Chapter Six

# Data Communications and Computer Networks

CS211 ICT Fundamentals

Agenda

- Data Communications
- Data transmission
  - Communication channels
  - Types of transmission mode
  - Components of Data communications
  - Applications of Data Comm.

- Computer Networks
  - Classification of networks
  - Networking components (devices, software, …)
  - Distributed systems

Data Communications

- Communications, also called telecommunications, refers to the transfer of data from a transmitter (sender or source) to a receiver across a distance. The term telecommunication means communication at a distance. The data transferred can be voice, sound, images, graphics, video, text, or a combination thereof (multimedia).

| Transmitter | Information channel | Receiver |
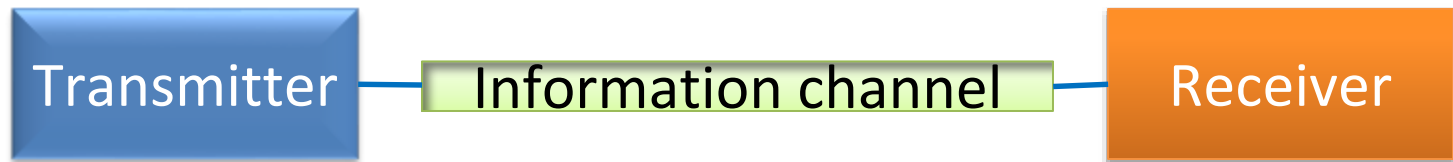
Telecommunications

- Tele (Far) + Communications
- Early telecommunications
  - smoke signals and drums
  - visual telegraphy
    (or semaphore in 1792)
- Telegram and telephone
  - Telegraph (1839)
  - Telephone (1876)
- Radio and television
- Telephony (VoIP)
  - Voice and Data

telegraph-machine

SEMAPHORE
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U   V   W   X

Y   Z   numerals follow   cancel
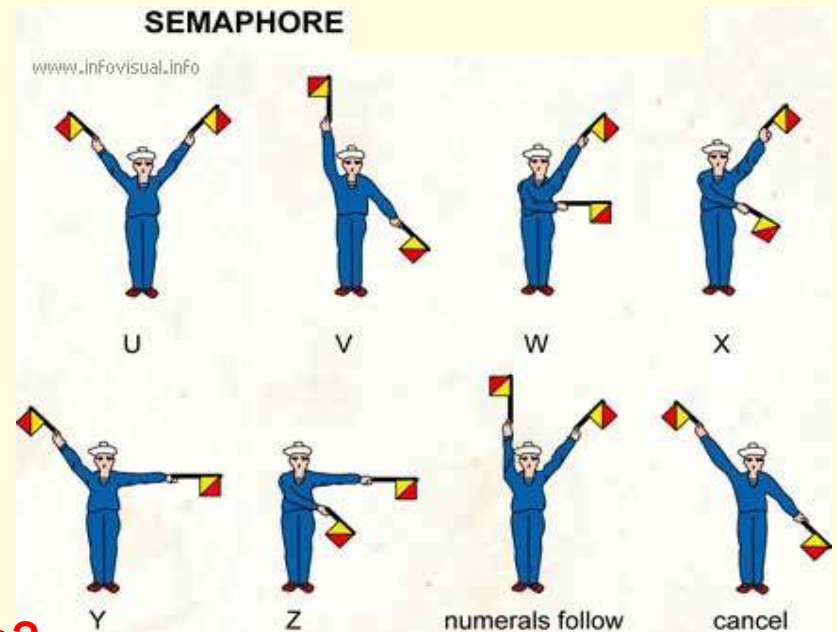
What is the medium here?

Data Communications

- The word data refers to information presented (encoded) in whatever form is agreed upon by the parties creating and using the data.

- Data communications are the exchange of data between two devices via some form of transmission medium such as a wire cable.

| Sender | → | Encoder | ⟨⟩ Message ⟩ | Decoder | → | Receiver |

Communication Channel

Communications Cont…

- Data Communications
  - Transmission of signals
    - Encoding (conversion, encrypting, modulating…), interfacing (modulating,…), signal integrity, multiplexing, compression, etc.
- To be transmitted data must be converted to electrical or electromagnetic signals.
- The methods include electrical signals carried along a conductor, optical signals along an optical fiber, and electromagnetic signals (waves) through space
- The two measure approaches to greater efficiency in using a shared medium for data communication are multiplexing and compression.

Data communication four basic terms

➢ **Data**: A collection of facts in raw forms that become information after processing.

➢ **Signals**: Electric or electromagnetic (radio and light waves) encoding of data.

➢ **Signaling**: Propagation of signals across a communication medium.

➢ **Transmission**: Communication of data achieved by the processing of signals.
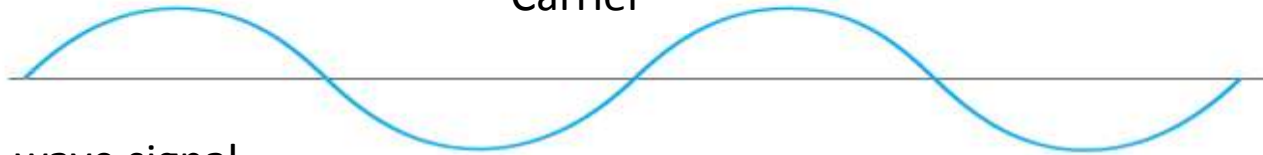
Analogue & Digital Signals

- Telephones, radios, and televisions – The older forms of communications technology – were designed to work with an analog signal.

- An analog signal is a continuous electrical signal in the form of a wave. The wave is called a carrier wave.

- Two characteristics of analog carrier waves that can be altered are frequency and amplitude.

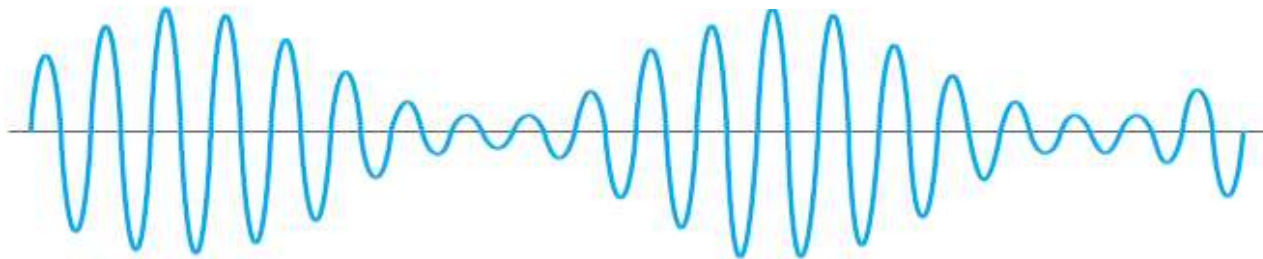- **Examples of analog values: Sound, Temperature, Pressure, Light, Video**
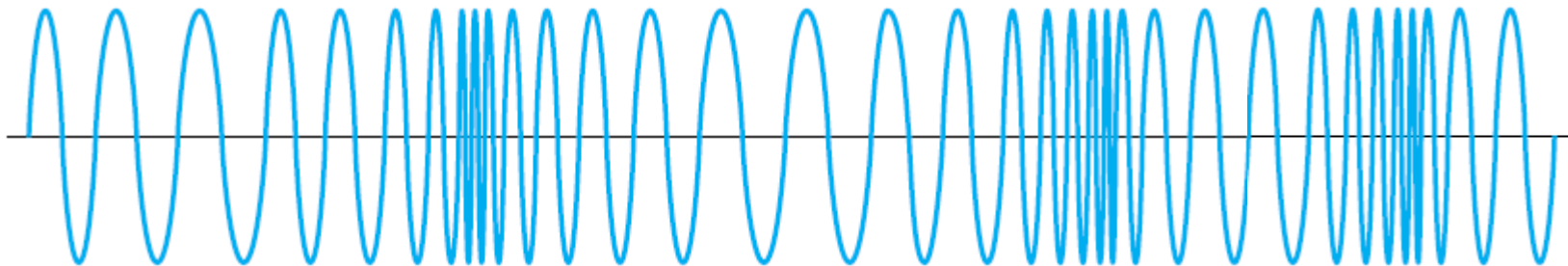
Analogue & Digital Signals Cont.
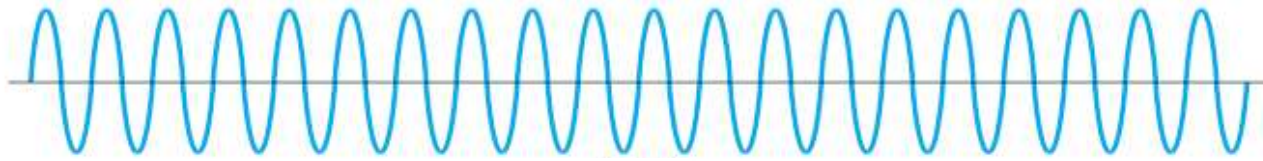
Carrier

Modulating sine-wave signal

Amplitude-modulated wave

Frequency-modulated wave

Processing of signals for transmission

Analogue & Digital Signals

Amplitude
(volts)

❑ Continuous values within some interval
e.g. sound, video

Time
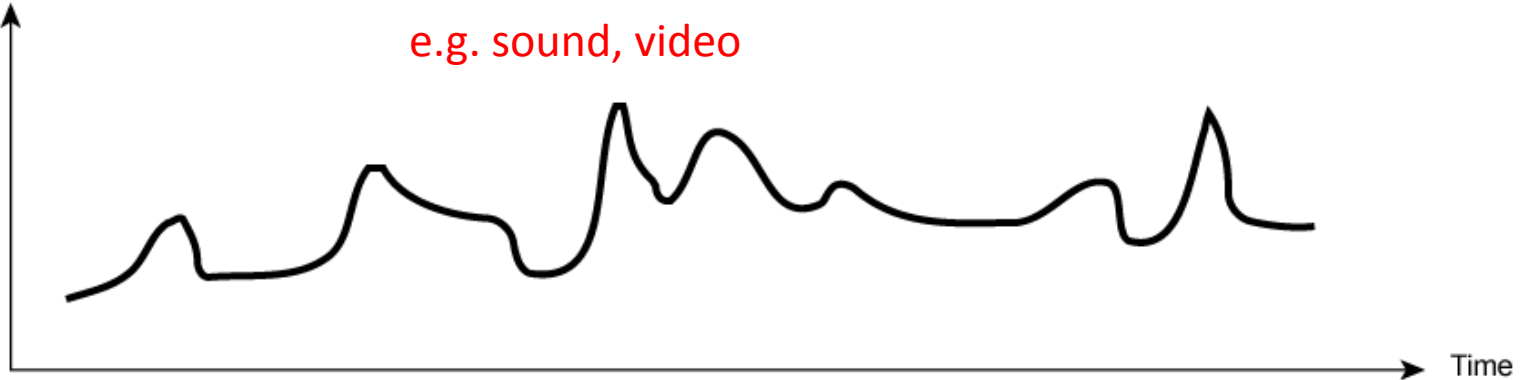
(a) Analog

Amplitude
(volts)

Detecting and correcting distortion due to noise (introduced during transmission) is relatively easy in digital transmission

❑ Discrete values
e.g. text, integers

Time

(b) Digital

The principal advantages of digital signaling are that it is generally cheaper than analog signaling and is less susceptible to noise interference.

Bandwidth of transmission

1. telecommunications: **range of radio frequencies:** a range of radio frequencies (hertz) used in radio or telecommunications transmission and reception.
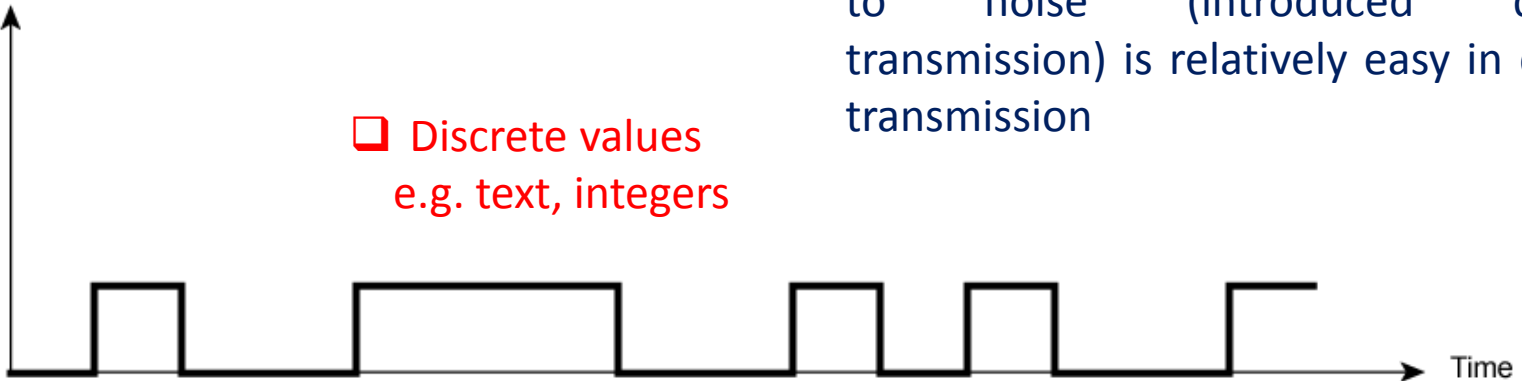
2. computing: **communications capacity:** the capacity of a communications channel, for example, a connection to the Internet, often measured in bits per second (bps).

3. a data **transmission rate**; the maximum amount of information (bits/second) that can be transmitted along a channel. Higher frequency and/or wider bandwidth results in transmission of more data per unit time. (bus speed, serial & parallel ports)

Bandwidth is limited by the type of transmission medium

Digital-to-Analog Conversion

- Required to send digital data over a public telephone channel
  - Also known as *modulation*

(telephone channel)
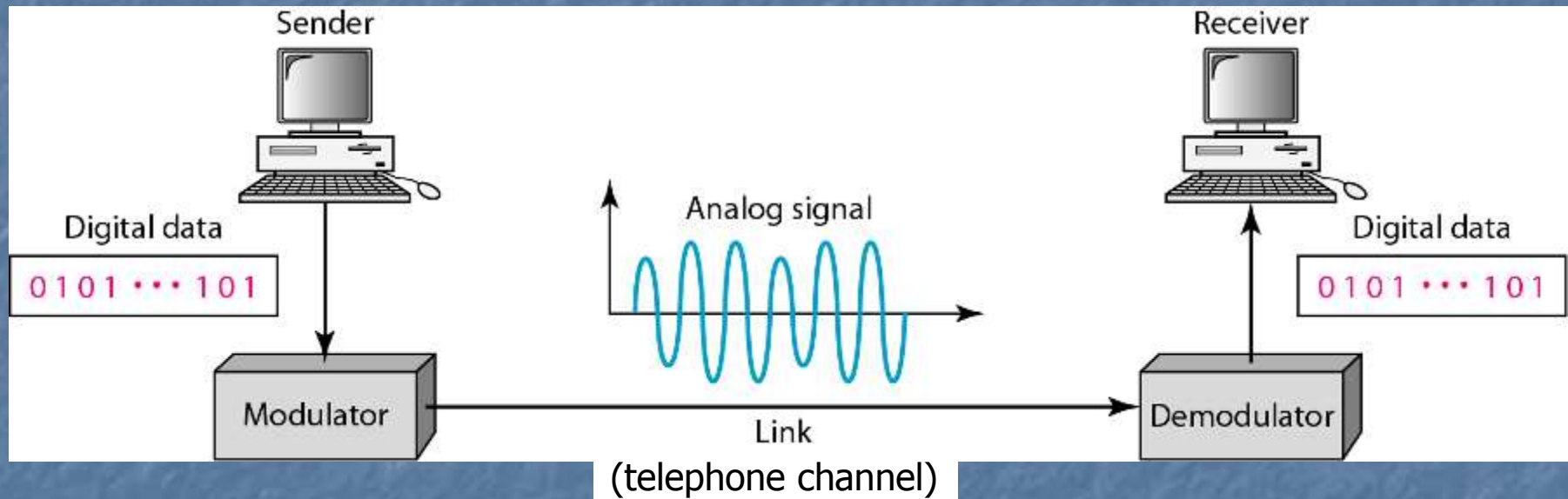
What are telecommuting and virtual offices?
"Move the work instead of the workers"

Devices of Data Communication

- **Video Display Terminals and printing terminals**
  - **I/O devices (microphones, speakers, cameras, etc.)**
- **Modem** – **transmission of data over telephone lines**
- **Interface units** (**modems, multiplexers, codecs**) - **Coordinates various types (aspects) of data transmission and receptions. Thereby greatly increasing the efficiency of data communication.**
- ❑ **An analog communication device always distorts the input and adds noise.**
- ❑ **Digital information doesn't become distorted while being stored, copied, or communicated.**

Data transmission

- **A basic communication system consists of :**

Transmitter	Information channel	Receiver
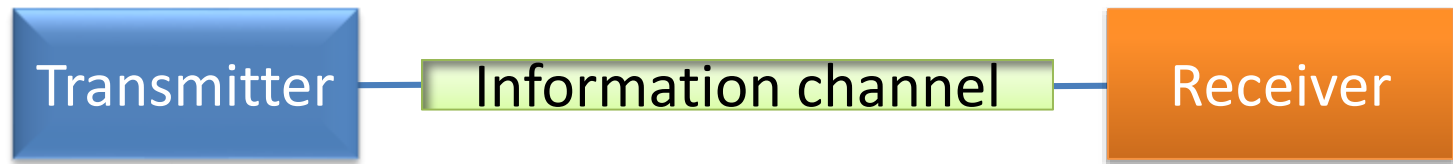
Example - consider a radio broadcast.

- **In this case**
  - the **broadcast tower (antenna)** is the **transmitter,**
  - the **radio** is the **receiver** and
  - the transmission **medium** is **free space.**

A Communications Model

- Source
  - —generates data to be transmitted
- Transmitter (some encoding is done here)
  - —Converts data into transmittable signals
- Transmission System
  - —Carries data
- Receiver (decoding…)
  - —Converts received signal into data
- Destination
  - —Takes incoming data

Simplified Communications Model - Diagram

SourceSystem

Destination System

Source → Trans-mitter → Trans-mission System → Receiver → Destination

(a) General block diagram

Workstation — Modem — Public Telephone Network — Modem — Server
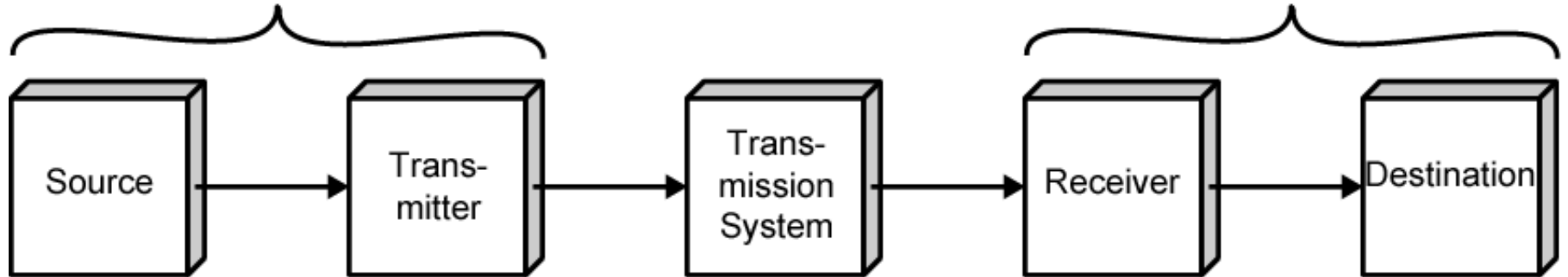
Five Components of Data Communication
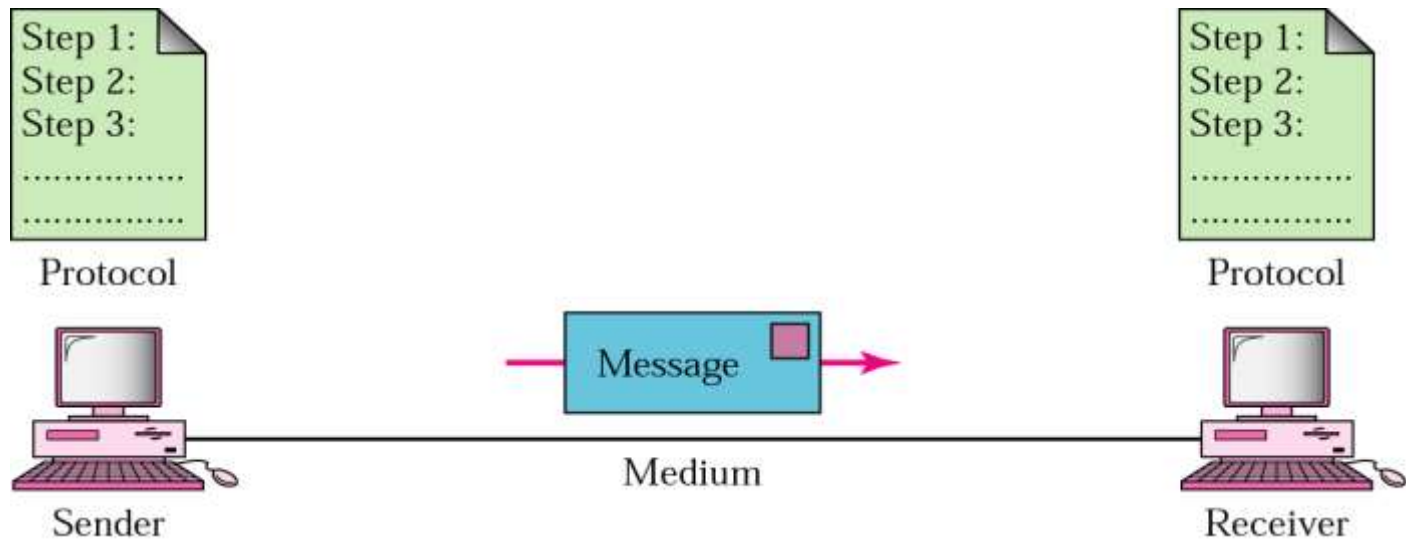
1. Message
2. Sender
3. Receiver
4. Medium
5. Protocol

Communication Protocols

➢ The procedure of data transmission in the form of software is commonly called *protocol*.

➢ *Data communication software* is the software that enables us to communicate with other systems.

➢ The data communication software instructs computer systems and devices as to how exactly data is to be transferred from one place to another.

Data transmission software or protocols (functions)

- The data transmission software or protocols performs the following functions for the efficient and error free transmission of data
  - **Data sequencing**: A long message to be transmitted is broken into smaller packets of fixed size and a unique sequence number is given for every packet.
  - **Data Routing**: It is the process of finding the most efficient route between source and destination before sending the data.

A protocol is synonymous with rule. It consists of a set of rules that govern data communications. **It determines what is communicated, how it is communicated and when it is communicated.** The key elements of a protocol are syntax, semantics and timing.

Cont…

- **Flow control:** enables a receiver to regulate the flow of data from a sender so that the receiver's buffers do not overflow. Regulates the process of sending data between fast sender and slow receiver.

- **Error Control**: Error detecting and recovering is one of the main function of communication software. It ensures that data is transmitted without any error and loss. (retransmit if not ack.)

- **Opening/closing comm. Lines**, message switching, circuit switching, multiple use of comm. lines, …

Transmission upon agreed encoding rules and protocols . Example is TCP/IP; TCP/IP means Transmission Control Protocol/Internet Protocol

Elements of a Protocol (Communications Software)

- **Syntax**
  - **Structure or format of the data blocks**
  - **Indicates how to read the bits - field delineation**

- **Semantics**
  - **Interprets the meaning of the bits**
  - **Knows which fields define what action**
  - **Control information for coordination and error handling**

- **Timing**
  - **When data should be sent and what**
  - **Speed at which data should be sent or speed at   which it is being received.**

A protocol is synonymous with rule. It consists of a set of rules that govern data communications. It determines what is communicated, how it is communicated and when it is communicated. The key elements of a protocol are syntax, semantics and timing.

We can group protocol functions into the following categories:

- Encapsulation (data + control information)
- Fragmentation and reassembly
- Connection control
- Ordered delivery
- Flow control
- Error control
- Addressing
- Multiplexing
- Transmission services (encryption, compression,...)

A human protocol and a computer network protocol
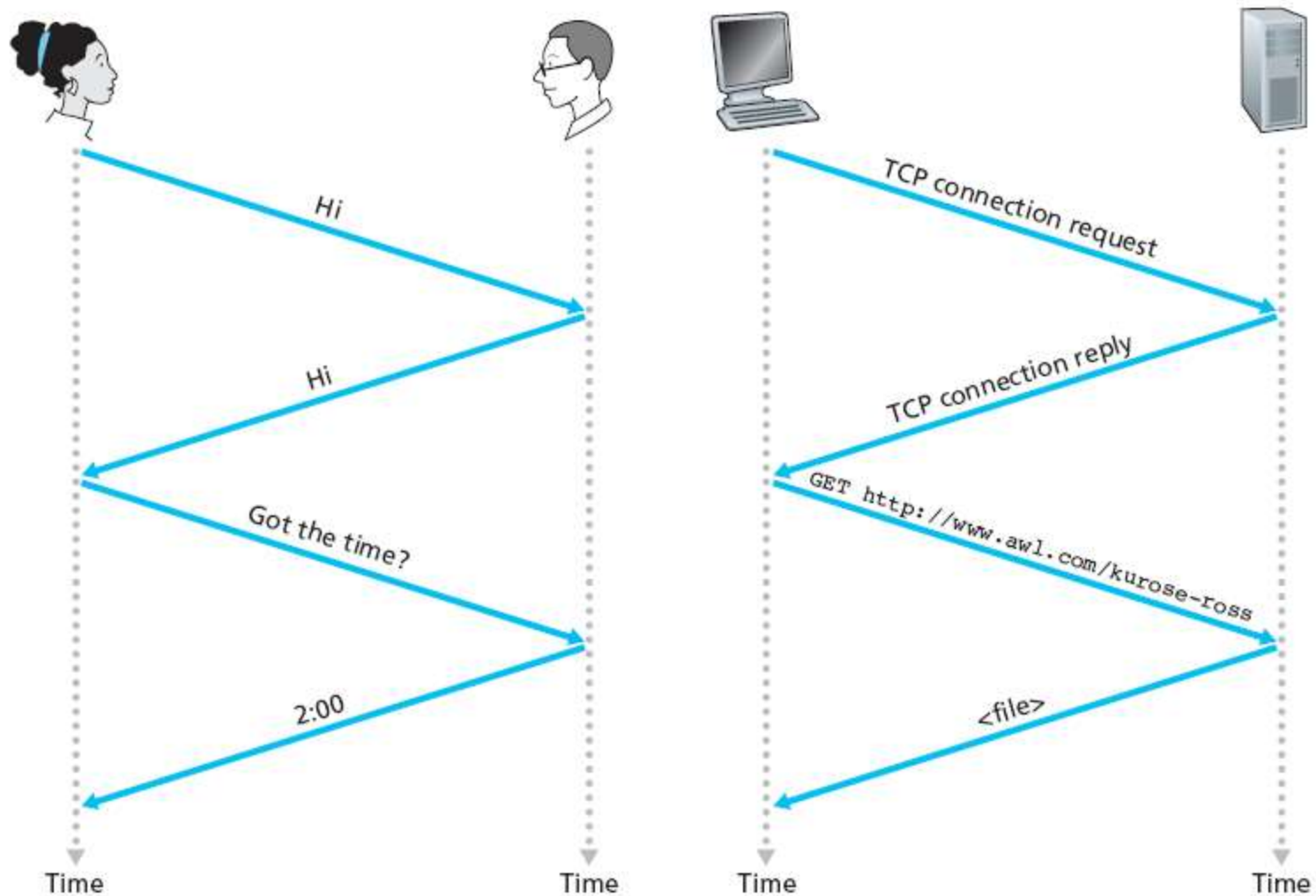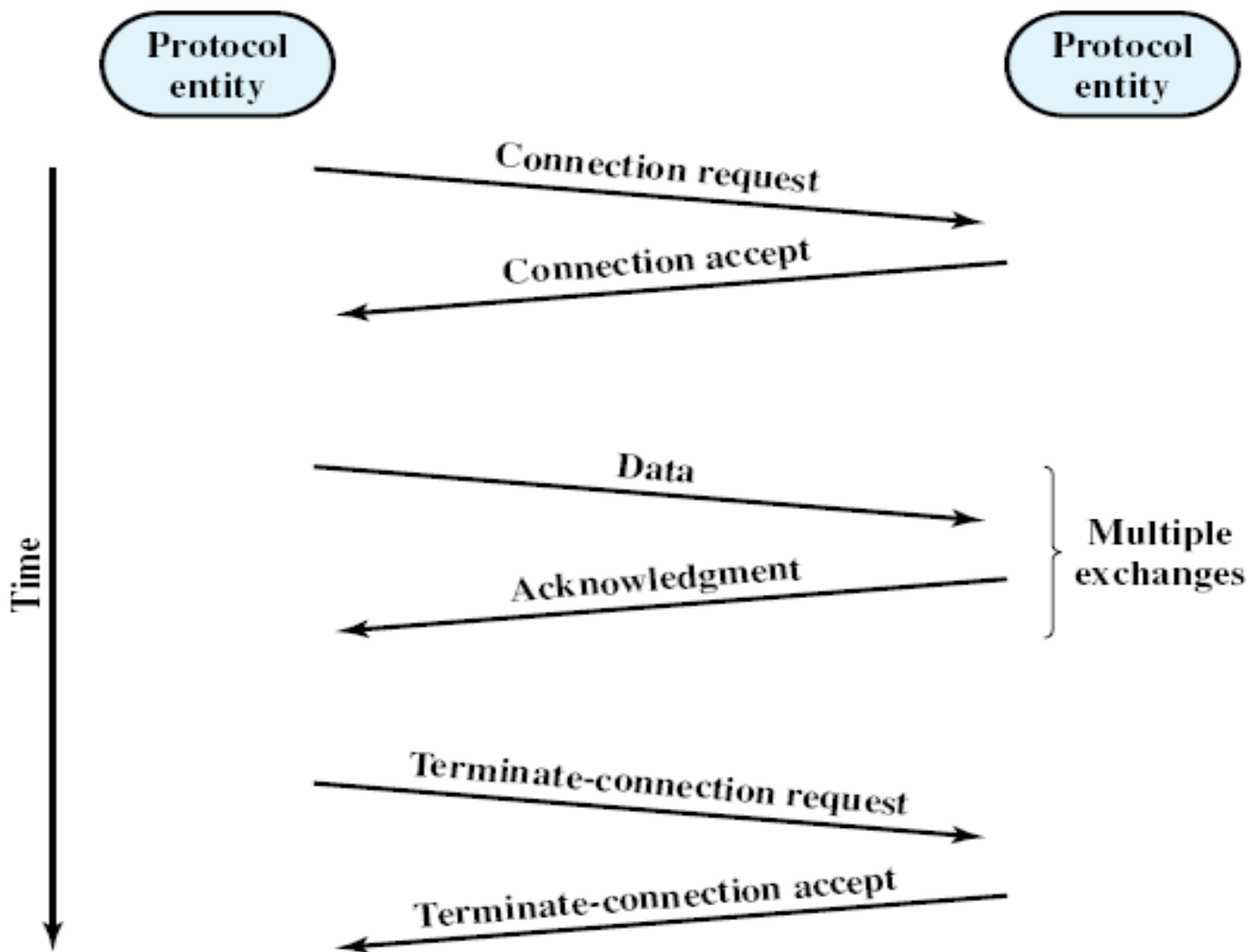
The Parts of a Connection-Oriented Data Transfer
Connection control function of a protocol

Data Transmission Modes

- **Simplex System**
  - **You can only send data from one location to another but you cannot receive. It is one way communication.**

    Ex. Telemetry, Broadcast radio
- **Half Duplex**
  - **You can send/receive but not simultaneously.**

    Ex. Marine Radio, Walky-talky (Police Radio)
- **Full Duplex**
  - **A system that allows communication in both directions simultaneously and synchronously. Use of full-duplex line improves efficiency.**
  - **The medium is carrying signals in both directions at the same time.**

    Ex. Telephone

Direction of data flow
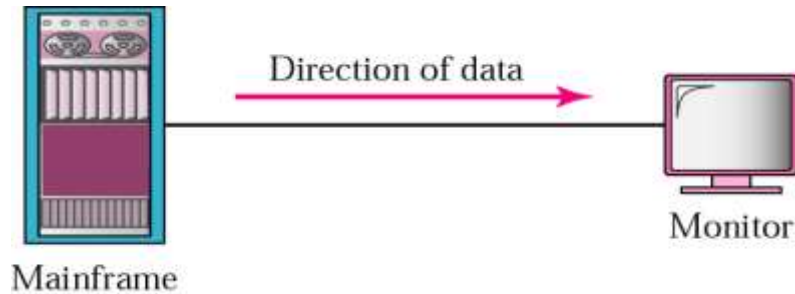
Simplex
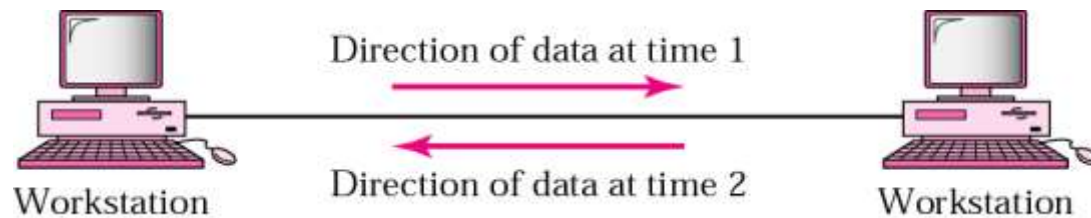
Half Duplex
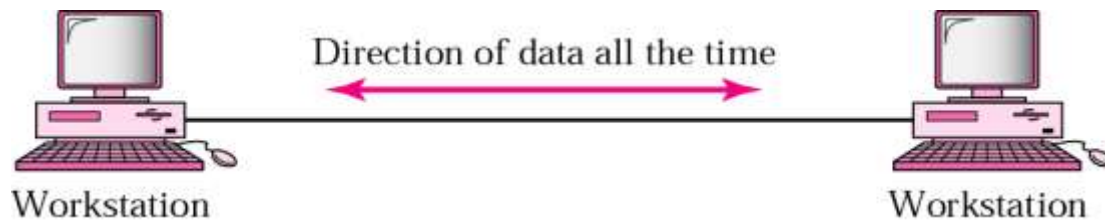
Full Duplex

Communication Channels

- A **channel** is a path between two communication devices

- **Channel capacity**: How much data can be passed through the channel (bits/sec or hz(frequency-range))
  - Also called **channel bandwidth (range of frequencies)**
  - The smaller the pipe the slower the data transfer!
  - **Analog bandwidth of a medium is expressed in hertz;**
  - **Digital bandwidth of a medium is expressed in bits per second.**

- Consists of one or more **transmission media**
  - Materials carrying the signal
  - Two types:
    - Physical: wire or cable   (Guided)
    - Wireless: air (or space)   (Unguided)

Transmission Channel (Media)

- Two main categories:

1.Guided (Physical)
- – Twisted-Pair cables:
  - ➢ Unshielded Twisted-Pair (UTP) cables
  - ➢ Shielded Twisted-Pair (STP) cables
- – Coaxial cables
- – Fiber-optic cables

2.Unguided (Wireless)
- – Wireless transmission, e.g. radio, microwave, infrared, sound, sonar (echolocation finding in air and water)
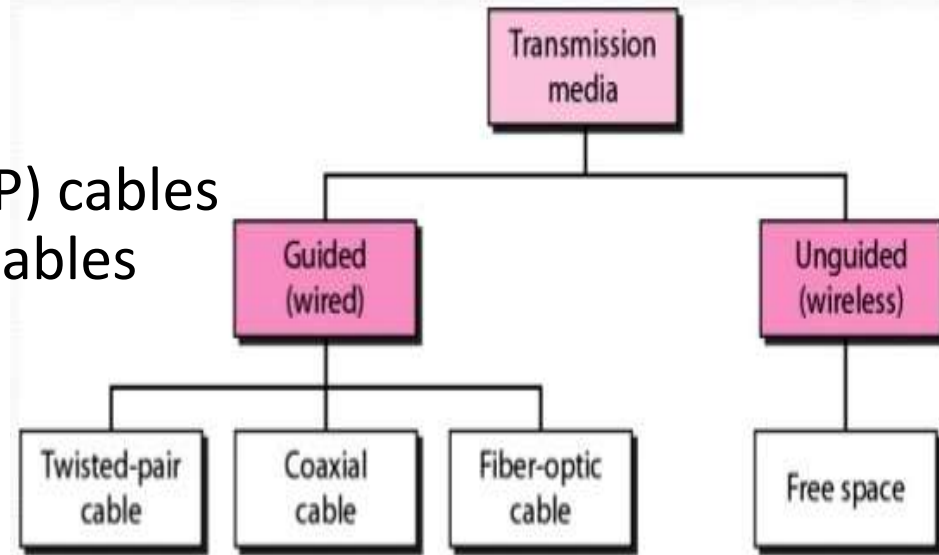
Unguided transmission is propagation through air, vacuum, and seawater.

Physical Media (Guided Channel)

- **A tangible media**
- **Twisted-pair cable:**
  - One or more twisted wires bundled together (why twist?)
  - Made of copper
- **Coax-Cable:**
  - Consists of single copper wire surrounded by three layers of insulating and metal materials
  - Typically used for cable TV
- **Fiber-optics:**
  - Strands of glass or plastic used to transmit light
  - Very high capacity, low noise, small size, less suitable to natural disturbances

Shielded twisted pair (STP)

Unshielded twisted pair (UTP)

8034

COAXIAL CABLE

braided shield   foil shield

center conductor

outer jacket   dielectric

UTP
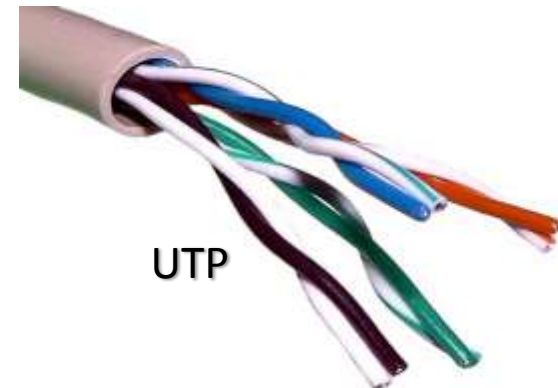
Information channel Cont'd …

- **Guided**
  - **Cable transmission** (Attenuation, Distortion & noise) (reduce the strength & change the form during transmission
    - **Fibre-optics**
      - **10GBPS and greater, long distance**
    - **Coaxial**
      - **10MBPS, 200M - 1KM**
    - **Twisted pair (Shielded Twisted Pair – STP - Cable)**
      - **10 to 1000MBPS, 100M**
    - **Twisted pair (unshielded twisted pair-UTP)**
      - **less interference protection and lower data rate than STP**
      - **Cross talk problem**

Coaxial cable connector

Fiber optic cables

Information channel or media Cont'd ...

Coaxial Cable

A thinnet coaxial cable.
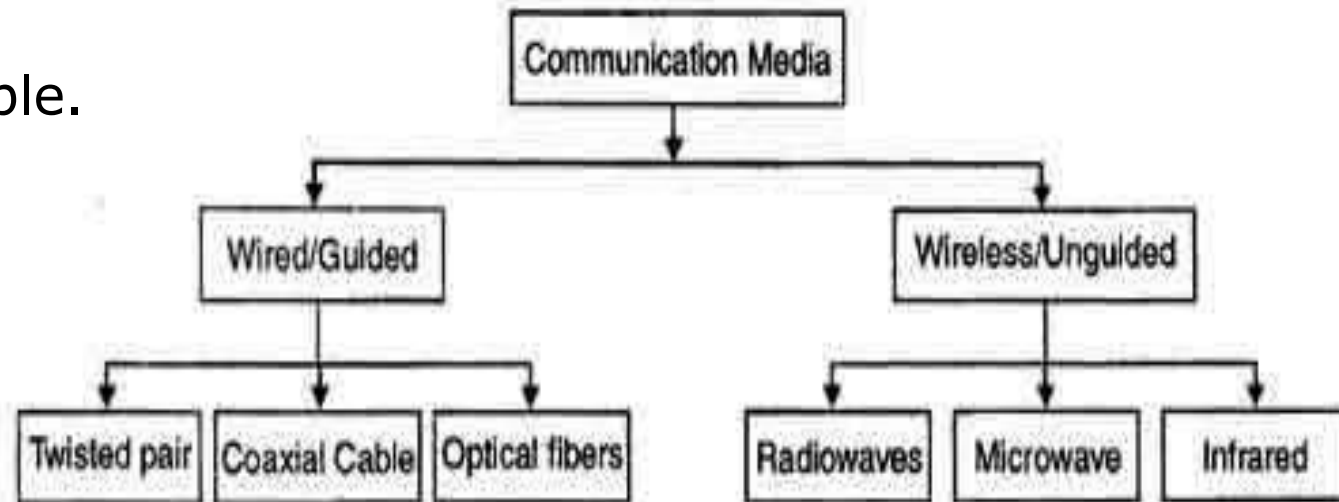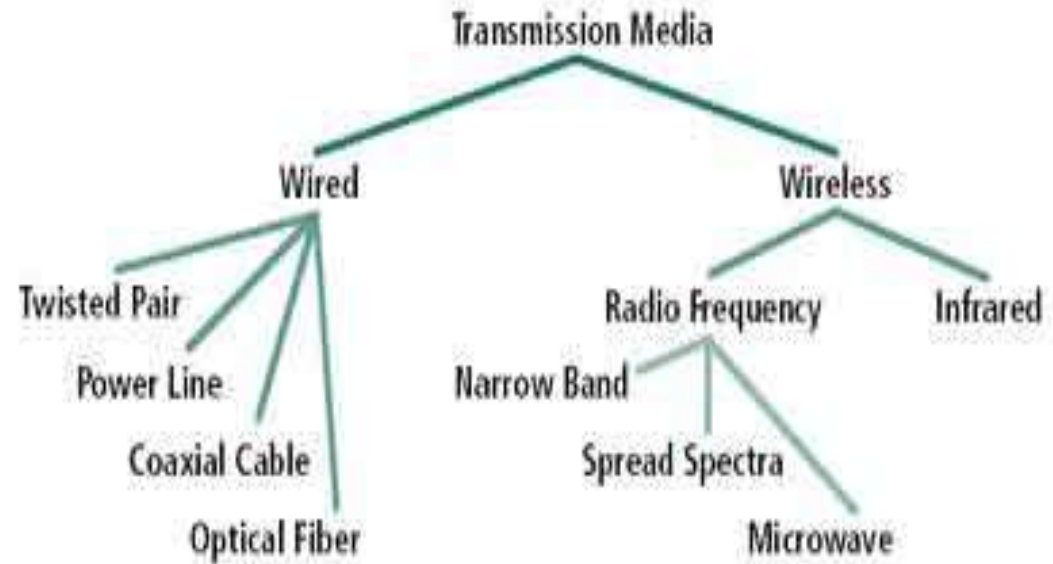
Fiber-Optic Cable

- Fiber-optic cables use light signals for data transmission.

- Either laser or other light producing mechanism, such as light emitting diodes (LEDs), are used as the source of light.

- Using a laser is more dependable, but more costly, so most fiber-optic networks use LEDs as the source of light.

Physical Transmission Media and wireless Infrared Characteristics Comparison

Twisted-Pair	Coaxial	Fiber-Optic	Infrared Light
			Wireless
Low Cost	Moderate Cost	High Cost	Moderate Cost
Best for short distances (330 ft.)	Moderate Distance (3300 ft. – thin) (8250 ft. – thick)	Long Distances (14,256 ft.)	Short distance (75 ft.)
Easy to Install	Professional Installation	Professional Installation	Easy to Install
Low Security	Average Security	High Security	Low Security
Low resistance to interference	Moderate resistance to interference	Very high resistance to interference	Very high resistance to interference

Transmission Media
Data Transmission Rate

Type of Cable and LAN	Transfer Rates
Twisted Pair	
• 10Base-T (Ethernet)	10 Mbps
• 100Base-T (Fast Ethernet)	100 Mbps
• 1000Base-T (Gigabit Ethernet)	1000 Mbps
• Token ring	4 - 16 Mbps
Coaxial Cable	
• 10Base2 (ThinWire Ethernet)	10 Mbps
• 10Base5 (ThickWire Ethernet)	10 Mbps
Fiber-Optic Cable	
• 10Base-F (Ethernet)	10 Mbps
• 100Base-FX (Fast Ethernet)	100 Mbps
• FDDI (Fiber Distributed-Data Interface) token ring	100 Mbps

Wireless channel capacity:

Channel	Transfer Rates
Broadcast radio	Up to 2 Mbps
Microwave radio	45 Mbps
Communications satellite	50 Mbps
Cellular radio	9,600 bps to 14.4 Kbps
Infrared	1 to 4 Mbps

Communication Satellite

- A communication satellite is a microwave relay station placed in outer space.

- In satellite communication, microwave signal is transmitted from a transmitter on earth to the satellite at space.

- The satellite amplifies the weak signal and transmits it back to the receiver.

- The main advantage of satellite communication is that it is a single microwave relay station visible from any point of a very large area.

Microwave Communications
Example: For Telephone Networks
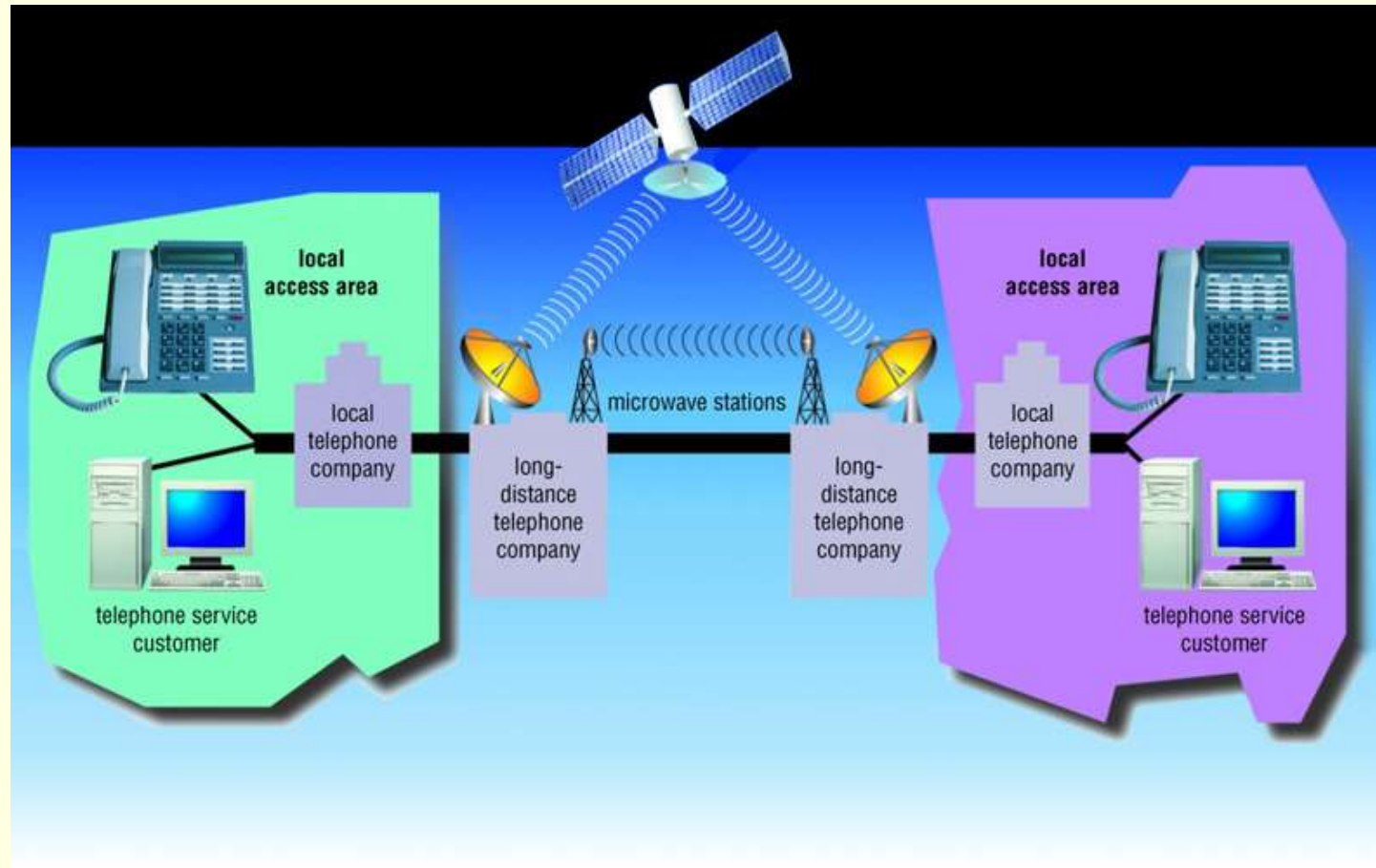
Communication Satellite Cont.

- **Unguided or Wireless**
  - ❖ **Microwave**
  - ❖ **Satellite (Example; GEO or Geostationary)**
    - – **A man made spacecraft, about 23,000 miles (37,030 km) above the earth (speed about 10,000 km/hr?); GEO (geosynchronous earth orbiting); 3 of them are enough to cover the whole world.**
    - – **500 MHZ bandwidth (analog);**
    - – **The data transmission rate is 16 Giga bits per second. They are mostly used to link big metropolitan cities;**
    - – **Receives analog and digital signals, amplifies the signal and retransmits back to earth.**
  - ❑ **How are satellites put into orbit?**

Microwave (Unguided)

- **Microwave** system uses very **high frequency radio signals (10Ghz-1000Ghz)** to transmit **data through space**.

  What is the speed of a radio signal?

- The **transmitter and receiver** of a microwave system should be in **line-of-sight** because the radio signal **cannot bend**.

- With microwave **very long distance** transmission is **not possible without using repeaters (due to line of sight)**.

- In order to overcome the **problem of line of sight** and **power amplification** of weak signals **(due to attenuation), repeaters** are used at intervals of **25 to 30 kilometers** between the transmitting and receiving end.

Electromagnetic Spectrum for Telecommunications
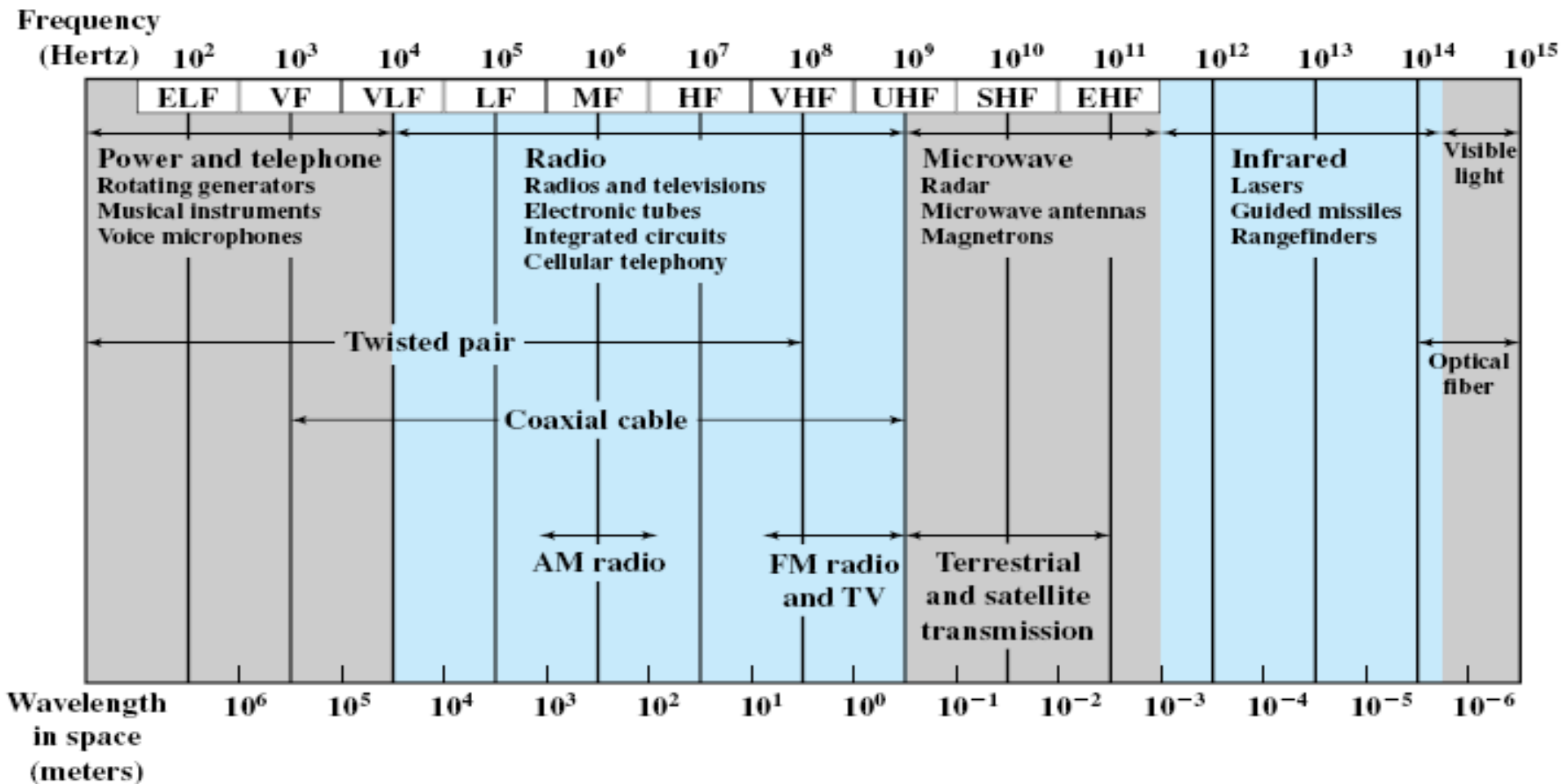
ELF = Extremely low frequency
VF = Voice frequency
VLF = Very low frequency
LF = Low frequency

MF = Medium frequency
HF = High frequency
VHF = Very high frequency

UHF = Ultra high frequency
SHF = Super high frequency
EHF = Extremely high frequency

Wireless Transmission Technologies

- Broadcast Radio (Example SW and AM)
  - Distribute signals through the air over long distance
  - Uses an antenna
  - Typically for stationary locations
  - Can be short range
- Cellular Radio
  - A form of broadcast radio used for mobile communication
  - High frequency radio waves to transmit voice or data
  - Utilizes frequency-reuse
  - Mobile TV phone

TV Network Satellite Uplink

Satellite Relay

Mobile TV Phone

Repeater Tower

Mobile TV Phone

Repeater Tower

Mobile TV Phone
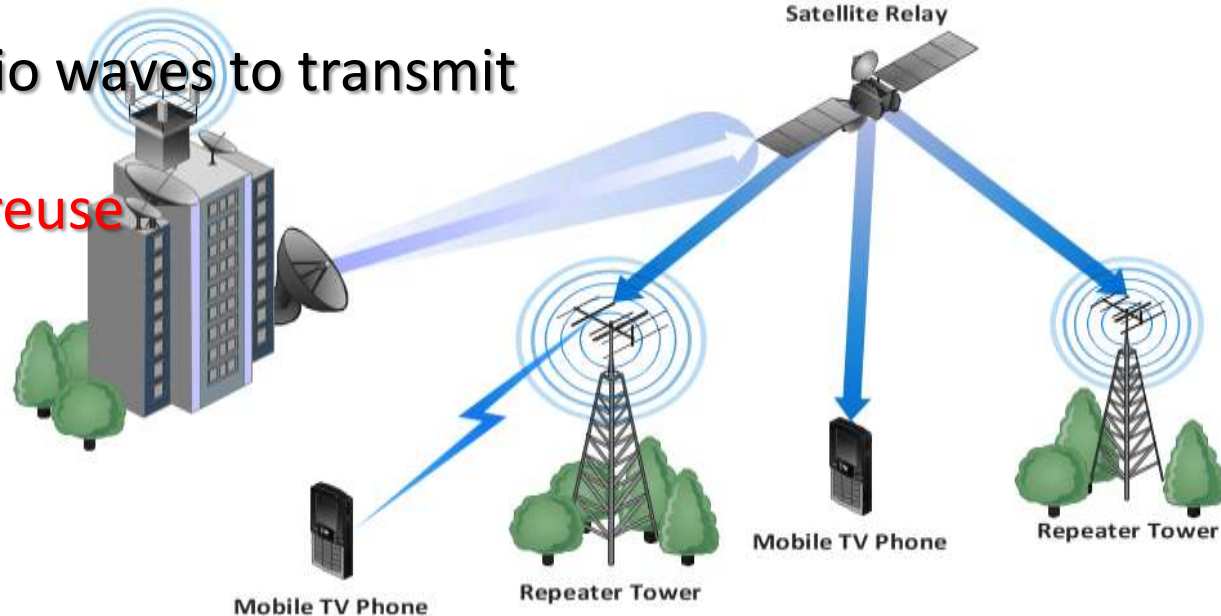
Wireless Transmission Cont'd…

- Microwaves
  - Radio waves providing high speed transmission
  - They are point-to-point (can't be obstructed)
  - Used for satellite communication
- Infrared (IR)
  - Wireless transmission media that sends signals using infrared light- waves; 16Mbps; point-to-point
  - Example, electronic device remote controllers

- Bluetooth: **envisioned for a cable-free world**
  - Radio frequency technology; 2Mbps
  - Can pass over obstacles
  - Can detect other nearby Bluetooth devices
  - The recent Apple wireless earphones
  - Bluetooth operates over a short range, at low power, and at low cost.

Asynchronous Versus Synchronous Transmission

❑ **Asynchronous Transmission:** This method, used with most microcomputers, is also called start-stop transmission.
   ▪ Data is sent one byte (or character) at a time.
   ▪ Not used when very large amount of data must be sent rapidly.
   ▪ Its advantage is that the data can be transmitted whenever and wherever it is convenient for the sender (store and forward delivery) (uses some form of message **switching and packet switching**)

❑ **Synchronous Transmission:** This method, sends data in blocks.
   ▪ Start and stop bit patterns, called sync bytes, are transmitted at the beginning and end of the blocks.
   ▪ This method is rarely used with microcomputers because it is more complicated and more expensive than asynchronous transmission.
   ▪ Appropriate for computer systems that need to transmit very large amount of data. (live transmission)(uses some form of **circuit switching**)

Asynchronous Versus Synchronous Cont...
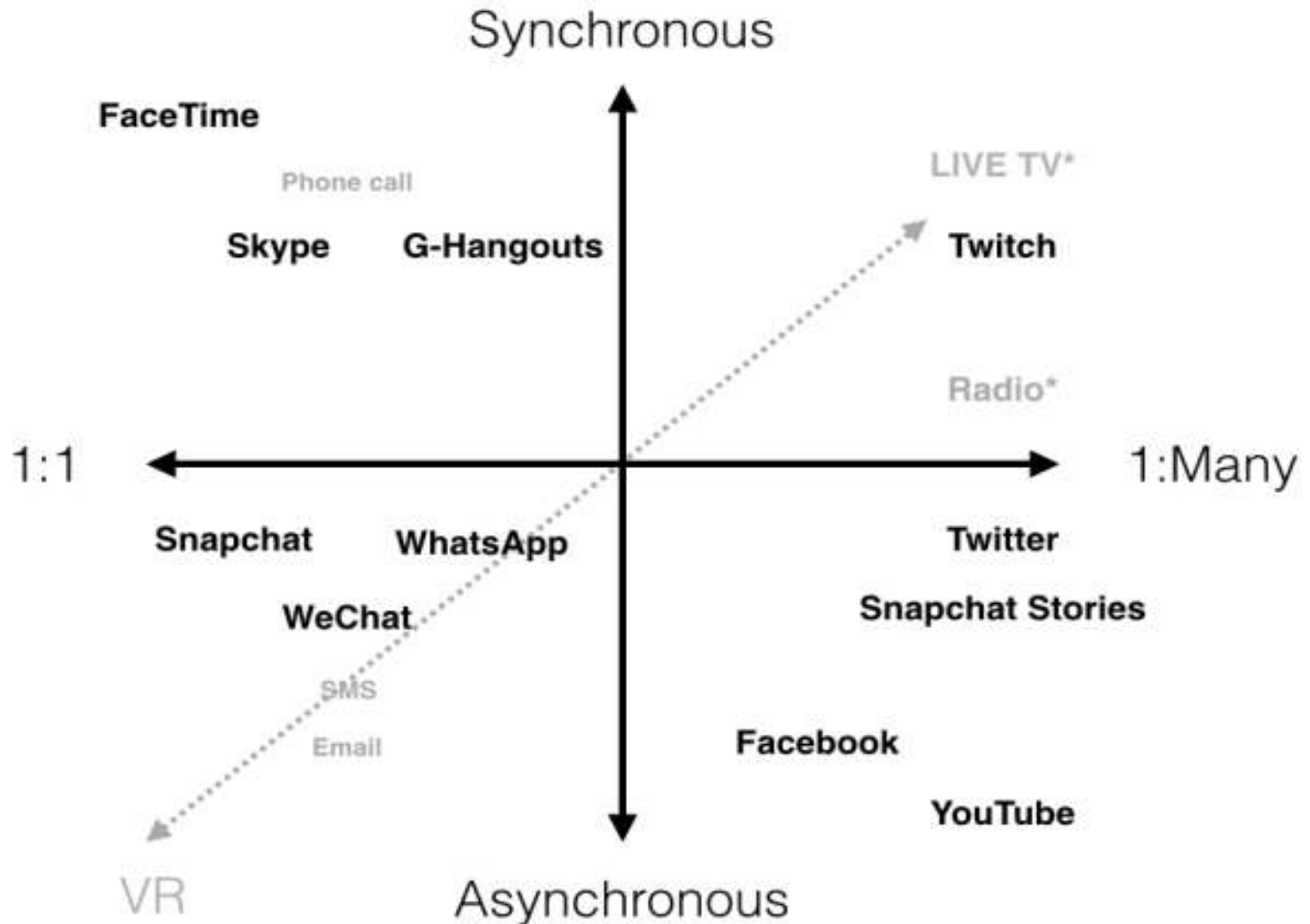
Applications of Data Communications

- E-mail
- Searchable Data (Web Sites)
- E-Commerce
- News Groups
- Internet Telephony (VoIP)
- Video Conferencing
- Chat Groups
- Instant Messengers
- Internet Radio
- Global Positioning System (GPS)
- Groupware
- Discussion Forums

Electronic Fund Transfer, Internet banking; Online education, Telemedicine; Online Employment or job/vacancy; Internet browsing/search engines and so on.

More on Data Communications

- **Requirements of Data comm.**

  – **At least two devices ready to communicate**
  – **A transmission medium**
  – **A set of rules and procedures for proper communication (protocol)**

- **Data communications** refers to the study of **low-level** mechanisms and technologies used to send information across a physical communication medium

- Data communications provides a foundation of concepts on which the rest of networking is built

Layered Tasks in Communications

An example from the everyday life

Sender   Receiver

	Higher Layers	
The letter is written, put in an envelope, and dropped in mailbox.		The letter is picked up, removed from the envelope, and read.

	Middle Layers	
The letter is carried from the mailbox to a post office.		The letter is carried from the post office to the mailbox.

	Lower Layers	
The letter is delivered to a carrier by the post office.		The letter is delivered from the carrier to the post office.

The parcel is carried from the source to the destination.

Hierarchy of Services

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Why layered communication?

- To reduce complexity of communication task by splitting it into several layered small tasks
- Functionality of the layers can be changed as long as the service provided to the layer above stays unchanged
  - makes easier maintenance & updating

- Each layer has its own task
- Each layer has its own <u>protocol</u>

Physical Layer

- What we call low level previously
- Specifies
  - the characteristics of the transmission medium
  - Nature of the signals
  - Data rate

Groups of Layers	OSI Model	Early Internet Model
Application Layers	7. Application Layer	4. Application Layer
	6. Presentation Layer	
	5. Session Layer	
Internetwork Layers	4. Transport Layer	3. Transport Layer
	3. Network Layer	2. Network Layer
Hardware Layers	2. Data Link Layer	1. Hardware Layer
	1. Physical Layer	

Network Models: OSI is Developed by ISO

Each layer has its own protocol

OSI model

Layer	Name	Example protocols
7	Application Layer	HTTP, FTP, DNS, SNMP, Telnet
6	Presentation Layer	SSL, TLS
5	Session Layer	NetBIOS, PPTP
4	Transport Layer	TCP, UDP
3	Network Layer	IP, ARP, ICMP, IPSec
2	Data Link Layer	PPP, ATM, Ethernet
1	Physical Layer	Ethernet, USB, Bluetooth, IEEE802.11

Ethernet (example network protocol) (Hardware Layer)

◆CSMA/CD: Carrier Sense, Multiple Access, Collision Detect. Simple rules!

◆Since Ethernet was designed to be on shared media, with 2 or more users, and the "more" part can be very big (that's the "Multiple Access" part) you have to listen to see if anyone else is talking before you talk (Carrier Sense) and if you and someone else start talking at the same time, notice it (Collision Detect), say "excuse me" stop and try again later. A polite free for all with rules.

Ethernet Protocol Main procedure

- When one computer wanted to send some information, it followed the following algorithm
  - **Make data ready for transmission.**
  - **Is medium idle? If not, wait for a period until it becomes ready.**
  - **Start transmitting.**
  - **Does a collision occur? If so, go to collision detected procedure (wait a couple of periods before retransmitting)**
  - **End successful transmission.**

		MIME			

BGP	FTP	HTTP	SMTP	TELNET	SNMP

TCP	UDP

			ICMP	IGMP	OSPF	RSVP

IP
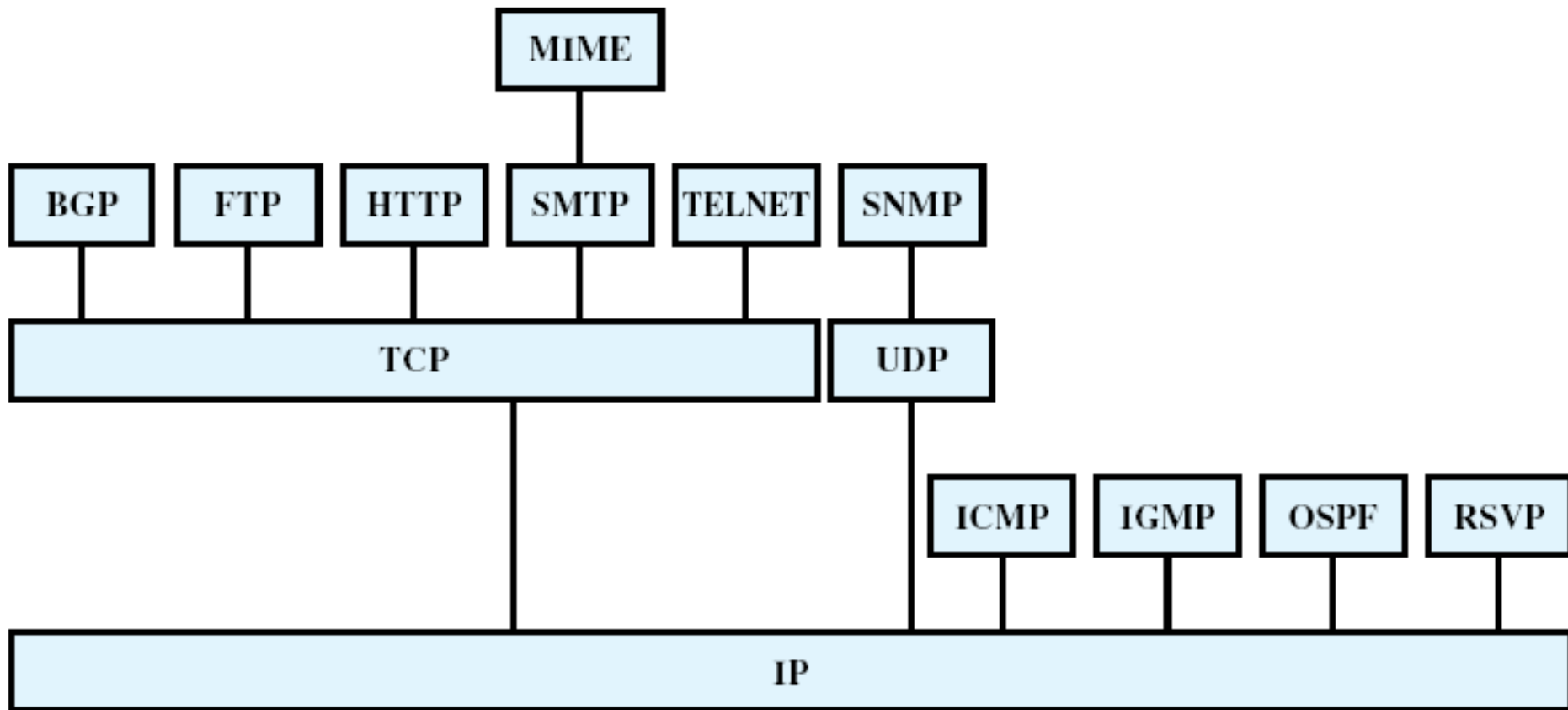
BGP	=	Border Gateway Protocol
FTP	=	File Transfer Protocol
HTTP	=	Hypertext Transfer Protocol
ICMP	=	Internet Control Message Protocol
IGMP	=	Internet Group Management Protocol
IP	=	Internet Protocol
MIME	=	Multipurpose Internet Mail Extension

OSPF	=	Open Shortest Path First
RSVP	=	Resource ReSerVation Protocol
SMTP	=	Simple Mail Transfer Protocol
SNMP	=	Simple Network Management Protocol
TCP	=	Transmission Control Protocol
UDP	=	User Datagram Protocol

Some Protocols in the TCP/IP Protocol Suite