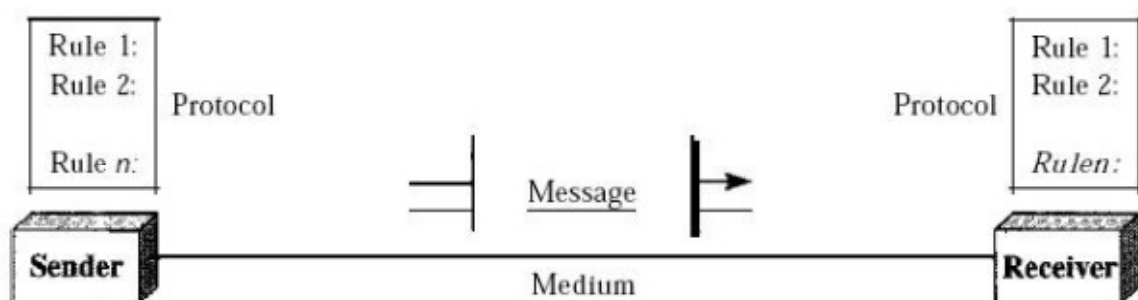# Chapter 1: Data Communication

INTRODUCTION TO DATA COMMUNICATION

- Data communications refers to the exchange of data between two devices via some form of transmission medium such as a wire cable.
- For data communications to occur, the communicating devices must be part of a communication system made up of a combination of hardware (physical equipment) and software (programs).
- The effectiveness of a data communications system depends on four fundamental characteristics: delivery, accuracy, timeliness, and jitter.

    1. **Delivery:** The system must deliver data to the correct destination. Data must be received by the intended device or user and only by that device or user.

    2. **Accuracy:** The system must deliver the data accurately. Data that have been altered in transmission and left uncorrected are unusable.

    3. **Timeliness:** The system must deliver data in a timely manner. Data delivered late are useless. In the case of video and audio, timely delivery means delivering data as they are produced, in the same order that they are produced, and without significant delay. This kind of delivery is called real-time transmission.

    4. **Jitter:** Jitter refers to the variation in the packet arrival time. It is the uneven delay in the delivery of audio or video packets. For example, let us assume that video packets are sent every 30ms. If some of the packets arrive with 30ms delay and others with 40ms delay, an uneven quality in the video is the result.

COMPONENTS OF A DATA COMMUNICATIONS SYSTEM

A data communications system has five components:

- **Message:** The message is the information (data) to be communicated. Popular forms of information include text, numbers, pictures, audio, and video.

- **Sender:** The sender is the device that sends the data message. It can be a computer, workstation, telephone handset, video camera, and so on.

- **Receiver:** The receiver is the device that receives the message. It can be a computer, workstation, telephone handset, television, and so on.

- **Transmission medium:** The transmission medium is the physical path by which a message travels from sender to receiver. Some examples of transmission media include twisted-pair wire, coaxial cable, fiber-optic cable, and radio waves.

- **Protocol:** A protocol is a set of rules that govern data communications. It represents an agreement between the communicating devices. Without a protocol, two devices may be connected but not communicating, just as a person speaking French cannot be understood by a person who speaks only Japanese.

THE TELEPHONE SYSTEM

- Telephone networks use circuit switching. The telephone network had its beginnings in the late 1800s. The entire network, which is referred to as the plain old telephone system (POTS), was originally an analog system using analog signals to transmit voice.
- With the advent of the computer era, the network, in the 1980s, began to carry data in addition to voice. During the last decade, the telephone network has undergone many technical changes. The network is now digital as well as analog.

Major Components
- The telephone network, as shown in Figure 1.1, is made of three major components: ***local loops***, ***trunks***, and ***switching offices***. The telephone network has several levels of switching offices such as end offices, tandem offices, and regional offices.
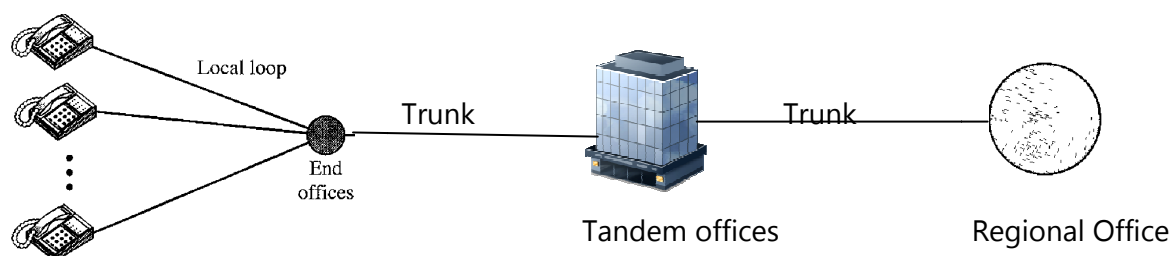

Figure 1.1 *A telephone system*

Local Loops

One component of the telephone network is the local loop, a twisted-pair cable that connects the subscriber telephone to the nearest end office or local central office. The local loop, when used for voice, has a bandwidth of 4000 Hz (4 kHz).

Trunks

Trunks are transmission media that handle the communication between offices. A Trunk normally handles hundreds or thousands of connections through multiplexing. Transmission is usually through optical fibers or satellite links.

Switching Offices

To avoid having a permanent physical link between any two subscribers, the telephone company has switches located in a switching office. A switch connects several local loops or trunks and allows a connection between different subscribers.

LATAs

After the divestiture of 1984, the United States was divided into more than 200 local-access transport areas (LATAs). The number of LATAs has increased since then. A LATA can be a small or large metropolitan area. A small state may have one single LATA; a large state may have several LATAs. A LATA boundary may overlap the boundary of a state; part of a LATA can be in one state, part in another state.

Intra-LATA Services

The services offered by the common carriers (telephone companies) inside a LATA are called intra-LATA services. The carrier that handles these services is called a local exchange carrier (LEC). Before the Telecommunications Act of 1996, intra-LATA services were granted to one single carrier. This was a monopoly. After 1996, more than one carrier could provide services inside a LATA. The carrier that provided services before 1996 owns the cabling system (local loops) and is called the *incumbent local exchange carrier (ILEC)*. The new carriers that can provide services are called *competitive local exchange carriers (CLECs)*. To avoid the costs of new cabling, it was agreed that the ILECs would continue to provide the main services, and the CLECs would provide other services such as mobile telephone service, toll calls inside a LATA, and so on.

INTRA-LATA SERVICES ARE PROVIDED BY LOCAL EXCHANGE CARRIERS. SINCE 1996, THERE ARE TWO TYPES OF LECS: INCUMBENT LOCAL EXCHANGE CARRIERS AND COMPETITIVE LOCAL EXCHANGE CARRIERS.
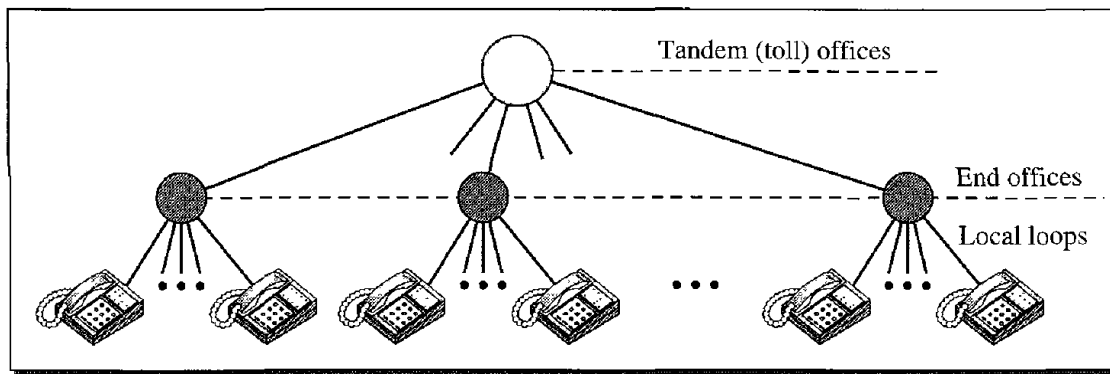
Figure 1.2 shows a LATA and switching offices.

Communication inside a LATA is handled by end switches and tandem switches. A call that can be completed by using only end offices is considered toll-free. A call that has to go through a tandem office (intra-LATA toll office) is charged.

Inter-LATA Services

The services between LATAs are handled by interexchange carriers (IXCs). These carriers, sometimes called long-distance companies, provide communication services between two customers in different LATAs. After the act of 1996, these services can be provided by any carrier, including those involved in intra-LATA services. The field is wide open. Carriers providing inter-LATA services include AT&T, MCI, WorldCom, Sprint, and Verizon.

The IXCs are long-distance carriers that provide general data communications services including telephone service. A telephone call going through an IXC is normally digitized, with the carriers using several types of networks to provide service.

Services Provided by Telephone Networks

Telephone companies provide two types of services: *Analog and Digital*.

Analog Services

In the beginning, telephone companies provided their subscribers with analog services. These services still continue today. We can categorize these services as either analog switched services or analog leased services.

- *Analog Switched Services* This is the familiar dial-up service most often encountered when a home telephone is used. The signal on a local loop is analog, and the bandwidth is usually between 0 and 4000 Hz. A local call service is normally provided for a flat monthly rate, although in some LATAs, the carrier charges for each call or a set of calls. The rationale for a non flat-rate charge is to provide cheaper service for those customers who do not make many calls. A toll call can be intra-LATA or inter-LATA. If the LATA is geographically large, a call may go through a tandem office (toll office) and the subscriber will pay a fee for the call. The inter-LATA calls are long-distance calls and are charged as such.

- Another service is called **800 services**. If a subscriber (normally an organization) needs to provide free connections for other subscribers (normally customers), it can request the 800 service. In this case, the call is free for the caller, but it is paid by the callee. An organization uses this service to encourage customers to call. The rate is less expensive than that for a normal long-distance call. The wide-area telephone service (WATS) is the opposite of the 800 service. The latter are inbound calls paid by the organization; the former are outbound calls paid by the organization. This service is a less expensive alternative to regular toll calls; charges are based on the number of calls. The service can be specified as outbound calls to the same state, to several states, or to the whole country, with rates charged accordingly.

- **The 900 services** are like the 800 service, in that they are inbound calls to a subscriber. However, unlike the 800 service, the call is paid by the caller and is normally much more expensive than a normal long-distance call. The reason is that the carrier charges *two* fees: the first is the long-distance toll, and the second is the fee paid to the callee for each call.

- **Analog Leased Service** An analog leased service offers customers the opportunity to lease a line, sometimes called a *dedicated line that* is permanently connected to another customer. Although the connection still passes through the switches in the telephone network, subscribers experience it as a single line because the switch is always closed; no dialling is needed.

Digital Services

Recently telephone companies began offering digital services to their subscribers. Digital services are less sensitive than analog services to noise and other forms of interference. The two most common digital services are **switched/56 service** and **digital data service (DDS)**

- **Switched/56 Service** Switched/56 service is the digital version of an analog switched line. It is a switched digital service that allows data rates of up to 56 kbps. To communicate through this service, both parties must subscribe. A caller with normal telephone service cannot connect to a telephone or computer with switched/56 service even if the caller is using a modem. On the whole, digital and analog services represent two completely different domains for the telephone companies. Because the line in a switched! 56 service is already digital, subscribers do not need modems to transmit digital data. However, they do need another device called a digital service unit (DSU).

- **Digital Data Service Digital data service (DDS)** is the digital version of an analog leased line; it is a digital leased line with a maximum data rate of 64 kbps.

PROTOCOLS AND STANDARDS

In this section, we define two widely used terms: **protocols** and **standards**. First, we define *protocol,* which is **synonymous with *rule***. Then we discuss *standards,* which are agreed-upon rules.

In computer networks, communication occurs between entities in different systems.

- An entity is anything capable of sending or receiving information. However, two entities cannot simply send bit streams to each other and expect to be understood. For communication to occur, the entities must agree on a protocol. **A protocol is a set of rules that govern data communications. A protocol defines what is communicated, how it is communicated, and when it is communicated**. The key elements of a protocol are syntax, semantics, and timing.

    o **Syntax**. The term *syntax* refers to the structure or format of the data, meaning the order in which they are presented.

        ▪ For example, a simple protocol might expect the first 8 bits of data to be the address of the sender, the second 8 bits to be the address of the receiver, and the rest of the stream to be the message itself.

    o **Semantics**. The word *semantics* refers to the meaning of each section of bits. How is a particular pattern to be interpreted, and what action is to be taken based on that interpretation? For example, does an address identify the route to be taken or the final destination of the message?

    o **Timing**. The term *timing* refers to two characteristics: when data should be sent and how fast they can be sent. For example, if a sender produces data at 100 Mbps but the receiver can process data at only 1 Mbps, the transmission will overload the receiver and some data will be lost.

Standards

Standards are essential in creating and maintaining an open and competitive market for equipment manufacturers and in guaranteeing national and international interoperability of data and telecommunications technology and processes. Standards provide guidelines to manufacturers, vendors, government agencies, and other service providers to ensure the kind of interconnectivity necessary in today's marketplace and in international communications.

Data communication standards fall into two categories: **de facto** (meaning "by fact" or "by convention") and **de jure** (meaning "by law" or "by regulation").

- **De facto**. Standards that have not been approved by an organized body but have been adopted as standards through widespread use are de facto standards. De facto standards are often established originally by manufacturers who seek to define the functionality of a new product or technology.
- **De jure**. Those standards that have been legislated by an officially recognized body are de jure standards.

Standards Organizations

Standards are developed through the cooperation of standards creation committees, forums, and government regulatory agencies.

STANDARDS CREATION COMMITTEES

While many organizations are dedicated to the establishment of standards, data telecommunications in North America rely primarily on those published by the following:

- ***International Organization for Standardization (ISO).*** The ISO is a multinational body whose membership is drawn mainly from the standards creation committees of various governments throughout the world. ***The ISO is active in developing cooperation in the realms*** *(field of something)* ***of scientific, technological, and economic activity***.

- ***International Telecommunication Union-Telecommunication Standards Sector (ITU-T)*** By the early 1970s, a number of countries were defining national standards for telecommunications, but there was still little international compatibility. *The United Nations responded by forming, as part of its International Telecommunication Union (ITU), a committee, the Consultative Committee for International Telegraphy and Telephony (CCITT).* ***This committee was devoted to the research and establishment of standards for telecommunications in general and for phone and data systems in particular***.

- ***American National Standards Institute (ANSI)***. Despite its name, the American National Standards Institute is a completely private, nonprofit corporation not affiliated with the U.S. federal government. However, all ANSI activities are undertaken with the welfare of the United States and its citizens occupying primary importance.

- ***Institute of Electrical and Electronics Engineers (IEEE)***. The Institute of Electrical and Electronics Engineers is the largest professional engineering society in the world. International in scope, ***it aims to advance theory, creativity, and product quality in the fields of electrical engineering, electronics, and radio as well as in all related branches of engineering***. As one of its goals, the IEEE oversees the development and adoption of international standards for computing and communications.

- ***Electronic Industries Association (EIA)***. Aligned with ANSI, the Electronic Industries Association is a nonprofit organization ***devoted to the promotion of electronics manufacturing concerns. Its activities include public awareness education and lobbying efforts in addition to standards development. In the field of information technology***, the EIA has made significant contributions by defining physical connection interfaces and electronic signaling specifications for data communication.

Forums

Telecommunications technology development is moving faster than the ability of standards committees to ratify standards. Standards committees are procedural bodies and by nature slow-moving. To accommodate the need for working models and agreements and to facilitate the standardization process, many special-interest groups have developed **forums** made up of representatives from interested corporations. ***The forums work with universities and users to test, evaluate, and standardize new technologies. By concentrating their efforts on a particular technology, the forums are able to speed acceptance and use of those technologies in the telecommunications community. The forums present their conclusions to the standards bodies.***

Regulatory Agencies

All communications technology is subject to regulation by government agencies such as the **Federal Communications Commission** (FCC) in the United States. The purpose of these agencies is to protect the public interest by regulating radio, television, and wire/cable communications. The FCC has authority over interstate and international commerce as it relates to *communications*.

HISTORY AND APPLICATION OF DATA COMMUNICATION

Data communication techniques predate computers by at least a hundred years - for example the MORSE code for communication over telegraph wires shown in ***Table 1.1***. Long before we had radio, telegraph wires carried messages from one end of a country to another. At each end of the wire, the telegraph operators used MORSE to communicate.

- *MORSE offcourse is just an encoding technique. The basic elements of the code are two signals - one with a short duration, and one long*. The signals were transmitted by just switching on and off an electric current (with a switch), and were received by checking the deflection of a magnet.
- Each letter is made from some sequence of short and long signals. If you examine the codes, you find that the most common letters are the ones with the shortest codes.
- The most common letters in western languages are (in order): E T A O I N S H R D L U ... and sure enough - the E is the shortest code (a single.). T is next with -, followed by A (.-) and so on. Obviously when the MORSE code was developed, someone was concerned with efficiency. Ham radio enthusiasts (Hams) use MORSE, but with higher level controls (protocols). They use short codes to encode commonly used requests or statements. They are known as the 'Q' codes Letter Code Letter Code Letter Code Letter Code

Letter	Code	Letter	Code	Letter	Code	Letter	Code
A	.-	B	-...	C	-.-.	D	-..
E	.	F	..-.	G	--.	H	....
I	..	J	.---	K	-.-	L	.-..
M	--	N	-.	O	---	P	.--.
Q	--.-	R	.-.	S	...	T	-
U	..-	V	...-	W	.--	X	-..-
Y	-.--	Z	--..				

Table 1.1: Morse Code.

Morse Voice Meaning

K Go ahead. Anyone go ahead
AR Over. Use at end of transmission before contact made
AS Stand by. Temporary interruption
R Roger! Transmission received OK
SK Clear. End of contact
CL Closing down. Shutting down transmitter

RECENT HISTORY

Since the early days of modern computing there has been a steadily increasing need for more sophisticated data transfer services.

- In the **1950**s, the early computers were simple machines with 'Single-task' operating systems. They typically had a single console, and data was entered either by cards, or on paper tape.
- In the **1960**s, demand for large scale data entry grew, and the 'on-line' batch system was developed. The operating systems were better, and allowed many terminals to be connected to the same computer. These terminals typically would allow deferred data entry - that is the files would not be updated until a 'batch' of data was ready. The data entry was often done during the day, the processing of the data at night.
- In the **1970**s, on-line integrated systems were developed. These allowed terminals to access the files, as well as update them. Database technology allowed immediate display of the effect of completed transactions. Integrated systems generated multiple transactions from single entries.
- Since the **1980**s we have moved to distributed databases and processing. In the 80s and 90s we see large machines - even the workstations have significant computing power.

*A **distributed system** is a computer network in which the processing may be distributed amongst the computers. The user may not be aware on which computer the software is actually running. A computer network by contrast has a collection of communicating processors, but each users processing is done on a single computer.*

Computer-based communications systems allow end users to transmit data from one location to another via various types of communications lines. This type of communication has dramatically expanded the scope of business activities. The most vital component of any data communications system is the network. The network is any system that makes interaction between two or more computers possible. Today, computer users can tap into a vast number of resources to retrieve information on a variety of subjects and events. For example, a CEO of a nationwide corporation may wish to examine information about regional sales levels or expected economic conditions.

This section examines two types of network applications: *Groupware* and the *Information Superhighway* (*Internet*). These two applications are the future of information technology.

Groupware

This is a communications application that is growing in popularity (also called collaboration technology). Groupware is software that helps groups of people to work together more productively. Groupware allows people to exchange ideas, debate issues, make decisions, and write reports without actually having to meet face-to-face. The most important advantage of Groupware is its ability to help groups make decisions faster. This section focuses on four popular types of Groupware:

Electronic Mail

Electronic mail (*E-Mail*) is one of the earliest Groupware tools and is also the most heavily used tool today. E-mail is faster and cheaper than regular mail, and can substitute for telephone conversations in some cases.

Document-based Groupware (Notes)

Notes were the first document-based Groupware product. It is a document database designed to store and manages large collections of text and graphics to support ongoing discussions.

Group Support Systems (GSS)

Group Support System, one of the most popular uses of Groupware, is a software tool designed to improve group decision making in special purpose meeting rooms that provide networked computers and large screen video projection systems. These rooms are equipped with special-purpose GSS software that enables participants to communicate, propose ideas, analyse options, and evaluate alternatives. A group of employees could view a document displayed on a projector screen. Then, each employee could manipulate the data from his station while others observed the resulting changes.

Video Teleconferencing

This is a video conference among several users, which is provided by one or more video cameras and several display monitors set up in special purpose meeting rooms. It provides real-time transmission of video and audio signals to help people in different locations to have a meeting. The advantage of this technology is the time and cost savings. Another form of video teleconferencing, desktop video conferencing, is growing up fast.

INFORMATION SUPERHIGHWAY (INTERNET)

The *information superhighway* or simply *Internet* is one of the most important developments in the history of information systems. It is growing fast. The Internet is not one network, but tens of thousands of networks linked together. In other words, it is a large network made up of thousands of smaller networks. Internet does not have overall central administration, because it is a collection of thousands of smaller networks. Internet provides four basic functions to its users:

- *E-mail*
- *Remote Login*
- *Discussion Groups*
- *Information Resources*

> **E-mail on the Internet**
>   - o Electronic mail (E-mail) is one of the most rapidly growing developments in networked communications. Users of E-mail have their own file stored on a computer system. This file can be called a "mailbox." Access to a person's mailbox is protected by means of a password. Once logged on to an E-mail account, an end user may send messages and files to other mailboxes. An individual electronic mail transmission may be sent to one or many recipient accounts. This person may also read messages that have "arrived" in her or his mailbox from other E-mail accounts.
>   - o One of the main advantages of using E-mail is confidentiality. No one can access an individual's mailbox without knowledge of the password. E-mail also allows recipients to know the exact transmission times for each incoming message. Popular uses of E-mail have been to set up meetings within business organizations and to distribute memoranda throughout an organization. E-mail is increasing in popularity for communication between businesses. The main reasons for this are speed and cost; there is no reason to spend postage on a letter that will take three to seven days to arrive when electronic mail could be used for virtually nothing and arrive instantaneously.
>   - o Anyone with access to the Internet can send E-mail to anyone else on the Internet. Internet E-mail addresses have two parts, the individual user's account address and the address of the computer. The computer's

address in turn has two parts, the computer name and its domain. The general format is therefore: *user@computer.domain*. Note that the "at" symbol (@) separates the user's account from the computer address, and that a period separates the name of the computer from its domain. Some computer names also have several parts separated by periods, so some addresses may have the format: *user@computer.computer.computer.domain*

o   (e.g., mayurtaunk@gmail.com)

Remote Login (Telnet)

Internet offers a large number of services. Among them, the service that allows users to connect to a remote Internet host is called Telnet. Users on one computer in the Internet can login into other computers on the Internet by a special program, called Telnet, on your computer. This program uses the Internet to connect to the computer users specify. The users should know the account name and password of the remote computer.

In Telnet, a user's computer is called the *local* computer. The other computer that the Telnet program connects is called the *remote* computer. An example of using Telnet is that users can read and send E-mail while travelling.

Discussion Groups

Discussion groups are internet users who have joined together to discuss some topic. There are many discussion groups on every topic imaginable, from cooking to biological science. Two groups are commonly used for business.

o   **Usenet Newsgroups:** Usenet is a large collection of discussion groups involving millions of people from all over the world. This is the most formally organized among the discussion groups. To read Usenet articles, users use a program called a *newsreader*. There are a number of different newsreaders.

o   **Listserv:** A listserv is simply a mailing list developed on the large Bitnet network (not on the Internet). The listserv processor processes listserv commands such as requests to subscribe and unsubscribe, while the listserv mailer mails any message it receives to everyone on the mailing list.

Information Resources

The major use of the Internet is to find information. There are six major ways to find and achieve information:

- *FTP*
- *Archie*
- *Gopher*
- *Veronica*
- *World Wide Web*
- *WAIS*

- **FTP:** File Transfer Protocol (FTP) is the underlying set of specifications that support Internet file transfer. In other words, FTP is a service that allows us to copy a file from any Internet host to any other Internet host. A *ftp* program acts as a client and connects to the FTP server on a remote host. Internet users can download (copy files from the remote computer into users' computer) and upload (copy files from users' computer to a remote computer) files. An anonymous FTP site permits any Internet user to login using anonymous as the account name and a user's mailing address as the password.

- **Archie:** Throughout the Internet, there are a number of computers, called *Archie servers*, which provide a service to help users find the name of Anonymous FTP hosts that carry a particular file. Archie is a tool that allows users to search most of the publicly available anonymous FTP sites worldwide for specific files of interest.

- **Gopher:** The Gopher is a powerful system that allows users to access many resources of the Internet in a simple, consistent manner. To use the Gopher, all users need to do are making selections from a menu. In other words, Gopher is a menu-based tool that enables users to search for publicly available information posted on the Internet. The power of the Gopher lies in the fact that the resources listed in a menu may be anywhere on the Internet.

- **Veronica:** Veronica is a Gopher-based resource that users can use to search gopher space for all the menu items that contain specified words. Veronica is to Gopher what Archie is to FTP. It enables users to search all publicly available Gopher sites by specifying key words.

- **World Wide Web:** WWW (World Wide Web) or simply Web is one type of information resource that is growing even faster than Internet itself is the World Wide Web. WWW is an attempt to organize all the information on the Internet as a set of hypermedia documents. Besides that, the WWW allows users to access all kinds of Internet resources, just by using a browser to read the appropriate document. The Web provides a graphical user interface and enables the display of rich graphical images, pictures, full motion video, and sound clips.

  The Web is the most common way for businesses to establish a presence on the Internet. This Web has two major components, a *Web browser* and a *Web server*. A browser is a software package for accessing a Web server that stores files using HTML. There are many *Web browsers* available, including Mosaic, Netscape, Cello, and WinWeb. Most browsers show these links by highlighting text in a different color, usually blue. To use a link to go to a new page, users simply click on the text, and the browser takes users to the new page.

  A *Web server* stores information in a series of text files called pages. These text files or pages use a structured language called HTML (Hypertext Markup

Language) to store their information. HTML enables the author of a page to define different typestyles and sizes for the text, titles, and headings, and a variety of other formatting information. HTML also allows the author to define links to other pages that may be stored on the same Web server, or on any Web server anywhere on the Internet.

o **WAIS:** The WAIS stands for Wide Area Information Service. The original idea behind WAIS was to develop a generalized system of information retrieval that could access collections of data all around the world.

FUNDAMENTALS OF DATA COMMUNICATION

Signal Representation

- *Digital and analog signals*

    - **To be transmitted, data must be transformed to electromagnetic signals.**
        1. **Analog data** refers to information that is continuous; ex. Sounds made by a human voice

        2. **Digital data** refers to information that has discrete states. Digital data take on discrete values.
        For example, data are stored in computer memory in the form of Os and 1s

    Signals can be of two types:

    1. Analog Signal: They have infinite values in a range.
    2. Digital Signal: They have limited number of defined values

a. Analog signal
b. Digital signal