Chapter 1

Introduction

Data Communications

- The term **telecommunication** means communication at a distance.
- The word **data** refers to information presented 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.
- The effectiveness of a data communications system depends on **four** fundamental characteristics:
  - **Delivery**
  - **Accuracy**
  - **Timeliness**
  - **Jitter**

Fundamental Characteristics

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

Data Communication Components

A data communications system has **five** components:

Message:

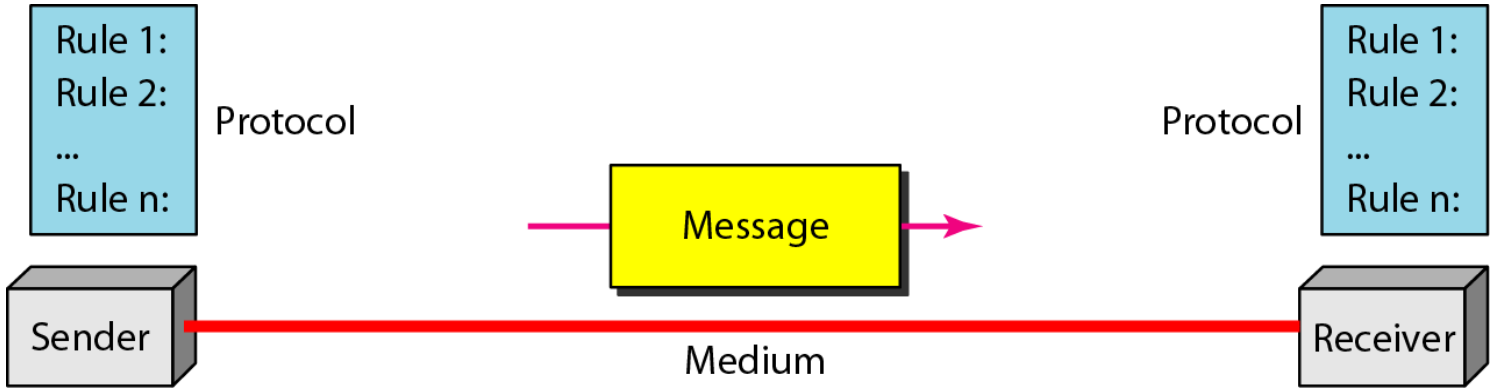
- The message is the information (data) to be communicated.
- Popular forms of information include text, numbers, pictures, audio, and video.

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.



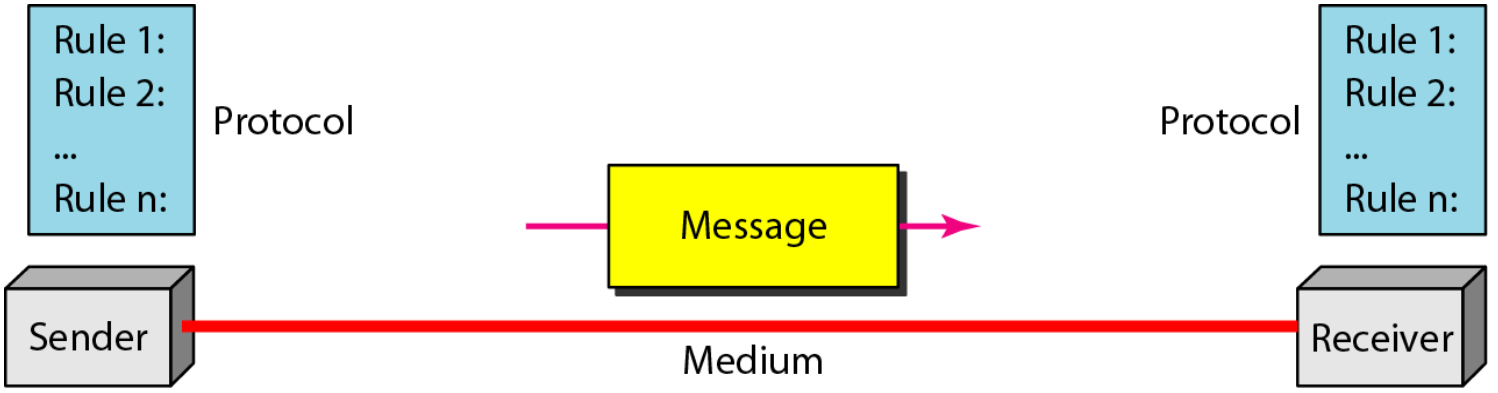
Data Communication Components

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.



Data Representation

Information today comes in 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 (0s or 1s).
- Different sets of bit patterns have been designed to represent text symbols. Each set is called a code.
- 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.

Numbers:

- 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.

Data Representation

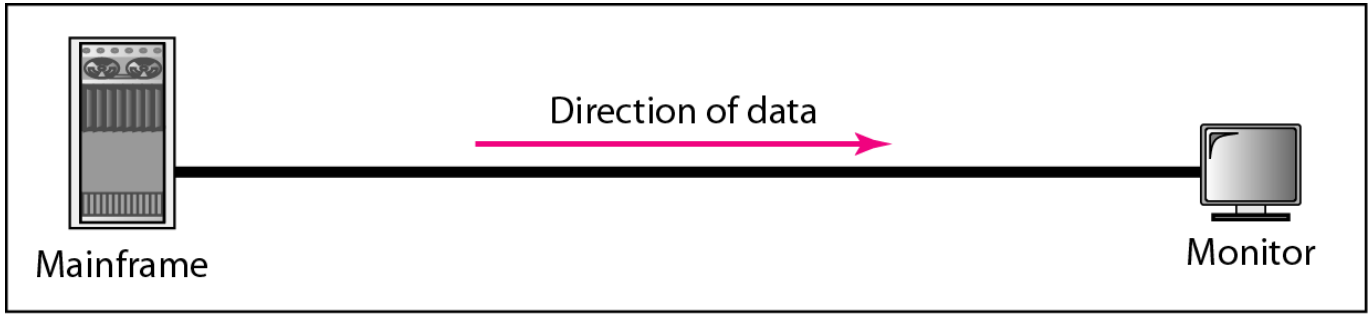
Audio:

- 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:

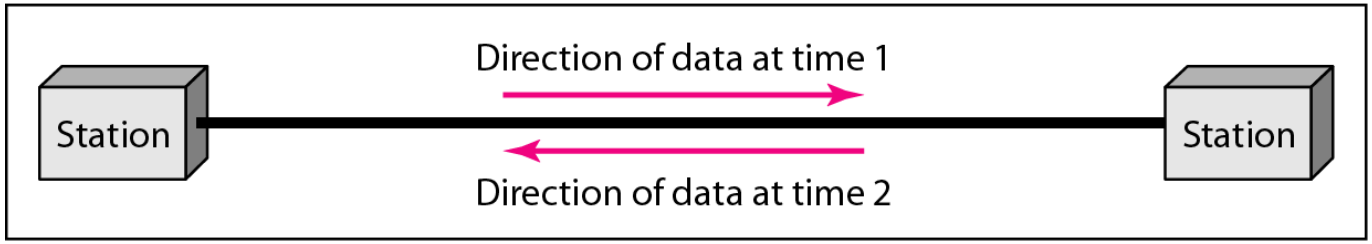
- Video refers to the recording or broadcasting of a picture or movie.
- Video can either be produced as a continuous entity (e.g., by a TV camera), or it can be a combination of images, each a discrete entity, arranged to convey the idea of motion.

Data Flow



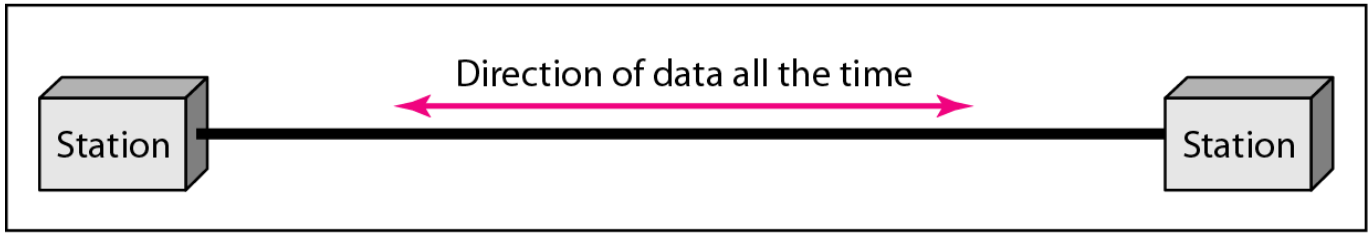
a. Simplex

In **simplex** mode, the communication is unidirectional



b. Half-duplex

In **half-duplex** mode, each station can both transmit and receive, but not at the same time



c. Full-duplex

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

Networks

- A **network** is the interconnection of a set of devices capable of communication.
- In this definition, a device can be a host (or an end system as it is sometimes called) such as a large computer, desktop, laptop, workstation, cellular phone, or security system.
- A device in this definition can also be a connecting device such as a router, which connects the network to other networks, a switch, which connects devices together, a modem (modulator-demodulator), which changes the form of data, and so on.
- These devices in a network are connected using wired or wireless transmission media such as cable or air.
- When we connect two computers at home using a plug-and-play router, we have created a network, although very small.

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.

Network Criteria

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's robustness in a catastrophe.

Security:

- Network security issues include protecting data from unauthorized access, protecting data from damage and development, and implementing policies and procedures for recovery from breaches and data losses.

Physical Structures: Type of Connection

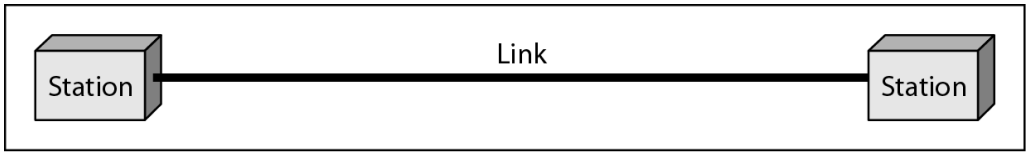
A network is two or more devices connected through links. A link is a communications pathway that transfers data from one device to another

Point-to-Point:

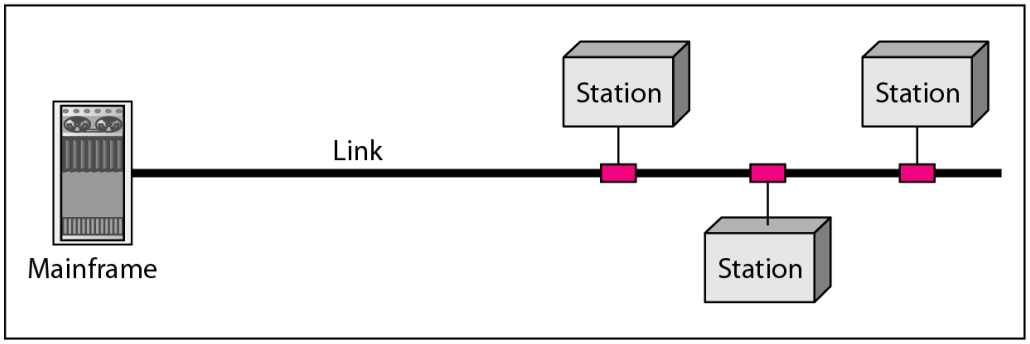
- A point-to-point connection provides a dedicated link between two devices.
- The entire capacity of the link is reserved for transmission between those two devices.

Multipoint:

- A multipoint connection is one in which more than two specific devices share a single link.
- In a multipoint environment, the capacity of the channel is shared, either spatially or temporally.



a. Point-to-point



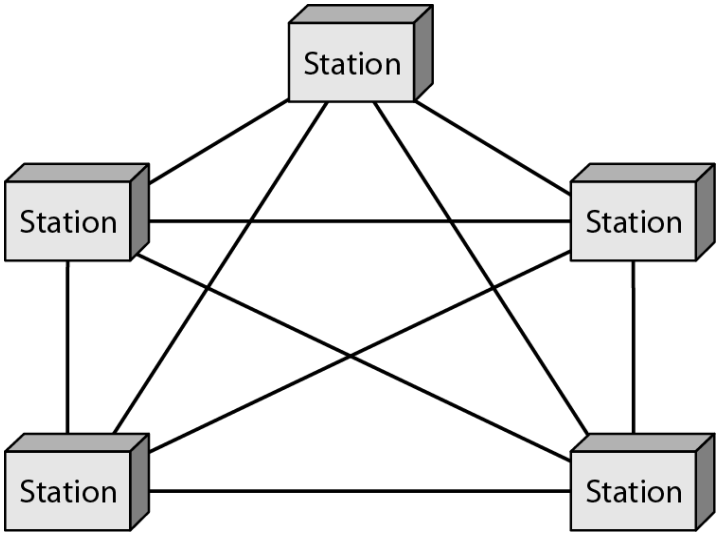
b. Multipoint

Physical Structures: 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 Topology**
  - **Star Topology**
  - **Bus Topology**
  - **Ring Topology**

Physical Topology: Mesh

- In a **mesh topology,** every device has a dedicated point-to-point link to every other device.
- The term dedicated means that the link carries traffic only between the two devices it connects.
- In a mesh topology, we need ***n* (*n* – 1) / 2** duplex-mode links, when number of nodes = ***n***



Physical Topology: Mesh

Several advantages

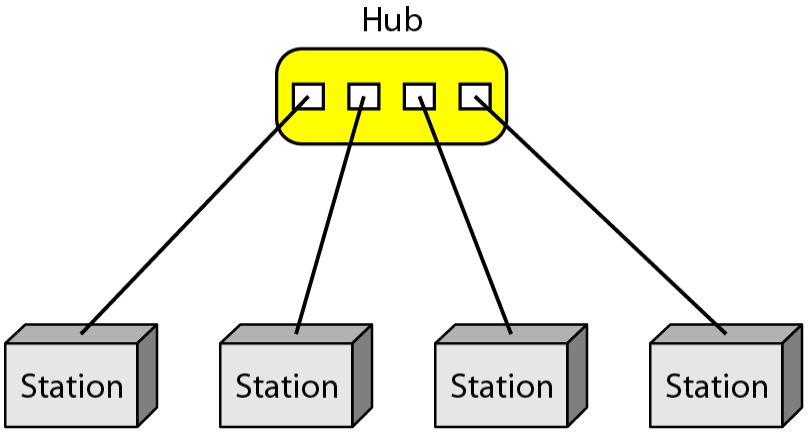
- The use of dedicated links
- A mesh topology is robust
- The advantage of privacy or security
- Point-to-point links make fault identification and fault isolation easy

Main disadvantages

- The amount of cabling and the number of I/O ports required
- Because every device must be connected to every other device, installation and reconnection are difficult.
- The sheer bulk of the wiring can be greater than the available space (in walls, ceilings, or floors) can accommodate.
- The hardware required to connect each link (I/O ports and cable) can be prohibitively expensive.

Physical Topology: Star

- In a **star topology**, each device has a dedicated point-to-point link only to a central controller, usually called a **hub**.
- The devices are not directly linked to one another.
- Unlike a mesh topology, a star topology does not allow direct traffic between devices



Physical Topology: Star

Advantages

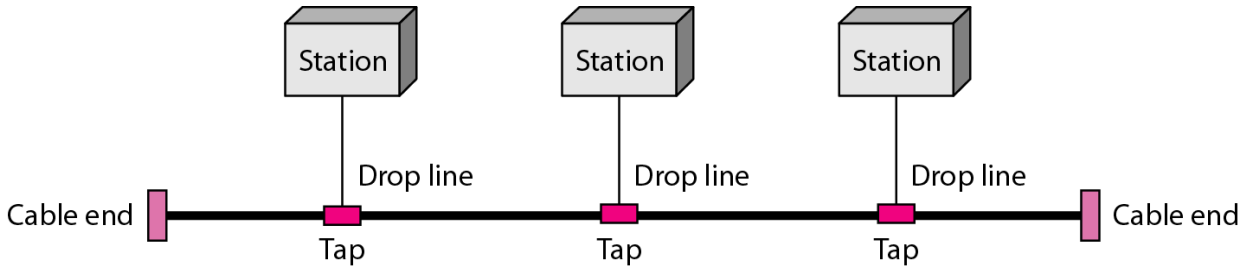
- A star topology is less expensive than a mesh topology.
- Easy to install and reconfigure
- Far less cabling needs to be housed
- Robustness: If one link fails, only that link is affected.

Disadvantage

- The dependency of the whole topology on one single point, the hub. If the hub goes down, the whole system is dead.

Physical Topology: Bus

- A **bus topology,** is multipoint. One long cable acts as a **backbone** to link all the devices in a network



Physical Topology: Bus

Advantages

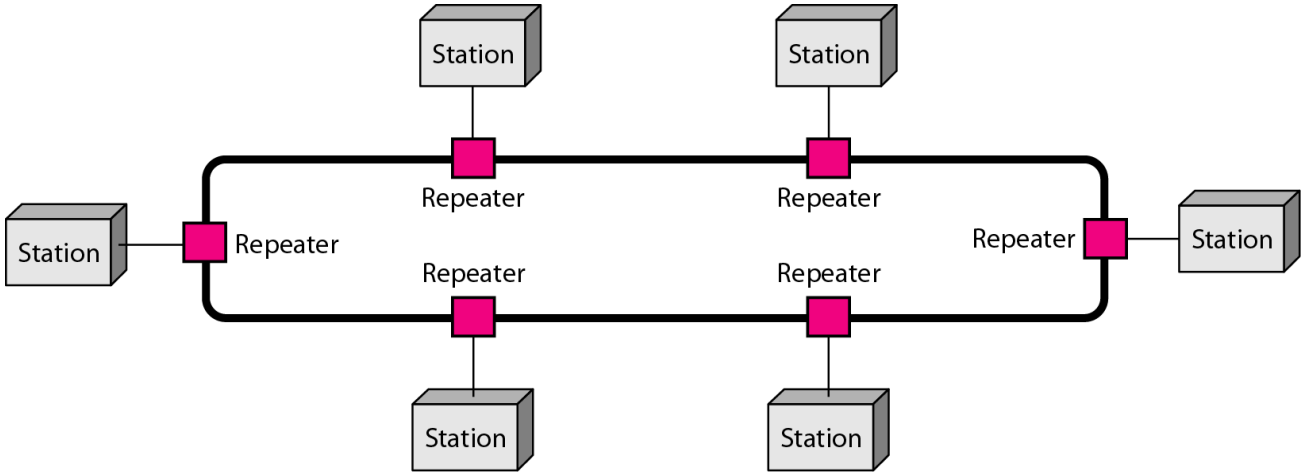
- Ease of installation
- Backbone cable can be laid along the most efficient path, then connected to the nodes by drop lines of various lengths.

Disadvantages

- Difficult reconnection and fault isolation
- Signal reflection at the taps can cause degradation in quality
- A fault or break in the bus cable stops all transmission, even between devices on the same side of the problem. The damaged area reflects signals back in the direction of origin, creating noise in both directions.

Physical Topology: Ring

- In a **ring topology,** each device has a dedicated point-to-point connection with only the two devices on either side of it.
- A signal is passed along the ring in one direction, from device to device, until it reaches its destination.
- Each device in the ring incorporates a repeater.
- When a device receives a signal intended for another device, its repeater regenerates the bits and passes them along



Physical Topology: Ring

Advantages

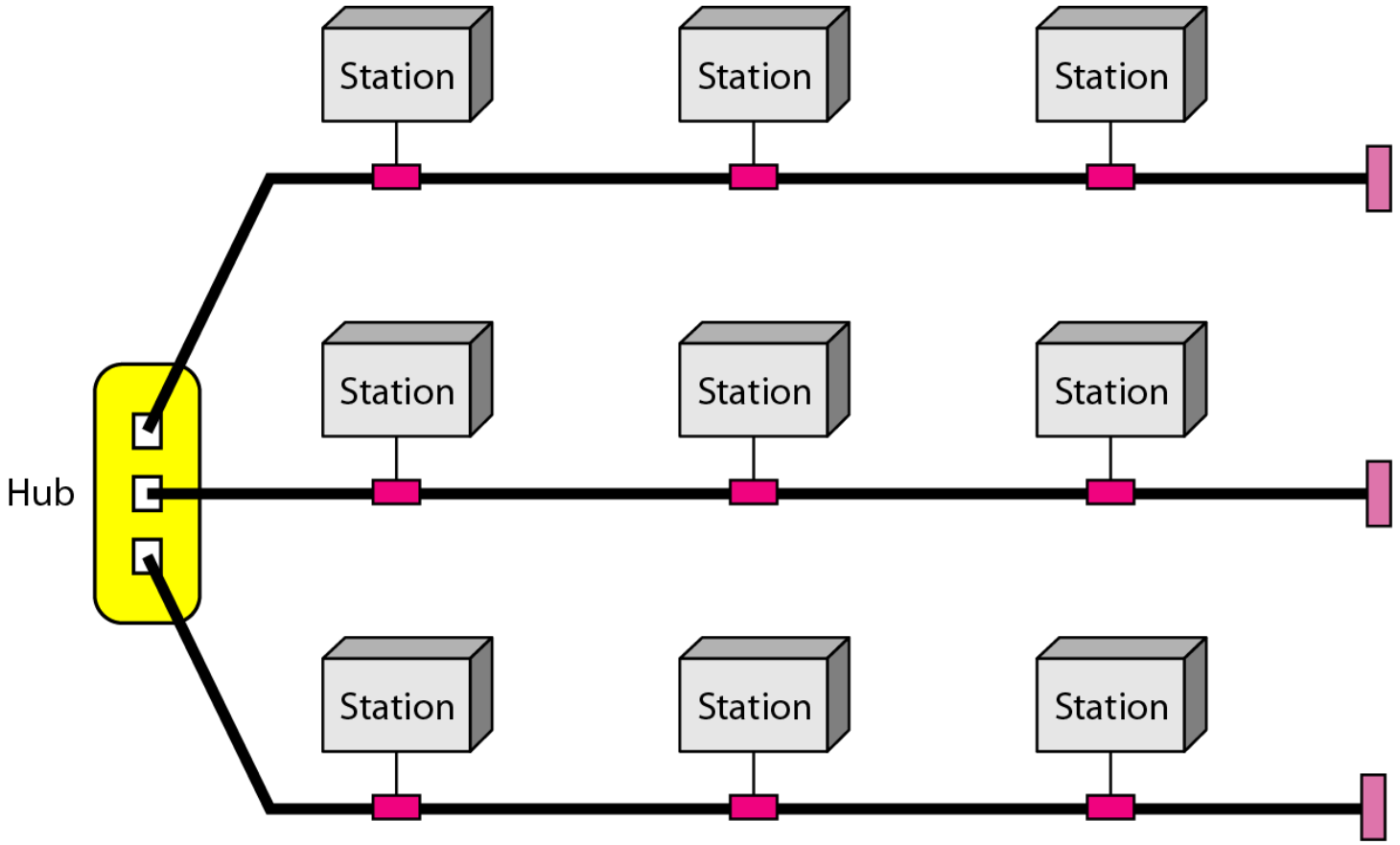
- To add or delete a device requires changing only two connections.
- Fault isolation is simplified.
- A signal is circulating at all times. If one device does not receive a signal within a specified period, it can issue an alarm.

Disadvantages

- Unidirectional traffic
- In a simple ring, a break in the ring (such as a disable station) can disable the entire network.
- This weakness (above) can be solved by using a dual ring or a switch capable of closing off the break.

Physical Topology: Hybrid

A **hybrid topology**: a star backbone with three bus networks

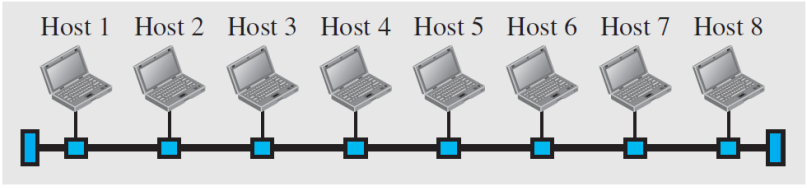


Network Types

- The criteria of distinguishing one type of network from another is difficult and sometimes confusing.
- We use a few criteria such as size, geographical coverage, and ownership to make this distinction.
- Two types of Networks:
  - **Local Area Network (LAN)**
  - **Wide Area Network (WAN)**

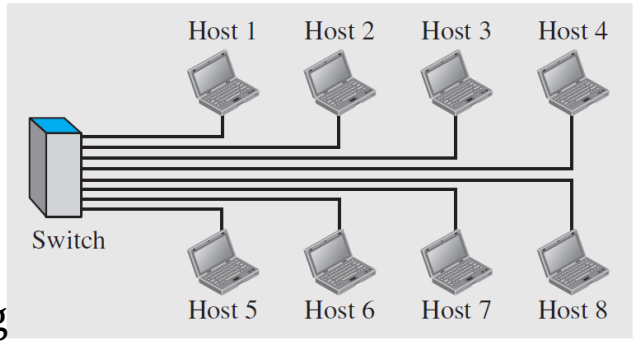
Local Area Network (LAN)

- A **local area network** (**LAN**) is usually privately owned and connects some hosts in a single office, building, or campus.
- Depending on the needs of an organization, a LAN can be as simple as two PCs and a printer in someone's home office, or it can extend throughout a company and include audio and video devices.
- Each host in a LAN has an identifier, an address, that uniquely defines the host in the LAN.
- A packet sent by a host to another host carries both the source host's and the destination host's addresses.



a. LAN with a common cable (past)

- In the past, all hosts in a network were connected through a common cable, which meant that a packet sent from one host to another was received by all hosts.
- The intended recipient kept the packet; the others dropped the packet.
- Today, most LANs use a smart connecting switch, which is able to recognize the destination address of the packet and guide the packet to its destination without sending it to all other hosts.



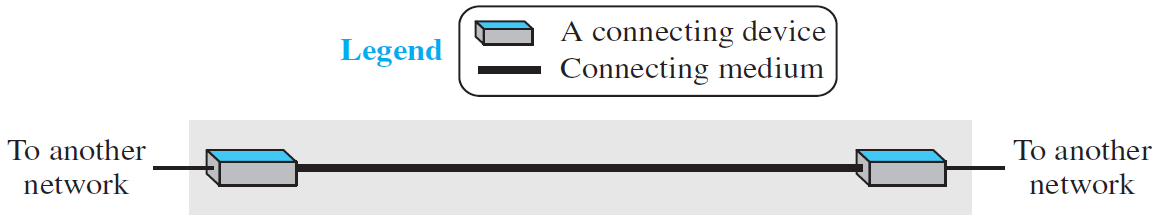
b. LAN with a switch (today)

Wide Area Network (WAN)

- A wide area network (WAN) is also an interconnection of devices capable of communication.
- However, there are some differences between a LAN and a WAN.
- A LAN is normally limited in size, spanning an office, a building, or a campus; a WAN has a wider geographical span, spanning a town, a state, a country, or even the world.
- A LAN interconnects hosts; a WAN interconnects connecting devices such as switches, routers, or modems.
- A LAN is normally privately owned by the organization that uses it.
- A WAN is normally created and run by communication companies and leased by an organization that uses it.
- We see two distinct examples of WANs today:
  - **Point-to-point WANs**
  - **Switched WANs.**

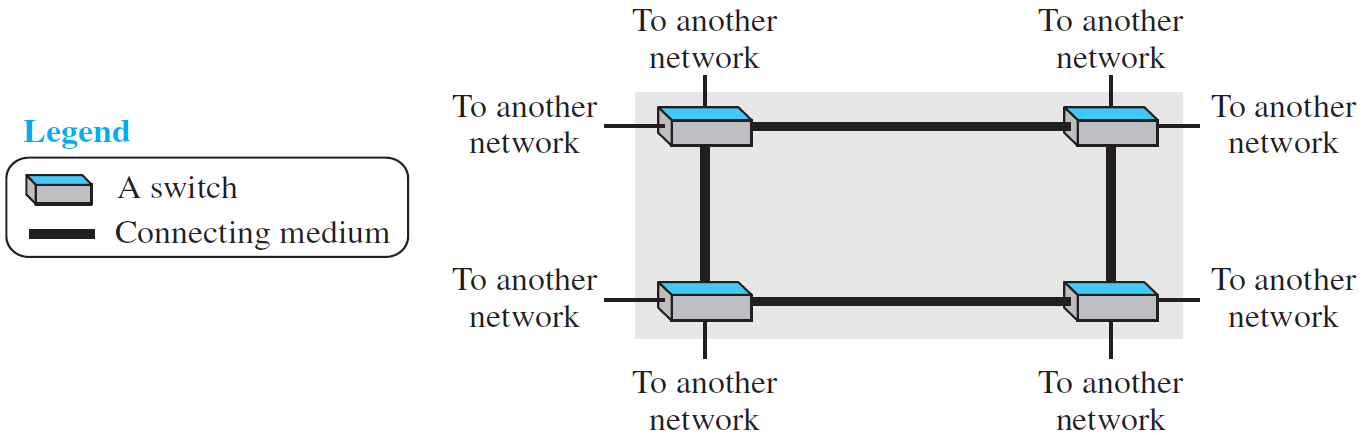
Point-to-point WAN

A point-to-point WAN is a network that connects two communicating devices through a transmission media (cable or air).



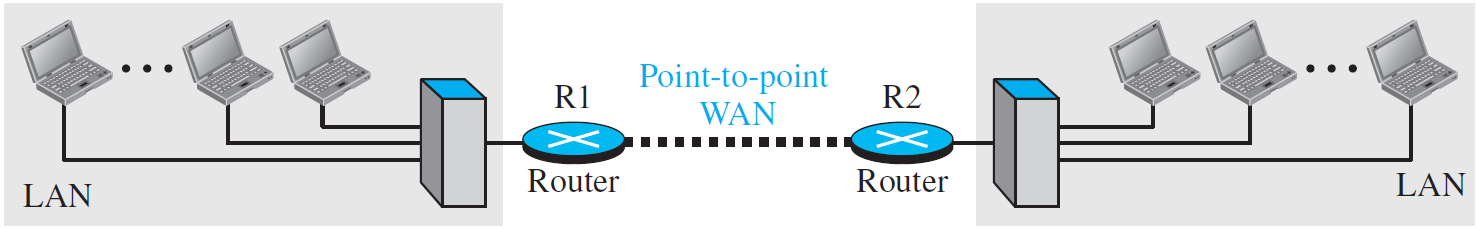
Switched WAN

- A switched WAN is a network with more than two ends.
- A switched WAN, is used in the backbone of global communication today.
- We can say that a switched WAN is a combination of several point-to-point WANs that are connected by switches.



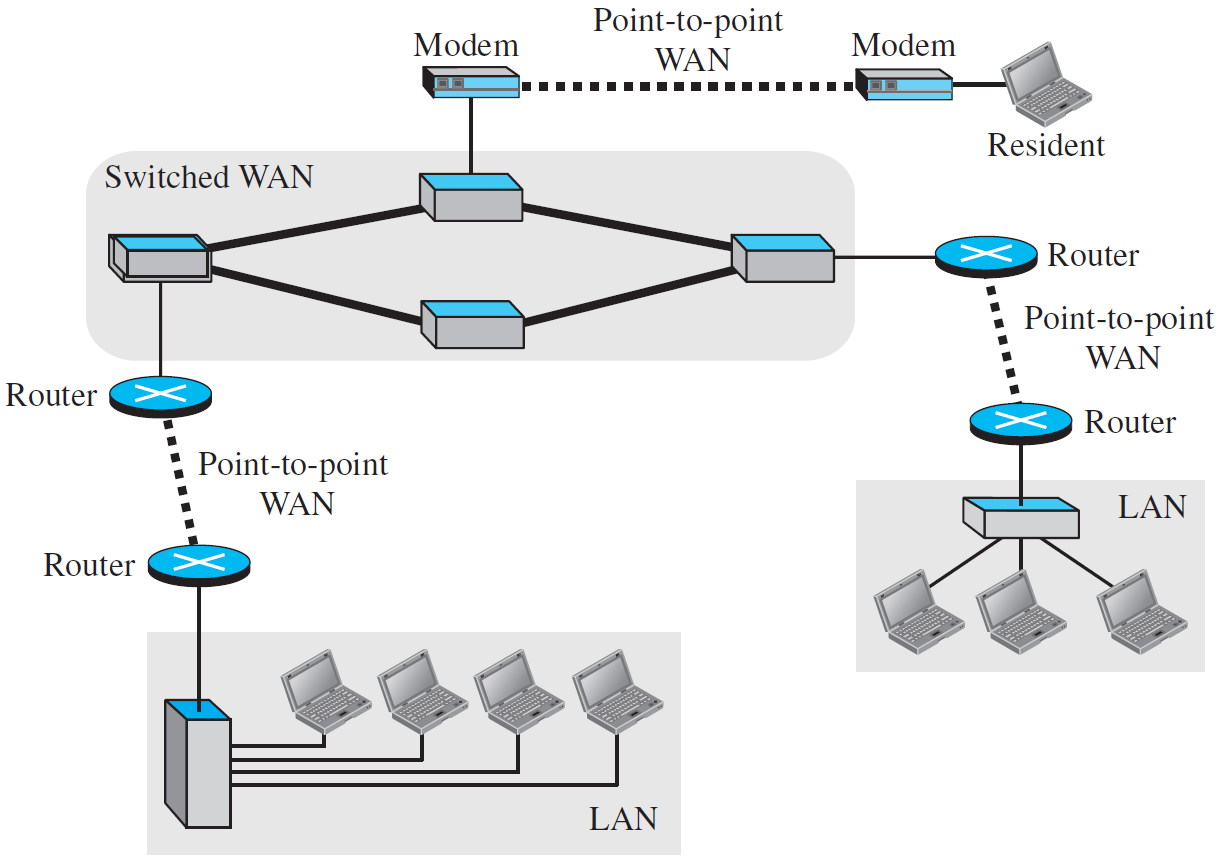
Internetwork

- It is very rare to see a LAN or a WAN in isolation; they are connected to one another
- When two or more networks are connected, they make an **internetwork or internet.**
- Assume that an organization has two offices, one on the east coast and the other on the west coast.
- Each office has a LAN that allows all employees in the office to communicate with each other.
- To make the communication between employees at different offices possible, the management leases a point-to-point dedicated WAN from a service provider, such as a telephone company, and connects the two LANs.
- Now the company has an internetwork, or a private internet communication between offices is now possible.



Internetwork

A heterogeneous network made of four WANs and three LANs

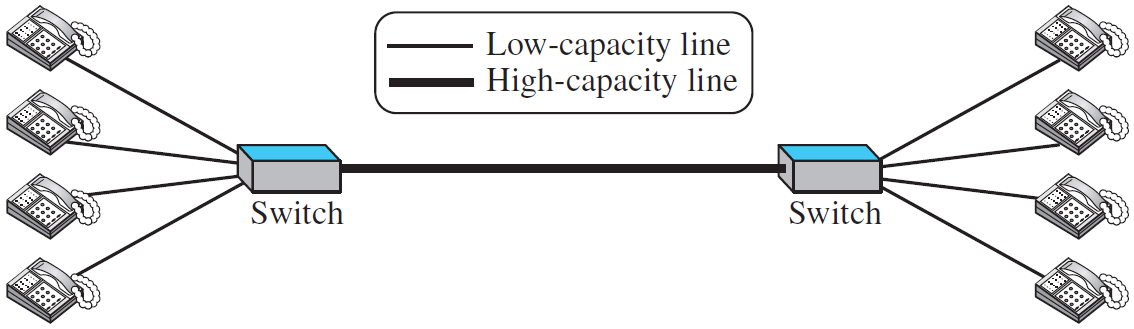


Switching

- An internet is a switched network in which a switch connects at least two links together.
- A switch needs to forward data from a network to another network when required.
- The two most common types of switched networks are:
  - **Circuit-switched network**
  - **Packet-switched networks**

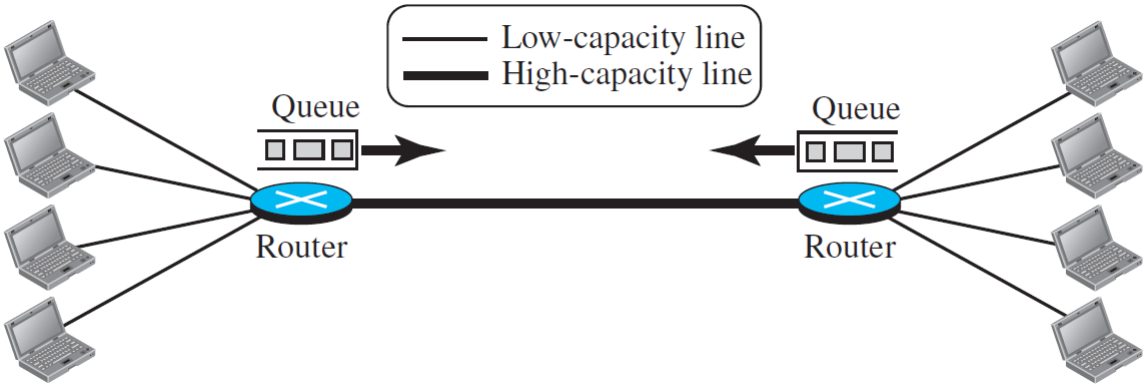
Circuit-Switched Network

- In a circuit-switched network, a dedicated connection, called a circuit, is always available between the two end systems.
- The switch can only make it active or inactive.
- We have used telephone sets instead of computers as an end system because circuit switching was very common in telephone networks in the past, although part of the telephone network today is a packet-switched network.



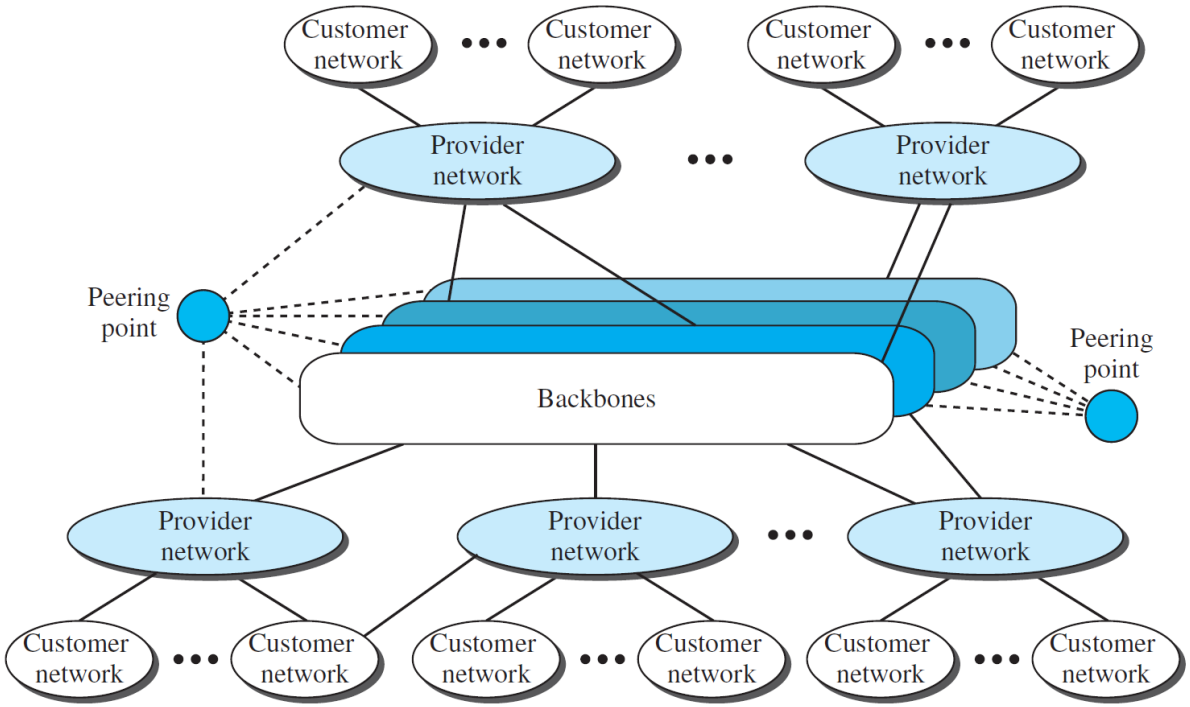
Packet-Switched Network

- In a computer network, the communication between the two ends is done in blocks of data called packets.
- In other words, instead of the continuous communication we see between two telephone sets when they are being used, we see the exchange of individual data packets between the two computers.
- This allows us to make the switches function for both storing and forwarding because a packet is an independent entity that can be stored and sent later..
- A router in a packet-switched network has a queue that can store and forward the packet.



The Internet

- An internet (note the lowercase i) is two or more networks that can communicate with each other.
- The most notable internet is called the Internet (uppercase I), and is composed of thousands of interconnected networks.



Accessing the Internet

- The Internet today is an internetwork that allows any user to become part of it.
- The user, however, needs to be physically connected to an ISP.
- The physical connection is normally done through a point-to-point WAN
- Connecting to internet:
  - **Using Telephone Networks**
    - **Dial-up service**
    - **DSL Service**
  - **Using Cable Networks**
  - **Using Wireless Networks**
  - **Direct Connection to the Internet**

A Brief History of the Internet

- Internet has evolved from a private network to a global one in less than 40 years
- Before 1960: telegraph and telephone networks
- In 1961: The theory of packet switching for bursty traffic was first presented by Leonard Kleinrock at MIT
- In 1967: Advanced Research Projects Agency (ARPA) in the Department of Defense (DOD) presented, its ideas for the Advanced Research Projects Agency Network (ARPANET), a small network of connected computers.
- In 1969: ARPANET was a reality. Four nodes, at the University of California at Los Angeles (UCLA), the University of California at Santa Barbara (UCSB), Stanford Research Institute (SRI), and the University of Utah, were connected
- Software called the Network Control Protocol (NCP) provided communication between the hosts.
- In 1972, Vint Cerf and Bob Kahn outlined the protocols (TCP) to achieve end-to-end delivery of packets.
- Shortly thereafter, authorities split TCP into two protocols:
  - Transmission Control Protocol (TCP) and
  - Internetworking Protocol (IP).

Internet Today

- Today, we witness a rapid growth both in the infrastructure and new applications.
- The Internet today is a set of pier networks that provide services to the whole world.
- What has made the Internet so popular is the invention of new applications:
  - **World Wide Web:** The 1990s saw the explosion of Internet applications due to the emergence of the World Wide Web (WWW). The Web was invented at CERN by Tim Berners-Lee. This invention has added the commercial applications to the Internet.
  - **Multimedia:** Recent developments in the multimedia applications such as voice over IP (telephony), video over IP (Skype), view sharing (YouTube), and television over IP (Willow TV) has increased the number of users and the amount of time each user spends on the network.
  - **Peer-to-Peer Applications:** Peer-to-peer networking is also a new area of communication with a lot of potential.

Protocols

- An entity is anything capable of sending or receiving information.
- A protocol defines what is communicated, how it is communicated, and when it is communicated.
- **Syntax**
  - Refers to the structure or format of the data, meaning the order in which they are presented.
- **Semantics**
  - Refers to the meaning of each section of bits.
- **Timing**
  - When data should be sent and how fast they can be sent.

Standards

- **De facto standards**
  - de facto means “by fact” or “by convention”
- **De jure standards**
  - De jure means “by law” or “by regulation”
- **Standard organizations**
  - International Organization for Standardization (ISO)
  - International Telecommunication Union-Telecommunication standards sector (ITU-T)
  - Consultative Committee for International Telegraphy and Telephony (CCITT)
  - American National Standards Institute (ANSI)
  - Institute of Electrical and Electronics Engineers (IEEE)
  - Electronic Industries Association (EIA)
- **Government agencies**
  - Federal Communications Commission (FCC)
- **Internet Standards**
  - Internet draft
  - Request for Comment (RFC)