Chapter 4
Network Devices and IP Address

4.1 Network Devices

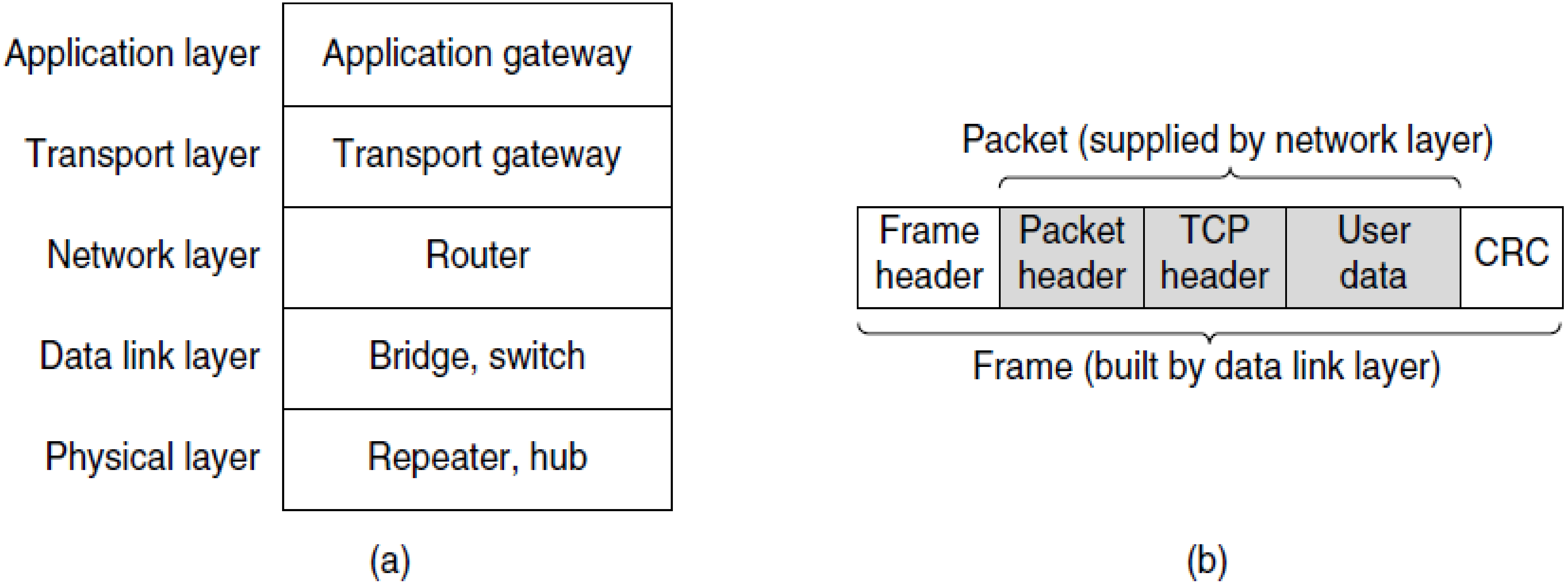
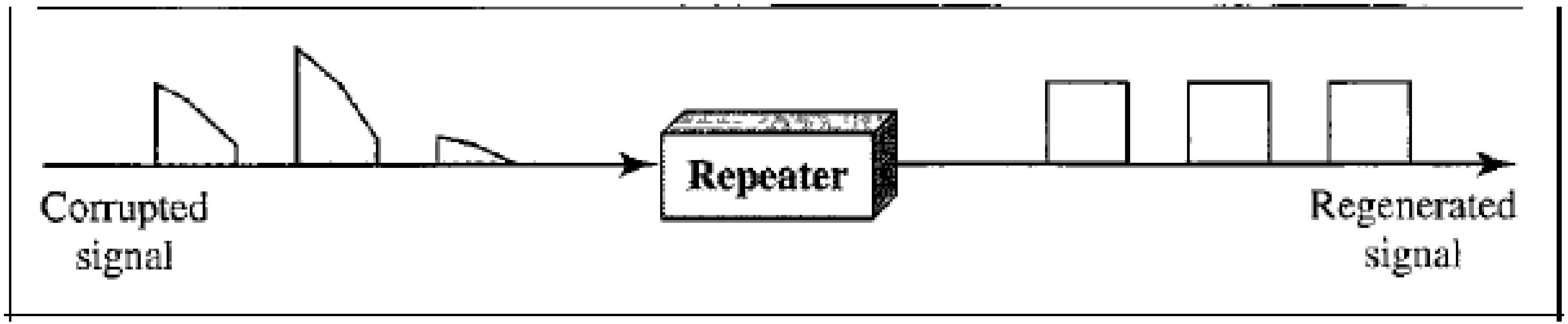


Figure 4-45. (a) Which device is in which layer. (b) Frames, packets, and headers.

4.1 Network Devices

Repeater

- A repeater is a device that operates only in ***the physical layer***. Signals that carry information within a network can travel a fixed distance before attenuation endangers the integrity of the data.
- A repeater receives a signal and, before it becomes too weak or corrupted, regenerates the original bit pattern. The repeater then sends the refreshed signal.
- A repeater can extend the physical length of a LAN.



b. Left-to-right transmission.

4.1 Network Devices

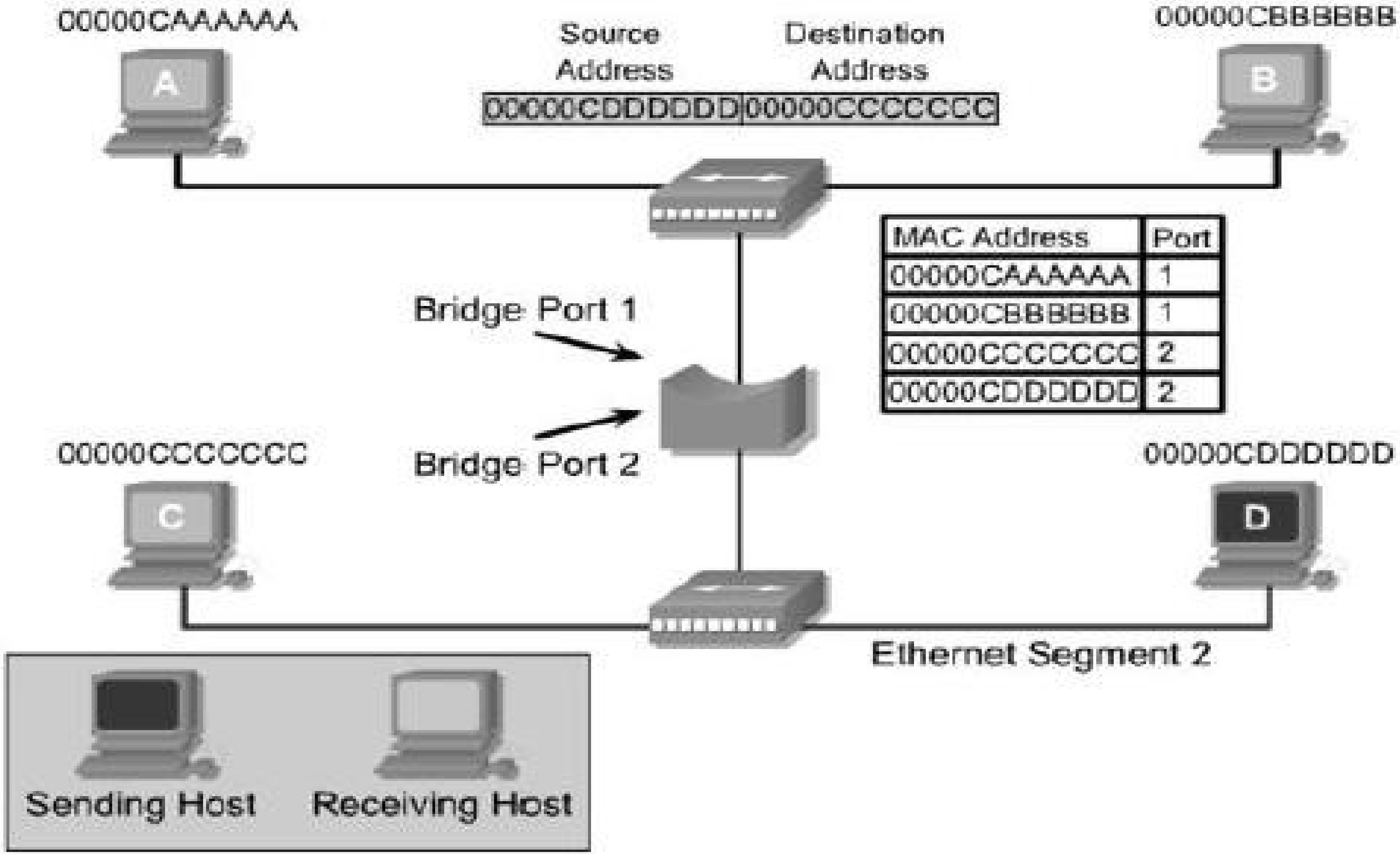
Hubs

- Hubs are used to build a LAN by connecting different computers in a star/hierarchal network topology.
- A hub is a very simple (or dumb) device, once it gets bits of data sent from computer A to B, it does not check the destination, instead, it forwards that signal to all other computers (B, C, D…) within the network. B will then pick it up while other nodes discard it.
- Hubs differ from repeaters in that they do not (usually) amplify the incoming signals and are designed for multiple input lines.
- Like repeaters, hubs are physical layer devices that do not examine the link layer addresses.
- *There are mainly two types of hubs:*
  1) **Passive:** The signal is forwarded as it is (so it doesn't need power supply). A passive hub is just a connector. It connects the wires coming from different branches. Its location in the Internet model is *below the physical layer.*
  2) **Active:** The signal is amplified, so they work as repeaters. In fact they have been called **multiport repeaters.**

4.1 Network Devices

Bridges

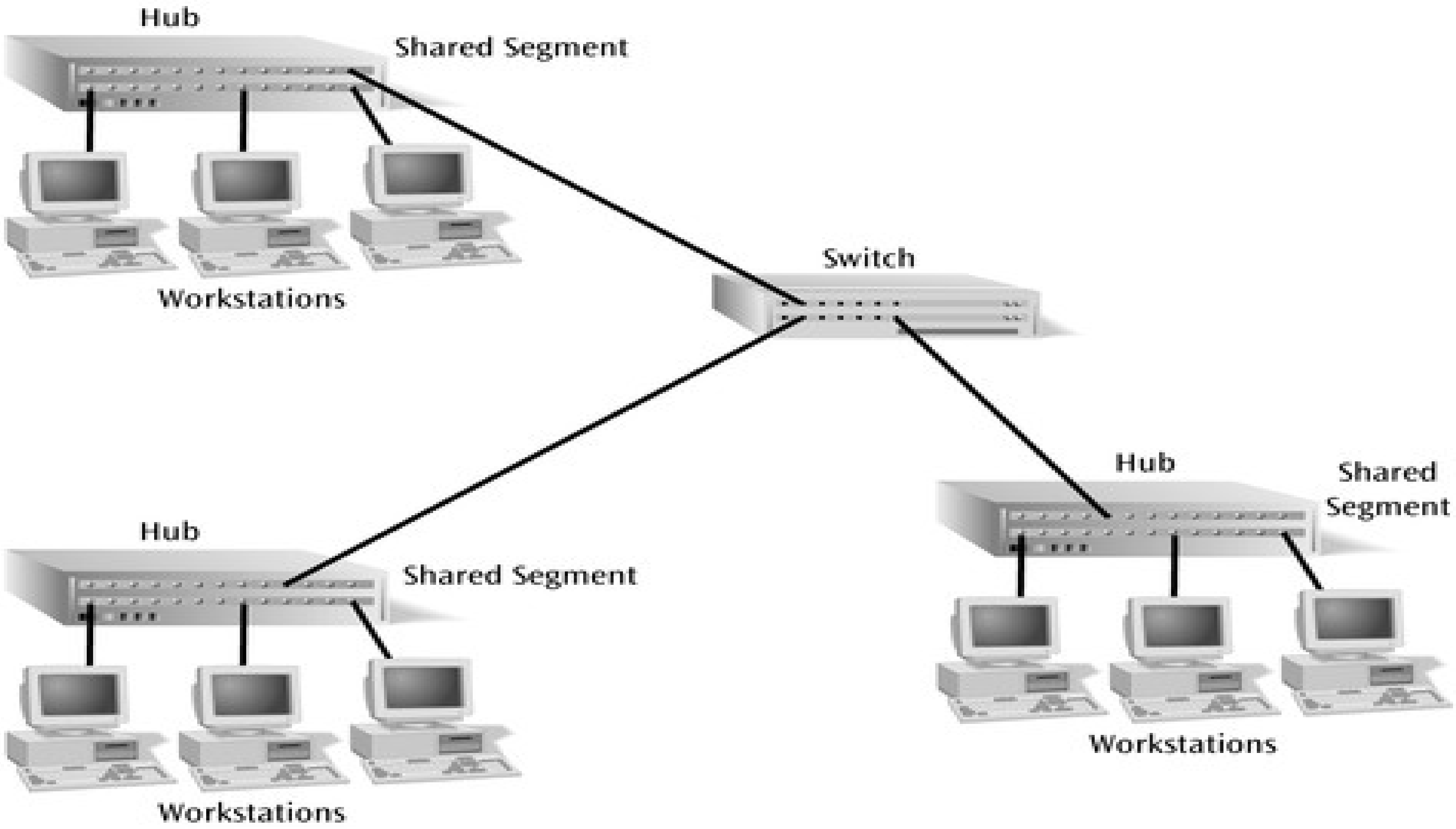
- Bridge connects two or more LANs. Like a hub, a modern bridge has multiple ports.
- Unlike in a hub, each port is isolated to be its own collision domain; if the port has a full-duplex point-to-point line, the CSMA/CD algorithm is not needed.
- When a frame arrives, the bridge extracts the destination address from the frame header and looks it up in a table to see where to send the frame.
- As a data link layer device, the bridge can check the physical (MAC) addresses (source and destination) contained in the frame.
- Bridges offer much better performance than hubs, and the isolation between bridge ports also means that the input lines may run at different speeds.
- In a comparison with switches, bridges are slower because they use software to perform switching. They do not control broadcast domains and usually come with less number of ports.
- **Multiport bridges are generally termed as switch.**


00000CAAAAAA
Source Address
Destination Address
00000CDDDDDD
00000CCCCCCC
00000CBBBBBB
A
B
MAC Address
Port
00000CAAAAAA
1
00000CBBBBBB
1
00000CCCCCCC
2
00000CDDDDDD
2
Bridge Port 1
Bridge Port 2
00000CCCCCCC
00000CDDDDDD
C
D
Ethernet Segment 2
Sending Host
Receiving Host

4.1 Network Devices

Switches

- **Switches** on the other hand are more advanced. Instead of broadcasting the frames everywhere, a switch actually checks for the destination MAC address and forwards it to the relevant port to reach that computer only. Switches reduce traffic and divide the collision domain into segments.
- They build a table of which MAC address belongs to which segment. If a destination MAC address is not in the table it forwards to all segments except the source segment. If the destination is same as the source, frame is discarded.
- Switches have built-in hardware chips solely designed to perform switching capabilities, therefore they are fast and come with many ports. Sometimes they are referred to as intelligent bridges or multiport bridges.
- Most common switching methods are:
  1) **Cut-through**: Directly forward what the switch gets.
  2) **Store and forward**: receive the full frame before retransmitting it.
- Normal Switches are on the data link layer , that’s why they deal with frames instead of bits and filter them based on MAC addresses.
- Intelligent switches works as a router.

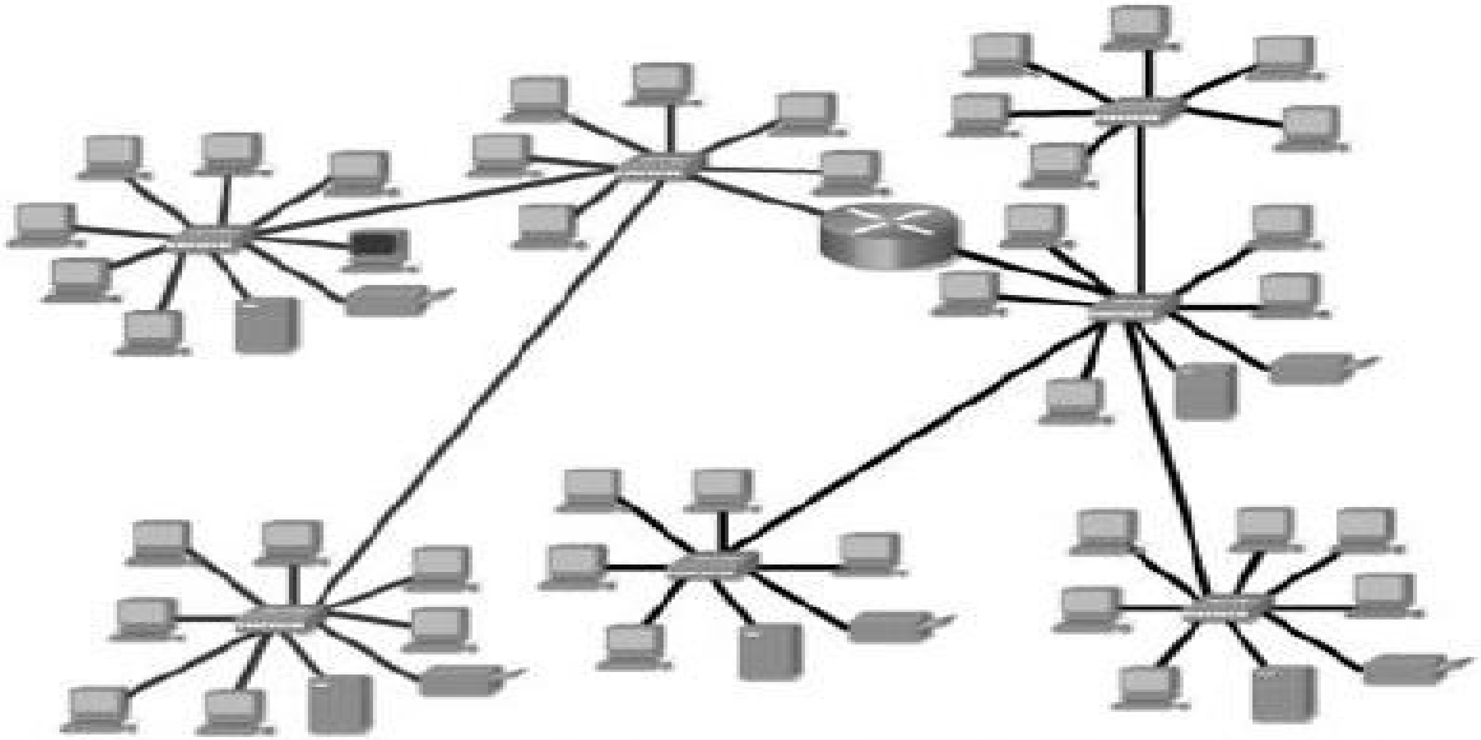

Hub
Shared Segment
Workstations
Switch
Hub
Shared Segment
Workstations
Hub
Shared
Segment
Workstations

4.1 Network Devices

Routers

- A router is a three-layer device that routes packets based on their logical addresses (host-to-host addressing).
- Routers are used to connect different LANs or a LAN with a WAN (e.g. the internet) and has a routing table that is used for making decisions about the route.
- Routers control both collision domains and broadcast domains. If the packet's destination is on a different network, a router is used to pass it the right way, so without routers, the internet could not functions.
- The routing tables are normally dynamic and are updated using routing protocols.
- A router is a special type of computer. It has the same basic components as a standard desktop PC. It has a CPU, memory, a system bus, and various input/output interfaces.

Router



By using a router in place of a bridging device a Layer 2 broadcast is contained. Layer 3 devices are the only devices that contain broadcasts.

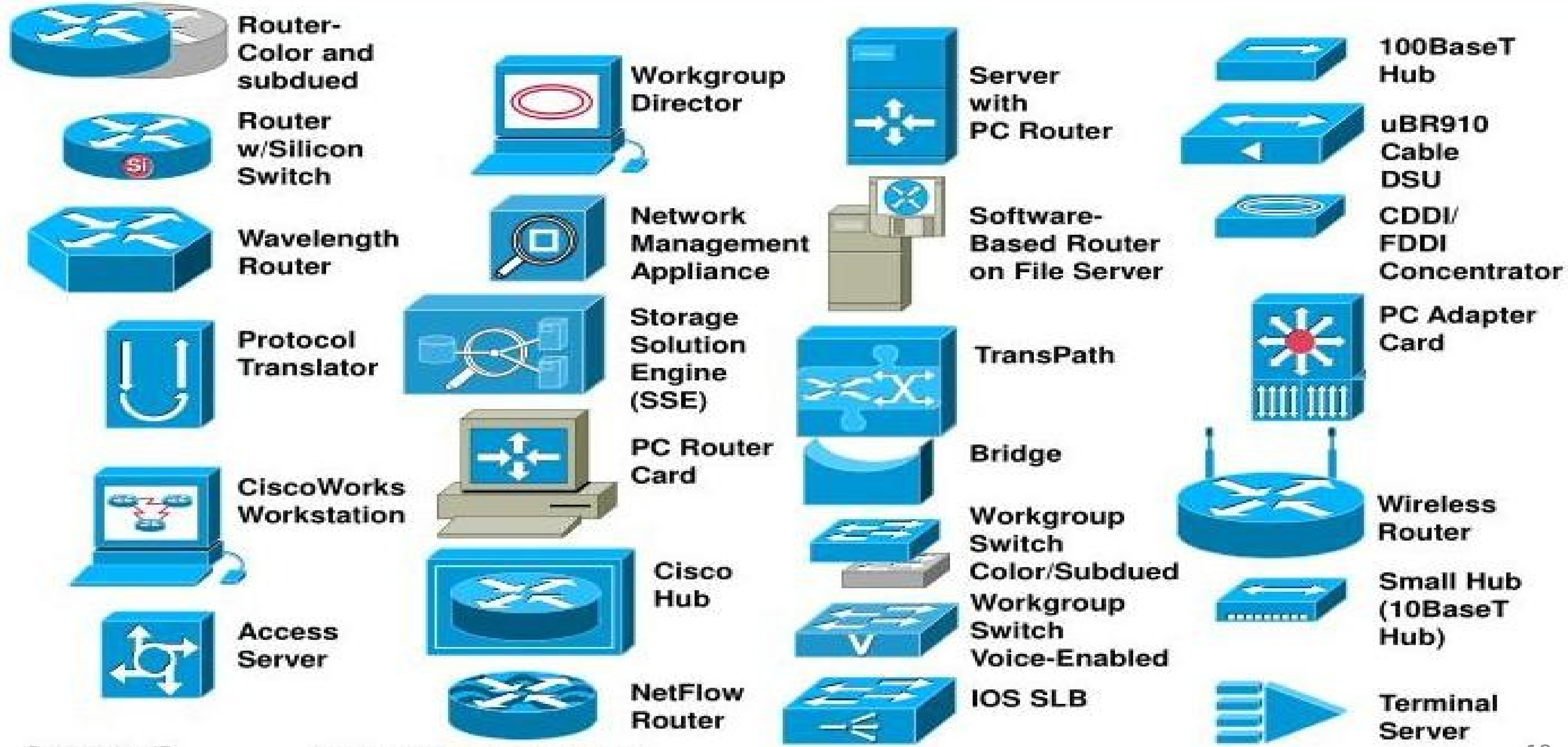
4.1 Network Devices

Gateways

- Gateways are very intelligent devices or else can be a computer running the appropriate software to connect and translate data between networks with different protocols or architecture, so their work is much more complex than a normal router.
- For example, suppose a computer using the connection-oriented TCP/IP protocol needs to talk to a computer using a different connection-oriented transport protocol called SCTP. The transport gateway can copy the packets from one connection to the other, reformatting them as need be.
- For example, application gateways understand the format and contents of the data and can translate messages from one format to another. An email gateway could translate Internet messages into SMS messages for mobile phones.
- A gateway links two systems that do not use the same:
  - *Communication protocols, Data formatting structures, Languages, and Architecture*

Icons: Cisco Products

Cisco.com



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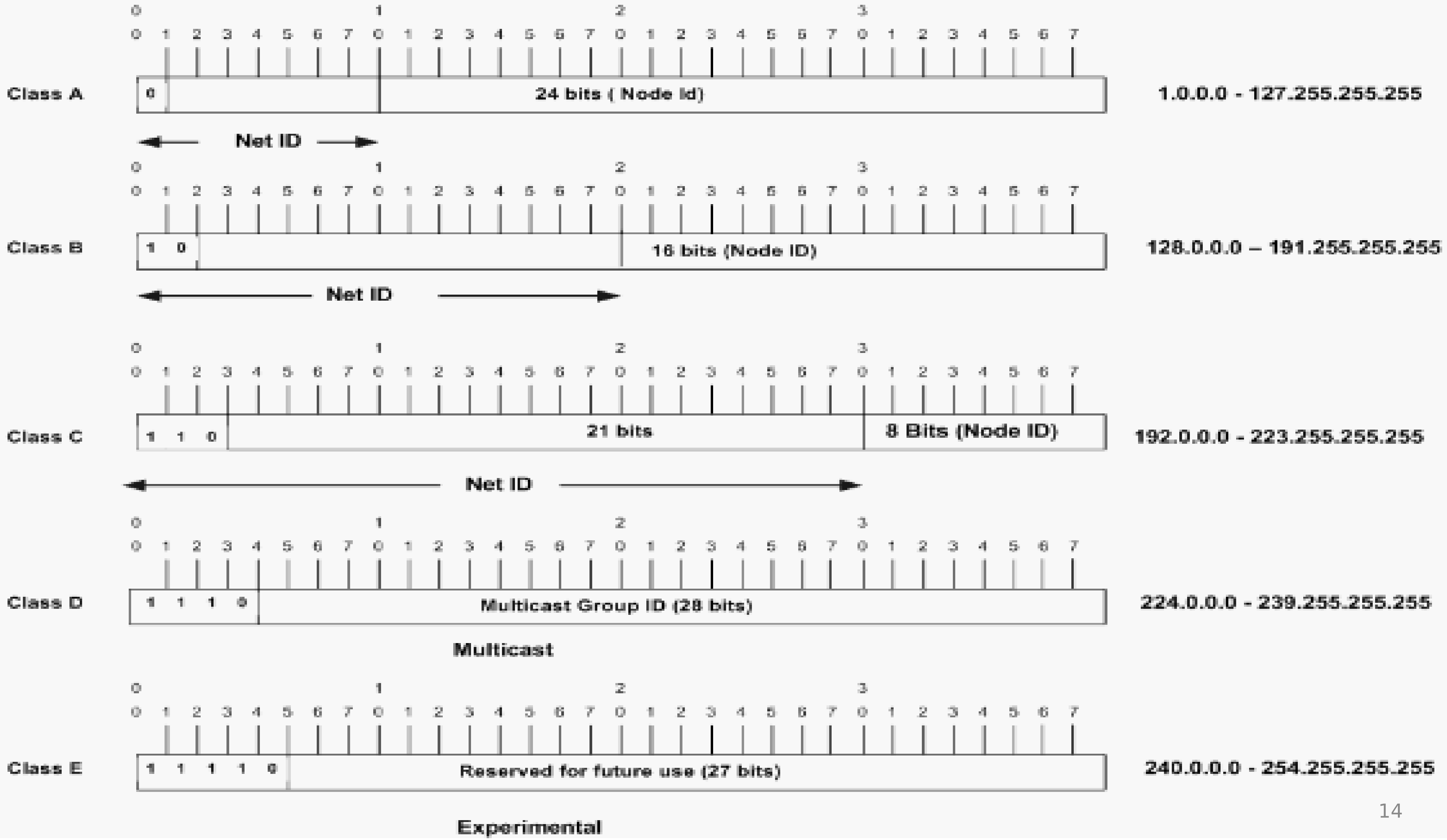
IP Address

- 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 32 binary bits are broken into four octets (1 octet = 8 bits). Each octet is converted to decimal and separated by a period (dot).
- For this reason, an IP address is said to be expressed in dotted decimal format (for example, 172.16.81.100). The value in each octet ranges from 0 to 255 decimal, or 00000000 - 11111111 binary.
- IPv4 addressing, at its inception, used the concept of classes. This architecture is called ***classful addressing.***
- *In classful addressing, the address space is divided into five classes: A, B, C, D, and E.*
- In common usage, the first address is a subset, ***all binary zero*** in the host identifier, is reserved for referring to ***network itself***, while the last address, ***all binary one*** in the host identifier, is used as a ***broadcast address*** for the network; this ***reduces the number of addresses available for hosts by 2.***


Class A
0
24 bits (Node Id)
1.0.0.0 - 127.255.255.255
Net ID
Class B
1 0
16 bits (Node ID)
128.0.0.0 – 191.255.255.255
Net ID
Class C
1 1 0
21 bits
8 Bits (Node ID)
192.0.0.0 - 223.255.255.255
Net ID
Class D
1 1 1 0
Multicast Group ID (28 bits)
224.0.0.0 - 239.255.255.255
Multicast
Class E
1 1 1 1 0
Reserved for future use (27 bits)
240.0.0.0 - 254.255.255.255
Experimental

Classful IP Address

Class A

- *N.H.H.H*
- Number of Network = 2^7
- Number of Host per Network

  = 2^{24} - 2= 16,777,214
- Network range 1.0.0.0 to

  127.255.255.255
- Default Subnet Mask = 255.0.0.0
- Private Network = 10.0.0.0 to

  10.255.255.255
- Loop back address 127.x.x.x

Class B

- *N.N.H.H*
- Number of Network = 2^{14} - 2= 16,382
- Number of Host per Network

  = 2^{16} - 2= 65,534
- Network range 128.0.0.0 to

  191.255.255.255
- Default Subnet Mask = 255.0.0.0
- ***Private Network= 172.16.0.0 to***

  172.16.255.255

Classful IP Address

👎 Class C

- ***N.N.N.H***
- Number of Network = 2^{21} - 2
- Number of Host per Network
  = 2^{8} - 2=254
- Network range 192.0.0.0 to
  223.255.255.255
- Default Subnet Mask = 255.255.255.0
- Private Network = ***192.168.0.0 to***
  192.168.255.255

👎 Class D

- Reserved for Multicasting
- Network range 224.0.0.0 to
  239.255.255.255

👎 Class E

- Used for experimental address not available for the public.
- Network range 240.0.0.0 to
  255.255.255.255

Subnet mask

- A subnet mask is a 32 bits number that masks an IP address, and **divides the IP** address into **Network address and Host Address**.
- Subnet mask is made by setting **Network bits to all "1's"** and setting **Host bits to all "0's"**.
- The mask can help us to find the Network address and the Host Address. For example, the mask for a class A address has eight 1s, which means the first 8 bits of any address in class A define the Network address ; the next 24 bits define the Host Address.
- It is used to identify network address of an IP address by preforming a **bitwise AND operation** on the subnet mask.
- The subnet mask is the classical way of representing which bits are part of the network portion of the address verses the host bits of the address. The subnet mask for a /24 network is 255.255.255.0.

Subnetting

- ***A Subnet denotes a range of addresses that can be allocated to hosts, such as 192.168.1.0/24.***
- It is a process of dividing large network into the smaller networks known as subnets based on IP address.
- Every computer on network has an IP address that represent its location on network. Two version of IP addresses are available IPv4 and IPv6.
- **Example 1:** What is the subnetwork address if the destination address is 200.45.34.56 and the subnet mask is 255.255.240.0?

Solution:

11001000 00101101 00100010 00111000

11111111 11111111 1111**0000 00000000**

11001000 00101101 0010**0000 00000000**

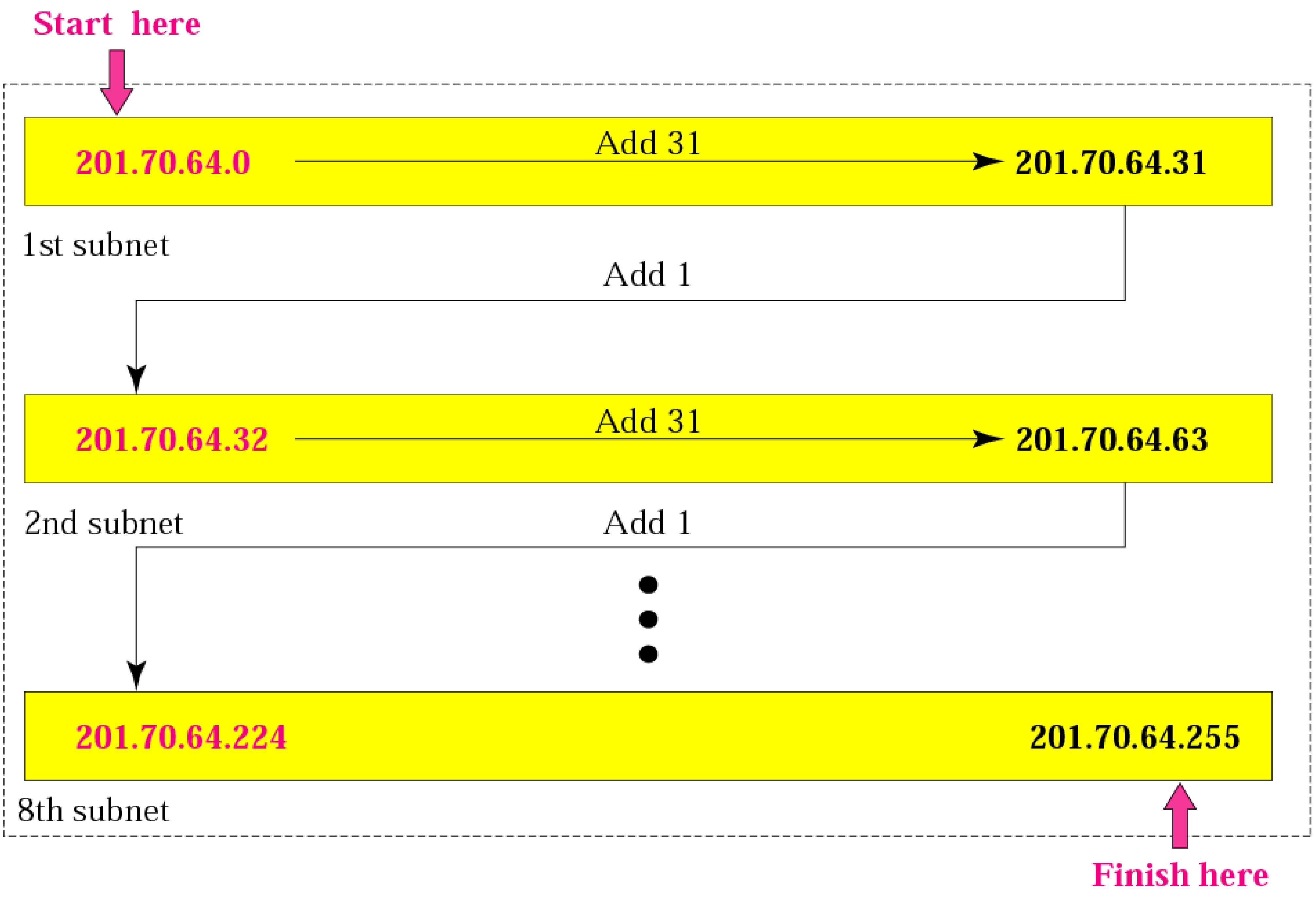
The subnetwork address is 200.45.32.0.

Subnetting

- **Example 2:** A company is granted the site address 201.70.64.0 (class C). The company needs six subnets. Design the subnets.

Solution:

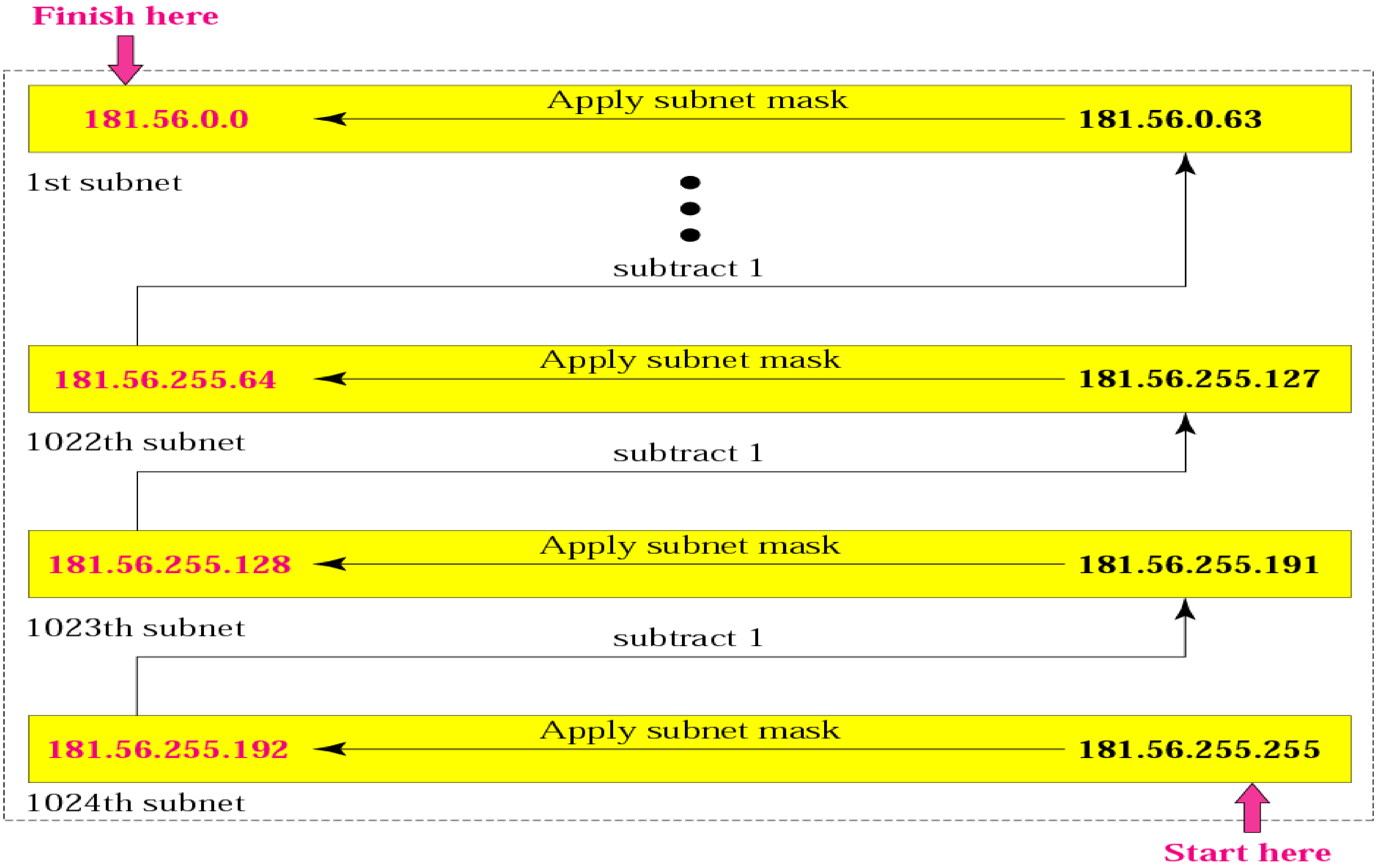
- The number of 1s in the default mask is 24 (class C).
- The company needs six subnets. This number 6 is not a power of 2. The next number that is a power of 2 is 8 (2^3). We need 3 more 1s in the subnet mask. The total number of 1s in the subnet mask is 27 (24 +3). The total number of 0s is 5 (32-27).
- The mask is 11111111. 11111111. 11111111. 11100000 OR 255.255.255.224
- The number of subnets is 8. The number of addresses in each subnet is 2^5 (5 is the number of 0s) or 32.


Start here
201.70.64.0
Add 31
201.70.64.31
1st subnet
Add 1
201.70.64.32
Add 31
201.70.64.63
2nd subnet
Add 1
201.70.64.224
201.70.64.255
8th subnet
Finish here

Example 3: A company is granted the site address 181.56.0.0 (class B). The company needs 1000 subnets. Design the subnets.

Solution:

- The number of 1s in the default mask is 16 (class B).
- The company needs 1000 subnets. This number is not a power of 2. The next number that is a power of 2 is 1024 (2^{10}). We need 10 more 1s in the subnet mask. The total number of 1s in the subnet mask is 26 (16 + 10).
- The total number of 0s is 6 (32 - 26).
- The mask is 11111111. 11111111. 11111111. 11000000 OR (255.255.255.192).
- The number of subnets is 1024. The number of addresses in each subnet is 2^6 (6 is the number of 0s) or 64.


Finish here
181.56.0.0
Apply subnet mask
181.56.0.63
1st subnet
subtract 1
181.56.255.64
Apply subnet mask
181.56.255.127
1022th subnet
subtract 1
181.56.255.128
Apply subnet mask
181.56.255.191
1023th subnet
subtract 1
181.56.255.192
Apply subnet mask
181.56.255.255
1024th subnet
Start here

👇Example 4: Consider the following table:

Department	No. of Hosts
Engineering	27
Customer Care	18
IT	8
Finance	12
HR	4

👇The Company is granted the Class-C site address . Design the subnets.

Solution:

- The number of 1s in the default mask is 24 (Class C).
- The company needs 5 subnets. This number is not a power of 2. The next number that is a power of 2 is 8 (2^3). We need 3 more 1s in the subnet mask.
- The total number of 1s in the subnet mask is 27 (24 + 3) ⟹ 255.255.255.224
- The total number of 0s is 5 (32 - 22).
- The maximum number of host addresses in each subnet is 2^5 (5 is the number of 0s) 32. Usable host addresses are 30.

Department	No. of Hosts	Subnet	Range of IP	Spare IP
Engineering	27	192.168.0.0	192.168.0.0 to 192.168.0.31	3
Customer Care	18	192.168.0.32	192.168.0.32 to 192.168.0.63	12
IT	8	192.168.0.64	192.168.0.64 to 192.168.0.95	12
Finance	12	192.168.0.96	192.168.0.96 to 192.168.0.127	18
HR	4	192.168.0.128	192.168.0.128 to 192.168.0.159	26

Classless Interdomain Routing (CIDR)

- Classful addressing is a special case of classless addressing.
- A CIDR IP address looks like a normal IP address except that it ends with a slash followed by a number, called the IP network prefix.
- CIDR addresses reduces the size of routing tables and make more IP addresses available with organization.
- CIDR is based on the variable length subnet masking (VLSM).
- CIDR reduced the problem of wasted address space by providing a new and more flexible way to specify network addresses in routers.
- Example
  - /10 → Network Address: 10 bits and Host Address: 22 bits
  - /24 → Network Address : 24 bits and Host Address: 8 bits
- A CIDR address of 192.168.0.0/24 defines a block of addresses in the range 192.168.0.0 through 192.168.0.255.
- While 192.168.0.0/20 would define a network 16 times as large from 192.168.0.0 through 192.168.0.255.
  - 192.168.0.0/20 → 192.168.00001111.11111111

Example 5: Consider the following table:

Department	No. of Hosts
Engineering	27
Customer Care	18
IT	8
Finance	12
HR	4

The Company is granted the Class-C site address . Design the subnets using CIDR subnet.

Solution:

- Start with the largest departments first, then size the subnet mask to fit by using the minimum number of host bits.

Department	No of Hosts	Subnet /Mask	Spare IP
Engineering	27	192.168.0.0/27 (30 Hosts)	3
Customer Care	18	192.168.0.32/27 (30 Hosts)	12
IT	8	192.168.0.64/28 (14 Hosts)	6
Finance	12	192.168.0.80/28 (14 Hosts)	2
HR	4	192.168.0.96/29 (6 Hosts)	2

👉Example 6: Consider the following requirements and design the network.

- We are given IP address 202.70.64.0/24 (255.255.255.0)
- Bits used for network= 24
- Bits used for host = 8, so total number of possible host = 2^8 =256 but usable IP address = 254
- For Department B we need 100 host
- For Department A we need 20 host
- For Department D we need 20 host
- For Department C we need 10 host
- For Point to point router link we need 2 host

Solution:

👇 **For Department B**

- we need 100 host, so we need last 7 bit for host .
- Total Number of Host possible = 2^7 but usable host = $2^7 -2 = 126$
- New subnet mask will be 255.255.255.(10000000)2 =255.255.255.128
- Subnet 202.70.64.0/25
- IP address for Department B: 202.70.64.0 - 202.70.64.127

👇 **For Department A**

- we need 20 host, so we need last 5 bit for host .
- Total Number of Host possible = 2^5 but usable host = $2^5 -2 = 30$
- New subnet mask will be 255.255.255.(11100000)2 =255.255.255.224
- Subnet 202.70.64.0/27
- IP address for Department B: 202.70.64.128 - 202.70.64.159

For Department D

- we need 20 host, so we need last 5 bit for host .
- Total Number of Host possible = 2^5 but usable host = 2^5 -2 = 30
- New subnet mask will be 255.255.255.(11100000)2 =255.255.255.224
- Subnet 202.70.64.0/25
- IP address for Department B: 202.70.64.160 - 202.70.64.191

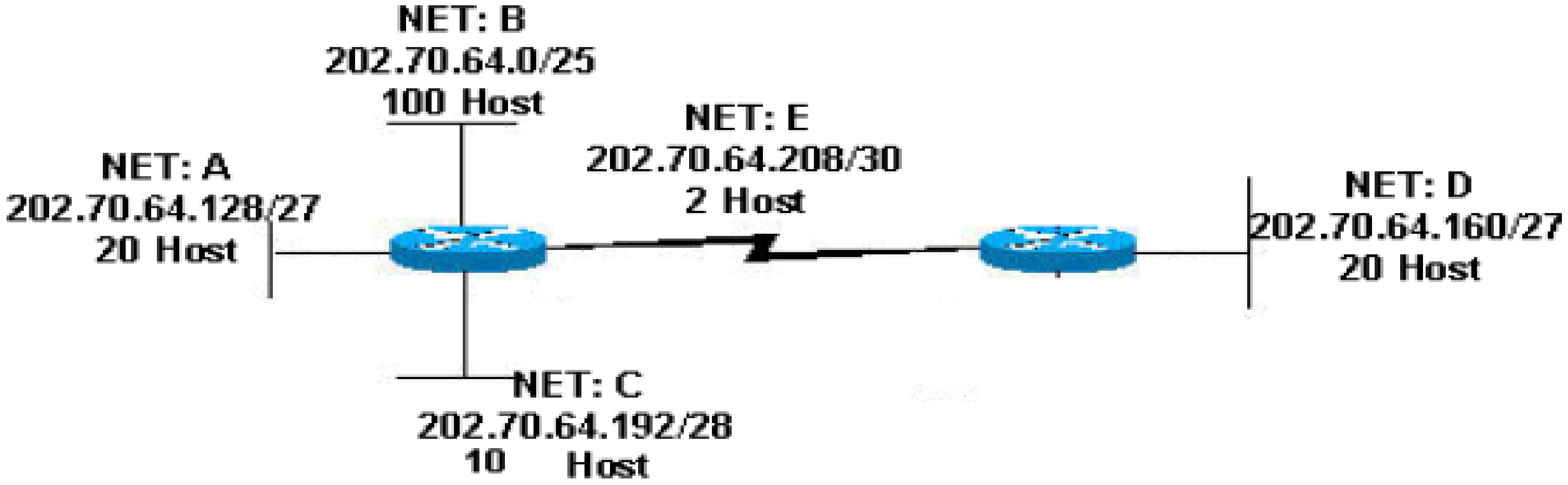
For Department C

- we need 10 host, so we need last 4 bit for host .
- Total Number of Host possible = 2^4 but usable host = 2^4 -2 = 14
- New subnet mask will be 255.255.255.(11110000)2 =255.255.255.240
- Subnet 202.70.64.0/28
- IP address for Department B: 202.70.64.192-202.70.64.207

For PPP router to router link

- we need 2 host, so we need last 2 bit for host .
- Total Number of Host possible = 2^2 but usable host = 2^2 -2 = 2
- New subnet mask will be 255.255.255.(11111100)2 =255.255.255.252
- Subnet 202.70.64.0/30
- IP address for Department B: 202.70.64.208 - 202.70.64.211

Network	Host	host bit allocation	Usable Host	IP-Address	Subnet mask
B	100	7	2^7-2 = 126	202.70.64.0-202.70.64.127	255.255.255.128/25
A	20	5	2^5-2 = 30	202.70.64.128-202.70.64.159	255.255.255.224/27
D	20	5	2^5-2 = 30	202.70.64.160-202.70.64.191	255.255.255.224/27
C	10	4	2^4-2 = 14	202.70.64.192-202.70.64.207	255.255.255.240/28
E	2	2	2^2-2=2	202.70.64.208-202.70.64.211	255.255.255.252/30



👎**Example 7:** Assume that you are a network administrator at ABC software. Company has three departments connected with WAN links.

- Development department has 74 computers.
- Production department has 52 computers.
- Administrative department has 28 computers.
- All departments are connected with each other via WAN link.
- Each WAN link requires two IP addresses.

- **With FLSM**
- **With VLSM**

Solution with FLSM

First choice (*purchase a class B IP address*)

- 172.168.1.0/23
- Subnetting of this address would give us 128 subnets and 510 hosts in each subnet.
- Our network requires only 6 subnets and 160 addresses. We would have to pay for 65356 addresses while you need only 160 addresses.

Second choice (*purchase at least two Class C IP addresses*)

- 192.168.1.0/25
- 192.168.2.0/26
- Subnetting of first address 192.168.1.0/25 would give us 2 subnets and 126 hosts in each subnet.
- Subnetting of second address 192.168.2.0/26 would give us 4 subnets and 62 hosts in each subnet.
- Collectively we are getting 6 subnets and 500 hosts from these two address spaces. We are still wasting more than 300 IP address, and we would have to purchase two address spaces.

Solution with VLSM

- Oder all segments according the hosts requirement (Largest to smallest).

Subnet	Segment	Hosts
1	Development	74
2	Production	52
3	Administrative	28
4	Wan link 1	2
5	Wan link 2	2
6	Wan link 3	2

- Do subnetting for largest segment. Our largest segment needs 74 host addresses.
- /25 provide us two subnets with 126 hosts in each subnet.

Subnet	Subnet 1	Subnet 2
Network ID	192.168.1.0	192.168.1.128
First host address	192.168.1.1	192.168.1.129
Last host address	192.168.1.126	192.168.1.254
Broadcast ID	192.168.1.127	192.168.1.255

Assign subnet mask to the largest segment.

Segment	Development
Requirement	74
CIDR	/25
Subnet mask	255.255.255.128
Network ID	192.168.1.0
First hosts	192.168.1.1
Last hosts	192.168.1.126
Broadcast ID	192.168.1.127

- Do subnetting for second largest segment from next available subnet. Next segment requires 52 host addresses.
- Subnetting of /25 has given us two subnets with 126 hosts in each, from that we have assigned first subnet to development segment. Second segment is available. we would do subnetting of this.
- /26 provide us 4 subnets with 62 hosts in each subnet.
- **192.168.1.0/26**

Subnet	Subnet 1	Subnet 2	Subnet 3	Subnet 4
Network ID	**0**	**64**	**128**	**192**
First address	**1**	**65**	**129**	**193**
Last address	**62**	**126**	**190**	**254**
Broadcast ID	**63**	**127**	**191**	**255**

- We cannot use subnet 1 and subnet 2 (address from 0 to 127) as they are already assigned to development department. We can assign subnet 3 to our production department.

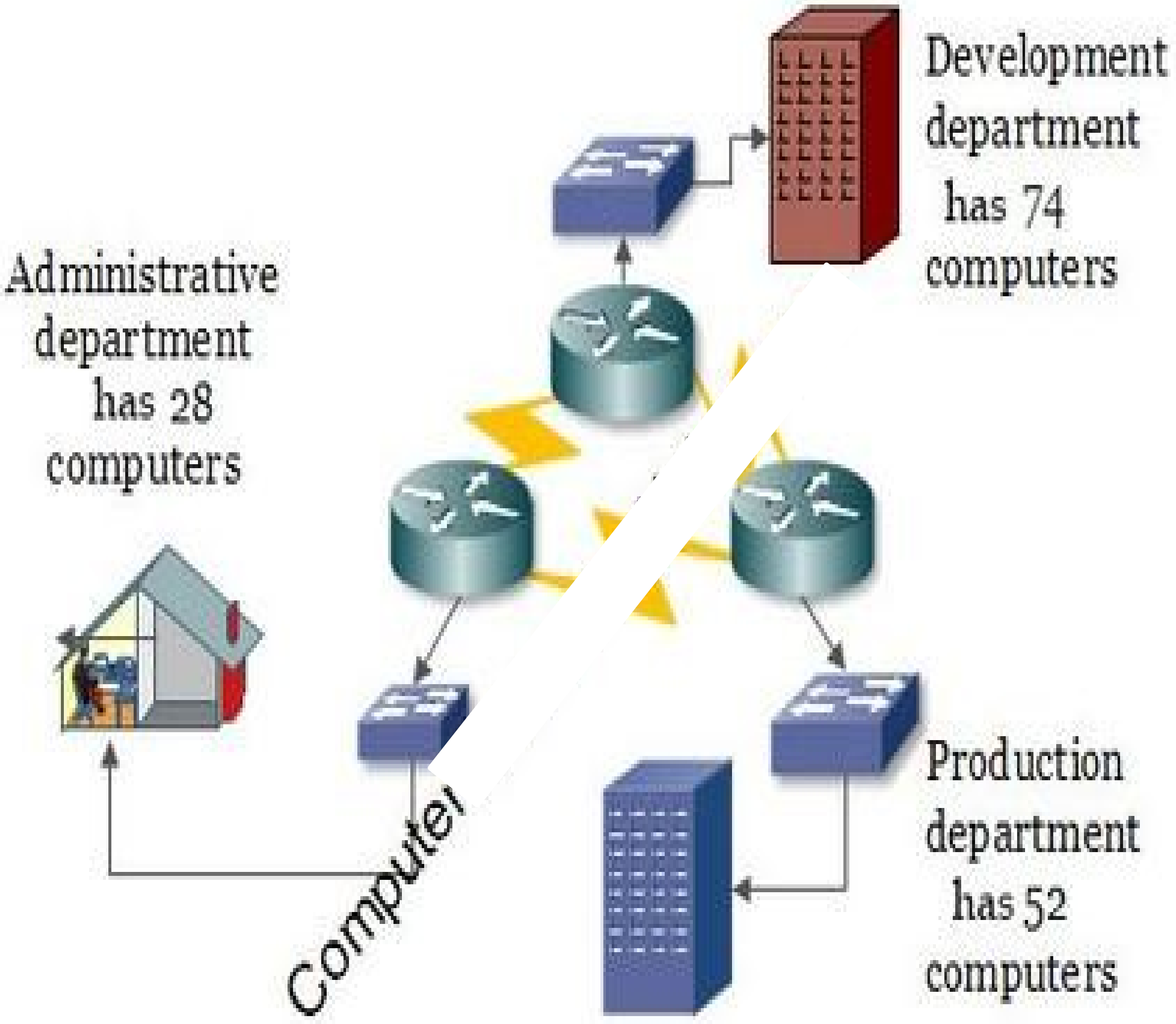
Segment	Production
Requirement	52
CIDR	/26
Subnet mask	255.255.255.192
Network ID	192.168.1.128
First hosts	192.168.1.129
Last hosts	192.168.1.190
Broadcast ID	192.168.1.191
Segment	Production

Segment	Administrative
Requirement	28
CIDR	/27
Subnet mask	255.255.255.224
Network ID	192.168.1.192
First hosts	192.168.1.193
Last hosts	192.168.1.222
Broadcast ID	192.168.1.223
Segment	Administrative

Segments	Wan Link 1
Requirement	2
CIDR	/30
Subnet mask	255.255.255.252
Network ID	192.168.1.224
First hosts	192.168.1.225
Last hosts	192.168.1.226
Broadcast ID	192.168.1.2
Segments	Wan Link 1

Segments	Wan Link 2
Requirement	2
CIDR	/30
Subnet mask	255.255.255.252
Network ID	192.168.1.228
First hosts	192.168.1.229
Last hosts	192.168.1.230
Broadcast ID	192.168.1.231
Segments	Wan Link 2

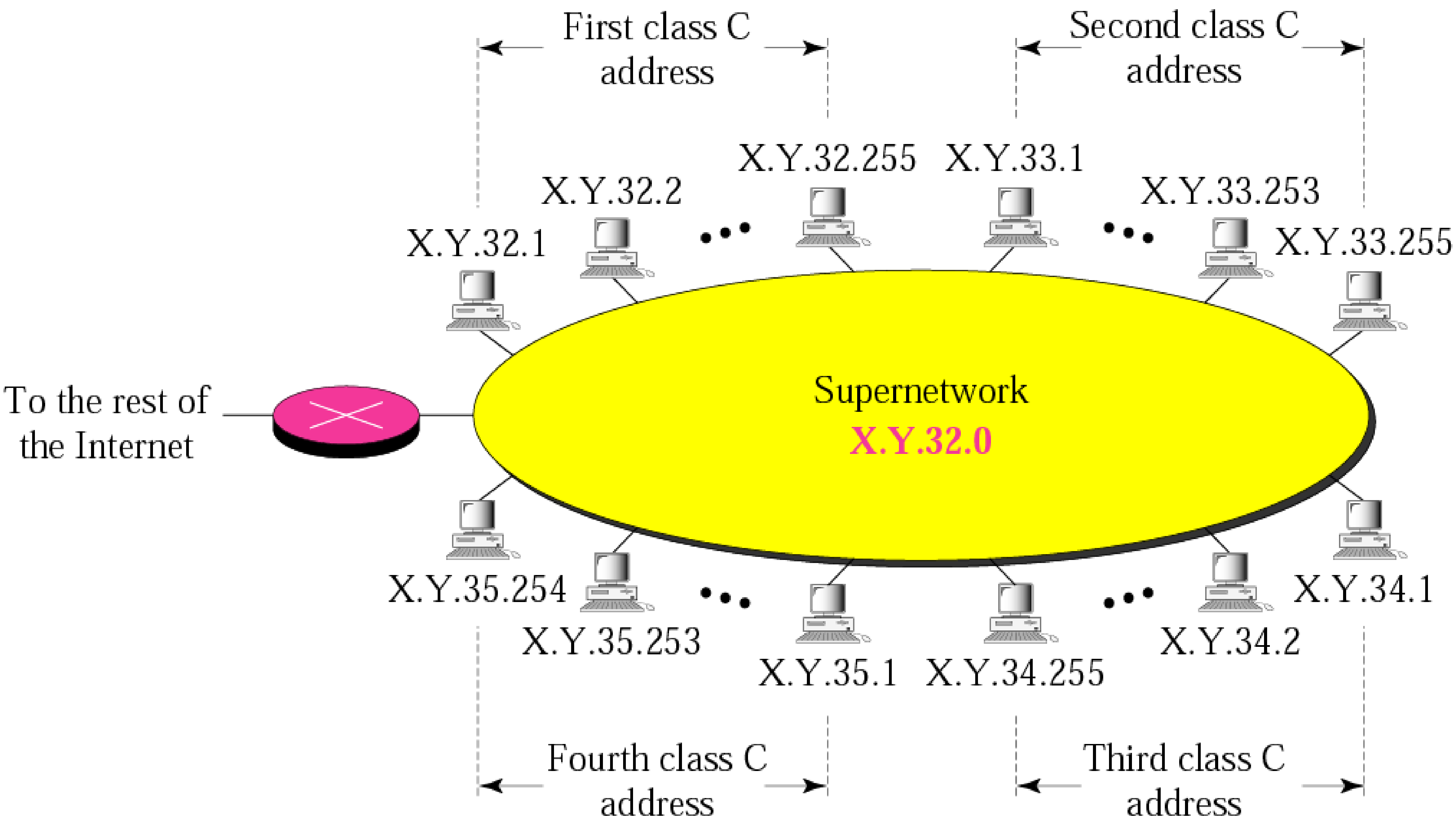
Segments	Wan Link 3
Requirement	2
CIDR	/30
Subnet mask	255.255.255.252
Network ID	192.168.1.232
First hosts	192.168.1.233
Last hosts	192.168.1.234
Broadcast ID	192.168.1.235
Segments	Wan Link 3



Supernetting

- Supernetting is the term for creating a larger network by encapsulating multiple smaller subnets. A primary use for supernetting is network summarization, sometimes called route aggregation, the process of combining networks using classless inter-domain routing (CIDR).
- In practical terms, one reason we'd want to supernet is to ***reduce the size of your IP routing table t***o improve network routing efficiency.
- Another use case of supernetting is ***to merge a bunch of smaller subnets to create a larger network*** capable of accommodating a more hosts (attached devices).
- For example, supernetting can allow you to grow your maximum number of hosts on a subnetwork from 254 to 1022 after the merge.
- ***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.

A supernetwork



Supernetting

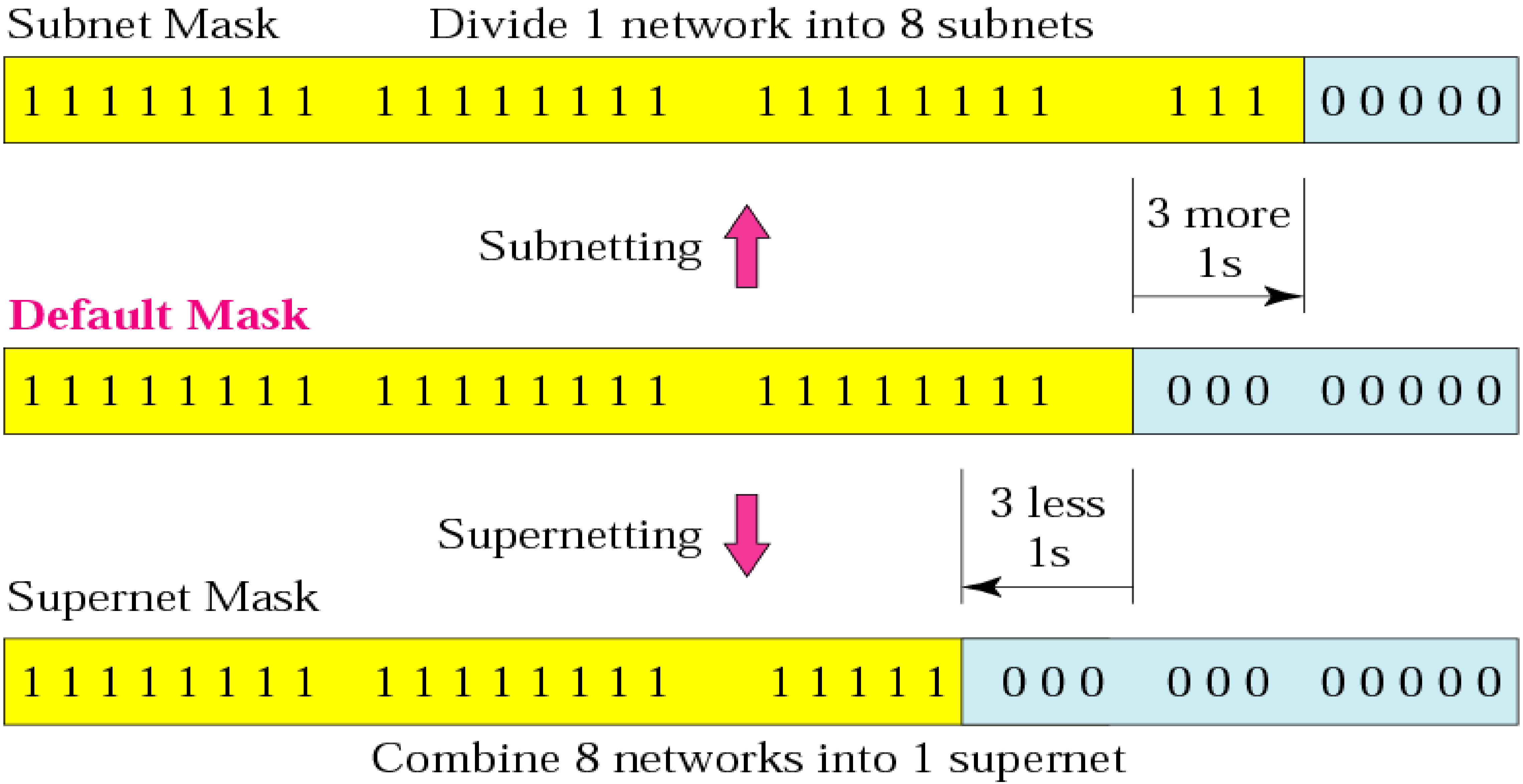
Rules:

- The number of blocks must be a power of 2 (1, 2, 4, 8, 16, . . .).
- The blocks must be contiguous in the address space (no gaps between the blocks).
- The third byte of the first address in the superblock must be evenly divisible by the number of blocks. In other words, if the number of blocks is *N*, the third byte must be divisible by *N*.

Supernetting

- A company needs 600 addresses. Which of the following set of class C blocks can be used to form a supernet for this company?
  - **198.47.32.0 198.47.33.0 198.47.34.0**
  - **198.47.32.0 198.47.42.0 198.47.52.0 198.47.62.0**
  - **198.47.31.0 198.47.32.0 198.47.33.0 198.47.52.0**
  - **198.47.32.0 198.47.33.0 198.47.34.0 198.47.35.0**
- **Solution**
  - 1: No, there are only three blocks.
  - 2: No, the blocks are not contiguous.
  - 3: No, 31 in the first block is not divisible by 4.
  - 4: Yes, all three requirements are fulfilled

Comparison of subnet, default, and supernet masks



Assignment 4

1) Design a network for the institute of engineering central campus having Five departments having 45,35,40,23 and 30 computers in their respective network by allocating public IP to each computer with minimum losses. Assume IP by yourself.
2) Suppose there are 4 departments A,B,C and D. The department A has 23 hosts, B has 16, C has 28 and D has 13 hosts. You are given a network 202.70.64.0/24. Perform the subnetting in such a way that the IP address wastage in each department are minimum and also find out the subnet mask, network address, broadcast address, and usable host ranges in each department.
3) XYZ Company need to allocate 15 IPs in HRD, 30 IPs in Finance department, 24 in Customer care unit and 25 in ATM machines. If you have one network of class C range public IP address. Describe your network with minimum loss of IPs.

Assignment 4

4) How can you dedicate 10,12,8,14 public IP address to departments A,B,C and D respectively from the pool of Class-C with minimum losses of IP? Explain.
5) Design IPV4 sub network for an organization having 16,48,61, 32 and 24 computers in each departments. Use 192.168.5.0/24 to distribute the network.
6) A large number of consecutive IP address are available at 202.70.64.0/19. Suppose that four organization A, B, C and D request 100, 500, 800, and 400 addresses respectively., how the subnetting can be performed so that address wastage will be minimum.
7) A large number of consecutive IP address are available at 193.122.2.1. Suppose that four organizations Pulchowk, Thapathali, WRC and ERC request 6000, 2000, 4000 and 2500 addresses respectively. Design the network and find the first valid IP address, last IP address and mask in w.x.y.z/s notation for each organization.

Thank You
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References:

👎 Data Communications and Networking “ Behrouz A. Forouzan” Fourth Edition.
👎 Computer Networks “A. S. Tanenbaum” Fifth Edition
👎 Data and Computer Communications “William Stallings” Tenth Edition.