Module 1

Introduction

Introduction

In this module we shall highlight some of the basic aspects of computer networks in two lessons. In lesson 1.1 we shall start with the historical background of computer networks, i.e. how the advancements in the field of communication and computers (which in turn is boosted by development in the field of VLSI) lead to the emergence of computer networks. Then we shall discuss different type of networks and their classification on the basis of transmission technology and scale. In the following section we shall focus on few applications of computer networks, which spans over different areas in a common man life. Finally, an outline of the entire course is presented in the last section.

An overview of layered network architecture is presented in lesson 1.2. The basic terminologies for layered architecture will be covered. Then this lesson provides an introduction of OSI layer architecture (Open System Interconnection Reference Model). Basic functionalities of different layers of OSI and concept of service access points and how information exchange between two peer layers of two different systems take place is explained.

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 the preceding module we have focused on sending signal over some communication link. In practice, much more is needed for effective data communication. In this module, we shall focus on some of the important issues for this purpose. The basic model that we shall use to discuss various issues related to data link control is shown in Fig. 3.1.1. Here two machines are directly connected with the help of a *point-to-point* communication link that act conceptually like a pair of wire. In many situations, the link may be multipoint, meaning that more than two stations connected to the communication link. In such cases, it is necessary to have mechanism to identify the source-destination pair involved in data transmission. Key features of the link are:

- Occasionally errors occur in the communication circuit.
- There is nonzero propagation delay.
- Communication link and the machines have finite data rate.

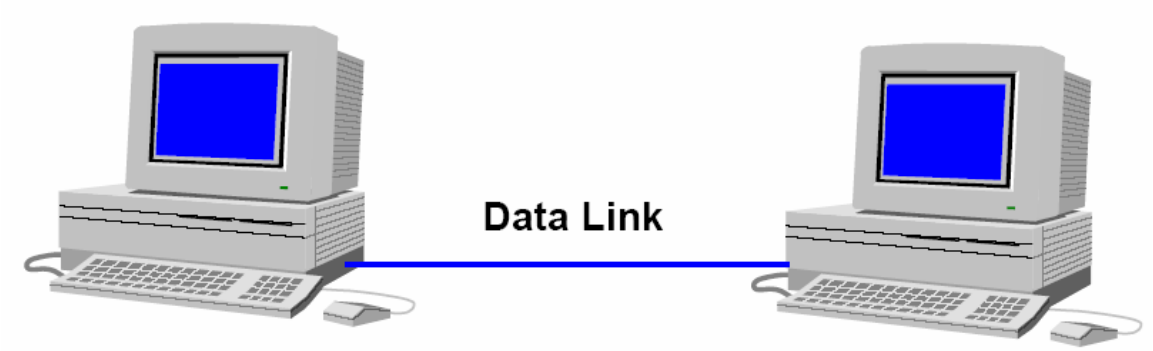

Figure 3.1.1 Data Link control model

Our objective is to devise suitable mechanism for efficient and reliable communication between the two machines through the link. This will require great deal of coordination between the two machines. A layer of logic is added above the physical interface to achieve the necessary control and management referred to as **Data Link Control**. Key components of the data link control are:

- **Frame synchronization**: The beginning and end of a data block (called *frame*) should be distinguishable.
- **Addressing:** In case of multipoint communication the identity of the two stations involved in the communication are to be specified.
- **Flow control**: The sender should send frames at a rate such that the receiver is not overwhelmed.
- **Error control:** Any bit errors introduced by the transmission system should be corrected.
- **Control and data on the same link:** The receiver must be able to distinguish control information from the data being transmitted.
- **Link management:** Procedures for the management of the initiation, maintenance, and termination of a sustained data exchange.

In this module we shall discuss various aspects of data link control. Lesson 3.1 will deal with framing and synchronization along with how one can interface the machine to the media. Error detection and error correction techniques will be presented in Lesson 3.2. Lesson 3.3 will introduce various protocols used for flow control and error control. Finally, lesson 3.4 will cover HDLC, the most popular data link control protocol.

Module 4

Switched Communication Networks

The techniques of communication between a pair of stations on a network can be classified into two broad categories.

- Switched network methodology
- Broadcast Methodology

In the **switched network** methodologies, the network consists of a set of interconnected stations, among which information is transmitted from source to destination through different routes, which is controlled by the switching mechanism.

In case of **broadcast network**, each station is a transmitter-receiver pair and is attached to the transmission medium, which is shared by all stations. Any transmission done by any one of the stations is received by all the stations of the network.

In this module we shall discuss about switched communication networks. First we shall have a look at various **switching** techniques in Lesson 4.1. In this lesson we shall discuss various aspects of circuit switching and discuss the operation of Public Switched Telephone Network (PSTN), which is based on circuit switching. 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, we shall introduce **ATM** (Asynchronous transfer mode), which can be used both as a LAN or WAN standard. We shall discuss various network devices used in ATM, concept of cell transfer and cell format, then we shall discuss VP switching and VP-VC switching, after that we will have a look at ATM reference model i.e. it's various planes and levels, and finally we will have a look at few of its application.

This module is organized in the following five lessons:

Lesson 4.1: Switching Techniques: Circuit Switching
Lesson 4.2: Switching Techniques: Packet Switching
Lesson 4.3: Synchronous Optical Network (SONET)
Lesson 4.4: X.25 and Frame Relay Networks
Lesson 4.5: ATM

Module 5

Broadcast Communication Networks

Data communication networks can be broadly divided into the following two types:

- **Switched communication networks**: Here the users are interconnected by means of transmission lines, multiplexers and switches.
- **Broadcast networks**: Here a single transmission media is shared by all the users and information is broadcast by an user into the medium.

In the preceding module we have covered various switched communication networks. In this module we shall focus on broadcast communication networks. Some examples of broadcast communication networks are:

- Local area network (LAN)
- Packet radio network
- Cellular telephone network
- Satellite Network

These networks can be characterized by the following three parameters:

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

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 in the subsequent lessons we shall consider the abovementioned networks one after the other.

Module 6

Internetworking

In the previous modules we have discussed various network technologies. We have observed that LAN technologies are designed to provide high-speed communication over a small geographical region, whereas WAN technologies are designed to provide communication across different cities, countries and continents. But, it has been found that isolated LANs and WANs have limited potential and usefulness. 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.

Lesson 6.1 Internetworking Devices
Lesson 6.2 Internet Protocol
Lesson 6.3 Transport and Application Layer Protocols

Module 7

Routing and Congestion Control

In Lesson number 6.1 we have seen that an internet can be considered as a network of networks connected by routers. 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.

This module consists of the following five lessons.

Lesson 7.1 Basics of Routing

Lesson 7.2 Routing Information Protocol (RIP)

Lesson 7.3 Open Shortest Path First (OSPF)

Lesson 7.4 Border Gateway Protocol (BGP)

Lesson 7.5 Congestion Control Algorithms

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 lesson 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. An overview of the functions Firewalls are given in Lesson 8.3.