Unit 3

WAN Configurations and Considerations

Overview

Description

This unit contains two lessons.

- The first lesson introduces the difference between a WAN and a LAN. It introduces the basic technology used to create a WAN including hardware, types of phone lines, and services that transmit information across those lines.

- The second lesson introduces several issues and questions a company might raise (or you might ask the company) to help choose among the various technologies for creating a WAN.

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Lesson 3-1: WAN Configurations

At a Glance

Many of the networks that you or others you know frequently use connect computers in distant parts of the country or even other parts of the world. The credit card scanner at the checkout counter often sends the card number for approval to a bank in another part of the country. The automatic teller machine that gives cash in California connects back to another bank’s network in Massachusetts. And, of course, there is the Internet, which connects networks and computers in nearly every part of the globe. These Wide Area Networks (WANs) differ from the LANs you have been studying in one important way: they must transmit information across much greater distances.

What You Will learn

After completing this unit, you will be able to:

- Explain the major difference between a local area network and a wide area network.
- Define a leased line, describe the most common types of leased lines, and explain some advantages and disadvantages of using leased lines.
- Describe two kinds of switching and the major differences between them.
- Describe several packet switching services used for WANs.
Tech Talk

- **Analog phone line**—A phone line that carries sound as a waveform. Digital data must be converted into analog data by a modem in order to travel over an analog phone line.
- **Asynchronous Transfer Mode (ATM)**—A very fast packet switching service that uses small packets called cells.
- **Cell**—A small packet of data used in certain high-speed packet switching services.
- **Circuit Switching**—Network connections in which an entire circuit is used to connect two LANs for a certain amount of time.
- **Data Service Unit/Channel Service Unit (DSU/CSU)**—A device that converts data signals so that they can transmit on digital telephone lines.
- **Digital Phone Line**—A phone line that carries digital data.
- **Frame Relay**—A packet switching service.
- **Integrated Services Digital Network (ISDN)**—Digital telephone lines that can be used for circuit switched or packet switched data transmission.
- **Leased Line (also called Dedicated Line or Private Line)**—A non-switched connection for a WAN. Only the company that leases it uses the line and the connection is always open.
- **Multipoint connection**—A wide area network connection that allows a single LAN to send and receive data from many other LANs.
- **Packet Switching**—A switched connection for WANs in which data from many different LANs may share a single circuit. Data is encapsulated in packets (sometimes called frames or cells) for transmission.
- **Synchronous Optical Network (SONET)**—A high-speed data transmission technology specifically designed for optical fiber cabling.
- **Switched Multimegabit Data Services (SMDS)**—A fast packet switching service that is connectionless.
- **T-carrier (also called Trunk Line, most common are T1 and T3)**—A kind of digital phone line. Data travels at up to 1.54 Mbps on a T1 line in the US (and even faster in Europe). Data travels at up to 45 Mbps on a T3 line.
- **X.25**—A packet switching service.
WAN Overview

- Wide area networks connect local area networks that are far apart. The LANs might be in neighboring cities or across the world.

- When you use a modem to dial up to a network, you are using a WAN connection.

- The Internet connects thousands of local area networks all over the world.

- WANs commonly transmit information across telephone lines. Some WANs make a “virtual” connection on the Internet and some WANs use satellite links.

- In many cases, data moves much more slowly across a WAN than it moves across a LAN. Some new technologies and transmission media, especially fiber optic cable, can transmit data over long distances as fast as over a LAN.

- Transmission speed, also called bandwidth, is most often measured in bits per second (b/s or bps). Commonly used abbreviations are:
  - Kbps (Kilobits per second): Thousand bits per second
  - Mbps (Megabits per second): Million bits per second
  - Gbps (Gigabits per second): Billion bits per second

Physical Interfaces

To build a LAN, you would typically run cable from computer to computer or from each computer to a hub. But this strategy has problems when the distances get longer. It’s difficult and extremely expensive to run cable across the city, let alone across the country. Installing cable over long distances requires purchasing or leasing the land between the locations (called the right of way), digging a trench, and then cutting and splicing and burying the cable. Most companies cannot afford to do this for themselves.

A second problem is that LAN connections can only carry a signal for a relatively short distance. For example, an Ethernet cable may not be more than 100 meters long. So, WANs use transmission media and protocols that work better for long distances. Some media that work well over long distances include microwave and optical fiber.
Transmission Media for WANs

Satellite

Microwave

Telephone Lines

Optical Fiber Cable
Microwave

Microwave is a form of radio transmission that uses ultra-high frequencies in the gigahertz (Ghz) range. The numbers on your AM radio dial go from 540 kHz up to 1600 kHz, while FM radio starts at 88 megahertz. Microwave transmissions can reach bandwidths over 6 Gbps—much faster than a typical LAN. Microwave hops are generally limited to 50 miles by line of sight due to the curvature of the Earth. Microwaves can’t pass through solid objects, including the Earth. Microwave dishes focus the microwave beam so that it can travel without weakening too much to be useable.

Microwave systems cost less than burying cable, but fiber optic cable is now used more frequently.

Satellite Microwave

As an alternative to sending a microwave signal directly from one dish on the ground to another, the signal can be bounced off a satellite. This overcomes the distance limits caused by the curvature of the Earth. The satellite must stay in the same location so that the microwave transmitter (the satellite dish on the ground or on a building, also called an uplink) can transmit directly to it at any time without changing its orientation. This is accomplished by putting the satellite into geostationary orbit (22,237 miles or 36,000 km above the equator). At that location, a satellite will revolve at the same speed as the Earth so it will always stay above the same point on Earth.

Microwave systems on the ground can only send a signal directly from one dish to another. Receiving dishes (or downlinks) in many different locations can receive a signal from a satellite.

One major problem with using satellites for distant communications is the delay. It takes about 1/3 of a second for the signal to travel up to the satellite, be converted for re-transmission, and then travel to the downlink. This may not seem like much, but consider that when data is travelling at 1 Mbps, 1/3 of a second is the time it takes for 333,000 bits of information to be transmitted. This creates problems for interactive voice and video use. Satellite broadcasting works much better for such one-way communication as TV and the Global Positioning System (GPS) that planes, ships, and fancy Cadillacs use to find their location.
Optical Fiber

Optical fiber is one type of media used for LANs that can also carry a signal a long way, up to 100 kilometers, by using an expensive repeater every two kilometers to boost the signal. Optical fiber can transmit data at the highest speeds now available. Using optical fiber a company can transmit huge video files across the country as fast as it can send them to the office down the hall. Optical fiber is making the difference between a LAN and a WAN invisible to the typical network user.

Public Telephone Networks

Instead of building a radio transmitter or laying new optical fiber, many companies pay to use physical media that’s already in place. Wiltel, MCI, and other companies make money by installing wide area connections and then charging customers to use them. These lines may be physically the same as the media described above: twisted pair copper wire, microwave, and optical fiber. The important difference is that the lines are part of a network owned and operated by a telephone company. Information travels across this public network on its way from one LAN to another or on the way to the office LAN from a telecommuter working at home.

Most WANs use telephone lines because phone lines are in place nearly everywhere. In fact, the Public Switched Telephone Network (PSTN) is the largest network in the world, much larger than the Internet. Telephone companies (AT&T, Nortel Networks, US Sprint, MCI, and others) offer many different types of telephone lines. Phone lines that transmit data faster cost more than slower lines but all phone lines except for those using optical fiber, transmit data at much slower speeds than a LAN.

### Comparing the Transmission Speeds of Telephone Lines

<table>
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<th>Speed</th>
<th>Description</th>
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<td>28 Kbps</td>
<td>Analog Line</td>
</tr>
<tr>
<td>56 Kbps</td>
<td>Switched 56</td>
</tr>
<tr>
<td>128 Kbps</td>
<td>ISDN Basic Rate</td>
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<tr>
<td>1,540 Kbps</td>
<td>T1</td>
</tr>
<tr>
<td>44,700 Mbps</td>
<td>T3</td>
</tr>
<tr>
<td>1,000,000 Kbps</td>
<td>Optical Fiber (SONET)</td>
</tr>
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</table>
Analog telephone lines

You may already be familiar with using the phone lines as the media for a wide area network. If you have used a modem to dial-up to an Internet Service Provider and log on to the Internet, you have used the regular analog phone lines as part of a WAN. The modem converts the digital data from your computer into sound that can travel across phone lines. At the receiving end, another modem converts the sound back into digital data. Information moves very slowly over regular telephone lines. Currently, the maximum speed of transmission is 56 Kbps but 28 Kbps is more typical. Compare this to the 10 Mbps to 100 Mbps of a LAN.

Digital telephone lines

To improve the speed of analog lines, phone companies began offering digital lines. The physical lines are the same copper wire that regular analog phone calls use but the data is transmitted as electrical impulses rather than as sound waves. As you learned in the Data Transmission lesson, digital transmissions take up less bandwidth and travel faster than analog transmissions. The slowest digital line transmits data at 56 Kbps, twice as fast as an analog line.

T-Carriers

The most commonly used digital lines are called T-carriers. These are also called trunk lines, because if you imagine the public telephone network as a tree, these lines would be the trunk. They are also called leased lines, because companies frequently lease them for private use.

T-carrier is not a physical media, it’s a way of using that media to carry more phone calls and more data. A T-carrier might use the same copper wire used by analog transmissions or it might use microwave, satellite, or optical fiber.

An analog line provides one channel capable of carrying a single telephone conversation or data transmission at about 28.8 Kbps. A T-carrier divides the line into many channels. Think of cable television, which uses one coaxial cable to carry many different channels. T-carrier channels can be used together or separately. Each channel can carry a single phone call or it can transmit data at 64 Kbps.
A T1 line contains 24 channels. Smaller businesses that don’t need a full T1 can lease one or more channels called fractional T1s. In this way, a single T1 line can carry connections for many networks.

A T3 can carry 44.736 Mbps and costs several times the price of a T1. Large corporations and Internet service providers (ISPs) might use a T3.

### Connecting a LAN to Digital Telephone Lines

LANs connect to digital phone lines through a router. Like the modem used for analog lines, special equipment is needed for connecting a LAN to a T-carrier line. Two devices are needed: a **channel service unit (CSU)** and a **data service unit (DSU)**. They are usually combined and sometimes built into the router, These devices physically connect the router to the telephone line and convert the data from the format on the LAN to the format for the WAN.

**SONET**

Telephone companies now use optical fiber for their trunk lines instead of copper wire. **Synchronous Optical Network (SONET)** are the standards that define how to set up an optical fiber network that can transmit data at over 1Gbps. Sound and video transmissions, such as video conferencing, demand this kind of bandwidth. SONET technology is advancing rapidly and may soon transmit data at over 13 Gbps.

For the 1996 Summer Olympics in Atlanta, The local telephone company, BellSouth, and several other companies set up a SONET system that connected the 26 sites around Atlanta where the competitions took place. The SONET system simultaneously carried the video from the cameras, the audio from the microphones, and data such as competition results. This information was then transmitted by satellite for television coverage all over the world. You can read a description at [http://www.ksu.edu/kse/spring96/olympics/olympics.html#com](http://www.ksu.edu/kse/spring96/olympics/olympics.html#com)
Integrated Services Digital Network (ISDN) is more than a kind of telephone line. It’s a whole set of technologies including special devices such as telephones and switches, and standards that tell how data is to be transmitted. It has been around for a long time but hasn’t become very popular in the United States. Different phone companies offered different versions and it was too confusing for most people. That situation is changing somewhat now, but it may be too late because newer, faster technologies are now available.

ISDN has certain advantages over T-carrier. T-carriers are frequently used by companies with lots of data to transmit, but even a fractional T1 is probably too expensive for an individual user who just wants to surf the Internet faster. Many people who work at home and many small businesses use ISDN Basic Rate Interface lines to connect to the Internet.

Like a T-carrier, ISDN-BRI uses the same twisted pair copper wire used for standard analog telephone lines and ISDN requires a device like a modem to convert the data from the digital format that comes from the computer to the digital format used on the ISDN lines. This device is called a terminal adapter.
ISDN BRI divides the line into two 64 Kbps channels and a 16 Kbps channel that can be used separately for three different “conversations.” ISDN lines can be used for regular phone conversations on the two 64 Kbps channels, as well as data transmission on any of the channels. The 64 Kbps channels can be combined to transmit data at 128 Kbps. This is an important advantage over T-carrier. ISDN channels can be combined and separated when needed. A graphic designer working from home with an ISDN line might use one channel for a telephone call to his/her office while the other channel is receiving a fax. Then s/he might combine the channels to access the Internet at 128 Kbps. In contrast, channels on a T-carrier are assigned to be used for voice calls or data transmission when the line is hooked up and can’t be easily changed.

A faster form of ISDN called ISDN Primary Rate Interface (PRI) contains 23 64-Kbps and one additional 64 Kbps channel and can transmit data at up to 1.52 Mbps. This is suitable for larger business LANs with more data to transmit. It’s no coincidence that T1 lines and ISDN-PRI lines have the same number of channels. ISDN PRI is designed to run over a T1.

The newest form of ISDN is Broadband ISDN (B-ISDN) that can handle data rates of 155-622 Mbps. B-ISDN has over 1000 times the bandwidth of regular ISDN, enough to carry cable television, interactive videoconferences, and other high-bandwidth data.

Check Your Understanding

♦ What is the major difference between a LAN and a WAN?

♦ Why are some transmission media unsuitable for WANs?

♦ What transmission media can be used for both LANs and WANs?

♦ Why do most WANs use telephone lines for transmission?
♦ At which layer of the OSI protocol would specifications for WAN transmission media fall?

♦ What do a modem, a terminal adapter, and a channel service unit/data service unit have in common?

WAN Connections

The first part of this lesson introduced the typical kinds of media and protocols (OSI Layer 2) used for wide area networks. The next few sections introduce some of the ways those transmission media can be used, including dedicated connections, dial-up connections, and packet switching connections. All of these types of connections are available through the telephone companies and so these sections will focus on telephone lines. A later section will introduce the use of the Internet to create a WAN.

Circuit Switching

Think about how you use a phone line to call a friend. You dial the number, wait for the connection to go through, wait for the phone at the other end to ring, wait for your friend to answer, and then you talk. This is called a dial-up connection.

Once you have dialed up, a regular phone call works by circuit switching. The phone company gives you a circuit to use. No one else can use that circuit until you hang up.

Circuit Switched Connections
A phone company can also provide circuit switching to create a WAN. Imagine a bank with offices in New York, London, Hong Kong, and Caracas, all connected by circuit switching. When the office in New York calls the office in London, the phone company creates a circuit that is only used by those two LANs until they hang up. The circuit may be created using Switched 56 lines, ISDN BRI lines, or faster digital lines such as a T1.

Circuit switching connects one point, which might be a LAN or a single computer, to one other point at a time. This is called a point-to-point connection. A company might pay the phone company for circuit switching to transmit data between its offices in four cities. In that case, each office could only transmit data to one other office at a time.

Unfortunately, there are only so many circuits available at one time. You may have heard a recorded message (especially if you’ve tried to make a call on Mother’s Day): “All circuits busy, please try your call again later.”

In terms of data transmission, circuit switching wastes valuable bandwidth. Think of a regular phone call. Suppose you put the phone down to go find the movie schedule or get a pen and paper. During all the time you’re not talking, no data is being transmitted. The bandwidth goes unused because circuit switching gives you the entire circuit until you hang up, whether you are using it or not. Even when you are talking, your pauses between words are times when the circuit is not in use. When LANs are connected by circuit switching, there are also times, similar to a pause in conversation, when nothing is transmitting.

Circuit switching may waste bandwidth, but it has an advantage for the user. When you use circuit switching, you only pay the phone company for the time you spend on line. Think of a store that has to communicate with the main office across the country to report its daily sales figures at the end of each day. Instead of paying for a leased line all day and night, the store might use circuit switching. Then it would only pay for one data transmission call each day.

**Leased Lines**

When you make a regular voice phone call it can take as long as 30 seconds to a minute from the time you start dialing to when the phone at the other end starts ringing. Digital phone lines make connections much faster but there is still a wait while the circuit is established. All that waiting makes a dial-up connection a very slow way to transmit data.
A company that needs to share data constantly wouldn’t want to wait for a circuit each time it must transmit data. For example, a stockbroker in London needs to see the prices of stocks on the New York Stock Exchange. S/he can’t wait to dial the phone and make the connection; in that time the stock market may have changed.

Instead of using a dial-up connection, the broker might use a leased line (also called a dedicated line). A leased line is always connected, much like the way computers on a LAN are always connected. For each leased line, the bank pays the phone company for a circuit that stays open all of the time, like an endless phone call. This is expensive. Phone companies offer fractional T1, full T1, T3, and faster leased lines. The faster the speed and the greater the distance, the more a leased line will cost.
A leased line connects through the phone company to one other point on the WAN. In the example, the leased line would connect the London office to New York. Like circuit switching, leased lines are point-to-point connections. If the bank also needed to connect an office in Hong Kong to New York, it would have to lease an additional line. And if it needed to connect London and Hong Kong, it would need a third leased line.

Some banks use leased lines for their automatic teller machines. Because the connection is always there, you don’t need to wait for the ATM to call the bank to check your card number, password, and account balance. This is why you can get money so quickly. Security is another reason why banks use leased lines. You will learn more about security in the next lesson, WAN Considerations.

Check Your Understanding

♦ List two advantages a leased line has over a dial-up connection.

♦ Why might a leased line be even more wasteful of bandwidth than a circuit switched connection?

Packet Switching

Because circuit switching is how regular phone calls work, that is the way data was transmitted when phone lines were first used for WANs. As more people wanted to transmit data, the phone companies had two choices: they could either string out more telephone lines to create more circuits, or they could find a way to make the circuits they had carry more data. So far, they have been very successful at increasing the capacity of telephone lines.
Airlines have a central database of seats available. Across the country, ticket agents in airports must check that database in order to know which tickets they can sell. If the agents needed to dial the phone and wait for the connection to be made, it would slow them down considerably and make your wait in line much longer. They need a dedicated line. But leasing a line from every airport in the country to the central database would be very expensive, especially since the lines must still be paid for even when they are not being used.

Packet Switched Connections

To solve the problem, airline reservation systems use *packet switching*. With packet switching, the phone company acts like a post office. All LANs send their data to the phone company in packets with a destination address. The phone company reads the address and takes care of sending (or in network terms, switching) the data to the correct destination.
Packet switching makes more efficient use of telephone circuits because the circuits are shared all the time. Data from many different sources can use the same circuits. These circuits are called virtual circuits because, they only seem to be complete circuits from one LAN through the phone company network to another LAN. In reality, the data traveling across the phone company network doesn’t follow a specific path, instead it follows whatever path happens to be available.

When a company pays the phone company for packet switching service, it pays only for the packets of data it sends over those lines. Unlike using a leased line, the company doesn’t have to pay when there is no data to transmit. (Companies using packet switching service may still lease a line but only between their LANs and the phone company switches rather than the entire distance through the phone company network.)

Another major advantage to packet switching is that a LAN can send data to many other LANs simply by sending data (with its destination address) to the phone company switch. The phone company takes care of distributing the data to the various addresses. This is called a multipoint connection.

**X.25**

Airline reservation systems previously used a packet switching network called X.25 (but they are moving to using Frame Relay, which is described next). You learned in the Data Transmissions lesson that protocols are rules for how data is to be transmitted. X.25 is actually a set of protocols that work at the physical, data link, and network layers. A set of protocols is often referred to as a service.

<table>
<thead>
<tr>
<th>X.25</th>
<th>PLP (Packet Level Procedure)</th>
<th>Routes packets from source to destination, also handles flow control and error checking</th>
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<tr>
<td>LAP-B (Link Access Protocol Balanced)</td>
<td>Error checking</td>
<td>Error checking</td>
<td>OSI Data Link Layer</td>
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<td>X.21</td>
<td>Physical transmission of packets</td>
<td>Physical transmission of packets</td>
<td>OSI Physical Layer</td>
</tr>
</tbody>
</table>

**X.25 Protocols**

This set of protocols creates a connection-oriented service, which means it waits for acknowledgement from the receiving switch before it transmits packets. Just as the friend you call picks up the phone and says “hello,” the receiving end of a connection-oriented service also acknowledges that it is ready to receive. A virtual circuit is then established and all the data travels along that circuit from one LAN to the other.
The X.25 protocol checks for errors and ensures that data travels at the proper rate (called flow control). These functions slow down the data transmissions. X.25 has been made obsolete by the faster Frame Relay protocol and even faster ATM protocol described below. But X.25 is still used where the transmission media is poor and requires much error checking.

**Frame Relay**

Frame Relay is also connection-oriented but it can transmit data much faster than X.25 because it leaves the error checking and flow control to higher level protocols in the OSI model.

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**Frame Relay Frames**

*Frames* in Frame Relay are packets that contain packets. When a data packet gets to the phone company switch, it is put into a frame that contains information about its destination. At the destination switch, the frame is stripped away and the packet goes on its way.
SMDS

*Switched Multimegabit Data Service* (SMDS) converts packets into small frames called *cells* that can transmit very quickly. Think of packets switching on a network like vehicles traveling on a highway. When the highway is crowded, it's easier for a small sports car to merge in than it is for a tractor-trailer. The sports car can merge in whenever there is a small gap between passing cars while the truck must wait for a larger opening. Many more small cars than trucks can fit on a stretch of highway. Likewise, data packets from many more users can fit on a network when the data packets are kept small.

SMDS's main advantage over X.25 and Frame Relay is that it is *connectionless*, it doesn't wait for the receiving switch to announce that it's ready to receive and for a circuit to be established. Eliminating this step allows SMDS to transmit data much faster.

Remember that a packet switching network contains many different paths that data can take to get from one place to another. At any particular moment, data might be moving faster along one path than another. With X.25 and Frame Relay, once the initial connection is made, that's the path that is used for the entire transmission. In contrast, with SMDS, if a faster path becomes available midway through the transmission, SMDS will start sending packets the faster way. This means that some packets sent later might arrive before packets sent earlier. The receiving switch must sort the packets into the correct order.
ATM

One of the newest, most exciting technologies for data transmission is Asynchronous Transfer Mode (ATM), which is similar to SMDS in that it converts packets into small cells that transmit at high speeds through the network. ATM cells can transmit at speeds of 155 to 622 Mbps. This is fast enough for use on a LAN.

ATM Cells

ATM cells travel on their own regular schedule rather than just when data needs to be transmitted. Think of ATM cells as cars on a train. When information (which could be data or video or sound) enters the ATM link, it's as if it goes to the station (the ATM switch) and boards the train (the ATM cells). The ATM switch takes packets from the LAN and puts them into the ATM cells as the cells pass by. The ATM train has an endless number of cars and moves extremely fast, so there's never a wait to board the train. If the LAN packet is larger than a single ATM cell, then it continues filling the next cell and the next until it is completely sent. If the LAN packet only partially fills an ATM cell, then padding (meaningless data) is added to fill the cell. Because all the cells are the same size and because there is a steady stream of cells, ATM is very predictable. The protocols that handle ATM only have to deal with one size of cell and a constant speed of information. This allows these protocols to be simpler and work faster.
Another advantage to ATM is that it keeps cells in the correct order so they don’t need to be sorted out at the receiving switch. One drawback is that ATM requires special switches.

ATM operates at the physical, data link, and network layers of the OSI model and can use a variety of physical transmission media. Of course, the faster transmission speeds the media can handle, the faster the data will transmit. Optical fiber (using SONET) is the best choice for the physical layer under ATM and SMDS.

Check Your Understanding

♦ List two disadvantages to circuit switching.

♦ Why might choosing packet switching service over leased lines save a company money on its WAN?

♦ Why might packet switching service still require a leased line?

♦ Which packet switching service places packets into other packets?

♦ Which packet switching service and transmission media would you choose if you wanted the highest transmission speed you could get?

♦ Name an advantage and a disadvantage that connectionless packet switching has over connection-oriented packet switching.
The Internet

While reading the descriptions of leased lines and switching services, you may have been wondering, Why not use the Internet? The Internet is a WAN. Any two LANs connected to the Internet (most likely by a phone line) can communicate. Therefore, to create a WAN, all you need to do is connect your LANs to the Internet. In fact, this is true and it is done. But the Internet offers many opportunities for other people to read or intercept your data. There is much less security on the Internet than on a leased line. Additionally, the speed of transmission on the Internet may not be as reliable as a private WAN connection. When there is heavy traffic on the Internet, transmission speeds decrease.

Virtual Private Network (VPN)

To solve the privacy problem, an ISP sets up a Virtual Private Network (VPN). It sets its router to transfer data from one particular LAN to another particular LAN, much like a point-to-point connection using telephone lines. It’s called virtual because it really doesn’t create a private network but instead uses parts of the (public) Internet. Think of a leased line as a private road, packet switching as a road you share with only certain others, and the Internet as the public highway. A VPN is like a private lane on the public highway.

In the next lesson, WAN Considerations, you will learn more about how a VPN deals with the problems of security and reliability.
Check Your Understanding

- Why might using a VPN require leasing a phone line?

- How does an ISP create a virtual private network?

- If you were very concerned about other people seeing your data, why might you choose a leased line instead of a VPN?
Try It Out

Sketching a WAN

Materials Needed

- None

Refer to the technologies described and the diagrams in this lesson to sketch a possible solution to the following:

1. Each day, a retail stereo equipment store in Miami reports its sales for the day to the headquarters in Atlanta.

2. Form a team to draw a diagram that shows a way that the store and the headquarters could exchange data. Be sure that your diagram clearly includes the following information:
   a. How the LANs at the store and at the headquarters are connected to the WAN link.
   b. The equipment needed.
   c. The type of lines or wireless technology that are used.
   d. The bandwidth of the connection.
   e. Whether the connection is always open or only available when needed.
   f. The kind of switching that happens on the WAN link.
   g. Whether the data from the LAN gets converted into packets or frames or cells.
   h. Any special equipment needed.
   i. The type of lines or wireless technology used. The bandwidth of the link.

3. Exchange your diagram with another team. Analyze the diagrams and indicate the following.
   a. Whether they are missing any required information.
   b. Whether the suggested solution would be acceptable to the company. Explain why or why not.

4. Return each diagram to the teams that drew it. Add to yours any missing information as indicated by the review team. Make a copy of the final corrected diagram for each member of the team to include in his or her portfolio.
5. Submit deliverables for performance evaluation.

**Rubric: Suggested Evaluation Criteria and Weightings**

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<tr>
<th>Criteria</th>
<th>%</th>
<th>Your Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>First draft of diagram clear and complete</td>
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<td></td>
</tr>
<tr>
<td>Review of other team’s diagrams</td>
<td>25</td>
<td></td>
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<td>Revised diagram, clear, complete, and correct</td>
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Stretch Yourself

WAN Activity

Materials Needed

- None

1. How many leased lines would it take to connect three LANs? How many would it take to connect four? Find a formula that will tell you how many leased lines you will need to connect any given number of LANs.

2. Research the cost of a leased line to connect two locations.

3. Research whether your school is part of a wide area network. What physical media does it use? Does it use a dial up connection, a dedicated line or switched service?

4. In recent years, companies whose business is focused on the Internet have been very popular with investors. The share prices of these companies have increased tremendously. For example, in the first few months of 1999, the 15 best performing internet stocks increased in value over 100%. Given a list of the 10 best performing internet stocks, research whether they are involved in Wide Area Networking. Write a one-page summary of what you found. Report to the class.

Rubric: Suggested Evaluation Criteria and Weightings

<table>
<thead>
<tr>
<th>Criteria</th>
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<td>On time</td>
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<tr>
<td>Complete and thorough research</td>
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<tr>
<td>One page report</td>
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<tr>
<td>List of 10 internet stocks and their involvement in WANs</td>
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<td>Oral presentation to class</td>
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Network Wizards

Virtual Private Network Research

Materials Needed
- Internet connection

Use the Internet to find several companies that provide Virtual Private Networks. Use the Internet to research VPNs. Write a one page report that includes the following information. Place report in your portfolio.

a. What are the questions that a VPN provider needs to ask in order to provide you with a cost estimate?
b. How long does it take to set up a VPN?
c. How are VPNs billed?

Rubric: Suggested Evaluation Criteria and Weightings

<table>
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<td>Complete and thorough list of questions</td>
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Summary

In this unit, you learned the following:

- The major difference between a local area network and a wide area network.
- The definition of a leased line, the most common types of leased lines, and some advantages and disadvantages to using them.
- Two kinds of switching and the major differences between them.
- Several packet switching services used for WANs.
Lesson 3-1: WAN Configurations

Part A

1. Local area networks transmit data at speeds between
   a. 20 Kbps and 56 Kbps.
   b. 56 Kbps and 128 Kbps.
   c. 128 Kbps and 1.5 Mbps.
   d. 1.5 Mbps and 10 Mbps.
   e. 10 Mbps and 100 Mbps.

2. Which type of transmission media would not be used for a WAN?
   a. UTP
   b. Microwaves.
   c. Coaxial cable.
   d. Optical fiber cable.
   e. Radio waves.

3. Most Wide Area Networks use telephone lines because
   a. Phone lines go everywhere.
   b. All phone lines are very fast.
   c. It’s less expensive than running new cables over long distances.
   d. a and c.
   f. All of the above.
Lesson 3-1: WAN Configurations

Part B

♦ Matching

<table>
<thead>
<tr>
<th></th>
<th>1. ___ The speed of the least expensive kind of leased line.</th>
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<tbody>
<tr>
<td>A. 8</td>
<td>2. ___ The speed of data on an ISDN-BRI line when both channels are used.</td>
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<tr>
<td>B. T1</td>
<td>3. ___ A digital telephone line likely to be used by an Internet Service Provider.</td>
</tr>
<tr>
<td>C. T3</td>
<td>4. ___ A digital telephone line that can carry data at 1.544 Mbps.</td>
</tr>
<tr>
<td>D. 64 Kbps</td>
<td>5. ___ The speed of a single channel on a T1 line.</td>
</tr>
<tr>
<td>E. 7</td>
<td></td>
</tr>
<tr>
<td>F. 6</td>
<td></td>
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<tr>
<td>G. 128 Kbps</td>
<td></td>
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<tr>
<td>H. 56 Kbps</td>
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</table>

♦ What are some of the features of leased lines?
Part C
Label each statement as C for Circuit Switching or P for Packet Switching

_____ A normal telephone call.

♦ _____ Only one user for an entire circuit.

♦ _____ Many users on a single circuit.

♦ _____ Pay only for data transmitted.

♦ _____ May transmit data as cells.

♦ _____ Pay for time on line.

♦ _____ Good for once-a-day data transmission.

♦ _____ Good for constant data transmission.

♦ _____ Connectionless service is possible.

♦ _____ Frame Relay.
Part D

1. Write a short paragraph explaining the advantages and disadvantages of using a leased line to connect two distant LANs.

2. Write a short paragraph that compares and contrasts the following three services:
   - X.25
   - Frame Relay
   - ATM
Scoring

Rubric: Suggested Evaluation Criteria and Weightings

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Resources

