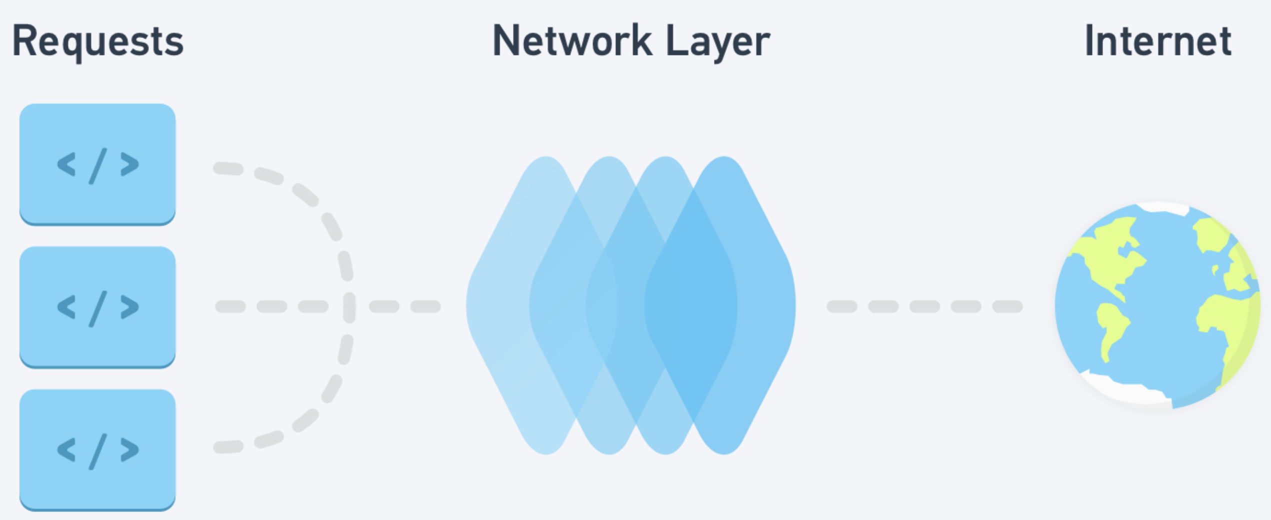
Computer Networks

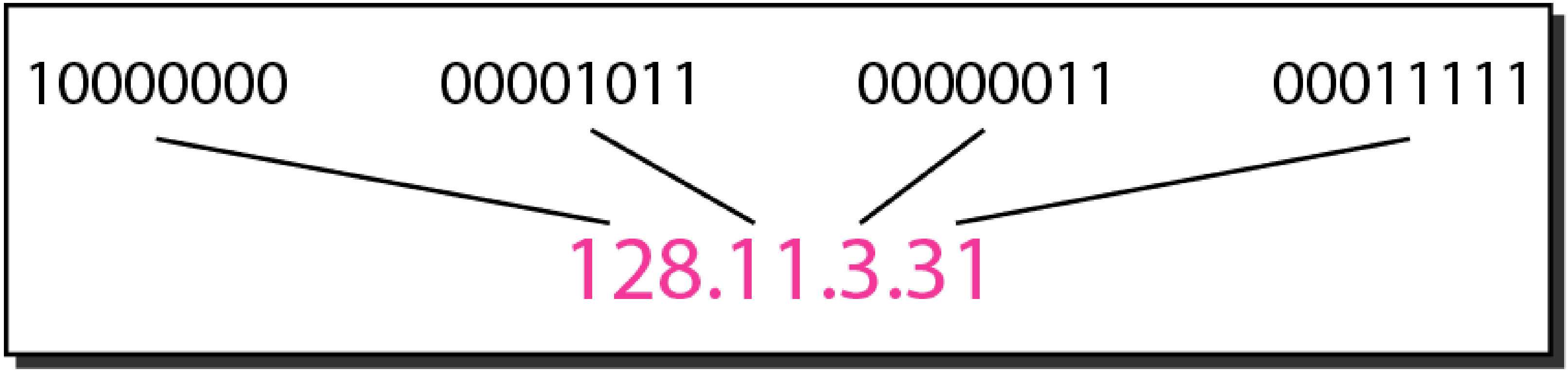
Day - 7

Network Layer



IPv4 ADDRESSES

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



Exercise

1. **Change the following IPv4 addresses from binary notation to dotted-decimal notation.**

   a. 10000001 00001011 00001011 11101111

   b. 11000001 10000011 00011011 11111111

Exercise

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

Exercise

2. **Change the following IPv4 addresses from dotted-decimal notation to binary notation.**

    a. 111.56.45.78

    b. 221.34.7.82

Exercise

Solution

We replace each decimal number with its binary equivalent (see Appendix B).

a. 01101111 00111000 00101101 01001110

b. 11011101 00100010 00000111 01010010

Exercise

3. Find the error, if any, in the following IPv4

a. 111.56.045.78

b. 221.34.7.8.20

c. 75.45.301.14

d. 11100010.23.14.67

Solution

a. There must be no leading zero (045).

b. There can be no more than four numbers.

c. Each number needs to be less than or equal to 255.

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

Classful Addressing

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

	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

0.0.0.0/8	"This host on this network"

Exercise

4. 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 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 byte is 14; the class is A.

d. The first byte is 252; the class is E.

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

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

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

Subnetting

- The process of dividing a single network into multiple sub networks
- The sub networks so created are called **subnets**.

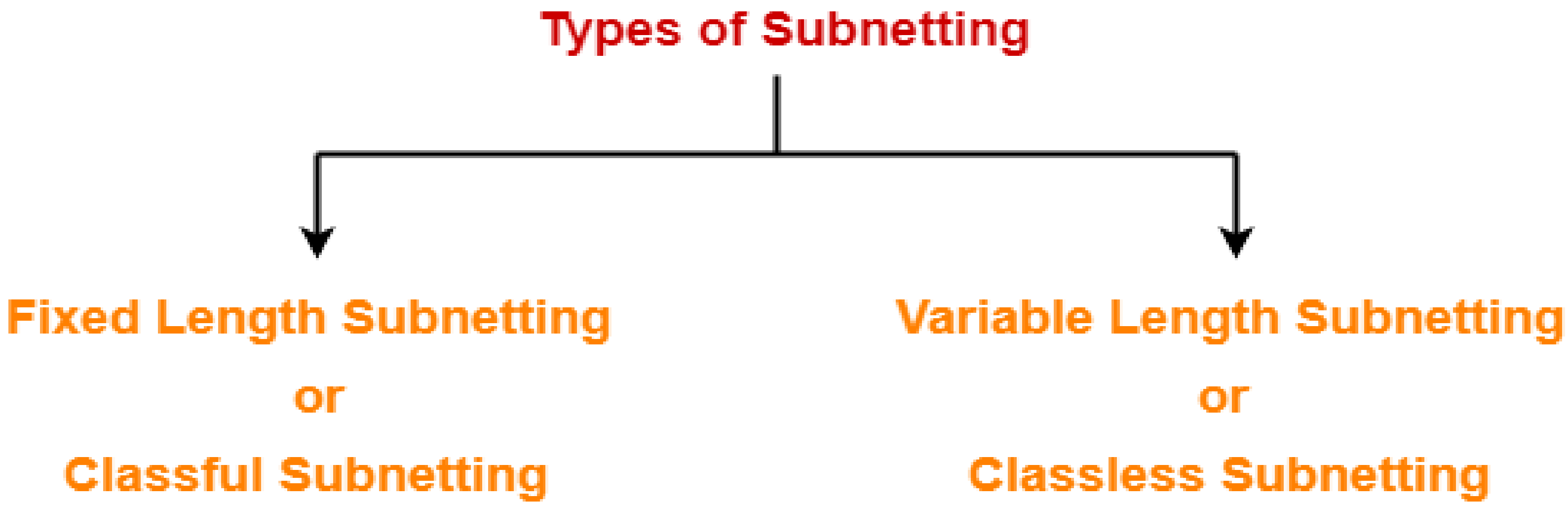
Advantages:

- It improves the security.
- The maintenance and administration of subnets is easy

Subnet ID:

- Each subnet has its unique network address known as its **Subnet ID**.
- The subnet ID is created by borrowing some bits from the Host ID part of the IP Address.
- The number of bits borrowed depends on the number of subnets created.

Subnetting

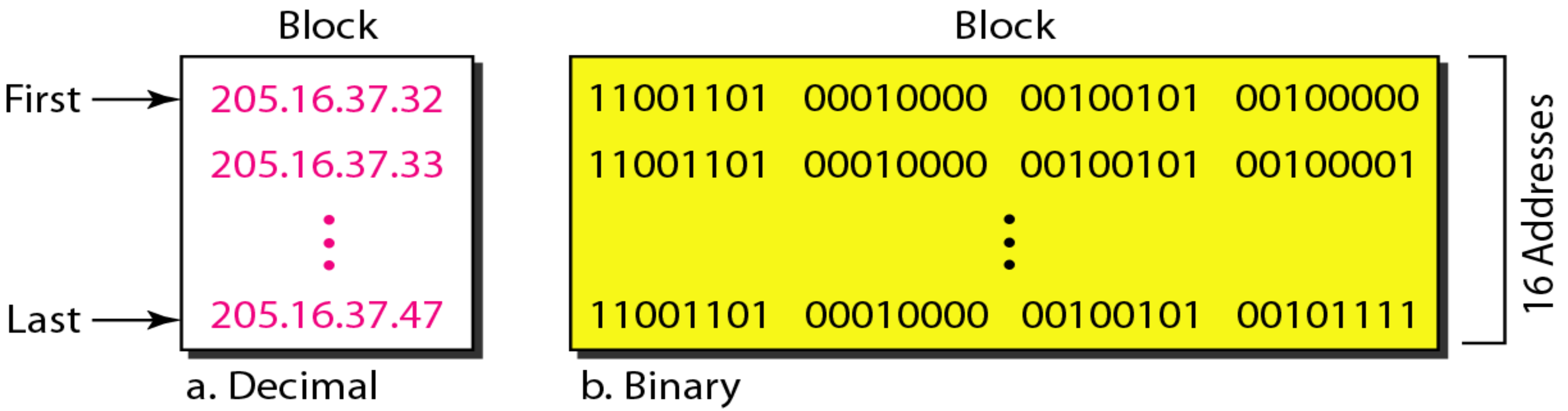


All the subnets are of same size.
All the subnets have equal number of hosts.
All the subnets have same subnet mask.

Classless Addressing

- Classless Addressing is an improved IP Addressing system.
- It makes the allocation of IP Addresses more efficient.
- It replaces the older classful addressing system based on classes.
- It is also known as **Classless Inter Domain Routing (CIDR)**.
- Block of IP Addresses (CIDR Block):
  - All the IP Addresses in the CIDR block must be contiguous.
  - The size of the block must be presentable as power of 2.
  - First IP Address of the block must be divisible by the size of the block.

Figure shows a block of addresses, in both binary and dotted-decimal notation, granted to a small business that needs 16 addresses.



We can see that the restrictions are applied to this block. The addresses are contiguous. The number of addresses is a power of 2 (16 = 2^4), and the first address is divisible by 16. The first address, when converted to a decimal number, is 3,440,387,360, which when divided by 16 results in 215,024,210.

Mask

- In IPv4 addressing, a block of addresses can be defined as :

  x.y.z.t /*n*

  x.y.z.t : one of the addresses

  /*n* : the mask.

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

Exercise

5. ***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? Find the last address for the block? Find the number of addresses?***

Solution

The binary representation of the given address is

11001101 00010000 00100101 00100111

First Address: we set 32−28 rightmost bits to 0, we get

11001101 00010000 00100101 0010000 or *205.16.37.32*.

Last Address: we set 32 − 28 rightmost bits to 1, we get

11001101 00010000 00100101 00101111 or *205.16.37.47*

Number of Addresses:

The value of n is 28, which means that number of addresses is 2^{32-28} *or 16.*

Exercise

6. **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. /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.

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.

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

Network Address

• Network address is an address that defines the network itself; it cannot be assigned to a host.

— All hostid bytes are 0s

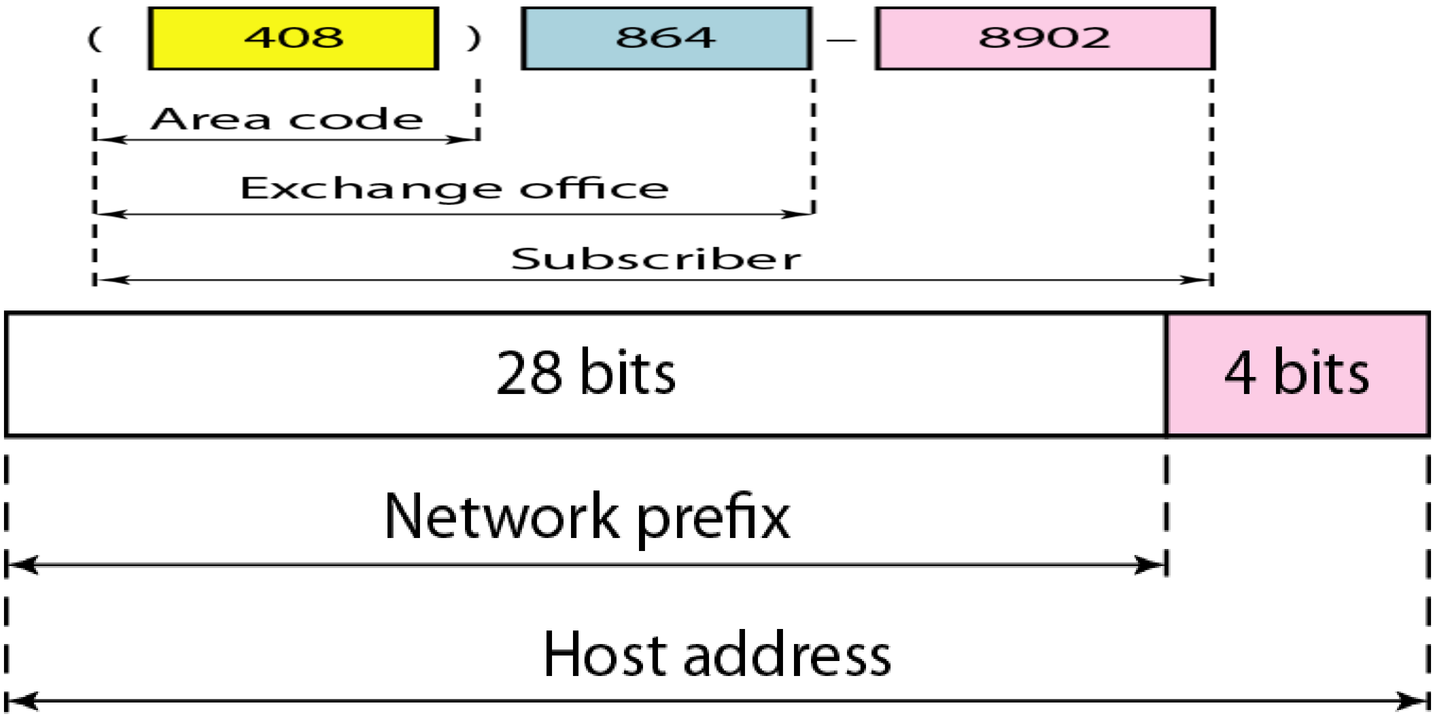
— Defines the network to the rest of the Internet.

— First address in the block

— Given the network address, we can find the class of the address.

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.

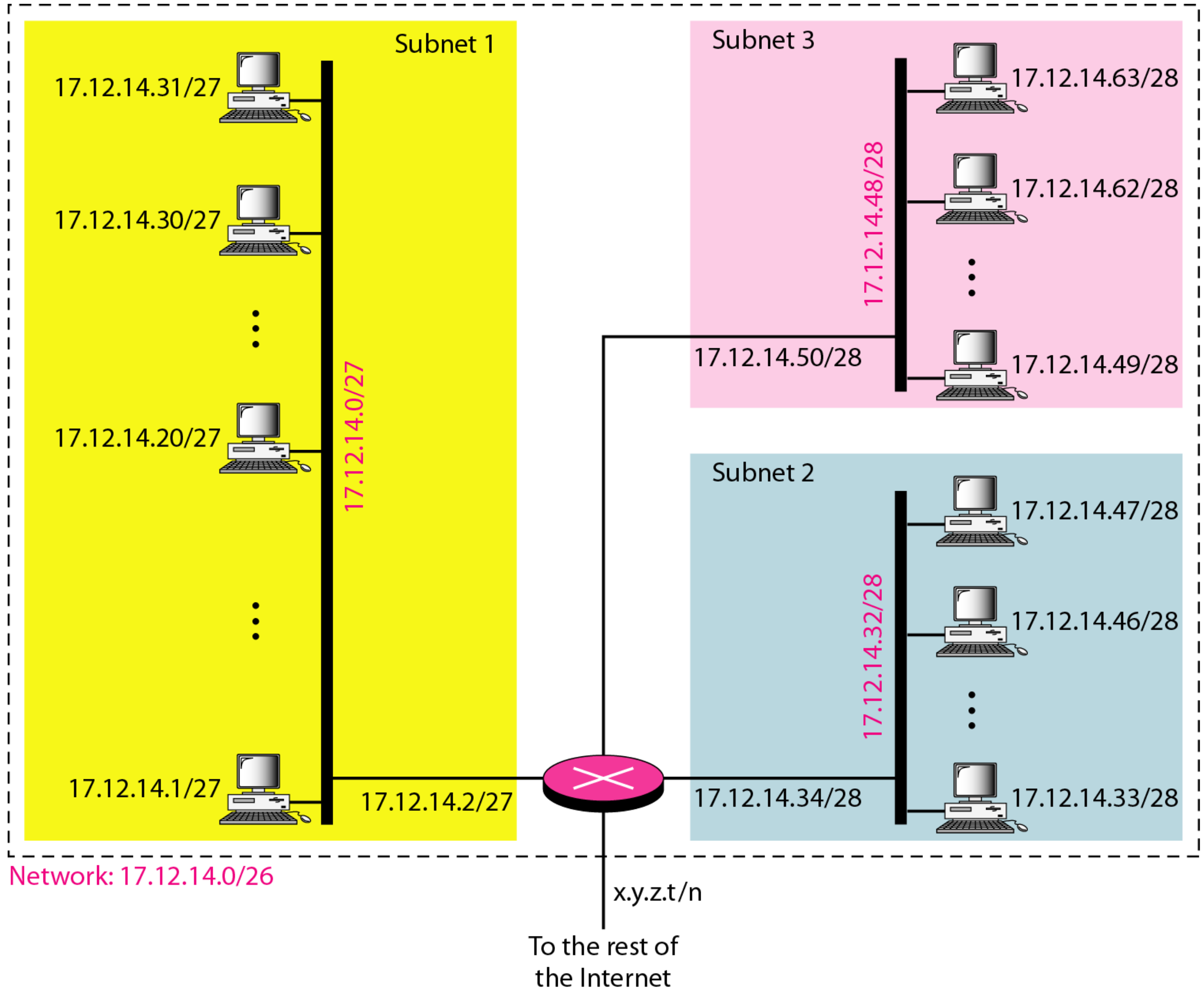
Classless Addressing: *Two levels of hierarchy in an IPv4 address*



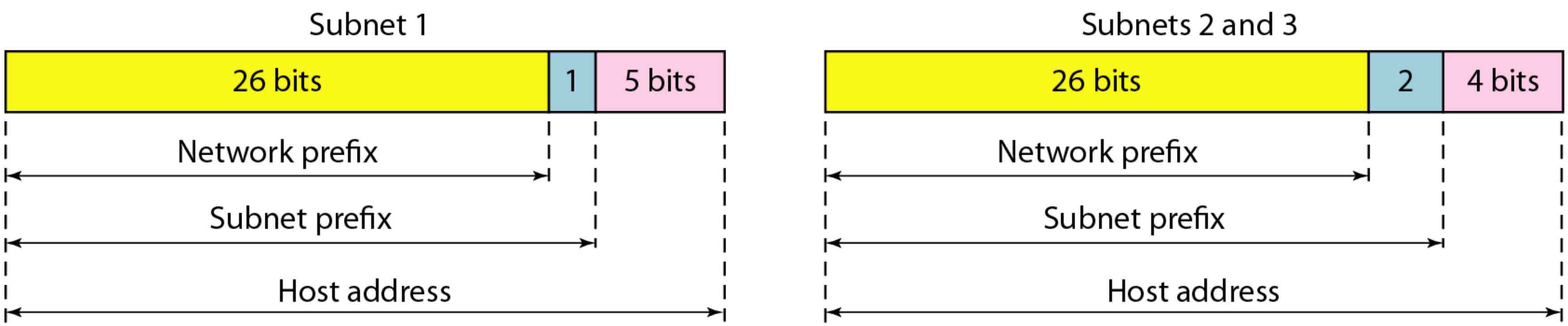
Each address in the block can be considered as a two-level hierarchical structure:

- the leftmost *n* bits (prefix) define the network;
- the rightmost 32 − n bits define the host.

Configuration and addresses in a subnetted network



Three-level hierarchy in an IPv4 address



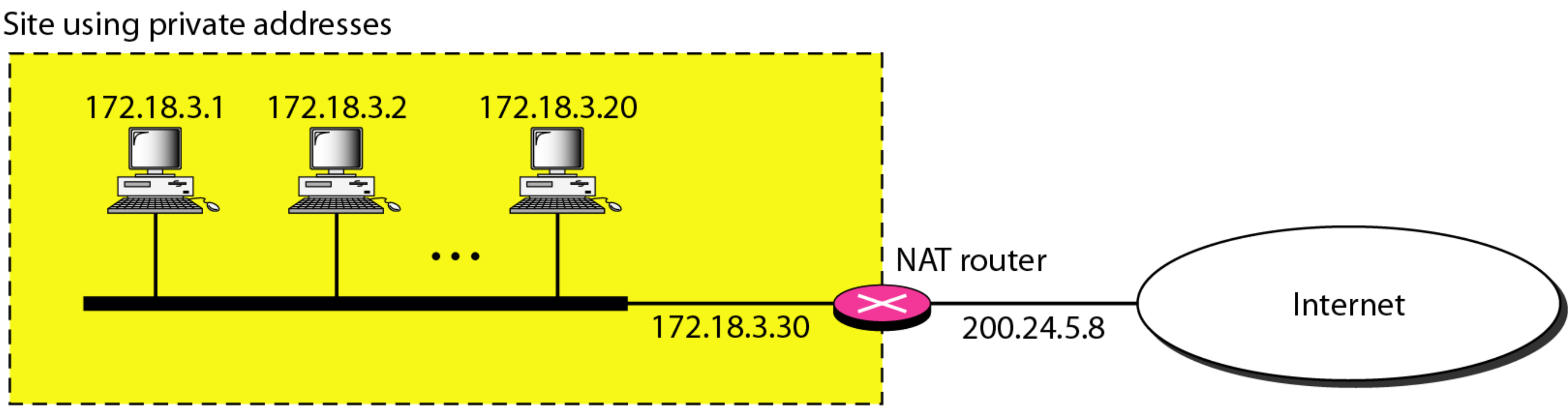
Points to remember:

- *For any given IP Address, IP Address of its network is obtained by setting all its Host ID part bits to 0.*
- *For any given IP Address, Direct Broadcast Address is obtained by setting all its Host ID part bits to 1.*
- *For any given IP Address, limited Broadcast Address is obtained by setting all its bits to 1.*
- *For any network, its limited broadcast address is always 255.255.255.255*
- Loop back Address: 127.0.0.1
- 0.0.0.0/8 "This host on this network"

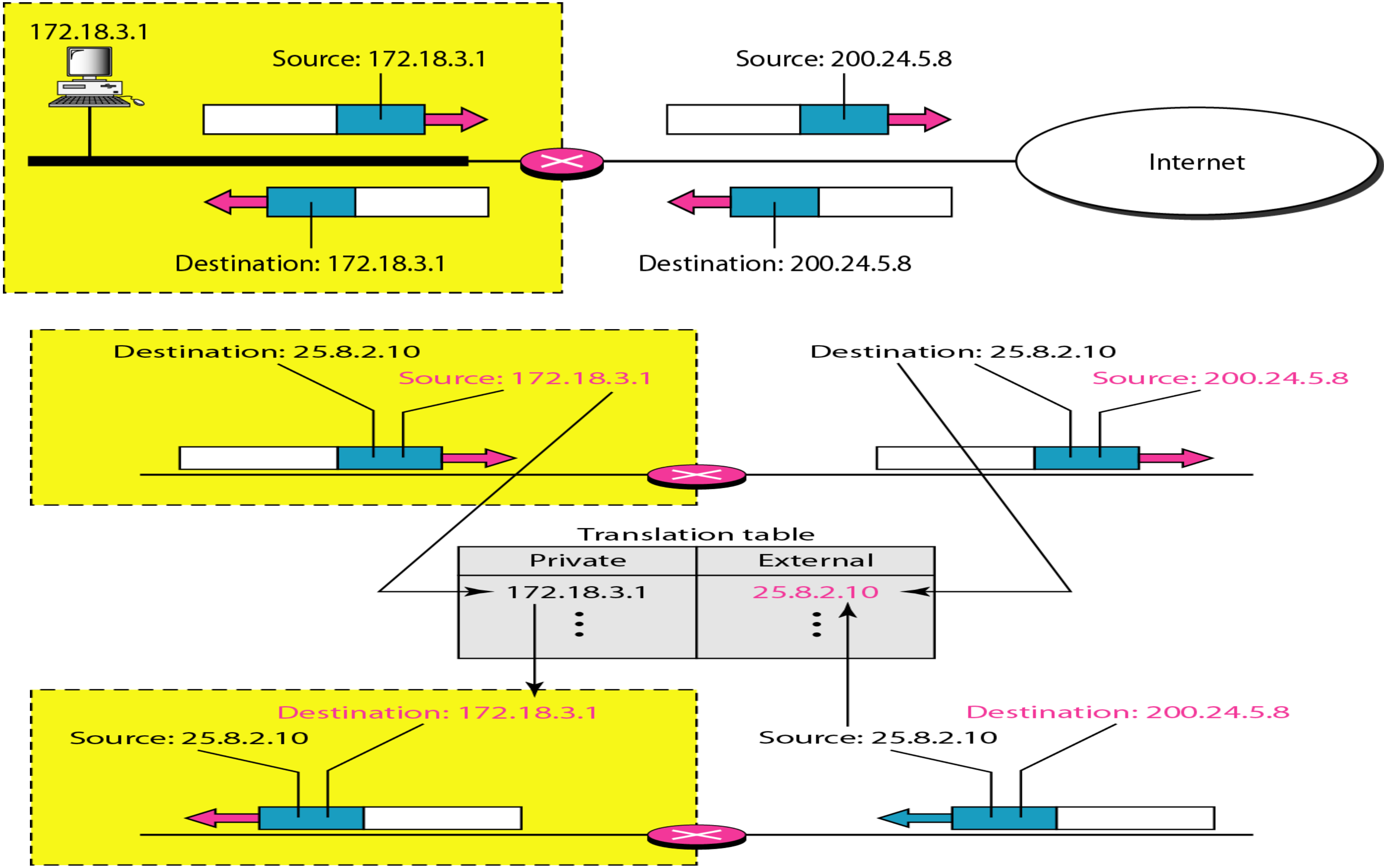
Network Address Translation

Addresses for private networks

Range			*Total*
10.0.0.0	to	10.255.255.255	2^{24}
172.16.0.0	to	172.31.255.255	2^{20}
192.168.0.0	to	192.168.255.255	2^{16}

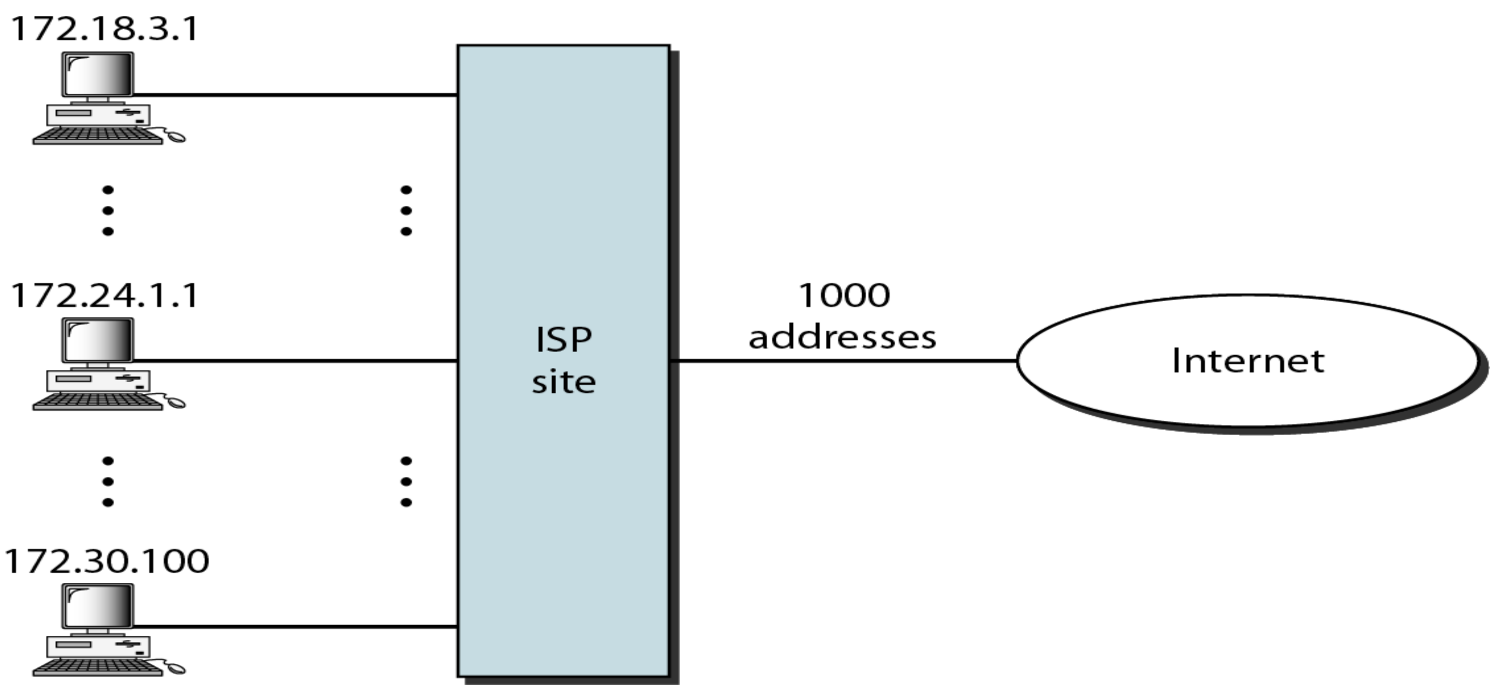


Addresses in a NAT



Five-column translation table

Private Address	*Private Port*	*External Address*	*External Port*	*Transport Protocol*
172.18.3.1	1400	25.8.3.2	80	TCP
172.18.3.2	1401	25.8.3.2	80	TCP
. . .	. . .	. . .	. . .	. . .



IPv6 ADDRESSES

Despite all short-term solutions, address depletion is still a long-term problem for the Internet. This and other problems in the IP protocol itself have been the motivation for IPv6.

- An IPv6 address is 128 bits long.

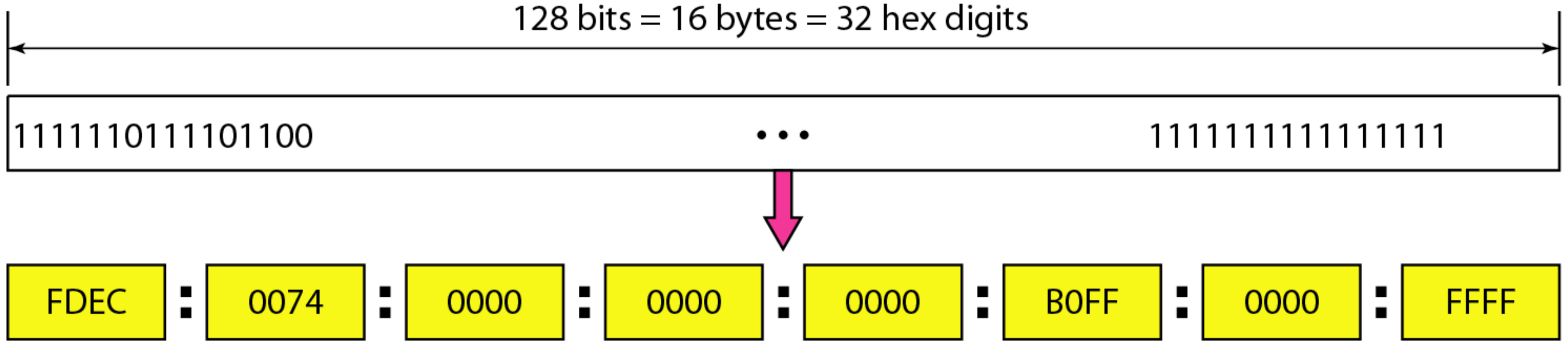
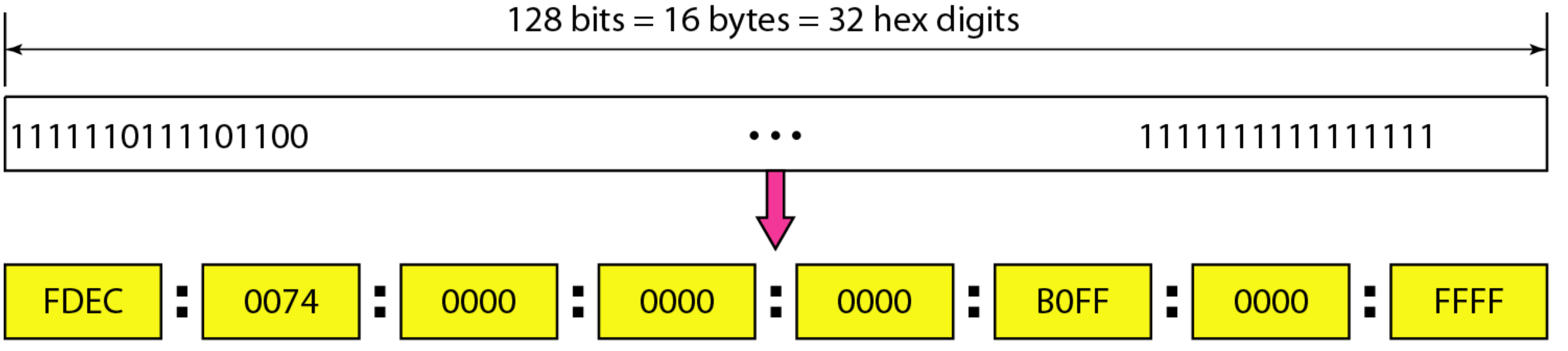
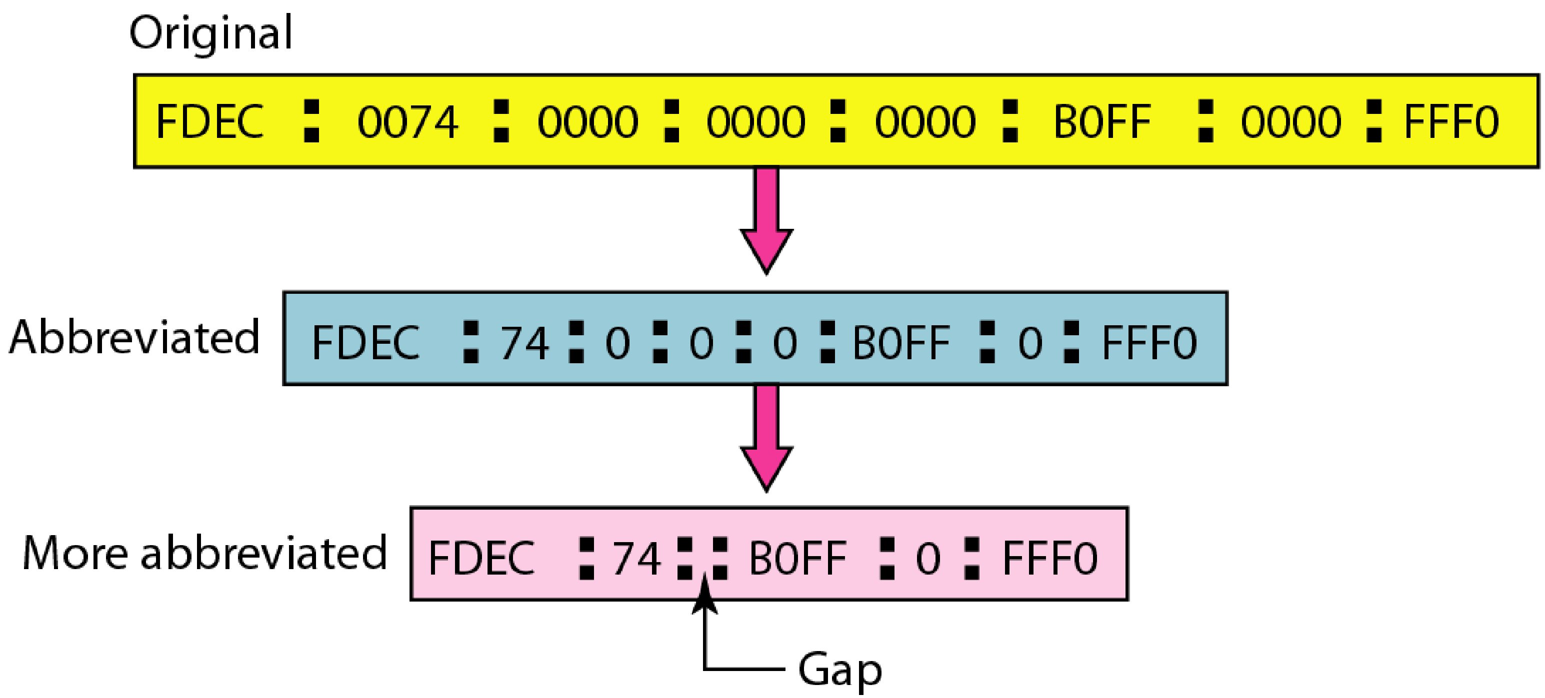


Figure: *IPv6 address in binary and hexadecimal colon notation*



Abbreviated IPv6 addresses



Exercise

8. Expand the address 0:15::1:12:1213 to its original.

Solution

We first need to align the left side of the double colon to the left of the original pattern and the right side of the double colon to the right of the original pattern to find how many 0s we need to replace the double colon.

xxxx:	xxxx:	xxxx:	xxxx:	xxxx:	xxxx:	xxxx:	xxxx
0:	15:			:	1:	12:	1213

This means that the original address is.

0000:0015:0000:0000:0000:0001:0012:1213

Exercise

1. A device has two or more IP Addresses, the device is called __________.

   a) Workstation

   b) Router

   c) Bridge

   d) All of these

Exercise

1. A device has two or more IP Addresses, the device is called __________.

    a) Workstation

    b) Router

    c) Bridge

    d) All of these

Exercise

2. What is the Destination address, when a host with IP Address 200.100.1.1 wants to send a packet to all the hosts in the same network.

   a) 200.100.0.0

   b) 200.100.0.1

   c) 255.255.255.255

   d) 0.0.0.0

Exercise

2. What is the Destination address, when a host with IP Address 200.100.1.1 wants to send a packet to all the hosts in the same network.

   a) 200.100.0.0

   b) 200.100.0.1

   c) 255.255.255.255

   d) 0.0.0.0

Exercise

3) What is the default mask for 192.0.46.10?

a) **255.255.255.0**

b) **255.255.0.0**

c) **255.0.0.0**

d) **255.0.0.0**

Exercise

3) What is the default mask for 192.0.46.10?

a) 255.255.255.0

b) 255.255.0.0

c) 255.0.0.0

d) 255.0.0.0

Exercise

4) In the IPv4 addressing format, the number of networks allowed under Class C addresses is

(A) 2^{14}

(B) 2^{7}

(C) 2^{21}

(B) 2^{24}

Exercise

4) In the IPv4 addressing format, the number of networks allowed under

Class C addresses is

(A) 2^{14}

(B) 2^{7}

(C) 2^{21}

(B) 2^{24}

Exercise

5. What is the network ID of the IP Address 230.100.123.70?

a) 230.100.123.0

b) 230.100.0.0

c) 230.0.0.0

d) No netid

Exercise

5. What is the network ID of the IP Address 230.100.123.70?

a) **230.100.123.0**

b) **230.100.0.0**

c) **230.0.0.0**

d) **No netid**

Exercise

6) An Internet Service Provider(ISP) has the following chunk of CIDR-based IP addresses available with it:245.248.128.0/20. The ISP wants to give half of this chunk of addreses to Organization A, and a quarter to Organization B, while retaining the remaining with itself. Which of the following is a valid allocation of addresses to A and B?

(A) 245.248.136.0/21 and 245.248.128.0/22

(B) 245.248.128.0/21 and 245.248.128.0/22

(C) 245.248.132.0/22 and 245.248.132.0/21

(D) 245.248.136.0/22 and 245.248.132.0/21

Exercise

6) **An Internet Service Provider(ISP) has the following chunk of CIDR-based IP addresses available with it:245.248.128.0/20. The ISP wants to give half of this chunk of addreses to Organization A, and a quarter to Organization B, while retaining the remaining with itself. Which of the following is a valid allocation of addresses to A and B?**
(A) 245.248.136.0/21 and 245.248.128.0/22
(B) 245.248.128.0/21 and 245.248.128.0/22
(C) 245.248.132.0/22 and 245.248.132.0/21
(D) 245.248.136.0/22 and 245.248.132.0/21

Since routing prefix is 20, the ISP has 2^(32-20) or 2^12 addresses. Out of these 2^12 addresses, half (or 2^11) addresses have to be given to organization A and quarter (2^10) addresses have to be given to organization B. So routing prefix for organization A will be 21. For B, it will be 22. If we see all options given in question, only options (A) and (B) are left as only these options have same number of routing prefixes. Now we need to choose from option (A) and (B).
To assign addresses to organization A, ISP needs to take first 20 bits from 245.248.128.0 and fix the 21st bit as 0 or 1. Similarly, ISP needs to fix 21st and 22nd bits for organization B. If we take a closer look at the options (A) and (B), we can see the 21st and 22nd bits for organization B are considered as 0 in both options. So 21st bit of organization A must be 1. Now take the first 20 bits from 245.248.128.0 and 21st bit as 1, we get addresses for organization A as 245.248.136.0/21

Exercise

7) Suppose computers A and B have IP addresses 10.105.1.113 and 10.105.1.91 respectively and they both use the same netmask N. Which of the values of N given below should not be used if A and B should belong to the same network?

(A) 255.255.255.0

(B) 255.255.255.128

(C) 255.255.255.192

(D) 255.255.255.224

Exercise

7) **Suppose computers A and B have IP addresses 10.105.1.113 and 10.105.1.91 respectively and they both use the same netmask N. Which of the values of N given below should not be used if A and B should belong to the same network?**

(A) 255.255.255.0

(B) 255.255.255.128

(C) 255.255.255.192

(D) 255.255.255.224

113 (**011**10001) and 91 (**010**11011) & N

Exercise

8 . If a class B network on the Internet has a subnet mask of 255.255.248.0, what is the maximum number of hosts per subnet?

(A) 1022

(B) 1023

(C) 2046

(D) 2047

Exercise

8 . If a class B network on the Internet has a subnet mask of 255.255.248.0, what is the maximum number of hosts per subnet?

(A) 1022

(B) 1023

(C) 2046

(D) 2047

Subnet Mask :
11111111.11111111.11111000.00000000
11 bits for host => 2048 -2 = 2046

Exercise

9. The address of a class B host is to be split into subnets with a 6-bit subnet number. What is the maximum number of subnets and the maximum number of hosts in each subnet?

(A) 62 subnets and 262142 hosts.

(B) 64 subnets and 262142 hosts.

(C) 62 subnets and 1022 hosts.

(D) 64 subnets and 1024 hosts.

Exercise

9. The address of a class B host is to be split into subnets with a 6-bit subnet number.

What is the maximum number of subnets and the maximum number of hosts in each subnet?

(A) 62 subnets and 262142 hosts.

(B) 64 subnets and 262142 hosts.

(C) 62 subnets and 1022 hosts.

(D) 64 subnets and 1024 hosts.

Netid: Netid: Hostid: Hostid

11111111.11111111.11111100:00000000

Exercise

10. The subnet mask for a particular network is 255.255.31.0. Which of the following pairs of IP addresses could belong to this network?

(A) 172.57.88.62 and 172.56.87.233

(B) 10.35.28.2 and 10.35.29.4

(C) 191.203.31.87 and 191.234.31.88

(D) 128.8.129.43 and 128.8.161.55

Exercise

10. The subnet mask for a particular network is 255.255.31.0. Which of the following pairs of IP addresses could belong to this network?

(A) 172.57.88.62 and 172.56.87.233

(B) 10.35.28.2 and 10.35.29.4

(C) 191.203.31.87 and 191.234.31.88

(D) 128.8.129.43 and 128.8.161.55

Exercise

11. An organization has a class B network and wishes to form subnets for 64 departments. The subnet mask would be

(A) 255.255.0.0

(B) 255.255.64.0

(C) 255.255.128.0

(D) 255.255.252.0

Exercise

11. An organization has a class B network and wishes to form subnets for 64 departments. The subnet mask would be

(A) 255.255.0.0

(B) 255.255.64.0

(C) 255.255.128.0

(D) 255.255.252.0

Netid: Netid: Hostid: Hostid
11111111.11111111.11111100:00000000

Exercise

12. Which of the following can be used as both Source and Destination IP?

a) **198.168.1.255**

b) **10.0.0.1**

c) **127.0.0.1**

d) **255.255.255.255**

Exercise

12. Which of the following can be used as both Source and Destination IP?

a) **198.168.1.255**

b) **10.0.0.1**

c) **127.0.0.1**

d) **255.255.255.255**

Exercise

13. Which of the following IP address can be used in WAN?

a) 10.0.0.1

b) 172.16.0.10

c) 15.1.5.6

d) None

Exercise

13. Which of the following IP address can be used in WAN?

a) **10.0.0.1**

b) **172.16.0.10**

c) **15.1.5.6**

d) **None**

Exercise

14. In class B if subnet mask is 255.192.0.0 Total Number of networks than can be joined

a) 32

b) 64

c) 16

d) None

Exercise

14. In class B if subnet mask is 255.192.0.0 Total Number of networks than can be joined

a) **32**

b) **64**

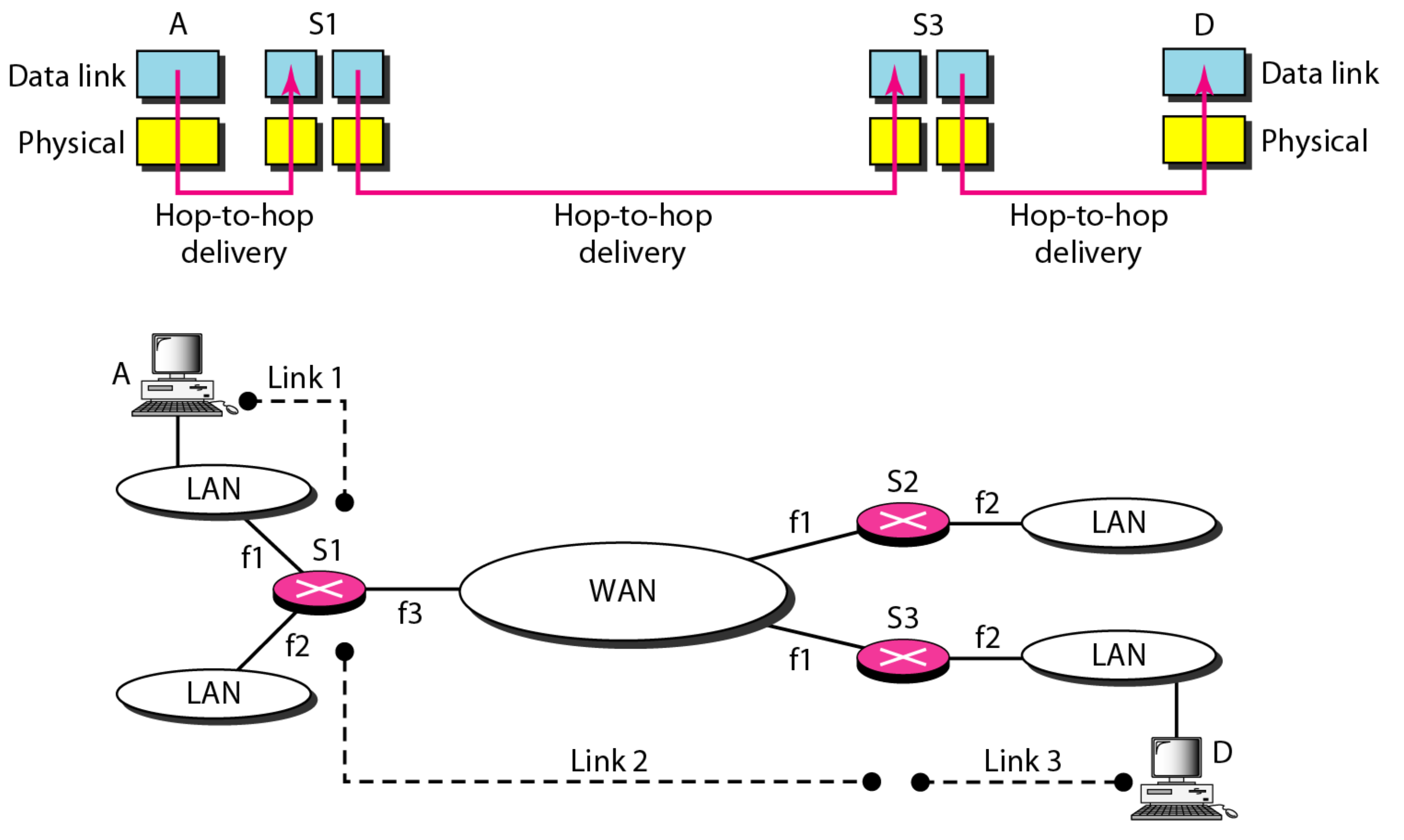
c) **16**

d) **None**

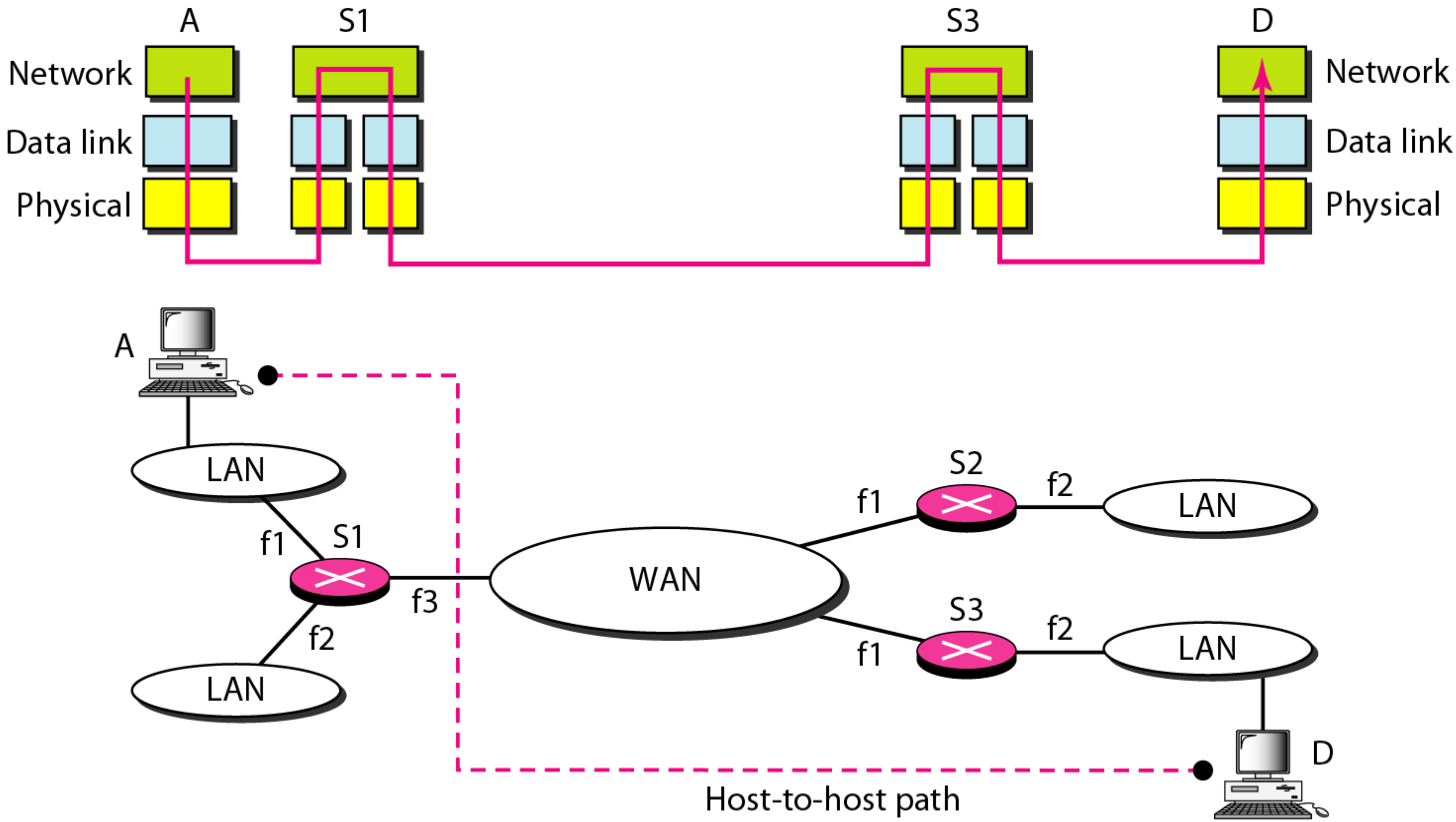
Subnet mask is
11111111.11000000.00000000.0000000

IPv4/IPv6

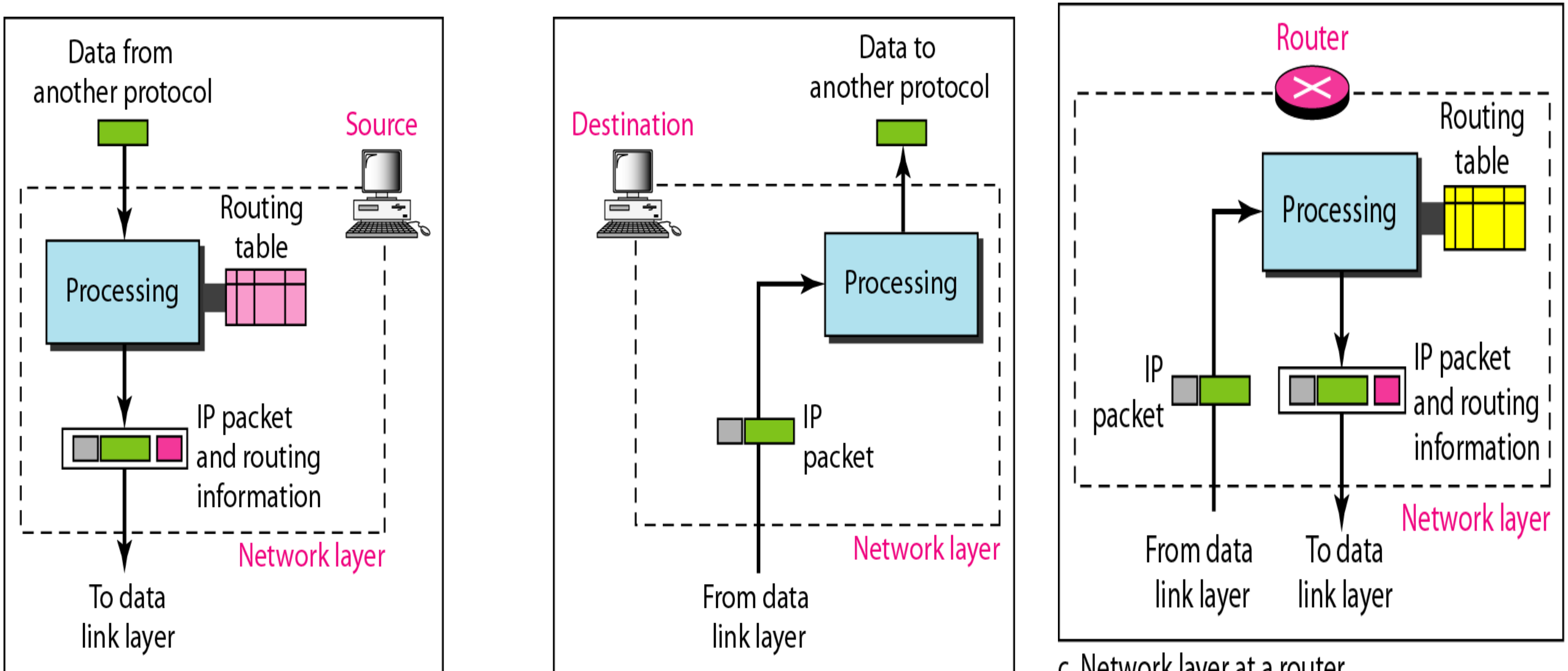
Links between two hosts



Network layer in an internetwork



Network layer at the source, router, and destination

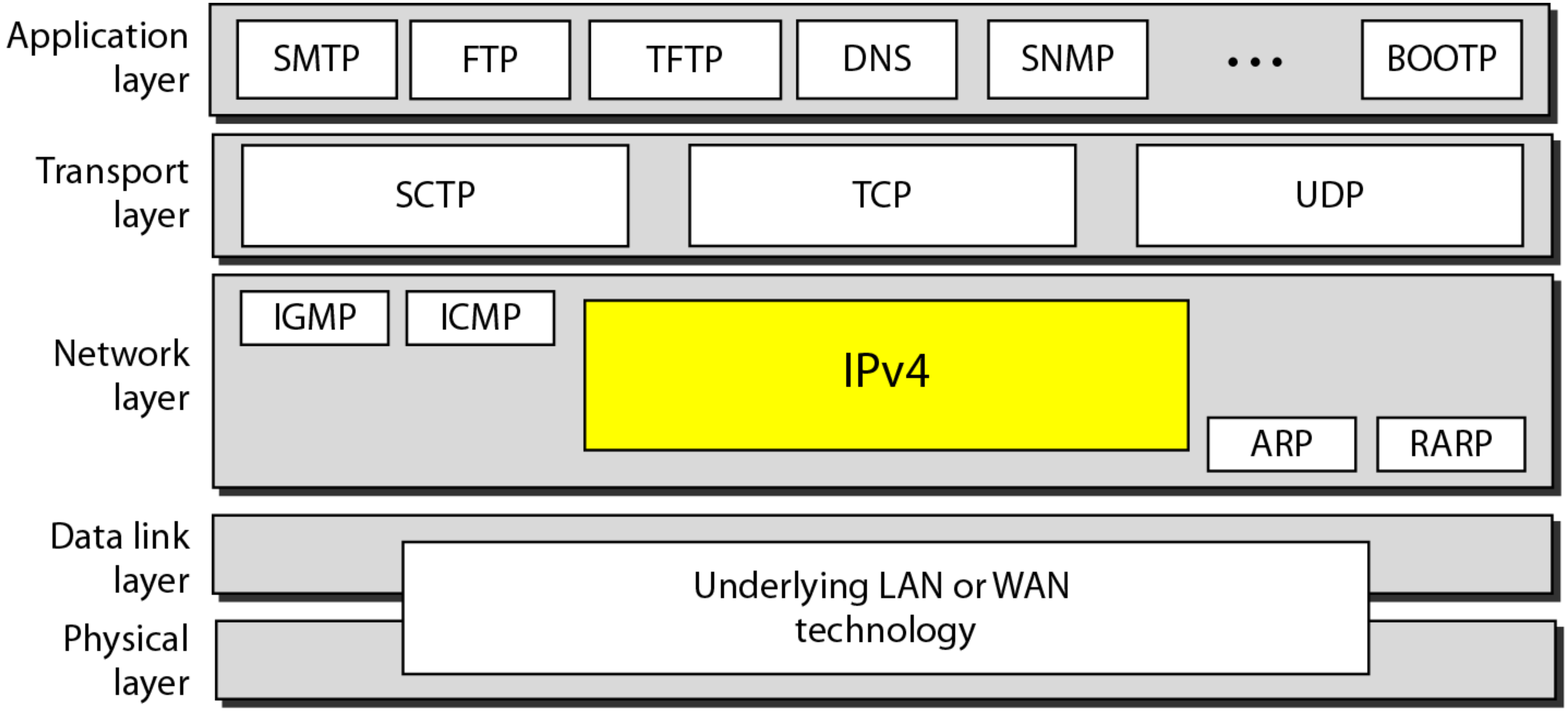


a. Network layer at source
b. Network layer at destination
c. Network layer at a router

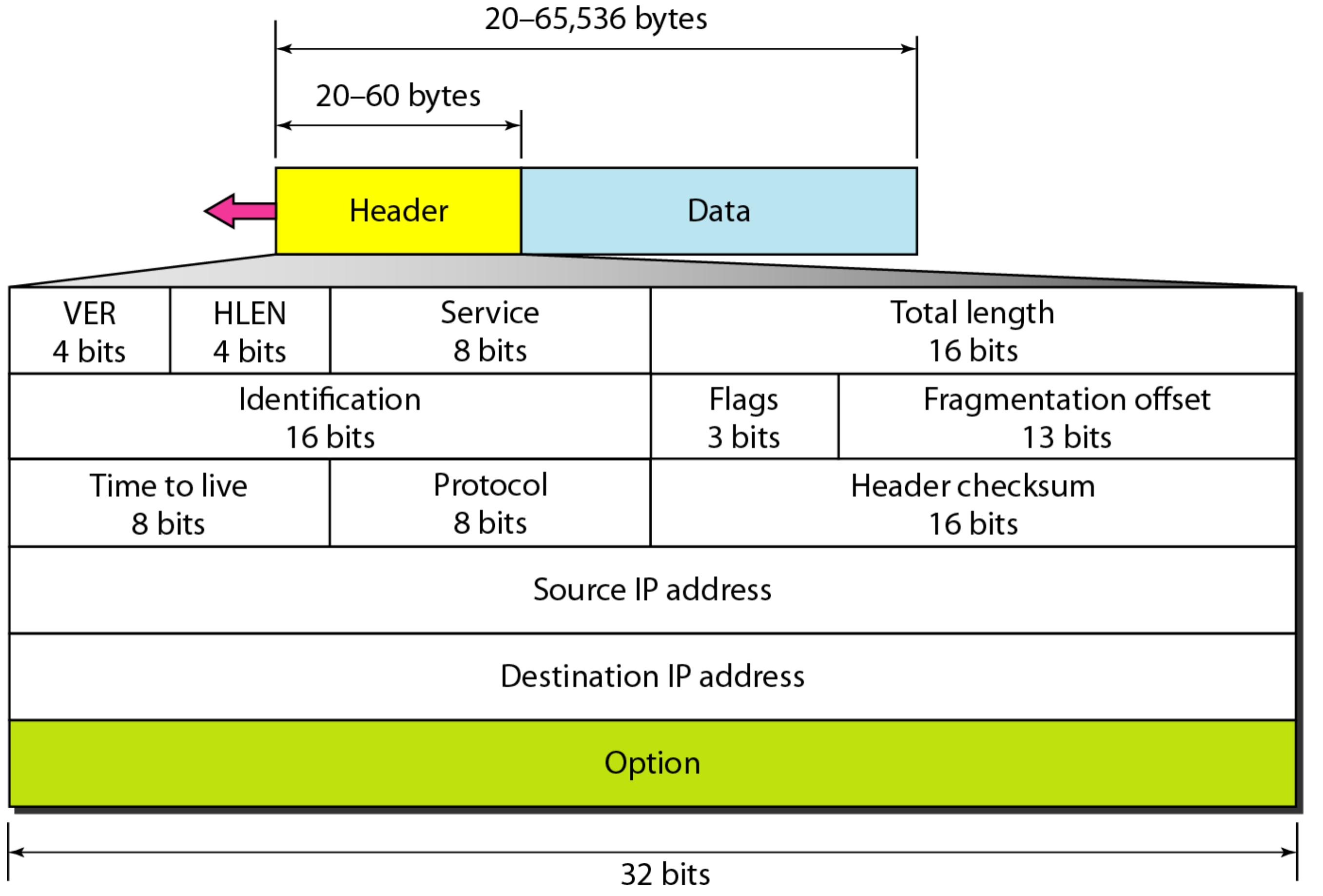
- Switching at the network layer in the Internet uses the datagram approach to packet switching.
- Communication at the network layer in the Internet is connectionless.

IPv4

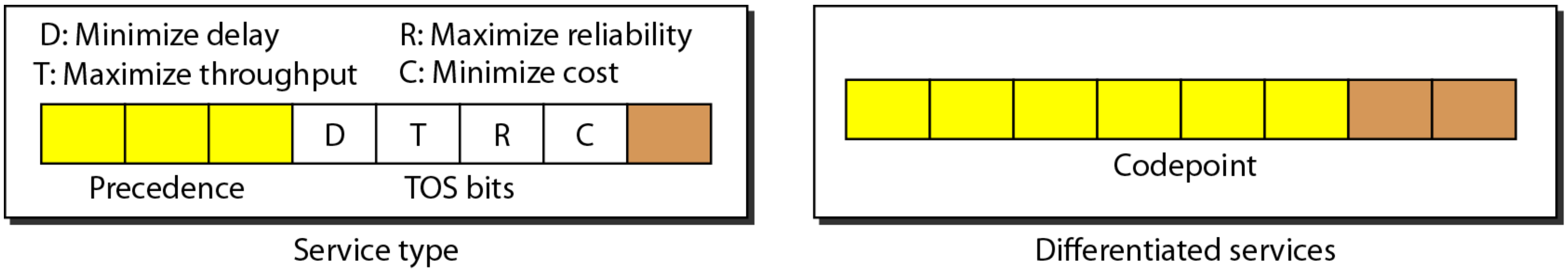
The Internet Protocol version 4 (IPv4) is the delivery mechanism used by the TCP/IP protocols.



IPv4 datagram format

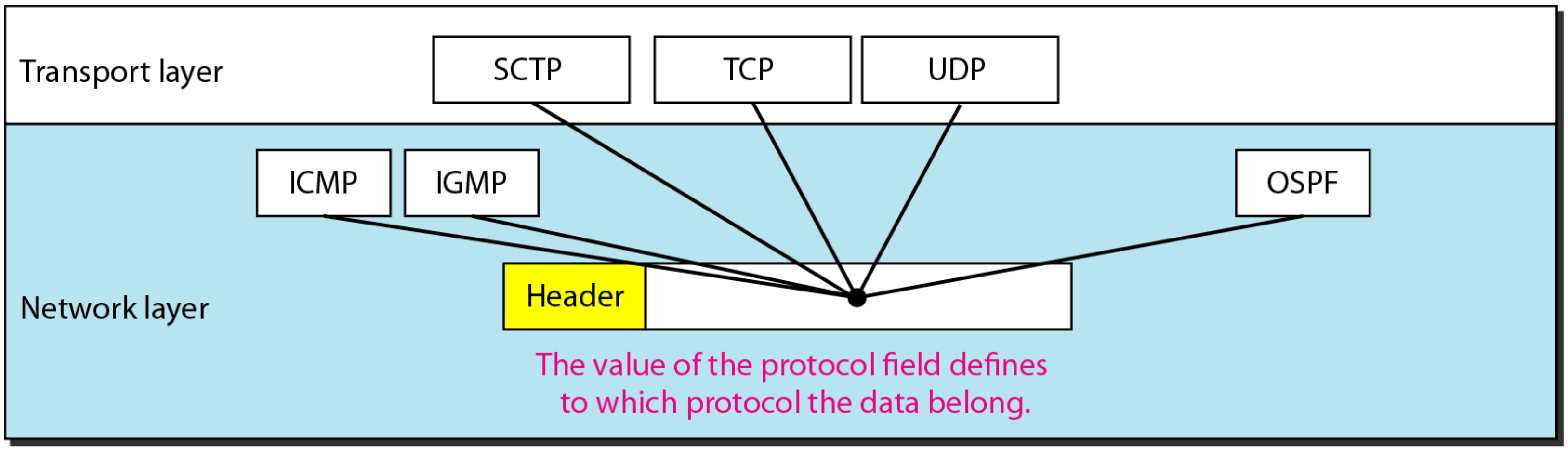


Service type or differentiated services



TOS Bits	*Description*
0000	Normal (default)
0001	Minimize cost
0010	Maximize reliability
0100	Maximize throughput
1000	Minimize delay

Protocol field and encapsulated data



Value	*Protocol*
1	ICMP
2	IGMP
6	TCP
17	UDP
89	OSPF

Exercise

An IPv4 packet has arrived with the first 8 bits as shown:

01000010

The receiver discards the packet. Why?

Solution

There is an error in this packet. The 4 leftmost bits (0100) show the version, which is correct. The next 4 bits (0010) show an invalid header length ($2 \times 4 = 8$). The minimum number of bytes in the header must be 20. The packet has been corrupted in transmission.

Exercise

In an IPv4 packet, the value of HLEN is 1000 in binary. How many bytes of options are being carried by this packet?

Solution

The HLEN value is 8, which means the total number of bytes in the header is 8 × 4, or 32 bytes. The first 20 bytes are the base header, the next 12 bytes are the options.

Exercise

In an IPv4 packet, the value of HLEN is 5, and the value of the total length field is 0x0028. How many bytes of data are being carried by this packet?

Solution

The HLEN value is 5, which means the total number of bytes in the header is 5 × 4, or 20 bytes (no options). The total length is 40 bytes, which means the packet is carrying 20 bytes of data (40 − 20).

Exercise

An IPv4 packet has arrived with the first few hexadecimal digits as shown.

0x45000028000100000102 . . .

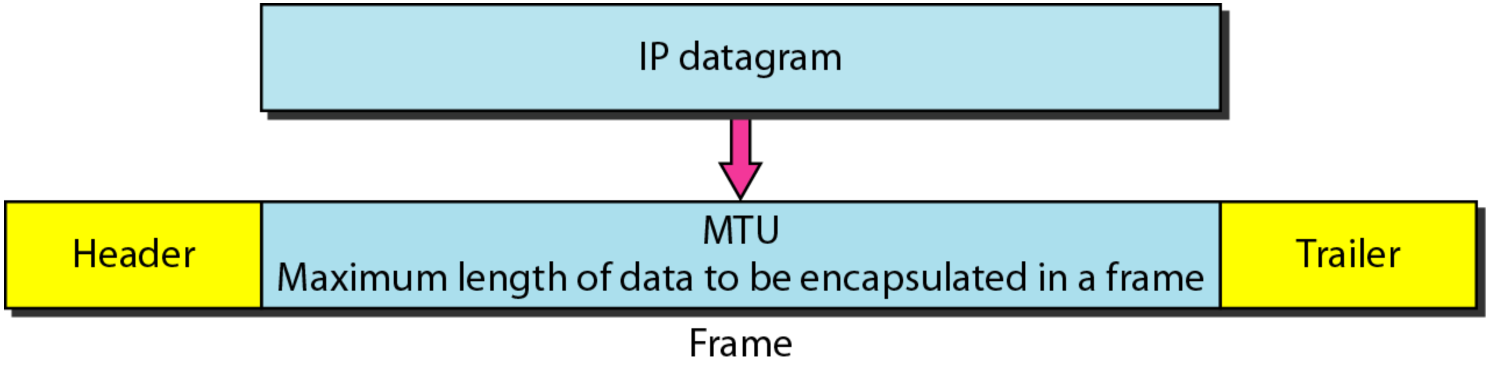
How many hops can this packet travel before being dropped? The data belong to what upper-layer protocol?

Solution

To find the time-to-live field, we skip 8 bytes. The time-to-live field is the ninth byte, which is 01. This means the packet can travel only one hop. The protocol field is the next byte (02), which means that the upper-layer protocol is IGMP.

Fragmentation

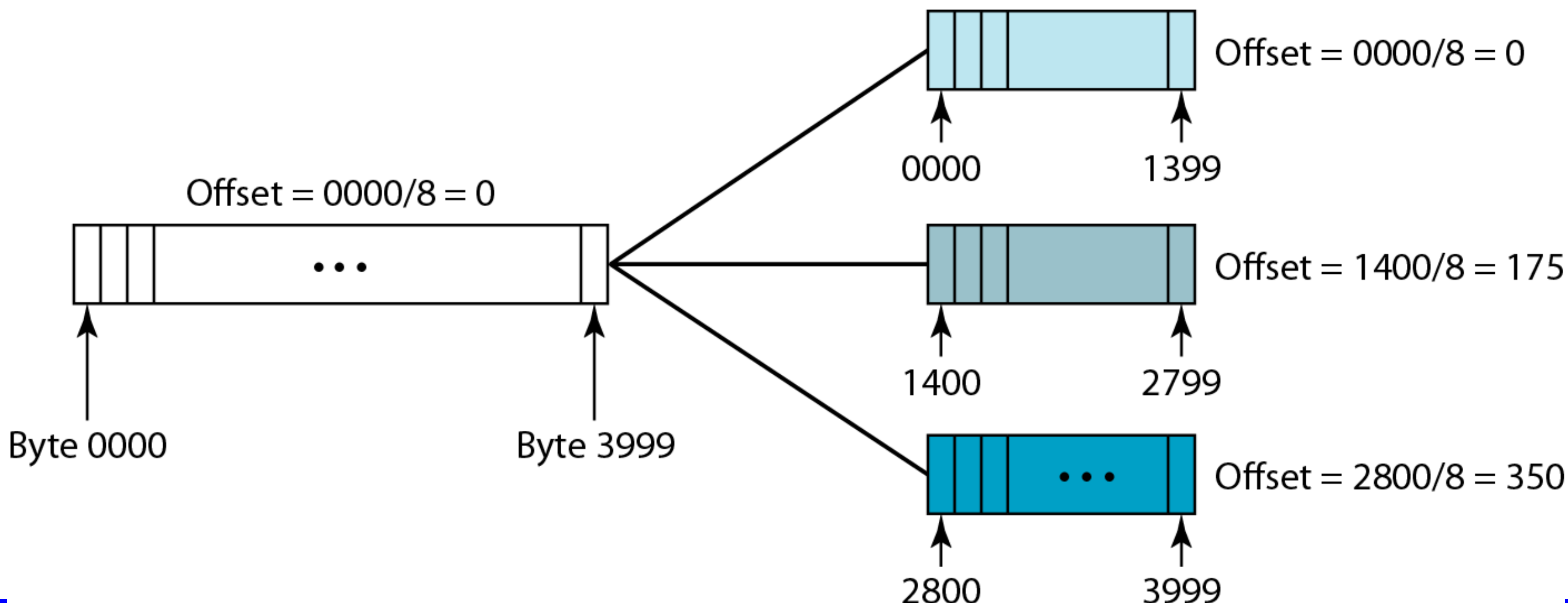
Maximum transfer unit (MTU)



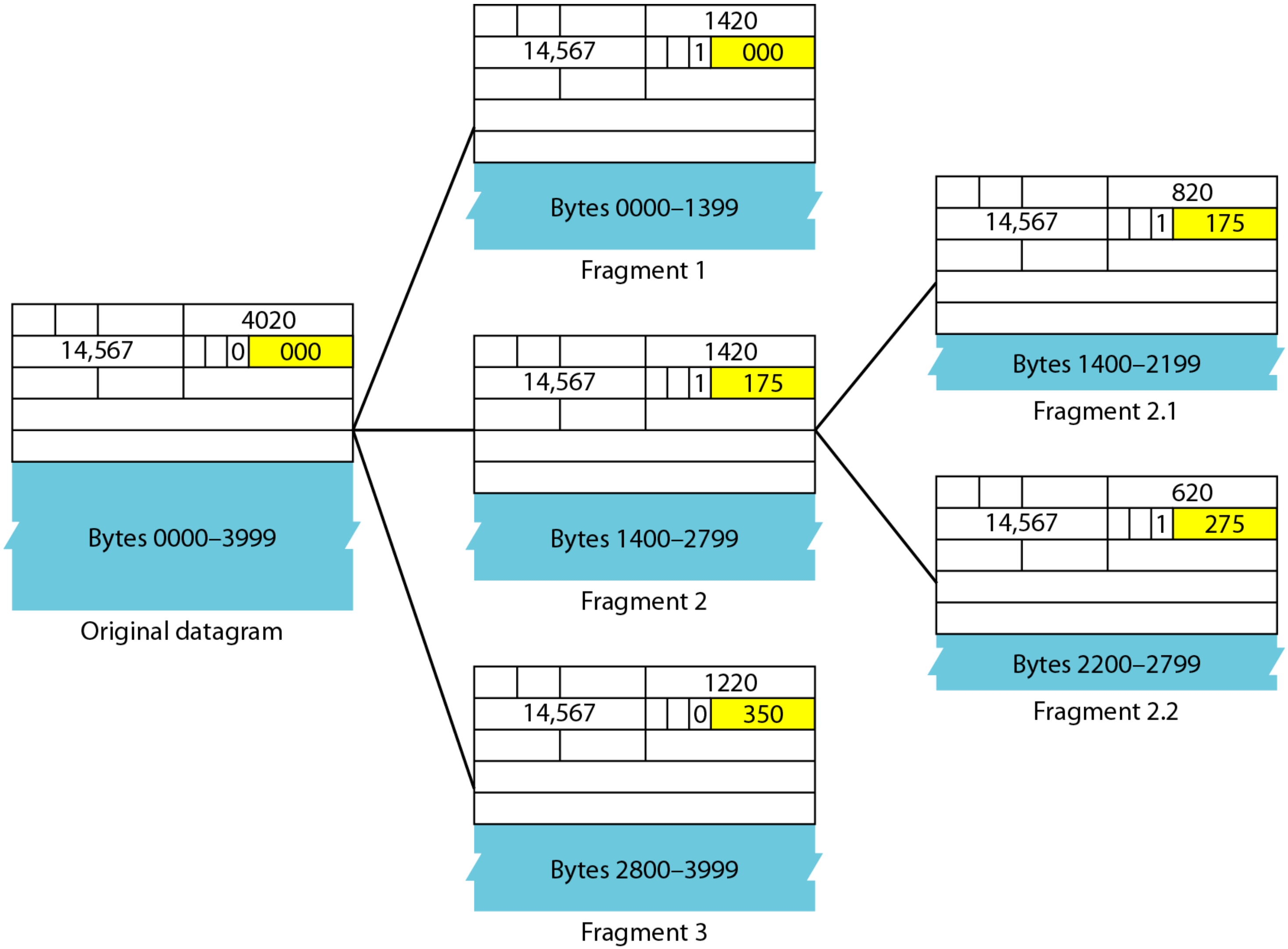
Protocol	*MTU*
Hyperchannel	65,535
Token Ring (16 Mbps)	17,914
Token Ring (4 Mbps)	4,464
FDDI	4,352
Ethernet	1,500
X.25	576
PPP	296

Flags used in fragmentation

Fragmentation example



Detailed fragmentation example



Exercise

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 non-fragmented packet is considered the last fragment.

Exercise

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).

Exercise

A packet has arrived with an M bit value of 1 and a fragmentation offset value of 0. 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.

Exercise

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.

Exercise

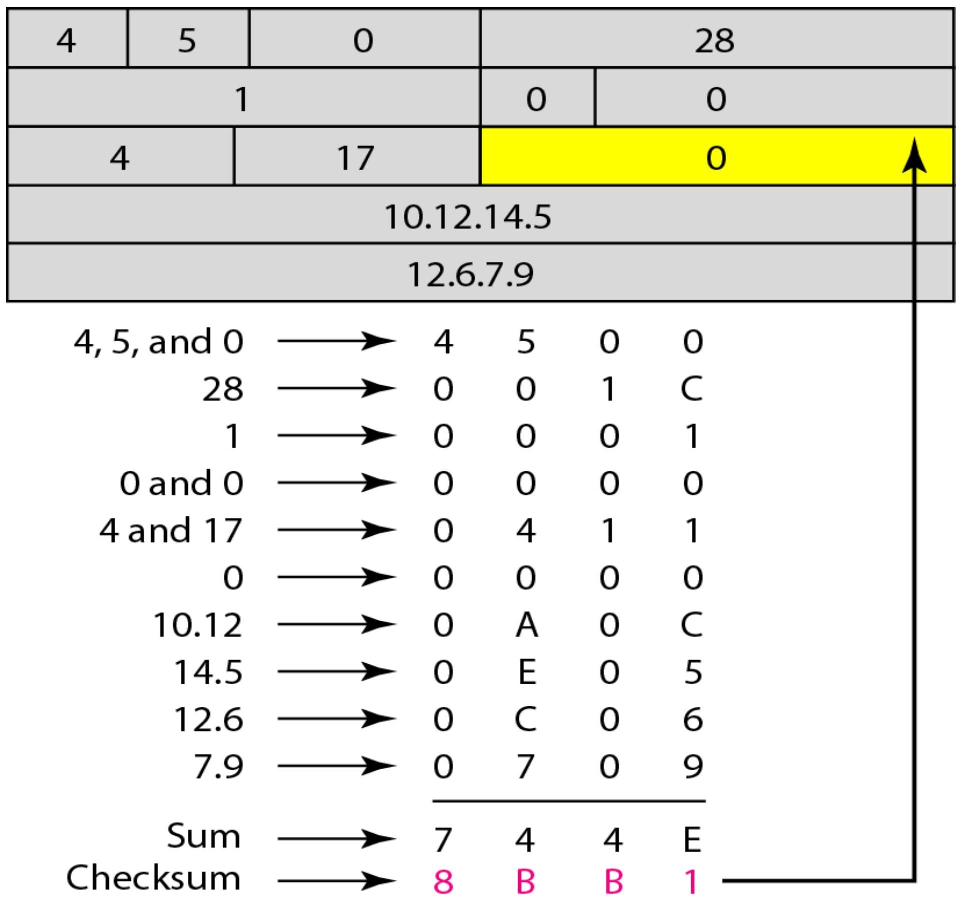
A packet has arrived in which the offset value is 100, the value of HLEN is 5, and the value of the total length field is 100. What are the numbers of the first byte and the last byte?

Solution

The first byte number is 100 × 8 = 800. The total length is 100 bytes, and the header length is 20 bytes (5 × 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

Checksum calculation for an IPv4 header without options. 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.



Taxonomy of options in IPv4