Chapter 9

Network Organization Concepts

At a Glance

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Lecture Notes

Overview

When computer facilities are connected by data-communication components, they form a network of automated resources to support the many functions of business, education, healthcare, government, and other organizations. These networks provide an essential infrastructure for members of the information-based society to process, manipulate, and distribute data and information to each other. This chapter introduces the terminology and basic concepts of networks.

The chapter begins with a description of different network topologies including star, ring, bus, tree, and hybrid. It explains how they connect numerous hosts to the network. It also explains three types of networks: LAN, MAN, and WAN. The differences between circuit switching and packet switching are discussed. The chapter then describes conflict resolution procedures that allow a network to share common transmission hardware and software effectively. The chapter concludes with a description of the two transport protocol models (OSI and TCP/IP) and how the layers of each one compare.

Learning Objectives

After completing this chapter, the student should be able to describe:

- Several different network topologies - including the star, ring, bus, tree, and hybrid - and how they connect numerous hosts to the network
- Several types of networks: LAN, MAN, WAN, and wireless LAN
- The difference between circuit switching and packet switching, and examples of everyday use that favor each
- Conflict resolution procedures that allow a network to share common transmission hardware and software effectively
- The two transport protocol models (OSI and TCP/IP) and how the layers of each one compare

Teaching Tips

Basic Terminology

1. Provide students with an introduction to the concept of a network, explaining that it is a collection of loosely coupled processors interconnected by communications links using cables, wireless technology, or a combination of both. Note the common goal of all networked systems: to provide a convenient way to share resources while controlling users' access to them. Identify the two general configurations for networks (network operating system (NOS) and distributed operating system (D/OS)).

2. Elaborate on the network operating system (NOS). Emphasize that users are aware of the specific assortment of computers and resources in the network, and they may access them by logging on to the appropriate remote host or by transferring data from the remote computer to their own.

3. Elaborate on the distributed operating system (D/OS). Emphasize that users do not need to be aware of every machine connected to the system. Note that users access remote resources as if they were local resources. Explain that the D/OS provides good control for distributed computing systems and allows their resources to be accessed in a unified way.

4. Point out that a distributed operating system is comprised of the same four managers previously discussed but with a wider scope. Use Figure 9.1 on page 287 in the text to illustrate the components.

5. Outline the important advantages of a distributed operating system over traditional operating system environments, such as easy and reliable resource sharing, faster computation, adequate load balancing, good reliability, and dependable electronic communications among the network's users.

6. Familiarize students with the basic terminology of network systems, including terms such as remote, local, site, host, and node. Use Figure 9.2 on page 287 in the text to clarify these terms.

Teaching Tip	Refer to the following Web site to learn more about network definitions: http://whatis.techtarget.com/definitionsCategory/0,289915,sid9_tax1681,00.html

Network Topologies

1. Outline different topologies in which sites in any networked system can be physically or logically connected to one another. The most common topologies include star, ring, bus, tree, and hybrid. Be sure to mention that the physical topology of a network may not reflect its logical topology.

2. Explain that in each topology, there are tradeoffs between the need for fast communication among all sites, the tolerance of failure at a site or communication link, the cost of long communication lines, and the difficulty of connecting one site to a large number of other sites.

3. Discuss briefly the criteria that designers should keep in mind when deciding which configuration to use, such as basic cost, communication cost, reliability, and user's environment. Use an example to clarify these criteria.

Star

1. Explain, using Figure 9.3 on page 289, the star topology, in which all transmitted data must pass through a central controller when going from a sender to a receiver. Note that this topology is sometimes referred to as a hub or centralized topology and reflects a traditional approach. Discuss its advantages and disadvantages, as well as the challenges involved with this topology.

Ring

1. Explain, using Figure 9.4 on page 289 in the text, the ring topology, where all sites are connected in a closed loop with the first site connected to the last.

2. Outline the two ways a network in a ring can be connected to other networks. Point out that a bridge is used when the two networks have the same protocols, and a gateway is used when the two networks have different protocols.

3. Explain the variations to the basic ring topology, such as the double loop network and a set of multiple rings bridged together. Use Figure 9.5 on page 290 and Figure 9.6 on page 291 to illustrate and explain these concepts. Point out that both variations provide more flexibility; however, there is a cost.

4. Discuss the advantages and disadvantages of a ring topology. Emphasize that in order for a ring topology to work properly, every node must be functional or failed nodes need to be bypassed.

Bus

1. Explain, using Figure 9.7 on page 291 in the text, the bus topology, where all sites are connected to a single communication line running the length of the network.

2. Explain that in this topology, since all sites share a common communication line, only one of them can successfully send messages at any one time. Therefore, a control mechanism is needed to prevent collisions.

Tree

1. Explain, using Figure 9.8 on page 292 in the text, the tree topology. Explain that it is a collection of buses and a communication line, which is a branching cable with no closed loops.

2. Discuss how this topology allows designers to create networks by using bridges.

3. Point out the major advantages of a tree topology over a ring topology, such as the fact that the message traffic in a tree topology can still flow through the network even if a single node fails.

Hybrid

1. Explain the concepts of the hybrid topology using Figures 9.9 and 9.10 on page 293. Point out that this topology selects among the strong points of each topology and combines them to meet the system's communications requirements most effectively.

Teaching Tip	Refer to the following Web site to learn more about network topologies: http://compnetworking.about.com/od/networkdesign/l/aa041601a.htm

Network Types

1. Provide students with a general overview of network types. Point out that grouping of networks is done according to the physical distances they cover. Outline three major network types: local area network (LAN), metropolitan area network (MAN), and wide area network (WAN).

Local Area Network

1. Explain various features of a local area network, including the physical distance it covers, topologies, data rates, transmission medium, and applications.

2. Briefly discuss bridges and gateways, the devices used to connect two or more LANs. Point out the differences between the two and cite examples.

3. Discuss the factors that need to be considered when selecting a transmission medium, such as cost, data rate, reliability, number of devices that can be supported, distance between units, and technical limitations.

Teaching Tip	Refer to the following Web site to read an article on how to build a local area network (LAN) consisting of two or more computers running the Red Hat Linux operating system: www-106.ibm.com/developerworks/linux/library/l-lan.html

Metropolitan Area Network

1. Explain the features of a metropolitan area network, including the physical distance it covers and applications. Point out that in some instances, MANs are owned and operated as public utilities, providing the means for internetworking several LANs. Outline the differences between LANs and MANs.

2. Discuss the configurations of MANs.

Wide Area Network

1. Explain the features of a wide area network, including the physical distance it covers, communication media used, and applications. Point out that WANs use the communications lines of common carriers, which are government-regulated private companies such as telephone companies.

2. Discuss briefly some of the most common examples of a WAN, such as ARPAnet (the first WAN) and the Internet (the most widely recognized WAN).

Wireless Local Area Network

1. Explain the wireless local area network (WLAN), which is a LAN using wireless technology to connect computers or workstations located within the range of the network.

2. Using Table 9.1 on page 296 in the text, outline the IEEE standards for wireless networking and note the differences in speed, range, frequency, and compatibility.

3. Use Figure 9.11 on page 296 in the text to illustrate how for wireless nodes, a WLAN may provide easy access to a large network or the Internet.

4. Briefly discuss the security issues related to WLANs.

5. Briefly discuss WiMAX, a technology that will enable wireless broadband connections over much greater ranges (up to 10 miles).

Teaching Tip	Refer to the following Web site to access different articles on WLANs: www.cisco.com/en/US/tech/tk722/tk809/tsd_technology_support_protocol_home.html

Teaching Tip	Refer to the following Web site to access The IEEE 802.16 Working Group on Broadband Wireless Access Standards: www.ieee802.org/16/

Quick Quiz 1

1. In which of the following topologies must all transmitted data pass through a central controller when going from a sender to a receiver?
   a. Ring
   b. Tree
   c. Star
   d. Bus

   Answer: c

2. Which of the following types of network typically ranges from several blocks of buildings to an entire city but without exceeding a circumference of 100 km?
   a. LAN
   b. MAN
   c. WAN
   d. WLAN
   Answer: b

3. A(n) _____ is a device, and the software to operate it, that connects two or more geographically distant local area networks that use the same protocols.
   Answer: bridge

Software Design Issues

1. Outline four software issues that must be addressed by network designers. Use the bullet points on page 297 in the text as a guide.

Addressing Conventions

1. Provide students with an overview of addressing conventions used in network systems. Point out that addressing protocols are closely related to the network topology and geographic location of each site. Make sure students understand the difference between local name and global name.

2. Discuss briefly the Domain Name Service (DNS) protocol, which is a distributed data query service used to resolve Internet addresses. Discuss the Internet address example on page 297 to illustrate that Internet addresses follow hierarchical organization (left to right).

Routing Strategies

1. Provide students with an overview of routers, discussing their features, functions, and applications.

2. List the various functions that the message formats allow the protocol to perform, such as finding new nodes on a network, testing to determine whether they are working, reporting error conditions, exchanging routing information, establishing connections, and transmitting data. Point out that routing protocols must consider addressing, address resolution, message format, and error reporting.

3. Describe two of the most widely used routing protocols on the Internet: routing information protocol and open shortest path first.

4. Explain briefly the routing information protocol (RIP), which selects a path based on the immediate number of nodes, or hops, between the source and destination. Point out that the path with the smallest number of hops is always chosen.

5. Discuss the advantages and disadvantages of the routing information protocol.

6. Explain briefly the open shortest path first (OSPF) protocol, which selects a path only after the state of a network has been determined.

7. Explain why the open shortest path first protocol results in more memory usage as compared to RIP. Point out the higher CPU usage in this protocol for the calculation of the shortest path, which is based on Dijkstra's algorithm.

Teaching Tip	Refer to the following Web site to learn about Cisco routers: www.cisco.com/en/US/products/hw/routers/

Connection Models

1. Provide students with a brief overview of connection models. Outline two ways to switch the data from node to node.

2. Briefly discuss circuit switching, a method in which a dedicated communication path is established between two hosts before data transmission begins. Use a telephone system as an example. Discuss the advantages and disadvantages of this method.

3. Explain the concept of packet switching using Figure 9.12 on page 301. Discuss the example provided in the text to clarify this switching method. Point out that it is an effective technology for long-distance data transmission and provides more flexibility than circuit switching.

4. Explain the difference between circuit switching and packet switching, using Table 9.2 on page 302 as a guide. Explain why packet switching provides greater line efficiency. Discuss the advantages of packet switching over other methods.

5. Explain the methods for selecting the path used to route packets, namely datagrams and virtual circuits. Discuss the advantages and disadvantages of both methods.

Teaching Tip	Refer to the following Web site to learn more about packet switching: www.cisco.com/en/US/products/hw/routers/ps167/products_tech_note09186a00801e1dc1.shtml

Conflict Resolution

1. Briefly discuss the need for access control methods in a network. Outline the three common access control techniques: round robin, reservation, and contention. Outline three common medium access control protocols such as carrier sense multiple access (CSMA); token passing; and distributed-queue, dual bus (DQDB).

2. Explain the round robin access control technique.

3. Explain the reservation access control technique.

4. Explain the contention access control technique.

5. Explain the carrier sense multiple access (CSMA) protocol. Make sure students understand the meaning of carrier sense and multiple access.

6. Discus the disadvantages of the CSMA protocol, such as the problem of collision if two or more nodes transmit at the same instant. Explain why this protocol is less appealing for large or complex networks.

7. Discuss the advantages of CSMA/CD protocol, which is a CSMA algorithm modified to include collision detection. An example is the Ethernet protocol.

8. Explain briefly the CSMA/CA protocol, which is a CSMA algorithm modified to avoid collision. Point out that the CSMA/CA protocol is implemented in LocalTalk, Apple's cabling system, which uses a protocol called LocalTalk link access protocol. Discuss briefly how it works.

9. Provide students with an introduction to the technique of token passing, pointing out its major advantage: that collision is nonexistent when using this technique. Outline two topologies that commonly employ token passing (bus and ring).

10. Explain the workings of a token-bus network. Point out that the initial node order is determined by a cooperative decentralized algorithm, and that once the network is running, turns are determined by priority, based on node activity. Point out the advantages and disadvantages of this technique.

11. Explain the workings of a token-ring network. Provide an example of an IBM Token-Ring Network as discussed on page 305 in the text. Point out its advantages and disadvantages.

12. Discuss briefly the distributed-queue, dual bus (DQDB) protocol, which is intended for use with a dual-bus configuration. Explain how it works using Figure 9.13 on page 306 as a guide.

13. Point out DQDB advantages. For example, it provides negligible delays under light loads and predictable queuing under heavy loads.

Transport Protocol Standards

1. Provide students with a brief overview of the transport protocol standards and why they are needed. Outline the two major models: OSI and TCP/IP.

OSI Reference Model

1. Provide students with a brief overview of the OSI reference model, which serves as a framework for defining the services that a network should provide to its users. Point out that in this model, similar functions are collected together into seven logical clusters known as layers. Use Figure 9.14 on page 308 to explain the seven-layer structure.

2. Explain briefly the functions of each of the seven layers along with examples. Mention that Layer 1 is the only layer concerned with hardware, and all data must be passed down to it for actual data transfer between units to occur. Layers 2 through 7 all are concerned with software, and communication between units at these levels is only virtual. Point out that Layer 7 provides the interface to users.

Teaching Tip	Refer to the following Web site to learn more details about OSI: http://computer.howstuffworks.com/osi.htm

TCP/IP Model

1. Provide students with a brief overview of the TCP/IP model. Point out that it is the oldest transport protocol standard and is the basis for Internet communications.

2. Use Figure 9.15 on page 312 in the text to compare and contrast the TCP/IP and OSI reference model layers.

3. List three main components that the TCP/IP model uses to organize a communication system (processes, hosts, and networks).

4. Explain briefly the functions of each of the four layers of the TCP/IP model. Specifically mention the network access layer, the Internet layer, the host-host layer, and the process/application layer. Discuss how they relate to the OSI model.

Teaching Tip	Refer to the following Web site to learn more details about TCP/IP: www.redbooks.ibm.com/. Search for Manual number GG243376.

Quick Quiz 2

1. Which of the following protocols selects a path based on the immediate number of nodes, or hops, between the source and destination?
   a. Open shortest path first
   b. Routing information protocol
   c. CSMA/CD
   d. CSMA
   Answer: b

2. Which of the following is true about packet switching? (Choose all that apply.)
   a. Shared by many transmissions
   b. Preferred in low volume networks
   c. Transmits in real time
   d. High line efficiency

   Answer: a and d

3. Which of the following layers of the OSI reference model provides an interface to the users?
   a. Layer 1
   b. Layer 7
   c. Network access layer
   d. Host-host layer

   Answer: b

Class Discussion Topics

1. Have students discuss different network topologies. Ask them to compare the relative advantages and disadvantages of these topologies. Which topology do they think is employed in their school or organization network? Why?

2. Have students compare different types of switching methods. Which switching method do they think is most commonly used on the Internet? Ask them to substantiate their answers.

Additional Projects

1. Have students research to find the transmission medium used in today's high-speed LANs. Ask them to compile a list of the key characteristics of that medium

2. Have students research to compile a list of any three routers employed in today's networks along with their key characteristics and applications.

Additional Resources

1. Cisco.com:
   www.cisco.com

2. IBM.com:
   www.ibm.com

3. Microsoft.com:
   www.microsoft.com

4. Intel.com:
   www.intel.com

5. Freescale.com:
   www.freescale.com

6. IEEE:
   www.ieee.org

Key Terms

- **Bridge:** a data-link layer device used to interconnect multiple networks using the same protocol.
- **Bus topology:** network architecture to connect elements together along a single line.
- **Circuit switching:** a communication model in which a dedicated communication path is established between two hosts and on which all messages travel.
- **Distributed operating system (D/OS):** an operating system that provides control for a distributed computing system, allowing its resources to be accessed in a unified way.
- **Domain Name Service (DNS):** a general-purpose, distributed, replicated data query service. Its principal function is the resolution of Internet addresses based on fully qualified domain names.
- **Ethernet:** popular LAN network technology in which nodes contend for access to a network. Inexpensive, easy to install and maintain.
- **Gateway:** a communications device or program that passes data between networks having similar functions but different protocols.
- **Host:** (1) the Internet term for a network node that is capable of communicating at the application layer. Each Internet host has a unique IP address. (2) a networked computer with centralized program or data files that makes those resources available to other computers on the network.
- **Hybrid topology:** a network architecture that combines other types of network topologies to accommodate particular operating characteristics or traffic volumes.
- **Internet:** the largest collection of networks interconnected with routers. The Internet is a multi-protocol internetwork.
- **International Organization for Standardization (ISO):** a voluntary, non-treaty organization responsible for creating international standards in many areas, including computers and communications.
- **Local:** pertaining to the network node to which a user is attached.
- **Local area network (LAN):** a data network intended to serve an area covering only a few square kilometers or less.
- **Metropolitan area network (MAN):** a data network intended to serve an area approximating that of a large city.
- **Network:** a collection of loosely coupled processors interconnected by communications links using cables, wireless technology, or a combination.
- **Network operating system (NOS):** the software that manages network resources for a node on a network and may provide security and access control.
- **Node:** a network-layer addressable device attached to a computer network.

- **Open shortest path first (OSPF):** a protocol designed for use in Internet Protocol (IP) networks, concerned with tracking the operational state of every network interface.
- **Open systems interconnection (OSI) reference model:** 7 layer conceptual structure describing computer network architectures and the ways in which data passes through them.
- **Packet:** a unit of data sent across a network.
- **Packet switching:** a communication model in which messages are individually routed between hosts, with no previously established communication path.
- **Protocol:** a set of rules to control the flow of messages through a network.
- **Remote:** pertaining to a node at the distant end of a network connection.
- **Ring topology:** network topology, each node is connected to two adjacent nodes.
- **Router:** a device that forwards traffic between networks.
- **Routing information protocol (RIP):** a routing protocol used by IP, based on a distance-vector algorithm.
- **Site:** a specific location on a network containing one or more computer systems.
- **Star topology:** a network topology in which multiple network nodes are connected through a single, central node.
- **Token ring:** a type of local area network with stations wired into a ring network.
- **Token bus:** a type of local area network with nodes connected to a common cable using a CSMA/CA protocol.
- **Topology:** in a network, the geometric arrangement of connections (cables, wireless, or both) that link the nodes.
- **Transmission Control Protocol/Internet Protocol (TCP/IP) reference model:** a common acronym for the suite of transport-layer and application-layer protocols that operate over the Internet Protocol.
- **Tree topology:** a network architecture in which elements are connected in a hierarchical structure.
- **Wide area network (WAN):** a network usually constructed with long distance, point-to-point lines, covering a large geographic area.
- **Wireless local area network (WLAN):** a local area network with wireless nodes.