MANs & WANs

Slide Set 6

MAN & WAN

- MAN & WAN Purposes
  - Link sites (usually) within the same corporation
  - Remote access for individuals who are off-site
  - Internet access for individuals or firms

MAN & WAN

- Technologies for Individual Internet Access
  - Telephone modems
  - DSL lines / Cable modems
  - Wireless Internet access
- Site-to-Site Transmission within a Firm
  - Private line networks
  - Public switched data networks (PSDNs)
  - Virtual Private Networks (VPNs)
    - Propagation over the Internet with added security
    - Low cost per bit transmitted

MAN & WAN

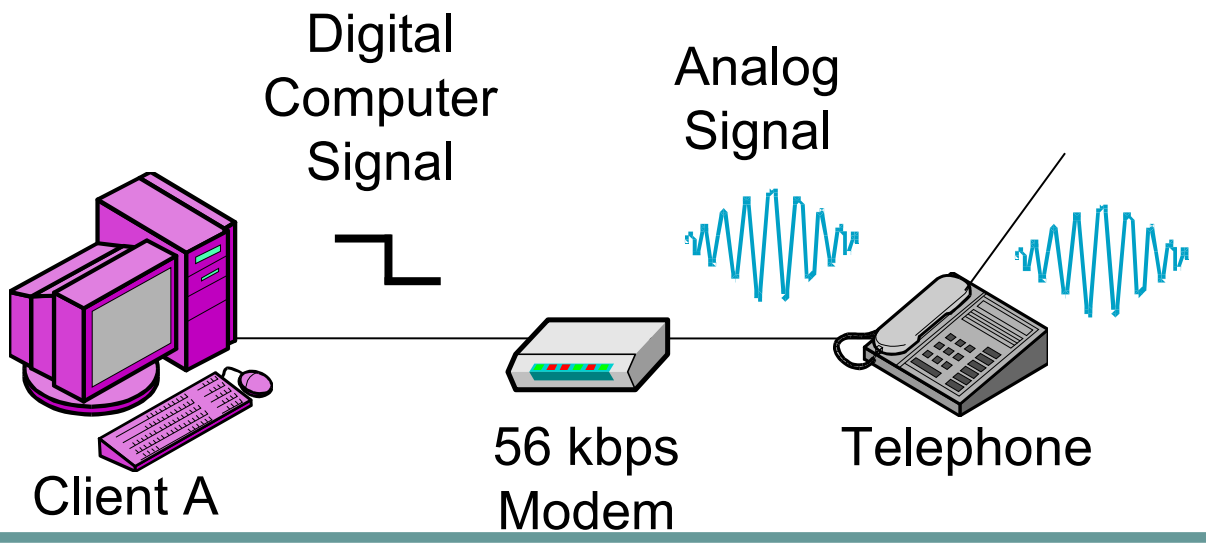
- High Costs and Low Speeds
  - High cost per bit transmitted compared to LANs
  - Lower speeds (most commonly 56 kbps to a few megabits per second)

Typical WAN speeds:
56 kbps to a few megabits per second.

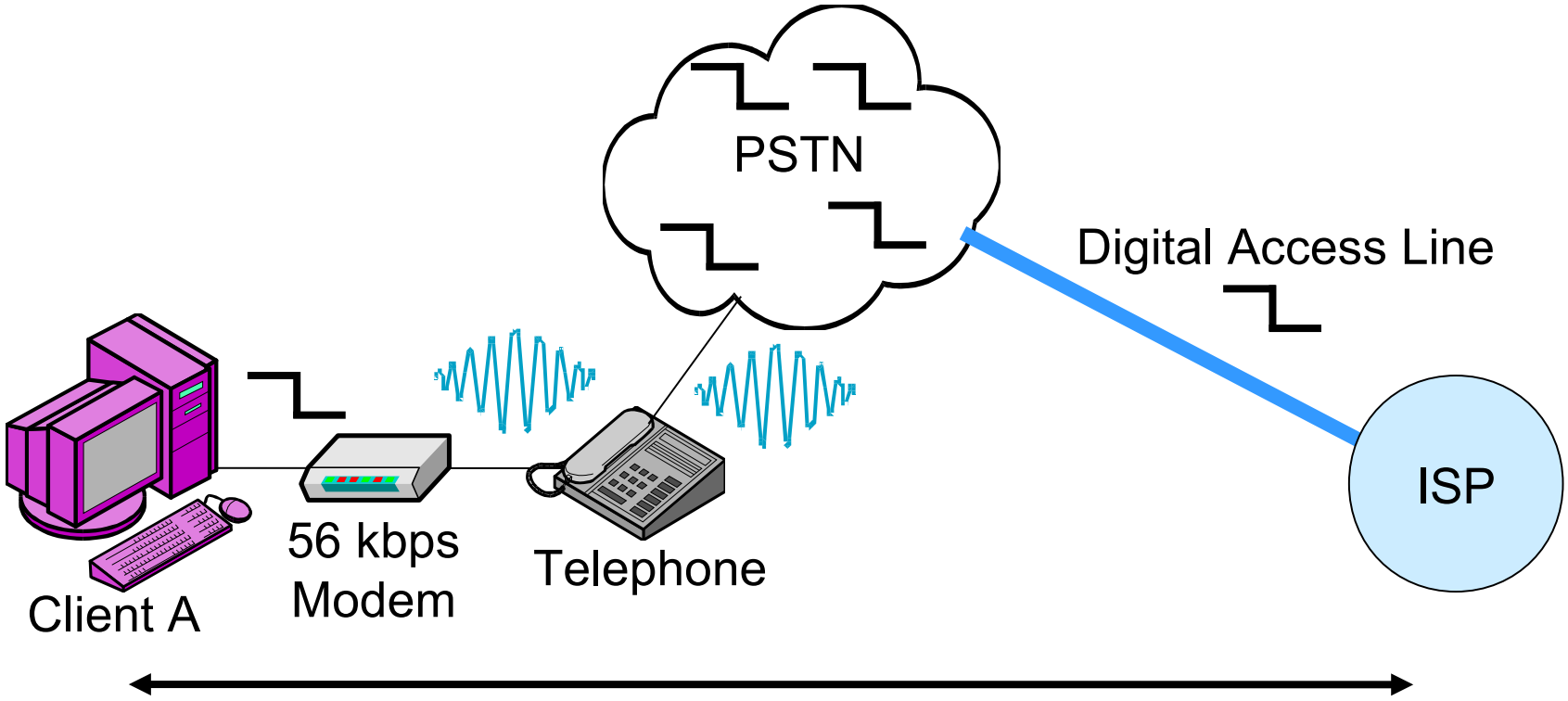
Individual Internet Access: Telephone Modems

Telephone Modem Communication

- Computers are digital sources
- Telephone transmission lines are analog
- A modem converts between the two



Telephone Modem Communication



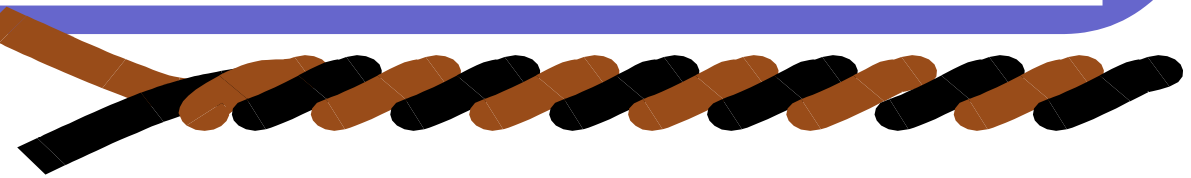
For 56 kbps Download Speed
ISP Must Have a Digital Connection, Not a Modem

Digital Subscriber Lines (DSLs)

DSLs provide data over the existing 1-pair voice-grade access line that already goes to residences and small businesses.

Nowadays, for higher connection speed, copper lines have been replace by optic fiber.

Digital Subscriber Lines (DSLs)



- DSLs provide digital data transmission over the single-pair voice-grade local loop that already runs to residential customer premises.
  - These lines are already installed, so no cost to run new access lines (as there is with private lines).
  - Single-pair voice-grade UTP was not meant to carry data. Sometimes it works. Other times, it does not. Depends primarily on whether distance to the nearest end office is too far.

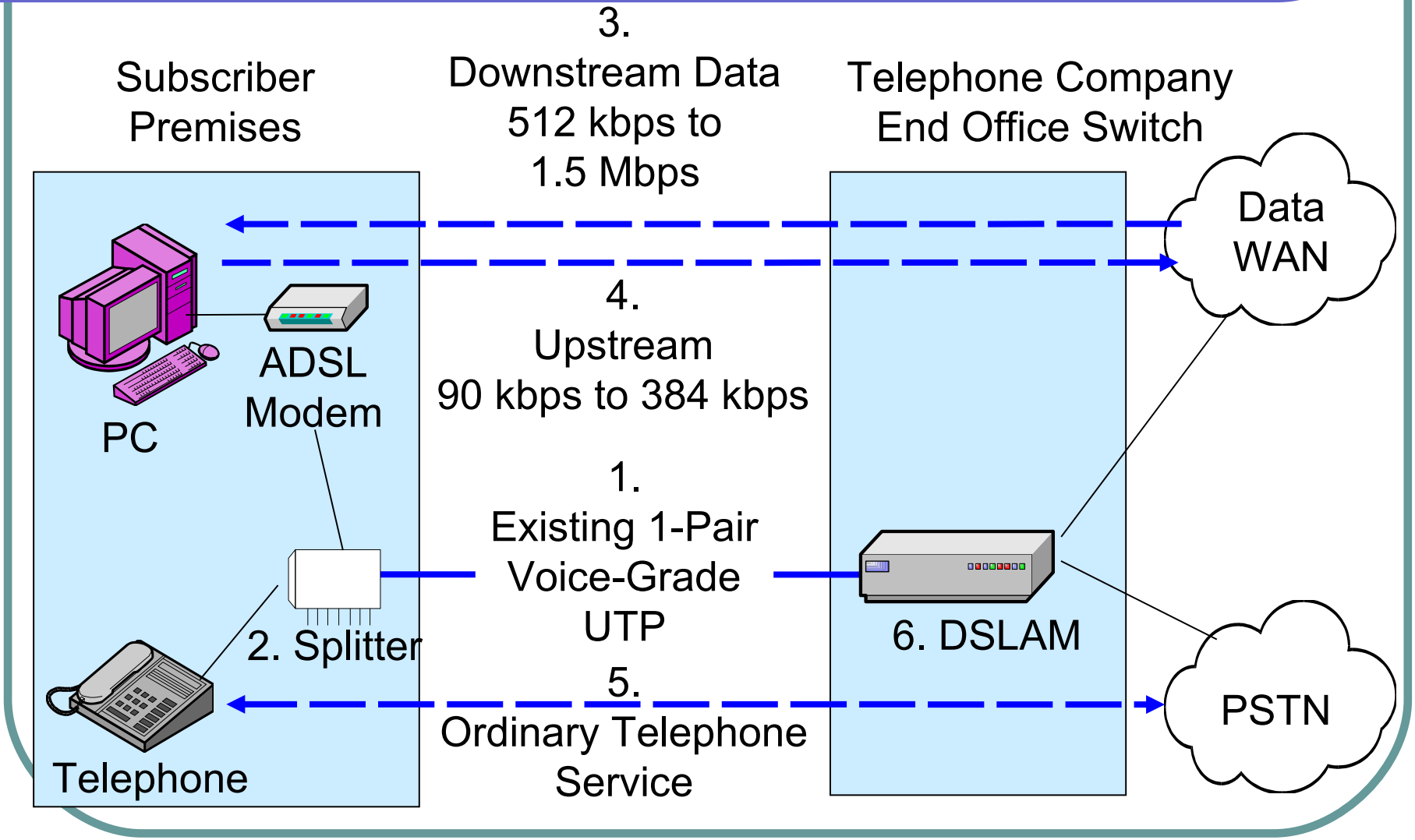
Digital Subscriber Lines (DSLs)

- Asymmetric DSL (ADSL)
  - Asymmetrical throughput
    - Downstream speed up to 1 Gbps
    - Upstream speed up to 60 Mbps
    - Excellent for Web access with large downloads and streaming content.
    - Convenient for e-mail
  - Aimed at residential customers
    - Throughput is NOT guaranteed
    - DSLAM often oversubscribed, slowing access

Digital Subscriber Lines (DSLs)

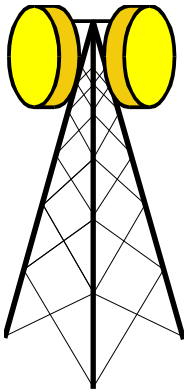
- Symmetric DSL Services
  - Speed is symmetric
    - Same upstream and downstream
  - Aimed at business customers
    - Throughput IS guaranteed
  - Several Types of Symmetric DSL
    - HDSL (768 kbps): Half of a T1 private line (later)
    - HDSL2 (1.544 kbps): Full T1 private line speed
    - SHDSL: Flexible (384 kbps to 2.3 Mbps)

Asymmetric Digital Subscriber Line (ADSL)



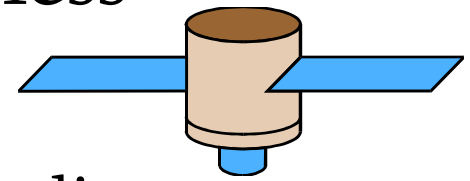
Wireless Access Systems

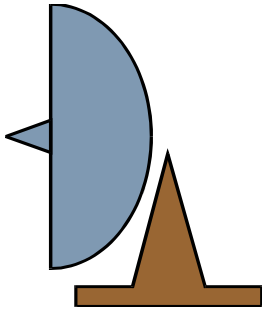
- Wireless Access to the Internet
- Fixed Versus Mobile
  - Fixed
    - For homes and offices (fixed locations)
    - Use dish antennas
    - Higher speeds
  - Mobile
    - People travelling within a city or farther
    - Need omnidirectional antennas
    - Lower speeds



Wireless Access Systems, Continued

- Satellite Versus Terrestrial Wireless
  - Satellite
    - Expensive because of transmission distance
    - Expensive because satellites are expensive to launch and maintain
    - Can cover large areas
  - Terrestrial
    - Earth-based radio stations
    - Service within a city





Wireless Access Systems, Continued

802.16 WiMAX

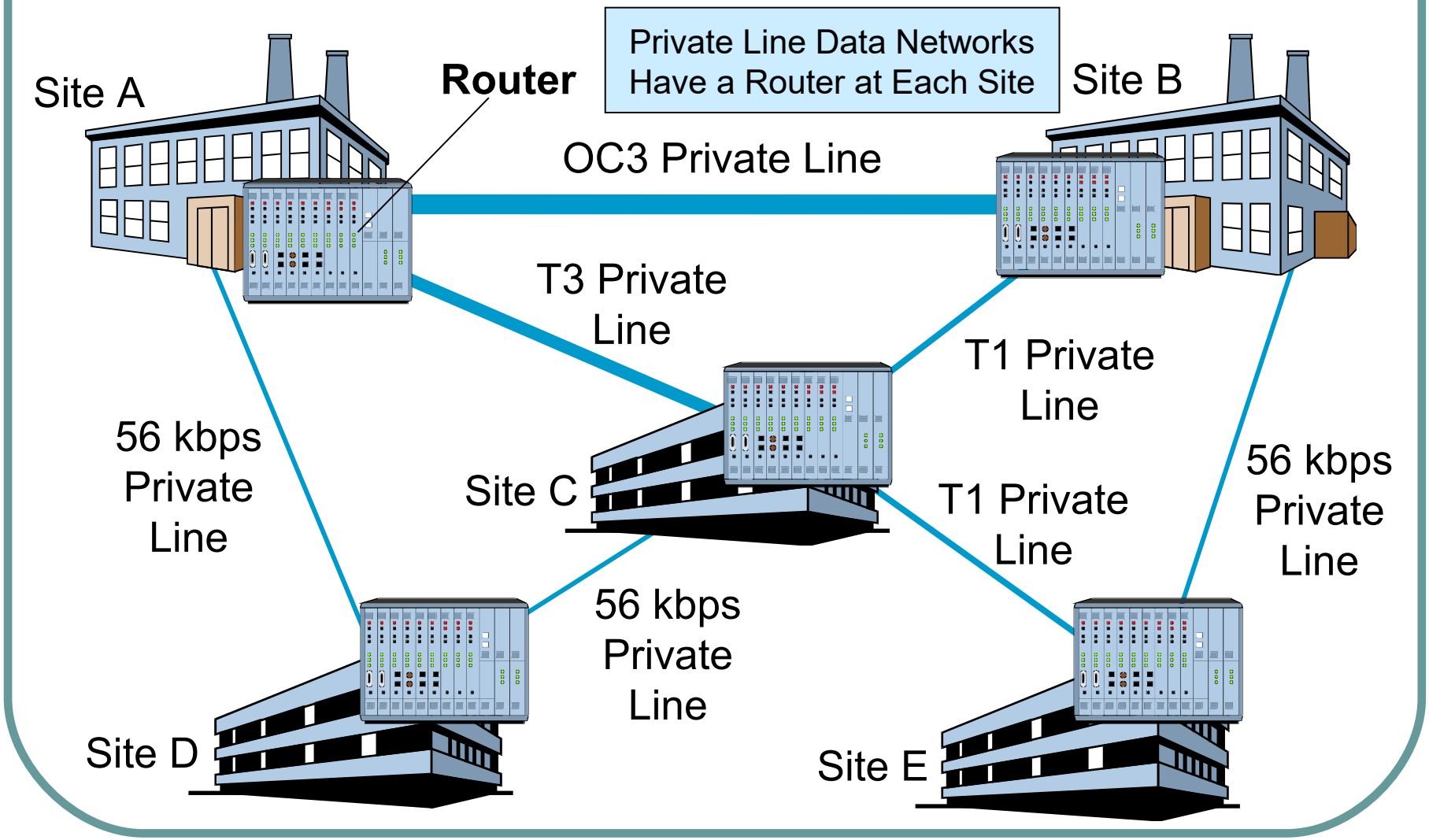
- One of several terrestrial wireless access standards under development
- Fixed version being standardized first
  - 20 Mbps up to 50 km (30 miles)
- Mobile version under development (802.16e)
  - 3 Mbps to 16 Mbps for mobile users

Site-to-Site Networking: Private Line Networks

Private Line Networks for Voice and Data

- Connect sites via private lines
- Perspective
  - User firm must do all the planning and installation
  - User firm must operate and maintain the network
  - Labour-intensive site-to-site networking

Private Line Networks for Data



Private Line Speeds

Trunk Line	Speed	Medium
North American Digital Hierarchy		
56 kbps (DS0 Signaling)	56 kbps (sometimes 64 kbps)	2-pair DG* UTP
T1 (DS1 Signaling)	1.544 Mbps	2-pair DG* UTP
Fractional T1	128 kbps, 256 kbps, 384 kbps, 512 kbps, and 768 kbps	2-pair DG* UTP
Bonded T1s (multiple T1s acting like a single line)	Varies (usually up to 6 Mbps)	2-pair DG* UTP
T3 (DS3 Signaling)	44.7 Mbps	Optical Fiber

*DG = Data Grade

Private Line Speeds, Continued

Trunk Line	Speed
CEPT Multiplexing Hierarchy (Europe)	
64 kbps	64 kbps
E1	2.048 Mbps
E3	34.4 Mbps
Japanese Multiplexing Hierarchy	
64 kbps	64 kbps
J1	1.544 Mbps (same as U.S. T1)
J3	32.1 Mbps

Private Line Speeds, Continued

Trunk Line	Speed
*SONET/SDH**	
OC3/STM1	156 Mbps
OC12/STM4	622 Mbps
OC48/STM16	2.5 Gbps
OC192/STM64	10 Gbps
OC768/STM256	40 Gbps

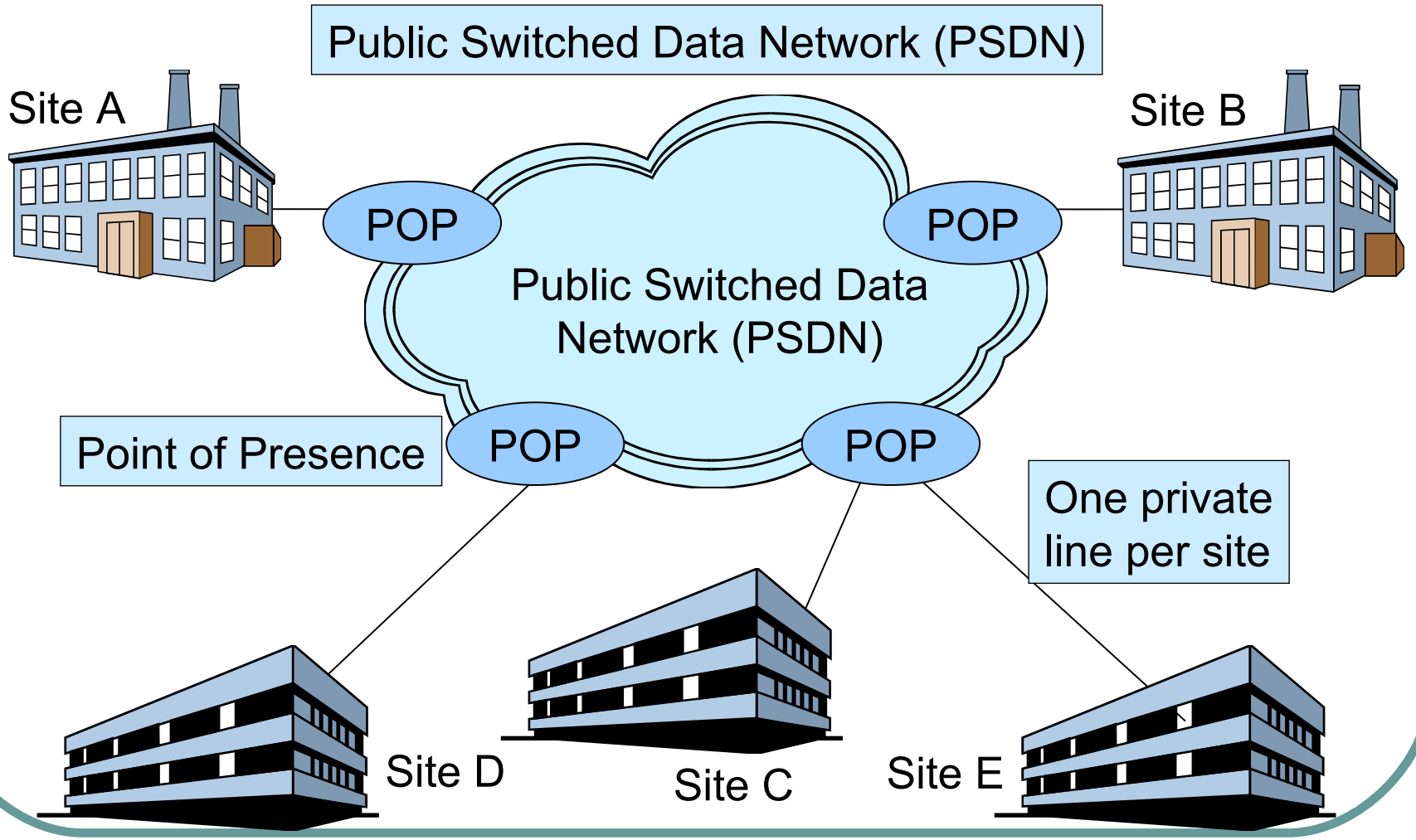
Notes: SONET and SDH speeds are multiples of 51.84 Mbps.
(Figures listed are rounded off for readability)
OCx is the SONET designation.
STMx is the SDH designation.

Private Line Speeds, Continued

- Perspective
  - Most the range of greatest demand for site-to-site transmission is 56 kbps to a few megabits per second
  - So the largest market for private lines consists of T1 and fractional T1 lines or the equivalent in various countries

Site-to-Site Networking: Public Switched Data Networks

Private Line versus Public Switched Data Networks

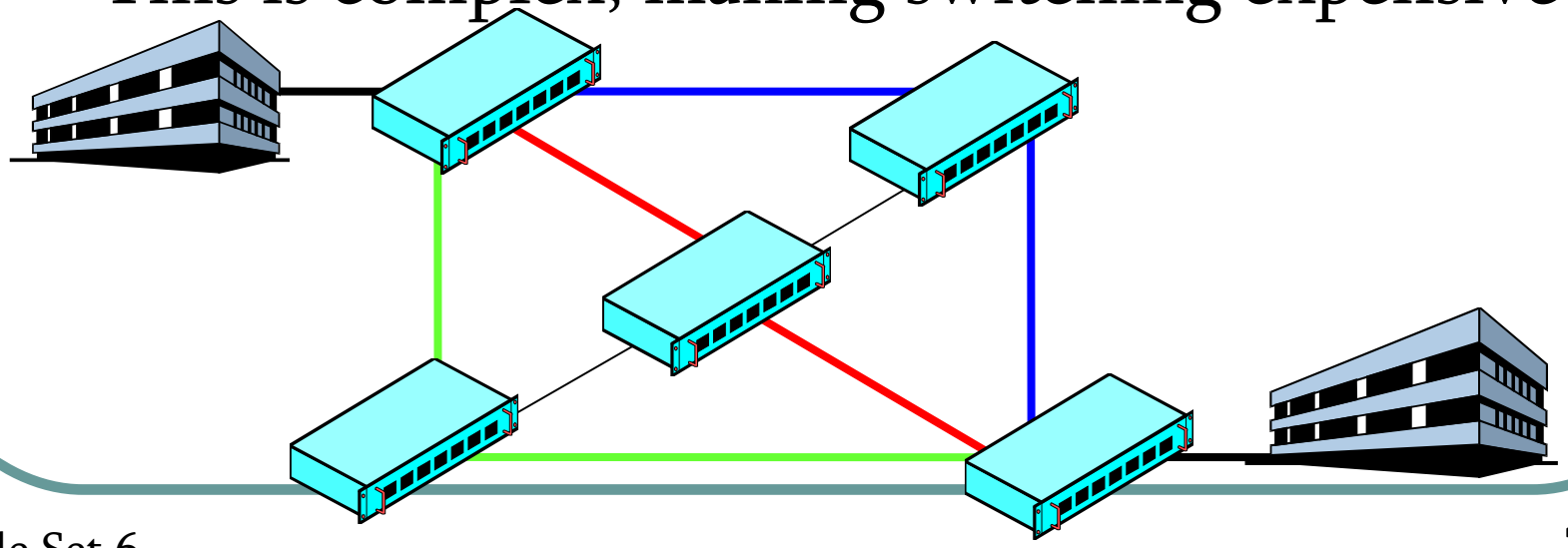


Private Line versus Public Switched Data Networks

- Private Line Network
  - Company must plan, buy switching equipment, and operate the network. Requires much labor.
- Public Switched Data Network
  - PSDN carrier provides planning, switching, and operation of the network. This greatly reduces corporate management labor.
  - PSDN drawn as a cloud to indicate that users do not need to understand it because the PSDN handles all of the details.

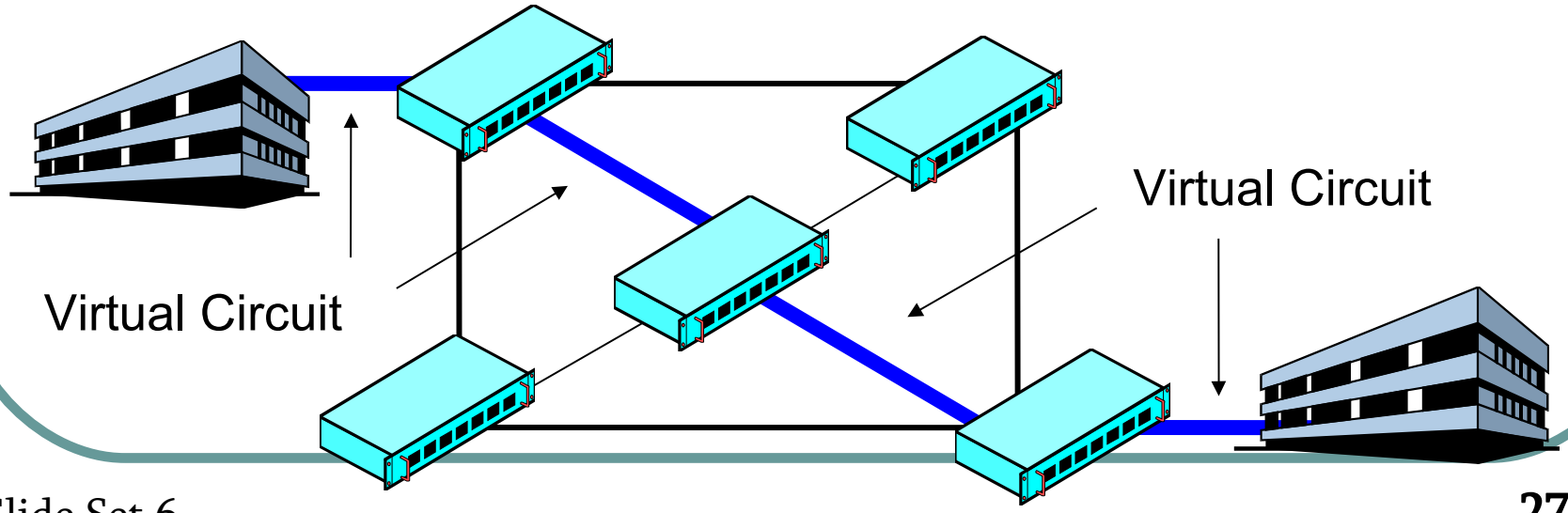
Virtual Circuit

- PSDN Switches Are Arranged in Meshes
  - Loops so multiple alternative paths between stations
  - Switches must consider alternative paths
  - This is complex, making switching expensive



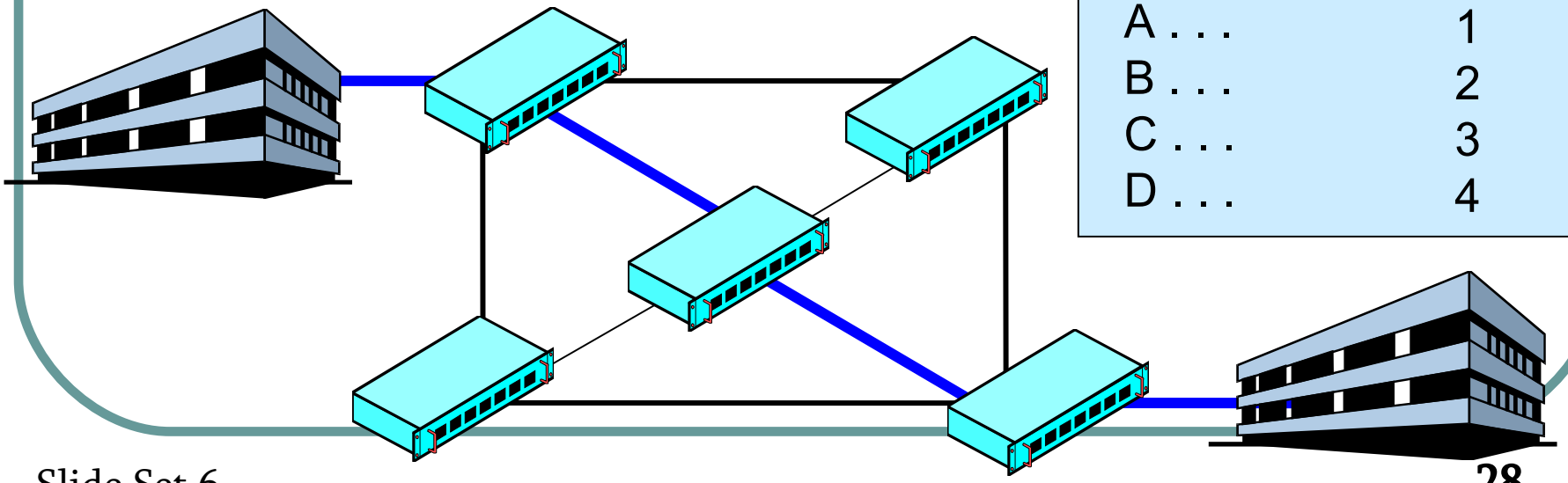
Virtual Circuit, Continued

- PSDNs Create Virtual Circuits
  - Virtual circuit is a single path (data link) between two stations
  - Set up before transmission begins
  - Only a single possible path, so switching is fast and inexpensive



Virtual Circuit, Continued

- PSDNs Create Virtual Circuits
  - Switching table has virtual circuit instead of data link layer addresses
  - Frame header has a virtual circuit number, NOT a destination address



Virtual Circuit	Port
A . . .	1
B . . .	2
C . . .	3
D . . .	4

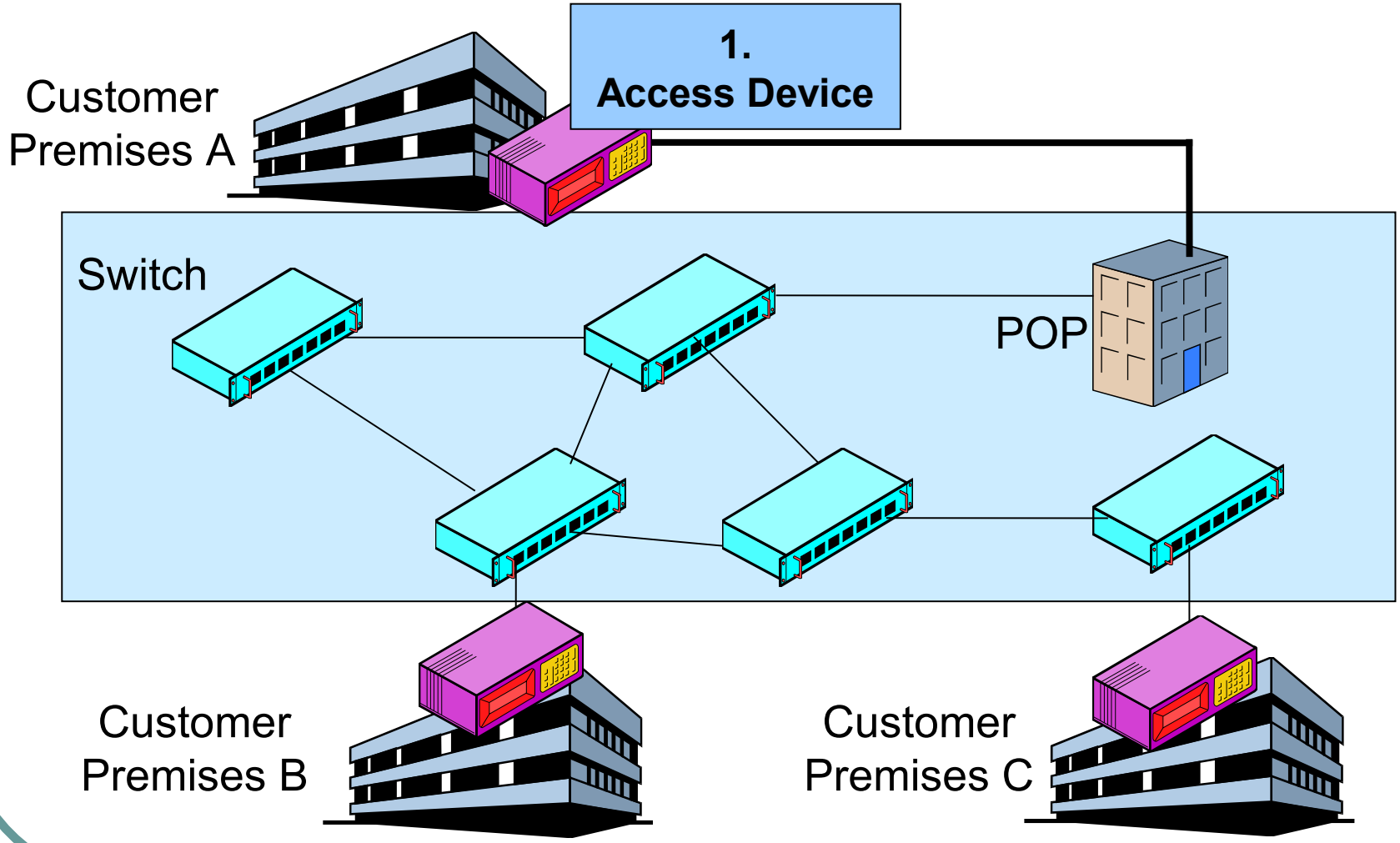
Site-to-Site Networking: Frame Relay (FR)

The most popular PSDN

Frame Relay (FR)

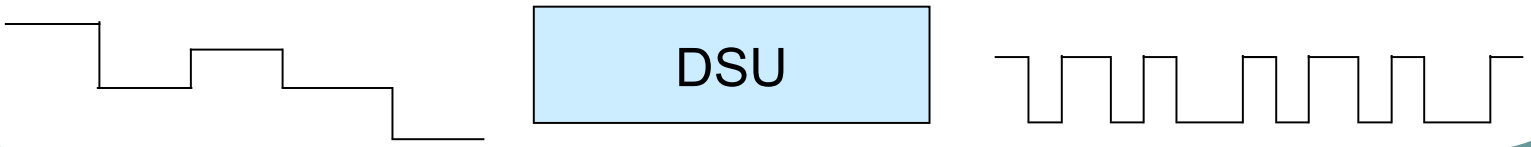
- The most popular PSDN Today
  - Speed range is 56 kbps to up to 40 Mbps
  - Matches main speed range of corporate WAN demand (56 kbps to a few megabits per second)
- FR Switching is Designed to Minimize Cost
  - Switching is somewhat unreliable to reduce cost per frame
  - Switching uses virtual circuits to reduce cost
  - Cost minimization is important in WAN communication

Frame Relay Network

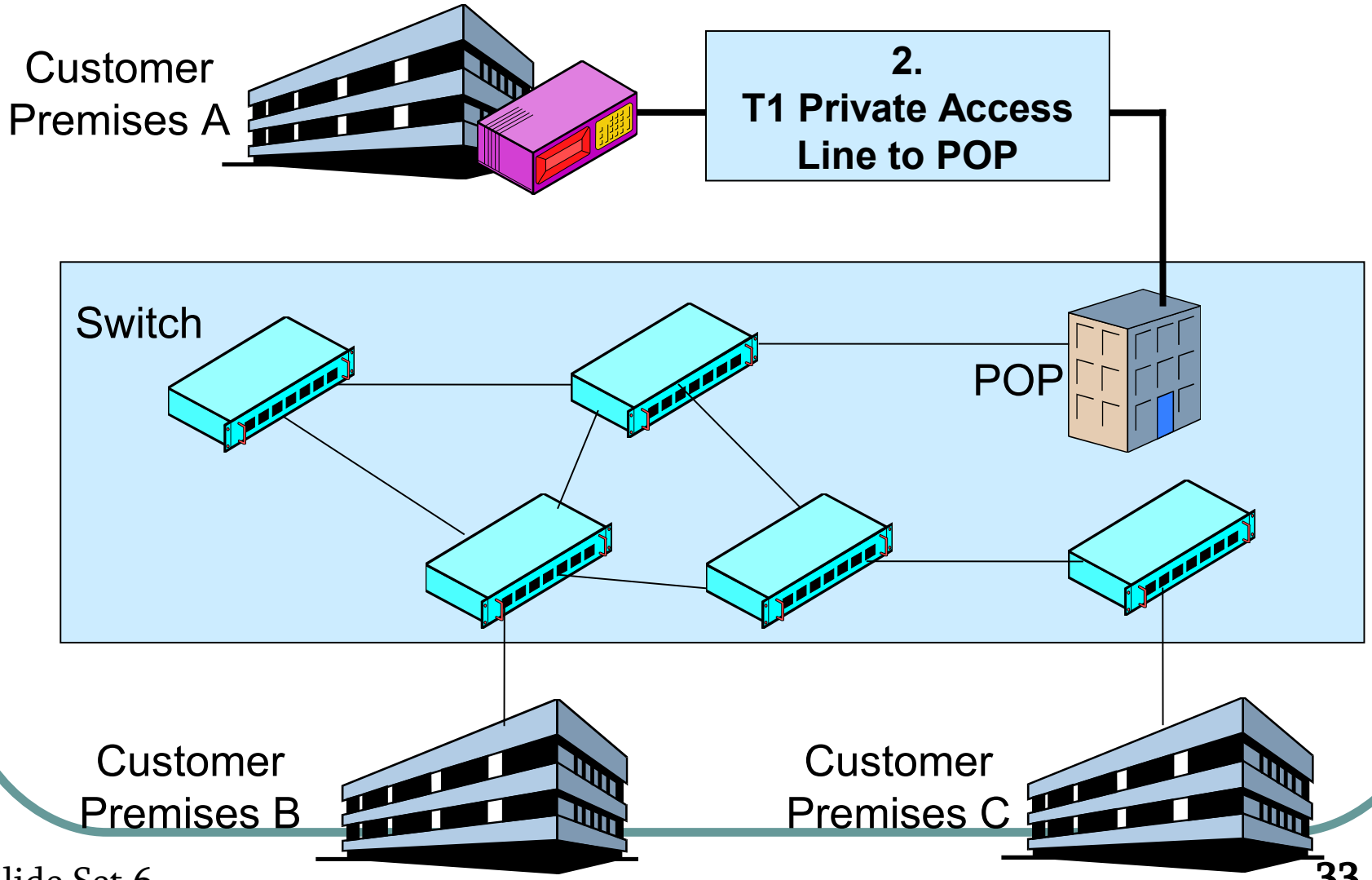


Frame Relay Network, Continued

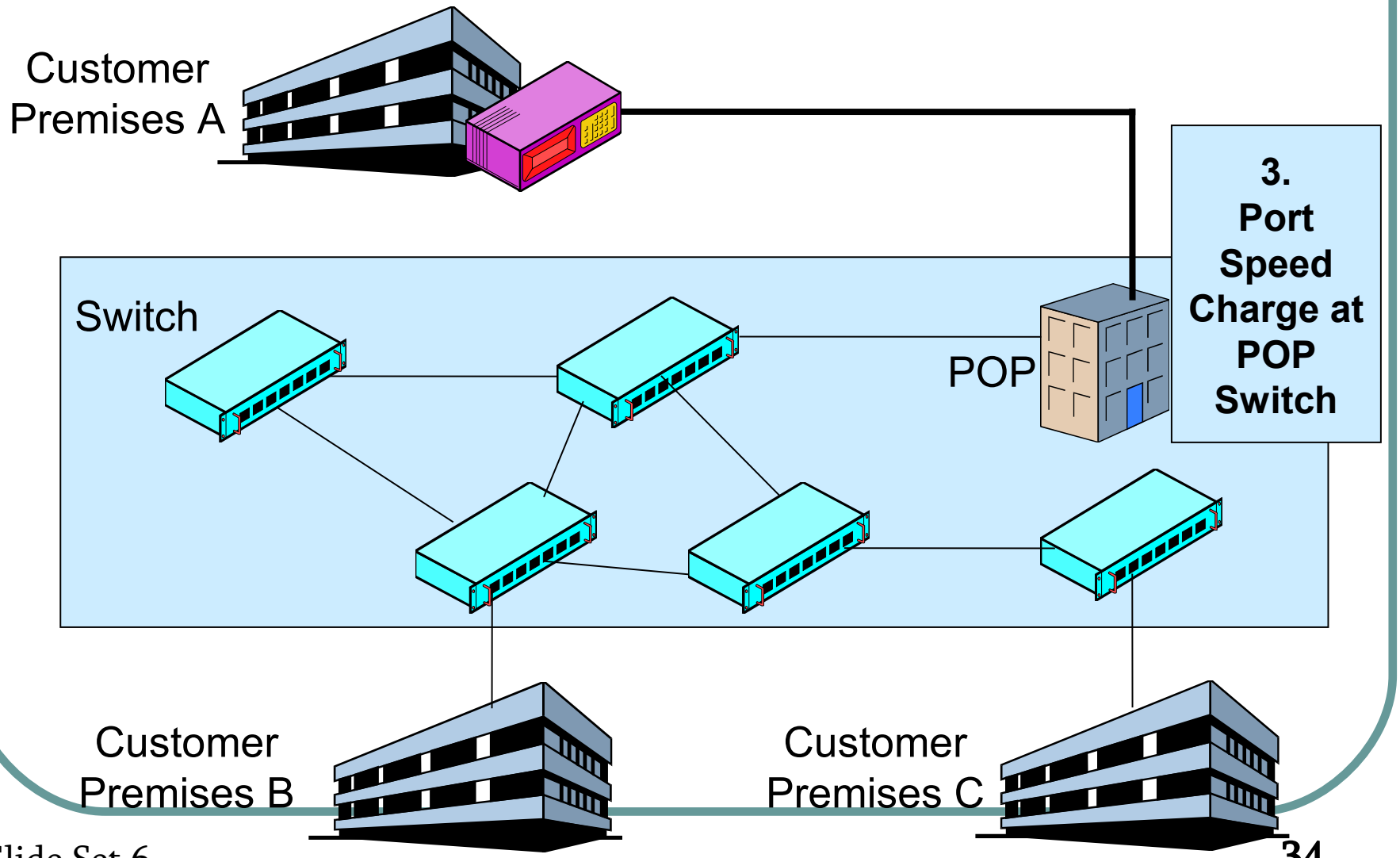
- CSU/DSU
  - Channel service unit (CSU) protects the access line from unapproved voltage levels, etc. coming from the firm
  - Data service unit (DSU) converts between internal digital format and digital format of access link to Frame Relay network.
    - May have different baud rate, number of states, voltage levels, etc.



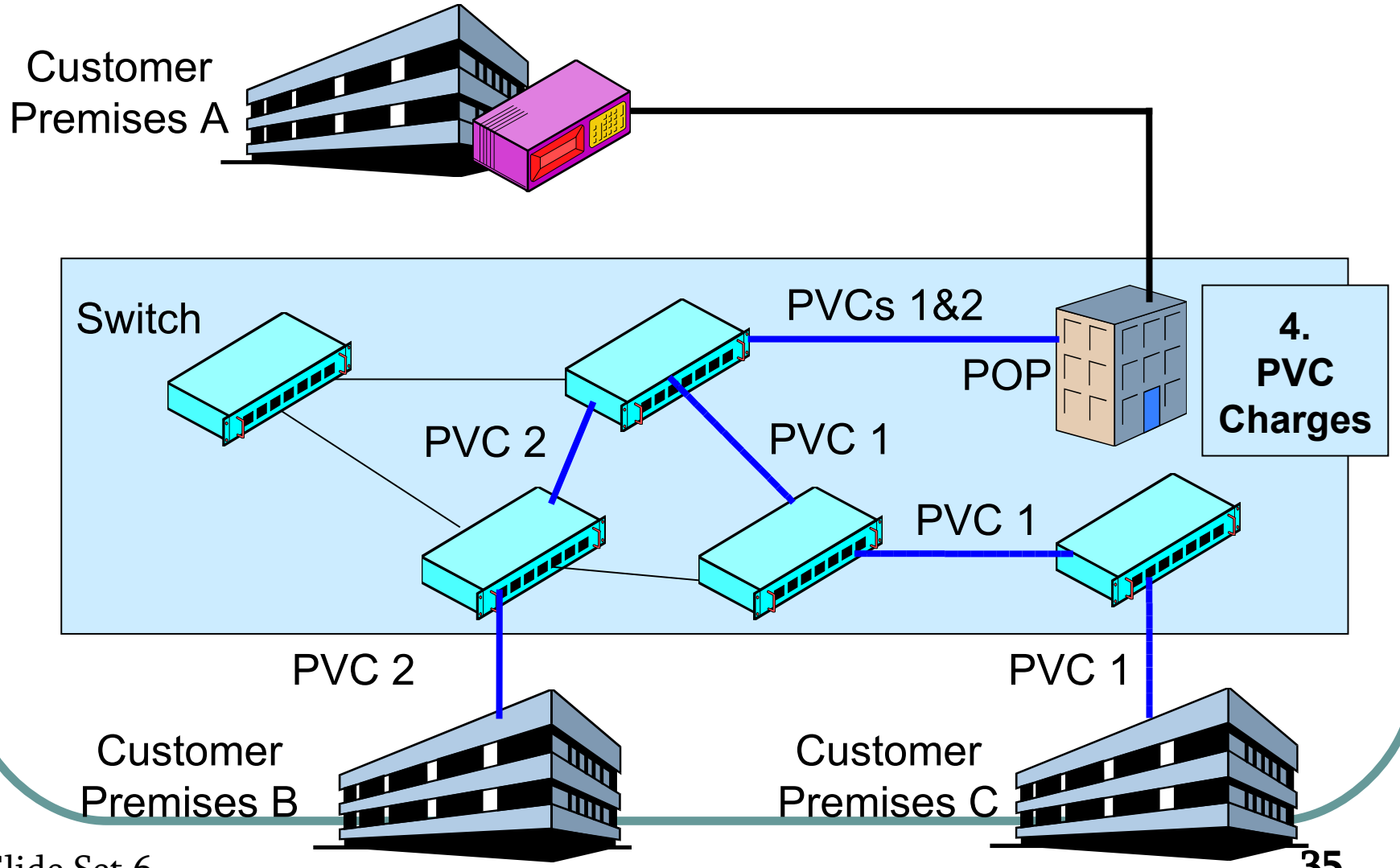
Frame Relay Network, Continued



Frame Relay Network, Continued



Frame Relay Network, Continued



Frame Relay Network, Continued

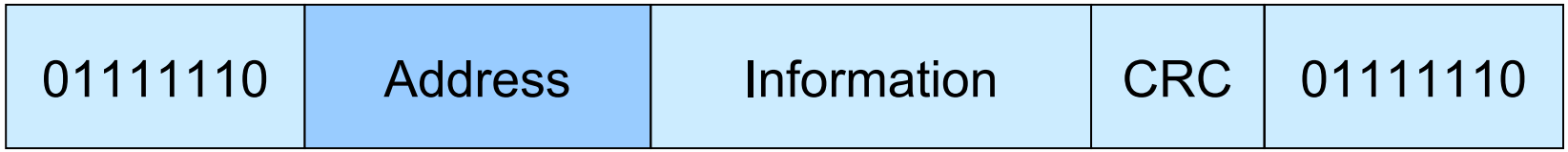
- Permanent Virtual Circuits (PVCs)
  - Set up once, kept in place for months or years
  - Between a firm's sites (which rarely change)
  - The most common form of virtual circuit today
- Switched Virtual Circuits (SVCs)
  - Set up at beginning of a communication session
  - Taken down at the end of the session
  - More expensive than PVCs, less common

Frame Relay Network, Continued

- Frame Relay Pricing Recap
  - Frame relay access device at site (or router)
  - Private line from site to POP
  - Port on the POP
    - Pay by port speed
    - **Usually the largest price component**
  - Permanent virtual circuits (PVCs) among communicating sites
    - **Usually the second-largest component of prices**
  - Other charges

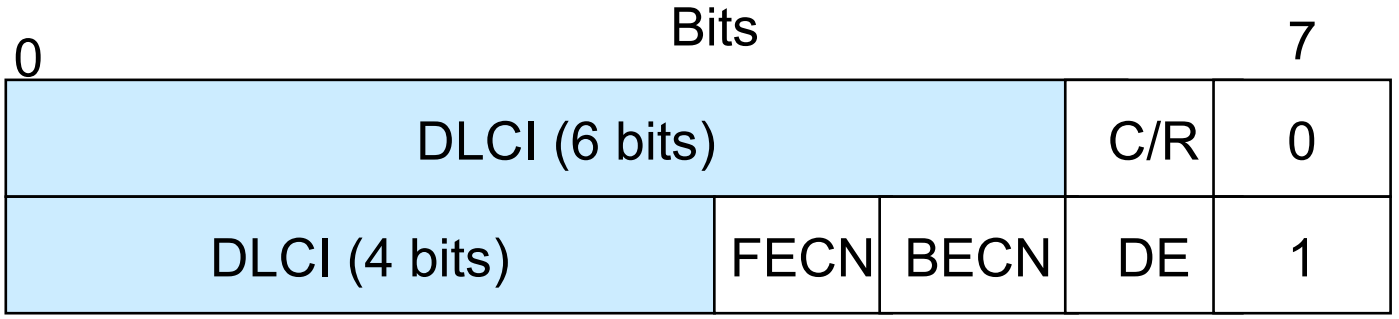
Frame Relay Frame

- Variable Length Frames
  - *Start flag* (01111110) to signal start of frame
  - *Address field* has variable length (2-4 octets)
  - *Information field* to carry data (variable)
  - *CRC (Cyclical Redundancy Check) field* to detect errors (2 octets)
    - If find errors, switch discards the frame
  - *Stop flag* (01111110) to signal end of frame



Frame Relay Frame, Continued

- Address Field of Frame Relay Frame
  - Variable Length: 2-4 octets
  - Usually 2 octets (as shown below)
  - Data link control indicator (DLCI, pronounced dull'-see) is the virtual circuit number (10 bits long in 2-octet form)



Site-to-Site Networking: Asynchronous Transfer Mode: ATM

Asynchronous Transfer Mode: ATM

- ATM is a faster PSDN than Frame Relay
  - Frame Relay: 56 kbps up to about 45 Mbps
  - ATM: 1.5 Mbps up to 155 Mbps
- Not Competitors. Most PSDN Vendors Offer Both to Customers
  - FR for low-speed customer needs
  - ATM for higher speeds (at higher prices)
- As corporate demand grows, ATM may increase its market share

ATM Cell

- Fixed length (53 octets) frame allows simpler and therefore faster processing at switches
  - For instance, switch does not have to do calculations to figure out how much buffer space it will need for a cell, as is the case with Frame Relay's variable-size frame.
  - 53 Octets
    - 5 octets of header
    - 48 octets of payload (data)
  - Fixed length frames are called ***cells.***

ATM Cell, Continued

- Short Cell Length Limits Latency at Each Switch
  - Switches may have to wait until the entire frame arrives before processing it and sending it back out.
    - With shorter frames, there is less latency at each switch along the path
  - Important in continent-wide WANs that require cells to pass through many switches
  - Especially important for voice, which is highly latency-intolerant (ATM was created for digitized voice)

Site-to-Site Networking:
Multi protocol Label Switching: MPLS

MPLS-Multi Protocol Label Switching

MPLS is a data-carrying mechanism for both circuit-based and packet-switched clients. It can be used to carry many different kinds of traffic, including IP packets, as well as native ATM, Frame Relay, and Ethernet frames.

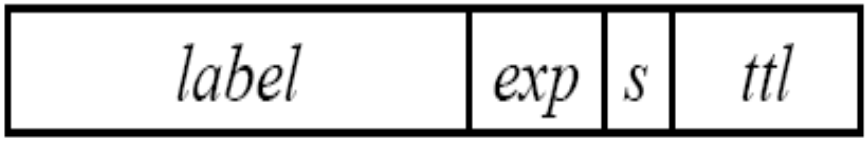
Router has two main elements

– Forwarding and routing

- Label switching is an alternative to IP forwarding
- MPLS (multi protocol label switching) combines benefits of virtual circuit with flexibility and robustness of datagram forwarding
- An MPLS-capable router uses traditional IP routing, but replaces IP forwarding with label switching.

Label Encoding

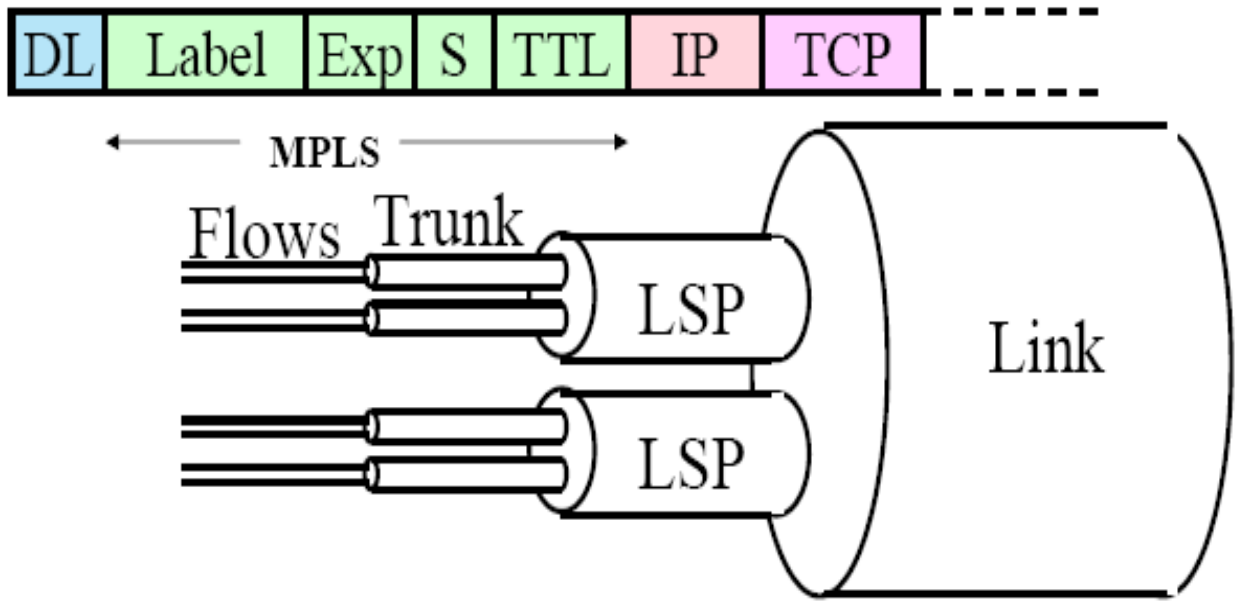
- MPLS uses 32 bits for label encoding
  - 20 bits for actual label
  - 2 power 20 (2^20) labels possible



Label: Label Value, 20 bits (0-16 reserved)
Exp.: Experimental, 3 bits (earlier Class of Service)
S: Bottom of Stack, 1 bit (1 = last entry in label stack)
TTL: 8 bit Time to Live

Flows, Trunks, LSPs, and Links

- Label Switched Path (LSP):
  All packets with the same label
- Trunk: Same Label+Exp
- Flow: Same MPLS+IP+TCP headers



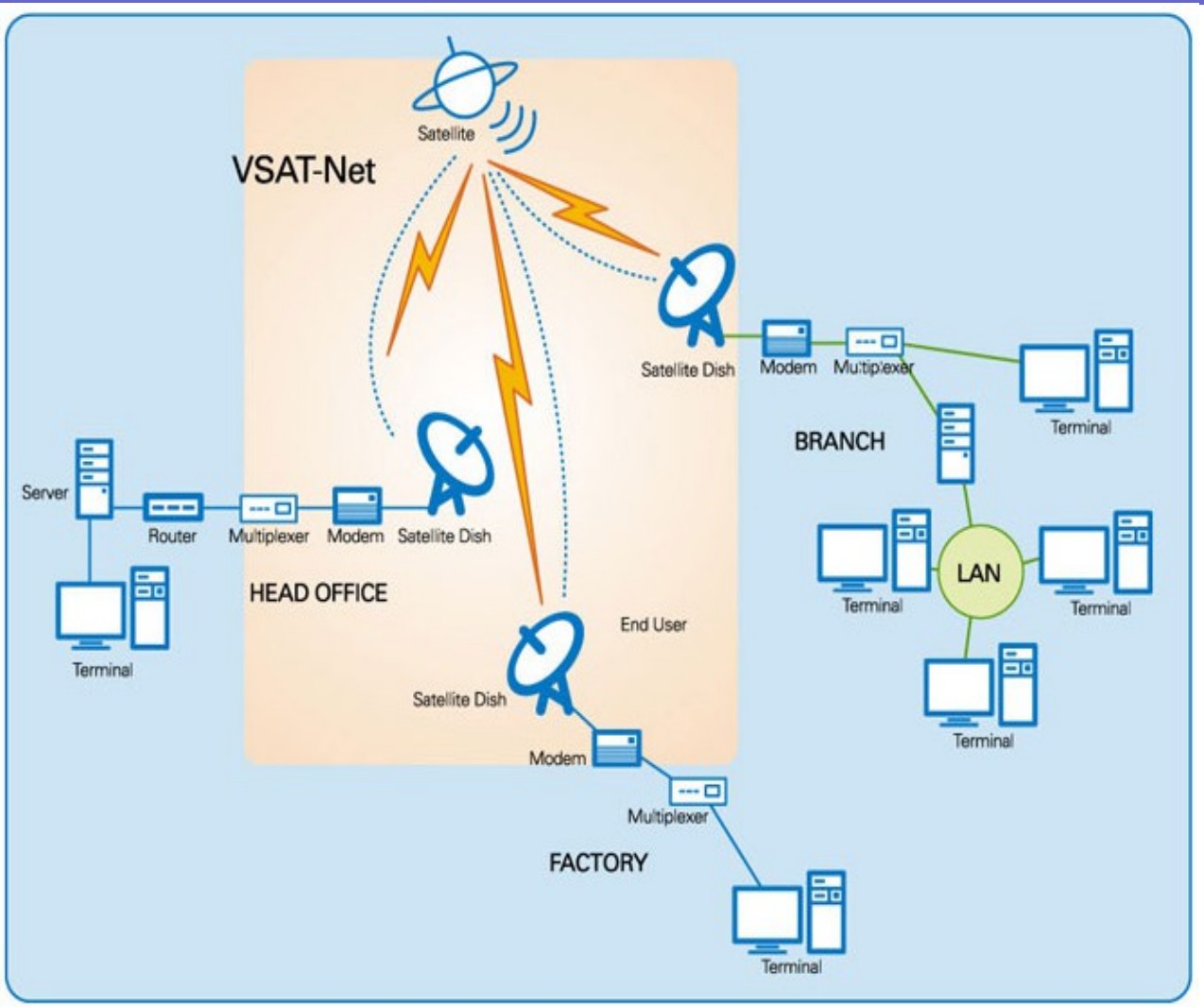
Site-to-Site Networking: Very Small Aperture Terminal: VSAT

is a two-way satellite, ground station with a dish antenna that is smaller than 3 meters

VSAT

VSAT can be used for data, voice, video or internet applications. It is used to communicate with or to link together locations using satellite connectivity. VSAT data rates typically range from narrowband up to 4 Mbps. A VSAT consists of two parts, a transceiver that is placed in direct line of sight to the satellite and a device that interfaces with the transceiver such as a PC. The transceiver receives or sends a signal to a satellite transponder in the sky. The satellite sends and receives signals from a ground station computer acting as a hub for the system. Each end user is interconnected with the hub station via the satellite, forming a star topology. The hub controls the entire operation of the network. For a user to communicate with another, each transmission has to first go to the hub station which then retransmits it via the satellite to the user's VSAT.

VSAT Illustration



Site-to-Site Networking: Metropolitan Area Ethernet

Ethernet is moving into metropolitan area networks

Metropolitan Area Ethernet

- Ethernet is moving beyond the LAN
  - Moving into the metropolitan area network (within a single urban area)
- New 802.3 standards (10 Gbps and 40 Gbps) being developed primarily for long distances of 10 km or more
- E-Line service: to connect LANs at two sites
- E-LAN service: to connect LANs at multiple sites
- Cheaper than ATM for high speeds
- Familiar technology so easy to manage
- Still lacks standards for carrier-class service
- New but growing rapidly compared to Frame Relay and ATM

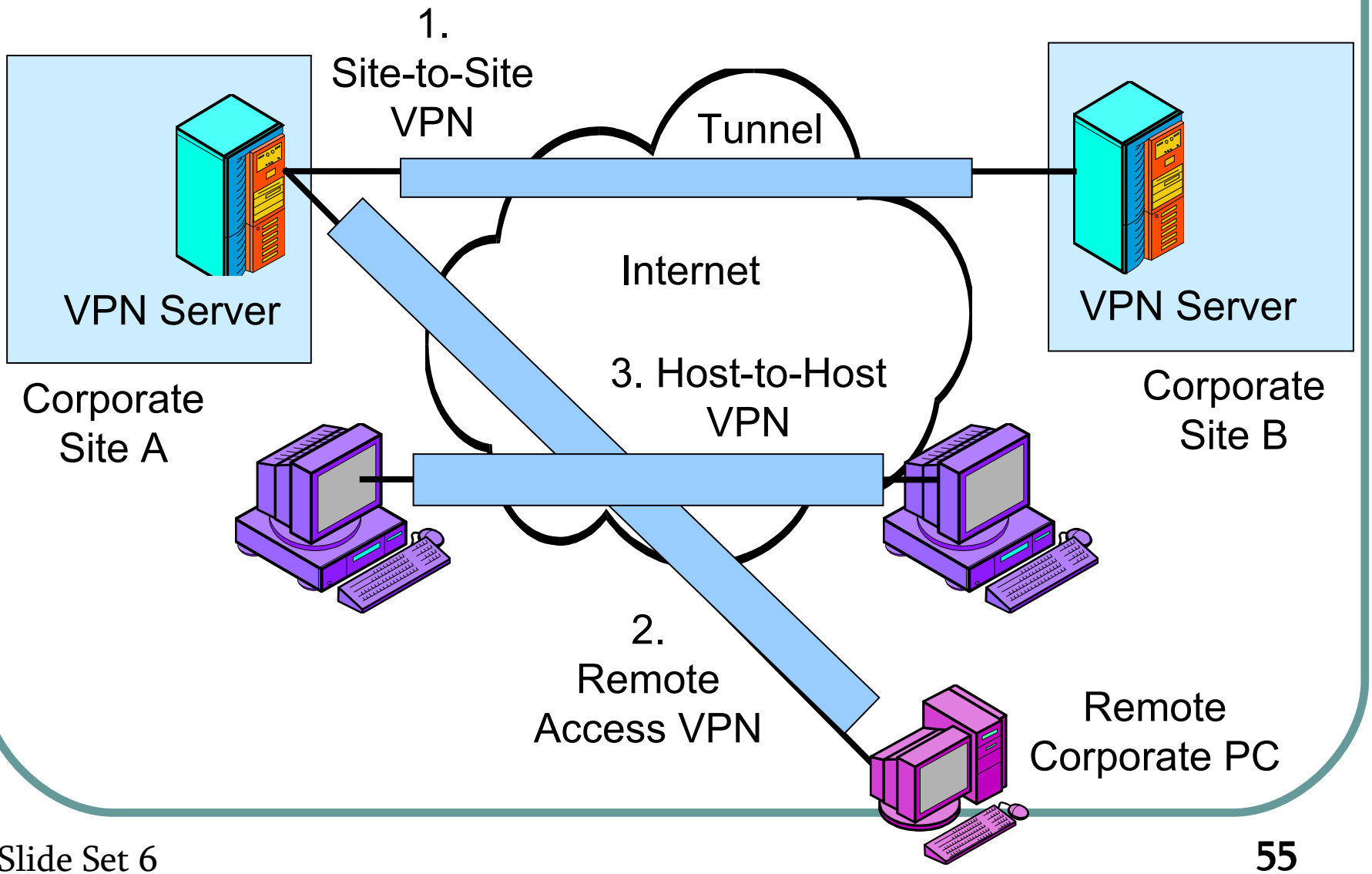
Site-to-Site Networking: Virtual Private Networks: VPNs

VPNs: Transmission over the Internet with added security

Virtual Private Network Issues

- Virtual Private Network (VPN)
  - Transmission over the Internet with added security
  - Some analysts include transmission over a PSDN with added security
- Why VPNs?
  - Lower transmission cost per bit transmitted than PSDNs
  - Adequate security

Virtual Private Network (VPN)



VPN Technologies

- SSL/TLS
  - Limited to remote access VPNs
  - SSL (Secure Sockets Layer) was its original name
    - IETF changed it to Transport Layer Security
  - Created to protect HTTP traffic in E-commerce
  - Built into every browser and web server, so easy to implement
  - Good if all traffic over the VPN will be HTTP
    - Beginning to handle other protocols
  - Moderate security

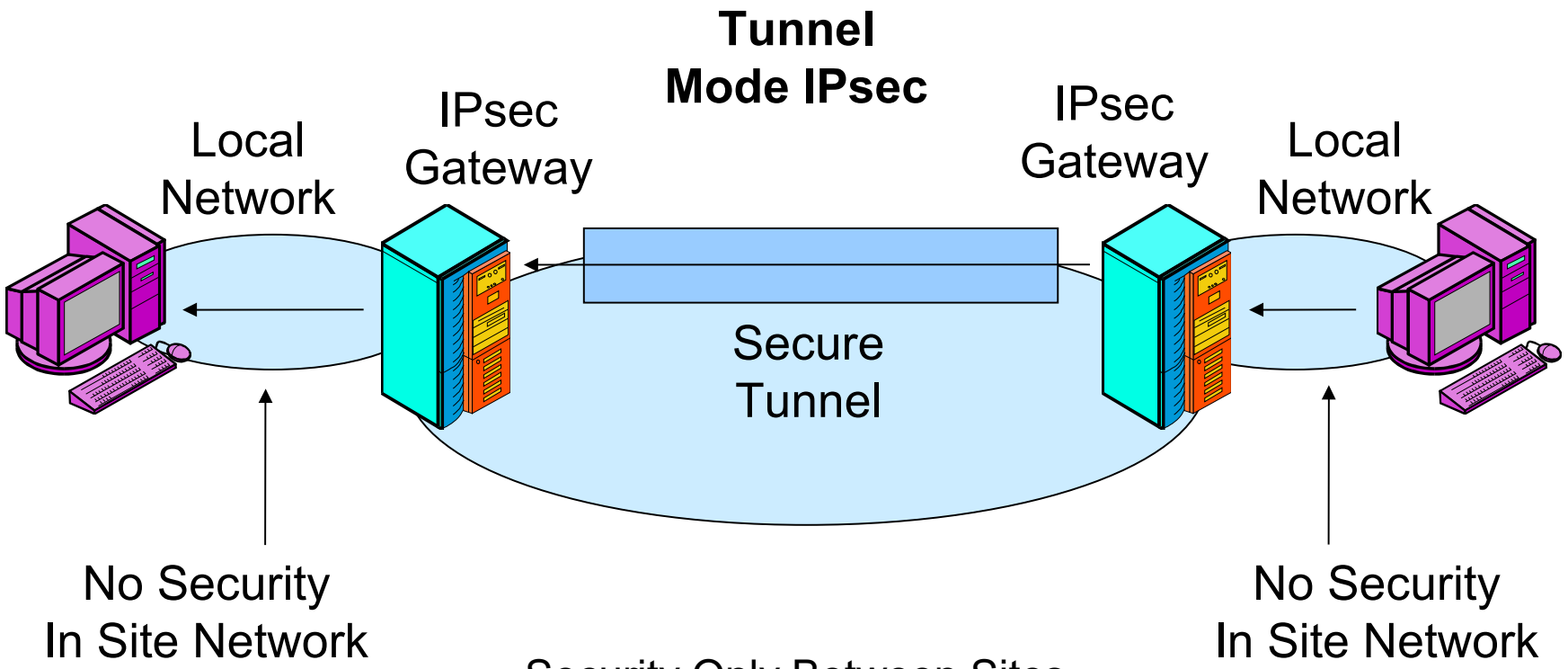
VPN Technologies, Continued

- Point-to-Point Tunneling Protocol (PPTP)
  - For remote access VPNs
  - Operates at the data link layer
  - Transparently provides security to all messages at higher layers
  - Software exists on all client PCs, but individual PCs must be configured to work with PPTP, and this is somewhat expensive
  - Good for remote access when not all traffic is HTTP
  - SSL/TLS has pushed PPTP almost entirely aside in the marketplace.

VPN Technologies, Continued

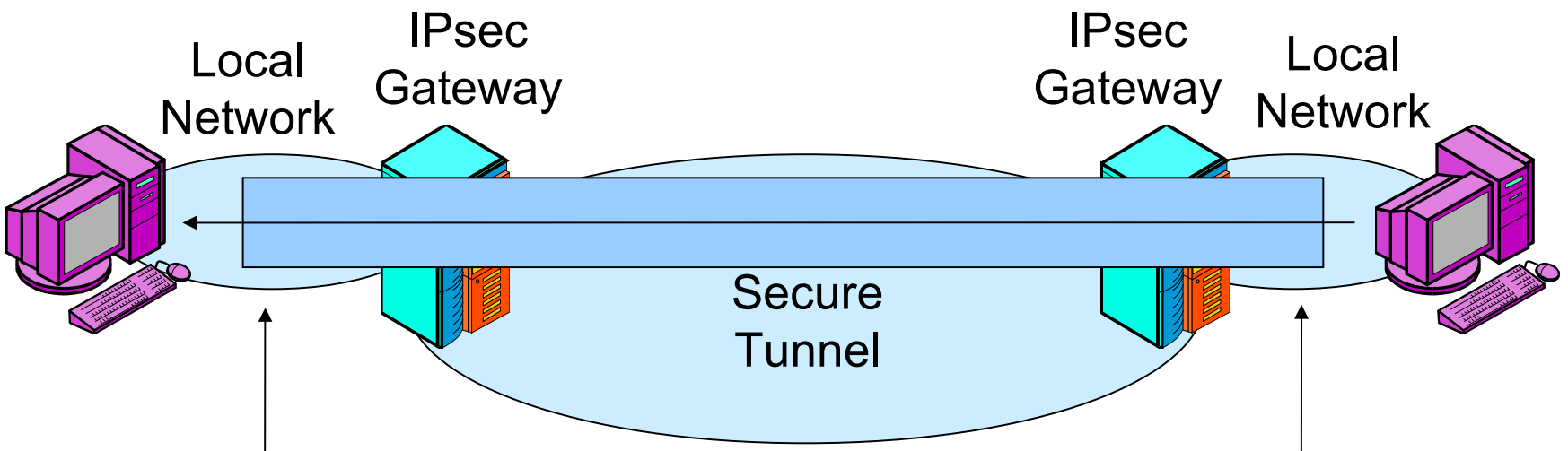
- IPSec
  - For all types of VPN (remote access, site-to-site, host-to-host)
  - Operates at the Internet layer
    - Transparently protects traffic at all higher layers
  - Very strong security
  - Requires digital certificates for all computers
    - Creating an infrastructure for certificates is expensive
    - Installation and setup on individual client PCs is expensive

IPsec in Tunnel Mode



Security Only Between Sites
Hosts Need No Extra Software
Only IPsec Gateways need Digital Certificates
Easier to Set Up than Transport Mode

IPSec in Transport Mode



End-to-End (Host-to-Host)
Tunnel
Each Host Needs IPsec Software
And Digital Certificate