

# TCP/IP Internetworking: Academic Student Guide



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# TCP/IP Internetworking

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## Course Description

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*TCP/IP Internetworking* is a two-day course that teaches key TCP/IP concepts and protocols so that network professionals can effectively plan, deploy and manage a TCP/IP enterprise network. Students will learn to build a TCP/IP network and to analyze protocol and application information.

This course is designed for professionals who need to define, manage and troubleshoot the corporate network infrastructure. Emphasis is on core protocol analysis, packet sniffing, dynamic addressing, and the Domain Name System on Windows 2000 and Linux.

Following this class, you should spend time with hands-on TCP/IP networking practice to apply what you have learned.

## Length

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*TCP/IP Internetworking* is a twelve-hour course that can be implemented in two days.

## Series

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*TCP/IP Internetworking* is the first course in the CIW Internetworking Professional series. CIW Internetworking Professional consists of the following two courses:

- *TCP/IP Internetworking*
- Advanced TCP/IP Concepts and Practices

## Prerequisites

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Students must have completed:

- CIW Foundations series certification (exam 1D0-410), or equivalent experience for those students not seeking MCIWA certification.
- CIW Server Administrator series certification (exam 1D0-450), or equivalent experience for those students not seeking Master CIW Administrator certification.

# ProsoftTraining Courseware

This coursebook was developed for instructor-led training and will assist you during class. Along with comprehensive instructional text and objectives checklists, this coursebook provides easy-to-follow hands-on labs and a glossary of course-specific terms. It also provides Internet addresses needed to complete some labs, although due to the constantly changing nature of the Internet, some addresses may no longer be valid.

The student coursebook is organized in the following manner:

course title
table of contents
list of labs
list of figures
list of tables
lessons
lesson objectives
pre-assessment questions
narrative text
<input checked="" type="checkbox"/> graphics
<input checked="" type="checkbox"/> tables and figures
<input checked="" type="checkbox"/> warnings
<input checked="" type="checkbox"/> tech notes
labs
<input checked="" type="checkbox"/> graphics
<input checked="" type="checkbox"/> tables and figures
<input checked="" type="checkbox"/> warnings
<input checked="" type="checkbox"/> tech notes
lesson summary
lesson review
appendixes
glossary
index
supplemental CD

When you return to your home or office, you will find this coursebook to be a valuable resource for applying the skills you have learned. Each lesson concludes with questions that review the material. Lesson review questions are provided as a study resource only and in no way guarantee a passing score on CIW exams.

The course is available in either an academic or a learning center version, and each version has an instructor book and a student book. Check your book to verify that you have the correct version, and whether it is an instructor or a student book. Following is a brief description of each version.

- **Academic:** Designed for students in an academic classroom environment; typically taught over a quarter (10-week) or semester (16-week) time period. Example syllabi for both timeframes are included on the instructor CD-ROM. The instructor's book and CD-ROM contain all answers, as well as activities (pen-and-paper-based labs), optional labs (computer-based labs), quizzes, a course assessment, and handouts for the instructor to assign during class or as homework. No answers exist in the student book or on the student CD-ROM. Students must obtain answers from the instructor.
- **Learning Center:** Designed for students in a learning center classroom environment; typically taught over a one-day to five-day time period (depending on the length of the course). An example implementation table is included on the instructor CD-ROM. Similar to the academic version, the instructor's book and CD-ROM contain all answers, as well as activities (pen-and-paper-based labs), optional labs (computer-based labs), quizzes, a course assessment, and handouts for the instructor to assign during class or as homework. However, the student CD-ROM also contains answers, including those to the pre-assessment questions, labs, review questions, activities, optional labs, quizzes, and the course assessment.

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## Course Objectives

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After completing this class, you will be able to:

- Define the Internet infrastructure, including the National Science Foundation network (NSFnet), the Internet Society (ISOC), and key internetworking protocols.
- Explain the Open Systems Interconnection reference model (OSI/RM) and the Internet architecture model, the operational essentials of TCP/IP, and the Requests for Comments (RFCs) that define these essential elements.
- Describe Internet Protocol version 4 (IPv4) addressing, the concept of uniqueness, IP address classes, and subnet address calculation.
- Identify the purpose, elements and functions of the network access layer, the Internet layer, and the transport layer.
- Define the functions of application-layer Internet protocols, such as Hypertext Transfer Protocol (HTTP), File Transfer Protocol (FTP), Simple Mail Transfer Protocol (SMTP), and Simple Network Management Protocol (SNMP).
- Explain the purpose of the Domain Name System (DNS), including its architecture and record types.
- Define the function and roles of the BOOTstrap Protocol (BOOTP) and the Dynamic Host Configuration Protocol (DHCP) server and client.

## Classroom Setup

Your instructor has probably set up the classroom computers based on the system requirements listed below. Most software configurations on your computer are identical to those on your instructor's computer. However, your instructor may use additional software to demonstrate network interaction or related technologies.

## System Requirements

### Hardware

The following table summarizes the hardware requirements for all courses in the CIW program. Each classroom should be equipped with enough personal computers to accommodate each student and the instructor with his or her own system.

*Note: The CIW hardware requirements are similar to the lowest system requirements for Microsoft implementation (Level 1 requirements) except that CIW requires increased hard disk space (8 GB) and RAM (128 MB). This comparison may be helpful for the many training centers that implement CIW and are also CTEC because personnel at these centers are familiar with the Microsoft hardware specifications.*

CIW hardware specifications	Greater than or equal to the following
Processor	Intel Pentium II (or equivalent) personal computer with processor speed greater than or equal to 300 MHz
L2 cache	256 KB
Hard disk	8-GB hard drive
RAM	At least 128 MB
CD-ROM	32X
Network interface card (NIC)	10BaseT or 100BaseTX (10 or 100 Mbps)
Sound card/speakers	Required for instructor's station, optional for student stations
Video adapter	At least 4 MB
Monitor	15-inch monitor
Network hubs	Two 10-port 10BaseT or 100BaseTX (10 or 100 Mbps) hubs
Router	Multi-homed system with three NICs (Windows NT 4.0/2000 server)*

\* *Must meet universal CIW hardware requirements.*

## Software

The recommended software configurations for computers used to complete the exercises in this book are as follows.

To be installed before class:

- Microsoft Windows 2000 Server  
and/or
- Red Hat Linux 7.0 or later
- All additional software is included with the operating system, on the student supplemental CD, or at <http://ss1.ciwcertified.com/internetworking>. These applications include Ethereal Network Analyzer for Linux and Windows, and the Microsoft and Linux DNS and DHCP services. Microsoft Windows 2000 Server Service Packs are optional.

## Connectivity

The course is designed for a TCP/IP network with three networks, connected by an IP router (which can be a multi-homed computer). Subnet A (192.168.3.0) students will use odd-numbered IP addresses. Subnet B (192.168.4.0) students will use even-numbered IP addresses. The instructor will use a third subnet with the network address 192.168.2.0. The subnet mask is 255.255.255.0. Classroom configuration is illustrated in Figure i-1.

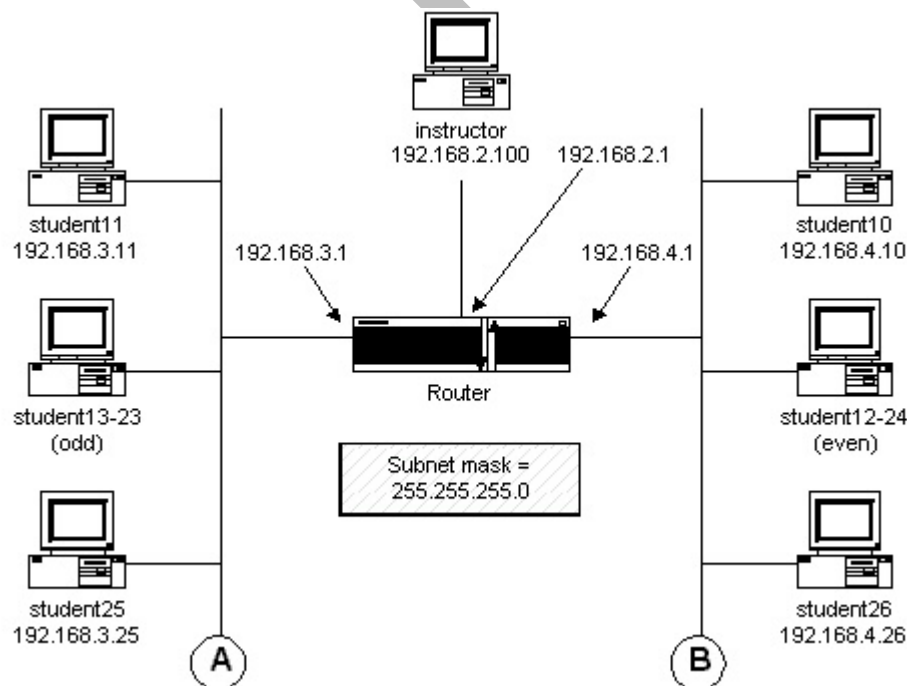


Figure i-1: Classroom configuration

Internet connectivity is recommended for researching RFCs on the Web, but not required for the course (the RFCs needed are on the student supplemental disk). If Internet connectivity is available, student computers can be configured as DHCP clients and valid IP addresses can be obtained from a DHCP server. The original classroom configuration can be restored as displayed in Figure i-1.

The instructor will find detailed configuration information regarding classroom hardware, software, and network connectivity in the Classroom Setup Guide.

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# Conventions and Graphics Used in This Book

The following conventions are used in Prosoft coursebooks.

<b>Terms</b>	Technology terms defined in the margins are indicated in <b>bold</b> the first time they appear in the text. Not every word in bold is a term requiring definition.
<b>Exercise Text</b>	Text that you enter in an exercise appears in <b>bold</b> . Names of components that you access or change in an exercise also appear in <b>bold</b> .
<b>Notations</b>	<i>Notations or comments regarding screenshots, exercises or other text are indicated in italic type.</i>
<b>Program Code or Commands</b>	Text used in program code or operating system commands appears in the Lucida Sans Typewriter font.

The following graphics are used in Prosoft coursebooks.



*Tech Notes* point out exceptions or special circumstances that you may find when working with a particular procedure. Tech Notes that occur within an exercise are displayed without the graphic.



*Tech Tips* offer special-interest information about the current subject.



*Warnings* alert you about cautions to observe or actions to avoid.



This graphic signals the start of an exercise or other hands-on activity.



Each lesson summary includes an *Application Project*. This project is designed to provoke interest and apply the skills taught in the lesson to your daily activities.



Each lesson concludes with a summary of the skills and objectives taught in that lesson. You can use the Skills Review checklist to evaluate what you have learned.



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# Lesson 1:

# The Internet Infrastructure

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## **Objectives**

By the end of this lesson, you will be able to:

- ↻ Define "internetwork" and explain this concept's importance in today's data communications marketplace.
- ↻ Describe how TCP/IP can use your existing LANs and WANs as backbones for interoperability.
- ↻ Relate internetworks to the concept of the corporate enterprise network.
- ↻ Explain the evolution of the Internet.
- ↻ Explain the nature, size, and other characteristics of the National Science Foundation network (NSFnet).
- ↻ Define and discuss Internet-related organizations, including ISOC, IAB, IETF and IRTF.
- ↻ Discuss how TCP/IP relates to standards such as SNA, OSI and IPX/SPX.
- ↻ Identify key internetworking protocols and explain the need for multiprotocol networks.

## Pre-Assessment Questions

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1. What is the name of the device used to translate between different networking protocols?
  - a. Universal translator
  - b. Protocol translator
  - c. Gateway
  - d. Gate manager
  
2. Encapsulation is also known as:
  - a. Burrowing.
  - b. Wrapping.
  - c. Parceling.
  - d. Tunneling.
  
3. What is the role of the IRTF?

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# Overview of Networking

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Networking is defined as two or more computers connected together that share data. Networks allow information to be distributed easily and quickly by means of a system of protocols, cables and hardware. You can use other media, such as wireless technology, to allow communication between two computers.

Networks have become extremely popular because they allow users to share data quickly. In the past, users had to place files on a floppy disk or print them and physically deliver them to the destination. Such "sneakernet" solutions may sometimes be appropriate, but when it comes to organizing and expediting the daily operation of a business, no better means exists than a well-run network.

## local area network (LAN)

A group of computers connected within a confined geographic area.

Given the definition of a network as two or more computers that share information via a physical medium and a protocol, networking can include a small business network in one room, which is called a **local area network (LAN)**. A network can also connect many different LANs over a long distance or wide area link, which is called a wide area network (WAN). A series of WANs can extend to a worldwide "internetwork" that connects millions of users, such as the Internet. Before you learn more about the Internet, internetworking, and TCP/IP, you must understand how networks traditionally functioned.

## Traditional networking

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Traditionally, whenever an organization chose a network, it tried to ensure that it chose and used only one type of network product. Such choices began the era of homogeneous, vendor-centric networks. Most organizations chose one vendor, such as Novell, IBM, or Microsoft, to provide their networking solution because a one-vendor network ensures a minimum of training for employees and IT professionals. The reasoning was that using the same network type made network communication as simple as possible.

As you pursue your career, it is quite possible that you will work with many different types of networks, such as UNIX, Novell NetWare, Windows NT and Windows 2000. At one time, you would probably have used only one type of network from company to company. Thus, you would have had to familiarize yourself with the new network and networking protocol with each move, but after learning the new protocol and topology, you would have learned all you needed to know.

## Internetworking

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Over the past decade, however, a fundamental change has occurred in networking. Now, many different types of networks have connected with one another, because different organizations and divisions need to communicate directly with one another in a timely way. The task of working with different, or heterogeneous, systems such as the Internet has been given its own name: internetworking. This type of networking represents quite a change, because with a traditional networking solution, an organization could communicate with itself on its own network. However, to communicate with others, it had to resort to personal delivery methods, such as traditional mail. The motivation behind the fact that networks have connected with one another has been the need for different organizations to transfer information across large geographic areas as rapidly as possible.

Given this change, you will probably have to connect different types of networks into a single logical network in which each type can communicate with the others.

## TCP/IP and Interoperability

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Many networks today use protocols other than TCP/IP. For instance, Novell NetWare networks used IPX/SPX as the default networking protocol until Novell NetWare 5. Many Novell networks still use IPX/SPX and are very productive. Such networks need not completely abandon the networking protocol they have traditionally used. They can use one protocol internally, and use TCP/IP as the protocol that will transport information between their network and another.

If one network used a networking protocol such as NetBEUI, and another used IPX/SPX, they could not communicate with each other. Such networks could employ special devices, called gateways, to translate between different networking protocols, but a much more effective solution would be to adopt TCP/IP.

As shown in Figure 1-1, TCP/IP can allow different types of networks to communicate with one another. Using only a router, TCP/IP allows your existing LAN or WAN to operate with another.

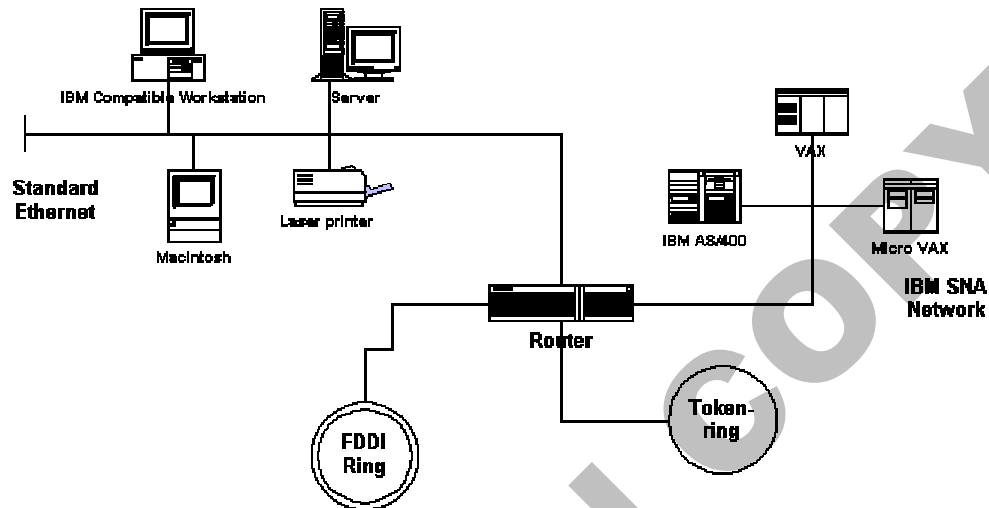


Figure 1-1: TCP/IP and interoperability

TCP/IP works with many different topologies. It also allows other protocols to operate in a NIC. Therefore, it acts as an ideal bridge that allows existing LANs and WANs to act as backbones for an enterprise.

## Internetworking and the Corporate Network

You have seen that TCP/IP is an ideal internetworking protocol because it allows different systems to work together. Such cross-platform capability means that legacy systems, such as IBM SNA, can communicate with newer client/server solutions such as UNIX, Windows NT, Windows 2000, Macintosh, and Novell networks. Older mainframe networks and the latest PC-based networks can communicate with one another, as well. Because it is vendor-neutral, TCP/IP allows internetworkers to connect each system without sacrificing the strengths inherent in any operating system or networking method.

TCP/IP for internetworking has been attractive because it allows corporations and networks to use past investments as wisely as possible. Therefore, even though the Internet and internetworking are revolutionary, this protocol presents an attractive alternative to businesses that do not want to discard an entire system. With careful planning and problem solving, organizations can make sure that their older systems can communicate with any other system on their internetwork.

## Evolution of the Internet

The Internet was formed in 1968, when the U.S. Department of Defense Advanced Research Projects Agency (ARPA) funded what would become the first global computer network, the Advanced Research Projects Agency Network (ARPANET). The ARPANET was launched in 1969 and connected four universities: two University of California campuses, the Stanford Research Institute, and the University of Utah. The network allowed university and government engineers to research and work from any location on the network. ARPANET's design featured multiple hosts and multiple connections among those hosts (see Figure 1-2), which greatly reduced the chances of total network failure. There was no central hub, which would have created a point of vulnerability; rather, control was spread throughout the network. This decentralization resulted in a robust and reliable network that would continue to function even if many of the hosts were incapacitated.

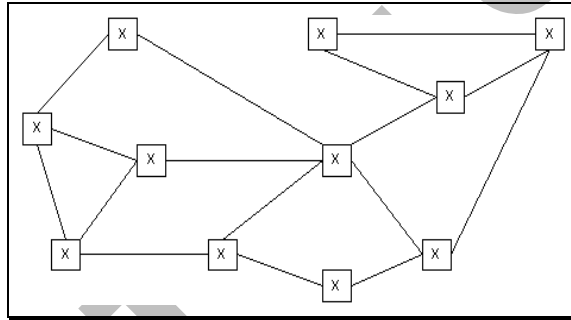


Figure 1-2: Multiple connections among hosts

**NSFnet**  
National Science  
Foundation network;  
the forerunner of  
the Internet, based  
on the ARPANET  
architecture.

In the early 1980s, the UNIX operating system from University of California, Berkeley, supported TCP/IP, and in 1981 TCP/IP became an official Internet standard. On January 1, 1983, TCP/IP was adopted as the Internet's official protocol. In the late 1980s, the Department of Defense decommissioned the ARPANET, and all sites transferred to the National Science Foundation (NSF) network, called the **NSFnet**. The NSF is an independent agency of the U.S. government that promotes the advancement of science and engineering. The NSF increased the number of NSFnet supercomputers to five in 1986 and added access to more networks, expanding the range of sites for businesses, universities, and government and military installations. These centers were connected with 56-Kbps telephone lines that created regional networks, with each supercomputing "center" as a hub for connections in a given region. In 1987, the NSFnet became known as the Internet.

Traffic on the network increased significantly. In 1989, the NSFnet was upgraded to support a 1.5-Mbps connection speed by contracting Merit Network, Inc. In the years that followed, more private companies joined the Internet, and now technologies exist to reach speeds over 1 Gbps. The hardware and communications links required to connect to the Internet were funded by a combination of private and government money. In 1995, the NSF decommissioned the NSFnet and gradually turned the Internet over to a consortium of private telecommunication companies, including Sprint, UUNet, PSINet and MCI.

## Internet-related Authorities

The authority for the Internet rests with the Internet Society (ISOC). ISOC is a voluntary membership organization whose objective is to promote global information exchange using Internet technology. You can visit the Internet Society at [www.isoc.org](http://www.isoc.org).

ISOC elects volunteers who are responsible for the technical management and direction of the Internet; these volunteers are called the Internet Architecture Board (IAB).

Another volunteer organization, called the Internet Engineering Task Force (IETF), meets regularly to discuss operational and near-term Internet technical problems. Recommendations made via working groups within the IETF can be sent to the IAB to be declared Internet standards. The IETF chairman and the area managers form the Internet Engineering Steering Group (IESG).

Another organization, called the Internet Research Task Force (IRTF), is responsible for network research and the development of new technology. The Internet Research Steering Group (IRSG) sets priorities and coordinates research activities. Figure 1-3 displays the ISOC structure.

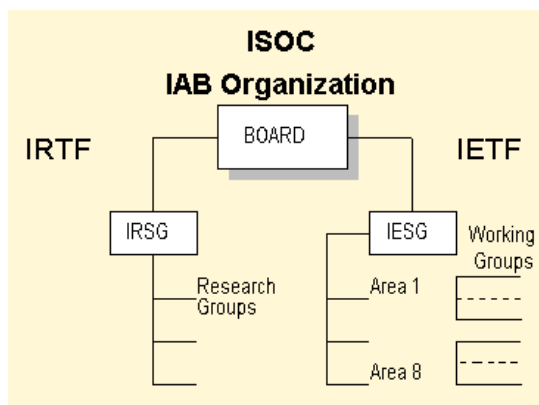


Figure 1-3: ISOC structure

## OSI Reference Model

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The Open Systems Interconnection reference model (OSI/RM) was defined by the International Organization for Standardization (ISO). Introduced in 1983, the OSI/RM has three practical functions:

- It gives developers necessary, universal concepts so they can develop and perfect protocols.
- It explains the framework used to connect heterogeneous systems. In other words, it allows clients and servers to communicate even if they are using different applications and operating systems. All they need is a common protocol, such as TCP/IP or IPX/SPX.
- It describes the process of packet creation. You will learn more about packet creation shortly.

Networks are built using the OSI/RM, just as a building is constructed from a blueprint. For instance, Novell NetWare, Microsoft Windows NT, Windows 2000, and UNIX are based on the OSI/RM. This common framework allows these network operating systems (NOS) to interoperate.

Also, whenever protocols are discussed, such as IP and IPX, they are usually linked to their OSI layer. For example, both IP and IPX are found at the OSI/RM network layer. The OSI/RM provides the concepts and nomenclature you need to be able to discuss packet creation and networking protocols.

Table 1-1 lists the seven layers of the OSI/RM and describes each layer's function.

Table 1-1: Layers of the OSI/RM

Layer	Layer Number	Description
<b>Application</b>	<b>7</b>	The interface to the end user in an OSI environment—supports file transfer, network management and other services.
<b>Presentation</b>	<b>6</b>	Responsible for providing useful transformations on data to support a standardized application interface and general communication services. For example, it converts text from American Standard Code for Information Interchange (ASCII) to Extended Binary Coded Decimal Interchange Code (EBCDIC).
<b>Session</b>	<b>5</b>	Establishes, manages, and terminates connections (sessions) between cooperating applications. This layer adds traffic flow information, as well.
<b>Transport</b>	<b>4</b>	Provides reliable, transparent transportation between end points (i.e., the source and destination hosts). It also supports end-to-end error recovery and flow control. Connection-oriented (stateful) protocols reside at this layer.
<b>Network</b>	<b>3</b>	Responsible for forwarding and routing datagrams. Connectionless (stateless) protocols reside at this layer.
<b>Data Link</b>	<b>2</b>	Provides reliable data transfer across the physical link. Frames are transmitted with the necessary synchronization, error control, and flow control. In short, it prepares the information so that it can be sent to the physical wire.  In the IEEE 802 series of LAN standards (a group of popular network standards that you will learn about in this course), the data link layer is divided into two sublayers, the Logical Link Control (LLC) layer and the Media Access Control (MAC) layer. The LLC is responsible for error and flow control and the MAC layer is responsible for placing data on the wire.
<b>Physical</b>	<b>1</b>	Concerned with transmission of unstructured bit stream over a physical link. Responsible for the mechanical, electrical, and procedural characteristics to establish, maintain, and deactivate the physical link.

## How the layers communicate

As shown in Figure 1-4, the OSI model describes interaction between the individual layers, as well as between hosts on a network.

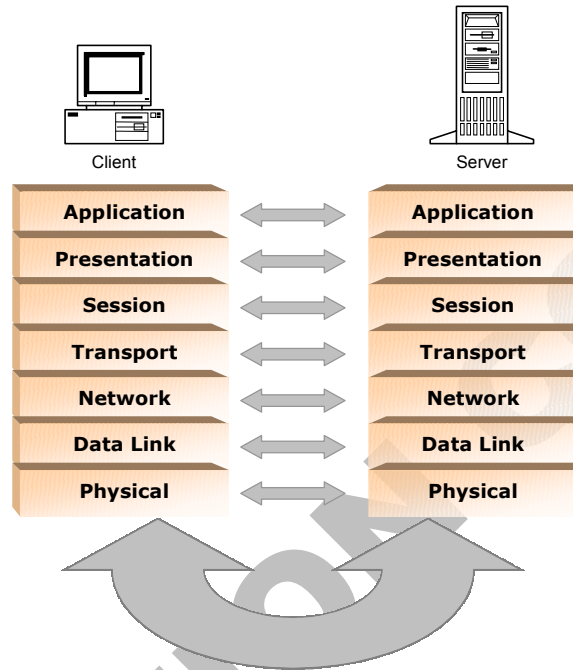


Figure 1-4: OSI model layers

A client/server example will be used to explain how the OSI/RM typically works. In the figure, the left column contains the seven OSI/RM layers that exist on the client. The right column contains the same seven layers that exist on the server.

If the client sends a request to the server, the request might begin with a mouse click by the user on a Web page hyperlink (application layer). The request travels down the OSI/RM until it reaches the data link layer, where it is placed onto a wire, cable, or whatever network media is used (the physical layer).

The client's request travels across the wire until it reaches the server. The server's data link layer pulls the request off the wire (physical layer) and sends it up the server's OSI/RM. When the request arrives at the server's application layer, the request is processed. The server then returns a response to the client, which may be a new Web page, using the same method.

In networking, information such as the client's request and the server's response is sent across the network in packets. Packets are discussed in the next section.

## Packets

A packet is a fixed piece of information sent across a network. Whenever you send information across any network, you begin the packet creation process. A packet consists of three elements: a header, the actual data, and a trailer.



Many networking professionals use the terms "packet," "datagram" and "frame" interchangeably. Although this usage is accurate most of the time, "packet" is a generic term for any piece of information passed through a network. A datagram is a packet at the network layer of the OSI/RM. A frame is a packet at the data link layer (used to traverse an ethernet network). Even though they are slightly different, these terms are used synonymously.

As shown in Figure 1-5, the header contains several different pieces of information, such as addressing information or an alert signal to the incoming computer.

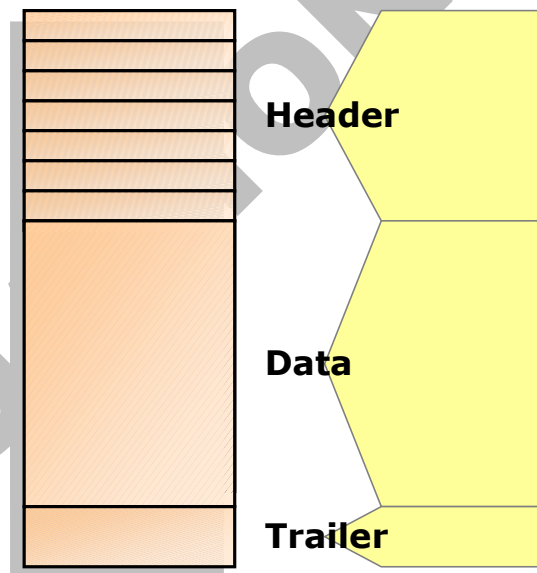


Figure 1-5: Packet structure

The preceding figure also shows that the packet contains the original data, such as an e-mail message. The trailer usually contains information that validates the packet. For example, it could contain Cyclical Redundancy Check (CRC) information.

## Cyclical Redundancy Check

A CRC is a mathematical calculation that allows the receiving computer to verify whether the packet is valid. When a sending host transmits a packet, it calculates a CRC, then adds this information to the trailer. When the receiving host reads the packet, it runs its own CRC, then compares it with the CRC stored in the trailer. If the two match, the packet is not damaged, and the receiving host processes the packet. If the CRCs do not match, the receiving host discards the entire packet.

## Packet creation: Adding headers

The packet creation process begins with Layer 7 of the OSI/RM (the application layer), and continues through Layer 1 (the physical layer). For example, when you send an e-mail message or transfer a file from one computer to another, this message or file undergoes a transformation from a discrete (i.e., complete) file into smaller pieces of information called packets. Beginning with the application layer of the OSI/RM, the file continues to be divided until the initial, discrete message becomes smaller, more manageable pieces of information sent at the physical layer.

As shown in Figure 1-6, each layer adds its own information, called a header, to the packet. This information enables each layer to communicate with the other, and also allows the receiving computer to process the message.

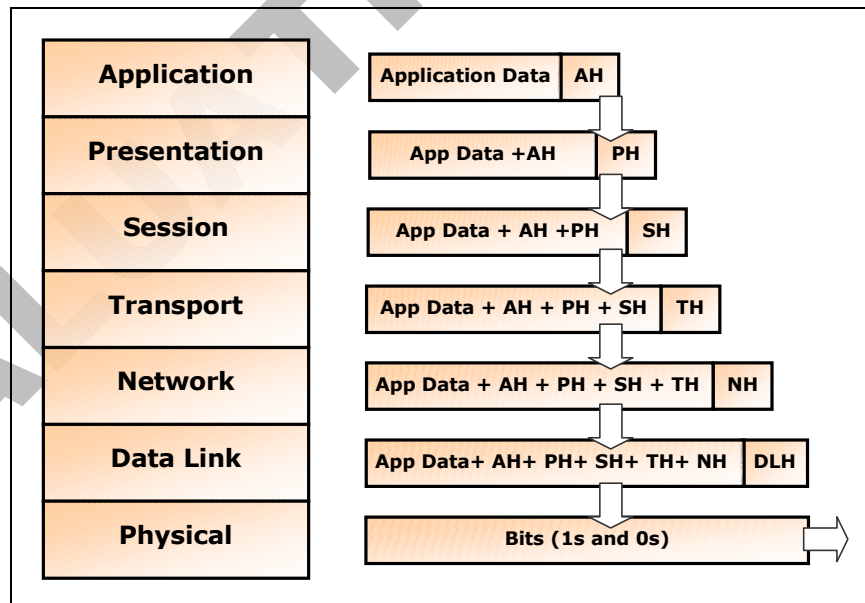


Figure 1-6: Headers added at each level of OSI/RM

## Packet creation: Removing headers

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You have already seen how a sending host creates a packet. When a receiving host processes a packet, it reverses the packet creation process and removes each header, beginning with Layer 1 (the physical layer) and ending with Layer 7. All that is left at the end of this process is the original, unaltered data, which the host can then process.

## OSI/RM Protocol Examples

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The networking protocols listed in this section are examples of common protocols that operate within the OSI/RM layers.

### Application-layer protocols

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Application layer protocols, often called upper-layer protocols, allow applications to speak to one another across a network. The application-layer protocols listed are those found in the upper layers of the OSI/RM, which are the application, presentation and session layers. No specific section is available for the presentation and session layers because the upper-layer protocols include them. More common application-layer protocols include:

- **Simple Mail Transfer Protocol (SMTP).** This TCP/IP suite protocol is used to send e-mail messages from host to host.
- **BOOTstrap Protocol (BOOTP).** Although seemingly obscure, BOOTP is responsible for sending TCP/IP address configuration information to hosts.
- **File Transfer Protocol (FTP).** Part of the TCP/IP suite, FTP is used to transfer files between two hosts.
- **Hypertext Transfer Protocol (HTTP).** The World Wide Web uses this TCP/IP suite protocol to interconnect Web pages.
- **AppleTalk Filing Protocol (AFP).** Used exclusively in AppleTalk networks, AFP allows such networks to exchange files.
- **Simple Network Management Protocol (SNMP).** This TCP/IP suite protocol allows network administrators to troubleshoot and manage networks, regardless of architecture.
- **Server Message Block Protocol (SMB).** Used in Microsoft networks, this protocol allows clients to work closely with servers. Specifically, it allows clients and servers to access files and request other services.

- **X.500.** This protocol manages online directories of users and resources; an OSI directory protocol. The Lightweight Directory Access Protocol (LDAP) is used to access X.500 directories.
- **NCP (NetWare Core Protocol).** NCP allows files and printers to be shared on a Novell NetWare network.
- **Network File System (NFS).** This protocol allows files and printers to be shared on a UNIX network.

## Transport-layer protocols

---

The transport layer provides reliable data delivery. Protocols used at this layer include:

- **Transmission Control Protocol (TCP).** Part of the TCP/IP suite; helps provide reliable delivery and manages sessions.
- **Sequenced Packet Exchange Protocol (SPX).** Part of the IPX/SPX protocol suite; similar to TCP in that it manages communication sessions.
- **NWLink.** The Microsoft implementation of IPX/SPX.
- **AppleTalk Transaction Protocol (ATP).** Part of the AppleTalk networking suite; provides reliable transmissions between hosts.
- **NetBEUI.** Allows different applications on different computers using NetBIOS to communicate with one another; a nonroutable protocol.

## Network-layer protocols

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Network-layer protocols provide routing information to routers and addresses to hosts. Network protocols include:

- **Internet Protocol (IP).** Part of the TCP/IP suite; responsible for addressing hosts and routing packets in any network running TCP/IP, including the Internet.
- **Internetwork Packet Exchange (IPX).** Provides addressing services for the Novell IPX/SPX suite.
- **NWLink.** The Microsoft implementation of IPX/SPX.

- **Datagram Delivery Protocol (DDP).** Part of the AppleTalk networking suite; a best-effort packet (also called datagram) delivery protocol.
- **NetBEUI.** Allows different applications on different computers using NetBIOS to communicate with one another; a nonroutable protocol.

## Data link-layer protocols

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Data link-layer protocols provide reliable data transfer across the physical link. Data link-layer protocols include:

- **Ethernet.** This LAN protocol was created by Xerox, Digital Equipment Corporation, and Intel. It is the most popular LAN technology.
- **Frame Relay.** This WAN protocol uses variable-length packets and allows high-speed connections using shared network facilities.
- **X.25.** This WAN protocol is a precursor to frame relay technology. It was developed in the early 1970s and was the first packet-switching network standard.

You will learn more about many of these protocols throughout this course.

## Major Networking Protocols

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Several networking protocols and architectures exist, all based on the OSI/RM. You have been introduced to TCP/IP and IPX/SPX briefly in a previous section; however, many additional protocols are used for networking. This section will explain several important networking protocol properties. Following are some important networking protocols.

- TCP/IP
- IPX/SPX
- NetBEUI
- AppleTalk
- Data Link Control (DLC)
- Systems Network Architecture (SNA)

## Connection-oriented (stateful) and connectionless (stateless)

---

Some network protocols require that a host establish a connection, or session, before it transfers information. Because of this requirement, session-oriented (i.e., connection-oriented) protocols are often called stateful protocols. A state is the name given to a session. Connection-oriented protocols are more reliable because they first gain a system's attention, prepare it to receive information, then send the information. However, connection-oriented protocols require more system overhead, and are not always appropriate for certain networking tasks. An example of a connection-oriented protocol is TCP.

Other network protocols do not require a previously established session; they rely on a "best-effort" technology that sends the information, hoping that it will reach the other system. This protocol type is called connectionless, or stateless. An example of a stateless protocol is IP, which provides addresses for the TCP/IP suite. Many connectionless protocols send information by means of short messages called datagrams.

Receiving a phone call, for example, is a connection-oriented activity, mainly because it requires you to establish a continuous session before you can communicate. You can also immediately acknowledge that you received the information a caller has sent you, and this acknowledgment is part of that session.

Sending a message via the U.S. Postal Service, however, is a connectionless activity because you do not initiate a continuous connection to transmit the message. You simply send the message and hope that it arrives. Rather than being able to send an immediate acknowledgment that the package was received, the recipient would have to send another message indicating that your message arrived.

Although it might be tempting to regard a connection-oriented protocol as more important or reliable, this is not necessarily the case. Each protocol type has its own use in a network.

## Routable and nonroutable protocols

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Some protocols can travel through LANs and WANs and beyond because they can pass through a router. Routable protocols include TCP/IP and IPX/SPX.

Nonroutable protocols use predefined, or static, routes that cannot be changed. Some protocols are nonroutable because they do not use the functions of the OSI/RM network layer. Nonroutable protocols include NetBEUI, NetBIOS, Systems Network Architecture (SNA), Local Area Transport (LAT) and the Data Link Control (DLC) protocols. You will learn more about routing later in the course.

To effectively use a nonroutable protocol, you can add a bridge (discussed later in the course) to your network or encapsulate the nonroutable protocol within a routable protocol, such as TCP/IP. Encapsulation is also called tunneling.

## TCP/IP

---

On January 1, 1983, the major networks that make up the Internet adopted the Transmission Control Protocol/Internet Protocol (TCP/IP) suite as the Internet's official protocol. One reason for the Internet's explosive growth and powerful communication ability is its adoption of this suite, which was originally developed in Berkeley, California.

TCP/IP is the default protocol for the following network operating systems:

- Windows NT 4.0
- Windows 2000
- UNIX
- NetWare 5

Currently, the Internet fully supports TCP/IP version 4. However, TCP/IP version 6 (known as IPv6) is being tested and is expected to gain full support in the coming decade.

You will learn more about TCP/IP in future lessons, but some of its basic principles are discussed in the following section.

### A collection of protocols

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TCP/IP is a suite of protocols that includes Transmission Control Protocol, Internet Protocol, User Datagram Protocol (UDP), Internet Control Message Protocol (ICMP), Address Resolution Protocol (ARP) and many others that will be discussed later in this course. Each of these protocols has a specific function. This lesson will discuss only TCP and IP.

## TCP

TCP ensures reliable communication and uses ports to deliver packets. It also fragments and reassembles messages, using a sequencing function to ensure that packets are reassembled in the correct order.

## IP

IP is a connectionless protocol responsible for providing addresses of each computer and performing routing. TCP/IP version 4 uses 32-bit addresses. The address scheme falls into five classes, only three of which are available for standard network addressing. The original plan was to assign class A addresses to large networks, class B to medium-sized networks, and class C to smaller networks. Class D addresses are used for multicasting, and class E addresses are experimental. You will learn more about these classes later in this course.

Thirty-two-bit IP addresses are divided into halves: the network portion and the host portion. The subnet mask helps determine which bits form the network and host portions.

### **An open standard**

TCP/IP is not tied to any one vendor, and therefore allows heterogeneous networks to communicate efficiently. It uses the Internet architecture model that divides its protocols into four layers. Each layer is responsible for specific communication tasks and coincides with layers in the OSI/RM. Note that several Internet architecture models exist, each slightly different from the others. A four-layer version was selected for this course, as shown in Figure 1-7. You will learn about the Internet architecture model in detail in an upcoming lesson.

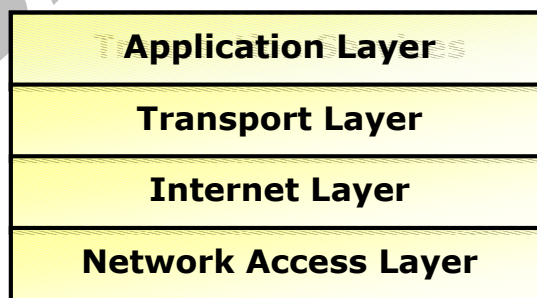


Figure 1-7: Internet architecture model

## IPX/SPX

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Novell, Inc., developed this once-dominant LAN and WAN protocol. Like TCP/IP, IPX/SPX is a protocol suite rather than a single protocol. Microsoft also supports IPX/SPX, although the corporation has renamed it NWLink (NetWare Link).

### IPX

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Internetwork Packet Exchange (IPX) is a connectionless protocol that resides at the network layer of the OSI/RM. It is responsible for network addressing and forwarding packets to their destination, an action called routing.

### SPX

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Sequenced Packet Exchange (SPX) is a connection-oriented transport-layer protocol that uses services provided by IPX. SPX provides reliability to IPX: It ensures that packets arrive intact at their destination. Because this protocol resides at the transport layer, it ensures reliable data delivery and manages sessions.

### IPX/SPX advantages and disadvantages

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IPX/SPX is not a vendor-neutral protocol. It was developed by Novell and is used mostly with Novell NetWare networks. TCP/IP has eclipsed IPX/SPX as the standard enterprise protocol due to its open nature. However, IPX/SPX is still common and it has always performed better than TCP/IP.

Although IPX/SPX is not supported on the Internet, thousands of IPX/SPX WANs use private networks or virtual private networks (VPNs) to communicate over long distances (you will learn about WANs, private networks and VPNs later in this course).

Novell has adopted TCP/IP as its default protocol in Novell NetWare 5, although the company still supports IPX/SPX.

### IPX/SPX frame type

IPX/SPX can use different frame types. Administrators can choose between the IEEE 802.2 or IEEE 802.3 frame types (you will learn about IEEE standards later in this course). Novell NetWare 3.12 and later default to the IEEE 802.3 frame type. Previous versions defaulted to IEEE 802.2. If you are using IPX/SPX and cannot make a connection, check to see whether your system's frame type is compatible with those used by the rest of the network.

## Novell NetWare layers

Novell NetWare protocols can be classified using the Internet architecture model (which will be discussed in detail in a later lesson). Each layer includes the following protocols:

- **Network access-layer protocols**—ethernet, token ring, and ARCNET.
- **Internet-layer protocol**—IPX.
- **Transport-layer protocols**—SPX and Packet Exchange Protocol (PEP).
- **Application-layer protocols**—Error, Echo, Service Advertisement Protocol (SAP) and others.

Figure 1-8 lists several Novell NetWare protocols.

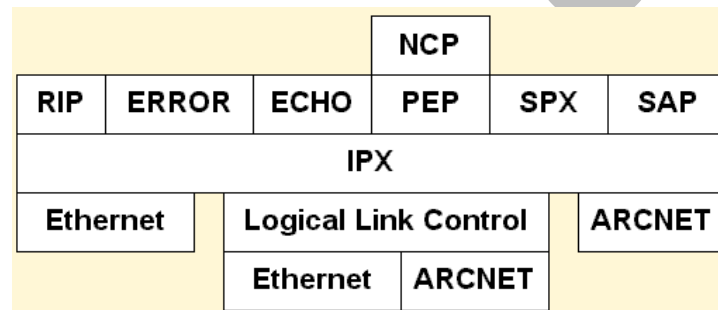


Figure 1-8: Novell NetWare protocols

## NetBEUI

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NetBEUI (pronounced "Net-boo-ee") is an acronym for Network Basic Input/Output System (NetBIOS) Extended User Interface. It was first developed by IBM, but Microsoft has since implemented it as a solution for its peer-to-peer networks. NetBEUI is a nonroutable protocol, which limits its usefulness in many networks.

## NetBIOS

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NetBIOS stands for Network Basic Input/Output System. It was originally designed for use with NetBEUI (hence the name NetBIOS Extended User Interface). Because NetBEUI is declining in popularity, NetBIOS is mainly used as a programming interface for applications. It resides at the session layer (Layer 5) of the OSI/RM. NetBIOS can operate over NetBEUI, as well as routable protocols such as TCP/IP and IPX/SPX. Microsoft Windows computers use NetBIOS names to identify one another and communicate on a network.

## AppleTalk

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AppleTalk is used only in Apple networks, and is thus proprietary. AppleTalk Phase II allows this protocol to work with others. Rather than using the term domain or network, AppleTalk divides groups of computers into zones.

## Data Link Control (DLC)

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IBM originally developed DLC to enable client machines to work with mainframes. However, Hewlett-Packard has adopted DLC as a means to connect its laser printers to LANs.

## Systems Network Architecture (SNA)

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IBM introduced SNA in 1974 as a mainframe network architecture. Because it is an architecture, it includes a network topology and a series of protocols. The SNA model is quite similar to the OSI/RM. In fact, SNA inspired the creation of the OSI/RM.

The SNA market is valued at about \$20 billion per year. Even though it is an older architecture, it is still widely used within mainframe networks.

## Multiprotocol Networks

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Networks commonly use two routable protocols, such as TCP/IP and IPX/SPX, although this combination could cause problems with system overhead in large, heavily visited sites. Such a combination provides system redundancy and can speed connectivity.

Sometimes routable and nonroutable protocols should be combined, even in a routed network. A nonroutable protocol such as NetBEUI could be quite useful in a LAN and WAN situation because it can deliver traffic to local computers without the overhead associated with TCP/IP. If a user sends a message to an employee in the same LAN, NetBEUI will handle all of this transaction. However, if someone sends a message to a recipient on another LAN (activity that involves a router), the system will automatically use a routable protocol such as TCP/IP.



*You should also consider, however, that using multiple protocols can increase the time it takes to maintain and troubleshoot a network. In addition, the more protocols you use, the more system overhead you create.*

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## Lesson Summary



### Application project

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Are the Internet architecture model and the Novell NetWare protocol stack related to the OSI/RM? Do you think interoperability transitions are easier if all protocols are based on a standard model? To learn more about the OSI/RM, visit the Cisco Web site and view its Internetworking Technologies handbook at:

*[www.cisco.com/cpress/cc/td/cpress/fund/ith/index.htm](http://www.cisco.com/cpress/cc/td/cpress/fund/ith/index.htm)*



### Skills review

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In this lesson, you defined the term "internetwork" and compared it with traditional networking. You learned about the importance of TCP/IP and the corporate environment, and how TCP/IP can use your existing LANs and WANs as backbones for interoperability. Next, you studied the evolution of the Internet and its organizations, including the ISOC, IAB, IETF, and IRTF, as well as how TCP/IP relates to standards such as the OSI/RM and IPX/SPX. Finally, you identified key internetworking protocols and explained the need for multiprotocol networks.

Now that you have completed this lesson, you should be able to:

- ✓ Define "internetwork" and explain this concept's importance in today's data communications marketplace.
  - ✓ Describe how TCP/IP can use your existing LANs and WANs as backbones for interoperability.
  - ✓ Relate internetworks to the concept of the corporate enterprise network.
  - ✓ Explain the evolution of the Internet.
  - ✓ Explain the nature, size, and other characteristics of the National Science Foundation network (NSFnet).
  - ✓ Define and discuss Internet-related organizations, including ISOC, IAB, IETF and IRTF.
  - ✓ Discuss how TCP/IP relates to standards such as SNA, OSI and IPX/SPX.
  - ✓ Identify key internetworking protocols and explain the need for multiprotocol networks.
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## Lesson 1 Review

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1. What is the definition of a network?

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2. What were the main design features of ARPANET?

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3. What does ISOC stand for?

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4. What are the seven layers of the OSI/RM?

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5. What is a packet?

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6. What is the Internet's official protocol?

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