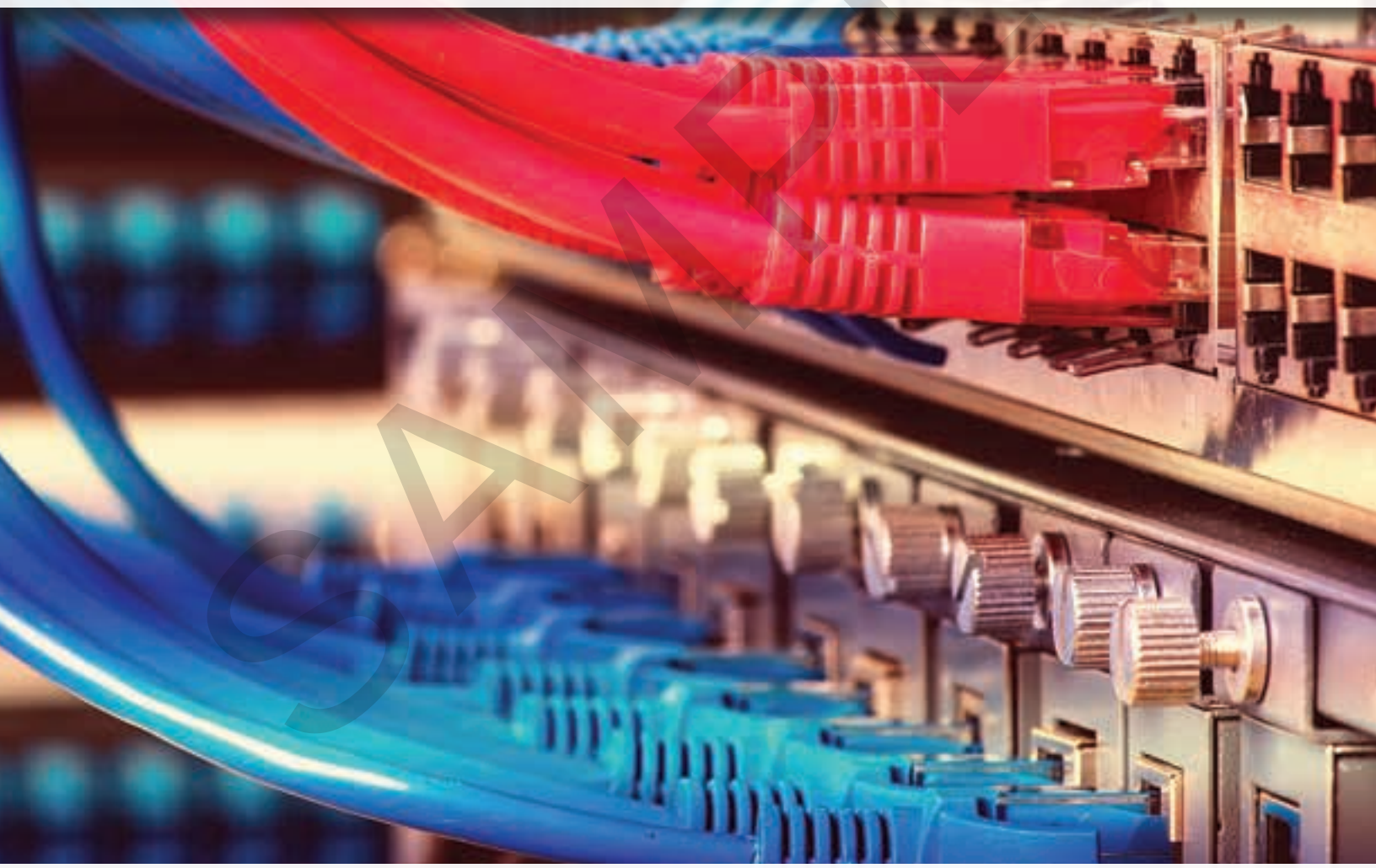
Networking Fundamentals

Fourth Edition

Chuck Easttom • Richard M. Roberts



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Preface

Networking Fundamentals was written for individuals wishing to pursue a career in information technology with a specific focus on networking and network administration. The text provides specific content about information technology as well as career information that is needed for employment. It is an introductory text, so no previous networking experience is required.

This text is aligned to the most recent CompTIA Network+ certification exam objectives. By studying *Networking Fundamentals* and using the ancillary lab manual and digital study guide, you can improve your chances of earning an industry-recognized certification. Upon completing this course, you will be able to:

- recall the foundational concepts of networking, including topologies, classifications, and the OSI model;
- understand copper-core transmissions, categorize Ethernet cable, and terminate twisted-pair cable;
- describe fiber-optic transmissions and characteristics;
- differentiate among wireless communication technologies and wireless networks;
- provide examples of digital signals and encoding;
- explain the use of network operating systems and the evolution of networking protocols;
- identify and use various Microsoft operating systems;
- compare and contrast UNIX/Linux-based software with Microsoft-based software;
- define the function of a server and describe server types and services;
- differentiate between IPv4 and IPv6 addresses, understand DNS operation, and list TCP/IP utilities;
- understand the concept of subnetting a network;
- describe the mechanics of voice, audio, and video transmission;
- discuss the function of a web server and describe specific web services, such as NNTP and e-mail;
- compare and contrast remote networking technologies;
- assess the security of a network and mitigate breaches and vulnerabilities;
- understand the basics of cloud computing;
- apply the CompTIA network troubleshooting strategy and diagnose and treat common network problems;
- summarize the processes for designing and installing a new network;
- complete and pass a CompTIA Network+ practice exam; and
- analyze networking employment opportunities in the information technology industry.

Information technology is an ever-changing landscape. A successful career in the IT industry requires you to continually learn and stay current with new information about networking, as well as every facet of computing. Earning certifications in IT and other specialty areas will help you stay current with hardware, software, and security changes. More importantly, it will help you further your information technology career.

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About the Authors

Dr. Chuck Easttom is the author of 36 books, including several on computer security, forensics, and cryptography. His books are used at over 60 universities. He has so far authored over 70 scientific papers on digital forensics, cyber warfare, cryptography, and applied mathematics. He is an inventor with 25 computer science patents. He holds a Doctor of Science in cybersecurity (dissertation topic: "A Study of Lattice-Based Cryptographic Algorithms for Post Quantum Computing") and three master degrees—one in applied computer science, one in education, and one in systems engineering. He also has a Ph.D. in technology, focusing on nanotechnology (dissertation title: "The Effects of Complexity on Carbon Nanotube Failures") and a Ph.D. in Computer Science (dissertation title: "A Systematic Framework for Network Forensics Using Graph Theory"). He is a senior member of the IEEE (Institute of Electrical and Electronics Engineers) and a senior member of the ACM (Association for Computing Machinery) as well as a member of IACR (International Association for Cryptologic Research) and INCOSE (International Council on Systems Engineering). He is also a distinguished speaker of the ACM and a distinguished visitor of the IEEE Computer Society. He currently is an adjunct lecturer for Georgetown University and Vanderbilt University.

Richard M. Roberts has designed curriculum; taught electricity, electronics, and computer technology; and supervised technical teachers for nearly 50 years. He was an adjunct instructor at South Florida State College. He has divided his time between consulting, teaching students and instructors, and writing instructional materials. He also authored the *Computer Service and Repair* textbook and coauthored the *Electricity and Electronics* textbook. He holds active CompTIA A+, Network+, and Security+ certifications.

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Reviewers

The author and publisher wish to thank the following industry and teaching professionals for their valuable input into the development of *Networking Fundamentals*.

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CompTIA Network+ Certification

How to Become CompTIA Certified

This training material can help learners prepare for the CompTIA Network+ certification exam N10-008. The Computing Technology Industry Association (CompTIA) is a nonprofit information technology (IT) trade association. Its certifications are designed by subject-matter experts. Each certification is vendor-neutral, covers multiple technologies, and requires demonstration of skills and knowledge widely sought after by employers in the IT industry. There are four general steps to achieving CompTIA certification:

1. Choose the desired IT certification from CompTIA.
2. Gain familiarity with the exam, its objectives, and the types of questions asked.
3. Begin studying, learning, and preparing for the exam.
4. Register for the exam, read and sign the Candidate Agreement, and take and pass the exam.

For more information about CompTIA certifications, such as industry acceptance, benefits, or updates, visit comptia.org.

CompTIA Network+ Correlation Charts

Complete mappings (correlation charts) of the CompTIA Network+ exam objectives to the content of the *Networking Fundamentals* textbook are located on the G-W website at www.g-w.com. The correlation chart lists the exam objectives and corresponding page numbers of where to find the related content.

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How to Use This Text

The *Networking Fundamentals* text and accompanying resources will help you prepare for and pass the CompTIA Network+ certification exam. You will learn about the foundations of computer networking, network media and devices, transmission methods, protocols, security, and other important topics. These are concepts that you will need to understand not only for the certification exam, but for your career as a networking professional.

Each chapter in *Networking Fundamentals* begins with a list of CompTIA Network+ certification exam objectives outlining the CompTIA content that will be discussed. Following these objectives, a set of learning outcomes indicates the goals you should focus on accomplishing by the time you complete each chapter. For each outcome, there is a corresponding top-level heading, one or more review questions, and summary bullet points to help ensure you understand the topics covered in the chapter.

In addition to learning outcomes, the chapter-opening material also lists a set of key terms that will be discussed throughout the chapter. These terms are printed in boldface when they appear in the content. This makes them easily distinguished from the rest of the text. There are also important words or phrases printed in italic text to which you should pay special attention and consideration. Studying these terms will help you understand the material and better prepare you for your certification and employment.

Each chapter concludes with a summary of important points to remember, organized by learning outcome and level-one heading. This summary will help you review important topics from each section of the chapter.

Following the suggested guidelines will help you make the most of your introduction to networking.

- Read the list of CompTIA objectives in the chapter-opening material. These objectives are also called out in the margin with an icon where the material is covered. Use the list of objectives in the chapter opener as a checklist to take inventory of CompTIA standards you understand as well as information you need to review. The icons in the margins are there to direct you to the coverage of each objective for review.
- Read the learning outcomes listed in the chapter opener. Each learning outcome is tied directly to the headings within the content. In addition, the concepts are repeated in the chapter summary and applied in the end-of-chapter review questions. The connection of learning outcomes throughout the content helps you focus and apply important information as you read each chapter.
- Pay attention to the illustrations. Each illustration is strategically created to highlight important information. By studying these, you will extend your learning and improve retention and application of the content.
- Read all Network+ Note, Tech Tip, and Caution features as you progress through the material. This information helps supplement your learning by highlighting study tips, providing useful industry information, and helping you ensure personal and machine safety when working with networking devices.
- Review the summary at the end of each chapter. This will help you retain important information from the chapter.
- Answer the review questions and sample Network+ exam questions in the end-of-chapter material. These questions provide exposure to the types of questions likely to be on the CompTIA Network+ certification exam. By practicing these questions, you increase your chances of successfully earning a Network+ certification.

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Focus on Certification

Networking Fundamentals is designed with certification in mind. This text has been updated to reflect current programs, systems, and practices in the information technology industry. It also adheres to the newest objectives of the CompTIA Network+ exam, ensuring students are up to date with the most recent testing domains.

Network+ Objectives

Network+ objectives are listed on each chapter opener to engage students and highlight important testing points presented in the content. Students can use the list of objectives as a checklist, verifying their understanding of the Network+ standards as they are presented in the material. In addition, the objectives are noted by an icon in the margin where the material is covered. This provides a visual clue as to where each objective is met in the chapter.

Learning Outcomes

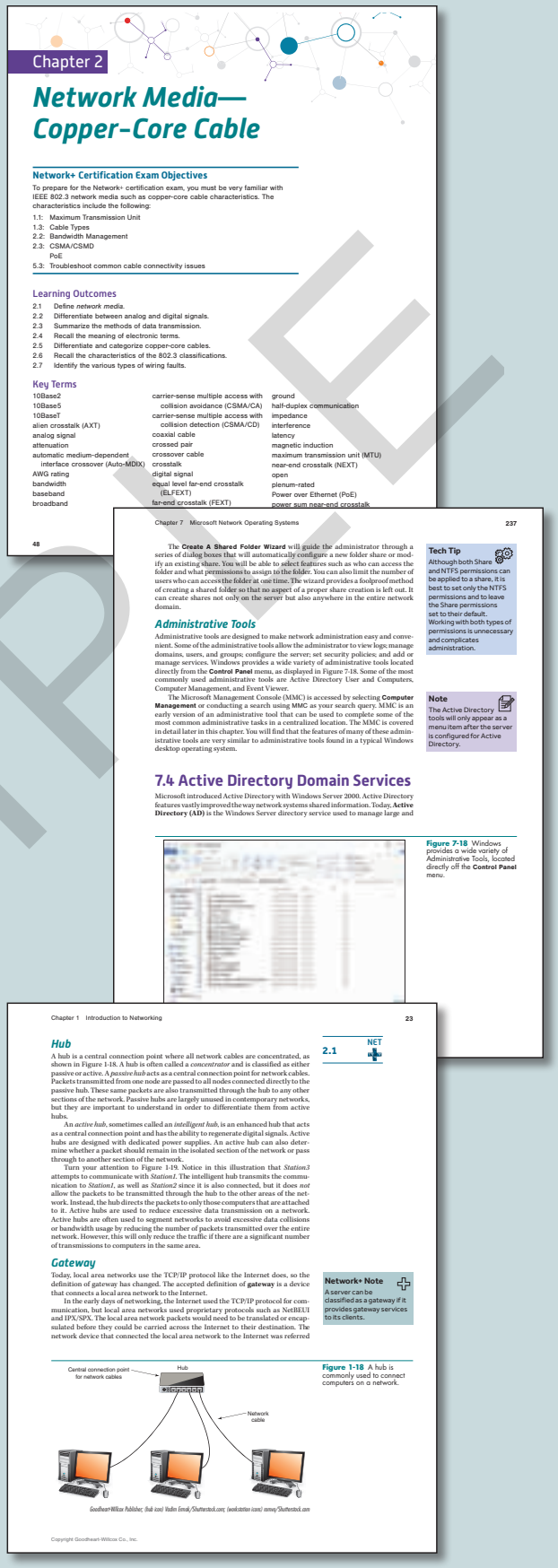
At the beginning of each chapter, a list of learning outcomes guides student learning as they read the material presented. Each learning outcome is aligned with the content headings, as well as with the summary bullet points and review questions at the end of the chapter. This alignment provides a logical flow through each page of the material so that students may build on individual knowledge as they progress through the chapters.

Tech Tip

The Tech Tip feature highlights supplemental information about practical application of networking concepts. These tips vary in their scope, ranging from simple synonyms or definitions of discussed material to real-world advice that provides students with insight that will help in their assignments and careers.

Note

The Note feature provides information that may not be tested on the CompTIA exam but will be helpful for students to know as they begin their careers. This information provides valuable insight to real-word situations in the workplace.


Chapter 2

Network Media—Copper-Core Cable

Network+ Certification Exam Objectives

To prepare for the Network+ certification exam, you must be very familiar with IEEE 802.3 network media such as copper-core cable characteristics. The characteristics include the following:

1.1: Maximum Transmission Unit
1.3: Cable Types
2.2: Bandwidth Management
2.3: CSMA/CSMD
PoE
5.3: Troubleshoot common cable connectivity issues

Learning Outcomes

2.1 Define *network media.*
2.2 Differentiate between analog and digital signals.
2.3 Summarize the methods of data transmission.
2.4 Recall the meaning of electronic terms.
2.5 Differentiate and categorize copper-core cables.
2.6 Recall the characteristics of the 802.3 classifications.
2.7 Identify the various types of wiring faults.

Key Terms

10Base2
10Base5
10BaseT
alien crosstalk (AXT)
analog signal
attenuation
automatic medium-dependent interface crossover (Auto-MDIX)
AWG rating
bandwidth
baseband
broadband
carrier-sense multiple access with collision avoidance (CSMA/CA)
carrier-sense multiple access with collision detection (CSMA/CD)
coaxial cable
crossed pair
crossover cable
crosstalk
digital signal
equal level far-end crosstalk (ELFEXT)
far-end crosstalk (FEXT)
ground
half-duplex communication
impedance
interference
latency
magnetic induction
maximum transmission unit (MTU)
near-end crosstalk (NEXT)
open
plenum-rated
Power over Ethernet (PoE)
power sum near-end crosstalk

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The **Create A Shared Folder Wizard** will guide the administrator through a series of dialog boxes that will automatically configure a new folder share or modify an existing share. You will be able to select features such as who can access the folder and what permissions to assign to the folder. You can also limit the number of users who can access the folder at one time. The wizard provides a foolproof method of creating a shared folder so that no aspect of a proper share creation is left out. It can create shares not only on the server but also anywhere in the entire network domain.

Tech Tip
Although both Share and NTFS permissions can be applied to a share, it is best to set only the NTFS permissions and to leave the Share permissions set to their default. Working with both types of permissions is unnecessary and complicates administration.

Administrative Tools

Administrative tools are designed to make network administration easy and convenient. Some of the administrative tools allow the administrator to view logs; manage domains, users, and groups; configure the server; set security policies; and add or manage services. Windows provides a wide variety of administrative tools located directly from the **Control Panel** menu, as displayed in Figure 7-18. Some of the most commonly used administrative tools are Active Directory User and Computers, Computer Management, and Event Viewer.

The Microsoft Management Console (MMC) is accessed by selecting **Computer Management** or conducting a search using MMC as your search query. MMC is an early version of an administrative tool that can be used to complete some of the most common administrative tasks in a centralized location. The MMC is covered in detail later in this chapter. You will find that the features of many of these administrative tools are very similar to administrative tools found in a typical Windows desktop operating system.

Note
The Active Directory tools will only appear as a menu item after the server is configured for Active Directory.

7.4 Active Directory Domain Services

Microsoft introduced Active Directory with Windows Server 2000. Active Directory features vastly improved the way network systems shared information. Today, **Active Directory (AD)** is the Windows Server directory service used to manage large and

Figure 7-18 Windows provides a wide variety of Administrative Tools, located directly off the **Control Panel** menu.

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Hub

A hub is a central connection point where all network cables are concentrated, as shown in Figure 1-18. A hub is often called a *concentrator* and is classified as either passive or active. A *passive hub* acts as a central connection point for network cables. Packets transmitted from one node are passed to all nodes connected directly to the passive hub. These same packets are also transmitted through the hub to any other sections of the network. Passive hubs are largely unused in contemporary networks, but they are important to understand in order to differentiate them from active hubs.

An *active hub*, sometimes called an *intelligent hub*, is an enhanced hub that acts as a central connection point and has the ability to regenerate digital signals. Active hubs are designed with dedicated power supplies. An active hub can also determine whether a packet should remain in the isolated section of the network or pass through to another section of the network.

Turn your attention to Figure 1-19. Notice in this illustration that *Station3* attempts to communicate with *Station1*. The intelligent hub transmits the communication to *Station1*, as well as *Station2* since it is also connected, but it does *not* allow the packets to be transmitted through the hub to the other areas of the network. Instead, the hub directs the packets to only those computers that are attached to it. Active hubs are used to reduce excessive data transmission on a network. Active hubs are often used to segment networks to avoid excessive data collisions or bandwidth usage by reducing the number of packets transmitted over the entire network. However, this will only reduce the traffic if there are a significant number of transmissions to computers in the same area.

2.1 NET

Gateway

Today, local area networks use the TCP/IP protocol like the Internet does, so the definition of gateway has changed. The accepted definition of **gateway** is a device that connects a local area network to the Internet.

In the early days of networking, the Internet used the TCP/IP protocol for communication, but local area networks used proprietary protocols such as NetBEUI and IPX/SPX. The local area network packets would need to be translated or encapsulated before they could be carried across the Internet to their destination. The network device that connected the local area network to the Internet was referred

Network+ Note
A server can be classified as a gateway if it provides gateway services to its clients.

Figure 1-18 A hub is commonly used to connect computers on a network.

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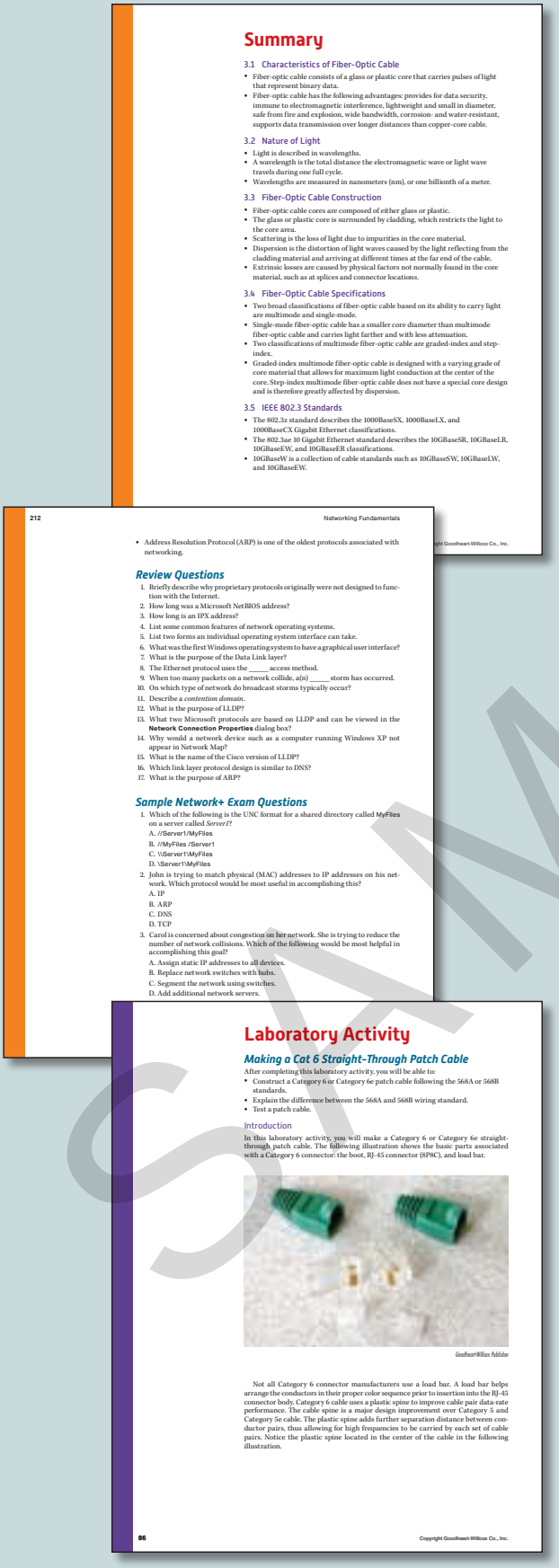

Summary

3.1 Characteristics of Fiber-Optic Cable

- Fiber-optic cable consists of a glass or plastic core that carries pulses of light that represent binary data.
- Fiber-optic cable has the following advantages: provides for data security, immune to electromagnetic interference, lightweight and small in diameter, safe from fire and explosion, wide bandwidth, corrosion- and water-resistant, supports data transmission over longer distances than copper-core cable.

3.2 Nature of Light

- Light is described in wavelengths.
- A wavelength is the total distance the electromagnetic wave or light wave travels during one full cycle.
- Wavelengths are measured in nanometers (nm), or one billionth of a meter.

3.3 Fiber-Optic Cable Construction

- Fiber-optic cable cores are composed of either glass or plastic.
- The glass or plastic core is surrounded by cladding, which restricts the light to the core area.
- Scattering is the loss of light due to impurities in the core material.
- Dispersion is the distortion of light waves caused by the light reflecting from the cladding material and arriving at different times at the far end of the cable.
- Extrinsic losses are caused by physical factors not normally found in the core material, such as at splices and connector locations.

3.4 Fiber-Optic Cable Specifications

- Two broad classifications of fiber-optic cable based on its ability to carry light are multimode and single-mode.
- Single-mode fiber-optic cable has a smaller core diameter than multimode fiber-optic cable and carries light farther and with less attenuation.
- Two classifications of multimode fiber-optic cable are graded-index and step-index.
- Graded-index multimode fiber-optic cable is designed with a varying grade of core material that allows for maximum light conduction at the center of the core. Step-index multimode fiber-optic cable does not have a special core design and is therefore greatly affected by dispersion.

3.5 IEEE 802.3 Standards

- The 802.3z standard describes the 1000BaseSX, 1000BaseLX, and 1000BaseCX Gigabit Ethernet classifications.
- The 802.3ae 10 Gigabit Ethernet standard describes the 10GBaseSR, 10GBaseLR, 10GBaseEW, and 10GBaseER classifications.
- 10GBaseW is a collection of cable standards such as 10GBaseSW, 10GBaseLW, and 10GBaseEW.

- Address Resolution Protocol (ARP) is one of the oldest protocols associated with networking.

Review Questions

1. Briefly describe why proprietary protocols originally were not designed to function with the Internet.
2. How long was a Microsoft NetBIOS address?
3. How long is an IPX address?
4. List some common features of network operating systems.
5. List two forms an individual operating system interface can take.
6. What was the first Windows operating system to have a graphical user interface?
7. What is the purpose of the Data Link layer?
8. The Ethernet protocol uses the _____ access method.
9. When too many packets on a network collide, a(n) _____ storm has occurred.
10. On which type of network do broadcast storms typically occur?
11. Describe a *contention domain*.
12. What is the purpose of LLDP?
13. What two Microsoft protocols are based on LLDP and can be viewed in the **Network Connection Properties** dialog box?
14. Why would a network device such as a computer running Windows XP not appear in Network Map?
15. What is the name of the Cisco version of LLDP?
16. Which link layer protocol design is similar to DNS?
17. What is the purpose of ARP?

Sample Network+ Exam Questions

1. Which of the following is the UNC format for a shared directory called MyFiles on a server called *Server1*?
   A. //Server1/MyFiles
   B. /\MyFiles /Server1
   C. \\Server1\MyFiles
   D. \Server1\MyFiles
2. John is trying to match physical (MAC) addresses to IP addresses on his network. Which protocol would be most useful in accomplishing this?
   A. IP
   B. ARP
   C. DNS
   D. TCP
3. Carol is concerned about congestion on her network. She is trying to reduce the number of network collisions. Which of the following would be most helpful in accomplishing this goal?
   A. Assign static IP addresses to all devices.
   B. Replace network switches with hubs.
   C. Segment the network using switches.
   D. Add additional network servers.

Laboratory Activity

Making a Cat 6 Straight-Through Patch Cable

After completing this laboratory activity, you will be able to:

- Construct a Category 6 or Category 6e patch cable following the 568A or 568B standards.
- Explain the difference between the 568A and 568B wiring standard.
- Test a patch cable.

Introduction

In this laboratory activity, you will make a Category 6 or Category 6e straight-through patch cable. The following illustration shows the basic parts associated with a Category 6 connector: the boot, RJ-45 connector (8P8C), and load bar.

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Not all Category 6 connector manufacturers use a load bar. A load bar helps arrange the conductors in their proper color sequence prior to insertion into the RJ-45 connector body. Category 6 cable uses a plastic spine to improve cable pair data-rate performance. The cable spine is a major design improvement over Category 5 and Category 5e cable. The plastic spine adds further separation distance between conductor pairs, thus allowing for high frequencies to be carried by each set of cable pairs. Notice the plastic spine located in the center of the cable in the following illustration.

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Network+ Note

The Network+ Note feature provides students with tips and facts regarding the CompTIA Network+ certification exam. These tips will help students study for the certification exam.

Visuals

Chapter figures have been strategically created to highlight important information. Illustrations, photos, diagrams, and screen captures help students visualize the concepts discussed in the chapter for better understanding and retention of the material, as well as future application of the content.

End-of-Chapter Content

End-of-chapter material provides an opportunity for review and application of concepts.

- A concise **Summary** reiterates the chapter learning outcomes and provides a brief review of the content for student reference. This helps students focus on important concepts presented in the text.
- **Review Questions** highlight basic concepts presented in the chapter so students can evaluate their understanding of the material.
- **Sample Network+ Exam Questions** challenge students to answer questions similar to those they will face on the CompTIA exam, providing a sample of what to expect on the exam.
- **Laboratory Activities** provide hands-on practice to help students gain real-world experience in the concepts presented in each chapter.

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TOOLS FOR STUDENT AND INSTRUCTOR SUCCESS

Student Tools

Student Text

Networking Fundamentals is an up-to-date text that covers computer networks as well as networking theory and concepts.

Lab Manual

- Hands-on practice includes questions and activities.
- Projects offer students opportunities to work on various networking challenges.

Digital Study Guide

- Practice exercises reinforce concepts and skills learned in the corresponding textbook chapters.
- A CompTIA Network+ Reference Guide helps students study and prepare for the CompTIA Network+ exam.

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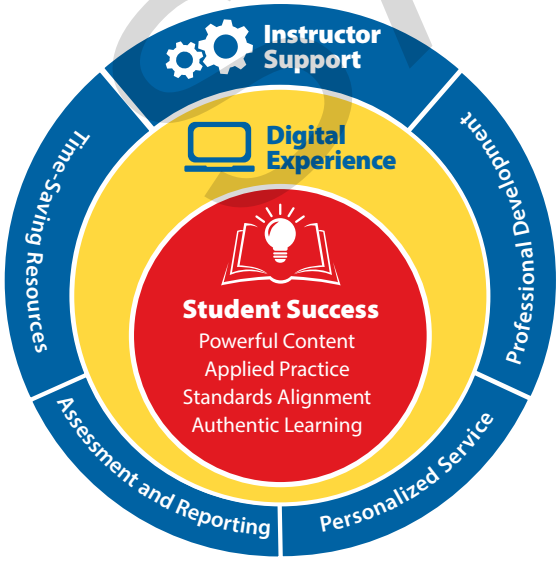

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Online Instructor Resources (OIR)

- The **Instructor Resources** provide instructors with time-saving preparation tools such as answer keys, editable lesson plans, and other teaching aids.
- **Instructor's Presentations for PowerPoint®** are fully customizable, richly illustrated slides that help you teach and visually reinforce the key concepts from each chapter.
- Administer and manage assessments to meet your classroom needs using **Assessment Software with Question Banks**, which includes hundreds of matching, completion, multiple choice, and short-answer questions to assess student knowledge of the content in each chapter.

See www.g-w.com/networking-fundamentals-2024 for a list of all available resources.

Professional Development

- Expert content specialists
- Research-based pedagogy and instructional practices
- Options for virtual and in-person Professional Development

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