Chapter 7

Connection Services

Communication must occur between distant points, but few organizations can justify the costs required to construct a private wide area network. Fortunately, a variety of commercial options are available that enable organizations to pay only for the level of service that they require. This chapter discusses some wide area network (WAN) service options. You also learn about analog and digital lines and dial-up versus dedicated service. This chapter describes some of the available types of digital communication lines and examines some standards for WAN connection services.

Chapter 7 targets the following objective in the Planning section of the Networking Essentials exam:

Test Objectives

- List the characteristics, requirements, and appropriate situations for WAN connection services. WAN connection services include: X.25, ISDN, Frame Relay, and ATM

Test Yourself

Stop! Before reading this chapter, test yourself to determine how much study time you will need to devote to this section.

1. A modem uses __________ signaling.
   - A. digital
   - B. analog
   - C. dedicated
   - D. none of the above
2. Which three of the following are digital line options?
   - A. Switched 16
   - B. T1
   - C. DDS
   - D. Switched 56
3. The __________ service uses a PAD.
   - A. X.25
   - B. Frame Relay
   - C. ATM
   - D. ISDN
4. The __________ service transfers data in fixed-length units called cells.
   - A. X.25
   - B. Frame Relay
   - C. ATM
   - D. ISDN

Digital and Analog Signaling

Signaling amounts to communicating information. The information being communicated can take one of two forms—analog or digital:

- *Analog information* changes continuously and can take on many different values. An analog clock's hands move constantly, displaying time on a continuous scale.
- *Digital information* is characterized by discrete states. A light bulb, for example, is on or off. A digital clock represents the time in one-minute intervals and doesn't change its numbers again until the next minute. A digital clock can represent exact minutes but not the seconds that pass in between.

Frequently, information existing as one form must be converted to the other. This conversion often involves the use of some encoding scheme that enables the original information to be recovered from a signal after the signal has been received.

When an analog or a digital signal is altered so that it contains information, the process is called *modulation* or *encoding*. AM radio, for example, transmits information by modulating the radio signal, which increases or decreases the amplitude (signal strength) depending on the information content. Many similar schemes are used to communicate information through different types of signals.

Figure 7.1 illustrates the difference between analog and digital signals. The analog signal constantly changes and takes on values throughout the range of possible values. The digital signal takes on only two (or a few) specific states.

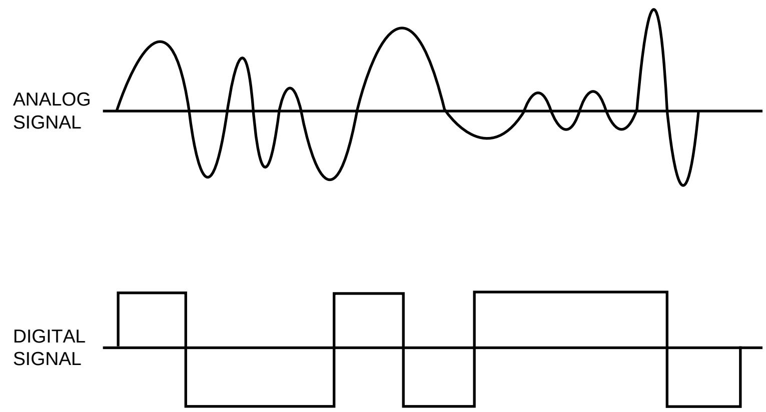


Figure 7.1

Analog and digital signals.

A *modem* is the most common computer connectivity device that transmits an analog signal. (Refer to Chapter 6, "Connectivity Devices," for more on modems.) Modems transmit digital computer signals over telephone lines by converting them to analog form. Modems are wonderfully handy for PC-to-PC communications or for accessing a LAN from a remote location, but modems generally are too slow and too unreliable for the high-tech task of linking busy LAN segments into a WAN. Because computer data is inherently digital, most WANs use some form of digital signaling.

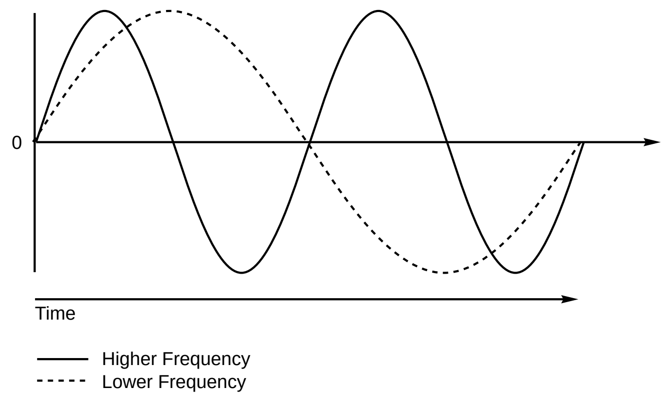
Analog Waveforms

Analog signals constantly vary in one or more values, and these changes in values can be used to represent data. Analog waveforms frequently take the form of sine waves. The two characteristics that define an analog waveform are as follows:

- **Frequency.** Indicates the rate at which the waveform changes. Frequency is associated with the wavelength of the waveform, which is a measure of the distance between two similar peaks on adjacent waves. Frequency generally is measured in Hertz (Hz), which indicates the frequency in cycles per second. Frequency is illustrated in figure 7.2.

Figure 7.2

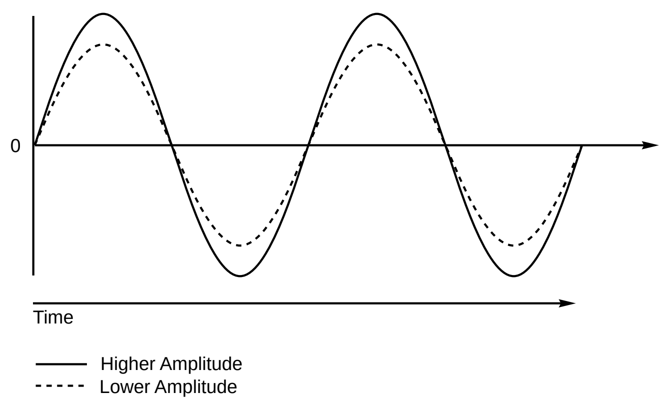
These two analog waveforms differ in frequency.



- **Amplitude.** Measures the strength of the waveform. Amplitude is illustrated in figure 7.3.

Figure 7.3

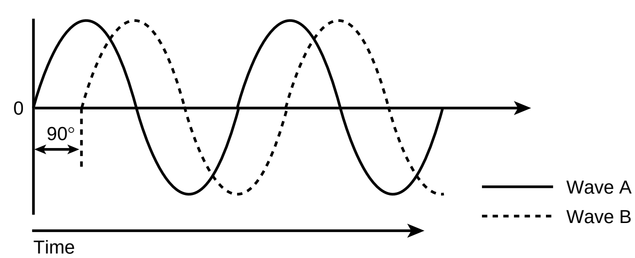
These two analog waveforms differ in amplitude.



Some analog devices can encode data using a property of waveforms called *phase*. Figure 7.4 illustrates waves that differ in phase. These waveforms have identical frequency and amplitude, but they do not begin their transitions at the same time.

Figure 7.4

These two analog waveforms differ in phase.



Each of these characteristics—frequency, amplitude, and phase—can be used to encode data.

The Public Telephone Network

Public telephone networks offer two general types of service:

- **Dial-up services.** The customer pays on a per-use basis.
- **Leased dedicated services.** The customer is granted exclusive access.

Switched services operate the Public Switched Telephone Network (PSTN), which we know as the telephone system. Voice-grade services have evolved to high levels of sophistication and can be adapted to provide many data services by using devices such as modems. Newer switched options provide higher levels of service while retaining the advantages of switched access.

With dial-up service, subscribers don't have exclusive access to a particular data path. The PSTN maintains large numbers of paths but not nearly enough to service all customers simultaneously. When a customer requests service, a path is switched in to service the customer's needs. When the customer hangs up, the path is reused for other customers. In situations in which the customer doesn't need full-time network access, switched service is extremely cost-effective.

Leased Line Types

When customers require full-time access to a communication path, a dedicated, leased line serves as one option. Several levels of digital lines are available, including those detailed in the following list:

- T1
- T3
- Fractional and multiple T1 or T3
- Digital data service
- Switched 56

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A very popular digital line, *T1,* provides point-to-point connections and transmits a total of 24 channels across two wire pairs—one pair for sending and one for receiving—for a transmission rate of 1.544 Mbps. *T3* is similar to T1, but T3 has an even higher capacity. In fact, a T3 line can transmit at up to 45 Mbps.

Very few private networks require the capacity of a T3 line, and many do not even need the full capacity of a T1. The channels of a T1 or T3 line thus can be subdivided or combined for *fractional* or *multiple* levels of service. For instance, one channel of a T1's 24-channel bandwidth can transmit at 64 Kbps. This single-channel service is called *DS-0. DS-1* service is a full T1 line. *DS-1C* is two T1 lines, *DS-2* is four T1 lines, and *DS-3* is a full T3 line (equivalent to 28 T1s). A level of service called *T4* is equal to 168 T1 lines.

note

> Microsoft reportedly has three T3 lines going into Redmond.

Digital Data Service (DDS) is a very basic form of digital service. DDS transmits point-to-point at 2.4, 4.8, 9.6, or 56 Kbps. In its most basic form, DDS provides a dedicated line. A special service related to DDS, *Switched 56*, offers a dial-up version of the 56 Kbps DDS. With Switched 56, users can dial other Switched 56 sites and pay only for the connect time.

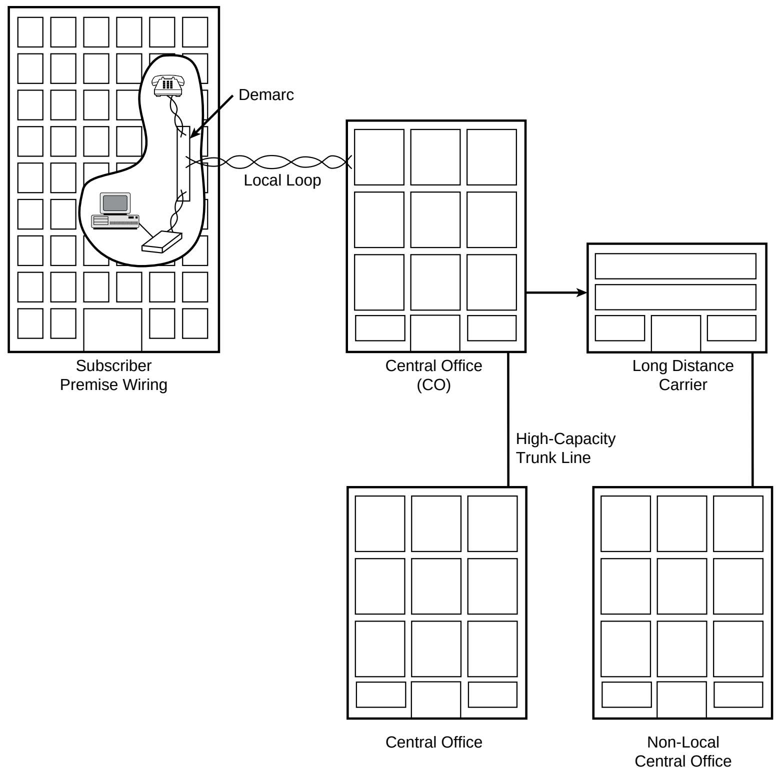
Packet Routing Services

Many organizations must communicate among several points. Leasing a line between each pair of points can prove too costly. Many services now are available that route packets between different sites. Some of the packet-routing services discussed in this chapter are as follows:

- X.25
- Frame Relay
- ISDN
- ATM

Figure 7.5

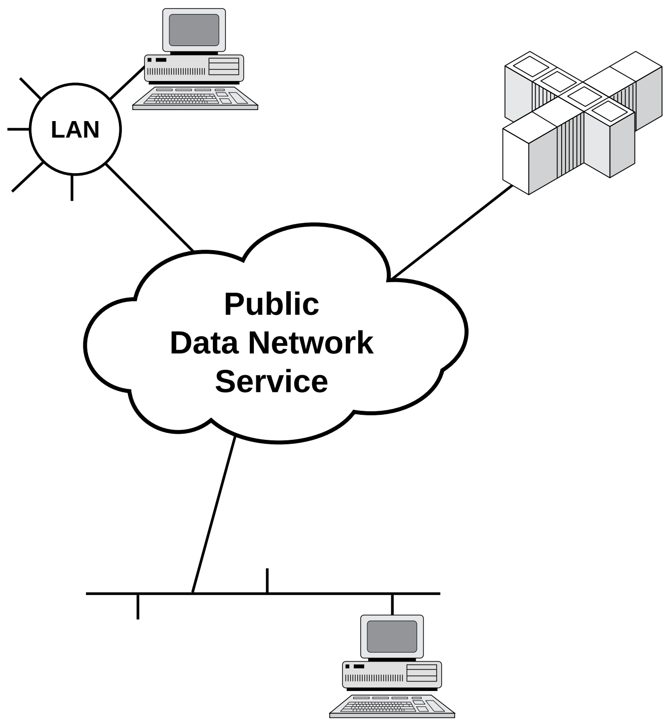
Elements of the Public Switched Telephone Service.



Each of these services has characteristics that suit it to particular uses, and all these services are available on a leased basis from service providers. An organization that must communicate among many sites simply pays to connect each site to the service, and the service assumes the responsibility of routing packets. The expense of operating the network is then shared among all network subscribers. Because the exact switching process is concealed from the subscriber, these networks frequently are depicted as a communication cloud, as shown in figure 7.6.

Figure 7.6

An example of a public network service.



These data rates can be compared to common LAN services such as Ethernet (10 Mbps) and Token Ring (4–16 Mbps).

note

Many digital transmission methods use a technique called multiplexing. *Multiplexing*, described in Chapter 3, "Transmission Media," enables broadband media to support multiple data channels.

Virtual Circuits

Chapter 2, "Networking Standards," introduces you to packet switching and other routing-related techniques used to send data over WAN links. Packet-switching networks often use virtual circuits to route data from the source to the destination. A virtual circuit is a specific path through the network—a chain of communication links leading from the source to the destination (as opposed to a scheme in which each packet finds its own path). Virtual circuits enable the network to provide better error checking and flow control.

A *switched virtual circuit (SVC)* is created for a specific communication session and then disappears after the session. The next time the computers communicate, a different virtual circuit might be used.

A *permanent virtual circuit (PVC)* is a permanent route through the network that is always available to the customer. With a PVC, charges are still billed on a per-use basis.

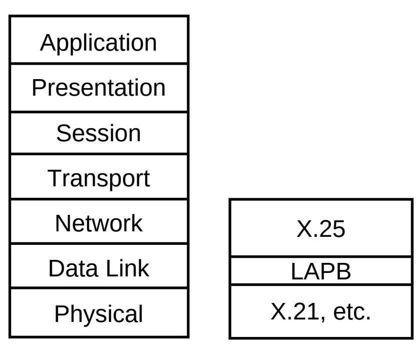
X.25

X.25 is a packet-switching network standard developed by the International Telegraph and Telephone Consultative Committee (CCITT), which has been renamed the International Telecommunications Union (ITU). The standard, referred to as *Recommendation X.25*, was introduced in 1974 and is now implemented most commonly in WANs.

As shown in figure 7.7, X.25 is one level of a three-level stack that spans the Network, Data Link, and Physical layers. The middle layer, *Link Access Procedures-Balanced (LAPB),* is a bit-oriented, full-duplex, synchronous Data Link layer LLC protocol. Physical layer connectivity is provided by a variety of standards, including X.21, X.21bis, and V.32.

Figure 7.7

The relationship of X.25 to the OSI reference model.



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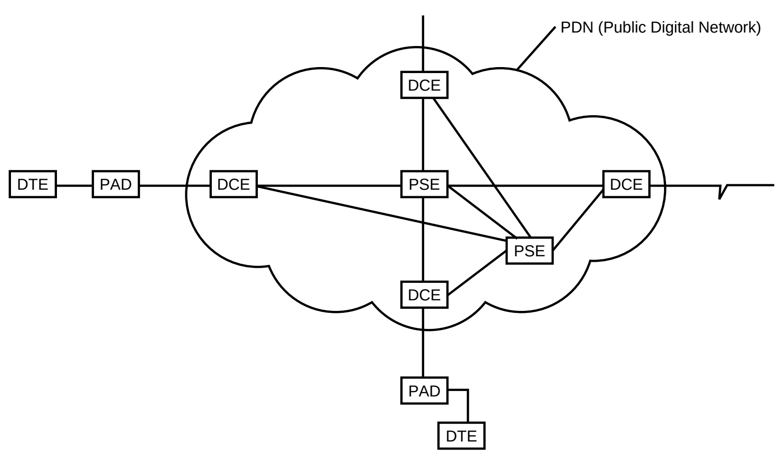
X.25 packet-switching networks provide the options of permanent or switched virtual circuits. Although a datagram (unreliable) protocol was supported until 1984, X.25 now is required to provide reliable service and end-to-end flow control. Because each device on a network can operate more than one virtual circuit, X.25 must provide error and flow control for each virtual circuit.

At the time X.25 was developed, this flow control and error checking was essential because X.25 was developed around relatively unreliable telephone line communications. The drawback is that error checking and flow control slow down X.25. Generally, X.25 networks are implemented with line speeds up to 64 Kbps. These speeds are suitable for the file transfer and terminal activity that comprised the bulk of network traffic when X.25 was defined. Such speeds, however, are inadequate to provide LAN-speed services, which typically require speeds of 1 Mbps or better. X.25 networks, therefore, are poor choices for providing LAN application services in a WAN environment. One advantage of X.25, however, is that it is an established standard that is used internationally.

Figure 7.8 shows a typical X.25 configuration. In X.25 parlance, a computer or terminal is called *data terminal equipment (DTE)*. A DTE could also be a gateway providing access to a local network. *Data communications equipment (DCE)* provides access to the *packet-switched network* (*PSN*). A PSE is a packet-switching exchange, also called a *switch* or *switching node*.

Figure 7.8

An X.25 network.



The X.25 protocol oversees the communication between the DTE and the DCE. A device called a *packet assembler/disassembler (PAD)* translates asynchronous input from the DTE into packets suitable for the PDN.

Frame Relay

Frame Relay was designed to support the *Broadband Integrated Services Digital Network (B-ISDN)*, which is discussed in the following section. The specifications for Frame Relay address some of the limitations of X.25. As with X.25, Frame Relay is a packet-switching network service, but Frame Relay was designed around newer, faster fiber-optic networks.

Unlike X.25, Frame Relay assumes a more reliable network. This enables Frame Relay to eliminate much of the X.25 overhead required to provide reliable service on less reliable networks. Frame Relay relies on higher-level protocol layers to provide flow and error control.

Frame Relay typically is implemented as a public data network and, therefore, is regarded as a WAN protocol. The relationship of Frame Relay to the OSI model is shown in figure 7.9. Notice that the scope of Frame Relay is limited to the Physical and Data Link layers.

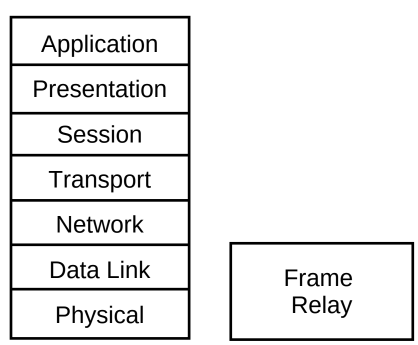


Figure 7.9

The relationship of Frame Relay to the OSI reference model.

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Frame Relay provides permanent virtual circuits, which supply permanent virtual pathways for WAN connections. Frame Relay services typically are implemented at line speeds from 56 Kbps up to 1.544 Mbps (T1).

Customers typically purchase access to a specific amount of bandwidth on a frame-relay service. This bandwidth is called the *committed information rate (CIR)*, a data rate for which the customer is guaranteed access. Customers might be permitted to access higher data rates on a pay-per-use, temporary basis. This arrangement enables customers to tailor their network access costs based on their bandwidth requirements.

To use Frame Relay, you must have special, Frame Relay-compatible connectivity devices (such as frame-relay-compatible routers and bridges).

ISDN and B-ISDN

Integrated Services Digital Network (ISDN) is a group of ITU (CCITT) standards designed to provide voice, video, and data-transmission services on digital telephone networks. ISDN uses multiplexing to support multiple channels on high-bandwidth circuits. The relationship of the ISDN protocols to the OSI reference model is shown in figure 7.10.

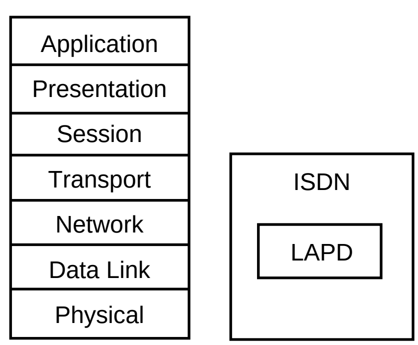


Figure 7.10

The relationship of ISDN protocols to the OSI reference model.

The original idea behind ISDN was to enable existing phone lines to carry digital communications. Thus, ISDN is more like traditional telephone service than some of the other WAN services discussed in this chapter. ISDN is intended as a dial-up service and not as a permanent, 24-hour connection.

ISDN separates the bandwidth into channels (see the following note for more information). Basic ISDN uses three channels. Two channels (called *B channels*) carry the digital data at 64 Kbps. A third channel (called the *D channel*) provides link and signaling information at 16 Kbps. *Basic Rate ISDN* thus is referred to as *2B+D*. A single PC transmitting through ISDN can use both B channels simultaneously, providing a maximum data rate of 128 Kbps (or higher with compression). The larger-scale *Primary Rate ISDN* supports 23 64 Kbps B channels and one 64 Kbps D channel.

note

A variety of ISDN channel types are defined. These channel types, often called *bit pipes*, provide different types and levels of service. The following list details the various channels:

- **A channel.** Provides 4 KHz analog telephone service.
- **B channels.** Support 64 Kbps digital data.
- **C channels.** Support 8 or 16 Kbps digital data, generally for out-of-band signaling.
- **D channels.** Support 16 or 64 Kbps digital data, also for out-of-band signaling. D channels support the following subchannels:
    - *p subchannels* support low-bandwidth packet data.
    - *s subchannels* are used for signaling (such as call setup).
    - *t subchannels* support telemetry data (such as utility meters).
- **E channels.** Provide 64 Kbps service used for internal ISDN signaling.
- **H channels.** Provide 384, 1,536, or 1,920 Kbps digital service.

ISDN functions as a data-transmission service only. Acknowledged, connectionless, full-duplex service is provided at the Data Link layer by the LAPD protocol, which operates on the D channel.

Broadband ISDN (B-ISDN) is a refinement of ISDN that is defined to support higher-bandwidth applications, such as video, imaging, and multimedia. Physical layer support for B-ISDN is provided by *Asynchronous Transfer Mode (ATM)* and the *Synchronous Optical Network (SONET),* discussed later in this chapter. Typical B-ISDN data rates are 51 Mbps, 155 Mbps, and 622 Mbps over fiber-optic media.

Asynchronous Transfer Mode (ATM)

Asynchronous Transfer Mode (ATM) is a high-bandwidth switching technology developed by the ITU Telecommunications Standards Sector (ITU-TSS). An organization called the ATM Forum is responsible for defining ATM implementation characteristics. ATM can be layered on other Physical layer technologies, such as *Fiber Distributed Data Interface* (FDDI) and SONET. The relationships of these protocols to the OSI model are shown in figure 7.11.

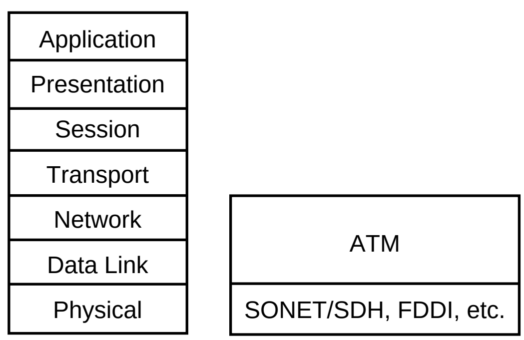


Figure 7.11

The relationship of ATM to the OSI reference model.

Several characteristics distinguish ATM from other switching technologies. ATM is based on fixed-length, 53-byte cells, whereas other technologies employ frames that vary in length to accommodate different amounts of data. Because ATM cells are uniform in length, switching mechanisms can operate with a high level of efficiency. This high efficiency results in high data transfer rates. Some ATM systems can operate at an incredible rate of 622 Mbps; a typical working speed for an ATM is around 155 Mbps.

The unit of transmission for ATM is called a *cell*. All cells are 53 bytes long and consist of a 5-byte header and 48 bytes of data. The 48-byte data size was selected by the standards committee as a compromise to suit both audio- and data-transmission needs. Audio information, for instance, must be delivered with little *latency* (delay) to maintain a smooth flow of sound. Audio engineers therefore preferred a small cell so that cells would be more readily available when needed. For data, however, large cells reduce the overhead required to deliver a byte of information.

Asynchronous delivery is another distinguishing feature of ATM. Asynchronous refers to the characteristic of ATM in which transmission time slots don't occur periodically but are granted at irregular intervals. ATM uses a technique called *label multiplexing*, which allocates time slots on demand. Traffic that is time-critical, such as voice or video, can be given priority over data traffic that can be delayed slightly with no ill effect. Channels are identified by cell labels, not by specific time slots. A high-priority transmission need not be held until its next time slot allocation. Instead, it might be required to wait only until the current 53-byte cell has been transmitted.

note

Other multichannel technologies utilize *time-division* techniques to allocate bandwidth to channels. A T1 (1.544 Mbps) line, for example, might be time-division multiplexed to provide 24 voice channels. With this technique, each channel is assigned a specific time slot in the transmission schedule. The disadvantage of this technique is that an idle channel doesn't yield its bandwidth for the creation of other channels.

Devices communicate on ATM networks by establishing a virtual path, which is identified by a *virtual path identifier (VPI)*. Within this virtual path, virtual circuits can be established, which are in turn associated with *virtual circuit identifiers (VCIs)*. The VPI and VCI together make up a three-byte field included in the cell header.

ATM is relatively new technology, and only a few suppliers provide the equipment necessary to support it. (ATM networks must use ATM-compatible switches, routers, and other connectivity devices.)

Other networks, such as a routed Ethernet, require a six-byte physical address as well as a network address to uniquely identify each device on an internetwork. An ATM can switch cells with three-byte identifiers because VPIs and VCIs apply only to a given device-to-device link. Each ATM switch can assign different VPIs and VCIs for each link, and up to 16 million circuits can be configured for any given device-to-device link.

Although ATM was developed primarily as a WAN technology, it has many characteristics of value for high-performance LANs. An interesting advantage of ATM is that ATM makes it possible to use the same technology for both LANs and WANs. Some disadvantages, however, include the cost, the limited availability of the equipment, and the present lack of expertise regarding ATM due to its recent arrival.

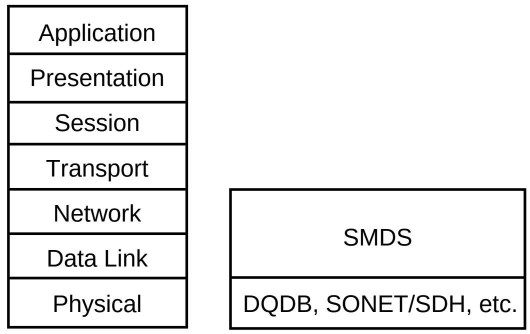
note

Two other evolving technologies show promise:

- **Synchronous Optical Network (SONET).** Bell Communications Research developed SONET, which has been accepted as an ANSI standard. As the "optical" in the name implies, SONET is a standard for communication over fiber-optic networks. Data rates for SONET are organized in a hierarchy based on the *Optical Carrier (OC)* speed and the corresponding *Synchronous Transport Signals (STS)* employed. The basic OC and STS data rate is 51.84 Mbps, but higher data rates are provided in multiples of the basic rate. Thus OC-48 is 48 × 51.84 Mbps or 2488.32 Mbps.
- **Switched Multimegabit Digital Service (SMDS).** Developed by Bell Communications Research in 1991, SMDS technology is related to ATM in that it transports data in 53-byte cells. SMDS (see fig. 7.12) is a connectionless Data Link layer service that supports cell switching at data rates of 1.544 to 45 Mbps. IEEE 802.6 (DQDB metropolitan area network) is the primary Physical layer standard employed with SMDS, although other Physical layer standards are supported.

Figure 7.12

The relationship of SMDS to the OSI reference model.



Summary

This chapter examined some basic WAN connectivity concepts, such as analog and digital signaling and dial-up and dedicated service lines. You learned about some types of digital lines, such as the following:

- T1
- T3
- Fractional and multiple T1 and T3 (the DS series)
- DDS
- Switched 56

This chapter also described the characteristics and appropriate situations for some important WAN connectivity service standards, including the following:

- X.25
- Frame Relay
- ISDN
- ATM

Refer to Chapter 2 for more information on packet switching and virtual circuits.

Exercises

Exercise 7.1: Accessing an X.25 Network Through Windows NT Dial-Up Networking

Objective: Learn how to configure Windows NT Dial-Up Networking to connect to an X.25 network provider.

Estimated time: 15 minutes

Windows NT Remote Access Service (RAS) usually is used for modem connections to remote PCs, but you also can use RAS to access an X.25 packet-switching network. RAS supports Packet Assembler/Disassembler (PAD) devices and X.25 smart cards. Alternatively, you can use Windows NT's Dial-Up Networking to connect to a commercial X.25 provider.

1. Click the Start menu and choose Settings/Control Panel. Double-click the Windows NT Control Panel Network application.

2. Choose the Network application's Services tab. Choose Remote Access Service from the Network Services list and click the Properties button to invoke the Remote Access Setup dialog box (see fig. 7.13).

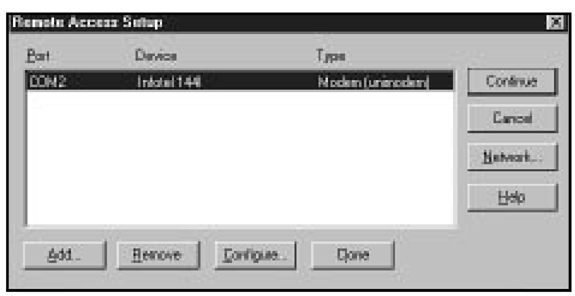


Figure 7.13

The Remote Access Setup dialog box.

note

If RAS isn't installed on your system, you might have to install it. To do so, click the Add button and choose Remote Access Service in the Select Network Service dialog box.

3. In the Remote Access Setup dialog box (refer to fig. 7.13), click the Add button. This invokes the Add RAS Device dialog box (see fig. 7.14). You could use this dialog box to install an X.25 PAD for your system. See the button labeled Install X.25 PAD. A port must be available for the Install X.25 PAD dialog box to appear. A number of X.25 PAD options appear in the Install X.25 PAD dialog box (see fig. 7.15).

Figure 7.14

The Add RAS Device dialog box.

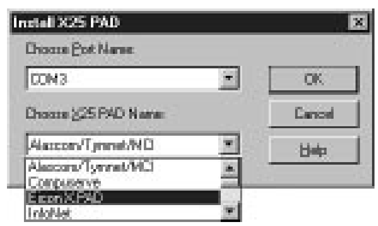


Figure 7.15

The Install X.25 PAD dialog box.

4. Close the Install X.25 PAD dialog box, the Add RAS Device dialog box, and the Network application.

5. Click the Start menu and choose Programs, Accessories, Dial-Up Networking. The Dial-Up Networking main window will appear on your screen. Click the New button.

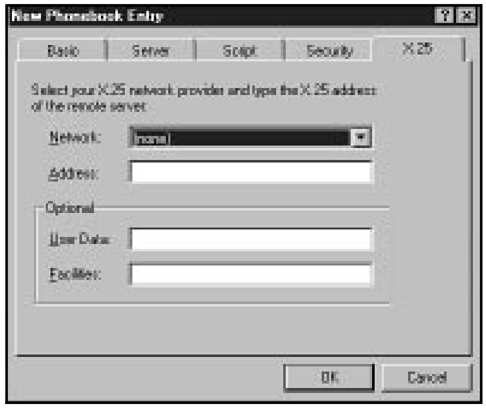
6. In the New Phonebook Entry dialog box, click the X.25 tab. This tab enables you to specify an X.25 provider and the remote server's X.25 address. The down arrow to the right of the Network box reveals a list of X.25 providers (see fig. 7.16).

continues

Exercise 7.1: Continued

Figure 7.16

The New Phonebook Entry dialog box X.25 tab contains X.25 provider options.



Review Questions

1. __________ signaling is characterized by discrete states.

   A. Analog

   B. Digital

   C. Frequency modulation

   D. None of the above

2. The DS-0 service level provides a transmission rate of __________.

   A. 64 Kbps

   B. 128 Kbps

   C. 1.544 Mbps

   D. 45 Mbps

3. A T3 line provides a transmission rate of __________.

   A. 64 Kbps

   B. 128 Kbps

   C. 1.544 Mbps

   D. 45 Mbps

4. An SVC __________

   A. is a permanent path. Charges are billed on a monthly basis.

   B. is a permanent path. Charges are billed on a per-use basis.

   C. is a temporary path created for a specific communication session.

   D. is none of the above.

5. X.25 is __________ Frame Relay.

    A. faster than
    B. slower than
    C. about the same speed as
    D. nearly identical to

6. __________ was designed to provide digital communications over existing phone lines.

    A. X.25
    B. ISDN
    C. ATM
    D. Frame Relay

7. _________ is sometimes called 2B+D.

    A. Primary rate ISDN
    B. Basic rate X.25
    C. Primary rate Frame Relay
    D. Basic rate ISDN

8. A typical working speed for ATM is __________.

    A. 1.544 Mbps
    B. 45 Mbps
    C. 155 Mbps
    D. 622 Mbps

9. ATM divides data into ________ byte blocks called __________.

    A. 53 / packets
    B. 53 / cells
    C. 56 / frames
    D. 128 / cells