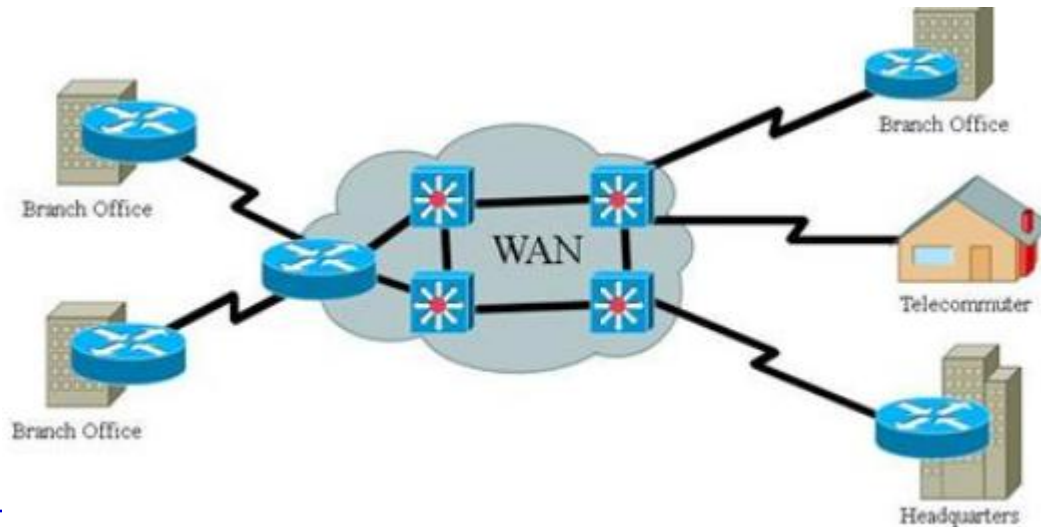


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# Chapter 8

# Wide Area Networks



# Outline

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**8.2 - Circuit-Switched Networks**

**8.3 - Dedicated-Circuit Networks**

**8.4 - Packet-Switched Networks**

**8.5 - Virtual Private Networks**

# **8.1 Introduction**

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- **Wide area networks (WANs)**
  - **Connect BNs and LANs across distance**
- **Utilize leased circuits from common carriers such as AT&T**
- **Common Carriers**
  - **Local Exchange Carriers (LECs) (Local Phone Company)**
    - **Verizon**
  - **Interexchange Carriers (IXCs) (Long Distance phone Company)**
    - **Sprint**

# WAN Services

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- **Common carrier networks**
  - **Circuit-Switched Networks**
  - **Dedicated-Circuit Networks**
  - **Packet-Switched Networks**
- **Public networks**
  - **Virtual Private Networks (VPN)**
- **Ethernet MAN**

<https://www.youtube.com/watch?v=nEUDzOptEn0>

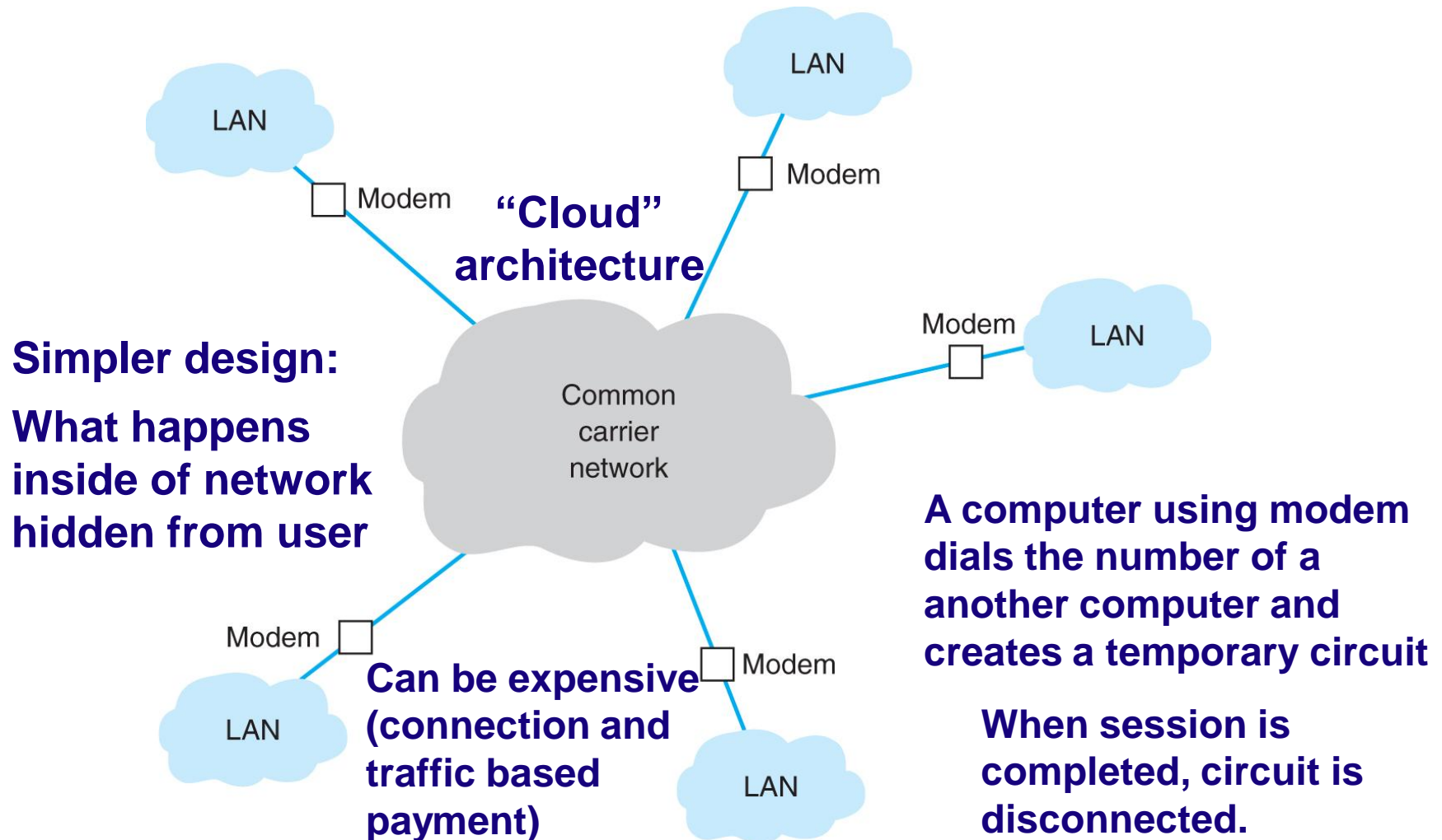
## **8.2 Circuit Switched Services**

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- **Public Switched Telephone Network (PSTN), (the telephone networks)**
  - **Provided by common carriers**
- **Common Carriers Used to Provide:**
  - **POTS (Plain Old Telephone Service)**
    - **Via use of modems to dial-up and connect to ISPs (5% of US population uses)**
    - **Oldest, simplest WAN technology**
  - **ISDN (Integrated Services Digital Network )**

# Basic Circuit Switched Architecture

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# Circuit Switched Services

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- **Simple, flexible, inexpensive, slow**
- **Main issues**
  - Need to make separate connection each time (Overhead)
  - Low Data transmission rates
    - Up to 56 Kbps for POTS, and up to 1.5 Mbps for ISDN
  - Slow
- **Alternative**
  - Private dedicated circuit
    - Leased from a common carrier for the user's exclusive use
  - Expensive

## **8.3 Dedicated Circuits**

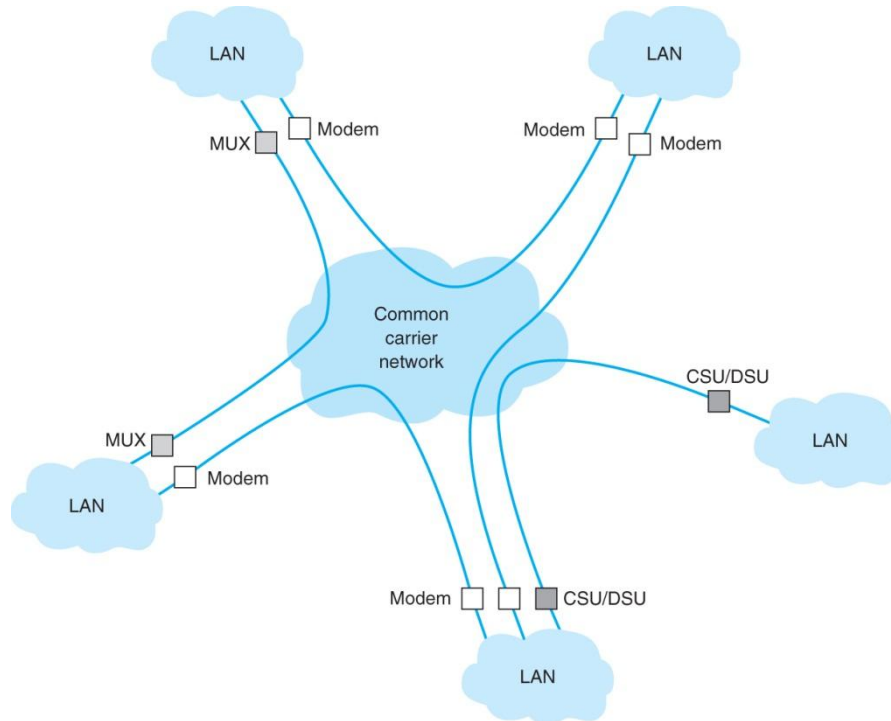
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- **Leased full duplex circuits from common carrier**
- **Point to point linking between locations**
  - Routers and switches connect locations
- **Flat monthly fee**
  - Unlimited use
- **Three basic dedicated circuit architectures (topologies)**
  - Ring, star, mesh
- **Dedicated Circuit Services**
  - T carrier services
  - Synchronous Optical Network (SONET) services
  - Ethernet WAN (EWAN)



# Dedicated Circuit Services

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Equipment installed at the end of dedicated circuits

- **CSU/DSU: Channel Service Unit / Data Service Unit** which is the WAN equivalent of a LAN NIC

# Ring Architecture

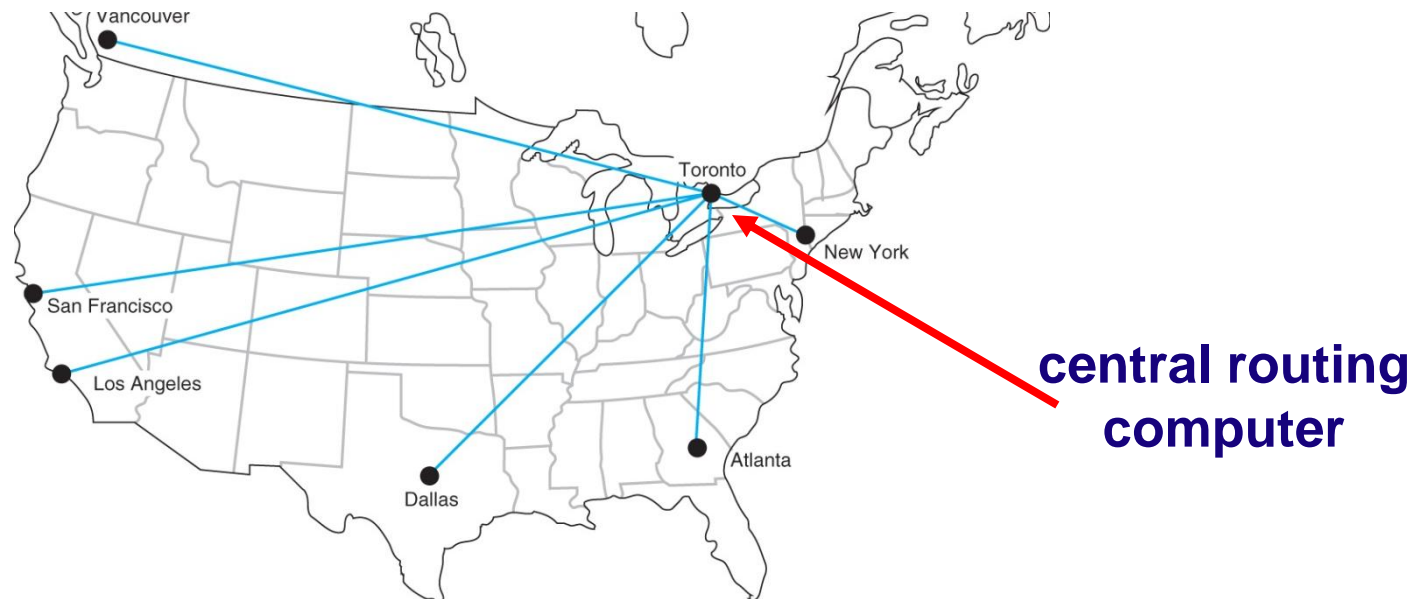
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- **Reliable**
  - Data can flow in both directions (full-duplex)
  - Even with break, data continues to flow
  - Dramatically reduced performance if ring breaks
- **Performance**
  - Messages travel through many nodes before reaching destination



# Star Architecture

- **Easy management**
  - Central computer routes all messages
- **Points of failure**
  - Failure of central computer brings the network down
  - Failure of any circuit or computer affects one site only
- **Performance**
  - Central computer can be bottleneck



# Mesh Architectures

- Combine performance benefits of ring and star networks
- Use decentralized routing, with each computer performing its own routing
- Impact of losing a circuit is minimal (because of the alternate routes)
- More expensive than setting up a star or ring network.

## Full mesh

- Expensive, seldom used



## Partial mesh

- More practical



# T-Carrier Services

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- **Most commonly used dedicated digital circuits**
  - Time Division Multiplexing
- **T-hierarchy**
  - DS-0 (64 Kbps); Basic T-1 unit, bound into groups of 24
  - T-1, also called DS-1 (1.544 Mbps)
    - 24 simultaneous 64 Kbps channels
      - Fractional T-1, (FT-1) offers a portion of a T-1
  - T-3 (44.376 Mbps); 28 T-1 capacity
- **Europe uses E-Carrier services...**

# T-Carrier Digital Hierarchy

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T Carrier Designation	DS Designation	Speed
FT1	DS0	64 Kbps
T1	DS1	1.544 Mbps
T2	DS2	6.312 Mbps
T3	DS3	44.376 Mbps
T4	DS4	274.176 Mbps

# 8.4 Packet Switched Services

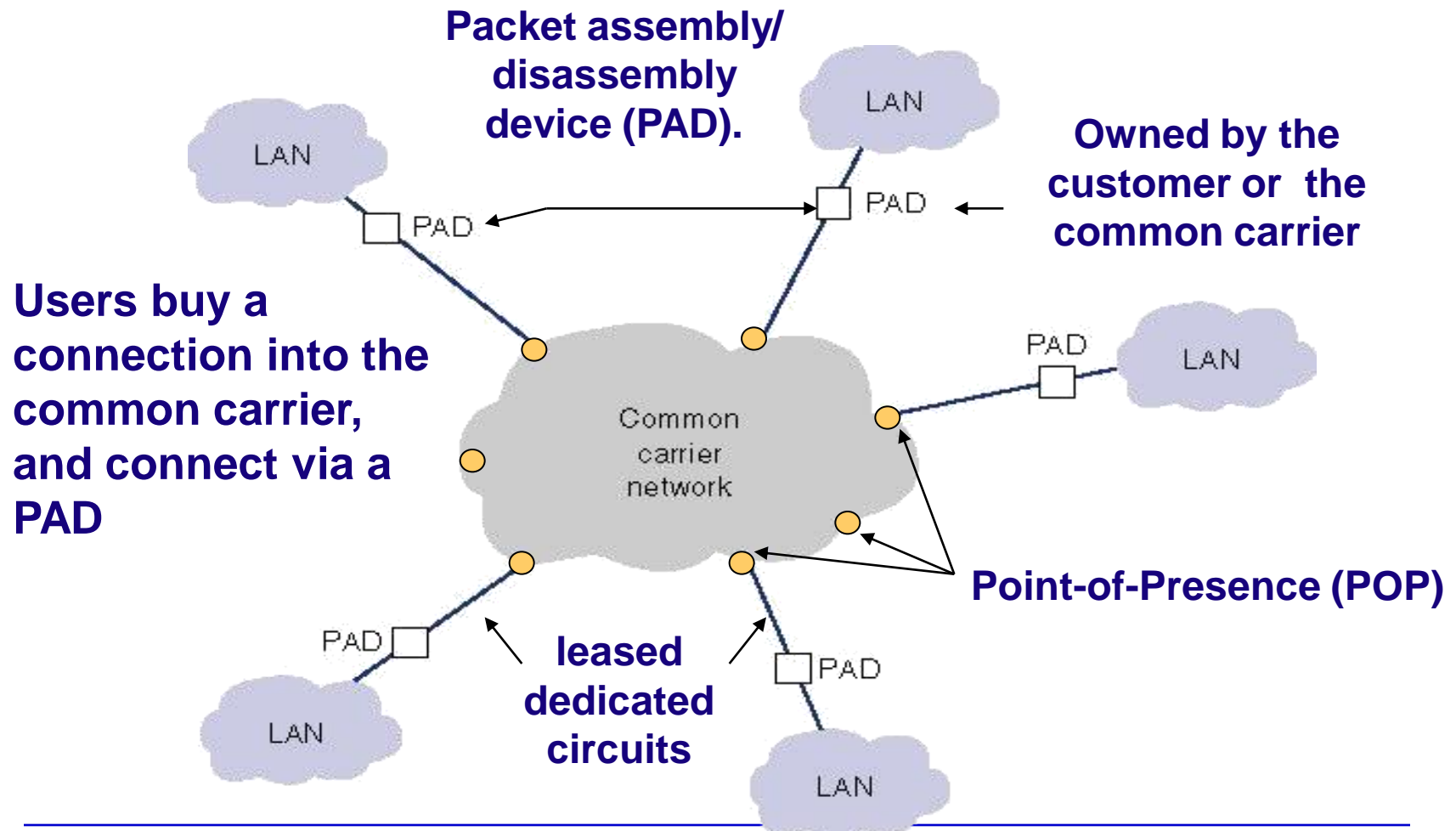
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- **In both circuit switched and dedicated services**
  - **Circuit established between two end points**
    - **Dedicated for exclusive use between these two end points**
    - **Circuit switched dedicated exclusively to communications between those two end points**
    - **Premium cost**
- **Packet switched services**
  - **Multiple connections exist simultaneously between computers over the same physical circuit**
  - **User pays a fixed fee for the connection to the network plus charges for packets transmitted**
    - **Frame Relay, SONET, MPLS**

# Basic Architecture

## Packet Switched Services

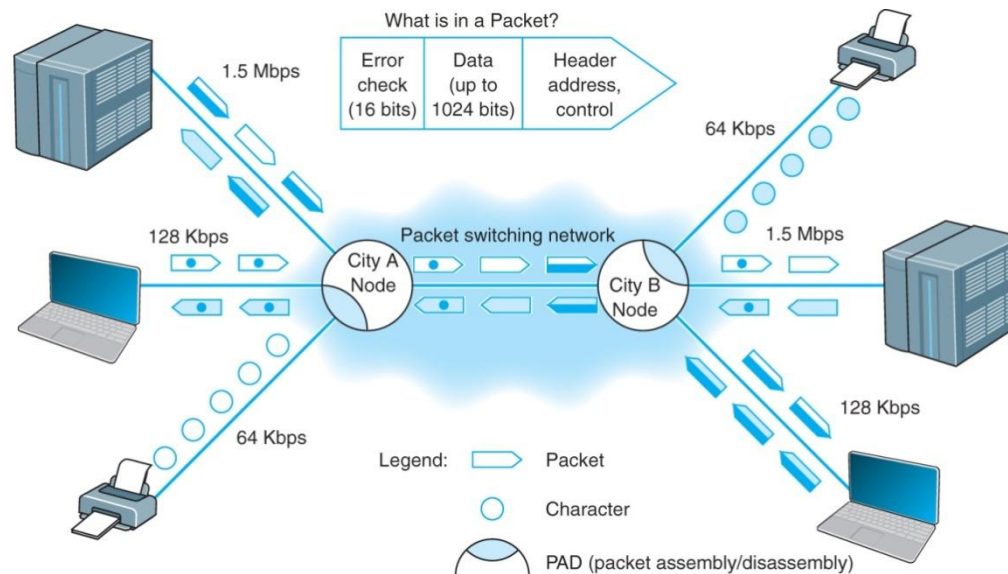
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# Packet Switching

- Interleaves packets from separate messages for transmission
  - Most data communications consists of short bursts
  - Packet switching takes advantage of burstiness
    - Interleaving bursts from many users optimizes shared network use



# Packet Routing

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- **Describe which intermediate devices the data is routed through**
- **Connectionless (Datagram)**
  - Adds a destination and sequence number to each packet
  - Individual packets can follow different routes through the network
  - Packets reassembled at destination
- **Connection Oriented (Virtual Circuit (VC))**
  - Establishes an end-to-end circuit between the sender and receiver
  - All packets for that transmission take the same route over the virtual circuit established
  - Same physical circuit can carry many VCs

# Virtual Circuit Types

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- **Permanent Virtual Circuit (PVCs)**
  - Long duration (days, weeks)
  - Changed only by the network administrator
    - Commonly used
  - Packet switched networks using PVCs behave like a dedicated circuit networks
- **Switched Virtual Circuit (SVC)**
  - Established dynamically on a per call basis
  - Disconnected when call ends

# **Packet Switched Protocols**

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- **Asynchronous Transfer Mode (ATM)**
- **Frame Relay**
- **IP/MPLS**
- **Ethernet Services**
  
- **Several common carriers have announced they will soon stop offering all but Ethernet and Internet services**

# **Asynchronous Transfer Mode (ATM)**

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- **Packet switching service**
- **Operating characteristics**
  - Performs packet encapsulation (no translation)
  - Provides no error control (unreliable protocol)
  - Provides extensive QoS information
  - Scalable (easy to multiplex ATM circuits onto much faster ones)
  - Typically uses SONET at layer 2
- **Data Rates**
  - Same rates as SONET: 51.8, 466.5, 622.08 Mbps
  - New versions: T1 ATM (1.5 Mbps), T3 ATM (45 Mbps)

# Ethernet WAN Services

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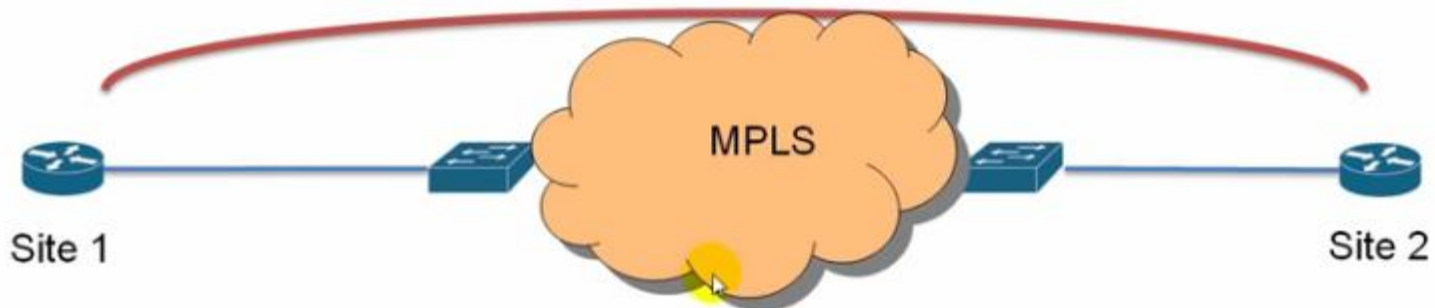
- **Most organizations use Ethernet /IP on their LAN and BN.**
- **Ethernet Services differ from WAN packet services like ATM or Frame Relay**
  - **Currently offer CIR speeds from 1 to 40 Gbps at a lower cost than traditional services**
- **No need to translate LAN protocol (Ethernet/IP) to WAN protocol**
- **Emerging technology**

# Ethernet WAN Services



## Ethernet as a WAN technology

- Normally Ethernet is a LAN technology due to distance limitations at layers 1 and 2
- Copper cables are limited to 100 meters
- Fiber is limited to just a few miles depending on the technology used
- However many service providers provision WAN circuits as Ethernet connections



- <https://www.youtube.com/watch?v=M9uKJ10Uffs>

# **Multi Protocol Label Switching (MPLS)**

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- **Relatively new WAN technology**
- **Designed to work with a variety of commonly used layer 2 protocols**



# MPLS – How It Works

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- **Customer connects to common carrier's network using any common layer 2 service**
  - T carrier, SONET, ATM, frame relay, Ethernet
- **At network entry point, carrier's switch examines incoming frame and converts incoming layer 2 or layer 3 address into an MPLS address label**
  - Carrier can use the same layer 2 protocol inside its network as the customer...
- **When delivered, MPLS switch removes MPLS header and delivers the packet into the customer's network using whatever layer 2 protocol the customer has used...**
  - Frame relay, T1.

# **MPLS Advantages**

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**1.) Faster than traditional routing**

**2.) Common carriers in the U.S. and Canada typically have a different way of charging for MPLS services.**

**•Common to use a full mesh design in which every location is connected to every other location. Packets take fewer hops and thus less time to reach their destinations**

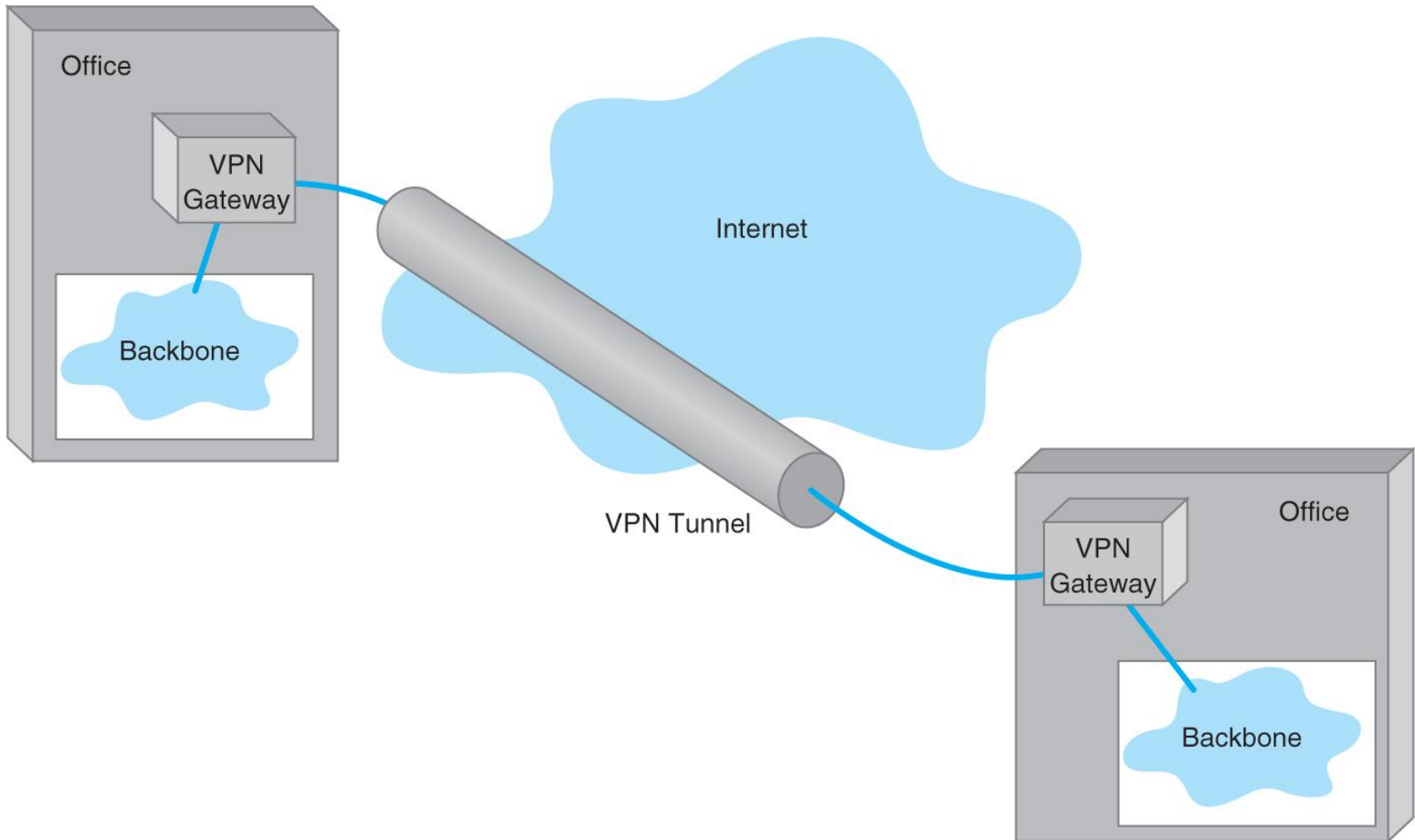
# 8.5 Virtual Private Networks

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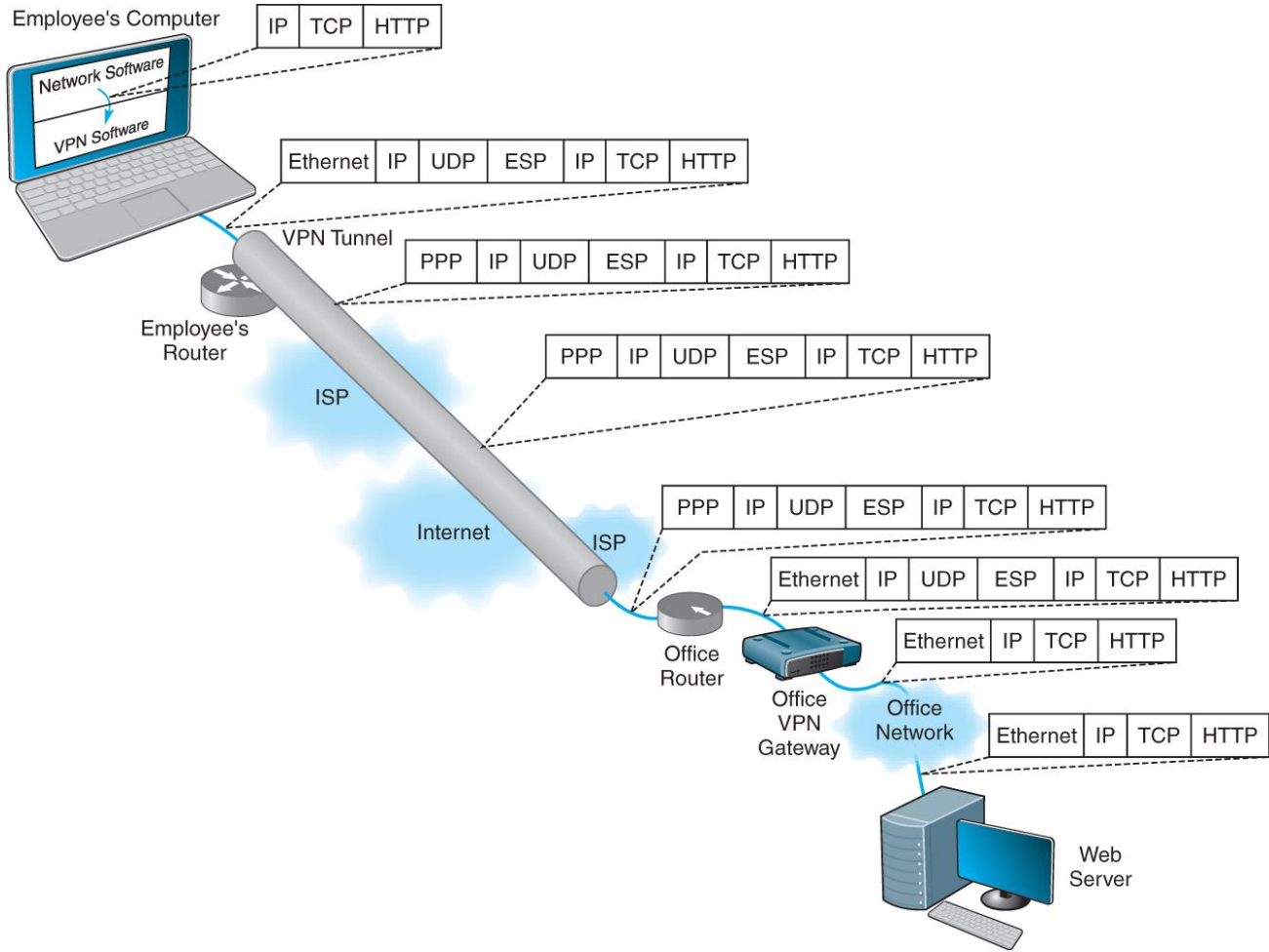
- **Equivalent of a private packet switched network over Internet**
  - Use Virtual Circuits (*tunnels*) that run over the Internet
    - Appear to the user as private networks
  - Encapsulate packets sent over these tunnels using special protocols that also encrypt the IP packets
- **Low cost and flexible**
- **Disadvantages:**
  - Unpredictability of Internet traffic
  - Not all vendor equipment and services are compatible

# One VPN Architecture

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# VPN Encapsulation of Packets



# Three VPN Types

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- **Intranet VPN**
  - Virtual circuits between organization offices over the Internet
- **Extranet VPN**
  - Connects several different organizations, e.g., customers and suppliers
- **Access VPN**
  - Enables employees to access an organization's networks from remote locations

# 8.8 Implications

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- **Changing role of networking and telecomm managers**
  - Increased and mostly digitized data transmission causing the merger of these positions
- **Changing technology**
  - Within 5 years, ATM may disappear
  - Increasing dominance of Ethernet and MPLS
  - Decreasing cost of setting up WANs
- **Changing vendor profiles**
  - From telecomm vendors to vendors with Ethernet and Internet experiences

# Questions?

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