Module 1

Introduction

Lesson 1

Introduction and Course Outline

Specific Instructional Objective

On Completion of this lesson, the students will be able to:

- Define Computer Networks
- State the evolution of Computer Networks
- Categorize different types of Computer Networks
- Specify some of the application of Computer Networks

1.1.1 Introduction

The concept of Network is not new. In simple terms it means an interconnected set of some objects. For decades we are familiar with the Radio, Television, railway, Highway, Bank and other types of networks. In recent years, the network that is making significant impact in our day-to-day life is the **Computer network**. By computer network we mean an interconnected set of autonomous computers. The term autonomous implies that the computers can function independent of others. However, these computers can exchange information with each other through the communication network system. Computer networks have emerged as a result of the convergence of two technologies of this century- Computer and Communication as shown in Fig. 1.1.1. The consequence of this revolutionary merger is the emergence of a integrated system that transmit all types of data and information. There is no fundamental difference between data communications and data processing and there are no fundamental differences among data, voice and video communications. After a brief historical background in Section 1.1.2, Section 1.1.2 introduces different network categories. A brief overview of the applications of computer networks is presented in Section 1.1.3. Finally an outline of the entire course is given in Section 1.1.4.

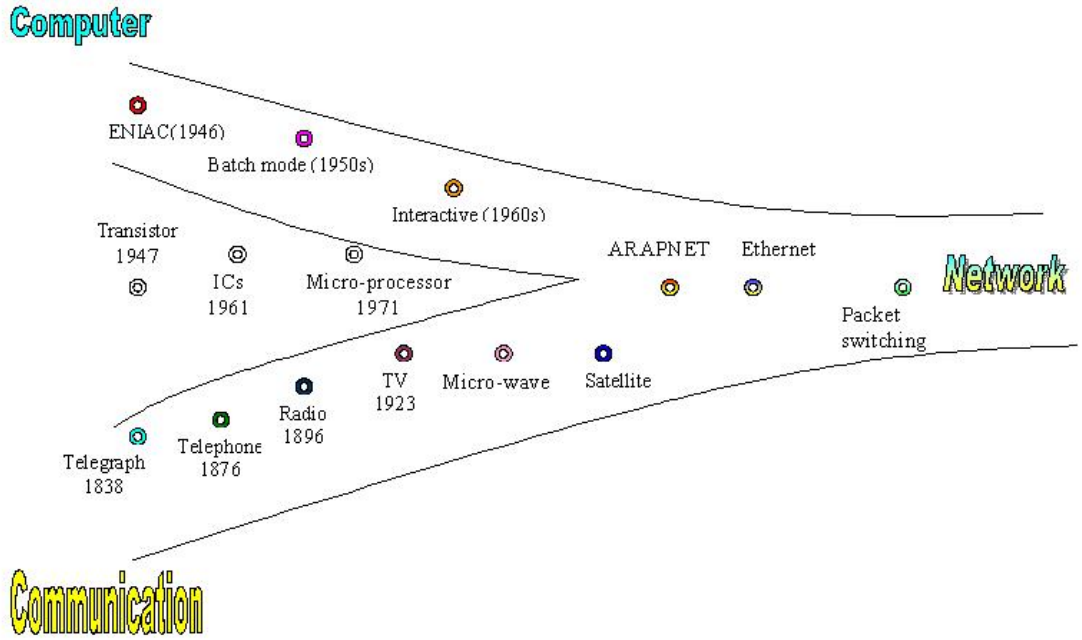

Figure 1.1.1 *Evolution of computer networks*

1.1.2 Historical Background

The history of electronic computers is not very old. It came into existence in the early 1950s and during the first two decades of its existence it remained as a centralized system housed in a single large room. In those days the computers were large in size and were operated by trained personnel. To the users it was a remote and mysterious object having no direct communication with the users. Jobs were submitted in the form of punched cards or paper tape and outputs were collected in the form of computer printouts. The submitted jobs were executed by the computer one after the other, which is referred to as batch mode of data processing. In this scenario, there was long delay between the submission of jobs and receipt of the results.

In the 1960s, computer systems were still centralize, but users provided with direct access through interactive terminals connected by point-to-point low-speed data links with the computer. In this situation, a large number of users, some of them located in remote locations could simultaneously access the centralized computer in time-division multiplexed mode. The users could now get immediate interactive feedback from the computer and correct errors immediately. Following the introduction of on-line terminals and time-sharing operating systems, remote terminals were used to use the central computer.

With the advancement of VLSI technology, and particularly, after the invention of microprocessors in the early 1970s, the computers became smaller in size and less expensive, but with significant increase in processing power. New breed of low-cost computers known as mini and personal computers were introduced. Instead of having a single central computer, an organization could now afford to own a number of computers located in different departments and sections.

Side-by-side, riding on the same VLSI technology the communication technology also advanced leading to the worldwide deployment of telephone network, developed primarily for voice communication. An organization having computers located geographically dispersed locations wanted to have data communications for diverse applications. Communication was required among the machines of the same kind for collaboration, for the use of common software or data or for sharing of some costly resources. This led to the development of computer networks by successful integration and cross-fertilization of communications and geographically dispersed computing facilities. One significant development was the APPANET (Advanced Research Projects Agency Network). Starting with four-node experimental network in 1969, it has subsequently grown into a network several thousand computers spanning half of the globe, from Hawaii to Sweden. Most of the present-day concepts such as packet switching evolved from the ARPANET project. The low bandwidth (3KHz on a voice grade line) telephone network was the only generally available communication system available for this type of network.

The bandwidth was clearly a problem, and in the late 1970s and early 80s another new communication technique known as Local Area Networks (LANs) evolved, which helped computers to communicate at high speed over a small geographical area. In the later years use of optical fiber and satellite communication allowed high-speed data communications over long distances.

1.1.3 Network Technologies

There is no generally accepted taxonomy into which all computer networks fit, but two dimensions stand out as important: **Transmission Technology** and **Scale**. The classifications based on these two basic approaches are considered in this section.

1.1.3.1 Classification Based on Transmission Technology

Computer networks can be broadly categorized into two types based on transmission technologies:

- Broadcast networks
- Point-to-point networks

1.2.3.1.1 Broadcast Networks

Broadcast network have a single communication channel that is shared by all the machines on the network as shown in Figs.1.1.2 and 1.1.3. All the machines on the network receive short messages, called packets in certain contexts, sent by any machine. An address field within the packet specifies the intended recipient. Upon receiving a packet, machine checks the address field. If packet is intended for itself, it processes the packet; if packet is not intended for itself it is simply ignored.

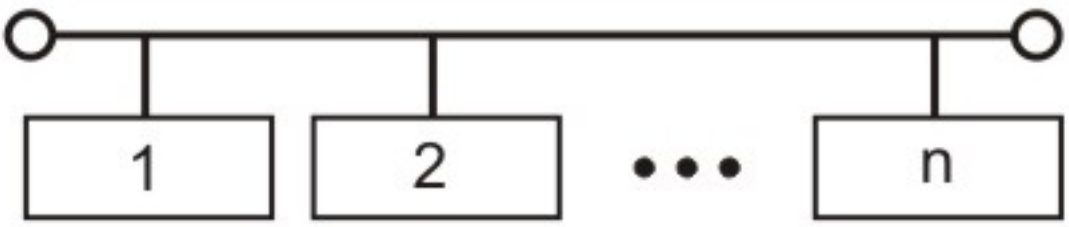

Figure 1.1.2 *Example of a broadcast network based on shared bus*

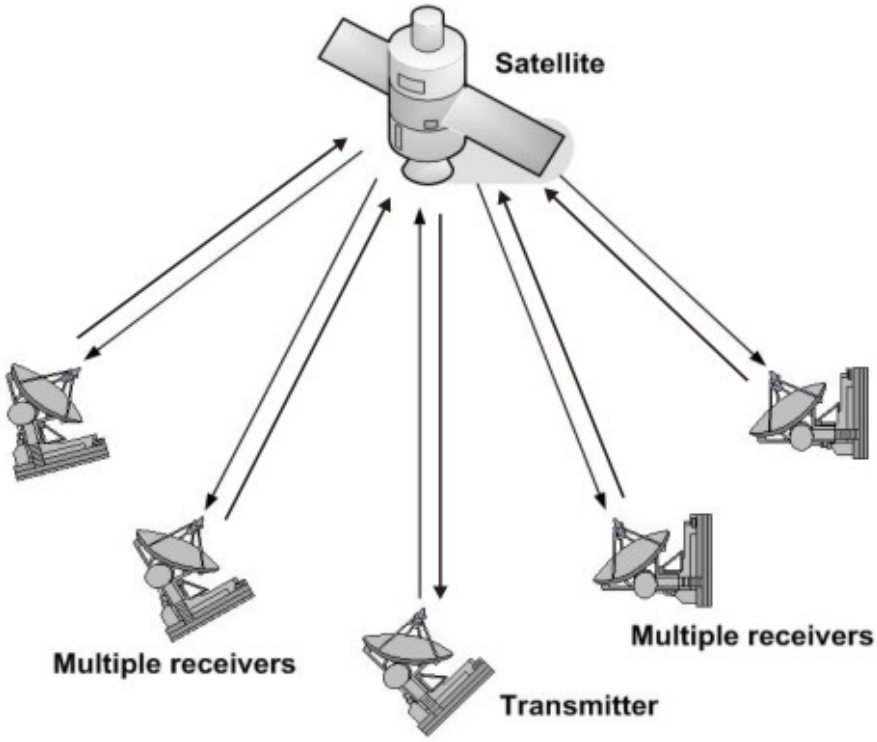

Figure 1.1.3 *Example of a broadcast network based on satellite communication*

This system generally also allows possibility of addressing the packet to all destinations (all nodes on the network). When such a packet is transmitted and received by all the machines on the network. This mode of operation is known as *Broadcast Mode*. Some Broadcast systems also supports transmission to a sub-set of machines, something known as *Multicasting*.

1.2.3.1.2 Point-to-Point Networks

A network based on point-to-point communication is shown in Fig. 1.1.4. The end devices that wish to communicate are called *stations*. The switching devices are called *nodes*. Some Nodes connect to other nodes and some to attached stations. It uses FDM or TDM for node-to-node communication. There may exist multiple paths between a source-destination pair for better network reliability. The switching nodes are not concerned with the contents of data. Their purpose is to provide a switching facility that will move data from node to node until they reach the destination.

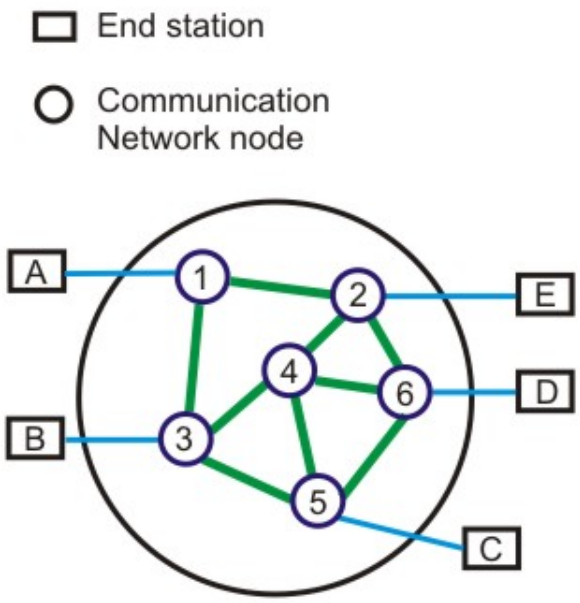

Figure 1.1.4 *Communication network based on point-to-point communication*

As a general rule (although there are many exceptions), smaller, geographically localized networks tend to use broadcasting, whereas larger networks normally use are point-to-point communication.

1.1.3.2 Classification based on Scale

Alternative criteria for classifying networks are their scale. They are divided into Local Area (LAN), Metropolitan Area Network (MAN) and Wide Area Networks (WAN).

1.1.3.2.1 Local Area Network (LAN)

LAN is usually privately owned and links the devices in a single office, building or campus of up to few kilometers in size. These are used to share resources (may be hardware or software resources) and to exchange information. LANs are distinguished from other kinds of networks by three categories: their size, transmission technology and topology.

LANs are restricted in size, which means that their worst-case transmission time is bounded and known in advance. Hence this is more reliable as compared to MAN and WAN. Knowing this bound makes it possible to use certain kinds of design that would not otherwise be possible. It also simplifies network management.

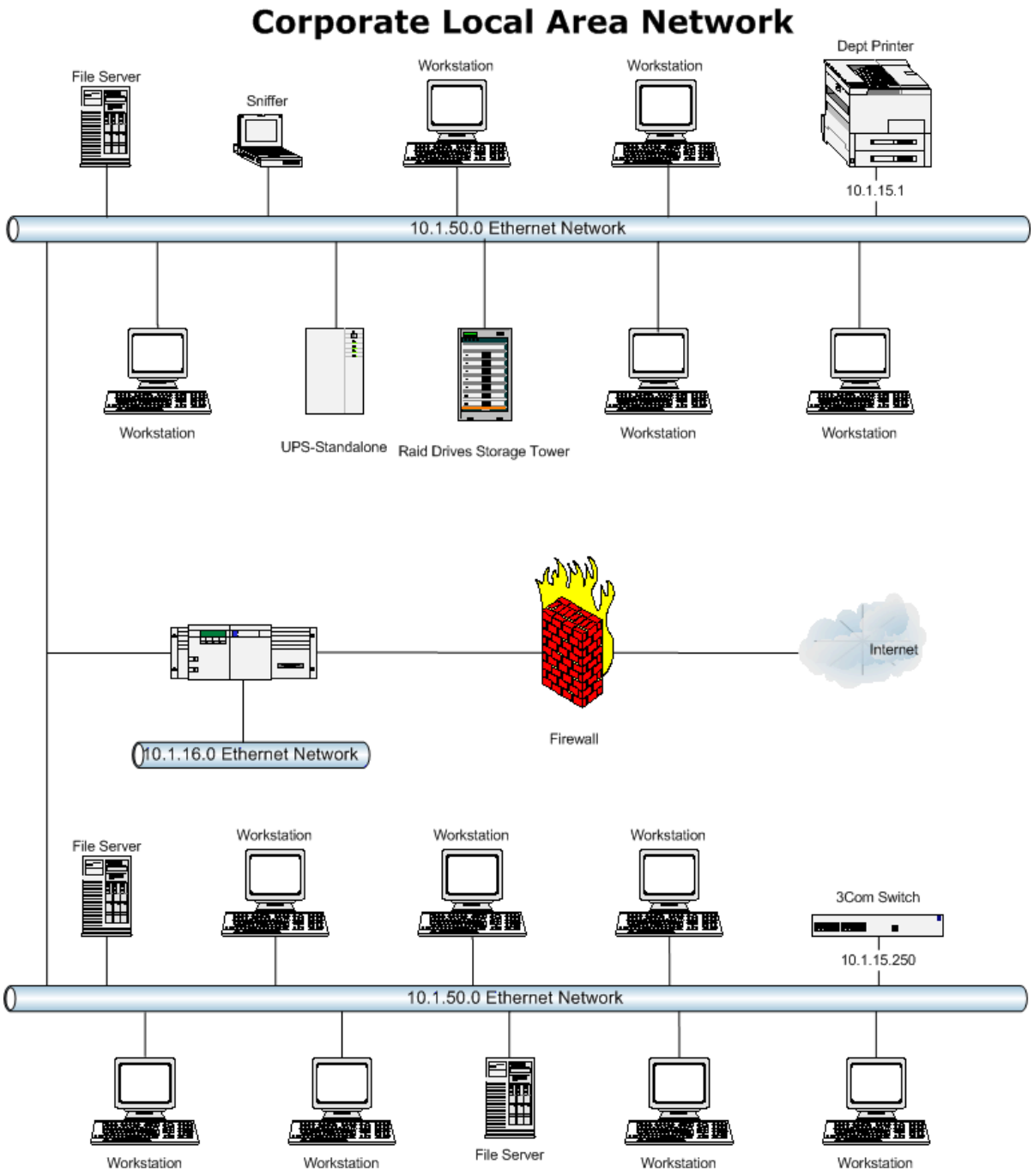

Figure 1.1.5 Local Area Network

LAN typically used transmission technology consisting of single cable to which all machines are connected. Traditional LANs run at speeds of 10 to 100 Mbps (but now much higher speeds can be achieved). The most common LAN topologies are bus, ring and star. A typical LAN is shown in Fig. 1.1.5.

1.1.3.2.2 Metropolitan Area Networks (MAN)

MAN is designed to extend over the entire city. It may be a single network as a cable TV network or it may be means of connecting a number of LANs into a larger network so that resources may be shared as shown in Fig. 1.1.6. For example, a company can use a MAN to connect the LANs in all its offices in a city. MAN is wholly owned and operated by a private company or may be a service provided by a public company.

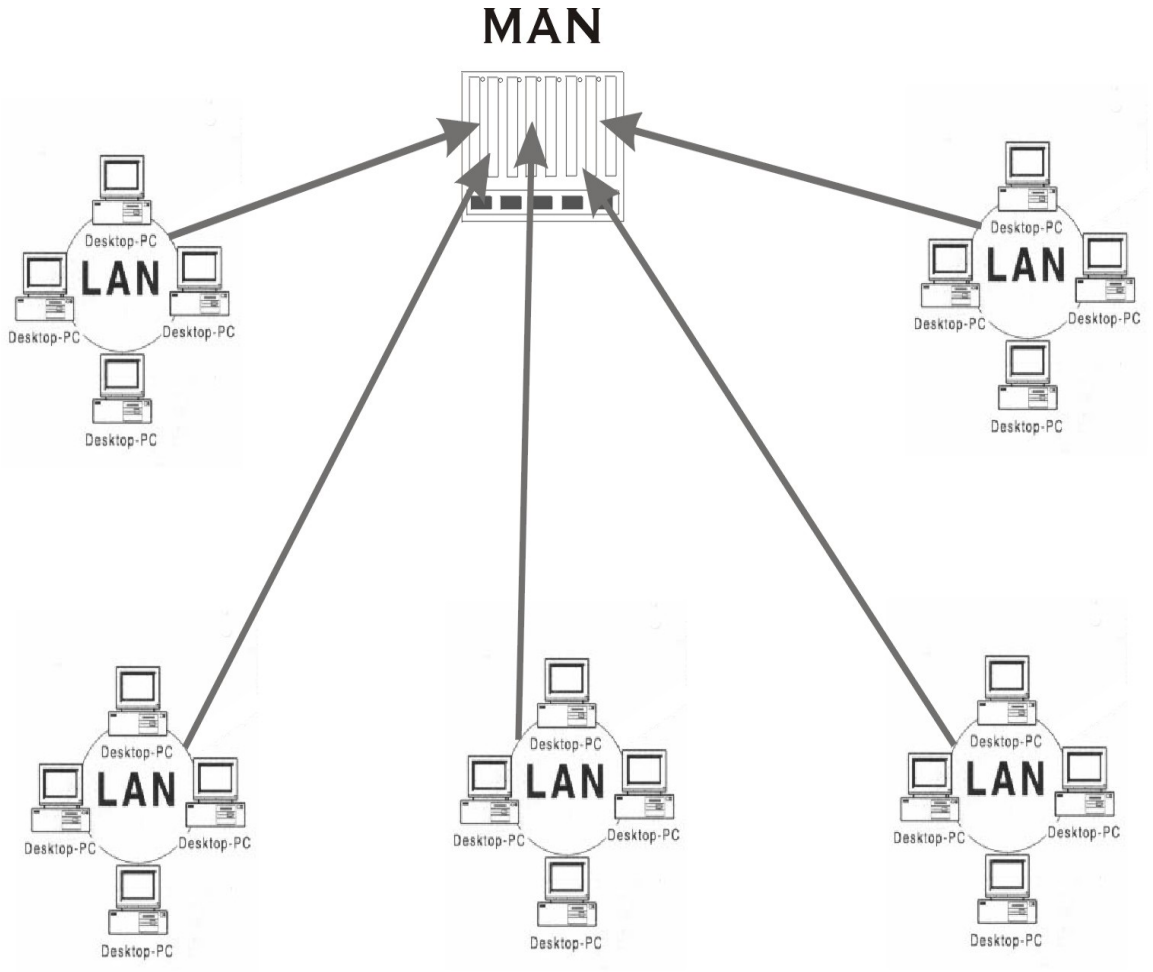

Figure 1.1.6 Metropolitan Area Networks (MAN)

The main reason for distinguishing MANs as a special category is that a standard has been adopted for them. It is **DQDB** (Distributed Queue Dual Bus) or IEEE 802.6.

1.1.3.2.3 Wide Area Network (WAN)

WAN provides long-distance transmission of data, voice, image and information over large geographical areas that may comprise a country, continent or even the whole world. In contrast to LANs, WANs may utilize public, leased or private communication devices, usually in combinations, and can therefore span an unlimited number of miles as shown

in Fig. 1.1.7. A WAN that is wholly owned and used by a single company is often referred to as *enterprise network.*

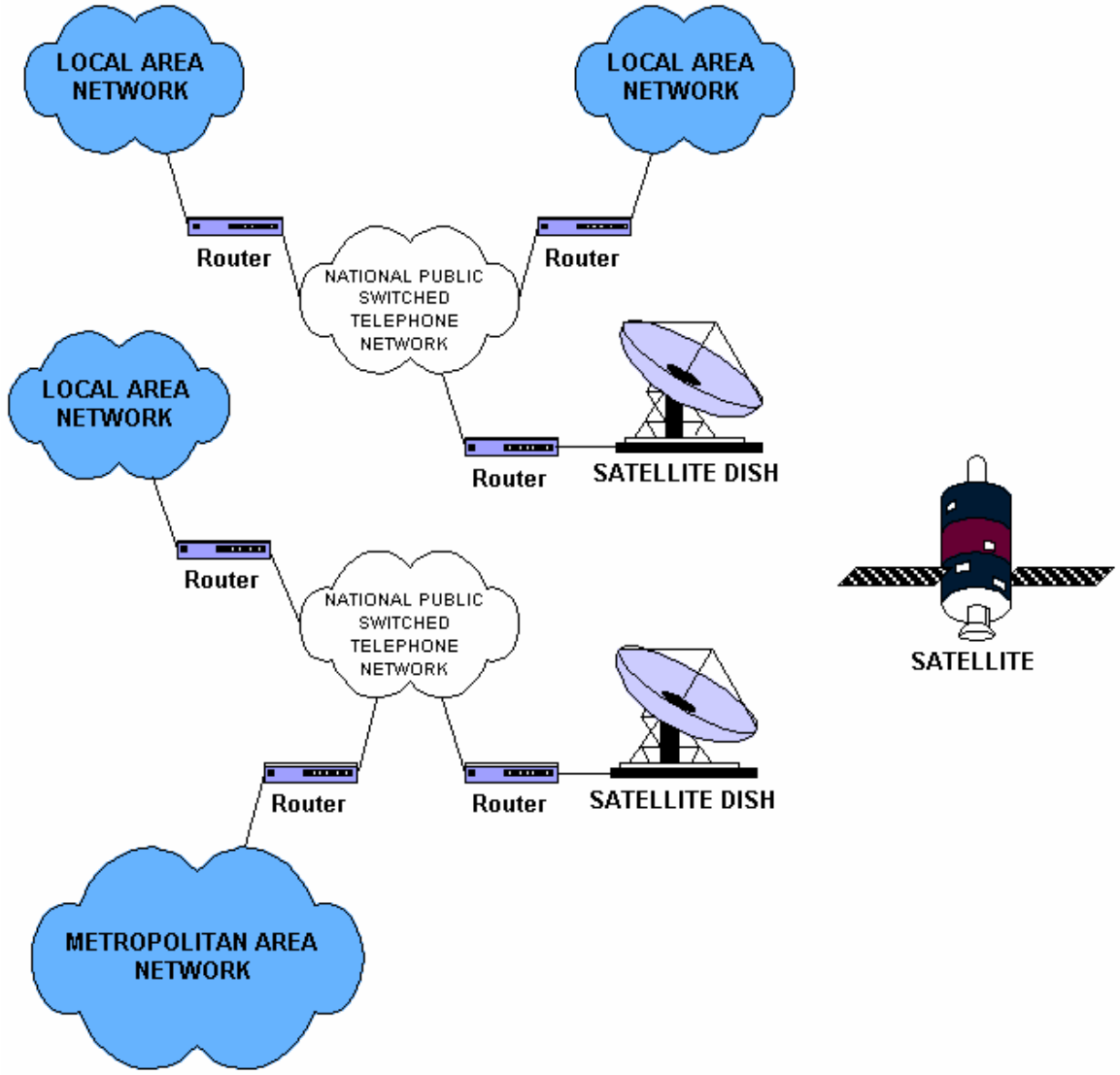

Figure 1.1.7 *Wide Area Network*

1.1.3.2.4 The Internet

Internet is a collection of networks or network of networks. Various networks such as LAN and WAN connected through suitable hardware and software to work in a seamless manner. Schematic diagram of the Internet is shown in Fig. 1.1.8. It allows various applications such as e-mail, file transfer, remote log-in, World Wide Web, Multimedia, etc run across the internet. The basic difference between WAN and Internet is that WAN is owned by a single organization while internet is not so. But with the time the line between WAN and Internet is shrinking, and these terms are sometimes used interchangeably.

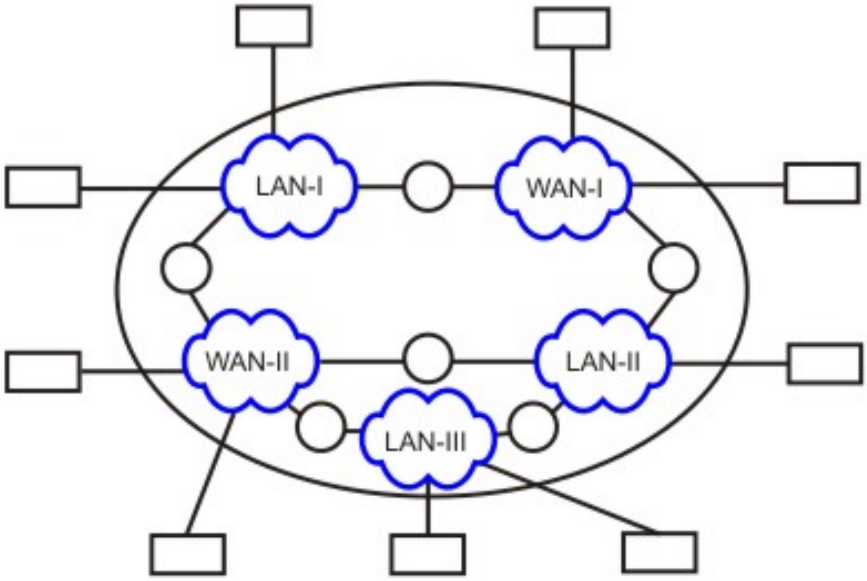

Figure 1.1.8 *Internet – network of networks*

1.1.4 Applications

In a short period of time computer networks have become an indispensable part of business, industry, entertainment as well as a common-man's life. These applications have changed tremendously from time and the motivation for building these networks are all essentially economic and technological.

Initially, computer network was developed for defense purpose, to have a secure communication network that can even withstand a nuclear attack. After a decade or so, companies, in various fields, started using computer networks for keeping track of inventories, monitor productivity, communication between their different branch offices located at different locations. For example, Railways started using computer networks by connecting their nationwide reservation counters to provide the facility of reservation and enquiry from any where across the country.

And now after almost two decades, computer networks have entered a new dimension; they are now an integral part of the society and people. In 1990s, computer network started delivering services to private individuals at home. These services and motivation for using them are quite different. Some of the services are access to remote information, person-person communication, and interactive entertainment. So, some of the applications of computer networks that we can see around us today are as follows:

Marketing and sales: Computer networks are used extensively in both marketing and sales organizations. Marketing professionals use them to collect, exchange, and analyze data related to customer needs and product development cycles. Sales application

includes teleshopping, which uses order-entry computers or telephones connected to order processing network, and online-reservation services for hotels, airlines and so on.

Financial services: Today's financial services are totally depended on computer networks. Application includes credit history searches, foreign exchange and investment services, and electronic fund transfer, which allow user to transfer money without going into a bank (an automated teller machine is an example of electronic fund transfer, automatic pay-check is another).

Manufacturing: Computer networks are used in many aspects of manufacturing including manufacturing process itself. Two of them that use network to provide essential services are computer-aided design (CAD) and computer-assisted manufacturing (CAM), both of which allow multiple users to work on a project simultaneously.

Directory services: Directory services allow list of files to be stored in central location to speed worldwide search operations.

Information services: A Network information service includes bulletin boards and data banks. A World Wide Web site offering technical specification for a new product is an information service.

Electronic data interchange (EDI): EDI allows business information, including documents such as purchase orders and invoices, to be transferred without using paper.

Electronic mail: probably it's the most widely used computer network application.

Teleconferencing: Teleconferencing allows conference to occur without the participants being in the same place. Applications include simple text conferencing (where participants communicate through their normal keyboards and monitor) and video conferencing where participants can even see as well as talk to other fellow participants. Different types of equipments are used for video conferencing depending on what quality of the motion you want to capture (whether you want just to see the face of other fellow participants or do you want to see the exact facial expression).

Voice over IP: Computer networks are also used to provide voice communication. This kind of voice communication is pretty cheap as compared to the normal telephonic conversation.

Video on demand: Future services provided by the cable television networks may include video on request where a person can request for a particular movie or any clip at anytime he wish to see.

Summary: The main area of applications can be broadly classified into following categories:

Scientific and Technical Computing

- Client Server Model, Distributed Processing

Parallel Processing, Communication Media

Commercial

- Advertisement, Telemarketing, Teleconferencing
- Worldwide Financial Services
-

Network for the People (this is the most widely used application nowadays)

- Telemedicine, Distance Education, Access to Remote Information, Person-to-Person Communication, Interactive Entertainment

1.1.5 Course Outline

Over the years the subject of computer networks has grown with advancement of technology and the emergence of new technologies and new applications. In this course, this massive subject has been divided into comprehensible parts and arranged in a structured and logical manner. It is organized in the following eight modules:

- Introduction
- Data Communication Fundamentals
- Data Link Control
- Switched Communication Networks
- Broadcast Communication Networks
- Internetworking
- Routing and Congestion Control
- Network Security

Module 1: Introduction

In this module some of the basic aspects of computer networks are presented in two lessons. In lesson 1.1 the historical background of computer networks is presented. Then different type of networks and their classification on the basis of transmission technology and scale are considered. In the next section important applications of computer networks, which spans over different areas in a common man life are discussed.

Lesson 1.2 presents the important concepts of layering. The basic terminologies in the context of layered architecture are also covered in this section. Then this lesson provides an introduction of OSI layered architecture - Open System Interconnection Reference Model. Basic functionalities of different layers of OSI and concept of service access points and information exchange will also be dealt in this lesson.

Module 2: Data Communication Fundamentals

This module is concerned with some of the important issues of the physical layer, which provides services to the layer above it, namely the data link layer. In the data link layer, the data consists of 0s and 1s, which are organized into frames to be sent through some transmission media. It is necessary to convert this data into another entity called signal.

After introducing the fundamental model of communication, Lesson 2.1 introduces the basic elements of communication such as data, signal and channel characteristics. Different data types, concept of time domain and frequency domain representation of signal, various channel characteristics such as bandwidth, bit interval and bit rate of a digital signal are considered in this section.

Lesson 2.2 introduces different transmission media, which are broadly divided into two categories, namely guided and unguided media. Typical characteristics and uses of each type of media starting from twisted-pair cables, coaxial cable, and optical fiber to line-of-sight and satellite communication have been covered in this lesson.

Lesson 2.3 will introduce various sources of impairments, such as attenuation, distortion and noise, that a signal suffers as it passes through a communication media. This lesson also will introduce the concept of channel capacity, which specifies the amount of information that can be sent through a medium.

Lesson 2.4 deals with the transmission of digital signals, which involves encoding of data. Encoding of digital data involves two types of coding namely line coding and block coding. Various line coding techniques such as unipolar, polar, and bipolar and block coding techniques are presented in this lesson. Encoding of analog data involves conversion to digital form by using techniques like pulse code modulation and delta modulation, which are also discussed in this lesson.

Transmission of analog signals is discussed in Lesson 2.5. It is necessary to perform modulation to convert analog data to analog signal. Various aspects of the three possible modulation techniques, namely amplitude, phase and frequency have been discussed in this lesson. Similarly, to convert digital data to analog signal, possible approaches such as amplitude, phase and frequency shift keying have been covered in lesson 2.6.

Lesson 2.7 deals with various multiplexing techniques such as Frequency division multiplexing (FDM), time division multiplexing (TDM), Statistical TDM, Wave Division multiplexing (WDM) and Orthogonal Frequency Division Multiplexing (OFDM).

So, this module provides necessary background to the students for understanding the topics to be covered in the subsequent lessons dealing with different aspects of computer networks.

Module 3: Data Link Control

In this module we shall discuss various aspects of data link control has been considered. Lesson 3.1 deals with framing and synchronization along with how one can interface the machine to the media. Error detection and error correction techniques are presented in Lesson 3.2. Lesson 3.3 introduces various protocols used for flow control and error control. Finally, lesson 3.4 provides an overview of HDLC, the most popular data link control protocol.

Module 4: Switched Communication Networks

In this module switched communication networks has been considered. First, various **switching** techniques have been presented in Lesson 4.1. In this lesson various aspects of circuit switching and the operation of Public Switched Telephone Network (PSTN), which is based on circuit switching, have been discussed. Various aspects of message switching, packet switching and virtual circuit switching have been addressed in Lesson 4.2.

Lesson 4.3 presents the Synchronous Optical Network (SONET) that defines a technology for carrying many signals of different capacities through a synchronous, flexible, optical hierarchy. It utilizes the enormous bandwidth of optical fiber to achieve date transfer at a very high rate.

X.25 is a packet-switched network developed by ITU-T in 1976. It defines how a packet-mode terminal can be interfaced to a packet network for data communication. However, X.25 does not satisfy the present day requirements of higher data rate. To overcome these limitations, a new standard, known as **frame relay** was introduced. Lesson 4.4 introduces these two packet switching networks.

In the last section of this module, **ATM** (Asynchronous transfer mode), which can be used both as a LAN or WAN standard has been introduced. Various network devices used in ATM, concept of cell transfer and cell format have been discussed.

Module 5: Broadcast Communication Networks

In Broadcast networks, one transmission media is shared by all the users and information is broadcast by an user into the medium. Some examples of broadcast communication networks are:

1. Local area network (LAN)
2. Packet radio network
3. Cellular telephone network
4. Satellite Network

These networks can be characterized by the following three parameters:

- Transmission media
- Topology
- Medium Access control (MAC) Techniques

Characteristics of different transmission media have been covered in Lesson 2.2. Topology and its interrelationship with the transmission media will be considered in Lesson 5.1. In Lesson 5.2 we shall discuss different MAC techniques and the abovementioned networks have been discussed in the remaining six lessons of this module.

Module 6: Internetworking

To make the computer networks more useful and suitable for many emerging applications, it is necessary to connect individual heterogeneous networks, both LAN and WAN, distributed across the world using suitable hardware and software in such a way that it gives the user the illusion of a single network. Basic motivations behind internetworking are as follows:

- To provide a link between networks.
- To provide a route for delivery of data between processes on different networks.
- To provide an accounting service that keeps track of the use of various networks and routers and also to maintain status information.
- To accommodate a number of differences among the networks:
    - Addressing scheme
    - Maximum packet size
    - Network-access mechanism
    - Timeouts, Error recovery
    - Status reporting
    - Routing techniques
    - User-access control
    - Connection oriented/connectionless services

This module is concerned with internetworking, which allows communication across isolated network boundaries in a seamless manner. Lesson 6.1 introduces various internetworking devices such as repeater/hub, bridge, router and gateway, which are used to interconnect separate LANs and WANs. Lesson 6.2 introduces IP addressing and various protocols at the IP layer and lesson 6.3 deals with Transmission Control and Application layer protocols such as Electronic mail, File transfer, and Remote login.

Module 7: Routing and Congestion Control

When a packet travels from a source to a destination, it is likely to pass through several routers and normally there exist multiple paths between any two source-destination pairs. The routing function of the network layer decides which path a packet to follow from a source node to a destination node. For a connectionless (datagram type) service, each

packet is routed independently, whereas for a virtual-circuit type of service, a route is set up at the beginning and all packets follow the same path. The attributes, which are expected from a routing function, are: *correctness, simplicity, robustness, stability, fairness* and *optimality* and the routing algorithms can be classified based on different metrics. Lesson 7.1 introduces various issues related to routing. In the subsequent three lessons three popular routing algorithms, namely *Routing Information Protocol* (RIP), *Open Shortest Path First* (OSPF) and *Border Gateway Protocol* (BGP) have been covered.

A packet switched network may be considered as a network of queues. If the rate at which packets arrive and queue up exceeds the rate at which packets are disbursed, the queue size grows without bounds leading to long delay and buffer overflow. Ultimately, it may lead to deadlock, a catastrophic situation in which the throughput drops to zero as shown in. The objective of the congestion control is to maintain the number of packets within the network or a region of network below the level at which queuing delays blow up. Various congestion control protocols have been covered in Lesson 7.5.

Module 8: Network Security

With the ability to contact anybody from anywhere and more and more people joining the internet with diverse applications, network security has become a very important issue. People are now very concerned about communication in a secured manner through internet, which is essentially an insecure public network. Cryptography has been considered to be the solution to this problem. Suitable *encryption/decryption* techniques can be used for transfer of data through internet between any two hosts in a secured manner. Lesson 8.1 of this module provides an overview of the vast subject of Cryptography. Then lesion 8.2 presents how cryptography can be applied in a number of ways to achieve secured communication through an insecure communication network. Moreover, many organizations have confidential or proprietary information, such as trade secrets, product development plans, marketing strategies, etc., which should be protected from unauthorized access and modification. Although cryptographic techniques can be used to protect data in transit, it does not protect data from digital pests and hackers. To accomplish this it is necessary to perform user authentication and access control to protect a private network from unauthorized traffic. This can be performed with the help of a *firewall*, which acts as an interface between a private network and an insecure public network. The functions Firewalls are elaborated in Lesson 8.3.

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Review Questions

Fill in the blanks

1. A computer network interconnects a number of _____ computers.
2. Computer network emerges due to the development between two fields, namely _____ and _____.
3. Three main categories of networks are _____, _____ and _____.
4. _____ are privately owned while _____ are usually owned by government
5. LAN operates at a _____ speed with _____error rate than WANs.
6. Internet is _____ of networks.
7. Initially, computer network was developed for _____.

Short answers

Q-1. Which Technologies of this age had led to the emergence of computer network?

Ans: The technologies are Computer technology and Communication technology with the support of VLSI Technology.

Q-2. What are the two broad classifications under which Networks can be divided?

Ans: All computer networks fit in one of the two dimensions namely,
a). **Transmission Technology**, this focuses on the basic underlying physical network, for e.g. whether the nodes share a communication media or each pair of node has a separate dedicated link.
b). **Scale**, it focuses on the scale of network how large is your network.

Q-3. Mention different categories of computer networks (on the basis of scale) and distinguish one from the other.

Ans: Local Area Network (LAN): It is privately owned communication systems that cover a small area, say a building or a complex of buildings. Length is about 10 meters to few kilometers and operates at a high speed like 10 MBPS to 1000 MBPS. It has very low error rate ($1:10^{11}$).

Metropolitan Area Network (MAN): It is public or privately owned communication system that typically covers a complete city. Speed is about 10 MBPS and follows DQDB (Distributed Queue Double Bus) standard. Its reliability is moderate.

Wide Area Network (WAN): It covers a large geographical area and usually owned by a state. Data transfer rate is low (few KBPS to 10 MBPS) and error rate is much higher.

Q-4. What are the two types of Transmission technologies, basis on which computer networks can be categorized?
Ans: Broadly there are two types of transmission technology:

1**. Broadcast networks**: a single communication channel that is shared by all the machines on the network

2. **Point-to-point networks**: This network consists of many connections between individual pairs of machines. To go from the source to destination a message (or packet) may have to visit one or more intermediate machines

Q-5. What is Internet?

Ans: Internet is a collection of networks or network of networks. Various networks such as LAN and WAN connected through suitable hardware and software to work in a seamless manner. It allows various applications such as e-mail; file transfer, remote log-in, World Wide Web, Multimedia, etc run across the internet.

Q-6. How do you account for higher reliability and scalability of computer network?

Ans: Computer network can have a large number of computers, which can share software, database and other resources. In the event of failure of one computer, its workload can be taken over by other computers. So, it provides higher reliability than centralized computing system.

Requirement of software, hardware, database etc. increases gradually. In centralized computing system, if one computer is not able to serve the purpose, we have to replace it by new one. Replacement of new computer requires lot of investment and effort, which can be avoided in computer network system. If there is need for more, one can buy another powerful computer, add it to computer network and use it. The various resources like computers, peripherals, etc. can be added in a scalable manner.

Q-7. Mention important benefits of computer network.

Ans: Important benefits of computer networks are:

i) Resource sharing
ii) Powerful communication medium
iii) Higher reliability
iv) Higher flexibility
v) Lower cost
vi) Incremental expansion

Q-8. What are the main categories based on which applications of computer network can be categorized?

Ans: The main areas under which the applications for computer network can be categorized are as follows:

Scientific and Technical Computing

- Client Server Model, Distributed Processing
- Parallel Processing, Communication Media

Commercial

- Advertisement, Telemarketing, Teleconferencing
- Worldwide Financial Services

Network for the People (this is the most widely used application nowadays)

- Telemedicine, Distance Education, Access to Remote Information, Person-to-Person Communication, Interactive Entertainment

Q-9 How is computer networks used in marketing and sales, financial services, teleconferencing?

Ans: Computer network have led to a new age of all of these services. They have helped in the following way to individual sector:

Marketing and sales: Computer networks are used extensively in both marketing and sales organizations. Marketing professionals use them to collect, exchange, and analyze data related to customer needs and product development cycles. Sales application includes teleshopping, which uses order-entry computers or telephones connected to order processing network, and online-reservation services for hotels, airlines and so on.

Financial services: Today's financial services are totally depended on computer networks. Application includes credit history searches, foreign exchange and investment services, and electronic fund transfer, which allow user to transfer money without going into a bank (an automated teller machine is an example of electronic fund transfer, automatic pay-check is another).

Teleconferencing: Teleconferencing allows conference to occur without the participants being in the same place. Applications include simple text conferencing (where participants communicate through their normal keyboards and monitor) and video conferencing where participants can even see as well as talk to other fellow participants. Different types of equipments are used for video conferencing depending on what quality of the motion you want to capture (whether you want just to see the face of other fellow participants or do you want to see the exact facial expression).