Data Communication and Networks

U.K.P. Mihiranga (MBA in MOT, B.Sc. Eng. (Hons), PMP-PMI(USA), AMIESL)

Data communication

- Communication - Sharing of information
- Sharing can be local or remote
- Local communication usually occurs face to face, while remote communication takes place over distance
- Data communications - exchange of data among devices via some form of transmission media
- Communicating devices must be a part of a communication system made of a combination of hardware and software

Telecommunication

- Communications at a distance
- Transmission of information over long distance, such as by telegraph, radio, telephony or television
- Encompasses the electrical communication of voice, data, and image information over a transmission medium
- Four basic types of medium: wire pair, coaxial cable, fiber optics, and radio
- The effectiveness of a data communications system depends on Delivery, Accuracy, Timeliness and Jitter

Fundamental Characteristics

- Delivery
  - Deliver data to the correct destination
  - Data must be received by the intended device or user

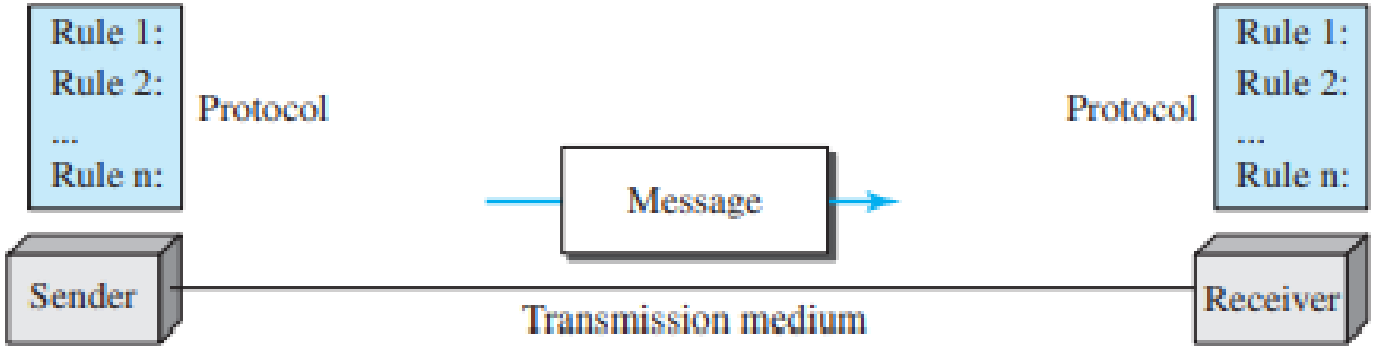
- Accuracy
  - The system must deliver the data accurately
  - Data that have been altered in transmission should be corrected

Fundamental Characteristics (Cont'd)

- Timeliness
  - The system must deliver data in a timely manner
  - Data delivered late are useless
  - 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

Components of data communication



➢Message

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

Components (cont’d)

- 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.

Components (cont’d)

- Protocol

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
- Video

Text

- Represented as a bit pattern, a sequence of bits
- Different sets of bit patterns have been designed to represent text symbols
- Each set is called a code
- The process of representing symbols is called coding

Ex: Unicode, which uses 32 bits to represent a symbol or character used in any language in the world

American Standard Code for Information Interchange (ASCII)

Numbers

- Represented by bit patterns
- Code such as ASCII is not used to represent numbers
- Number is directly converted to a binary number to simplify mathematical operations

Images

- Represented by bit patterns
- Image is composed of a matrix of pixels (picture elements), where each pixel is a small dot
- Size of the pixel depends on the resolution
- Example:
  - Image can be divided into 1000 pixels or 10,000 pixels.
  - Better resolution for better representation of the image, but more memory is needed to store the image
  - After an image is divided into pixels, each pixel is assigned a bit pattern
  - Several methods to represent color images
  - RGB- combination of three primary colors: red, green, and blue
  - YCM-combination of three other primary colors: yellow, cyan, and magenta

Audio

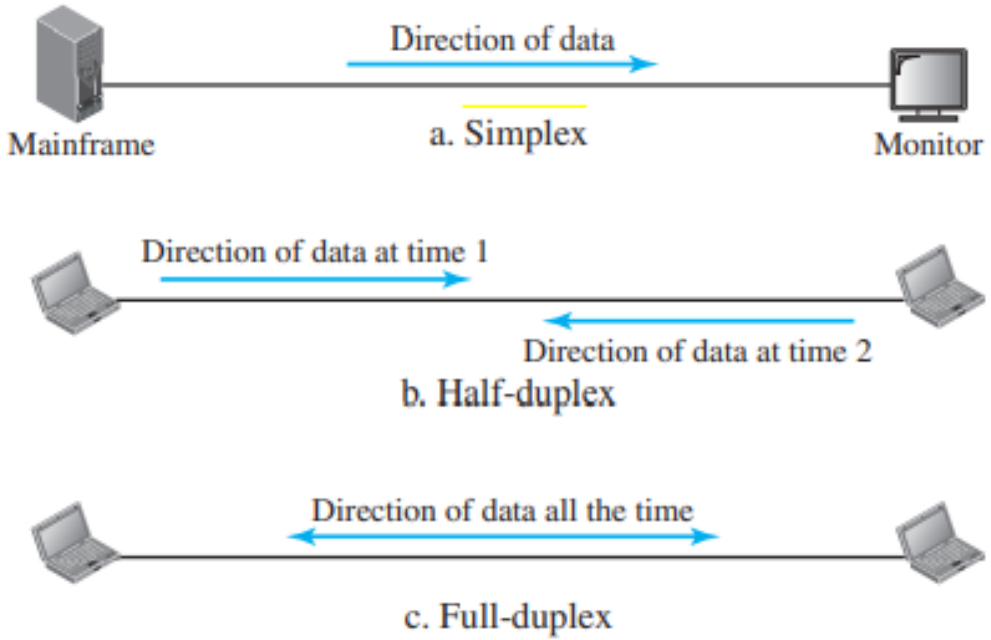
- Refers to the recording or broadcasting of sound or music
- Different from text, numbers, or images
- It is continuous, not discrete
- When it uses a microphone to change voice or music to an electric signal, we create a continuous signal

Video

- Refers to the recording or broadcasting of a picture or movie
- Different from text, numbers, or images
- 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

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.

  Ex: Keyboard of the PC- Can only introduce input

  Monitor of the PC- Can only accept output
- It can use the entire capacity of the channel to send data in one direction

Half-Duplex

- 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

  Ex: Walkie-talkies

  CB (citizens band) radios
- 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

- Both stations can transmit and receive simultaneously
- Signals going in one direction share the capacity of the link with signals going in the other direction

  Ex: Telephone network
- Link must contain two physically separate paths, or the capacity of the channel is divided between signals traveling in both directions
- Used when communication in both directions is required all the time
- The capacity of the channel, however, must be divided between the two directions

Networks

- Set of devices (often referred to as nodes) connected by communication links
- Node can be a computer, printer, or any other device
- Distributed Processing

Task is divided among multiple computers. Instead of one single large machine being responsible for all aspects of a process

- Different types of criteria to evaluate
  - Performance
  - Reliability
  - Security

Performance

- Can be measured in many ways, including transit time and response time

Transit time-Time required for a message to travel from one device to another

Response time-The elapsed time between an inquiry and a response

- Performance depends on the Number of users, Type of transmission medium, Capabilities of the connected hardware and Efficiency of the software
- Performance is evaluated by throughput and delay
- Need more throughput and less delay

Reliability

- Network reliability is measured by the
  - Frequency of failure
  - Time to recover the link from a failure
  - Network's robustness in a catastrophe

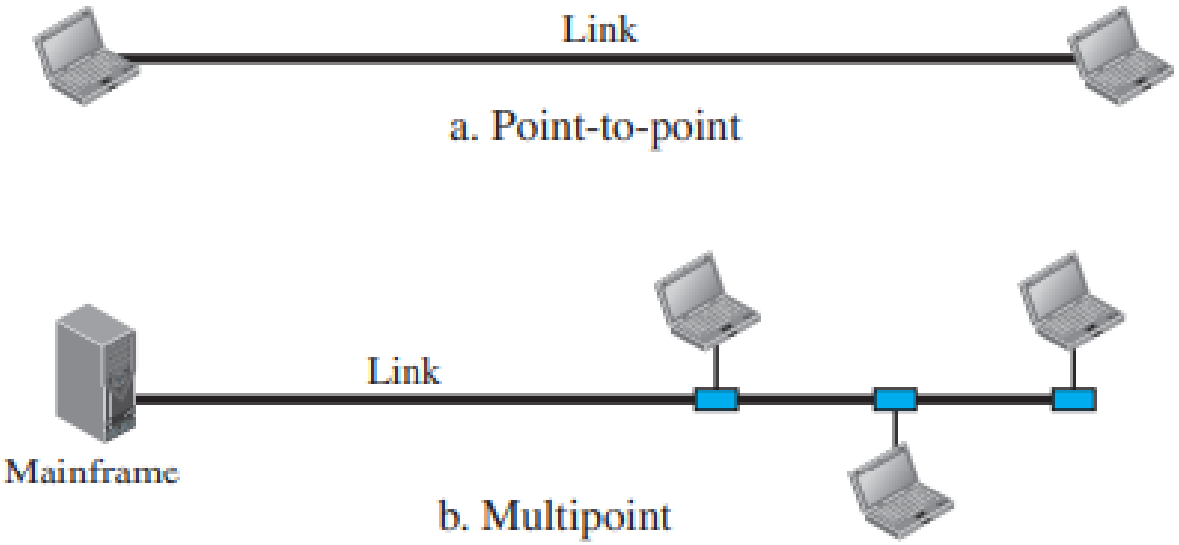
Security

- Network security issues include
  - Protecting data from unauthorized access
  - Protecting data from damage and development
  - Implementing policies and procedures for recovery from breaches and data losses

Physical Structures

There are two possible types of connections

- Point-to-point
- Multipoint



Point-to-Point

- Provides a dedicated link between two devices
- Entire capacity of the link is reserved for transmission between those two devices

Ex: length of wire or cable to connect the two ends

Microwave

Satellite links

When you change television channels by infrared remote control, you are establishing a point-to-point connection between the remote control and the television's control system.

Multipoint (Multi-drop)

- More than two specific devices share a single link
- Capacity of the channel is shared, either spatially or temporally
- Several devices can use the link simultaneously, it is a spatially shared Connection
- If users must take turns, it is a timeshared connection

Physical Topology

- The way in which a network is laid out physically
- One or more devices connect to a link
- Two or more links form a topology
- 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
  - Ring

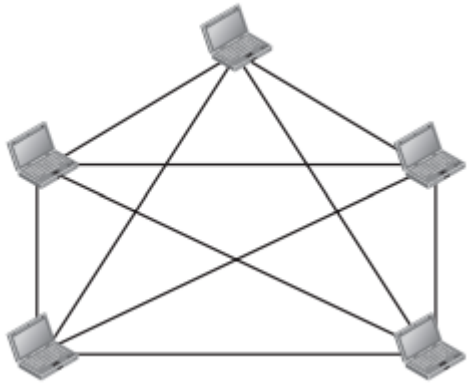
Mesh Topology

- Every device has a dedicated point-to-point link to every other device
- Total no of physical links in a network with n number of nodes is

$$n(n-1)/2$$

- Allows duplex mode communication

$n = 5$
10 links.



Advantages of Mesh Topology

- Dedicated links guarantees that each connection- Eliminating the traffic problems
- Robust-No outage when one link becomes unusable
- Privacy or security is high
- Fault identification and fault isolation easy

Disadvantages of Mesh Topology

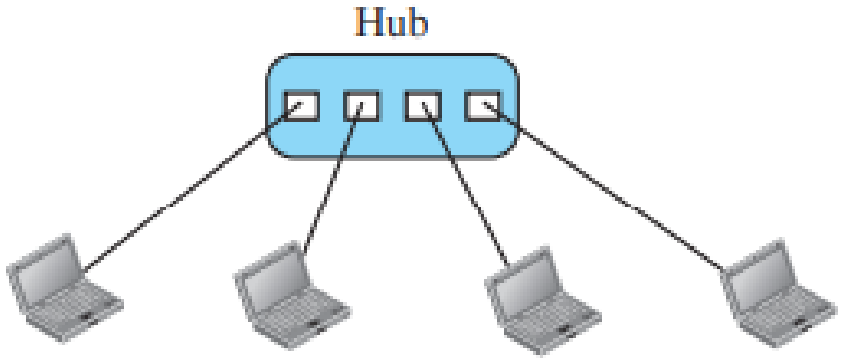
- Amount of cabling and the number of I/O ports required
  - Installation and reconnection are difficult because every device must be connected to every other device
  - Sheer bulk of the wiring can be greater than the available space
  - Hardware required to connect each link (I/O ports and cable) can be prohibitively expensive

  Example:

  Backbone connection of telephone regional offices to interconnect each other regional offices

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
- No direct traffic between devices
- Controller acts as an exchange
- If a device wants to send data to another, it sends the data to the controller
- Then the hub relays the data to the other Connected device



Advantages of Star Topology

- Less expensive than a mesh topology

Each device needs only one link and one I/O port to connect it to any number of others

- Easy to install and reconfigure

Less cabling needs to be housed

- Robustness

If one link fails, only that link is affected. All other links remain active

- Easy fault identification and fault isolation

Disadvantages of Star Topology

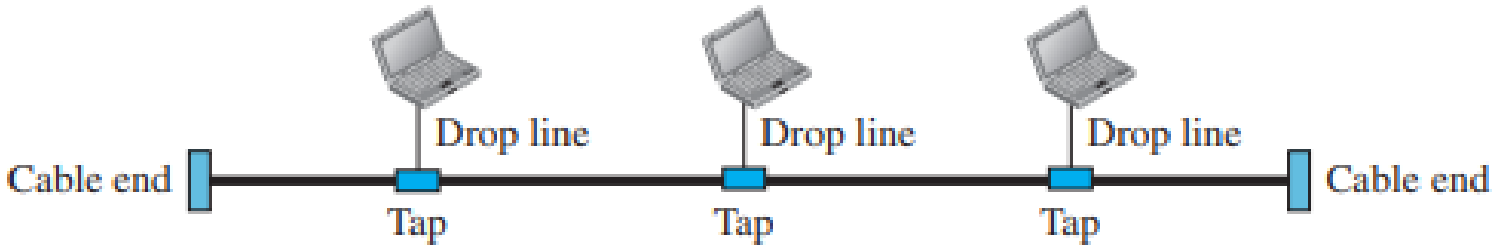
- Dependency of the whole topology on one single point, the hub. If the hub goes down, the whole system is dead
- More cabling is required in a star than in some other topologies except mesh

Example:

High-speed LANs often use a star topology with a central hub

Bus Topology

- Multipoint links
- 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
- Tap is a connector that either splices into the main cable or punctures the sheathing of a cable to create a contact with the metallic core
- Signal travels along the backbone, some of its energy is transformed into heat



Advantages of Bus Topology

- Ease of installation
- Bus uses less cabling than mesh or star topologies

Disadvantages of Bus Topology

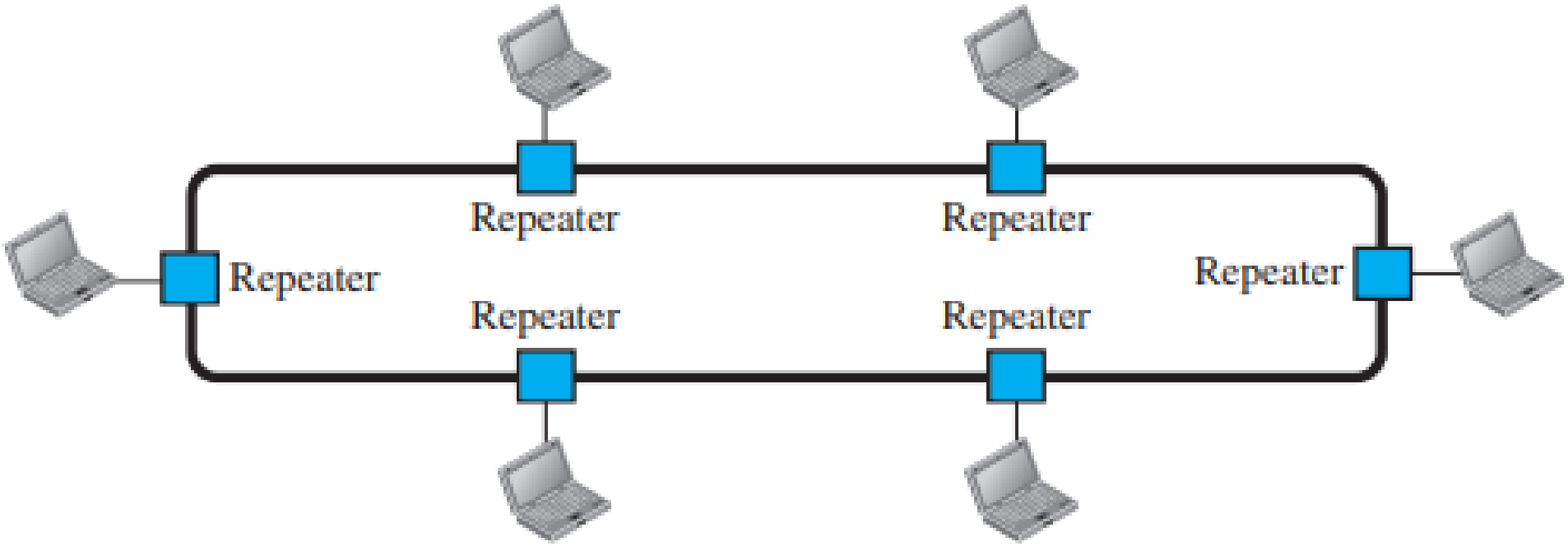
- Difficult reconnection and fault isolation
- Signal reflection at the taps can cause degradation in quality
- Fault or break in the bus cable stops all transmission

Example: Early Ethernet LAN

Ring Topology

- Each device has a dedicated point-to-point connection with only the two devices on either side of it
- 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

Ring topology connecting six stations



Advantages Ring Topology

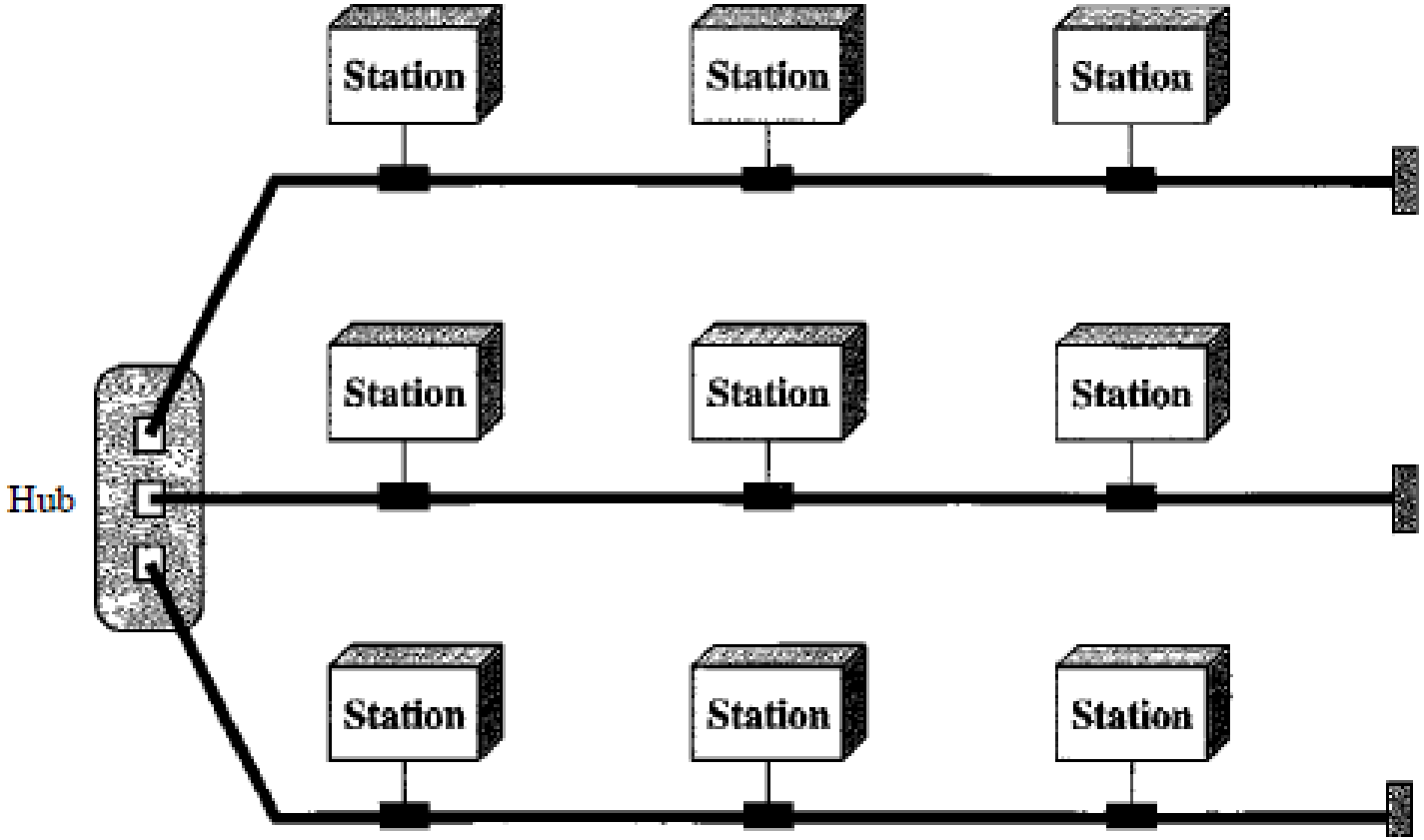
- Relatively easy to install and reconfigure
  - Device is linked to only its immediate neighbors (either physically or logically
  - To add or delete a device requires changing only two connections
  - The only constraints are media and traffic considerations (maximum ring length and number of devices)
- Fault isolation is simplified
  - Signal is circulating at all times

Disadvantages Ring Topology

- Unidirectional traffic can be a disadvantage
  - Break in the ring (such as a disabled station) can disable the entire network
  - This weakness can be solved by using a dual ring or a switch capable of closing off the break
  - Ex: Microwave ring protection in Telecommunication networks

Hybrid Topology

- Network can be hybrid
- Star backbone with three bus networks

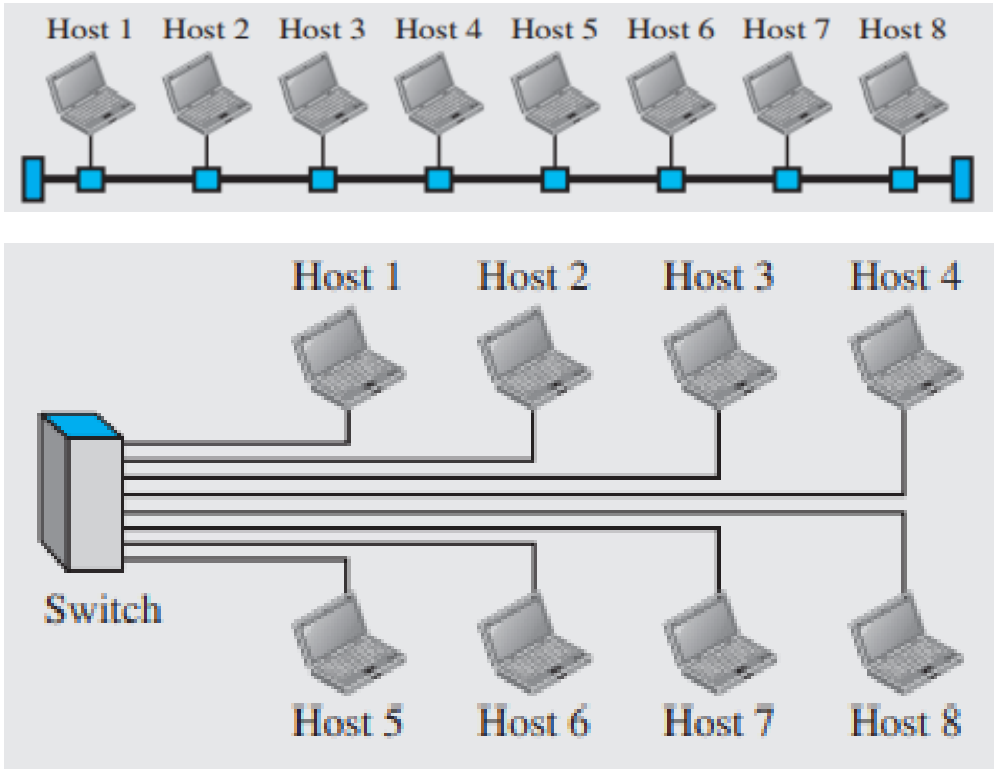


Network Models

- Two best known standards
  - OSI(Open Systems Interconnection) model
    - Defines a seven-layer network
  - Internet model
    - Five-layer network
- Categories of Network
    - Local-area networks (LAN)
      - Network that covers an area less than 2 miles
    - Metropolitan Area Networks
    - Wide-area networks (WAN)
      - Network that covers world wide

Local Area Network

- Usually privately owned and links the devices in a single office, building, or campus
- LAN size is limited to a few kilometers



b. LAN with a switch (today)

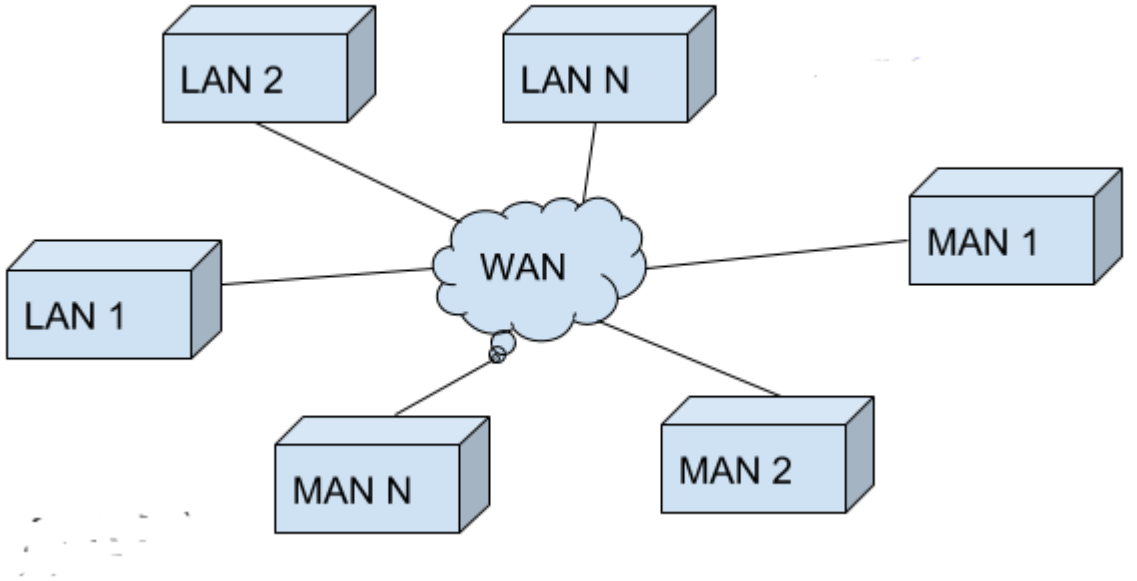
Metropolitan Area Networks

- Network with a size between a LAN and a WAN
- Normally covers the area inside a town or a city
- Designed for customers who need a high-speed connectivity, normally to the Internet
- Contains endpoints spread over a city or part of city
- Ex: ISP that can provide a high-speed DSL line to the customer

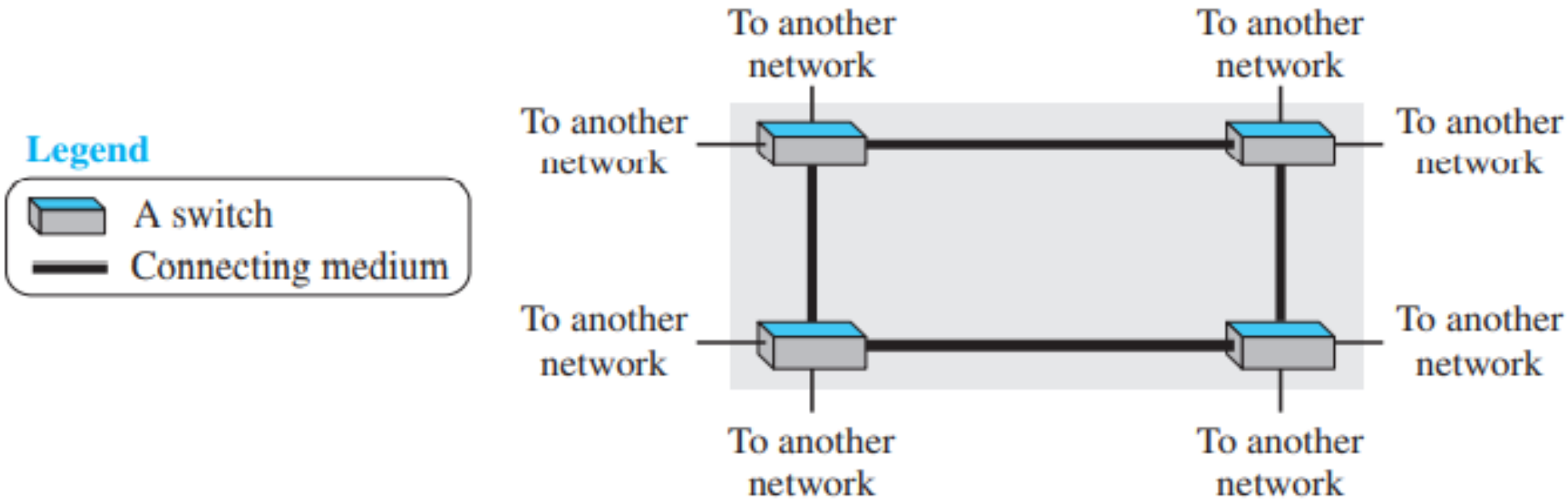
  Cable TV network that can also be used for high-speed data connection to the Internet

Wide Area Network

- 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
- Two types of WAN
  - Switched WAN
  - Point-to-point WAN

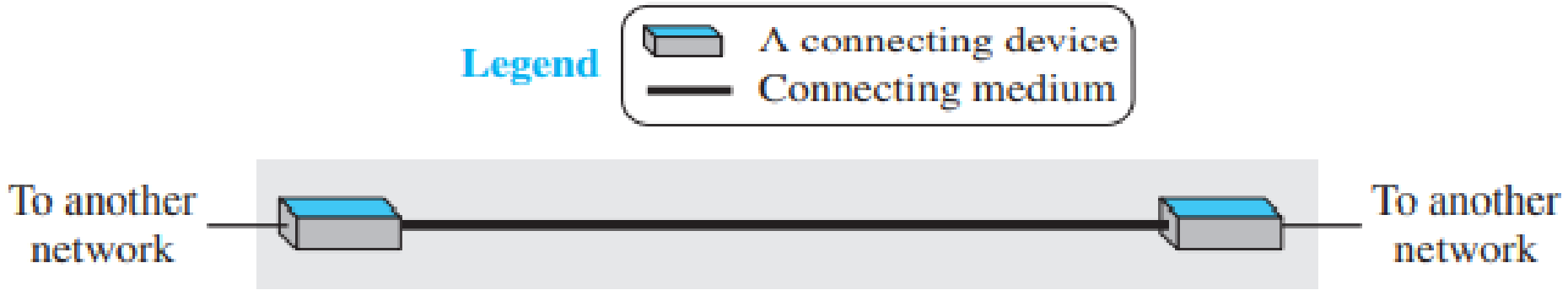


Switched WAN



- Connects the end systems, which usually comprise a router (internetworking connecting device) that connects to another LAN or WAN

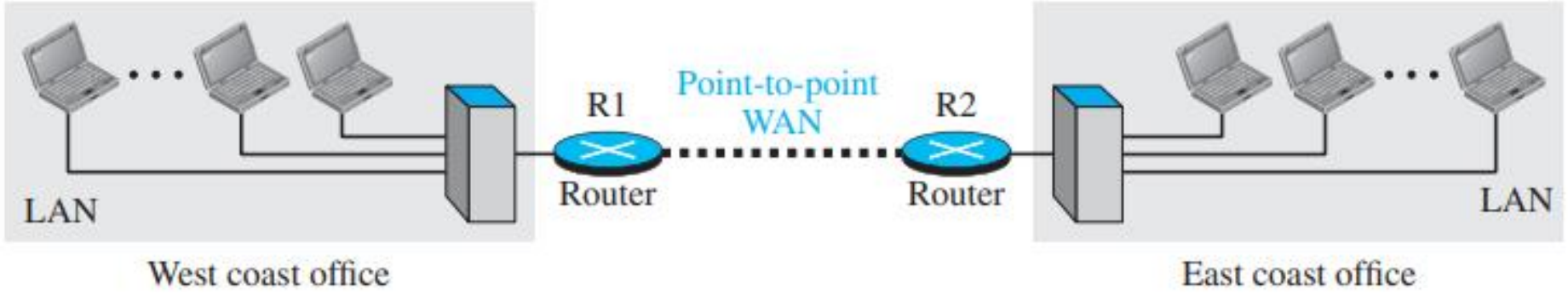
Point-to-point WAN



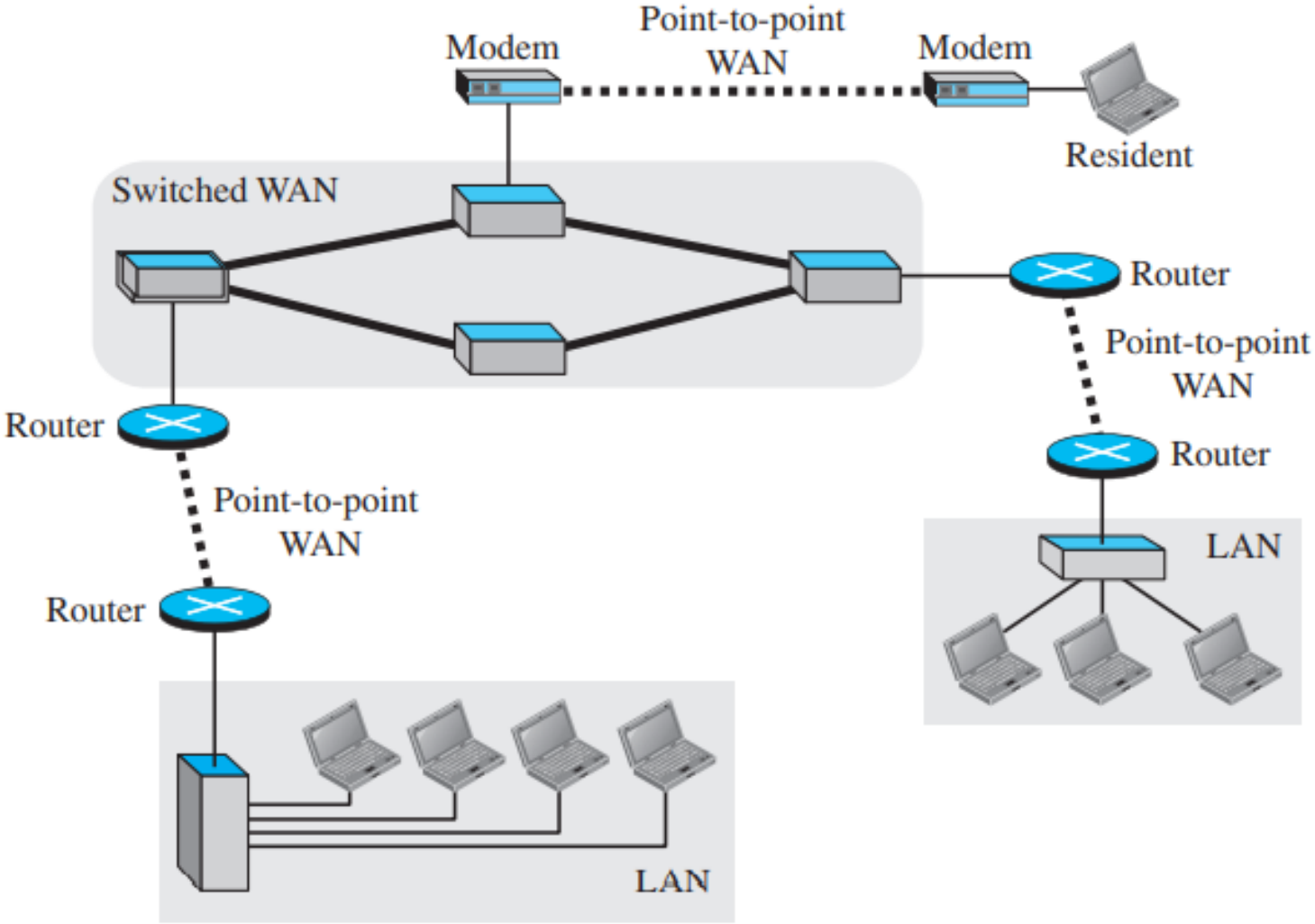
- Point-to-point WAN is normally a line leased from a telephone or cable TV provider that connects a home computer or a small LAN to an Internet service provider (ISP)
- Often use to provide Internet access

Interconnection of Networks: Inter-network

- 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

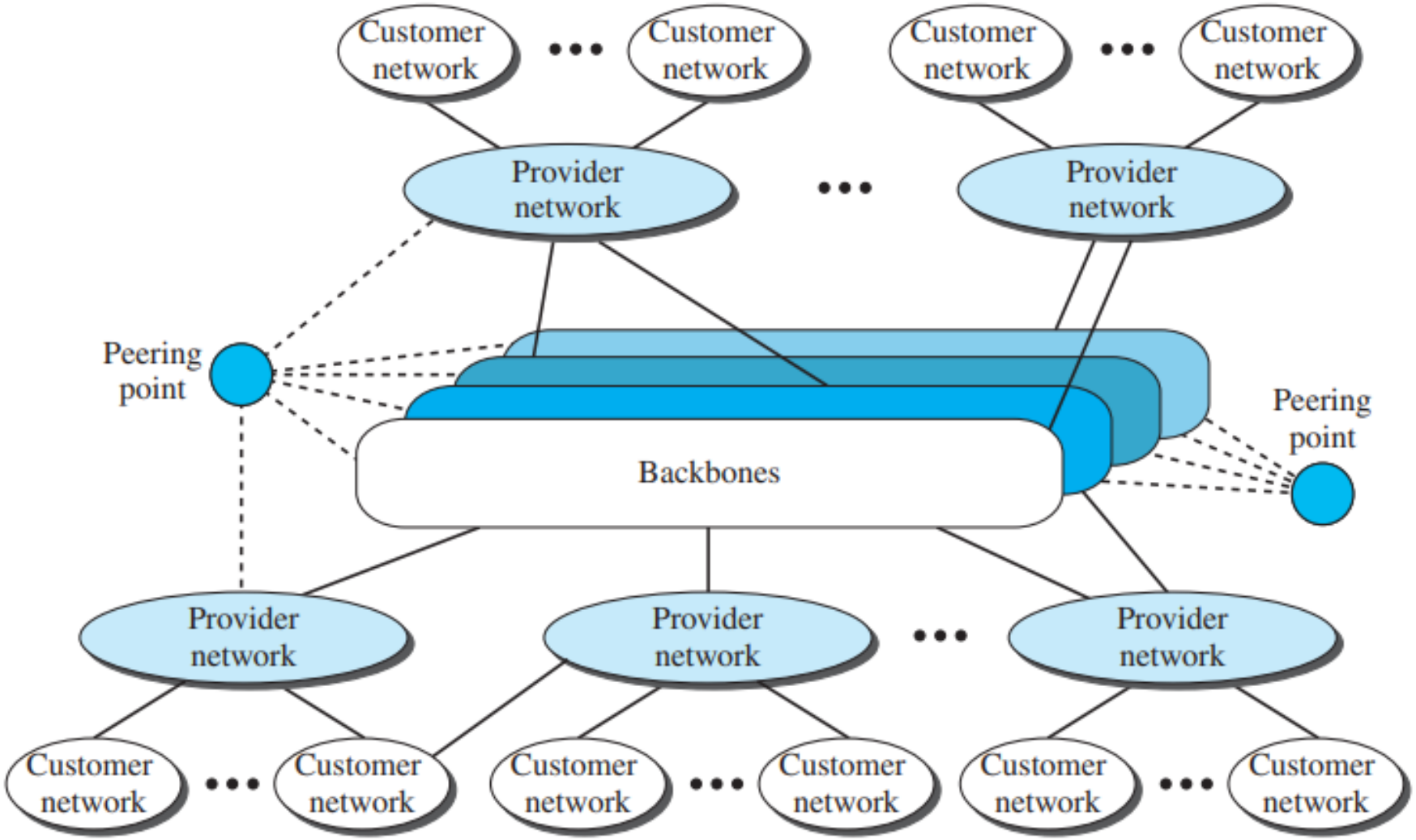


Case: Assume that an organization has two offices, one on the east coast and the other on the west coast. The established office on the west coast has a bus topology LAN; the newly opened office on the east coast has a star topology LAN. The president of the company lives somewhere in the middle and needs to have control over the company from her home



THE INTERNET

- Collaboration of more than hundreds or thousands of interconnected networks
- Made up of many wide- and local-area networks joined by connecting devices and switching stations
- Internet connection offers by Internet Service Providers (ISPs)
- Conceptual (not geographic) view of the Internet

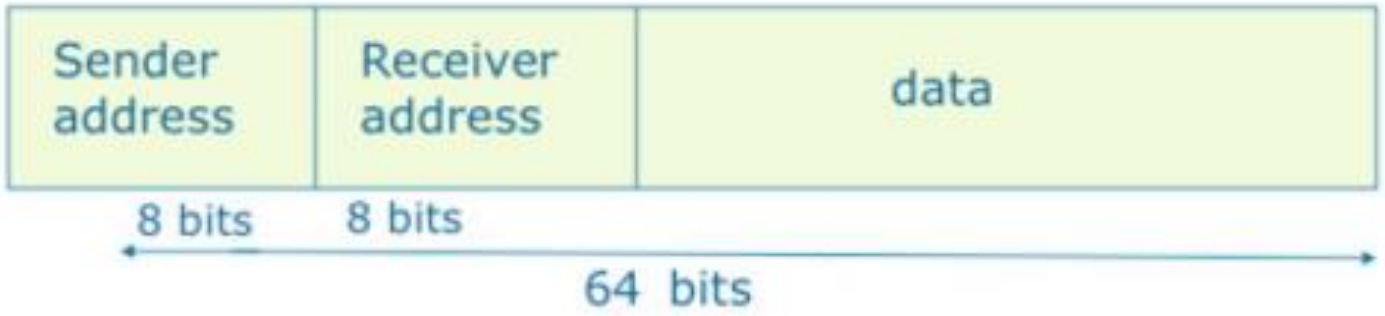

Customer network
Customer network
Customer network
Customer network
Provider network
Provider network
Peering point
Backbones
Peering point
Provider network
Provider network
Provider network
Customer network
Customer network
Customer network
Customer network
Customer network
Customer network

PROTOCOLS

- Entities in a network cannot simply send bit streams to each other and expect to be understood
- For communication to occur, the entities must agree on a protocol
- Set of rules that govern data communications
- Defines what is communicated, how it is communicated, and when it is communicated
- Key elements of a protocol are
  - Syntax
  - Semantics
  - Timing

Syntax

- Structure or format of the data
- Order in which they are presented
- Example: 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

- 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?
- Example: Does an address identify the route to be taken or the final destination of the message?

Timing

- Refers to two characteristics: when data should be sent and how fast they can be sent.
- 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

- 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:
  - By convention
    - Not been approved by an organized body but have been adopted as standards through widespread use
    - Established originally by manufacturers who seek to define the functionality of a new product or technology
  - By regulation

  Legislated by an officially recognized body

The End