Data Communications and Networking

Lecture 1

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Basic Course Information

- Course Title

  - Data Communications and Networking

- Textbook and Reference Materials

  - Data Communications and Networking: The Complete Reference, Fifth Edition by Behrouz A. Forouzan

  - Data Communications and Networking, Fourth Edition by Behrouz A. Forouzan

- Course Duration

  - 12 Weeks

Course Objectives

- To understanding the concepts of the layered protocol model
- To analyze and evaluate a number of data-link, network, and transport layer protocols
- To understand how to program network communication services for client/server paradigm

Course Schedule

Week	Topics
Week 1	Introduction to Data Communications and Network, Network Models
Week 2	Physical Layer: Introduction
Week 3	Physical Layer: Digital Transmission, Analog Transmission
Week 4	Physical layer: Bandwidth Utilization, Transmission Media, Switching
Week 5	Data-Link Layer: Introduction, Error Detection and Correction, Data Link Control, Media Access Control
Week 6	Data-Link Layer: Wired LANs (Ethernet), Other Wired Networks, Wireless LANs, Other Wireless Networks, Connecting Devices and Virtual LANs
Week 7	Network Layer: Introduction
Week 8	Network Layer: Protocols
Week 9	Network Layer: Routing Algorithms
Week 10	Transport Layer: Introduction
Week 11	Transport Layer: Protocols
Week 12	Application Layer

Exam and Grading System

Task	Mark
Final Exam	80%
Practical, Tutorial	20%

Mark	Grade
85 ~ 100	A^+
80 ~ 85	A
70 ~ 80	B
50 ~ 70	C
< 50	F

Outlines

- Introduction to Data Communications and Network
- Network Models

Lecture Objectives

- To introduce
  - What data communication is
  - Components in Data Communications System
  - What Network is
  - Network Criteria
  - Network Topologies
- To understand the basic concepts of data communication
- To meet a certain number of network criteria, and know types of network topologies
- To learn the 7-layer OSI network model (each layer and its responsibilities) and understand the TCP/IP suite of protocols and the networked applications supported by it.

Topic 1: Introduction to Data Communications and Network

Data Communication

- 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, 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.
3. **Timeliness.** The system must deliver data in a timely manner.
4. **Jitter.** Jitter refers to the variation in the packet arrival time.

Data Communication (Continue)

Components

- A data communications system has five components as shown in figure 1.

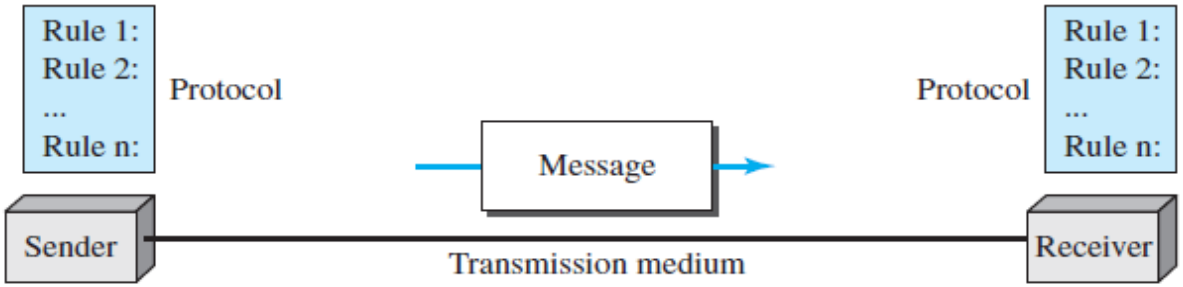


Figure 1. Five Components of Data Communication

1. Message. The message is the information (data) to be communicated Popular forms information include text, numbers, pictures, audio, and video.
2. Sender. The sender is the device that sends the data message. It can be a computer, workstation, telephone handset, video camera, and so on.

Data Communication (Continue)

3. Receiver. The receiver is the device that receives the message. It can be a computer, workstation, telephone handset, television, and so on.
4. 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.
5. 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.

Data Communication (Continue)

Data Representation

- Today, information 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).

Number: Numbers are also represented by bit patterns.

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. Three types of image: black and white image, gray scale image and color image.

Black and white image: 1-bit pattern (0 represents black and 1 represents white)

Data Communication (Continue)

Gray scale image: 2-bit patterns (A black pixel can be represented by 00, a dark gray pixel by 01, a light gray pixel by 10, and a white pixel by 11)

Color image: There are several methods to represent color images. One method is RGB (red, green, and blue) and another method is YCM (yellow, cyan, and magenta).

Audio: Audio refers to the recording or broadcasting of sound or music. Audio is by nature different from text, numbers, or images. It is continuous, not discrete.

Video: Video refers to the recording or broadcasting of a picture or movie. Video can either be produced as a continuous entity, or it can be a combination of images, each a discrete entity, arranged to convey the idea of motion.

Data Communication (Continue)

Data Flow

- Communication between two devices can be simplex, half-duplex, or full-duplex as shown in figure 2.

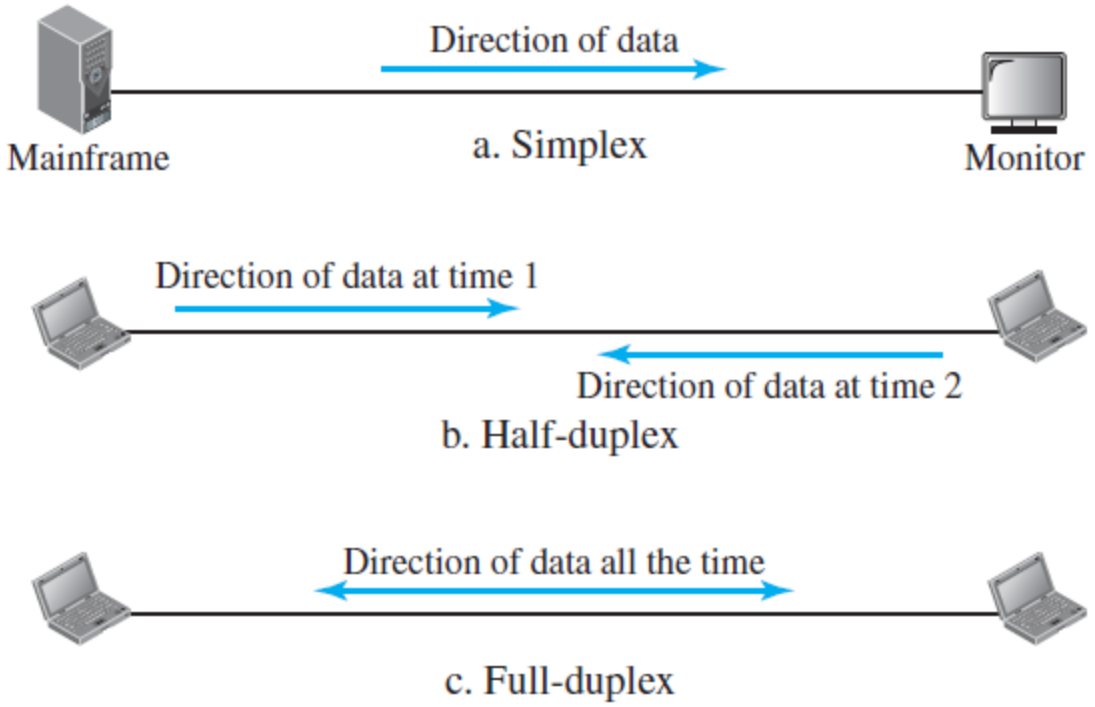


Figure 2. Data Flow (simplex, half-duplex, and full-duplex)

Data Communication (Continue)

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.

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.

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 such as a large computer, desktop, laptop, workstation, cellular phone, or security system.

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. Performance is often evaluated by two networking metrics: throughput and delay.

Networks (Continue)

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.

Networks (Continue)

Physical Structures

- Before discussing networks, it is needed to define some network attributes.

Type of Connection

- A network is two or more devices connected through links.
- A link is a communications pathway that transfers data from one device to another.
- There are two possible types of connections: point-to-point and multipoint.

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 as shown in figure 3a.

Multipoint

- A multipoint connection is one in which more than two specific devices share a single link (see Figure 3b).

Networks (Continue)

- In a multipoint environment, the capacity of the channel is shared, either spatially or temporally.
- If several devices can use the link simultaneously, it is a spatially shared connection.
- If users must take turns, it is a timeshared connection.

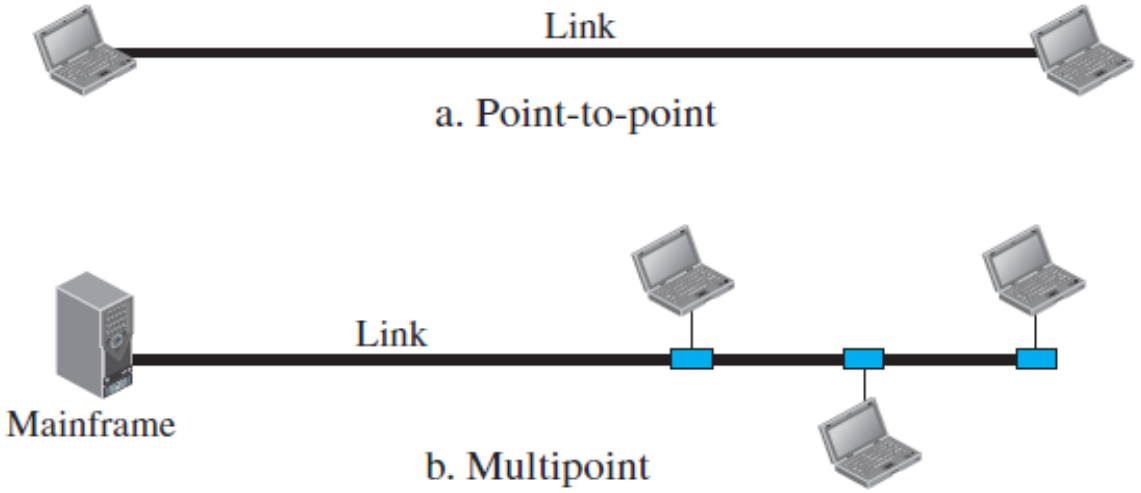


Figure 3. Types of connections: point-to-point and multipoint

Networks (Continue)

Physical Topology

- The term physical topology refers to the way in which a network is laid out physically.
- There are four basic topologies : mesh, star, bus, and ring.

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.
- A mesh offers several advantages over other network topologies.
- First, the use of dedicated links guarantees that each connection can carry its own data load.

Networks (Continue)

- Second, a mesh topology is robust.
- Third, there is the advantage of privacy or security.
- Finally, point-to-point links make fault identification and fault isolation easy.
- The main disadvantages of a mesh are related to the amount of cabling and the number of I/O ports required.
- First, because every device must be connected to every other device, installation and reconnection are difficult.
- Second, the sheer bulk of the wiring can be greater than the available space can accommodate.
- Finally, the hardware required to connect each link (I/O ports and cable) can be prohibitively expensive.

Networks (Continue)

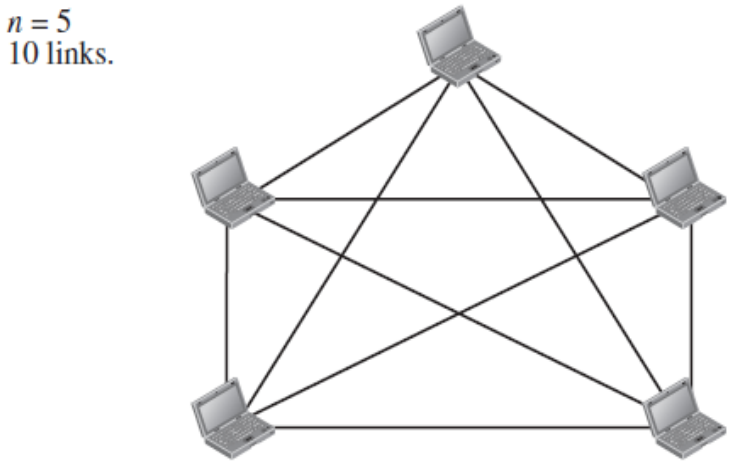


Figure 4. A fully connected mesh topology (five devices)

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 as depicted in figure 5.

Networks (Continue)

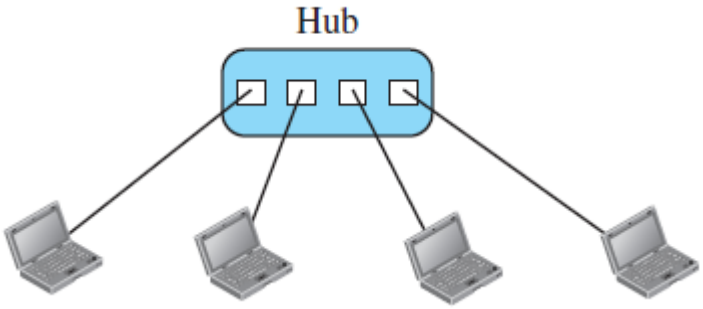


Figure 5. A star topology connecting four stations

- 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.
- Other advantages include robustness.
- If one link fails, only that link is affected.
- All other links remain active.
- One big disadvantage of a star topology is the dependency of the whole topology on one single point, the hub.
- If the hub goes down, the whole system is dead.

Networks (Continue)

Bus Topology

- A bus topology is multipoint.
- One long cable acts as a backbone to link all the devices in a network as shown in figure 6.

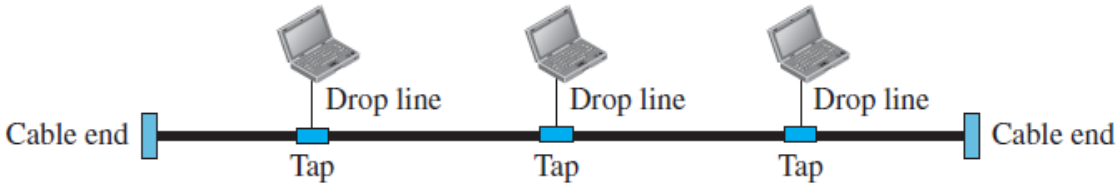


Figure 6 A bus topology connecting three stations

- Nodes are connected to the bus cable by drop lines and taps.
- A drop line is a connection running between the device and the main cable.
- A 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.
- As a signal travels along the backbone, some of its energy is transformed into heat.

Networks (Continue)

- Advantages of a bus topology include ease of installation.
- Disadvantages include difficult reconnection and fault isolation.

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.
- 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 as shown in figure 7.

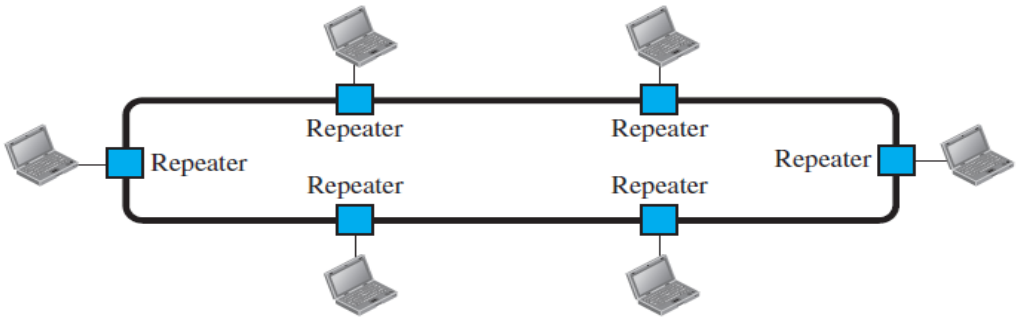


Figure 7. A ring topology connecting six stations

Networks (Continue)

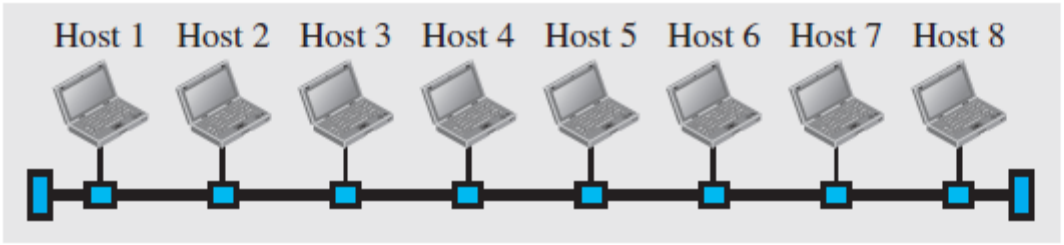
Network Types

- Two types of networks: LANs and WANs.

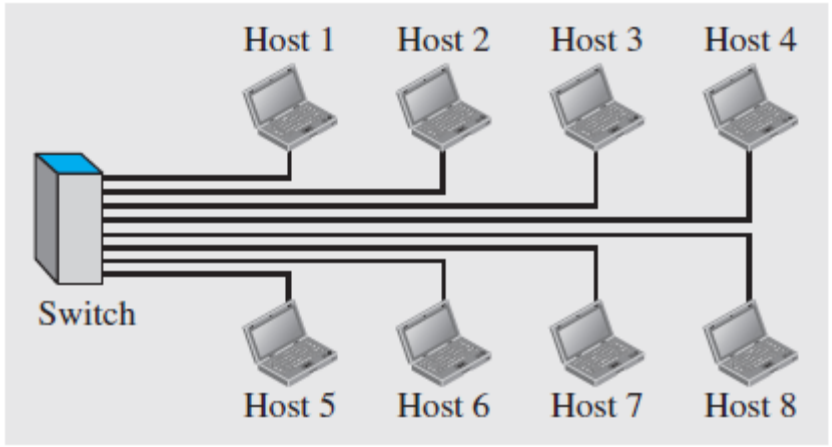
Local Area Network

- 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.
- 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.
- 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 as shown in figure 8.

Networks (Continue)



a. LAN with a common cable (past)



b. LAN with a switch (today)

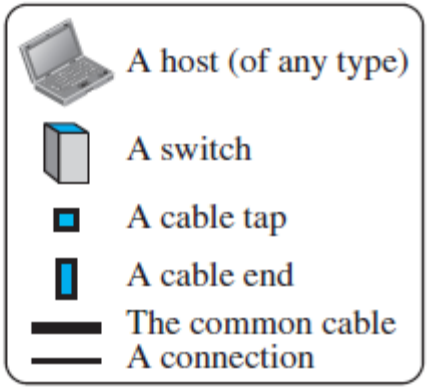


Figure 8. An isolated LAN in the past and today

Networks (Continue)

Wide Area Network

- A wide area network (WAN) is also an interconnection of devices capable of communication.
- In WAN, there are point-to-point WANs and 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) as shown in Fig. 9.

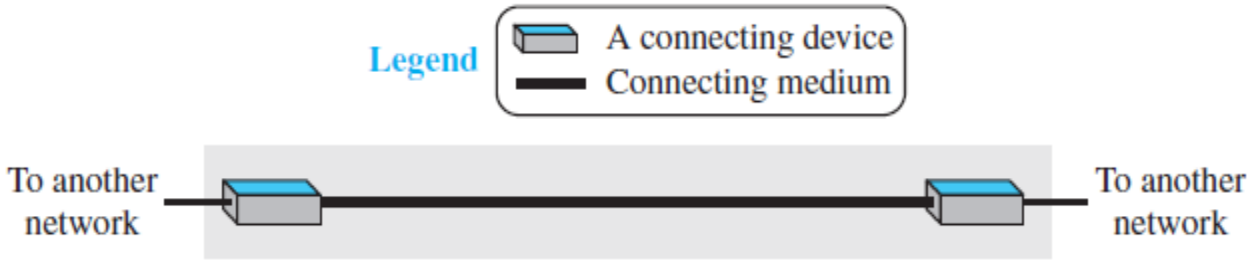


Figure 9. A point-to-point WAN

Networks (Continue)

Switch WAN

- A switch WAN is a network with more than two ends.
- A switched WAN is used in the backbone of global communication today as shown in Fig. 10.

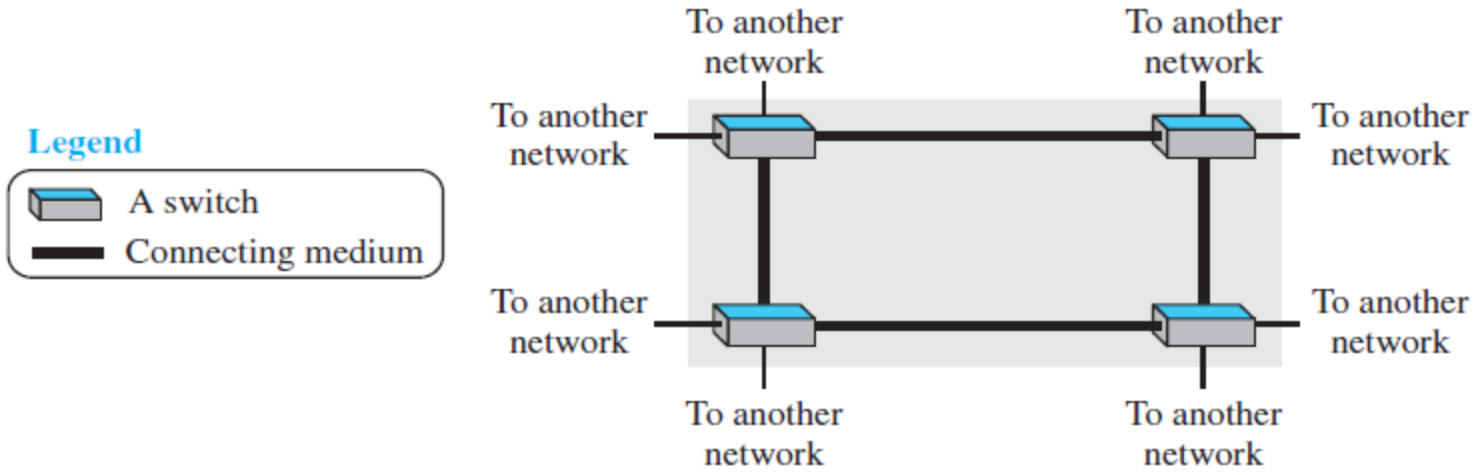


Figure 10. A switched WAN

Networks (Continue)

Internetwork

- Today, 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 as shown in figure 11.

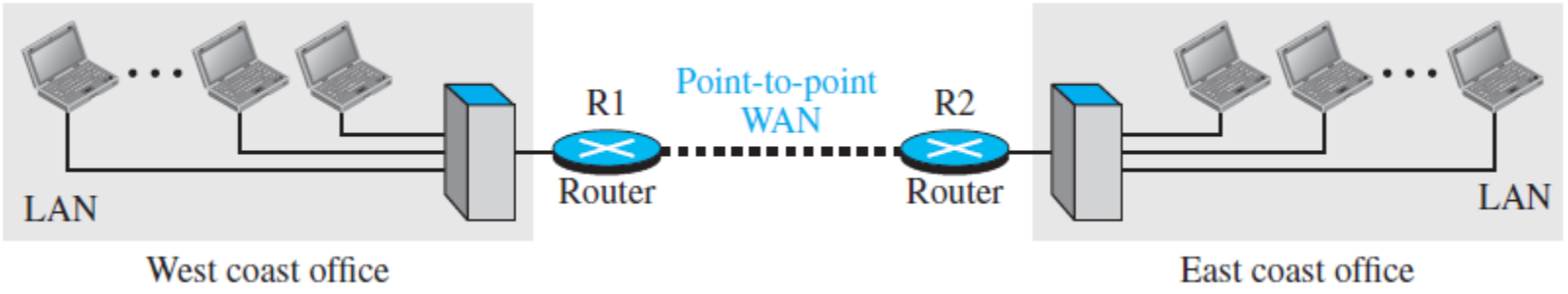


Figure 11. An internetwork made of two LANs and one point-to-point WAN

Networks (Continue)

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 and 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.
- Figure 12 shows a very simple switched network that connects four telephones to each end.

Networks (Continue)

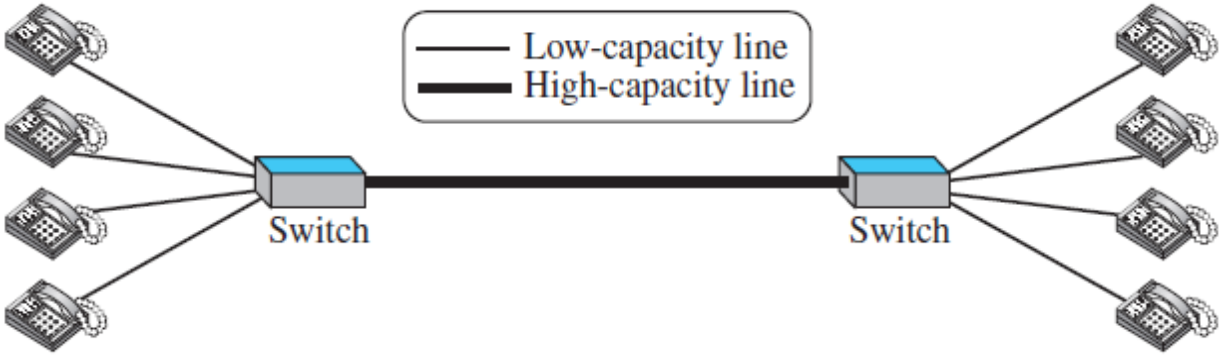


Figure 12. A circuit-switched network

Packet-Switched Network

- In a computer network, the communication between the two ends is done in blocks of data called packets.
- Figure 13 shows a small packet-switched network that connects four computers at one site to four computers at the other site.
- A router in a packet-switched network has a queue that can store and forward the packet.

Networks (Continue)

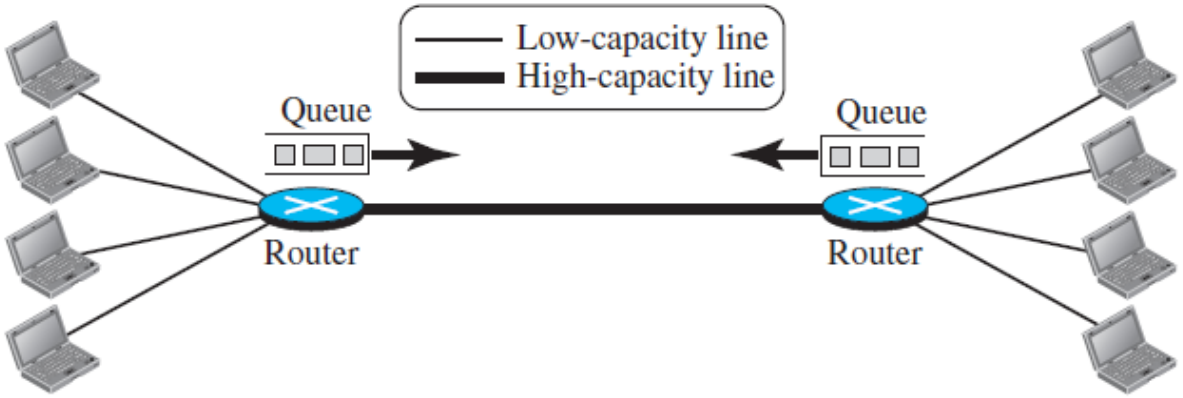


Figure 13. A packet-switched network

The Internet

- The most notable internet is called the Internet, and is composed of thousands of interconnected networks.
- Figure 14 shows a conceptual view of the Internet.
- Backbone and provider networks are also called Internet Service Providers (ISPs).
- Backbones are often referred to as international ISPs; the provider networks are often referred to as national or regional ISPs

Networks (Continue)

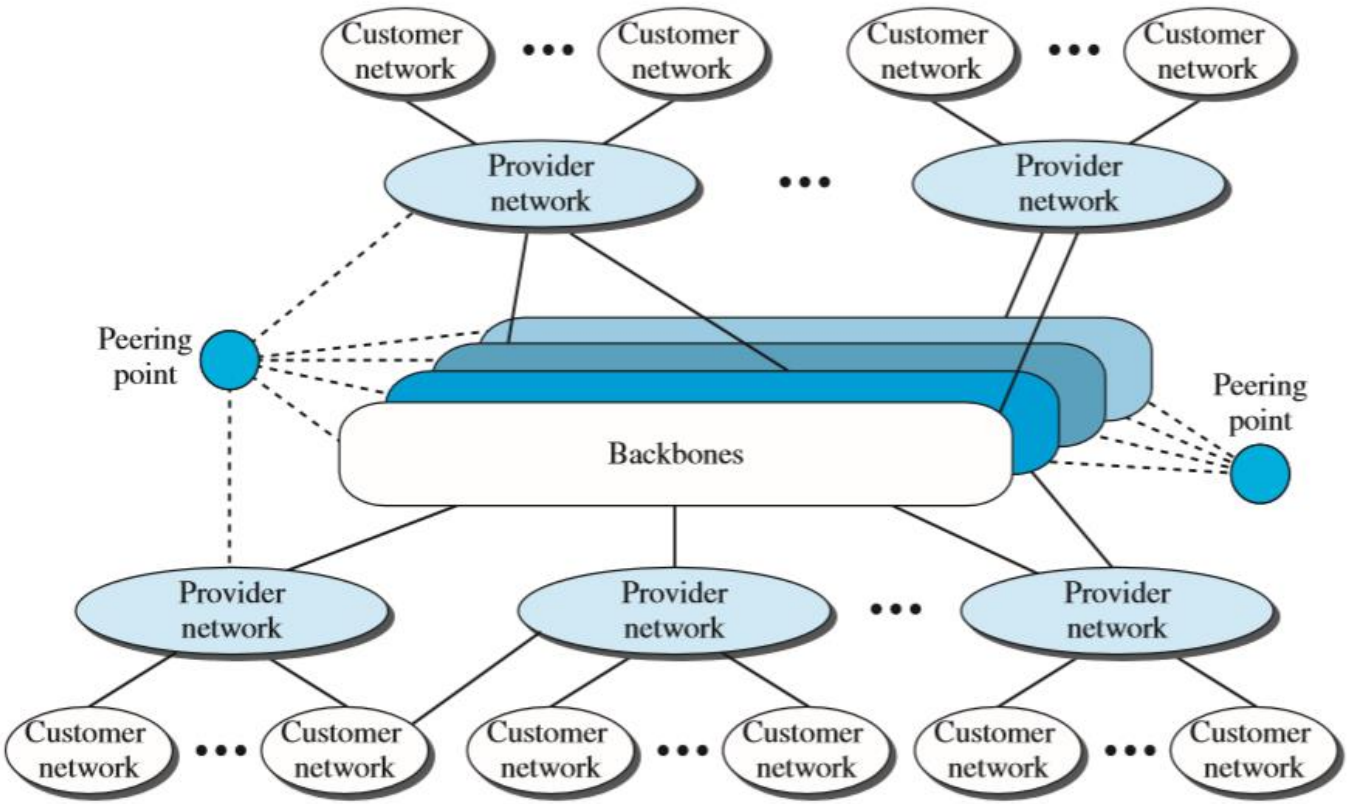


Figure 14. The Internet Today

Questions for Topic 1

1. Identify the five components of a data communications system.
2. What are the three criteria necessary for an effective and efficient network?
3. Categorize the four basic topologies in terms of line configuration.
4. Name the four basic network topologies, and cite an advantage of each type.
5. What is the difference between half-duplex and full-duplex transmission modes?
6. Why are protocols needed?
7. When we use local telephones to talk to a friend, are we using a circuitswitched network or a packet-switched network?

Topic 2: Network Models

Network Models

- When communication is simple, it is needed only one simple protocol.
- When the communication is complex, it is needed to divide the task between different layers, in which case it is needed a protocol at each layer, or protocol layering.

Scenarios

- There are two simple scenarios to better understand the need for protocol layering.

First Scenario

- In the first scenario, communication is so simple that it can occur in only one layer as shown in figure 15.

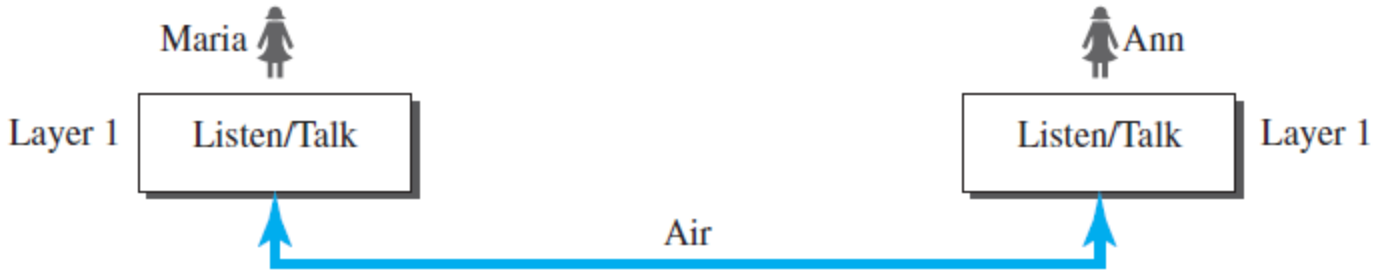


Figure 15. A single-layer protocol

Network Models (Continue)

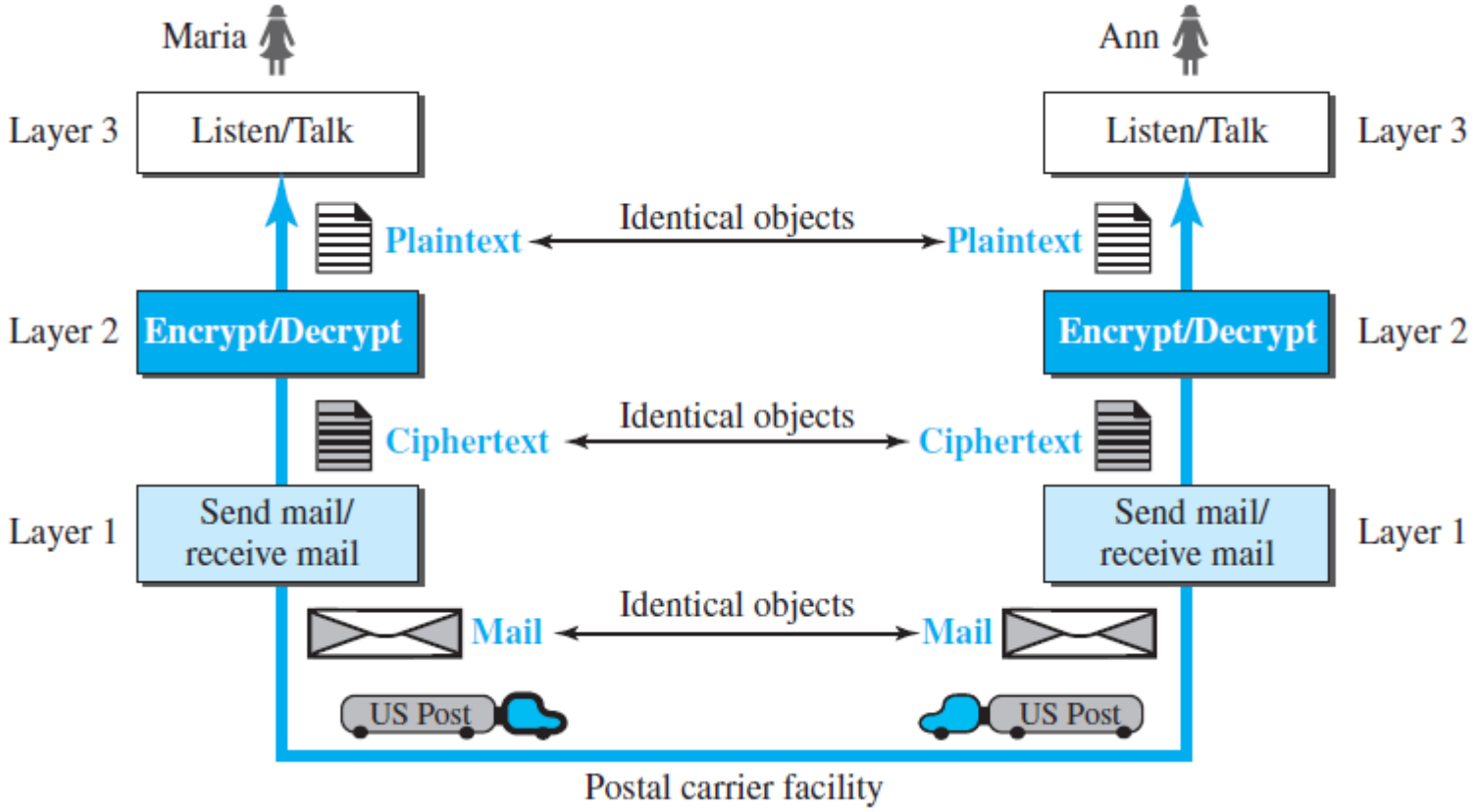


Figure 16. A three-layer protocol

Network Models (Continue)

First Principle

- The first principle dictates that if it wants bidirectional communication, it is needed to make each layer so that it is able to perform two opposite tasks, one in each direction.

Second Principle

- The second principle that it is needed to follow in protocol layering is that the two objects under each layer at both sites should be identical.

Network Models (Continue)

TCP/IP Protocol Suite

- TCP/IP is a protocol suite (a set of protocol organized in different layers) used in the Internet today.
- Today, however, TCP/IP is thought of as a five-layer model as shown in Fig.17.
- It is assumed that the links are connected by one router as shown in Fig.18.

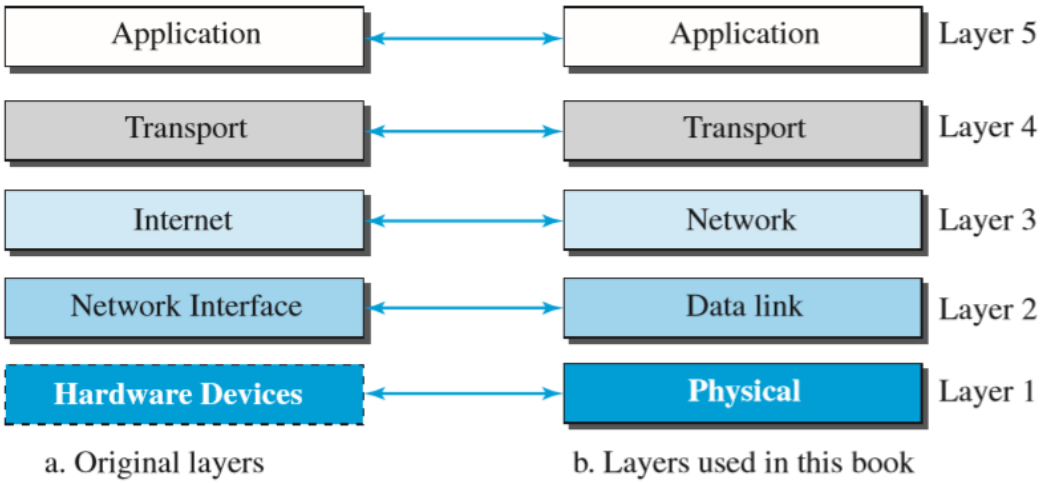


Fig. 17. Layers in the TCP/IP protocol suite

Network Models (Continue)

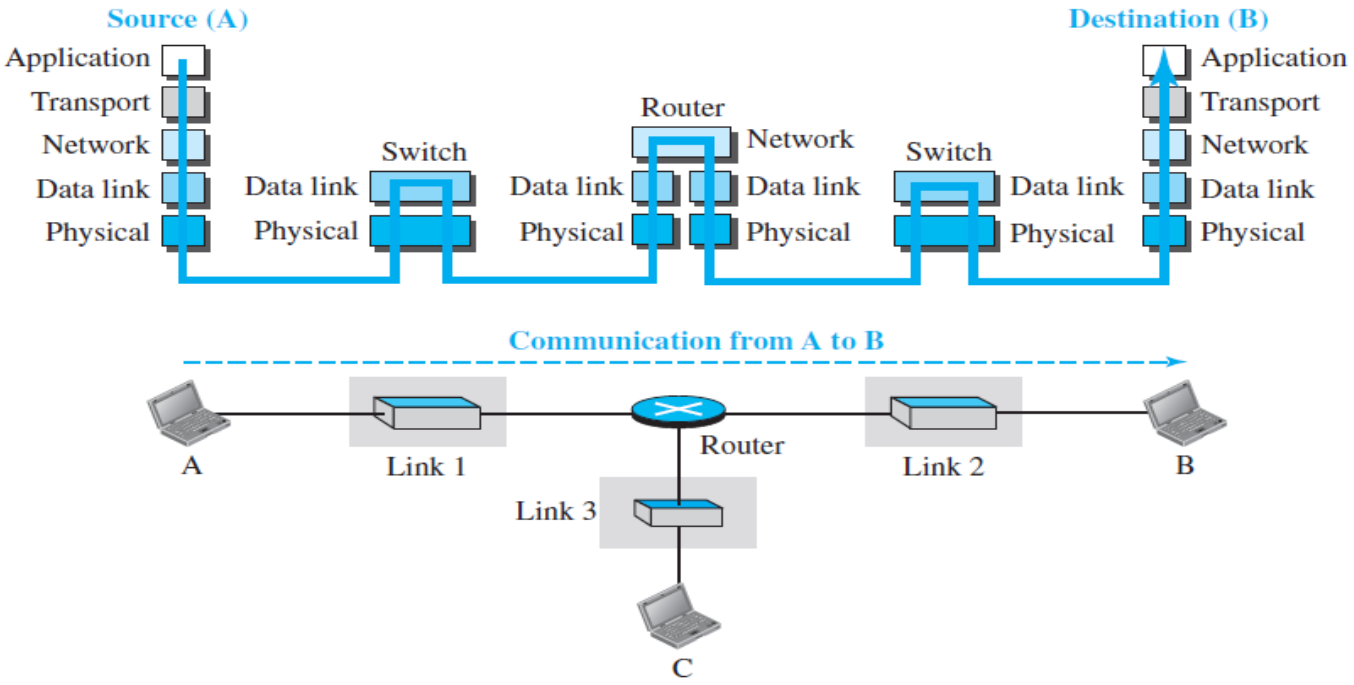


Figure 18. Communication through an internet

Network Models (Continue)

Description of Each Layer

Physical Layer: The physical layer is responsible for carrying individual bits in a frame across the link.

Data-link Layer: It is responsible for moving the packet through the link.

Network Layer: It is responsible for creating a connection between the source computer and the destination computer. The network layer also has some auxiliary protocols such as ICMP, DHCP and so on that help IP in its delivery and routing tasks

Internet Protocol is responsible for routing a packet from source to destination

Transport Layer: The logical connection at the transport layer is also end-to-end. The transport layer at the source host gets the message

Network Models (Continue)

from the application layer, encapsulates it in a transport layer packet (called a segment or a user datagram in different protocols) and sends it, through the logical connection, to the transport layer at the destination host.

Application Layer: Communication at the application layer is between two processes (two programs running at this layer). To communicate, a process sends a request to the other process and receives a response. The application layer has some protocols such as FTP, SMTP, DNS and so on.

Network Models (Continue)

Encapsulation and Decapsulation

- One of the important concepts in protocol layering in the Internet is encapsulation/ decapsulation as depicted in figure 19.

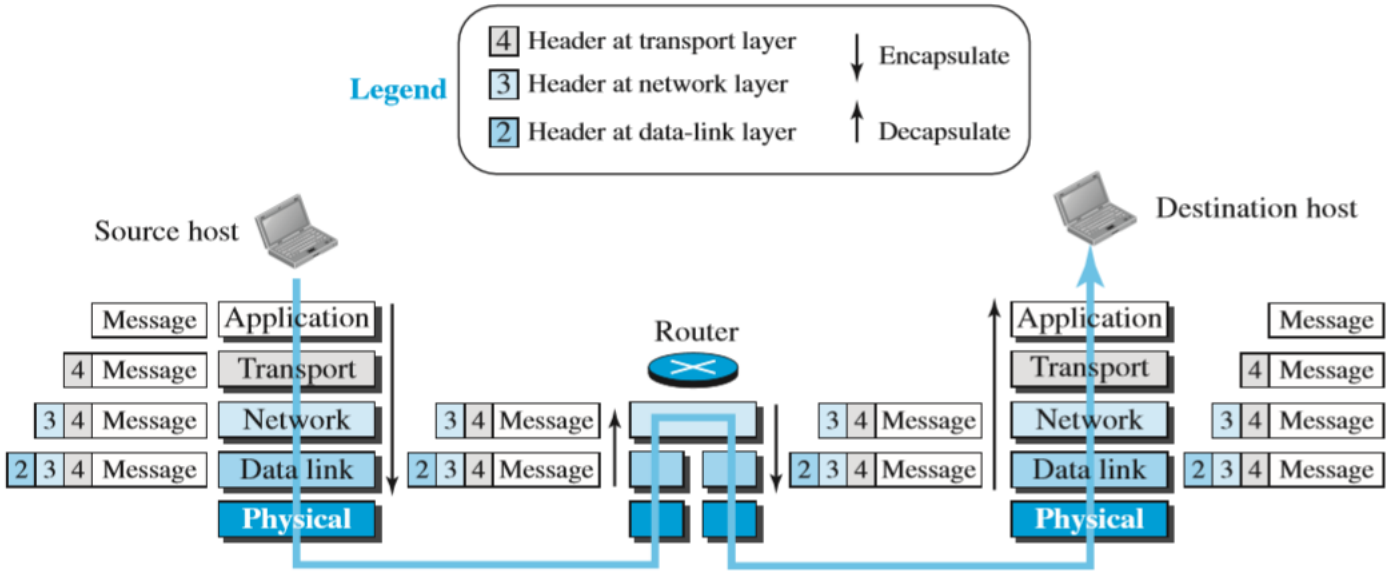


Figure 19. Encapsulation/Decapsulation

Network Models (Continue)

Addressing

- It is worth mentioning another concept related to protocol layering in the Internet, addressing.
- It has logical communication between pairs of layers in this model.
- Any communication that involves two parties needs two addresses: source address and destination address.
- Figure 20 shows the addressing at each layer.

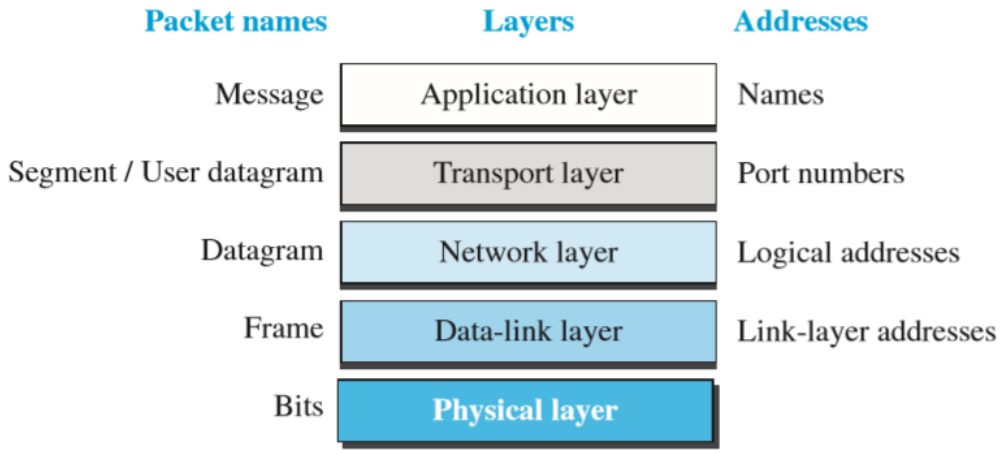


Figure 20. Addressing in the TCP/IP protocol suite

Network Models (Continue)

Multiplexing and Demultiplexing

- Since the TCP/IP protocol suite uses several protocols at some layers, it has multiplexing at the source and demultiplexing at the destination as depicted in figure 21.

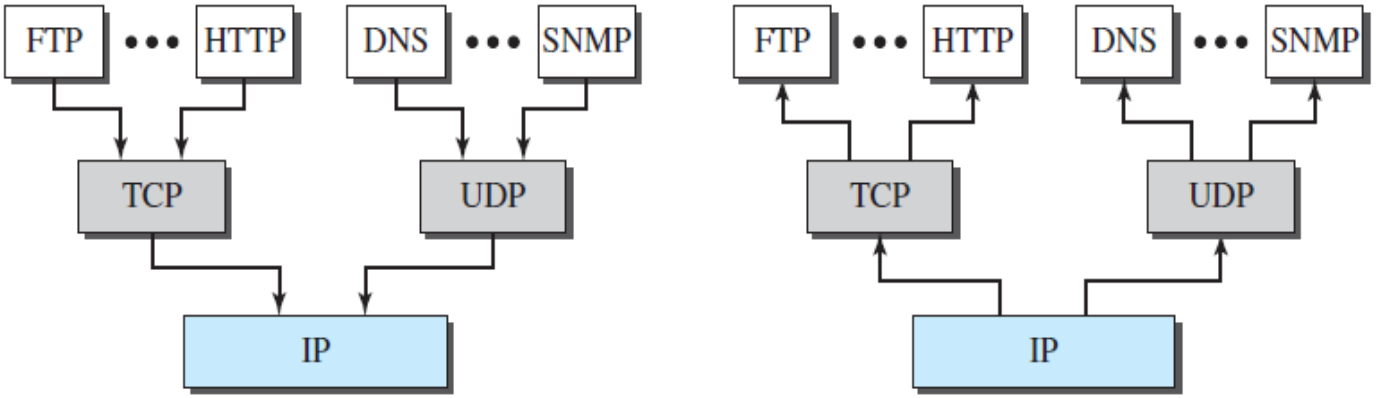


Figure 21. Multiplexing and demultiplexing

Network Models (Continue)

The OSI Model

- The OSI model is a layered framework for the design of network systems that allows communication between all types of computer systems.
- It consists of seven separate but related layers, each of which defines a part of the process of moving information across a network as depicted in figure 22.

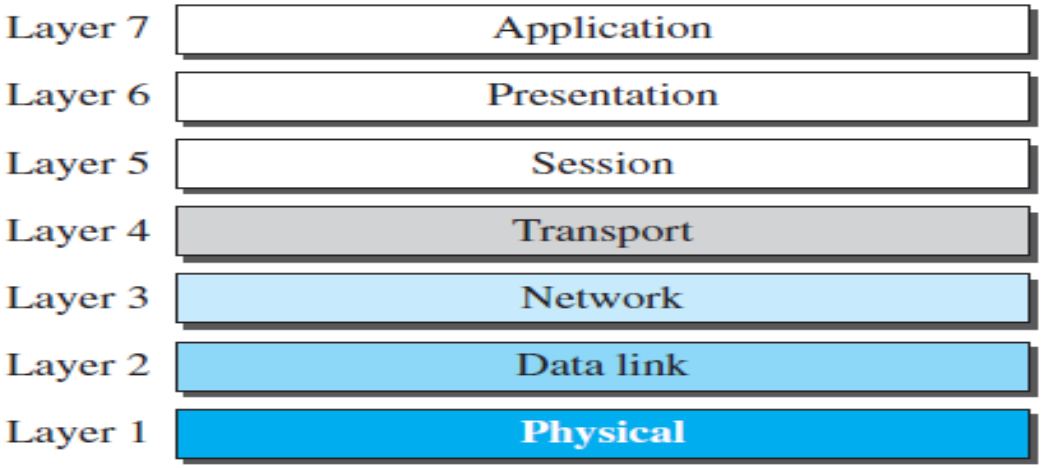


Figure 22. The OSI model

Network Models (Continue)

Functions of Seven Layers

- Application layer: provides access for the end user
  uses HTTP, DNS, FTP, SMTP,… protocols
- Presentation layer: compression and decompression
  encryption and decryption
- Session layer: establish session (connection)
  maintain session
  end session
- Transport layer: data segmentation
  error recovery
  flow control
  connection oriented protocol (TCP)
  connectionless protocol (UDP)

Network Models (Continue)

- Network layer: addressing (IP, MAC)

  routing

- Data link layer: frame creation by adding header and trailer

  error detection

  avoiding collision

- Physical layer: using cable types, cable distance, connector to build a network

  receiving frames from data link layer to transmit as signal

  producing electrical signal

Network Models (Continue)

OSI versus TCP/IP

- To compare the two models, it finds that two layers, session and presentation, are missing from the TCP/IP protocol suite.
- These two layers were not added to the TCP/IP protocol suite after the publication of the OSI model.
- The application layer in the suite is usually considered to be the combination of three layers in the OSI model, as shown in Figure 23.
- Two reasons were mentioned for this decision. First, TCP/IP has more than one transport-layer protocol.
- Some of the functionalities of the session layer are available in some of the transport-layer protocols. Second, the application layer is not only one piece of software.

Network Models (Continue)

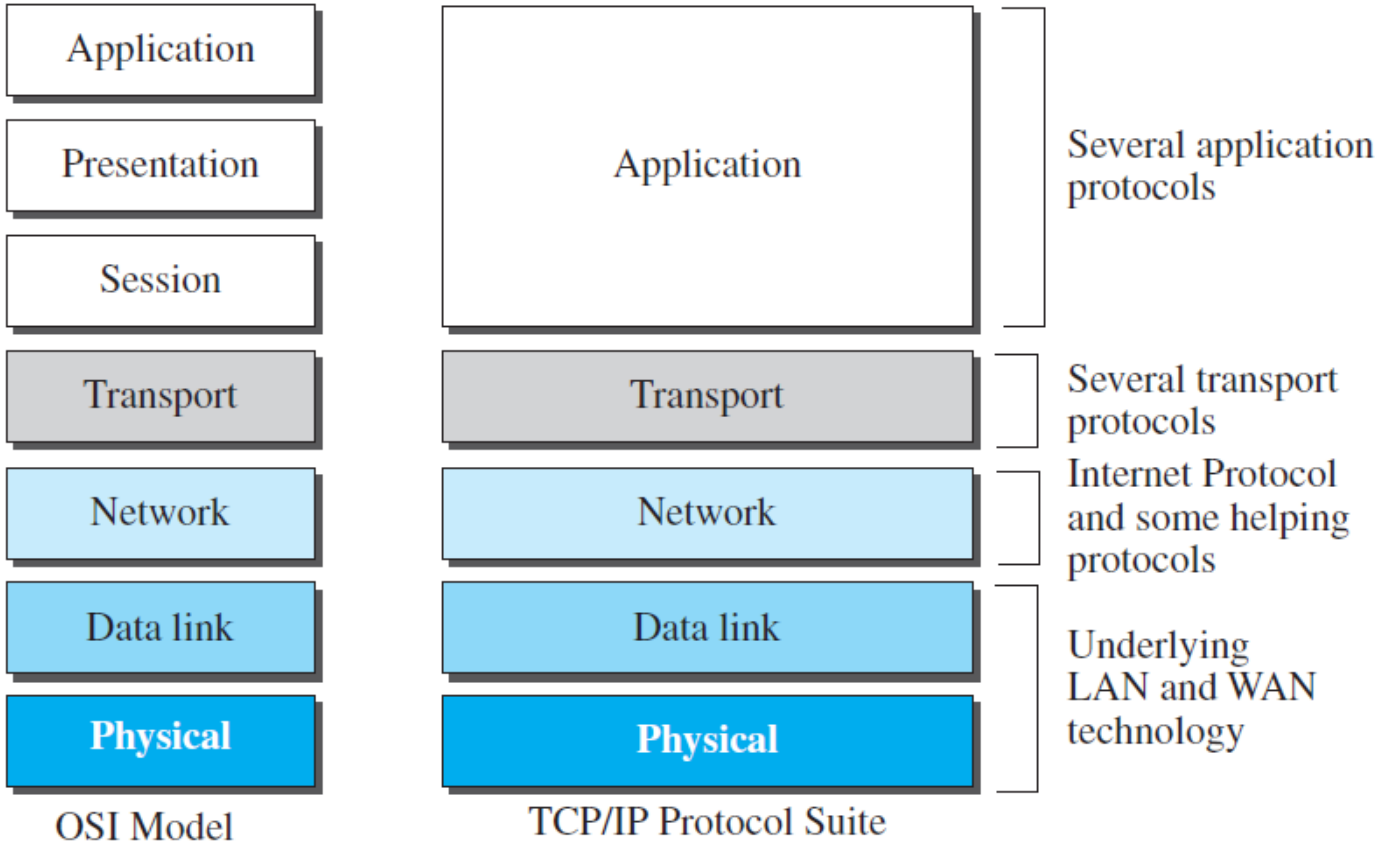


Figure 23. TCP/IP and OSI model

Questions for Topic 2

1. Which layers of the TCP/IP protocol suite are involved in a link-layer switch?
2. In the TCP/IP protocol suite, what are the identical objects at the sender and the receiver sites when we think about the logical connection at the application layer?
3. A host communicates with another host using the TCP/IP protocol suite. What is the unit of data sent or received at each of the following layers?

   a. application layer **b.** network layer **c.** data-link layer
4. Which of the following data units is encapsulated in a frame?

   a. a user datagram **b.** a datagram **c.** a segment
5. Which of the following data units is decapsulated from a user datagram?

   a. a datagram **b.** a segment **c.** a message

Questions for Topic 2 (Continue)

6. Which of the following data units has an application-layer message plus the header from layer 4?

a. a frame **b.** a user datagram **c.** a bit

7. What are the types of addresses (identifiers) used in each of the following layers?

a. application layer **b.** network layer **c.** data-link layer

Next Week Lecture

- Introduction to Physical Layer
  - Data and Signals
  - Periodic Analog Signals
  - Digital Signals
  - Transmission Impairment
  - Data Rate Limits
  - Performance

Thank You