CONTENTS

COMPUTER NETWORKS

SYLLABUS

UNIT I

Computer Networks: Introduction – Growth Complexity in Network Systems – Concepts and Terminology. Motivation and Tools: Resource sharing-growth of the internet – Probing the internet – Tracing a route. Data Transmission: Copperwires – Glass fibers – Radio – Satellites – Geosynchronous, Low Earth Orbit Satellites – Arrays-Microwave, infrared – Light from a laser.

UNIT II

Local Asynchronous Communication: The need – Standards for communication – Baud rate, framing and errors – Full duplex – Limitations of real hardware – Transmission of bits – Significance of Data Networks. Long Distance Communication: Introduction – Sending signals across long distance – Modem – Leased Analog Data Circuits – Baseband and broadband technologies – Wave Division Multiplexing – Spread Spectrum – Time Division Multiplexing.

UNIT III

Packet Transmission: Packets – Hardware Frames – Byte stuffing – Transmission errors – Probability, Mathematics and error detection – Cyclic Redundancy Checks – Burst errors – Building blocks – Frame Formats and error Detection Mechanisms. LAN Technologies Network Topology: Lab Topologies – CSMA-CSMA/CD – Wireless LAN's-IBM Token Ring – ATM. Hardware Addressing and Frame Type Identification; Specifying a receipient – Broadcasting – multicasting – multicast addressing – Frame Headers and Frame Format – Network Analysers-Frame Types.

UNIT IV

LAN wiring – Physical Topology – Interface Hardware: Speeds of LAN's and Computers – Network Interface Hardware – Connection Multiplexing – The topology paradox – Network Interface Cards – Other Network Technologies. Fiber Modems – Repeaters – Bridge and Switches – Long Distance Digital Connection Technologies: Digital Telephony – ISDN – SONET – DSL Technologies – Cable Modem Technologies: WAN Technologies-Routing. A WAN – SPF – Examples of WAN. Network Ownerships – Service Paradigms and Performance. Protocols and Layers: Seven Layers – Multiple Nested Headers – Techniques Protocols use – Protocol Design.

UNIT V

Internetworking Concepts – Architecture and Protocols – IP Addresses – Binding Protocol Addresses (ARP) – The Future IP – Error Reporting Mechanism-TCP-Network Applications-Client – Server Interaction – World Wide Web pages and Browsing.

UNIT I

LESSON

1

COMPUTER NETWORKS: AN INTRODUCTION

CONTENTS

1.0 AIMS AND OBJECTIVES

After studying this lesson, you will be able to:

- Discuss use of computer networks
- Understand goals and applications of computer networks
- Explain network concept
- Know network examples
- Discuss complexity in computer networks

1.1 INTRODUCTION

In data communication system, digital and analog communication together plays a very important integrated role irrespective of many advantages of digital communications over analog. Figure 1.1 shows the integrated role of digital and analog communication to complete data communication system.

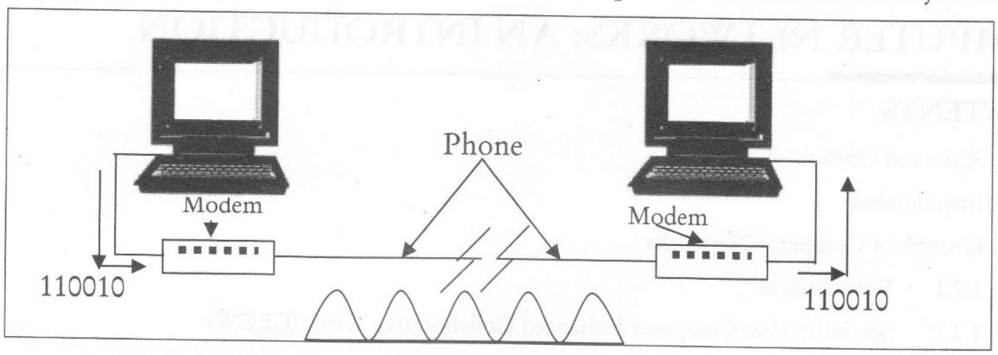


Figure 1.1 Data Communication System

As these two signals are different in nature, how can these be connected together or communicated over the communication channel? This question can be understood by communication channels, which provide the link for data communications. Figure 1.1 shows that the link between modems is modulated analog signal created by the modem. Likewise we may consider Figure 1.2 where data communication system is presented in a wider sense. The communication from PC to modem is consisted of binary signal whereas the communication between Central Telephone Office (CTO) and modem takes place in modulated analog signal. The communication between CTO to another CTO is by digital signal using time division multiplexers, which are codecs. Thereafter CTO feeds modulated analog signal to modem and modem converts it into binary signal for the PC. We may now say that different types of signals emerging on the communication link and reaching to CTO on their way across a big city. These can be multiplexed to share the same communication link for transmitting to destination.

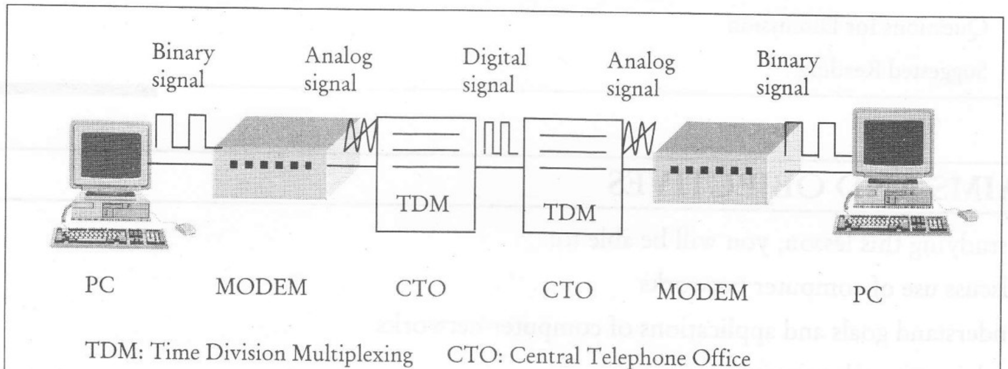


Figure 1.2: Data Communication System

Development in data communication field has fuelled the use of computer networks in different fields of life. It enables the people to archive information at different websites and access them to as and when need arises. Computer networks to serve the people are available as Local Area Network, Metropolitan Area Network and Wide Area Network depending upon on technologies and their geographical span.

1.2 GROWTH OF COMPUTER NETWORKS

A network is connection of independent computers to communicate with one another over a shared network medium. A network may be consisted of two or more computers. In other words, computer networks are collections of computers, software and hardware, which are connected to share resources together. A network connects computers using transmission media either in the forms of cables or wireless, specialized software and devices that manage data traffic. It enables to share files and resources, such as printers and send messages electronically to each other. Thus, the term computer network applies to the exchange of information among computers of individuals, groups or institutions and helps in processing of electronic voice or data communications.

Computer Networks have rapidly become an integral part of human life and in many cases, computer networks are considered as the solution to every problem not only within business but also in day-to-day life. The main purpose of computer networks is to enable people to exchange data and information over email, LAN, Intranet or Extranet etc. At the basic level, computer networks share resources, such as printers and storage space. On the advanced level, computer networks enables to carry video data for remote video conferencing.

Growth of computer networks have proved beneficial in day to day life where it allows you to handle your work from your home as well.

The following points can justify the use of computer networks:

1.2.1 Business Use

The business uses of computer networks include storage and retrieval of information, reducing the need for paper and moving towards paperless office and rationalizing the time for producing correspondence and accounts. In the context of business, generally computer networks provide the following uses:

1. *Sharing of resources:* Computer networking allows sharing of resources. Connections of computers in a network will enable you to share files and devices such as printers, CD-ROM drives, etc. It makes available programs, data, and equipment available to anyone on the network irrespective of the physical location of the resource and the user. In case of over capacity utilization of the Central Processing Unit (CPU) of any one computer in network, the computer networks helps in transferring loads to another computer in the network. This aspect of load sharing is the key to the grid computing.

   Example: In Today's world, floppy disks and Cds have taken a back space whereas networking is taking place to share the files and folders .So people now share their files and folders with their friends, relatives or their colleagues directly through computer networks. Now a days file sharing or any resource sharing is done through internet. Computer networks provide you with more flexible options. The process of copying files from one computer to another is done using a live network connection.

2. ***Reliability:*** It is also due to sharing of different resources as it provides alternative sources such as replicated files, multiple CPUs, etc. When one computer breaks down, you can use other computer available on the network with your replicated files etc available thereon. Thus, the system continues to operate but at reduced performance. This could be possible because there is no central computer as in the case of mainframe. This is very important property for applications of computer networks in financial services, air traffic control and many other applications.

3. *Saving money:* Computer networks help in collecting data on either one server or many servers in the form of file servers in the same network. Thus, a computer network consisting of many powerful small computers, one per user will be able to access data collected in file servers. This provides a better price/performance ratio than mainframes. This model is called the client-server model where the users are called clients.

   Example: Suppose a file is to be shared between employees and their senior head. So, instead of every employee going to their head by getting their data on removable media to show the files, the network allows them to share files without making any effort of moving from their seat. Also networking allows management to monitor what the employees are doing on their computers, thus reducing wasted time.

4. *Scalability:* Use of computer networks facilitates connections of different networks at multiple locations to communicate with the computers of other network. This is accomplished by using phone services and other mode of communication services.

5. *Powerful communication medium:* Networks make communication among groups of people easy at remote locations through e-mail, chat, etc. It also facilitates rapid exchange of information and business data over the company's internal network. Use of the computer network and the Internet allows users to access to data from anywhere in the world.

6. *Integration of the business operations:* It helps in Integrating the whole business operation into a networked operation, including sales activity, stock holding, quotations, ordering raw materials, control the production process, process invoices, process all the accounts, analyze business performance, quality control, etc.

1.2.2 Scientific Use: Computer Enhanced Collaborative Work (CECW)

Scientific use of computer networks can be traced back to the beginnings of the Internet for sharing resources and exchanging data. The Internet, as we know it today, was created in a laboratory.

In scientific applications, computer networks were useful for sharing data and using remote computers to carry out large computations. This may include the use of supercomputers in various locations. Apart from the "outsourcing" of computing power, the old system of using one powerful computer within a department to carry out large computations and many small hosts for the creation of reports is very common application of computer networks. Grid computing is an area in which networked computers can be used for the parallel processing of large computations using processors with local memory and shared memory. The distinction between processor and computer is that a computer is the combination of a processor, memory and peripheral devices. A processor is an integrated circuit in which the processing takes place.

Networks for Citizens

Computer network is an important information gathering and transferring tool for common citizens where interactions between a person and a remote database take place. They provide access to remote information *such as*:

- E-governance applications are aimed with the vision of providing citizen services in an integrated manner. To achieve this mission, the government and private sector develops citizen centric applications and provides access points in the forms of Community Information Centers. These services may also be accessed from home. Some of the applications include land records, agricultural products price, driving licenses, railway reservations etc.

- Reservations for trains, airplanes, hotels, restaurants, theaters, and so on, anywhere in the world with instant confirmation.
- Networks have made possible online banking and shopping from home or office.
- Proliferation of computer networks is providing on-line and personalized electronic newspapers, journals, and libraries at your desktop.
- Networks allow us to be mobile because we can access our own computer while traveling or transfer files to some remote computer.
- Access to WWW (World Wide Web), which contains information about several topics, has changed the world into global village.

Person-to-person Communication

It involves:

- Exchange of message via emails that may contain text, digitized voice, pictures, video images, etc.
- Newsgroups covering topics for a particular group.
- Real-time collaborative approaches such as videoconferencing and virtual meeting environments that allow remote users to communicate with negligible delay with seeing and hearing each other.

Entertainment

It involves:

- Video on demand allows the user to select any movie or TV program available in the video library for having it displayed on screen instantly.
- Interactive films where the user has an opportunity to select any scene of his/her choice to create his/her own film.
- Live and interactive TV enables users to participate in quiz shows, and so on.
- Due to all these benefits and other also, computer networking becomes increasingly more important.

1.3 COMPLEXITY IN NETWORK SYSTEMS

- Viruses can easily attack the system. A system can easily be destroyed through viruses that appears easily in network systems. It takes much time to remove any virus, so its very important to keep your systems away from viruses.
- Also a system can be attacked by hackers. They can hack your passwords and may affect the security of the system.
- ***Expensive to install:*** Although a network will generally save money over time, the initial costs of installation can be prohibitive. Cables, network cards, and software are expensive, and the installation may require the services of a technician.
- ***Requires administrative time:*** Proper maintenance of a network requires considerable time and expertise. Many schools have installed a network, only to find that they did not budget for the necessary administrative support.

- *File server may fail:* Although a file server is no more susceptible to failure than any other computer, when the files server "goes down," the entire network may come to a halt. When this happens, the entire school may lose access to necessary programs and files.
- *Cables may break:* The Topology chapter presents information about the various configurations of cables. Some of the configurations are designed to minimize the inconvenience of a broken cable; with other configurations, one broken cable can stop the entire network.

1.4 COMPUTER NETWORK CONCEPT

The development of computer networks took place in gradual manner and is built in a highly structured way. They are designed in such a way so that the network architecture and structure could reduce the design complexity and enable the system designer to scale up and upgrade the networks.

1.4.1 Network Architecture

Network architecture defines the communications products and services, which ensure that the various components can work together. In the early days of data communication systems, the majority of communications were between the DTE and the host computer. Therefore, transmission control procedures were alone enough as communication protocols. However, recent computer systems link with other systems to form a network, resulting in a situation where in different protocols serving different purposes are required. Hence, the network architecture represents a systemization of the various kinds of protocols needed to build a network.

Computer manufacturers have developed different protocols as needed. This means that each type of computer needed to support different protocols. This also necessitated large development and maintenance costs. All computer manufacturers, therefore worked together to standardize and systemize protocols to link their models and thereby reduce the development and maintenance costs. This was how each manufacturer built own network architecture. Since the concept of the network architecture was first introduced to connect the computers of the same manufacture, the process has become easier. However, from user's perspective, the ideal form of network architecture is one, which enables machines of all manufacturers to connect to each other. Therefore, the need of standardization of network architecture arose.

Table 1.1: Network Architecture by Vendor

Manufacturer	Network Architecture
IBM	System Network Architecture (SNA)
DEC	Digital Network Architecture (DEC)
Borroughs	Borroughs Network Architecture (BNA)
UNIV AC	Distributed Communication Architecture (DCA)
Toshiba	Advanced Network System Architecture (ANSA)
NEC	Distributed Information Processing Architecture (DINA)
Honeywell	Distributed System Environment (DSE)

Following are the ways to achieve connection between different manufacturers:

1. *Protocol Converters:* These are devices that translate from one native protocol into another, for example, from ASCII to IBM SNA/SDLC

2. *Gateways:* These are hardware/software combinations that connect devices running different native protocols. In addition to protocol conversion, gateways provide a gateway connection between incompatible networks. Examples include Ethernet-to-Token Ring gateways, X.25-to-Frame Relay gateways, and T-carrier-to-E-Carrier International Gateway Facilities (IGFs).
3. In addition to the above, **Protocol Analyzers** are available as diagnostic tools for displaying and analyzing communications protocols. Analyzers allow technicians, engineers and managers to test the performance of the network to ensure that the systems and the network are functioning according to specifications. LAN managers, for instance, use protocol analyzers to perform network maintenance and troubleshooting and to plan network upgrades and expansions.

1.4.2 OSI Model

Open Systems Interconnection (OSI) was set up as an international standard for network architecture. OSI Reference Model developed by the International standard organization deals with connecting open systems. Open systems are open for communication with other systems. The OSI model contains seven layers. A detailed discussion of the network architecture has been provided under the topic network software in this Unit only. The International Organization for Standardization (ISO) took the initiative in setting up OSI. OSI has two meanings.It refers to the protocols that are authorized by ISO.

OSI Basic Reference Model

OSI reference model divides the required functions of the network architecture into several layers and defines the function of each layer. Layering the communications process means breaking it down the communication process into smaller and easier to handle interdependent categories, with each solving an important and somehow distinct aspect of the data exchange process. The objective of this detail is to develop an understanding of the complexity and sophistication that this technology has achieved, in addition to developing the concept for the inner workings of the various components that contribute to the data communications process.

1.5 NETWORK EXAMPLES

Types of networks in operation:

- Public networks run by common carriers or PTTs.
- Research networks.
- Cooperative networks run by their users.
- Commercial or corporate networks.

Networks differ in the following aspects:

- *History and administration* - from well-planed and defined networks to ad hoc collection of machines connected together over the years.
- *Facilities* - from arbitrary process-to-process communication to email, file transfer, remote login and remote execution.
- *Technical designs* - transmission media, the naming and routing algorithms, the number and contents of the layers and protocols.
- *User community* - from a single corporation to all the academic computer scientists in the industrialized world.

We have discussed below some Computer Network Examples that will make you understand the network concept in a much better manner.

1. The most common example of computer networks is "Internet" that is being used by people in a wider way. It is defined as a network of computers across the world. In today's world, there is no need to have a conference room to attend a particular meeting. Every participant can attend the meeting through video conferencing just by sitting at their place in front of their desktop. Every file and folder or any kind of presentation can be shared easily without any need to upload them.
2. Another example would be a building lan. Let us consider an office building. Here all the computer systems are connected to each other through LAN and they can be shared easily such as they could have a common printer that can be used by every user.

Some other networking packages are discussed below:

1.5.1 Novell NetWare

It is the most popular commercial LAN networking package in the PC world.

IPX is an unreliable connectionless internetwork protocol, similar to IP, except that it uses 12-byte addresses instead of 4-byte addresses.

NCP (Network Core Protocol) is a connection-oriented transport protocol, plus various other services besides user data transport.

SPX and TCP are other options for providing transport only.

The client-server binding process:

1. About once a minute, each server broadcasts a packet giving its address and telling what services it offer, using the **SAP (Service Advertising Protocol)**.
2. The packets are seen and collected by special agent processes running on the router machines. The agents use the information contained in them to construct databases of which servers are running where.
3. When a client machine is booted, it broadcasts a request asking where the nearest server is.
4. The agent on the local router machine sees this request, looks its database of servers, and matches up the request with the best server. The choice of server to use is then sent back to the client.
5. The client establishes an NCP connection with the server.
6. The client and server negotiate the maximum packet size.
7. From this point on, the client can access this service using this connection.

1.5.2 ARPANET

It is the creation of ARPA (later DARPA, now ARPA), the (periodically Defense) Advanced Research Projects Agency of the US Department of Defense.

Much of our present knowledge about networking is a direct result of the ARPANET project.

ARPANET technologies:

1. *IMP (Interface Message Processor):* Originally Honeywell DDP-316 mini. with 12K 16-bit words memory. Replaced several times by more powerful machines.

Some IMPs allow direct terminal connection. They were called **TIPs** (Terminal Interface Processors).

IMPs were connected by 56 kbps or 230.4 kbps leased lines. Each IMP could originally handle only one to four hosts, and subsequently tens of hosts and hundreds of terminals simultaneously.

2. *Protocols:* ARPANET did not follow the OSI model at all (it predates OSI by more than a decade).

   The first experimental system consisted of four nodes (Dec. 1969).

   The TCP/IP model and protocols were specifically designed to handle the interconnection of the vast number of WANs and LANs comprising the ARPA internet.

   TCP/IP protocols were then integrated in Berkeley UNIX by a convenient program interface to the network (sockets), which makes TCP/IP very widespread.

   To facilitate finding hosts in the ARPANET, **DNS** (Domain Naming System) was created to organize machines into domains and map host names onto IP addresses.

   By 1990, the ARPANET had been overtaken by newer networks that it itself had spawned, so it was shut down and dismantled.

1.5.3 NSFNET

By the late 1970s, the NSF (National Science Foundation, USA) set up **CSNET** to provide networking facilities to the computer science community in USA as a whole (particularly those without access to ARPANET).

CSNET was centered around a single machine (CSNET-RELAY) at BBN that supports dial-up lines (PHONENET) and had connections to the ARPANET and other networks (e.g., X.25, CYPRESS).

Its major services include – emails, file transfer and remote login.

By 1984, NSF began designing a high-speed network, called **NSFNET**, that would be open to all university research groups.

NSFNET consists of a backbone network connecting six supercomputer centers, and about 20 regional networks. Backbone speeds: 56 kbps, 448 kbps, 1.5 Mbps, 45 Mbps (ANSNET).

Check Your Progress

1. What are the uses of computer networks?
2. What are goals and applications of computer networks?

1.6 LET US SUM UP

The role of computer networks in development is multi-faceted. A computer, along with the necessary networking infrastructure, is required it to be connected with either LAN or WAN or Internet or all, so as to play based on the needs a greater role in e-governance, telemedicine, e-education, e-business etc. We have learnt and understood about the necessity of computer networks in various fields in today's ever expanding technology, reference models to widely distributed computers and networks working on different operating systems and protocols, etc. Goals and applications are mandatory to implement a computer network. We have discussed various examples of computer networks that would help in understanding the concept in a better way. Also limitations or complexity in computer networks are discussed which would alert you regarding the various problems that could occur in computer networks.

1.7 KEYWORDS

Central Telephone Office (CTO): Central Telephone Office (CTO) and modem takes place in modulated analog signal.

LAN: A LAN is a form of local (limited distance), shared packet network for computer communications.

Internet: Internetworking is a scheme for interconnecting multiple networks of dissimilar technologies.

Computer Enhanced Collaborative Work (CECW): Scientific use of computer networks can be traced back to the beginnings of the Internet for sharing resources and exchanging data

WWW: World Wide Web

1.8 QUESTIONS FOR DISCUSSION

1. What are the major factors that have made the use of computer networks as an integral part of the business?
2. Explain major scientific factors of computer networks that have proved beneficial for the day to day life.
3. Describe network architecture.
4. Give some examples of computer networks.
5. What are the disadvantages of computer networks?

Check Your Progress: Model Answers

1. Computer Networks have rapidly become an integral part of human life and in many cases, computer networks are considered as the solution to every problem not only within business but also in day-to-day life.
2. Computer networks were initially developed to share files and resources among users. However, with the time, the role of computer networks in society has become a necessity. Applications of the computer networks can be broadly classified into Access to remote programs, Access to remote databases, Value-added communication facilities.

1.9 SUGGESTED READING

Anuranjan Misra, *Computer Networks*, Acme Learning Pvt. Ltd. publications

Rajneesh Agrawal and Bhata Bhushan Tiwari, *Computer Networks and Internet,* Vikas Publication

Burton, Bill, *Remote Access for Cisco Networks*, McGraw-Hill Osborne Media

Behrouz A. Forouzan, Sophia Chung Fegan, *Data Communications and Networking,* McGraw-Hill Companies

Andrew S. Tanenbaum, *Computer Networks,* Prentice Hall

LESSON

2

MOTIVATION AND TOOLS

CONTENTS

2.0 AIMS AND OBJECTIVES

After studying this lesson, you will be able to:

- Understand the importance of internet as a network tool
- Discuss data transmission concepts
- Discuss guided transmission media
- Discuss wireless transmission

2.1 INTRODUCTION

The word Internet is a short form of a complete word internetwork or interconnected network. Therefore, it can be said that the Internet is not a single network, but a collection of networks. Internet is a form of resource sharing. The commonality between them in order to communicate with each other is TCP/IP. The Internet consists of the following groups of networks:

- *Backbones:* These are large networks that exist primarily to interconnect other networks. Some examples of backbones are NSFNET in the USA, EBONE in Europe and large commercial backbones.
- *Regional networks:* These connect, for example, universities and colleges. ERNET (Education and Research Network) is an example in the Indian context.
- *Commercial networks:* They provide access to the backbones to subscribers, and networks owned by commercial organizations for internal use and also have connections to the Internet. Mainly, Internet Service Providers come into this category.
- *Local networks:* These are campus-wide university networks.

The networks connect users to the Internet using special devices that are called gateways or routers. These devices provide connection and protocol conversion of dissimilar networks to the Internet. Gateways or routers are responsible for routing data around the global network until they reach their ultimate destination as shown in Figure 2.1. The delivery of data to its final destination takes place based on some routing table maintained by router or gateways. These are mentioned at various places in this book, as these are the fundamental devices to connect similar or dissimilar networks together.

Over time, TCP/IP defined several protocol sets for the exchange of routing information. Each set pertains to a different historic phase in the evolution of architecture of the Internet backbone.

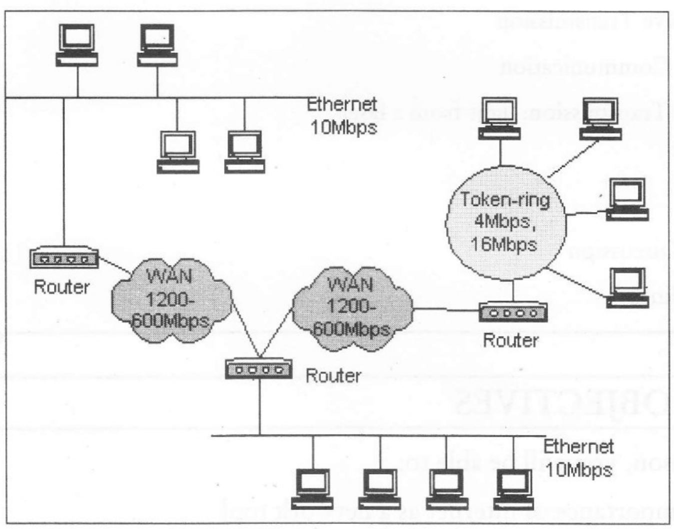


Figure 2.1: Local Area Networks connected to the Internet via Gateways or Routers

2.1.1 Growth of the internet

The rapid advances in TCP/IP technologies allowed to grow many regional networks in the world. The Internet, www and information super highways are the terms familiar to millions of people globally.

The evolution of Internet may be traced to the late 60s and 70s, when most of the networks were implemented, based on multiple networking models such as packet-switching technology, collision-detection LAN etc. The development of protocol or layer structure of networking allowed applications to communicate with each other. The availability of different operating systems, hardware platforms and the geographical dispersion of computing resources necessitated the need of networking in such a manner that computers of all sizes could communicate with each other, regardless of the vendor, the operating system, the hardware platform, or geographical proximity. Therefore, we may say that internetworking is a scheme for interconnecting multiple networks of dissimilar technologies. This system of interconnected networks is called an internetwork or an Internet. The need to share information between groups of users using each others systems on different networks with different protocols led to the development of an internetworking technology that can physically interconnect the two user groups, their applications etc on agreement. Organizations involved in this area of interconnecting networks were DARPA, ITU-T (formerly CCITT) and ISO. These organizations were trying to define a set of protocols, layered in a well-defined suite, so that applications would be able to communicate with other applications, regardless of the underlying network technology and the operating systems where those applications run. In the mid-1980s, collection of networks able to share information among different groups was termed as an Internet, and later as the Internet.

The popularity of Internet may be witnessed in the services provided by Internet. These are in the fields of electronics commerce, EDI, www, electronic mail, chat and instant messaging etc. The growth of Internet is so phenomenal that there were about 3000 networks and 200,000 computers in Internet by 1990. In the next five years, the Internet was consisted of multiple backbones, hundreds of regional networks, tens of thousands of LANs, millions of hosts, and tens of millions of users. Its size doubles approximately every year.

In fact, Internet is an example of a self-regulating mechanism where no one is in charge. While there are organizations, which are entrusted to develop technical aspects of this network, no governing body is in control. Private companies own the Internet backbone, through which Internet traffic or data in the form of text, video, graphics, sound and image etc flows. All computers on the Internet communicate with one another using the Transmission Control Protocol/Internet Protocol architecture, abbreviated to TCP/IP, based on client/server architecture. This means that the remote server machine provides files and services to the user's local client machine. Software can be installed on a client computer to take advantage of the latest access technology.

Briefly, a machine on the Internet means that the machine should:

- Run the TCP/IP protocol stack,
- Have an IP address, and
- Have the ability to send IP packets to all other machines on the Internet.

The Internet is becoming a necessary tool rather than a convenient tool in society. It has proved its utility in all walks of life such as education, economy, social and political. This is because of the presence of extensive networks with wide information sources, commercial vehicles, Internet and provision of applications and information to carry out useful tasks. Daily users of the Internet are allowed to access these applications to reach other users, which was not possible few years ago. Today they can be accessed on his/her terminal in a very short time. Moreover, they are not required to know the details of the technology underlying the Internet. This is the major reason behind the popularity of Internet among laymen. The information available on the Internet is making them more confident about their area of working and without which they feel their productivity and profitability of their businesses would be seriously affected.

2.1.2 Probing the internet

There are some probing tools such as ping and trace route.

- Ping is one of the probing tools which is used generally and it can be used to test a remote computer that is whether it is alive or not.
- Trace route is used to examine the computers which are along the path to a remote computer.

2.2 DATA TRANSMISSION: INTRODUCTION

Information has been attached with considerably increased value if it can be conveyed clearly to others. The conveyance, or transmission, of information across a distance necessarily involves some form of transmission medium. The selection of physical transmission media that serve to transport the information is critical to its successful conveyance. In interactive communication, the medium can be critical to the message. The transmission of an electrical signal requires the use of a transmission medium, which normally takes the form of a transmission line. There are various ways to transmit the signal. These ways can be broadly categorized into guided and unguided media. The guided media includes all wired media, also referred to as conducted or bounded media. The second category includes all traditional wireless media, also referred to as radiated, or unbounded. In the transmission of signal the data is encoded to energy and then energy is transmitted. Similarly at the receiving end the energy is decoded back to data. This energy can be electrical, light and radio, etc. Therefore this transmitted energy is carried through some sort of medium, which depends upon the type of energy being transmitted. Each form of energy has different properties and requirements for transmission. This requires special hardware for data encoding and connection to transmission medium. Media can be copper, glass and air, etc.

2.2.1 Transmission Concepts

Before discussing different kinds of transmission medium, it becomes necessary to know a little about the basic concepts and terminology associated with the transmission of a signal.

Frequency Spectrum: In the transmission of data the range of carrier frequencies depends on the nature of the medium and the requirements of the applications supported. Therefore, frequency spectrum may be defined as the range of frequencies being supported by a particular transmission medium. The actual range of frequencies supporting a given communication is known as a pass band.

Bandwidth: In a very general way bandwidth may be defined as the range of frequencies assigned to a channel. In other words we may say that bandwidth is the difference, expressed in Hertz, between the highest and the lowest frequencies of a band. In general, the higher the bandwidth, the more will be the data transmission rate or throughput. It should be noted that bandwidth and data transmission rate are very closely interrelated to each other. Clearly, any transmission system becomes more attractive if the available bandwidth is greater, introduced errors are fewer, and the maximum distance between various network elements (amplifiers, repeaters, and antennae) is greater.

Distances: The higher frequency signals offer greater bandwidth; they also generally suffer to a greater extent from signal attenuation than lower frequencies. This fact results in more errors in transmission, unless the amplifiers/repeaters are spaced more closely together. It clearly demonstrates the close and direct relationship between bandwidth, distance, and error performance.

Bandwidth, in this context, refers to the raw amount of bandwidth the medium supports. Error performance refers to the number or percentage of errors, which are introduced in the process of transmission. Distance refers to the minimum and maximum spatial separation between devices over a link, in the context of a complete, end-to-end circuit.

Propagation Delay: Propagation delay refers to the length of time required for a signal to travel from transmitter to receiver across a transmission system. While electromagnetic energy travels at roughly the speed of light (30,000 Kms per second) in free space. In contrast, the speed of propagation for twisted pair or coaxial cable is a fraction of this figure. The nature of the transmission system will have considerable impact on the level of propagation delay. In other words, the total length of the circuit directly influences the length of time it takes for the signal to reach the receiver.

Security: Security, in the context of transmission systems, addresses the protection of data from interception as it transverses the network. Particularly in the case of data networking, it also is important that access to a remote system and the data resident on it be limited to authorized users; therefore, some method of authentication must be employed in order to verify that the access request is legitimate and authentic.

Resistance to Environmental Conditions: Resistance to Environmental Conditions applies most especially to wired systems. Twisted pair, coaxial, and fiber optic cables are manipulated physically as they are deployed and reconfigured. Clearly, each has certain physical limits to the amount of bending and twisting (flex strength) they can tolerate, as well as the amount of weight or longitudinal stress they can support (tensile strength), without breaking (break strength). Fiber optic cables are notoriously susceptible in this regard. Cables hung from poles expand and contract with changes in ambient temperature; while glass fiber optic cables expand and contract relatively little, twisted pair copper wire is more expansive.

The issue of Resistance to Environmental Conditions also applies to airwave systems, as reflective dishes, antennae, and other devices used in microwave, satellite, and infrared technologies must be mounted securely to deal with wind and other forces of nature. Additionally, the towers, walls and roofs on which they are mounted must be constructed and braced properly in order to withstand such forces.

Physical Dimensions: The physical dimensions of a transmission system must be considered as well. This is especially true, once again, in the case of wired systems. Certainly, the sheer weight of a cable system must be considered as one attempts to deploy it effectively. Additionally, the bulk (diameter) of the cable is of importance, as conduit and raceway space often is at a premium. The physical dimensions of airwave systems also must be considered, as the size and weight of the reflective dish and mounting system (e.g., bracket and tower) may require support.

Cost and Ease of Installation: Cost issues abound in the selection of an appropriate transmission medium. Such issues include the cost of acquisition, deployment, operation, and maintenance (O&M), and upgrade or replacement. Without a lengthy discussion of each cost issue, it is particularly noteworthy to compare the costs of deployment of wired versus wireless media.

Wired transmission systems require that a right-of-way and this should be secured. Wired transmission involves a cost component in the form infrastructure. The infrastructure includes digging of trenches and boring of holes under streets so that cable can be pulled and poles may be mounted. In addition, amplifiers or repeaters may be placed. Such costs are not trivial. Unlike wired system, wireless systems require secured right-of-way and antennae. It may be inferred that the deployment of wired systems certainly speak to a set of cost issues that often can be more problematic.

2.3 GUIDED TRANSMISSION MEDIA

Guided transmission media or bounded media or wired transmission systems employ physical media, which are tangible. Also known as conducted systems, wired media generally employ a metallic or glass conductor which serves to conduct, some form of electromagnetic energy. For example, twisted pair and coaxial cable systems conduct electrical energy, employing a copper medium. Fiber optic systems conduct light or optical, energy, generally using a glass conductor. The term bounded or guided media refers to the fact that the signal is contained within an enclosed physical path. Finally, bounded media refers to the fact that some form of shield, cladding, and/or insulation is employed to bind the signal within the core medium, thereby improving signal strength over a distance and enhancing the performance of the transmission system in the process. Twisted pair (both unshielded and shielded), coaxial and fiber optic cable systems fall into this category.

2.3.1 Twisted Pair (Copper Conductors)

A twisted pair as shown in Figure 2.2 is a pair of copper wires, with diameters of 0.4-0.8 mm, twisted together and wrapped with a plastic coating. The twisting increases the electrical noise immunity, and reduces the error rate of the data transmission. Each conductor is separately insulated by some low-smoke and fires retardant substance. Polyethylene, polyvinyl chloride, flouropolymer resin and Teflon® are the some substances that are used for insulation purposes.

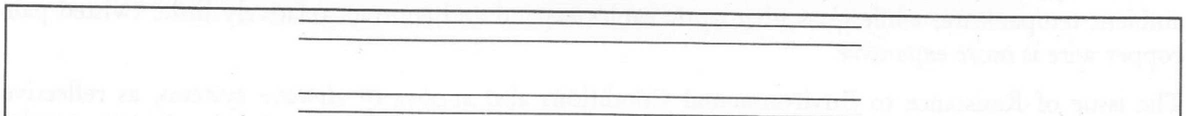


Figure 2.2: Two Wires Open Lines

This twisting process serves to improve the performance of the medium by containing the electromagnetic field within the pair. Thereby, the radiation of electromagnetic energy is reduced and the strength of the signal within the wire is improved over a distance. Clearly, this reduction of radiated energy also serves to minimize the impact on adjacent pairs in a multiple cable configuration. This is especially important in high-bandwidth applications, as higher frequency signals tend to lose power more rapidly over distance. Additionally, the radiated electromagnetic field tends to be greater at higher frequencies, impacting adjacent pairs to a greater extent. Generally speaking, the more twists per foot, the better the performance of the wire.

These are popular for telephone network. The energy flow is in guided media. Metallic wires were used almost exclusively in telecommunications networks for the last 80 years, until the development of microwave and satellite radio communications systems. Therefore, copper wire is now a mature technology, rugged and inexpensive. In certain applications, copper-covered steel, copper alloy, nickel- and/or gold-plated copper and even aluminum metallic conductors are employed.

The maximum transmission speed is limited in this case. The copper conductor that carries analogue data can be used to carry digital data also in association with Modem. Modem is a device to convert digital signal into analog signal and vice versa. The data rate in this category is limited to around 28 Kbps. The introduction of the Integrated Services Digital Network (ISDN) led to the use of improved modulation and coding schemes and data rate up to 128 Kbps. Local Area Networks (LANs) also use twisted pairs. These networks also upgraded to support for high bit rate real time multimedia. A recent development is Asymmetric Digital Subscriber Lines (ADSL) technology which is aimed at using two wire copper loops at data rates of 1.544 Mbps in the network to user direction and about 600 Kbps from the user to network.

The twisted pair cable may be defined in two categories based upon the shielding and without shielding.

Unshielded Twisted Pair (UTP)

UTP as depicted in Figure 2.3 is the copper media, inherited from telephony, which is being used for increasingly higher data rates, and is rapidly becoming the de facto standard for horizontal wiring. Horizontal wiring specifies the connection between, and including, the outlet and the termination in the communication closet. The horizontal is limited to a maximum of 90 meters. This is independent of the media type so that the communication closet is common to all media and all applications operating over the media. In addition, there is an allowance for 3 meters in the work area and 6 meters for cross connecting in the closet for a total of 99 meters.

The recommended media and connectors for the horizontal are as follow:

- 100-ohm unshielded twisted pair - 4 pairs, 8-pin modular connector (ISDN).
- 150-ohm shielded twisted pair - 2 pairs (IBM connector or RJ45).
- 50-ohm coax (thin) - IEEE 10BASE2, standard BNC connector.
- 62.5/125 multi mode fiber.

A UTP cable contains from 2 to 4200 twisted pairs. The advantages of UTP are the flexibility, low cost media, and can be used for either voice or data communications. Its greatest disadvantage is the limited bandwidth, which restricts long distance transmission with low error rates.

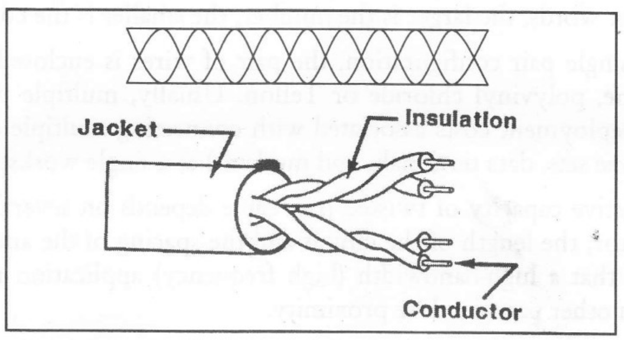


Figure 2.3: Unshielded Twisted Pair (UTP)

Shielded Copper or STP

Shielded Twisted Pair (STP) differs from UTP in that a metallic shield or screen surrounds the pairs, which may or may not be twisted. As illustrated in Figure 2.4, the pairs can be individually shielded. A single shield can surround a cable containing multiple pairs or both techniques can be employed in tandem. The shield itself is made of aluminum, steel, or copper. This is in the form of a metallic foil or woven meshes and is electrically grounded. Although less effective, the shield sometimes is in the form of nickel and/or gold plating of the individual conductors.

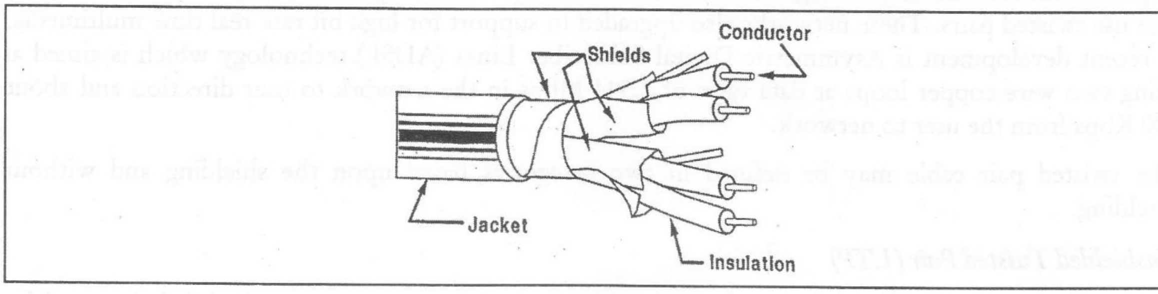


Figure 2.4: Shielded Twisted Pair (STP) Configuration

Shielded copper offers the advantage of enhanced performance for reasons of reduced emissions and reduction of electromagnetic interference. Reduction of emissions offers the advantage of maintaining the strength of the signal through the confinement of the electromagnetic field within the conductor. In other words, signal loss is reduced. An additional benefit of this reduction of emissions is that high-frequency signals do not cause interference in adjacent pairs or cables. Immunity from interference is realized through the shielding process, which reflects electromagnetic noise from outside sources, such as electric motors, other cables and wires, and radio systems.

Shielded twisted pair, on the other hand, has several disadvantages. First, the raw cost of acquisition is greater as the medium is more expensive to produce. Second, the cost of deployment is greater as the additional weight of the shield makes it more difficult to deploy. Additionally, the electrical grounding of the shield requires more time and effort.

General Properties of Twisted Pair

1. *Gauge:* Gauge is a measure of the thickness of the conductor. The thicker the wire, the less the resistance, the stronger the signal over a given distance, and the better the performance of the medium. Thicker wires also offer the advantage of greater break strength. The gauge numbers are retrogressive. In other words, the larger is the number, the smaller is the conductor.

2. *Configuration:* In a single pair configuration, the pair of wires is enclosed in a sheath or jacket, made of polyethylene, polyvinyl chloride or Teflon. Usually, multiple pairs are so bundled in order to minimize deployment costs associated with connecting multiple devices (e.g., electronic PBX or KTS telephone sets, data terminals, and modems) at a single workstation.

3. *Bandwidth:* The effective capacity of twisted pair cable depends on several factors, including the gauge of the conductor, the length of the circuit and the spacing of the amplifiers/repeaters. One must also recognize that a high-bandwidth (high frequency) application may cause interference with other signals on other pairs in close proximity.

4. *Error Performance:* Signal quality is always important, especially relative to data transmission. Twisted pair is especially susceptible to the impacts of outside interference, as the lightly insulated wire act as antennae and, thereby, absorbs such errant signals. Potential sources of Electro Magnetic Interference (EMI) include electric motors, radio transmissions and fluorescent light boxes. As transmission frequency increases, the error performance of copper degrades significantly with signal attenuation increasing approximately as the square root of frequency.

5. *Distance:* Twisted pair is distance limited. As distance between network elements increases, attenuation (signal loss) increases and quality decreases at a given frequency. As bandwidth increases, the carrier frequency increases, attenuation becomes more of an issue, and amplifiers/repeaters must be spaced more closely.
6. *Security:* Twisted pair is inherently an insecure transmission medium. It is relatively simple to place physical taps on UTP. Additionally, the radiated energy is easily intercepted through the use of antennae or inductive coils, without the requirement for placement of a physical tap.
7. *Cost:* The acquisition, deployment and rearrangement costs of UTP are very low, at least in inside wire applications. In, high-capacity, long distance applications, such as inter-office trunking, however, the relative cost is very high, due to the requirements for trenching or boring, conduit placement, and splicing of large, multi pair cables. Additionally, there are finite limits to the capacity and other performance characteristics of UTP, regardless of the inventiveness of technologists. Hence, the popularity of alternatives such as microwave and fiber-optic cable.
8. *Applications:* UTP's low cost including recently developed methods of improving its performance has increased its application in short-haul distribution systems or inside wire applications. Current and continuing applications include the local loop, inside wire and cable, and terminal-to-LAN. Generally speaking, UTP no longer is deployed in long haul or outside the premises transmission systems.

The additional cost of shielded copper limits its application to inside wire applications. Specifically, it generally is limited to application in high-noise environments. It also is deployed where high frequency signals are transmitted and there is concern about either distance performance or interference with adjacent pairs. Examples include LANs and image transmission.

2.3.2 Optical Fiber

We have seen in the previous section that the geometry of coaxial cable significantly reduces the various limiting effects, the maximum signal frequency, and hence the information rate that can be transmitted using a solid conductor, although very high, is limited. This is also the case for twisted lines. Optical fiber differs from both these transmission media in that it carries the transmitted information in the form of a fluctuating beam of light in a glass fiber rather than as an electrical signal on a wire. This type of transmission has become strong support for digital network owing to its high capacity and other factors favorable for digital communication.

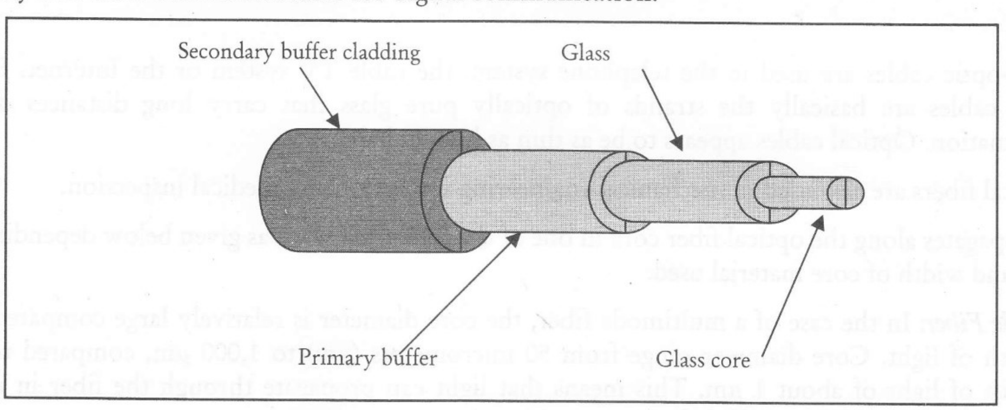


Figure 2.5: Fiber Optic Cables - General View

Fiber optic transmission systems are opto-electric in nature. In other words, a combination of optical and electrical electromagnetic energy is involved. The signal originates as an electrical signal, which is translated into an optical signal, which subsequently is reconverted into an electrical signal at the receiving end. Thin glass fiber as shown in Figure 2.5 is very clear and designed to reflect light internally for efficient transmission carries light with encoded data. Plastic jacket allows fiber to bend (some!) without breaking. Light Emitting Diode (LED) or laser injects light into fiber for transmission. Light sensitive receiver at other end translates light back into data.

The optical fiber consists of a number of substructures as shown in Figure 2.6.In this case, a core made of glass, which carries most of the light is surrounded by a cladding made of glass with lower refractive index. This bends the light and confines it to the core. The core is surrounded by a substrate layer (in some fibers) of glass, which does not carry light, but adds to the diameter and strength of the fiber. A primary buffer coating and a secondary buffer coating to provide mechanical protection cover all these.

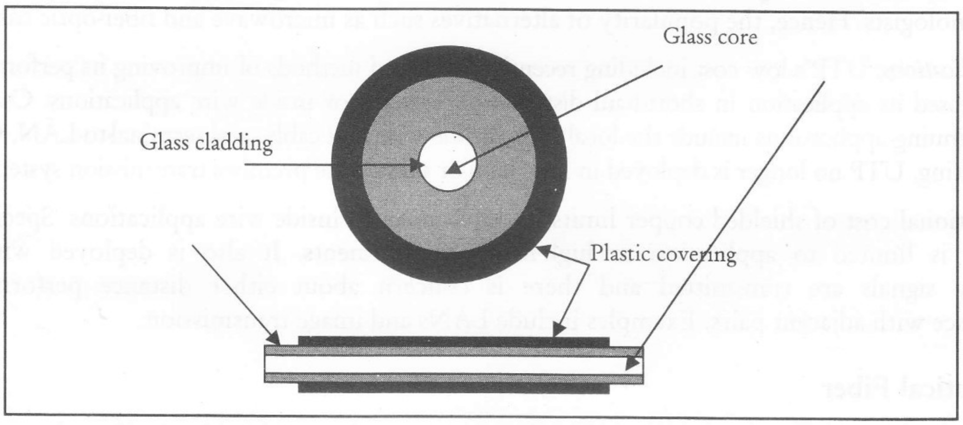


Figure 2.6: Glass Fiber Optic Cable, Side View, and Cross Section

The light pulse travels down the center core of the glass fiber. Surrounding the inner core is a layer of glass cladding, with a slightly different refractive index. The cladding serves to reflect the light waves back into the inner core. Surrounding the cladding is a layer of protective plastic coating that seals the cable and provides mechanical protection. This is shown in Figure 2.6 Typically, multiple fibers are housed in a single sheath, which may be heavily armored.

Example:

- Fiber-optic cables are used in the telephone system, the cable TV system or the Internet. Fiber-optic cables are basically the strands of optically pure glass that carry long distances digital information. Optical cables appears to be as thin as human hair.
- Optical fibers are also used in mechanical engineering inspection and medical inspection.

Light propagates along the optical fiber core in one of the following ways as given below depending on the type and width of core material used.

Multimode Fiber: In the case of a multimode fiber, the core diameter is relatively large compared to a wavelength of light. Core diameter range from 50 micrometers (μm) to 1,000 μm, compared to the wavelength of light of about 1 μm. This means that light can propagate through the fiber in many different ray paths, or modes, hence the name multimode.

Multimode fiber is less expensive to produce and inferior in performance because of the larger diameter of the inner core. When the light rays travel down the fiber, they spread out due to a phenomenon known as modal dispersion. Although reflected back into the inner core by the cladding, they travel different distances and, therefore, arrive at different times. The received signal thus has a wider pulse width than the input signal with a corresponding decrease in the speed of transmission. As a result, multimode fiber is relegated to applications involving relatively short distances and lower speeds of transmission, for example, LANs and campus environments.

Two basic types of multimode fibers exist. The simpler and older type is a "step index" fiber, where the index of refraction (the ability of a material to bend light) is the same all across the core of the fiber.

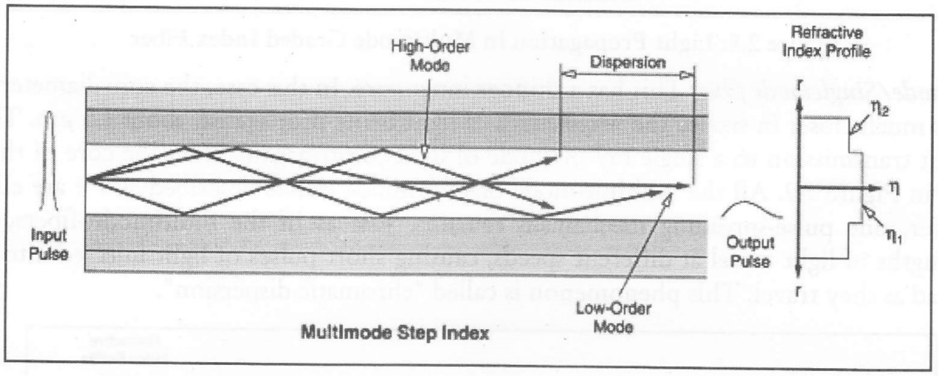


Figure 2.7: Multimode Step Index Fiber

1. *Step Index Multimode Fiber:* This is shown in Figure 2.7. With all these different ray paths or modes of propagation, different rays travel different distances, and take different amounts of time to transit the length of a fiber. This being the case, if a short pulse of light is injected into a fiber, the various rays emanating from that pulse will arrive at the other end of the fiber at different times, and the output pulse will be of longer duration than the input pulse. This phenomenon is called "modal dispersion" (pulse spreading), and limits the number of pulses per second that can be transmitted down a fiber and still be recognizable as separate pulses at the other end. This, therefore, limits the bit rate or bandwidth of a multimode fiber. For step index fibers, wherein no effort is made to compensate for modal dispersion, the bandwidth is typically 20 to 30 MHz over a length of one kilometer of fiber, expressed as "MHz - km".

2. *Graded Index Multimode Fiber:* In the case of a graded index multimode fiber, the index of refraction across the core is gradually changed from a maximum at the center to a minimum near the edges, hence the name graded index. This design takes advantage of the phenomenon that light travels faster in a low-index-of-refraction material than a high-index material. If a short pulse of light is launched into the graded index fiber, it may spread some during its transit of the fiber, but much less than in the case of a step index fiber. Therefore, dispersion can be reduced using a core material that has a variable refractive index. In such multimode graded index fiber light is refracted by an increasing amount as it moves away from the core as shown in Figure 2.8. This has the effect of narrowing the pulse width of the received signal compared with stepped index fiber, allowing a corresponding increase in the speed of transmission. They therefore can support a much higher bit rate or bandwidth. Typical bandwidths of graded index fibers range from 100 MHz-km to well over 1GHz-km. The actual bandwidth depends on how well a particular fiber's index profile minimizes modal dispersion, and on the wavelength of light launched into the fiber.

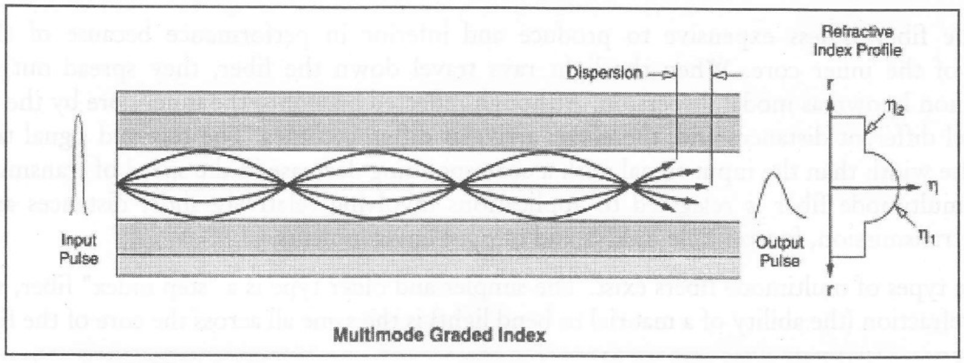


Figure 2.8: Light Propagation in Multimode Graded Index Fiber

Monomode/Singlemode fiber: This has a thinner inner core. In this case, the core diameter of about 9 μm is much closer in size to the wavelength of light being propagated, about 1.3 μm. This limits the light transmission to a single ray or mode of light to propagate down the core of the fiber as shown in Figure 2.9. All the multiple-mode or multimode effects described above are eliminated. However, one pulse-spreading mechanism remains. Just as in the multimode fibers, different wavelengths of light travel at different speeds, causing short pulses of light injected into the fiber to spread as they travel. This phenomenon is called "chromatic dispersion".

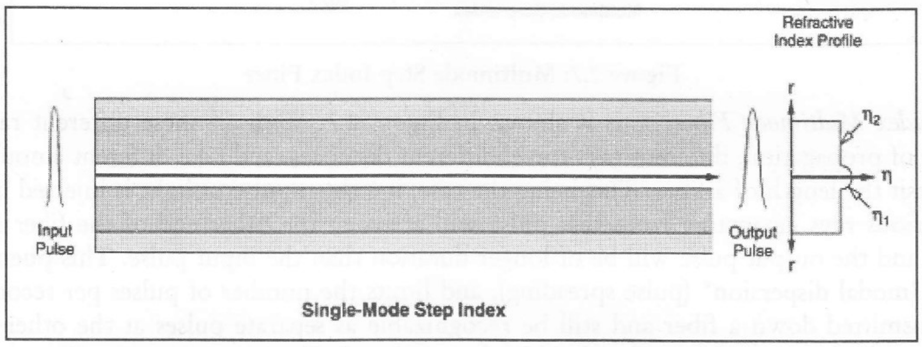


Figure 2.9: Light Propagation in Single Mode Step Index Fiber

It performs better than does multimode fiber over longer distances at higher transmission rates. Due to reduced core diameter all the emitted light propagates along a single path. Consequently the received signal is of a comparable width to the input signal. Although more costly, monomode fiber is used to advantage in long haul, and especially in high bandwidth, applications.

Single-mode fibers have the very broadest bandwidth, lowest cost and lowest attenuation of any available optical fiber. Therefore, they are universally used in long-distance telephony and cable television applications.

Advantages of Optical Fibers

- Immunity to electromagnetic interference and crosstalk
- No electrical ground loop or short circuit problems
- Small size and light-weight
- Large bandwidth for size and weight

- Safe in combustible areas (no arching)
- Immunity to lightning and electrical discharges
- Longer cable runs between repeaters
- Flexibility and high strength
- Potential high temperature operation
- Secure against signal leakage and interference
- No electrical hazard when cut or damaged.

General Properties of Optical Fiber

- *Configuration:* Fiber optic systems consist of light sources, cables and light detectors, as depicted in Figure 2.10. In a simple configuration, one of each is used. In a more complex configuration over longer distances, many such sets of elements are employed. Much as is the case in other transmission systems, long haul optical communications involves a number of regenerative repeaters. In a fiber optic system, repeaters are opto-electric devices. On the incoming side of the repeater, a light detector receives the optical signal, converts it into an electrical signal, boosts it, converts it into an optical signal, and places it onto a fiber, and so on. There may be many such optical repeaters in a long haul transmission system, although typically far fewer than would be required using other transmission media.

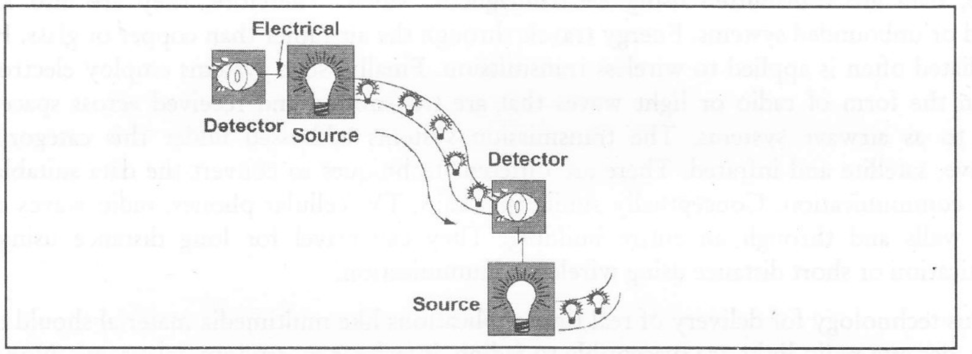


Figure 2.10: Fiber Optic System

- *Bandwidth:* Fiber offers by far the greatest bandwidth of any transmission system, often in excess of 2 Gbps in long haul carrier networks. Systems with 40 Gbps have been tested successfully on numerous occasions. The theoretical capacity of fiber is in the terabit (Tbps) range, with current monomode fiber capacity being expandable to that level.
- *Error Performance:* Fiber being a dielectric (a nonconductor of direct electric current), it is not susceptible to Electro Magnetic Interference/Radio Frequency Interference (EMI/RFI). This also does not emit EMI/RFI. The light signal will suffer from attenuation, although less so than other media. Scattering of the optical signal, bending in the fiber cable, translation of light energy to heat, and splices in the cable system can cause such optical attenuation.
- *Distance:* Monomode fiber optic systems routinely are capable of transmitting signals over distances in excess of 325 km. Therefore, relatively few optical repeaters are required in a long-haul system. This will reduce costs, and eliminating points of potential failure.

- *Security:* Fiber is intrinsically secure, as it is virtually impossible to place a physical tap without detection because no light is radiated outside the cable. Therefore, interception of signal is almost impossible. Additionally, the fiber system supports such a high volume of traffic that it is difficult to intercept and distinguish a single transmission from the tens of thousands of other transmissions that might ride the same cable system. The digital nature of most fibers, coupled with encryption techniques frequently are used to protect transmission from interception, make fibers highly secure.
- *Cost:* While the acquisition, deployment, and rearrangement costs of fiber are relatively high, the immense bandwidth can outweigh that cost in bandwidth-intensive applications. At Gbps speeds, a single set of fibers can carry huge volumes of digital transmissions over longer distances than alternative systems, thereby lowering the transport cost per bit and cost per conversation to fractions of a penny per minute.
- *Applications:* Applications for fiber optic transmission systems are bandwidth intensive. Such applications include backbone carrier networks, international submarine cables, backbone LANs (FDDI), interoffice trunking, computer-to-computer distribution networks (CATV and Information Superhighway) and fiber to the desktop (Computer Aided Design).

2.4 UNGUIDED OR WIRELESS TRANSMISSION

Wireless transmission systems do not make use of a physical conductor, or guide, to bind the signal. In this case, data are transmitted using electromagnetic waves. Therefore, they are also known as unguided or unbounded systems. Energy travels through the air rather than copper or glass. Hence the term radiated often is applied to wireless transmission. Finally, such systems employ electromagnetic energy in the form of radio or light waves that are transmitted and received across space, and are referred to as airwave systems. The transmission systems addressed under this category include microwave, satellite and infrared. There are different techniques to convert the data suitable for this mode of communication. Conceptually similar to radio, TV, cellular phones, radio waves can travel through walls and through an entire building. They can travel for long distance using satellite communication or short distance using wireless communication.

Use of this technology for delivery of real time applications like multimedia material should be treated carefully, because radio links are susceptible to fading, interference, random delays, etc. Non-real time use of this technology is likely to perform as well as current Ethernet LANs.

2.4.1 Radio Transmission

It is a technique where data is transmitted using radio waves and therefore energy travels through the air rather than copper or glass. Conceptually, radio, TV, cellular phones, etc uses radio transmission in one form or another. The radio waves can travel through walls and through an entire building. Depending upon the frequency, they can travel long distance or short distance. Satellite relay is the one example of long distance communication. Therefore, each frequency range is divided into different bands, which has a specific range of frequencies in the Radio Frequency (RF) spectrum. The RF is divided in different ranges starting from Very Low Frequencies (VLF) to Extremely High Frequencies (EHF). Figure 2.11 shows each band with a defined upper and lower frequency limit.

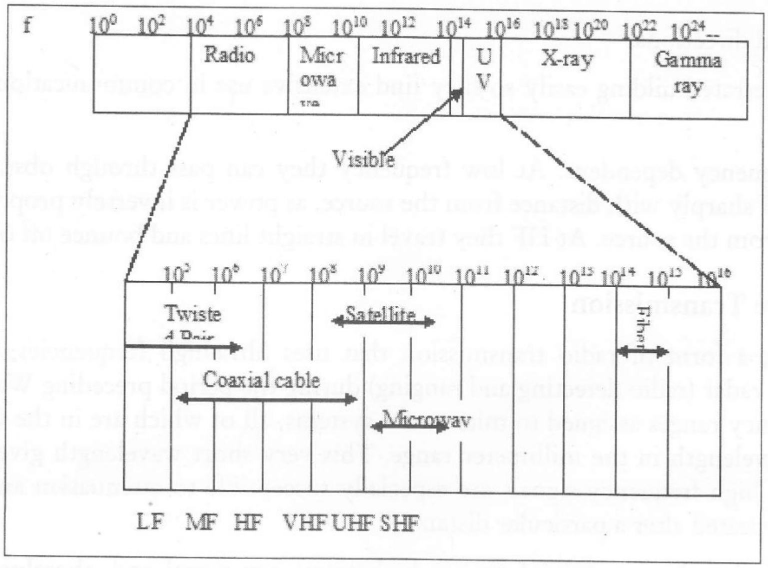


Figure 2.11: Radio Frequency Range and Types of Transmission Media

Two transmitters cannot share the same frequency band because of mutual interference and therefore band usage is regulated. International use of the radio spectrum is regulated by the International Telecommunication Union (ITU). Domestic use of the radio spectrum is regulated by national agencies such as Wireless Planning and Coordination (WPC) in India. WPC assigns each transmission source a band of operation, a transmitter radiation pattern, and a maximum transmitter power. Omni directional or directional antennas are used to broadcast radio waves depending upon band. The transceiver unit, which is consisted of transmitter and receiver along with the antenna, determines the power of RF signal. Other characteristics of radio waves are that in vacuum all electromagnetic waves or radio waves travel at the same speed i.e. at the speed of light which is equal to $3x10^8$ meter per seconds. In any medium this speed gets reduced and also becomes frequency dependent. In case of copper the speed of light becomes approximately two thirds of the speed of light.

Example:

- *Audio:* AM radio uses amplitude modulation, i.e., AM radio is processed through radio waves. FM radio sends music and voice with higher fidelity than AM radio.
- *Telephony:* Mobile phones transmit to a local cell site (transmitter/receiver) which leads to the working of mobiles in the network area only. Its working is done through optic fiber or microwave radio and other network elements.
- *Video:* Television sends the picture as AM and the sound as AM or FM
- *Heating:* Heating of objects is basically processed by the radio-frequency energy generated for it. Microwave ovens use radio waves to heat food.

The Basic Features of the Radio Waves

- They are easy to generate
- They have same velocity in vacuum
- They may traverse long distances

- They are omni directional
- They can penetrate building easily so they find extensive use in communication both indoor and outdoor
- They are frequency dependent. At low frequency they can pass through obstacles well but the power falls off sharply with distance from the source, as power is inversely proportional to cube of the distance from the source. At HF they travel in straight lines and bounce off obstacles.

2.4.2 Microwave Transmission

Microwave radio, a form of radio transmission that uses ultra-high frequencies, developed out of experiments with radar (radio detecting and ranging) during the period preceding World War II. There are several frequency ranges assigned to microwave systems, all of which are in the Giga Hertz (GHz) range and the wavelength in the millimeter range. This very short wavelength gives rise to the term microwave. Such high frequency signals are especially susceptible to attenuation and, therefore must be amplified or repeated after a particular distance.

In order to maximize the strength of such a high frequency signal and, therefore, to increase the distance of transmission at acceptable levels, the radio beams are highly focused. The transmit antenna is centered in a concave, reflective metal dish which serves to focus the radio beam with maximum effect on the receiving antenna, as illustrated in Figure 2.12. The receiving antenna, similarly, is centered in a concave metal dish, which serves to collect the maximum amount of incoming signal.

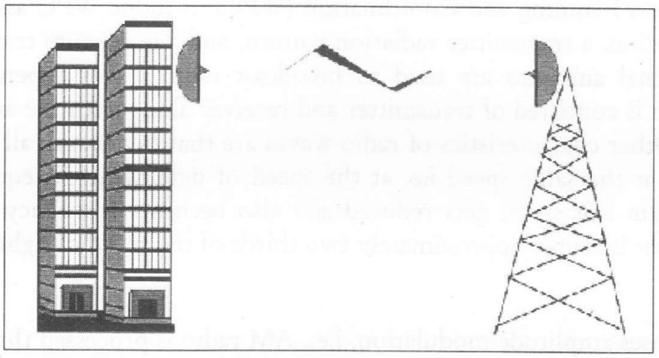


Figure 2.12: Point-to-point Microwave

It is a point-to-point, rather than a broadcast, transmission system. Additionally, each antenna must be within line of sight of the next antenna. Given the curvature of the earth, and the obvious problems of transmitting through it, microwave hops generally are limited to 50 miles (80 km). If the frequencies are higher within the microwave band given in Table 2.1. This impact is more than lower frequencies in the same band.

Table 2.1: Microwave Frequency Bands

Frequency Bands	Maximum Antenna Separation	Analog/Digital
4-6 GHz	32-48 Km	Analog
10-12 GHz	16-24 Km	Digital
18-23 GHz	8-11 Km	Digital

General Properties of Microwave Transmission

- *Configuration:* Microwave radio consists of antennae centered within reflective dishes that are attached to structures such as towers or buildings. Cables connect the antennae to the actual transmit/receive equipment.
- *Bandwidth:* Microwave offers substantial bandwidth, often in excess of 6 Gbps.
- *Error Performance:* Microwave, especially digital microwave, performs well in this regard, assuming proper design. However, such high frequency radio is particularly susceptible to environmental interference e.g. precipitation, haze, smog, and smoke. Generally speaking, however, microwave performs well in this regard.
- *Distance:* Microwave clearly is distance limited, especially at the higher frequencies. This limitation can be mitigated through special and more complex arrays of antennae incorporating spatial diversity in order to collect more signals.
- *Security:* As is the case with all radio systems, microwave is inherently not secure. Security must be imposed through encryption (scrambling) of the signal.
- *Cost:* The acquisition, deployment and rearrangement costs of microwave can be high. However, it often compares very favorably with cabled systems, which require right-of-way, trenching, conduit, splicing, etc.
- *Applications:* Microwave originally was used for long haul voice and data communications. Competing long distance carriers, microwave was found a most attractive alternative to cabled systems, due to the speed and low cost of deployment where feasible, however, fiber optic technology is currently used in this regard. Contemporary applications include private networks, interconnection of cellular radio switches, and as an alternative to cabled systems in consideration of difficult terrain.

2.4.3 Satellite Communication

Satellite radio, quite simply, is a non-terrestrial microwave transmission system utilizing a space relay station. Satellites have proved invaluable in extending the reach of voice, data, and video communications around the globe and into the most remote regions of the world. Exotic applications such as the Global Positioning System (GPS) would have been unthinkable without the benefit of satellites.

Geostationary Satellite

Contemporary satellite communications systems involve a satellite relay station that is launched into a geostationary, geosynchronous, or geostatic orbit. Such satellites are called geostationary satellite. Such an orbit is approximately 36,000 kms above the equator as depicted in Figure 2.13. At that altitude and in an equatorial orbital slot, the satellite revolves around the earth with the same speed as of that the speed of revolution of earth and maintains its relative position over the same spot of the earth's surface. Consequently, transmit and receive earth stations can be pointed reliably at the satellite for communications purposes.

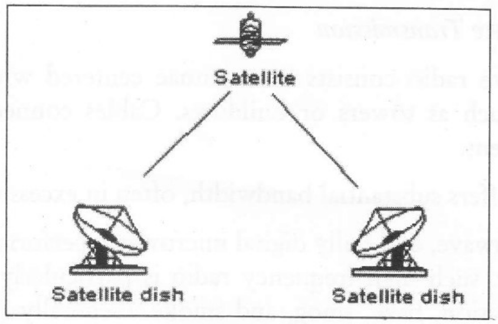


Figure 2.13: Satellites in Geostationary Earth Orbit

The popularity of satellite communications has placed great demands on the international regulators to manage and allocate available frequencies, as well as the limited number of orbital slots available for satellite positioning are managed at national, regional and international levels. Generally speaking, geostationary satellites are positioned approximately 2° apart in order to minimize interference from adjacent satellites using overlapping frequencies.

Such high frequency signals are especially susceptible to attenuation in the atmosphere. Therefore, in case of satellite communication two different frequencies are used as carrier frequencies to avoid interference between incoming and outgoing signals. These are:

- *Uplink frequency:* It is the frequency used to transmit signal from earth station to satellite. Table 2.2 shows the higher of the two frequencies is used for the uplink. The uplink signal can be tailored stronger and therefore can better deal with atmospheric distortion. The antenna at transmitting side is centered in a concave, reflective dish that serves to focus the radio beam, with maximum effect, on the receiving satellite antenna. The receiving antenna, similarly, is centered in a concave metal dish, which serves to collect the maximum amount of incoming signal.
- *Downlink frequency:* It is the frequency used to transmit the signal from satellite to earth station. In other words, the downlink transmission is focused on a particular footprint, or area of coverage. The lower frequency, used for the downlink, can better penetrate the earth's atmosphere and electromagnetic field, which can act to bend the incoming signal much as light bends when entering a pool of water.

Table 2.2: Example Uplink/Downlink Satellite Frequencies

Frequency Band	Uplink/Downlink Frequency Range	Example
C-band	6 GHz/4 GHz	TV, Voice, Videoconferencing
Ku-band	14 GHz/11 GHz	TV, Direct Broadcast Satellite /DSS
Ka-band	30 GHz/20 GHz	Mobile Voice

Broadcast: The wide footprint of a satellite radio system allows a signal to be broadcast over a wide area. Thereby any number (theoretically an infinite number) of terrestrial antennae can receive the signal, more or less simultaneously. In this manner, satellites can serve a point-to-multipoint network requirement through a single uplink station and multiple downlink stations.

Recently, satellites have been developed which can serve a mesh network requirement, whereby each terrestrial site can communicate directly with any other site. Previously, all such communications were required to travel through a centralized site, known as a head end. Such a mesh network, of course, imposes an additional level of difficulty on the network in terms of management of the flow and direction of traffic.

General Properties of Satellite Communication

- *Configuration:* Satellite communication systems consist of antennae and reflective dishes, much as in terrestrial microwave. The dish serves to focus the signal from a transmitting antenna to a receiving antenna. The send/receive dishes that make up the earth segment are of varying sizes, depending on power levels and frequency bands. They generally are mounted on a tripod or other type of brace, which is anchored to the earth, pad or roof, or attached to a structure such as building. Cables connect the antennae to the actual transmit/receive equipment. The terrestrial antennae support a single frequency band for example, C-band, Ku-band or Ka-band. The higher the frequency bands the smaller the possible size of the dish. Therefore, while C-band TV dishes tend to be rather large, Ku-band DBS (Direct Broadcast Satellite) TV dishes tend to be very small. The space segment dishes are mounted on a satellite, of course. The satellite can support multiple transmit/receive dishes, depending on the various frequencies, which it employs to support various applications, and depending on whether it covers an entire footprint or divides the footprint into smaller areas of coverage through the use of more tightly focused spot beams. Satellite repeaters are in the form of number of transponders. The transponders accept the weak incoming signals, boost them, shift from the uplink to the downlink frequencies, and transmit the information to the earth stations.
- *Bandwidth:* Satellites can support multiple transponders and, therefore, substantial bandwidth, with each transponder generally providing increments in bandwidth.
- *Error Performance:* Satellite transmission is susceptible to environmental interference, particularly at frequencies above 20 GHz. Sunspots and other types of electromagnetic interference affect satellite and microwave transmission. Additionally, some satellite frequency bands, for example, C-band needs careful frequency management. As a result of these factors, satellite transmission often requires rather extensive error detection and correction capabilities.
- *Distance:* Satellite is not considered to be distance limited as the signal largely travels through the vacuum of space. Further each signal travels approximately 36,000 kms in each direction.
- *Propagation Delay:* Geostationary satellites, by virtue of their high orbital altitude, impose rather significant propagation delay on the signal. Hence, highly interactive voice, data, and video applications are not effectively supported via two-way satellite communications.
- *Security:* As is the case with all microwave and other radio systems, satellite transmission is inherently not secure. Satellite transmission is especially vulnerable to interception, as the signal is broadcast over the entire area of the footprint. Therefore, the unauthorized user must know only the satellite and associated frequency range being employed. Security must be imposed through encryption (scrambling) of the signal.
- *Cost:* The acquisition, deployment, and rearrangement costs of the space segment of satellite systems can be quite high in several millions dollars. However, the satellite can be shared by a large number of users, with each user perhaps connecting a large number of sites. As a result, satellite networks often compare very favorably with cabled systems or microwave systems for many point-to-multipoint applications.

- *Applications:* Satellite applications are many and increasing rapidly as the traditional voice and data services have been augmented. Traditional international voice and data services have been supplanted to a considerable extent by submarine fiber optic cable system.

Traditional, applications include international voice and data, remote voice and data, television and radio broadcast, maritime navigation, videoconferencing, inventory management and control through VSATs, disaster recovery and paging. More recent and emerging applications include air navigation, Global Positioning Systems (GPS), mobile voice and data because of Low Earth Orbit Satellites (LEOs), Advanced Traffic Management Systems (ATMS), Direct Broadcast Satellite (DBS) TV, Integrated Digital Services Network (ISDN), interactive television, and interactive multimedia.

2.4.4 Infrared Transmission: Light from a Laser

Infrared light transmissions have existed for many years and their use having been limited to TV remote controls and wireless slide projector remote controls. However, they now are assuming a position of some, if still limited, importance. Infrared systems use the infrared light spectrum to send a focused light beam to a receiver, much, as would a microwave system, although no reflective dish is used. Rather, pair of lenses is used, with a focused lens employed in the transmitting device and a collective lens in the receiving device as shown in Figure 2.14. Infrared is an airwave, rather that a conducted transmission system. Although generally used in short-haul transmission, they do offer substantial bandwidth, but with risks of interference.

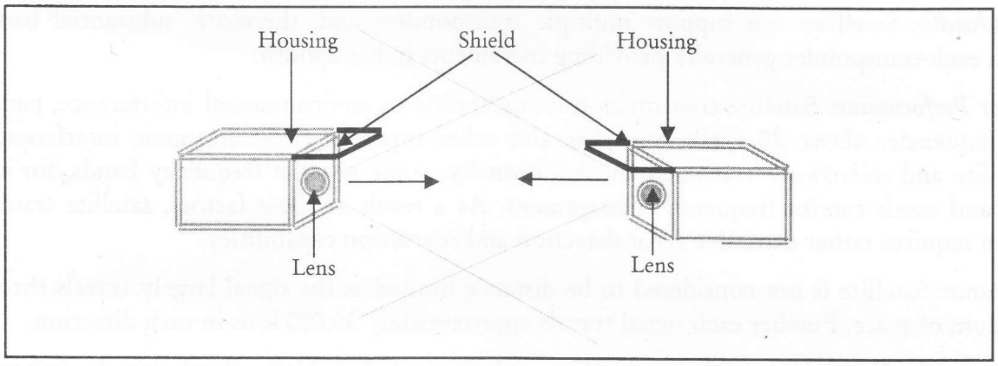


Figure 2.14: Infrared Transmission Systems

Advantages

Advantages include rapid deployment, especially as there are no licensing requirements as typically is the case with microwave. Additionally, infrared offers fairly substantial bandwidth at relatively low cost. However, infrared systems require line-of- sight and suffer from environmental interference, as do microwave systems. Error performance is also satisfactory. Additionally, infrared is distance limited. However, infrared often is an attractive alternative to leased lines or private cabled systems for building-to-building connectivity in a campus environment. Infrared transmission also is used in certain wireless LAN systems and is incorporated into some PDAs (Personal Digital Assistants).

The fiber optic communication enables us to use enhanced bandwidth. The Wavelength-Division Multiplexing (WDM) technology is used in fiber optic communication to multiplex multiple optical carrier signals on a single optical fiber by using different wavelengths of laser light to carry different signals.

Check Your Progress

1. What is guided transmission media? Discuss its classification.
2. What is Satellite communication?

2.5 LET US SUM UP

There are several kinds of bounded transmission media. These media technologies starting from copper wire to fiber optic has grownup so rapidly and replacing other very quickly in this information age. Transmission media describes the data path forming the physical channel between the sender and the receiver. Transmission media may be twisted pair, coaxial cable, fiber optics etc.

Selection of media depends on several factors including data rates, range, noise absorption, radiation, attenuation, bandwidth, error performance etc. Noise absorption of different transmission media defines the susceptibility of the media to external causes that tends to distort the data signal and thus introduces data errors. Radiation is the leakages of data signal from the transmission media due to the undesirable characteristics of the transmission media. Attenuation that degrades the signal strength as the signal travels over the transmission media is the outcome of the radiation and the physical characteristics of the media. Attenuation limits the distance to which a signal with enough information and less noise is received. Bandwidth indicates the data rate of the signal over transmission media. If the bandwidth higher, the data rate would be higher.

These media technologies starting from copper wire to wireless and fiber optic has grownup so rapidly and replacing other very quickly in this information age. Gradually, these were replaced with the use of microwave stations because of the cost of copper and related infrastructure. Long distance communication could be made affordable, feasible and reliable using high microwave towers coupled with the repeater stations at specified distances. This involves less maintenance and improved reliability because of a real interface instead of physical lines in the form of coaxial cables. The satellite communication has large delay problem. Now fiber optic cables are being used as a preferred means of interconnecting main centers together.

This does not mean that these new media like fiber optic and satellite has completely outdated conventional one. In fact, in this information age, each media is suited to different purposes and each has their place.

Nowadays, user is becoming more information starved and therefore to satiate his hunger it is necessary to go for some kind of alternative media to overcome the limitations imposed by the conventional media like coaxial cable for telephone lines. Moreover, his thirst for varied information has evolved the concept of multi-service in the form of text, voice, graphics, sound and picture on one hardware device only. This has created the need of multimedia service on broadband. Therefore, fiber optic cable is becoming more and more popular to quench the thirst for multi-service.

2.6 KEYWORDS

Bandwidth: It is defined as the size of the range of frequencies that can be transmitted through a channel.

Coaxial Cable: A very robust shielded copper wire two-conductor cable in which a solid center conductor runs concentrically (coaxial) inside a solid outer circular conductor.

Fourier Analysis: It is carried over to analyze the signal traveling over the transmission media.

Optical Fiber: carries the transmitted information in the form of a fluctuating beam of light in a glass fiber rather than as an electrical signal on a wire amount of time needed for information to propagate from source to destination through the channel.

Shielded Copper or STP: A metallic shield or screen surrounds the pairs, which may or may not be twisted.

Twisted Pair Cable: Two conductors are wrapped together for the purposes of canceling out Electromagnetic Interference (EMI) from external sources

Downlink Frequency: It is the frequency used to transmit the signal from satellite to earth station.

Microwave Radio: It is a form of radio transmission that uses ultra-high frequencies.

Radio: A technique where data is transmitted using radio waves and therefore energy travels through the air rather than copper or glass.

Uplink Frequency: It is the frequency used to transmit signal from earth station to satellite.

2.7 QUESTIONS FOR DISCUSSION

1. What are different Internet services available? Why has Internet become a necessity rather than convenience for society?
2. What is the difference between UTP and STP?
3. What is the purpose of cladding in an optical fiber? Discuss its density with respect to the core.
4. Explain the mechanism by which an optical pulse traveling along an optical fiber suffers from dispersion.
5. Describe how satellite communication is different from radio broadcast.
6. Write down any two advantages and disadvantages of using satellite communication.
7. How is the microwave signal strengthened to maximize its value to increase the distance of transmission at acceptable levels?
8. Discuss Infrared Transmission.

Check Your Progress: Model Answers

1. Twisted pair (both unshielded and shielded), coaxial and fiber optic cable systems fall into this category.
2. Satellite radio, quite simply, is a non-terrestrial microwave transmission system utilizing a space relay station

2.8 SUGGESTED READINGS

Rajneesh Agrawal and Bhata Bhushan Tiwari, *Computer Networks and Internet*, Vikas Publication.

Burton, Bill, *Remote Access for Cisco Networks*, McGraw-Hill, Osborne Media.

Behrouz A. Forouzan and Sophia Chung Fegan, *Data Communications and Networking*, McGraw-Hill Companies.

Andrew S. Tanenbaum, *Computer Networks*, Prentice Hall.

UNIT II

LESSON

3

LOCAL ASYNCRONOUS COMMUNICATION

CONTENTS

3.0 AIMS AND OBJECTIVES

After studying this lesson, you will be able to:

- Understand need and standard for communication
- Discuss factors determining the rate of data transmission
- Understand communication links
- Discuss framing and errors

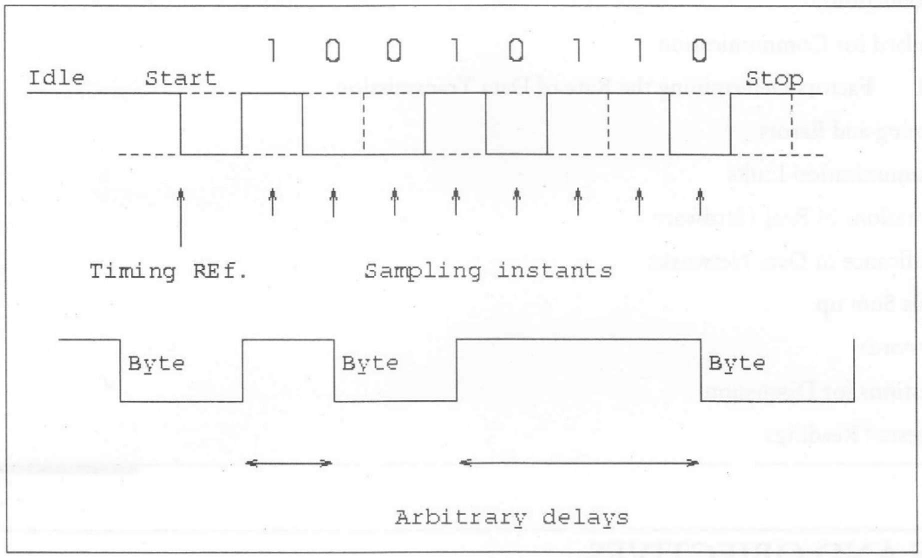
3.1 INTRODUCTION

Asynchronous: Small blocks of bits (generally bytes) are sent at a time without any time relation between consecutive bytes, when no transmission occurs a default state is maintained corresponding to bit 1. Due to arbitrary delay between consecutive bytes, the time occurrences of the clock pulses at the receiving end need to be synchronized for each byte. This is achieved by providing two extra bits start and stop.

Start Bit: It is prefixed to each byte and equals 0. Thus it ensures a transition from 1 to 0 at onset of transmission of byte. The leading edge of start bit is used as a reference for generating clock pulses at required sampling instants. Thus each onset of a byte results in resynchronization of receiver clock.

Stop Bit: To ensure that transition from 1 to 0 is always present at beginning of a byte it is necessary that default state be 1. But there may be two bytes one immediately following the other and if last bit of first byte is 0, transition from 1 to 0 will not occur. Therefore a stop bit is suffixed to each byte equaling 1. Its duration is usually 1,1.5,2 bits.

Asynchronous transmission is simple and cheap but requires an overhead of 3 bits i.e. for 7 bit code 2 (start, stop bits)+1 parity bit implying 30% overhead. However % can be reduced by sending larger blocks of data but then timing errors between receiver and sender cannot be tolerated beyond [50/no. of bits in block] % (assuming sampling is done at middle of bit interval). It will not only result in incorrect sampling but also misaligned bit count i.e. a data bit can be mistaken for stop bit if receiver's clock is faster.



3.2 STANDARD FOR COMMUNICATION

A network is connection of independent computers to communicate with one another over a shared network medium. The physical layer deals with transmission medium to transport information in the form of bits between different computers on the network. The Physical layer is responsible for communicating 0's and 1's across a medium by varying some sort of physical property such as voltage or current. This layer also ensures the reliable delivery of bits. It means that when sending side sends a 1 bit, it is received by the receiving side as a 1 bit, not as a 0 bit. Hence, it defines the electrical and mechanical aspects of interfacing to a physical medium for transmitting data, as well as setting up, maintaining, and disconnecting physical links. It is primarily concerned with moving bits from one node to next over the physical link. The issues concerning with the physical layer involve amplitude of the pulses to define 1 and 0 level, width of the pulse in microseconds, types and mode of communications, establishment and breaking of connections at the time of communications, types of connectors, etc.

It accepts data from the Data Link layer in bit streams for the subsequent transmission over the physical medium. At this layer, the mechanical (connector type), electrical (voltage levels), functional (ping assignments), and procedural (handshake) characteristics are defined. RS-232C/D is an example of a physical layer definition. The bit stream is represented as a function of time and can be analyzed mathematically. Analysis is required to know the physical characteristics of a signal as it travels across some physical media. Even, if there are some changes in the properties of the signal, how it can be reproduced in its original form so that the receiver receives it as sent by sender.

3.2.1 Factors Determining the Rate of Data Transmission

Baud Rate

The baud rate determines how fast the signal changes value or its amplitude. The baud rate is computed as the number of times per second the signal switches as it's transmitting a string of alternating 0's and 1's. A higher data rate can be achieved by switching the amplitude of the signal faster. The amplitude may be voltage. In digital notation, +5 Volt signifies 1 and - 5 Volt signifies 0. Baud rate is different from data rate. Channel characteristics are the major factors determining the rate of data transmission. A channel may be defined as a path between transmitter and receiver. This path may be logical or physical in nature. It may also be hard wired or wireless. The path provides a passage for the information or data from transmitter to receiver with certain amount of loss of information or data, which may be reproduced with other techniques. In some cases, the information may not be reproduced or the information may not reach at receiver at all. Such kinds of phenomenon may be very well understood from the following channel characteristic issues:

Channel Noise

It is a small amount of background interference presents on the channel or unwanted electrical or electromagnetic energy that carries no data or information but interferes with the information or data. Hence, noise degrades the quality of information and data by affecting files and communications of all types, including text, programs, images, audio, and telemetry. Here, information and data may be treated as signal in either electrical or electromagnetic form. If it is more than a threshold value, the data or information may not be reproduced at the receiver end. Therefore, this may be considered as the main source for transmission errors.

The noise may be classified as external or internal noise based upon the sources. External noise is generally picked up from electrical appliances in the vicinity, from electrical transformers, from the atmosphere, and even from outer space. Normally, this noise does not hamper the performance very seriously. However, if there are a number of electrical appliances are in use or heavy current machines, external noise can affect communications. It also makes impact on communication during severe thunderstorms. A remarkably good external noise slows down the data transfer rate. In a voice telephone conversation, noise rarely sounds like anything other than a faint hissing or rushing.

The external noise is generally in inverse proportional to the frequency and in direct proportional to the wavelength and therefore has a remarkable impact in wireless systems than in hard-wired systems. The noise generated because of electricity or atmospheric disturbances is of the order of 300 kHz that is quite lower than the high frequency range of 300 MHz and therefore may have more interference with the signal or information.

Noise generated inside channel or receivers, known as internal noise. Internal noise is less dependent on frequency but have a significant affect at higher frequency because external noise has less effecting at these frequencies. Minimizing the signal bandwidth may contain the internal noise but this will limit the maximum speed of the data that can be delivered. Internal noise is fairly low in case of digital signal processing, fiber optics technology.

Noise is measured in terms of the signal to noise ratio S/N or SNR with decibels (dB) as unit. Hence a low ratio implies that it is not worth paying attention to the medium in question. The signal to noise ratio is calculated as follows:

$$SNR = 20 \log_{10} (Signal/Noise) \text{ dB}$$

Channel Bandwidth

Channel bandwidth may be defined as the size of the range of frequencies that can be transmitted through a channel. In other words we may define it as the volume of information per unit time that a computer, person, or transmission medium can handle. It is measured in Hertz (Hz). Bandwidth is expressed as data speed in bits per second (bps) in digital systems while as the difference between highest frequency to lowest frequency in analog system. Bandwidth determines how fast data flows on a given transmission path. It is determined as the amount of data transmitted or received per unit time. As it has already been explained in noise that low bandwidth signal produces less internal noise compared to high bandwidth signal therefore these are preferred. However in this case, we have to sacrifice data transmission speed. Therefore, a trade-off is required to be determined based on the performance requirements.

Bandwidth is affected by the type and physical characteristics of media used, amount of noise present in transmission channel and data encoding method used.

Transmission of Bits (Bit Rate)

Channel data transmission rate is determined by the maximum number of bits that can be transmitted per unit time through the physical medium. It is measured in bits per second (bps). H Nyquist gave the maximum data rate of a noiseless channel in 1924. Further, C Shannon extended the work of H Nyquist and proposed a data rate for random noise.

Nyquist stated that if an arbitrary signal has been run through a low pass filter of bandwidth H, the filtered signal can be reconstructed by sampling the signal twice the frequency of the signal. Mathematically,

$$\text{Maximum data rate} = 2H \log_2 W/\text{second}$$

where W represents the number of discrete levels in the signal

Shannon's Theorem

The above is a case of a noiseless channel. If random (internal) noise is present the situation deteriorates rapidly. As we have already explained that SNR is given by a quantity $10 \log_{10} S/N$ dB.

Shannon's theorem computes the maximum data rate for channels having noise. All real channels have certain amount of noise. According to Shannon's theorem, the maximum data rate of a noisy channel of bandwidth H, signal-to-noise ratio of S/N is given by:

$$\text{Maximum data rate} = H \log_2 (1 + S/N)$$

Channel Capacity

It is the amount of information per unit time handled by either a link or a node (system, element). The messages transmitted may be either similar or different. It is usually measured in bits per second.

Transmission Time

It is the time required transmitting a message through the channel. It is the size of the message in bits divided by the data rate in bits per second (bps) of the channel over which the transmission takes place. It is also given as the packet length divided by the channel capacity.

Propagation Time (Channel Latency)

The amount of time needed for information to propagate from source to destination through the channel. It is the distance divided by the signal propagation speed (usually the speed of light). Channel latency depends on media characteristics, signal propagation speed, and transmission distance.

Throughput

Throughput may be defined as the number of bits, characters, or blocks passing through a data communication system over a period of time.

Throughput = Packet length in bits/Transmission time + Propagation time

Channel Utilization

Channel utilization is nothing but the fraction of the channel's data rate actually used to transmit data. From the throughput it is observed that the propagation time and transmission time are two different parameters which are respectively depended upon the path length and packet length (number of bits in a message).

Hence,

Channel Utilization = a/1+a

Where a is given as the ratio of propagation time and transmission time and is known as bit length.

We may now consider an example to understand the above concepts. Suppose a channel data transmission rate as 10Mbps and time taken by one bit to transmit through channel as 10^{-7} seconds. The signal propagation speed in the medium is 2x 10^{8}m/s.

The transmission rate is 1bit/10^{-7} seconds that is equal to 10^{7} bit per second (bps).

Therefore bit length will be equal to 2x 10^{8}m/s/10^{7} bps which is equal to 20 meters.

3.3 FRAMING AND ERRORS

The Data Link Layer is the second layer in the OSI model, above the Physical Layer, which ensures that the error free data is transferred between the adjacent nodes in the network. It breaks the datagrams passed down by above layers and convert them into frames ready for transfer. This is called Framing. It provides two main functionalities

1. Reliable data transfer service between two peer network layers
2. Flow Control mechanism which regulates the flow of frames such that data congestion is not there at slow receivers due to fast senders.

Framing and errors have been discussed in detail in lesson 5.

3.4 COMMUNICATION LINKS

In a network nodes are connected through links. The communication through links can be classified as:

- *Simplex:* Communication can take place only in one direction. For example T.V broadcasting.
- *Half duplex:* Communication can take place in one direction at a time. Suppose node A and B are connected then half-duplex communication means that at a time data can flow from A to B or from B to A but not simultaneously. For example two persons talking to each other such that when speaks the other listens and vice versa.
- *Full duplex:* Communication can take place simultaneously in both directions. For example, a discussion in a group without discipline.

Links can be further classified as:

- *Point to Point:* In this communication only two nodes are connected to each other. When a node sends a packet then it can be received only by the node on the other side and none else.
- *Multipoint:* It is a kind of sharing communication, in which signal, can be received by all nodes. This is also called broadcast.

Generally two kinds of problems are associated in transmission of signals.

- *Attenuation:* When a signal transmits in a network then the quality of signal degrades as the signal travels longer distances in the wire. This is called attenuation. To improve quality of signal amplifiers are used at regular distances.
- *Noise:* In a communication channel many signals transmits simultaneously, certain random signals are also present in the medium. Due to interference of these signals our signal gets disrupted a bit.

3.5 LIMITATIONS OF REAL HARDWARE

1. Longer wire and its external interference may make signal look even worse.
2. RS-232 standard specifies how precise a waveform the transmitter must generate, and how tolerant the receiver must be of imprecise waveform.

3.6 SIGNIFICANCE OF DATA NETWORKS

A network is connection of independent computers to communicate with one another over a shared network medium. A network may be consisted of two or more computers. In other words, computer networks are collections of computers, software and hardware, which are connected to share resources together. A network connects computers using transmission media either in the forms of cables or wireless, specialized software and devices that manage data traffic. It enables to share files and resources, such as printers and send messages electronically to each other. Thus, the term computer network applies to the exchange of information among computers of individuals, groups or institutions and helps in processing of electronic voice or data communications.

Computer Networks have rapidly become an integral part of human life and in many cases, computer networks are considered as the solution to every problem not only within business but also in day-to-day life. The main purpose of computer networks is to enable people to exchange data and information over email, LAN, Intranet or Extranet etc. At the basic level, computer networks share resources, such as printers and storage space.

Some uses of computer networks have been discussed in lesson 1.

Check Your Progress

1. How data transmission is determined by bit rate?
2. What is Full-Duplex?

3.7 LET US SUM UP

There are several kinds of bounded transmission media. These media technologies starting from copper wire to fiber optic has grownup so rapidly and replacing other very quickly in this information age. Transmission media describes the data path forming the physical channel between the sender and the receiver. Transmission media may be twisted pair, coaxial cable, fiber optics etc.

Selection of media depends on several factors including data rates, range, noise absorption, radiation, attenuation, bandwidth, error performance etc. Noise absorption of different transmission media defines the susceptibility of the media to external causes that tends to distort the data signal and thus introduces data errors. Radiation is the leakages of data signal from the transmission media due to the undesirable characteristics of the transmission media. Attenuation that degrades the signal strength as the signal travels over the transmission media is the outcome of the radiation and the physical characteristics of the media. Attenuation limits the distance to which a signal with enough information and less noise is received. Bandwidth indicates the data rate of the signal over transmission media. If the bandwidth higher, the data rate would be higher.

3.8 KEYWORDS

Bandwidth: It is defined as the size of the range of frequencies that can be transmitted through a channel.

Channel Utilization: Channel utilization is nothing but the fraction of the channel's data rate actually used to transmit data.

Fourier Analysis: It is carried over to analyze the signal traveling over the transmission media.

Noise: It is a small amount of background interference presents on the channel or unwanted electrical or electromagnetic energy that carries no data or information but interferes with the information or data.

Propagation Time (Channel Latency): The amount of time needed for information to propagate from source to destination through the channel.

Throughput: is defined as the number of bits, characters, or blocks passing through a data communication system over a period of time.

3.9 QUESTIONS FOR DISCUSSION

1. What is asynchronous communication? Discuss start bit and stop bit.
2. Discuss the needs and standards for communication.
3. How is Fourier analysis used to analyze the signal traveling over the transmission media?
4. Discuss the Factors Determining the Rate of Data Transmission.
5. What is full-duplex? Discuss its classification.
6. What is framing? Discuss the process of transferring error free data in the network.
7. How is Data Transmission determined through bit rate?
8. What is baud-rate?

Check Your Progress: Model Answers

1. Channel data transmission rate is determined by the maximum number of bits that can be transmitted per unit time through the physical medium. It is measured in bits per second (bps).
2. Communication can take place simultaneously in both directions in full deuplex.

3.10 SUGGESTED READINGS

Anuranjan Misra, *Computer Networks*, Acme Learning Pvt Ltd.

Rajneesh Agrawal and Bhata Bhushan Tiwari, *Computer Networks and Internet*, Vikas Publication.

Burton, Bill, *Remote Access for Cisco Networks*, McGraw-Hill, Osborne Media.

Behrouz A. Forouzan and Sophia Chung Fegan, *Data Communications and Networking*, McGraw-Hill Companies.

Andrew S. Tanenbaum, *Computer Networks*, Prentice Hall.

LESSON

4

LONG DISTANCE COMMUNICATION

CONTENTS

4.0 AIMS AND OBJECTIVES

After studying this lesson, you will be able to:

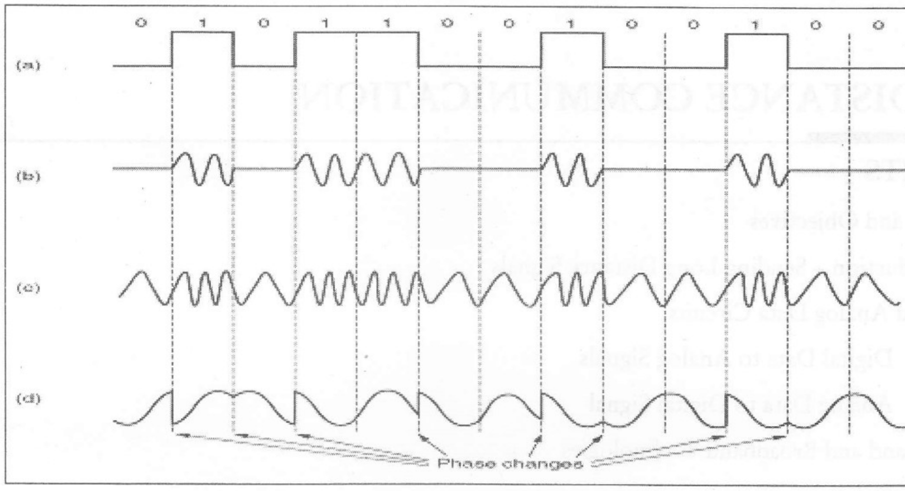
- Understand the concept of sending long distance signals
- Understand spread spectrum
- Discuss leased analog digital circuit concept
- Understand baseband and broadband technologies
- Discuss multiplexing and its types

4.1 INTRODUCTION – SENDING LONG DISTANCE SIGNALS

To transmit signals over the local loop, a continuous tone in the 1000 to 2000 Hz range is used, called a **sine wave carrier**. There are three ways of modulating it (to transmit information):

1. *Amplitude modulation:* Two different voltage levels are used to represent 0 and 1, respectively.

2. ***Frequency modulation:*** Two (or more) different tones are used.
3. ***Phase modulation:*** The carrier wave is systematically shifted certain degrees at uniformly spaced intervals.



A **modem** (modulator-demodulator) is a device which accepts a serial stream of bits as input and produces a modulated signal as output (or vice versa). It is inserted between the digit computer and the analog telephone system.

Most advanced modems use a combination of modulation techniques to transmit multiple bits per baud. Over a standard 2400-baud line, a modem can run at the following speeds:

- 9600 bps (a V.32 modem) by transmitting 4 bits per baud.
- 14,400 bps (a V.32 bis modem) by transmitting 6 bits per baud.
- 28,800 bps (a V.34 modem) by transmitting 12 bits per baud.

Many modems now have compression (e.g., run-length encoding) and error correction built into the modems to improve the effective data rate without requiring any changes to existing software.

RS-232-C and RS-449

The interface between the computer (or terminal) and the modem is an example of a physical layer protocol.

The RS-232-C (or V.24) Standard

- ***Mechanical specification:*** the sizes and numbering of the 25 pin connector.
- ***Electrical specification:*** 1: -3 volts. 0: +4. Data rates: 20 kbps. Cable length: 15 meters.
- ***Functional specification:*** which circuits are connected to which pins.
- ***Procedure specification:*** the legal sequence of events (protocol). Based on action-reaction pairs.
- Two computers are connected using RS-232-C but with a null modem, which connects the transmit line of one machine to the receive line of the other.

RS-449

It is a new standard which was introduced to overcome the limitations of the RS-232-C standard, e.g., data rates up to 2 Mbps over 60 meter cables.

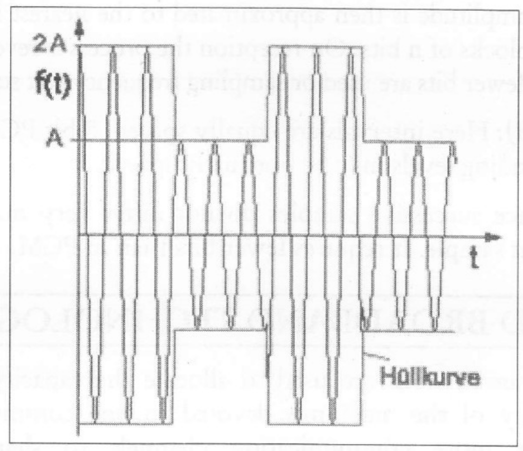
4.2 LEASED ANALOG DATA CIRCUITS

One of the major concern of the physical layer lies in moving data in the form of electromagnetic signals across a transmission medium. To be transmitted, data mustbe transformed to electromagnetic signals.

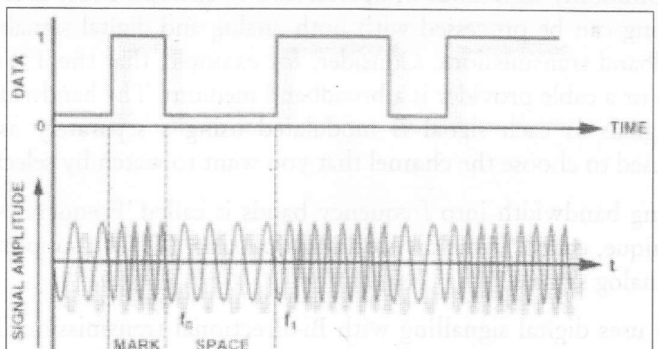
4.2.1 Digital Data to Analog Signals

A modem (modulator-demodulator) converts digital data to analog signal. There are three ways to modulate a digital signal on an analog carrier signal.

- *Amplitude Shift Keying (ASK):* is a form of modulation, which represents digital data as variations in the amplitude of a carrier wave. Two different amplitudes of carrier frequency represent '0' , '1'.



- *Frequency Shift Keying (FSK):* In Frequency Shift Keying, the change in frequency defines different digits. Two different frequencies near carrier frequency represent '0' ,''1'.



- *Phase Shift Keying (PSK):* The phase of the carrier is discretely varied in relation either to a reference phase or to the phase of the immediately preceding signal element, in accordance with data being transmitted. Phase of carrier signal is shifted to represent '0' , '1'.