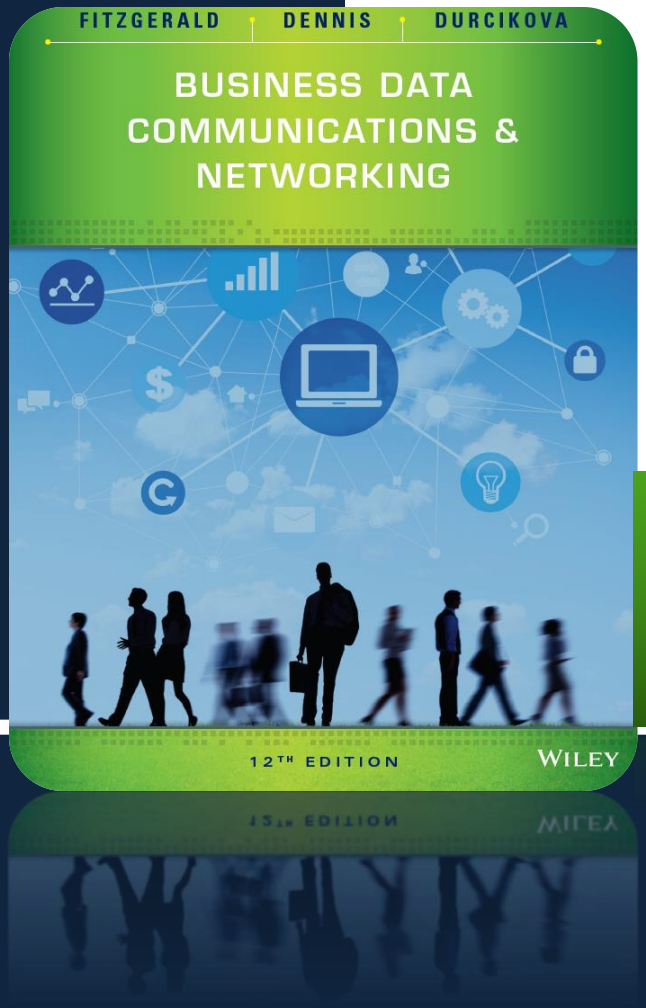

BUSINESS DATA COMMUNICATIONS & NETWORKING

Chapter 9
Wide Area Networks

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Outline

- WAN Service Types
  - Dedicated-Circuit Networks
  - Packet-Switched Networks
  - Virtual Private Networks
- WAN Design Practices
- Implications for Management

Wide Area Networks

- **Wide area networks (WANs)** run long distances connecting different buildings or offices
  - Organizations typically do not own all of the land upon which the WAN circuits run
  - May span a city, regions, or even countries
- Often built using leased circuits from **common carriers**
  - e.g., AT&T, Sprint, Verizon, BT, Telefónica, Level 3, Tata Communications

Wide Area Networks

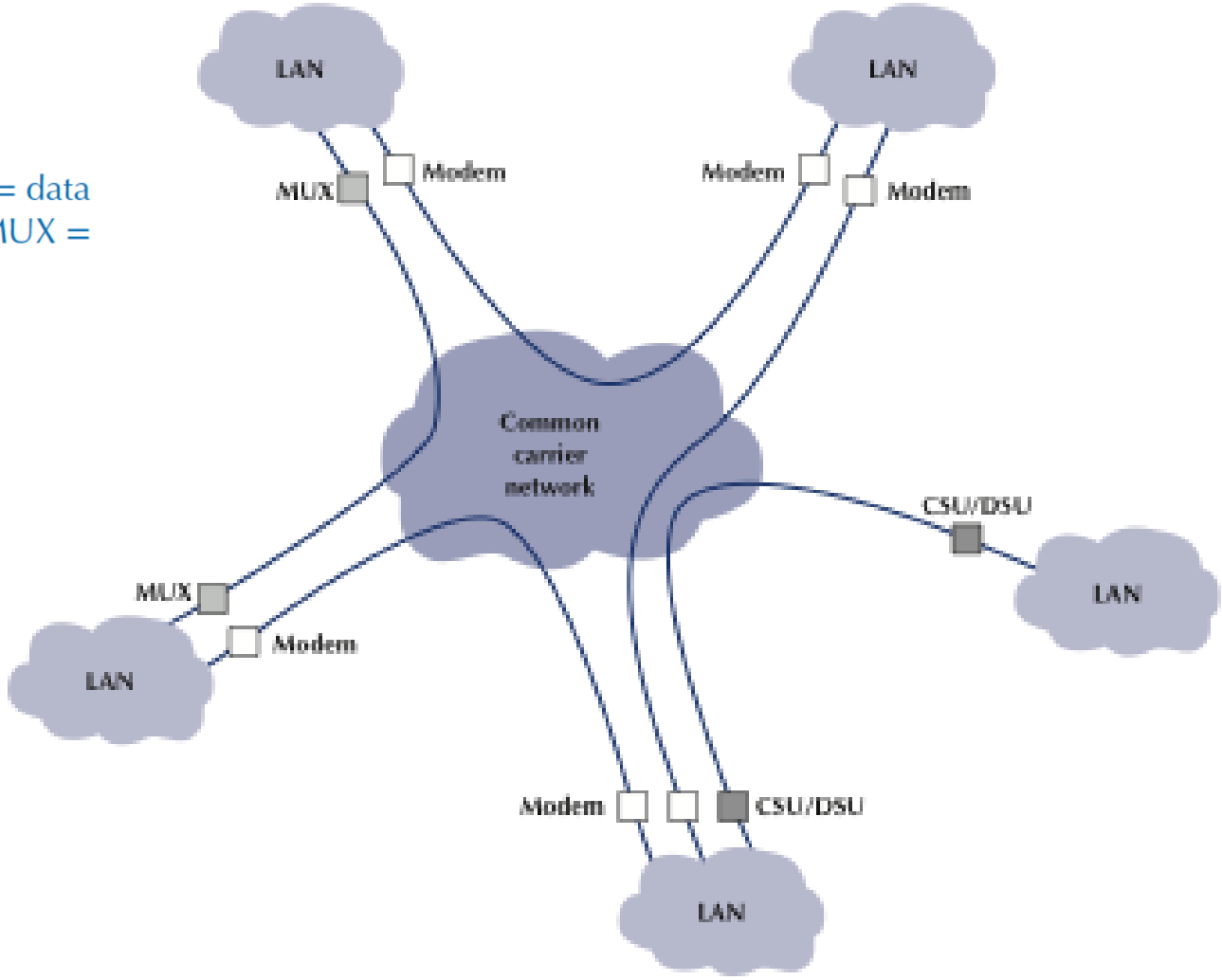
- Common services
  - Dedicated-circuit networks
  - Packet-switched networks
  - Virtual private networks (VPNs)

Dedicated-Circuit Networks

- Use full duplex circuits from common carriers called **leased lines** or **private lines** to create point-to-point links between organizational locations
- Carrier installs circuit that connects locations
- Connect LANs to leased lines using **modem**, **multiplexer**, or **channel service unit / data service unit (CSU/DSU)**
- Billed at a flat fee per month with unlimited use of the circuit
- Adding/removing lines or increasing/decreasing capacity may be difficult, time consuming, and expensive

Dedicated-Circuit Networks

FIGURE 9-1
Dedicated-circuit services.
CSU = channel service unit; DSU = data service unit; and MUX = multiplexer



Dedicated-Circuit Networks

- Three architectures (physical topologies) for dedicated-circuit networks
  1. Ring
  2. Star
  3. Mesh

Ring Architecture

FIGURE 9-2 Ring-based design

Star Architecture

FIGURE 9-3 Star-based design

Mesh Architecture

FIGURE 9-4
Mesh design

Dedicated-Circuit Networks

Architecture	Advantages	Disadvantages
Ring	• Robust to loss of any one circuit	• Long routes may increase communication latency
Star	• Simpler management • Messages require 1 or 2 hops • Circuit failure primarily affects a single site	• Susceptible to traffic problems • Failure of the central site will cause complete network failure
Mesh	• Generally short routes • Robust to the circuit loss or overloaded circuits	• Expensive

Dedicated-Circuit Networks

- Two types of dedicated circuit services:
  1. **T-carrier network**
  2. **Synchronous optical network (SONET)**

Dedicated-Circuit Networks

- T-carrier services
  - Most common dedicated circuit used in North America using copper wires
  - Similar to E-carrier services in Europe

T-carrier Designation	Digital Signal Designation	Speed
Fractional T1*	DS0	64 Kbps
T1*	DS1	1.544 Mbps
T2	DS2	6.312 Mbps
T3*	DS3	44.736 Mbps
T4	DS4	274.176 Mbps

*Commercially available

Dedicated-Circuit Networks

- Synchronous optical network (SONET)
  - ANSI standard for optical fiber transmission
  - Similar to synchronous digital hierarchy (SDH) used outside of North America

SONET Designation	SDH Designation	Speed
OC-1	STM-0	51.84 Mbps
OC-3	STM-1	155.52 Mbps
OC-12	STM-4	622.08 Mbps
OC-48	STM-16	2.488 Gbps
OC-192	STM-64	9.953 Gbps

Packet-Switched Networks

- Operate more like LANs and BNs than dedicated-circuit networks
- Connect to carrier network using **packet assembler/disassember (PAD)**
  - Translates messages between protocols
  - e.g. Frame Relay Assembler/Disassembler
- Customers pay a fixed price for a connection to the carrier and then a fee for the data transmitted

Packet-Switched Networks

- Packets from separate messages may be **interleaved** to maximize efficiency
- **Permanent Virtual Circuits (PVCs)** are connections between different locations in the packet network
  - Make packet-switched networks act like dedicated circuit networks
- **Switched Virtual Circuits (SVCs)** change dynamically

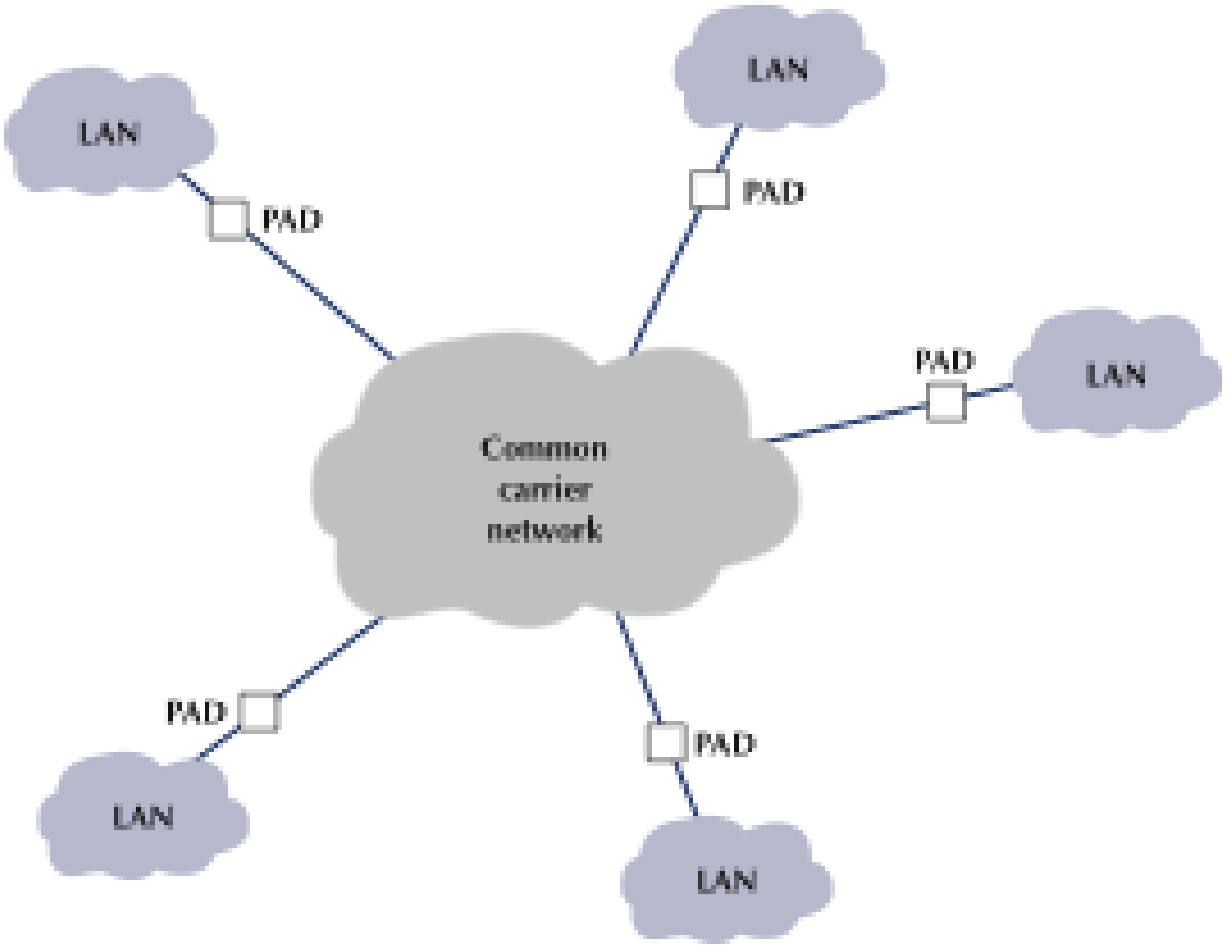
Packet-Switched Networks

- Data rates
  - Different locations may have different transmission speeds to the carrier network
  - Customers specify the rates per PVC
  - The **committed information rate (CIR)** is guaranteed by the service provider
  - Packets exceeding the CIR up to the **maximum allowable rate (MAR)** may be discarded if the network becomes overloaded

Packet-Switched Networks

FIGURE 9-7

Packet-switched services. LAN = local area network and PAD = packet assembly/disassembly device

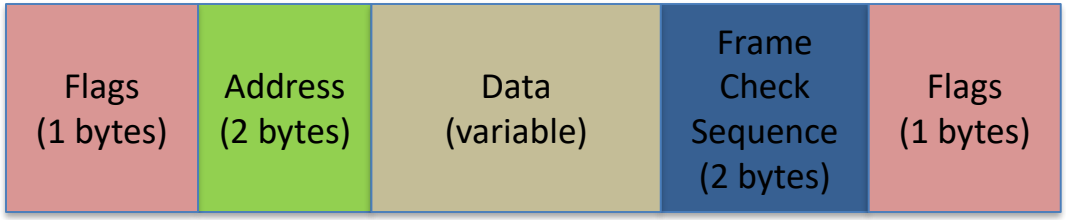


Packet-Switched Networks

- Types of packet-switched services
  - Frame relay
  - Ethernet
  - MPLS

Packet-Switched Networks

- **Frame relay**
  - Flexible layer 2 standard for encapsulation and packet-switching in WANs
  - Still common, but usage is declining
  - Designed for high performance and efficiency
  - Does not provide error control (unreliable)

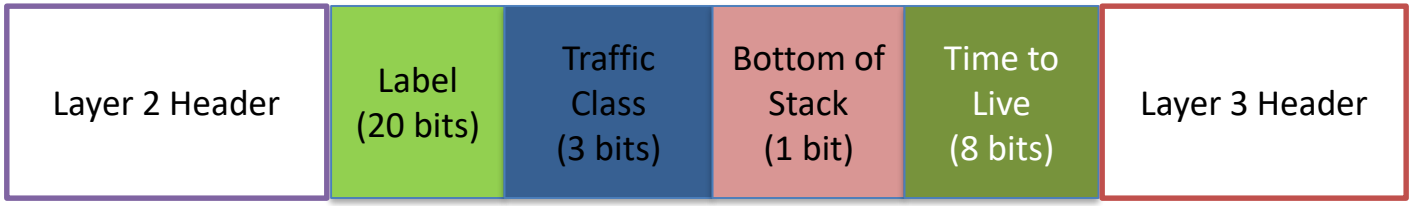


Packet-Switched Networks

- **Ethernet**
  - Converting to and from LAN/BN protocols and WAN protocols slows communication
  - Many carriers have switched or are switching to Ethernet for WANs
  - These new packet services bypass the **public switched telephone network (PSTN)**
  - May be less expensive than other alternatives

Packet-Switched Networks

- **Multiprotocol label switching (MPLS)**
  - Can be used with a variety of layer 2 protocols
  - Label is applied when entering carrier network between layer 2 and layer 3 headers
    - MPLS is sometimes called a layer 2.5 protocol
  - Label is used in forwarding decisions and traffic engineering
  - Packets can be switched using labels faster than using complete IP addresses and routing tables



Packet-Switched Networks

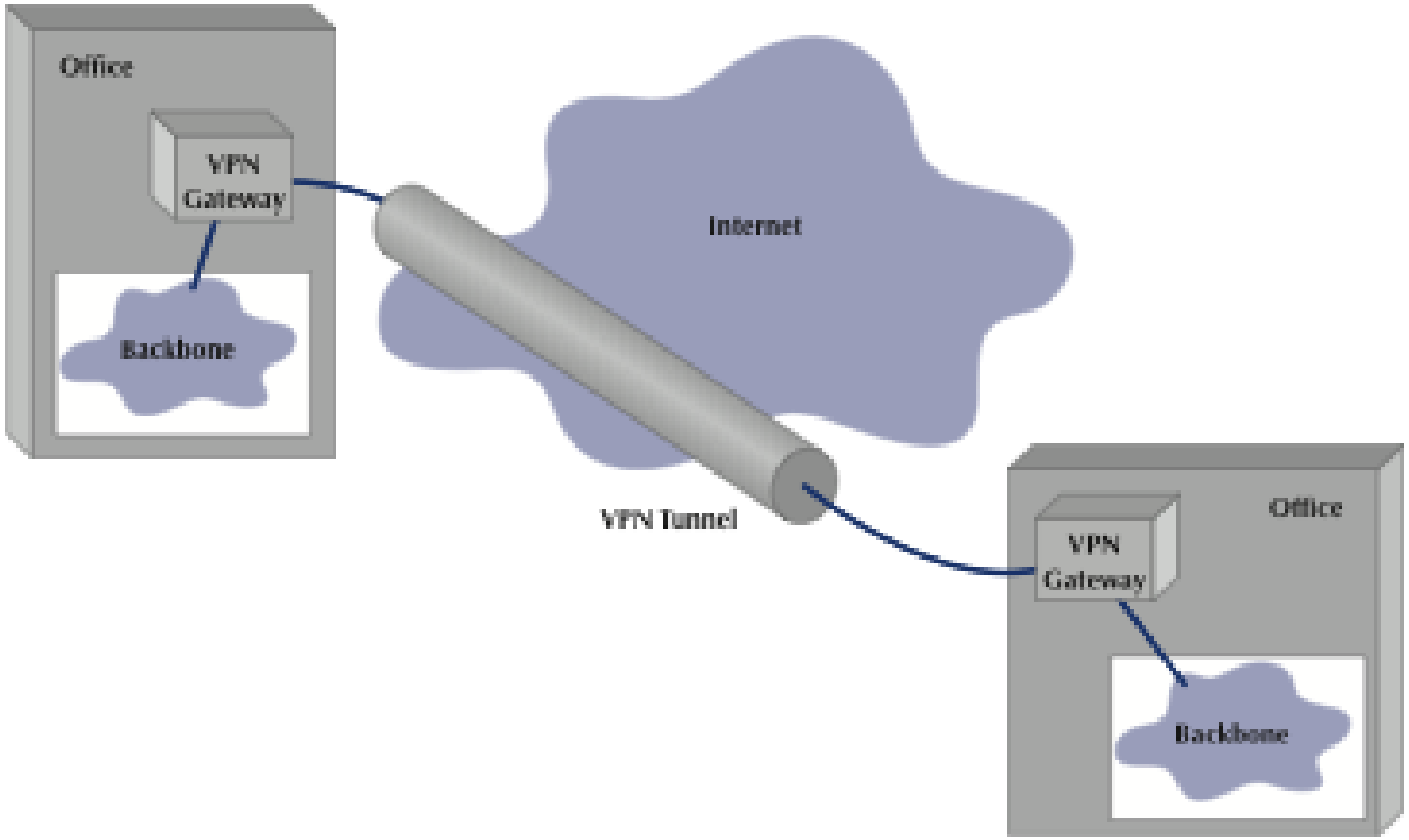
- Movement towards IP Services
  - Telecommunications companies are moving towards "all IP" networks
  - Replacing PSTN networks
  - Ethernet and MPLS commonly used in these networks

Virtual Private Networks (VPNs)

- Provide equivalent of private packet-switched network over the public Internet
- Creates a **virtual circuit** often called a tunnel
- May use dedicated hardware (**VPN gateways**) or be implemented in software
- VPNs can be implemented at layer 2 or layer 3

Virtual Private Networks (VPNs)

FIGURE 9-8 A virtual private network (VPN).
ISP = Internet service provider

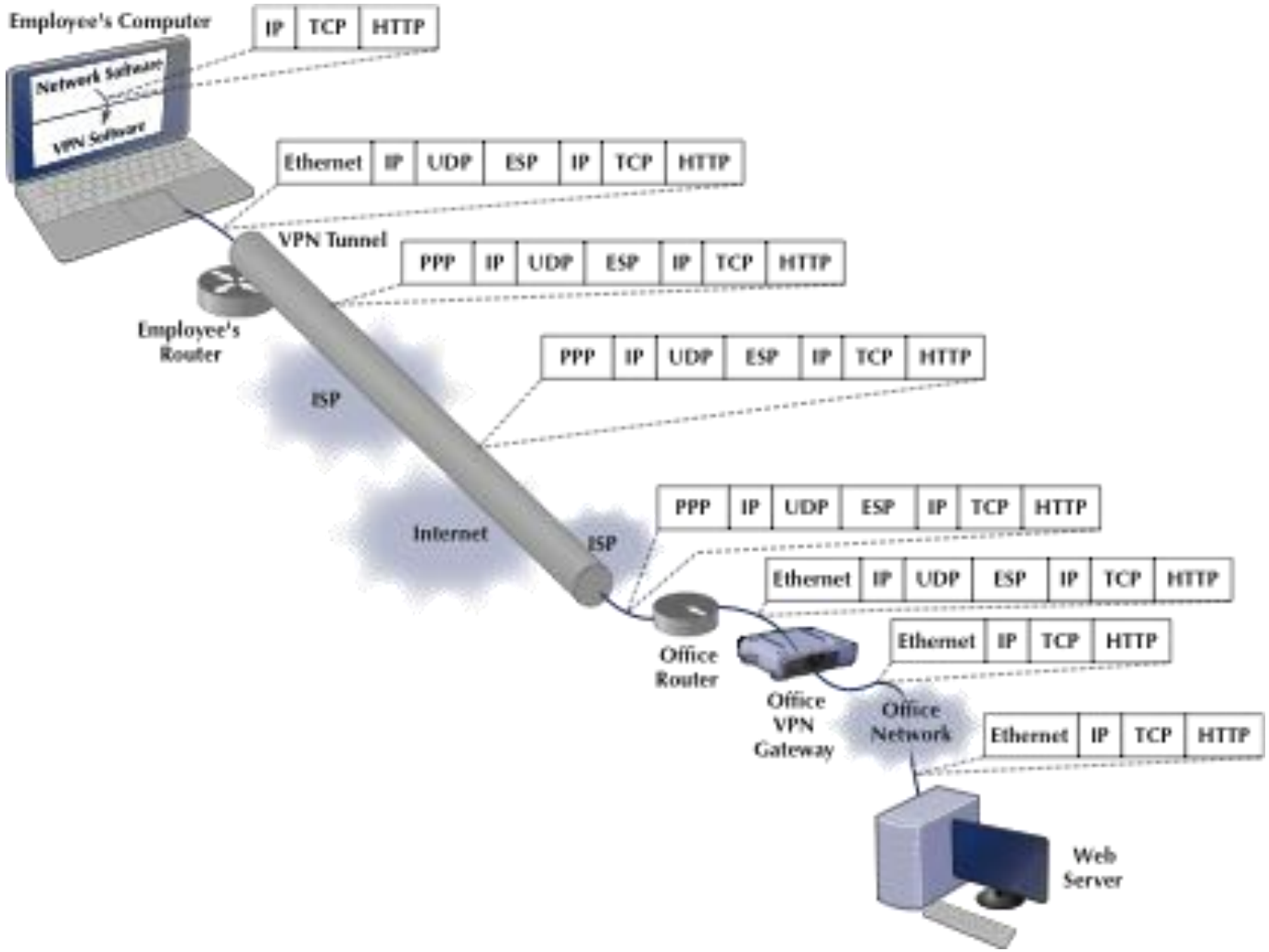


Virtual Private Networks (VPNs)

- Intranet VPN
  - Provides virtual circuits between organization locations over the Internet
- Extranet VPN
  - Same as an intranet VPN except that the VPN connects different organizations over the Internet
    - e.g., customers and suppliers
- Access VPN
  - Enables employees to access an organization's networks from remote locations over the Internet

Virtual Private Networks (VPNs)

FIGURE 9-9 Using VPN software



Virtual Private Networks (VPN)

- Advantages
  - Inexpensive
  - Flexible
- Disadvantages
  - Internet traffic unpredictable
  - Multiple incompatible implementations
    - Not all vendor equipment and services are compatible

WAN Design Practices

Service	Data Rates	Relative Cost	Reliability
Dedicated-Circuit Services			
• **T-Carrier**	64 Kbps to 45 Mbps	Moderate	High
• **SONET**	50 Mbps to 10 Gbps	High	High
Packet-Switched Services			
• **Frame Relay**	64 Kbps to 45 Mbps	Moderate	High
• **Ethernet**	1 Mbps to 40 Gbps	Moderate	High
• **MPLS**	64 Kbps to 10 Gbps	Moderate	High
VPN Services			
• **VPN**	64 Kbps to 50 Mbps	Low	Moderate

WAN Design Practices

Network Needs	Recommendation
Low to Moderate Traffic (10Mbps or less)	VPN if reliability is less important Frame relay otherwise
High Traffic (10-50 Mbps)	Ethernet or MPLS if available T3 if network volume is stable and predictable Frame relay otherwise
Very High Traffic (50 Mbps – 100 Gbps)	Ethernet or MPLS if available SONET if network volume is stable and predictable

Improving WAN Performance

- Devices
- Circuits
- Demand

Implications for Management

- Shift to Ethernet and MPLS
  - Legacy technologies such as frame relay will be phased out like ATM
  - Cost of WAN hardware and services decreasing
  - Similar to LANs and BNs, WANs are experiencing standardization and commoditization