Chapter 10

LAN Interconnection Devices

Outline

Objectives After completing this chapter, you will be able to:

- List LAN Interconnection devices
- Describe the function and operation of a repeater
- Describe the function and application of a bridge
- Explain switch operation
- Discuss the applications of LAN switching
- Distinguish between symmetric and asymmetric switches
- Understand the technology of a cut-through switch and store-and-forward switch
- Identify the application of a L2 switch, L3 switch and L4 switch
- Discuss the application of virtual LANs
- Understand the function of a router and the layers of the OSI model corresponding to a Router
- Describe the function and application of a gateway

Introduction:

An **LAN Interconnection** is the linking of Local Area Networks (LANs) to form a single network. LANs of different floors of a building or LANs in separate buildings can be connected so that all computers in the site are linked. Two reasons for linking LANs together are to expand the geographic coverage of the network, and to divide the traffic load through internetworking.

The devices discussed in this chapter are used for linking LANs together and can be distinguished by the OSI layer at which they are operating.

10.1 Repeaters

A repeater is a device used to connect several segments of an LAN to extend the allowable length of a network. A repeater accepts traffic from its input port and then retransmits the traffic at its output port. A hub is a multiple output repeater. A repeater works in the physical layer of the OSI Model. Figure 10.1 shows a repeater connecting two segments of an LAN together.

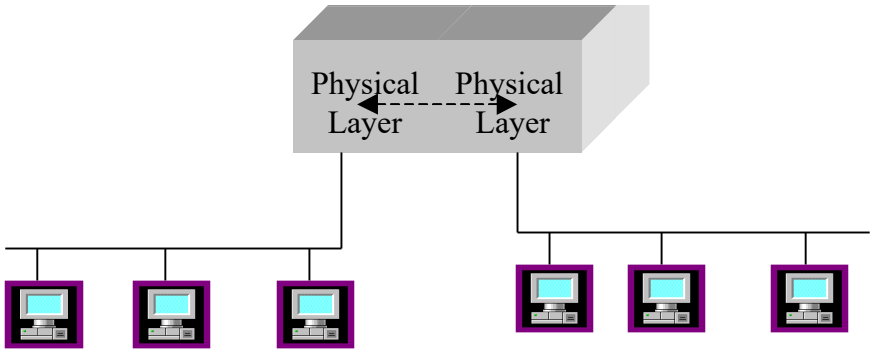

Figure 10.1 Two segment of a LANs connected by a repeater

10.2 Bridges

A **Bridge** is used to connect same segments of a network together (Homogeneous Network) and operates in the data link layer, as shown in Figure 10.2. Bridges forward frames based on the destination addresses of the frames, as well as control data flow and detect transmission errors.

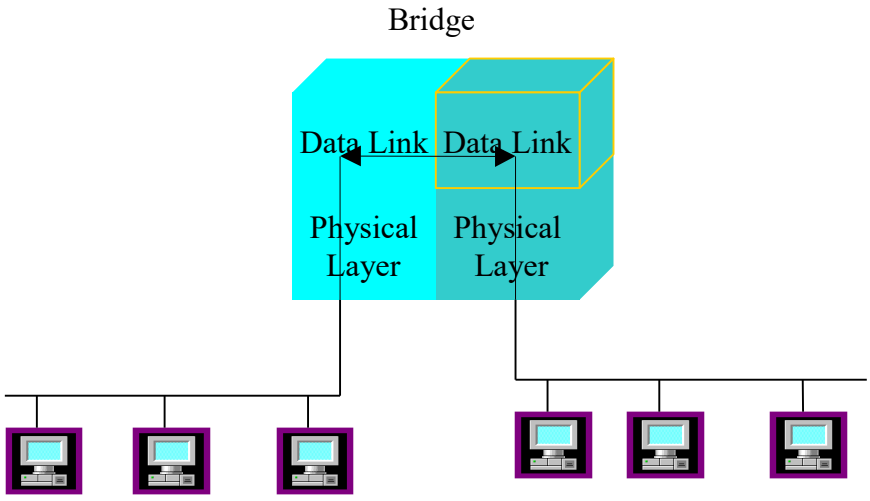

Figure 10.2: OSI reference model of a bridge

Functions of a Bridge

The function of a bridge is to analyze the incoming destination address of a frame and make a forwarding decision based on the location of the station. Figure 10.3 shows a bridge that is used to connect two Ethernet LANs together. For example, if station A sends a frame to station B, the bridge gets the frame and sees that station B is in the same segment as A and discards the frame. However, if station A forwards a frame to station C, the bridge would realize that station C is in a different LAN segment, so the bridge then forwards the frame to station C. The bridge forwards the data from one LAN to another without alteration of the frame. Bridges allow network administrators to segment their networks transparently, meaning that the individual station does not need to know that there is a bridge in the network.

Bridges are capable of **Filtering,** which is useful for eliminating unnecessary broadcast frames. They can also be programmed not to forward frames from specific sources.

By dividing a large network into segments and using a bridge to link the segments together, the throughput of the network will increase. If one segment of the network has failed, the other segments connected to the bridge can keep the network alive.

Bridges also extend the length of the LAN. While stations A and B are communicating with each other, stations C and D can communicate with each other too.

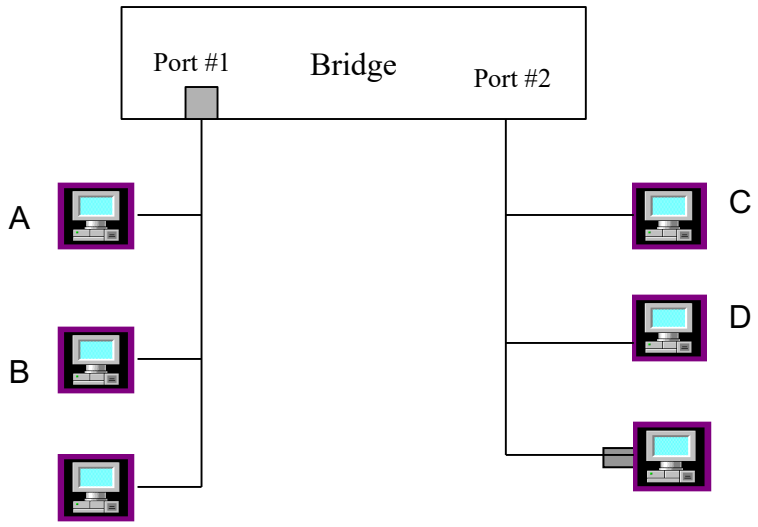

Figure 10.3: Two Ethernet segments connected by a bridge.

There are two types of Bridges. One type is the **Transparent Bridge,** or **Learning Bridge,** and the other is the **Source Routing Bridge.**

Learning Bridge or Transparent Bridge: The Learning Bridge requires no initial programming. It can learn the location of each device by accepting a frame from the network segment and recording the MAC address and the port number. The frame comes to the bridge, which then retransmits the frame to all the segments of the network except the segment which sent the frame. By using this method, the learning bridge learns which station is connected to which segment of the network.

Source Routing Bridge: The frame contains the entire route to the destination. A source routing bridge is used for a Token Ring Network because a token ring frame has a field that specifies the routing of the frame.

10.3 Switch

LAN switching is the fastest growing technology in the networking industry. Switches are used to connect LAN segments together to increase network throughput. A **switch** is a device with multiple ports which accepts packets from the ports of other computing devices. When a switch

receives packets, it examines the destination address, then transmits the packets to the intended port of a host with the same destination address, as shown in Figure 10.4. Most LAN switches operate at the Data Link Layer of the OSI model. Figure 10.5 shows a symbolic representation of a switch. When a switch operates in data link layer, it performs function of a bridge.

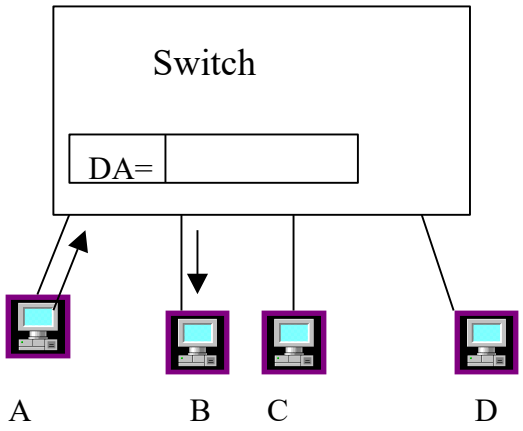

Figure 10.4: Switch operation

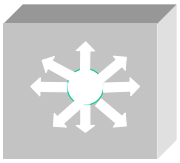

Figure 10.5 Symbolic representation of a switch

10.3.1 Ethernet LAN Switching

Ethernet is one of the most popular LAN technologies because it uses unshielded twisted-pair cables. However, when the number of stations increases in an Ethernet LAN, the number of collisions also increases, and performance decreases accordingly. In order to increase the performance of an Ethernet LAN, it can be segmented, with the segments connected to switch

ports. In Figure 10.6, each segment acts as an independent LAN, and each segment has its collision domain.

An **LAN switch** is similar to a multiport bridge. As each LAN frame enters the switch, the switch compares the frame's destination with a table of previously learned addresses, and the frame is sent to the proper port.

If an Ethernet LAN is comprised of 20 stations, the bandwidth of each station is equal to the network bandwidth divided by 20. If this LAN were divided into five segments, with each segment connected to a switch, the bandwidth of each station becomes the network bandwidth divided by five.

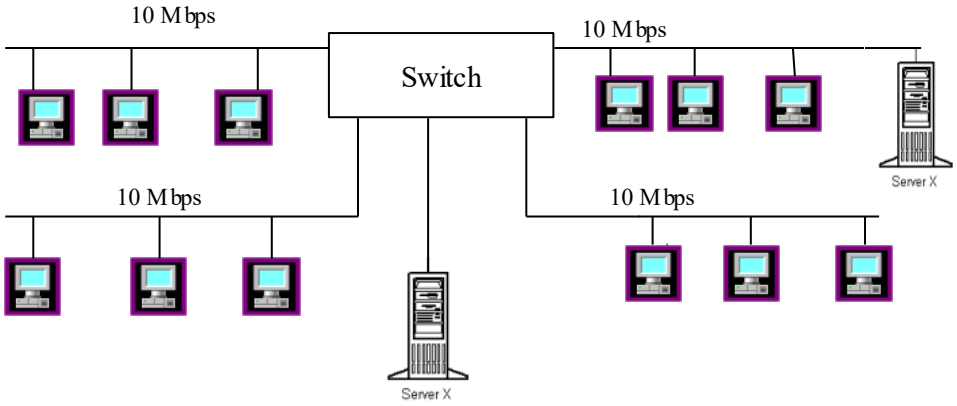

Figure 10.6: Connection of LAN segments to a switch

10.3.2 Switch Classifications

The manufacturers of switches classify the switches based on their applications: symmetrical and asymmetrical switching.

1. *Symmetric Switching* provides switching between segments which have the same bandwidth. For example, 10Mbps to 10Mbps or 100Mbps to 100Mbps, as shown in Figure 10.7.

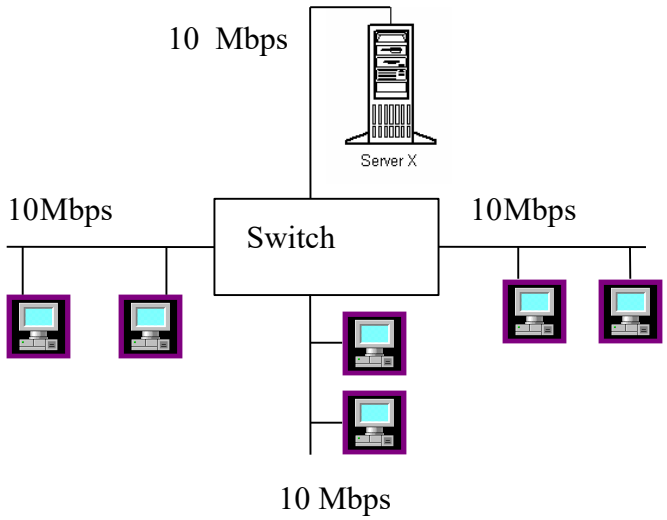

Figure 10.7: Symmetric switch

2. *Asymmetric Switching* provides switching between segments of different bandwidths. For example, 10Mbps to 100Mbps or 100Mbps to 10Mbps, as shown in Figure 10.8.

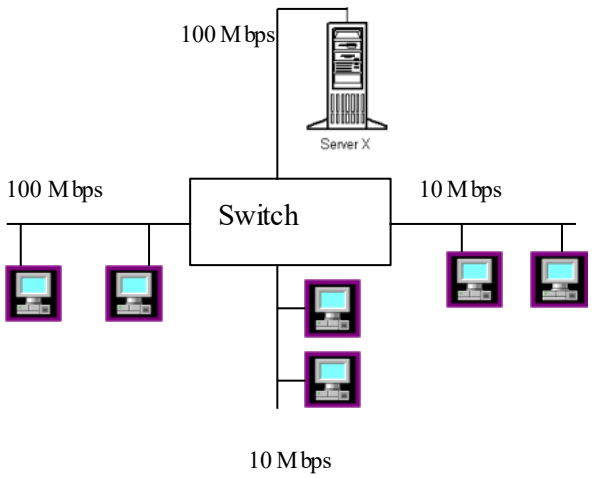

Figure 10.8 Asymmetric switch

10.3.3 Switch Operations

An LAN switch uses RISC (Reduced Instruction Set Computer) processors and ASIC (Application Specific Integrated Circuit) processors to increase performance. RISC processors are not as fast as ASIC, but they are less expensive. ASIC switches are custom designed for specific operations, and all of their operations are accomplished through hardware. There are two types of switches:

1. *Cut-Through Switch*: A **cut-through switch** reads the first few bytes of the packet to obtain the source and destination addresses. The packets are sent to the destination segment without checking the rest of the packet for errors. The cut-through switch uses an ASIC processor for processing the packet.

2. *Store-and-Forward Switch*: The **store-and-forward switch** stores the entire packet, then checks for errors in the packet. If a packet contains errors, it is discarded, otherwise the switch forwards the packet to the specified destination. The store-and-forward switch is more suitable for an Ethernet LAN because it will filter out any corrupted packets to the other segments and therefore reduce collision.

10.3.4 Switch Architecture

Switch architecture is based on the OSI model. The different types of switch architectures are described in the following paragraphs.

Layer 2 Switching (L2 Switch): A Layer 2 switch (L2 switch**)** operates in the Data Link layer of the OSI model. It is used for network segmentation and for creating workgroups. The operation of a Layer 2 switch is similar to that of a multiport bridge where a frame enters the switch from one port and is forwarded to the intended port based on the MAC address of the frame. A frame with a broadcast address will be repeated to all ports of the switch. During this process, a layer 2 switch learns the MAC addresses of the hosts connected to each port and creates a switching table which maps MAC addresses to port numbers, as seen in Table 10.1. The switch makes this table through a learning method. When PC1 sends a packet to PC2, the switch recognizes that PC1 is connected to port 1, and when PC2 sends a packet to PC1 the switch recognizes that PC2 is connected to Port 2. The switch then uses this table to forward frames to the proper ports. Figure 10.9 shows a 4-port switch with 4 PCs and their MAC addresses represented by MAC1 through MAC4.

MAC Address	Port Number
MAC1	Port1
MAC2	Port2
MAC3	Port3
MAC4	Port4

Table 10.1: Switch Forwarding Table

Figure 10. 9: Switch with 4 ports

Figure 10.10 shows two connected switches: Switch 1 and Switch 2. The switching table for Switch 1 can be seen in Table 10.2. Assume PC1 needs to send a packet to PC5. In order to forward the packet to PC5, Switch 1 must check the destination MAC address of PC5 by consulting its switch forwarding table. Since the MAC address for PC5 is not listed in its table, Switch 1 forwards the packet to default port 4, which then forwards the packet to default port 5 of Switch 2. When the packet reaches Switch 2, Switch 2 then uses the information on its forwarding table to forward the packet to PC5.

MAC Address	Port Number
MAC1	Port1
MAC2	Port2
MAC3	Port3
MAC4	Default

Table 10.2: Switch forwarding table for figure 10.10

Figure 10.10: Connecting two switches

10.3.5 Spanning Tree Protocol (STP) or IEEE 802.1d

The spanning tree protocol is used to ensure a free loop topology in a network with multiple switches or bridges. A switch will forward a broadcast and multicast frame to its port. Figure 10.11 shows a network with loop,

Figure 10.11: Spanning Tree Operation

In order to overcome loop problems, each switch runs the Spanning Tree Algorithm (STP) or IEEE 802.1d. Basic STP operation is described in the following steps.

1. Each switch is identified by an 8-byte ID. This ID is a combination of a two-byte priority field and the switch's 6-byte MAC address.
2. The switches exchange their IDs using Bridge Protocol Data Units (BPDU). The switch with the lowest ID is elected as the Root Bridge/Switch.
3. The Root Bridge/Switch places all its ports in the forwarding state.
4. Each non-root bridge/switch finds the shortest path to the root bridge. The port used for shortest path to root bridge is call root port and is placed in forwarding state.
5. If a switch has more than one path to the root bridge, all ports not in the forwarding state are placed in the blocking state.

10.3.6 Layer 3 Switch (L3 Switch) and Layer 4 switch

Layer 3 Switch (L3 Switch): A Layer 3 switch (L3 switch) is a type of router that uses hardware rather than software. An L3 switch, sometimes called a routing switch, uses ASIC switching technology such as a crossbar switch. This switch operates on the Network layer of the OSI model. The function of an L3 switch is to route the packet based on the logical address (layer 3) information. An L3 Switch accepts the packet from the incoming port and forwards the packet to the proper port based on a logical address such as an IP address. In order to increase performance, the switch finds the route for the first packet and establishes a connection between the incoming and outgoing port for transferring the rest of the packets. This is called "route once and switch many". Figure 10.12 shows an application of L3 switches in which they are used to connect the networks of two buildings.

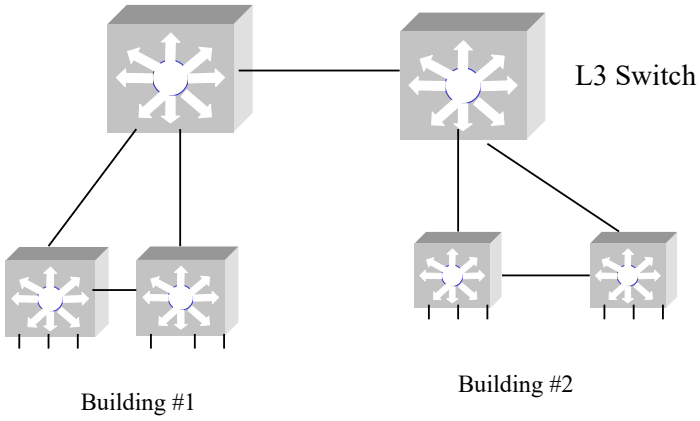

Figure 10.12: Connecting the networks of two building using L3 switches

Layer 4 Switch (L4 Switch): A Layer 4 switch operates on the Transport layer of the OSI model. The Internet uses the transport layer with TCP and UDP. TCP is used for reliable communication and UDP is used for unreliable communication. Examples of application protocols running on top of TCP are Telnet, FTP, HTTP, and SMTP. The TCP header contains fields called source port number and destination port number. The Source port number identifies the source protocol of an incoming packet and the destination port number identifies the destination protocol for an incoming packet. A layer 4 switch operates on the port number to forward a packet to the destination. An L4 switch is used for network security and for filtering packets based on application protocol.

10.4 Virtual LAN

A **Virtual LAN (VLAN) (or IEEE 802.1q)** is a configuration option on an LAN switch which allows network managers the flexibility to group or segment ports on an individual switch into logically defined LANs. There are two immediate benefits from a VLAN. First, it provides a way for network administrators to decrease the size of a broadcast domain and second, VLANs can provide security options for administrators. A VLAN is one way to prevent hosts on virtual segments from reaching one another. Another application of a VLAN is for logical segmentation of workgroups within an organization.

Port-based VLAN*:* In this method, VLAN membership is based on a switch port where the network administrator assigns each port of the switch to a specific VLAN ID. Only the stations connected to ports with same VLAN ID can communicate with each other. For example, Figure 10.13 shows a four-port switch where ports 1 and 2 are assigned to VLAN ID 10 and ports 4 and 5 are assigned to VLAN ID 20. In this case, PC1 and PC2 can only communicate with each other and PC3 and PC4 can only communicate with each other.

Figure 10.13: A Four port switch with 2 VLANs

VLAN operation

A VLAN ID is assigned to each port of a switch. When a PC transmits a packet to a switch port, the switch inserts a tag into the packet. This tag includes the VLAN ID as shown in figure 10.14. The switch then checks the VLAN ID of the packet and transmits it to the ports which have the same VLAN ID.

IEEE 802.1q developed a standard for the tagging frame for use in VLAN. The IEEE 802.1q defines a method which allows a switch to add a tag to the frame. It can process an untagged frame or a tagged frame. Figure 10.14 shows an IEEE802.1q frame format. The tag is 4 bytes and is inserted between source address (SA) and Type/Length field in Ethernet frame format.

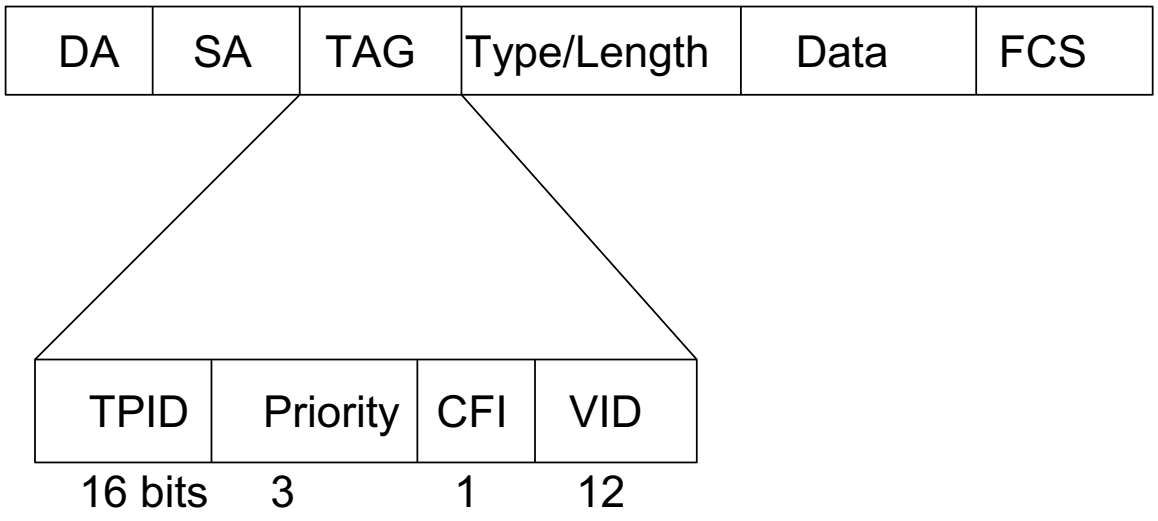

Figure 10.14: IEEE 802.1q Frame Format.

The functions of each field in the Tag field are described below.

TPID (Tag Protocol Identifier): This field is 16 bits and is set to 8100 (Hex) to identify the frame in IEEE 802.1q.

Priority: This field is 3 bits and identifies the priority of the frame.

CFI (Canonical Format Indicator): The CFI bit is mainly used for compatibility between Ethernet and token ring Networks and is set to 0 for Ethernet Switches.

VID (VLAN ID): This field is 12 bits and represents the VLAN number to which the frame belongs.

10.5. Routers

A **router** works in the Network Layer of the OSI model to route a frame from one LAN to another LAN, as shown in Figure 10.14. To do this, a router must recognize each network layer of the LAN segments connected to the router. Therefore, a router that recognizes multiple network layers is called a multi-port protocol router.

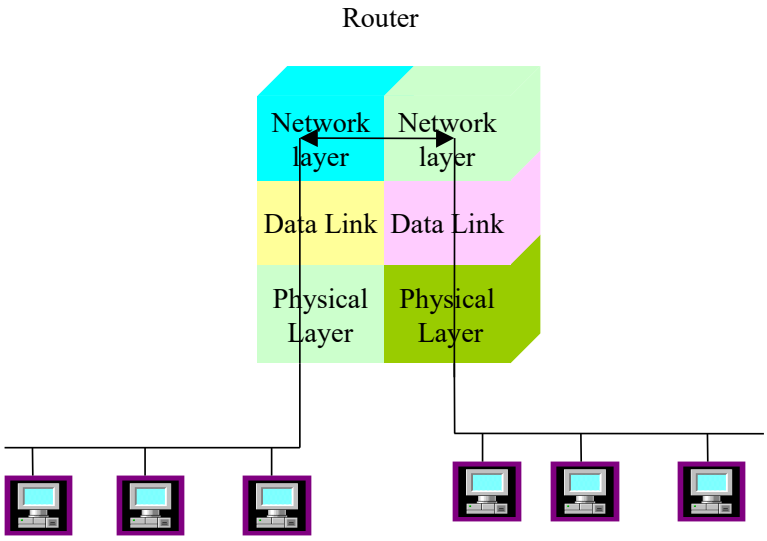

Figure 10.14: OSI Reference model for a router

The main function of a router is to determine the optimal data path and transfer information using that path. Figure 10.15 shows how routers can be used to connect several LANs together at different locations.

Another function of a router is to convert one type of frame to another type. In figure 10.15, Station B is connected to a Token Ring Network and has a frame for station A. Router C is capable of converting the token ring frame format to an Ethernet frame format.

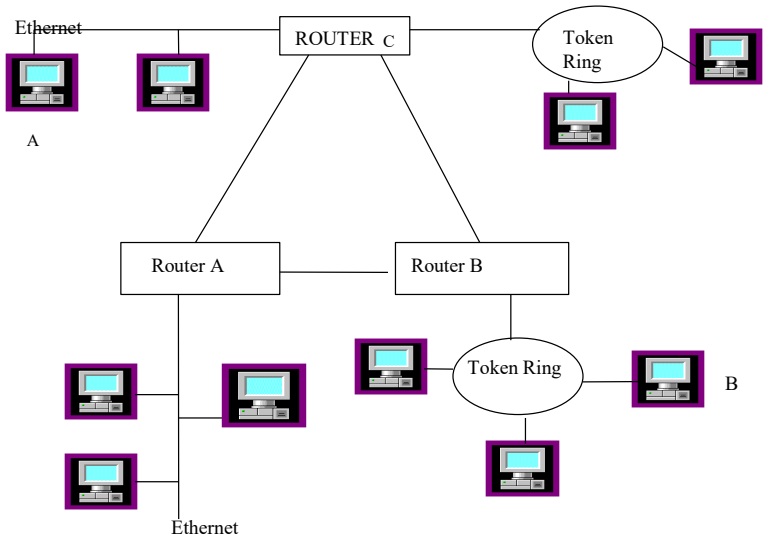

Figure 10.15: Several LANs connected together using routers

A router which can be configured manually by a network administrator is called a static router and a router that is configured by itself is called a dynamic router.

In a static router, the routing table is administered manually by the network administrator who determines the route. In a dynamic router, the router sets up its own routing table and updates it automatically. The dynamic router also exchanges information with the next router on the network.

10.6 Gateways

Gateways operate up to the application layer, as shown in Figure 10.16. The application of a **gateway** is to convert one protocol to another protocol. Figure 10.16 shows a network with IBM SNA architecture connected through a gateway, with an LAN running the TCP/IP protocol.

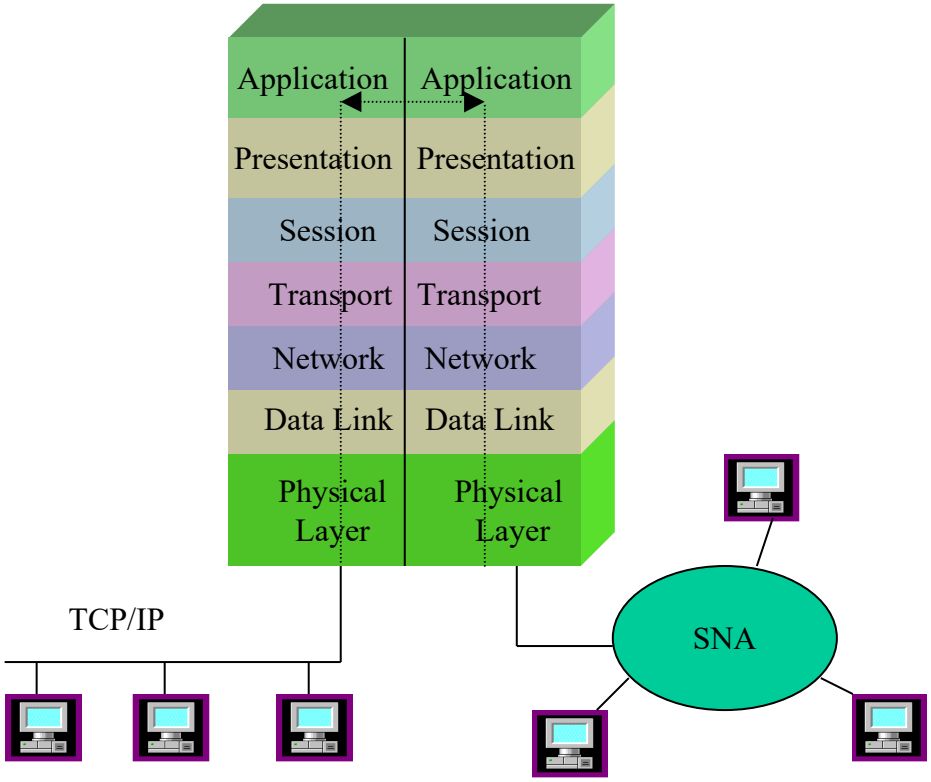

Figure 10.16: OSI reference model for a gateway

Summary

- LAN Interconnection Devices are repeaters, bridges, routers, switches, and gateways.
- A repeater is used to extend the length of the network and operates at the physical layer of an OSI model. A repeater accepts traffic from its input and repeats it at its output.
- A bridge is used to connect segments of same-type networks; the function of the bridge is to analyze the incoming frame's destination address and forward the frame to the proper segment. Bridges operate on the Data Link layer of the OSI model.
- A Learning Bridge or Transparent Bridge learns the location of each station by recording the NIC address and the port number of which frame enters the bridge.
- A Source Routing Bridge routes the frame based on information in the routing field of the frame.
- A switch accepts a packet from one port and examines the destination address; it then retransmits the packet to the port having a host with the same destination address.
- When the number of users is increased in an Ethernet LAN, the number of collision will increase. To overcome this problem Ethernet LAN can be segmented, with each segment connected to a port on a switch.
- Symmetric Switch: provides switching between LAN segments with the same data rate.
- Asymmetric Switch: provides switching between LAN segments with different data rates.
- Cut-Through Switch: reads the first few bytes of the frame to determine by which output port the frame must leave.
- Store and Forward Switch: stores the entire frame and checks for errors. If the frame is corrupted, then it is discarded, otherwise the frame is sent to the proper port for its destination.
- Virtual LAN (VLAN): The IEEE802.10 committee approved the standard for VLAN. In VLAN the switch port can be enabled and disabled by a network administrator. The administrator can also connect several ports to make a VLAN.
- Layer 2 Switch: A multiport device that operates on layer 2 of the OSI model.
- Layer 3 Switch: A type of router that uses integrated switching technology.
- Layer 4 Switch: A type of switch that operates on layer 4 (transport layer) of the OSI model.
- A router is used to route a frame from one LAN to another LAN according to its routing table. Routers operate in the network layer of the OSI model.

- A gateway is used to convert one protocol to another protocol and operates in all seven layers of the OSI model.

Key Terms

Asymmetric Switch
Bridge
Router
Cut-Through Switch
Dynamic Router

LAN interconnection
LAN Switch
Layer 2 (L2) Switch
Layer 3 (L3) Switch
Learning Bridge
Layer 4 (L4) Switch

Proxy Server
Repeater

Source Routing Bridge
Store –and Forward Gateway
Static Router
Transparent Bridge
Switch

Symmetric Switch
Virtual LAN (VLAN)

Review Questions

- **Multiple choice questions**

1. A hub is a multiple port _____.
a. server
b. client
c. modem
d. repeater

2. _____ operate in the data link layer.
a. Bridges
b. Repeaters
c. Switches
d. Gateways

3. _____ are capable of filtering.
a. Bridges
b. Repeaters
c. Switches
d. Hubs

4. In a _____, the frame contains the entire route to the destination.
a. Source routing bridge
b. Learning bridge
c. Repeater

d. Gateway

5. _____ are more complex Internet working devices than bridges.
a. switches
b. routers
c. Gateways
d. Hubs

6. A _____ operates up to the application layer.
a. Router
b. Switch
c. Gateway
d. Repeater
7. A _____ bridge learns the location of each station by recording the NIC address and the port number.
a. Source routing
b. Transparent
c. a and b
d. none of the above

8. A _____ is used to convert one protocol to another protocol.
a. router
b. switch
c. gateway
d. hub

9. The _____ is used to connect segments of a LAN.
a. router
b. hub
c. switch
d. gateway

10. A switch is a device with _____ port(s).
a. single
b. two
c. multiple
d. none of the above

11. _____ provides switching between different bandwidth segments.
a. symmetric switch
b. asymmetric switch
c. store- and -forward switch
d. cut-through switch

12. A _____ switch reads only the first few bytes of the packet.

a. cut-through
b. store-and-forward
c. symmetric
d. asymmetric

13. Layer 3 switches or routing switches work on the OSI physical layer, data link layer and _____ layer.
a. Application
b. Session
c. Presentation
d. Network

14. A _____ is a configuration option on a LAN switch.
a. VLAN
b. Firewall
c. Repeater
d. Router

15. A /AN_____ server is one of the firewall techniques.
a. application
b. communication
c. file
d. proxy

16. A _____ is a system which is used to prevent unauthorized user to access an organization's network.
a. VLAN
b. Firewall
c. a and b
d. router

17. What type of switch is used to connect the segments of a LAN?_____
a. Layer 2 switch
b. Layer 3 switch
c. Layer 4 switch
d. All of the above

18. A Layer 2 switch operates at_____.
a. Physical layer
b. Data link layer
c. Network layer
d. Application layer

19. What type of switch is used to connect a token Ring LAN and an Ethernet LAN?_____
a. Layer 2 switch
b. Layer 3 switch

c. Layer 4 switch
d. None of the above

20. Which of the following switches is fastest?_____
a. Store forward
b. Cut-through
c. Layer 3
d. Layer 4

21. Which of the following switches can check for errors in an incoming frame?_____
a. Store forward
b. Cut-through
c. Layer 3
d. Layer 2

22. What is the application of a layer 4 switch?_____
a. Connecting LAN segments
b. Connecting two different LAN technologies
c. Used for security
d. Used for routing

- **Short Answer Questions**

1. List LAN interconnection devices.
2. What is the function of a repeater?
3. Describe the function of a bridge?
4. what layer of OSI model bridge operate
5. Explain the operation of a transparent bridge.
6. Explain the operation of source routing bridge.
7. Explain the function of a Router.
8. Explain a static router.
9. what is function of a router?
10. A Router works in which layer of the OSI model?
11. Explain dynamic router.
12. What is the application of a gateway?
13. A Gateway operates in which layers of the OSI model?
14. What is the difference between a Gateway and a Router?
15. Explain switch operation.
16. What is the application of a symmetric switch?
17. What is application of an asymmetric switch?
18. Explain the operation of a cut-through Switch.
19. Explain the operation of a store-and-forward Switch.
20. What does VLAN stand for?

21. What is the difference between a router and a L3 Switch?
22. What is the application of a L4 switch?
23. Suppose a company has two working groups, A and B. Group A has 4 computers and group B has 3 computers; all connected to an eight port Ethernet switch. Both groups need to access a common file server FS1. There is an in-house requirement that group A computers should not be able to see Group B computers in the Network.
    a. Draw a diagram showing an Ethernet switch with seven computers and file server.
    b. Show the VLAN connectivity matrix for the above requirements.