Chapter 2

How LAN and WAN Communications Work

At a Glance

Instructor's Manual Table of Contents

Lecture Notes

Overview

In this chapter, the student is introduced to the OSI model. The layers of the OSI model will be examined. Students will also learn about different network types, such as Ethernet and token ring.

Objectives

- Explain the OSI reference model, which sets standards for LAN and WAN communications
- Discuss communication between OSI stacks when two computers are linked through a network
- Apply the OSI model to realistic networking situations
- Describe major LAN transmission methods
- Explain the basic WAN network communications topologies and transmission methods, including telecommunications, cable TV, satellite, and wireless technologies.
- Explain the advantages of using Ethernet in network designs

Teaching Tips

The OSI Reference Model

1. Explain what the Open Systems Interconnection (OSI) reference model is and why it is valuable in designing and troubleshooting networks.
2. Provide detail about the origins of the OSI model and its creators:
    a. International Organization for Standardization (ISO)
    b. IEEE
    c. American National Standards Institute (ANSI)
    d. International Telecommunication Union (ITU)
3. Show what the OSI model looks like in practice:
    a. Application (Layer 7)
    b. Presentation (Layer 6)
    c. Session (Layer 5)
    d. Transport (Layer 4)
    e. Network (Layer 3)
    f. Data Link (Layer 2)
    g. Physical (Layer 1)

Teaching Tip	There are several mnemonics for memorizing the order for the OSI model, but the most commonly used of these methods is "All People Seem To Need Data Processing".

Physical Layer

1. Discuss with students how the physical layer includes devices, media, and encoding methods.
2. Show students what an analog signal is, and provide examples of services that use analog signals such as the plain old telephone system.
3. Compare analog signals to digital signals. Students should be basically aware of the different ways a digital signal can be represented.
4. Explain that issues at the physical layer are typically problems with devices themselves, such as a fried network card, or shorted electrical circuit.
5. Define Electromagnetic Interference (EMI) and Radio Frequency Interference (RFI) and explain how each can affect wired and wireless network devices.

Data Link Layer

1. Explain what a frame is, and what information it contains, such as the start of frame information, source and destination MAC address, and error checking.
2. Describe the path of data from the Data Link layer to the Physical layer. Students should understand that data at this layer becomes electrical signals at the physical layer.
3. Provide an understanding of the Cyclic Redundancy Check error checking method.
4. Introduce the Logical Link Control (LLC) and media access control (MAC) sublayers.
    a. Explain how the LLC sublayer handles flow control, error control, and frame synchronization.
    b. Detail how the MAC sublayer examines the physical address information in each frame.
5. Give an example of a MAC address and explain how it ties to a physical device on the network.
6. Explain the connectionless service and the connection-oriented service terms. Students should understand how these two services differ from each other.

Network Layer

1. Describe a packet and how a packet travels from the Network Layer down.
2. Explain the existence of logical routes for controlling the destination of packets at this layer, as opposed to physical cable routes.
3. Describe the discovery process at the Network layer.
4. Define what a virtual circuit is, and how the network layer manages data that arrives in the wrong order.

Transport Layer

1. Discuss the purpose of the transport layer in the OSI model. At this layer, communications occur between nodes listening on different ports.

2. Explain what a network socket is.
3. Detail how flow control is used to ensure that one device does not send data faster than the receiving device can handle.
4. Discuss the role of the transport layer in fragmenting data into smaller units.

Session Layer

1. Explain the Session layer's role in the OSI model as the layer where communications are established and maintained.
2. Define what half-duplex and full-duplex means, explaining which is using two-way alternate (TWA) mode and two-way simultaneous (TWS) mode.
3. Compare simplex mode to half-duplex and full-duplex.

Presentation Layer

1. Explain how the Presentation layer ensures that data sent from one node is presented properly on another node, such as when a sending node uses Extended Binary Coded Decimal Interchange Code (EBCDIC) and needs to be translated to American Standard Code for Information Interchange (ASCII).
2. Discuss how encryption can be used to protect data from being viewed, and provide an example of the use of encryption, such as with Secure Sockets Layer (SSL)

Application Layer

1. Detail the role of the Application layer in the OSI model. Students should understand that applications such as mail clients and applications in general exist at this layer.
2. Discuss the Windows redirector application, and how it exists at the Application level.

Communicating Between Stacks

1. Demonstrate how data moves up and down through the OSI model's layers using a diagram.
2. Peer protocols should be explained as a way for a sending node to communicate with a receiving node on the same OSI layer.
3. Define primitives as a series of commands that transfer information from one layer to the next.
4. Explain what a protocol data unit (PDU) is, and how the service data unit (SDU) is created from the PDU.

<u>Quick Quiz 1</u>

1. A _____ is a Type 2 operation in which a logical connection is established between sending and receiving nodes.
    a. Connectionless service
    b. Connection-oriented service
    c. Packet

   d. Frame

   Answer: B

2. Radio Frequency Interference (RFI) is caused by magnetic fields that are generated by electrical devices.
   a. True
   b. False

   Answer: B

3. Which answer describes a logical communication path set up to send and receive data?
   a. Virtual circuits
   b. Virtual packet routing
   c. Network route
   d. Switched circuits

   Answer: A

4. A _____ is an error detection method that calculates a value for the total size of information fields in a frame.

   Answer: Cyclic redundancy check (CRC)

5. An analog signal uses voltage levels to generate binary ones or zeroes.
   a. True
   b. False

   Answer: B

Applying the OSI Model

1. Show students what happens at each layer as the data is passed through it, and how each layer encapsulates data. Provide details at each layer as to encapsulation.

Understanding the Role of Requests for Comments

1. Explain what a Request for Comments (RFC) is and how they are used to help create standards for network communications.
2. Define the role of the Internet Engineering Task Force (IETF) in managing RFCs.

LAN Transmission Methods

Ethernet

1. Introduce students to the Ethernet IEEE 802.3 standard, and the speeds it has available.
   a. 10 Mbps
   b. 100 Mbps
   c. 1 Gbps
   d. 10 Gbps
   e. 40 Gbps
   f. 100 Gbps

2. Explain the Carrier Sense Multiple Access with Collision Detection (CSMA/CD) algorithm's role in detecting collisions and facilitating multi-node network communications.
3. Carrier-sense should be introduced as a way of checking for a data carrying signal using voltage levels.
4. Define a network collision as what occurs when more than one node tries to transmit on a network at the same time. Students should understand how nodes respond to a collision.
5. Discuss the fields that are encapsulated into a frame:
    a. Preamble
    b. Start of frame delimiter
    c. Destination and source addresses
    d. Length
    e. Data and pad
    f. Frame check sequence or frame checksum
6. Compare the more widely used Ethernet II standard to the original Ethernet specification.
7. Explain the Subnetwork Access Protocol (SNAP) as a way to quickly adapt protocols that are not fully compliant with 802.2 standards.

Token Ring

1. Review the ring topology when introducing the Token Ring standard to provide a basic idea of how the ring functions.
2. List the speeds at which traditional token ring networks function:
    a. 4 Mbps
    b. 16 Mbps
    c. 100 mbps
3. Explain the multistation access unit (MAU) as a special hub to connect all the nodes in a token ring network.
4. Detail how broadcast frames or broadcast packets are used on a network. Students should understand that both of these are present on Ethernet networks as well, not just token ring.
5. Explain how beaconing is used in token ring to indicate a possible problem with the network.
6. Describe what a broadcast storm is, and why they're uncommon on token ring networks. Explain how they can occur on an Ethernet network.

Fiber Distributed Data Interface

1. Introduce the Fiber Distributed Data Interface (FDDI) standard as one that was intended to provide faster speeds than what was available for Ethernet or token ring at the time.
2. Provide information on the two types of packets that can be sent with FDDI:
    a. Synchronous communication
    b. Asynchronous communication
3. Students should be aware that FDDI provides two rings instead of just one to provide redundancy.

WAN Network Communications

1. Regional telephone companies can also be referred to as telcos or regional bell operating companies (RBOCs). List some of the commonly known telcos in your local area.
2. The definition of the term cablecos or multiple system operators (MSOs) should be given also. List some of the available cablecos in your area.

Telecommunications WANs

1. Explain what the plain old telephone service (POTS) or public switched telephone network (PSTN) are.
2. Briefly detail how a local access and transport area (LATA) and interexchange carrier (IXC) lines make up communications between RBOCs. Additionally, explain what a point of presence (POP) is.
3. Introduce the T-Carrier line as a dedicated telephone line that can be used for data communications. Define the speed of a T-Carrier line, and explain how its individual channels make up this speed.

Teaching Tip	While T-Carrier lines are traditionally passed through telephone lines, they can also be passed over fiber links through the use of a multiplexer. This is usually done to ensure more reliable communications, as fiber buried underground is typically safer than copper lines on a telephone pole.

Cable TV WANs

1. Describe a headend as the central receiving point for signals of various origins.
2. Trunk lines should be explained as a link between two switches (not just necessarily network switches)
3. Provide students with an understanding of how a cable network works, and how a cable modem is used to connect home networks.
4. Give information about the typical speeds at which a cable network offers Internet access.

Wireless WANs

1. Introduce and compare the different methods available for wireless WAN communication, such as radio and microwave.
2. Explain the term packet radio as process for transmission of data-carrying packets.
3. Inform students about the different wireless data transmission services available from cell phone providers:
    a. 2G Wireless
    b. 3G Wireless
    c. 4G Wireless

4. Discuss how a codec is used to encode and decode digital signals for analog / radio transmission.
5. When discussing the 3G wireless network service, introduce the International Mobile Telecommunications-2000 (IMT-2000) standard, and some of the standards that follow it.
6. Mention the International Mobile Telecommunications-Advanced (IMT-Advanced) standards for mobile communications as the standard used by 4G. Provide information on how the 4G wireless service improves on the 3G wireless service.

Teaching Tip	Codecs, while used for networking, are also used for digital media. Students most likely have more experience with audio codecs, such as those used for playing mp3 files.

WAN Transmission Methods

1. Explain the following switching techniques used by WANs:
    a. Time Division Multiple Access (TDMA) divides channels into distinct time slots
    b. Frequency Division Multiple Access (FDMA) divides channels into frequencies
    c. Statistical Multiple Access dynamically allocates bandwidth based on application need
    d. Circuit switching creates a dedicated physical circuit between sending and receiving nodes
    e. Message switching uses store and forward communication to transmit information
    f. Packet switching behaves similarly to circuit and message switching.

<u>Quick Quiz 2</u>

1. A trunk line is a low capacity line that goes between two switches.
    a. True
    b. False

    Answer: B
2. Which of the following uses dedicated physical circuits between the sending and receiving nodes?
    a. Packet switching
    b. Message switching
    c. Circuit switching
    d. Packet messaging

    Answer: C
3. Select the standard below that makes use of two rings of fiber with a max bandwidth of 100 Mbps:
    a. Fiber Distributed Data Interface (FDDI)
    b. Token ring

   c. Ethernet
   d. Packet switching

   Answer: A

4. A _____ is a dedicated telephone line that can be used for data communications.
   a. Circuit switched line
   b. DSL line
   c. Trunk line
   d. T-Carrier

   Answer: D

5. _____ establishes a dedicated logical circuit between two transmitting nodes and may have different physical routes during the session.
   Answer: Packet switching

Class Discussion Topics

1. Many sites use encryption via SSL for protecting data. Get students to discuss what sites / information they feel should be encrypted on the Internet. While some choices might be immediately obvious (banks, monetary transactions), some sites used for social media would also be good choices.

Additional Projects

1. Have students price a T-1 connection online, which are typically billed monthly. Many providers online will give a basic price, but some may require quotes. Once pricing information is gathered, compare T-1s to residential Internet services, and explain why a company would choose a T-1 instead.
2. While MAC addresses are intended to be permanent and unchangeable, many MAC address changers exist for Windows. Linux and Mac OS X are both able to modify their MAC addresses via the ifconfig <iface> ether <mac> command. These changes are not permanent.

Additional Resources

1. http://en.wikipedia.org/wiki/OSI_model
2. http://en.wikipedia.org/wiki/List_of_United_States_telephone_companies
3. http://en.wikipedia.org/wiki/List_of_cable_television_companies

Key Terms

- **2nd generation (2G)** Second generation of mobile telecommunications technology, which is notable because it introduces the use of digital signals instead of analog signals (1G) for mobile radio transmissions and enables the use of codecs for handling many more calls per radio frequency or bandwidth. *See* **codecs.**
- **3rd generation (3G)** Third generation mobile telecommunications technology for cell phones, tablet computers, and other devices that is based on the IMT-2000 standards for

mobile communications. The data transfer rate is up to 5.8 Mbps upstream and 14.4 Mbps downstream.

- **4th generation (4G)** Fourth generation mobile telecommunications technology that is faster than 3G and is built on the IMT-Advanced standards. Data transfer rates are based on whether a device is used in low (100 Mbps) or high (1Gbps) mobility situation.
- **American National Standards Institute (ASCII)** An 8-bit character-coding method consisting of 96 uppercase and lowercase characters and numbers, plus 32 nonprinting characters.
- **analog**A type of transmission that can vary continuously, as in a wave pattern with positive and negative voltage levels.
- **asynchronous communication** Communication that occurs in discrete units where the start of a unit is signaled by a start bit at the front and the end of the unit is signaled by a stop bit at the back.
- **beaconing**An error condition on a token ring network that indicates one or more nodes are not functioning.
- **broadcast frame** A frame sent to all nodes on a network.
- **broadcast packet** A packet sent to all nodes on a network.
- **broadcast storm** Saturation of network bandwidth caused by excessive traffic, as when a large number of computers or devices attempt to transmit simultaneously, or when computers or devices persist in transmitting repeatedly.
- **cableco**A cable TV company, such as Comcast or Time Warner.
- **carrier sense** The process of checking a communications medium, such as cable, for a voltage level, signal transition, or light, indicating the presence of a data-carrying signal.
- **Carrier Sense Multiple Access with Collision Detection (CSMA/CD)** A network transport control method used in Ethernet networks. It regulates transmission by sensing the presence of packet collisions.
- **circuit switching** A network communications technique that uses a dedicated channel to transmit information between two nodes.
- **codec**Method of coding and encoding a digital signal to enable loading a specific radio frequency or bandwidth with more individual radio transmissions (calls).
- **collision**A situation in which two or more packets are detected at the same time on an Ethernet network.
- **connectionless service** Also known as Type 1 operation, services that occur between the LLC sublayer and the Network layer, but that provide no checks to make sure data accurately reaches the receiving node.
- **connection-oriented service** Type 2 operation services that occur between the LLC sublayer and the Network layer, providing several ways to ensure data is successfully received by the destination node.
- **cyclic redundancy check (CRC)** An error detection method that calculates a value for the total size of the information fields contained in a frame. The value is inserted near the end of a frame by the Data Link layer on the sending node and checked by the Data Link layer on the receiving node to determine if a transmission error has occurred.
- **device address** Also called the physical or MAC address, the hexadecimal number permanently assigned to a network interface and used by the MAC sublayer within the Data Link layer, or Layer 2.
- **digital signal (DS)** A transmission method that has distinct signal levels to represent binary zeroes or ones, such as +5 volts and 0 volts.

- **discovery**A process used by routers that involves gathering information about how many nodes are on a network and where they are located.
- **electromagnetic interference (EMI)** Signal interference caused by magnetic force fields generated by electrical devices such as motors.
- **encapsulate**In the context of OSI layers, the process of wrapping the information in one layer inside the information within the next layer. In the context of protocols, the process of placing the information formatted for one protocol inside the information formatted for a different protocol, as is done in TCP/IP communications.
- **encryption**A process that scrambles data so that it cannot be read if intercepted by unauthorized users.
- **ethernet** A transport system that uses the CSMA/CD access method for data transmission on a network. Ethernet typically is implemented in a bus or star-bus hybrid topology.
- **European Telecommunications Standards Institute (ETSI)** Organization that develops "globally applicable" radio and broadcast communications standards and Internet standards under the endorsements of the European Union.
- **Extended Binary Coded Decimal Interchange Code (EBCDIC)** A character-coding technique used mainly on IBM mainframe computers and consisting of an 8-bit coding method for a 256-character set of letters, numbers, and special characters.
- **Fiber-distributed Data Interface (FDDI)** A fiber-optic data transport method capable of a 100-Mbps transfer rate using a dual ring topology; largely supplanted today by faster Ethernet methods.
- **flow control** A process that ensures one device does not send information faster than it can be received by another device.
- **frame** A unit of data transmitted on a network that contains control and address information corresponding to the OSI Data Link layer, or Layer 2
- **Frequency Division Multiple Access (FDMA)** A switching method that creates separate channels on one communication medium by establishing different frequencies for each channel.
- **full-duplex**The capacity to send and receive signals at the same time on the same medium.
- **half-duplex**The ability to send or receive signals on a medium, but not at the same time.
- **headend**On a cable TV WAN, a central receiving point for signals from various sources, including satellite, other major cable sources, and local television sources.
- **International Mobile Telecommunications-2000 (IMT-2000)** 3G standards provided through the ITU that cover voice, mobile telephone, mobile video, mobile TV, Internet, and mobile data communications over mobile communications devices such as smartphones. *See* 3G.
- **International Mobile Telecommunications-Advanced (IMT-Advanced)** 4G standards provided through the ITU that offer higher data transfer rates, higher quality of services, and better security than IMT-2000. *See* IMT-2000 and 4G.
- **International Organization for Standardization (ISO)** An international body that establishes communications and networking standards and that is particularly known for its contributions to network protocol standards.
- **International Telecommunication Union (ITU)** A United Nations agency that develops international communications standards; allocates international radio spectrums; and sets standards for modems, e-mail, mobile wireless communications, and digital telephone systems.
- **Internet Engineering Task Force (IETF)** An arm of the Internet Society (ISOC) that works on Internet-related technical issues. *See* Request for Comments (RFC).

- **logical link control (LLC)** A Data Link sublayer of the OSI model that initiates the communications link between nodes and ensures the link is not unintentionally broken.
- **MAC address***See* device address.
- **media access control (MAC)** A Data Link sublayer that examines addressing information contained in a network frame and controls how devices share communications on the same network.
- **message switching** A switching method that sends data from point to point, with each intermediate node storing the data, waiting for a free transmission channel, and forwarding the data to the next point until the destination is reached.
- **multiple system operator (MSO)** A cable TV company that offers WAN or Internet services. *See* cableco.
- **multistation access unit (MAU)** A central hub that links token ring nodes into a topology that physically resembles a star, but in which frames are transmitted in a logical ring pattern.
- **Open Systems Interconnection (OSI) reference model** Developed by the ISO and ANSI, a model that provides a framework for networked hardware and software communications based on seven layers.
- **packet** A unit of data formatted for transmission over a network that contains control and other information that corresponds to the OSI Network layer, also called Layer 3.
- **packet radio** The process of transmitting a data-carrying packet over radio waves through short bursts.
- **packet switching** A data transmission technique that establishes a logical channel between two transmitting nodes, but uses several different paths of transmission to continually find the best routes to the destination.
- **peer protocol** Protocol used to enable an OSI layer on a sending node to communicate with the same layer on the receiving node.
- **physical address** *See* device address.
- **plain old telephone service (POTS)** Regular voice-grade telephone service.
- **port***See* socket.
- **primitive** A command used to transfer information from one layer in an OSI stack to another layer, such as from the Physical layer to the Data Link layer
- **protocol data unit (PDU)** The information transferred between layers in the same OSI stack.
- **public switched telephone network (PSTN)** Regular voice-grade telephone service.
- **radio frequency interference (RFI)** Signal interference caused by electrical devices that emit radio waves at the same frequency used by network-signal transmissions.
- **redirector**A service used via the Application layer to recognize and access other computers.
- **regional bell operating companies (RBOCs)** A telecommunications company that provides telephone services to a designated region.
- **Request for Comments (RFC)** A document prepared and distributed by any individual or group as a way to further network, Internet, and computer communications. RFCs help ensure that network standards and conventions are provided so one network can talk to another. Every RFC is assigned a number to distinguish it from other RFCs and to provide a way to track it. Each RFC is tracked and published by the Internet Engineering Task Force (IETF). *See* Internet Engineering Task Force (IETF).
- **Secure Sockets Layer (SSL)** A data encryption technique employed between a server and a client, such as between a client's browser and an Internet server.

- **service data unit (SDU)** A protocol data unit that has been transferred between OSI layers and then stripped of control information and transfer instructions.
- **simplex** The capacity for a signal to travel on a medium in only one direction.
- **socket** A value or means of identifying a service on a network node, such as a socket or port 103 for standardized e-mail services in the TCP protocol.
- **Statistical Multiple Access** A switching method that allocates the communications resources according to what is needed for the task, such as providing more bandwidth for a video file and less for a small spreadsheet file.
- **synchronous communications** Communications of continuous bursts of data controlled by a clock signal that starts each burst.
- **T-carrier** A dedicated telephone line that can be used for data communications to connect two different locations for continuous point-to-point communications.
- **telco** A regional telephone company. *See***RBOC**.
- **Time Division Multiple Access (TDMA)** A switching method that enables multiple devices to communicate over the same communications medium by creating time slots in which each device transmits.
- **token ring** An access method developed by IBM in the 1970s and which is still used on some networks. Variations of the technology are used for WANs. This transport method employs a physical star topology along with the logic of a ring topology. Although each node is connected to a central hub, the frame travels from node to node as though there were no starting or ending point.
- **trunk line** In a cable TV or telecommunications system, a high-capacity communications line that goes between two switches (often over several miles) or it is generally a main line that has multiple channels.
- **unicode** A character coding standard that enables consistent coding of characters covering 93 scripts for most languages used through the world. Unicode enables data to be translated between different systems and languages while retaining the original data integrity.
- **virtual circuit** A logical communications path established by the OSI Network layer for sending and receiving data.
- **Virtual LAN (VLAN)** A logical LAN that links together specific switches on a large LAN or on separate LANs so that the switches act as though they compose one unified logical or virtual LAN.