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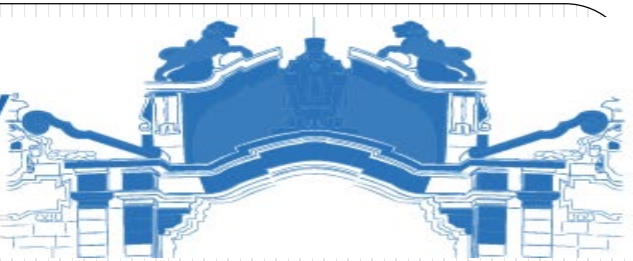


Data Communication and Computer Networks

INSY3071

Instructor: *Tsegaye Berhanu*

Chapter 6

Introduction to IP Addressing and Subnetting

Objective

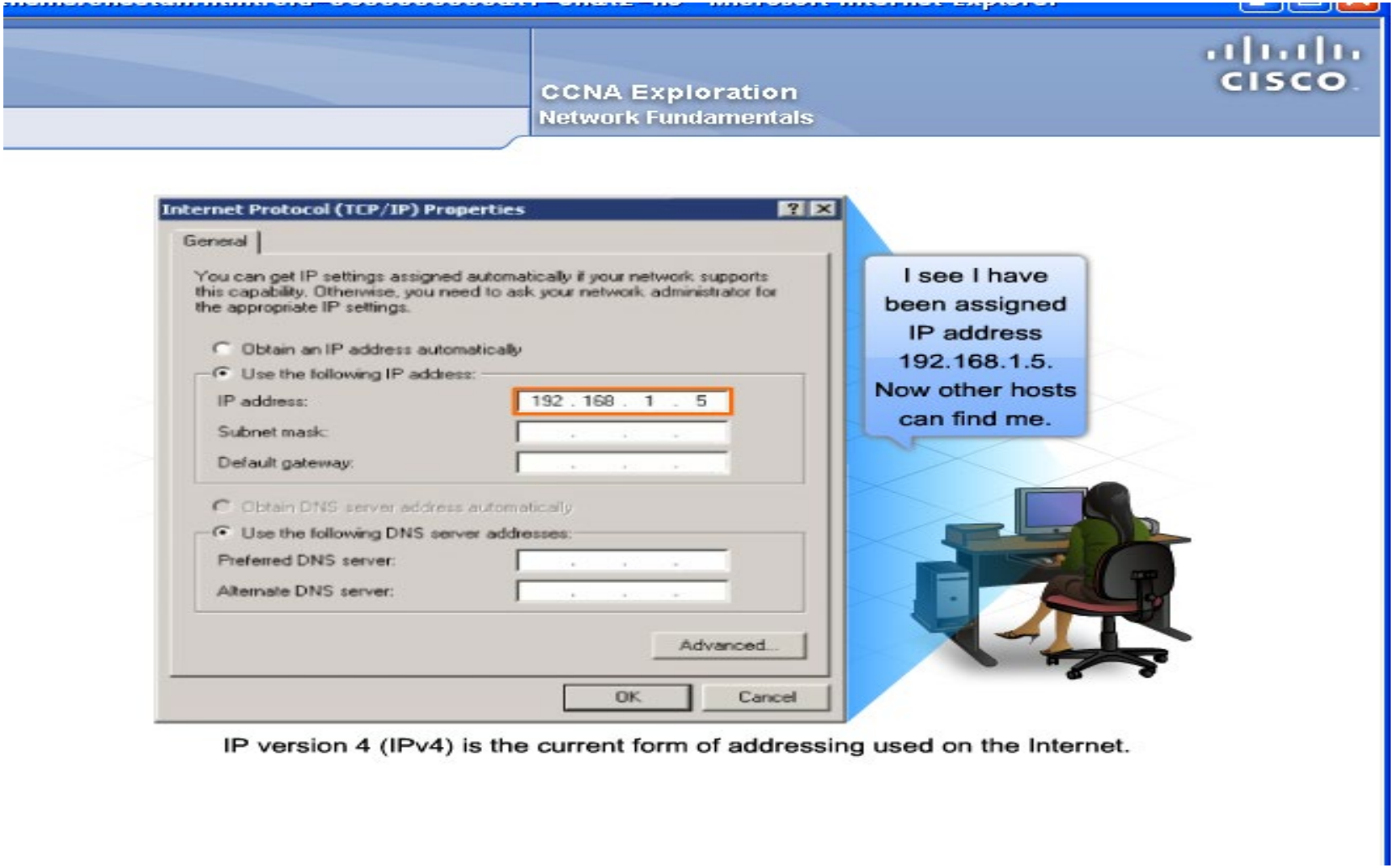
In this chapter, you will learn to:

- Explain the structure IP addressing
- convert between 8-bit binary and decimal numbers.
- classify by type and describe how it is used in the network.
- Determine the network portion of the host address and explain the role of the subnet mask in dividing networks.
- Given IPv4 addressing information and design criteria, calculate the appropriate addressing components.

IP Addressing

- Each device on a network must be uniquely identified.
- At the Network layer, the packets of the communication need to be identified with the source and destination addresses of the two end systems
- With IPv4, this means that each packet has a 32-bit source address and a 32-bit destination address in the Layer 3 header.

IP Addressing



IP Addressing

- These addresses are used in the data network as binary patterns (0 and 1). Inside the devices, digital logic is applied for their interpretation

- For us in the human network, a string of 32 bits is difficult to interpret and even more difficult to remember.

- Therefore, IPv4 addresses are represented using dotted decimal format.

IP Address

- The address space in a protocol that uses N-bits to define an Address is 2n
- The address space of IPv4 is

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

- IPv6 addresses are 128 bits in length and are made up of hexadecimal characters.
- In IPv6, addresses are expressed as a series of eight 4-character hexadecimal numbers, which represent 16 bits each.

2001:0db8:85a3:0000:0000:8a2e:0370:7334

Dotted Decimal

- Binary patterns representing IPv4 addresses are expressed as dotted decimals by separating each byte of the binary pattern, called an octet, with a dot.
- It is called an octet because each decimal number represents one byte or 8 bits.

For example, the address:

10101100 00010000 00000100 00010100

is expressed in dotted decimal as:

172.16.4.20

Network Address and Host Address

- Some portion of the high-order bits represents the network address.
- At Layer 3, a network is a group of hosts that have identical bit patterns in the network address portion of their addresses.
- All 32 bits define the IPv4 host address, there are a variable number of bits that are called the host portion of the address.

Cont'd

- The number of bits used in this host portion determines the number of hosts that we can have within the network.

192.168.10.1

11000000 10101000 00001010 00000001

The computer using this network is on network address:

192.168.10.0

Binary to Decimal & Decimal to Binary Conversion

Positional Notation

- Positional notation means that a digit represents different values depending on the position it occupies.
- Using positional notation in the base 10 number system, 245 represents:

$$245 = (2 * 10^2) + (4 * 10^1) + (5 * 10^0)$$

or

$$245 = (2 * 100) + (4 * 10) + (5 * 1)$$

Cont'd

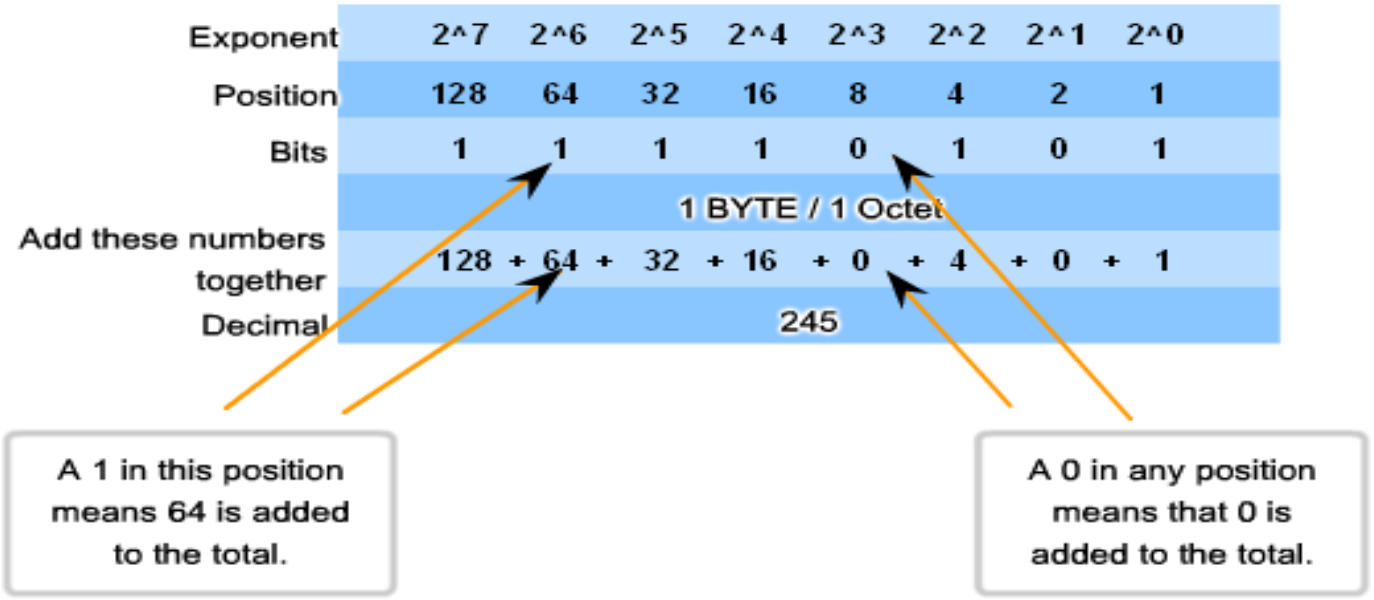
- Using positional notation in the base 2 number system, 245 represents:

$$2^7\ 2^6\ 2^5\ 2^4\ 2^3\ 2^2\ 2^1\ 2^0$$

$$128\ 64\ 32\ 16\ 8\ 4\ 2\ 1$$

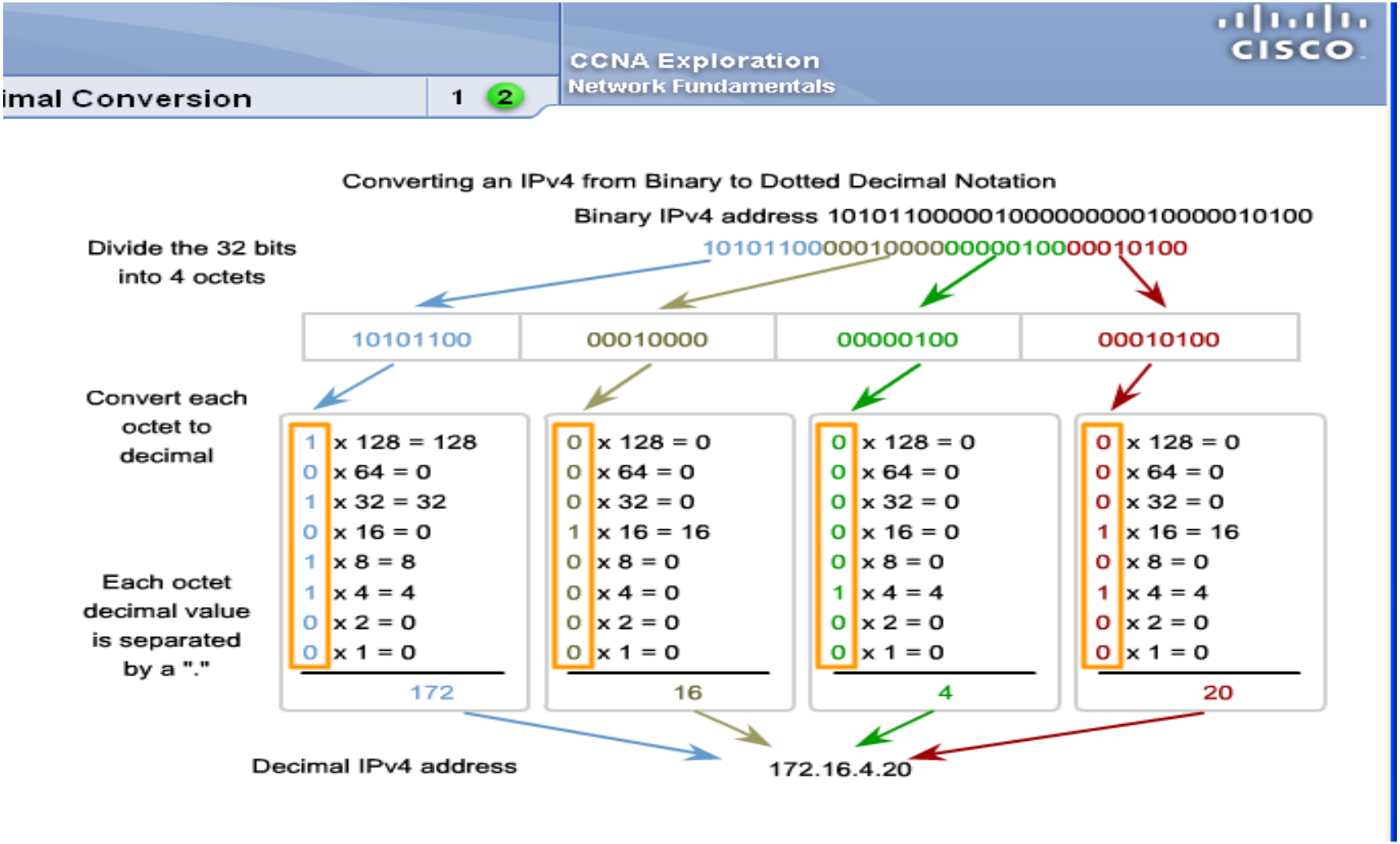
- The base 2 numbering system only has two digits: 0 and 1.
- A byte is interpreted as a decimal number, we have the quantity that position represents if the digit is a 1 and we do not have that quantity if the digit is a 0.

Binary To Decimal Conversion



11110101 in Binary = Decimal Number 245

Cont'd


imal Conversion
1
2
CCNA Exploration
Network Fundamentals
CISCO
Converting an IPv4 from Binary to Dotted Decimal Notation
Binary IPv4 address 10101100000100000000010000010100
Divide the 32 bits into 4 octets
10101100000100000000010000010100
10101100
00010000
00000100
00010100
Convert each octet to decimal
Each octet decimal value is separated by a "."
1 x 128 = 128
0 x 64 = 0
1 x 32 = 32
0 x 16 = 0
1 x 8 = 8
1 x 4 = 4
0 x 2 = 0
0 x 1 = 0
172
0 x 128 = 0
0 x 64 = 0
0 x 32 = 0
1 x 16 = 16
0 x 8 = 0
0 x 4 = 0
0 x 2 = 0
0 x 1 = 0
16
0 x 128 = 0
0 x 64 = 0
0 x 32 = 0
0 x 16 = 0
0 x 8 = 0
1 x 4 = 4
0 x 2 = 0
0 x 1 = 0
4
0 x 128 = 0
0 x 64 = 0
0 x 32 = 0
1 x 16 = 16
0 x 8 = 0
1 x 4 = 4
0 x 2 = 0
0 x 1 = 0
20
Decimal IPv4 address
172.16.4.20

Types of IP addresses

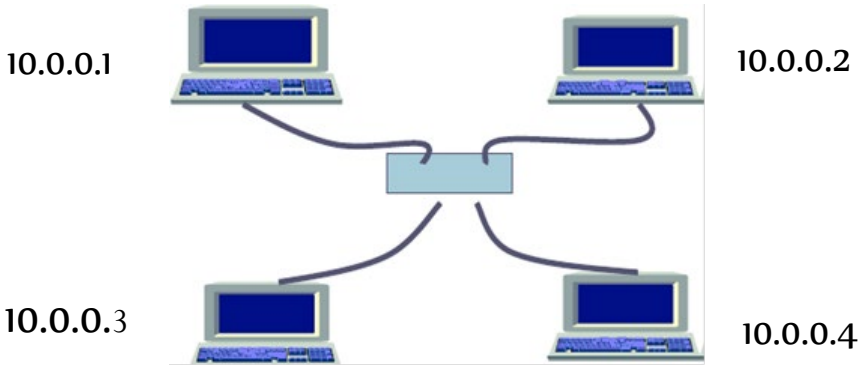
Within the address range of each IPv4 network, we have three types of addresses:

- **Network address**- The address by which we refer to the network
- **Broadcast address**- A special address used to send data to all hosts in the network
- **Host addresses**- The addresses assigned to the end devices in the network

Cont'd

Red Network Portion , Blue Host portion

- **Network Address:** 10.0.0.0
  00001010 00000000 00000000 00000000
- **Broadcast Address:** 10.0.0.255
  00001010 00000000 00000000 11111111
- **Host Address:** 10.0.0.1
  00001010 00000000 00000000 00000001



Network Addresses

- The network address is a standard way to refer to a network. For example, we could refer to the network shown in the figure as "the 10.0.0.0 network."
- The network is the first network.
- All hosts in the 10.0.0.0 network will have the same network bits.
- Within the IPv4 address range of a network, the *lowest address* is reserved for the network address.
- This address has a 0 for each host bit in the host portion of the address.

Broadcast Address

- Broadcast address is a special address for each network that allows communication to all the hosts in that network.
- To send data to all hosts in a network, a host can send a single packet that is addressed to the broadcast address of the network.
- The broadcast address uses the *highest address* in the network range. This is the address in which the bits in the host portion are all 1s.
- For the network 10.*0.0*.*0* with 24 network bits, the broadcast address would be 10.0.0.255. This address is also referred to as the directed broadcast.

Host Addresses

- Every end device requires a unique address to deliver a packet to that host.
- In IPv4 addresses, we assign the host address values between the network address and the broadcast address to the devices in that network.

Network Prefixes

- How do we know how many bits represent the network portion and how many bits represent the host portion?
- When we express an IPv4 network address, we add a *prefix length* to the network address.
- The *prefix length* is the number of bits in the address that gives us the *network portion*.
- For example, in 172.16.4.0 /24, the /24 is the prefix length - it tells us that the first 24 bits are the network address. This leaves the remaining 8 bits, the last octet, as the host portion

Network Prefixes

- The Subnet masks in 172.16.4.0 /24 can also be represented as 255.255.255.0 or

11111111 11111111 11111111 00000000

which is equivalent to /24

- Specify the network portion of an IPv4 address to the network devices.
- The subnet mask consists of 32 bits, just as the address does, and uses 1s and 0s to indicate which bits of the address are network bits and which bits are hosts bits.

Calculating Network, Host and Broadcast addresses

Given an 172.16.20.0 /25

- With a 25 bit prefix, the last 7 bits are host bits, and the 25 bits are for the network bits
- To represent the network address, all of these host bits are '0'.

Calculating Network, Host and Broadcast addresses

Given the address 172.16.20.0 /25

Network address:

10101100 00010000 00010100 00000000 thus 172.16.20.0

First host address:

10101100 00010000 00010100 00000001 thus 172.16.20.1

Last host address

10101100 00010000 00010100 01111110 thus 172.16.20.126

Broad Cast address:

10101100 00010000 00010100 01111111 thus 172.16.20.127

Cont'd

- How many hosts can be represented in this network /24?

$$2^8-2 = 126$$

- The minus two is because one is for network address and the other is for broadcast address.

Given the address 191.30.168.213/29 calculate the BA,NA,HA and number of hosts represented?

Classful IP Addressing

- The designers of the Internet created classes of networks based on network size.

- Subdividing an IP address into a network and node address is determined by the class designation of one's network.

Classful Addressing

- The 32 bit IP address is divided into five sub-classes. These are:
  - Class A addresses
  - Class B addresses
  - Class C addresses
  - Class D addresses
  - Class E addresses

Class A Addresses

- The designers of the IP address scheme said that the first bit of the first byte in a Class A network address must always be off, or 0.
- This means a Class A address must be between 0 and 127, inclusive.

First Octet **Range in Binary= 0**0000000 - **0**1111111

Range in Decimal = 0-127

- A Class A network is defined in the first octet between 0 and 127,
- **Network** HOST HOST HOST
- Default Subnet 255.0.0.0
- The 24 bits of host ID are used to determine the host in any network.
- 2^7-2= 126 network ID (Here 2 address is subtracted because 0.0.0.0 and 127.x.y.z are special address.)
- $2^{24} - 2 = 16,777,214$ host ID
- IP addresses belonging to class A ranges from 1.x.x.x – 126.x.x.x

Class B Addresses

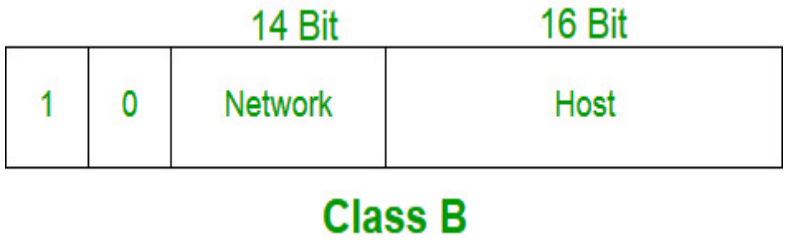
- The first bit of the first byte must always be turned on, but the second bit must always be turned off.
- If you turn the other 6 bits all off and then all on, you will find the range for a Class B network:

First Octet

10000000 = 128

10111111 = 191

- A Class B network is defined when the first byte is configured from 128 to 191.
- Network Network HOST HOST
- Default Subnet 255.255.0.0
- 2^{14} = 16384 network address
- $2^{16} - 2$ = 65534 host address



Class C Addresses

- The first 2 bits of the first octet as always turned on, but the third bit can never be on.
- Following the same process as the previous classes, convert from binary to decimal to find the range.

First Octet

11000000 = 192

11011111 = 223

NETWORK NETWORK NETWORK HOST

Default Subnet 255.255.255.0

- 2^{21} = 2097152 network address
- $2^{8} - 2$ = 254 host address

- Show that Class A *has*

$$2^{31} = 2{,}147{,}483{,}648 \text{ addresses}$$

50% of the IP addresses are used by class A

- Calculate the total IP address generated in Class B

2^n n=?

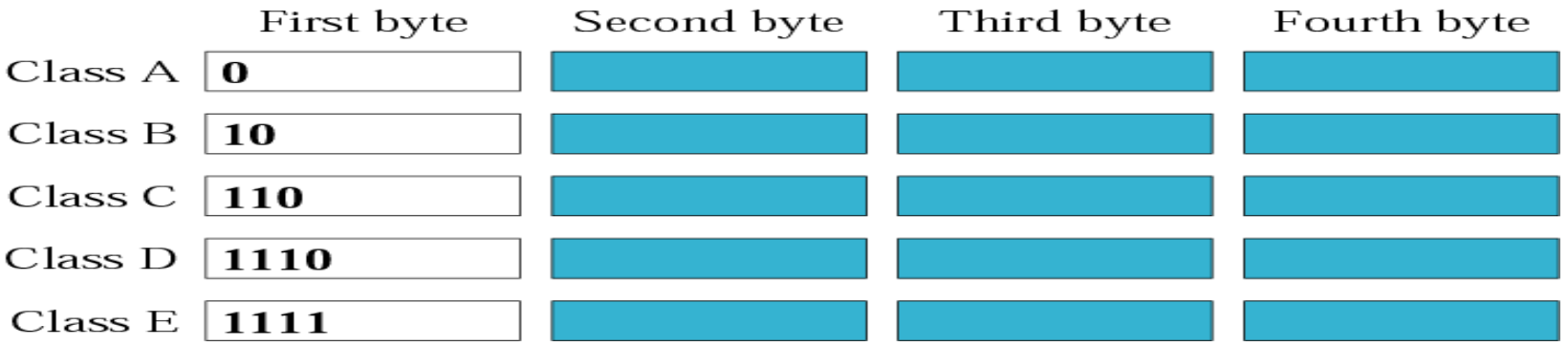
- Calculate the total IP address generated in Class C

2^n n=?

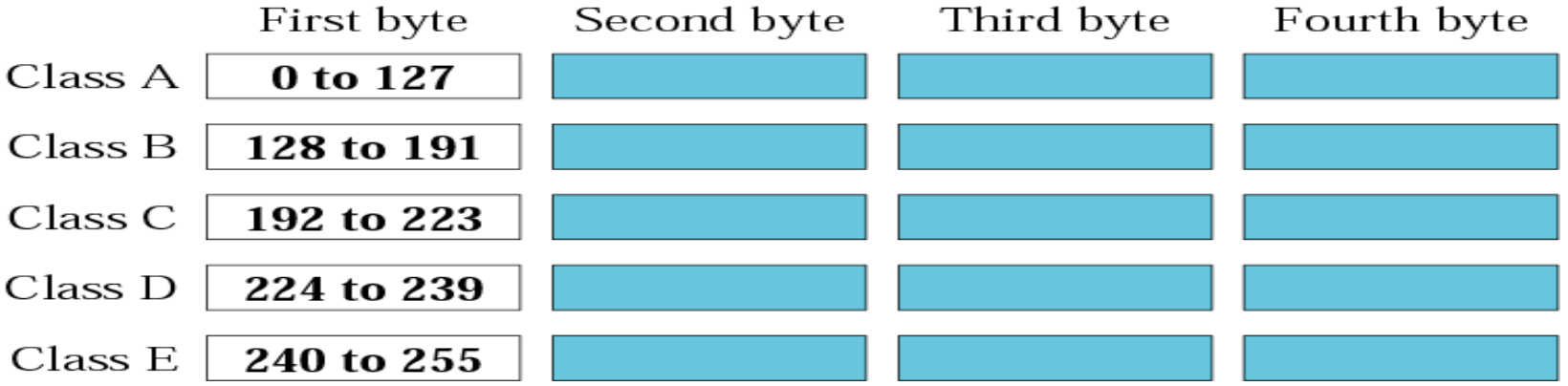
Class D and Class E

- The addresses between 224 and 255 are reserved for Class D and E networks.
- Class D ranges from (224–239) is used for multicast addresses
- Class E ranges from (240–255) for scientific purposes.

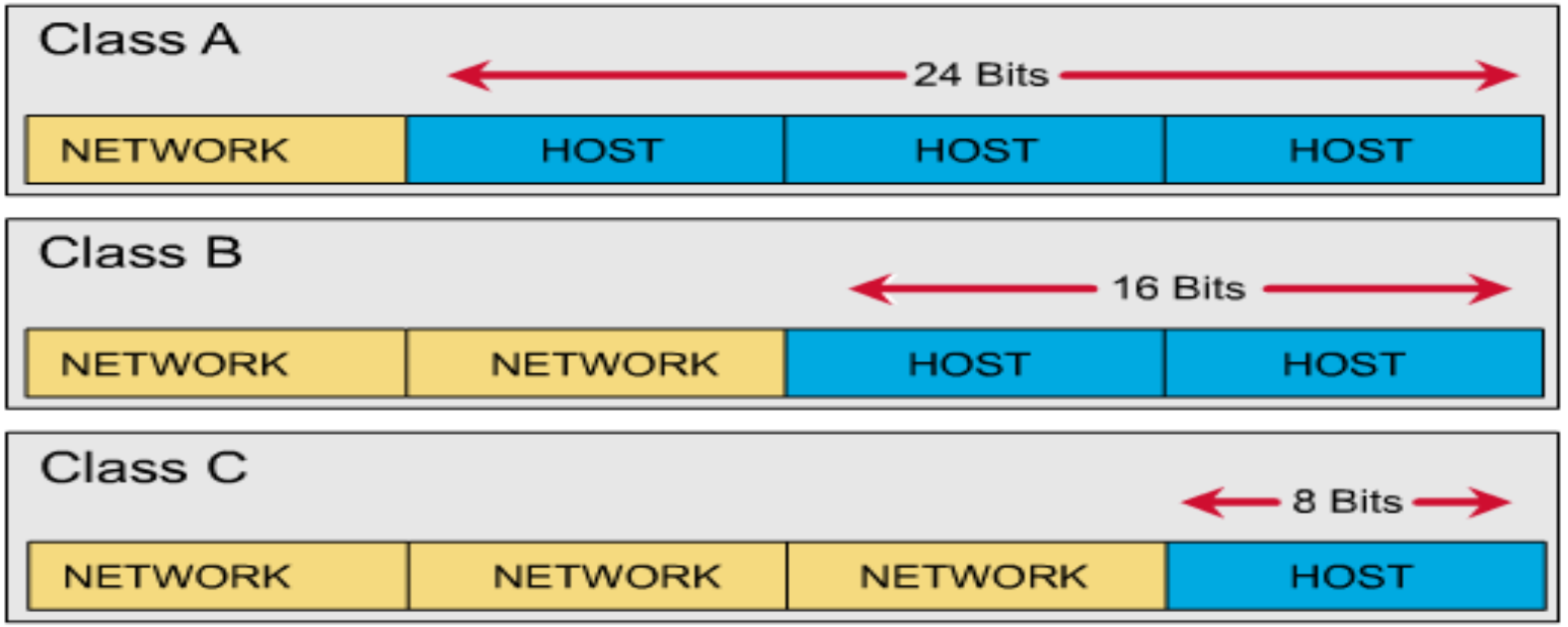
Finding the class in Binary notation



Finding the class in decimal notation



Hosts for Classes of IP Addresses

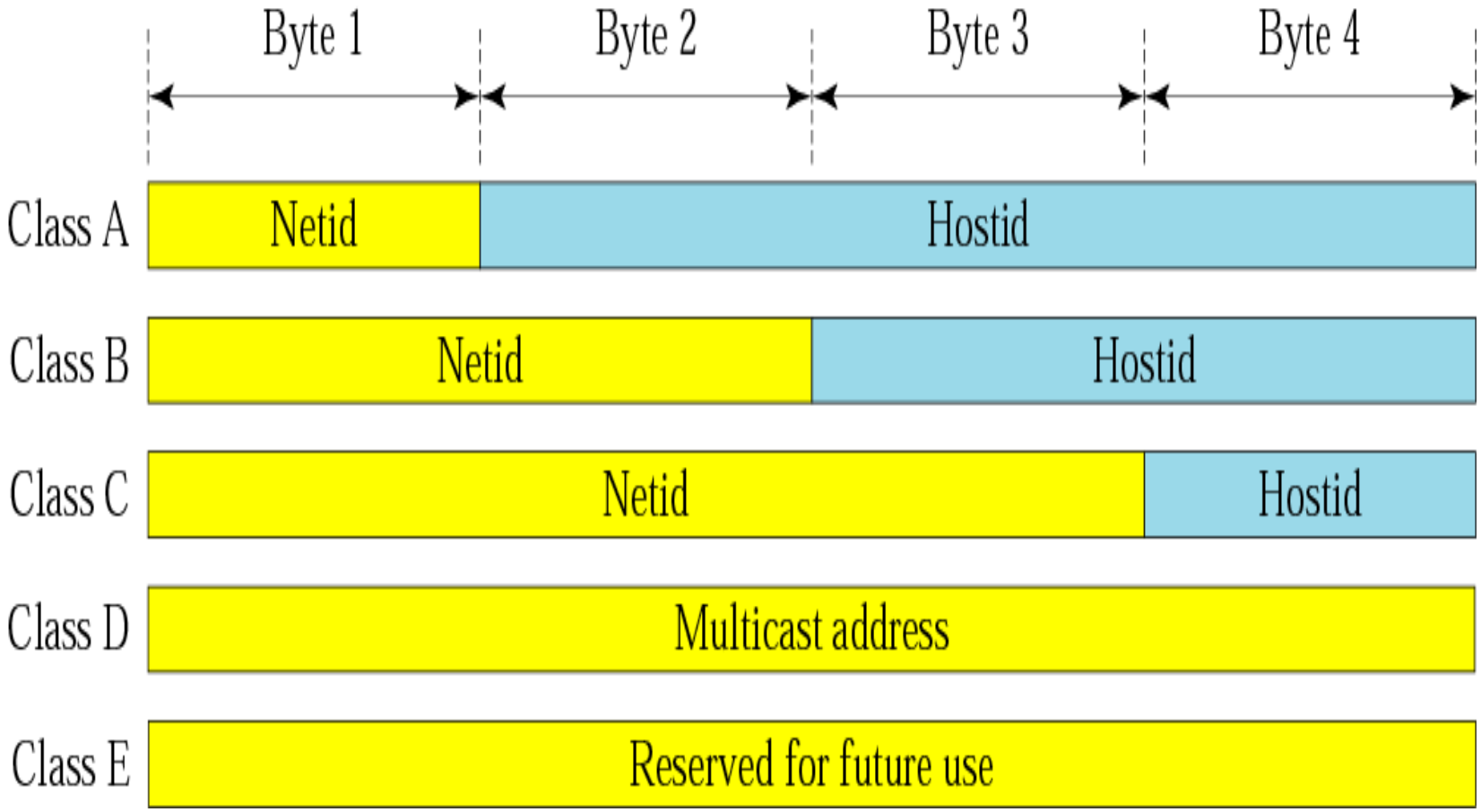


Class A (24 bits for hosts) $2^{24} - 2^{*} = 16{,}777{,}214$ maximum hosts

Class B (16 bits for hosts) $2^{16} - 2^{*} = 65{,}534$ maximum hosts

Class C (8 bits for hosts) $2^{8} - 2^{*} = 254$ maximum hosts

Network id and Host id



IP Addresses as Decimal Numbers

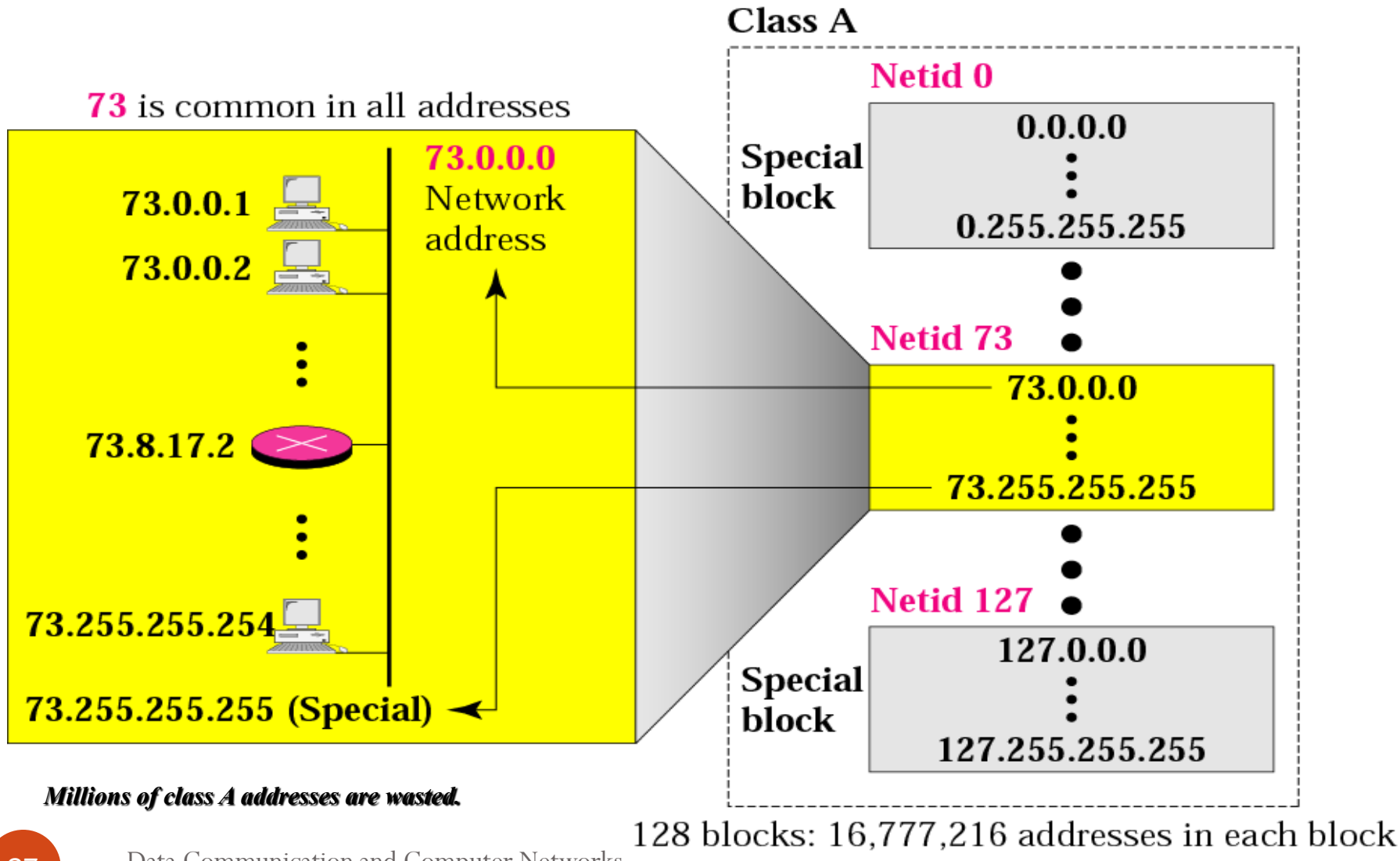
Class	Starts with	Binary range	Decimal Value range	Maximum subnets	Maximum hosts	Routing mask
A	0	00000000-01111111	0-127*	127	16,777,214	255.0.0.0
B	10	10000000-10111111	128-191	16,384	65,534	255.255.0.0
C	110	11000000-11011111	192-223	2,097,152	254	255.255.255.0
D	1110	11100000-11101111	224-239			
E	1111	11110000-11111111	240-255			

* The 0 octet is forbidden in the RFC, and 127 is reserved for loopback testing.

IP Addresses as Decimal Numbers

CLASS	1ST OCTET RANGE	Highest Order Bit HOB	Format	Default Subnet mask		
A	1-126	0-------	N.H.H.H	255.0.0.0		
B	128-191	10------	N.N.H.H	255.255.0.0		
C	192-223	110-----	N.N.N.H	255.255.255.0		
D	**224-239**	**1110----**	**-------**	**-------**		
E	**240-255**	**1111----**	**-------**	**-------**		

Blocks in class A



Millions of class A addresses are wasted.

Reserved IP addresses

- Expressed in dotted decimal format, the IPv4 address range is from:

0.0.0.0 to 255.255.255.255

- Not all of these addresses can be used as host addresses for communication.

Experimental Addresses

- Class E addresses reserved for special purposes is the IPv4 experimental address range from:

  240.0.0.0 to 255.255.255.254

- Currently, these addresses are listed as reserved for future use.
- Currently, they cannot be used in IPv4 networks. However, these addresses could be used for research or experimentation.

Multicast Addresses

- Another major block of addresses (Class D) reserved for special purposes is the IPv4 multicast address range:

  224.0.0.0 to 239.255.255.255

- The IPv4 multicast addresses 224.0.0.0 to 224.0.0.255 are reserved link local addresses.
- These addresses are to be used for multicast groups on a local network.
- A router connected to the local network should never forward them.
- A multicast address identifies a group of hosts sharing the same address.

Host Addresses

- After accounting for the ranges reserved for experimental addresses and multicast addresses, this leaves an address range of 0.0.0.0 to 223.255.255.255 that could be used for IPv4 hosts.
- However, within this range are many addresses that are already reserved for special purposes.

Private Addresses

- Although most IPv4 host addresses are public addresses designated for use in the Internet, there are blocks of addresses that are used in networks that require limited or no Internet access.
- These addresses are called private addresses.
  - 10.0.0.0 to 10.255.255.255
  - 172.16.0.0 to 172.31.255.255
  - 192.168.0.0 to 192.168.255.255

Private Addresses

- Private addresses are set aside for use in private networks.
- The use of these addresses need not be unique among outside networks.
- Hosts that do not require access to the Internet at large may make unrestricted use of private addresses.
- Private IP address of a system is the IP address which is used to communicate within the same network.
- Using private IP data or information can be sent or received within the same network.

Public Addresses

- The vast majority of the addresses in the IPv4 unicast host range are public addresses.
- **Public IP address** of a system is the IP address which is used to communicate outside the network.
- Public IP address is basically assigned by the ISP (Internet Service Provider)
- These addresses are designed to be used in the hosts that are publicly accessible from the Internet.

Loopback / localhost

- One such reserved address is the IPv4 loopback address 127.0.0.1.
- The loopback is a special address that hosts use to direct traffic to themselves.
- You can also ping the loopback address to test the configuration of TCP/IP on the local host.

Ex. Given the network address 132.21.0.0, find

the class

the block

the range of the addresses

- The 1st byte is between 128 and 191. Hence, Class B
- The block has a netid of 132.21.
- The addresses range from 132.21.0.0 to 132.21.255.255.

Subnet Mask

- It determines which part of an IP address is the network field and which part is the host field
- Follow these steps to determine the subnet mask:
  1. Express the subnetwork IP address in binary form.
  2. Replace the network and subnet portion of the address with all 1s.
  3. Replace the host portion of the address with all 0s.
  4. Convert the binary expression back to dotted-decimal notation.

Subnet Mask

11111111.11111111.11110000.00000000

Class B Network
16 bits for the Network
4 bits for the Subnetwork
12 bits for the Host

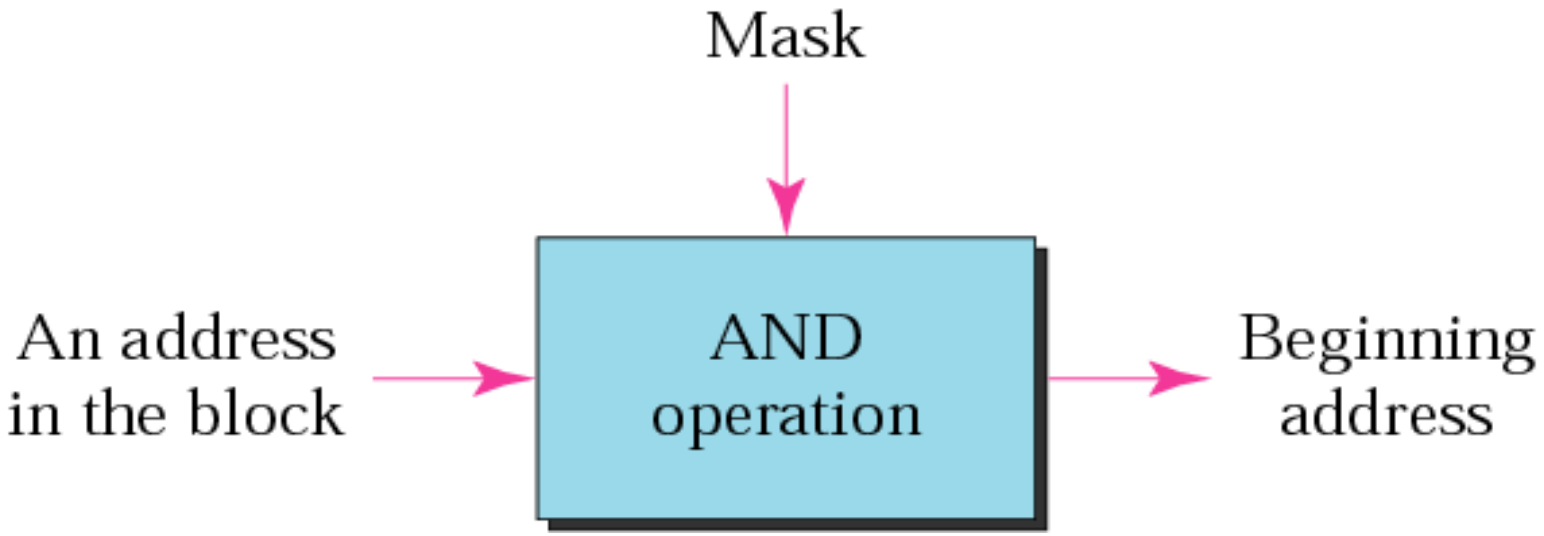
Subnet mask in decimal = 255.255.240.0

- 32 bits long
- Divided into four octets
- Network and subnet portions all 1's
- Host portion all 0's

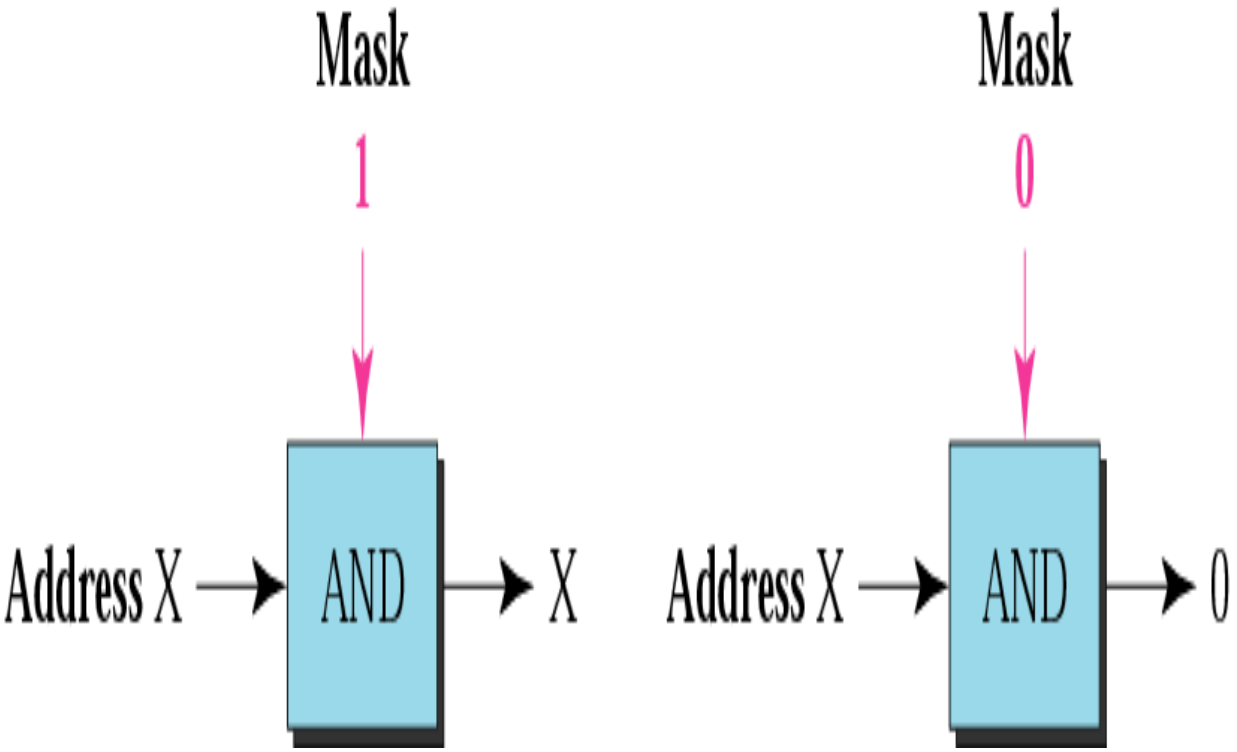
Subnet Mask

- A mask is a 32-bit binary number.
- The mask is ANDed with IP address to get the block address (Network address)

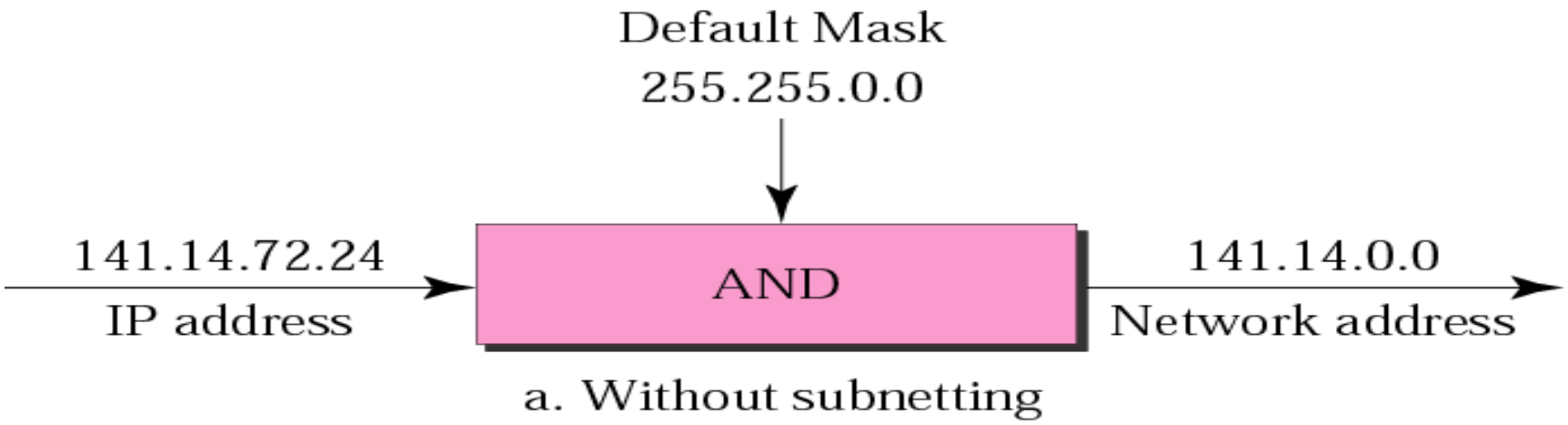
Mask And IP address = Block Address



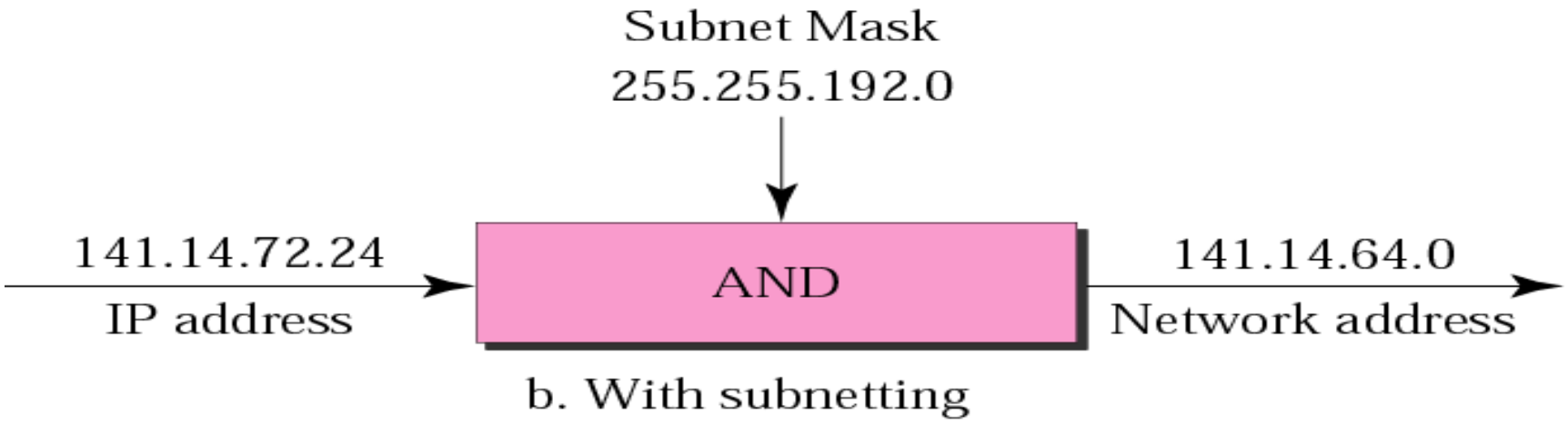
AND operation



Default mask and subnet mask



a. Without subnetting



b. With subnetting

Finding the Subnet Address

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

- 11001000 00101101 00100010 00111000
- 11111111 11111111 11110000 00000000
- 11001000 00101101 00100000 00000000

The subnetwork address is 200.45.32.0.

1. 192.168.3.55/24
   - What is the subnet mask?
   - What is the network address?
2. 192.168.3.55/28
   - What is the subnet mask?
   - What is the network address?
   - What is the broadcast address?

Subnetting

- Subnetting allows you to create multiple logical networks that exist within a single Class A, B, or C network.
- If you do not subnet, you are only able to use one network from your Class A, B, or C network, which is unrealistic.
- What happens if you wanted to take one network address and create six networks from it?

Subnetting

- The process of splitting a network into smaller networks is called subnetting, and the smaller networks thus formed are known as subnets
- If you break a major network (Class A, B, or C) into smaller subnetworks, it allows you to create a network of interconnecting subnetworks.
- In order to subnet a network, extend the subnet mask using some of the bits from the host ID portion of the address to create a subnetwork ID.

Subnetting

- Subnets are connected to the rest of the network through address-resolving devices called routers.
- Network address translation (**NAT**) is a method of remapping one IP address space into another by modifying network address information in the IP header of packets while they are in transit across a traffic routing device
- Subnets can be freely assigned within the organization
  - Internally, subnets are treated as separate networks
  - Subnet structure is not visible outside the organization

Advantages of Subnetting

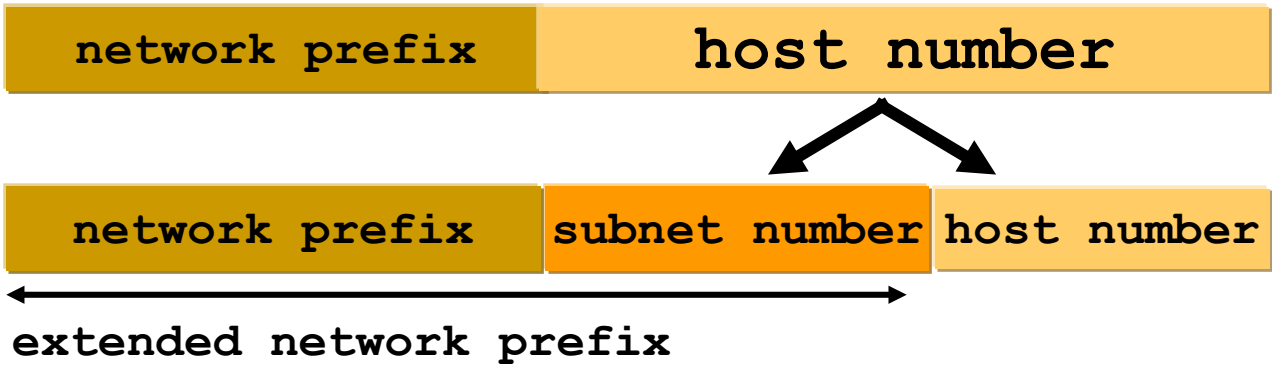
- Improves efficiency of IP addresses by not consuming an entire address space for each physical network.
- Reduces router complexity. Since external routers do not know about subnetting, the complexity of routing tables at external routers is reduced.
- Reduced network traffic
- Optimized network performance
  - This is a result of reduced network traffic.
- Simplified management
  - It's easier to identify and isolate network problems in a group of smaller connected networks than within one gigantic network

How to create subnets

- To create a subnet address, a network administrator borrows bits from the original host portion and designates them as the subnet field.
- A network with no subnets will have one of these default subnet mask values depending upon its class address.
- However, when subnetting is implemented, the actual subnet mask value is calculated to determine valid IP addresses for hosts on a subnet.
- This means fewer bits for hosts, so the more subnets, the fewer bits available for defining hosts.

Basic Idea of Subnetting

- Split the host number portion of an IP address into a **subnet number** and **host number**.
- Result is a 3-layer hierarchy



Subnetting Example

193.16.4.0 /24 divide it into four networks

First Subnet

- 00 000000 = 0 The network (do this first)
- 00 000001 = 1 The first valid host
- 00 111110 = 62 The last valid host
- 00 111111 = 63 The broadcast address (do this second)

Second Subnet

- 01 000000 = 64 The network
- 01 000001 = 65 The first valid host
- 01 111110 = 126 The last valid host
- 01 111111 = 127 The broadcast address

Third Subnet

- 10 000000 = 128 The subnet address
- 10 000001 = 129 The first valid host
- 10 111110 = 190 The last valid host
- 10 111111 = 191 The broadcast address

Fourth Subnet

- 11 000000 = 192 The subnet address
- 11 000001 = 193 The first valid host
- 11 111110 = 254 The last valid host
- 11 111111 = 255 The broadcast address

Exercise 1:

Exercise 1:

You have a network that needs 29 subnets while maximizing the number of host addresses available on each subnet.

How many bits must you borrow from the host field to provide the correct subnet mask?

Exercise 2:

- A company is granted the site address 201.70.64.0 (class C). The subnet mask is 255.255.255.224.

1. How many subnets?
2. How many total hosts in each subnet?
3. What are the Network address for each subnet?
4. What are the range of valid hosts in each subnet?
5. What are the Broadcast address for each subnet?

Exercise 3:

172.16.0.0

255.255.255.224

1. how many subnets?
2. how many hosts?
3. what are the network address of each subnet?
4. what are the broadcast address for each subnet?
5. what are the valid hosts?

Exercise 4:

- If an Ethernet port on a router were assigned an IP address of 172.16.112.1/25, what would be the valid subnet address of this host?

A. 172.16.112.0

B. 172.16.0.0

C. 172.16.96.0

D. 172.16.255.0

Exercise 5:

- If an Ethernet port on a router were assigned an IP address of 172.16.112.1/25, what would be the valid subnet address of this host?

A. 172.16.112.0

B. 172.16.0.0

C. 172.16.96.0

D. 172.16.255.0

Exercise 6:

A company would like to break its Class B private IP address 172.16.0.0 into as many subnets as possible provided that they can get at least 300 clients per subnet. Find ranges of IP addresses for each subnet and new mask.

Exercise 7:

A company is granted the site address 181.56.0.0 (class B). The company needs 1000 subnets. Design the subnets.