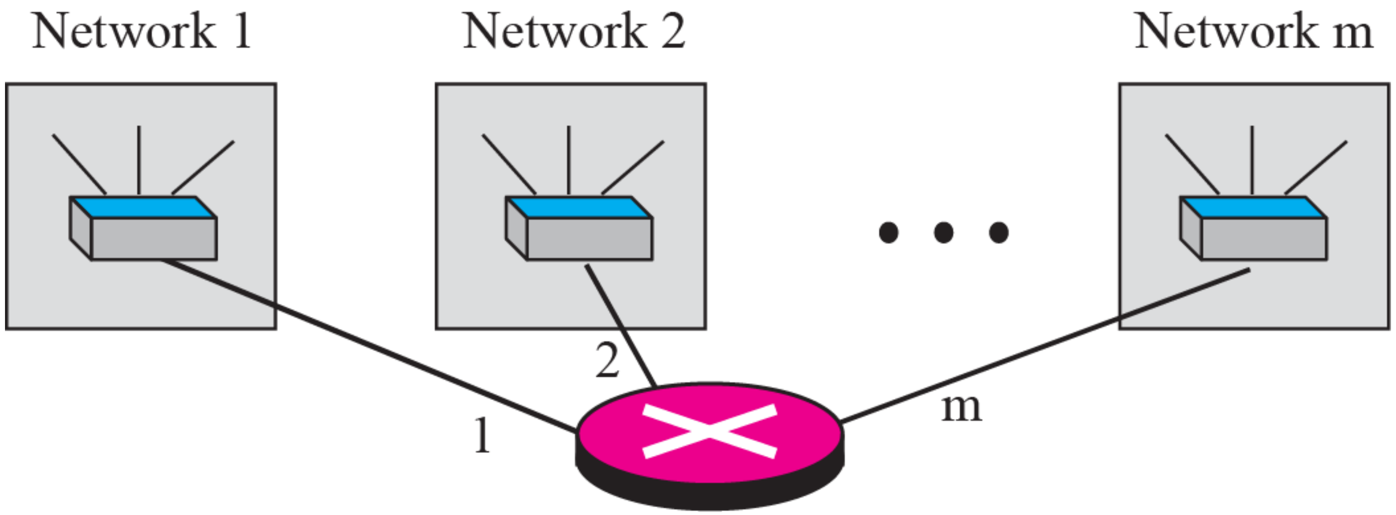
Netid 200.11.8: common in all addresses
200.11.8.1
200.11.8.7
200.11.8.45
200.11.8.254
Switch
Network address: 200.11.8.0/24
200.11.8.255 (Special)
Block
200.11.8.0
• • •
200.11.8.255

Sample Internet

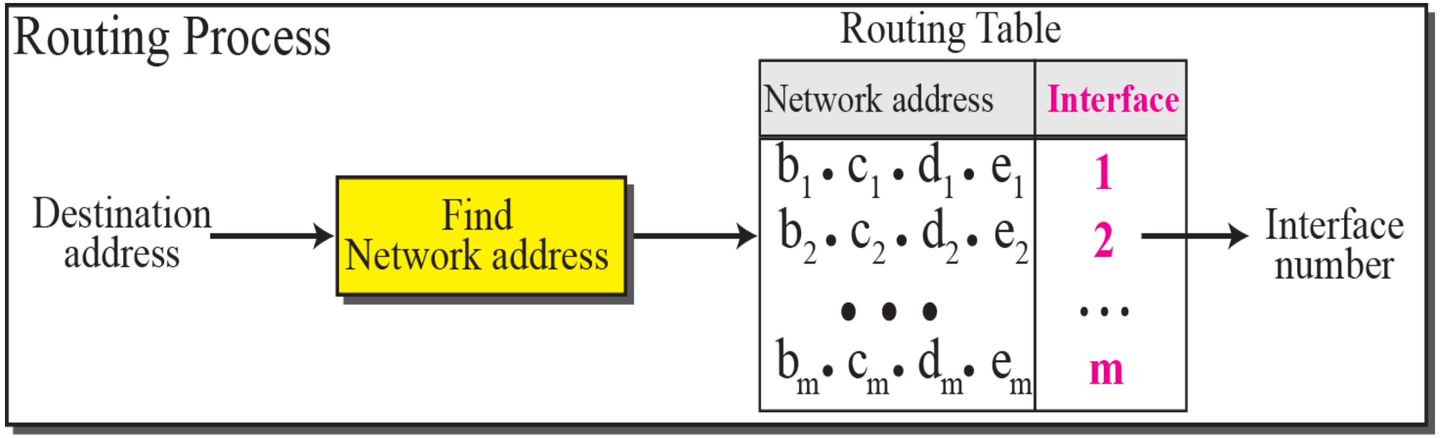


The network address is the identifier of a network.

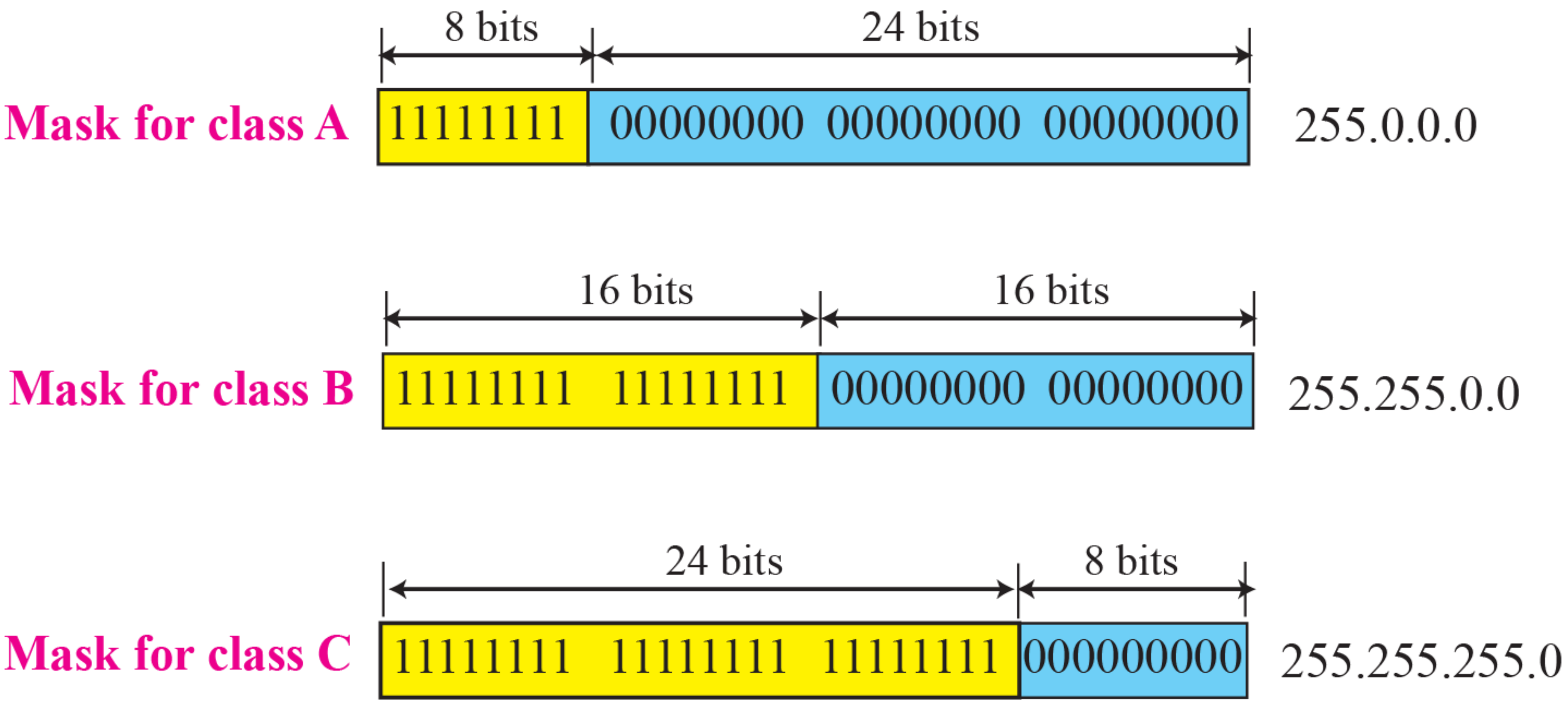
Network Address



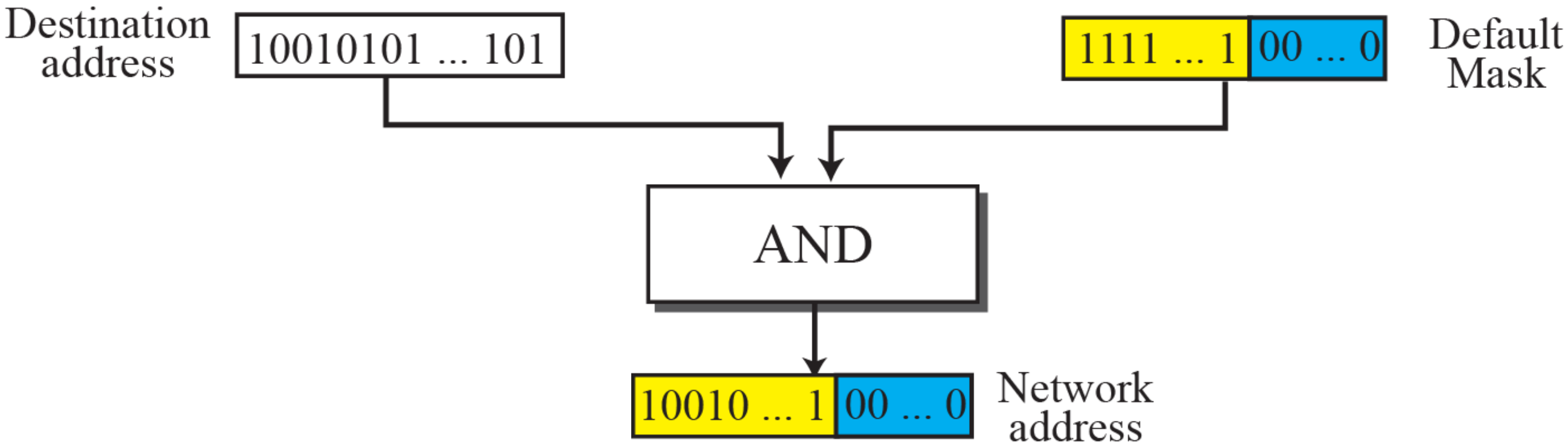
Destination	Subnet mask	Interface
199.75.43.0	255.255.255.0	Eth0
166.75.0.0	255.255.0.0	Eth3
10.0.0.0	255.0.0.0	Eth1
Default		Eth2



Network mask



Finding a network address using the default mask



Example

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 C, we assume that the router applies the default mask for class C, 255.255.255.0 to find the network address.

Destination Address	**→**	**201**	**.**	**24**	**.**	**67**	**.**	**32**
Default Mask	→	255	.	255	.	255	.	0
Network Address	→	201	.	24	.	67	.	0