SIGNALS AND THE PHYSICAL LAYER 2

2.1 INTRODUCTION

Physical layer is the lowest layer in the OSI reference model. Information can be transmitted or received using cables. The main purpose of the physical layer is to transmit information (data or text or even animated pictures) from a source to a destination. Any form of such information cannot be transmitted as it is, just as in a postal service. Information is transmitted from a source computer to a destination computer in the form of electromagnetic signals using the transmission medium. For example, if you want to transmit a photograph from a source computer to a destination computer, it is first encoded as a stream of bits 0s and 1s. Then this stream is reconverted as energy in the form of electromagnetic signals. Then only these electromagnetic signals can be transmitted over the network, through a transmission medium. The destination computer receives these signals. They are encoded to the original form. As such signals play a very important role in transmitting information. In view of this, we first pay our attention to the study of signals and the terminology used with respect to signals.

2.2 ANALOG AND DIGITAL SIGNALS

There are two types of signals, namely **analog** (also called **continuous**) and **digital** (also called **discrete**). Analog quantities are used for measurement, whereas digital quantities are used for counting. For example, you can go to a provision shop and ask for 1.25 kg of sugar. But, you cannot ask for 1.25 number of bananas. The first one is a continuous one and the second one is a measurement. Graphs of these two types of signals are shown below.

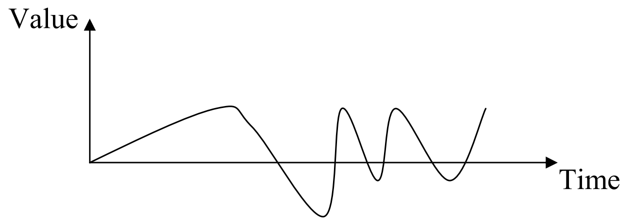


Fig. 2.1 An analog signal.

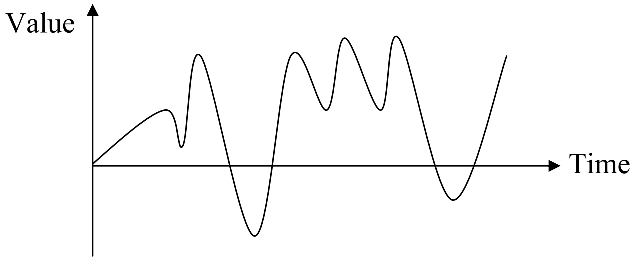


Fig. 2.5 A non-periodic analog signal.

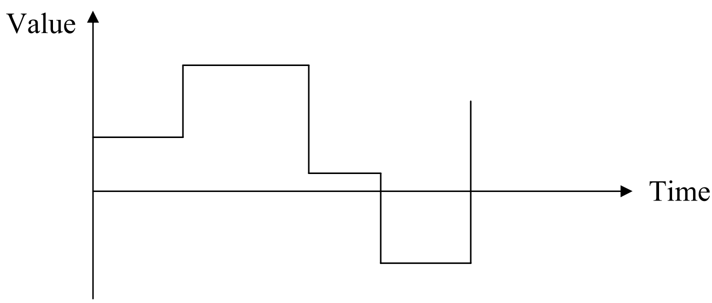


Fig. 2.6 A non-periodic digital signal.

In fact, the wave in Figure 2.3 represents a sine wave. In the graphs of analog signals we speak of its quantifiers like amplitude, period or frequency and phase.

2.2.2 Amplitude

The amplitude of a signal is the value of the signal at any point on the wave and is measured normally either in volts, amperes, or watts. That is, it is the vertical distance of the point on the wave from the X-axis.

2.2.3 Period and Frequency

Period (T) of an analog signal is the time in seconds required to complete one full cycle. Frequency (f) of an analog signal is its number of cycles per second. The mathematical relation between period (T) and frequency (f) is

Frequency = 1/Period, ($f = 1/T$).

2.2.4 Phase

Phase expresses the position of the waveform relative to time zero and is measured either in degrees or in radians.

The main issues in transmitting data are:

1. **Line configuration:** The line configuration is concerned about the mode of connecting devices, about the number of devices that use the transmission line, about the problem whether the lines to be shared or limited just to two devices and also whether line is available for transmission or not.
2. **Data transmission mode:** The transmission mode whether it is one-way or two-way is to be specified.
3. **Topology:** The topology and path used in arranging network devices is to be made clear.
4. **Signals:** The type of signals used is to be specified.
5. **Encoding:** This aspect is about the encoding methods used.
6. **Interface:** Issues regarding the controls to be imposed on what information and its amount that can be shared and the method of sharing information by two nearby devices have to be resolved.
7. **Medium:** The type of the physical medium used is to be decided.

2.3.1 Guided Media

Guided media is the physical connection (cables) between two devices. Magnetic media, twisted pair of cables, coaxial cables, fibre-optic cables come under this category.

2.3.1.1 Magnetic Media

Magnetic media in the form of magnetic tapes or floppy disks is the simplest and widely used transmission technique. One carries these physically from the source to destination. This method is not safe. Also this method is not a good one and the cost involved is prohibitively high, particularly when high bandwidth is used. The density of data transported is less.

2.3.1.2 Twisted Pair of Cables

This is a widely used transmission medium. A twisted pair consists of two insulated copper wires, twisted in helical form. By using a **twisted pair (TP)** one can reduce any electrical interference. Before the use of twisted pairs, **untwisted pair (UTP)** of cables are being used by running the two cables parallel to each other and shielded in a cover. Normally the thickness of these wires is about 1 mm. By twisting the wires, one can reduce the electrical interference from nearby similar pairs. The bandwidth depends on the thickness of the wire and distance travelled. Twisted pairs are used in telephone system, as they can run several kilometres without amplification. For longer distances repeaters are used. When a number of twisted wires are to be used in parallel, they are bundled together and encased in a protective sheath. But for the twisting the pairs in these bundles interface with one another.

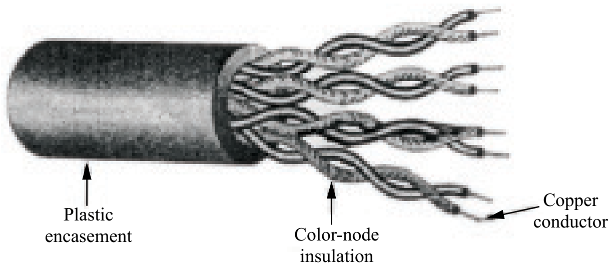


Fig. 2.9 An unshielded four-pair cable.

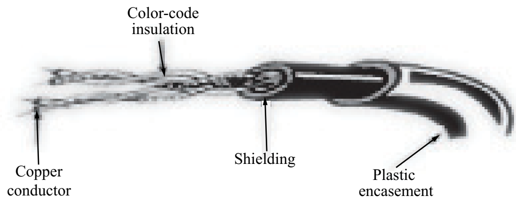


Fig. 2.10 Shielded twisted pair.

2.3.1.3 Baseband Coaxial Cables

Coaxial cable is also used commonly as transmission medium. A coaxial cable consists of a copper wire, covered with an insulated material. Both these are covered by a braided outer conductor and above all a protective plastic covering. This ensures high bandwidth and excellent noise immunity. Coaxial cables come either in baseband (50 to 75-ohm cables) or in broadband (up to 300 MHz).

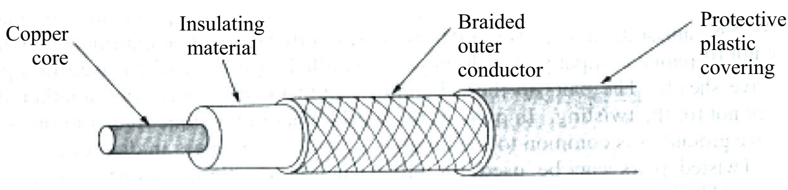


Fig. 2.11 A coaxial cable.

2.3.1.4 Broadband Coaxial Cables

Broadband networks use the television technology (300 MHz to 450 MHz). The cables can be used up to 100 km. They use multiple channels. Unlike baseband cabling system, broadband systems are used to cover large areas, using amplifiers. When amplifiers are used then one should use the cable for one-way transmission. To overcome this problem, we have dual cable (running in parallel) and single cable systems.

2.3.1.5 Fibre Optic Cables

The data communication in recent years has increased multifold. To meet this demand fibre optics are being used. The transmission system using fibre optics has basically three components: **the light source, the transmission medium,** and **the detector**. The source device consists of a **light source** like **light-emitting diode** (**LED**) and the receiving one a photodiode. This photodiode translates the light signal into electrical form. At the centre of the fibre cable is the glass core, through which the light propagates. The core is surrounded by a glass cladding that keeps all the light in the core. There is a thin plastic jacket over it to protect the cladding. Presence of a pulse of light indicates a 1-bit and the absence a zero bit. The transmission is carried through an ultra-thin fibre of glass. An electrical pulse is generated by the detector, when light falls on it. The transmission is unidirectional. The detector converts the electrical signal and transmits it by light pulses. The light pulses are reconverted at the destination back to electrical signals.

Fibre optics can be used in LANs and also for long-haul transmission. The significant advantages of fibre optics are: wide bandwidth, low losses, immunity to crosstalk, to interference, and to environment, light weight, small size, more strength, security, long distance transmission, safe and easy installation and cost-effectiveness. However, fibre optics have their own disadvantages in the following aspects: high initial cost, high maintenance cost.

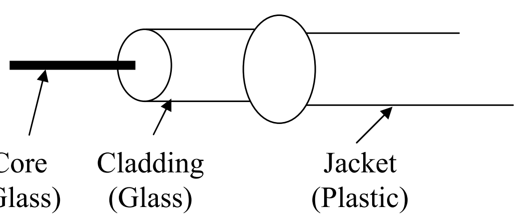


Fig. 2.12 A fibre optic cable.

2.3.1.6 Comparison between Different Guided Transmission Media

	Coaxial	Twisted Pair	Fibre Optics
1.	Uses electrical signals.	Uses electrical signals.	Uses optical form.
2.	Less effect on EMI.	Effected by EMI.	Not effected by EMI.
3.	Moderate bandwidth (350 MHz).	Bandwidth is low.	Very high bandwidth (GHz).
4.	Supports high data rates (500 Mbps).	Low data rates (4 Mbps).	Very high data rate (2 Gbps).
5.	Less cost.	Cheapest.	Costly.

Coaxial	Twisted Pair	Fibre Optics
6. Repeater spacing is 1–10 km.	Repeater spacing 2–10 km.	Spacing between 10–100 km.
7. Supports all radio frequencies.	Supports all radio frequencies.	Range 902 MHz to 928 MHz

2.3.2 Unguided Media

We now consider the unguided transmission media. All the above said types of guided transmission media are not well suited to meet the present-day transmission requirements, more particularly of the mobile users and in view of the heavy amount of information that is being exchanged between a number of users either within a network or in between networks. To meet this natural demand, we use the unguided or otherwise called wireless media. In unguided transmission media, no physical conductor (cable) is used. Information in the form of electromagnetic energy is being transmitted either through air or through water.

It is universally accepted to treat the entire electromagnetic spectrum (also called radio communication area) as being consisting of the eight ranges, called bands: Very low frequency, Low frequency (LF), Middle frequency (MF), High frequency (HF), Very high frequency (VHF), Ultra high frequency (UHF), Super high frequency (SHF), and Extremely high frequency (EHF). Propagation of radio waves is carried out in any of the following types: surface, troposphere, ionosphere, line of sight, and the space. Through space the radio waves travel in vacuum. Their presence above the surface of the earth in terms of the frequency ranges of reaching a point in that region are shown graphically below. The boundaries of different bands, their propagation regions are described in the next table. The troposphere is what we call the atmosphere. The ionosphere contains free electrically charged particles.

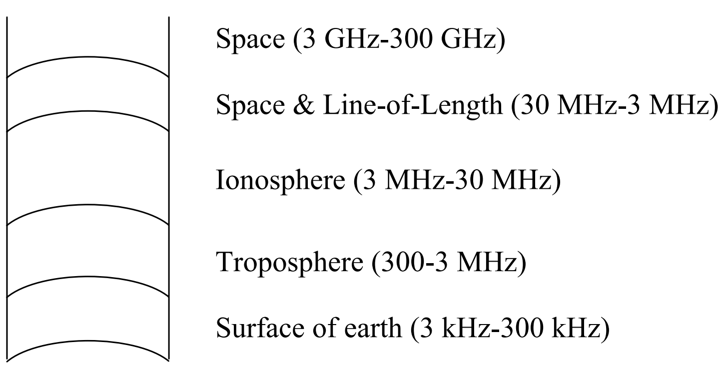


Fig. 2.13 Different types of radio waves propagation.

Type of the band	Frequency	Type of propagation
Very low frequency (VLF)	3 kHz–30 kHz	Surface
Low frequency (LF)	30 kHz–300 kHz	Surface
Middle frequency (MF)	300 kHz–3 MHz	Tropospheric
High frequency (HF)	3 MHz–30 MHz	Ionospheric
Very high frequency (VHF)	30 MHz–300 MHz	Space & line-of-length
Ultra high frequency (UHF)	300 MHz–3GHz	Space & line-of-length
Super high frequency (SHF)	3 GHz–30 GHz	Space
Extremely high frequency (EHF)	30 GHz–300 GHz	Space

The radio waves with VLF, LF, or MF bands are just above the earth's surface (for example, radio broadcasting). The waves that reach the ionosphere are refracted and sent back to the earth (using hams).

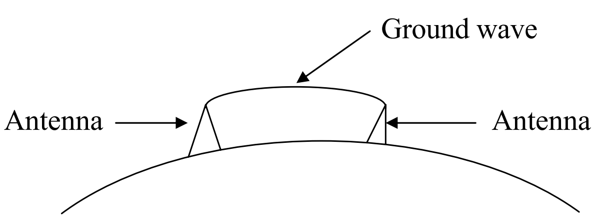


Fig. 2.14 Movement of a ground wave in VLF, VF, and MF media.

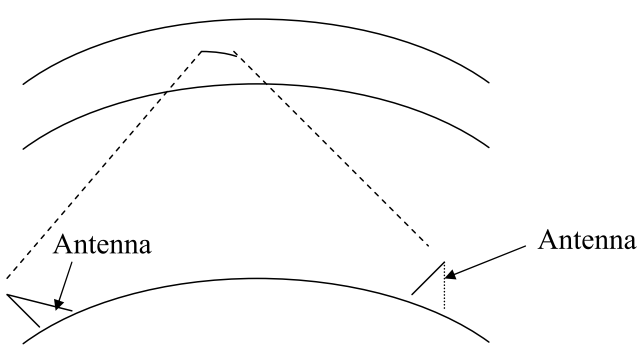


Fig. 2.15 Refraction of radio wave to the earth from the ionosphere in HF mode.

We now describe the basic characteristics of the different types of propagation of radio waves.

Surface Propagation: The frequency range of radio waves in this region is 3 kHz–300 kHz. The radio waves in surface propagation travel either in air in smaller distances above the earth or can also travel in seawater.

Tropospheric Propagation: The frequency range of waves in this type of propagation is 300 kHz–3 MHz. Normally the broadcast is carried out in straight lines from the transmitting antenna to the receiving antenna by arranging both the antennas within line-of-sight distances. To cover greater distances of broadcasting it is possible, if necessary, to broadcast the signals at an angle into the higher layers of propagation from where they are reflected back to the earth.

Inospheric Propagation: The frequency range of radio wave propagation is 3 MHz–30 MHz (higher frequency). When once these waves enter into the inospheric zone they are reflected back to the earth. They cover far greater distances.

Line-of-Sight Propagation: In this type of propagation very high frequency (30 MHz–3GHz) signals are broadcast in straight lines. Both the antennas must face each other.

Space Propagation: Frequency range of transmission of waves in this type is 3 GHz–300 GHz. Satellites, either stationary or orbiting, are being used to relay the waves. These satellites receive radio signals and rebroadcast them to the earth. Global broadcast is possible using this type of propagation.

2.3.2.1 Terrestrial Microwaves

Line-of-sight transmission is followed when microwaves during transmission depend more on the height of the two antennas. To avoid any blocking of transmission because of a hill or tall buildings on the line-of-sight of transmission taller antennas are used. Higher the height, greater is the distance coverage. Another important feature of transmission of microwaves is that the transmission is one way. As such two-way transmission is required for sending and receiving signals.

Necessary number of repeaters are used at each antenna to increase the coverage distance. Each of the intermittent antennas can receive signals of different frequencies. The signal received by one antenna converts them into a form that is acceptable by the next antenna and then only transmits these converted signals.

Antennas that are used in terrestrial transmission are of two types: parabolic and horn.

2.3.2.2 Cellular Phones

The number of persons using cellular phones has been increasing at a rapid rate. Both the moving users may want to communicate with each other or one moving user wants to communicate with a landline telephone. A central service unit called the server is put to use that identifies the address of the caller and assigns a channel and transmits that call on that channel. As the caller moves, the server transfers the signal from one channel to another channel. For accomplishing this process of changing channels, a geographic region is divided into a number of cells. Each cell has its own frequency range. Each cell that contains an antenna is controlled by an office called the cell office, which in turn is controlled by a switching office. This switching office is called a mobile telephone switching office (MTSO). The main function of an MSTO is to coordinate communications between all cell offices.

2.4 THE TELEPHONE SYSTEM

Two computers can be connected by a cable for their communication needs, if they are located close to each other and owned by the same organization. But if the distance between them is large, connecting them by cables poses some problems, mostly legal, as they may have to cross private lands, government roads, etc. The "**Public Switched Telephone Network** (**PSTN**)" system is then used. But, their use in the present day is minimal.

The telephone system consists of two parts: the switching office and the switches. From the beginning and till recently analog signalling is being used by the telephone systems. But analog signalling is subjected to lot of distortion due to the electrical voltage fluctuations. Also time duration to represent different information streams is not uniform. Problems creep in analog transmission due to transmission failures. These problems are identified as follows:

Attenuation: This tells the loss of energy (decibels/km) as the signal moves forward. This factor depends on the frequency in signalling. Less the attenuation, better is the signal transmission. Amplifiers can be used to lessen attenuation.

Delay distortion: This is caused because of varied speeds of different components of signals.

Noise: There is noise in transmission because of wasted energy from external sources. These phenomena cannot be avoided. It may occur due to random motion of electrons, or due to crosstalk across the line.

Because of these problems, wide range of frequencies cannot be accommodated in signals. The signal's amplitude, frequency, phase is modulated for a better transmission. In this context one distinguishes between **amplitude modulation** (modulation of voltage levels), frequency modulation

(modulation of different frequency levels of signals) and **phase modulation** (phase shift). The device used to generate a modulated carrier as output from a signal is called a **modem** (**modulator demodulator**). The technology of modems has improved a lot. One can send 9600 bps over a 2400-baud based line. The device used is called **quadrature amplitude modulator** (**QAM**).

Nowadays digital signalling is used. Digital signalling has lot of advantages. By using digital regenerators, losses in signals can be avoided and the signals can travel long distances. Voice, data, music and images can be transmitted very effectively using digital signalling. It is much cheaper and is easy to maintain.

2.5 TRANSMISSION MEDIA: SELECTION CRITERIA

There are a number of factors that finally decide the type of transmission media. The main factors are: (1) Attenuation, (2) Electromagnetic interference, (3) Security, (4) Speed, and (4) Cost. Attenuation means the possibility of a signal to become weak or distorted during transmission. This is to be avoided. The other factors are self-explanatory.

2.6 SWITCHING

For transmitting data between two or more devices on a network, they must be connected by either point-to-point links between every two devices or between a central device (hub) and a device. That is, they must be made active. We saw all these while discussing the different topologies. Establishing links will pose some problems sometimes. A better way is to use switches. A switched network is a series of interlinked switches. Switches are used for temporary connections between physical links. Switching results in longer links for network transmission (Example, telephone transmission). Switches can either be hardware or software devices.

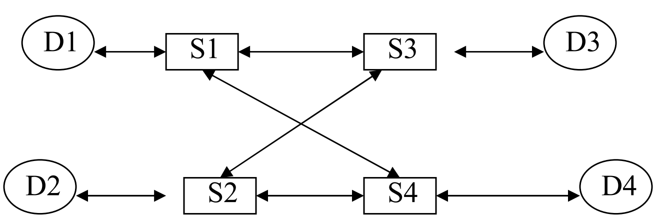


Fig. 2.16 A typical switching network with four devices D1-D4 and for switches S1-S4.

The different switching techniques used in networking are:

(1) Circuit switching,
(2) Packet switching, and
(3) Message switching.

2.6.1 Circuit Switching

This technique of circuit switching uses a dedicated line (connection/path) established for transferring data from one device in the network to another. Best example of this type of switching is “telephone”. When you want to talk to your friend using your telephone, you lift the cradle of your telephone and press the necessary numbered keys. Then a dedicated path is established between you (source device) and your friend (destination device). When your friend responds (in other words, the receiving device must be ready to receive data from this source device), then you talk to your friend (transfer of data) and then put down the cradle on your phone (disconnect).

The following are the three steps involved in the communication between two devices:

(1) Setting up a connection,
(2) Transfer of data, and
(3) Terminating the connection.

(1) **Setting up a Connection**

First a connection must be established between the source device and the destination device.

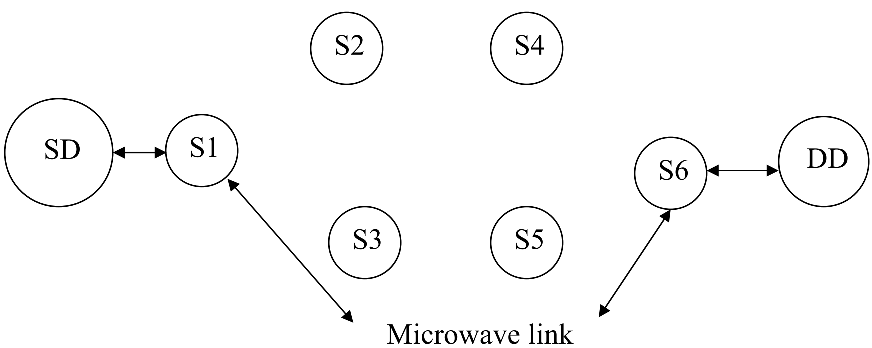


Fig. 2.17 Circuit switching between the devices SD and DD.

Figure 2.17 shows the setting up a connection between the source device SD and the destination device DD, using switches S1 and S6.

(2) **Transfer of Data**

Once a connection is set up between two or more devices, data can be transferred in either way.

(3) **Terminating the Connection**

When once the transmission of data is completed, the connection is terminated. Following figure shows the network of Figure 2.17 after termination of connection between the source device SD and destination device DD.

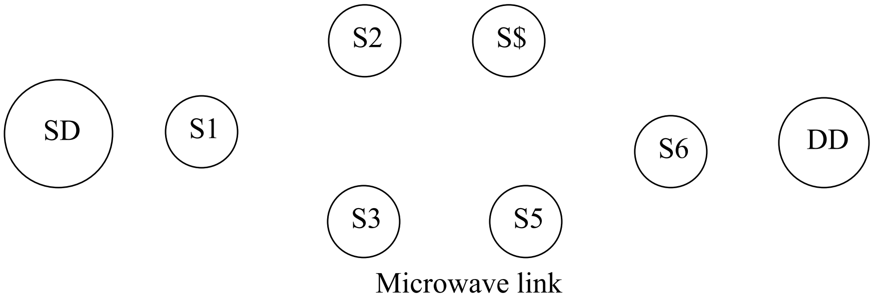


Fig. 2.18 Network after terminating the connection between SD and DD.

Circuit switching is done using either of the following two methods:

(1) Space-division circuit switching, and
(2) Time-division circuit switching.

2.6.1.1 Space-Division Circuit Switching

In this type of circuit switching some gaps or spaces are present between different paths in the circuit. Paths in the circuit are separated from each other leaving some spaces in between them. A special type of switches called "crossbar" switches are used in this type of switching.

Crossbar Switches: Using electronic micro-switches (transistors) all the input can be connected to all the outputs in a network, at every junction of two switches. The following figure shows the presence of 9 crossbar switches. Use of crossbar switching is not practical, as it requires the use of too many switches. The number of crossbar switches required for n inputs and m outputs is n*m (imagine the situation when n = m = 10000).

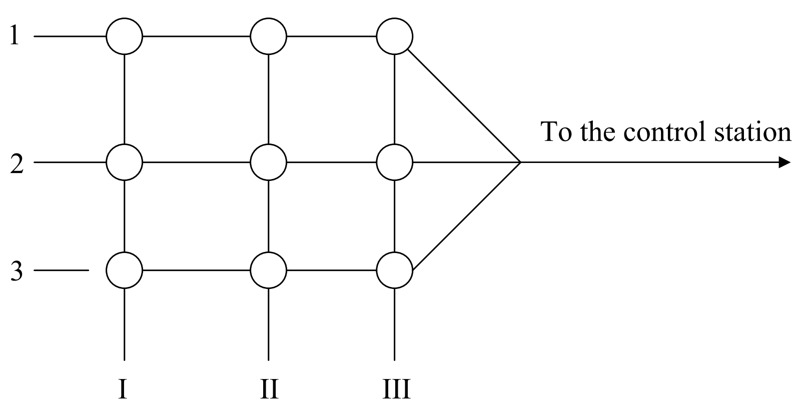


Fig. 2.19 Crossbar switches.

A to P, B to Q, C to R, D to S, and E to T as per the order of the input lines and the output lines.

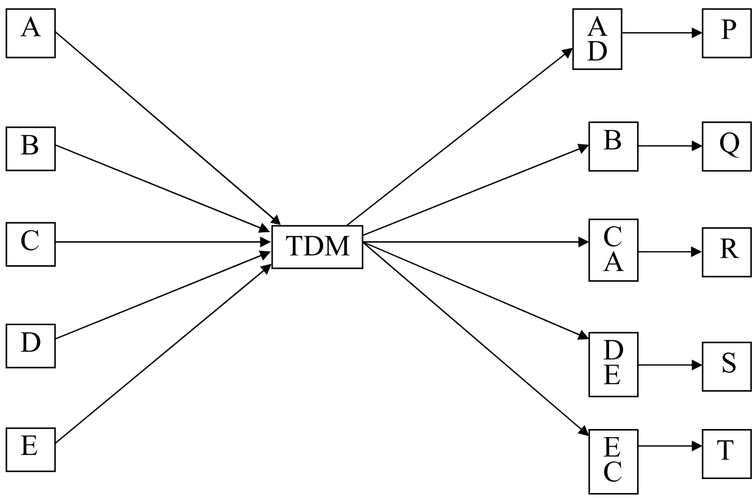


Fig. 2.21 Time-division switching when no TSI is used.

Circuit switching is designed mainly for the purpose of voice communication. It cannot be used for transmission of any other non-conversational transmission, photos. Most of the time is idle. The transmission rate is low. The circuit switching is inflexible in the sense that when once a path is established, every other transmission has to take place only through that path only. Suppose more than one sender wants to transmit his data to the same receiver. No priority is given to the inputs. These are the main disadvantages of circuit switching. All these problems are solved using packet switching.

2.6.2 Packet Switching

In this type of switching, data to be transferred is broken into discrete units. Length of one unit can be different from that of another. Besides a portion of data, each packet contains a header that contains information like the addresses of destination, its priority and others. At each node each packet is stored and its header may be changed if necessary. The following two methods are used in packet switching:

(1) Datagram method, and
(2) Virtual circuit method.

2.6.2.1 Datagram Method

In this approach of packet switching, each packet, from hitherto called a datagram is given an independent status. Even a multipacket transmission is treated as though it is a single datagram. The following figure shows the working of datagram method in transferring four datagrams from station A to station P.

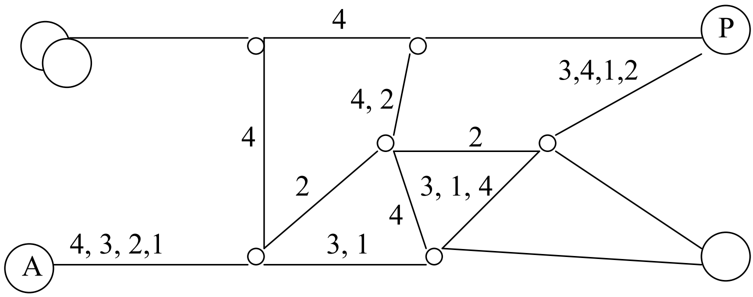


Fig. 2.22 Datagram method of switching 4 packets.

Multiple channels can be created between any two nodes as shown below.

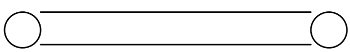


Fig. 2.23 Multiple channels.

2.6.2.2 Virtual Circuit Method

In this method of packet switching, a relationship is maintained between all datagrams involved in a session. All datagrams choose a single route. Some important features of this method are:

1. It reduces transmission delay,
2. It improves performance,
3. Datagrams can be buffered in router's main memory,
4. It allows for an orderly flow of datagrams in the network, and
5. It is cost-effective as there will be no need for establishing a dedicated point-to-point link.

2.6.3 Message Switching

It is observed that for establishing a connection either in circuit switching or in packet switching, it takes some time (5 to 10 sec). Also some delay in transmission takes place (about 5 Msec per every 1000 km).

The above problems are overcome by using another type of switching called "message switching". In this method, the entire block of data to be sent by the sender is first stored in the switching office (equivalent of a router) and is then transmitted block by block with one hop at a time. This is called **store-and-forward** technique.

2.6.4 Comparison between Circuit and Packet Types of Switching

Basis	Circuit switching	Packet switching
1. Transmission	Through a dedicated line	No dedicated line but through a routing mechanism
2. Bandwidth	Fixed	Dynamic
3. Movement of data	Entire data is treated as a single unit	Data is divided into smaller units called packets
4. Route followed	One single route	Different routes if necessary for different packets
5. Call setup	Necessary	Not necessary
6. Occurrence of congestion	At setup time	Whenever a packet is transmitted
7. Transfer rate	Fixed	Can vary from packet to packet
8. Cost	Per unit of time	Per packet

2.7 ENCODING ASYNCHRONOUS COMMUNICATIONS

The word encoding means transforming information into signals. The information is encoded based on a number of factors like its original format and the format used by the communication hardware. The following are the different types of encoding:

(i) digital-to-digital,
(ii) analog-to-digital.
(iii) digital-to-analog, and
(iv) analog-to-analog.

We now consider these encoding methods.

2.7.1 Digital-to-Digital Encoding

In this type the information is digital and the signal is also digital. Transmitting information from a computer to a printer comes under this type. Information within the computer in 0's and 1's is digital and the data transmitted is also digital. Again the different types of digital-to-digital encoding are:

2.7.2 Analog-to-Digital Encoding

Here the information (x-axis) is in analog mode and the signal (y-axis) in digital mode. The process of recording your Professor's lecture on CD comes under this type. That is, a wave signal is represented as a digital signal.

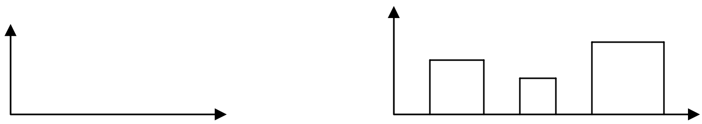


Fig. 2.24 Analog-to-digital encoding.

It is to be observed that a wave signal is an infinite number of values and a digital signal is a discrete number of values. As such, the analog-to-digital encoding represents an infinite number of values to a discrete number of values. This representation is carried out in the following two phases.

Pulse Amplitude Modulation (PAM): The first phase, called PAM (Pulse Amplitude Modulation) considers the portions of the wave in equal intervals. Then it records the amplitude of the signal at these selected equal intervals. It divides the wave into a selected list of amplitude values of the wave signal at equal intervals. Such a collection of values is called **sampling.**

Pulse Code Modulation (PCM): The PCM takes into consideration the amplitudes of the pulses selected by PAM. That means PCM assigns the PAM pulses integer values, based on their amplitudes. A zero (0) is prefixed if the amplitude is positive and a one (1) if it is negative. Suppose the amplitude of a PAM pulse is +14. It is then digitized as 0001110. On the other hand, if it is –14, then it is digitized as 1001110.

The corresponding digital codes for the two pulses with amplitudes +14 and +22 are shown below:

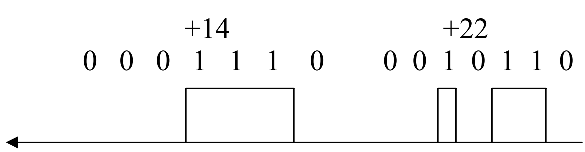


Fig. 2.25 Conversion of analog signals into digital codes.

2.7.3 Digital-to-Analog Encoding

Here a digital signal is encoded into an analog signal. Consider the case when one wants to transmit data from one computer to another computer using a telephone. A computer uses digital signals, whereas a telephone uses analog signals. As such, conversion of digital signals to analog signals is to be done first.

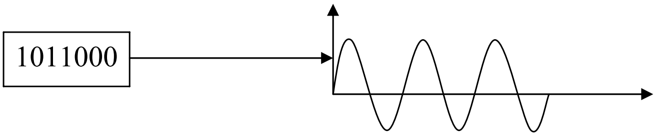


Fig. 2.26 Digital-to-analog encoding.

A special device, called "modem" is used for this type of digital to analog conversion. Modem is used for modulating and demodulating. An analog curve is characterized by amplitude, frequency, and phase. A digital code is encoded into an analog code by applying either **amplitude shift keying** (**ASK**), or a **frequency shift keying** (**FSK**) or a **phase shift keying** (**PSK**). A better and efficient method is to use **quadrature shift keying** (**QAM**) using any of the mechanism. QAM combines the features of ASK and PSK.

2.7.4 Analog-to-Analog Encoding

Here the information is in analog form and the signals encoded are also in the same analog form. This type of encoding is carried out in either of the following three ways: Amplitude Modulation, Frequency Modulation, or Phase Modulation (PM).

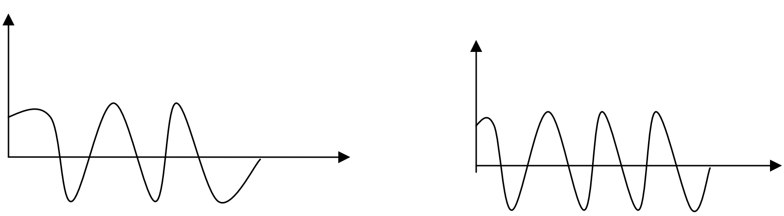


Fig. 2.27 Analog-to-analog transmission.

2.8 COMPONENTS OF DATA TRANSMISSION

The main four elements involved in any data transfer are:

(1) Data Element,
(2) Signal Element,
(3) Bit Rate, and
(4) Signal Rate.

A data element is a binary bit 0 or 1 that represents the smallest part of information. A data element is transferred into a digital signal. Signal element is the smallest part of this digital signal. Bit rate is a measure of the number of bits that can be transferred in a specified unit of time. Signal rate is the number of signal elements that can be transferred per unit of time. Signal rate is also called modulation rate.

2.9 TYPES OF TRANSMISSION

We have the following two types of data transmission:

(1) Asynchronous Transmission, and
(2) Synchronous Transmission.

2.9.1 Asynchronous Transmission

In this type of transmission, data in the form of a series of digital signals, each as a sequence of binary bits of length seven, are transferred sequentially one after another. For the receiving station to know about the beginning and end of each binary stream of bits, two more binary bits called the start and stop bits are used. The binary bit 0 is added at the beginning of this sequence and the bit 1 is added at the end. For accurate implementation purpose, another binary bit can be used before the stop bit. Asynchronous transmission is effective and cheap. But the speed of transmission is low. As seen above, it has an overload of bits for transmission in terms of the two start and stop bits and the parity bit.

2.9.2 Synchronous Transmission

In this type of data transmission, all strings of data elements are transferred at regular time intervals. This avoids the confusion that will arise in identifying the beginning and end of each string. Thus, this type of transmission synchronizes the speed of transmission at both the ends. If necessary, two control fields in the form of binary strings can be used at the beginning and end of transmission. Also two more strings of binary bits can be used to indicate the beginning and end of this particular transmission. The transmission rate is higher here. The transmission is efficient. Sometimes the design of this type of transmission becomes difficult.

2.10 INTEGRATED SERVICES DIGITAL NETWORK (ISDN)

Earlier in this chapter, the need for switching and different types of switching were explained. **Integrated Services Digital Network (ISDN**) is a circuit-switched network. As the name itself indicates, ISDN integrates the different digital services for data and voice. This is of great help to the user as he can access all those different services at a time. By implementing ISDN, the user can transfer data, voice, image, facsimile and others, by using the same path. It provides end-to-end connectivity.

2.10.1 Services Provided by ISDN

The services provided by ISDN are classified as:

(1) Bearer services,
(2) Teleservices, and
(3) Supplementary services.

2.10.1.1 Bearer Services

The basic services demanded by almost all users in a network are transfer of data, voice, and video. Such services are called bearer services as they don't allow the network to intervene with the information that is being transferred. No processing of the information is carried out. The contents of the information are not altered. Bearer services can be made available in the physical layer, data link layer, network layer by using circuit-switched circuits (for either voice or data) and packet-switched connections (for data) in increments of 64 kbits/s, frame-relay, or cell-relay networks. A significant application of ISDN is Internet access. This application provides a maximum access of 128 kbits/s in both the directions (upward or downward).

2.10.1.2 Teleservices

In bearer ISDN services there is rigidity in transferring data in the sense that the network will not interfere with the data that is transferred and do not change it before or during transmission. In teleservicing the network can modify or apply any process to the information that is transmitted. Some examples of teleservices are: telephony, telex, teleconferencing, telefax, teletex, and videotex.

2.10.1.3 Supplementary Services

These are the services provided by ISDN other than the bearer services and video services. Some of the ISDN supplementary services are: message handling, call waiting, and reverse charging.

2.10.2 Subscriber Access to the ISDN and User Interfaces

To meet the heavy demand for data transmission, a number of channels are provided between users and the ISDN. The ISDN standard defines three channels, each of different transmission rates. They are:

(1) B-Channels,
(2) D-Channels, and
(3) H-Channels.

ISDN layers for B and D channels

Layer	B channel	D channel
4, 5, 6, 7	User's choice	End-to-end user signalling
Network	X.25 and others	Call control Q.931
Data link	LAPB and others	LAPD
Physical	BRI (1.430) PRI (1.431)	BRI (1.430) PRI (1.431)

2.11 THE ATM NETWORK

Asynchronous Transfer Mode (ATM) network is a cell relay protocol designed by the ATM standards. ATM is a packet-oriented transfer method that uses time-division multiplexing (TDM) protocols.

2.11.1 Characteristic Features of ATM

The ATM networks are designed to reach certain goals and they have the following characteristics that are unique to these networks only.

1. The transmission rate is the maximum possible, more particularly in an optical type of transmission.
2. They have always an interface with the existing packet networks and provide wide area interconnectivity between them.
3. They are cost effective and thereby became the backbone of international communications.
4. They work and support the existing telecommunications.
5. They are connection-oriented. This feature ensures accurate transmission.
6. Most of the software functions are moved to hardware. This feature increases the data rate.

2.11.2 Cell Networks

A cell is a small unit of data of fixed size of 53 bytes long and is shown below.

Bytes	5	48
	Header	User data

A cell is used as a basic unit of data exchange in cell networking. Data frames of different sizes are split into number of smaller units of equal size.

These units are called cells. Then these cells are transmitted through the network using multiplexers. ATM provides data link layer services through layer 1 physical links. This type of uniformity in the sizes of the cells allows for a transmission with complete predictability. This factor overcomes the problems faced with packet internetworking. This also overcomes the problems associated with multiplexing packets of different sizes. All ATM networks are connection-oriented.

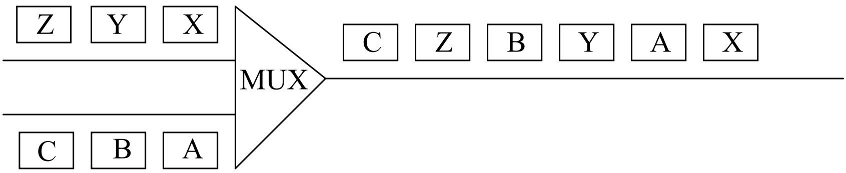


Fig. 2.28 Multiplexing using cells.

Figure 2.28 shows the functioning of a multiplexer with cells on two channels as shown in it. Observe that the first cell on the first channel gets priority over the first cell on the second channel during the process of transmission.

2.11.3 Cell Routing-Virtual Circuits

Routing of cells in cell networking is virtual circuit routing. The routing in cell networks is the virtual circuit routing on which all cells of the data unit travel on the same path. This sees that all these cells reach the destination in the order in which they are sent. If different paths are used, the cells may reach the destination in a disorderly manner incurring erratic delays.

The path followed is identified by a set of numbers assigned by the network manager. These numbers are contained in a header field called the "**Virtual Path Identifier**" (**VPI**).

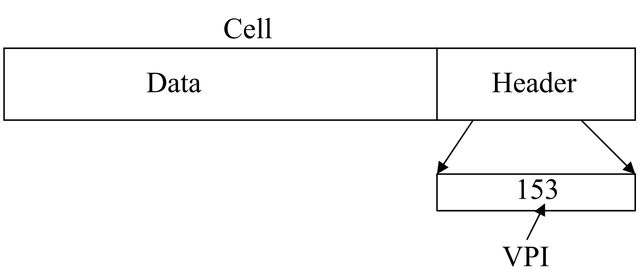


Fig. 2.29 Virtual path identifier.

If there are multiple channels in each path, one uses switches and the header contains both a Virtual Path Identifier (VPI) and a Virtual Circuit Identifier (VCI).

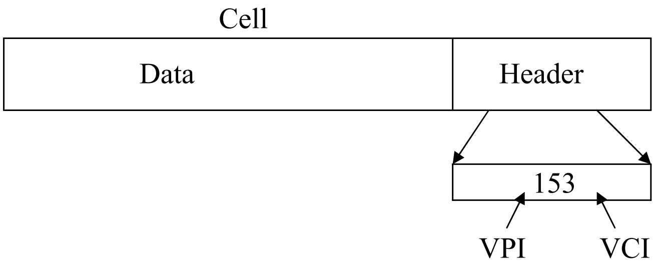


Fig. 2.30 Virtual circuit identifier.

2.11.4 ATM Interfaces

The two interfaces of ATM are the "User Network Interface" (UNI) and the "Network-to-Network Interface (NNI)". The UNI is the interface between a user and the wide area ATM network and NNI is the interface between two wide area ATM networks.

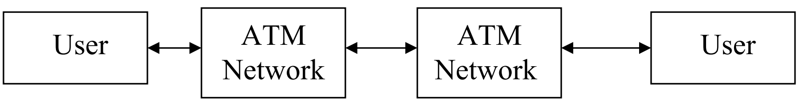


Fig. 2.31 ATM interfaces.

The ATM private switches can be used outside a public ATM network, such as ATM LANs. For connecting those switches that are involved, two types of switches, namely, a private UNI and a public UNI switches are used. A private INI is used to connect a user with an ATM switch and a public key connects a user to a public ATM network.

2.11.5 ATM Protocols

The ATM standard defines three ATM layers, namely, (1) Application Adoptation Layer (AAL), (2) ATM Layer, and (3) Physical Layer.

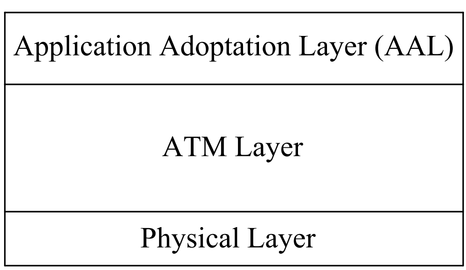


Fig. 2.32 ATM layers.

4-kHz analog telephone channel
A– 64-kbps digital PCM channel for voice or data
B– 8/16 kbps digital channel
C– 16-kbps digital channel for out-of-band signalling
D– 64-kbps digital channel for internal ISDN signalling
H– 384-, 1536-, or 1920-kbps digital channel

2.15 SYNCHRONOUS OPTICAL NETWORK/SYNCHRONOUS DIGITAL HIERARCHY (SONET/SDH)

In this speed age, it is but natural that one needs highest data-rate transmission in addition to the day-to-day lower data-rate transmissions. A videoconferencing needs highest data-rate transmission. Necessary technologies are to be developed to cater to the first said requirement. For example, Chief Executive Officer of a multinational company calls various country managers for a videoconferencing to discuss their production plans and budget requirements for the current financial year. The Chief Minister of a state calls all the district collectors for a videoconferencing to discuss progress in the implementation of different welfare schemes. The fibre-optic cable is well suited to be used in this context, in view of its high bandwidth. For a better implementation of these technologies, some standardization of protocols involved is required. The ANSI standard developed by the United States is called the "**Synchronous Optical Network (SONET)**" and the ITU-T standard developed by Europe is called the "**Synchronous Digital Hierarchy (SDH)**".

The characteristic features that identify SONET/SDH from other networks are three in number and we now discuss them.

The first one is that SONET/SDH is a synchronous network. That is, the duration (the time interval, the beginning and end) of transmission is known to the network at all its points with the help of an inbuilt clock. Any synchronous transmission ensures total safety. When fibre-optic cable is used for a synchronous transmission on different channels, each channel can be put to use without demultiplexing the transmission signal. This feature makes the transmission very fast.

The second feature is that the standardization lays down stringent specifications on the "**Fibre-Optic Transmission Systems (FOTS)**".

Thirdly, SONET/SDH is a flexible transmission system. It can be used as a carrier for broadband services like ATM and B-ISDN.

Different signalling levels, called "**Synchronous Transport Signals (STSs)**" are used in a SONET. The different STS levels available are: STS-1, STS-3, STS-9, STS-12, STS-18, STS-24, STS-36, STS-48, STS-96, and STS-192. Each of these STS levels specify its rate of transmission through physical

Drop multiplexing device. This device deletes unwanted signals and adds new signals if necessary. Then these signals are sent to another regenerator. Finally all these signals reach the destination STS multiplexer, where demultiplexing takes place. Any two neighbouring devices are connected by optical links called **sections**. The segment between two multiplexers is called a line and the one between the source STS multiplexer and the destination multiplexer is called the **SONET path**.

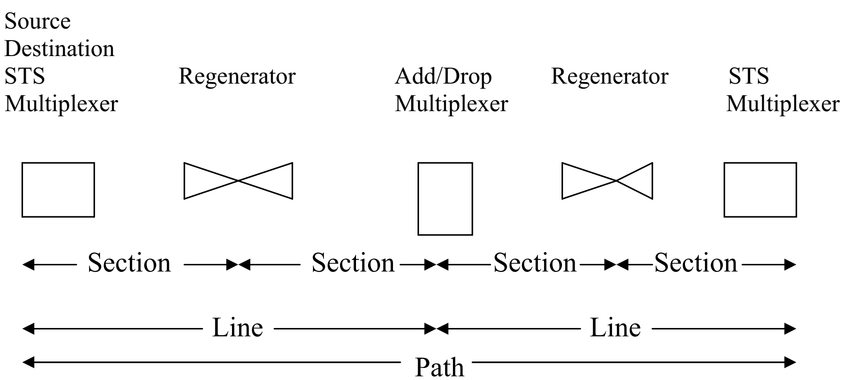
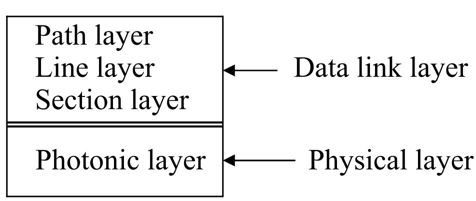


Fig. 2.36 A SONET path.

The ANSI SONET standard identifies four levels. These are: (1) The **photonic level,** (2) The **section layer,** (3) The **line layer,** and (4) The **path layer**. The equivalent of the photonic SONET level in the OSI reference model is the physical layer. The other three layers correspond to the data link layer of the OSI model.



The photonic SONET layer describes the physical properties of the optical channels, receivers, multiplexing modes and other such things. The section layer transmits signals safely to the destination passing through different sections. The line layer passes the signals through different lines. The path layer is responsible for transmitting the signals from the source SONET to the destination one.