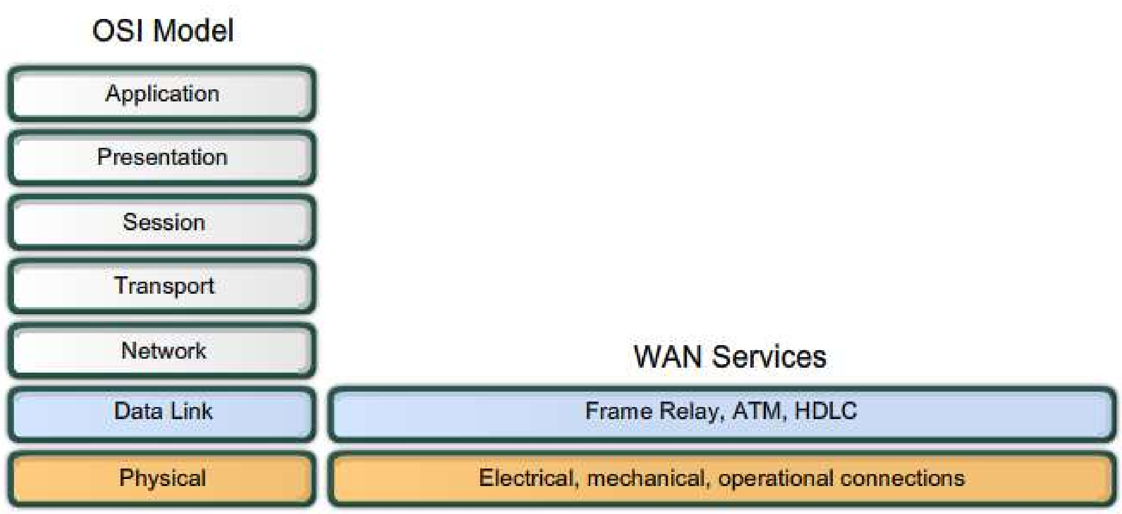
1.2 WANs and the OSI Model

As described in relation to the OSI reference model, WAN operations focus primarily on Layer 1 and Layer 2. WAN access standards typically describe both Physical layer delivery methods and Data Link layer requirements, including physical addressing, flow control, and encapsulation. WAN access standards are defined and managed by a number of recognized authorities, including the International Organization for Standardization (ISO), the Telecommunication Industry Association (TIA), and the Electronic Industries Alliance (EIA).

The Physical layer (OSI Layer 1) protocols describe how to provide electrical, mechanical, operational, and functional connections to the services of a communications service provider.

The Data Link layer (OSI Layer 2) protocols define how data is encapsulated for transmission toward a remote location and the mechanisms for transferring the resulting frames. A variety of different technologies are used, such as Frame Relay and ATM. Some of these protocols use the same basic framing mechanism, High-Level Data Link Control (HDLC), an ISO standard, or one of its subsets or variants.



WAN Physical Layer Terminology

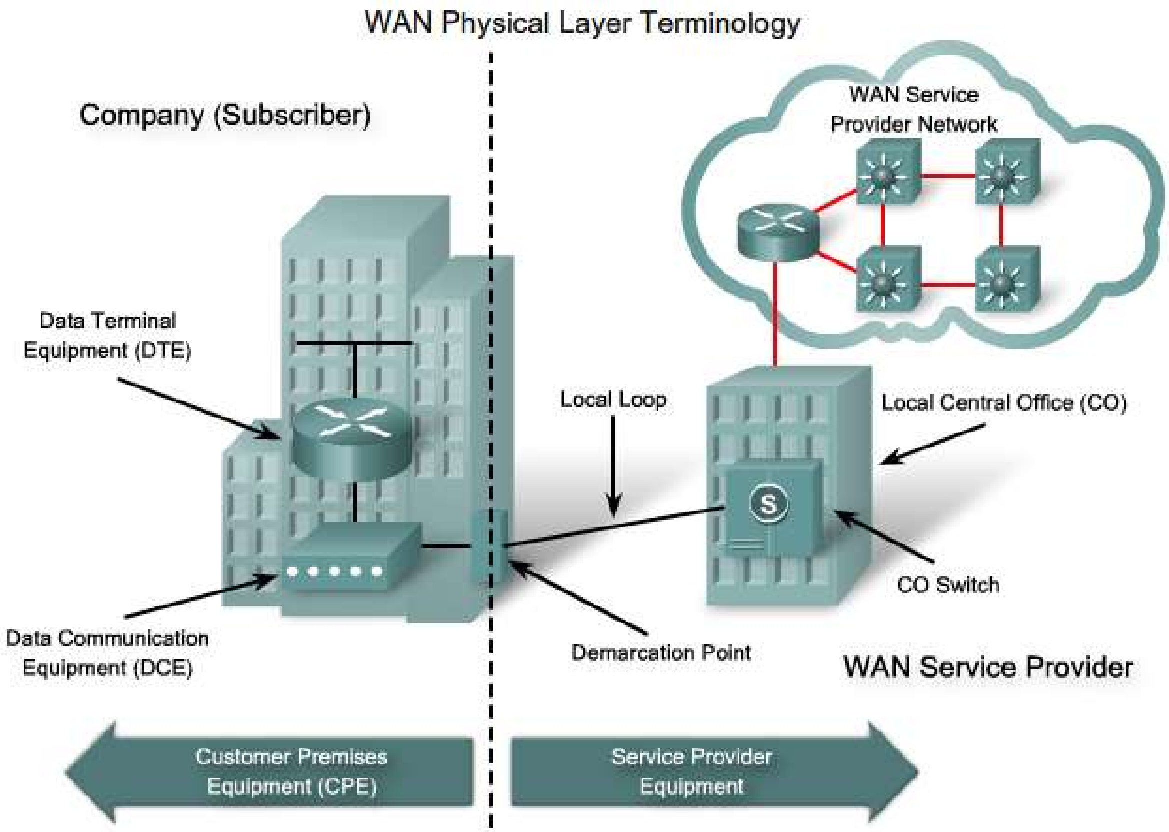
One primary difference between a WAN and a LAN is that a company or organization must subscribe to an outside WAN service provider to use WAN carrier network services. A WAN uses data links provided by carrier services to access the Internet and connect the locations of an organization to each other, to locations of other organizations, to external services, and to remote users. The WAN access Physical layer describes the physical connection between the company network and the service provider network. The figure illustrates the terminology commonly used to describe physical WAN connections, including:

Customer Premises Equipment (CPE)-The devices and inside wiring located at the premises of the subscriber and connected with a telecommunication channel of a carrier. The subscriber either owns the CPE or leases the CPE from the service provider. A subscriber, in this context, is a company that arranges for WAN services from a service provider or carrier.

Data Communications Equipment (DCE)-Also called data circuit-terminating equipment, the DCE consists of devices that put data on the local loop. The DCE primarily provides an interface to connect subscribers to a communication link on the WAN cloud.

Data Terminal Equipment (DTE)-The customer devices that pass the data from a customer network or host computer for transmission over the WAN. The DTE connects to the local loop through the DCE.
Demarcation Point-A point established in a building or complex to separate customer equipment from service provider equipment. Physically, the demarcation point is the cabling junction box, located on the customer premises, that connects the CPE wiring to the local loop. It is usually placed for easy access by a technician. The demarcation point is the place where the responsibility for the connection changes from the user to the service provider. This is very important because when problems arise, it is necessary to determine whether the user or the service provider is responsible for troubleshooting or repair.

Local Loop-The copper or fiber telephone cable that connects the CPE at the subscriber site to the CO of the service provider. The local loop is also sometimes called the "last-mile."
Central Office (CO)-A local service provider facility or building where local telephone cables link to long-haul, all-digital, fiber-optic communications lines through a system of switches and other equipment.



WAN Devices

WANs use numerous types of devices that are specific to WAN environments, including:

- **Modem**- Modulates an analog carrier signal to encode digital information, and also demodulates the carrier signal to decode the transmitted information. A voiceband modem converts the digital signals produced by a computer into voice frequencies that can be transmitted over the analog lines of the public telephone network. On the other side of the connection, another modem converts the sounds back into a digital signal for input to a computer or network connection. Faster modems, such as cable modems and DSL modems, transmit using higher broadband frequencies.

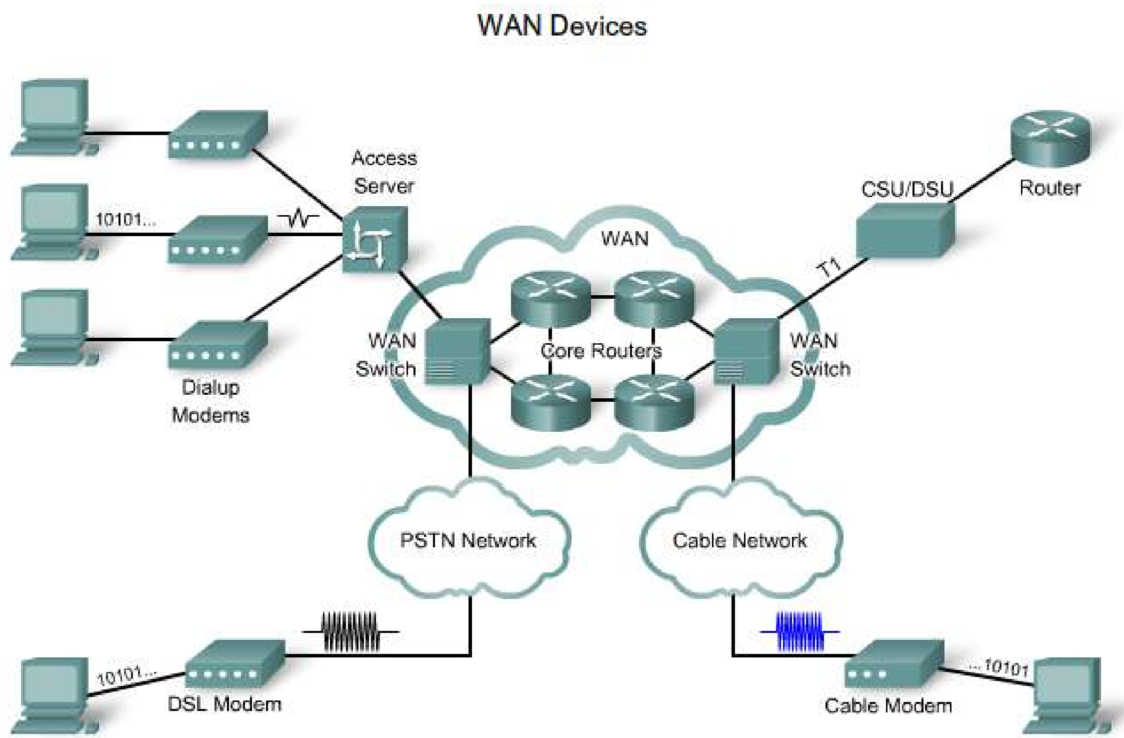
- **CSU/DSU**- Digital lines, such as T1 or T3 carrier lines, require a channel service unit (CSU) and a data service unit (DSU). The two are often combined into a single piece of equipment, called the CSU/DSU. The CSU provides termination for the digital signal and ensures connection integrity through error correction and line monitoring. The DSU converts the T-carrier line frames into frames that the LAN can interpret and vice versa.

- **Access server**- Concentrates dial-in and dial-out user communications. An access server may have a mixture of analog and digital interfaces and support hundreds of simultaneous users.
- **WAN switch**-A multiport internetworking device used in carrier networks. These devices typically switch traffic such as Frame Relay, ATM, or X.25, and operate at the Data Link layer of the OSI reference model. Public switched telephone network (PSTN) switches may also be used

within the cloud for circuit-switched connections like Integrated Services Digital Network (ISDN) or analog dialup.

- **Router**- Provides internetworking and WAN access interface ports that are used to connect to the service provider network. These interfaces may be serial connections or other WAN interfaces. With some types of WAN interfaces, an external device such as a DSU/CSU or modem (analog, cable, or DSL) is required to connect the router to the local point of presence (POP) of the service provider.

- **Core router**- A router that resides within the middle or backbone of the WAN rather than at its periphery. To fulfill this role, a router must be able to support multiple telecommunications interfaces of the highest speed in use in the WAN core, and it must be able to forward IP packets at full speed on all of those interfaces. The router must also support the routing protocols being used in the core.



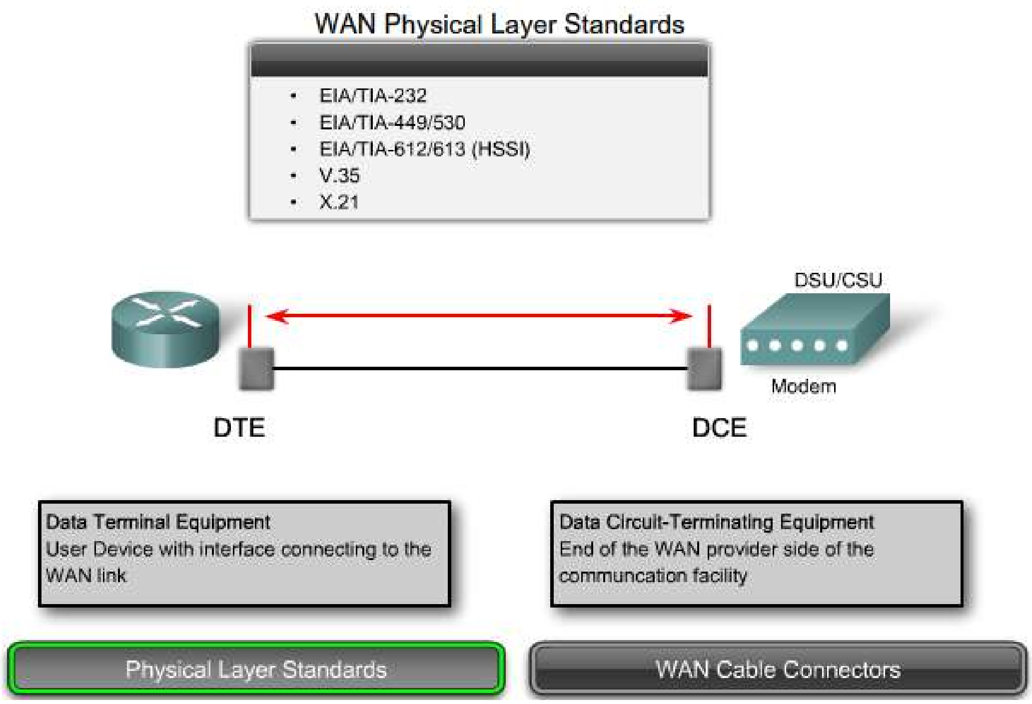
WAN Physical Layer Standards

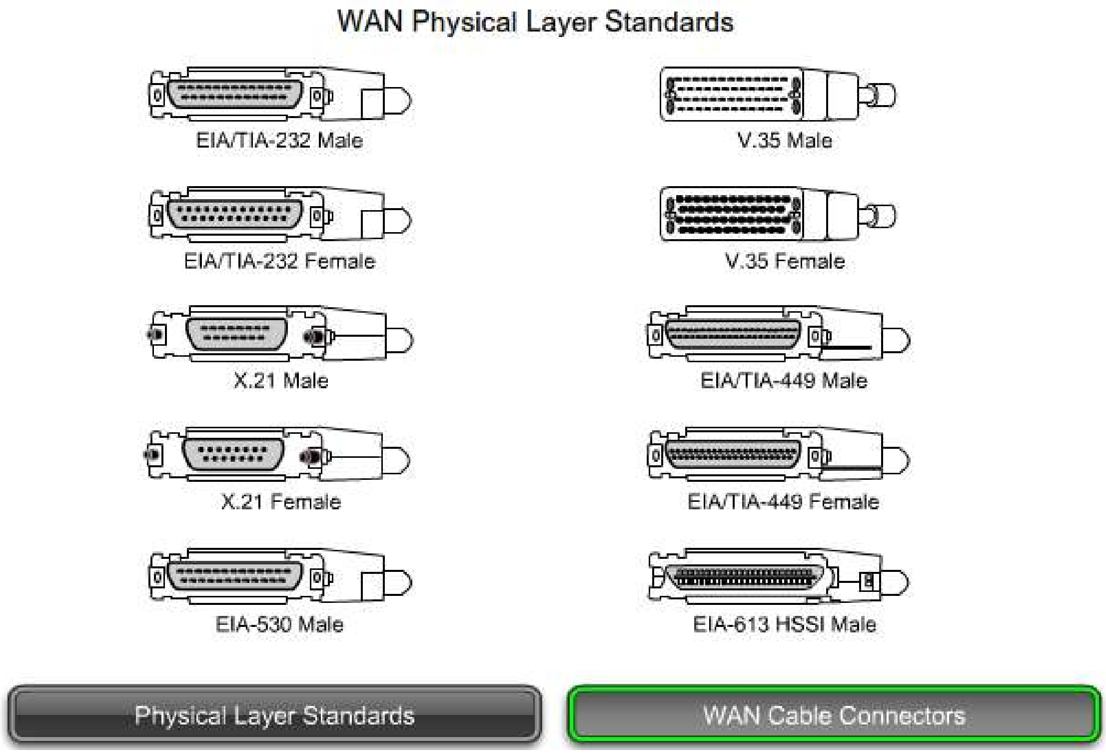
WAN Physical layer protocols describe how to provide electrical, mechanical, operational, and functional connections for WAN services. The WAN Physical layer also describes the interface between the DTE and the DCE. The DTE/DCE interface uses various Physical layer protocols, including:

- **EIA/TIA-232**-This protocol allows signal speeds of up to 64 kb/s on a 25-pin D-connector over short distances. It was formerly known as RS-232. The ITU-T V.24 specification is effectively the same.

- **EIA/TIA-449/530**-This protocol is a faster (up to 2 Mb/s) version of EIA/TIA-232. It uses a 36-pin D-connector and is capable of longer cable runs. There are several versions. This standard is also known as RS422 and RS-423.
- **EIA/TIA-612/613**-This standard describes the High-Speed Serial Interface (HSSI) protocol, which provides access to services up to 52 Mb/s on a 60-pin D-connector.
- **V.35**-This is the ITU-T standard for synchronous communications between a network access device and a packet network. Originally specified to support data rates of 48 kb/s, it now supports speeds of up to 2.048 Mb/s using a 34-pin rectangular connector.
- **X.21**-This protocol is an ITU-T standard for synchronous digital communications. It uses a 15-pin D-connector.

These protocols establish the codes and electrical parameters the devices use to communicate with each other. Choosing a protocol is largely determined by the service provider's method of facilitation.





Data Link Protocols

In addition to Physical layer devices, WANs require Data Link layer protocols to establish the link across the communication line from the sending to the receiving device. This topic describes the common data link protocols that are used in today's enterprise networks to implement WAN connections.

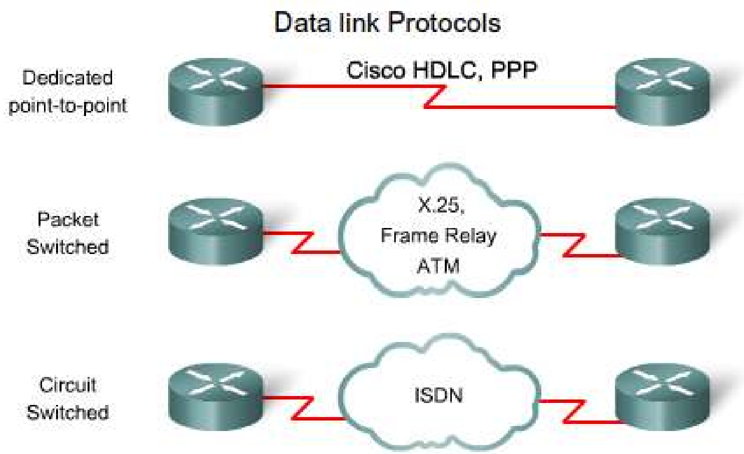
Data Link layer protocols define how data is encapsulated for transmission to remote sites and the mechanisms for transferring the resulting frames. A variety of different technologies, such as ISDN, Frame Relay, or ATM, are used. Many of these protocols use the same basic framing mechanism, HDLC, an ISO standard, or one of its subsets or variants. ATM is different from the others, because it uses small fixed-size cells of 53 bytes (48 bytes for data), unlike the other packet-switched technologies, which use variable-sized packets.

The most common WAN data-link protocols are:

- HDLC
- PPP
- Frame Relay
- ATM

ISDN and X.25 are older data-link protocols that are less frequently used today. However, ISDN is still covered in this course because of its use when provisioning VoIP network using PRI links. X.25 is mentioned to help explain the relevance of Frame Relay. As well, X.25 is still in use in developing countries where packet data networks (PDN) are used to transmit credit card and debit card transactions from retailers.

Note: Another Data Link layer protocol is the **Multiprotocol Label Switching (MPLS)** protocol. MPLS is increasingly being deployed by service providers to provide an economical solution to carry circuit-switched as well as packet-switched network traffic. It can operate over any existing infrastructure, such as IP, Frame Relay, ATM, or Ethernet. It sits between Layer 2 and Layer 3 and is sometimes referred to as a Layer 2.5 protocol. However, MPLS is beyond the scope of this course but is covered in the CCNP: Implementing Secure Converged Wide-area Networks.



Protocol	Usage
Link Access Procedure Balanced (LAPB)	X.25
Link Access Procedure D Channel (LAPD)	ISDN D channel
Link Access Procedure Frame (LAPF)	Frame Relay
High-Level Data Link Control (HDLC)	Cisco default
Point-to-Point Protocol (PPP)	Serial WAN switched connections

WAN Encapsulation

Data from the Network layer is passed to the Data Link layer for delivery on a physical link, which is normally point-to-point on a WAN connection. The Data Link layer builds a frame around the Network layer data so that the necessary checks and controls can be applied. Each WAN connection type uses a Layer 2 protocol to encapsulate a packet while it is crossing the WAN link. To ensure that the correct encapsulation protocol is used, the Layer 2 encapsulation type used for each router serial interface must be configured. The choice of encapsulation protocols depends on the WAN technology and the equipment. HDLC was first proposed in 1979 and for this reason, most framing protocols which were developed afterwards are based on it.

WAN Encapsulation

Network Data is encapsulated in an HDLC frame

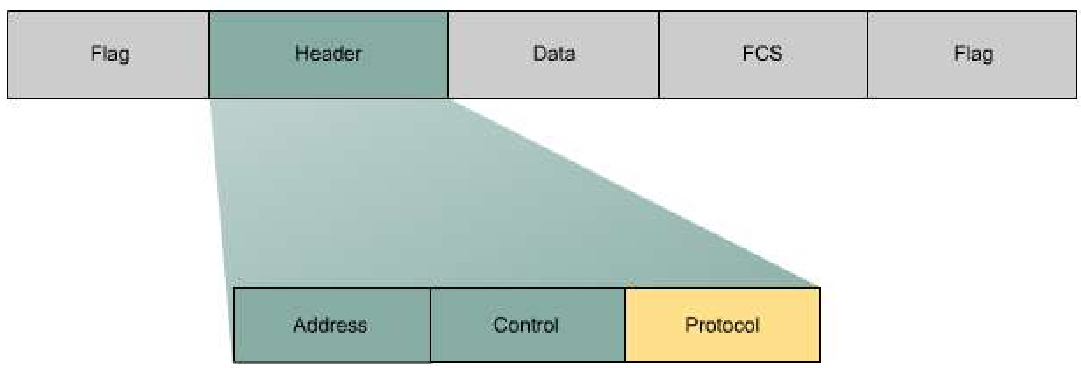
WAN Frame Encapsulation Formats

Examining the header portion of an HDLC frame will help identify common fields used by many WAN encapsulation protocols. The frame always starts and ends with an 8-bit flag field. The bit pattern is 01111110. The address field is not needed for WAN links, which are almost always point-to-point. The address field is still present and may be 1 or 2 bytes long. The control field is protocol dependent, but usually indicates whether the content of the data is control information or Network layer data. The control field is normally 1 byte.

Together the address and control fields are called the frame header. The encapsulated data follows the control field. Then a frame check sequence (FCS) uses the cyclic redundancy check (CRC) mechanism to establish a 2 or 4 byte field.

Several data-link protocols are used, including subsets and proprietary versions of HDLC. Both PPP and the Cisco version of HDLC have an extra field in the header to identify the Network layer protocol of the encapsulated data.

WAN Frame Encapsulation Formats



A WAN header address field is usually a broadcast address on a point-to-point link. The control field identifies the data portion as either information or control. The protocol field identifies the intended layer 3 protocol (e.g., IP, IPX).

Circuit Switching

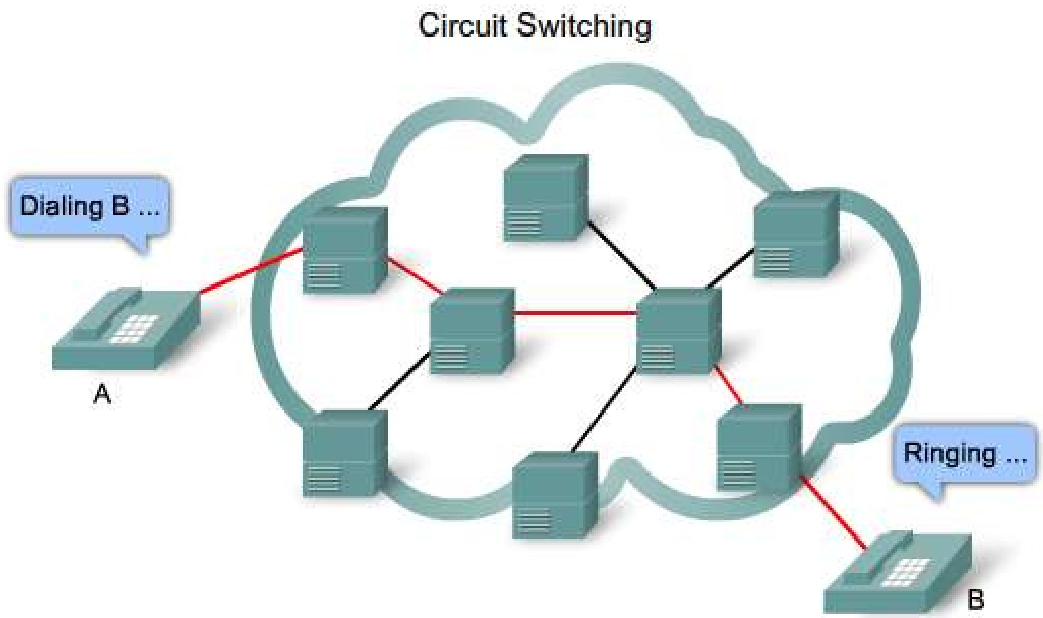
A circuit-switched network is one that establishes a dedicated circuit (or channel) between nodes and terminals before the users may communicate.

As an example, when a subscriber makes a telephone call, the dialed number is used to set switches in the exchanges along the route of the call so that there is a continuous circuit from the caller to the called party. Because of the switching operation used to establish the circuit, the telephone system is called a circuit-switched network. If the telephones are replaced with modems, then the switched circuit is able to carry computer data.

The internal path taken by the circuit between exchanges is shared by a number of conversations. Time-division multiplexing (TDM) gives each conversation a share of the connection in turn. TDM assures that a fixed capacity connection is made available to the subscriber.

If the circuit carries computer data, the usage of this fixed capacity may not be efficient. For example, if the circuit is used to access the Internet, there is a burst of activity on the circuit while a web page is transferred. This could be followed by no activity while the user reads the page, and then another burst of activity while the next page is transferred. This variation in usage between none and maximum is typical of computer network traffic. Because the subscriber has sole use of the fixed capacity allocation, switched circuits are generally an expensive way of moving data.

PSTN and ISDN are two types of circuit-switching technology that may be used to implement a WAN in an enterprise setting.



Packet Switching

In contrast to circuit switching, packet switching splits traffic data into packets that are routed over a shared network. Packet-switching networks do not require a circuit to be established, and they allow many pairs of nodes to communicate over the same channel.

The switches in a packet-switched network determine which link the packet must be sent on next from the addressing information in each packet. There are two approaches to this link determination, connectionless or connection-oriented.

Connectionless systems, such as the Internet, carry full addressing information in each packet. Each switch must evaluate the address to determine where to send the packet.
Connection-oriented systems predetermine the route for a packet, and each packet only has to carry an identifier. In the case of Frame Relay, these are called Data Link Connection Identifiers (DLCIs). The switch determines the onward route by looking up the identifier in tables held in memory. The set of entries in the tables identifies a particular route or circuit through the system. If this circuit is only physically in existence while a packet is traveling through it, it is called a virtual circuit (VC).

Because the internal links between the switches are shared between many users, the costs of packet switching are lower than those of circuit switching. Delays (latency) and variability of delay (jitter) are greater in packet-switched than in circuit-switched networks. This is because the links are shared, and packets must be entirely received at one switch before moving to the next. Despite the latency and jitter inherent in shared networks, modern technology allows satisfactory transport of voice and even video communications on these networks.

Server A is sending data to server B. As the packet traverses the provider network, it arrives at the second provider switch. The packet is added to the queue and forwarded after the other packets in the queue have been forwarded. Eventually, the packet reaches server B.

Virtual Circuits

Packet-switched networks may establish routes through the switches for particular end-to-end connections. These routes are called virtual circuits. A VC is a logical circuit created within a shared network between two network devices. Two types of VCs exist:

Permanent Virtual Circuit (PVC)-A permanently established virtual circuit that consists of one mode: data transfer. PVCs are used in situations in which data transfer between devices is constant. PVCs decrease the bandwidth use associated with establishing and terminating VCs, but they increase costs because of constant virtual circuit availability. PVCs are generally configured by the service provider when an order is placed for service.
Switched Virtual Circuit (SVC)-A VC that is dynamically established on demand and terminated when transmission is complete. Communication over an SVC consists of three phases: circuit establishment, data transfer, and circuit termination. The establishment phase involves creating the VC between the source and destination devices. Data transfer involves transmitting data between the devices over the VC, and the circuit termination phase involves tearing down the VC between the source and destination devices. SVCs are used in situations in which data transmission between devices is intermittent, largely to save costs. SVCs release the circuit when transmission is complete, which results in less expensive connection charges than those incurred by PVCs, which maintain constant virtual circuit availability.

Connecting to a Packet-Switched Network

To connect to a packet-switched network, a subscriber needs a local loop to the nearest location where the provider makes the service available. This is called the point-of-presence (POP) of the service. Normally this is a dedicated leased line. This line is much shorter than a leased line directly connected to the subscriber locations, and often carries several VCs. Because it is likely that not all the VCs require maximum demand simultaneously, the capacity of the leased line can be smaller than the sum of the individual VCs. Examples of packet- or cell-switched connections include:

- X.25
- Frame Relay
- ATM

Packet Switching