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Chapter 2

Networking Standards and the OSI Model

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Overview

In the field of networking, even though the communication that occurs between two nodes on a network cannot be seen, a model may be used to depict how the communication takes place. The model commonly used to describe network communications is called the OSI (Open Systems Interconnection) model.

In this chapter, the student will learn about the standards organizations that have helped create the various conventions (such as the OSI model) used in networking. Next, the student will be introduced to the seven layers of the OSI model and learn how they interact. The student will then take a closer look at what goes on in each layer. Finally, the student will learn to apply those details to a practical networking environment. Thoroughly understanding the OSI model is essential to proficient network design and troubleshooting.

Chapter Objectives

After reading this chapter and completing the exercises, the student will be able to:
Identify organizations that set standards for networking
Describe the purpose of the OSI model and each of its layers
Explain specific functions belonging to each OSI model layer
Understand how two network nodes communicate through the OSI model Discuss the structure and purpose of data packets and frames
Describe the two types of addressing covered by the OSI model

Teaching Tips

Networking Standards Organizations

1. Define a standard.

2. Explain why standards are important in the world of networking.

3. Emphasize that standards define the minimum acceptable performance of a product or service - not the ideal.

4. Explain why there are many different organizations to oversee computer industry standards.

5. Using ANSI and IEEE as an example, point out that standards organizations may overlap in their responsibilities.

6. Note the importance of being familiar with the groups that set networking standards and the critical aspects of standards required by a student's network.

ANSI

1. Describe the ANSI (American National Standards Institute) organization.

2. Point out that ANSI does not dictate that manufacturers comply with its standards, but requests voluntarily compliance.

3. Note that new electronic equipment and methods must undergo rigorous testing to prove they are worthy of ANSI's approval.

4. Mention that ANSI standards documents are available for purchase online from ANSI's Web site (www.ansi.org).

Teaching Tip	Go to the ANSI website at http://www.ansi.org to provide a demonstration of the ANSI material available online.

EIA and TIA

1. Describe the EIA (Electronic Industries Alliance) trade organization.

2. Explain how the TIA (Telecommunications Industry Association) subgroup was formed and describe its relation to EIA.

3. Identify the best-known standard to come from EIA/TIA (TIA/EIA 568-B Series).

Teaching Tip	Go to the EIA website at http://www.eia.org and provide an example of the EIA material available online.

Teaching Tip	Go to the TIA website at http://www.tiaonline.org and provide an example of the TIA material available online.

IEEE

1. Describe the IEEE (Institute of Electrical and Electronics Engineers).

2. Explain the goal of IEEE.

3. Mention that IEEE technical papers and standards are highly respected in the networking profession.

Teaching Tip	Go to the IEEE website at http://www.ieee.org and provide an example of the IEEE material available online.

ISO

1. Describe the ISO (International Organization for Standardization).
2. Explain the goal of ISO.
3. Describe the realm of ISO's authority.

Teaching Tip	Go to the ISO website at http://www.iso.org and provide a demonstration of the ISO material available online.

ITU

1. Describe the ITU (International Telecommunication Union).
2. Describe the history of the ITU.
3. Explain the focus areas of the ITU.

Teaching Tip	Go to the ITU website at http://www.itu.int and provide an example of the ITU material available online.

ISOC

1. Describe the ISOC (Internet Society).
2. Explain current ISOC concerns.
3. Describe two groups the ISOC oversees:
    a. IAB (Internet Architecture Board)
    b. IETF (Internet Engineering Task Force)
4. Describe the general process for submitting a standard proposal to the ISOC.

Teaching Tip	Go to the ISOC website at http://www.isoc.org and provide an example of ISOC material available online.

IANA and ICANN

1. Explain why it is important for every computer on a network (including the Internet) to have a unique address.

2. Describe an IP (Internet Protocol) address.

3. Explain how every Internet-connected device is given a unique IP address.

4. Explain the history of IP address distribution.

5. Explain how an individual or business obtains IP addresses.

Teaching Tip	Go to the IANA website at http://www.iana.org and provide an example of the IANA material available online.

Teaching Tip	Go to the ICANN website at http://www.icann.org and provide an example of the ICANN material available online.

Quick Quiz 1

1. True or False: Standards define maximum acceptable performance.
   Answer: False

2. True or False: Standards help to ensure interoperability between software and hardware from different manufacturers.
   Answer: True

3. Which standards organization requests voluntary compliance with their standards?
   a) IANA
   b) ISO
   c) ITU
   d) ANSI
   Answer: D

4. Which standards organization's technical papers and standards are highly respected in the networking profession?
   a) ICANN
   b) ANSI
   c) IEEE
   d) ISO
   Answer: C

5. Which standards organization is a professional membership society that helps to establish technical standards for the Internet?
   a) ISOC
   b) ANSI
   c) IEEE
   d) ISO

   Answer: A

The OSI Model

1. Define and describe the OSI model.

2. Introduce the seven layers of the OSI model.

3. Review the definition of a protocol.

4. Explain how the services at each layer use protocols.

5. Emphasize that the OSI model is a theoretical representation of what happens between two nodes communicating on a network.

6. Describe a PDU (protocol data units) and explain how it flows through the model.

7. Use Figure 2-1 to illustrate the flow of data through the OSI model.

Teaching Tip	Students may find more information on the OSI Model's seven layers at http://support.microsoft.com/kb/103884

Application Layer

1. Introduce and describe the Application layer.

2. Explain how the Application Layer facilitates communication between software applications and lower-layer network services.

3. Explain how software applications negotiate their formatting, procedural, security, synchronization, and other requirements with the network.

Presentation Layer

1. Introduce and describe the function of the protocols in the Presentation layer.

2. Note that the Presentation layer protocols also interpret coded and compressed formats in data received from other computers.

3. Explain how the Presentation layer services also manage data encryption (such as the scrambling of passwords) and decryption.

Session Layer

1. Introduce and describe the function of the protocols in the Session layer.
2. Define the term session.
3. Describe the functions of the Session layer.
4. Explain how the Session layer protocols keep connections alive for the duration of a session.

Transport Layer

1. Introduce and describe the function of the protocols in the Transport layer.
2. Define and describe connection-oriented protocols.
3. Define and describe a checksum.
4. Define and describe connectionless protocols.
5. Define and describe segmentation.
6. Define and describe MTU (maximum transmission unit).
7. Explain how Transport layer protocols determine a network's MTU.
8. Define and discuss reassembly.
9. Define and discuss sequencing.
10. Use Figure 2-5 to illustrate the concept of segmentation and reassembly.
11. Use Figure 2-6 to illustrate the information contained in an actual TCP segment used to request the Web page www.loc.gov/index.html.

Network Layer

1. Introduce and describe the function of the protocols in the Network layer.
2. Define and discuss addressing.
3. Explain the two types of node addresses:
    a. Network address

   b. Physical address

4. Explain how the data unit accepted from the Transport layer is transformed into a packet.

5. Explain routing.

6. Define a router.

7. Note that the IP protocol is the most common Network layer protocol.

8. Use Figure 2-7 to illustrate an IP packet.

9. Define and discuss fragmentation.

Data Link Layer

1. Introduce and describe the function of the protocols in the Data Link layer.

2. Define a frame and explain its purpose.

3. Explain the function of the Data Link layer using an analogy where computers communicate as humans do.

4. Describe the communication mishap referred to as partial communication.

5. Explain how partial communication is addressed using error checking and CRC (cyclic redundancy check).

6. Describe the possible communication mishap referred to as a glut of communication.

7. Explain how the glut of communication mishap is controlled by allowing the data link layer to control the flow of information, allowing the NIC to process data without error.

8. Define and describe the two Data Link layer sublayers:
   a. LLC (Logical Link Control) sublayer
   b. MAC (Media Access Control) sublayer

9. Describe where a student may find a NIC's MAC address.

10. Use Figure 2-9 to illustrate a NIC's MAC address.

11. Describe the two components of a MAC address:
   a. Block ID
   b. Device ID

12. Explain how the components obtain numeric values.

13. Emphasize the combination of the block ID and device ID result in a unique, 12-character MAC address.

14. Mention the newer EUI-64 standard for physical addresses.

15. Note the use of hexadecimal notation to represent the MAC address.

16. Explain how a student can determine which company manufactured a NIC by looking up its block ID if you know a computer's MAC address.

Physical Layer

1. Introduce and describe the function of the protocols in the Physical layer.

2. Explain the different signal types corresponding to the different transmission media.

3. Explain the process that occurs when the Physical layer protocols receive data.

4. Note that Physical layer protocols cannot perform error checking.

5. Describe the devices operating at the Physical layer.

6. Explain the OSI layers where a NIC may operate.

Applying the OSI Model

1. Use Table 2-1 to review the functions of the OSI layers.

Communication Between Two Systems

1. Remind students how the original data issued by the software applications is significantly transformed as it passes from the Application layer to the Physical layer.

2. Use Figure 2-11 to illustrate data transformation through the OSI model. Focus on the header data added at each layer.

Frame Specifications

1. Review the definition of a frame.

2. Mention that the characteristics of frame components depend on the type of network on which the frames run and on the standards that they must follow.

3. Introduce the Ethernet network and discuss Ethernet frames.

4. Introduce the Token Ring network.

5. Discuss how Ethernet frames and Token Ring frames differ.

IEEE Networking Specifications

1. Introduce and describe the IEEE Project 802.

2. Describe the networking specifications covered under IEEE's Project 802.

3. Use Table 2-2 to illustrate IEEE 802 specifications.

Quick Quiz 2

1. Which standards organization is responsible for providing the OSI model?
   a) ISOC
   b) ANSI
   c) IEEE
   d) ISO
   Answer: D

2. The seventh layer of the OSI model is the ____ layer.
   Answer: Application

3. The Application layer separates data into ____, or discrete amounts of data.
   Answer: PDUs (protocol data units)

4. Protocols in the ____layer accept data from the Session layer and manage end-to-end delivery of data.
   Answer: Transport

5. True or False: The IP (Internet Protocol) operates in the Transport layer.
   Answer: False

Class Discussion Topics

1. Discuss whether the OSI model is "out of date" for today's modern networks.

2. Discuss whether there are too many standards organizations attempting to regulate the networking field. Ask students to consider whether consultation is necessary, and whether governmental or larger international bodies should be formed to manage standards.

Additional Projects

1. The student has learned that the OSI model allows TCP to function at the Transportation layer and IP to function at the Network layer. Have the students' research TCP/IP protocols functions in more depth in relation to the OSI model. The students should then prepare a report summarizing their research. Included in the report should be a critique of the question, "Does the OSI models conform to the TCP/IP protocols, or vice versa? Require students to defend their thoughts.

2. Have the students research IEEE Project 802 and prepare a report of their research.

Additional Resources

1. OSI Model
   http://en.wikipedia.org/wiki/OSI_model

2. OSI 7 Layers Reference Model For Network Communication
   http://www.javvin.com/osimodel.html

3. CompTIA Site
   http://www.comptia.org/

4. ISO site
   http://www.iso.org

Key Terms

- **802.2** The IEEE standard for error and flow control in data frames.
- **802.3** The IEEE standard for Ethernet networking devices and data handling (using the CSMA/CD access method).
- **802.5** The IEEE standard for token ring networking devices and data handling.
- **802.11** The IEEE standard for wireless networking.
- **ACK (acknowledgment)** A response generated at the Transport layer of the OSI model that confirms to a sender that its frame was received. The ACK packet is the third of three in the three-step process of establishing a connection.
- **acknowledgment** See ACK.
- **American National Standards Institute** See ANSI.
- **ANSI (American National Standards Institute)** An organization composed of more than 1000 representatives from industry and government who together determine standards for the electronics industry in addition to other fields, such as chemical and nuclear engineering, health and safety, and construction.
- **API (application programming interface)** A set of routines that make up part of a software application.

- **Application layer** The seventh layer of the OSI model. Application layer protocols enable software programs to negotiate formatting, procedural, security, synchronization, and other requirements with the network.
- **application programming interface** See API.
- **block ID** See OUI.
- **checksum** A method of error checking that determines if the contents of an arriving data unit match the contents of the data unit sent by the source.
- **company id** See OUI.
- **connection oriented** A type of Transport layer protocol that requires the establishment of a connection between communicating nodes before it will transmit data.
- **connectionless** A type of Transport layer protocol that services a request without requiring a verified session and without guaranteeing delivery of data.
- **CRC (cyclic redundancy check)** An algorithm (or mathematical routine) used to verify the accuracy of data contained in a data frame.
- **cyclic redundancy check** See CRC.
- **Data Link layer** The second layer in the OSI model. The Data Link layer bridges the networking media with the Network layer. Its primary function is to divide the data it receives from the Network layer into frames that can then be transmitted by the Physical layer.
- **Data Link layer address** See MAC address.
- **device ID** See extension identifier.
- **EIA (Electronic Industries Alliance)** A trade organization composed of representatives from electronics manufacturing firms across the United States that sets standards for electronic equipment and lobbies for legislation favorable to the growth of the computer and electronics industries.
- **Electronic Industries Alliance** See EIA.
- **encapsulate** The process of wrapping one layer's PDU with protocol information so that it can be interpreted by a lower layer. For example, Data Link layer protocols encapsulate Network layer packets in frames.
- **Ethernet** A networking technology originally developed at Xerox in the 1970s and improved by Digital Equipment Corporation, Intel, and Xerox. Ethernet, which is the most common form of network transmission technology, follows the IEEE 802.3 standard.
- **EUI-64 (Extended Unique Identifier-64)** The IEEE standard defining 64-bit physical addresses. In the EUI-64 scheme, the OUI portion of an address is 24 bits in length. A 40-bit extension identifier makes up the rest of the physical address to total 64 bits.
- **Extended Unique Identifier-64** See EUI-64.
- **extension identifier** A unique set of characters assigned to each NIC by its manufacturer. In the traditional, 48-bit physical addressing scheme, the extension identifier is 24 bits long. In EUI-64, the extension identifier is 40 bits long.
- **FCS (frame check sequence)** The field in a frame responsible for ensuring that data carried by the frame arrives intact. It uses an algorithm, such as CRC, to accomplish this verification.
- **flow control** A method of gauging the appropriate rate of data transmission based on how fast the recipient can accept data.
- **fragmentation** A Network layer service that subdivides segments it receives from the Transport layer into smaller packets.

- **frame** A package for data that includes not only the raw data, or "payload," but also the sender's and recipient's addressing and control information. Frames are generated at the Data Link layer of the OSI model and are issued to the network at the Physical layer.
- **frame check sequence** See FCS.
- **hardware address** See MAC address.
- **HTTP (Hypertext Transfer Protocol)** An Application layer protocol that formulates and interprets requests between Web clients and servers.
- **Hypertext Transfer Protocol** See HTTP.
- **IAB (Internet Architecture Board)** A technical advisory group of researchers and technical professionals responsible for Internet growth and management strategy, resolution of technical disputes, and standards oversight.
- **IANA (Internet Assigned Numbers Authority)** A nonprofit, United States government-funded group that was established at the University of Southern California and charged with managing IP address allocation and the Domain Name System. The oversight for many of IANA's functions was given to ICANN in 1998; however, IANA continues to perform Internet addressing and Domain Name System administration.
- **ICANN (Internet Corporation for Assigned Names and Numbers)** The non-profit corporation currently designated by the United States government to maintain and assign IP addresses.
- **IEEE (Institute of Electrical and Electronics Engineers)** An international society composed of engineering professionals. Its goals are to promote development and education in the electrical engineering and computer science fields.
- **IETF (Internet Engineering Task Force)** An organization that sets standards for how systems communicate over the Internet (for example, how protocols operate and interact).
- **Institute of Electrical and Electronics Engineers** See IEEE.
- **International Organization for Standardization** See ISO.
- **International Telecommunication Union** See ITU.
- **Internet Architecture Board** See IAB.
- **Internet Assigned Numbers Authority** See IANA.
- **Internet Corporation for Assigned Names and Numbers** See ICANN.
- **Internet Engineering Task Force** See IETF.
- **Internet Protocol** See IP.
- **Internet Protocol address** See IP address.
- **Internet service provider** See ISP.
- **Internet Society** See ISOC.
- **IP (Internet Protocol)** A core protocol in the TCP/IP suite that operates in the Network layer of the OSI model and provides information about how and where data should be delivered. IP is the subprotocol that enables TCP/IP to internetwork.
- **IP address (Internet Protocol address)** The Network layer address assigned to nodes to uniquely identify them on a TCP/IP network. IPv4 addresses consist of 32 bits divided into four octets, or bytes. IPv6 addresses are composed of eight 16-bit fields, for a total of 128 bits.
- **ISO (International Organization for Standardization)** A collection of standards organizations representing 162 countries with headquarters located in Geneva, Switzerland. Its goal is to establish international technological standards to facilitate the global exchange of information and barrier-free trade.

- **ISOC (Internet Society)** A professional organization with members from 90 chapters around the world that helps to establish technical standards for the Internet.
- **ISP (Internet service provider)** A business that provides organizations and individuals with Internet access and often, other services, such as e-mail and Web hosting.
- **ITU (International Telecommunication Union)** A United Nations agency that regulates international telecommunications and provides developing countries with technical expertise and equipment to advance their technological bases.
- **LLC (Logical Link Control) sublayer** The upper sublayer in the Data Link layer. The LLC provides a common interface and supplies reliability and flow control services.
- **logical address** See network address.
- **Logical Link Control sublayer** See LLC (Logical Link Control) sublayer.
- **MAC address** See physical address.
- **MAC (Media Access Control) sublayer** The lower sublayer of the Data Link layer. The MAC appends the physical address of the destination computer onto the frame.
- **maximum transmission unit** See MTU.
- **Media Access Control sublayer** See MAC (Media Access Control) sublayer.
- **MTU (maximum transmission unit)** The largest data unit a network (for example, Ethernet or token ring) will accept for transmission.
- **network address** A unique identifying number for a network node that follows a hierarchical addressing scheme and can be assigned through operating system software. Network addresses are added to data packets and interpreted by protocols at the Network layer of the OSI model.
- **Network layer** The third layer in the OSI model. Protocols in the Network layer translate network addresses into their physical counterparts and decide how to route data from the sender to the receiver.
- **Network layer address** See network address.
- **Open Systems Interconnection model** See OSI (Open Systems Interconnection) model.
- **Organizationally Unique Identifier** See OUI.
- **OSI (Open Systems Interconnection) model** A model for understanding and developing computer-to-computer communication developed in the 1980s by ISO. It divides networking functions among seven layers: Physical, Data Link, Network, Transport, Session, Presentation, and Application.
- **OUI (Organizationally Unique Identifier)** A 24-bit character sequence assigned by IEEE that appears at the beginning of a network interface's physical address and identifies the NIC's manufacturer.
- **PDU (protocol data unit)** A unit of data at any layer of the OSI model.
- **physical address** A 48- or 64-bit network interface identifier that includes two parts: the OUI, assigned by IEEE to the manufacturer, and the extension identifier, a unique number assigned to each NIC by the manufacturer.
- **Physical layer** The lowest, or first, layer of the OSI model. Protocols in the Physical layer generate and detect signals so as to transmit and receive data over a network medium. These protocols also set the data transmission rate and monitor data error rates, but do not provide error correction.

- **Presentation layer** The sixth layer of the OSI model. Protocols in the Presentation layer translate between the application and the network. Here, data are formatted in a schema that the network can understand, with the format varying according to the type of network used. The Presentation layer also manages data encryption and decryption, such as the scrambling of system passwords.
- **protocol data unit** See PDU.
- **reassembly** The process of reconstructing data units that have been segmented.
- **Regional Internet Registry** See RIR.
- **RIR (Regional Internet Registry)** A not-for-profit agency that manages the distribution of IP addresses to private and public entities. ARIN is the RIR for North, Central, and South America and sub-Saharan Africa. APNIC is the RIR for Asia and the Pacific region. RIPE is the RIR for Europe and North Africa.
- **route** To intelligently direct data between networks based on addressing, patterns of usage, and availability of network segments.
- **router** A device that connects network segments and directs data based on information contained in the data packet.
- **segment** A unit of data that results from subdividing a larger protocol data unit.
- **segmentation** The process of decreasing the size of data units when moving data from a network that can handle larger data units to a network that can handle only smaller data units.
- **sequencing** The process of assigning a placeholder to each piece of a data block to allow the receiving node's Transport layer to reassemble the data in the correct order.
- **session** A connection for data exchange between two parties. The term session may be used in the context of Web, remote access, or terminal and mainframe communications, for example.
- **Session layer** The fifth layer in the OSI model. The Session layer establishes and maintains communication between two nodes on the network. It can be considered the "traffic cop" for communications, such as videoconferencing, that require precisely coordinated data exchange.
- **standard** A documented agreement containing technical specifications or other precise criteria that are used as guidelines to ensure that materials, products, processes, and services suit their intended purpose.
- **SYN (synchronization)** The packet one node sends to request a connection with another node on the network. The SYN packet is the first of three in the three-step process of establishing a connection.
- **SYN-ACK (synchronization-acknowledgment)** The packet a node sends to acknowledge to another node that it has received a SYN request for connection. The SYN-ACK packet is the second of three in the three-step process of establishing a connection.
- **synchronization** See SYN.
- **synchronization-acknowledgment** See SYN-ACK.
- **Telecommunications Industry Association** See TIA.
- **terminal** A device with little (if any) of its own processing or disk capacity that depends on a host to supply it with applications and data-processing services.
- **three-way handshake** A three-step process in which Transport layer protocols establish a connection between nodes. The three steps are: Node A issues a SYN packet to node B, node B responds with SYN-ACK, and node A responds with ACK.

- **TIA (Telecommunications Industry Association)** A subgroup of the EIA that focuses on standards for information technology, wireless, satellite, fiber optics, and telephone equipment. Probably the best known standards to come from the TIA/EIA alliance are its guidelines for how network cable should be installed in commercial buildings, known as the "TIA/EIA 568-B Series."
- **token** A special control frame that indicates to the rest of the network that a particular node has the right to transmit data.
- **token ring** A networking technology developed by IBM in the 1980s. It relies upon direct links between nodes and a ring topology, using tokens to allow nodes to transmit data.
- **Transport layer** The fourth layer of the OSI model. In the Transport layer, protocols ensure that data are transferred from point A to point B reliably and without errors. Transport layer services include flow control, acknowledgment, error correction, segmentation, reassembly, and sequencing.
- **virtual address** See network address.