31 Days Before Your CompTIA® Network+ Certification Exam

A Day-By-Day Review Guide for the N10-006 Certification Exam

ALLAN JOHNSON

PEARSON IT CERTIFICATION

31 Days Before Your CompTIA Network+ Certification Exam

Allan Johnson

PEARSON IT CERTIFICATION • 800 East 96th Street • Indianapolis, Indiana 46240 USA

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About the Author

Allan Johnson entered the academic world in 1999 after 10 years as a business owner/operator to dedicate his efforts to his passion for teaching. He holds both an MBA and an M.Ed in Occupational Training and Development. He taught CCNA courses at the high school level for 7 years and has taught both CCNA and CCNP courses at Del Mar College in Corpus Christi, Texas. In 2003, Allan began to commit much of his time and energy to the CCNA Instructional Support Team, providing services to Networking Academy instructors worldwide and creating training materials. He now works full time for Cisco Networking Academy as a Learning Systems Developer.

About the Technical Reviewer

Chris Crayton (MCSE) is an author, technical consultant, and trainer. He has worked as a computer technology and networking instructor, information security director, network administrator, network engineer, and PC specialist. Chris has authored several print and online books on PC repair, CompTIA A+, CompTIA Security+, and Microsoft Windows. He has also served as technical editor and content contributor on numerous technical titles for several of the leading publishing companies. He holds numerous industry certifications, has been recognized with many professional teaching awards, and has served as a state-level SkillsUSA competition judge.

Dedication

For my wife, Becky. You continue to travel with me through those "thin times" when projects like these need to be nurtured. Without your constant vigilance and loving support, this work would not have come to fruition.

Acknowledgments

This book is a concise summary of networking concepts and draws upon the work of several Pearson authors. Thank you to Keith Barker, Emmett Dulaney, Anthony Sequeira, and Kevin Wallace for blazing a trail in the Network+ domain by authoring some outstanding resources for the reader.

Thank you to my technical editor, Chris Crayton, who is a tough task master and excellent subject matter expert. This book was made much better by his attentive guidance.

The Digital Study Guide version of this book includes activities, videos, and quizzes for each day.

I am grateful to Dan Alberghetti for agreeing to do the videos. Students of Cisco Network Academy will be familiar with his work. But you can also find Dan's work at his website, http://danscourses.com, and his YouTube channel, http://youtube.com/danscourses.

For writing outstanding quiz items to challenge our readers, we called on Troy McMillan. Thank you, Troy, for your attention to detail and assessment-authoring skill.

Lisa Matthews took my activity designs and Troy's quiz questions and made them interactive—a task that requires creativity, talent, and skill. Thank you, Lisa, for taking the final steps to make activities and quizzes available on PCs, tablets, and mobile devices.

Thank you to Drew Cupp, development editor, and Tonya Simpson, project editor, for juggling all the many pieces that must be managed to bring this product to our students, both in a book format and as a digital study guide.

A project like this goes through many review cycles. One of the very last reviews is for grammar and style. It always amazes me how much of an impact a copy editor can have on the final readability of a product. Thank you, Bart Reed, for making me look good.

And, finally, thank you to my editor, Mary Beth Ray, for bringing me this project when I said, "Okay, what's next?" You continue to challenge me to grow and expand my horizons.

Command Syntax Conventions

The conventions used to present command syntax in this book are the same conventions used in the IOS Command Reference. The Command Reference describes these conventions as follows:

- **Boldface** indicates commands and keywords that are entered literally as shown. In actual configuration examples and output (not general command syntax), boldface indicates commands that are manually input by the user (such as a **show** command).
- *Italic* indicates arguments for which you supply actual values.
- Vertical bars (|) separate alternative, mutually exclusive elements.
- Square brackets ([ ]) indicate an optional element.
- Braces ({ }) indicate a required choice.
- Braces within brackets ([{ }]) indicate a required choice within an optional element.

We Want to Hear from You!

As the reader of this book, *you* are our most important critic and commentator. We value your opinion and want to know what we're doing right, what we could do better, what areas you'd like to see us publish in, and any other words of wisdom you're willing to pass our way.

We welcome your comments. You can email or write to let us know what you did or didn't like about this book—as well as what we can do to make our books better.

Please note that we cannot help you with technical problems related to the topic of this book.

When you write, please be sure to include this book's title and author as well as your name and email address. We will carefully review your comments and share them with the author and editors who worked on the book.

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Introduction

You are almost there! If you're reading this Introduction, you've probably already spent a considerable amount of time and energy pursuing your CompTIA Network+ certification. Regardless of how you got to this point in your travels through your networking studies, *31 Days Before Your CompTIA Network+ Certification Exam* most likely represents the last leg of your journey on your way to the destination: to become Network+ certified.

However, if you're like me, you might be reading this book at the *beginning* of your studies. If such is the case, then this book provides you with an excellent overview of the material you must now spend a great deal of time studying and practicing. However, I must warn you: unless you are extremely well-versed in networking technologies and have considerable experience as a network technician or administrator, this book will not serve you well as the sole resource for Network+ exam preparation. I know this first hand. I recently took the Network+ exam and was impressed with both the breadth and depth of knowledge required to pass. I have been teaching, writing about, and implementing networks for more than a decade, and yet there was a moment during the Network+ exam where I thought, "Wow, this is really a tough exam!"

You see, CompTIA states that the Network+ exam "covers the configuration, management, and troubleshooting of common wired and wireless network devices." You simply cannot just study this content. You must practice it. Although I have a solid understanding of networking concepts and technologies, I also have extensive experience implementing and troubleshooting networks. That's why I was able to easily pass the exam. There really is no other way to correctly answer the many scenario-based questions a candidate will receive during the exam than to have experienced the same or similar scenarios in the real-world or a lab simulation.

Now that I've sufficiently challenged you, let me spend some time discussing my recommendations for study resources.

Study Resources

Pearson IT Certification offers an abundance of books and resources to serve you well as you learn how to configure, manage, and troubleshoot wired and wireless networks. Most of the resources can be purchased in book form or as e-books for your tablet reader by visiting www.pearsonitcertification.com.

Safari Books Online

All the resources I reference in the book are available with a subscription to Safari Books Online (https://www.safaribooksonline.com). If you don't have an account, you can try it free for 10 days.

Primary Resources

First on the list must be Keith Barker and Kevin Wallace's book *CompTIA Network+ N10-006 Cert Guide* (ISBN: 9780789754080). These two Cisco Certified Internetwork Experts (CCIE) do an outstanding job of gathering together and organizing all the material you need to study for the Network+ certification exam. If you get the premium edition bundle, you'll also receive an e-book version, more practice exams, a free copy of the CompTIA Network+ Simulator Lite software, and more than 60 minutes of video mentoring from the author. The practice exams and study materials

on the DVD in the back of the book are worth the price of the book. There is no better resource on the market for a Network+ candidate.

Kevin Wallace also recorded more than 17 hours of video in his *CompTIA Network+ N10-006 Complete Video Course* (ISBN: 9780789754721), which is available free with your Safari Books Online account. You can also purchase it separately at pearsonitcertification.com. Kevin walks you through the full range of topics on the CompTIA Network+ exam using a variety of presentation styles, including live instructor whiteboarding, real-world demonstrations, animations of network activity, dynamic KeyNote presentations, and doodle videos. He also demonstrates hands-on router and switch CLI configuration and troubleshooting in real lab environments, enabling you to learn both the concepts and the hands-on application.

Next on the list must be Emmett Dulaney and Mike Harwood's *CompTIA Network+ N10-006 Exam Cram, Fifth Edition* (ISBN: 9780789754103). This dense Exam Cram book is jam packed with essential content for the Network+ exam. It also includes a handy, pullout exam cram sheet and a CD with practice exams.

At the end of each day in *31 Days Before Your CompTIA Network+ Certification Exam*, you will find a handy reference of what topics to look at in these three resources. They are referred to as "Certification Guide," "Video Course," and "Exam Cram," respectively.

Supplemental Resources

In addition to the book you hold in your hands, there are two more supplemental resources I recommend to augment your final 31 days of review and preparation.

Michael Taylor's *CompTIA Network+ N10-006 Hands-on Lab Simulator* (ISBN: 9780789755179) helps you gain hands-on experience with the concepts presented on the Network+ exam. Using the labs in this software, you will be able to experience realistic operating system and network device configuration and troubleshooting. The three types of labs in the software present you with progressively more difficult real-world challenges. Drag-and-drop labs demonstrate network design concepts and allow you to manipulate physical network cables. Matching labs help reinforce key networking concepts. Operating system and Cisco router and switch command-line interface (CLI) simulator labs present real-world configuration and troubleshooting scenarios for you to solve.

Anthony Sequeira is a CCIE and well-respected networking technologies author. His *CompTIA Network+ N10-006 Flash Cards and Exam Practice Pack* (ISBN: 9780789754646) is a compilation of more than 700 flash cards, practice questions, and quick reference sheets to help you prepare for the Network+ exam. Go through the printed flash cards or install the flash card software on your computer. The CD also includes the practice test software as well as 40 performance-based question exercises, including drag-and-drop and command-line interface questions that mimic the kinds of hands-on questions you will face on the actual exam.

So which resources should you buy? That question is largely up to how deep your pockets are or how much you like books. If you're like me, you want it all—online access for mobile and tablet reading, as well as hard copies for intensive study sessions with a pencil in hand. I admit it: My bookcase is a testament to my "geekness." However, that's not practical for most students. So if you are on a budget, then choose one of the primary study resources and one of the supplemental resources, such as the Cert Guide and the Lab Simulator. Whatever you choose, you will be in good hands. Any or all of these authors will serve you well.

Digital Study Guide

Pearson offers this book in an online digital format that includes enhancements such as video, activities, and Check Your Understanding questions:

- Read the complete text of the book on any web browser that supports HTML5, including mobile.
- Watch dozens of unique embedded videos that demonstrate configurations, explain important topics, and visually describe key Network+ exam objectives.
- Reinforce key network concepts with more than 30 dynamic and interactive hands-on exercises, and see the results with the click of a button.
- Test your understanding of the material at the end of each day with more than 300 fully interactive online quiz questions.

31 Days Before Your CompTIA Network+ Certification Exam Digital Study Guide is available at a discount for anyone who purchases this book. You can find details about redeeming this offer in the back of the book.

Throughout this book you'll see references to the Digital Study Guide enhancements that look like this:

Video: Data Encapsulation Summary

Refer to the Digital Study Guide to view this video.

Activity: Identify the Encapsulation Layer

Refer to the Digital Study Guide to complete this activity.

Check Your Understanding

Refer to the Digital Study Guide to take a 10-question quiz covering the content of this day.

When you are at these points in the Digital Study Guide, you can start the enhancement.

Goals and Methods

The main goal of this book is to provide you with a clear and succinct review of the Network+ exam objectives. Each day's exam topics are grouped into a common conceptual framework and uses the following format:

- A title for the day that concisely states the overall topic
- A list of one or more CompTIA Network+ N10-006 exam topics to be reviewed
- A "Key Topics" section to introduce the review material and quickly orient you to the day's focus

- An extensive review section consisting of short paragraphs, lists, tables, examples, and graphics
- A "Study Resources" section to provide you a quick reference for locating more in-depth treatment of the day's topics

The book counts down starting with Day 31 and continues through the exam day to provide post-test information. You will also find a calendar and checklist that you can tear out and use during your exam preparation inside the book.

Use the calendar to enter each actual date beside the countdown day and the exact day, time, and location of your Network+ exam. The calendar provides a visual for the time that you can dedicate to each Network+ exam topic.

The checklist highlights important tasks and deadlines leading up to your exam. Use it to help you map out your studies.

Who Should Read This?

The audience for this guide is anyone finishing his or her preparation for taking the CompTIA Network+ N10-006 exam. A secondary audience is anyone needing a refresher review of Network+ exam topics—possibly before attempting to recertify.

Getting to Know the CompTIA Network+ N10-006 Exam

CompTIA launched the newest version of the Network+ exam, numbered N10-006, in February 2015. The exam covers the configuration, management, and troubleshooting of common wired and wireless network devices. Also included are emerging technologies such as unified communications, mobile, cloud, and virtualization technologies. CompTIA recommends that you are A+ certified and have at least 9 months of networking experience.

Currently for the Network+ exam, you are allowed 90 minutes to answer a maximum of 90 questions. A passing score is 720 on a scale of 100 to 900. If you've never taken a certification exam before with Pearson VUE, there is a 2-minute 45-second video titled "What to expect in a Pearson VUE test center" that nicely summarizes the experience. You will find it under "Related Links" at http://www.pearsonvue.com/comptia, or you can search for it on YouTube.

When you get to the testing center and check in, the proctor verifies your identity, gives you some general instructions, and then takes you into a quiet room containing a PC. When you're at the PC, you have a few things to do before the timer starts on your exam. For instance, you can take the tutorial to get accustomed to the PC and the testing engine. Every time I sit for an exam, I go through the tutorial even though I know how the test engine works. It helps me settle my nerves and get focused. Anyone who has user-level skills in getting around a PC should have no problems with the testing environment.

What Topics Are Covered on the Network+ Exam

Table I-1 summarizes the five domains of the Network+ exam.

Table I-1 Network+ Domains and Weightings

Domain	% of Examination
1.0 Network architecture	22%
2.0 Network operations	20%
3.0 Network security	18%
4.0 Troubleshooting	24%
5.0 Industry standards, practices, and network theory	16%
Total	100%

Registering for the Network+ N10-006 Exam

If you are starting your *31 Days Before Your CompTIA Network+ Certification Exam* today, register for the exam right now. In my testing experience, there is no better motivator than a scheduled test date staring me in the face. I'm willing to bet it's the same for you. Don't worry about unforeseen circumstances. You can cancel your exam registration for a full refund up to 24 hours before taking the exam. So if you're ready, then you should gather the following information and register right now:

- Legal name
- Social Security or passport number
- Company name
- Valid email address
- Method of payment

You can schedule your exam at any time by visiting http://www.pearsonvue.com/comptia/. I recommend you schedule it for 31 days from now. The process and available test times will vary based on the local testing center you choose.

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Day 29

WAN Technologies

CompTIA Network+ N10-006 Exam Topics

- 1.4 Explain the characteristics and benefits of various WAN technologies

Key Topics

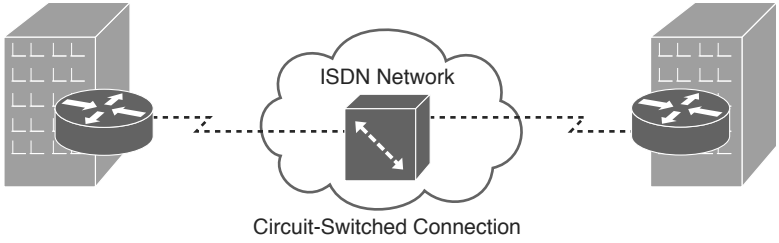
First today, we review packet switching and circuit switching. Then we review all the various ways networks are connected together through WAN technologies.

Packet Switching and Circuit Switching

The switching function provides communication pathways between two endpoints and manages how data flows between them. The two most common switching methods are circuit switching and packet switching.

Integrated Service Digital Network (ISDN), shown in Figure 29-1, is an example of a circuit-switched network.

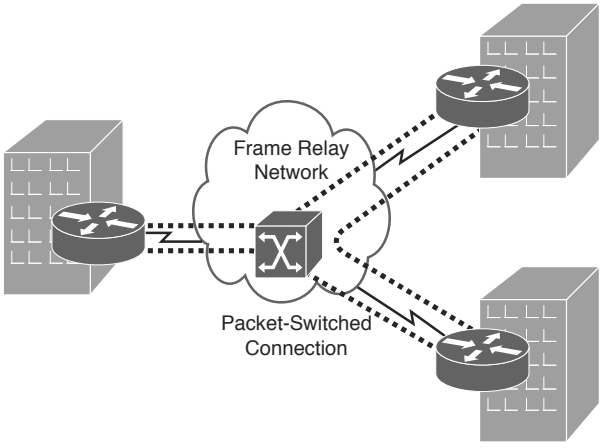
Figure 29-1 Circuit Switching ISDN Topology



Circuit switching requires a dedicated physical connection between the sending and receiving devices. For example, parties involved in a phone call have a dedicated link between them for the duration of the conversation. When either party disconnects, the circuit is broken, and the data path is lost. This is an accurate representation of how circuit switching works with network and data transmissions. The sending system establishes a physical connection, and the data is transmitted between the two. When the transmission is complete, the channel is closed.

A Frame Relay network, shown in Figure 29-2, is an example of a packet-switched network.

Figure 29-2 Packet Switching Frame Relay Topology



In packet switching, messages are broken into smaller pieces called packets. Each packet is assigned source and destination addresses. Packets are required to have this information because they do not always use the same path or route to get to their intended destination. Packets can take an alternative route if a particular route is unavailable for some reason.

Table 29-1 compares circuit switching and packet switching.

Table 29-1 Circuit Switching and Packet Switching Comparison

Switching Method	Pros	Cons	Key Features
Circuit switching	Offers a dedicated transmission channel that is reserved until it is disconnected.	Dedicated channels can cause delays because a channel is unavailable until one side disconnects. Uses a dedicated physical link between the sending and receiving devices.	Offers the capability of storing messages temporarily to reduce network congestion.
Packet switching	Packets can be routed around network congestion. Packet switching makes efficient use of network bandwidth.	Packets can become lost while taking alternative routes to the destination. Messages are divided into packets that contain source and destination information.	The two types of packet switching are datagram and virtual circuit. Datagram packets are independently sent and can take different paths throughout the network. Virtual circuit uses a logical connection between the source and destination device.

WAN Link Options

A variety of different methods can be used to link networks together. To select an appropriate WAN technology, you need the ability to compare one WAN technology to another.

Home and Small Office

Home and small office networks can connect to other networks and the Internet through a variety of methods.

Dialup

Dialup connectivity is done through the Public Switched Telephone Network (PSTN), which is composed of multiple telephone carriers from around the world. Although the bandwidth available on the PSTN is limited, it is more likely to be available in a given location than other wired WAN solutions. A dialup connection can be used to access the Internet by connecting a computer to a modem, connecting the modem to an analog phone line, and dialing in to a service provider. The service provider can then connect to the Internet, as shown in Figure 29-3. Modems in the United States and Canada are limited to 53.3Kbps download and 48.0Kbps upload.

Figure 29-3 PSTN Dialup Topology

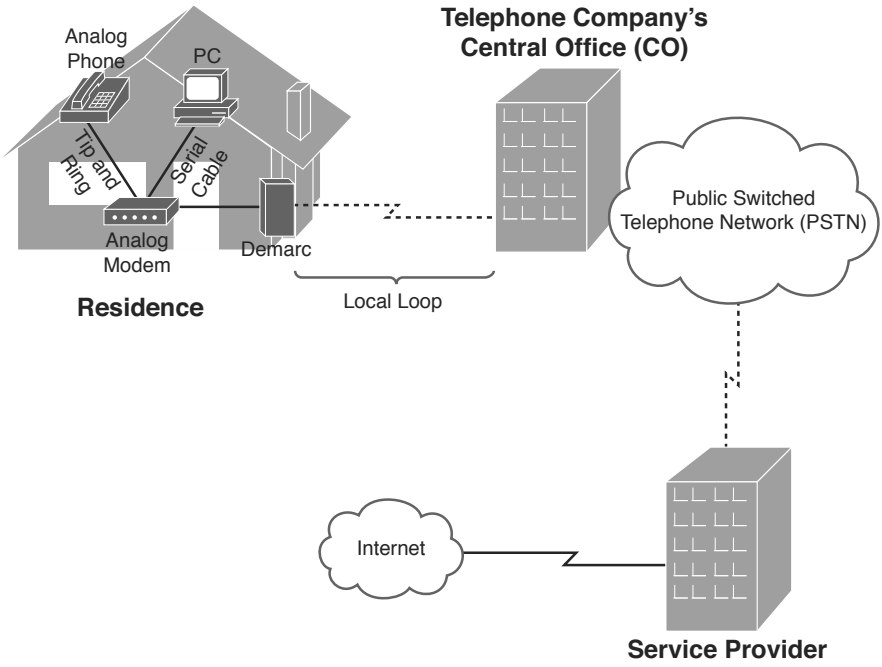


Table 29-2 describes some of the common terminology used to describe PSTNs.

Table 29-2 Common PSTN Terms

Term	Definition
Telco	Abbreviation for telephone company.
Local loop	A local loop is a connection between a customer's premises and his local telephone central office (CO).

Term	Definition
Central office (CO)	A building containing a telephone company's telephone switching equipment is referred to a central office (CO).
Tip and ring	The tip and ring wires are the red and green wires found in an RJ-11 wall jack, which carry voice, ringing voltage, and signaling information between an analog device and a telephone's wall jack.
Demarc	A demarc, short for demarcation point, is the point in a telephone network where the maintenance responsibility passes from a telephone company to the subscriber.
Smart jack	A smart jack is a type of network interface device that adds features such as converting between framing formats on digital circuits, supporting remote diagnostics, and regenerating a digital signal.

ISDN

ISDN connections are considerably faster than regular modem connections. ISDN is a digital technology that supports multiple 64Kbps channels on a single connection. ISDN circuits are classified as either a basic rate interface (BRI) circuit or a primary rate interface (PRI) circuit:

- **BRI**—A BRI circuit consists of two 64Kbps bearer (B) channels and one 16Kbps delta (D) channel. The B channels carry voice, video, and data. They can carry two separate voice conversations or they can be combined using PPP multilink. The D channel carries Layer 2 (Q.921) and Layer 3 (Q.931) signaling.
- **PRI**—A PRI circuit is equivalent to a 1.544Mbps T1 circuit. Therefore, it consists of 23 B channels and one 64Kbps D channel.

The components of an ISDN network are shown in Figure 29-4.

Figure 29-4 ISDN Topology

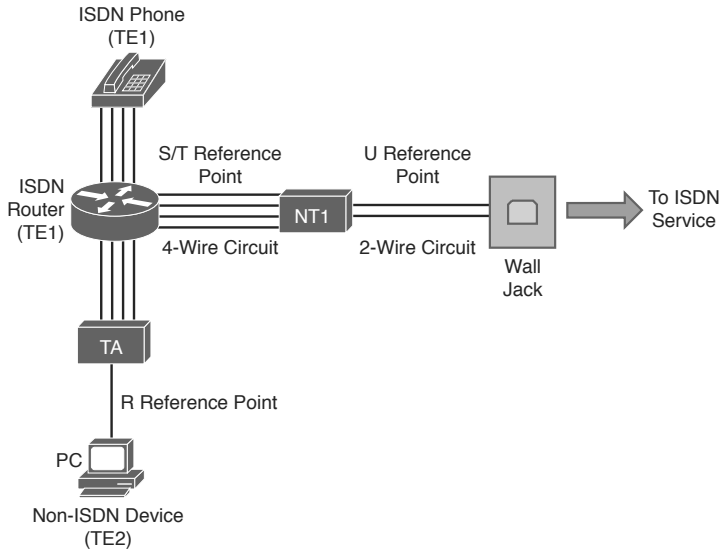


Table 29-3 lists a brief description of the ISDN components shown in Figure 29-4.

Table 29-3 ISDN Components

Term	Definition
R reference point	The R reference point resides between a non-ISDN device and a terminal adapter (TA).
S/T reference point	The S/T reference point resides between a network termination 1 (NT1) and a terminal endpoint 1 (TE1).
U reference point	The U reference point resides between a network termination 1 (NT1) and the wall jack connecting back to an ISDN service provider.
Terminal adapter (TA)	A TA performs protocol conversion between a non-ISDN device and a terminal endpoint 1 (TE1) device.
Terminal endpoint 1 (TE1)	A TE1 is a device (such as an ISDN phone) that natively supports ISDN.
Terminal endpoint 2 (TE2)	A TE2 is a device (such as a PC) that does not natively support ISDN.
Network termination 1 (NT1)	An NT1 is a device that interconnects a four-wire ISDN circuit and a two-wire ISDN circuit.

DSL

Digital Subscriber Line (DSL) is a group of technologies that provide high-speed data transmission over existing telephone wiring. There are many different varieties of DSL. Together, all these variations are referred to as xDSL. Popular variants include the following:

- **Asymmetric DSL (ADSL)**—ADSL is the most popular variant. It include a channel for analog voice conversations, a channel for uploads, and a channel for downloads. It is called asymmetrical because the download channel is faster than the upload channel.
- **Symmetric DSL (SDSL)**—SDSL is more suited to business applications because it offers the same speeds for uploads and downloads.
- **Very High Bit-Rate DSL (VDSL)**—VDSL is a variant of ADSL that provides data speeds of up to 13Mbps.

Table 29-4 summarizes the maximum speeds for all the DSL variants.

Table 29-4 DSL Speeds

DSL Variation	Upload Speed	Download Speed
ADSL	1Mbps	3Mbps
ADSL2	1.3Mbps	12Mbps
ADSL2+	1.4Mbps	24Mbps
SDSL	1.5Mbps	1.5Mbps
IDSL (ISDN DSL)	144Kbps	144Kbps
RADSL (Rate-adaptive DSL)	1Mbps	7Mbps

DSL Variation	Upload Speed	Download Speed
VHDSL	1.6Mbps	13Mbps
HDSL (High bit rate DSL)	768Kbps	768Kbps

PPP

Point-to-Point Protocol (PPP) is a common Layer 2 protocol used on dedicated leased lines. It can carry multiple Layer 3 protocols, such as IPv4 and IPv6. IP uses PPP's IP control protocol (IPCP). When a link is configured with IP and PPP, IPCP initiates the Link Control Protocol (LCP), which can provide any or all of the following features:

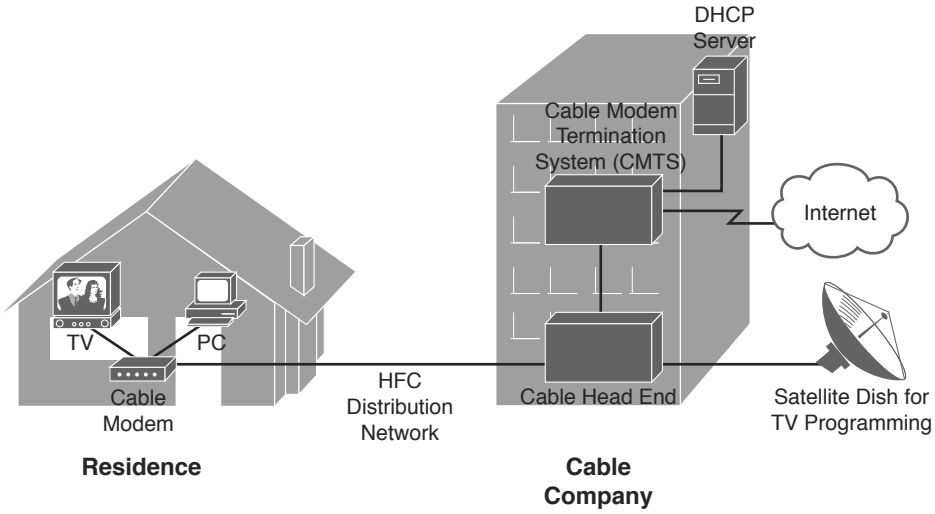
- **Multilink interface**—PPP multilink allows multiple interfaces to be combined into one logical interface.
- **Looped link detection**—A Layer 2 loop (of PPP links) can be detected and prevented.
- **Error detection**—Frames containing errors can be detected and discarded by PPP.
- **Authentication**—PPP provides three methods of authentication methods:
  - **Password Authentication Protocol (PAP)**—PAP performs one-way authentication. Passwords are sent in clear text.
  - **Challenge Handshake Authentication Protocol (CHAP)**—CHAP performs one-way authentication using a three-way handshake (challenge, response, and acceptance). Passwords are not sent across the link.
  - **Microsoft Challenge Handshake Authentication Protocol (MS-CHAP)**—MS-CHAP is a Microsoft-enhanced version of CHAP, offering a collection of additional features, including two-way authentication.

Broadband Cable

Broadband cable is an always-on Internet access method available in areas that have digital cable television. Connectivity is achieved by using a device called a cable modem. It has a coaxial connection for connecting to the provider's outlet and an unshielded twisted-pair (UTP) connection for connecting directly to a system or to a hub, switch, or router.

The provider's infrastructure probably has a mix of coaxial and fiber cabling called hybrid fiber-coax (HFC). A broadband cable network is shown in Figure 29-5.

Figure 29-5 Broadband Cable Topology



Wireless

Wireless WAN connection options include satellite, Worldwide Interoperability for Microwave Access (WiMAX), and several varieties of cellular technologies.

Satellite

Some locations do not have the WAN connectivity options, such as DSL connections or cable modems, commonly available in urban areas. However, these locations might be able to connect to the Internet or to a remote office using satellite communications, where a transmission is bounced off of a satellite, received by a satellite ground station, and then sent to its destination using either another satellite hop or a wired WAN connection.

Two different types of broadband Internet satellite services are deployed:

- **One-way satellite system**—A one-way satellite system requires a satellite card and a satellite dish installed at the end user's site. Outgoing requests are sent using a phone line. Inbound traffic returns on the satellite link.
- **Two-way satellite system**—A two-way satellite system, in contrast, provides data paths for both upstream and downstream data. Bidirectional communication occurs directly between the end user's site and the satellite.

WiMAX

WiMAX (Worldwide Interoperability for Microwave Access) provides wireless Internet broadband access to fixed locations (as an alternative to technologies such as DSL or cable). Depending on the WiMAX service provider, WiMAX coverage areas could encompass entire cities or small countries. Based on the IEEE 802.16 standard, WiMAX can provide data rates up to 1Gbps. Although WiMAX can send data up to 31 miles (50 km), it is most effective within one mile. WiMAX is a popular choice for connecting cell towers in cellular networks.

Cellular Technologies

Some cellular phone technologies (for example, Long-Term Evolution [LTE], which supports a 100Mbps data rate to mobile devices and a 1Gbps data rate for stationary devices) can be used to connect a mobile device (such as a smartphone) to the Internet. Other technologies for cellular phones include the older 2G edge, which provides slow data rates. 2G edge was improved upon with 3G, in addition to the newer 4G, LTE, and Evolved High-Speed Packet Access (HSPA+). Code division multiple access (CDMA) and Global System for Mobile Communications (GSM) are the two major radio systems used in cell phones.

SONET

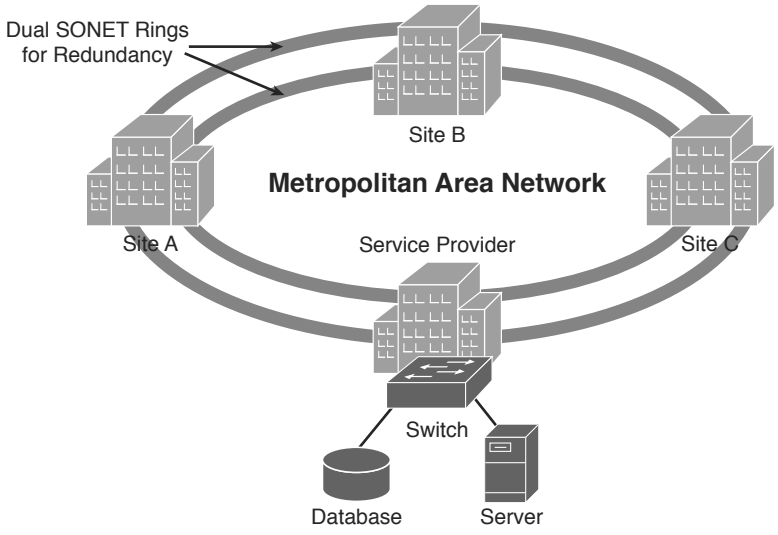
Synchronous Optical Network (SONET) is a fiber-optic WAN technology that delivers voice, data, and video at speeds starting at 51.84Mbps. SONET uses dense wavelength-division multiplexing (DWDM), which uses erbium-doped fiber amplifiers (EDFA) to amplify the signal and allow it to travel greater distances. An alternative to DWDM is CWDM (coarse wavelength-division multiplexing), which is commonly used with television cable networks. SONET is classified into various Optical Carrier (OCx) levels, as shown in Table 29-5.

Table 29-5 Optical Carrier Data Rates

OCx Level	Data Rate
OC-1	51.84Mbps
OC-3	155.52Mbps
OC-12	622.08Mbps
OC-24	1.244Gbps
OC-48	2.488Gbps
OC-96	4.976Gbps
OC-192	9.953Gbps
OC-768	39.813Gbps

SONET can connect as many as 16 other devices in a linear fashion (similar to a bus topology) or in a ring topology. A metropolitan area network (MAN), as depicted in Figure 29-6, often uses SONET in a ring topology.

Figure 29-6 SONET Ring Topology



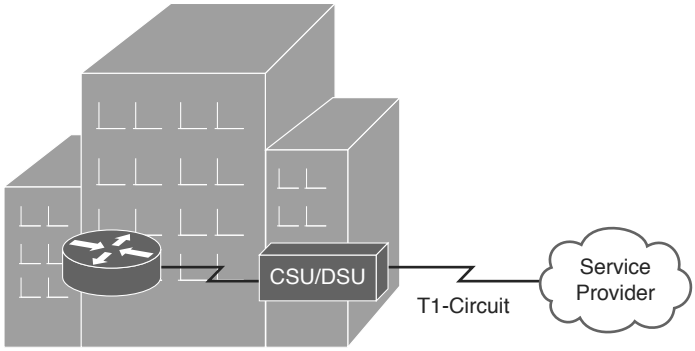
Dedicated Leased Lines

A dedicated leased line is typically a point-to-point digital circuit interconnecting two sites. All the bandwidth on that circuit is available to those sites. These circuits can use multiplexing technology to simultaneously carry multiple conversations in different 64Kbps channels. A single 64Kbps channel is called a Digital Signal 0 (DS0). WAN technologies commonly used with dedicated leased lines include the following:

- **T1**—T1 circuits were originally used in telephony networks, with the intent of one voice conversation being carried in a single channel. A T1 circuit is composed of 24 DS0s, which is called a Digital Signal 1 (DS1). The bandwidth of a T1 circuit is 1.544Mbps.
- **T3**—T3 circuits combine 672 DS0s into a single physical connection, which is called a Digital Signal 3 (DS3). A T3 circuit has a bandwidth capacity of 44.7Mbps.
- **E1**—E1 circuits are popular outside of North America and Japan. They contain 32 channels, in contrast to the 24 channels on a T1 circuit, for a bandwidth capacity of 2.048Mbps.
- **E3**—E3 circuits have a bandwidth capacity of 34.4Mbps, which is less than a T3 circuit.

Dedicated leased lines are terminated at the customer's premises with a channel service unit/data service unit (CSU/DSU), as shown in Figure 29-7.

Figure 29-7 Terminating a Leased Line



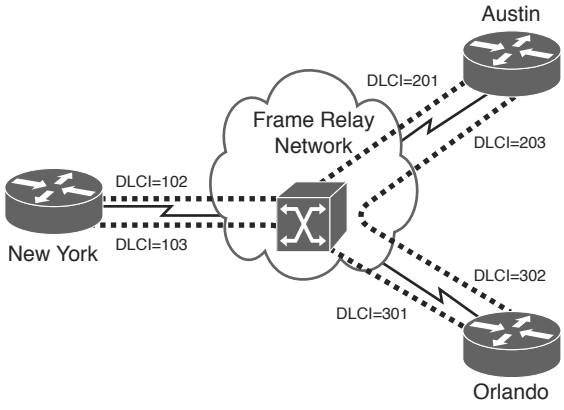
Enterprise WANs

Initially, dedicated leased lines were used by enterprises to connect various sites. However, as network traffic and the number of required WAN connections grew, leased lines became cost prohibitive. Several technologies emerged to answer the need, including Frame Relay, Asynchronous Transfer Mode (ATM), Multiprotocol Label Switching (MPLS), and Metro Ethernet.

Frame Relay

Frame Relay sites are interconnected using virtual circuits (VCs). Frame Relay is a Layer 2 technology that uses locally significant identifiers called data-link connection identifiers (DLCI). DLCIs identify the VC. A single router interface can have multiple VCs, as shown in Figure 29-8.

Figure 29-8 Frame Relay Topology



Unlike a dedicated leased line, Frame Relay shares a service provider's bandwidth with other customers of its service provider. Therefore, subscribers might purchase a service level agreement (SLA) to guarantee a minimum level of service. Part of the Frame Relay SLA would be a minimum bandwidth guarantee called a committed information rate (CIR).

During times of congestion, the service provider manages transmission rates using the backward explicit congestion notification (BECN) and forward explicit congestion notification (FECN) bits in the frame relay header. The BECN and FECN bits inform the customers to slow down the transmission rates.

If the service is not congested, a customer might have an SLA that allows transmission rates higher than the CIR. In such cases, the discard eligibility (DE) bit is set in each frame. If the service becomes congested, these frames can be discarded by the Frame Relay service provider.

ATM

ATM is a Layer 2 technology that uses VCs. However, ATM uses a fixed-length frame, called a cell, which includes 48 bytes of data and a 5-byte header, as shown in Figure 29-9.

Figure 29-9 ATM Cell Format

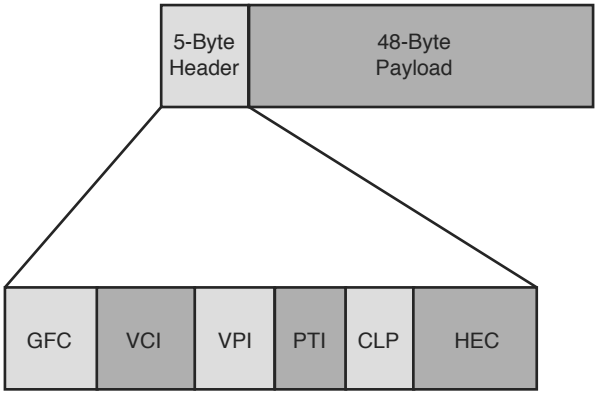


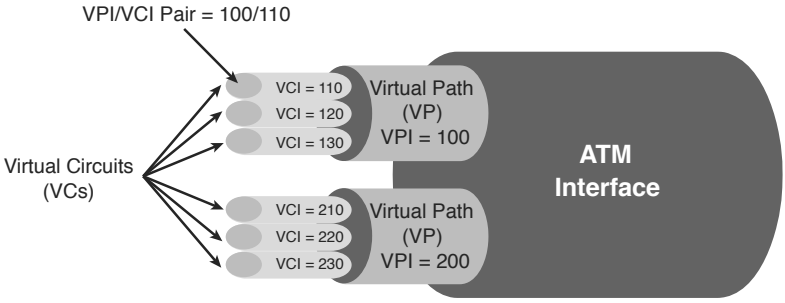
Table 29-6 details the fields of the ATM cell header.

Table 29-6 ATM Header Fields

Field	Description
GFC (4 bits)	The Generic Flow Control (GFC) field is used to indicate congestion.
VCI (16 bits)	The Virtual Circuit Identifier (VCI) field indicates a VC.
VPI (8 bits)	The Virtual Path Identifier (VPI) indicates the virtual path, which could contain multiple VCs.
PTI (3 bits)	The Payload Type Indicator (PTI) indicates the type of payload (for example, user data versus ATM management data).
HEC (8 bits)	The Header Error Control (HEC) field is used to detect and correct errors in the header.

ATM VCs are identified with a VPI/VCI pair, as shown in Figure 29-10.

Figure 29-10 Identifying ATM VCs



MPLS

Multiprotocol Label Switching (MPLS) can accommodate both Frame Relay and ATM on the same backbone. It does this by inserting a 32-bit header between the Layer 2 and Layer 3 headers. The 32-bit header contains a 20-bit label. This label is used to make forwarding decisions within an MPLS cloud. Therefore, the process of routing MPLS frames through an MPLS cloud is commonly referred to as label switching. Figure 29-11 shows an MPLS topology.

Figure 29-11 MPLS Topology

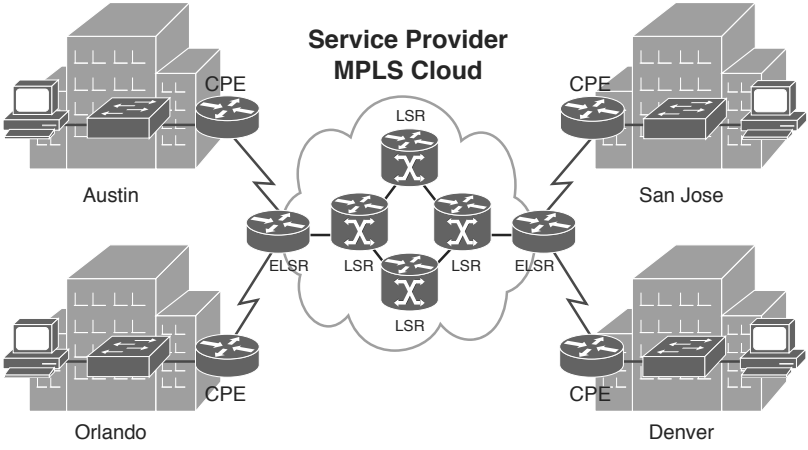


Table 29-7 lists the definitions for the components of the MPLS topology shown in Figure 29-11.

Table 29-7 MPLS Components

Component	Description
CPE	A customer premises equipment (CPE) device resides at a customer site.
ELSR	An edge label switch router (ELSR) resides at the edge of an MPLS service provider's cloud and interconnects a service provider to one or more customers.
LSR	A label switch router (LSR) resides as part of a service provider's MPLS cloud and makes frame-forwarding decisions based on labels applied to frames.

Metro Ethernet

Metro Ethernet is simply Ethernet technology extended into the metropolitan area network (MAN). The customer connects to the service provider through an Ethernet connection (using an RJ-45 connector). This effectively extends the LAN into the MAN. The service provider is responsible for configuring the logical connections between the customer sites. The technologies used with the service provider network are hidden from the customer.

Video: WAN Links (Circuit Switched)

Refer to the Digital Study Guide to view this video.

Video: WAN Links (Packet Switched)

Refer to the Digital Study Guide to view this video.

Activity: Identify the WAN Technology

Refer to the Digital Study Guide to complete this activity.

Study Resources

For today's exam topics, refer to the following resources for more study.

Resource	Location	Topic
Primary Resources		
Certification Guide	7	All
Video Course	5	All
Exam Cram	6	WAN Technologies
		Internet Access Technologies
Supplemental Resources		
Lab Simulator	7	Configuring a VPN Client
Flash Cards	3	WAN Technologies
Quick Reference	3	WAN Technologies

Check Your Understanding

Refer to the Digital Study Guide to take a 10-question quiz covering the content of this day.

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