



Wide Area Networks (WANs)

CompTIA Network+ (N10-007)

Wide Area Networks (WANs)

- In the early 1990s, computer-networking design guides commonly invoked the *Pareto principle* (80-20 rule)
- Concept is that 80% of traffic stays on the LAN, while only 20% of traffic goes to WAN
- Today, most network traffic leaves the LAN and travels across the WAN



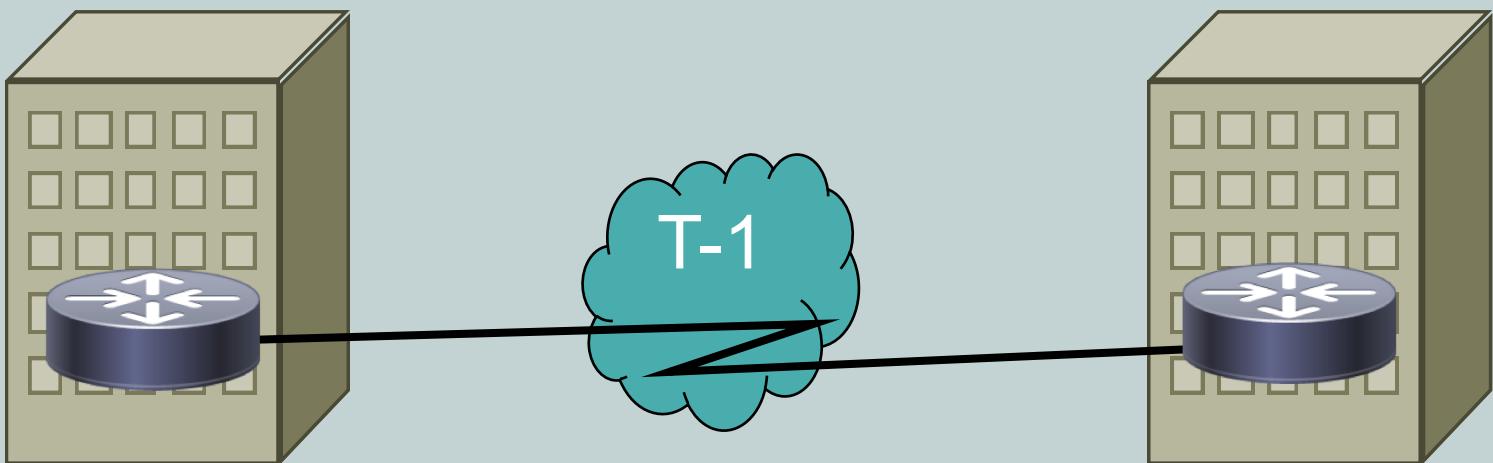
WAN Connection Types

- Dedicated leased line
- Circuit-switched connection
- Packet-switched connection



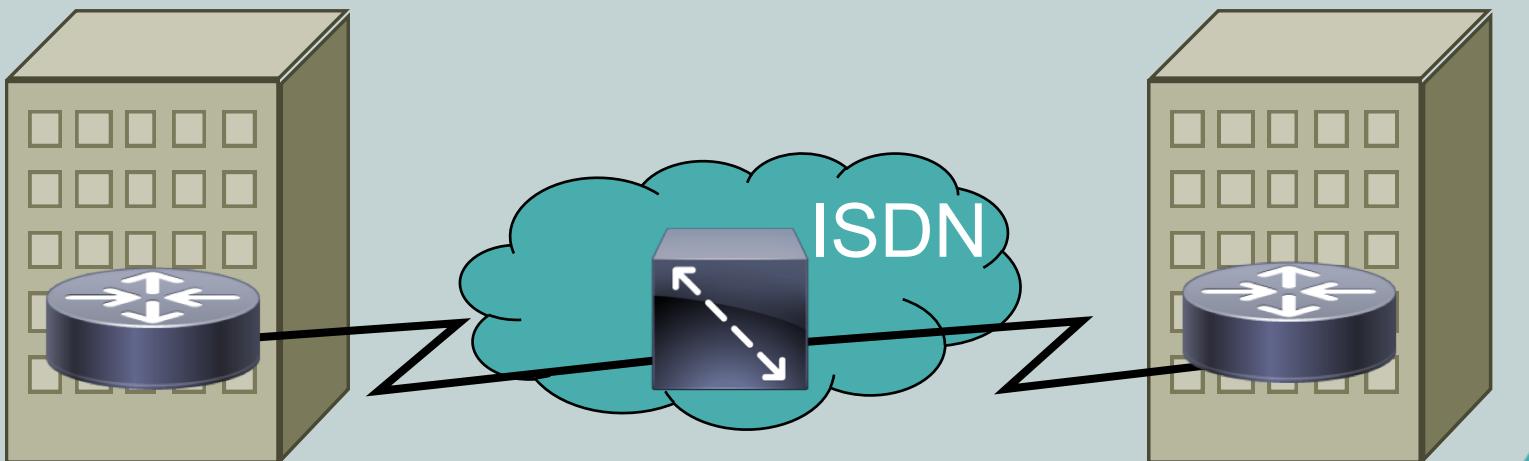
Dedicated Leased Line

- Logical connection that connects two sites through a service provider's facility or telephone company's central office
- More expensive than other WAN technologies because a customer doesn't share bandwidth with other customers



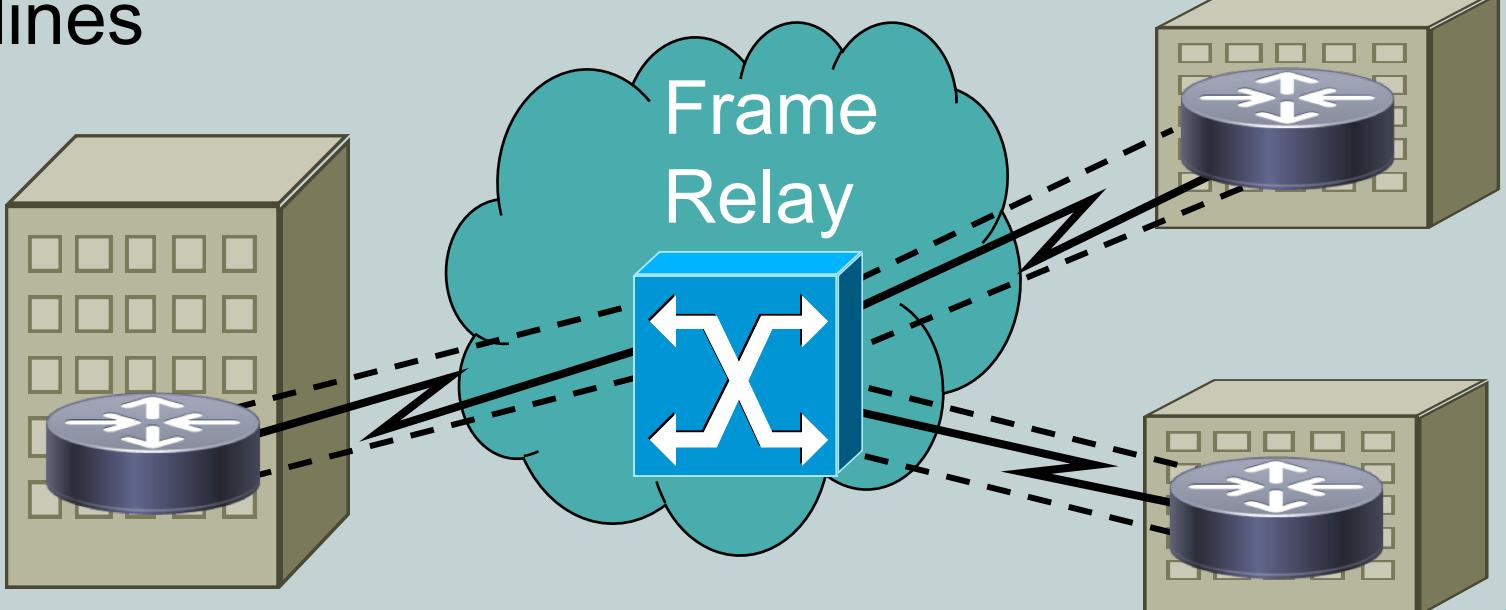
Circuit-Switched Connection

- Connection is brought up only when needed, like making a phone call
- On-demand bandwidth can provide cost savings for customers who only need periodic connectivity to a remote site



Packet-Switched Connection

- Always on like a dedicated leased line, but multiple customers share the bandwidth
 - SLAs used to guarantee a certain quality (5mbps at least 80% of the time)
- Virtual circuits are represented as dashed lines



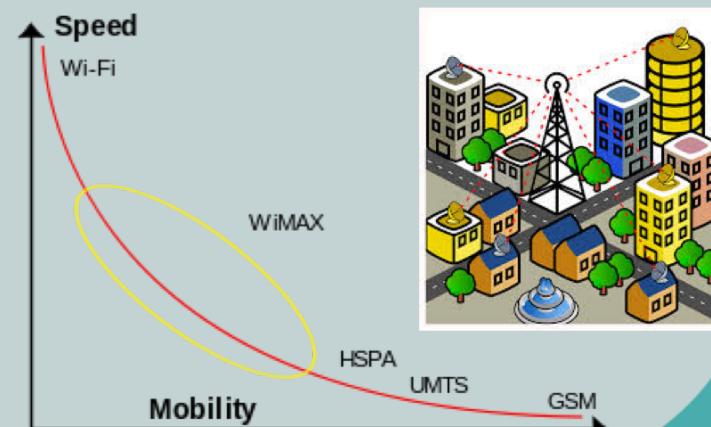
WAN Physical Media

- Unshielded twisted-pair (UTP)
 - Supports analog/digital
 - Examples (T1, DSL, Dial-up, ISDN)
- Coaxial cable
 - RG-6 cabling
 - Example (Cable modems)
- Fiber-optic cable
 - High bandwidth, long distance, and no EMI
- Electric power lines
 - Broadband over Power Lines (BPL)
 - Supports up to 2.7 Mbps
 - Utilizes extensive infrastructure already in place (Power lines)



WAN Wireless Media

- Cellular (Phones and Hot Spots)
 - LTE, 4G, 3G, 2G
 - GSM vs CDMA
 - Tethering or ICS (Internet Connection Sharing)
- HSPA+: Evolved High-Speed Packet Access
 - Advancements over LTE and 4G
 - Wireless broadband up to 84 Mbps
- Worldwide Interoperability for Microwave Access (WiMAX)
 - Alternative to DSL/Cellular
 - Wireless fixed location service



WAN Wireless Media

- Satellite
 - HughesNet Gen 5
 - Very Small Aperture Terminal (VSAT)
 - Used for remote areas
 - Shipboard use
 - Expensive in comparison to cellular, cable, or fiber connections
- Radio
 - Implementation varies country based on frequencies



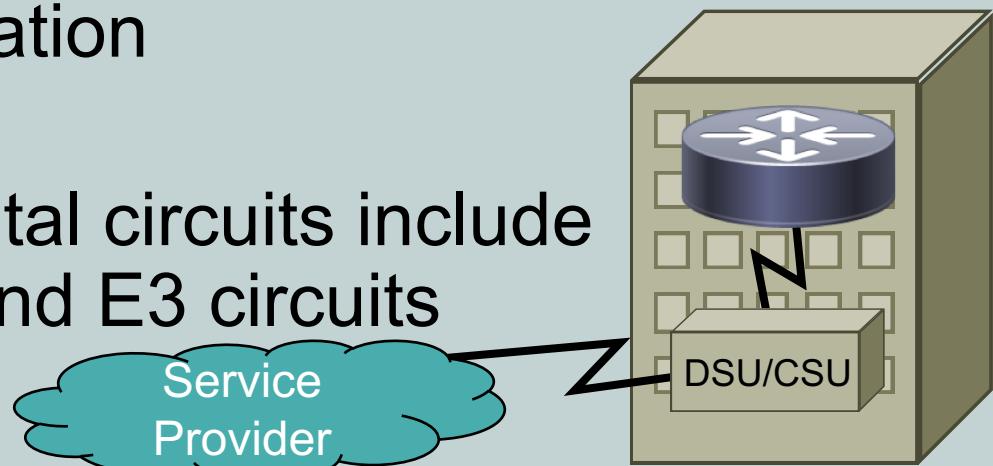


WAN Technologies (Part 1)

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Dedicated Leased Line

- Point-to-point connection between two sites
 - All bandwidth on line is available all the time
- Digital circuits are measured in 64-kbps channels called *Digital Signal 0* (DS0)
- Channel Service Unit / Data Service Unit (CSU/DSU) terminates the digital signals at customer location
- Common digital circuits include T1, E1, T3, and E3 circuits



Examples of Digital Signal Levels

Carrier	Signal Level	Number of T1 Signals	Number of Voice Channels	Speed
T1	DS1	1	24	1.544 Mbps
T1c	DS1c	2	48	3.152 Mbps
T2	DS2	4	96	6.312 Mbps
T3	DS3	28	672	44.736 Mbps
T4	DS4	168	4032	274.760 Mbps
E1	n/a	n/a	30	2.0 Mbps
E3	n/a	n/a	n/a	34.4 Mbps



Metro Ethernet

- Service providers are beginning to offer Ethernet interfaces to their customers
- Less expensive and more common than specialized serial ports used in a CSU/DSU
- Technology used by service provider is hidden from customer and they only need to connect their network's router to a Smart Jack



Point-to-Point Protocol (PPP)

- Commonly used Layer 2 protocol on dedicated leased lines to simultaneously transmits multiple Layer 3 protocols (IP, IPX)
- Each Layer 3 control protocol runs an instance of PPP's *Link Control Protocol* (LCP)
 - Multilink interface
 - Allows multiple physical connections to be bonded together into a logical interface
 - Looped link detection
 - Layer 2 loop can be detected and prevented
 - Error detection
 - Frames containing errors can be detected and discarded
 - Authentication
 - Device on other end can authenticate the link



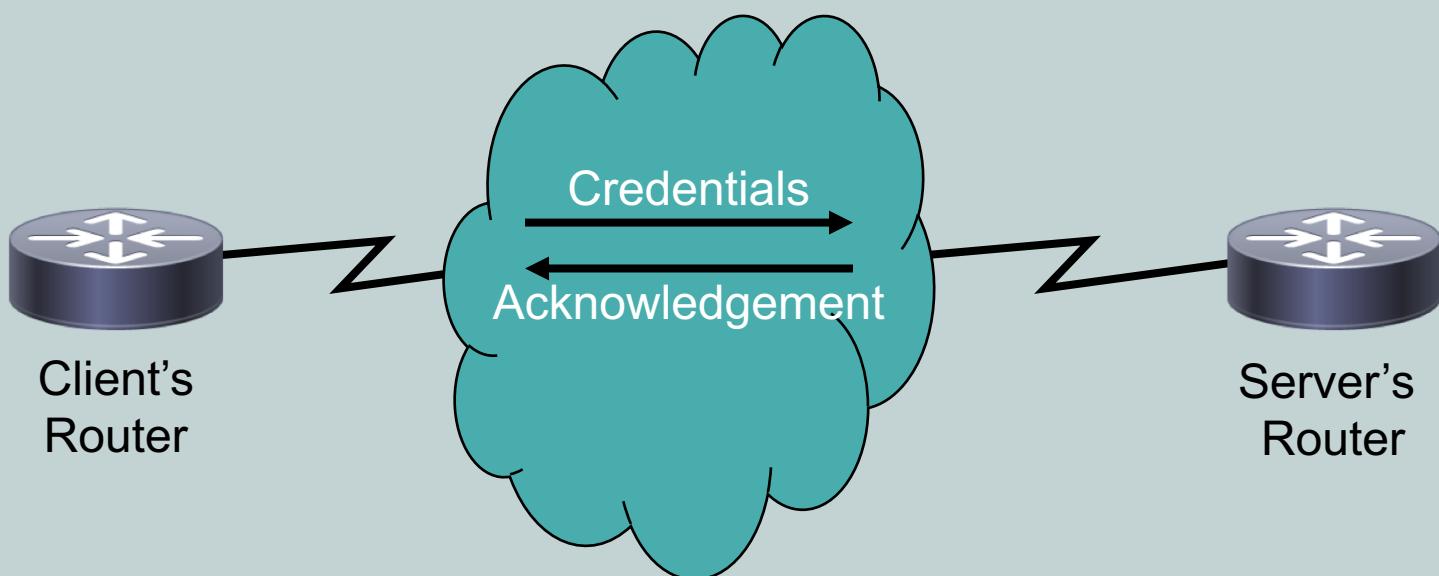
PPP Authentication Methods

- Password Authentication Protocol (PAP)
- Challenge-Handshake Authentication Protocol (CHAP)
- Microsoft Challenge-Handshake Authentication Protocol (MS-CHAP)



Password Authentication Protocol (PAP)

- Performs one-way authentication between client and server
- Credentials sent in clear-text



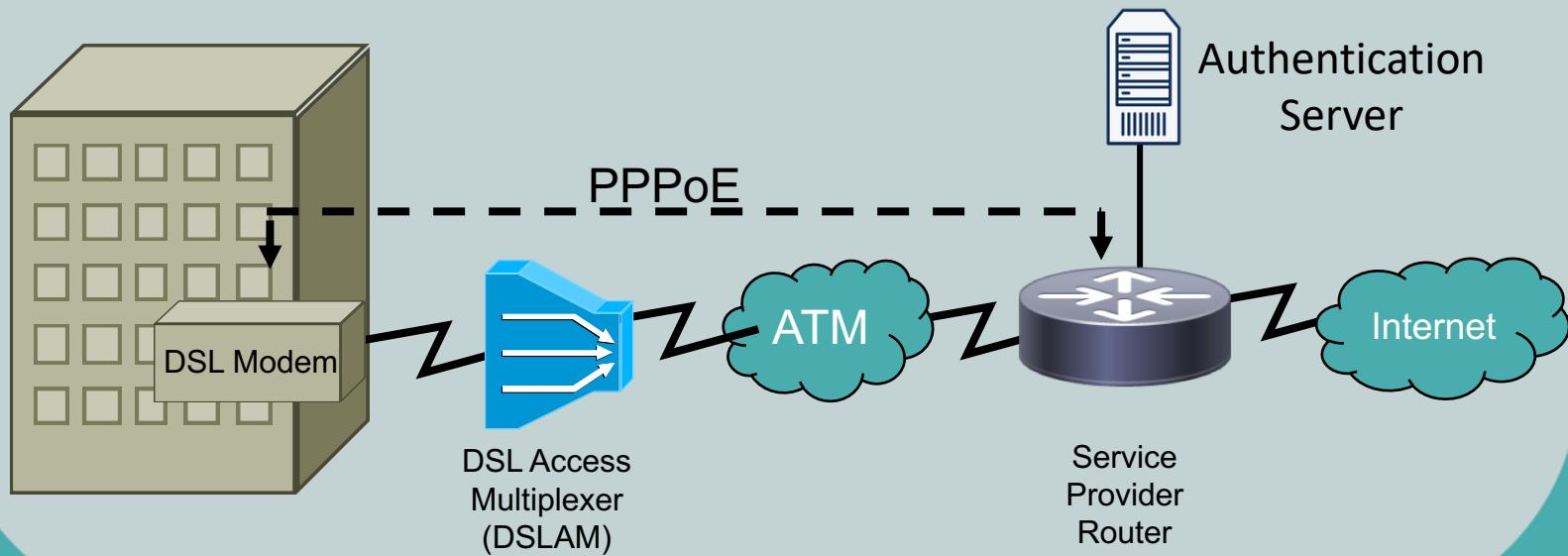
CHAP and MS-CHAP

- CHAP
 - Challenge-Handshake Authentication Protocol
 - Performs one-way authentication using a three-way handshake
 - Credentials are hashed before transmission
- MS-CHAP
 - Microsoft Challenge-Handshake Authentication Protocol
 - Microsoft-enhanced version of CHAP, includes two-way authentication



PPP over Ethernet (PPPoE)

- Commonly used with DSL modems
- PPPoE encapsulates PPP frames within Ethernet frames
- Allows for authentication over Ethernet



Digital Subscriber Line (DSL)

- Asymmetric DSL (ADSL)
 - Maximum distance to DSLAM: 18,000 feet
 - Voice and Data on same line
 - Downstream: Up to 8 Mbps
 - Upstream : Up to 1.544 Mbps
- Symmetric DSL (SDSL)
 - Maximum distance to DSLAM: 12,000 feet
 - No simultaneous voice and data on same line
 - Downstream: 1.168 Mbps
 - Upstream: 1.168 Mbps
- Very High Bit-Rate DSL (VDSL)
 - Maximum distance to DSLAM: 4,000 feet
 - Downstream: Up to 52 Mbps
 - Upstream: Up to 12 Mbps





WAN Technologies (Part 2)

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Cable Modems

- Hybrid Fiber-Coax (HFC) distribution network is a cable television infrastructure containing both coaxial and fiber-optic cabling
- Specific frequency ranges are used for upstream and downstream data transmission as determined by Data-Over-Cable Service Interface Specification (DOCSIS)
 - Upstream (5 MHz to 42 MHz)
 - Downstream (50 MHz to 860 MHz)
- Transmits and receives over cable television infrastructure



Satellite Modems

- Used in remote, rural, or disconnected locations where other connections are not available
- Provides relatively fast speeds like a DSL modem, but contain low bandwidth usage limits and charge high costs for over limit usage
- Potential issues with Satellite communications:
 - Delays - Time to satellite and back ($> \frac{1}{4}$ second)
 - Weather conditions
 - Thunderstorms and snow can cause loss of connectivity between satellite and receiver



Plain Old Telephone Service (POTS)

- *Public switched telephone network* (PSTN) consists of telephone carriers from around the world
- Analog connections (voice and/or data) using the PSTN are called POTS connections
- Dial-up modems have a maximum bandwidth of 53.3-kbps because they can only access one 64-kbps channel at a time



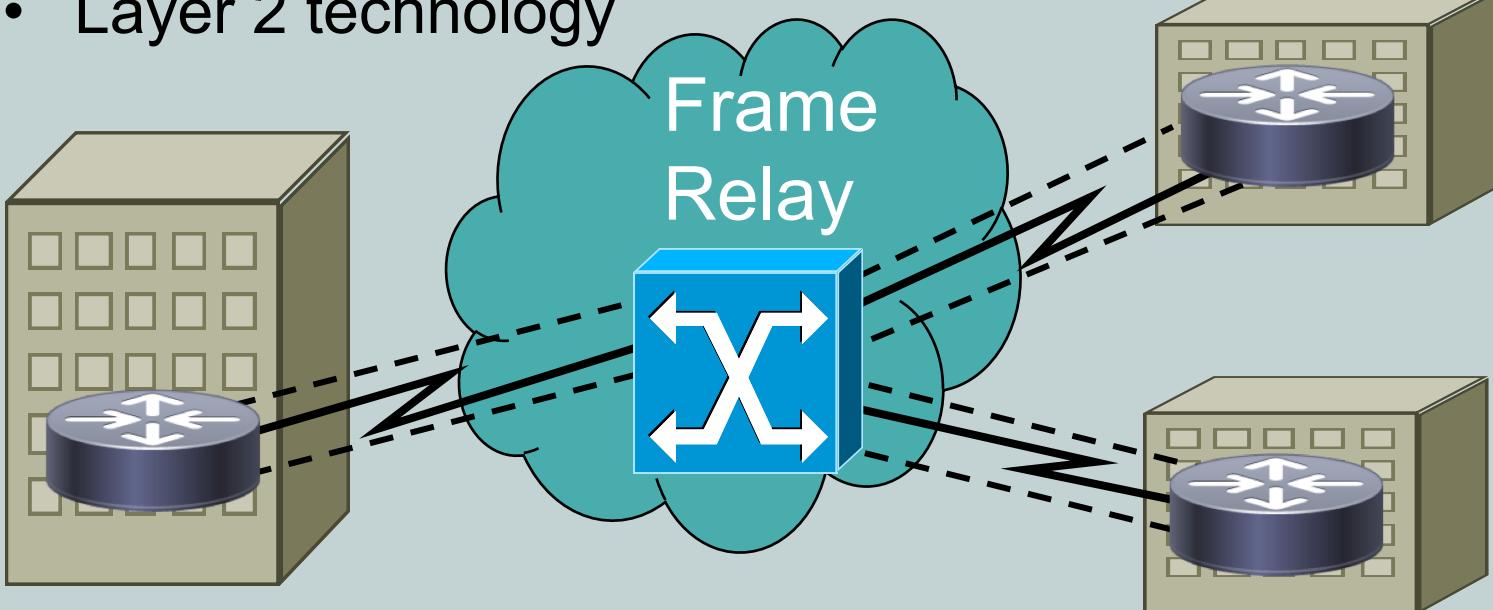
Integrated Services Digital Network (ISDN)

- Supports multiple 64-kbps B (Bearer) channels
- Older technology designed to carry voice, video, or data over B channels
- *D channel (data or delta channel)* existed for 64-kbps signaling data
- Circuits classified as a *basic rate interface* (BRI) or *primary rate interface* (PRI):
 - BRI: Offers a two 64-kbps B-channels with a 16kbps D-channel
 - PRI: Offers a 1.472-Mbps data path over 23 B-channels and a 64-kbps D-channel



Frame Relay

- Losing market share due to cable and DSL
 - Frame Relay sites connected to virtual circuits (VC)
 - VCs are *point-to-point* or *point-to-multipoint*
 - Low cost and widely available
 - Always-on or on-demand
 - Layer 2 technology



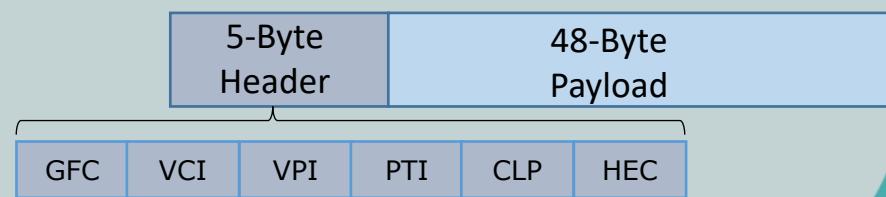
Synchronous Optical Network (SONET)

- Layer 1 technology using fiber as media
- Transports Layer 2 encapsulation (like ATM)
- High data rates (155 Mbps to 10 Gbps)
- Covers large distances (20 km to 250 km)
- Physical topology can be a bus or ring



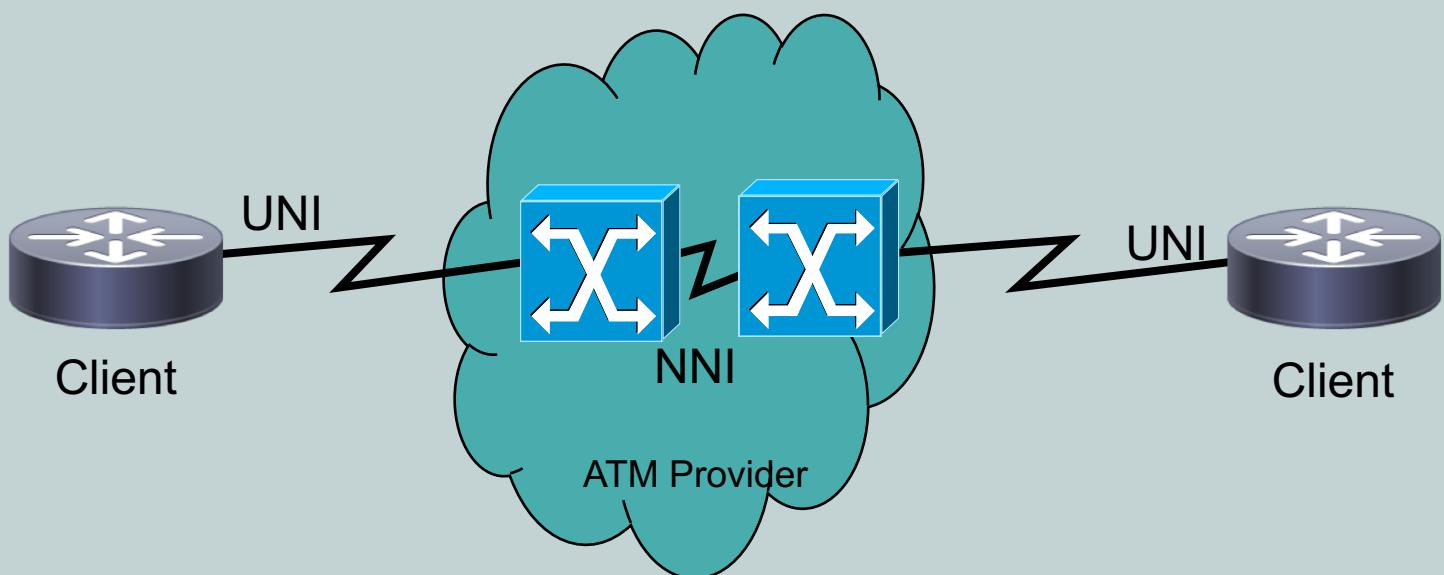
Asynchronous Transfer Mode (ATM)

- Layer 2 WAN technology operating using Permanent Virtual Circuits (PVCs) and Switched Virtual Circuits (SVCs)
- Similar to Frame Relay, except all frames are transferred as fixed-length (cells) as its protocol data unit (PDU)
- Fixed-length cells of 53-bytes used to increase speed of transmissions
 - Contains 48-byte payload and 5-byte header
 - Generic Flow Control (GFC)
 - Virtual Circuit Identifier (VCI)
 - Virtual Path Indicator (VPI)
 - Payload Type Indicator (PTI)
 - Cell Loss Priority (CLP)
 - Header Error Control (HEC)



ATM Virtual Circuits

- User-Network Interface (UNI)
 - Used to connect ATM switches and endpoints
- Network-Node Interface (NNI)
 - Used to connect ATM switches together



Multiprotocol Label Switching (MPLS)

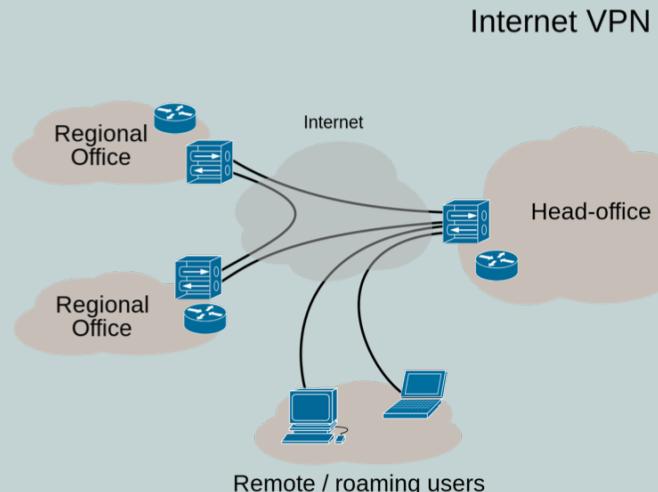
- Supports multiple protocols on the same network (used by service providers)
- Supports both Frame Relay and ATM on the same MPLS backbone
- Allows traffic to be dynamically routed based on load conditions and path availability
- Label switching is more efficient than Layer 3 IP address routing
- Used by service providers for forwarding data in the backend, the customer remains unaware of the details



Dynamic Multipoint Virtual Private Network (DMVPN)

- Allow Internet to be used as WAN connection for secure site-to-site communication
- VPN tunnel has authentication and encryption so users on the unsecure network cannot read or decrypt the traffic without proper keys

- Can connect remote locations with low cost, instead of dedicated or leased-line access



WAN Data Rates

- Bandwidth measured in Kbps, Mbps, & Gbps
- ATM and SONET measured by *optical carrier*
 - OC levels are based off of OC-1 (51.84 Mbps)
 - All others are multiples (OC-3 is 155.52 Mbps))

WAN Technology	Typical Available Bandwidth
Frame Relay	56 kbps – 1.544 Mbps
T1	1.544 Mbps
T3	44.736 Mbps
E1	2.048 Mbps
E3	34.4 Mbps
ATM	155 Mbps – 622 Mbps
SONET	51.84 Mbps (OC-1) – 159.25 Gbps (OC-3072)

