KEMENTERIAN PENDIDIKAN MALAYSIA

UTeM
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

FTMK
Fakulti Teknologi Maklumat dan Komunikasi

Chapter 8

by

Nazrulazhar Bahaman

nazrulazhar@utem.edu.my

WAN TECHNOLOGIES

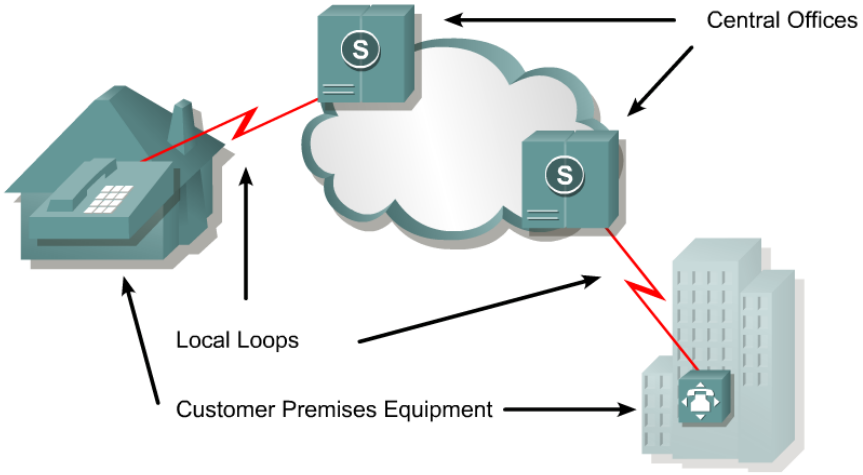
Objectives

- Identify the devices used in a WAN
- Classify the various WAN link options
- Differentiate between packet-switched and circuit-switched WAN technologies
- Describe DSL and cable modem connectivity basics
- Describe equipment involved in the implementation of various WAN services
- Compare and contrast WAN topologies and WAN design models.

What is a WAN?

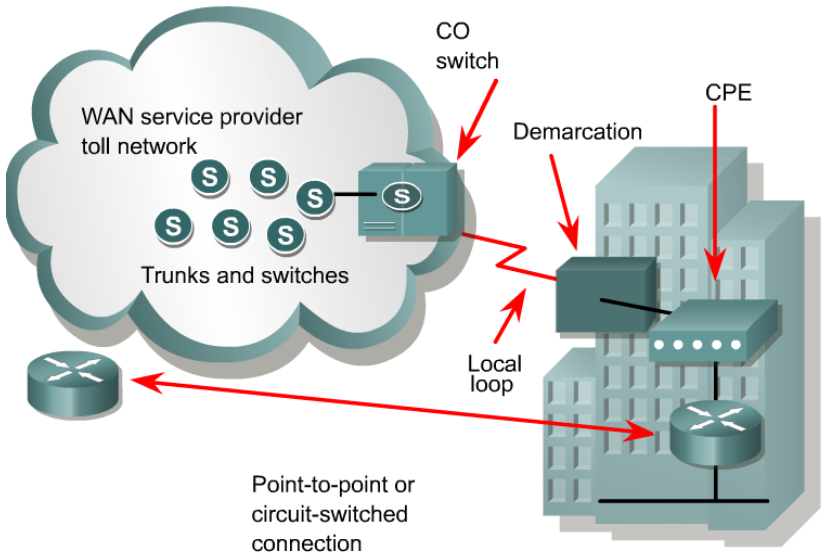
- There are two prevailing definitions of a Wide Area Network (WAN).
- The book definition of a WAN is a network that spans large geographical locations, usually to interconnect multiple Local Area Networks (LANs).
- The practical definition of a WAN is a network that traverses a public network or commercial carrier, using one of several WAN technologies.

WAN Terminology



- Devices on the subscriber premises are called **Customer Premises Equipment (CPE).**
- The subscriber owns the CPE or leases the CPE from the service provider.
- A copper or fiber cable connects the CPE to the service provider's nearest exchange or **Central Office (CO).**
- This cabling is often called the local loop, or **"last-mile".**

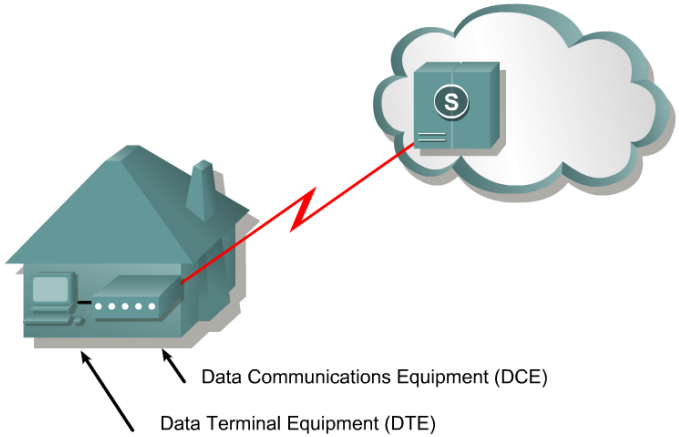
WAN Terminology



** Demarcation refers to the point of last responsibility for the service provider*

- A dialed call is connected locally to other local loops, or non-locally through a trunk to a primary center.
- It then goes to a sectional center and on to a regional or international carrier center as the call travels to its destination.

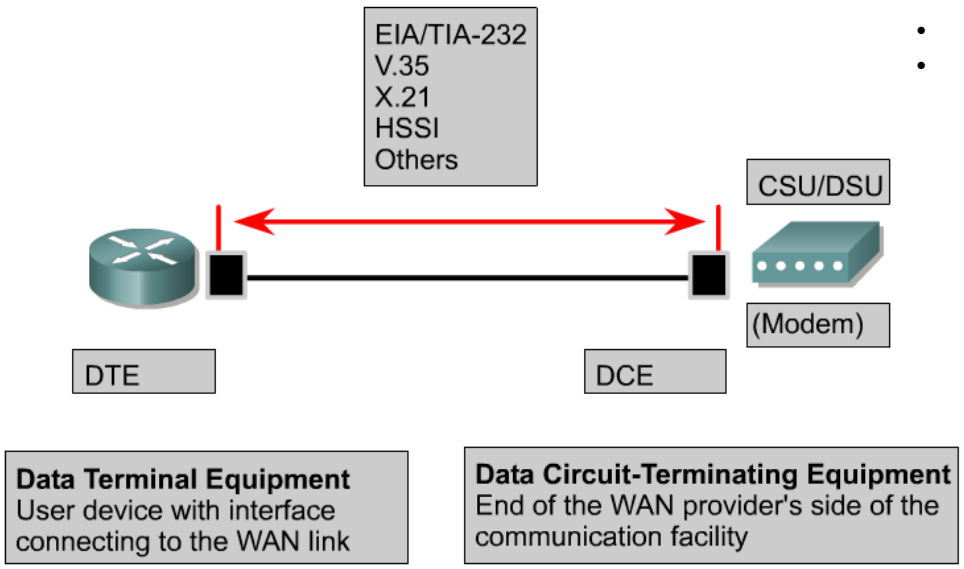
WAN Terminology



- Devices that put data on the local loop are called D**ata Communications Equipment (DCE).**
- The customer devices that pass the data to the DCE are called **Data Terminal Equipment (DTE).**
- The DCE primarily provides an interface for the DTE into the communication link on the **WAN cloud**.

WAN Terminology

- *T1,T3 – CSU/DSU*
- *ISDN – a terminal adapter*
- *Dialup – a modem*

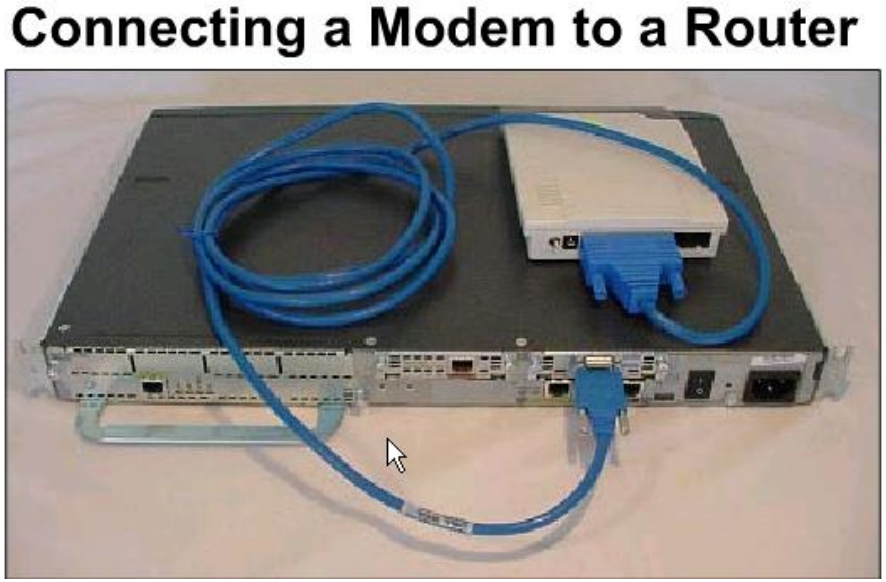


- The DTE/DCE interface uses various physical layer protocols, such as High-Speed Serial Interface (HSSI) and V.35.
- These protocols establish the codes and electrical parameters the devices use to communicate with each other.

WAN Terminology

Connecting a Modem To a Router

- Connecting to a serial interface:
  - physical-layer async interface command
- The Picture shows a connection between a Cisco 2620 series router and an external modem using an EIA/TIA-232 Smart Serial cable.



WAN Terminology

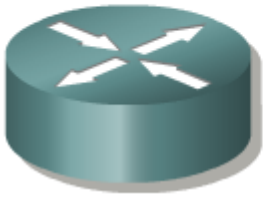
Line Type	Signal Standard	Bit Rate Capacity
56	DS0	56 Kbps
64	DS0	64 Kbps
T1	DS1	1.544 Mbps
E1	ZM	2.048 Mbps
E3	M3	34.064 Mbps
J1	Y1	2.048 Mbps
T3	DS3	44.736 Mbps
OC-1	SONET	51.84 Mbps
OC-3	SONET	155.54 Mbps
OC-9	SONET	466.56 Mbps
OC-12	SONET	622.08 Mbps
OC-18	SONET	933.12 Mbps
OC-24	SONET	1244.16 Mbps
OC-36	SONET	1866.24 Mbps
OC-48	SONET	2488.32 Mbps

- The bps values are generally full duplex.

Name	Abbr.	Size
Kilo	K	2^{10} = 1,024
Mega	M	2^{20} = 1,048,576
Giga	G	2^{30} = 1,073,741,824
Tera	T	2^{40} = 1,099,511,627,776
Peta	P	2^{50} = 1,125,899,906,842,624
Exa	E	2^{60} = 1,152,921,504,606,846,976
Zetta	Z	2^{70} = 1,180,591,620,717,411,303,424
Yotta	Y	2^{80} = 1,208,925,819,614,629,174,706,176

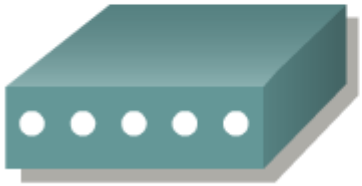
WAN Devices

Router



Switch

Modem (CSU/DSU)

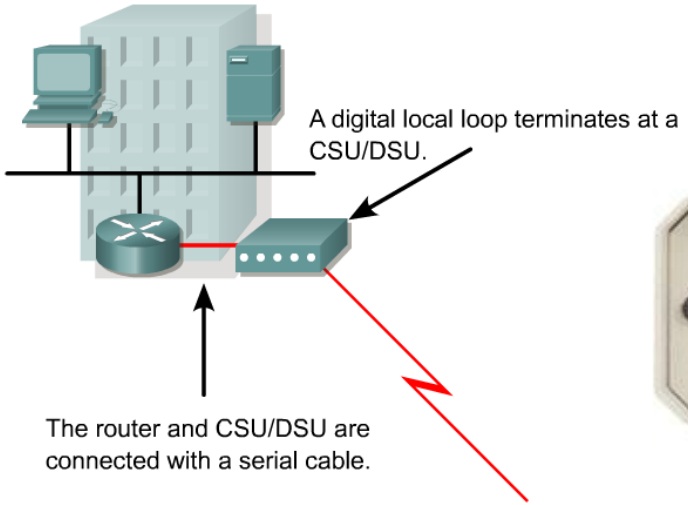


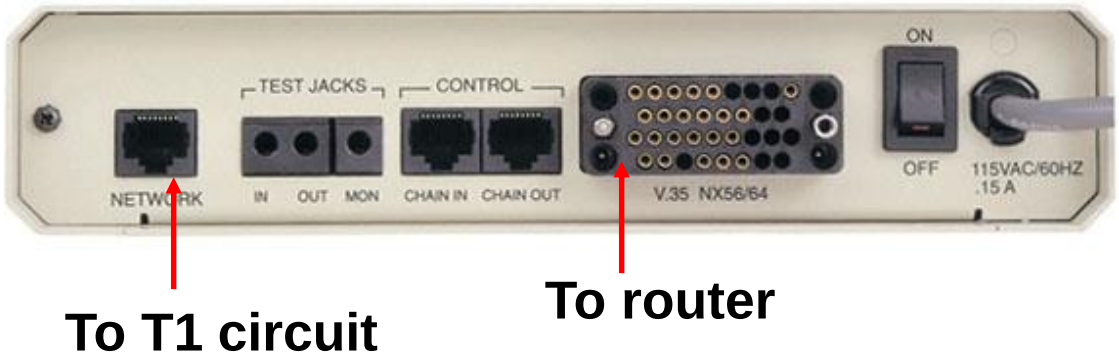
Communication Server

- Frame Relay,
- ATM,
- X.25 switch

WAN Devices

External CSU/DSU





- For digital lines, a **channel service unit (CSU)** and a **data service unit (DSU)** are required.
  - We won't go into the differences here.
- The two are often combined into a single piece of equipment, called the **CSU/DSU**.

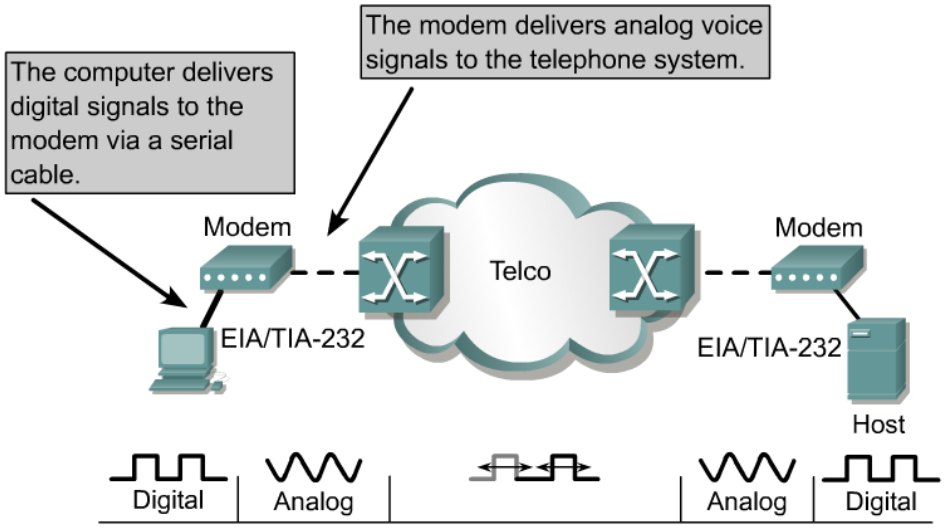
WAN Devices

CSU/DSU Interface Card

- The CSU/DSU may also be built into the **interface card** in the router.

WAN Devices

Modems



- Modems transmit data over voice-grade telephone lines by modulating and demodulating the signal.
- The digital signals are superimposed on an analog voice signal that is modulated for transmission.
- The modulated signal can be heard as a series of whistles by turning on the internal modem speaker.
- At the receiving end the analog signals are returned to their digital form, or demodulated.

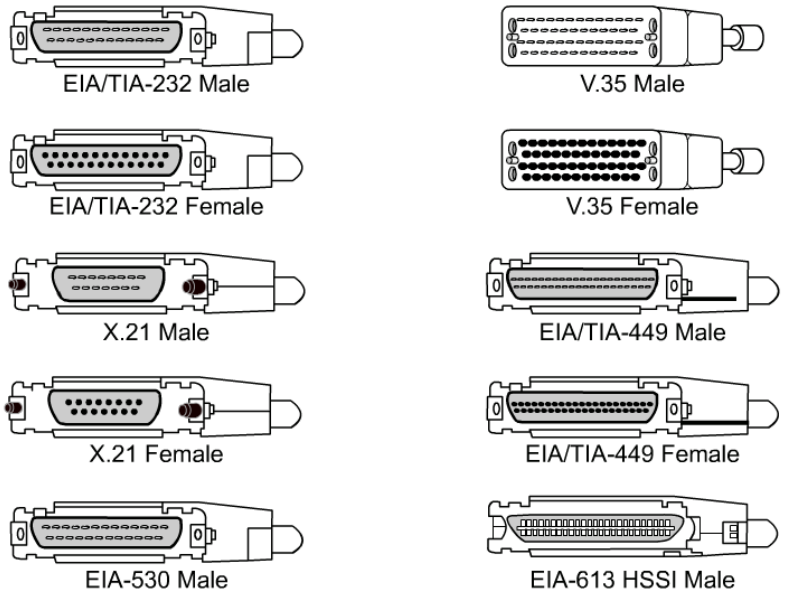
WAN Standards

- WAN standards typically describe both physical layer delivery methods and data link layer requirements, including physical addressing, flow control, and encapsulation.
- WAN standards are defined and managed by a number of recognized authorities.

Acronym	Organization
ITU-T (was CCITT)	International Telecommunication Union Telecommunication Standardization Sector, formerly the Consultative Committee for International Telegraph and Telephone
ISO	International Organization for Standardization
IETF	Internet Engineering Task Force
EIA	Electronic Industries Association
TIA	Telecommunications Industries Association

Physical Layer Standards

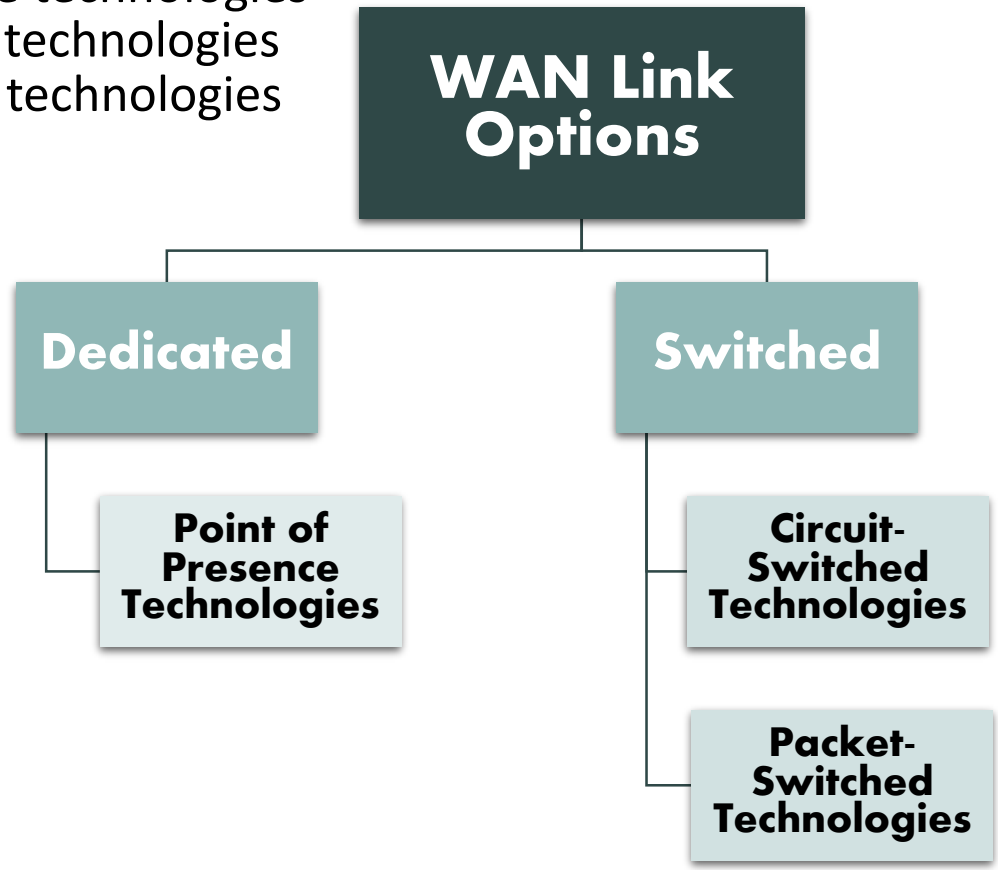
Standard	Description
EIA/TIA-232	Allows signal speeds of up to 64 Kbps on a 25 pin D connector over short distances. It was formerly known as RS-232. The ITU-T V.24 specification is effectively the same.
EIA/TIA-449/530	A faster (up to 2 Mbps) version of EIA/TIA-232. It uses a 36 pin D connector and is capable of longer cable runs. There are several versions. Also known as RS-422 and RS-423.
EIA/TIA-612/613	The High Speed Serial Interface (HSSI), which provides access to services at up to 52 Mbps on a 60 pin D connector.
V.35	An ITU-T standard for synchronous communications between a network access device and a packet network at speeds up to 48 Kbps. It uses a 34 pin rectangular connector.
X.21	An ITU-T standard for synchronous digital communications. It uses a 15 pin D connector.



- The physical layer protocols describe how to provide electrical, mechanical, operational, and functional connections to the services provided by a communications service provider.

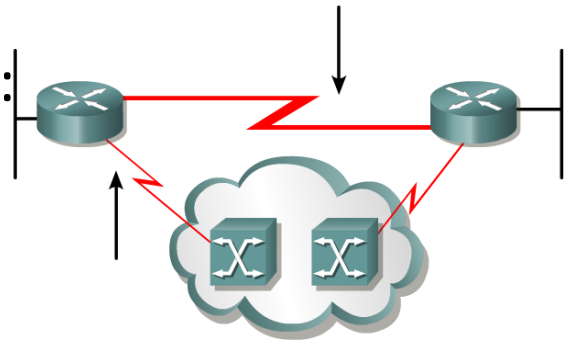
WAN Link Options

- WANs are generally grouped into three separate link or connection types:
  - Point of Presence technologies
  - Circuit-switched technologies
  - Packet-switched technologies



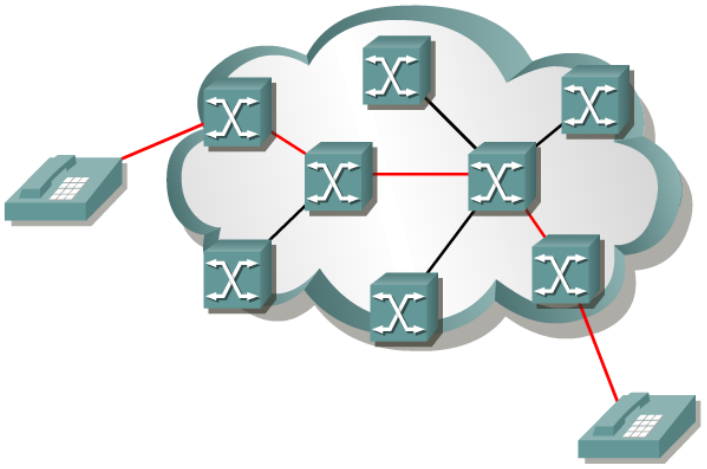
Point of Presence Technologies

- Commonly called dedicated or leased lines are usually the most expensive form of WAN technology.
- POP technologies are leased from a service provider and provide guaranteed bandwidth from location to another (hence point-to-point).
- Cost is determined by the distance of the connection, and the amount of bandwidth allocated.
- Generally, POP links require no call-setup, and the connection is usually always on.
- Examples of POP technologies include:
  - T1 lines
  - T3 lines
  - DSL

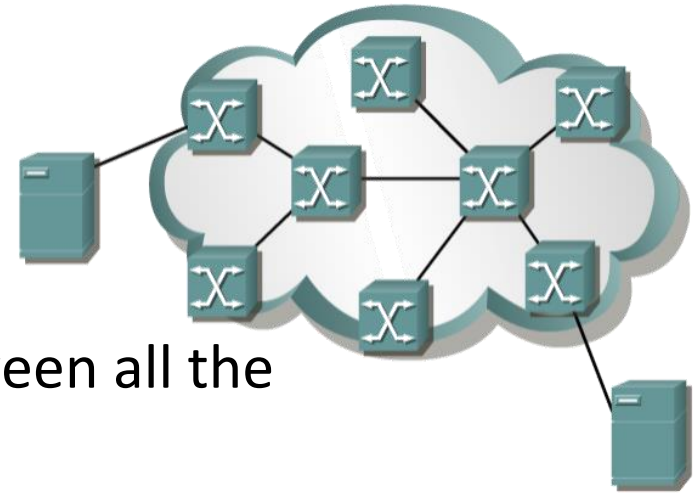


Circuit-Switched technologies

- Require call-setup to occur before information can be transferred.
- The session is usually ended once data transfer is complete (this is identified as an On-Demand Circuit).
- Circuit switched lines are generally low-speed compared to point of presence lines.
- Examples of circuit-switched technologies include:
  - Dial-up
  - ISDN



Packet-Switched Technologies



- Share a common infrastructure between all the provider's subscribers.
- Thus, bandwidth is not guaranteed but is instead allocated on a best effort basis. Also known as connectionless
- Packet-switched technologies are inappropriate for applications that require consistent bandwidth, but are considerably less expensive than dedicated point of presence lines.
- Examples of packet-switched technologies include:
  - Frame-Relay
  - X25

WAN Encapsulation Protocols

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)	Dialup connections

- WAN technologies operate at both Physical and Data-link layers of the OSI models, and that higher-layer protocols such as IP are encapsulated when sent across the WAN link.

WAN Connection	Protocol/Usage
Dedicated	PPP, HDLC – T1 Connection
Circuit-Switched	PPP, LAPD – Dialup connections and ISDN
Packet-Switched	LAPB, LAPF -- X.25, Frame Relay

The differences between Circuit Switching and Packet Switching

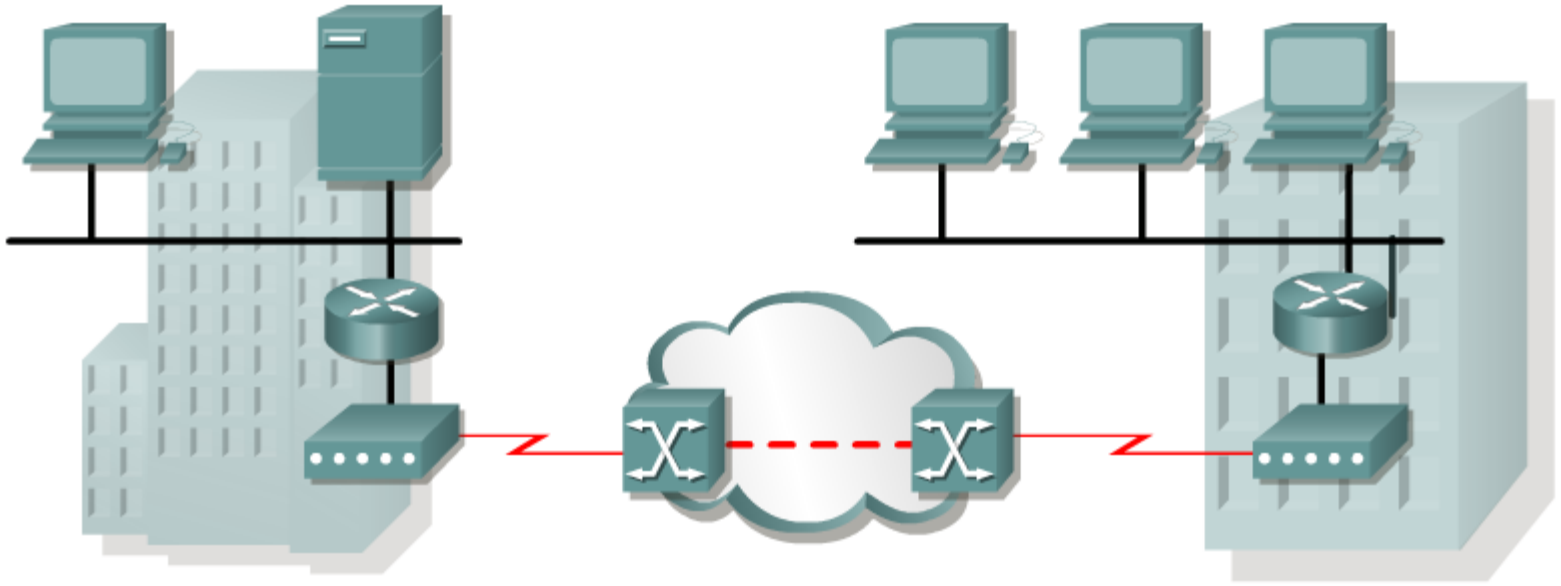
Circuit Switching

- uses a dedicated path between two stations.
- has three phases
  - establish
  - transfer
  - disconnect
- inefficient
  - channel capacity dedicated for duration of connection
  - if no data, capacity wasted
- set up (connection) takes time

Packet Switching

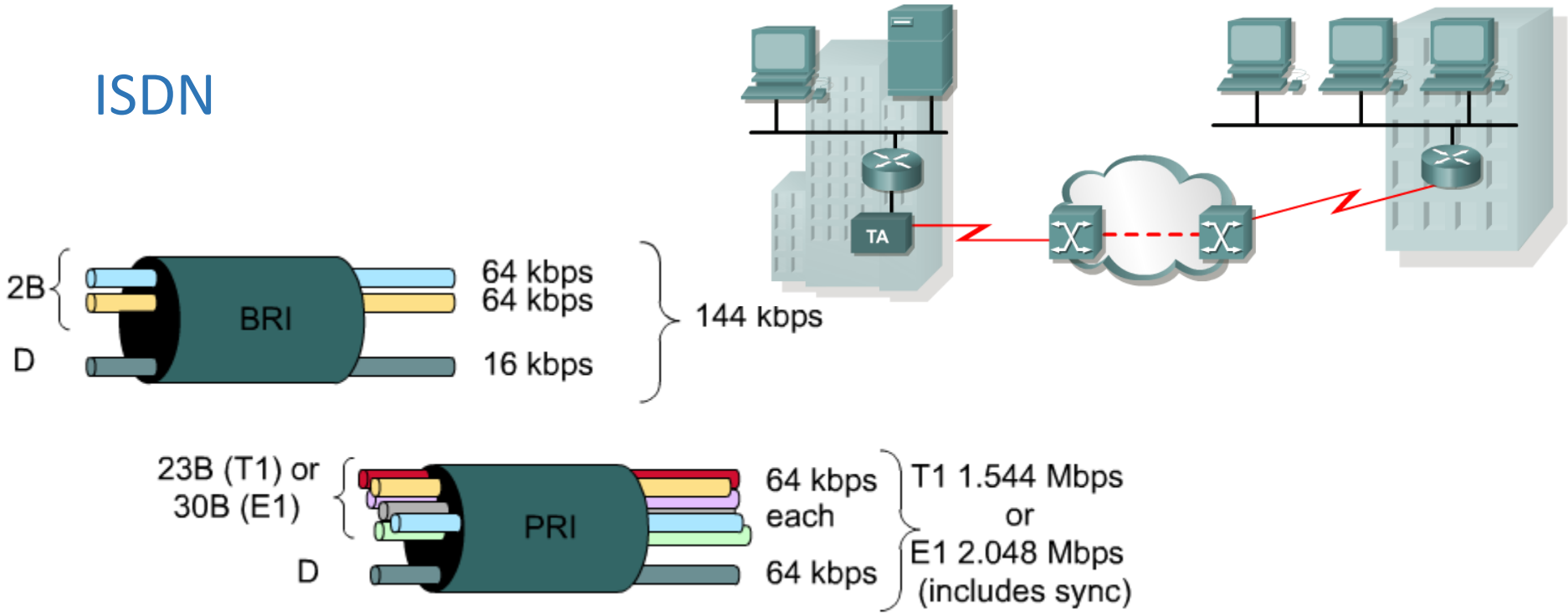
- line efficiency
  - single link shared by many packets over time
  - packets queued and transmitted as fast as possible
- data rate conversion
  - stations connects to local node at own speed
  - nodes buffer data if required to equalize rates
- packets accepted even when network is busy
- priorities can be used

Analog Dialup



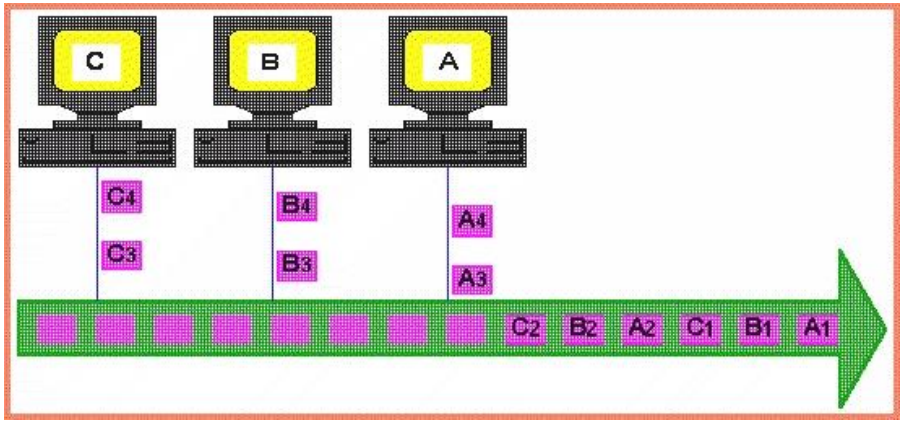
- When intermittent, low-volume data transfers are needed, modems and analog dialed telephone lines provide low capacity and dedicated switched connections.

ISDN



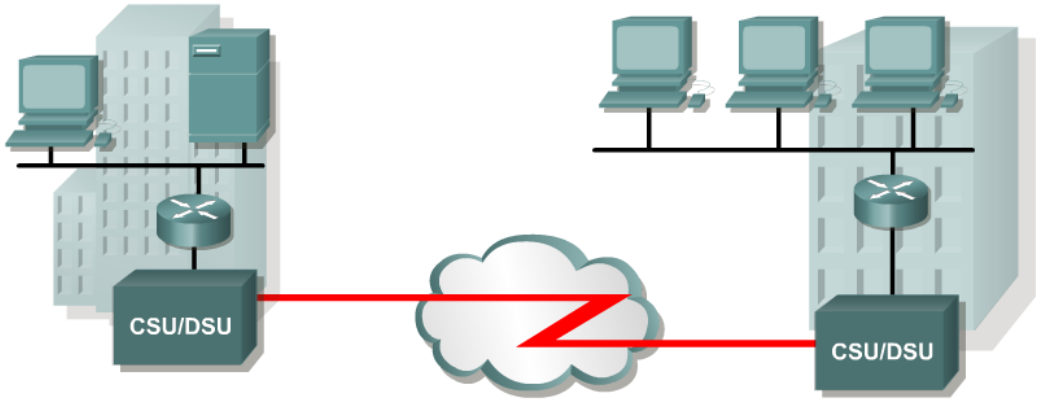
- **Integrated Services Digital Network (ISDN)** turns the local loop into a TDM digital connection.
  - Usually requires a new circuit.
- The connection uses 64 kbps bearer channels (B) for carrying voice or data and a signaling, delta channel (D) for call set-up and other purposes.
- Never really became popular in the U.S., known as It-Still-Does-Nothing or I-Still-Don't Know

Time Division Multiplexing (TDM)



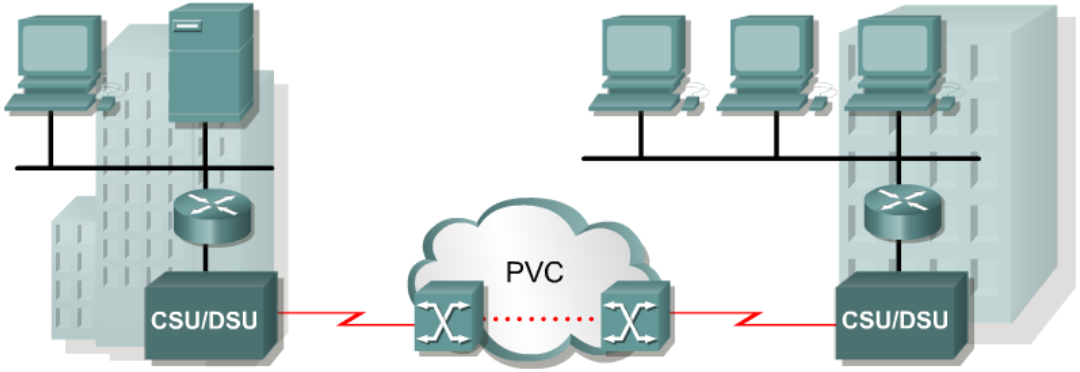
- Two or more “channels” of information are transmitted over the same link by allocating a different time interval for the transmission of each channel, i.e. the channels take turns to use the link.
- Some kind of periodic synchronizing signal or distinguishing identifier is required so that the receiver can tell which channel is which.
- TDM becomes inefficient when traffic is intermittent because the time slot is still allocated even when the channel has no data to transmit

Leased Lines



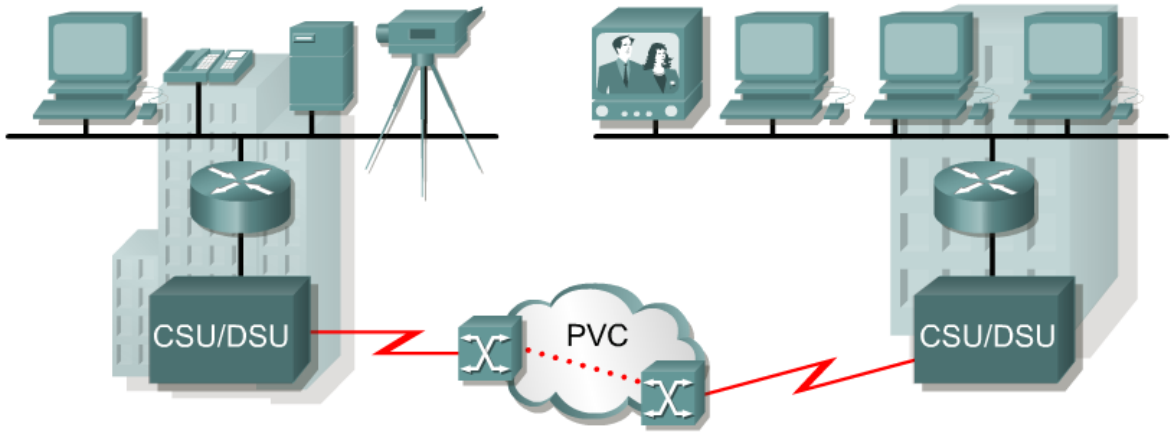
- A point-to-point link provides a pre-established WAN communications path from the customer premises through the provider network to a remote destination.
- Point-to-point lines are usually leased from a carrier and are called leased lines.
- Leased lines are available in different capacities.
- Leased lines provide direct point-to-point connections between enterprise LANs and connect individual branches to a packet-switched network.

Frame Relay



- Works at the data link 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.
- Most Frame Relay connections are PVCs
- Frame Relay provides permanent shared medium bandwidth connectivity that carries both voice and data traffic.

ATM



- Communications providers saw a need for a permanent shared network technology that offered very low latency and jitter at much higher bandwidths.
- Their solution was Asynchronous Transfer Mode (ATM). ATM has data rates beyond 155 Mbps.

ATM

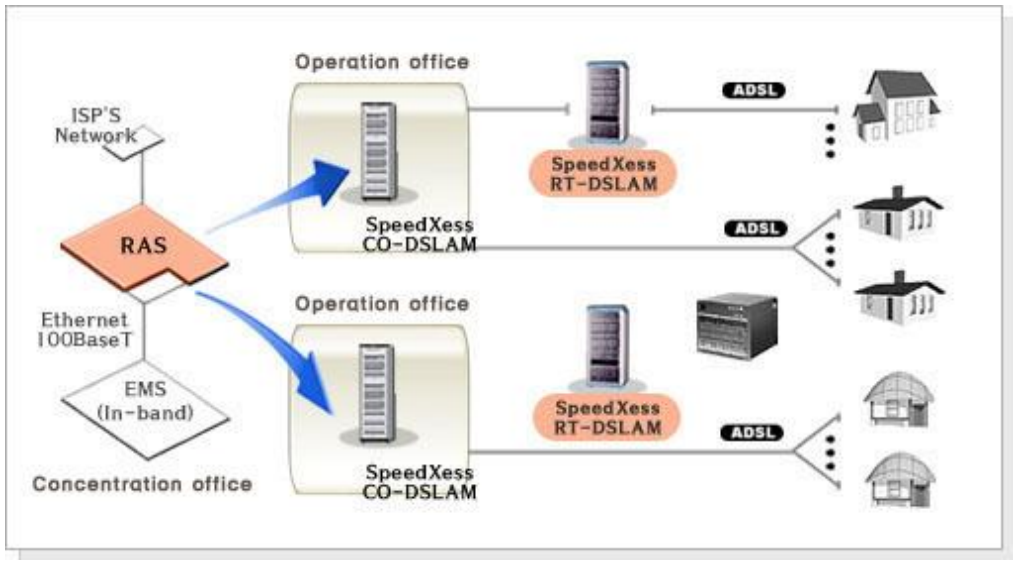
- ATM is a technology that is capable of transferring voice, video, and data through private and public networks.
- It is built on a cell-based architecture rather than on a frame-based architecture.
- ATM cells are always a fixed length of 53 bytes. The 53 byte ATM cell contains a 5 byte ATM header 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.
- A typical ATM line needs almost 20% greater bandwidth than Frame Relay to carry the same volume of network layer data.

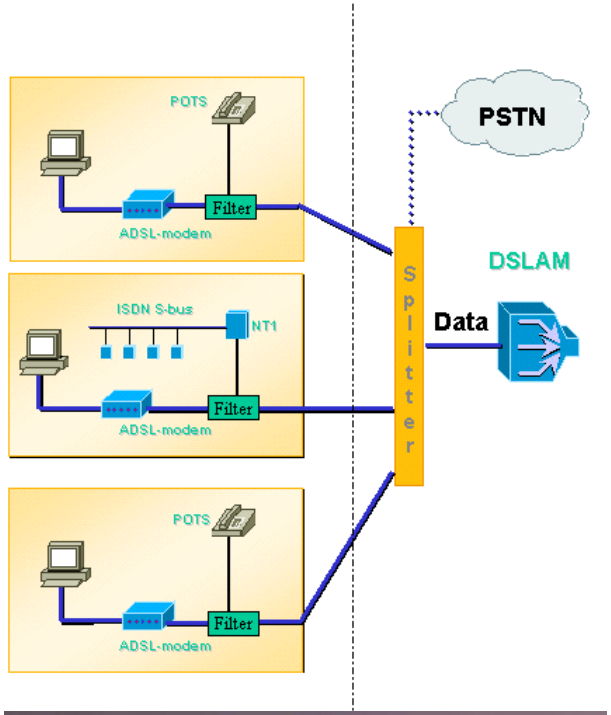
DSL

Service	Download	Upload
ADSL	1.544 Mbps - 8.192 Mbps	16 kbps - 640 kbps
SDSL	1.544 Mbps - 2.048 Mbps	1.544 Mbps - 2.048 Mbps
HDSL	1.544 Mbps - 2.048 Mbps	1.544 Mbps - 2.048 Mbps
IDSL	144 kbps	144 kbps
RADSL	64 kbps - 8.192 Mbps	16 Mbps - 768 Mbps
CDSL	1 Mbps	16 kbps - 160 kbps

- Digital Subscriber Line (DSL) technology is a broadband technology that uses existing twisted-pair telephone lines to transport high-bandwidth data to service subscribers.
- The term xDSL covers a number of similar yet competing forms of DSL technologies.
- DSL technology allows the local loop line to be used for normal telephone voice connection and an always-on connection for instant network connectivity. The two basic types of DSL technologies are asymmetric (ADSL) and symmetric (SDSL).
- All forms of DSL service are categorized as ADSL or SDSL and there are several varieties of each type.
- Asymmetric service provides higher download or downstream bandwidth to the user than upload bandwidth.
- Symmetric service provides the same capacity in both directions.

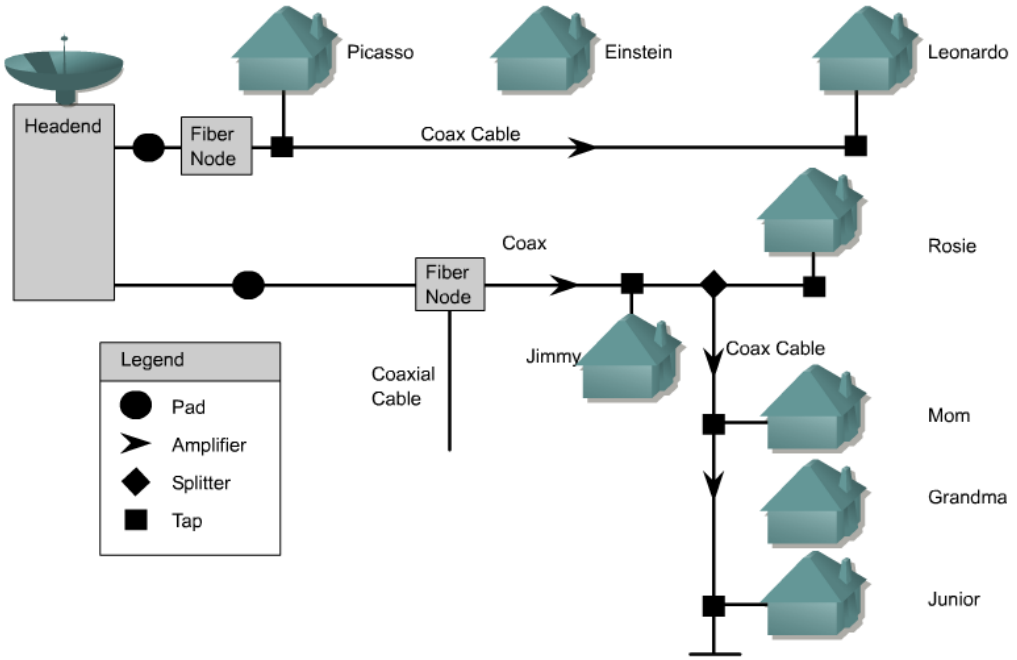
DSL





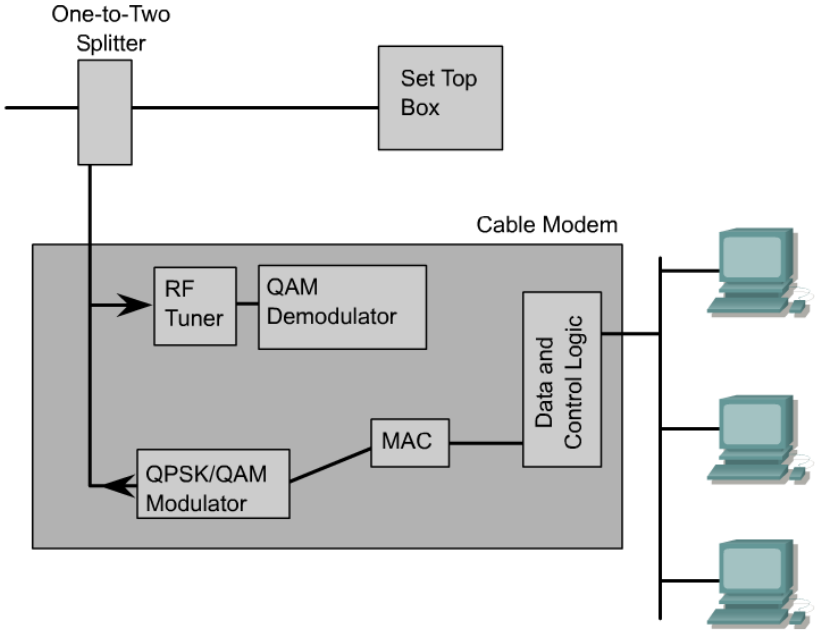
- Multiple DSL subscriber lines are multiplexed into a single, high capacity link by the use of a DSL Access Multiplexer (DSLAM) at the provider location.
- DSLAMs incorporate TDM technology to aggregate many subscriber lines into a less cumbersome single medium, generally a T3/DS3 connection techniques to achieve data rates up to 8.192 Mbps.

Cable Modem



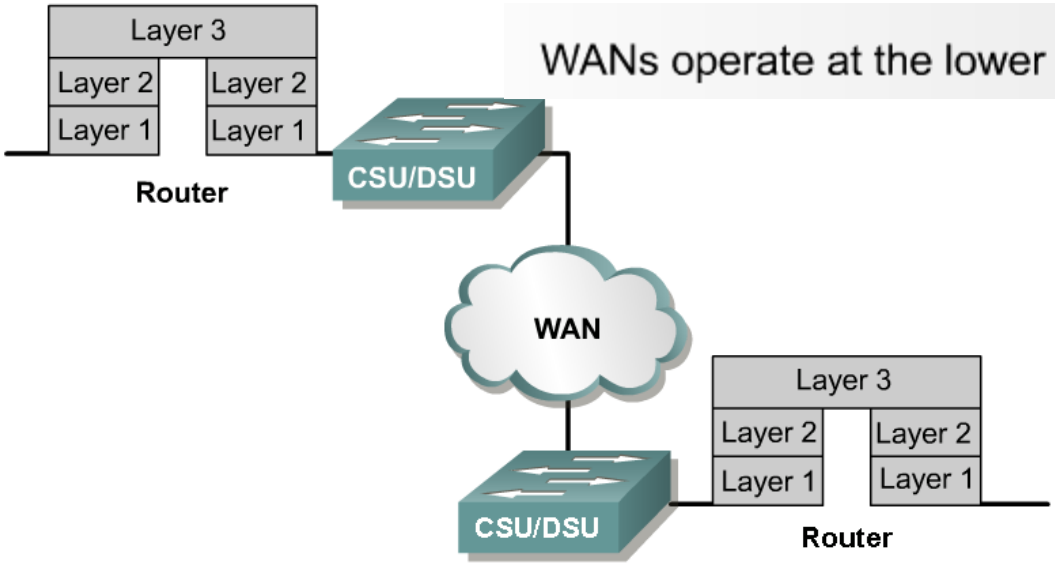
- Coaxial cable is widely used in urban areas to distribute television signals.
- This allows for greater bandwidth than the conventional telephone local loop.
- Enhanced cable modems enable two-way, high-speed data transmissions using the same coaxial lines that transmit cable television.
- Some cable service providers are promising data speeds up to 6.5 times that of T1 leased lines.

Cable Modem



- Cable modems provide an always-on connection and a simple installation.
- A cable modem is capable of delivering up to 30 to 40 Mbps of data on one 6 MHz cable channel.
- With a cable modem, a subscriber can continue to receive cable television service while simultaneously receiving data to a personal computer.
- This is accomplished with the help of a simple one-to-two splitter.

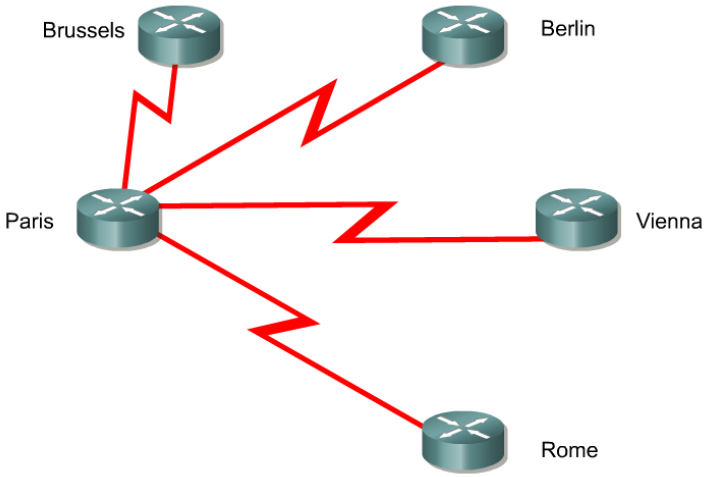
WAN Communication



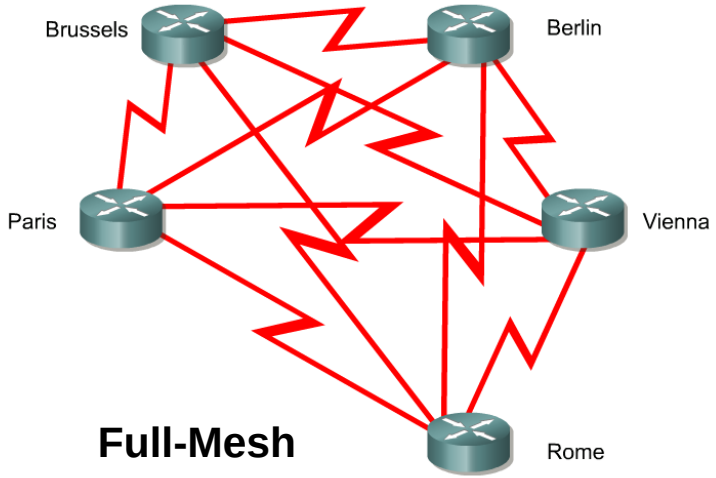
WANs operate at the lower three levels of the OSI protocol stack.

- WAN protocols operate at only the lower TWO layers of the OSI stack.

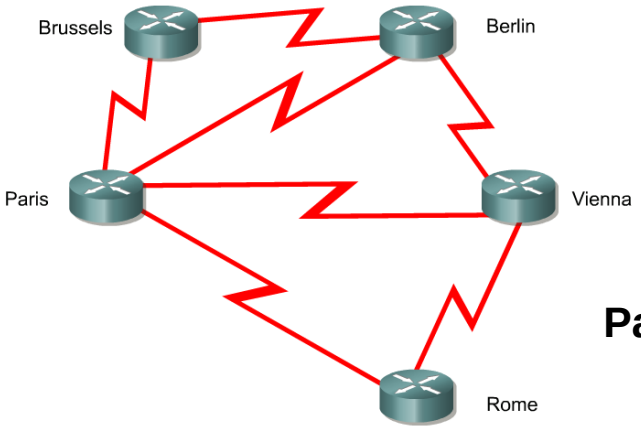
WAN Topologies



Star or Hub-and-Spoke



Full-Mesh



Partial-Mesh

STAR / Hub-and-Spoke

- In a Hub-and-spoke Site-to-Site Wide Area Network (WAN) network topology, one physical site act as Hub (Example, Main Office), while other physical sites act as spokes.
- Spoke sites are connected to each other via Hub site. In Hub-and-spoke Wide Area Network (WAN) topology, the network communication between two spokes always travel through the hub.
- Wide Area Network (WAN) links are costly and they always involve a monthly bill payment to Internet Service Providers (ISPs) for connectivity services.
- Main disadvantage of Hub-and-spoke Wide Area Network (WAN) network topology is that it may cause communication time lags. Wide Area Network (WAN) network topology also has redundancy issues.
- If the Main Office network fails, entire Enterprise network communication may fail.

Partial-Mesh

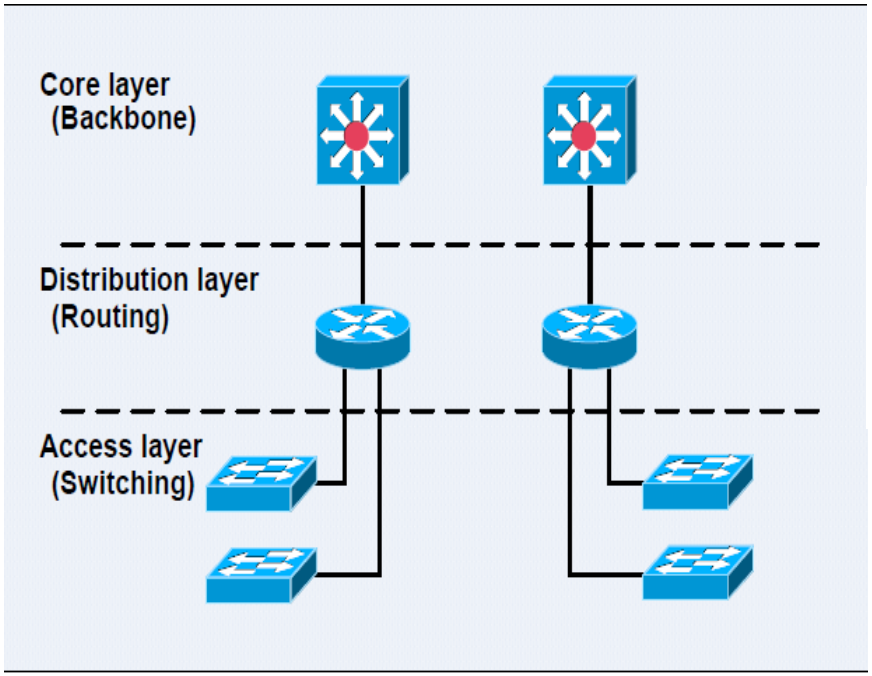
- Physical sites are connected together using Wide Area Network (WAN) links.
- Less important sites are connected to other sites via the Main Office.
- A Partial-mesh Wide Area Network (WAN) topology is more redundant than a Hub-and-spoke Wide Area Network (WAN) topology.
- Since A Partial-mesh Wide Area Network (WAN) topology requires more WAN links, Partial-mesh topology is more expensive than a Hub-and-spoke WAN topology, but less expensive than Full-mesh WAN topology.
- Partial-mesh Wide Area Network (WAN) topology reduces time lag in network communication.

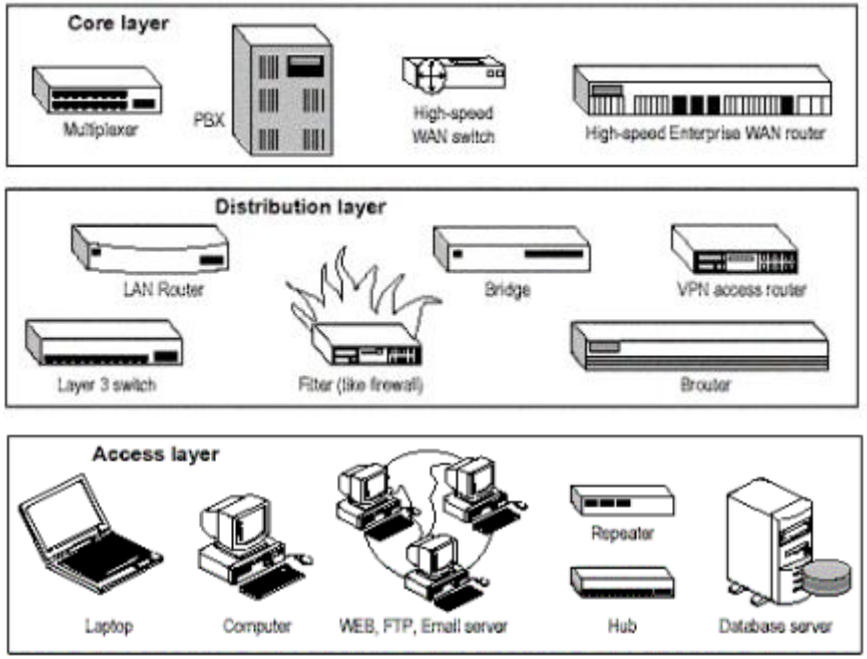
Full Mesh

- Every physical sites are connected to every other site, using WAN links.
- Since all physical sites are connected together, Full-mesh topology is highly redundant.
- Time lag is least in Full-mesh topology, when comparing Hub-and-spoke and Partial-mesh topologies.
- A Full-mesh Site-to-Site WAN topology is the most desirable WAN topology.

- A Full-mesh network is difficult to build and maintain.
- Full-mesh network is much expensive than Hub-and-spoke and Partial-mesh topologies because every physical site requires a WAN link to connect every other physical sites

Three Layer Hierarchical Model





Core Layer

- Core layer is know as core of network as it is on the top of the network and it is responsible to transfer heavy amount of traffic in reliable and quick manner.
- Objective of core layer is to speed up the network traffic as much as possible.
- Traffic at core layer is common for most of users and user data is transported to distribution layers which forwards requests if it is required.
- If core layer is affected by a failure, every user is affected on network.
- Fault tolerance is main thing to consider on this layer.

Distribution Layer

- It is also known as workgroup layer and it is called communication point between access and core layer.
- Basic function of distribution layer is routing, filtering and WAN access and find out the method by which packets can access the core.
- This layer must find out the fastest mechanism to handle network operations like how to handling and forwarding a file to server on request.
- After finding best path, distribution layer forward request towards core layer and then to the right service.
- Policy implementation is done on distribution layer and you can exercise flexibility defining network operations

The Access Layer

- User and workgroup access to network and resources is defined at access layer and this layer is also known as desktop layer.
- Here are some functions of access layers.
  - Manage access control and policy
  - Create separate collision domains
  - Connectivity of workgroup through distribution layer
- DDR (Double Data Rate) and Ethernet switching technology are mainly used in access layer with Static routing.

THE END