COMMUNICATION NETWORKS

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October 25, 2025

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LIST OF ACRONYMS

TIDOII IIII III III III III III III III I	ASCII	American Standard	Code for Information	Interchange		7
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Course Overview

0.A Course in Brief

0.A.1 COURSE CATALOG

3 Credit hours (3 h lectures, R1). Introduction to queuing theory. Physical data link and network layers. Network topologies. Basic performance evaluation methods. Circuit and packet switching. Local area networks.

0.A.2 TEXTBOOK

- **★** Data Communications and Networking: Fifth Edition [1].
 - ◆ No single textbook.
 - ◆ Students will be referred to several recent books and journal articles (mainly survey papers).

0.A.3 RECOMMENDED READINGS

- **★** Communication Networks: A Concise Introduction [2].
- **★** Data Networks [3].
- \star Networks [4].

0.A.4 Instructor

Dr. Mohammad M. Banat (banat@just.edu.jo).

0.A.5 Prerequisites

Level	Subjects						
Background	Probability and Random Variables						
Dackground	Communication Systems						
Advanced	Digital Communications						
Advanced	Random Processes						

0.A.6 Topics

Weeks	Topics
1-2	Introduction to Communication Networks
3-5	Introduction to Queuing Theory
6-9	Physical, Data, Link and Network Layers
10	Network Topologies
11	Network Performance
12	Circuit and Packet Switching
13	Local Area Networks
14	Optical Networks
15-16	Wireless Networks

0.A.7 EVALUATION

Assessment Tool	Due Week	Weight $\%$
Mid-Term Exam	9	20
Term Project Report	13	15
Term Project Presentation	14	10
Class Work	15	15
Final Exam	16	40

Part I

BACKGROUND AND PRELIMINARIES

REVIEW OF SIGNALS AND LINEAR SYSTEMS

REVIEW OF RANDOM PROCESSES

REVIEW OF COMMUNICATION SYSTEMS

Introduction to Communication Networks

4.A DATA

Data communications and networking are changing the way we do business and the way we live. Business decisions have to be made ever more quickly, and the decision makers require immediate access to accurate information. Why wait a week for that report from far away to arrive by mail when it could appear almost instantaneously through communication networks? It is very important to know how networks operate, what types of technologies are available, and which design best fills which set of needs.

The development of the personal computer brought about tremendous changes for business, industry, science, and education. A similar revolution is occurring in data communications and networking. Technological advances are making it possible for communications links to carry more and faster signals. As a result, services are evolving to allow use of this expanded capacity. Research in data communications and networking has resulted in new technologies. One goal is to be able to exchange data such as text, audio, and video from all points in the world. We want to access the Internet to download and upload information quickly and accurately and at any time.

When we communicate, we are sharing information. This sharing can be local or remote. Between individuals, local communication usually occurs face to face, while remote communication takes place over distance. The term telecommunication, which includes telephony, telegraphy, and television, means communication at a distance (tele is Greek for "far").

Data communication is the exchange of data between two devices via some form of transmission medium such as a wire cable. For data communication to occur, the communicating devices must be part of a communication system made up of a combination of hardware (physical equipment) and software (programs).

4.A.1 EFFECTIVENESS OF DATA COMMUNICATION

The effectiveness of a data communication system depends on four fundamental characteristics: delivery, accuracy, timeliness, and jitter.

- **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.
- * Accuracy: The system must deliver the data accurately. Data that have been altered in transmission and left uncorrected are unusable.
- * 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.
- * **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 30 ms. If some of the packets arrive with 30 ms delay and others with 40 ms delay, an uneven quality in the video is the result.

4.A.2 Data Communications System Components

A data communications system has five components, as shown in Fig. 4.1.

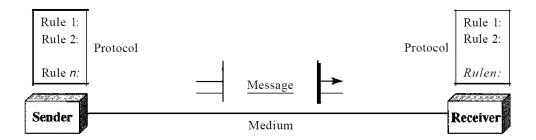


Fig. 4.1: Data Communication System Components

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

4.A.3 DATA REPRESENTATIONS

Data can have different forms such as text, numbers, images, audio, and video.

- * Text: In data communications, text is represented as a bit pattern, a sequence of bits (Os or Is). Different sets of bit patterns have been designed to represent text symbols. Each set is called a code, and the process of representing symbols is called coding. Today, the prevalent coding system is called Unicode, which uses 32 bits to represent a symbol or character used in any language in the world. The American Standard Code for Information Interchange (ASCII), developed some decades ago in the United States, now constitutes the first 127 characters in Unicode and is also referred to as Basic Latin.
- * Numbers: Numbers are also represented by bit patterns. However, a code such as ASCII is not used to represent numbers; the number is directly converted to a binary number to simplify mathematical operations.
- * Images: Images are also represented by bit patterns. In its simplest form, an image is composed of a matrix of pixels (picture elements), where each pixel is a small dot. The size of the pixel depends on the resolution. For example, an image can be divided into 1000 pixels or 10,000 pixels. In the second case, there is a better representation of the image (better resolution), but more memory is needed to store the image. After an image is divided into pixels, each pixel is assigned a bit pattern. The size and the value of the pattern depend on the image. For an image made of only black and white dots (e.g., a chessboard), a 1-bit pattern is enough to represent a pixel. If an image is not made of pure white and pure black pixels, you can increase the size of the bit pattern to include gray scale. For example, to show four levels of gray scale, you can use 2-bit patterns. There are several methods to represent color images. One method uses a 24-bit color code, and is called RGB, where each color is made of a combination of three primary colors: red, green, and blue. The intensity of each color is measured, and an 8-bit pattern is assigned to it. The values for red, green, and blue are each specified on a scale from 0–255 (decimal) or 00–FF (hex). The number of RGB colors is equal to

$$N_{RGB} = 2^{24}$$

= 256^3
= $16,777,216$. (4.1)

Although these colors are more than our eyes can distinguish, this is an easy representation for computers to handle, and is a great way for rendering images and videos. Higher numbers mean lighter, lower numbers mean darker. Another method is called YCM, in which a color is made of a combination of three other primary colors: yellow, cyan, and magenta.

- * Audio: Audio refers to the recording or broadcasting of sound or music. Audio is by nature different from text, numbers, or images. It is continuous, not discrete. Even when we use a microphone to change voice or music to an electric signal, we create a continuous signal.
- * Video: Video refers to the recording or broadcasting of a picture or movie. Video can either be produced as a continuous entity (e.g., by a TV camera), or it can be a combination of images, each a discrete entity, arranged to convey the idea of motion.

4.A.4 DATA FLOW

Data flow between two devices can be simplex, half-duplex, or full-duplex.

- * Simplex: In simplex mode, the communication is unidirectional, as on a one-way street. Only one of the two devices on a link can transmit; the other can only receive. Keyboards and traditional monitors are examples of simplex devices. The keyboard can only introduce input; the monitor can only accept output. The simplex mode can use the entire capacity of the channel to send data in one direction.
- * Half-Duplex: In half-duplex mode, each station can both transmit and receive, but not at the same time. When one device is sending, the other can only receive, and vice versa.

The half-duplex mode is like a one-lane road with traffic allowed in both directions. When cars are traveling in one direction, cars going the other way must wait. In a half-duplex transmission, the entire capacity of a channel is taken over by whichever of the two devices is transmitting at the time.

The half-duplex mode is used in cases where there is no need for communication in both directions at the same time; the entire capacity of the channel can be utilized for each direction.

* Full-Duplex: In full-duplex mode (also called duplex), both stations can transmit and receive simultaneously.

The full-duplex mode is like a two-way street with traffic flowing in both directions at the same time. In full-duplex mode, signals going in one direction share the capacity of the link with signals going in the other direction. This sharing can occur in two ways: either the link must contain two physically separate transmission paths, one for sending and the other for receiving; or the capacity of the channel is divided between signals traveling in both directions.

One common example of full-duplex communication is the telephone network. When two people are communicating by a telephone line, both can talk and listen at the same time.

The full-duplex mode is used when communication in both directions is required all the time. The capacity of the channel, however, must be divided between the two directions.

4.B Networks

A network is a set of devices (often referred to as nodes) connected by communication links. A node can be a computer, printer, or any other device capable of sending and/or receiving data generated by other nodes on the network.

Most networks use distributed (as opposed to centralized) processing, in which a task is divided among multiple computers. Instead of one single large machine being responsible for all aspects of a process, separate computers (usually a personal computer or workstation) handle a subset.

4.B.1 Network Criteria

A network must be able to meet a certain number of criteria. The most important of these are performance, reliability, and security.

- * Performance: Performance can be measured in many ways, including transit time and response time. Transit time is the amount of time required for a message to travel from one device to another. Response time is the elapsed time between an inquiry and a response. The performance of a network depends on a number of factors, including the number of users, the type of transmission medium, the capabilities of the connected hardware, and the efficiency of the software. Performance is often evaluated by two networking metrics: throughput and delay. We often need more throughput and less delay. However, these two criteria are often contradictory. If we try to send more data to the network, we may increase throughput but we increase the delay because of traffic congestion in the network.
- * **Reliability:** In addition to accuracy of delivery, network reliability is measured by the frequency of failure, the time it takes a link to recover from a failure, and the network robustness in a catastrophe.
- * Security: Network security issues include protecting data from unauthorized access, protecting data from damage and theft, and implementing policies and procedures for recovery from breaches and data losses.

4.B.2 Network Attributes

- * Type of Connection: A network is two or more devices connected through links. A link is a communications pathway that transfers data from one device to another. For visualization purposes, it is simplest to imagine any link as a line drawn between two points. For communication to occur, two devices must be connected in some way to the same link at the same time. There are two possible types of connections:
 - ♦ **Point-to-Point:** A point-to-point connection provides a dedicated link between two devices, as shown in Fig. 4.2. The entire capacity of the link is reserved for transmission between those two devices. Most point-to-point connections use a wire or cable to connect the two ends, but other options, such as microwave

or satellite links, are also possible. When you change television channels by infrared remote control, you are establishing a point-to-point connection between the remote control and the television control system.

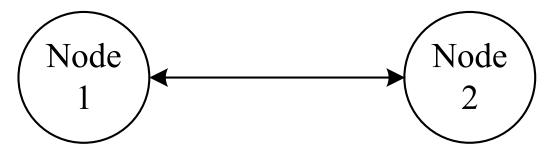


Fig. 4.2: Ponit-to-Point Link

◆ Multipoint: A multipoint connection is one in which more than two devices share a single link. In a multipoint environment, the capacity of the channel is shared, either spatially or temporally. If several devices can use the link simultaneously, it is a spatially shared connection. If users must take turns, it is a time-shared connection.

* Physical Topology:

The term physical Topology refers to the way in which a network is laid out physically. Two or more devices connect to a link; two or more links form a topology. The topology of a network is the geometric representation of the relationship of all the links and linking devices (usually called nodes) to one another. There are four basic topologies possible: mesh, star, bus, and ring.

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