UNIT 3: MULTIPLEXING AND SWITCHING

Structure **Page No.**

3.0 INTRODUCTION

The most fundamental need of any communication system design is to cater to large number of users. But this requires a large number of resources and large bandwidths supporting multiple channels. Requirement for large number of resources can be met if the resources are available, but this makes it cost ineffective. Therefore, the aim is always to use minimum number of resources and make their utilisation to their fullest potential. Bandwidth always remains a critical resource due to its limited availability and therefore, communication systems try to harness its fullest potential. Networks always require us to accommodate multiple signals utilizing a single piece of cabling to make it cost effective and reduce complexity. This need is seen throughout networking whether we are talking about local area networks or wide area ones. Modern telephone systems must place a large number of calls over a limited amount of bandwidth (i.e. a trunk). Broadband LANs must have several different types of data on a single wire at once. For these applications, we need to share the resources and in particular the bandwidth. Multiplexing and Switching are the two most important techniques being employed for this purpose in the present day communication systems and have been discussed in the present unit.

3.1 OBJECTIVES

After going through this unit, you should be able to:

- Know the concept of Multiplexing and Switching in computer networks
- Understand the basic multiplexing techniques like FDM, TDM, CDM and SDM
- Differentiate between different types of multiplexing techniques
- Know the switching mechanisms
- Differentiate between packet, circuit and message switching
- Understand the different packet switching mechanisms

3.2 MULTIPLEXING CONCEPT

In general, a medium can carry only one signal at any moment in time. For multiple signals to share one medium, the medium must somehow be divided, giving each signal a portion of the total bandwidth. Multiplexing (also known as MUXing) is a method by which multiple analog message signals or digital data streams are combined into one signal over a shared medium. The basic aim of the Multiplexing is to share an expensive resource by putting-up multiple signals on the same channel. For example, in telecommunications, several telephone calls may be carried using one wire. Multiplexing originated in telegraphy in the 1870s, and is now widely applied in different streams of communications. When several communication channels are needed between the same two points, significant economies may be realized by sending all the messages on one transmission facility – called multiplexing. As shown in Figure 1, n number of signals from the low speed channels have been combined to one sigh speed link using a n:1 multiplexer. Whereas the opposite process is carried out at the other end, where the signals are further separated into n number of low speed channels. This opposite process is referred as demultiplexing.

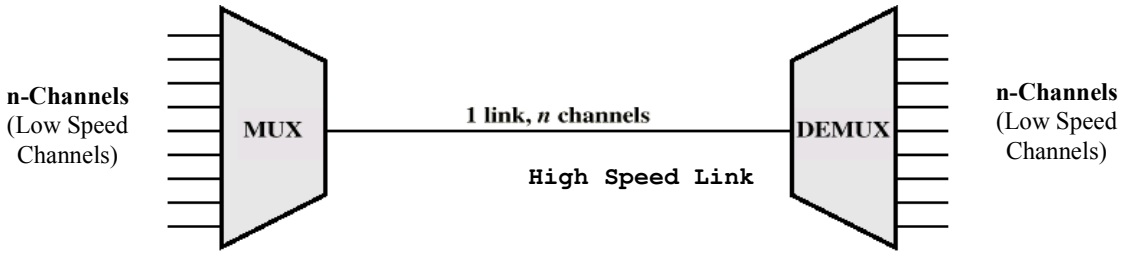

Figure 1: Multiplexing and De-Multiplexing

Thus, Multiplexing refers to the ability to transmit data coming from several pairs of equipment (transmitters and receivers) called *low-speed channels* on a single physical medium (called the *high-speed channel*). Whereas, a *multiplexer* is the multiplexing device that combines the signals from the different transmitters and sends them over the *high-speed channel*. A *demultiplexer* is the device which separates signal received from a *high-speed channel* into different signal and sends them to receivers.

There are four basic multiplexing techniques:

- Frequency division multiplexing (FDM)
- Time division Multiplexing (TDM)
- Code division Multiplexing (CDM)
- Space-division Multiplexing (SDM)
- Frequency division Multiplexing: Bandwidth is divided into different smaller frequency bands (range).
- Time division Multiplexing (TDM) (Time slots are allocated to message signals in an non overlapping manner in the time domain so that individual messages can be recovered from time synchronized switches)
- Quadrature Carrier/amplitude Multiplexing (QAM): Two message signals are transmitted in the same frequency band. The recovery is possible due to the carrier signals being orthogonal)

- Code division Multiplexing (CDM) users occupy the same frequency band but modulate their messages with different codes TDMA FDMA CDMA when used for multiple access TDMA, FDMA, e.g., GSM, FM, AM, Wireless networks

☞ Check Your Progress 1

1. Define multiplexing.

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2. State the importance of multiplexing.

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3. What are the multiplexing techniques?

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3.3 FREQUENCY-DIVISION MULTIPLEXING

Frequency division multiplexing (FDM) is the technique used to divide the available bandwidth into a number of smaller independent logical channels with each channel having a small bandwidth. The method of using a number of carrier frequencies each of which is modulated by an independent speech signal is in fact frequency division multiplexing. The following Figure 2 depicts the basic process of frequency division multiplexing, in which the total bandwidth has been divided into n-number of different channels and each one of them working with a specific bandwidth.

The following figure 2 depicts how three voice-grade telephone channels are multiplexed using FDM. When many channels are multiplexed together, 4000Hz is allocated to each channel to keep them well separated. First the voice channels are raised in frequency, each by a different amount. Then they can be combined, because no two channels can occupy the same portion of the spectrum. Notice that even though there are gaps (guard bands) between the channels, there is some overlap between adjacent channels, because the filters do not have sharp edges. This overlap means that a strong spike at the edge of one channel will be felt in the adjacent one as non-thermal noise.

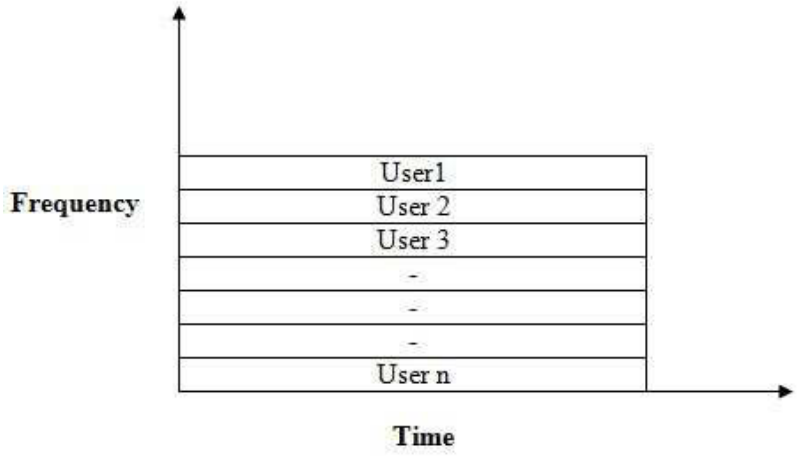

Figure 2: Frequency Division Multiplexing

In the telecommunication technology, the total bandwidth available in a communication medium is divided into a series of non-overlapping frequencies sub-bands using the frequency division multiplexing. Each one of these sub-bands then carries a separate signal. This allows a single transmission medium such as a cable or optical fiber to be shared by many signals. An example of a system using FDM is cable television, in which many television channels are carried simultaneously on a single cable. FDM is also used by telephone systems to transmit multiple telephone calls through high capacity trunk lines, communications satellites to transmit multiple channels of data on uplink and downlink radio beams, and broadband DSL modems to transmit large amounts of computer data through twisted pairs telephone lines, among many other uses.Frequency-division multiplexing works best with low-speed devices. The frequency division multiplexing schemes used around the world are very standardized. A wide spread standard is 12, 4000-Hz each voice channels (3000Hz for user, plus two guard bands of 500Hz each) multiplexed into the 60 to 108 KHz band. Many carriers offer a 48 to 56 kbps leased line service to customers, based on the group. The frequency band division has been illustrated in the Figure 3 taking some example frequencies.

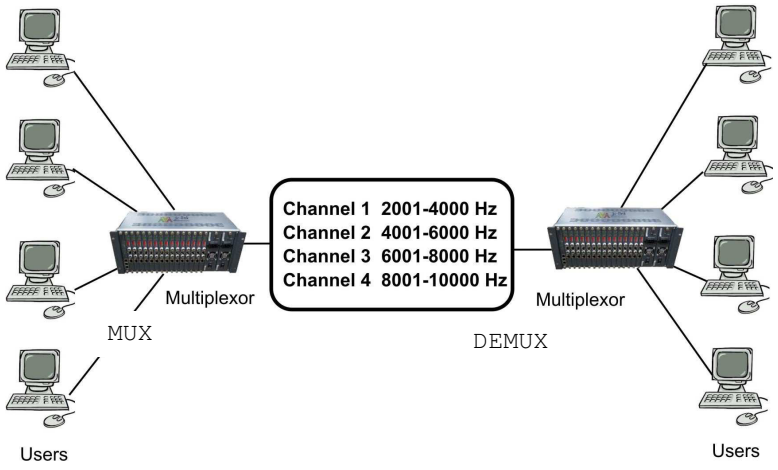

Figure 3: Illustration of FDM using four different channels

In Telephony, the most widely used method of modulation in FDM is single sideband modulation, which, in the case of voice signals, requires a bandwidth that is approximately equal to that of the original voice signal. Each voice input is usually assigned a bandwidth of 4 KHz. The bandpass filters following the modulators are used to restrict the band of each modulated signal to its prescribed range. The

resulting bandpass filter outputs are combined in parallel to form the input to the common channel. At the receiving terminal, a bank of band pass filters, with their inputs connected in parallel, is used to separate the message signals on a frequency-occupancy basis. The original message signals are recovered by individual demodulators

Frequency division multiplexing (FDM) is also referred as the Wavelength division multiplexing (WDM), where we are using the optical communications focusing on the wavelength rather than the frequency.

Advantages of FDM:

1. The users can be added to the system by simply adding another pair of transmitter modulator and receiver demodulators.
2. FDM system support full duplex information (Both side simultaneous Communication) flow which is required by most of application.

Disadvantages of FDM:

1. In FDM system, the initial cost is high. This may include the cable between the two ends and the associated connectors for the cable.
2. A problem with one user can sometimes affect the others.
3. Each user requires a precise carrier frequency for transmission of the signals.

3.4 TIME-DIVISION MULTIPLEXING

Time Division Multiplexing (TDM) is another popular method of utilizing the capacity of a physical channel effectively. Each user of the channel is allotted a small time interval during which it may transmit a message. Thus the total time available in the channel is divided and each user is allocated a time slot. Data from each user is multiplexed into a frame which is transmitted over the channel. In TDM, user's messages are buffered as they received and read from the buffer during its time slot to make a frame. Therefore each user can use the full channel bandwidth. The channel capacity is fully utilized in TDM by interleaving a number of messages belonging to different users into one long message. This message sent through the physical channel must be separated at the receiving end. Individual chunks of message sent by each user should be reassembled into a full message. The process of the Time division multiplexing has been shown in Figure 4.

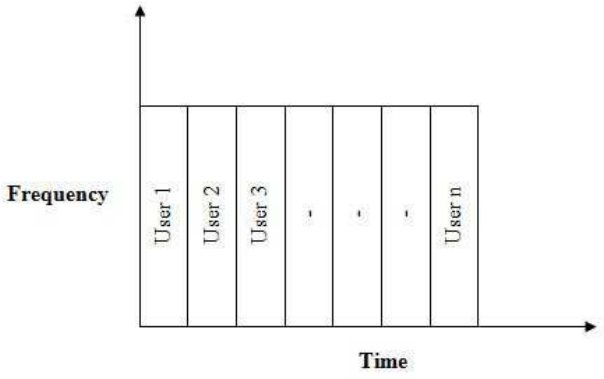

Figure 4: Time Division Multiplexing

Sharing of the signal is accomplished by dividing available transmission time on a medium among users. For example, in some countries, the individual stations have two logical sub channels: music and advertising. These two alternate in time on the same frequency first a burst of music, then a burst of advertising, then more music and

so on. This situation is time division multiplexing. Unfortunately, TDM can only be used for digital data multiplexing. Since local loops produce analog signals, a conversion is needed from analog to digital in the end office. Where all the individual local loops come together to be combined onto outgoing trucks. The TDM process is further illustrated in Figure 5 with the digital data stream.

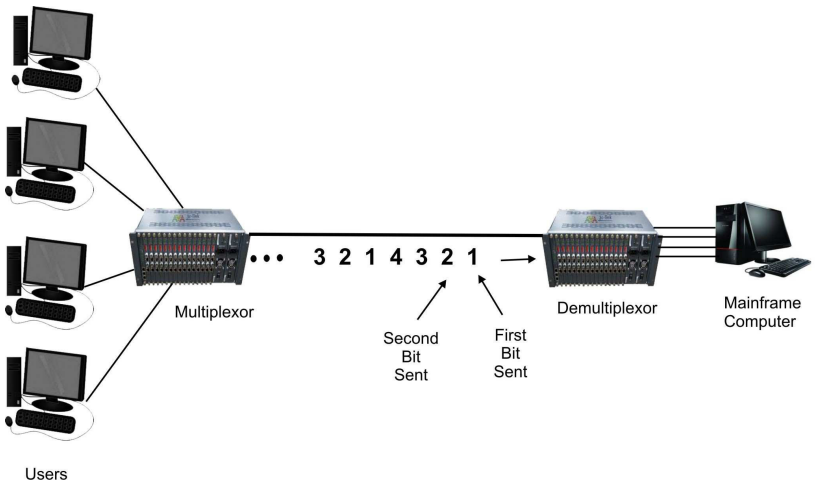

Figure 5: Digital Transmission using TDM

Applications of TDM

- The PDH (Plesiochronous Digital Hierarchy) system, also known as the PCM (Pulse Code Modulation) systems
- The synchronous digital hierarchy (SDH) / synchronous optical networking (SONET) network transmission standards.
- TDM can be further extended into the time division multiple Channel (TDMA) scheme, where several stations connected to the same physical medium, for example sharing the same frequency channel, can communicate. Application examples include the widely used GSM telephone system

Advantages of TDM

1. It uses a single link
2. It does not require precise carrier matching at both end of the links.
3. Use of the channel capacity is high.
4. Each to expand the number of users on a system at a low cost.
5. There is no need to include identification of the traffic stream on each packet.

Disadvantages of TDM

1. The sensitivity to other user is very high and causes problems
2. Initial cost is high
3. Technical complexity is more

3.5 CODE DIVISION MULTIPLEXING

As you may know, the concept of multiple access where we can allow several transmitters to send information simultaneously over a single communication channel and it allows several users to share a band of frequencies (or you can say bandwidth).

CDMA uses spread-spectrum technology and a special coding scheme (where each transmitter is assigned a code generally pseudorandom code) to allow multiple users to be multiplexed over the same physical channel. By contrast, time division multiple access (TDMA) divides access by time, while frequency-division multiple access (FDMA) divides it by frequency. CDMA is a form of spread-spectrum signalling, since the modulated coded signal has a much higher data bandwidth than the data being communicated. This allows more users to communicate on the same network at one time than if each user was allotted a specific frequency range. Remember that CDMA is a digital technology, so analog signals must be digitized before being transmitted on the network.

3.6 SPACE DIVISION MULTIPLEXING

When we want to transmit multiple messages through any of the communication media, the ultimate goal is to maximize the use of the given resources (e.g. time and frequency in general). It involves grouping many separate wires into a common cable enclosure. A cable that has, for example, 50 twisted pairs inside it can support 50 channels. SDM has the unique advantage of not requiring any multiplexing equipment. It is usually combined with other multiplexing techniques to better utilize the individual physical channels. For example, if there are six persons in the office and all of them want to talk at the same time, this will give rise to interference between the conversations. To reduce the interference they may divide themselves into three groups of two, such that the conversation is between each pair of people. If the pairs continue talking whilst sitting next to each other, the interference would still be present. The best way for each pair to converse with minimal interference would be to sit a few feet away from the other pairs (within the same room) and converse. They would still be sharing the same medium for their conversations but the physical space in the room would be divided for each conversation. This is the simplest example of Space Division Multiplexing. The concept of SDM has been illustrated in Figure 6.

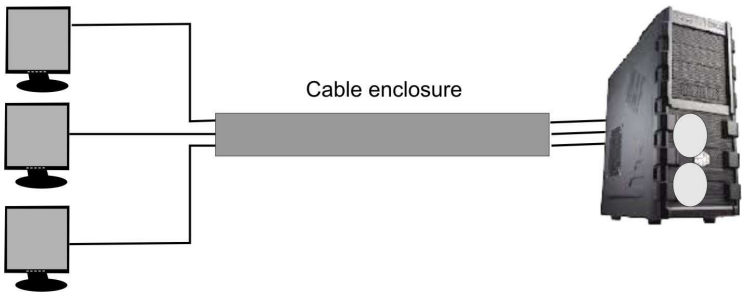

Figure 6: Space Division Multiplexing

Space Division Multiplexing is the multiplexing technique in which both the time and frequency can be reused by transmitting our information through a parallel set of channels.

In wired communication, space-division multiplexing simply implies different point-to-point wires for different channels. Examples include an analogue stereo audio cable, with one pair of wires for the left channel and another for the right channel, and a multipair telephone cable usually employed to provide PSTN connections in different homes. Another example is a switched star network such as the analog telephone access network (although inside the telephone exchange or between the exchanges, other multiplexing techniques are typically employed). In wireless communication, space-division multiplexing is achieved by multiple antenna elements forming a phased array antenna. Examples are multiple-input and multiple-output (MIMO), single-input and multiple-output (SIMO) and multiple-input and single-output (MISO) multiplexing.

3.7 SWITCHING

Switching forms a very important process in a communication system. A switch is used to connect the incoming link to the desired outgoing link and directs the incoming message to the appropriate outgoing link. Let us understand the concept of switching with the help of a simple illustrative example.

Consider a group of 8 people with telephones. If we were to use direct lines between all the people, we would need 28 duplex (wires that allow simultaneous two-way conversation) lines. The arithmetic is pretty simple - to connect **n** subscribers directly, we need **n(n-1)/2** lines. This is alright as long as the number of subscribers is less and the distances are also small. But in the present day electronic communication systems, we are talking about connecting the entire world - obviously direct connections are not the answer. We need to design a system, which can connect the people from anywhere. Now, if we were to use a switch instead, we could reduce the number of lines needed to just 4, because with 8 subscribers, there would at the most be just 4 conversations simultaneously. The switch would have 4 lines internally and it would use the each line to connect a pair of subscribers. This has been illustrated in Figure 7 below.

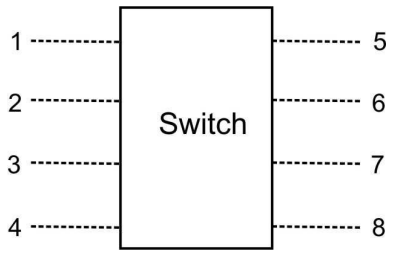

Figure 7: A simple switch with 4-input and 4-output lines

Let us assume the switch in the above diagram has 4 internal lines A, B, C and D. Say A is being used to connect 1 to 7 and B to connect 4 to 5. Now if 3 were to wish to get connected to 8, the switch would 'patch' the ends of C so that 3 and 8 are connected. Instead, if 6 had lifted the phone before the 3 and tried to get connected to 2, the switch would use C to 'patch' a connection between 6 and 2. We assume that the order in which the lines A, B, C and D are used is in accordance with their alphabetical order. This assumption is valid and any other order would not have any bearing upon the concept of switching. The fact remains that the lines A, B, C and D are not fixed. Their end-points change from time to time. *Thus they are* switched *circuits.*

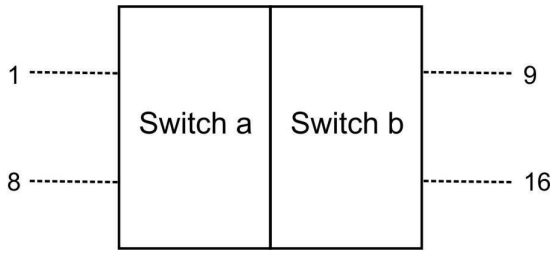

Figure 8: Two Switches with 8-subscribers

Consider 2 such 8-subscriber switches as shown in the Figure 8. They are seemingly connected by just one line. But this line is a multiplexed line, and is not switched. It is called a trunk. It is not switched because it always carries traffic from switch a switch b. Let us assume the multiplexer is capable of sending 4 simultaneous conversations over one line. Then the trunk could be carrying conversations between 1-15, 4-9, 8-11 and 5-12. The lines internal to switch a would connect 1,4,8 and 5 to the multiplexer /

demultiplexer (remember the line is duplex) and therefore the trunk. Similarly, the lines internal to switch b would connect 15, 9, 11 and 12 to the multiplexer/ demultiplexer. The switched circuits are inside the switches a and b. But the trunk between a and b is multiplexed with 4 conversations. So in a sense, the trunk is not switched. But if you had more than one trunk between switches a and b, then the trunks would also be switched. Why, because a call from 1 to 15 could go on either trunk 1 or trunk 2 (assuming there are two trunks each capable of carrying 4 conversations). Thus, the trunks are now switched, in addition to being multiplexed.

It is very important to understand the difference between switching and multiplexing. In simple terms, multiplexing is done to maximize the use of a communications channel. Whereas, the switching is the manipulation of the ends of the communications channel and is used to make the connections. The purpose of an electrical switch is to close /open a circuit to allow/stop flow of current. A communication switch is similarly used to allow/stop flow of message through the path connecting the receiver and the transmitter. Two users, one can be called sender and the other receiver, can be connected by a medium like a conducting wire over which messages in the form of electrical signals can be transmitted from one user to the other. A switch inserted in the electrical path between the two users facilitates connection/disconnection of the users as desired by controlling the switch. The path need not be on all the time. It needs to be switched on only when the users need to communicate. The role of such a switch becomes more important when there are a large number of users and a particular user at one time may want to communicate with another user and wants to communicate still another user at a different time. Thus the same user has to be connected to two different users at two different times. This can be done by a controlled switch. Thus in a set of say n users, different users may like to communicate with different users at different time. The simple 2 X 2 switch has been illustrated in the Figure 9 below.

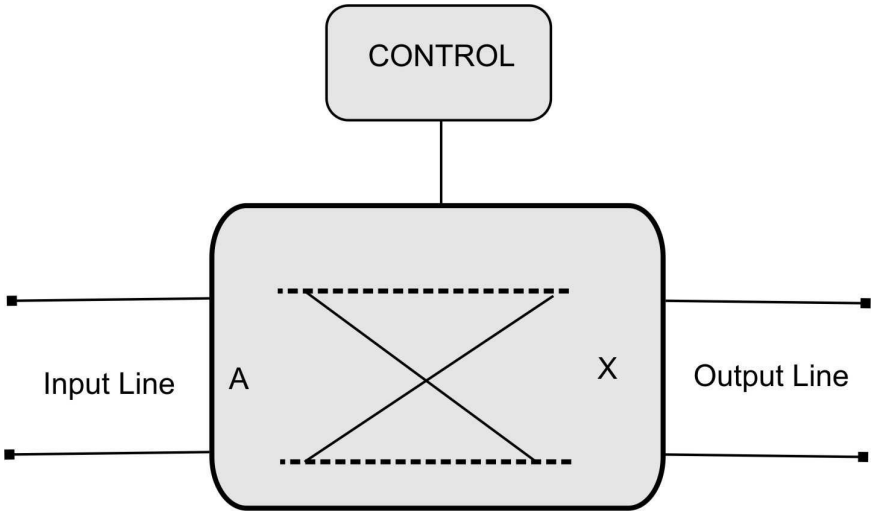

Figure 9: A Simple 2 X 2 Switch

Switching plays a very important role in telecommunication networks. It enables any two users to communicate with each other. Basically, there are three categories of Switching

a) Message Switching

b) Circuit Switching

c) Packet Switching

A circuit switch closes a circuit between the incoming and the outgoing paths so that the incoming message can go to the output link. The circuit between any two desired paths is closed by a control signal applied to the switch. In message and packet switching, the incoming message/packet to the node is stored in a memory location. Then the stored message/packet is transferred to another desired memory location, from where the message/packet can be delivered/forwarded to the next node or the receiver. The transfer from the incoming bin to the outgoing bin is done with a control/command signal.

3.8 MESSAGE SWITCHING

Message switching is one of the initial mode of switching, which helped a lot in the proliferation of the electrical communication. It is interesting to know that electrical communication in the form of Telegraph arrived earlier than the Telephone. Let us try to understand the working of the Telegraph system to build the concept of message switching. Consider the Figure 10 as a working model of the Telegraph Network. As an example of message switching: A, B, ….F are the message switching nodes/telegraph offices.

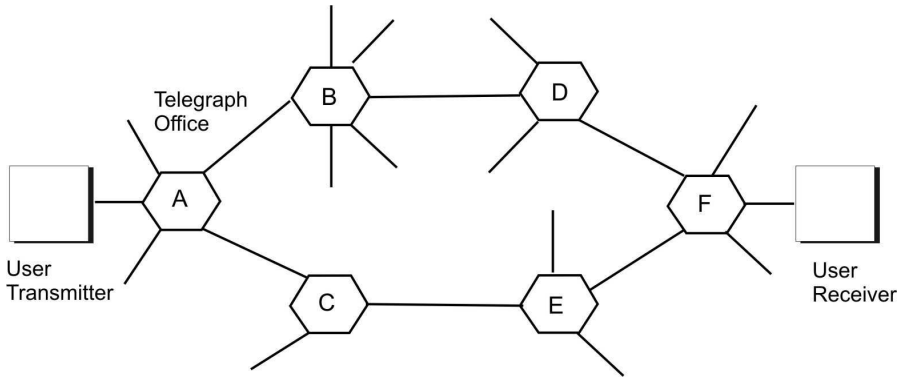

Figure 10: Working Model of the Telegraph Systems

The User who wants to send a telegraph comes to a Telegraph office with his message and hands it over to the counter operator. Now the following sequences of events occur:

- This message is sorted on the basis of the receiver's address and clubbed with other messages moving in the same direction, i.e., if in the Delhi's telegraph office the operator receives 10 messages for addresses in Mumbai, then they are bundled and are sent.
- The operator in this case does not bother if the entire path (to Mumbai) is available or not. He just forwards this message to the next node (Telegraph Office) in the path (generally predetermined).
- The operator at the next node receives all these messages, stores, sorts and forwards them.

In the olden days, the storage was done by manually. Human beings then did the sorting. Later on the storage process was automated using paper tapes. The advantage of using paper tapes is that the incoming signal is punched onto it automatically and the same tape can be directly fed into the telegraph machine for further transmission. In the Telegraph system, unlike telephones, no circuits are switched. Information is transmitted as discrete messages. So this method of switching is known as Message Switching. The important context is *'Store and Forward'*. At each node (telegraph office) the message that arrives from the previous node in the path is stored for some time, sorted, and depending on the availability of the path from this node to the next in the path, the message is forwarded.

There were central telegraph offices which acted like nodes of telegraph network and performed the task of message switching. as the teleprinters came, Morse code was replaced by machine telegraphy resulting in faster operations. Later computers were introduced to do the function of message switching. Computer based message switching is still used many organizations having many locations of working. However, if we compare the cost, the telegraph is less costly than the telephone due to the following reasons:

- Better utilization of transmission media
- The message switching is done over distributed time.
- Hogging (Capturing the entire path) does not occur in message switching. Only one of the links in the entire path may be busy at a given time.

However, message switching requires storage and this may raise-up the cost of the systems.

3.9 CIRCUIT SWITCHING

Circuit switching is defined as a mechanism applied in telecommunications (mainly in PSTN) whereby the user is allocated the full use of the communication channel for the duration of the call. That is if two parties wish to communicate, the calling party has to first dial the numbers of the called party. Once those numbers are dialed, the originating exchange will find a path to the terminating exchange, which will in turn find the called party. After the circuit or channel has been set up, then communication will take place, then once they are through the channel will be cleared. This mechanism is referred to as being connection-oriented.

Voice being a very vital medium of human communication, telephone was invented. It permitted long distance voice communication. The need of a user to talk to a desired person out of many persons on a real time basis leads to the concept of establishing a direct path between the caller and the called users. Circuit switching was conceived to be an appropriate technique for the purpose. Telephone systems use circuit switching largely to date because it serves the purpose very well. However, a major drawback of circuit switching is the requirement of a dedicated path between the calling and the called parties. This means reserving resources like the chain of switches and transmission media over the entire path. This is obviously a costly proposition. The circuit switching process has been illustrated in the Figure 11, for the telephone network. In which, the physical connections are made by the switching offices to connect the call of two users.

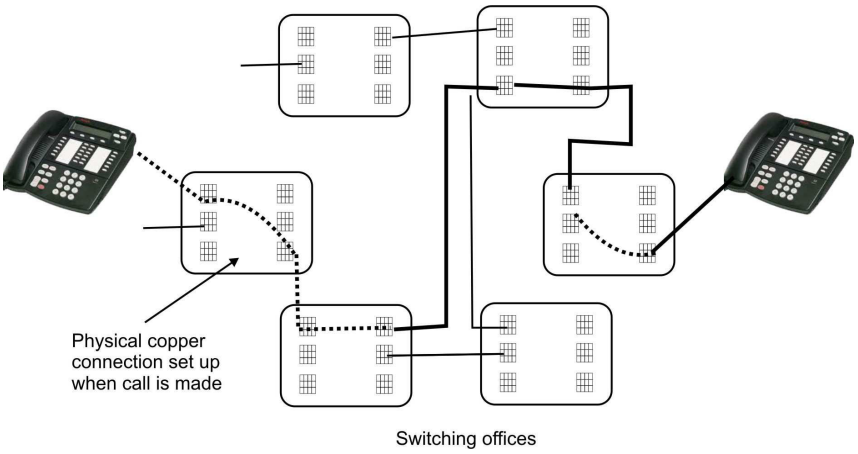

Figure 11: Circuit Switching in the Telephone Network

For each connection, physical switches are set in the telephone network to create a physical "circuit" – That's the job of the switching office Switches are set up at the beginning of the connection and maintained throughout the connection. Network resources reserved and dedicated from sender to receiver. However this is not a very efficient strategy as a connection "holds" a physical line even during "silence" periods (when there is nothing to transmit)

Advantages of Circuit Switching:

- Once the circuit has been set up, communication is fast and without error.
- It is highly reliable

Disadvantages:

- Involves a lot of overhead, during channel set up.
- Waists a lot of bandwidth, especial in speech whereby a user is sometimes listening, and not talking.
- Channel set up may take longer.

To overcome the disadvantages of circuit switching, packet switching was introduced, and instead of dedicating a channel to only two parties for the duration of the call it routes packets individually as they are available. This mechanism is referred to as being connectionless packet switching as discussed in the next section.

☞ Check Your Progress 2

1. Write differences between FDM and TDM.

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2. What is CDMA?

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3. What is Circuit Switching?

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3.10 PACKET SWITCHING

Packet Switching is the backbone of the present day communication systems. The packet switching works on the principle that the long messages are fragmented into small size units, known as *packets*. It is these packets that are transmitted instead of the single long message. This method is slightly different from **Message switching** and is called **Packet switching**. Figure12 shows a message broken down into small sized packets P_1, P_2 …P5.

P1
P2
P3
P4
-
-
Pn

Figure 12: A Message broken into n number of packets

These packets are now transmitted over the network in the same manner as the messages in message switching. The model is just like Sharing by taking turn and is analogous to the conveyor belt in a warehouse. In this case, the Items are picked from the storage room and placed on the conveyor belt every time a customer makes an order. In this model, this is important that Different customers may request a different number of items and Different users' items may be interspersed on the conveyor belt (they are "multiplexed"). Similarly in the Packet Switching, packetizes the data to transfer and Multiplex it onto the wire. Thus packets from different connections share the same link

The packets are stored and forwarded at every node. Obviously every packet now has to have the source and destination addresses. Even in message switching repeated transmission of addresses at every node consumes network bandwidth. In packet switching the overhead/wastage is more because every packet is now required to carry the addresses on their head. Thus each packet is composed of the payload (the data we want to transmit) and a header. The header contains information useful for transmission, such as:

- Source (sender's) address
- Destination (recipient's) address
- Packet size
- Sequence number
- Error checking information

The header introduces overheads, that is, additional bits to be sent. Therefore, it is not wise to have packets that are too small. In the packet switching, each computer attached to a network is assigned a unique number (called address). A packet contains the address of the computer that sent it and the address of the computer to which it is sent. In general, packets need not be of the same size, The Internet Protocol specifies the maximum size in the form of Maximum transmission unit (MTU) and does not give the No minimum size. But, header size is fixed (e.g., 20 bytes for TCP/IP in the IP version 4). Packets are generated by the network hardware, however the application (e.g., email) does not know that the data to be transmitted is packetized. When packets are received, they are put together before the application accesses the data. The process is shown in the Figure 13 below, where A and B are the sender and C and D are the receiver.

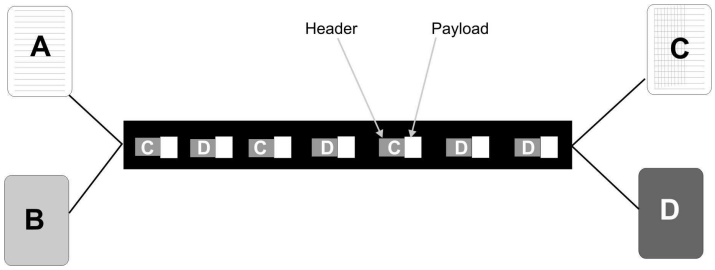

Figure13: Packet Switching Example

So with the user message in a packet with the header is to be transmitted also. From this point of view network bandwidth consumed is maximum in packet switching and minimum in circuit switching. Packets of the same message are launched into the network in parallel over different available forward links at a node. These packets would travel through different paths to arrive at the destination. This simultaneous transmission of packets over different paths results in further improvement of the link utilization compared to the message switching. Another advantage is that no link is engaged for a long time since the packets are of smaller size than the single message.

This permits better sharing of the links amongst multiple users. However the scheme just discussed has two major drawbacks. Firstly, the packets of the same message traveling through different paths may arrive at the destination at different times due to different delays encountered in different paths. Thus the packets may arrive out of order. In order to deliver them to the destination, they need to be ordered which requires extra processing and so more delay. They need to be given sequence numbers for reordering them. The sequence number increases the overhead and requires more network bandwidth. Secondly, some of the paths may not be very good and some packets may get lost. This worsens the quality. To improve quality, they require retransmission which in turn requires more processing time and more bandwidth. In spite of these drawbacks the packet switching is the most favored technique in the present day communication systems. The basic reasons behind this choice are:

a) Computer traffic being mostly text is non real time (in the beginning of the networking)

b) Computer data traffic is highly bursty in nature

Considering these features it becomes obvious that circuit switching was not the right kind of switching. Message switching can do the job but for better line utilization packet switching is preferable. Thus computer networks used packet switching. The difference between the packet switching and the circuit switching has been outlined in the Table 1.

Table 1: Difference between the packet switching and Circuit Switching

S.No.	Packet Switching	Circuit Switching
1	Bandwidth is allocated dynamically.	Fixed bandwidth allocation.
2	Packets has header, FCS.	Don't deal with data content and error-checking
3	Better buffering. System can be operated at different bit rate to inter-network.	Simple buffering
4	May be more economical as not needed dedicated circuit.	Costs more for hardware.
5	The packet needs to be re-transmitted every time when it gets lost, damaged before it is received in this method.	Once connection is established, communication is fast and almost errorless.
6.	Useful for bursty applications	Useful for delay sensitive applications

Categories of Packet Switching

The packet switching is basically, categorized in the following two categories:

a) Connection Less Packet Switching

b) Connection Oriented Packet Switching

3.10.1 Connection Less Packet Switching

In this mode of transmission, packets from a source machine to a destination machine are transmitted as per-packet basis, meaning that each packet is transmitted and routed independently from all other packets. So, even if the source and destination machines do not change, routers in the middle may decide to change the routes that different packets follow , resulting in the different packets reaching their destination in a different order from the sender because of the different transmission path length , difference in transmission rates, and the amount of congestion in the different paths. This is illustrated in the following Figure 14.

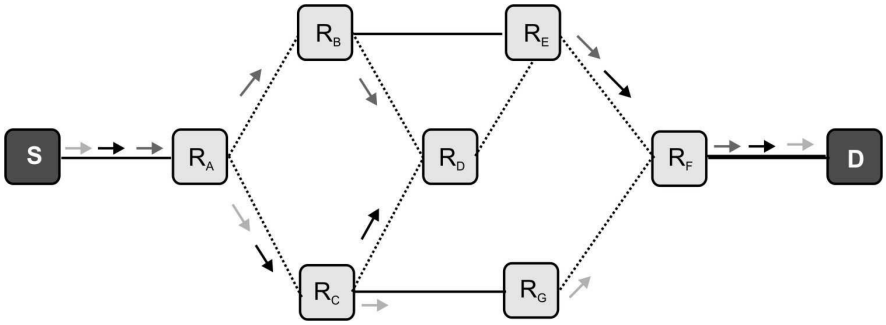

Figure 14: Connection less Packet Switching

In the figure 14, S denotes the source and D denotes the destination. R represents the router, whereas the packets have been shown by the arrow. Three packets are transmitted from the same source machine heading towards the same destination machine. Each route of the network shows the packets that have travelled over it. It is clear that the packets may arrive at the destination machine in an order different from the transmission order. Since the details of this routing table change with the movement of the packets, the routing of different packets often changes. The transmission process involves the following steps:

- Transmit Packet 1
- Transmit Packet 2
- ……
- ……..
- Transmit Packet N

Examples:

- POTS (Plane Old Telephone Systems)
- ATM (Asynchronous Transmission Mode)
- Frame Relay
- MPLS (Multi Protocol Label Switching)

Disadvantages of connectionless packet switching:

1. Extra processing power is required at the nodes for attaching source and destination addresses with every packet which also increases the required time of transmission.
2. Connectionless Packet switching requires overhead bits for indexing/numbering the packets.

3. Packets may arrive at the destination in a random manner. This requires that all the arriving packets are stored and rearranged.
4. Some packets may be lost in the network.

3.10.2 Connection Oriented Packet Switching

In this mode of transmission, packets from a source machine to a destination machine are moved as per the source destination pair basis, meaning that all packets from the same source going to the same destination are transmitted over the same routes and through the same routers. This results in having almost a constant delay of transmission for the different packets and the different packets reaching their destination in order

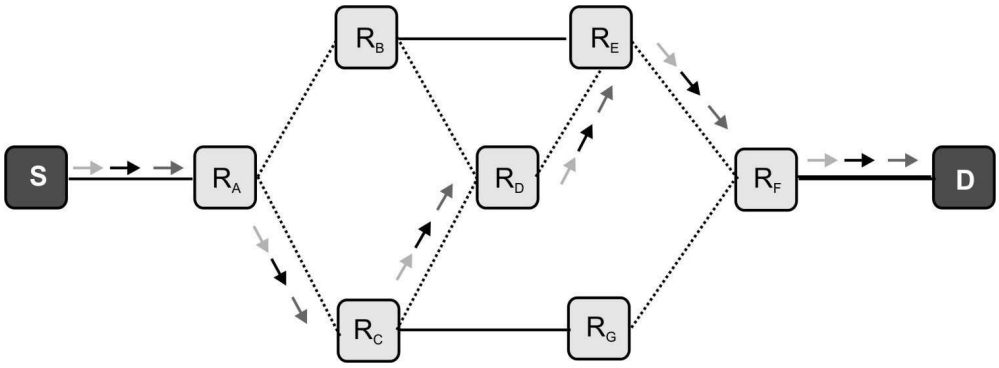

Figure 15: Connection Oriented Packet Switching

It is clear from the above Figure 15 that a circuit - like connection has been established. The process of transmission in the above case is also called Virtual - Circuit Packet Switching as it involves the establishment of a fixed path called Virtual Circuit or Virtual Connection between the source and destination prior to the transfer of packets. The transmission of packets involves the following steps:

1. Connection Request
2. Connection Confirm \
3. Transmit Packet 1
4. Transmit Packet 2
5. ……
6. ……
7. Transmit Packet N
8. Connection Release

Example:

ATM Networks

☞ Check Your Progress 3

1. Define the difference between switched and leased lines.

……..

……..

2. What are switched communications networks?

……..

……..

3. Discuss the advantages of packet switching over circuit switching.

……..

……..

3.11 SUMMARY

We hope you must have understood the concept of multiplexing and switching. As we discussed Multiplexing refers to the ability to transmit data coming from several pairs of equipment (transmitters and receivers) called *low-speed channels* on a single physical medium (called the *high-speed channel*). Whereas, A *multiplexer* is the multiplexing device that combines the signals from the different transmitters and sends them over the *high-speed channel*. Further in this unit you have studied four basic multiplexing techniques are frequency division multiplexing (FDM), Time division Multiplexing (TDM), Code division Multiplexing (CDM) and Space-division Multiplexing (SDM). As you have studied that Switching plays a very important role in telecommunication networks. It enables any two users to communicate with each other. Basically, there are three categories of Switching like Message Switching, Circuit Switching and Packet Switching.

3.12 REFERENCES/FURTHER READING

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3.13 SOLUTIONS/ANSWERS

☞ Check Your Progress 1

1. Multiplexing is the set of techniques that allows the simultaneous transmission of multiple signals across a single data link.

2. To make efficient use of high speed telecommunications lines, some form of multiplexing is used. Multiplexing allows several transmission sources to share a larger transmission capacity.

A common application of multiplexing is in long-haul communications. Trunks on long-haul networks are high capacity fiber, coaxial or microwave links. These links can carry large numbers of voice and data transmission simultaneously using multiplexing.

3. Four basic multiplexing techniques are frequency division multiplexing (FDM), Time division Multiplexing (TDM), Code division Multiplexing (CDM) and Space-division Multiplexing (SDM).

☞ Check Your Progress 2

1. Frequency-Division Multiplexing (FDM) is a form of signal multiplexing where multiple baseband signals are modulated on different frequency carrier waves and added together to create a composite signal.

   Time-Division Multiplexing (TDM) is a type of digital multiplexing in which two or more signals or bit streams are combined into different slots of a frame. Transmission of frame carries simultaneously data from sub-channels in one communication channel, but are physically taking turns on the channel.

2. What is CDMA?

3. Circuit switching is defined as a mechanism applied in telecommunications hereby the user is allocated the full use of the communication channel for the duration of the call and hence a physical connection is set-up between the caller and the receiver.

☞ Check Your Progress 3

1. In switched line communications, a link that is established in a switched network, such as the international dial-up telephone system.

   A leased line is a symmetric dedicated service (the same upstream and downstream bandwidth) creating a permanent connection between your premises and the Internet.

2. In the switched communications networks data entering the network from a station are routed to the destination by being switched from node to node. For example in the Figure 16 data from station A intended for station F are send to node 4. They may then be routed via nodes 5 and 6 or nodes 7 and 6 to the destination. This is called switched communication networks.

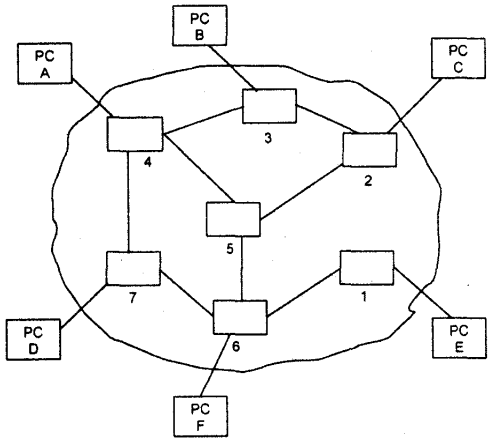

Figure 16: Simple Switching Network

3. i) Line efficiency is greater, because single node to node link can be dynamically shared by many packets over time. in other hand in circuit switching time on a node to node link is pre-allocated using synchronous time division multiplexing.

   ii) A packet switching network can perform data rate conversion.

   iii) When traffic becomes heavy on a circuit switching network, some caller are blocked, on the packet switching network, packets are still accepted, hut delivery delay increases.

   iv) Priorities can be used. Thus it can transmit higher priority packet first.