

# WAN Technology

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Version 2.0

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## Module 7

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- Plug the equipment into an outlet that is on a different circuit from the television or radio. (That is, make certain the equipment and the television or radio are on circuits controlled by different circuit breakers or fuses.)

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## Module 7

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# WAN Technologies

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## Overview

This module introduces the various protocols and technologies used in wide-area network (WAN) environments. You will learn about the basics of WANs, including common WAN technologies, types of wide-area services, encapsulation formats, and link options. In this module, you also will learn about point-to-point links, circuit switching, packet switching, virtual circuits, dialup services, and WAN devices.

Upon completing this module, you will be able to:

- Describe the function and operation of WAN technologies, including leased line, Frame Relay, ATM, and Synchronous Optical Network (SONET)
- Describe the function and operation of dialup access technologies, including ISDN, Point-to-Point Protocol (PPP), Password Authentication Protocol (PAP), Challenge Handshake Authentication Protocol (CHAP), and High-Level Data Link Control (HDLC)
- Describe the WAN encapsulation formats
- Describe the types and standards of the analog modem
- Describe the digital subscriber line (DSL) technology
- Describe the types and standards of the cable modem

## Outline

This module contains the following lessons:

- Overview
- Traditional WAN Services
- Dialup Access Technologies
- Analog Modems
- DSL
- Cable Models
- Summary

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# 7.1 Traditional WAN Services

## Overview

This lesson introduces various WAN connection options and technologies, including leased line, Frame Relay, ATM, and SONET.

## Objectives

Upon completing this lesson, you will be able to:

- Describe different WAN connection options
- Define packet switching and circuit switching
- Describe the operation of leased lines
- Describe the function of Frame Relay
- Describe features of ATM and define cell switching
- Describe features of SONET

## Outline

This lesson includes these sections:

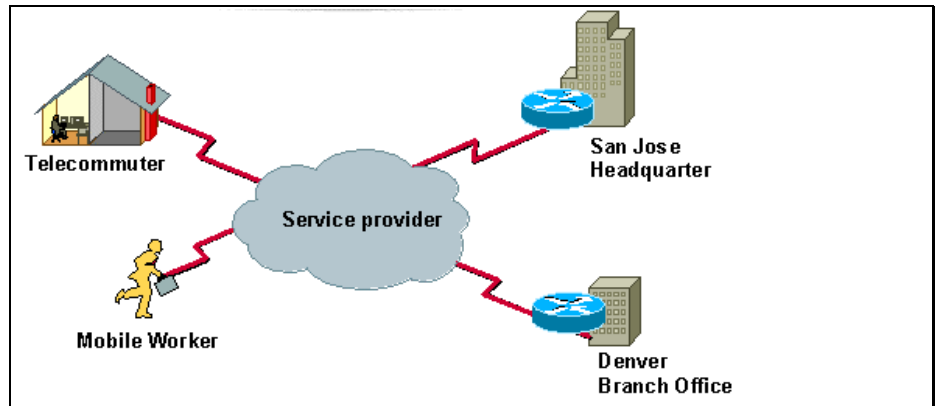
- Overview
- WAN Connection Options
- Packet vs. Circuit Switching
- Leased Line
- Frame Relay
- ATM and Cell Switching
- SONET
- Summary

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## 7.1.1 WAN Connection Options

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Figure 1: WAN Connection

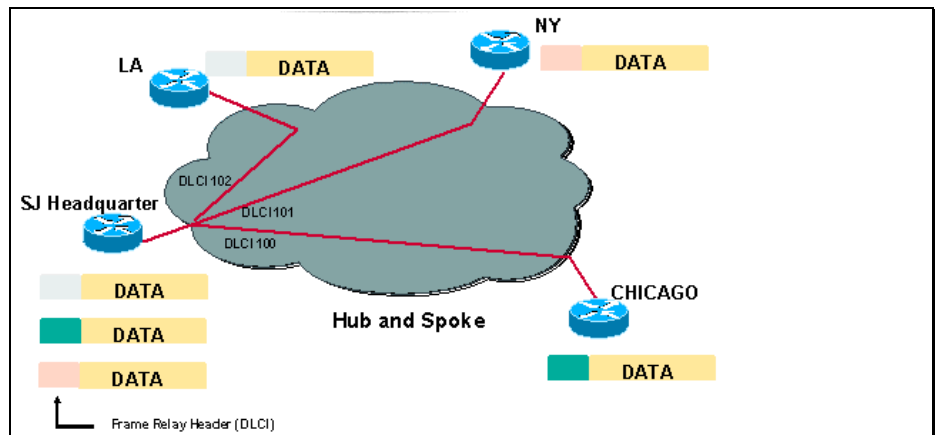


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Figure 2: Virtual Circuit



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Figure 3: WAN Connection Bandwidth

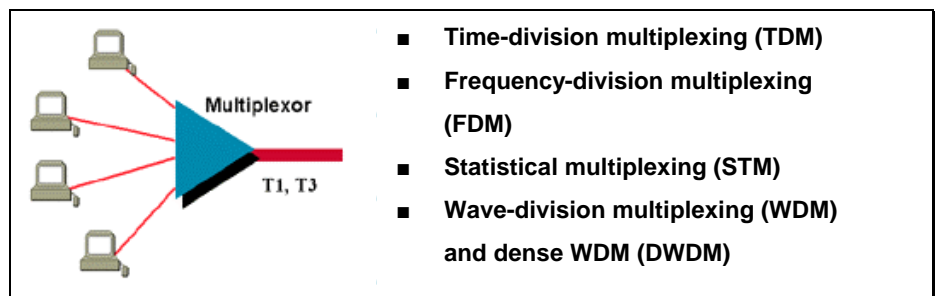


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Figure 4: Multiplexing Technologies



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Figure 5: TDM

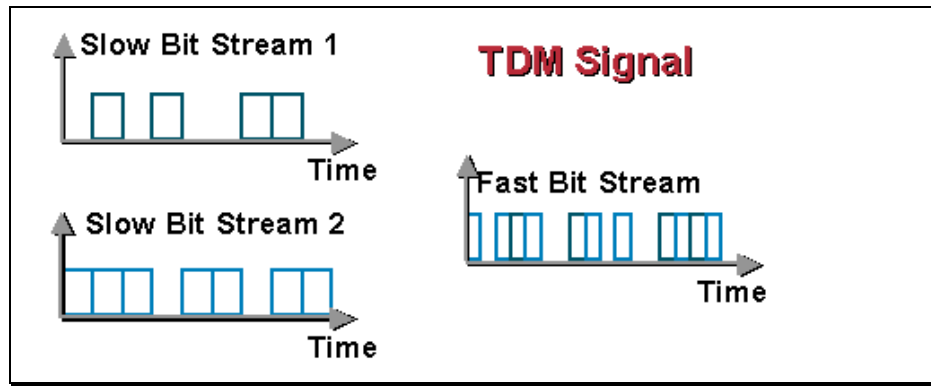


Figure 6: FDM

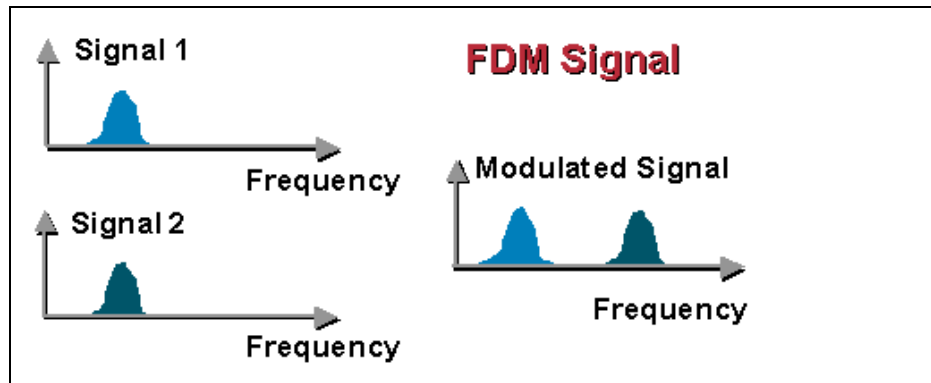
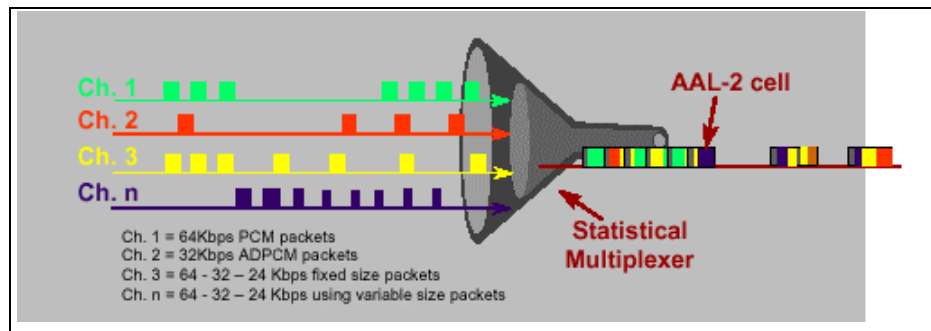


Figure 7: STM



A wide-area network (WAN) is a data communications network that covers a relatively broad geographic area and that often uses transmission facilities provided by common carriers, such as telephone companies.

WAN connections may be made through a service provider in several ways, including (see Figure [1]):

- Dialup:** Dialup lines are paid for only when they are used. Dialup lines are perfect for the small or branch office or for telecommuters or mobile workers. This means that the line is active only when the user dials up. The disadvantage of dialup connection is that the connection speed is slow (less than 56 Kbps).

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- **ISDN:** Integrated Services Digital Network (ISDN) is an efficient alternative to dialup for connecting over basic telephone service (POTS). ISDN is explained further in this lesson.
  - **Leased line:** Service providers also offer leased lines, or point-to-point connections. With leased lines, companies pay for a continuous connection between two remote sites. This means the line is active 24 hours a day, 7 days a week. The disadvantage of leased lines is that they are generally expensive, and the expense is related to distance.
  - **Frame Relay:** Frame Relay provides connection-oriented data link layer communication. This service is implemented using *virtual circuits*.

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A *virtual circuit* is a logical circuit created to ensure reliable communication between two remote network devices. For example, Figure [2] shows a hub and spoke topology used to connect a headquarter router to three remote routers. Even though the headquarter router only has one physical connection to the service provider (like a Frame Relay service provider), that physical connection is logically divided into three logical connections (virtual circuits), with each virtual circuit connecting to a different remote router. At the remote routers, their physical connection will only contain one virtual circuit since the remote routers only need to connect to the headquarter router.

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Frame Relay works at Layer 2 of the OSI reference model, within the Frame Relay (Layer 2) header, there is an identifier (Data Link Connection Identifier [DLCI]) used to indicate which virtual circuit a frame belongs to, the Frame Relay service provider make its switching decision based on the DLCI. In Figure [2], the headquarter Frame Relay connection is provisioned with three virtual circuits. The headquarter router will use DLCI 102 in the Frame Relay header for sending data to the LA router, DLCI 101 for the NY router, and DLCI 100 for the Chicago router.

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- **ATM:** Asynchronous Transfer Mode (ATM) comprises specifications at both the physical and data link layers. Like Frame Relay, this service is implemented using virtual circuits. With ATM, the data packet is divided into small 53 bytes cells before it is transmitted. In the ATM cell header, there a field called the VPI/VCI (Virtual Path Identifier/Virtual Channel Identifier) used to indicate which virtual circuit an ATM cell belongs to. At the physical layer, ATM can run over a variety of physical media, including fiber optics using SONET framing and coaxial cable using digital signal level 3 (DS3).
  - **Other:** Additional WAN connection options include using DSL, cable, wireless, and X.25.

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WAN technologies generally function at the lower three layers of the OSI reference model: the physical layer, the data link layer, and the network layer. WAN connections can be purchased or leased in a variety of speeds or *bandwidths*. Start with the simple DS0 (64 Kbps), which is the speed of a typical digitized phone call. Bundle (Multiplexing) 24 DS0s to get a DS1/T1 line (1.544 Mbps). Then bundle (Multiplex) 28 DS1s to get a DS3/T3 (44.736 Mbps). The DS technically refers to the rate and format of the signal, whereas the T designation refers to the equipment providing the signals. In practice, “DS” and “T” are used synonymously (see Figure [3]).

187 E1 (2.048 Mbps) and E3 (34.368 Mbps) are European standards similar to T1 and  
188 T3, but they possess different bandwidths.

189  
190 Multiplexing is a process in which multiple data channels are combined into a  
191 single data or physical channel at the source. Multiplexing can be implemented at  
192 any of the OSI layers. Broadband WAN lines use multiplexing technology.

193  
194 Demultiplexing is the process of separating multiplexed data channels at the  
195 destination.

196  
197 There are four primary types of multiplexing (see Figures [4]):

- 198  
199 ■ **Time-division multiplexing (TDM):** In TDM, information from each data  
200 channel is allocated bandwidth based on preassigned time slots, regardless  
201 of whether there is data to transmit (see Figure [5]). As a result, bandwidth  
202 is wasted when a data channel has nothing to transmit during its assigned  
203 time slot.
- 204  
205 ■ **Frequency-division multiplexing (FDM):** In FDM, information from each  
206 data channel is allocated bandwidth based on the signal frequency of the  
207 traffic (see Figure [6]). For example, FM radio broadcast used FDM. Each  
208 FM station is assigned a specific frequency to use for broadcasting their  
radio programs.
- 209  
210 ■ **Statistical multiplexing (STM):** In statistical multiplexing, bandwidth is  
211 dynamically allocated to any data channels that have information to transmit  
212 (see Figure [7]). With STM, bandwidth is not wasted when a data channel  
213 has nothing to transmit, because the time slot is given to a data channel that  
has something to transmit.
- 214  
215 ■ **Wave-division multiplexing (WDM) and dense WDM (DWDM):** These  
optical multiplexing technologies are discussed in Module 9 of this course.

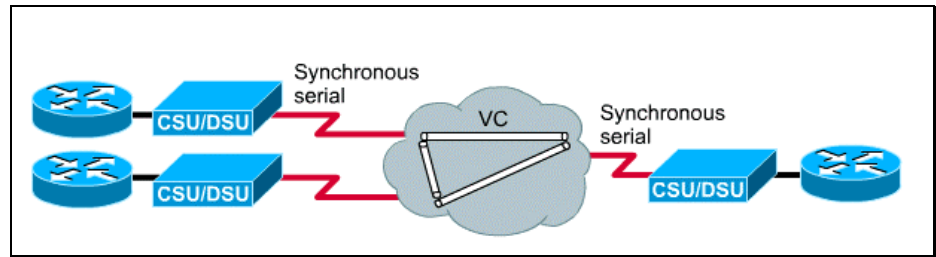
## 216 Practice

- 217 1. Which of the following is not a type of multiplexing?  
218  
219 A. TDM  
220 B. FDM  
221 C. ATM \*\*  
222 D. WDM
- 223  
224 2. Which of the following best describes a WAN?  
225  
226 A. Connects LANs that are separated by a large geographic area. \*\*  
227 B. Connects workstations, terminals, and other devices in a metropolitan  
228 area.  
229 C. Connects LAN within a large building.  
230 D. Connects workstation, terminals, and other devices within a building.  
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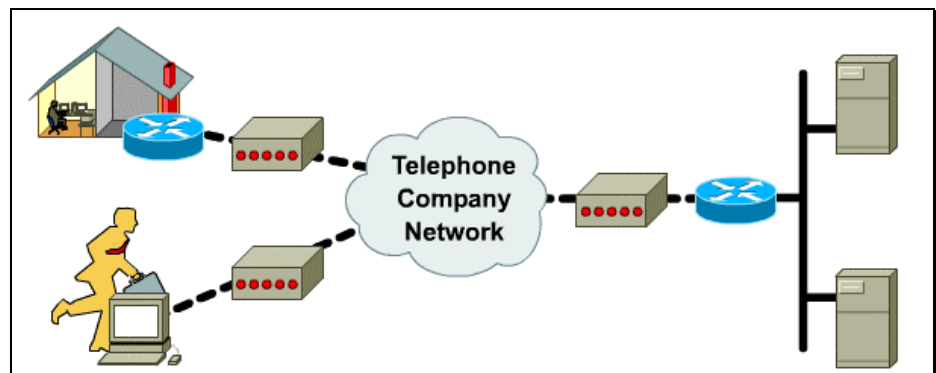
## 7.1.2 Packet vs. Circuit Switching

Figure 1: Packet Switching



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Figure 1: Circuit Switching



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Packet switching is a WAN switching method in which users share common carrier resources. Because this allows the carrier to make more efficient use of its infrastructure, the cost to the customer is generally much better than with point-to-point lease lines. In a packet switching setup, networks have connections into the carrier's network, and many customers share the carrier's network. The carrier can then create virtual circuits between customers' sites by which packets of data are delivered from one to the other through the network. The section of the carrier's network that is shared is often referred to as a cloud. Frame Relay is an example of packet-switched WAN technology (see Figure [1]).

Circuit switching is a WAN switching method in which a dedicated physical circuit is established, maintained, and terminated through a carrier network for each communication session (see Figure [2]).

Circuit switching operates much like a normal telephone call and is used extensively in telephone company networks. ISDN is an example of a circuit-switched WAN technology.

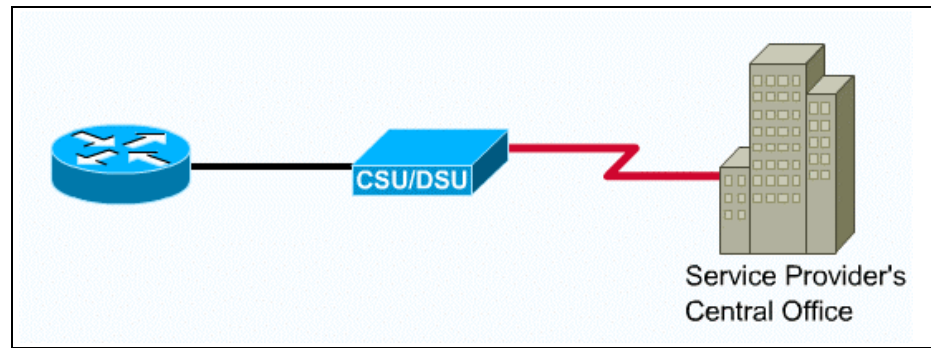
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### Practice

1. Which of the following is an example of a packet-switching protocol?
  - A. ISDN
  - B. Frame Relay \*\*
  - C. PPP
  - D. HDLC

## 7.1.3 Leased Line

**Figure 1: Leased Line**



A point-to-point link provides a single, pre-established WAN communications path from the customer premises through a carrier network, such as a telephone company, to a remote network. Point-to-point lines are usually leased from a carrier and thus are often called leased lines. For a point-to-point line, the carrier allocates pairs of wire and facility hardware to your line only. These circuits are generally priced based on bandwidth required and distance between the two connected points. Point-to-point links are generally more expensive than shared services such as Frame Relay. The cost of leased-line solutions can become significant when they are used to connect many sites.

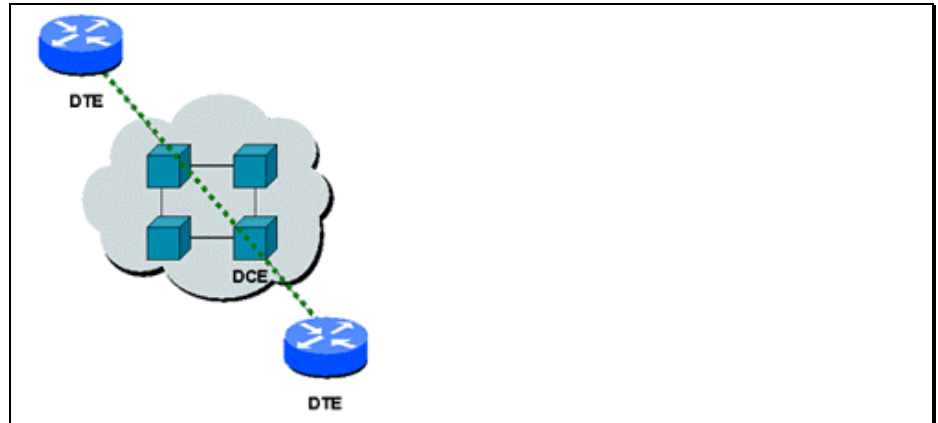
### Practice

1. A leased line is a \_\_\_\_\_ link provides a single, pre-established WAN communication path from the customer to a remote network.
  - A. Point-to-point \*\*
  - B. Point-to-multipoint
  - C. Analog
  - D. Digital

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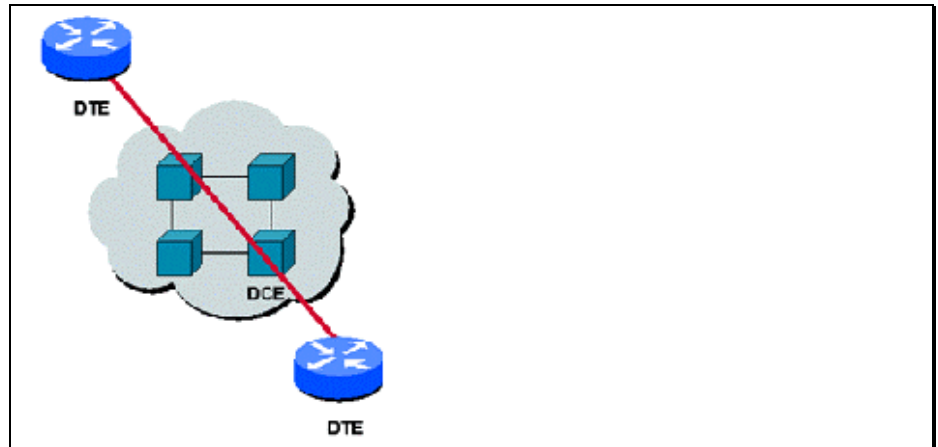
## 7.1.4 Frame Relay

Figure 1: Frame Relay Virtual Circuits



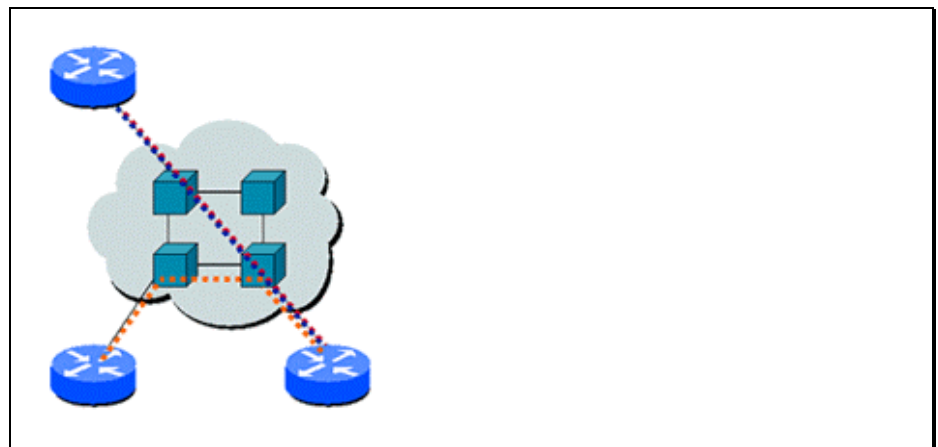
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Figure 2: PVC



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Figure 3: SVC



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Frame Relay provides connection-oriented data link layer communication. This service is implemented using virtual circuits.

312 Frame Relay devices have two classes:

- 313 ■ **Data terminal equipment (DTE):** Terminating equipment for a specific
- 314 network and typically located on customer premises. Examples of a Frame
- 315 Relay DTE device is a router or a FRAD (Frame Relay Access Device)
- 316
- 317 ■ **Data communications equipment (DCE):** Carrier-owned internetworking
- 318 devices that provide clocking and switching services within a network.
- 319 Example of a Frame Relay DCE device is the Frame Relay Switch.

### 320 **Frame Relay Virtual Circuits**

321 A Frame Relay virtual circuit is a logical connection created between two DTE

322 devices across a Frame Relay network (see Figure [1]). Frame Relay virtual circuits

323 fall into two categories:

324

- 325 ■ Permanent virtual circuit (PVC)
- 326
- 327 ■ Switched virtual circuit (SVC)

328 Virtual circuits provide a bidirectional communications path from one DTE device

329 to another. A data-link connection identifier (DLCI) within the Frame Relay address

330 header uniquely identifies them.

331

332 A virtual circuit can pass through any number of intermediate DCE devices (Frame

333 Relay switches) located within the Frame Relay packet-switched network (PSN).

334 Numerous virtual circuits can be multiplexed into a single physical circuit for

335 transmission across the network.

336

### 337 **PVC [2]**

338 PVCs are permanently established connections that are used when there is frequent

339 and consistent data transfer between DTE devices across the Frame Relay network.

340 Communication across a PVC does not require the call setup and termination states

341 that are used with SVCs. DTE devices can begin transferring data whenever they

342 are ready because the circuit is permanently established. PVC works like a lease-

343 line connection, it is always connected.

344

### 345 **SVC [3]**

346 SVCs are temporary connections that are used when there is only sporadic data

347 transfer between DTE devices across the Frame Relay network. After the virtual

348 circuit is terminated, the DTE devices must establish a new SVC if there is

349 additional data to be exchanged. SVC works like a dialup connection, where a call

350 has to be made before the data can be transmitted, like making a telephone call.

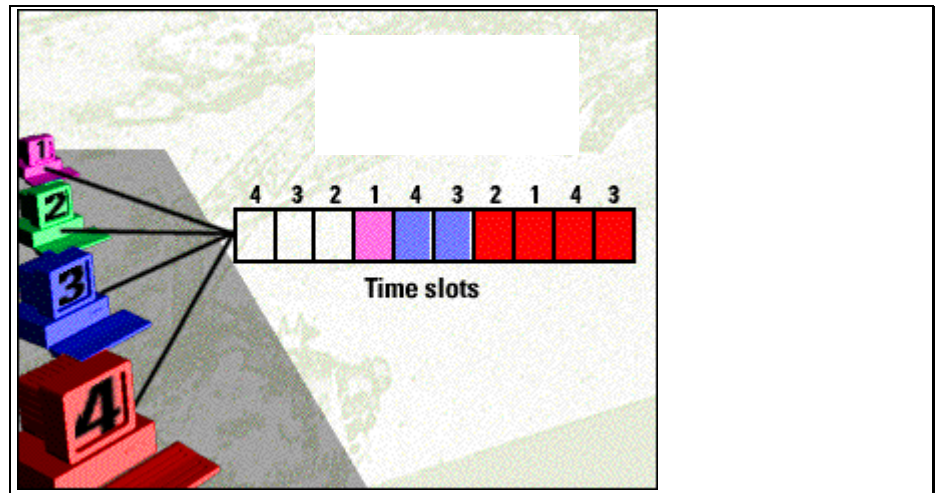
## 351 **Practice**

- 352 1. How does Frame Relay handle multiple conversations on the same physical
- 353 connection?
- 354
- 355 A. Multiplexing the circuits \*\*
- 356 B. Multiple conversations are not allowed
- 357 C. Duplexing the conversation
- 358 D. Converts it to an ATM cell
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## 7.1.5 ATM and Cell Switching

Figure 1: ATM and Cell Switching



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Asynchronous Transfer Mode (ATM) is a technology that is capable of transferring voice, video, and data through private and public networks. It is built on a cell-based architecture rather than a frame-based architecture. ATM cells are always a fixed length of 53 bytes, whereas the sizes of frames and packets vary. The 53 bytes ATM cell is made up of a 5 bytes ATM header followed by 48 bytes of ATM Payload (User Data). Small fixed-length 53 bytes cells are well-suited for carrying data, voice, and video traffic because voice and video traffic are intolerant of delay that can result from having to wait for a larger data packet to be transmitted ahead of a voice or video packet.

An ATM switch is responsible for cell transit through an ATM network. It accepts the incoming cell from an ATM endpoint or another ATM switch. It then reads and updates the cell-header information and quickly switches the cell to an output interface toward its destination.

ATM is used primarily in enterprise LAN backbones or WAN links.

An ATM virtual circuit is a logical connection created between two ATM endpoints across an ATM network. ATM virtual circuits fall into two categories:

- Permanent virtual circuit (PVC)
- Switched virtual circuit (SVC)

Virtual circuits provide a bidirectional communications path from one ATM endpoint to another. The VPI/VCI (Virtual Path Identifier/Virtual Channel Identifier) within the ATM cell header uniquely identifies them.

A virtual circuit can pass through any number of intermediate ATM switches in the ATM network. Numerous virtual circuits can be multiplexed into a single physical circuit for transmission across the network.

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## Practice

1. Which of the following is *not* true about ATM technology?
  - A. It is capable of transferring voice, video, and data.
  - B. ATM is used primarily in enterprise LAN backbones or WAN links.
  - C. It is based on a cell-based architecture rather than a frame-based architecture.
  - D. ATM cells are always a fixed length of 35 bytes, whereas the sizes of frames and packets vary. \*\*

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## 7.1.6 SONET

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**Figure 1: SONET Optical Carrier Standards**

OC Level	Signal Transmission Rate
OC-1 (Base Rate)	51.84 Mbps
OC-3	155.52 Mbps
OC-12	622.08 Mbps
OC-24	1.244 Gbps
OC-48	2.488 Gbps
OC-192	10 Gbps
OC-256	13.271 Gbps
OC-768	40 Gbps

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SONET, which stands for Synchronous Optical Network, is a physical layer protocol that provides for high-speed transmission using fiber-optic media. ATM can run over SONET to achieve very high data-transfer speeds.

You might see the term Synchronous Digital Hierarchy (SDH) used to refer to the SONET technology outside the United States. The SONET signal rate is measured by optical carrier (OC) standards. Figure [1] illustrates the available transmission rates (called optical carrier levels). SONET/SDH are discussed in *Module 9, Optical Networking*.

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### Practice

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- Which is a family of very high-speed physical layer technologies with a series of data rates available with special designations, implemented at different OC level ranging 51.85 Mbps to 40 Gbps?
  - ADSL
  - ATM
  - SONET \*\*
  - ISDN

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## Summary

This section summarizes the key points you learned in this lesson.

- WAN networks operate beyond a company's control, and they offer access to internetworks and connection between geographically distant nodes.
- Not all WAN services are available in all locations.
- WAN customers pay service providers for WAN connections, including dialup, leased line, ISDN and Frame Relay.
- WANs have a variety of protocols that all operate at physical, data link, and network layers of the OSI model.
- WAN switching methods include packet switching (Frame Relay), circuit switching (ISDN), and cell switching (ATM).

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## 7.2 Dialup Access Technologies

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### Overview

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This lesson describes the functions and operation of dialup access technologies, including ISDN, PPP, PAP, CHAP, and HDLC. This lesson also introduces the primary WAN OSI Layer 2 encapsulation formats: PPP and HDLC.

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### Objectives

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Upon completing this lesson, you will be able to:

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452

- Describe the function and operation of ISDN

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- Describe the function and operation of PPP

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- Describe the function and operation of PAP

455

- Describe the function and operation of CHAP

456

- Describe the function and operation of HDLC

457

### Outline

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This lesson includes these sections:

459

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- Overview

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- ISDN

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- PPP

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- PAP

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- CHAP

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- HDLC

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- Summary

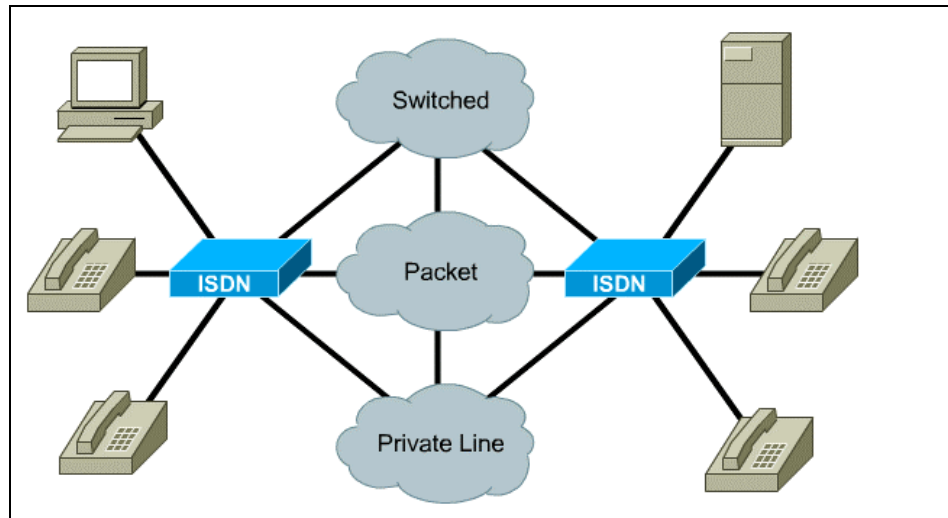
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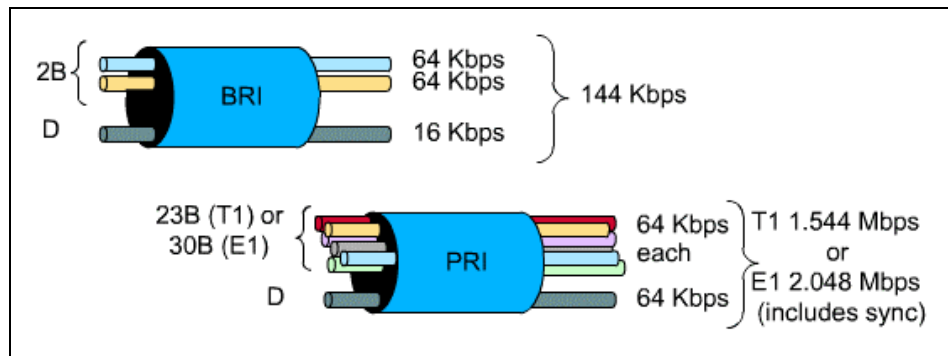
## 7.2.1 ISDN

Figure 1: ISDN



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Figure 2: BRI and PRI



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Integrated Services Digital Network (ISDN) refers to a set of communication protocols proposed by telephone companies to permit telephone networks to carry data, voice, and video (see Figure [1]).

In general, ISDN provides a set of digital services that concurrently deliver voice, data, text, graphics, music, video, and information to end users. ISDN was developed to permit faster access over existing telephone systems without the additional call setup time.

ISDN offers two types of services: Basic Rate Interface (BRI) or Primary Rate Interface (PRI).

The ISDN BRI service, intended for the home and small enterprise, provides two B channels (128 Kbps) and one D channel (16 Kbps). The BRI B channel carries user data, whereas the BRI D channel usually carries control and signaling information.

The ISDN PRI service, intended for larger installations, delivers 23 B channels and one D channel in North America for a total bit rate of up to 1.544 Mbps (T1).

494 In Europe, Australia, and other parts of the world, ISDN PRI provides 30 B  
495 channels and one D channel, for a total bit rate of up to 2.048 Mbps (E1) (see Figure  
496 [\[2\]](#)).

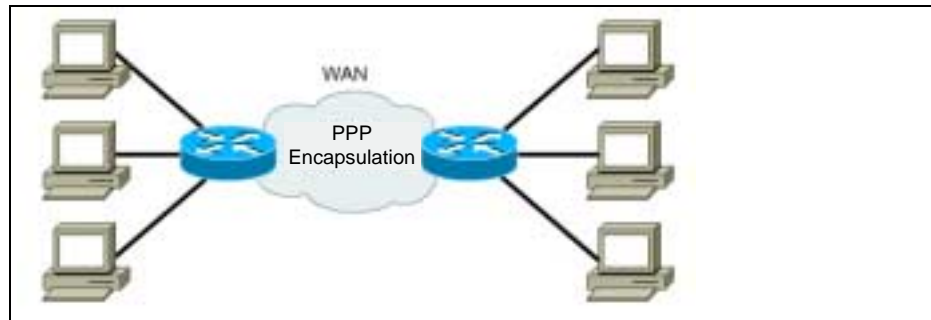
497 **Practice**

- 498 1. Which of the following statements pertaining to ISDN is true?  
499  
500 A. The ISDN BRI offers two B channels and one D channel.  
501 B. The D channel, operating at 16 Kbps, is meant to carry user data.  
502 C. The ISDN BRI offers 23 B channels and one D channel in North  
503 America. \*\*  
504 D. The total bit rate of the ISDN BRI is 2.533 Mbps.  
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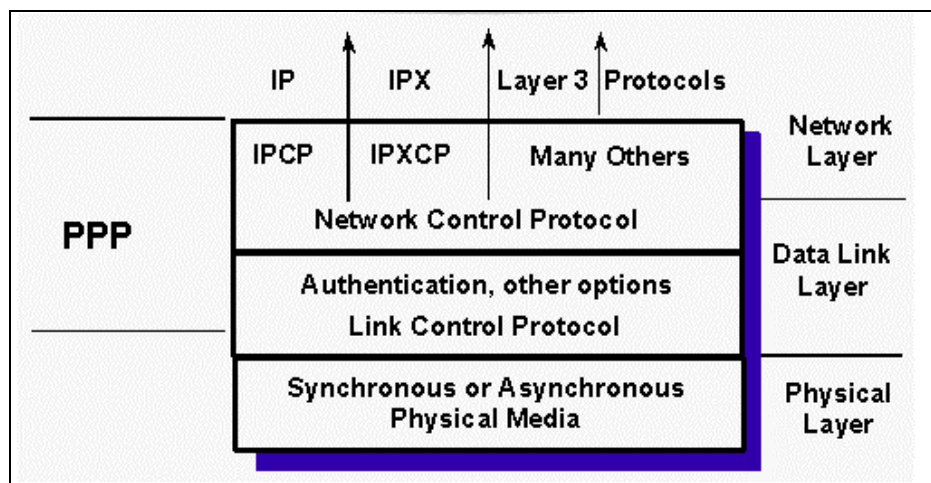
## 7.2.2 PPP

Figure 1: PPP



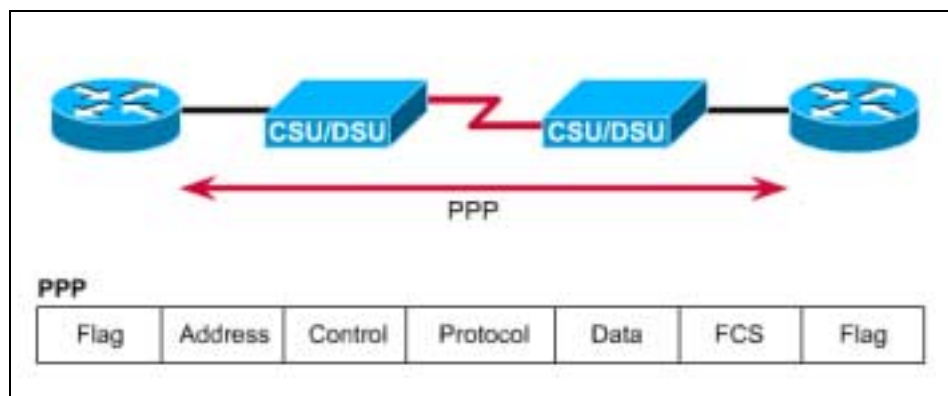
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Figure 2: PPP Elements



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Figure 3: PPP Encapsulation



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In the late 1980s, Serial Line Internet Protocol (SLIP) was limiting growth of the Internet. Point-to-Point Protocol (PPP) was created to solve remote Internet connectivity problems (see Figure [1]). Additionally, PPP was needed to be able to dynamically assign IP addresses and allow for use of multiple routed protocols. PPP provides router-to-router and host-to-network connections over both synchronous and asynchronous circuits.

522  
523 The PPP provides a standard method for transporting multi-protocol datagrams over  
524 point-to-point links. PPP is comprised of three main components (see Figure [2]):  
525  
526

- A method for encapsulating multi-protocol datagrams.
- A Link Control Protocol (LCP) for establishing, configuring, and testing the  
527 data-link connection.
- A family of Network Control Protocols (NCPs) for establishing and  
528 configuring different network-layer protocols.

  
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531  
532 In order to be sufficiently versatile to be portable to a wide variety of environments,  
533 PPP provides a Link Control Protocol (LCP). The LCP is used to automatically  
534 agree upon the encapsulation format options, handle varying limits on sizes of  
535 packets, detect a looped-back link and other common misconfiguration errors, and  
536 terminate the link. Other optional facilities provided are authentication of the  
537 identity of its peer on the link, and determination when a link is functioning  
538 properly and when it is failing.

539  
540 The authentication phase of a PPP session is optional. After the link has been  
541 established and the authentication protocol chosen, the peer can be authenticated. If  
542 it is used, authentication takes place before the network-layer protocol configuration  
543 phase begins.

544  
545 The authentication options require that the calling side of the link enter  
546 authentication information to help ensure that the user has the network  
547 administrator's permission to make the call. Peer routers exchange authentication  
548 messages.

549  
550 When configuring PPP authentication, you can select Password Authentication  
551 Protocol (PAP) or Challenge Handshake Authentication Protocol (CHAP). In  
552 general, CHAP is the preferred protocol. PAP and CHAP are discussed in the  
553 following sections.

### 554 **PPP Encapsulation [3]**

555 PPP is a standard serial-line encapsulation method (described in RFCs 1332 and  
556 1661). This protocol can, among other things, check for link quality during  
557 connection establishment. In addition, there is support for authentication through  
558 Password Authentication Protocol (PAP) and Challenge Handshake Authentication  
559 Protocol (CHAP).  
560

### 561 **Practice**

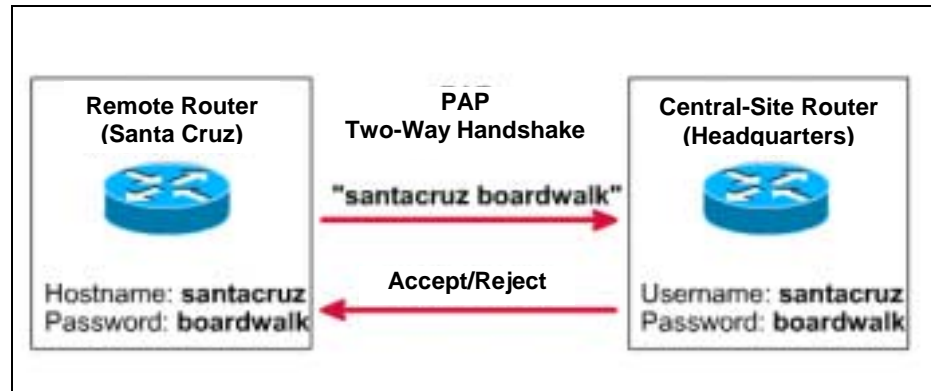
- 562 1. Which protocol does PPP use for establishing and maintaining point-to-point  
563 connections?
- 564
- 565 A. HDLC
  - 566 B. LCP \*\*
  - 567 C. LAPD
  - 568 D. Cisco IETF
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## 7.2.3 PAP

Figure 1: PAP



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As shown in Figure [1], PAP provides a simple method for a remote node to establish its identity, using a two-way handshake. After the PPP link establishment phase is complete, a username/password pair is repeatedly sent by the remote node across the link until authentication is acknowledged or the connection is terminated. PAP is not a strong authentication protocol. Passwords are sent across the link in clear text (not encrypted), and there is no protection from playback or repeated trial-and-error attacks. The remote node controls the frequency and timing of the login attempts.

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### Practice

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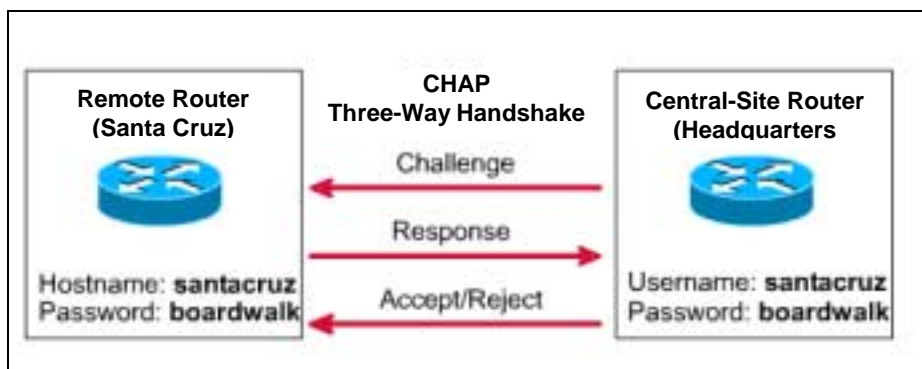
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1. What type of handshaking occurs when PAP is your selected authentication when using PPP?
  - A. One-way
  - B. Two-way \*\*
  - C. Three-way
  - D. Four-way

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## 7.2.4 CHAP

Figure 1: CHAP



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CHAP is used to periodically verify the identity of the remote node, using a three-way handshake, as shown in Figure [1]. This is done upon initial link establishment and can be repeated any time after the link has been established. CHAP offers features such as periodic verification to improve security, making CHAP more effective than PAP. PAP verifies only once, making it vulnerable to hacks and modem playback.

Further, PAP allows the caller to attempt authentication at will (without first receiving a challenge), making it vulnerable to brute-force attacks, whereas CHAP does not allow a caller to attempt authentication without a challenge.

After the PPP link establishment phase is complete, the host sends a challenge message to the remote node. The remote node responds with a value. The response value is calculated based on the shared password between the two devices. The host checks the response against its own calculated value. If the values match, the authentication is acknowledged. Otherwise, the connection is terminated.

CHAP provides protection against playback attacks through the use of a variable challenge value that is unique and unpredictable. The use of repeated challenges is intended to limit the time of exposure to any single attack. The local router (or a third-party authentication server, such as Netscape Commerce Server) controls the frequency and timing of the challenges.

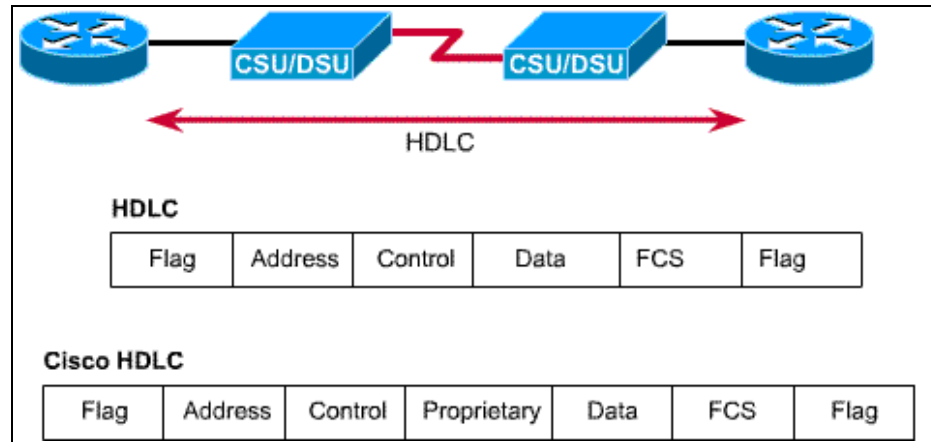
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### Practice

1. What type of handshaking occurs when CHAP is your selected authentication when using PPP?
  - A. One-way
  - B. Two-way
  - C. Three-way \*\*
  - D. Four-way

## 7.2.5 HDLC

Figure 1: HDLC and Cisco HDLC



High-Level Data Link Control (HDLC) is an IOS standard data link layer protocol. It specifies an encapsulation method for data on synchronous serial data links using frame character and checksum. HDLC supports both point-to-point and multipoint configurations. No authentication can be used with HDLC. HDLC might not be compatible between different vendors because of the way each vendor has chosen to implement it.

HDLC is Cisco's default encapsulation for serial lines. This implementation is very streamlined; there is no windowing or flow control, and only point-to-point connections are allowed. Cisco's HDLC is proprietary—it will not communicate with any other vendor's HDLC implementation.

As shown in Figure [1], the reason that each vendor has a proprietary HDLC encapsulation method is that each vendor has a different way for the HDLC protocol to communicate with the network layer protocols. This proprietary header is placed in the data field of the HDLC encapsulation. The Address field is always set to all ones. Furthermore, Cisco's HDLC include a 2-byte proprietary type code is inserted after the control field, meaning that the Cisco's HDLC framing is not interoperable with other vendors' equipment.

If both ends of a dedicated-line connection are routers or access servers running Cisco IOS® Software, Cisco's HDLC encapsulation typically is used. Because HDLC encapsulation methods may vary, you should use PPP with devices that are not running Cisco IOS Software.

### Practice

1. Which encapsulation type is the default encapsulation for serial interfaces on a Cisco router?
  - A. PPP
  - B. HDLC \*\*
  - C. Frame Relay
  - D. X.25

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## Summary

This section summarizes the key points you learned in this lesson.

- There are two ISDN services: BRI and PRI.
- ISDN provides an integrated data, voice and video capability that uses the public switched network.
- You can select PAP or CHAP when configuring PPP authentication.
- PAP is not a strong authentication protocol.
- CHAP provides protection against playback attacks through the use of a variable challenge value that is unique and unpredictable.
- WAN encapsulation formats include PPP and HDLC encapsulation.
- HDLC is Cisco's default encapsulation for serial line.

## 7.3 Analog Modems

### Overview

This lesson describes different types of analog modems and the analog modem standards.

### Objectives

Upon completing this lesson, you will be able to:

- Describe analog modem types
- Describe commonly used analog modem standards

### Outline

This lesson includes these sections:

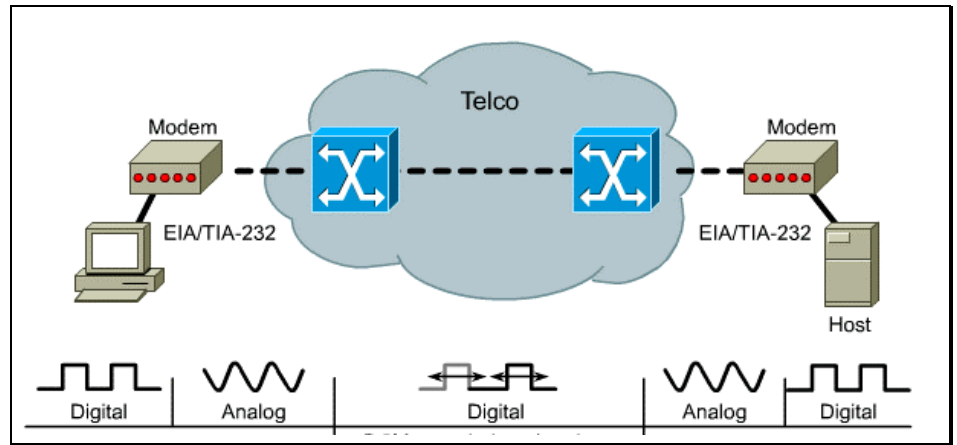
- Overview
- Modem Types
- Analog Modem Standards
- Summary

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## 7.3.1 Modem Overview

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Figure 1: Modem Transmission

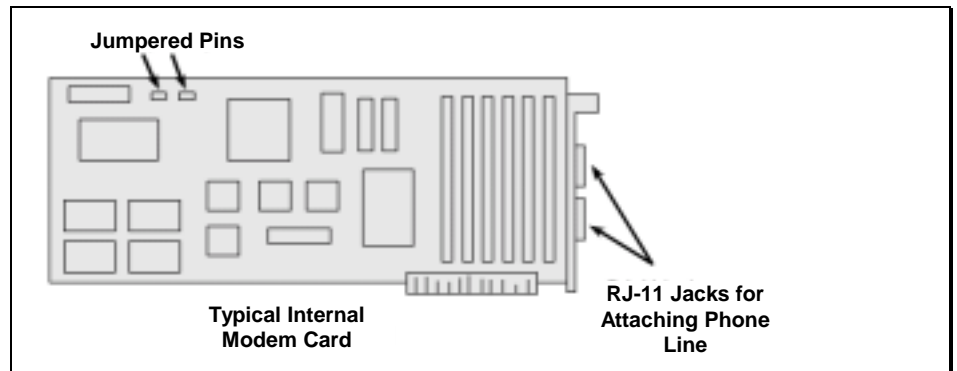


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Figure 2: Internal Modems

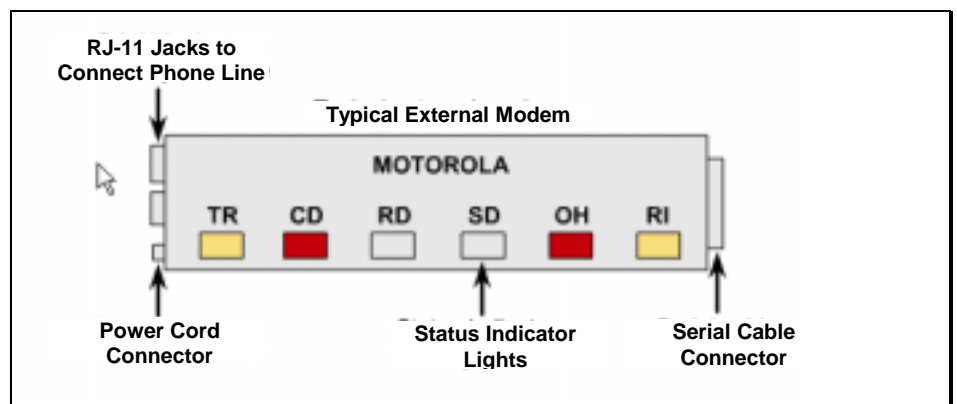


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Figure 3: External Modem



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A modem is an electronic device that is used for computer communications through telephone lines. It allows data transfer between one computer and another over the PSTN. Typically, modems send data in blocks of bytes. After each block, some basic math is performed to analyze the block, and the computer on the receiving end is asked whether it agrees with the results. If any differences appear, the block is

713 sent again. The modems convert digital data to analog signals and analog signals  
714 back to digital data.

715  
716 The term *modem* actually derives from the function of this device. The process of  
717 converting analog signals to digital and back again is called  
718 *modulation/demodulation* (hence the term *modem*).

719  
720 A typical modem connection is depicted in Figure [1]. The modems connect digital  
721 computers to the digital telecommunications company (Telco) network via analog  
722 local loops. When the Telco switch receives the modems's analog signal, it must  
723 encode the signals so that it can traverse the digital network.

724  
725 Modem-based transmission is remarkably accurate, despite the fact that telephone  
726 lines can be quite noisy because of clicks, static, and other problems.

727  
728 There are four main types of modems:

- 729  
730 ■ **Expansion cards:** They are the most common. They plug into the  
731 motherboard expansion slots (Industry-Standard Architecture [ISA] or  
732 peripheral component interconnect [PCI]) and are called internal modems.
- 733  
734 ■ **PC Card modems:** They are a variation of modems designed for easy  
735 installation in notebook computers. Also known as PC Cards, they look like  
credit cards and are small and very portable.
- 736  
737 ■ **External modems:** They can be used with any computer by simply  
plugging into a serial port (COM1 or COM2) on the back of the computer.
- 738  
739 ■ **Built-in modems:** Some notebook computers have dedicated, built-in  
modems.

740  
741 Internal modems simply plug into one of the expansion slots on the motherboard  
742 (see Figure [2]). These internal modem varieties, therefore, do not take up extra  
743 space on the desktop. They usually cost a little less than the ones that are plugged  
744 externally into the computer. To configure them, jumpers may have to be set in  
745 order to select the interrupt request (IRQ) line and input/output (I/O) addresses. No  
746 configuration is needed for a “plug-and-play” modem, which is installed on a  
747 motherboard that supports plug and play. A modem using a serial (COM) port that  
748 is not yet in use must be configured. Additionally, the software drivers that come  
749 with the modem must be installed for the modem to work.

750  
751 External modems are typically a bit more expensive than the internal varieties (see  
752 Figure [3]). However, they connect to the computer simply by plugging into one of  
753 the serial ports. The computer case does not have to be opened. Newer universal  
754 serial bus -(USB) modems are plugged into a USB port or hub. An external modem  
755 uses the IRQ and I/O address assigned to the serial port. A status light on the  
756 modem indicates whether or not the modem is on line. Software must be installed in  
order for the external modem to work properly.

## 757 Practice

758 1. Which of the following is true of analog modems?

- 759  
760 A. They allow data transfer between one computer and another over the  
761 PSTN.
- 762 B. They send data in blocks of bytes.

763  
764  
765

- C. They convert digital data to analog signals and vice versa.
- D. All of the above. \*\*

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## 7.3.2 Analog Modem Standards

**Figure1: Analog Modem Standards**

Standard	Meaning
V.22bis	The first true worldwide standard for full-duplex modems sending and receiving data across telephone line at 2400 bps at 600 baud.
V.32	The standard for full-duplex modems allows sending and receiving data across phone lines at 4800 or 9600 bps at 2400 baud. V.32 modems automatically adjust their transmission speed based on the quality of the lines.
V.34	The standard for full-duplex modems sending and receiving data across phone lines at up to 28.8 Kbps. V.34 modems automatically adjust their transmission speed based on the quality of the lines. It is backward compatible with V.32.
V.42	It has the same transfer rate as V.32, but with better error correction and therefore more reliable. V.42 can be used with digital telephone networks.
V.90	The standard for full-duplex modems sending and receiving data across phone lines at up to 56 Kbps downstream.

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A modem modulates outgoing digital signals from a computer or other digital device to analog signals for a conventional copper twisted pair telephone line and demodulates the incoming analog signal and converts it to a digital signal for the digital device. Modems work at OSI model Layer 1. At Layer 2, a protocol like PPP is often used.

Figure [1] includes several most commonly used modem standards approved by the International Telecommunications Union (ITU-T).

The first true worldwide standard for modems is V.22bit, which allows 2400 bits per second (bps) at 600 baud. V.34 is a full-duplex modem standard that allows the modems to send and receive data across phone lines at up to 28.8 Kbps and 19.2 Kbps. V.34 modems can automatically adjust their transmission rate according to the quality of the phone lines.

V.90 standard was approved by ITU-T in February 1998. V.90 allows the data downstream transmission rate up to 56,000 bps and data upstream transmission rate up to 33,000 bps. V.90 standard was a combination of the x2 technology from US Robotics (now part of 3Com) and the K56flex technology from Rockwell.

In recent years, the 2400 bits per second modem that could carry e-mail has become obsolete. 14.4 Kbps and 28.8 Kbps modems were temporary landing places on the way to the much higher bandwidth devices and carriers of tomorrow. From early 1998, most new personal computers came with 56 Kbps modems.

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### Practice

1. Which of the following cable standard allows 56,000 bps downstream data transmission rate?
  - A. V.32
  - B. V.34

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C. V.42  
D. V.90 \*\*

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## Summary

This section summarizes the key points you learned in this lesson.

- There are several types of analog modems. The four main types are internal, external, PC Card, and built-in (notebook) modems.
- Modems work at OSI model Layer 1.
- V.90 standard allows the data downstream rate up to 56 Kbps.

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## 7.4 DSL

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### Overview

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This lesson describes two main different types of DSL, DSL standards, and DSL encapsulation and protocols. This lesson also discusses the advantages and disadvantages of the DSL technology.

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### Objectives

822

Upon completing this lesson, you will be able to:

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824

- Define DSL

825

- Identify different types of DSL

826

- Describe DSL standards

827

- Describe DSL encapsulation and protocols

828

- Describe benefits of DSL

829

### Outline

830

This lesson includes these sections:

831

832

- Overview

833

- Basic DSL

834

- DSL Types

835

- DSL Standards

836

- Encapsulation and Protocols

837

- DSL Benefits

838

- Summary

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## 7.4.1 Basic DSL

Figure 1: DSL

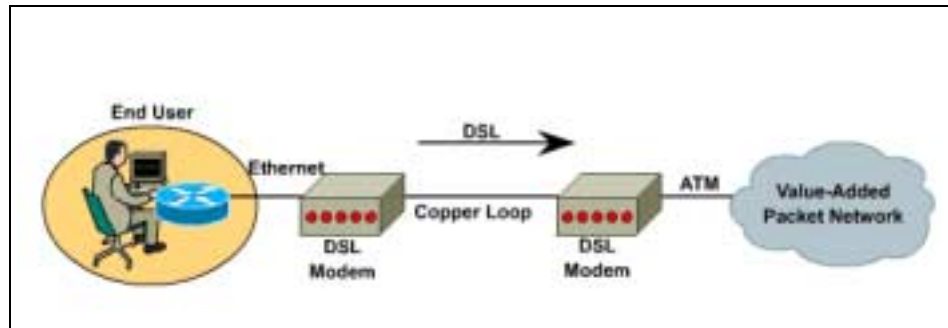


Figure 2: Cisco 827 ADSL Router



Digital subscriber line (DSL) technology is a modem technology that uses existing twisted-pair telephone lines to transport high-bandwidth data, such as multimedia and video, to service subscribers. Because DSL uses existing phone lines, in most cases there is no need to dig a new trench as with cable or install a dish as with wireless (see Figure [1]). Wherever there is a phone line there is the potential of getting DSL service, if the line conditions are right, for example, you must be within a certain distance of the central office and the central office must have DSL equipment to connect to.

Products such as the Cisco 827 ADSL router integrate a fully functional Cisco IOS router and DSL modem into one unit (see Figure [2]).

DSL provide a full-time connection. As soon as users turn on their computers connected to the DSL modem, they are connected. This setup removes the time and effort of dialing in to establish a connection.

### Practice

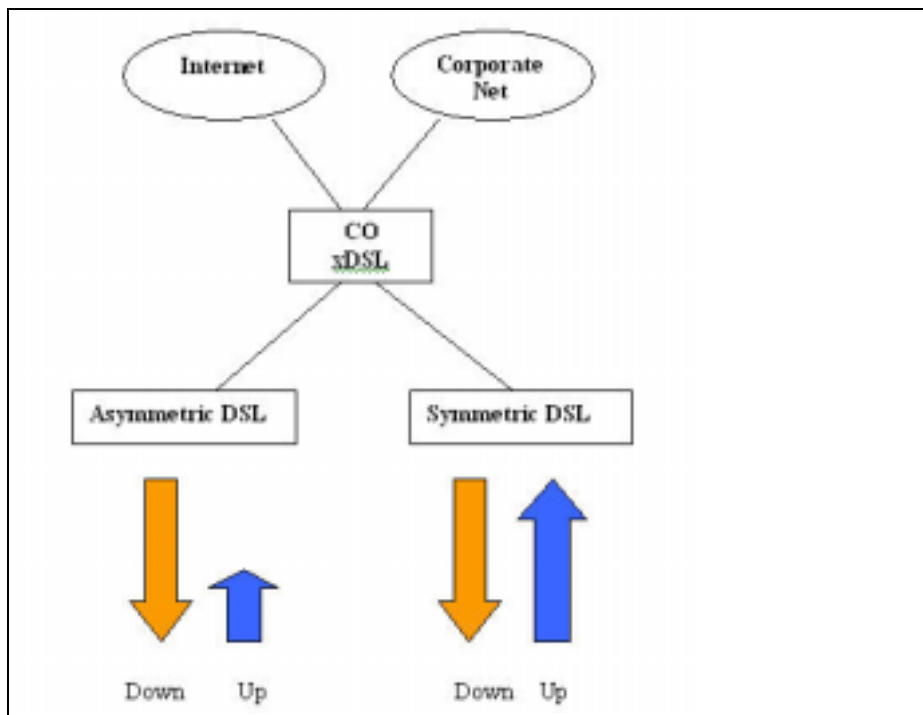
1. Which of the following media is used by DSL to transport data?
  - A. Existing coaxial cable TV lines
  - B. Existing twisted-pair telephone lines \*\*
  - C. Existing Ethernet lines
  - D. Wireless transmission

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## 7.4.2 DSL Types

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Figure 1: DSL Service Types Overview



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The two basic types of DSL technologies are asymmetric (ADSL) and symmetric (SDSL). All forms of DSL service are categorized as one or the other, and there are numerous varieties of each type.

The term xDSL is sometimes used to refer generically to any of the various forms that exist. Asymmetric service provides a higher download or *downstream* speed (in bits per second, or bps) than *upstream* speeds. Symmetric service provides the same speed in both directions.

Downstream information, such as requested Web pages, comes from the Internet to the user (from the central office [CO] to the subscriber). Upstream information is sent from the user to the Internet (from the subscriber to the CO). Asymmetric types of DSL generally use analog transmission encoding (modulation) technology, whereas symmetric forms generally use digital transmission encoding (modulation) techniques.

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### Practice

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1. What are the two basic types of DSL technology?

- A. Downstream DSL and Upstream DSL
- B. xDSL and yDSL
- C. Asymmetric DSL and Symmetric DSL \*\*
- D. None of the above

## 7.4.3 DSL Standards

**Figure 1: DSL Standards**

Industry Consortia and Useful URLs	
DSL Forum	<a href="http://www.dslforum.org">http://www.dslforum.org</a>
DSL Reports	<a href="http://www.dslreports.com">http://www.dslreports.com</a>
DSL Life	<a href="http://www.dsllife.com">http://www.dsllife.com</a>
Telcordia	<a href="http://www.telcordia.com">http://www.telcordia.com</a>
Telechoice	<a href="http://www.xdsl.com">http://www.xdsl.com</a>
IEC International Engineering Consortium	<a href="http://www.iec.org">http://www.iec.org</a>
Standards Organizations and Useful URLs	
ANSI American National Standards Organization	<a href="http://www.ansi.org">http://www.ansi.org</a>
ATIS (T1) Alliance for Telecommunications Industry Standards	<a href="http://www.atis.org">http://www.atis.org</a>
DAVIC Digital Audio Video Council	<a href="http://www.davic.org">http://www.davic.org</a>
ETSI European Telecommunications Standards Institute	<a href="http://www.etsi.org">http://www.etsi.org</a>
IEEE Institute for Electrical and Electronics Engineers	<a href="http://www.ieee.org">http://www.ieee.org</a>
ITU-T International Telecommunications Union	<a href="http://www.itu.int">http://www.itu.int</a>

**Figure 2: DSL Technologies Standards Comparison**

DSL Types	Standards	Modulation/Encoding Technique	Speed	Distance Limit
<b>ADSL Full /G.DMT</b>	ANSI T1.413 Issue 2/ITU-U G.992.1	DMT2	Downstream speeds of 384 Kbps to 6 Mbps; upstream slower	18,000 feet on 1.544 Mbps; 16,000 feet on 1.028 Mbps
<b>G.Lite</b>	ITU-T G 992.2	DMT2	1.544 Mbps to 6 Mbps, depending on the subscribed service	18,000 feet on 24 gauge wire
<b>Very-High-Data-Rate DSL (VDSL)</b>	ETSI and ANSI in process	DMT/SCM	12.96 Mbps to 52.8 Mbps for both upstream and downstream.	45,00 feet at 12.96 Mbps; 3,00 feet at 25.82 Mbps; 1,000 feet at 51.84 Mbps
<b>ISDN DSL (IDSL)</b>	ANSI TR 28	2B1Q	144 Kbps for both upstream and downstream.	18,000 feet on 24 gauge wire
<b>SDSL</b>	None	2B1Q	Up to 3 Mbps for both upstream and downstream	12,000 feet on 24 gauge wire
<b>High-Data-Rate DSL (HDSL)</b>	ITU G991.1, ANSI TR 28	2B1Q	768 Kbps for both upstream and downstream.	12,000 feet on 24 gauge wire
<b>G.SHDSL</b>	ITU G.991.2	TC PAM	192 kbps - 2.360 Mbps or 384 kbps - 4.720 Mbps for both upstream and downstream	1,500 feet - 60,000 feet

**Note: ADSLs are marked in Red; SDSLs are marked in green.**

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904 Standards benefit the consumer and the industry in general. They may take a while  
905 to evolve, but they tend to level the playing field, allowing more competition with  
906 improved interoperability. They also contribute to consumer confidence. Numerous  
907 standards organizations and industry consortia have contributed to the evolution of  
908 DSL. Among these are the DSL Forum, ANSI, ITU-T, DAVIC, and ETSI. Web sites  
909 for these organizations and others are listed in Figure [1] along with some other  
910 informative DSL Web sites.

911  
912 Figure [2] lists each DSL technology and the relevant standards organizations and  
913 standard numbers associated with those technologies. Not all the DSL technologies  
914 listed have a standard associated with them. Also listed is the modulation or  
915 encoding standard(s) used by the DSL modems to place digital data bits onto the  
916 wire. The most important standards listed in Figure [2] are asymmetric DSL  
917 standards G.992.1 (G.DMT) and G.992.2 (G.lite) as well as symmetric standard  
918 G.991.2 (G.SHDSL). These international standards are supported by all vendors  
919 who are currently building DSL.

## 920 Practice

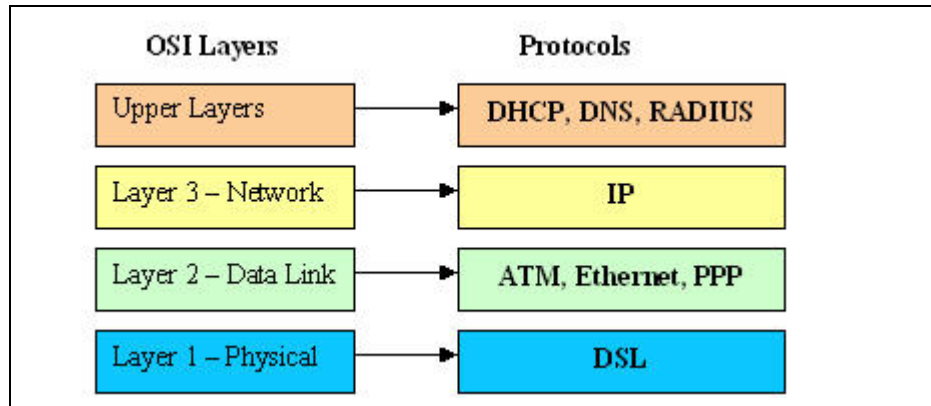
- 921 1. Which of the following standard organizations and industry have contributed to  
922 the evolution of DSL?  
923  
924 A. ANSI  
925 B. ITU-T  
926 C. ETSI  
927 D. All of the above \*\*  
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## 7.4.4 Encapsulation and Protocols

Figure 1: OSI and DSL Related Protocols



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DSL operates at Layer 1 or the physical layer of the OSI model. It is basically a bit pump data-transmission technology that relies on higher-layer protocols to encapsulate the data to the central office and the Internet service provider (ISP). Protocols most often include Layer 2 protocols such as Ethernet, ATM, and PPP, as well as the IP Layer 3 protocol. Other higher-layer protocols such as Dynamic Host Configuration Protocol (DHCP) and Domain Name System (DNS) and services such as Remote Authentication Dial-In User Service (RADIUS) also play a part in the complete DSL picture from subscriber to ISP. The DSL provider and ISP also have a choice of providing bridged or routed service to the subscriber.

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### Practice

1. Which of the Layer 2 protocols are often used by DSL?
  - A. HDLC
  - B. IPX
  - C. PPP \*\*
  - D. LLC

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## 7.4.5 DSL Benefits

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**Figure 1: Advantages and Disadvantages of DSL**

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### Advantages of DSL

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- DSL offers speeds up to and exceeding those of T-1, at just a fraction of the cost.

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- DSL service can be added incrementally as more users subscribe.

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- Both voice and data can be transmitted over the same line at the same time.

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- DSL is an always-on technology. This means users do not need to dial up each time they wish to connect to the Internet.

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- DSL is backward compatible with conventional analog phones.

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### Disadvantage of DSL

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- The availability of DSL is presently still limited, with service for most "flavors" or varieties only possible for areas that fall within a specified number of feed from the telephone company central office (CO) of the service provider.

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- The telephone company CO that is servicing the location must have DSL equipment installed.

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- The best form of voice support is still being debated.

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DSL service can be added incrementally in any area. That means that the service provider can literally start up with a handful of clients and upgrade the bandwidth to coincide with the growth in subscriber. DSL is also backward compatible with analog voice and makes good use of the existing local loop. This means that very little need to be done to use the cable services simultaneously with normal phone service.

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However, DSL suffers from distance limitations. Most DSL service offerings currently require the customer to be within 18,000 feet of the provider's central office (CO) location. Additionally, the longer and older loops present problems, and the best form of voice support is still being debated. Also, upstream (upload) speed is usually considerably lower than the downstream (download) speed.

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### Practice

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1. Which of the following is *not* one of the benefits of DSL?

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A. DSL service can be added incrementally in any area.

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B. DSL is backward compatible with conventional analog voice.

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C. DSL service has distance limitations. \*\*

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D. DSL is an always-on technology.

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## Summary

This section summarizes the key points you learned in this lesson.

- DSL operates at Layer 1 of the OSI model.
- DSL is a relatively new and developing WAN technology that uses existing twisted-pair telephone lines to transport data.
- There are two basic types of DSL technology: asymmetric and symmetric. Asymmetric service provides a higher downstream speed than upstream speed. Symmetric service provides the same speed in both directions.
- G.992.1 and G992.2 are asymmetric DSL standards, and G991.2 is a symmetric standard.
- DSL service can be added incrementally as more users subscribe. However, DSL service has distance limitations.

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# 7.5 Cable Modems

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## Overview

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This lesson describes cable modem, cable-modem transmission, and the benefits of cable modem.

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## Objectives

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Upon completing this lesson, you will be able to:

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- Describe cable-modem types

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- Describe cable-modem transmission

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- Describe benefits of cable modems

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## Outline

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This lesson includes these sections:

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- Overview

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- Cable-Modem Basic

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- Cable-Modem Transmission

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- Cable-Modem Benefits

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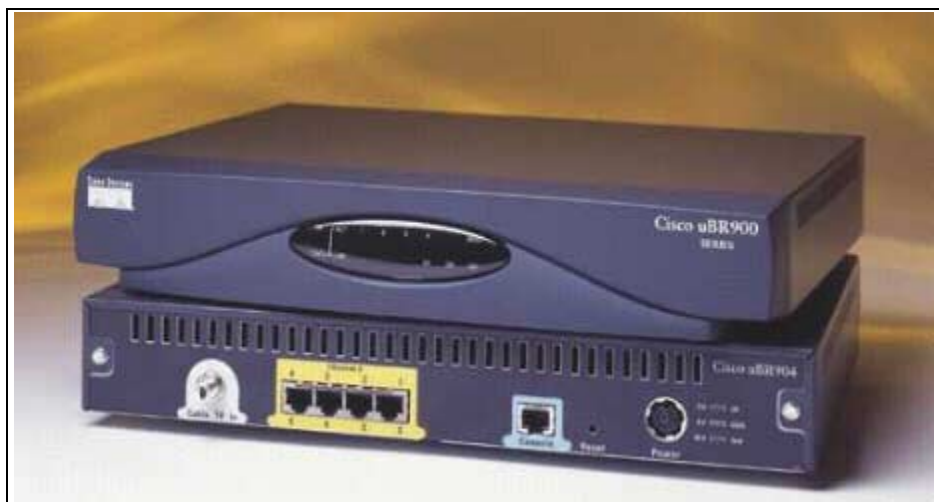
- Summary

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## 7.5.1 Cable-Modem Basics

Figure 1: Cisco uBR 900 Universal Broadband Router Cable Modem



Cable modems enable two-way, high-speed data transmissions using the same coaxial lines that transmit cable television. Some cable service providers are promising data speeds up to 6.5 times that of T1 leased lines. This speed makes cable an attractive medium for transferring large amounts of digital information quickly, including video clips, audio files, and large chunks of data. Information that would take two minutes to download using ISDN BRI can be downloaded in two seconds through a cable-modem connection.

Cable-modem access provides speeds superior to leased lines, with lower costs and simpler installation. When the cable infrastructure is in place, a firm can connect through installation of a modem or router. Additionally, because cable modems do not use the telephone system infrastructure, there are no local-loop charges. Products such as the Cisco uBR 904 Universal Broadband Router Cable Modem make cable access an even more attractive investment by integrating a fully functional Cisco IOS router, four-port hub, and cable modem into one unit (see Figure [1]). This combination allows businesses to replace combinations of routers, bridges, hubs, and single-port cable modems with one product.

Cable modems provide a full-time connection. As soon as users turn on their computers, they are connected to the Internet. This setup removes the time and effort of dialing in to establish a connection. The “always-on” cable connection also means that a company's “information pipe” is open at all times. This setup increases the vulnerability of data to hackers and is a good reason to install firewalls and configure cable routers to maximize security. Fortunately, the industry is moving toward the standardization of cable modems, and the move is likely to address encryption needs. For instance, new models of the Cisco uBR 904 Cable Modem will provide IP Security (IPSec) and firewall capabilities. These features protect company LANs and provide virtual private network (VPN) tunneling, with options for authentication and encryption.

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There is currently no standard for cable modems in the cable access industry. As a result, there are many competing proprietary products. Cable service, speed, reliability, setup, and configurations may vary significantly from one cable company to another. Currently, the most common cable-modem brands are from Cisco Systems, 3Com, Com21, Bay Networks, Motorola, RCA, Toshiba, and Terayon. The following sites offer more information:

<http://www.catv.org>  
<http://www.cable-modems.org/tutorial/index.htm>

### **Practice**

1. Which of the following media is used by DSL to transport data?
  - A. Existing coaxial cable TV lines \*\*
  - B. Existing twisted-pair telephone lines
  - C. Existing Ethernet lines
  - D. None of the above



1106 *Note:* Quadrature amplitude modulation (QAM) is a method for encoding digital  
1107 data in an analog signal in which each combination of phase and amplitude  
1108 represents one of 16 four-bit patterns.  
1109  
1110 With a cable modem, a subscriber can continue to receive cable television service  
1111 while simultaneously receiving data to be delivered to a personal computer. This is  
1112 accomplished with the help of a simple one-to-two splitter (see Figure [2]). The data  
1113 service offered by a cable modem can be shared by up to 16 users in a LAN  
1114 configuration.

1115 **Practice**

- 1116 1. Which of the following best describe upstream?  
1117  
1118 A. Data flowing from the user to the network. \*\*  
1119 B. Data flowing from the network to the user.  
1120 C. Data flowing between networks  
1121 D. Data flowing between routers.  
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## 7.5.3 Cable-Modem Benefits

Figure 1: Advantages and Disadvantages of Cable Modems

### Advantages

- ◆ Existing cable TV systems offer plenty of available bandwidth for both upstream and downstream traffic.
- ◆ A cable TV infrastructure upgrade with hybrid fiber coaxial (HFC) has addressed many of the existing service bottlenecks.

### Disadvantages

- ◆ Cable modems almost always require an overhaul of the existing cable infrastructure, an expensive undertaking for smaller providers.
- ◆ Because cable modems exist in a shared-media structure, the more users that come on the network the less bandwidth is available for users.

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The advantage of using cable-modem high-speed access is that coaxial cable wiring offers greater bandwidth using broadband for more applications to the home network LAN. Additionally, cable lines are already in place in most of the country because of the wide deployment of cable television throughout the last few decades. Therefore, cable-modem high-speed Internet access is more readily available in most areas than DSL.

Unfortunately, upgrading of the cabling infrastructure that is needed to support cable-modem technology has been slow, so most homes in the United States cannot use this technology. Upgrading is a big investment, particularly for small providers.

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### Practice

1. Which of the following is an advantage of cable modem?
  - A. Upgrading of the cabling infrastructure.
  - B. Because cable modems exist in a shared-media structure, the more users come on the network, the less bandwidth is available for each user.
  - C. Coaxial cable wiring offers greater bandwidth using broadband for more applications to the home network. \*\*
  - D. None of the above

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## 7.5.4 Cable and the OSI Model

Figure 1: Cable and the OSI Model

OSI	MCNS Data over Cable	
	TCP or UDP	MCNS
Transport	IP	
Network	IEEE 802.2	
Data Link	MCNS MAC (MPEG Frames)	
Physical	Upstream TDMA Digital IF Modulation (QPSK or QAM-16)	Downstream TDM Digital RF Modulation (QAM-64 or QAM-256)
	HFC	

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The cable data system comprises many different technologies and standards. For cable modems to be mainstreamed, modems from different vendors must interoperate.

### Physical Layer

#### Downstream Data Channel

At the physical layer, downstream data channel is based on North American digital video specifications (specifically, International Telecommunications Union [ITU-T] Recommendation J.83 Annex B) and includes the following features:

- 64 and 256 quadrature amplitude modulation (QAM)
- 6 MHz-occupied spectrum that coexists with other signals in the cable plant
- Variable-length interleaving support, both latency-sensitive and latency-insensitive data services
- Contiguous serial bit stream with no implied framing, providing complete physical and MAC-layer decoupling

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#### Upstream Data Channel

The upstream data channel is a shared channel featuring the following:

- Quaternary phase-shift keying (QPSK) and 16 QAM formats
- Data rates from 320 kbps to 10 Mbps
- Flexible and programmable cable modem under control of cable modem terminal server (CMTS)
- Time-division multiple access
- Support of both fixed-frame and variable-length protocol data units (PDUs)

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*Note:* Quaternary phase-shift keying (QPSK) is a digital frequency modulation technique used for sending data over coaxial cable network.

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#### Data Link Layer

The data link layer provides the general requirements for many cable-modem subscribers to share a single upstream data channel for transmission to the network. Among these requirements are collision detection and retransmission capability.

1185 The large geographic reach of a cable data network poses special problems. These  
1186 problems are as a result of the transmission delay between users close to headend  
1187 versus users at a distance from cable headend. To compensate for cable losses and  
1188 delay as a result of distance, the MAC layer performs ranging, by which each cable  
1189 modem can assess time delay in transmitting to the headend. The MAC layer  
1190 supports:

- 1191 ■ Timing and synchronization
- 1192 ■ Bandwidth allocation to cable modems at the control of CMTS
- 1193 ■ Error detection, handling and error recovery
- 1194 ■ Procedures for registering new cable modems
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### 1197 **Network Layer**

1198 Cable data networks use IP for communication from the cable modem to the  
1199 network. The Internet Engineering Task Force (IETF) compliant DHCP typically  
1200 forms the basis for IP address assignment and administration in the cable network.  
1201

### 1202 **Transport Layer**

1203 Cable data networks support both the Transmission Control Protocol (TCP) and the  
1204 User Datagram Protocol (UDP) at the transport layer.  
1205

### 1206 **Application Layer**

1207 All of the Internet-related applications are supported here. These applications  
1208 include HTTP, FTP, e-mail, Trivial File Transfer Protocol (TFTP), news, chat, and  
1209 Simple Network Management Protocol (SNMP). The use of SNMP provides for  
1210 management of the CMTS and cable data networks.

## 1211 **Practice**

- 1212 1. Which of the following applications is supported by the cable network?  
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    - 1214 A. HTTP
    - 1215 B. FTP
    - 1216 C. SNMP
    - 1217 D. All of the above \*\*
- 1218

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## Summary

This section summarizes the key points you learned in this lesson.

- Cable modems put data signals on the same cable as television signals. Cable-modem access provides speed superior to leased lines, and cable modems provide a full-time connection.
- The advantage of using cable-modem access is that coaxial cable is already in place in most of the country. However, the disadvantage is that the cable modem shares the media with cable TV. Thus, the more users that come on the network the less bandwidth is available for users.

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# Summary

This module includes these key points:

- WAN connection has several options, including dialup, ISDN, leased line, Frame Relay, ATM, DSL, and so on.
- WAN switching methods include packet switching, circuit switching, and cell switching.
- Frame Relay virtual circuits fall into two categories: PVC and SVC.
- ISDN is a type of high-speed dialup access from the WAN to the home. Two levels of service exist: the Basic Rate Interface (BRI), intended for home and smaller enterprises, and Primary Rate Interface (PRI), for larger installations.
- When configuring PPP authentication, you can select Password Authentication Protocol (PAP) or Challenge Handshake Authentication Protocol (CHAP). In general, CHAP is the preferred protocol.
- Analog modem provides connection at 56Kbps or less using the existing telephone lines.
- DSL modem provides high-speed connection using the existing telephone lines. DSL comes in two categories, Asymmetric or Symmetric service.
- Cable modem provides high-speed connection using the existing Cable Television lines.