Data Communications and Networking Fourth Edition

Forouzan

Chapter 1

Introduction

1-1 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.

Topics discussed in this section:

- Characteristics of Communication
- Components of a data communications system
- Data Flow

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.*

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 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.*

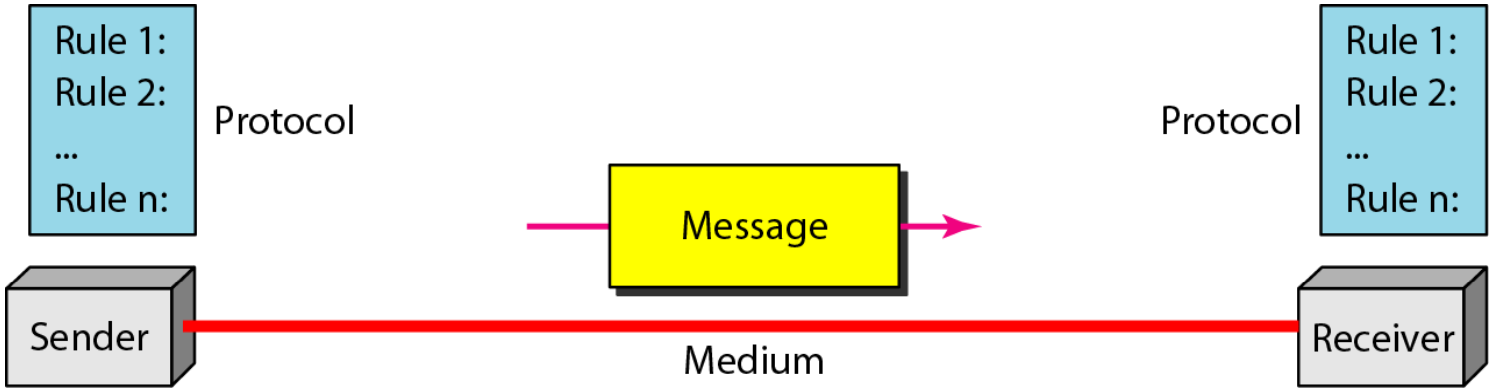
***Sender**: The sender is the device that sends the data message. It can be a computer, workstation, telephone handset, video camera, and so on.*

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.***

Figure 1.1 *Components of a data communication system*



Data Flow

Communication 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.

Full Duplex

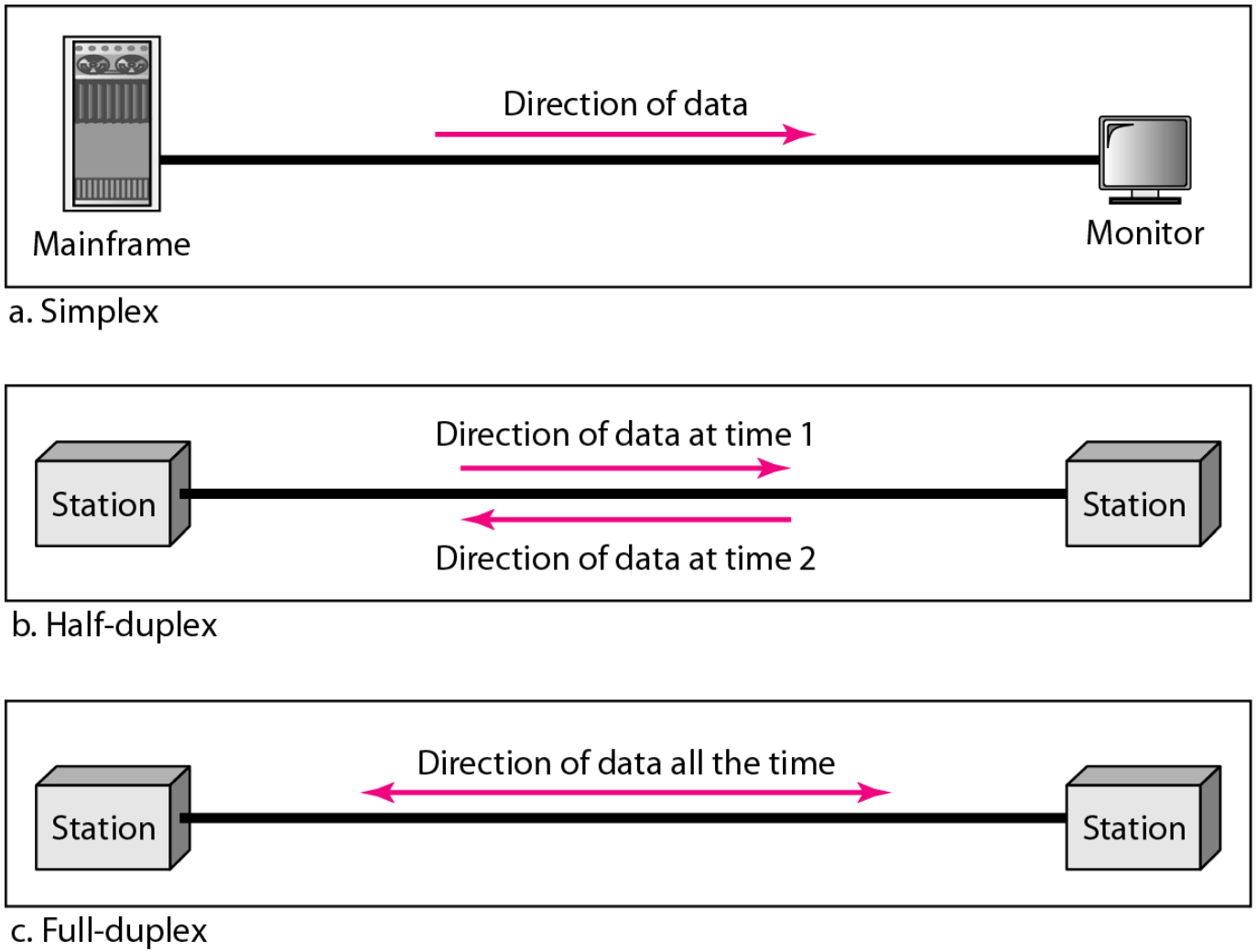
- *In full-duplex mode, both stations can transmit and receive simultaneously.*

- *The full-duplex mode is like a two way street with traffic flowing in both directions at the same time.*

- *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.*

Figure 1.2 *Data flow (simplex, half-duplex, and full-duplex)*



1-2 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. A link can be a cable, air, optical fiber, or any medium which can transport a signal carrying information.

Topics discussed in this section:

- **Network Criteria**
- **Physical Structures**
- **Categories of Networks**

Network Criteria

A network must be able to meet a certain number of criteria.

The most important of these are

- *Performance*
- *Reliability*
- *Security*

Performance

Performance can be measured in many ways, including transmit time and response time.

***Transmit 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 throughputs and less delay.

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.

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
  - Point to Point – Single Transmitter and Receiver
  - Multipoint - Multiple recipients of Single Transmission
- Physical Topology
  - Connection of Devices
  - Type of Transmission - Unicast, Mulitcast, Broadcast

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.*

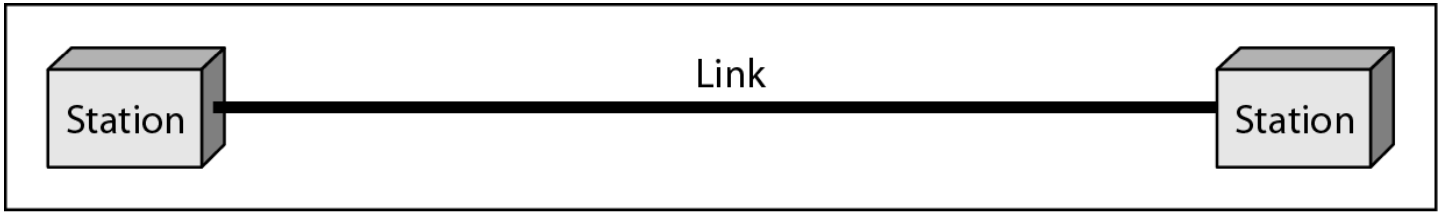
Point-to-Point:

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

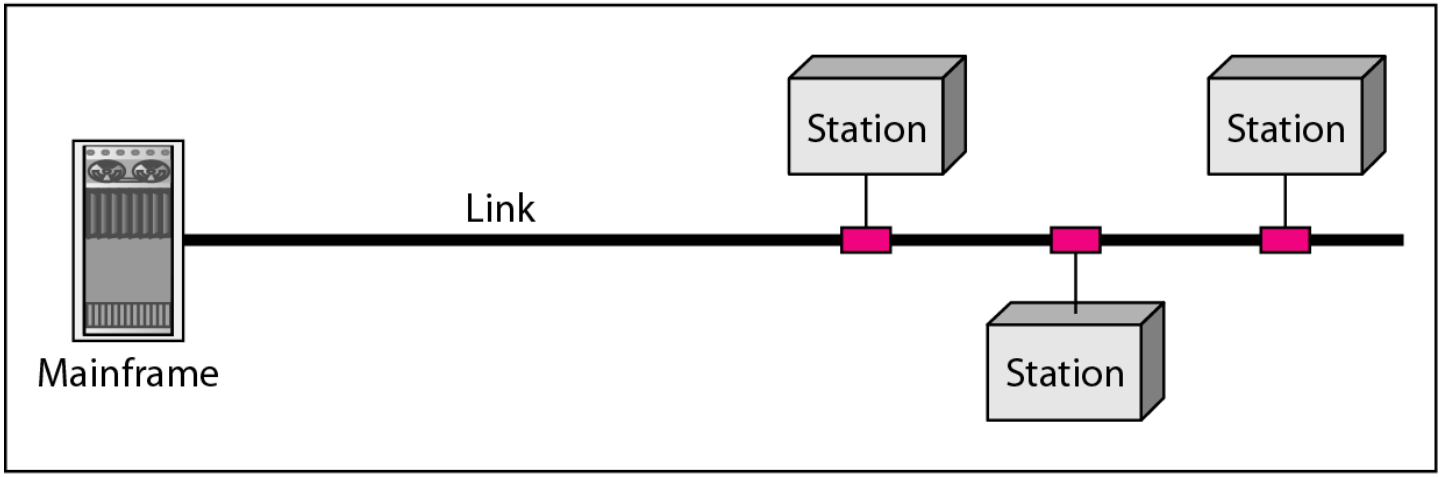
Multipoint:

- ***A multipoint (also called multi drop) 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.***

Figure 1.3 *Types of connections: point-to-point and multipoint*



a. Point-to-point



b. Multipoint

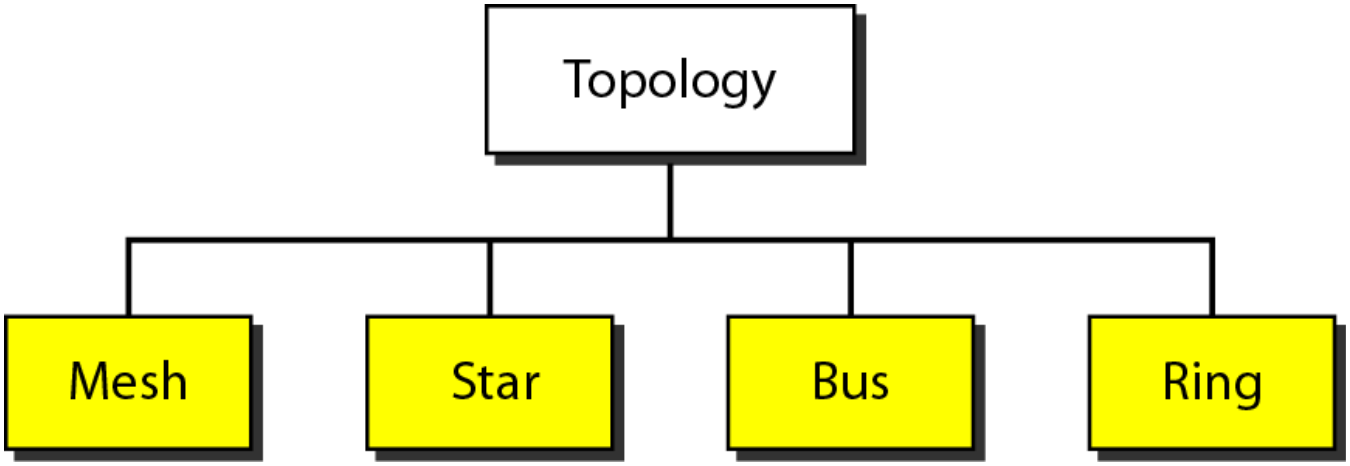
NETWORK TOPOLOGY

- ***A Network Topology is the way computer systems or network equipment connected to each other.***
- ***Topologies may define both physical and logical aspect of the network.***
- ***Two or more links form a topology.***

There are four basic topologies possible:

- ***Mesh***
- ***Star***
- ***Bus and***
- ***Ring***

Figure 1.4 *Categories of topology*

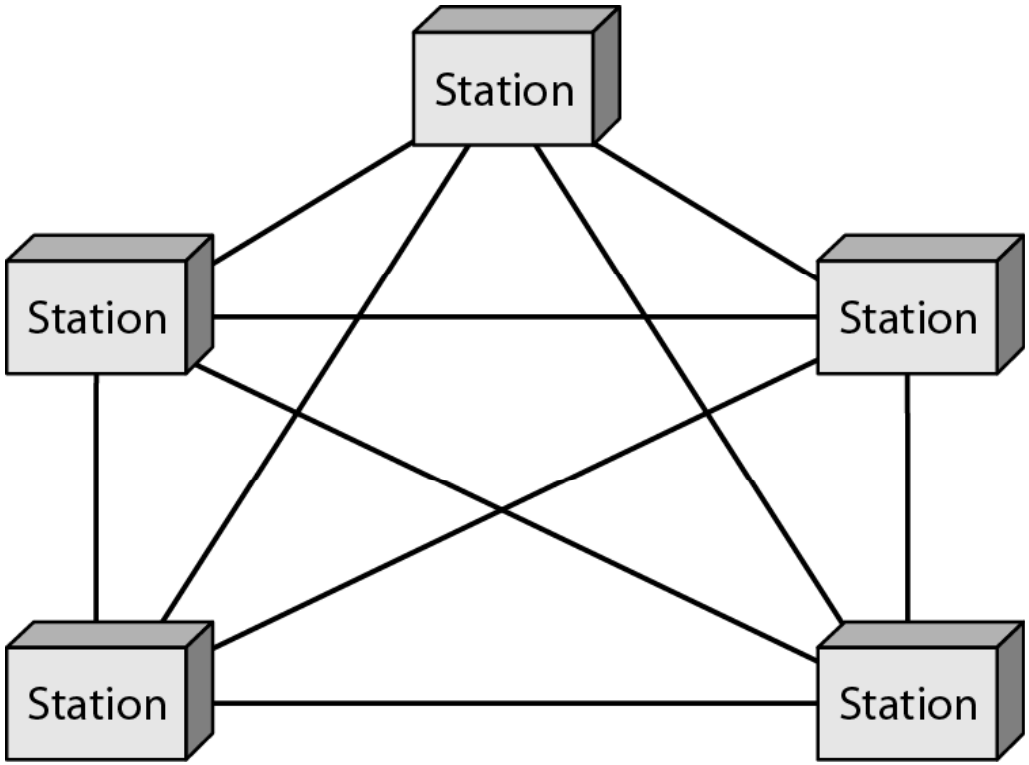


MESH TOPOLOGY

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.

Figure 1.5 *A fully connected mesh topology (five devices)*



Advantages

- ***The use of dedicated links guarantees that each connection can carry its own data load, thus eliminating the traffic problems that can occur when links must be shared by multiple devices.***

- ***A mesh topology is robust. If one link becomes unusable, it does not incapacitate the entire system.***

- ***There is the advantage of privacy or security. When every message travels along a dedicated line, only the intended recipient sees it.***

- ***Point-to-point links make fault identification and fault isolation easy.***

Disadvantages

- **Amount of cabling and the number of I/O ports required.**

- **The 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.**

STAR Topology

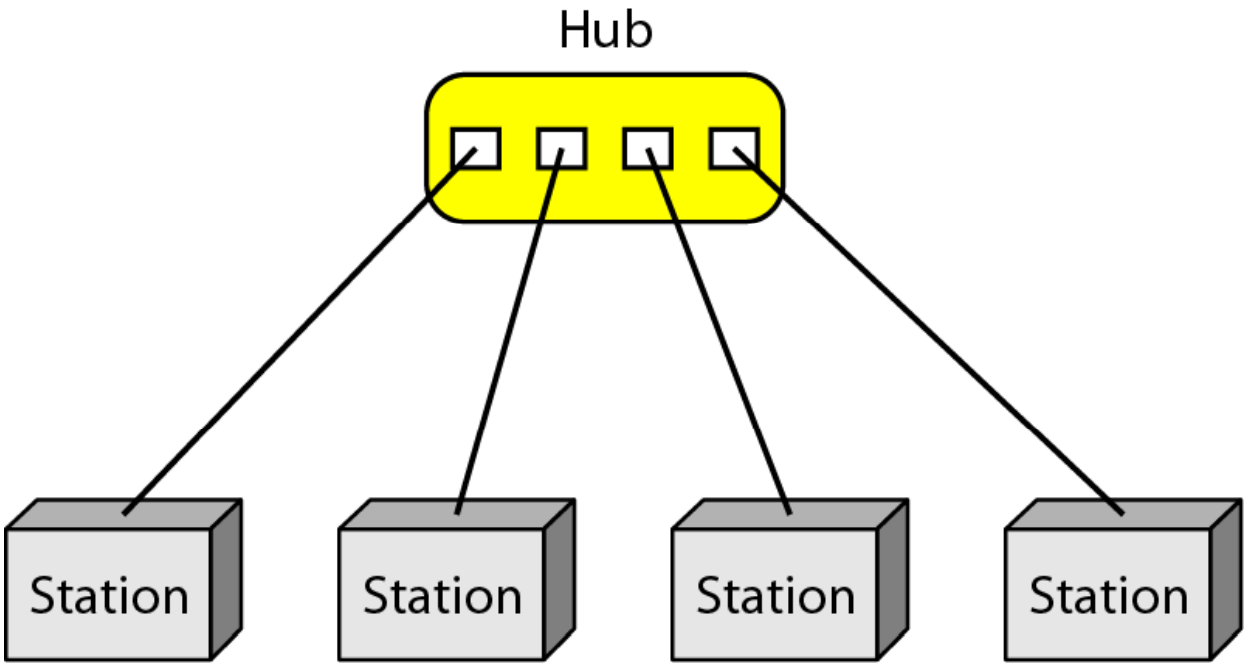
In a star topology, each device has a dedicated point-to-point link only to a central controller, usually called a hub.

The devices are not directly linked to one another.

Unlike a mesh topology, a star topology does not allow direct traffic between devices.

The controller acts as an exchange: If one device wants to send data to another, it sends the data to the controller, which then relays the data to the other connected device.

Figure 1.6 *A star topology connecting four stations*



Advantages

- *A star topology is less expensive than a mesh topology.*

- *In a star, each device needs only one link and one I/O port to connect it to any number of others. This factor also makes it easy to install and reconfigure.*

- *Far less cabling needs to be housed, and additions, moves, and deletions involve only one connection: between that device and the hub.*

- *Other advantages include robustness. If one link fails, only that link is affected. All other links remain active.*

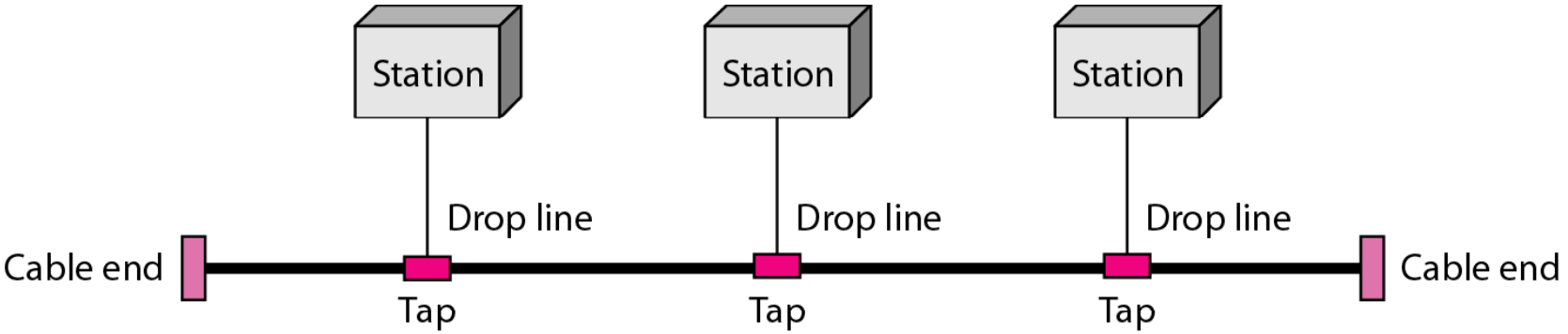
Disadvantages

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

BUS TOPOLOGY

- *The preceding examples all describe point-to-point connections.*
- *A bus topology, on the other hand, is multipoint.*
- *One long cable acts as a Backbone to link all the devices in a network.*
- *Nodes are connected to the bus cable by drop lines and taps.*

Figure 1.7 *A bus topology connecting three stations*



Advantages

- ***Bus topology includes ease of installation.***
- ***A bus uses less cabling than mesh or star topologies.***

Disadvantages

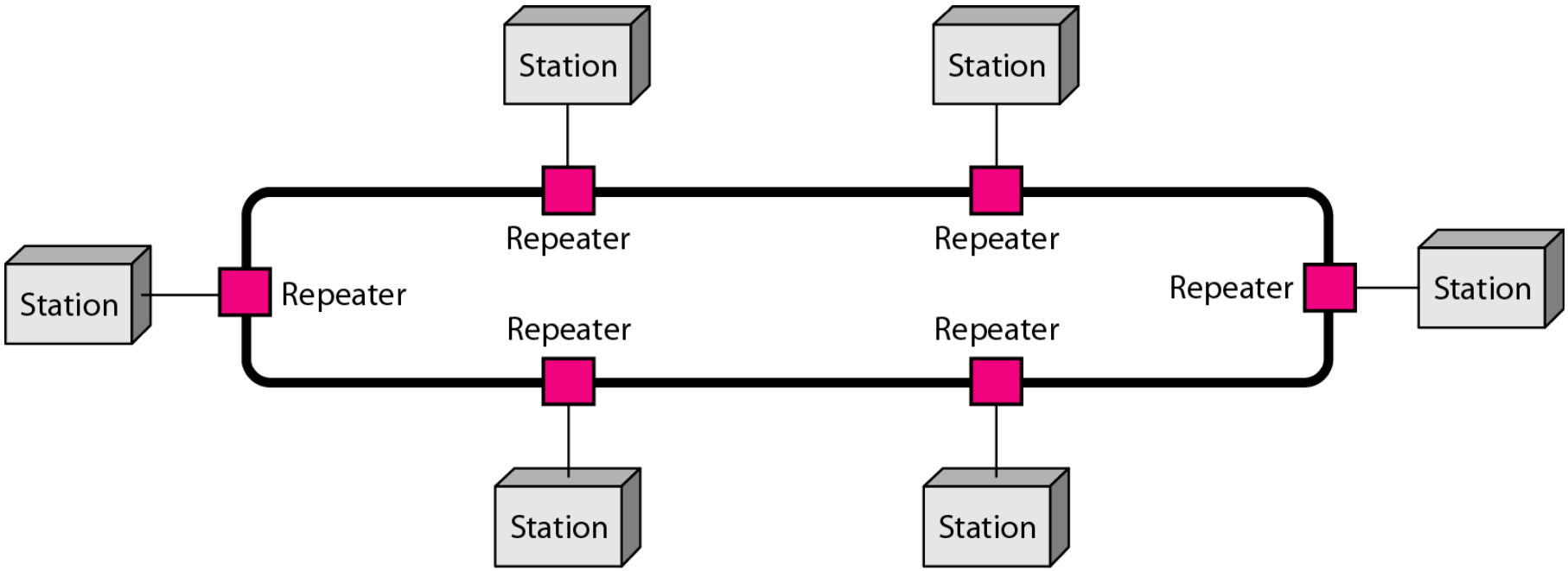
- ***Difficult reconnection and fault isolation.***
- ***A fault or break in the bus cable stops all transmission, even between devices on the same side of the problem.***

RING TOPOLOGY

- *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.*

Figure 1.8 *A ring topology connecting six stations*



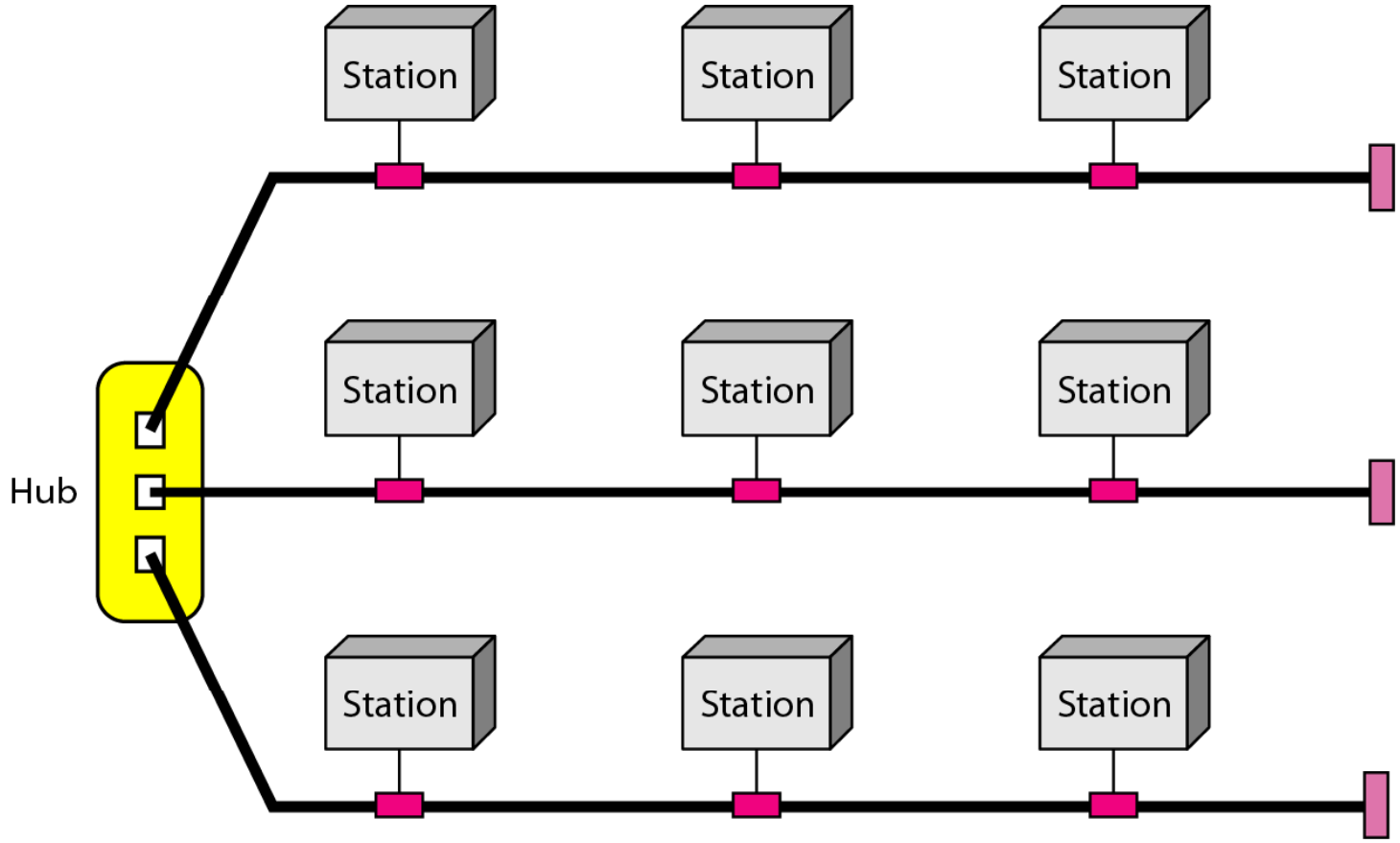
Advantages

- *A ring is relatively easy to install and reconfigure.*
- *Fault isolation is simplified.*

Disadvantages

- *Unidirectional traffic can be a disadvantage.*
- *In a simple ring, a break in the ring (such as a disabled station) can disable the entire network.*

Figure 1.9 *A hybrid topology: a star backbone with three bus networks*



Categories of Networks

There are two primary categories:

- ***Local-Area Networks* and *Wide-Area Networks*.**

- ***The category into which a network falls is determined by its size.***

- ***A LAN normally covers an area less than 2 miles; A WAN can be worldwide.***

- ***Networks of a size in between are normally referred to as *Metropolitan Area Networks* and span tens of miles.***

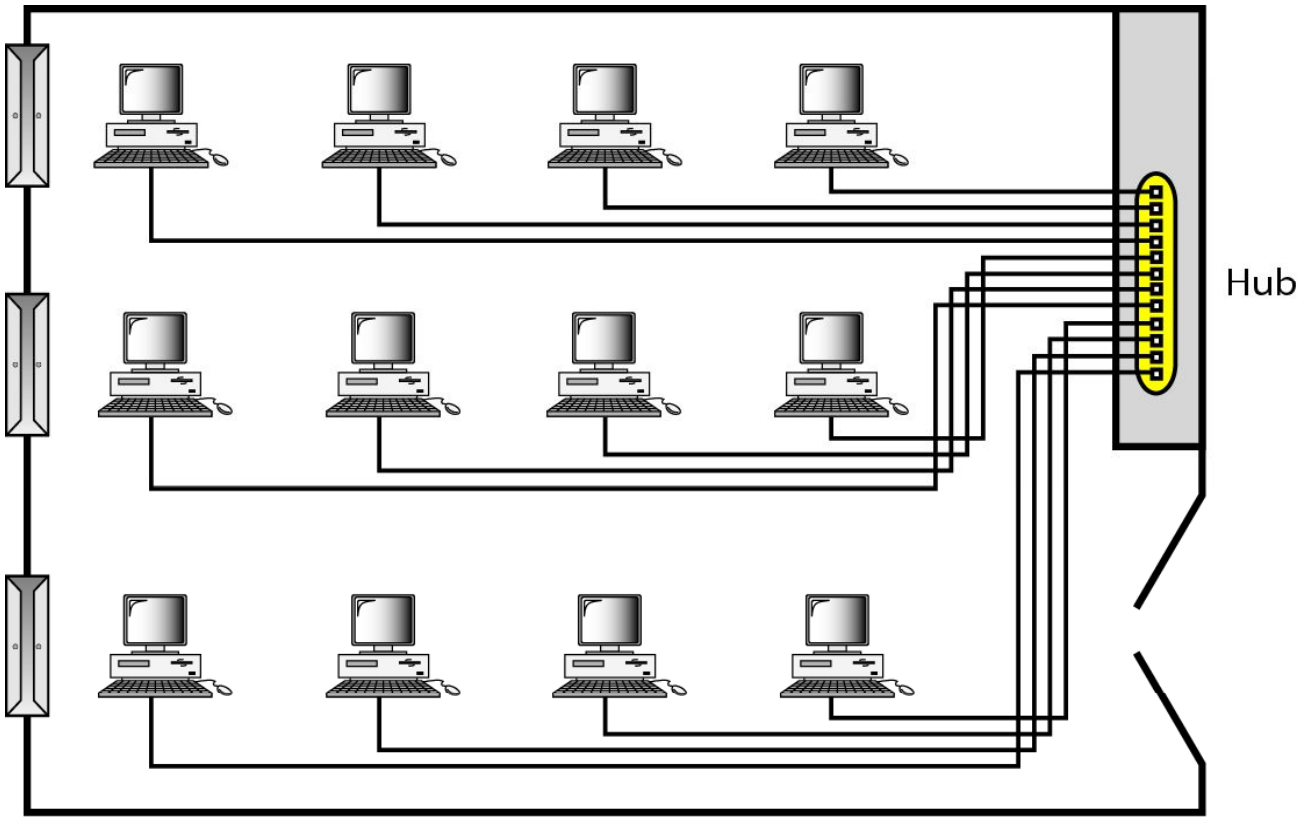
Categories of Networks

- Local Area Networks (LANs)
  - Short distances
  - Designed to provide local interconnectivity
- Wide Area Networks (WANs)
  - Long distances
  - Provide connectivity over large areas
- Metropolitan Area Networks (MANs)
  - Provide connectivity over areas such as a city, a campus

Local Area Network

- ***A local area network (LAN) is usually privately owned and links the devices in a single office, building, or campus.***
- ***LANs are designed to allow resources to be shared between personal computers or workstations.***
- ***The resources to be shared can include hardware (e.g., a printer), software (e.g., an application program), or data.***
- ***In addition to size, LANs are distinguished from other types of networks by their transmission media and topology.***
- ***In general, a given LAN will use only one type of transmission medium.***
- ***The most common LAN topologies are bus, ring, and star.***

Figure 1.10 *An isolated LAN connecting 12 computers to a hub in a closet*

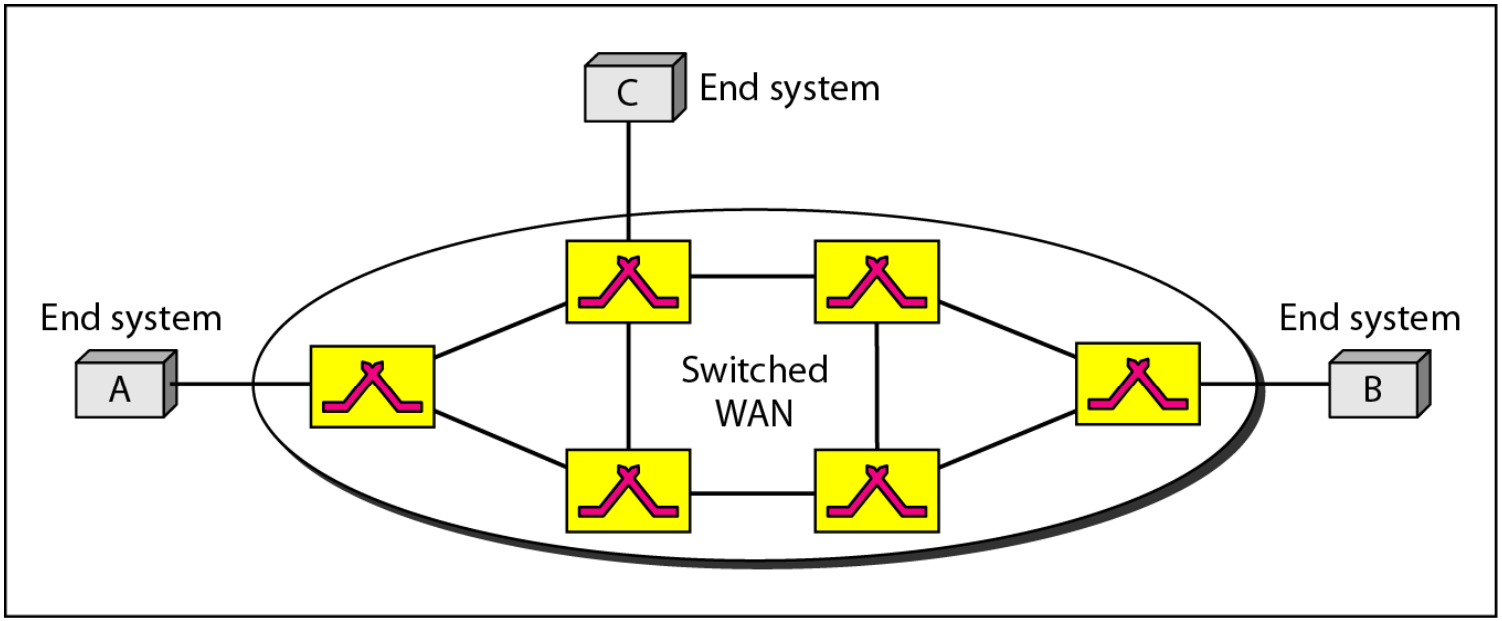


Wide Area Network

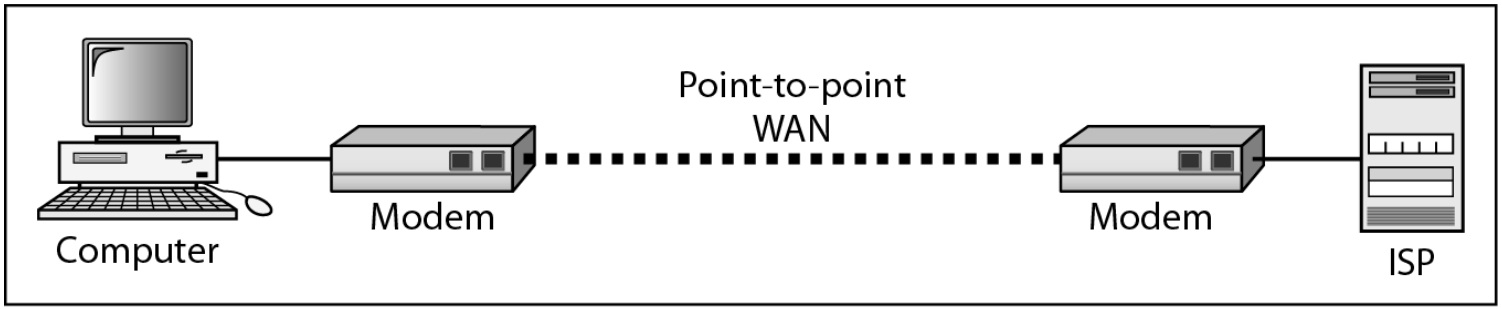
- ***A wide area network (WAN) provides long-distance transmission of data, image, audio, and video information over large geographic areas that may comprise a country, a continent, or even the whole world.***

- ***A WAN can be complex that connect the Internet or as simple as a dial-up line that connects a home computer to the Internet.***

Figure 1.11 *WANs: a switched WAN and a point-to-point WAN*



a. Switched WAN



b. Point-to-point WAN

Switched WAN & point-to-point WAN

- ***The switched WAN connects the end systems, which usually comprise a router (connecting device) that connects to another LAN or WAN.***

- ***The point-to-point WAN is normally a line leased from a telephone or cable TV provider that connects a home computer or a small LAN to an Internet service provider (lSP).***

Metropolitan Area Networks

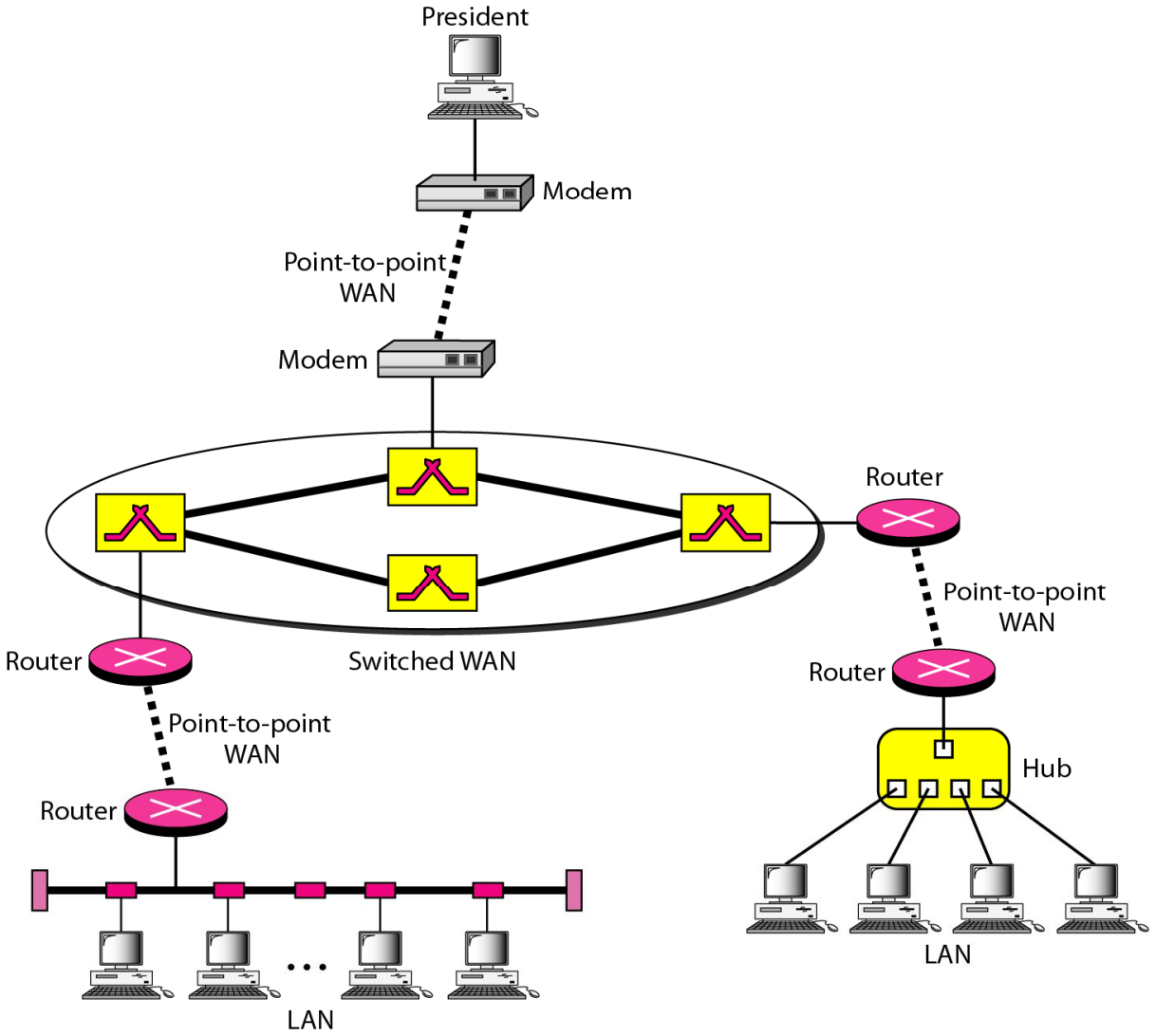
- ***A metropolitan area network (MAN) is a network with a size between a LAN and a WAN.***
- ***It normally covers the area inside a town or a city.***
- ***It is designed for customers who need a high-speed connectivity, normally to the Internet, and have endpoints spread over a city or part of city.***
- ***A good example of a MAN is the cable TV network that originally was designed for cable TV***

Interconnection of Networks: Internetwork

- ***Today, it is very rare to see a LAN, a MAN, or a LAN in isolation; they are connected to one another.***

- ***When two or more networks are connected, they become an internetwork, or internet.***

Figure 1.12 *A heterogeneous network made of four WANs and two LANs*



1-3 THE INTERNET

The Internet has revolutionized many aspects of our daily lives.

It has affected the way we do business as well as the way we spend our leisure time.

The Internet is a communication system that has brought a wealth of information to our fingertips and organized it for our use.

Topics discussed in this section:

Organization of the Internet

Internet Service Providers (ISPs)

- *The Internet today is not a simple hierarchical structure.*

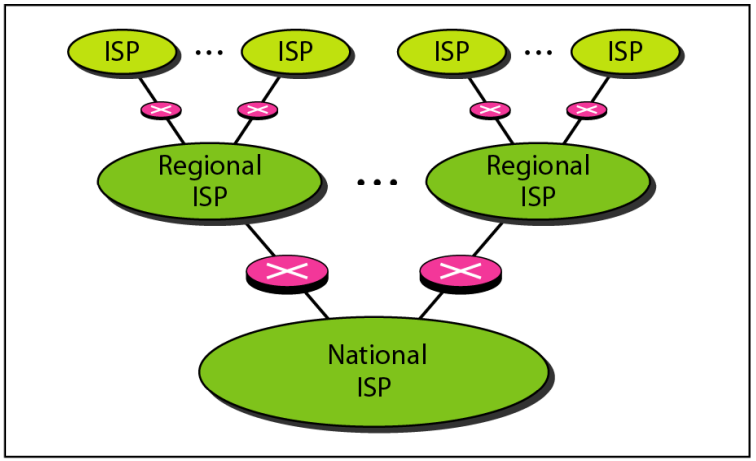
- *It is difficult to give an accurate representation of the Internet because it is continually changing.*

- *Today most end users who want Internet connection use the services of Internet service providers (lSPs).*

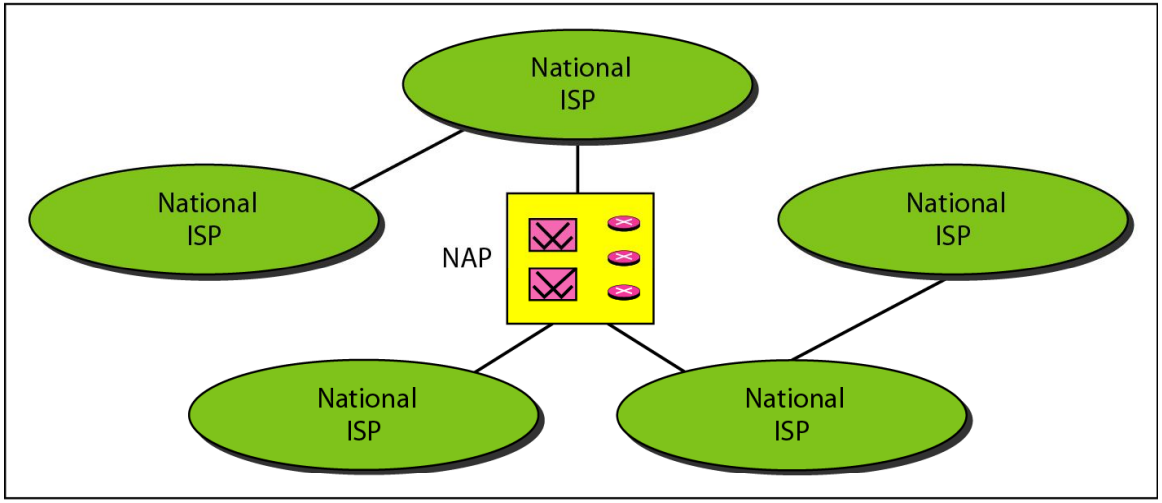
- *There are international service providers, national service providers, regional service providers, and local service providers.*

- *The Internet today is run by private companies, not the government.*

Figure 1.13 *Hierarchical organization of the Internet*



a. Structure of a national ISP



b. Interconnection of national ISPs

International Internet Service Providers

At the top of the hierarchy are the international service providers that connect nations together.

National Internet Service Providers

The national Internet service providers are backbone networks created and maintained by specialized companies.

Regional Internet Service Providers

Regional internet service providers or regional ISPs are smaller ISPs that are connected to one or more national ISPs.

Local Internet Service Providers

- ***Local Internet service providers provide direct service to the end users.***

- ***The local ISPs can be connected to regional ISPs or directly to national ISPs.***

- ***Most end users are connected to the local ISPs.***

1-4 PROTOCOLS

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

Topics discussed in this section:

- **Syntax**
- **Semantics**
- **Timing**

Elements of a Protocol

- **Syntax**
  - Structure or format of the data
  - Indicates how to read the bits - field delineation
- **Semantics**
  - Interprets the meaning of the bits
  - Knows which fields define what action
- **Timing**
  - When data should be sent and what
  - Speed at which data should be sent or speed at which it is being received.

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.***

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?***

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

- ***Essential in creating and maintaining an open and competitive market for equipment manufacturers.***

- ***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.***

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 realm of scientific, technological, and economic activity.***

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. 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.***