Local Area Networks – The Basics

Chapter 7

Learning Objectives

After reading this chapter, you should be able to:

- State the definition of a local area network
- List the primary function, activities, and application areas of a local area network
- Cite the advantages and disadvantages of local area networks
- Identify the physical and logical local area networks
- Cite the characteristics of wireless local area networks and their medium access control protocols
- Specify the different medium access control techniques
- Recognize the different IEEE 802 frame formats
- Describe the common local area network systems

Chapter Outline

1. Introduction

2. Primary Function of Local Area Networks

3. Advantages and Disadvantages of Local Area Networks

4. The First Local Area Network – The Bus/Tree

5. Star-Wired Bus LANs

6. Medium Access Control Protocols
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7. Bridges
    a. Transparent bridge

8. Switches
    a. Virtual LANs
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9. Popular Local Area Networks
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Lecture Notes

Introduction

A local area network (LAN) is a communication network that interconnects a variety of data communicating devices within a small geographic area and broadcasts data at high data transfer rates with very low error rates. Since the local area network first appeared in the 1970s, its use has become widespread in commercial and academic environments. It would be very difficult to imagine a collection of personal computers within a computing environment that does not employ some form of local area network. This chapter begins by discussing the basic layouts or topologies of the most commonly found local area networks, followed by the medium access control protocols that allow a workstation to transmit data on the network. We will then examine most of the common local area network products such as Ethernet and token ring.

Functions of a Local Area Network

The majority of users expect a local area network to perform the following functions and provide the following applications: file serving, database and application serving, print serving, electronic mail, remote links, video transfers, process control and monitoring, and distributed processing.

Advantages and Disadvantages of Local Area Networks

Local area networks have several advantages, including hardware and software sharing, workstation survival during network failure, component and system evolution, heterogeneous mix of hardware and software, and access to other LANs, WANs, and mainframe computers. Disadvantages include complexity, maintenance costs, and the fact that the network is only as strong as the weakest link.

The First Local Area Network – The Bus/Tree

The bus local area network was the first physical design when LANs became commercially available in the late 1970s, and it essentially consists of a single cable, or bus, to which all devices attach. Since then, the bus has diminished significantly to the point of near extinction. It is interesting to note that cable television signals are still delivered by a network bus. Thus, understanding the bus/tee network is still important.

Star-Wired Bus LANs

The most popular configuration for a local area network is the star-wired bus. This form of LAN should not be confused with an older technology called the star topology. Today's modern star-wired bus network acts like a bus but looks like a star. The logical design operates as a bus where one workstation can transmit to all other workstations. The physical design, however, more resembles a star, with the hub or switch acting as the central point.

Medium Access Control Protocols

A medium access control protocol is part of the software that allows a workstation to place data onto a local area network. Depending on the network's topology, several types of protocols may be applicable. The bottom line with all medium access control protocols is this: Since a local area network is a broadcast network, it is imperative that only one workstation at a time be allowed to transmit its data onto the network. In the case of a broadband local area network, which can support multiple channels at the same time, it is imperative that only one workstation at a time be allowed to transmit its data onto a channel on the network. There are two basic categories of medium access control protocols for local area networks: contention-based protocols, such as carrier sense multiple access with collision detection, and round-robin protocols, such as token passing.

Bridges

Let's define a bridge as a device that interconnects two local area networks that both have a medium access control sublayer. CSMA/CD and token ring local area networks both have a medium access control sublayer, but as was shown in Chapter 7, they have slightly different frame formats. The CSMA/CD frame has an 8-byte header and a length field, while the token ring frame has a 1-byte starting delimiter, an access control byte, a frame control byte, an ending delimiter, and a frame status byte. To interconnect these two networks, a device must be capable of converting one frame format to another. Bridges exist that can perform this conversion.

Switches

Recently a new device called a switch has emerged that is useful in high-traffic situations. A **switch** is a combination of a hub and a bridge and can interconnect multiple workstations like a hub, but can also filter out frames, providing a segmentation of the network. Switches can provide a significant decrease in interconnection traffic and increase the throughput of the interconnected networks while requiring no additional cabling or rearranging of the network devices.

Popular Local Area Network Systems

The discussion of local area networks started by examining the main types of network topologies: bus, star-wired bus, ring, and wireless. Then the three major categories of medium access control protocols that can operate on these different topologies were introduced: CSMA/CD, token passing, and demand priority. Let's now turn our attention to actual products or local area network systems that are found in a typical computer environment. Three of the most popular local area network systems are Ethernet, IBM token ring, and fiber data distributed interface.

IEEE 802

Although the seven-layer OSI model was designed to support most types of communication systems, it fell short in several areas. One of these areas was the data link layer. Thus, the IEEE 802 set of standards has split the data link layer into two sublayers: the medium access control sublayer and the logical link control sublayer. The medium access control (MAC) sublayer works more closely with the physical layer and contains a header, computer (physical) addresses, error detection codes, and control information. The logical link control (LLC) sublayer is primarily responsible for logical addressing and providing error control and flow control information.

LANs In Action: A Small Office Solution

The first In Action example examines how a small business decides to incorporate a LAN into their business solution. The business included 35 to 40 workstations with word processing, spreadsheets, and database applications. In order to add internal e-mail, a central database system, and print sharing, the company will consider the addition of a local area network.

LANs In Action: A Home Office Local Area Network Solution

The second In Action example examines how a home user can use a network-in-a-box solution to connect two workstations, a printer, and Internet access together.

Quick Quiz

1. What are the major functions of a LAN?

File and print serving; access to other LANs, WANs and mainframes; distributed processing; process control

2. What are the various medium access control techniques?

Contention-based, round-robin

3. What is the difference between a hub, a bridge, a switch, and a router?

Hub broadcasts any input onto all outgoing lines; bridge interconnects two LANs and provides filtering; switch replaces a hub and provides filtering; router interconnects a LAN with a WAN.

4. What are the basic functions of a network server?

It holds the network operating system as well as application programs and data set; it may also function as a hub, switch, bridge, or router.

Discussion Topics

1. Couldn't IEEE have made a single frame format for all the forms of local area networks?

2. Are LANs a stable technology or are they changing just as quickly as other forms of communication technologies?

3. Is Ethernet that good that it's the predominant form of LAN? Will everything eventually be Ethernet / CSMA/CD?

4. Will hubs be obsolete someday? What might replace them?

5. What are the advantages of creating virtual LANs?

Teaching Tips

1. Be sure to emphasize the difference between logical view and physical view. For example, a star-wired bus logically acts like a bus but physically looks like a star. A star-wire ring logically acts like a ring but physically looks like a star. A bus logically and physically is a bus.

2. The frame is the name of the package at the data link layer. It is the frame that is placed onto the medium of the physical layer. The IEEE 802 frame formats describe the layout of the frame and what the data looks like as it moves over a LAN. The frame addresses are the ones used to address an NIC in a machine. This is not the address that is used to send a packet over the Internet (that is the IP address).

3. Discuss the nondeterminism of the CSMA/CD LAN and how collisions create this characteristic.

4. What kind of mix does your school or company have of hubs, routers, bridges, and switches? Use this information as an example in class.

5. Take your students to one or more locations on campus and show them an actual, working hub/bridge/switch/router.

6. Make sure you emphasize how a bridge and switch filter out unnecessary packets.

Solutions to Review Questions

1. What is the definition of a local area network?

A communication network that interconnects a variety of data communicating devices within a small geographic area and broadcasts data at high data transfer rates with very low error rates

2. List the primary activities and application areas of a local area network.

File serving, print serving, connection to other networks and mainframes

3. List the advantages and disadvantages of local area networks.

Advantages: share files and devices, intercommunication
Disadvantages: maintenance, complexity, costs

4. What are the basic layouts of local area networks? List two advantages that each layout has over the others.

Bus: uses low-noise coaxial cable, inexpensive taps
Star-wired bus: simple to interconnect, easy to add components, most popular
Star-wired ring: simple to interconnect and easy to add components (but no more so than star-wired bus)

5. What is meant by a *passive device*?

A signal that enters is neither amplified nor regenerated. The signal is simply passed on.

6. What is meant by a *bidirectional signal*?

A signal that propagates in either direction on a medium

7. What are the primary differences between baseband technology and broadband technology?

Baseband is a signal digital signal, while broadband is analog and may carry many signals.

8. What purpose does a hub serve?

The hub is a collection point for workstations.

9. What is the difference between a physical design and a logical design?

Physical is the wiring and components; logical is how the software passes the data.

10. What is a medium access control protocol?

The software that allows a workstation to insert its data onto the LAN

11. What are the basic operating principles behind CSMA/CD? CSMA/CA?

CSMA/CD: Listen to medium; if no one transmitting, transmit. Continue to listen for collisions. If someone is transmitting, wait.
CSMA/CA: Wait to transmit; transmit; if collision, then retransmit.

12. What is meant by a "nondeterministic" protocol?

You cannot determine precisely when a workstation will get a chance to transmit (because of potential collisions).

13. What does the term *100BaseT* stand for?

One hundred mega-bits per second transmission over baseband (digital) signals, using twisted pair wiring

14. What is the difference between Fast Ethernet and regular Ethernet?

Fast Ethernet transmits at 100 Mbps, while regular Ethernet transmits at 10 Mbps.

15. What are the latest 10-Gbps Ethernet standards?

10GBase-fiber, 10GBase-T, 10GBase-CS

16. What is the primary advantage of power over Ethernet? The primary disadvantage?

The primary advantage is not having to run a separate power line to power device; the primary disadvantage is making sure the switch has enough power to run PoE devices.

17. What are the basic functions of a bridge?

To filter out unnecessary packets; to perform an interconnection between two LANs

18. What does a filter do?

It stops a packet from traversing to the next network.

19. How does a transparent bridge work?

It observes traffic on a LAN and creates a set of routing tables.

20. What is backward learning?

Watching where packets are coming from and assuming they are on that particular segment

21. How does a bridge encapsulate a message for transmission?

Only remote bridges encapsulate wide area network headers onto an existing data packet.

22. When referring to a bridge or a switch, what is a port?

The port is the connection that is used to connect a workstation or another bridge or switch to this bridge or switch.

23. What are the basic functions of a switch?

A switch examines a packet’s destination address and routes the packet to the appropriate workstation.

24. How does a switch differ from a hub? From a bridge?

A switch examines addresses; a hub does not. A switch has multiple ports and takes the place of a hub; a bridge only has two ports and interconnects two LANs.

25. What is cut-through architecture?

The device is passing the data packet on before it has even finished entering the device.

26. How is a full-duplex switch different than a switch?

A full-duplex switch has one set of lines for receiving and one set of lines for transmitting; thus, it can do both operations at the same time.

27. How is an ad-hoc wireless LAN different from the others?

There is usually no central server.

Suggested Solutions to Exercises

1. What properties set a local area network apart from other forms of networks?

Small geographic distances using broadband transmissions

2. You have a broadband bus local area network with four stations, numbered 1 through 4, left to right. Because of cable lengths, there are amplifiers at various points along the cable. Station 3 wants to send a copy of a data frame to both station 2 and station 4. Show a cable configuration and a sequence of events that will allow this transmission to take place.

Might want to use stations with multiple taps; using two cables, each transmitting in a different direction

3. Describe another example of a broadband bus system besides cable television.

Cable modems, video surveillance systems

4. Of all the local area networks introduced in this chapter, is any system capable of supporting a full-duplex connection? Which one?

CSMA/CD can support full duplex if two sets of cables are used to connect a workstation to a switch.

5. State the primary advantage of a deterministic local area network protocol over a nondeterministic local area network protocol. Give a real-life example of this advantage.

An advantage of a deterministic local area network is that you can fairly accurately predict when a workstation will be able to transmit. This can be extremely important in real-time environments. An example of this is an assembly line in which real-time transactions must be responded to in an appropriate manner.

6. Physically, a hub looks the same as a MAU. Logically, they are different. Explain how they are different.

A hub immediately broadcasts any incoming data out to all ports. A MAU (the hub in a token ring-type network) passes the data around the ports in a ring fashion.

7. What are the primary functions of the medium access control layer?

Create an error-resistant frame; synchronize incoming stream with receiver.

8. What are the primary functions of the logical link control layer?

To provide a service access point for a connection

9. Is a hub a passive device? Explain.

Not completely. A hub does regenerate a digital signal. And there may be some simple network management functions performed in a hub.

10. Which of the Ethernet standards (10 Mbps, 100 Mbps, 1000 Mbps, 10 Gbps) allow for twisted pair media? What are the corresponding IEEE standard names?

Currently all but 10 Gbps Ethernet can run over twisted pair.

11. If a network is described as 1000BaseT, list everything you know about that network.

CSMA/CD LAN, 1000 Mbps transmission, baseband or digital signaling, twisted pair wiring

12. In the IEEE 802.3 frame format, what is the PAD field used for? What is the minimum packet size?

The PAD field makes sure the frame is not misinterpreted as a runt. The minimum packet size is 64 bytes.

13. List one advantage of IEEE 802.11a over IEEE 802.11g. List one advantage of IEEE 802.11g over IEEE 802.11a.

A over g: more concurrent channels; g over a: lower frequencies and longer transmission distances

14. Suppose workstation A wants to send the message HELLO to workstation B. Both workstations are on an IEEE 802.3 local area network. Workstation A has the binary address "1" and workstation B has the binary address "10." Show the resulting MAC sublayer frame (in binary) that is transmitted. Don't calculate a CRC; just make one up.

HEADER 10 1 5(data length) HELLO PAD(33 bytes) CHECKSUM

15. What is the difference between the physical representation of a star-wired ring LAN and the logical representation?

A star-wired ring LAN physically looks like a star but acts logically like a ring. A star-wired bus physically looks like a star but acts logically like a bus.

16. Which of the wireless LAN protocols can support data rates as high as 54 Mbps? Theoretical or actual?

Only IEEE 802.11a and g, and not even that high (22 Mbps under ideal or actual conditions)

Problem 17 is missing from the book.

18. Your company wants to create a wireless network for the entire office building. The building is 10 stories high, and the company wants to incorporate IEEE 802.11a by placing one access point on the 10th floor. Will this layout work? Explain.

Probably not. Wireless signals don't travel that far and won't penetrate that many floors and ceilings.

19. Give two examples of how a company might use an ad hoc wireless layout.

Conference rooms, meeting rooms, think tanks, teams working on special projects

20. In wireless CSMA/CA, if a user device is trying to transmit standard data and an access point device is trying to issue a poll at the same time, which device will transmit first, and why?

The poll, because polls get a smaller interframe space.

21. Explain the difference between 1000BaseSX and 1000BaseLX.

1000BaseSX is designed for shorter distances of multimode fiber-optic cable (thick cable, slower rates), while 1000BaseLX can run longer distances using either multimode fiber or higher rate single-mode fiber.

22. Describe an application that would operate more effectively using a wireless local area network (ad hoc design).

Just about any nomadic operation

23. What are the advantages that Ethernet (CSMA/CD) has over all other local area network forms?

Fairly simple protocol, inexpensive, widely used

24. What are the disadvantages unique to Ethernet?

Collisions are the biggest disadvantage.

25. Modify Hannah's network solution in the In Action section so that it violates the 5-4-3 rule.

26. Explain whether or not each of the following is a reason to segment a LAN into smaller segments:
Large number of network collisions Yes
Administrators decide it is time to add an additional Web server No
Users complain of very slow response time Maybe yes
Large number of frame runts Maybe yes
A new network operating system is installed No

27. How is a bridge similar to a switch?

Both look at the MAC address and either forward or drop the frame.

28. Are bridges and switches interchangeable? Explain.

You can probably substitute a switch for a bridge but not necessarily the other way around. Bridges are usually 2-port devices. Switches can have many ports.

29. A transparent bridge is inserted between two local area networks ABC and XYZ. Network ABC has workstations 1, 2 and 3, and network XYZ has workstations 4, 5, and 6. Show the contents of the two routing tables in the bridge as the following packets are transmitted. Both routing tables start off empty.

- **Workstation 2 sends a packet to workstation 3.**
- **Workstation 2 sends a packet to workstation 5.**
- **Workstation 1 sends a packet to workstation 2.**
- **Workstation 2 sends a packet to workstation 3.**
- **Workstation 2 sends a packet to workstation 6.**
- **Workstation 6 sends a packet to workstation 3.**
- **Workstation 5 sends a packet to workstation 4.**
- **Workstation 2 sends a packet to workstation 1.**
- **Workstation 1 sends a packet to workstation 3.**
- **Workstation 1 sends a packet to workstation 5.**
- **Workstation 5 sends a packet to workstation 4.**
- **Workstation 4 sends a packet to workstation 5.**

At the end:
Routing table on ABC's port: 1, 2
Routing table on XYZ's port: 4, 5, 6

30. A CSMA/CD network is bridged to a token ring network. A user on the CSMA/CD network sends an e-mail to a user on the token ring network. Show how the e-mail message is encapsulated as it leaves the CSMA/CD network, enters and leaves the bridge, and arrives at the token ring network.

The CSMA/CD frame going into the bridge: Header, Destination Address, Source Address, Data Length, Data, Pad, Checksum. Header, Data Length, and Pad are discarded. Preamble, Starting Delimiter, Frame Control, and Ending Delimiter are created and applied. Addresses are converted if necessary, and checksum is recalculated.
The token ring frame as it leaves the bridge: Preamble, Starting Delimiter, Frame Control, Destination Address, Source Address, Data, Checksum, and Ending Delimiter.

31. Give an example of a situation in which a virtual LAN might be a useful tool in a business environment. What about in an educational environment?

If you want a certain group of users to work together on a project, you might want to place them on a virtual LAN; likewise for school.

32. Draw a layout of a business in which remote bridges would be beneficial. What would need to change in this scenario to eliminate the need for the remote bridges?

Draw a business with two offices separated by a long distance. If the two offices installed routers and interconnected the routers with a long-distance telephone service, the remote bridges could be eliminated.

33. Is the hub the only device on a local area network that can be managed? Explain.

No, any device (routers, bridges, switches, printers) on a network can be managed.

34. a. The local area network shown in Figure 7-28 has two hubs (X and Y) interconnecting the workstations and servers. What workstations and servers will receive a copy of a packet if the following workstations/servers transmit a message:

- **Workstation 1 sends a message to workstation 3:**
- **Workstation 2 sends a message to server 1:**
- **Server 1 sends a message to workstation 3:**

All devices will receive all messages.

b. Replace hub Y with a switch. Now what workstations and servers will receive a copy of a packet if the following workstations/servers transmit a message:

- **Workstation 1 sends a message to workstation 3:**
- **Workstation 2 sends a message to Server 1:**
- **Server 1 sends a message to workstation 3:**

Workstations 1, 2, and 3
Workstations 1, 2, and the server
Only workstation 3

35. What does it mean when a switch or device is cut-through? What is the main disadvantage of a cut-through switch? Is there a way to solve this disadvantage of a cut-through switch without losing the advantages?

Cut-through means the beginning of the data packet is leaving the switch before the end of the packet has entered the switch. A disadvantage is that errors are propagated. There's not a way if you want to keep it truly cut-through.

36. Give a common business example that mimics the differences between a shared network segment and a dedicated network segment.

Wide range of possible answers here

37. Your company's bridge between its two networks has just died. You have a router lying on your desk that is not currently being used. Will the router work in place of the broken bridge? Explain.

More than likely not. Routers operate on IP addresses, while bridges operate on NIC addresses.

38. A CSMA/CD network is connected to the Internet via a router. A user on the CSMA/CD network sends an e-mail to a user on the Internet. Show how the e-mail message is encapsulated as it leaves the CSMA/CD network, enters the router, and then leaves the router.

Leaving the LAN:
Data
App + Data
TCP + App + Data
IP + TCP + App + Data
MAC + IP + TCP + App + Data + MAC

Entering router:
MAC + IP + TCP + App + Data + MAC
IP + TCP + App + Data

Leaving router:
IP + TCP + App + Data
WAN + IP + TCP + App + Data + WAN

Thinking Outside the Box

1. You can interconnect all cash registers into one or two centrally located hubs. Cat 5e twisted pair should be sufficient. If hubs can't be centrally located and cable distance exceeds 100 meters, be careful; might need better medium.

3. Run twisted pair cable; run fiber-optic cable; use wireless LANs; use HomePlug technology that transmits data through electrical wires

5. An ad-hoc network (less reliant on central server) might be an interesting solution.

6. Dial-up modems with connections to Internet service provider; high-speed data line (such as DSL or cable modem) with small router