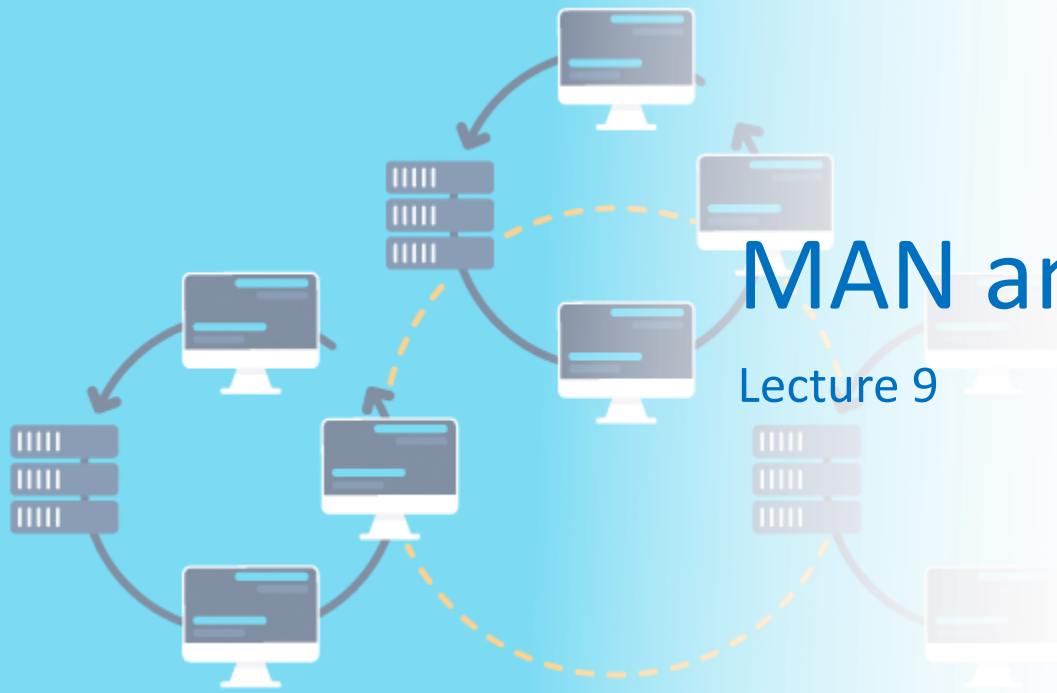


MAN and WAN Networks

Lecture 9



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MAN Definition

- **Metropolitan Area Network (MAN)**
 - is computer network that connects computers within a **metropolitan area**: which could be a single large city or multiple cities
 - No precise definition available
 - Somewhere between a LAN and a WAN with some features of each
 - Serves a geographic area larger than a LAN, such as a city or metropolitan region



MAN Definition

- MANs can interconnect various sites for one company, or interconnect many companies
- MANs transfer data at LAN speeds (and higher) but often use more complicated protocols



MAN Application Areas

- Interconnection and consolidation of corporate data centers
- Transparent extension of the LAN by interconnecting distributed corporate locations
- Support of SAN (storage area networks)
 - SAN: a specialized, high-speed network that provides network access to storage / stored data. SANs are typically composed of hosts, switches, storage elements, and storage devices that are interconnected using a variety of technologies, topologies, and protocols
- Server-less offices



MAN Application Areas

- Real-time transaction backups
- High-speed disaster recovery
- Interconnection between corporate data center and ISP (Internet Service Providers)
- Government, business, medicine and education high-speed interconnections



MAN Features

- Why use a MAN?
 - Very high speeds (in Gbps)
 - Self-healing networks
 - Network self-healing is when network problems are resolved without the need for humans to get involved. A network automation tool can detect and resolve outages, failures, and breaches.
 - Bandwidth on demand
 - MANs cover distances that LANs cannot
 - But MANs often provide a lower level of complexity than many WANs



MAN Topologies

- Point-to-point
 - Characterized by very high speeds (10 to 40 Gbps)
 - Often DWDM over fiber
 - Redundancy is provided with redundant equipment at the endpoints:
 - Network redundancy is whereby additional network devices and connections are installed to ensure an alternate path in case of a failure on the primary service

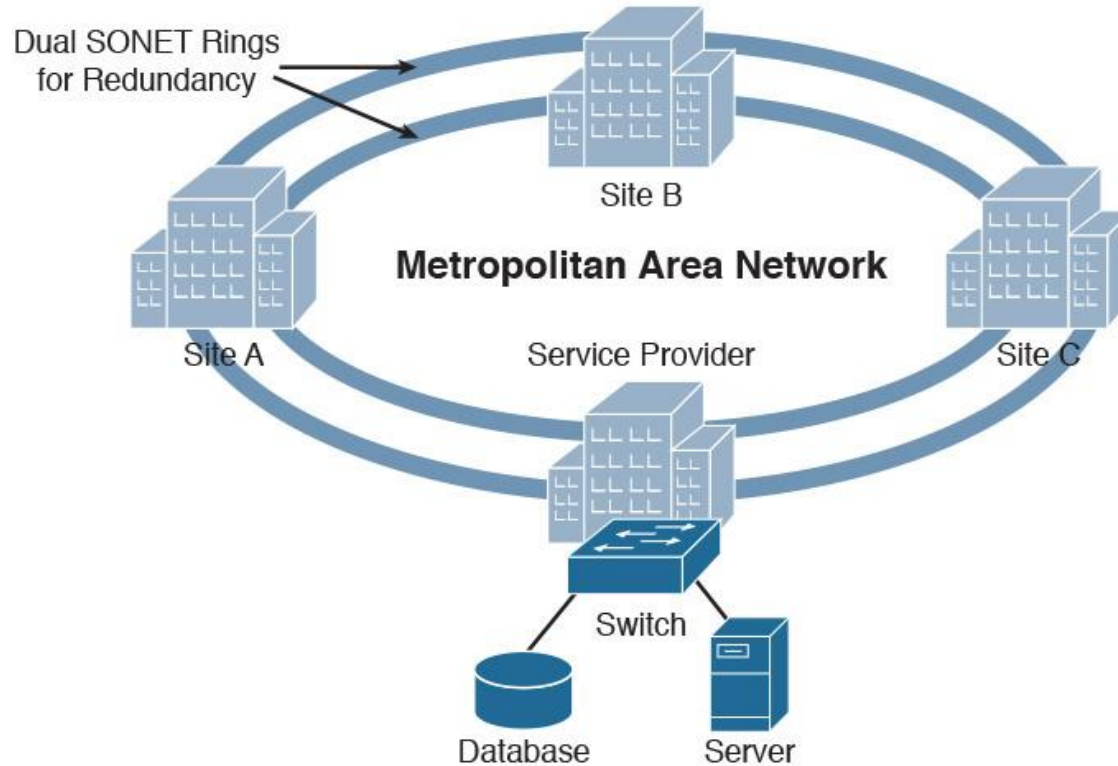
MAN Topologies

- Ring
 - Most common architecture
 - Can span tens of kilometers
 - Data rates range from 622 Mbps to 10 Gbps per channel
 - SONET rings are typical example
 - Multiple rings with very fast failover provide stability



MAN Topologies

- Ring (cont.) - SONET ring illustration



MAN Topologies

- Mesh
 - Potentially the future of MANs
 - A natural extension of point-to-point MANs
 - Can also connect to established rings
 - High speeds, long distances, good redundancy



Support Technologies

- SONET/SDH
- ATM
- Gigabit Ethernet
- IP
- Fibre Channel
- FDDI



Support Technology - SONET

- Synchronous Optical Network (SONET)
 - a standard for synchronous data transmission on optical fibers.
 - SONET is a standardized digital communication protocol.
 - SONET can be utilized to transmit and multiplex multiple data streams across a fiber optic cable.
 - **Multiplex:** a system or signal involving simultaneous transmission of several messages along a single channel of communication

SONET is an American-based standard, while SDH is a European-based standard. Both are essentially the same and, therefore, often listed as SONET/SDH

Support Technology - SONET

- Currently most MANs are supported by SONET rings
- SONET is the fundamental transmission technology for TDM-based circuit switched networks
 - **time-division multiplexing (TDM)**: whereby the data from different input channels is divided into fixed-length segments and then combined such that each signal, carrying data, uses the communication channel for only a fraction of time in an alternating pattern



Support Technology - SONET

- SONET disadvantages:
 - Bandwidth efficiency is a problem at higher capacity
 - Complex and costly SONET equipment compared to cheaper optical Ethernet and other alternate MAN technologies
 - SONET cannot be provisioned dynamically
 - Inflexible multiplexing hierarchy



Support Technology - ATM

- **Asynchronous Transfer Mode (ATM)**
 - a digital data transfer technology.
 - Developed in the 1980s
 - with ATM: data is separated in the form of fixed equal sized packets and is transferred overtime
- Favored by many service providers because it can support different protocols and different traffic types into a common protocol format for transmission over SONET
- Unfortunately, ATM is complex, costly, and provides an extra layer of complexity



Support Technology - Gigabit Ethernet



- Gigabit Ethernet:
 - An interesting newcomer to MAN technology
 - A very common and well-understood technology
 - Can scale from 10 Mbps, 100 Mbps, 1000 Mbps, to 10 Gbps **easily**
 - Low cost
 - No need for ATM or SONET



Support Technology - IP

- Internet Protocol (IP)
 - Almost entire data world uses IP
 - Also well known, widely adopted, reasonably flexible, relatively simple
 - IP is a layer 3 protocol, and so possible combinations are:
 - IP over ATM over SONET
 - IP over SONET
 - IP over Ethernet



Support Technology - Fibre Channel

- Fibre Channel
 - Predominant data link technology used in SANs
 - Interfaces available at 100 MBps with 200 MBps soon and 400 MBps testing
 - Does not have a short distance limitation like SCSI
 - Found in point-to-point and mesh topologies

Exercise: define SCSI

Support Technology - FDDI



- **Fiber Distributed Data Interface (FDDI)**
 - network standard that uses fiber optic connections in a local area network (LAN) that can extend up to 200 kilometers

- **A legacy technology**
 - Older technology
 - Being replaced by Gigabit Ethernet or ATM



SONET vs. Gigabit Ethernet

- Why SONET vs. Gigabit Ethernet?
- Regarding MANs:
 - SONET is the ruler
 - Gigabit Ethernet is trying to dethrone that ruler



SONET vs. Gigabit Ethernet

- Ethernet is less expensive than current SONET technology
- Ethernet is a simple and widely understood technology
- Ethernet is a highly suitable technology for carrying IP traffic
 - IP and Ethernet have evolved together

SONET vs. Gigabit Ethernet

- Optical Ethernet can support links in the network range from 3 to 6 miles using single mode 1310 nm wavelength and up to 43.4 miles for 1550 nm wavelength
- Optical Ethernet can segregate traffic of different users and deliver the particular service level each user purchases



SONET vs. Gigabit Ethernet

- Traffic segregation is accomplished by using the IEEE 802.1pQ VLAN standard
- With this standard, each user's frame is marked with a VLAN tag as it enters the network
- This tag keeps each user's traffic separate as it crosses the network



SONET vs. Gigabit Ethernet

- One of the big advantages of Gigabit Ethernet over SONET is the levels of complexity
- SONET has multiple layers - the router network running over the ATM network running over the SONET network running over a collection of point-to-point DWDM links
 - **Dense Wavelength Division Multiplexing (DWDM)** is an optical multiplexing technology used to increase bandwidth over existing fiber networks.

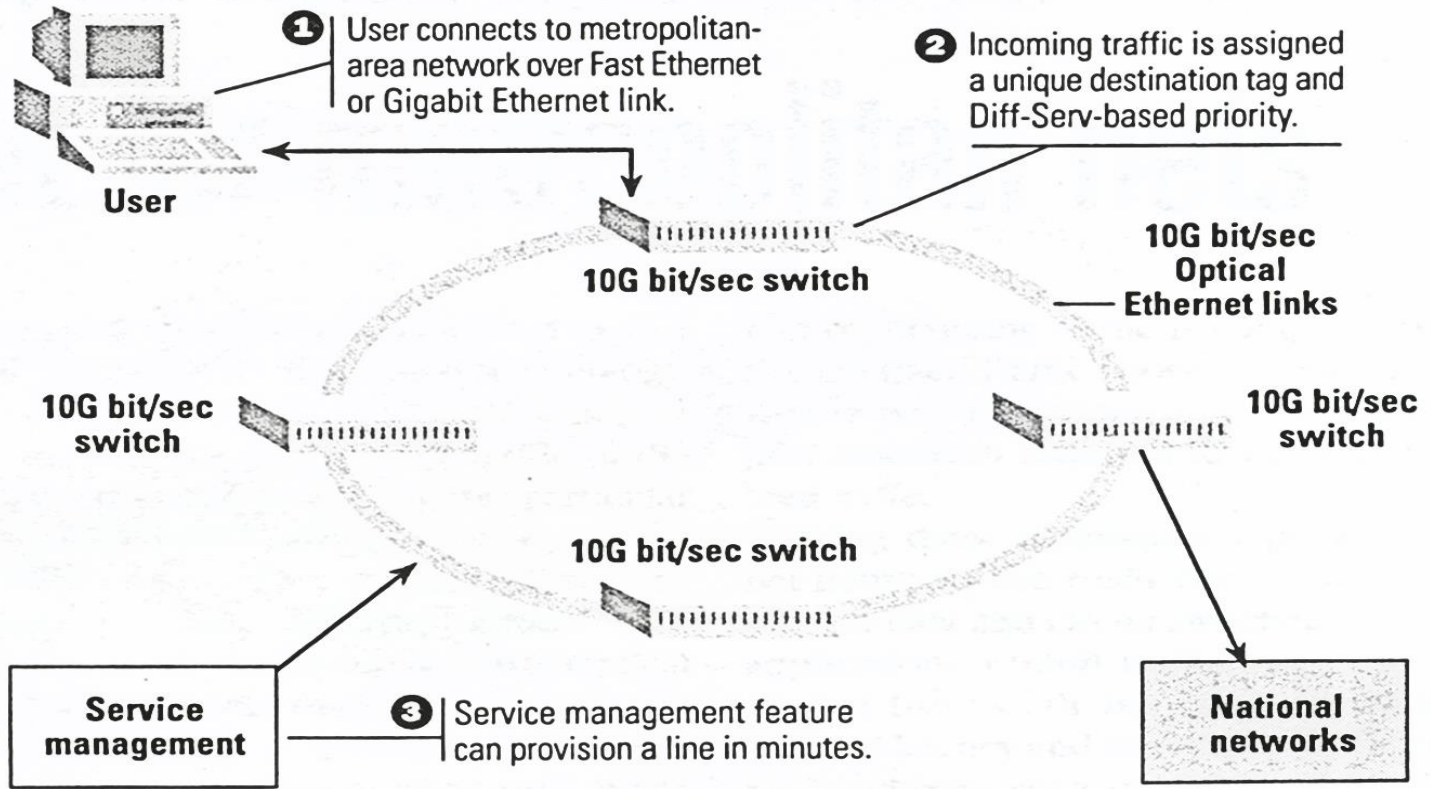


SONET vs. Gigabit Ethernet

- Gigabit Ethernet, however, does not have all the levels, making the technology much simpler and much less expensive



Optical Ethernet for Metropolitan Networks



Wide Area Network

- Wide area networks (WAN)
 - a form of telecommunication networks that can connect devices from **multiple locations** and **across the globe**.
 - WANs are the largest and most expansive forms of computer networks available currently
 - WANs are very high speed with very low error rates.
 - WANs usually follow a *mesh* topology.

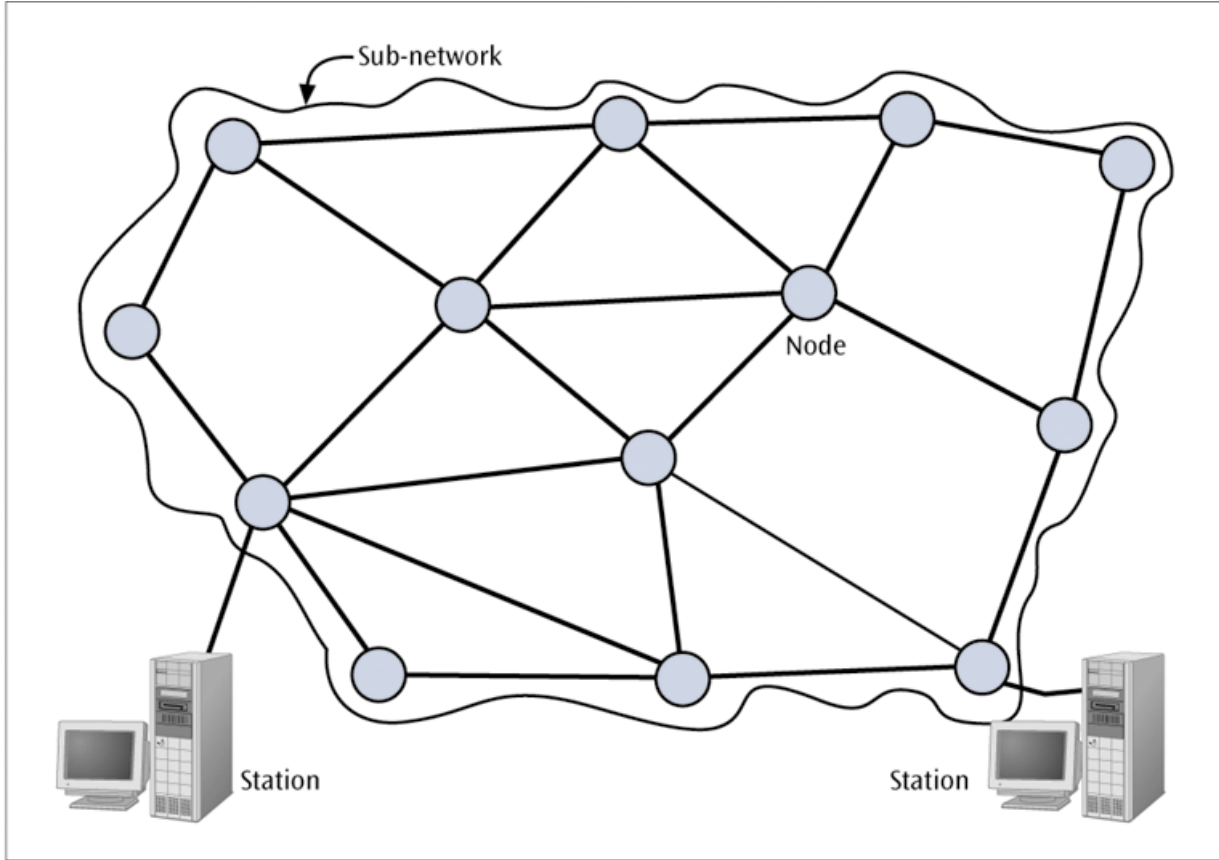




Wide Area Network Concepts

- A *station* is a device that connects a user to a network.
- A *node* is a device that allows one or more stations to access the physical network and is a transfer point for passing information through a network.
 - A node is often a computer, a router, or a telephone switch.

Wide Area Network



WAN - Types of Network Structures

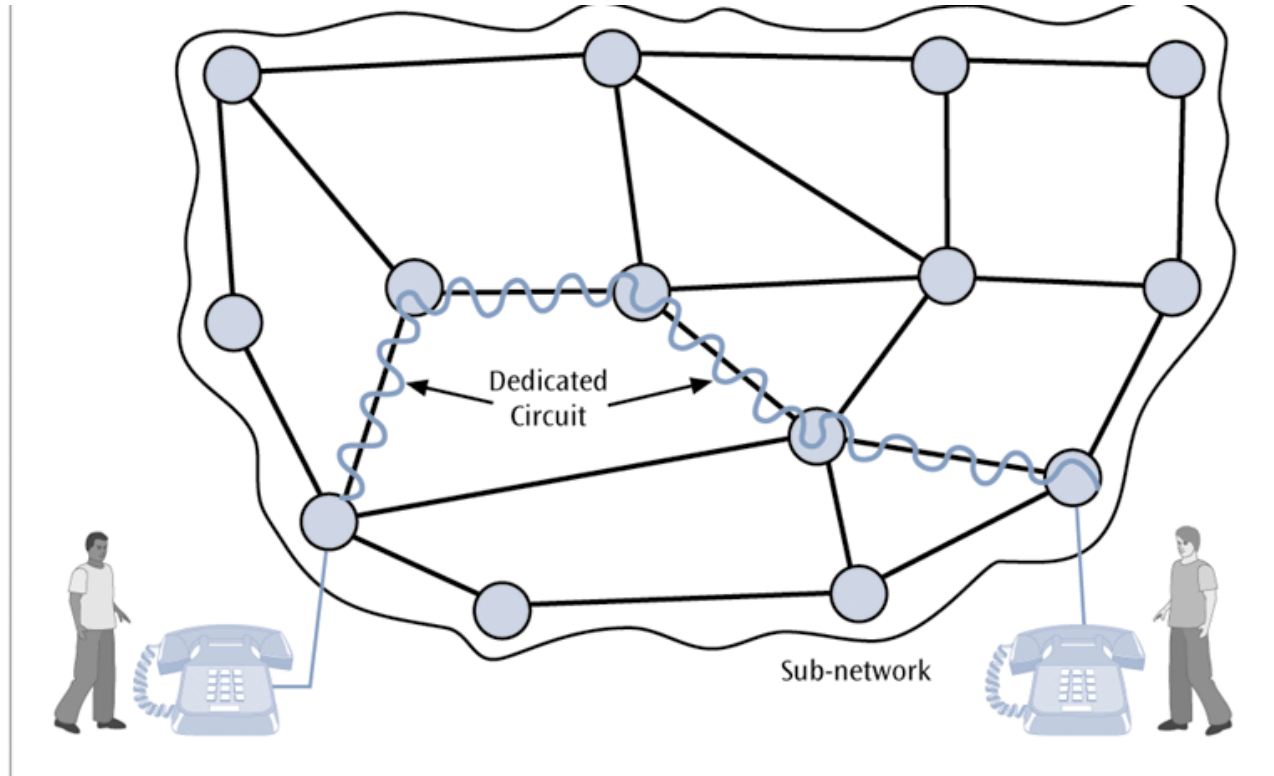


- *Circuit switched network*
 - a sub-network in which a dedicated circuit is established between sender and receiver and all data passes over this circuit
 - common example: the telephone system
 - The connection is dedicated until one party or another terminates the connection



WAN - Types of Network Structures

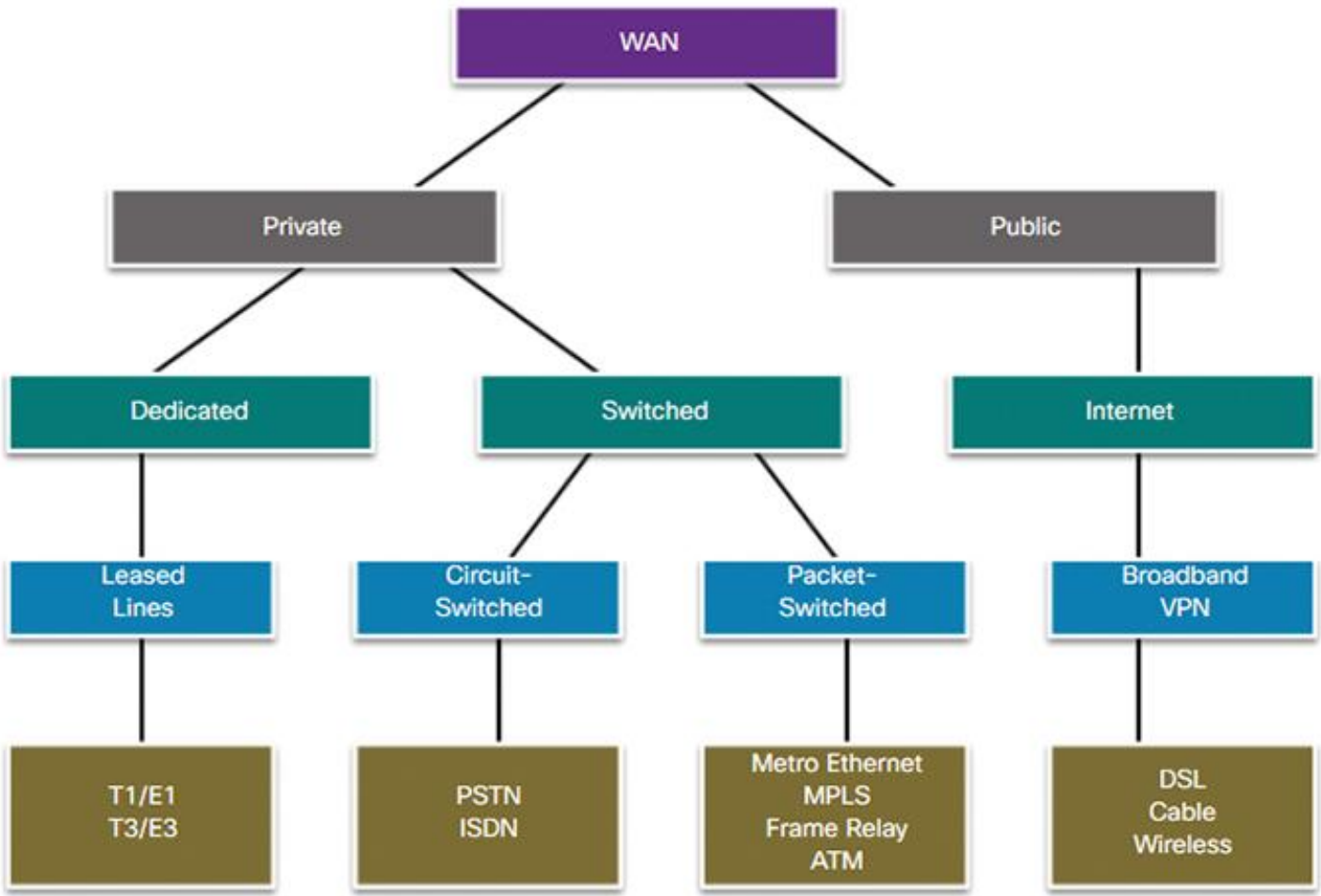
Two people carrying on a telephone conversation using a circuit-switched network



WAN - Types of Network Structures



- *Packet switched network*
 - a network in which all data messages are transmitted using fixed-sized packages, called packets.
 - More efficient use of a telecommunications line since packets from multiple sources can share the same medium
 - One form of packet switched network is the *datagram*. With a datagram: each packet is on its own and may follow its own path.





Purpose of WAN Connections

- As organizations grow and become international, WANs allow them to communicate between branches, share information and stay connected
- WANs also provide an essential service to the public.
 - Universities rely on WANs to access websites, databases , university research
 - people rely on WANs to communicate, bank, shop and more.

Note that the Internet is a WAN network

WAN and LAN Difference

- WANs can exist globally, without ties to a physical location through the use of a leased network provider, LANs exist within a limited area.
- LANs can be used to access a greater WAN (such as the Internet)



LANs, MANs, WANs – Quality of Service

- Quality of Service (QoS)
 - the set of technologies used to manage network resources by allocating different network behaviors to different traffic types
 - QoS involves traffic shaping
 - prioritizing traffic.
 - QoS specifies rules about which traffic has priority on a network

Note: details on QoS (how QoS is carried out) are beyond our current scope



LANs, MANs, WANs – Class of Service

- Class of Service (CoS)
 - a way of managing traffic in a network by grouping similar types of traffic - such as email, streaming video, voice over IP and large document file transfer
 - treating each type as a class with its own level of network service priority
 - CoS is used at the data link layer, OSI Layer 2
 - consists of a 3-bit field within a frame header



Types of WAN Technologies

- IPsec VPN
- SD-WAN
- Metro Ethernet
- EPL
- MPLS VPN
- EVPL
- VPLS
- Wavelength



Types of WAN Technologies

	Topology	Speeds	OSI	CoS/QoS	Network	Technology	Cost
IPsec VPN	Point to Point, Multi-Point, Mesh	Varies	Layer 3	Low	Shared	IP	Low
SD-WAN	Point to Point, Multi-Point, Mesh	Varies	Layer 3-7	Low- High	Shared	SDN	Low- Mid
Metro Ethernet	Point to Point	10Mbps to 10Gbps	Layer 2	High	Dedicated	SONET	Low- Mid
EPL	Point to Point	10Mbps to 10Gbps	Layer 2	High	Dedicated	SONET	High
MPLS VPN	Point to Point, Multi-Point, Mesh	10Mbps to 10Gbps	Layer 2-3	Low- High	Shared	MPLS	Mid- High



Types of WAN Technologies



	Topology	Speeds	OSI	CoS/QoS	Network	Technology	Cost
EVPL	Point to Point, Multi-Point	10Mbps to 10Gbps	Layer 2	Low- High	Shared	MPLS	Mid- High
VPLS	Point to Point, Multi-Point, Mesh	10Mbps to 10Gbps	Layer 2	Low- High	Shared	MPLS	Mid- High
Wavelength	Point to Point	2.5Gbps to 100Gbps	Layer 2	High	Dedicated	DWDM	Low



Types of WAN Technologies

- **IPsec VPN**
- IPsec VPN securely connects various sites on the same private network using Internet connectivity for the data communications
- VPN network topologies are available in a hub or meshed configuration.
- main benefit is cost
 - the ability to use existing Internet connectivity for data transport
 - and easy integration of remote users with VPN software



Types of WAN Technologies

- **Software-Defined WAN (SD-WAN)**

- an emerging type of WAN technology
- Software-Defined Networking (**SDN**) is used to automatically determine the best routes to and from locations over Internet connections and private data networks
- SD-WAN can use Internet connections like DSL, cable, wireless, shared fiber, or dedicated connectivity
- SD-WAN is a good option for businesses of all sizes and needs

Exercise: find out more on SDN technology

Types of WAN Technologies



- **Metro Ethernet**

- a point-to-point Ethernet data networking service connecting locations within a metropolitan area (MAN)
- Ethernet over Synchronous Optical Network (SONET) technology is used for secure point to point WAN connectivity.
- Data transfer speeds typically range from 10 Mbps to 10 Gbps, with 100Gbps available in some metropolitan areas.



Types of WAN Technologies

- **Ethernet Private Line (EPL)**

- Ethernet Private Line service (EPL) provides dedicated point-to-point Ethernet network connectivity between two or more locations.
- Like Metro Ethernet, SONET is used for secure point to point WAN connectivity
- A key component of EPL service is network resiliency and performance
 - this networking service is for the most **mission-critical** applications
 - e.g. railway and aircraft control systems
 - Electric power grid systems



Types of WAN Technologies

- **MPLS VPN**

- Multiprotocol Label Switching (*MPLS*)

- routing technique designed to speed up and shape traffic flows across enterprise wide area and service provider networks
 - labels are attached to data packets, whereby these labels are utilized in identifying virtual links between distant nodes
 - Multiprotocol and tagging capabilities of MPLS connect remote sites into a common type of data communication network. the configurations available include site to site, multipoint, and meshed networks



Types of WAN Technologies

- **MPLS VPN (cont.)**
- MPLS is different from other VPN services due to:
 - MPLS can prioritize traffic types over the MPLS providers network. This allows control over application performance (low to high QoS).
 - **MPLS networks are the current industry standard for a private data networking service, due to its superior performance, reliability, flexibility, and competitive pricing**



Types of WAN Technologies

- **Ethernet Virtual Private Line (EVPL)**

- Ethernet Virtual Private Line (EVPL) or E-Line provides point-to-multipoint connectivity over a provider's MPLS network.
- EVPL uses Ethernet Virtual Connections (EVCs) to connect multiple locations together
- E-Lines are available from 10 Mbps to 10 Gbps.

Types of WAN Technologies

- **Virtual Private LAN Service – VPLS**

- A network service for multiple sites in a single bridged domain over a provider managed MPLS network.
- All sites on a VPLS network will appear to be on the same LAN, regardless of the location
- VPLS also supports multiple classes of service (CoS) for low to high QoS application needs



Types of WAN Technologies

- **Wavelength**

- Wavelength Service is an optical data networking solution for customers requiring very large dedicated point-to-point data connections.
- This is ideal for business communication, data centers, backup solutions, streaming media, or very large data transfers.
- Applications that require low latency and high-speed connectivity are ideal for this type of WAN technology.
 - *Latency is a measure of delay. In a network, latency measures the time it takes for some data to get to its destination across the network*



Types of WAN Technologies

- **Wavelength (cont.)**

- Speeds typically available are 2.5Gbps, 10Gbps, 40Gbps, 100Gbps
- Wavelength service is provisioned over a Dense Wave Division Multiplexing (DWDM) network.
- **Wavelength service has the lowest ‘cost per Gbps’ of all data networking services, but an overall higher price point due to large bandwidth sizes.**
- This type of WAN technology is used by ISPs (Internet Service Providers), telecoms companies, data centers, media companies, and big tech companies



Leased Lines

- A leased line is a dedicated, fixed-bandwidth data connection.
- It allows data-intensive businesses to have a reliable, high-quality internet connection with guarantees of upload and download speed, uptime and resilience.
- “**Leased**” refers to the connection which is rented by the Internet Service Provider (ISP) directly to a business, resulting in a service above and beyond what standard broadband provides

Exercise: define network resilience

Broadband

- Broadband is the transmission of wide bandwidth data over a high speed internet connection
- Broadband provides high speed internet access via multiple types of technologies including fiber optics, wireless, cable, DSL and satellite
 - minimum of 25 Mbps download and 3 Mbps upload speeds



X.25

- X.25 **was** a standard of protocols used for packet-switched communications over a wide area network
 - Invented in 1976, latest version in 1996
- X.25 offered three basic layers of protocols:
 - Physical layer
 - Data link layer
 - Packet layer
- X.25 pre-dates the OSI Reference Model, but the X.25 layers are similar to the physical layer, data link layer and network layer of the OSI model.



X.25

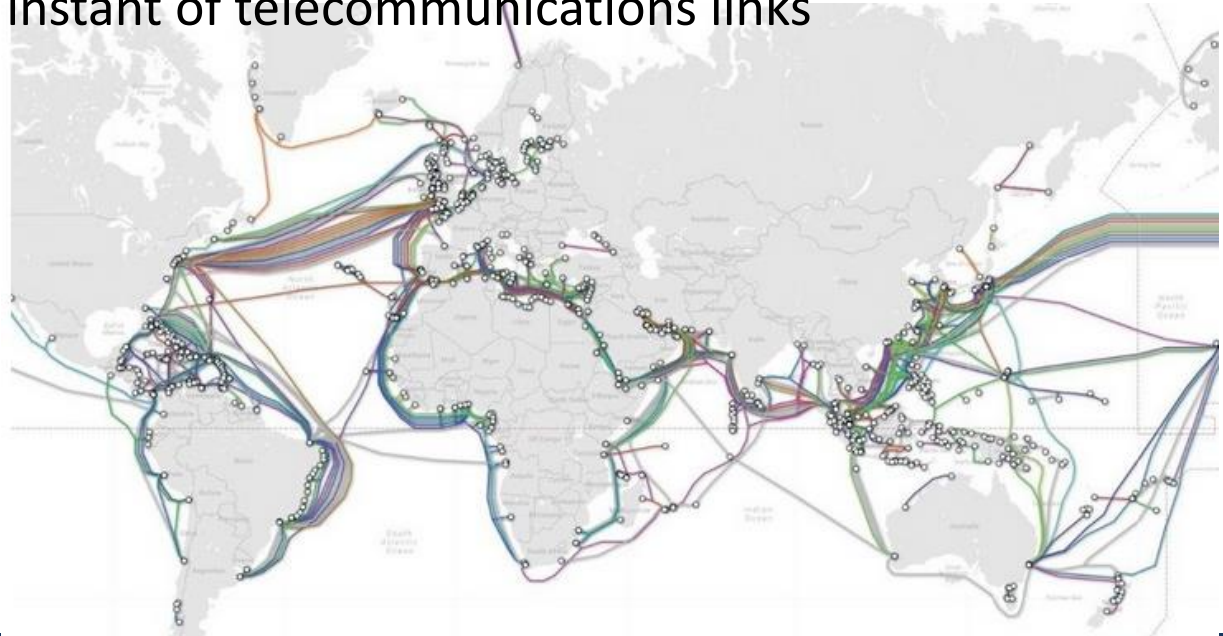
- With the widespread acceptance of **Internet Protocol (IP)** as a standard for corporate networks, X.25 applications migrated to cheaper solutions using IP as the network layer protocol and replacing the lower layers of X.25 with Ethernet





Internet Connections Across Continents

- Submarine Internet Cables
 - The first submarine communications cables laid beginning in the 1850s carrying telegraphy traffic, establishing the first instant of telecommunications links between continents



Internet Connections Across Continents



- Submarine Internet Cables
 - Traditionally, telecommunication companies have been the ones to invest in building submarine cables.
 - However, tech companies like Microsoft, Facebook and Google are increasingly building submarine cables, for example:
 - Microsoft and Facebook laid a super-fast 4000-mile (6437-km) internet cable across the Atlantic ocean, from USA to Spain
 - Amazon Web Services (AWS) invested in the Hawaiki Submarine Cable to speed up performance for its cloud customers
 - *View updated map of submarine cables:*
<https://www.submarinecablemap.com/>