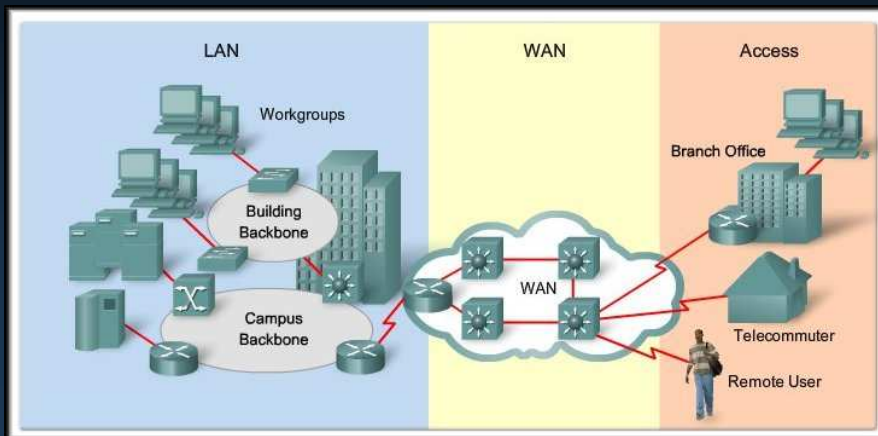# Chapter 1

Introduction to WANs

## Introduction to WANs

Introducing Wide Area Networks

What is a WAN?

- A WAN is a data communications network that operates **beyond the geographic scope of a LAN**.
  - Connect devices that are separated by a broader geographical area than a LAN.
  - Use **carriers** (phone companies, cable companies, network providers).
 - Use **serial connections** of various types.

What is a WAN?

- A WAN is a data communications network that operates **beyond the geographic scope of a LAN**.
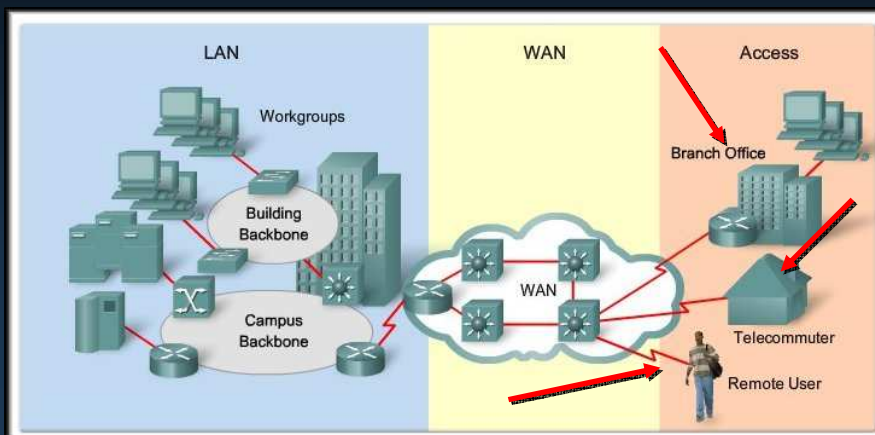
The Evolving Enterprise

- As companies grow, they hire more employees, open branch offices, and expand into global markets.
- These changes also **influence their requirements for integrated services** and drive their network requirements.
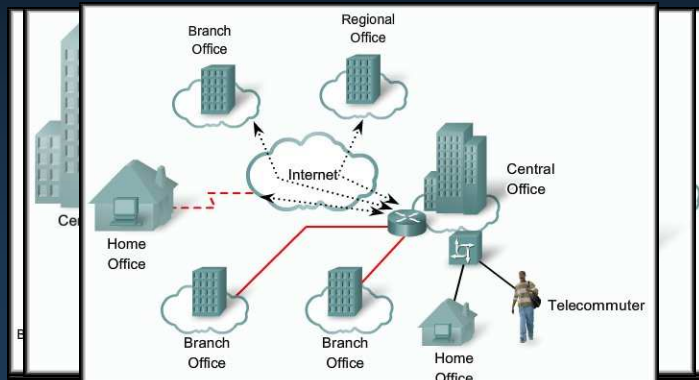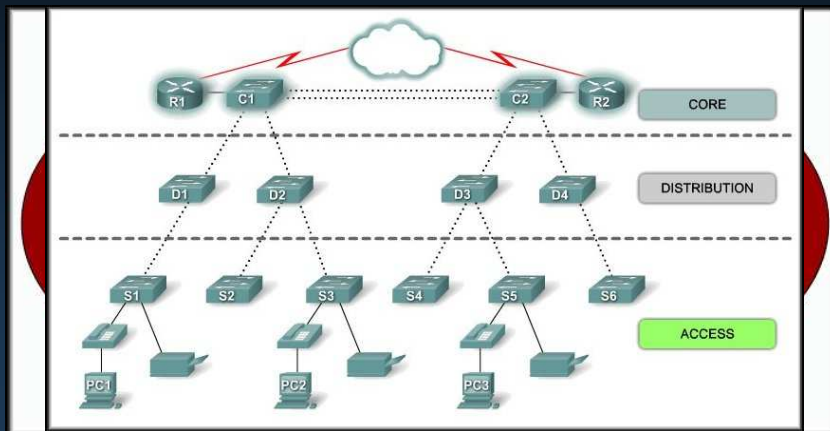
The Evolving Network Model

- As networks grow, the hierarchical design model must grow with it.

The Evolving Network Model
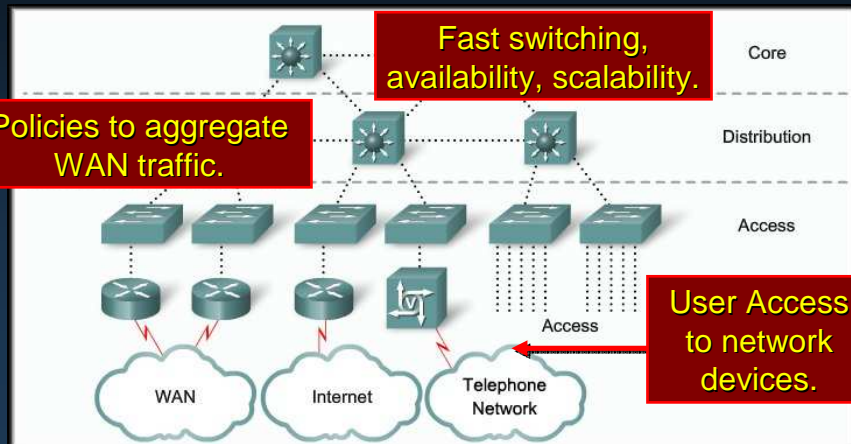
- As networks grow, the hierarchical design model must grow with it.

The Evolving Network Model

- Cisco Enterprise Architecture:
  - Different businesses need different types of networks.
  - All too often networks grow in a haphazard way as new components are added in response to immediate needs.
  - Because the network is a mixture of newer and older technologies, it can be difficult to support and maintain.
  - The Cisco architecture is designed to provide network planners with a roadmap for network growth as the business moves through different stages.
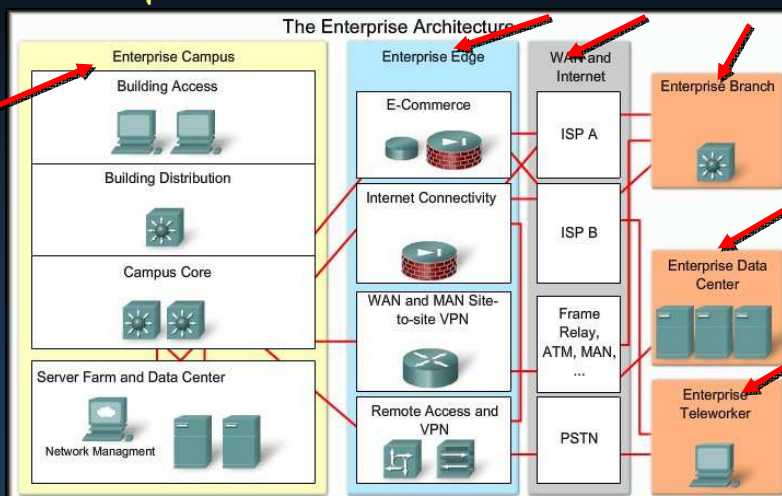
The Evolving Network Model

- **Cisco Enterprise Architecture:**
  - Consists of modules.
  - Each module has a distinct network infrastructure with services and network applications that extend across the modules.
    - Enterprise **Campus** Architecture
    - Enterprise **Branch** Architecture
    - Enterprise **Data Center** Architecture
    - Enterprise **Teleworker** Architecture
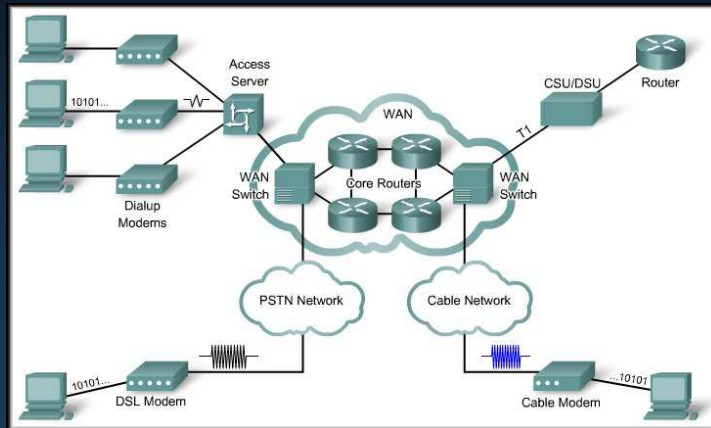

The Evolving Network Model

- **Cisco Enterprise Architecture:**

More information in the text and online curriculum.

The Enterprise Architecture

Enterprise Campus
- Building Access
- Building Distribution
- Campus Core
- Server Farm and Data Center
- Network Managment

Enterprise Edge
- E-Commerce
- Internet Connectivity
- WAN and MAN Site-to-site VPN
- Remote Access and VPN

WAN and Internet
- ISP A
- ISP B
- Frame Relay, ATM, MAN, ...
- PSTN

Enterprise Branch

Enterprise Data Center

Enterprise Teleworker

Introduction to WANs

WAN Technology Concepts

WAN Technology Overview

- **WAN and the OSI Model:**
  - In relation to the OSI reference model, WAN operations focus on **Layer 1 and Layer 2**.

WAN access standards typically describe both Physical layer delivery methods and Data Link layer requirements.
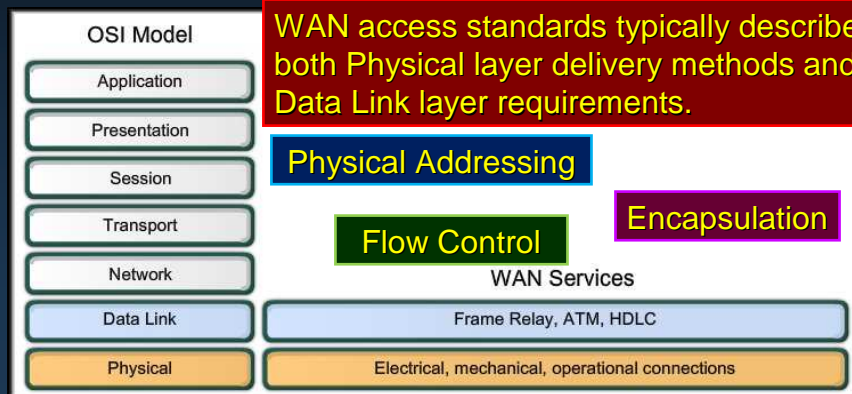
Physical Addressing

Flow Control

Encapsulation

WAN Technology Overview

- **WAN and the OSI Model:**
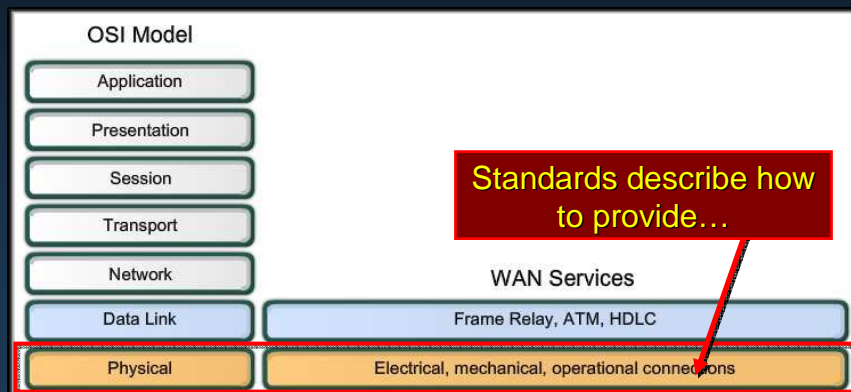 - In relation to the OSI reference model, WAN operations focus on **Layer 1 and Layer 2**.

OSI Model	
Application	WAN access standards are defined and managed by a number of recognized authorities, including the International Organization for Standardization (ISO), the Telecommunication Industry Association (TIA), and the Electronic Industries Alliance (EIA).
Presentation	
Session	
Transport	
Network	
Data Link	Frame Relay, ATM, HDLC
Physical	Electrical, mechanical, operational connections

WAN Technology Overview

- **WAN and the OSI Model:**
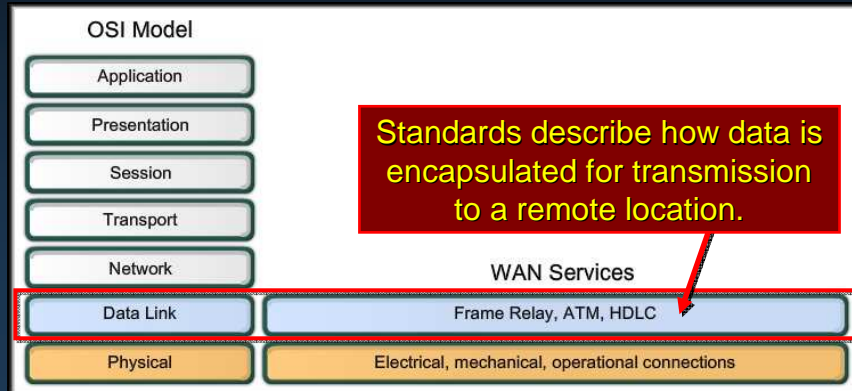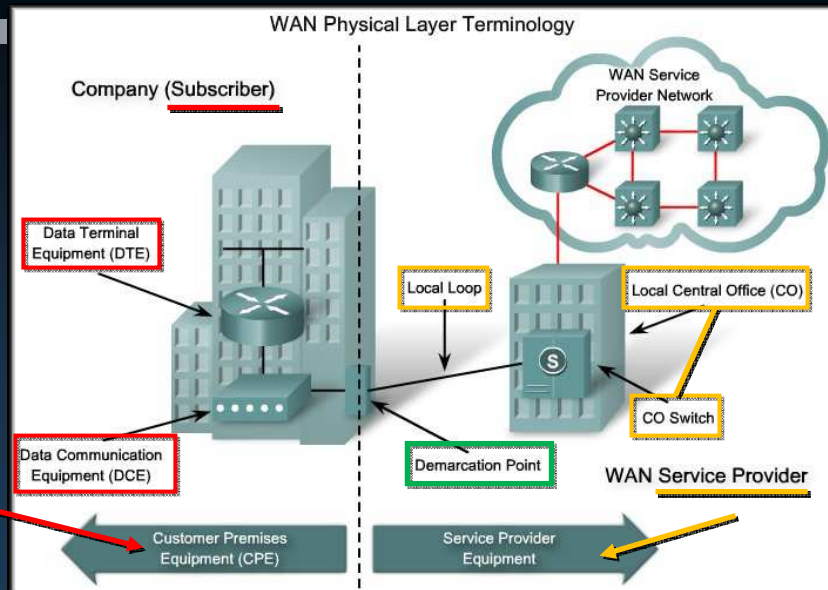 - In relation to the OSI reference model, WAN operations focus on **Layer 1 and Layer 2**.

OSI Model

| Application |
| Presentation |
| Session |
| Transport |
Network	WAN Services
Data Link	Frame Relay, ATM, HDLC
Physical	Electrical, mechanical, operational connections

Standards describe how to provide…

WAN Technology Overview

- **WAN and the OSI Model:**
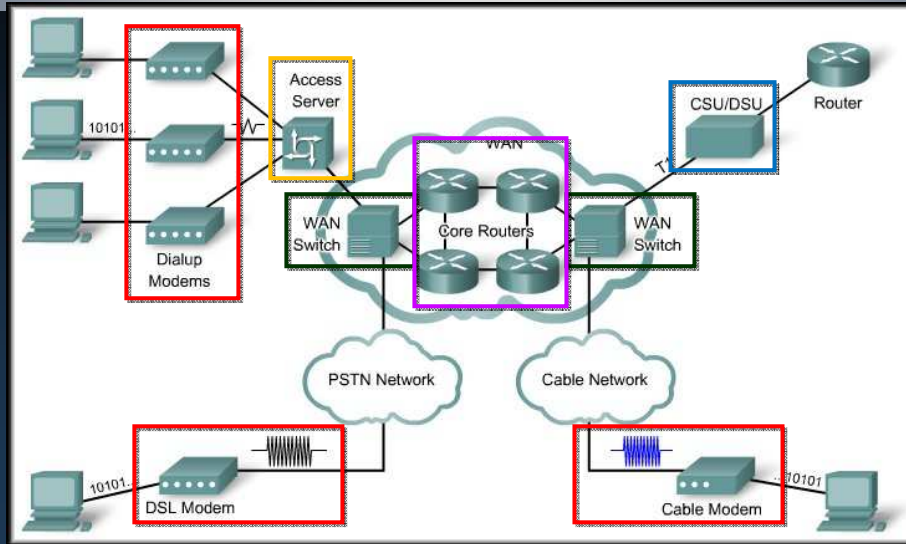 - In relation to the OSI reference model, WAN operations focus on **Layer 1 and Layer 2**.

OSI Model

Application
Presentation
Session
Transport
Network

Standards describe how data is encapsulated for transmission to a remote location.

WAN Services

Data Link	Frame Relay, ATM, HDLC
Physical	Electrical, mechanical, operational connections

WAN Physical Layer Concepts

WAN Physical Layer Terminology

Company (Subscriber)

WAN Service Provider Network

Data Terminal Equipment (DTE)

Local Loop

Local Central Office (CO)

CO Switch

Data Communication Equipment (DCE)

Demarcation Point

WAN Service Provider

Customer Premises Equipment (CPE)

Service Provider Equipment

WAN Devices

WAN Physical Layer Standards

WAN Physical Layer Standards

- EIA/TIA-232
- EIA/TIA-449/530
- EIA/TIA-612/613 (HSSI)
- V.35
- X.21
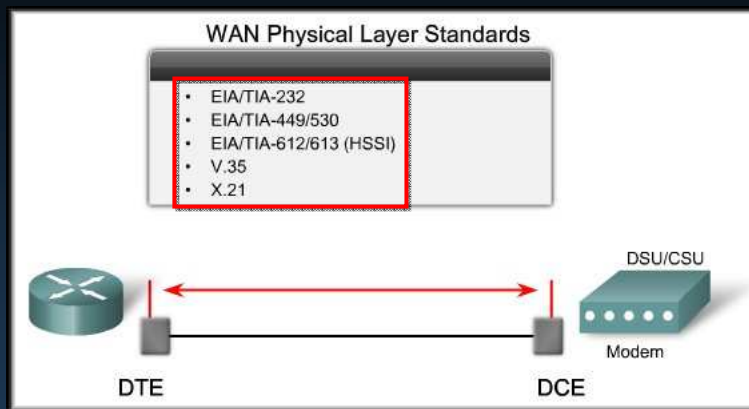
Data Terminal Equipment
User Device with interface connecting to the WAN link

Data Circuit-Terminating Equipment
End of the WAN provider side of the communcation facility

WAN Data Link Layer Concepts

- Data Link layer protocols define how data is encapsulated for transmission to remote sites and the mechanisms for transferring the resulting frames.
- A variety of different technologies, such as ISDN, Frame Relay, or ATM, are used to move the data across the WAN connection.
- Many of these protocols use the same basic framing mechanism, High-Level Data Link Control (HDLC).
  - An ISO standard.
  - Many subsets or variants as we will see.

WAN Data Link Layer Concepts

- The most common WAN data-link protocols are:
  - HDLC
  - PPP
  - Frame Relay
  - ATM

- ATM is different from the others, because it uses small fixed-size cells of 53 bytes (48 bytes for data), unlike the other packet-switched technologies, which use variable-sized packets.

WAN Data Link Layer Concepts

- FYI:
  - Another Data Link layer protocol is the **Multiprotocol Label Switching** (MPLS) protocol.
  - MPLS is increasingly being deployed by service providers to provide an economical solution to carry **circuit-switched as well as packet-switched** network traffic.
  - It can operate over any existing infrastructure, such as IP, Frame Relay, ATM, or Ethernet.
  - It sits between Layer 2 and Layer 3 and is sometimes referred to as a Layer 2.5 protocol.

WAN Data Link Layer Concepts

Protocol	Usage
Link Access Procedure Balanced (LAPB)	X.25
Link Access Procedure D Channel (LAPD)	ISDN D channel
Link Access Procedure Frame (LAPF)	Frame Relay
High-Level Data Link Control (HDLC)	Cisco default
Point-to-Point Protocol (PPP)	Serial WAN switched connections

Data Link layer protocols define **how the data is encapsulated** as well as how it is transported between sites.

WAN Data Link Layer Concepts
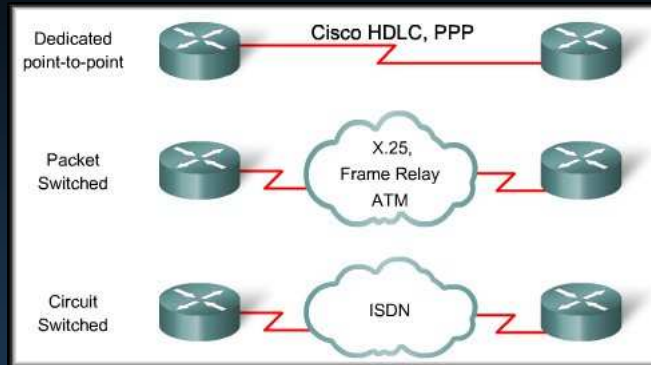
A number of technologies for the transport of data exist.
While the encapsulation will vary with the technology, most use
the ISO HDLC standard or a modification of it.

WAN Encapsulation

- Data Link layer protocols: How the data is encapsulated.
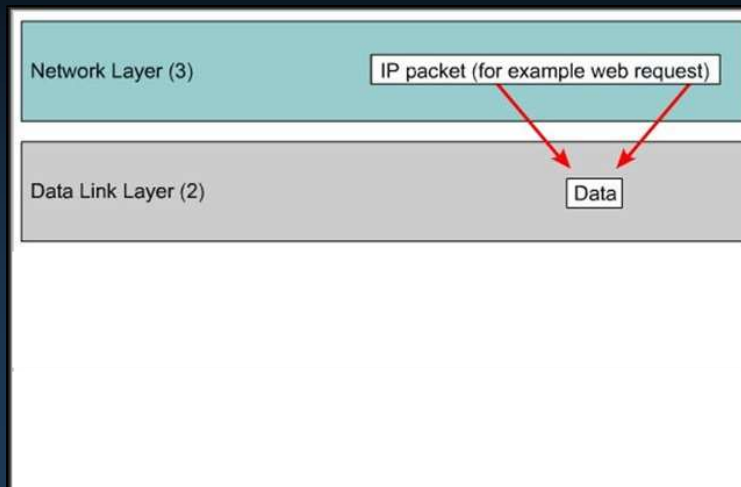
WAN Encapsulation

- The choice of encapsulation protocols depends on the WAN technology and the equipment.
  - Most framing is based on the HDLC standard.
  - The data is encapsulated with some form of header information and an FCS field.
  - The entire frame is then encapsulated with Flag fields to indicate the beginning and end of the frame.

FLAG	HEADER	DATA	FCS	FLAG

It is important to note that most vendors (Cisco included) use their own proprietary version of HDLC on HDLC links between their own products.

WAN Encapsulation

- Examining the Frame:

Flag	Header	Data	FCS	Flag

Address	Control	Protocol
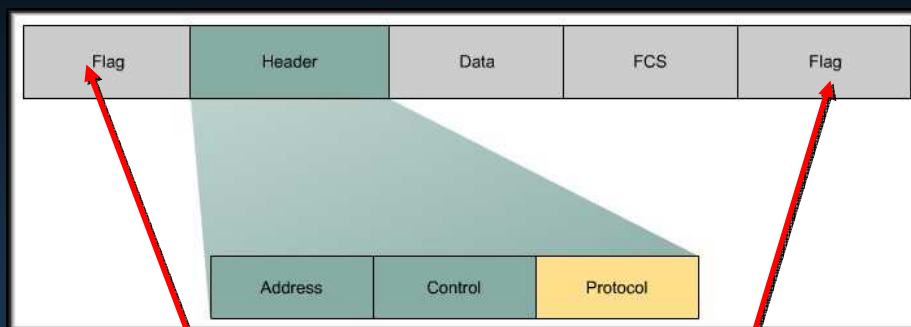
The frame always starts and ends with an 8-bit flag field to indicate the beginning and end of the frame. The bit pattern is 01111110. (0x7E)

WAN Encapsulation

- **Examining the Frame:**

Flag	Header	Data	FCS	Flag

Address	Control	Protocol
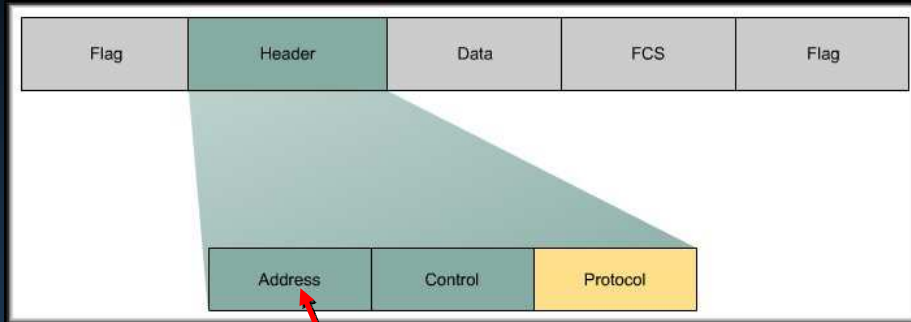
The address field may not needed for
WAN links, depending upon the
technology.
The address may be 1 or 2 bytes long.

WAN Encapsulation

- **Examining the Frame:**

Flag	Header	Data	FCS	Flag

Address	Control	Protocol
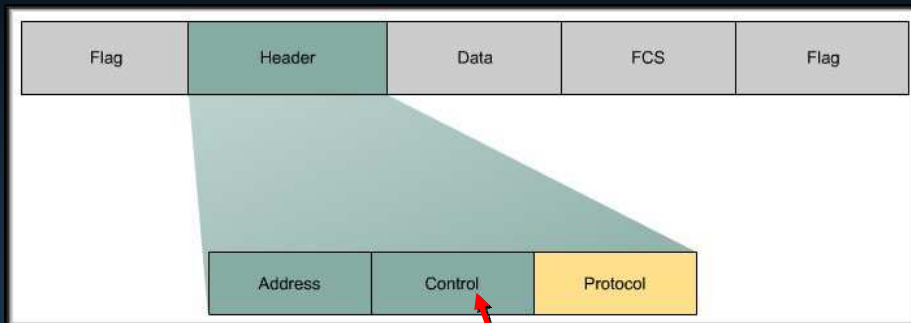
The control field is protocol dependent.
It usually indicates whether the content
of the data is control information or
Network layer data (1 Byte).

WAN Encapsulation

- **Examining the Frame:**
  - The address and control fields form the header information in the standard HDLC frame.
    - **Both PPP and Cisco HDLC add the Protocol field** to the header to identify the Layer 3 protocol of the encapsulated data.

Flag	Header	Data	FCS	Flag

Address	Control	Protocol
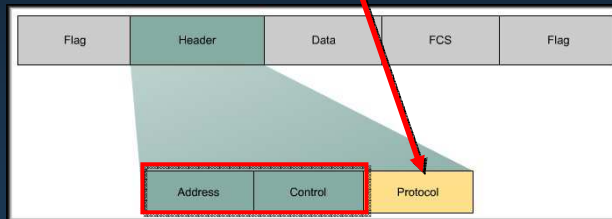
  - *Cisco HDLC only communicates with Cisco HDLC…..*

WAN Switching Concepts

- WAN switched networks fall into two categories:
  - **Circuit** switched.
    - POTS, ISDN
  - **Packet** switched.
    - Frame Relay, ATM, X.25

WAN Switching Concepts – Circuit Switched

- When a subscriber makes a telephone call, the dialed number is used to set switches in the exchanges along the route of the call so that there is a continuous circuit from the originating caller to that of the called party.
- Because of the switching operation used to establish the circuit, the telephone system is called a circuit-switched network.
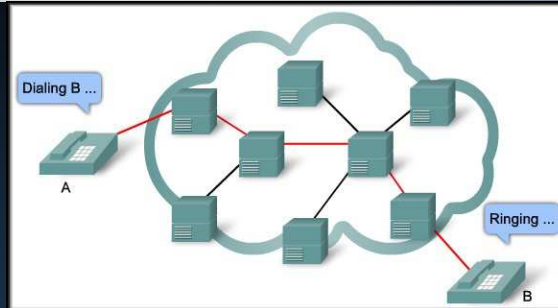
WAN Switching Concepts – Circuit Switched

- If the telephones are replaced with modems, then the switched circuit is able to carry data.
- Suppose it is used to access a web page.
- There will be a burst of activity that uses the entire bandwidth while the page is being downloaded.
- That will be followed by no activity while the user reads the page and followed again by another burst while another page is accessed.
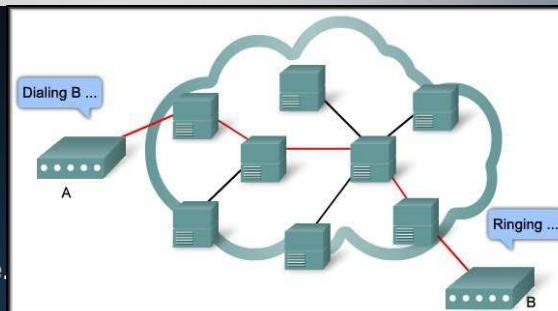
WAN Switching Concepts – Circuit Switched

- If the circuit carries data, it may not be very efficient.

- The internal path is **shared** by several conversations.

- **Time Division Multiplexing (TDM)** is used to give each conversation a share of the connection in turn.
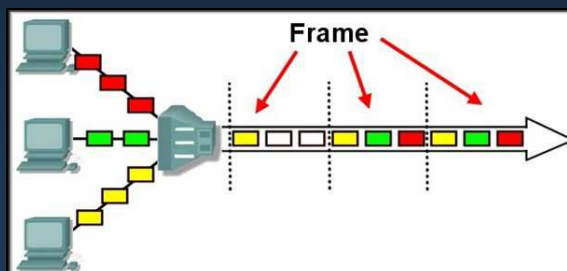 - TDM assures that a fixed capacity connection is made available to the subscriber.

WAN Switching Concepts   FYI

- Circuit Switching and TDM:
  - Each device to be multiplexed is assigned a specific *"time slot"* in the frame.
  - At each time slot, 8 bits is read from each device and a fixed length frame is built using that data.
  - If there is nothing to send for that time slot, 8 null bits are placed in the frame for that device.

WAN Switching Concepts – Packet Switched

- An alternative is to allocate the capacity to the traffic only when it is needed and share capacity among many users.

- If the circuit is to be shared, there must be some mechanism to label the bits so that the system knows where to deliver them.

- The bits are gathered into groups called cells, frames, or packets.

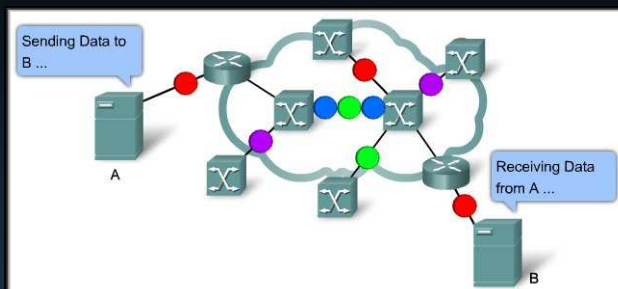# WAN Switching Concepts – Packet Switched

- Each packet must contain the network information in order to be delivered to the correct destination.

- The packet passes from exchange to exchange for delivery through the provider network.

  - *Packet Switched describes the type of network in which relatively small units of data called packets are routed through a network based on the destination address contained within each packet.*

WAN Switching Concepts – Packet Switched

- The circuits only exist while data travels through them.
- They are termed *virtual circuits* and are categorized as switched or permanent.
  - Switched Virtual Circuit (SVC): Is constructed at the time of the connection and disappears when the user is done.
  - Permanent Virtual Circuit (PVC): Is a pre-configured pathway through the provider's network. This path is always available to the user for data transmission.
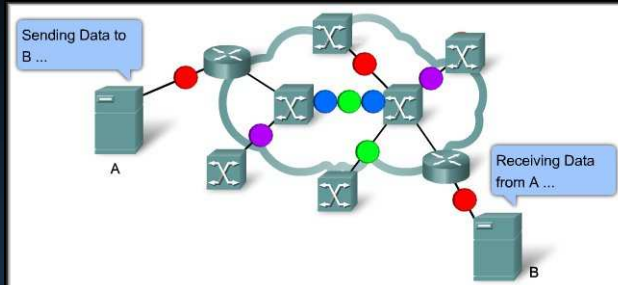
CCNA4-37   Chapter 1

WAN Switching Concepts – Packet Switched

- These networks can also be *connectionless* or *connection-oriented*.
- The *Internet* is a good example of a connectionless, packet switched network. Each packet contains all of the addressing information required for successful packet delivery.
- *Frame Relay* is an example of a connection-oriented packet switched network. Each packet does not require addressing information and travels a pre-configured path between the source and the destination.
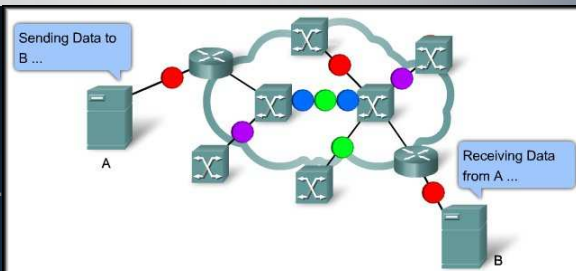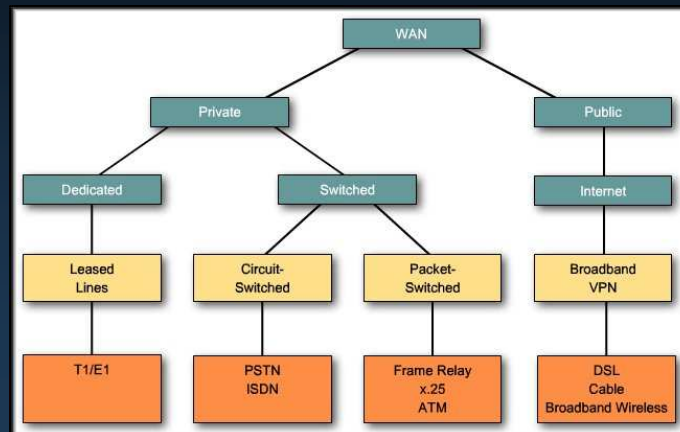

CCNA4-38   Chapter 1

Introduction to WANs

WAN Connection Options

WAN Link Connection Options

- **Dedicated or leased-line** networks are the simplest of the implementations.

- A dedicated point-to-point link is provided by the vendor.

- Bandwidth is guaranteed between the end points.

- Leased lines are also used to connect the subscriber to the vendor to make use of other technologies. Once that connection is made, the other options come into play.
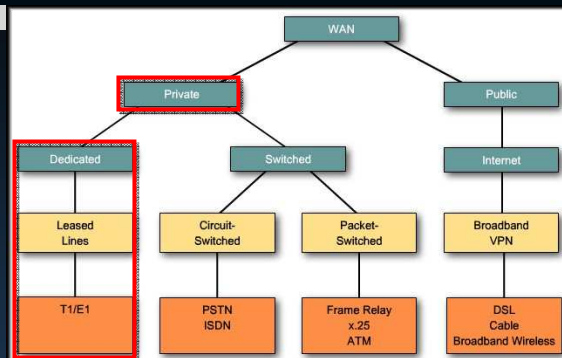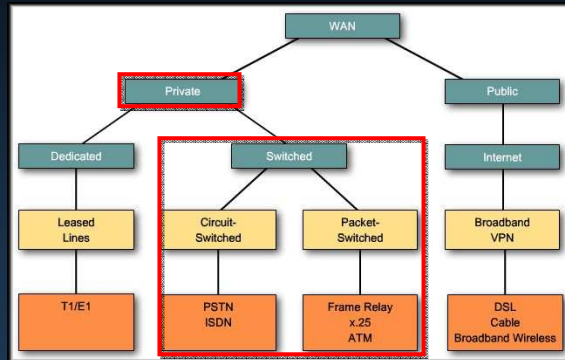
WAN Link Connection Options

- **Switched** communication links can be either circuit switched or packet switched.
- **Circuit Switched:**
  - PSTN
  - ISDN
- **Packet Switched:**
  - Frame Relay
 - X.25
  - ATM

WAN Link Connection Options

- **Public:**
  Public connections use the global Internet infrastructure
- Until the development of VPN technology, the Internet was not a viable connection option. Security issues prevented its use.
- The Internet is now an inexpensive and secure option for connecting to teleworkers and remote offices where performance guarantees are not critical.
- **DSL, Cable Broadband Wireless**

Dedicated Connection Link Options

Dedicated or Leased Line Connection
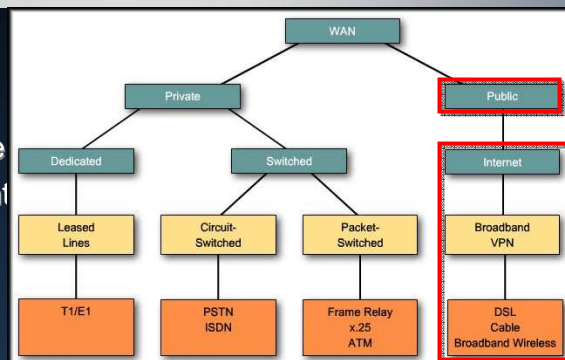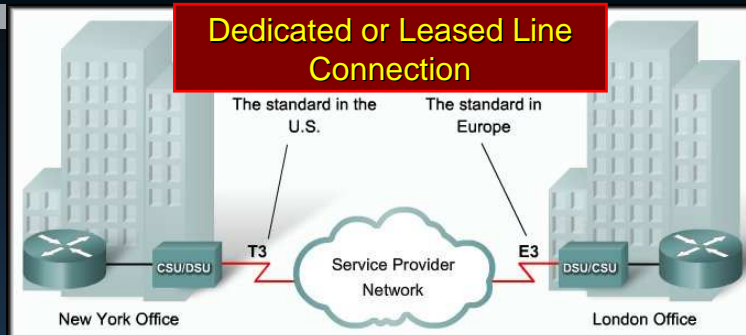
- A **point-to-point link** is used to provide a **pre-established WAN communications path** from the customer premises **through the provider network** to a remote destination.
- Point-to-point links are **usually more expensive** than shared services such as Frame Relay.

Dedicated Connection Link Options

- **Types of Leased Lines and Capacities:**

Line Type	Bit Rate Capacity	Line Type	Bit Rate Capacity
56	56 kb/s	OC-9	466.56 Mb/s
64	64 kb/s	OC-12	622.08 Mb/s
T1	1.544 Mb/s	OC-18	933.12 Mb/s
E1	2.048 Mb/s	OC-24	1244.16 Mb/s
J1	2.048 Mb/s	OC-36	1866.24 Mb/s
E3	34.064 Mb/s	OC-48	2488.32 Mb/s
T3	44.736 Mb/s	OC-96	4976.64 Mb/s
OC-1	51.84 Mb/s	OC-192	9953.28 Mb/s
OC-3	155.54 Mb/s	OC-768	39813.12 Mb/s

Dedicated Connection Link Options - FYI

| Name	Abbr.	Size
Kilo	K	2^{10} = 1,024
Mega	M	2^{20} = 1,048,576
Giga	G	2^{30} = 1,073,741,824
Tera	T	2^{40} = 1,099,511,627,776
Peta	P	2^{50} = 1,125,899,906,842,624
Exa	E	2^{60} = 1,152,921,504,606,846,976
Zetta	Z	2^{70} = 1,180,591,620,717,411,303,424
Yotta	Y	2^{80} = 1,208,925,819,614,629,174,706,176

Circuit-Switched Link Options
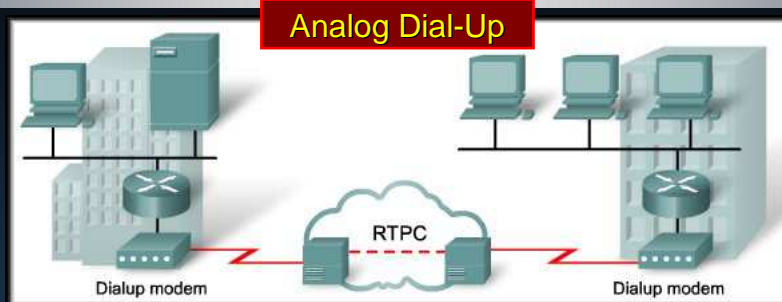
- Intermittent, low-volume data transfers.
- Uses the local loop, to connect to the CO.
- Limited to less than 56 kb/s.
- Advantages: simplicity, availability, low implementation cost.
- Disadvantages: low data rates, long connection time.

Circuit-Switched Link Options

Integrated Services Digital Network (ISDN)
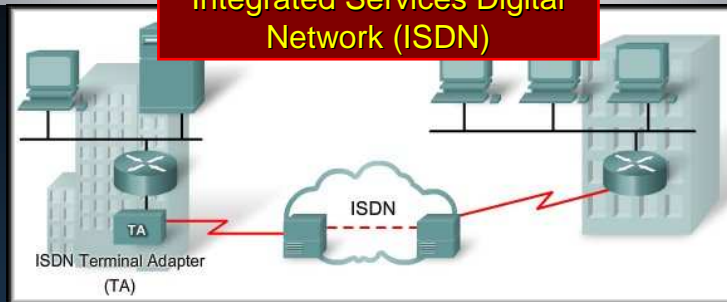
- Enables the local loop to carry **end-to-end digital signals.**
- Higher capacity connections.
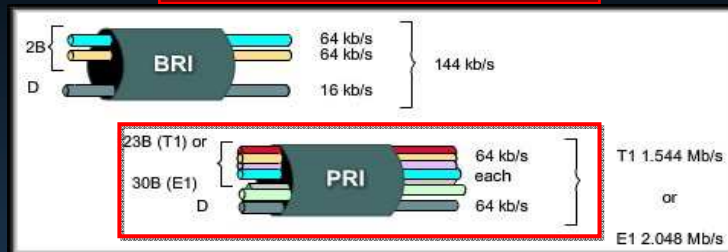- ISDN changes the internal connections of the PSTN from carrying analog signals to time-division multiplexed (TDM) digital signals.

Circuit-Switched Link Options

Integrated Services Digital Network (ISDN)
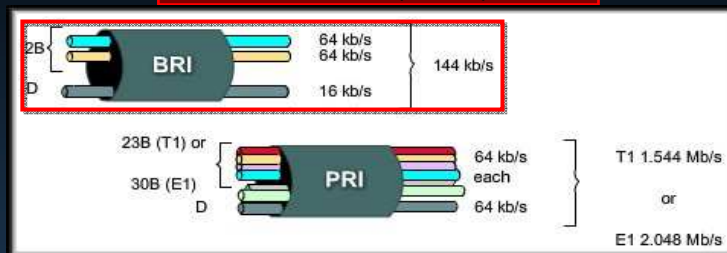
- **Basic Rate Interface (BRI):**
    - Two 64 kb/s B (bearer) and a 16 kb/s D (delta) channel.
        - Bearer channels (B) for carry voice or data.
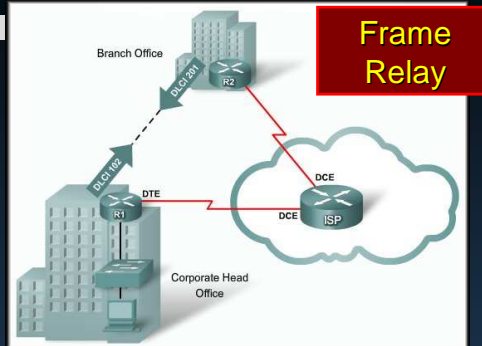   - Delta channel (D) for call setup and signaling.
    - Home, small business, leased line backup.

Circuit-Switched Link Options

Integrated Services Digital Network (ISDN)

| 2B | BRI | 64 kb/s
64 kb/s | 144 kb/s |
| D | | 16 kb/s | |

23B (T1) or	PRI	64 kb/s each	T1 1.544 Mb/s
30B (E1)			or
D		64 kb/s	E1 2.048 Mb/s

- **Primary Rate Interface (PRI):**
  - 23 - 64 kb/s B (bearer) and 1 - 64 kb/s D (delta) channel.
    - Bearer channels (B) for carry voice or data.
    - Delta channel (D) for call setup and signaling.
  - Large enterprise, dial-in access

Packet-Switched Connection Options

- **X.25:**
- Legacy **network layer** protocol.
- Typical applications are point-of-sale card readers.
- Speeds vary from 2400 b/s up to 2 Mb/s. However, public networks are usually low capacity and rarely exceeding 64 kb/s.
- Now in dramatic decline.
- They are still in use in many portions of the developing world.
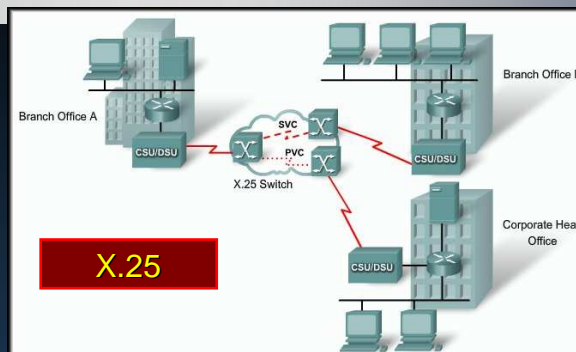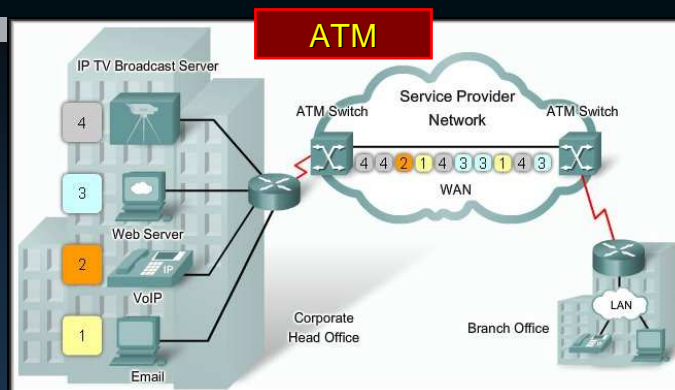
Packet-Switched Connection Options

- **Frame Relay:**
- Much simpler protocol at the data link layer.
- Implements no error or flow control.
- Data rates up to 4 Mb/s.
- Virtual Circuits are permanent and uniquely identified by a Data Link Connection Identifier (DLCI).
- The router on the LAN needs only a single interface.
- The short-leased line to the Frame Relay network edge allows cost-effective connections between widely scattered LANs.

Frame Relay

Branch Office

R2

DLCI 201

DLCI 102

DTE

R1

DCE

DCE

ISP

Corporate Head Office

Packet-Switched Connection Options

ATM

IP TV Broadcast Server

4

3

Web Server

2

VoIP

1

Email

ATM Switch

Service Provider Network

4 4 2 1 4 3 3 1 4 3

WAN

ATM Switch

LAN

Corporate Head Office

Branch Office

- **Asynchronous Transfer Mode (ATM):**
  - ATM technology is capable of transferring voice, video, and data simultaneously through private and public networks.
  - It is built on a cell-based architecture.
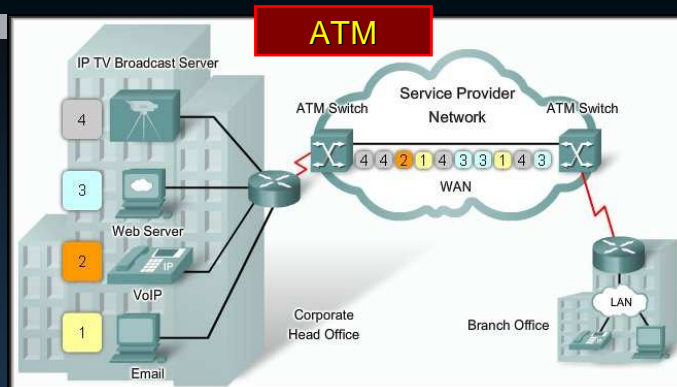
Packet-Switched Connection Options
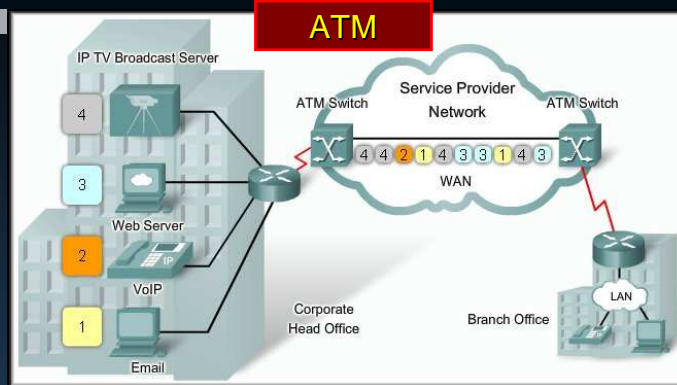
- **Asynchronous Transfer Mode (ATM):**
  - ATM cells are always a **fixed length of 53 bytes.**
    - 5 byte ATM header.
    - 48 bytes of ATM payload.

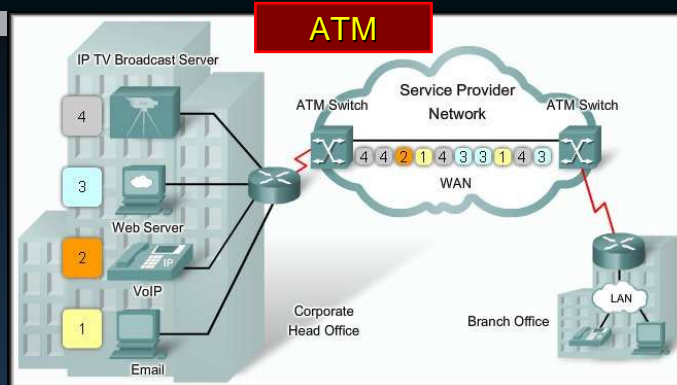# Packet-Switched Connection Options

- **Asynchronous Transfer Mode (ATM):**
  - The ATM cell is less efficient than the bigger frames and packets of Frame Relay and X.25.
  - Needs almost 20 percent greater bandwidth than Frame Relay to carry the same amount of data.

Packet-Switched Connection Options

- **Asynchronous Transfer Mode (ATM):**
  - ATM was designed to be **extremely scalable** and can support link speeds of T1/E1 to OC-12 (622 Mb/s) and higher.
  - PVCs are most common.
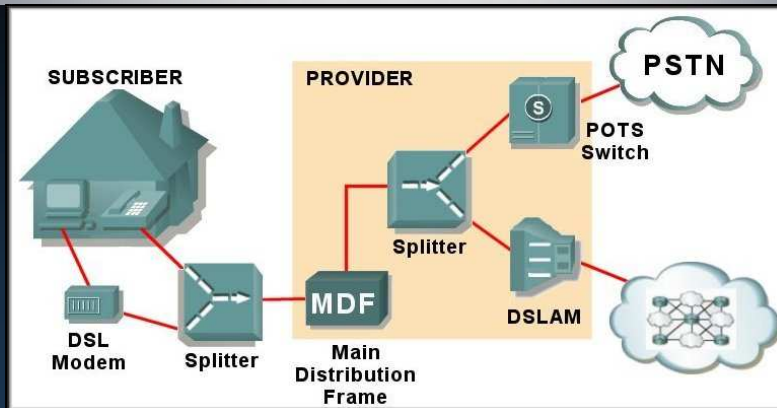
Internet Connection Options - DSL
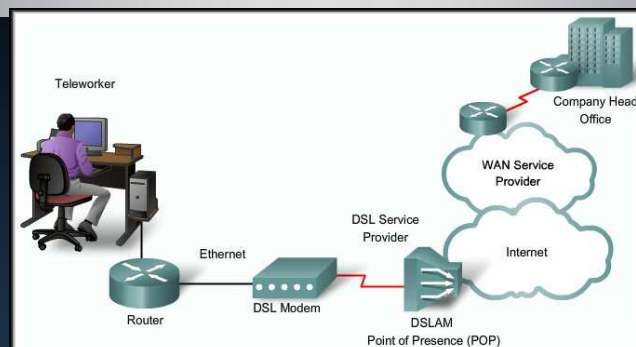
- **Digital Subscriber Line (DSL):**
  - DSL technology is an always-on connection that uses existing telephone lines to transport high-bandwidth data, and provides IP services to subscribers.
  - Modem converts an Ethernet signal to a DSL signal.

Internet Connection Options - DSL

- Multiple DSL subscriber lines are multiplexed into a single, high capacity link by the use of a **DSL Access Multiplexer (DSLAM)** at the provider location.
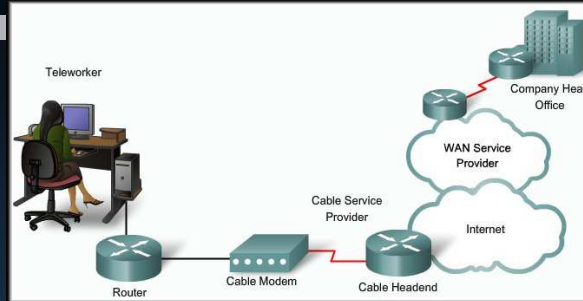

Internet Connection Options - DSL
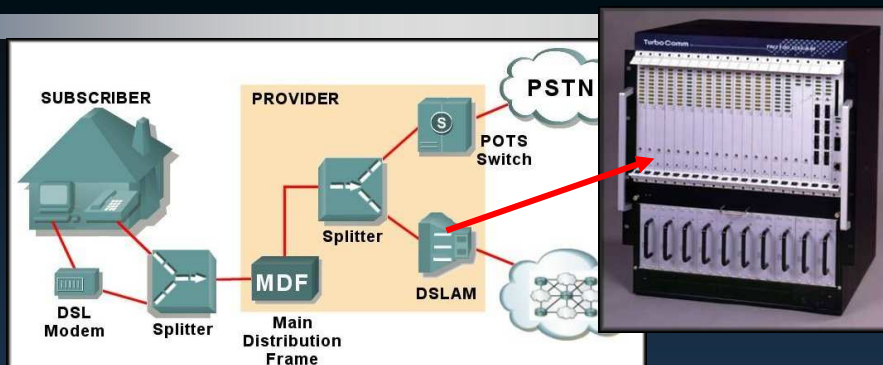
- DSLAMs incorporate TDM technology to aggregate many subscriber lines into a less cumbersome single medium, generally a T3/DS3.
- Connection techniques achieve data rates up to 8.192 Mbps.
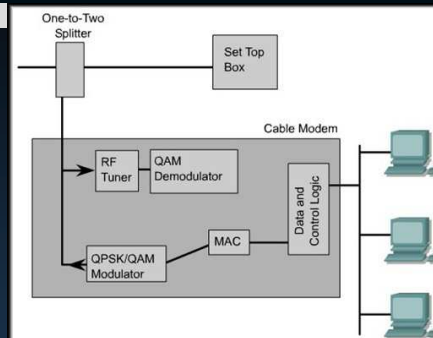
Internet Connection Options - Cable

- Coaxial cable is widely used in urban areas to distribute television signals.
- This allows for greater bandwidth than the conventional telephone local loop.
- Enhanced cable modems enable two-way, high-speed data transmissions using the same coaxial lines that transmit cable television.

Internet Connection Options - Cable
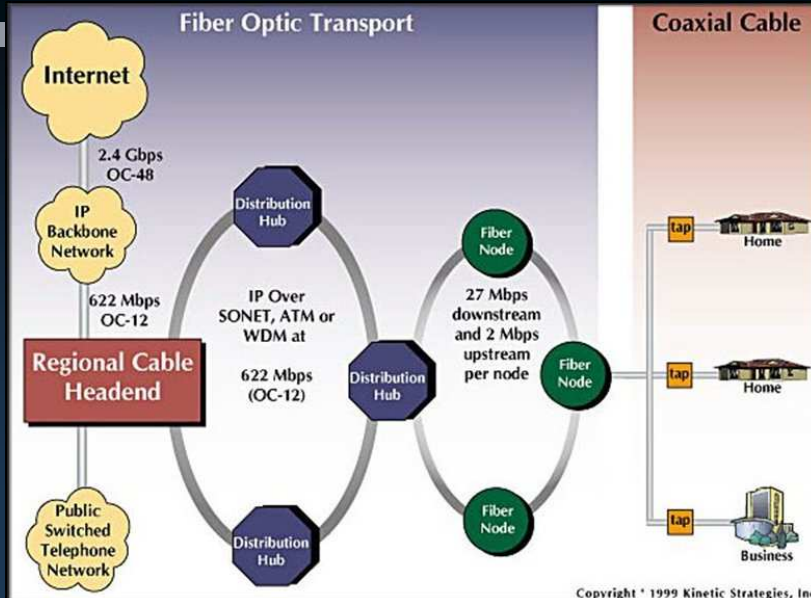

- Cable modems provide an always-on connection and a simple installation.
- While delivering up to 30 to 40 Mbps of data on one 6 MHz cable channel, a subscriber can continue to receive cable television service while simultaneously receiving data to a personal computer.
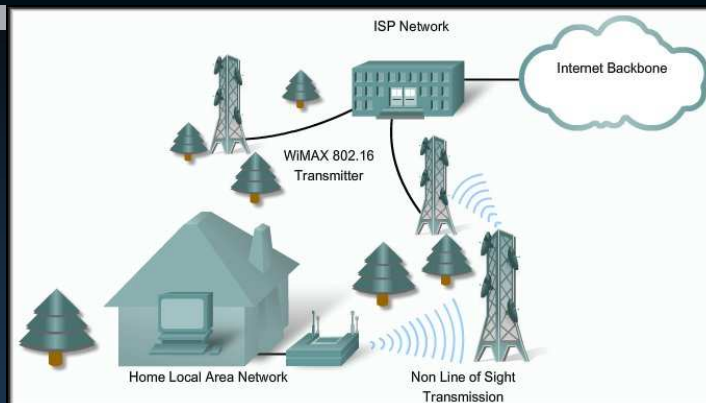
Internet Connection Options - Cable

Internet Connection Options - Wireless

- Wireless technology uses the unlicensed radio spectrum to send and receive data.
- The limitation of the local transmission range (< 30.5m) is changing due to new developments.
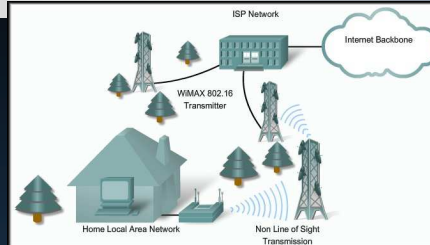
Internet Connection Options - Wireless

- **Municipal Wi-Fi:**
  - Many cities have begun setting up municipal wireless networks.
  - Some of these networks provide high-speed Internet access for free or for substantially less than the price of other broadband services.
  - Others are for city use only, allowing police and fire departments and other city employees to do certain aspects of their jobs remotely.
 - A subscriber typically needs a wireless modem.

Internet Connection Options - Wireless

- **WiMAX:**
  - Worldwide Interoperability for Microwave Access.
  - It is described in the IEEE standard 802.16.
  - WiMAX provides high-speed wireless access with coverage like a cell phone network rather than through WiFi hotspots.
  - To access a WiMAX network, subscribers must subscribe to an ISP with a WiMAX tower within 10 miles of their location.
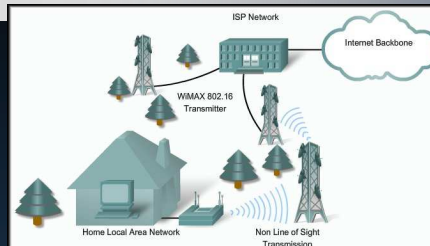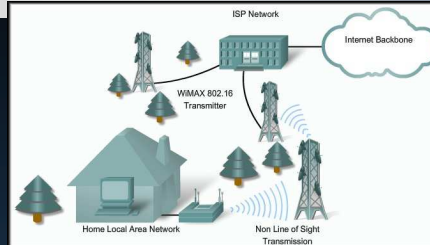
Internet Connection Options - Wireless

- **Satellite Internet:**
    - A satellite dish provides two-way (upload and download) data communications.
    - The upload speed is about one-tenth of the download speed.
    - To access satellite Internet services, subscribers need a satellite dish, two modems (uplink and downlink), and coaxial cables between the dish and the modem.

    MUCH MORE IN CHAPTER 6!
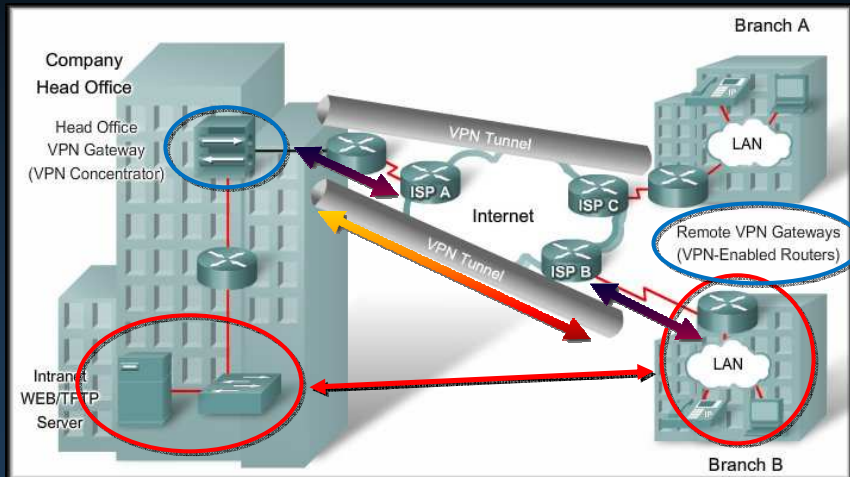
Internet Connection Options - VPN

- **Virtual Private Network:**
    - A VPN is an encrypted connection between private networks over a public network such as the Internet.
    - Benefits:
        - Cost Savings.
        - Security: encryption and authentication protocols that protect data.
        - Scalability.
        - Compatibility with broadband technology.
    - Two Types:
        - Site-to-Site.
        - Remote Access.

Internet Connection Options - VPN
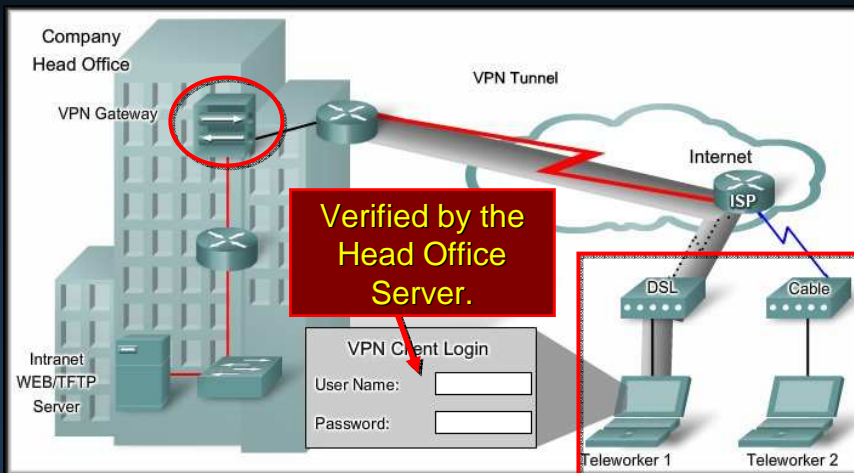
- **Virtual Private Network:** Site-to-Site

Internet Connection Options - VPN

- **Virtual Private Network:** Remote Access

Internet Connection Options – Metro Ethernet

- Metro Ethernet is a rapidly maturing networking technology that broadens Ethernet to the public networks run by telecommunications companies.
- By extending Ethernet to the metropolitan area, companies can provide their remote offices with reliable access to applications and data on the corporate headquarters LAN.
- IP-aware Ethernet switches enable service providers to offer enterprises converged voice, data, and video services.

Internet Connection Options – Metro Ethernet
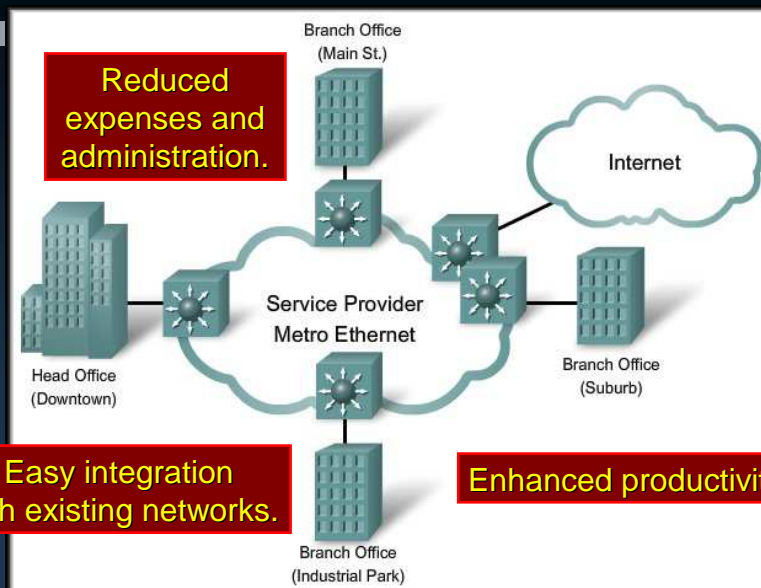
Choosing a WAN Link Connection

- What is the purpose of the WAN?
- What is the geographic scope?
- What are the traffic requirements?
- Should the WAN use a private or public infrastructure?
- For a private WAN, should it be dedicated or switched?
- For a public WAN, what type of VPN access do you need?
- Which connection options are available locally?
- What is the cost of the available connection options?

Chart – Page 45 in the text or 1.3.5 in the Online curriculum