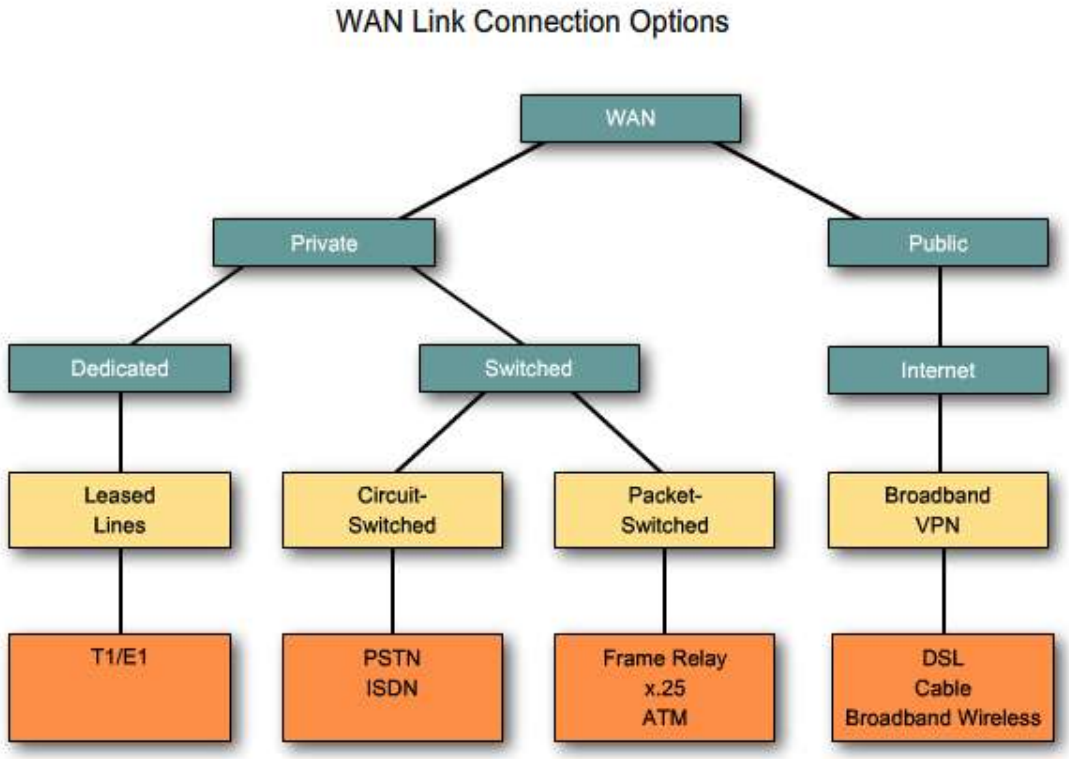
1.3 WAN Connection Options

Leased Lines



Many options for implementing WAN solutions are currently available. They differ in technology, speed, and cost. Familiarity with these technologies is an important part of network design and evaluation.

WAN connections can be either over a private infrastructure or over a public infrastructure, such as the Internet.

Private WAN Connection Options

Private WAN connections include both dedicated and switched communication link options.

Dedicated communication links

When permanent dedicated connections are required, point-to-point lines are used with various capacities that are limited only by the underlying physical facilities and the willingness of users to pay for these dedicated lines. A point-to-point link provides a pre-established WAN communications path from the customer premises through the provider network to a remote destination. Point-to-point lines are usually leased from a carrier and are also called leased lines.

Switched communication links

Switched communication links can be either circuit switched or packet switched.

- **Circuit-switched communication links**-Circuit switching dynamically establishes a dedicated virtual connection for voice or data between a sender and a receiver. Before communication can start, it is necessary to establish the connection through the network of the service provider. Examples of circuit-switched communication links are analog dialup (PSTN) and ISDN.
- **Packet-switched communication links-**Many WAN users do not make efficient use of the fixed bandwidth that is available with dedicated, switched, or permanent circuits because the data flow fluctuates. Communications providers have data networks available to more appropriately service these users. In packet-switched networks, the data is transmitted in labeled frames, cells, or packets. Packet-switched communication links include Frame Relay, ATM, X.25, and Metro Ethernet.

Public WAN Connection Options

Public connections use the global Internet infrastructure. Until recently, the Internet was not a viable networking option for many businesses because of the significant security risks and lack of adequate performance guarantees in an end-to end Internet connection. With the development of VPN technology, however, the Internet is now an inexpensive and secure option for connecting to teleworkers and remote offices where performance guarantees are not critical. Internet WAN connection links are through broadband services such as DSL, cable modem, and broadband wireless, and combined with VPN technology to provide privacy across the Internet.

When permanent dedicated connections are required, a point-to-point link is used to provide a pre-established WAN communications path from the customer premises through the provider network to a remote destination. Point-to-point lines are usually leased from a carrier and are called leased lines. This topic describes how enterprises use leased lines to provide a dedicated WAN connection.

Line Types and Bandwidth in the figure to view a list of the available leased line types and their bit rate capacities.

Line Type	Bit Rate Capacity
56	56 kb/s
64	64 kb/s
T1	1.544 Mb/s
E1	2.048 Mb/s
J1	2.048 Mb/s
E3	34.064 Mb/s
T3	44.736 Mb/s
OC-1	51.84 Mb/s
OC-3	155.54 Mb/s

Line Type	Bit Rate Capacity
OC-9	466.56 Mb/s
OC-12	622.08 Mb/s
OC-18	933.12 Mb/s
OC-24	1244.16 Mb/s
OC-36	1866.24 Mb/s
OC-48	2488.32 Mb/s
OC-96	4976.64 Mb/s
OC-192	9953.28 Mb/s
OC-768	39813.12 Mb/s

Leased lines are available in different capacities and are generally priced based on the bandwidth required and the distance between the two connected points.

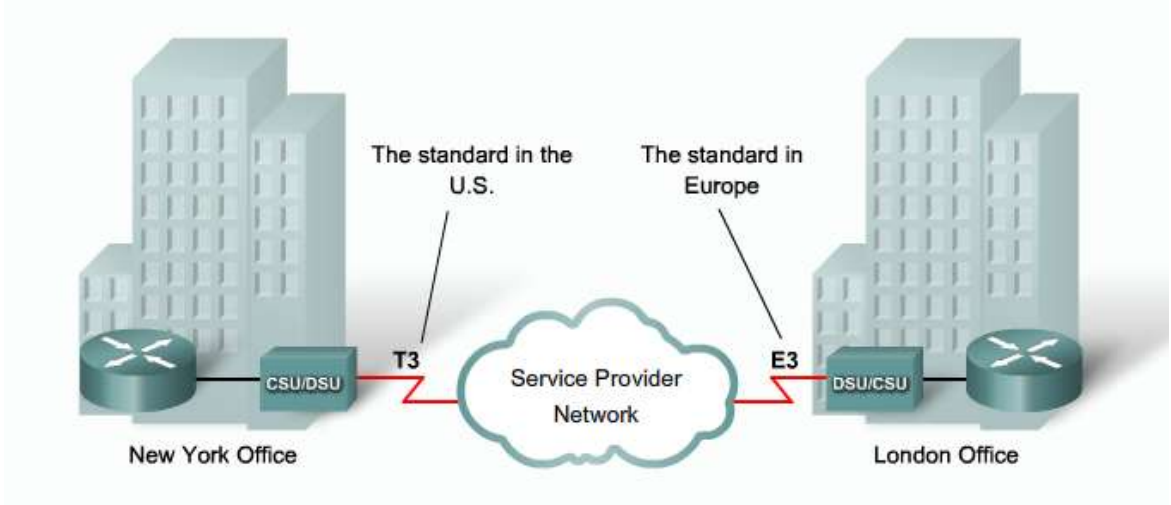
Point-to-point links are usually more expensive than shared services such as Frame Relay. The cost of leased line solutions can become significant when they are used to connect many sites over increasing distances. However, there are times when the benefits outweigh the cost of the leased line. The dedicated capacity removes latency or jitter between the endpoints. Constant availability is essential for some applications such as VoIP or Video over IP.

A router serial port is required for each leased line connection. A CSU/DSU and the actual circuit from the service provider are also required.

Leased lines provide permanent dedicated capacity and are used extensively for building WANs. They have been the traditional connection of choice but have a number of disadvantages. Leased lines have a fixed capacity; however, WAN traffic is often variable leaving some of the capacity unused. In addition, each endpoint needs a separate physical interface on the router, which increases equipment costs. Any changes to the leased line generally require a site visit by the carrier.

1.3.2 Dedicated Connection Link Options

Leased Lines



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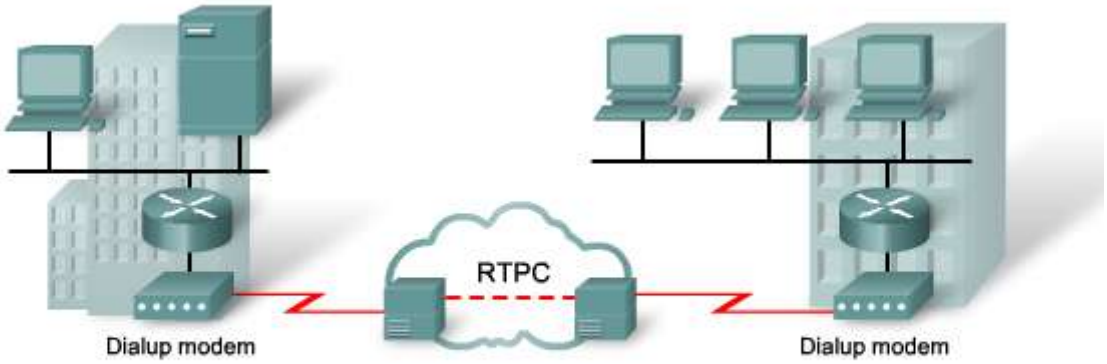
1.3.3 Circuit Switched Connection Options

Analog Dialup



WAN built with intermittent connection using a modem and the voice telephone network.

When intermittent, low-volume data transfers are needed, modems and analog dialed telephone lines provide low capacity and dedicated switched connections. This topic describes the pros and cons of using analog dialup connection options, and identifies the types of business scenarios that benefit most from this type of option.

Traditional telephony uses a copper cable, called the local loop, to connect the telephone handset in the subscriber premises to the CO. The signal on the local loop during a call is a continuously varying electronic signal that is a translation of the subscriber voice, analog.

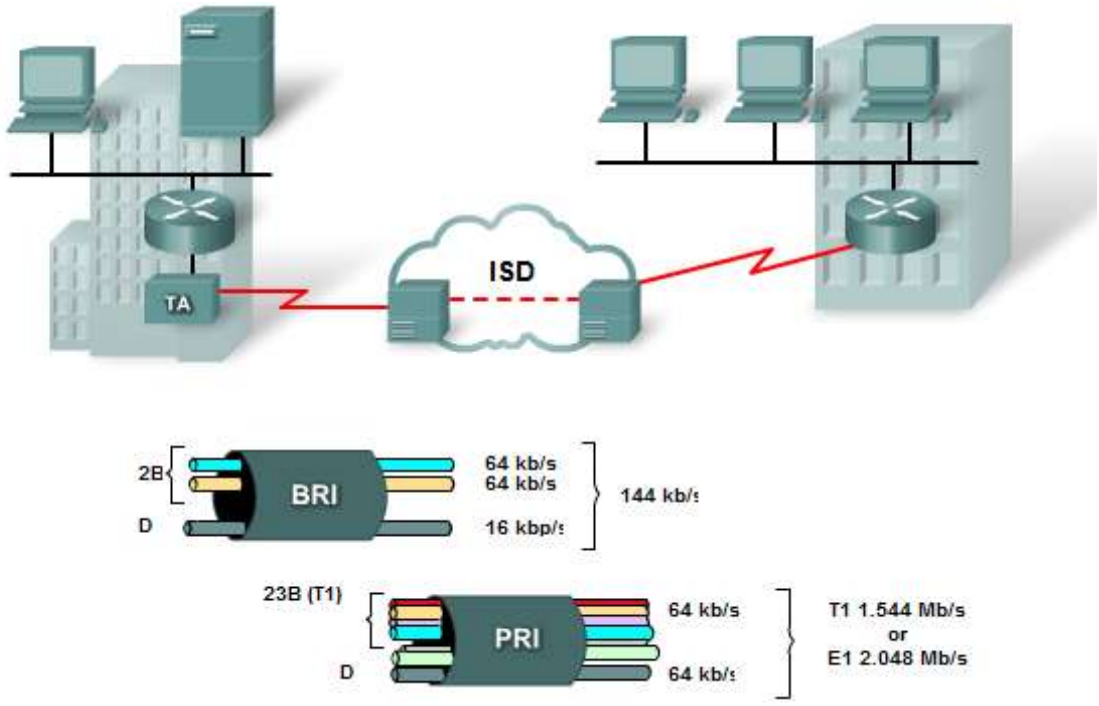
Traditional local loops can transport binary computer data through the voice telephone network using a modem. The modem modulates the binary data into an analog signal at the source and demodulates the

analog signal to binary data at the destination. The physical characteristics of the local loop and its connection to the PSTN limit the rate of the signal to less than 56 kb/s.

For small businesses, these relatively low-speed dialup connections are adequate for the exchange of sales figures, prices, routine reports, and e-mail. Using automatic dialup at night or on weekends for large file transfers and data backup can take advantage of lower off-peak tariffs (line charges). Tariffs are based on the distance between the endpoints, time of day, and the duration of the call.

The advantages of modem and analog lines are simplicity, availability, and low implementation cost. The disadvantages are the low data rates and a relatively long connection time. The dedicated circuit has little delay or jitter for point-to-point traffic, but voice or video traffic does not operate adequately at these low bit rates.

Integrated Services Digital Network



Integrated Services Digital Network (ISDN) is a circuit-switching technology that enables the local loop of a PSTN to carry digital signals, resulting in higher capacity switched connections. ISDN changes the internal connections of the PSTN from carrying analog signals to time-division multiplexed (TDM) digital signals. TDM allows two or more signals or bit streams to be transferred as subchannels in one communication channel. The signals appear to transfer simultaneously, but physically are taking turns on the channel. A data block of subchannel 1 is transmitted during timeslot 1, subchannel 2 during timeslot 2, and so on. One TDM frame consists of one timeslot per subchannel.

ISDN turns the local loop into a TDM digital connection. This change enables the local loop to carry digital signals that result in higher capacity switched connections. The connection uses 64 kb/s bearer channels (B) for carrying voice or data and a signaling, delta channel (D) for call setup and other purposes.

There are two types of ISDN interfaces:

- **Basic Rate Interface (BRI)**-ISDN is intended for the home and small enterprise and provides two 64 kb/s B channels and a 16 kb/s D channel. The BRI D channel is designed for control and often underused, because it has only two B channels to control. Therefore, some providers allow the D channel to carry data at low bit rates, such as X.25 connections at 9.6 kb/s.
- **Primary Rate Interface (PRI)**-ISDN is also available for larger installations. PRI delivers 23 B channels with 64 kb/s and one D channel with 64 kb/s in North America, for a total bit rate of up to 1.544 Mb/s. This includes some additional overhead for synchronization. In Europe, Australia, and other parts of the world, ISDN PRI provides 30 B channels and one D channel, for a total bit rate of up to 2.048 Mb/s, including synchronization overhead. In North America, PRI corresponds to a T1 connection. The rate of international PRI corresponds to an E1 or J1 connection.

For small WANs, the BRI ISDN can provide an ideal connection mechanism. BRI has a call setup time that is less than a second, and the 64 kb/s B channel provides greater capacity than an analog modem link. If greater capacity is required, a second B channel can be activated to provide a total of 128 kb/s. Although inadequate for video, this permits several simultaneous voice conversations in addition to data traffic.

Another common application of ISDN is to provide additional capacity as needed on a leased line connection. The leased line is sized to carry average traffic loads while ISDN is added during peak demand periods. ISDN is also used as a backup if the leased line fails. ISDN tariffs are based on a per-B channel basis and are similar to those of analog voice connections.

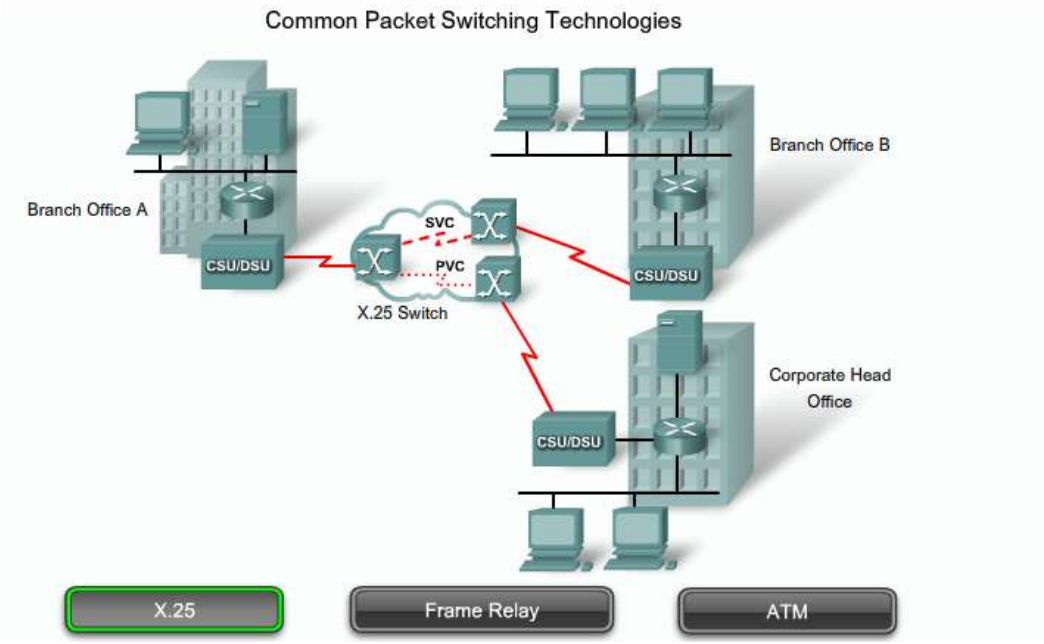
With PRI ISDN, multiple B channels can be connected between two endpoints. This allows for videoconferencing and high-bandwidth data connections with no latency or jitter. However, multiple connections can be very expensive over long distances.

Note: Although ISDN is still an important technology for telephone service provider networks, it is declining in popularity as an Internet connection option with the introduction of high-speed DSL and other broadband services.

1.3.4 Packet Switched Connection Options

Common Packet Switching WAN Technologies

The most common packet-switching technologies used in today's enterprise WAN networks include Frame Relay, ATM, and legacy X.25.



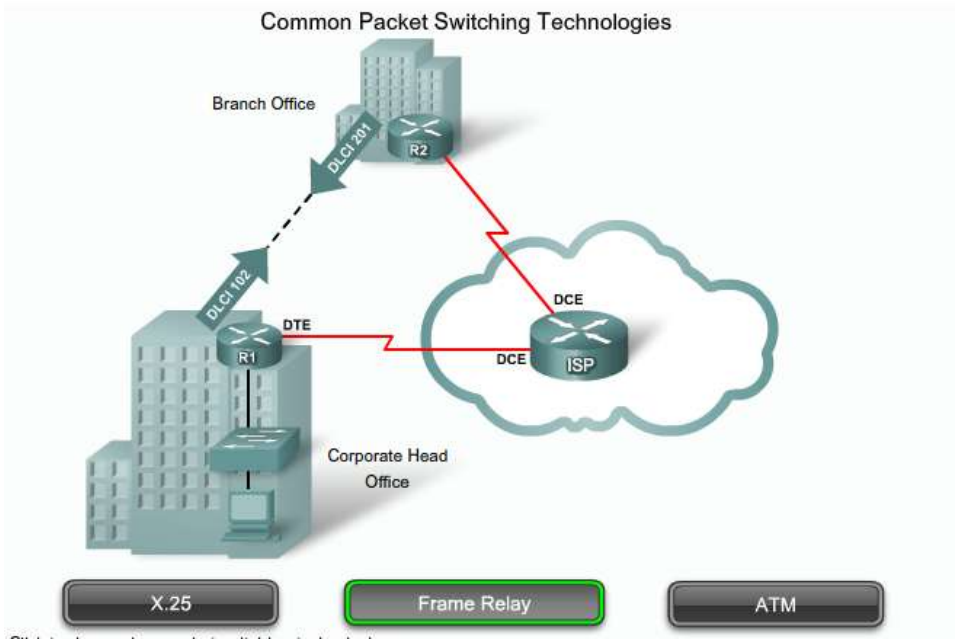
X.25

X.25 is a legacy Network layer protocol that provides subscribers with a network address. Virtual circuits can be established through the network with call request packets to the target address. The resulting SVC is identified by a channel number. Data packets labeled with the channel number are delivered to the corresponding address. Multiple channels can be active on a single connection.

Typical X.25 applications are point-of-sale card readers. These readers use X.25 in dialup mode to validate transactions on a central computer. For these applications, the low bandwidth and high latency are not a concern, and the low cost makes X.25 affordable.

X.25 link speeds vary from 2400 b/s up to 2 Mb/s. However, public networks are usually low capacity with speeds rarely exceeding above 64 kb/s.

X.25 networks are now in dramatic decline being replaced by newer Layer 2 technologies such as Frame Relay, ATM, and ADSL. However, they are still in use in many portions of the developing world, where there is limited access to newer technologies.

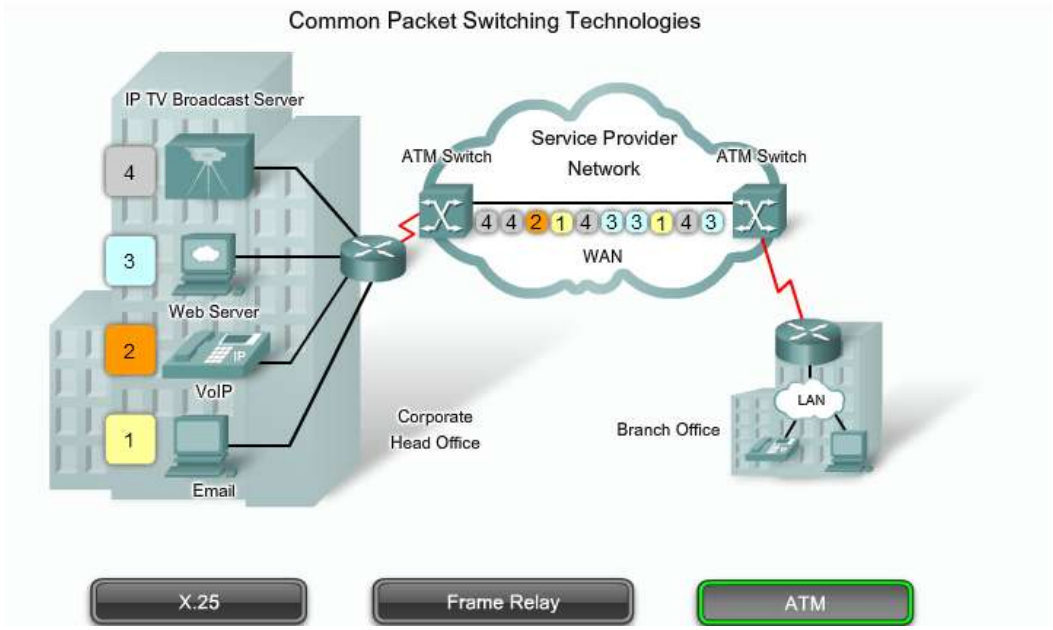


Frame Relay

Although the network layout appears similar to X.25, Frame Relay differs from X.25 in several ways. Most importantly, it is a much simpler protocol that works at the Data Link layer rather than the Network layer. Frame Relay implements no error or flow control. The simplified handling of frames leads to reduced latency, and measures taken to avoid frame build-up at intermediate switches help reduce jitter. Frame Relay offers data rates up to 4 Mb/s, with some providers offering even higher rates.

Frame Relay VCs are uniquely identified by a DLCI, which ensures bidirectional communication from one DTE device to another. Most Frame Relay connections are PVCs rather than SVCs.

Frame Relay provides permanent, shared, medium-bandwidth connectivity that carries both voice and data traffic. Frame Relay is ideal for connecting enterprise LANs. The router on the LAN needs only a single interface, even when multiple VCs are used. The short-leased line to the Frame Relay network edge allows cost-effective connections between widely scattered LANs.



ATM

Asynchronous Transfer Mode (ATM) technology is capable of transferring voice, video, and data through private and public networks. It is built on a cell-based architecture rather than on a frame-based architecture. ATM cells are always a fixed length of 53 bytes. The ATM cell contains a 5 byte ATM header followed by 48 bytes of ATM payload. Small, fixed-length cells are well suited for carrying voice and video traffic because this traffic is intolerant of delay. Video and voice traffic do not have to wait for a larger data packet to be transmitted.

The 53 byte ATM cell is less efficient than the bigger frames and packets of Frame Relay and X.25. Furthermore, the ATM cell has at least 5 bytes of overhead for each 48-byte payload. When the cell is carrying segmented Network layer packets, the overhead is higher because the ATM switch must be able to reassemble the packets at the destination. A typical ATM line needs almost 20 percent greater bandwidth than Frame Relay to carry the same volume of Network layer data.

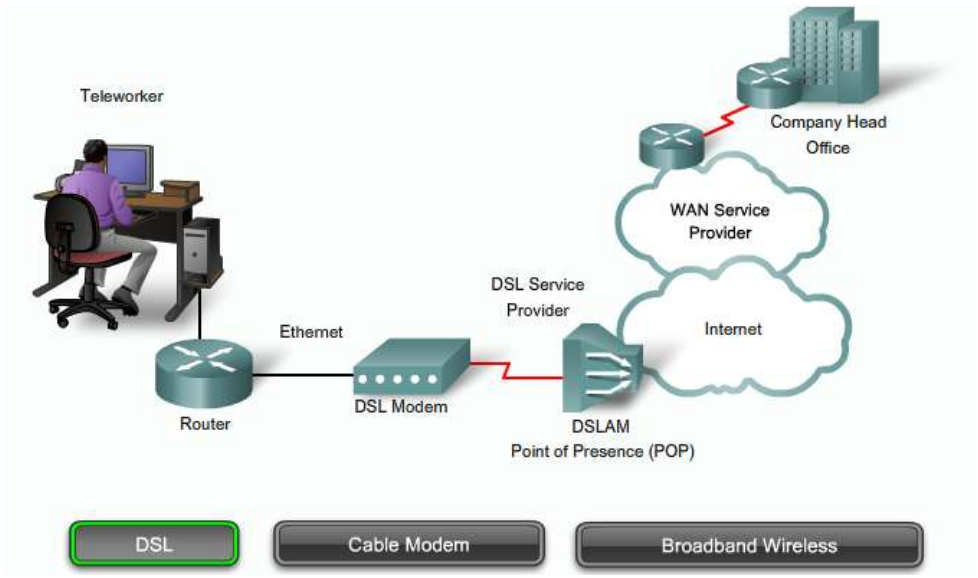
ATM was designed to be extremely scalable and can support link speeds of T1/E1 to OC-12 (622 Mb/s) and higher.

ATM offers both PVCs and SVCs, although PVCs are more common with WANs. And as with other shared technologies, ATM allows multiple VCs on a single leased-line connection to the network edge.

1.3.5 Internet Connection Options

Broadband Services

Broadband connection options are typically used to connect telecommuting employees to a corporate site over the Internet. These options include cable, DSL, and wireless.

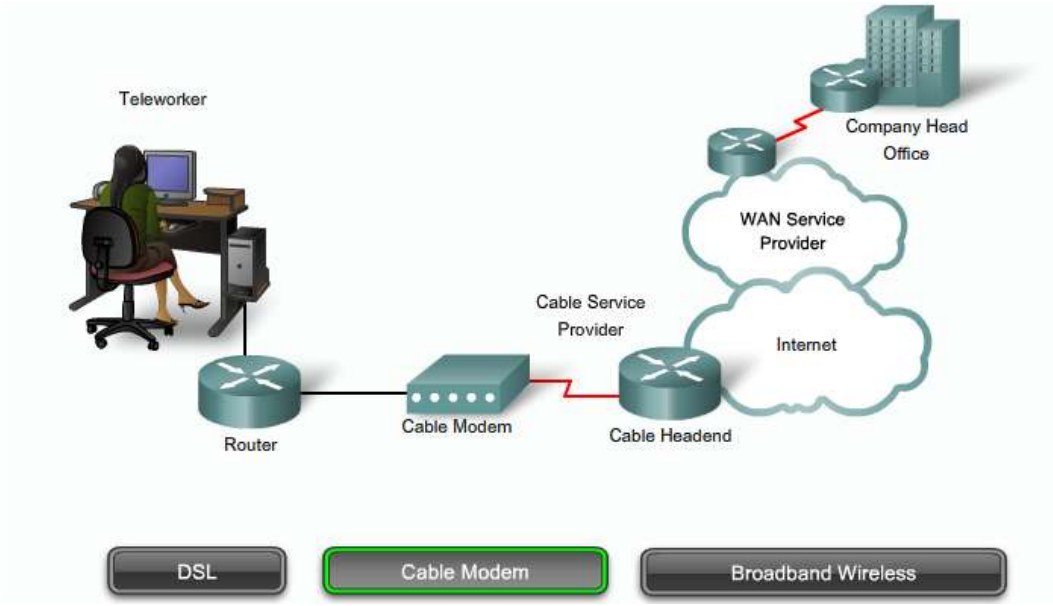


DSL

DSL technology is an always-on connection technology that uses existing twisted-pair telephone lines to transport high-bandwidth data, and provides IP services to subscribers. A DSL modem converts an Ethernet signal from the user device to a DSL signal, which is transmitted to the central office.

Multiple DSL subscriber lines are multiplexed into a single, high-capacity link using a DSL access multiplexer (DSLAM) at the provider location. DSLAMs incorporate TDM technology to aggregate many subscriber lines into a single medium, generally a T3 (DS3) connection. Current DSL technologies use sophisticated coding and modulation techniques to achieve data rates of up to 8.192 Mb/s.

There is a wide variety of DSL types, standards, and emerging standards. DSL is now a popular choice for enterprise IT departments to support home workers. Generally, a subscriber cannot choose to connect to an enterprise network directly, but must first connect to an ISP, and then an IP connection is made through the Internet to the enterprise. Security risks are incurred in this process, but can be mediated with security measures.

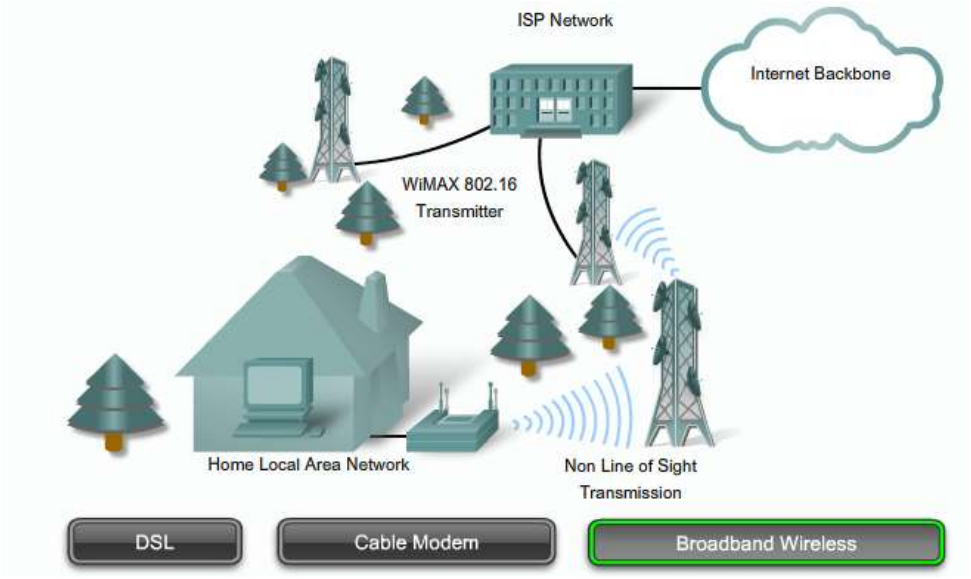


Cable Modem

Coaxial cable is widely used in urban areas to distribute television signals. Network access is available from some cable television networks. This allows for greater bandwidth than the conventional telephone local loop.

Cable modems provide an always-on connection and a simple installation. A subscriber connects a computer or LAN router to the cable modem, which translates the digital signals into the broadband frequencies used for transmitting on a cable television network. The local cable TV office, which is called the cable headend, contains the computer system and databases needed to provide Internet access. The most important component located at the headend is the cable modem termination system (CMTS), which sends and receives digital cable modem signals on a cable network and is necessary for providing Internet services to cable subscribers.

Cable modem subscribers must use the ISP associated with the service provider. All the local subscribers share the same cable bandwidth. As more users join the service, available bandwidth may be below the expected rate.



Broadband Wireless

Wireless technology uses the unlicensed radio spectrum to send and receive data. The unlicensed spectrum is accessible to anyone who has a wireless router and wireless technology in the device they are using.

Until recently, one limitation of wireless access has been the need to be within the local transmission range (typically less than 100 feet) of a wireless router or a wireless modem that has a wired connection to the Internet. The following new developments in broadband wireless technology are changing this situation:

Municipal WiFi-Many cities have begun setting up municipal wireless networks. Some of these networks provide high-speed Internet access for free or for substantially less than the price of other broadband services. Others are for city use only, allowing police and fire departments and other city employees to do certain aspects of their jobs remotely. To connect to a municipal WiFi, a subscriber typically needs a wireless modem, which provides a stronger radio and directional antenna than conventional wireless adapters. Most service providers provide the necessary equipment for free or for a fee, much like they do with DSL or cable modems.

WiMAX-Worldwide Interoperability for Microwave Access (WiMAX) is a new technology that is just beginning to come into use. It is described in the IEEE standard 802.16. WiMAX provides high-speed broadband service with wireless access and provides broad coverage like a cell phone network rather than through small WiFi hotspots. WiMAX operates in a similar way to WiFi, but at higher speeds, over greater distances, and for a greater number of users. It uses a network of WiMAX towers that are similar to cell phone towers. To access a WiMAX network, subscribers must subscribe to an ISP with a WiMAX tower within 10 miles of their location. They also need a WiMAX-enabled computer and a special encryption code to get access to the base station.

Satellite Internet-Typically used by rural users where cable and DSL are not available. A satellite dish provides two-way (upload and download) data communications. The upload speed is about one-tenth of the 500 kb/s download speed. Cable and DSL have higher download speeds, but satellite systems are about 10 times faster than an analog modem. To access satellite Internet services, subscribers need a satellite dish, two modems (uplink and downlink), and coaxial cables between the dish and the modem.

DSL, cable, and wireless broadband services are described in more detail in Chapter 6, "Teleworker Services."

1.3.5 Internet Connection Options

VPN Technology

Security risks are incurred when a teleworker or remote office uses broadband services to access the corporate WAN over the Internet. To address security concerns, broadband services provide capabilities for using Virtual Private Network (VPN) connections to a VPN server, which is typically located at the corporate site.

A VPN is an encrypted connection between private networks over a public network such as the Internet. Instead of using a dedicated Layer 2 connection such as a leased line, a VPN uses virtual connections called VPN tunnels, which are routed through the Internet from the private network of the company to the remote site or employee host.

VPN Benefits

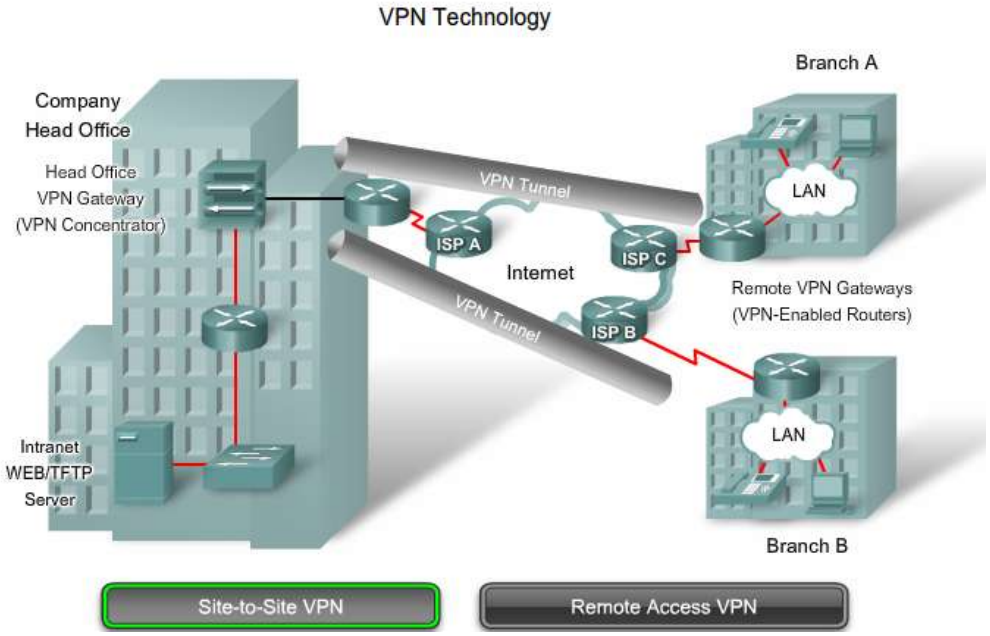
Benefits of VPN include the following:

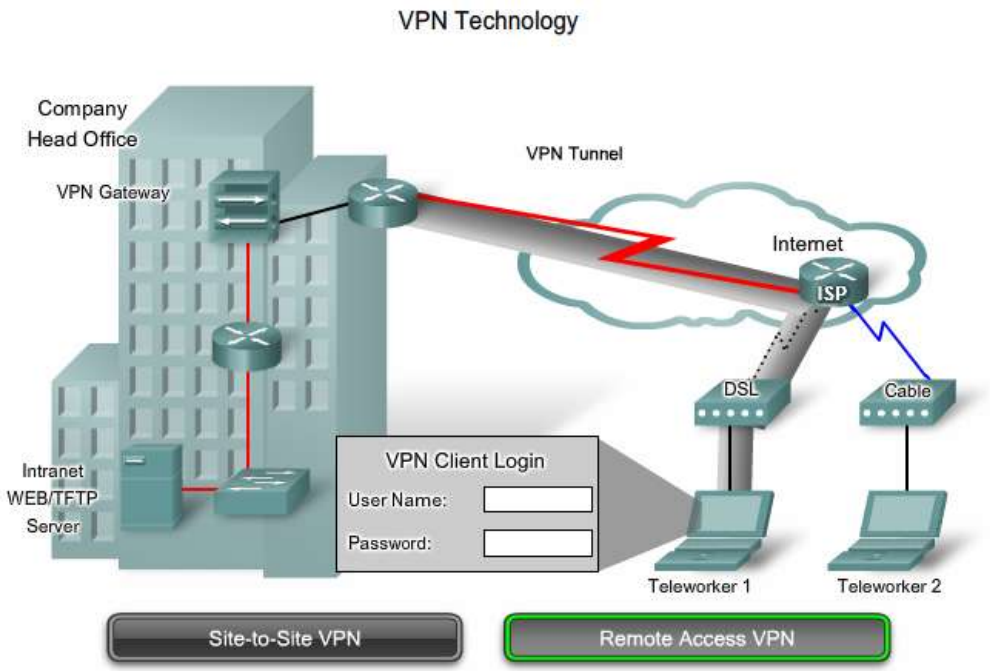
- Cost savings-VPNs enable organizations to use the global Internet to connect remote offices and remote users to the main corporate site, thus eliminating expensive dedicated WAN links and modem banks.
- Security-VPNs provide the highest level of security by using advanced encryption and authentication protocols that protect data from unauthorized access.
- Scalability-Because VPNs use the Internet infrastructure within ISPs and devices, it is easy to add new users. Corporations are able to add large amounts of capacity without adding significant infrastructure.
- Compatibility with broadband technology-VPN technology is supported by broadband service providers such as DSL and cable, so mobile workers and telecommuters can take advantage of their home high-speed Internet service to access their corporate networks. Business-grade, high-speed broadband connections can also provide a cost-effective solution for connecting remote offices.

Types of VPN Access

There are two types of VPN access:

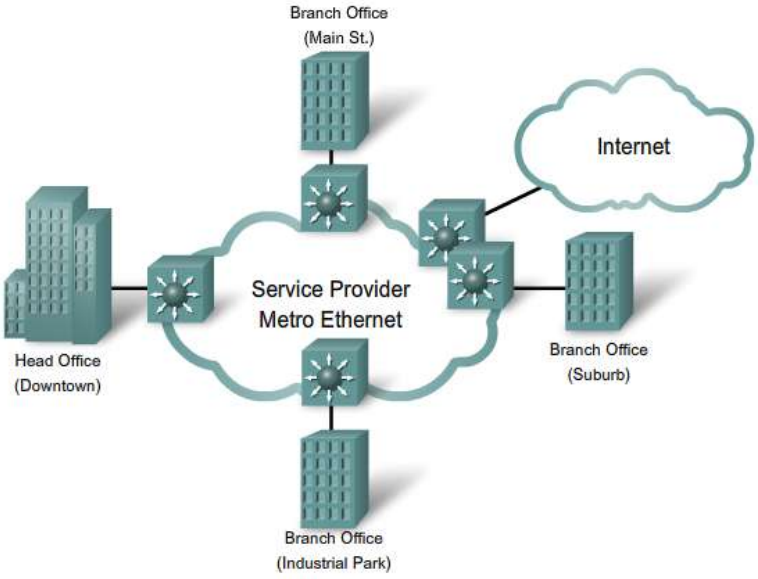
- **Site-to-site VPNs**-Site-to-site VPNs connect entire networks to each other, for example, they can connect a branch office network to a company headquarters network, as shown in the figure. Each site is equipped with a VPN gateway, such as a router, firewall, VPN concentrator, or security appliance. In the figure, a remote branch office uses a site-to-site-VPN to connect with the corporate head office.
- **Remote-access VPNs**-Remote-access VPNs enable individual hosts, such as telecommuters, mobile users, and extranet consumers, to access a company network securely over the Internet. Each host typically has VPN client software loaded or uses a web-based client.





1.3.5 Internet Connection Options

Metro Ethernet



Metro Ethernet is a rapidly maturing networking technology that broadens Ethernet to the public networks run by telecommunications companies. IP-aware Ethernet switches enable service providers to offer enterprises converged voice, data, and video services such as IP telephony, video streaming,

imaging, and data storage. By extending Ethernet to the metropolitan area, companies can provide their remote offices with reliable access to applications and data on the corporate headquarters LAN.

Benefits of Metro Ethernet include:

- **Reduced expenses and administration**-Metro Ethernet provides a switched, high-bandwidth Layer 2 network capable of managing data, voice, and video all on the same infrastructure. This characteristic increases bandwidth and eliminates expensive conversions to ATM and Frame Relay. The technology enables businesses to inexpensively connect numerous sites in a metropolitan area to each other and to the Internet.
- **Easy integration with existing networks**-Metro Ethernet connects easily to existing Ethernet LANs, reducing installation costs and time.
- **Enhanced business productivity**-Metro Ethernet enables businesses to take advantage of productivity-enhancing IP applications that are difficult to implement on TDM or Frame Relay networks, such as hosted IP communications, VoIP, and streaming and broadcast video.

1.3.5 Internet Connection Options

Choosing a WAN Link Connection

Now that we have looked at the variety of WAN connection options, how do you choose the best technology to meet the requirements of a specific business? The figure compares the advantages and disadvantages of the WAN connection options that we have discussed in this chapter. This information is a good start. In addition, to help in the decision-making process, here are some questions to ask yourself when choosing a WAN connection option.

What is the purpose of the WAN?

Do you want to connect local branches in the same city area, connect remote branches, connect to a single branch, connect to customers, connect to business partners, or some combination of these? If the WAN is for providing authorized customers or business partners limited access to the company intranet, what is the best option?

What is the geographic scope?

Is it local, regional, global, one-to-one (single branch), one-to-many branches, many-to-many (distributed)? Depending on the range, some WAN connection options may be better than others.

What are the traffic requirements?

Traffic requirements to consider include:

- Traffic type (data only, VoIP, video, large files, streaming files) determines the quality and performance requirements. For example, if you are sending a lot of voice or streaming video traffic, ATM may be the best choice.
- Traffic volumes depending on type (voice, video, or data) for each destination determine the bandwidth capacity required for the WAN connection to the ISP.
- Quality requirements may limit your choices. If your traffic is highly sensitive to latency and jitter, you can eliminate any WAN connection options that cannot provide the required quality.
- Security requirements (data integrity, confidentiality, and security) is an important factor if the traffic is of a highly confidential nature or if provides essential services, such as emergency response.

Should the WAN use a private or public infrastructure?

A private infrastructure offers the best security and confidentiality, whereas the public Internet infrastructure offers the most flexibility and lowest ongoing expense. Your choice depends on the purpose of the WAN, the types of traffic it carries, and available operating budget. For example, if the purpose is to provide a nearby branch with high-speed secure services, a private dedicated or switched connection may be best. If the purpose is to connect many remote offices, an public WAN using the Internet may be the best choice. For distributed operations, a combination of options may be the solution.

For a private WAN, should it be dedicated or switched?

Real-time, high-volume transactions have special requirements that could favor a dedicated line, such as traffic flowing between the data center and the corporate head office. If you are connecting to a local single branch, you could use a dedicated leased line. However, that option would become very expensive for a WAN connecting multiple offices. In that case, a switched connection might be better.

For a public WAN, what type of VPN access do you need?

If the purpose of the WAN is to connect a remote office, a site-to-site VPN may be the best choice. To connect teleworkers or customers, remote-access VPNs are a better option. If the WAN is serving a mixture of remote offices, teleworkers, and authorized customers, such as a global company with distributed operations, a combination of VPN options may be required.

Which connection options are available locally?

In some areas, not all WAN connection options are available. In this case, your selection process is simplified, although the resulting WAN may provide less than optimal performance. For example, in a rural or remote area, the only option may be broadband satellite Internet access.

What is the cost of the available connection options?

Depending on the option you choose, the WAN can be a significant ongoing expense. The cost of a particular option must be weighed against how well it meets your other requirements. For example, a dedicated leased line is the most expensive option, but the expense may be justified if it is critical to ensure secure transmission of high volumes of real-time data. For less demanding applications, a cheaper switched or Internet connection option may be more suitable.

As you can see, there are many important factors to consider when choosing an appropriate WAN connection. Following the guidelines described above, as well as those described by the Cisco Enterprise Architecture, you should now be able to choose an appropriate WAN connection to meet the requirements of different business scenarios.

Choosing a WAN Link Connection

Option	Description	Advantages	Disadvantages	Sample protocols used
Leased line	Point-to-Point connection between two computers or Local Area Networks (LANs).	Most secure	Expensive	PPP, HDLC, SDLC, HNAS
Circuit switching	A dedicated circuit path is created between endpoints. Best example is dialup connections.	Less expensive	Call setup	PPP, ISDN
Packet switching	Devices transport packets via a shared single point-to-point or point-to-multipoint link across a carrier interwork. Variable length packets are transmitted over permanent virtual circuits (PVCs) or switched virtual circuits (SVCs).	Widely supported and less expensive than Leased line	Shared media across link	X.25, Frame Relay

Choosing a WAN Link Connection

Option	Description	Advantages	Disadvantages	Sample protocols used
	permanent virtual circuits (PVCs) or switched virtual circuits (SVCs).			
Cell relay	Similar to packet switching, but uses fixed length cells instead of variable length packets. Data is divided into fixed-length cells and then transported across virtual circuits.	Best for simulated use of voice and data	Overhead can be considerable	ATM
Internet	Connectionless packet switching using the Internet as the WAN infrastructure, uses network addressing to deliver packets. Because of security issues, VPN technology must be used.	Least expensive Globally available	Least secure	VPN, DSL, Cable-Modem, Wireless