BACHELOR OF COMPUTER APPLICATIONS

SEMESTER 3

DCA2104

BASICS OF DATA COMMUNICATION

Unit 7

Switching

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1. INTRODUCTION

This unit introduces the concept of switching. We can connect multiple devices using a point to point connection or connect between a central device and every other device. In the case of a large network, these methods are impractical and a better solution is switching. A switched network consists of a series of interlinked nodes called switches.

In this unit, we will discuss taxonomy of switched networks. We will know what a packet switched network and datagram networks are. In this unit, we will also discuss virtual circuit networks. In the last session, we will discuss structure of a switch.

1.1 Objectives

After studying this unit, you should be able to:

- *Describe switches and its taxonomy*
- *Explain circuit switched networks*
- *Describe datagram networks*
- *Explain virtual circuit networks*
- *Describe structure of a switch*

2. CIRCUIT SWITCHED NETWORKS

A circuit-switched network consists of a set of switches connected by physical links. A connection between two stations is a dedicated path made of one or more links. But each connection uses only dedicated channel on each link. Each link is divided into n channels using frequency division multiplexing (FDM) or time division multiplexing (TDM).

Figure 7.1 shows a trivial circuit-switched network with four switches and four links. Each link is divided into n (here, n=3) channels by using FDM or TDM.

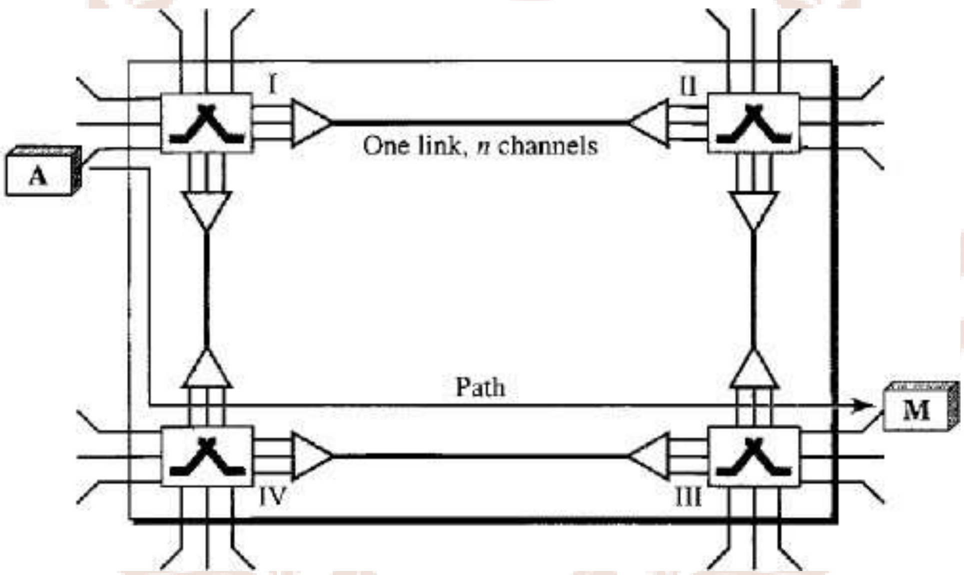

Figure 7.1: A trivial circuit-switched network

The end systems such as computers or telephones are directly connected to a switch. In the figure 7.1, two end systems are shown for simplicity. When A needs to communicate with end system M, end system A needs to request a connection to M that must be accepted by all switches as well as by M itself. This is called the setup phase. In circuit switching, a circuit is reserved on each link, and the combination of circuits or channels defines the dedicated path. After dedicated path made of connected circuits is established, data transfer can take place. The resources need to be reserved during the setup phase; the resources remain dedicated for the entire duration of data transfer. After all data have been transferred, the circuits are torn down.

Circuit switching takes place at the physical layer. Before starting communication, the stations must make a reservation for the resources to be used during the communication. These resources such as channels, switch buffers, switch processing time, and switch input/output ports must remain dedicated during the entire duration of data transfer until the teardown phase. Data transferred between two stations are not packetized. The data are a continuous flow sent by the source station and received by the destination station, although there may be delay during transmission. There is no addressing involved during data transfer. The switches route data based on their occupied band or timeslot. There is an end to end addressing used during setup phase.

Three Phases

The actual communication in a circuit-switched network requires three phases. Connection setup, data transfer, and connection teardown.

Setup phase

Before starting of a communication, a dedicated circuit needs to be established. The end systems are normally connected through dedicated lines to the switches, so connection setup means creating dedicated channels between the switches. For example, in figure 7.1, when system A wants to connect to system M, it sends a setup request that includes the address of system M to switch I. Switch I finds a channel between itself and switch IV that can be dedicated for this purpose. Switch I then sends the request to switch IV, which finds a dedicated channel between itself and switch III. Switch III informs system M of system A's intention at this time.

Next step in making the connection is that an acknowledgement from system M needs to be sent in the opposite direction to system A. Only after system A receives this acknowledgement is the connection established. Note that end to end addressing is required for creating a connection between the two end systems. These can be the addresses of the computers assigned by the administrator in a TDM network or telephone numbers in an FDM network.

Data transfer phase: After the establishment of the dedicated circuit, the two parties can transfer data.

Teardown phase: When one of the parties needs to disconnect, a signal is sent to each switch to release the resources.

Efficiency

It can be argued that circuit-switched networks are not as efficient as the other two types of networks because resources are allocated during the entire duration of the connection so these resources are unavailable to other connections. For example, in a telephone communication people terminate the communication when they finished their conversation. But in computer networks, a computer can be connected to another even if there is no activity for a long time. In this case if resources allocated are dedicated for that connection, then other connections cannot use the resources.

Delay

The delay in circuit switched network is minimal. During data transfer the data are not delayed at each switch, the resources are allocated for the duration of the connection. Figure 7.2 illustrates the idea of delay in a circuit-switched network when two switches are involved.

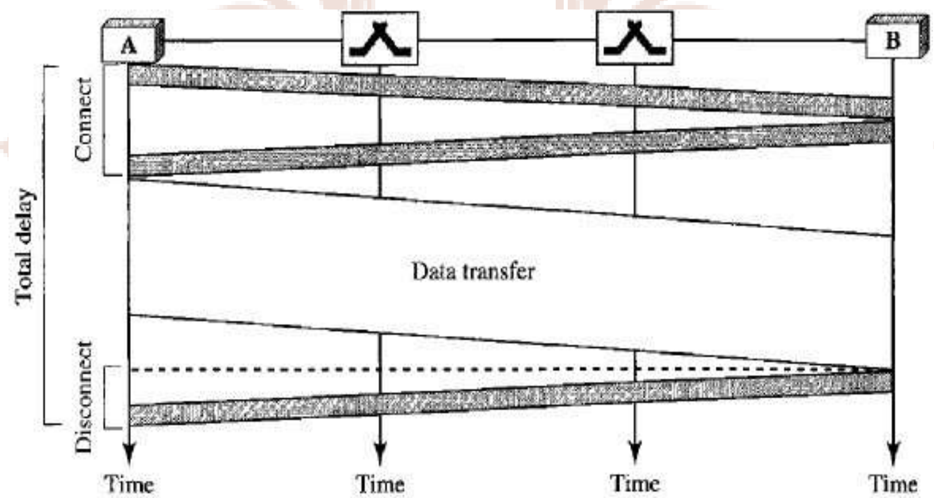

Figure 7.2: Delay in a circuit-switched network

As figure 7.2 shows, there is no waiting time at each switch. Total delay is the time needed to create the connection, transfer data and disconnect the circuit. The delay caused by the setup is the sum of four parts. The delay caused by the setup is the sum of four parts. The propagation time of the source computer request (slope of the first gray box), the request signal transfer time (height of the first gray box), the propagation time of the acknowledgment from the destination computer (slope of the second gray box) and the signal transfer time of the acknowledgment (height of the second gray box). The delay due to data transfer is the sum of two parts: the propagation time (slope of the colored box) and data transfer time (height of the colored box) which can be very long. The third box shows the time needed to tear down the circuit. We can see in figure that, the receiver request disconnection which cause the maximum delay.

Circuit switching in telephone network

Switching at the physical layer in the traditional telephone network uses the circuit switching approach. But today, the telephone number is used as the global address and the signaling system is used for the setup and teardown phase.

Self-Assessment Questions - 1

1. In circuit-switched network, each link is divided into n channels using __________and__________ .
2. In which of the following layer, circuit switching takes place?

a) Physical layer
b) Datalink layer
c) Network layer
d) Transport layer

3. 'In teardown phase, a signal is sent to each switch to release the resources'. State true or false.

   (a) True (b) False

3. DATAGRAM NETWORKS

In data communication, data is transmitted from a sender to receiver. If the data is passing through a packet-switched network, it would be divided into packets of fixed or variable size. The size of the network is determined by the network and protocol.

In packet switching, there is no resource allocation for a packet. That is, there is no reserved bandwidth on the links and there is no scheduled processing time for each packet. Resources are allocated on demand. The allocation is done on a first come first served basis. When switch receives a packet, the packet must wait if there are other packets being processed. This lack of reservation may create delay. In a packet-switched network, there is no resource reservation, resources are allocated on demand.

In a datagram network, each packet is treated independently of all others. Even if a packet is part of a multi packet transmission, the network treats it as though it existed alone. Packets in this approach are referred to as datagrams. Datagram switching is normally done at the network layer.

Figure 7.3 shows how the datagram approach is used to deliver four packets from station A to station X. The switches in a datagram network are traditionally referred to as routers.

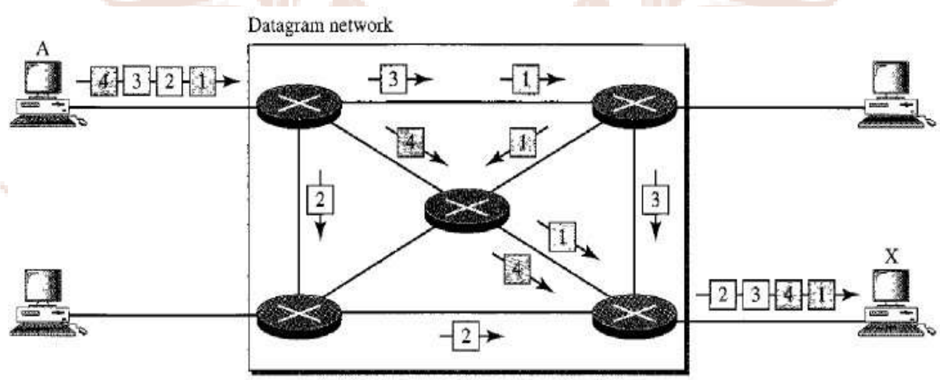

Figure 7.3: A datagram network with four switches

In the example given in figure 7.3, all four packets belong to the same message but may travel different paths to reach their destination. This is because the links may be involved in carrying packets from other sources and do not have the necessary bandwidth available to carry all the packets from A to X. This results in the arrival of datagrams at their destination out of order with different delays between the packets. Packets can also be dropped because of lack of resources. It is the responsibility of the upper layer protocol to rearrange the datagrams or ask for lost datagrams before passing them on to the application.

Datagram networks are also called connectionless networks. That means the switch does not keep information about the connection state. So there are no setup or teardown phases. Each packet is treated the same by a switch irrespective of its source or destination.

Routing Table

In connectionless network, each switch has a routing table which is based on the destination address. The routing tables are dynamic and are updated periodically. In the tables, destination address and corresponding forwarding output ports are recorded. Figure 7.4 shows the routing table for a switch.

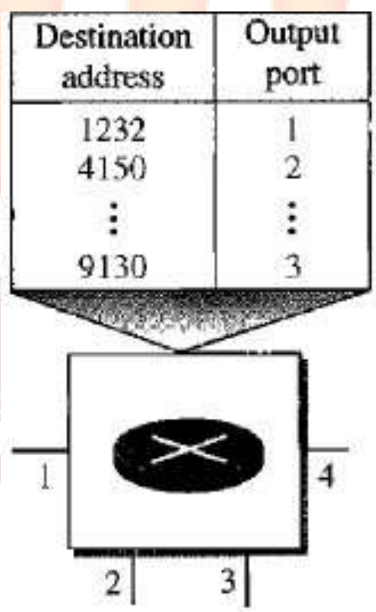

Figure 7.4: Routing table in a datagram network

Destination address

Datagram packet contains a header contains destination address of the packet. When the packet is received by the switch, this address is examined. Switch checks the routing table to find corresponding port through which the packet should be forwarded. The destination address in the header of a packet in a datagram network remains the same during entire journey of the packet.

Efficiency

Datagram network is more efficient than circuit-switched network. Resources are allocated only when there are packets to be transferred. That is, if source sends a packet and there is a delay before another packet then the resources can be reallocated during this time for other packets from other sources.

Delay

Delay in datagram circuit is more compared to virtual circuit. Also, since there is no setup and teardown phase, each packet should wait at the switch before it is forwarded. Also, since not all packets in a message necessarily travel through the same switches, the delay is not uniform for the packets of a message. Figure 7.5 shows delay in a datagram network. Here, packets travels through two switches. Total delay is the sum of three transmission times, three propagation delays and two waiting times.

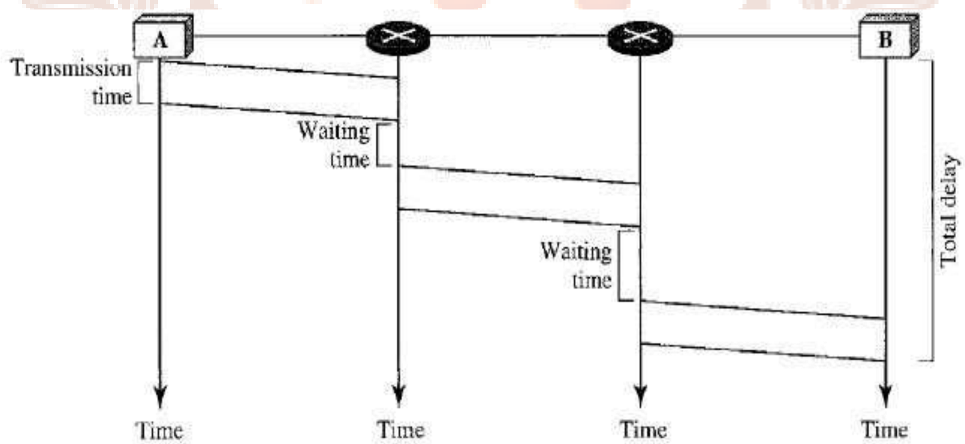

Figure 7.5: Delay in datagram network

Datagram networks in the internet

Switching in the internet is done by using the datagram approach to packet switching at the network layer. It uses universal address defined in the network layer to route packets from source to destination.

Self-Assessment Questions - 2

4. In a _______________ network, there is no resource reservation, resources are allocated on demand.
5. In a_____________ network, each packet is treated independently.
6. In which of the following layer datagram switching occurs?
   (a) Physical layer
   (b) Datalink layer
   (c) Network layer
   (d) Transport layer
7. The switches in a datagram network are traditionally referred to as___________.

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4. VIRTUAL CIRCUIT NETWORKS

We can say, virtual circuit network is a combination of circuit switched network and datagram network. Similar to circuit switched network, there are setup and teardown phases in addition to the data transfer phase. Resources can be allocated during the setup phase, as in a circuit switched network or on demand similar to datagram network. Similar to datagram network, data are packetized and each packet carries an address in the header. Similar to circuit switched network, all packets follow the same path established during the connection. A virtual circuit network is normally implemented in the data link layer, but circuit switched network is implemented in the physical layer and datagram network in the network layer.

Figure 7.6 shows an example of a virtual circuit network. The network has switches that allow traffic from sources to destinations. A source or destination can be a computer, packet switch, bridge or any other device that connects other networks.

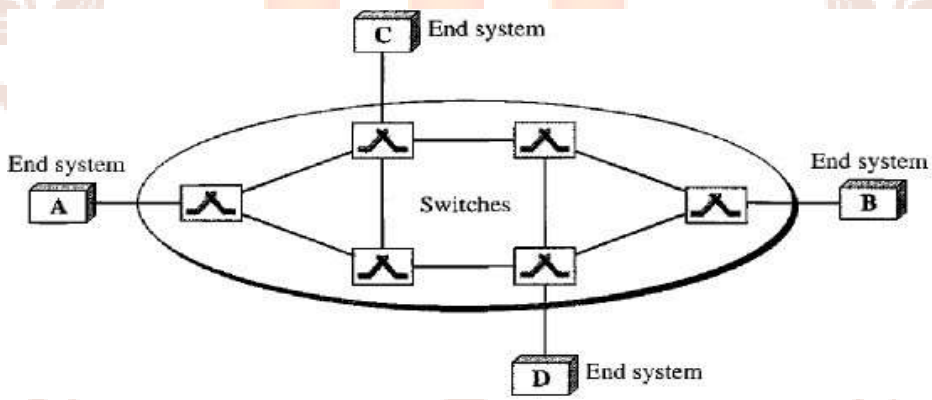

Figure 7.6: virtual circuit network

Addressing

In virtual circuit, two types of addressing are involved. They are global and virtual circuit identifier (local).

Global addressing

A source or destination should have a global address which can be unique in the scope of the network or internationally if the network is part of an international network. However, a global address in virtual circuit network is used to create a virtual circuit identifier.

Virtual circuit identifier

The identifier that is actually used for data transfer is called the virtual circuit identifier (VCI). Unlike global address, VCI is a small number that has only switch scope. It is used by a frame between two switches. When a frame arrive at a switch, it has a VCI. When it leaves, it has a different VCI. Figure 7.7 shows how VCI in a data frame changes from one switch to another.

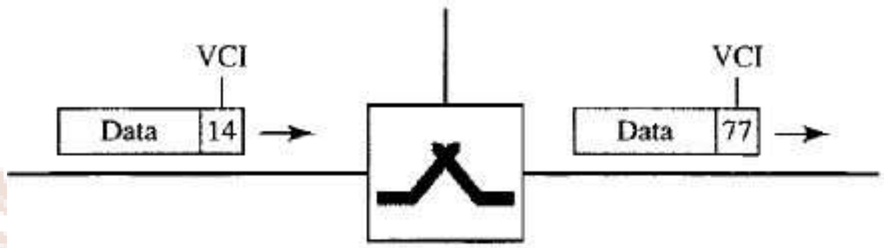

Figure 7.7: Virtual circuit identifier

Three Phases

Similar to circuit switched network, a source and destination should go through three phases in a virtual circuit network. They are setup, data transfer and teardown. During setup phase, the source and destination use their global addresses to help switches make table entries for the connection. In teardown phase, the source and destination inform the switches to delete the corresponding entry. Data transfer occurs between these two phases.

Data Transfer phase

All switches should have a table entry for the virtual circuit to transmit a frame from source to destination. The switch holds four pieces of information for each virtual circuit so the table has four columns. Let us assume that each switch has a table with entries for all active virtual circuits. Figure 7.8 shows a switch and corresponding table.

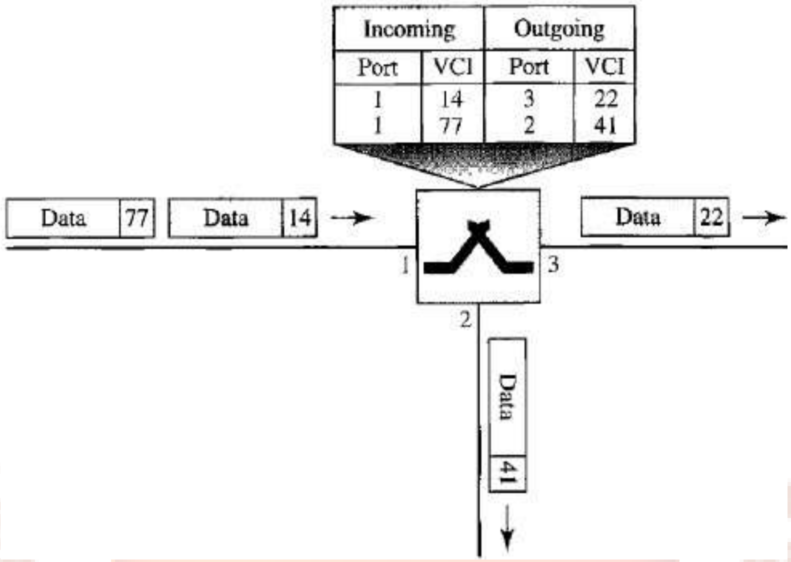

Figure 7.8: switch and tables in a virtual circuit network

Figure 7.8 shows a frame arriving at port 1 and a VCI of 14. When frame arrives, the switch looks in its table to find port 1 and a VCI of 14. When it is found, the switch knows to change the VCI to 22 and send out the frame from port 3. Figure 7.9 shows how a frame from source A reaches destination B and how its VCI changes during the trip. Each switch changes the VCI and routes the frame.

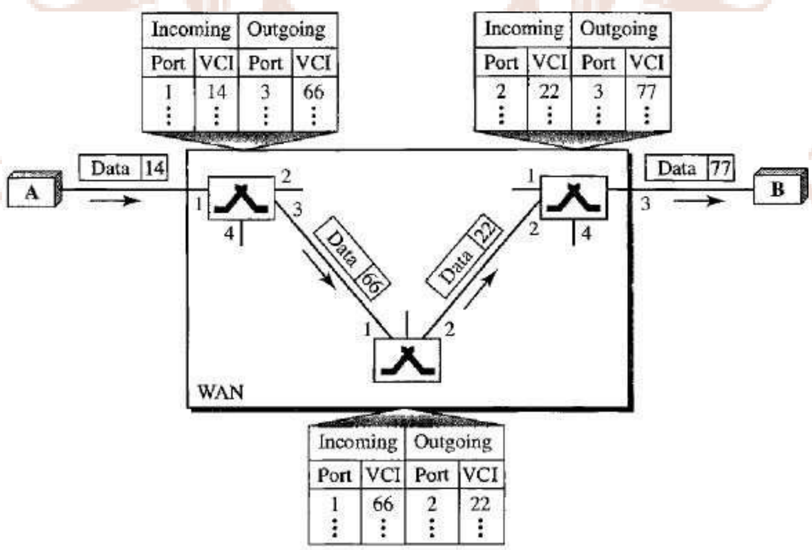

Figure 7.9: source to destination data transfer in a virtual circuit

The data transfer phase is active until the source sends all its frames to the destination. The procedure at the switch is same for each frame of a message. The process creates a virtual circuit between source and destination.

Setup Phase

In setup phase, a switch creates an entry for a virtual circuit. Suppose source A needs to create a virtual circuit to B. Two steps are required, the setup request and acknowledgement. A setup request frame is sent from source to destination. Figure 7.10 shows the process. In that source A sends a setup frame to switch 1. Switch 1 receives the setup request frame. It knows that a frame going from A to B goes out through port 3. The switch act as a packet switch in the setup phase. It has a routing table which is different from the switching table. The switch creates an entry in its table for this virtual circuit, but it is only able to fill three of the four columns. The switch assigns the incoming port and chooses an available incoming VCI

(14) and the outgoing port (3). It does not know the outgoing VCI which will be found during the acknowledgement step. The switch then forwards the frame via port 3 to switch 2.

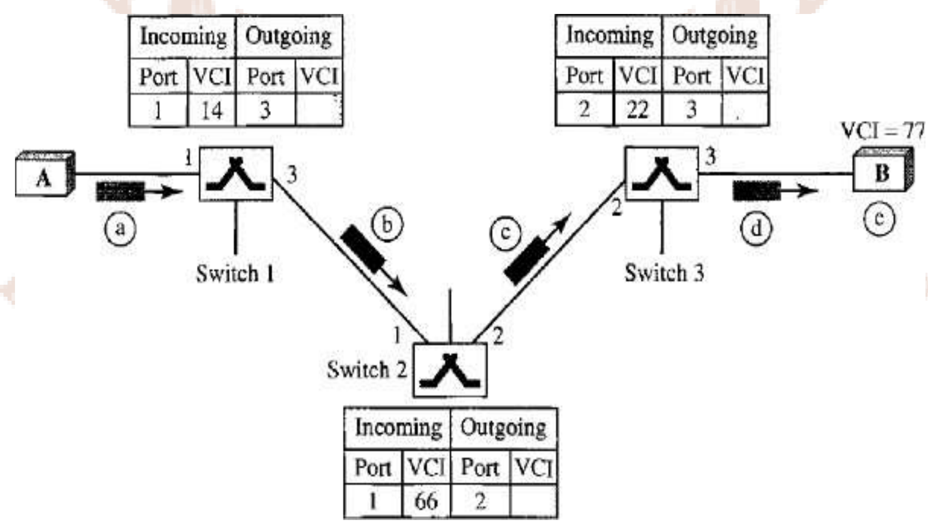

Figure 7.10: setup request in a virtual circuit network

Switch 2 receives the setup request frame. The same event happen here as at switch1. Three columns of the table are completed, they are incoming port (1), incoming VCI (66) and outgoing port (2). Switch 3 receives the setup request frame. Again three columns are filled, they are incoming port (2), incoming VCI (22) and outgoing port (3). Destination B receives the setup frame and if it is ready to receive frames from A, it assigns a VCI to the incoming frames that come from A (here it is 77). This VCI informs the destination that frame come from A, and not from other sources.

Acknowledgment

A special frame known as acknowledgment frame completes the entries in the switching tables. Figure 7.11 shows the process. Here, destination sends an acknowledgment to switch 3. The acknowledgement carries global source and destination addresses so the switch knows which entry in the table is to be completed. The frame also carries VCI77, chosen by the destination as the incoming VCI for frames from A. switch 3 uses this VCI to complete the outgoing VCI column for this entry. Here 77 is the incoming VCI for destination B but outgoing VCI for switch3. Switch 3 sends an acknowledgement to switch 2 that contains its incoming VCI in the table. Switch 2 uses this as the outgoing VCI in the table. Switch 2 sends an acknowledgement to switch 1 that contains its incoming VCI in the table. Switch 1 uses this as the outgoing VCI in the table. Finally switch 1 sends an acknowledgement to source A that contains its incoming VCI in the table. The source uses this as the outgoing VCI for the data frames to be sent to destination B.

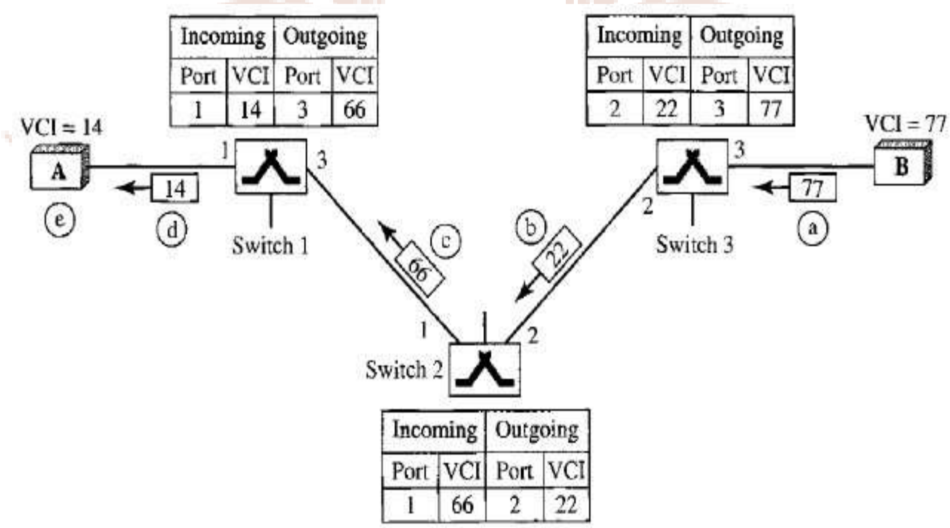

Figure 7.11: setup acknowledgement in a virtual circuit network

Teardown phase

After sending all frames to B, source A sends a special frame called a teardown request. Destination B responds with a teardown confirmation frame. Then all switches delete the corresponding entry from their tables.

Efficiency

Resource reservation in a virtual circuit network can be made during the setup or can be on demand during the data transfer phase. In first case, the delay for each packet is same. In second case, each packet may encounter different delays. One of the main advantage in virtual circuit is that the source can check the availability of resources even if the resource allocation is on demand.

Delay

In virtual circuit network, there is one time delay for setup and one time delay for teardown. If resources are allocated during setup phase, there is no waiting time for individual packets. Figure 7.12 shows the delay for a packet travelling through two switches in a virtual circuit network. The packet is travelling through two switches. Total delay is the sum of three transmission times, three propagation times, setup delay and teardown delay.

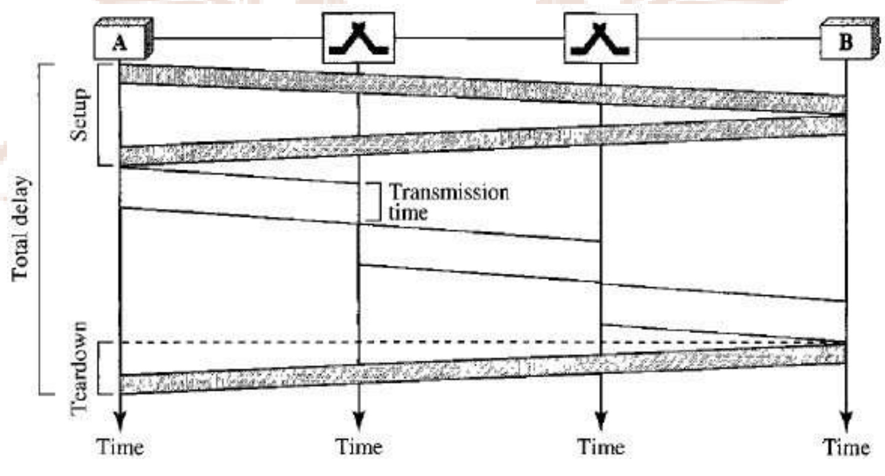

Figure 7.12: Delay in a virtual circuit network

Virtual circuit networks are used in switched WANs such as frame relay and ATM networks. The data link layer of these technologies is well suited to virtual circuit technology.

Self-Assessment Questions - 3

8. Virtual circuit network is a combination of ___________ network and ____________network.
9. In virtual circuit, two types of addressing involved are_____________ and ____________.
10. The identifier that is actually used for data transfer is called __________.

5. STRUCTURE OF A SWITCH

In this section, we discuss the structure of a switches used in circuit switched and packet switched networks.

5.1 Structure Of Circuit Switches

The space division switch or the time division switch are the circuit switches.

Space-division switch

In space division switching, the paths in the circuit are separated from one another with regard to space. This was originally designed to use in analog networks but is currently used in both analog and digital networks. It includes many designs.

Crossbar switch

A crossbar switch connects n inputs to m outputs in a grid using electronic microswitches (transistors) at each crosspoint. Figure 7.13 shows crossbar switch with three inputs and four outputs. Main drawback of this design is the number of crosspoints required.

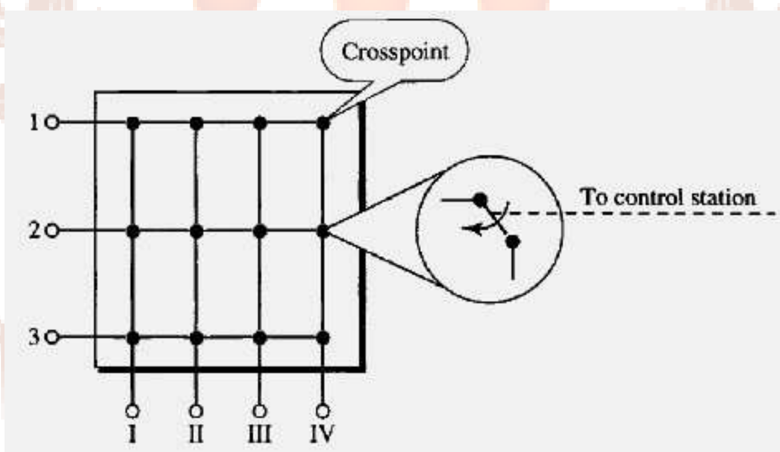

Figure 7.13: crossbar switch with three inputs and four outputs

To connect n inputs to m outputs using a crossbar switch requires $n \times m$ crosspoints. For instance, to connect 1000 inputs to 1000 outputs, we require a switch with 1,000,000 crosspoints which is impractical. Such a switch is also inefficient because in practice, fewer than 25 percent of the crosspoints are in use at any given time.

Multistage switch

The solution to the limitation of the crossbar switch is the multistage switch that combines crossbar switches in several stages. Figure 7.14 shows a multistage switch. In a single crossbar switch, for any connection, only one row or column is active. So we need N N crosspoints. If we can allow multiple paths inside the switch, we can decrease the number of crosspoints. Each crosspoints in the middle stage can be accessed by multiple crosspoints in the first or third stage.

The idea of multistage switching is to share the crosspoints in middle stage crossbars. Sharing can cause lack of availability if the resources are limited and all users want a connection at the same time. Blocking occurs when one input cannot be connected to output because there is no path available between them because all possible intermediate switches are occupied. In a single stage switch, blocking does not occur because every pair of input and output has its own crosspoint and there is always a path.

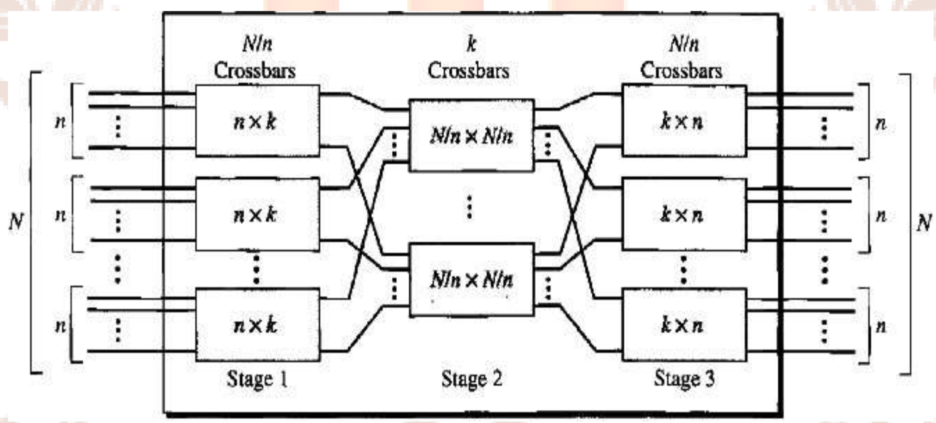

Figure 7.14: Multistage switch

In large systems contains 10,000 inputs and outputs, the number of stages can be increased to cut down on the number of crosspoints required. As the number of stages increases, possible blocking increases as well. For example, many people experienced blocking on public telephone systems during natural disaster when the call being made to check on relatives that increases the regular load of the system. Today telephone companies use time division switching or a combination of space-time division switches.

Time-division Switch

Time-division switching uses time division multiplexing inside a switch. The most popular technology is called time-slot interchange (TSI).

Time-slot Interchange

Figure 7.15 shows time slot interchange with a system connecting four input lines to four output lines. Suppose each input line wants to send data to an output line according to the following pattern.

$$1 \rightarrow 3 \quad 2 \rightarrow 4 \quad 3 \rightarrow 1 \quad 4 \rightarrow 2$$

The figure 7.15 combines a TDM multiplexer, a TDM demultiplexer and a TSI (time slot interchange) consisting of random access memory with several memory locations. The size of each location is same as the size of a single time slot. The number of location is same as the number of inputs. The RAM fills up with incoming data from time slots in the order received. Slots are then sent out in an order based on the decisions of a control unit.

Time-division switch

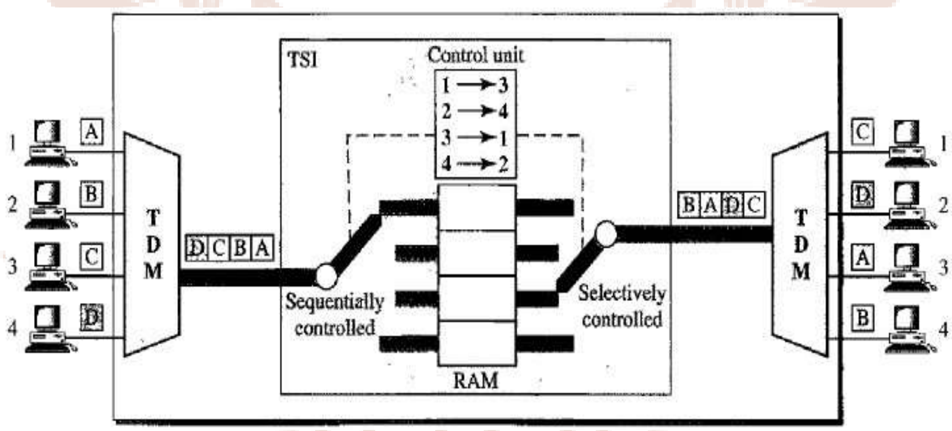

Figure 7.15: Time slot interchange

Time- and Space- Division Switch Combinations

The advantage of space division switching is that it is instantaneous. Its disadvantage is the number of crosspoints required to make space division switching acceptable in terms of blocking. The advantage of time division switching is that it needs no crosspoints. Disadvantage in case of TSI is that processing each connection creates delays.

We combine space division and time division technologies to take advantage of both. Multistage switches of this sort can be designed as ***time-space-time*** (TST) switch. Figure 7.16 shows a simple TST switch that consists of two time stages and one space stage and has 12 inputs and 12 outputs. Instead of one time division switch, it divides the input into three groups and directs them to three time slot interchanges. The result is that the average delay is one third of what would result from using one time slot interchange to handle all 12 inputs.

The last stage is a mirror image of the first stage. The middle stage is a space division switch that connects the TSI groups to allow connectivity between all possible input and output pairs.

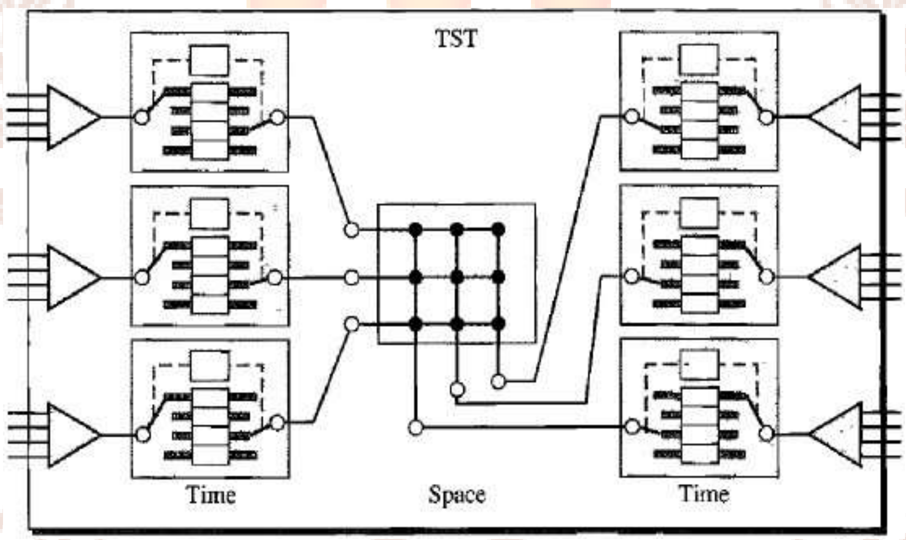

Figure 7.16: Time-space-time switch

5.2 Structure Of Packet Switches

A packet switch has four components. They are input ports, output ports, the routing processor and the switching fabric as shown in figure 7.17.

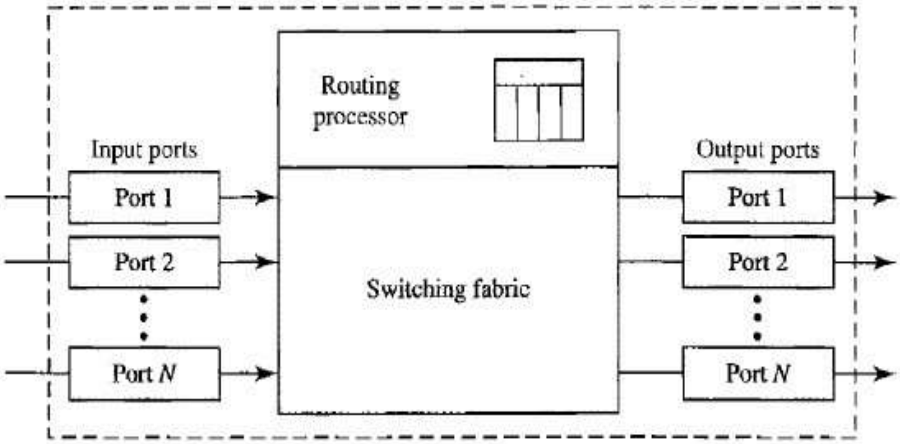

Figure 7.17: Packet switch components

Input ports

An input port performs the physical and data link functions of the packet switch. The bits are constructed from the received signal. The packet is decapsulated from the frame. Errors are detected and corrected. Then packets should be routed by the network layer. In addition to a physical layer processor and data link layer processor, the input port has buffers to hold the packet before it is directed to the switching fabric. Figure 7.18 shows an input port.

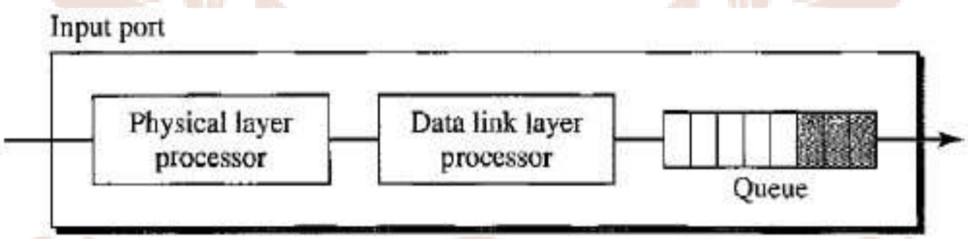

Figure 7.18: Input port

Output Port

The output port performs same functions as the input port, but in reverse order. First, the ongoing packets are queued, then the packet is encapsulated in a frame and then physical layer functions are applied to the frame to create the signal to be sent on the line. Figure 7.19 shows output port.

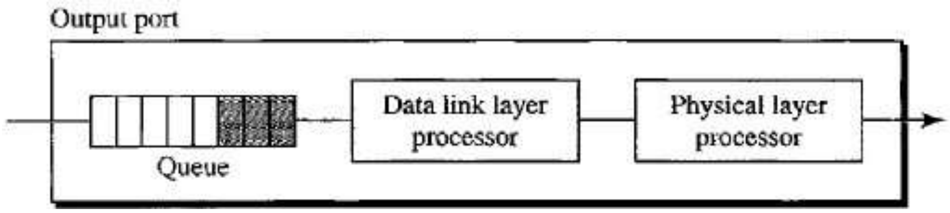

Figure 7.19: Output port

Routing Processor

Routing processor performs the functions of the network layer. Destination address is used to find the address of the next hop and the output port number from which packet is sent out. This activity is sometimes referred to as table lookup because the routing processor searches the routing table. In the newer packet switches, this function of the routing processor is being moved to the input ports to facilitate and speedup the process.

Switching Fabrics

In packet switching, moving of packet from the input queue to output queue is the most difficult task. The speed of this transfer affects the size of the input output queue and the overall delay in packet delivery. In the past, when a packet switch was actually a dedicated computer, the memory of the computer or a bus was used as the switching fabric. The input port stored the packet in memory, the output port retrieved the packet from memory. Now, packet switches are specialized mechanisms that use a variety of switching fabrics. Few of these fabrics are given below

a) Crossbar Switch

The simplest type of switching fabric is the crossbar switch, which we have already discussed in 7.5.1

b) Banyan Switch

Banyan switch is a more realistic approach than the crossbar switch, which is named after the banyan tree. A banyan switch is a multistage switch with microswitches at each stage that route the packets based on the output port represented as a binary string. For n inputs and n outputs we have log2 n stages with n/2 microswitches at each stage. The first stage routes the packet based on the high order bit of the binary string. The second stage routes the packet based on the second high-order bit and so on. Figure 7.20 shows a banyan switch with eight inputs and eight outputs. The number of stages is $\log_2(8) = 3$.

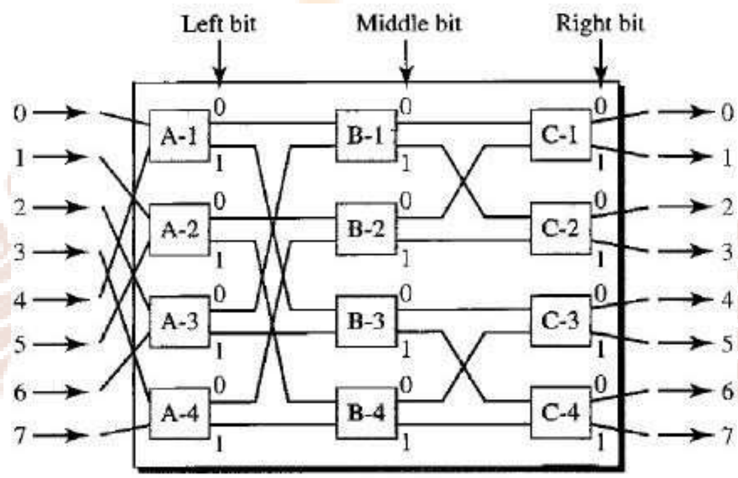

Figure 7.20: A banyan switch

c) Batcher-Banyan Switch

The issue with the banyan switch is the possibility of internal collision even if the two packets are not heading for the same output port. We can solve this issue by sorting the arriving packets based on their destination port. K.E.Batcher designed a switch that comes before the banyan switch and sorts the incoming packets according to their final destination. The combination is called the batcher-banyan switch. Another hardware module called a **trap** is added between the batcher switch and the banyan switch. Figure 7.21 shows a batcher-banyan switch.

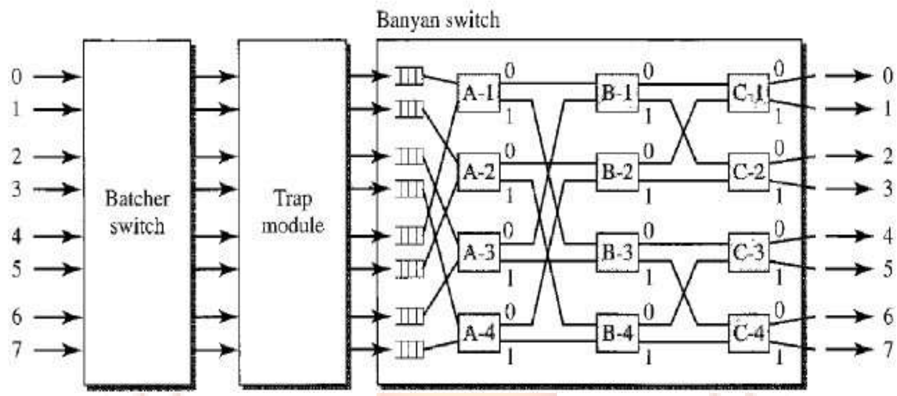

Figure 7.21: Batcher-Banyan Switch

The trap module prevents duplicate packets from passing to the banyan switch simultaneously. Only one packet for each destination is allowed at each tick. If there are more than one, they wait for the next tick.

Self-Assessment Questions - 4

11. The ___________ or the___________ are the circuit switches.
12. The most popular Time-division switching is known as__________ .
13. The simplest type of switching fabric is known as______________ .
14. A switch that comes before the banyan switch and sorts the incoming packets according to their final destination is designed by_____________.

6. SUMMARY

Let us recapitulate the important concepts discussed in this unit:

- A switched network consists of a series of interlinked nodes called switches.
- In circuit switched network, each link is divided into n channels using frequency division multiplexing (FDM) or time division multiplexing (TDM).
- The actual communication in a circuit-switched network requires three phases. Connection setup, data transfer, and connection teardown.
- In a packet-switched network, there is no resource reservation, resources are allocated on demand.
- Virtual circuit network is a combination of circuit switched network and datagram network.
- The identifier that is actually used for data transfer is called the virtual circuit identifier (VCI).
- The space division switch or the time division switch are the circuit switches.
- In space division switching, the paths in the circuit are separated from one another with regard to space.
- Time-division switching uses time division multiplexing inside a switch.
- The most popular technology is called time-slot interchange (TSI).
- Both space division and time division technologies are combined together to form time-space-time (TST) switch.

7. TERMINAL QUESTIONS

1. Explain circuit switched network.
2. Describe datagram networks.
3. Explain virtual circuit networks.
4. Explain the structure of circuit switches.
5. Describe the structure of packet switches.

8. ANSWERS

Self-Assessment Questions

1. Frequency division multiplexing, time division multiplexing
2. (a) physical layer
3. (a) true
4. Packet switched
5. Datagram
6. (c) Network layer
7. Routers
8. Circuit switched network, datagram network
9. Global, virtual circuit identifier
10. Virtual circuit identifier
11. Space division switch, time division switch
12. Time slot interchange (TSI)
13. Crossbar switch
14. K.E.Batcher

Terminal Questions

1. A circuit-switched network consists of a set of switches connected by physical links. A connection between two stations is a dedicated path made of one or more links. But each connection uses only dedicated channel on each link. (Refer section 2 for detail).
2. In a datagram network, each packet is treated independently of all others. Even if a packet is part of a multi packet transmission, the network treats it as though it existed alone. (Refer section 3 for detail).
3. Virtual circuit network is a combination of circuit switched network and datagram network. Similar to circuit switched network, there are setup and teardown phases in addition to the data transfer phase. (Refer section 4 for detail).
4. The space division switch or the time division switch are the circuit switches. In space division switching, the paths in the circuit are separated from one another with regard

to space. This was originally designed to use in analog networks but is currently used in both analog and digital networks. (Refer section 5.1 for detail).

5. A packet switch has four components. They are input ports, output ports, the routing processor and the switching fabric. (Refer section 5.2 for detail)

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