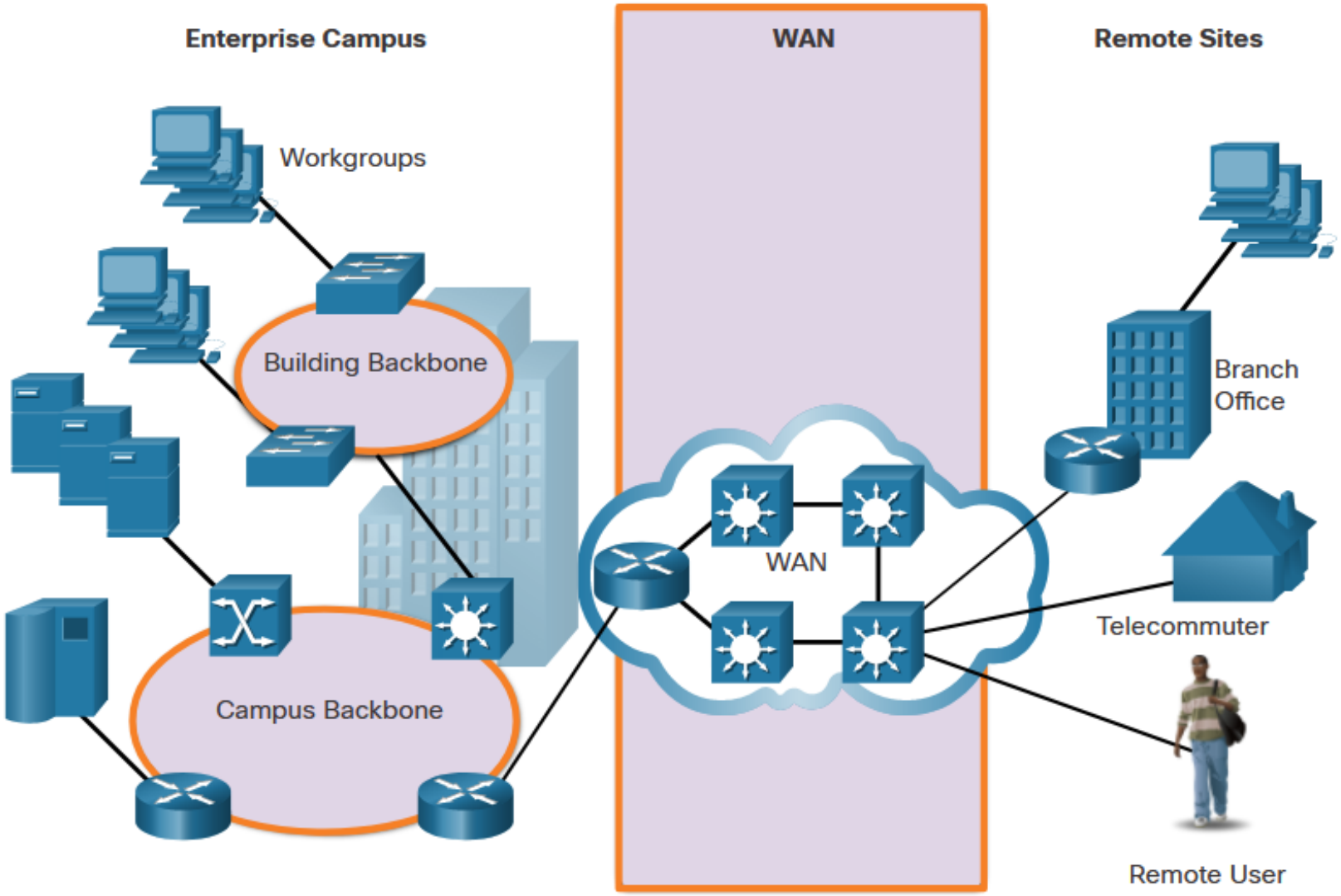
# WAN INTRODUCTION

# LANs and WANs

A WAN is a telecommunications network that spans over a relatively large geographical area and is required to connect beyond the boundary of the LAN.

| Local Area Networks (LANs) | Wide Area Networks (WANs) |
|---|---|
| LANs provide networking services within a small geographic area. | WANs provide networking services over large geographical areas. |
| LANs are used to interconnect local computers, peripherals, and other devices. | WANs are used to interconnect remote users, networks, and sites. |
| A LAN is owned and managed by an organization or home user. | WANs are owned and managed by internet service, telephone, cable, and satellite providers. |
| Other than the network infrastructure costs, there is no fee to use a LAN. | WAN services are provided for a fee. |
| LANs provide high bandwidth speeds using wired Ethernet and Wi-Fi services. | WANs providers offer low to high bandwidth speeds, over long distances. |

# LANs and WANs



# WAN Topologies

WANs are implemented using the following logical topology designs:

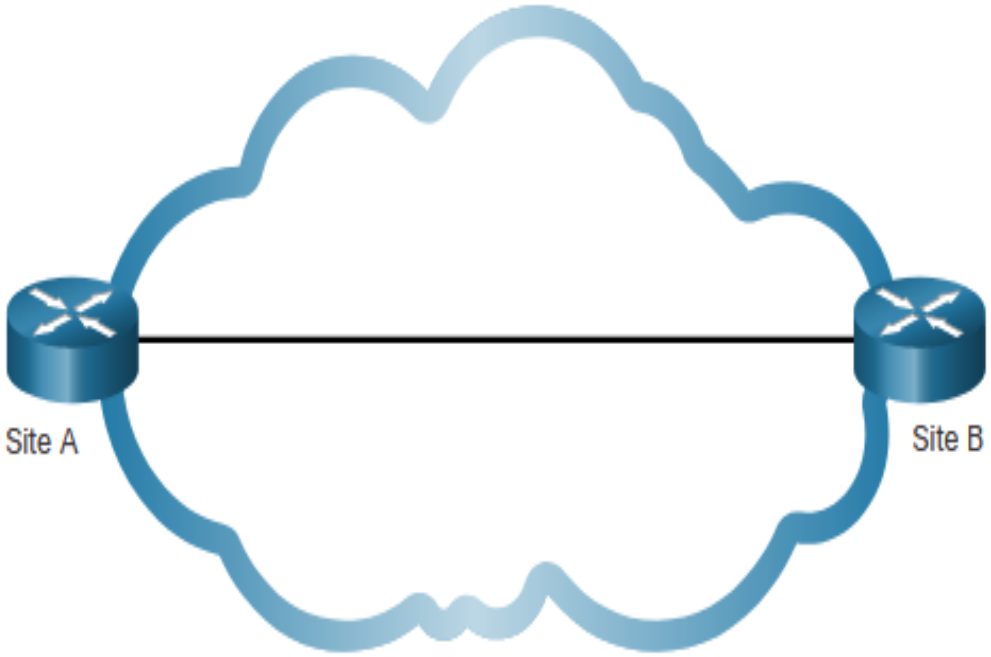
- Point-to-Point Topology
- Hub-and-Spoke Topology
- Dual-homed Topology
- Fully Meshed Topology
- Partially Meshed Topology

Note: Large networks usually deploy a combination of these topologies.

# WAN Topologies (Cont.)

Point-to-Point Topology

- Employs a point-to-point circuit between two endpoints.
- Involves a Layer 2 transport service through the service provider network.
- The point-to-point connection is transparent to the customer network.



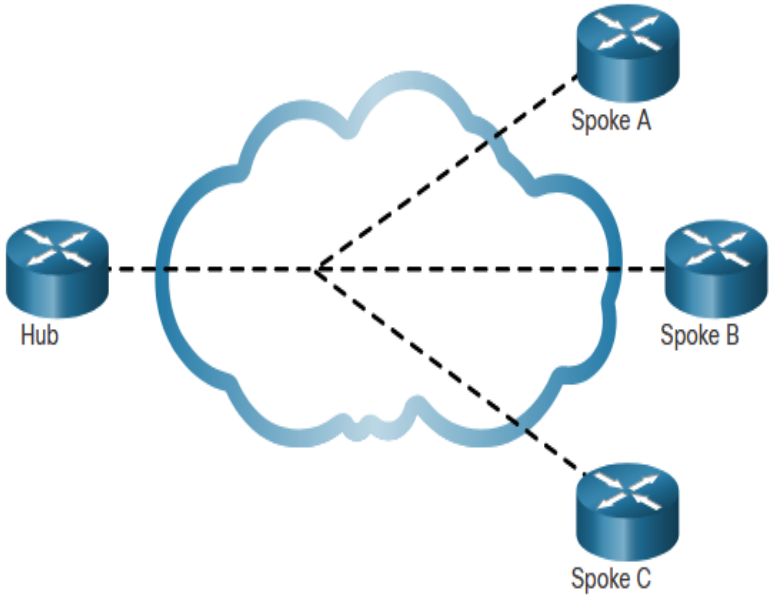

Note: It can become expensive if many point-to-point connections are required.

# WAN Topologies (Cont.)

Hub-and-Spoke Topology

- Enables a single interface on the hub router to be shared by all spoke circuits.
- Spoke routers can be interconnected through the hub router using virtual circuits and routed subinterfaces.
- Spoke routers can only communicate with each other through the hub router.

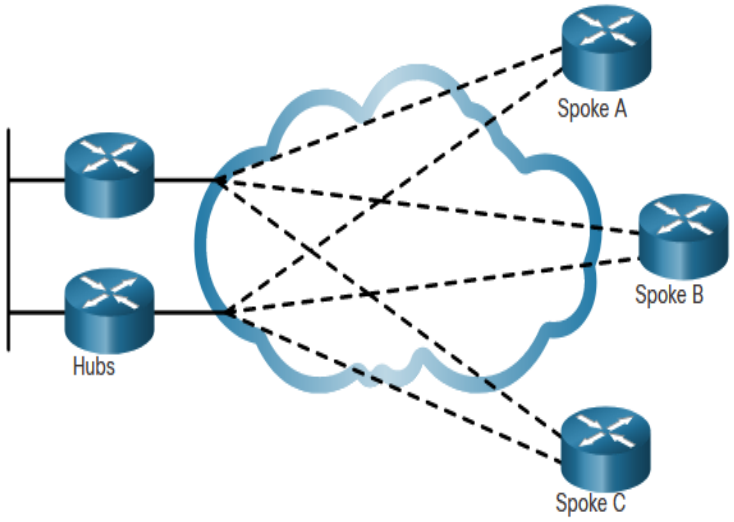
Note: The hub router represents a single point of failure. If it fails, inter-spoke communication also fails.



# WAN Topologies (Cont.)

Dual-homed Topology

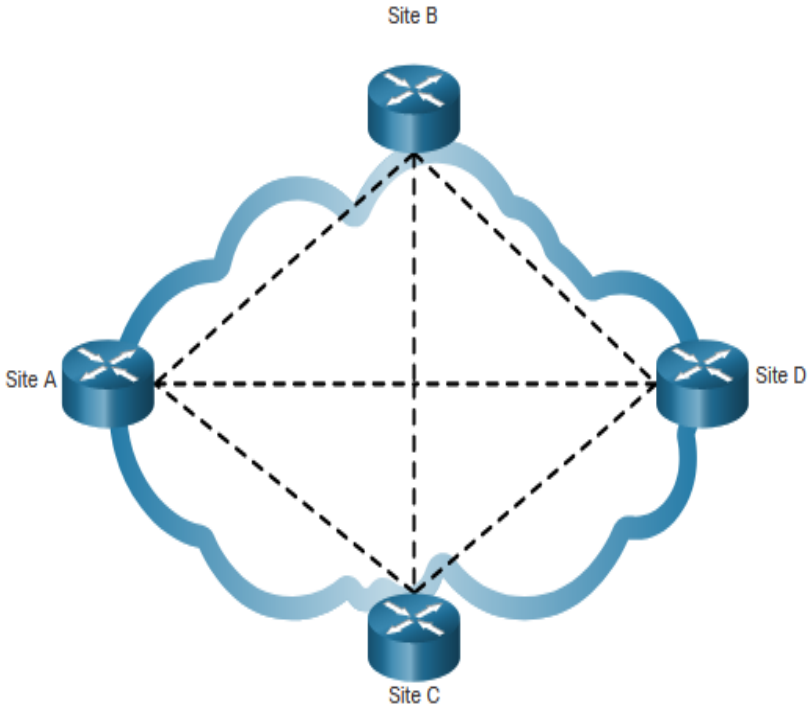
- Offers enhanced network redundancy, load balancing, distributed computing and processing, and the ability to implement backup service provider connections.
- More expensive to implement than single-homed topologies. This is because they require additional networking hardware, such as additional routers and switches.
- More difficult to implement because they require additional, and more complex, configurations.



# WAN Topologies (Cont.)

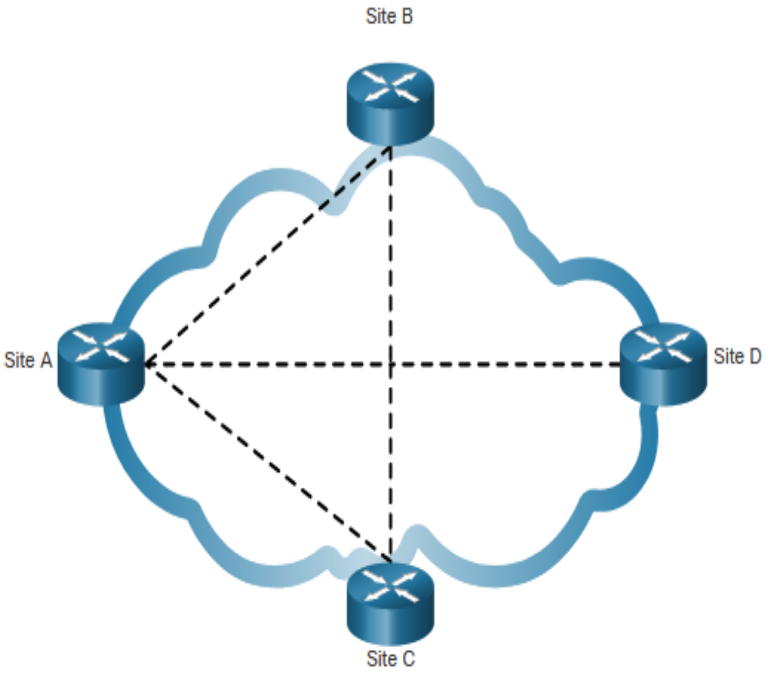
Fully Meshed Topology

- Uses multiple virtual circuits to connect all sites
- The most fault-tolerant topology




Partially Meshed Topology

- Connects many but not all sites



# Carrier Connections

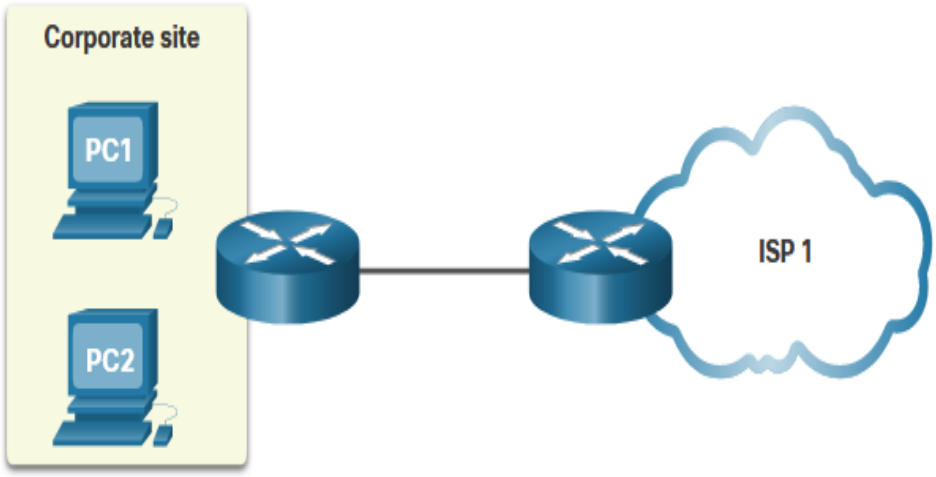
Another aspect of WAN design is how an organization connects to the internet. An organization usually signs a service level agreement (SLA) with a service provider. The SLA outlines the expected services relating to the reliability and availability of the connection.

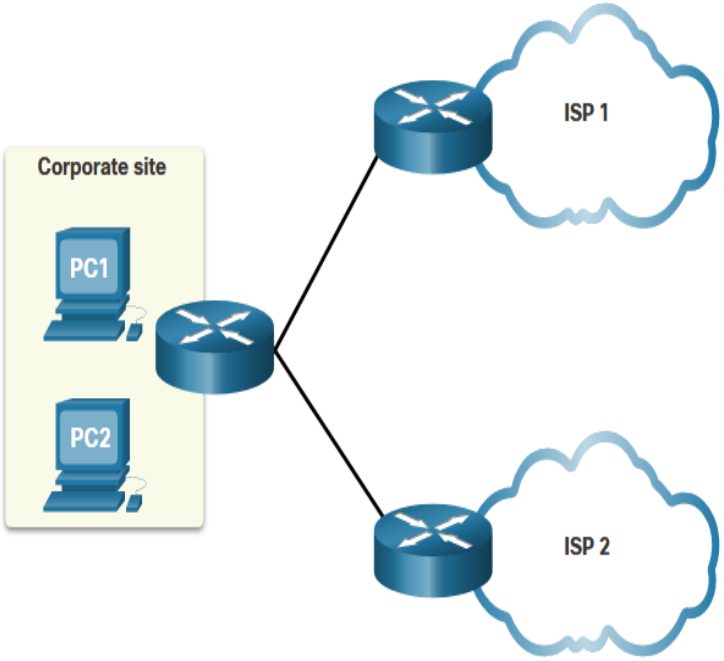
The service provider may or may not be the actual carrier. A carrier owns and maintains the physical connection and equipment between the provider and the customer. Typically, an organization will choose either a single-carrier or dual-carrier WAN connection.

# Carrier Connections (Cont.)

**A single-carrier connection is when an organization connects to only one service provider. An SLA is negotiated between the organization and the service provider.**

**A dual-carrier connection provides redundancy and increases network availability. The organization negotiates separate SLAs with two different service providers.**



# Evolving Networks

Network requirements of a company can change dramatically as the company grows over time.

- A network must meet the day-to-day operational needs of business, and it must be able to adapt and grow as a company changes.
- Network designers and administrators meet these challenges by carefully choosing network technologies, protocols, and service providers.
- Networks can be optimized by using a variety of network design techniques and architectures.

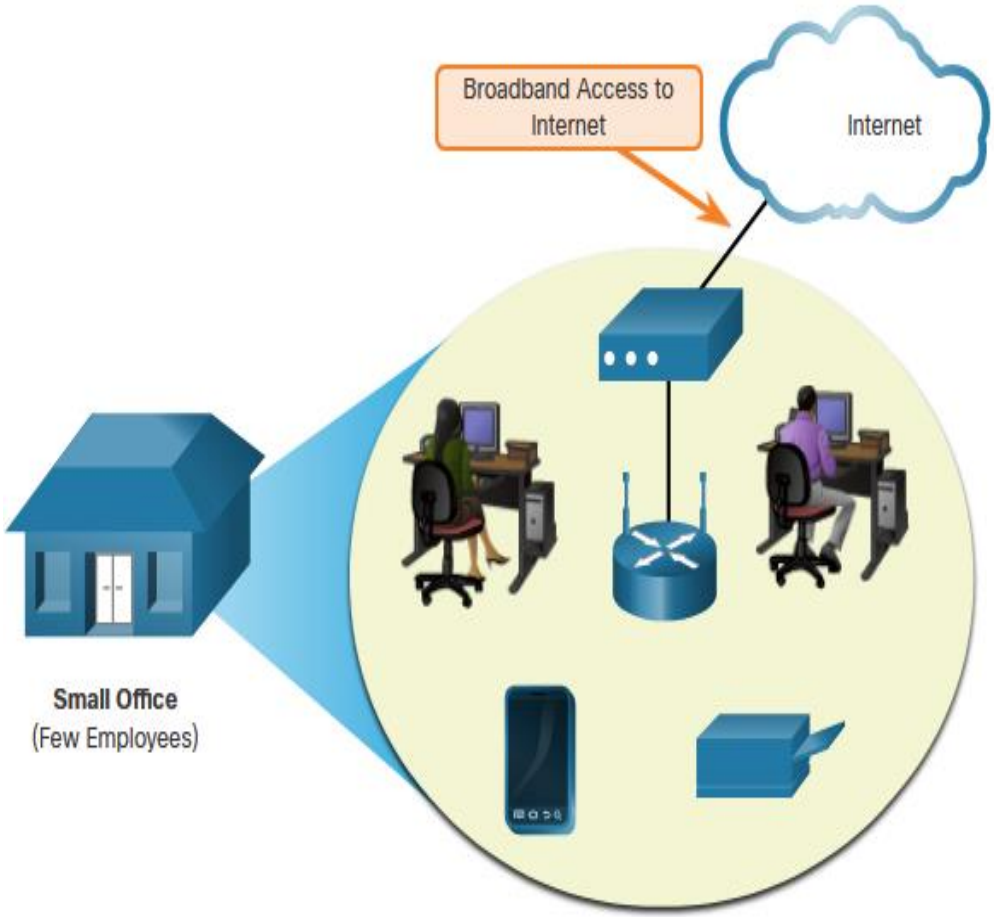
To illustrate differences between network size, we will use a fictitious company called SPAN Engineering as it grows from a small, local, business into a global enterprise.

# Evolving Networks (Cont.)

Small Network

SPAN, a small fictitious company, started with a few employees in a small office.

- Uses a single LAN connected to a wireless router for sharing data and peripherals.
- Connection to the internet is through a common broadband service called Digital Subscriber Line (DSL)
- IT support is contracted from the DSL provider.



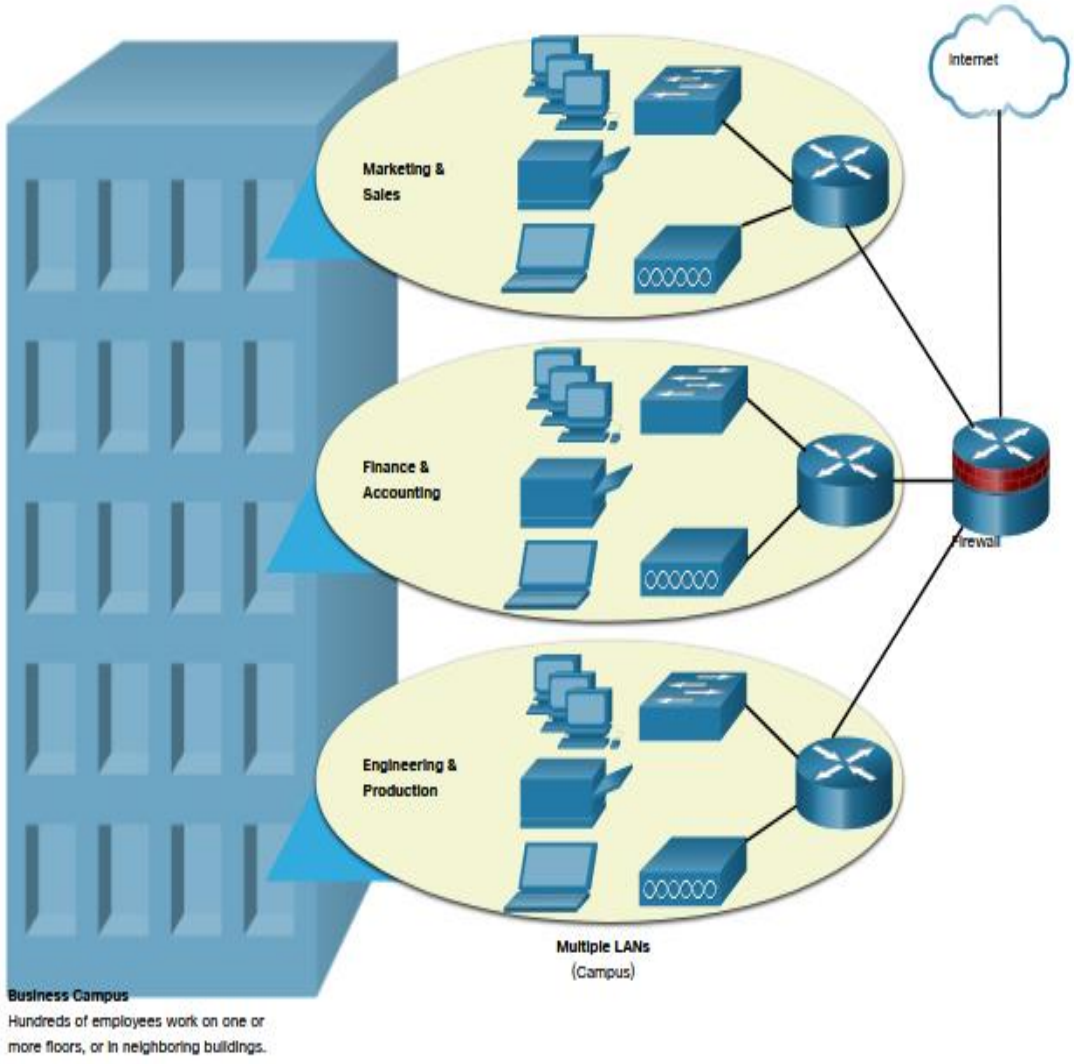
# Evolving Networks (Cont.)

Campus Network

Within a few years SPAN grew and required several floors of a building.

The company now required a Campus Area Network (CAN).

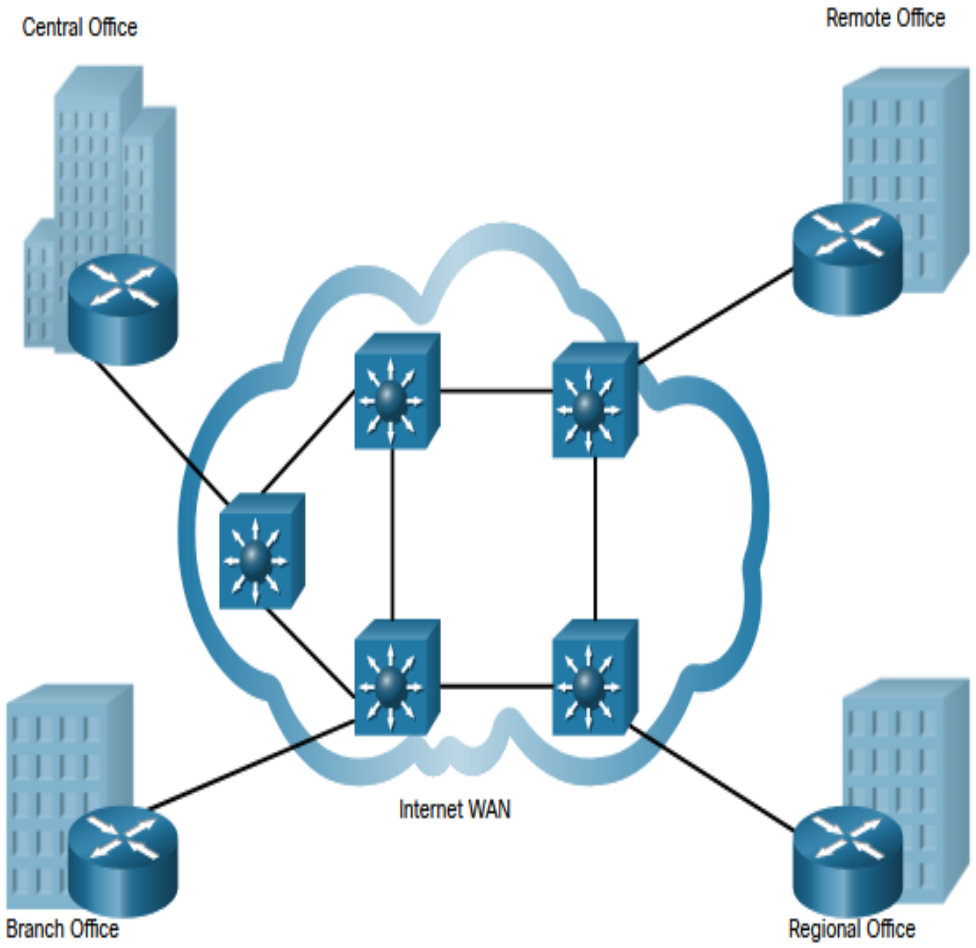
- A firewall secures internet access to corporate users.
- In-house IT staff to support and maintain the network.



# Evolving Networks (Cont.)

Branch Network

- A few years later, the company expanded and added a branch site in the city, and remote and regional sites in other cities.
- The company now required a metropolitan area network (MAN) to interconnect sites within the city.
- To connect to the central office, branch offices in nearby cities used private dedicated lines through their local service provider.

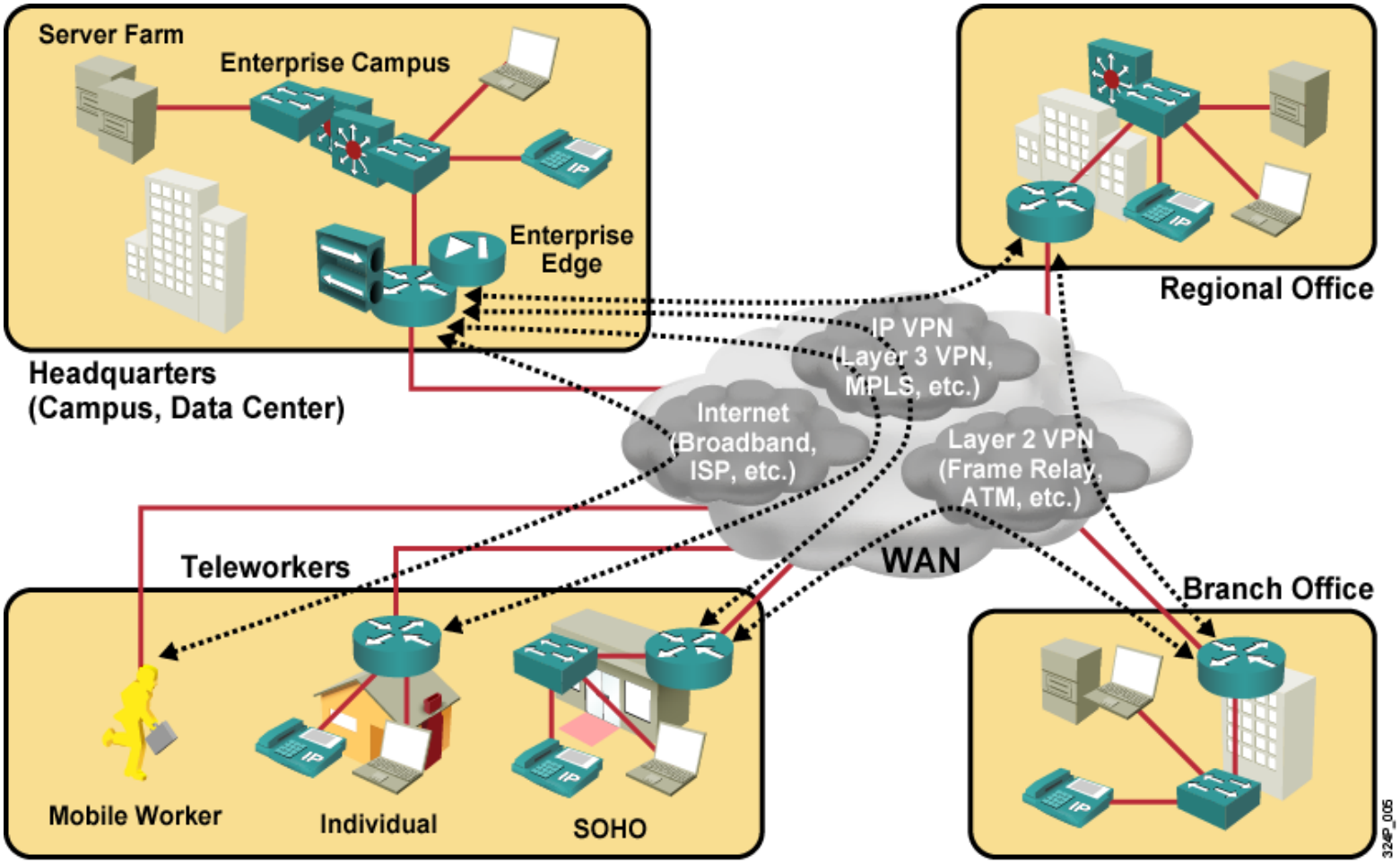


# Evolving Networks (Cont.)

Distributed Network

- SPAN Engineering has now been in business for 20 years and has grown to thousands of employees distributed in offices worldwide.
- Site-to-site and remote access Virtual Private Networks (VPNs) enable the company to use the internet to connect easily and securely with employees and facilities around the world.

# WAN Operations



# WANs in the OSI Model

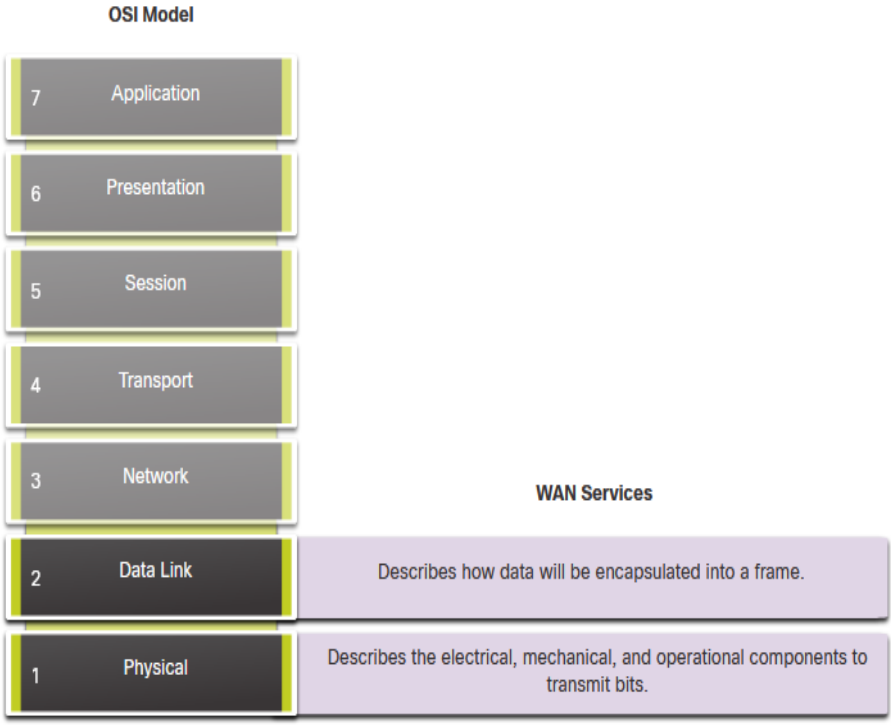
**Most WAN standards focus on the physical layer and the data link layer.**

**Layer 1 Protocols**

- **Synchronous Digital Hierarchy (SDH)**
- **Synchronous Optical Networking (SONET)**
- **Dense Wavelength Division Multiplexing (DWDM)**

**Layer 2 Protocols**

- **Broadband (i.e., DSL and Cable)**
- **Wireless**
- **Ethernet WAN (Metro Ethernet)**
- **Multiprotocol Label Switching (MPLS)**
- **Point-to-Point Protocol (PPP) (less used)**
- **High-Level Data Link Control (HDLC) (less used)**
- **Frame Relay (legacy)**
- **Asynchronous Transfer Mode (ATM) (legacy)**



# SDH, SONET, and DWDM

Service provider networks use fiber-optic infrastructures to transport user data between destinations.

There are two optical fiber OSI layer 1 standards available to service providers:

- SDH - Synchronous Digital Hierarchy (SDH) is a global standard for transporting data over fiber-optic cable.
- SONET - Synchronous Optical Networking (SONET) is the North American standard that provides the same services as SDH.

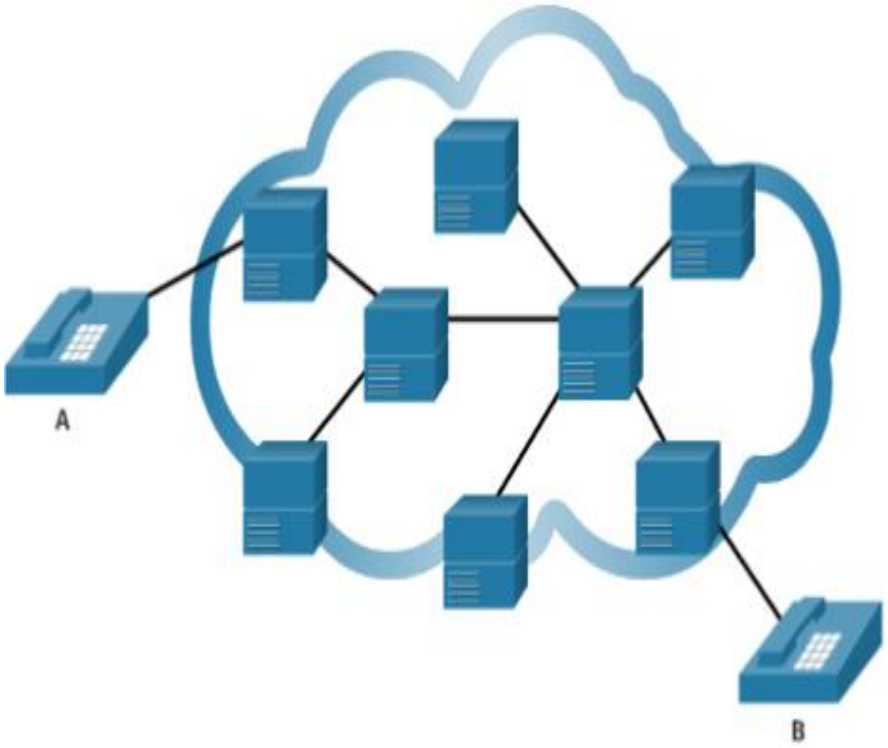
SDH/SONET define how to transfer multiple data, voice, and video communications over optical fiber using lasers or light-emitting diodes (LEDs) over great distances.

Dense Wavelength Division Multiplexing (DWDM) is a newer technology that increases the data-carrying capacity of SDH and SONET by simultaneously sending multiple streams of data (multiplexing) using different wavelengths of light.

# Circuit-Switched Communication

A circuit-switched network establishes a dedicated circuit (or channel) between endpoints before the users can communicate.

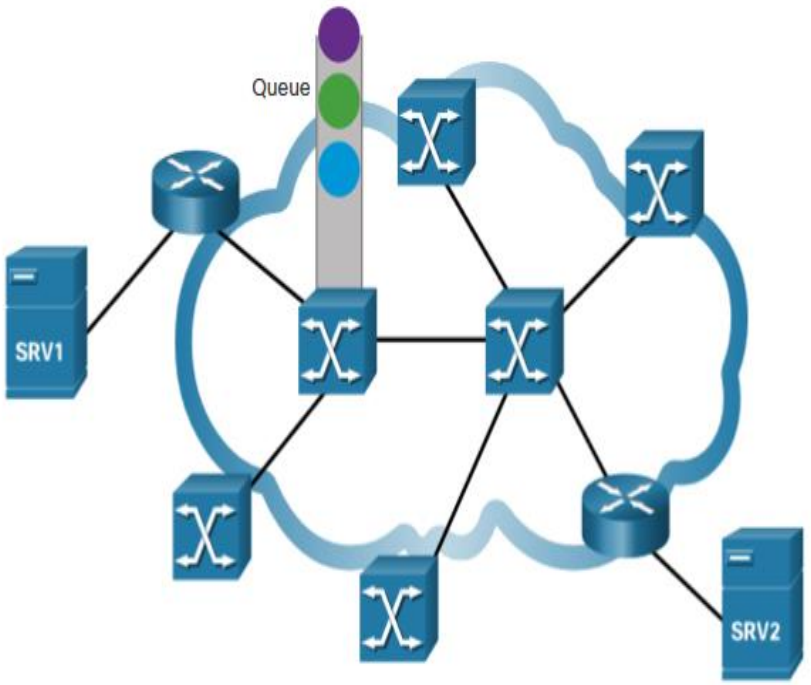
- Establishes a dedicated virtual connection through the service provider network before communication can start.
- All communication uses the same path.
- The two most common types of circuit-switched WAN technologies are the public switched telephone network (PSTN) and the legacy Integrated Services Digital Network (ISDN).



# Packet-Switched Communication

Network communication is most commonly implemented using packet-switched communication.

- Segments traffic data into packets that are routed over a shared network.
- Much less expensive and more flexible than circuit switching.
- Common types of packet-switched WAN technologies are:
  - Ethernet WAN (Metro Ethernet)
  - Multiprotocol Label Switching (MPLS)
  - Frame Relay
  - Asynchronous Transfer Mode (ATM).

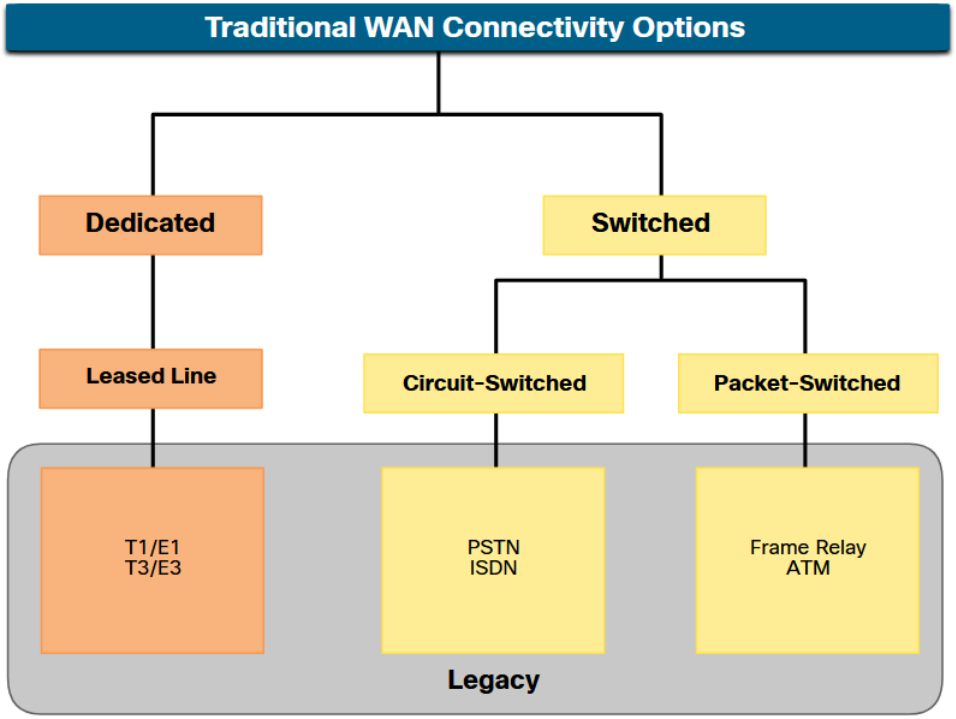


# Traditional WAN Connectivity

Point-to-point lines could be leased from a service provider and were called “leased lines”. The term refers to the fact that the organization pays a monthly lease fee to a service provider to use the line.

Leased lines are available in different fixed capacities and are generally priced based on the bandwidth required and the distance between the two connected points.

There are two systems used to define the digital capacity of a copper media serial link:




T-carrier - Used in North America, provides T1 links supporting bandwidth up to 1.544 Mbps and T3 links supporting bandwidth up to 43.7 Mbps.

E-carrier – Used in Europe, provides E1 links supporting bandwidth up to 2.048 Mbps and E3 links supporting bandwidth up to 34.368 Mbps.

# Leased lines.

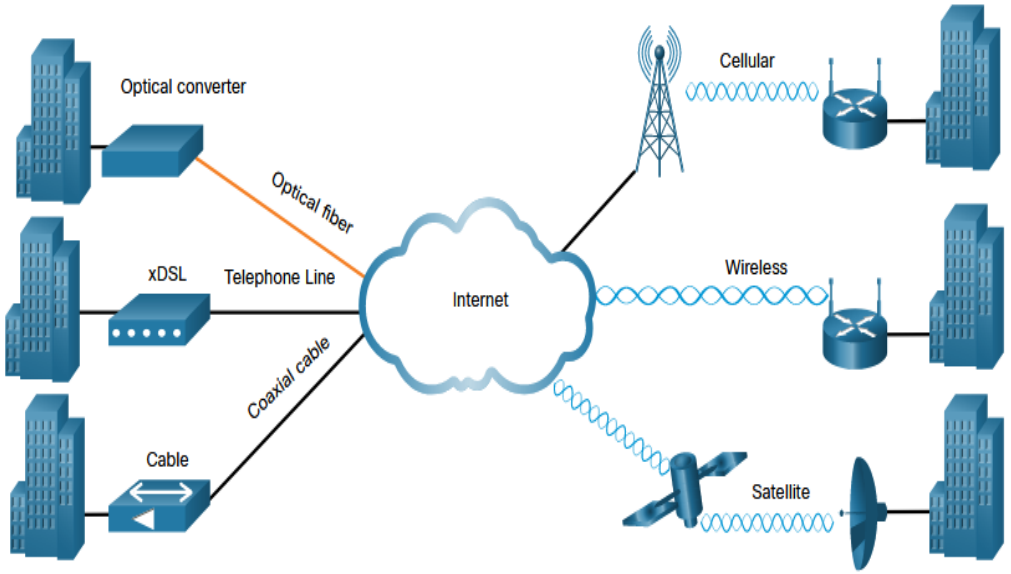
The table summarizes the advantages and disadvantages of leased lines.

| Advantages | |
|---|---|
| **Simplicity** | Point-to-point communication links require minimal expertise to install and maintain. |
| **Quality** | Point-to-point communication links usually offer high quality service, if they have adequate bandwidth. |
| **Availability** | Constant availability is essential for some applications, such as e-commerce. Point-to-point communication links provide permanent, dedicated capacity which is required for VoIP or Video over IP. |
| **Disadvantages** | |
| **Cost** | Point-to-point links are generally the most expensive type of WAN access. The cost of leased line solutions can become significant when they are used to connect many sites over increasing distances. |
| **Limited flexibility** | WAN traffic is often variable, and leased lines have a fixed capacity, so that the bandwidth of the line seldom matches the need exactly. |

# Modern WAN Connectivity

Modern WANS have more connectivity options than traditional WANs.

- Enterprises now require faster and more flexible WAN connectivity options.
- Traditional WAN connectivity options have rapidly declined in use because they are either no longer available, too expensive, or have limited bandwidth.




The figure displays the local loop connections most likely encountered today.

# Modern WAN Connectivity Options

New technologies are continually emerging. The figure summarizes the modern WAN connectivity options.

Dedicated broadband

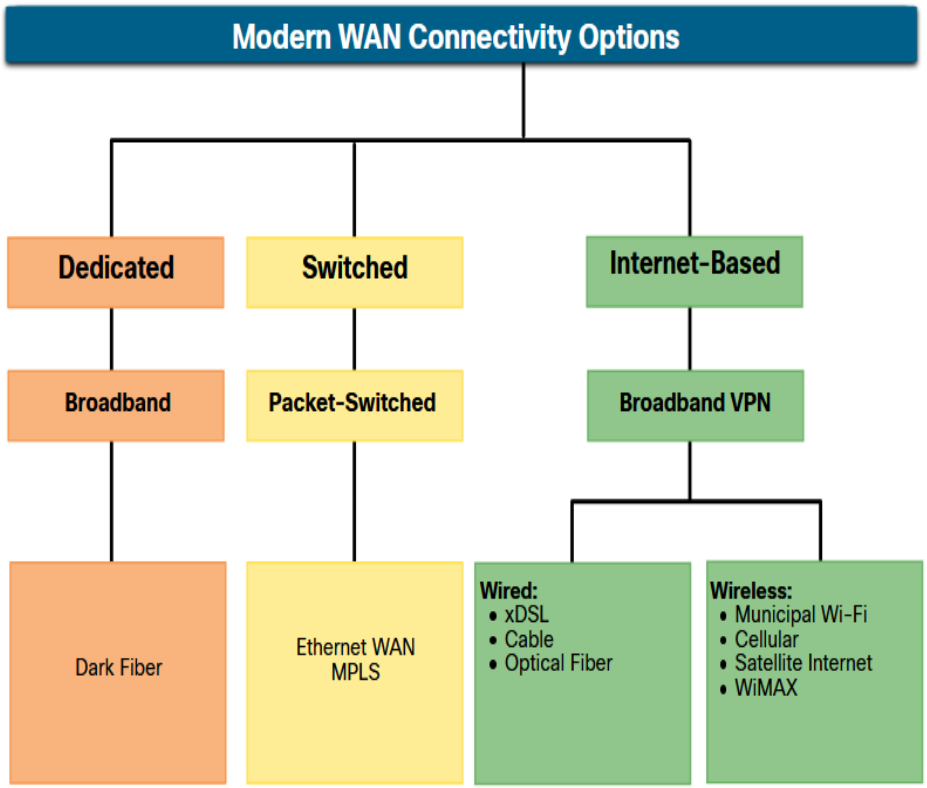
- Fiber can be installed independently by an organization to connect remote locations directly together.
- Dark fiber can be leased or purchased from a supplier.

Packet-switched

- Metro Ethernet – Replacing many traditional WAN options.
- MPLS – Enables sites to connect to the provider regardless of its access technologies.

Internet-based broadband

- Organizations are now commonly using the global internet infrastructure for WAN connectivity.



# Ethernet WAN

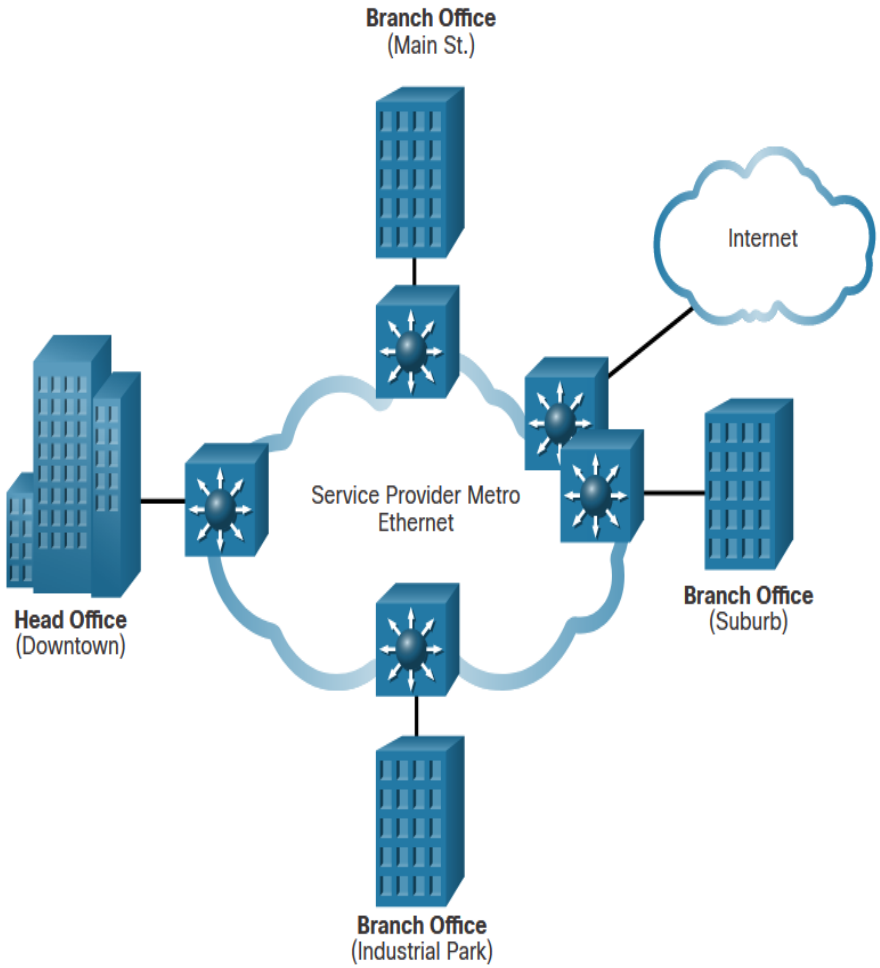
Service providers now offer Ethernet WAN service using fiber-optic cabling.

The Ethernet WAN service can go by many names, including the following:

- Metropolitan Ethernet (**Metro E**)
- Ethernet over MPLS (**EoMPLS**)
- Virtual Private LAN Service (**VPLS**)

There are several benefits to an Ethernet WAN:

- Reduced expenses and administration
- Easy integration with existing networks
- Enhanced business productivity

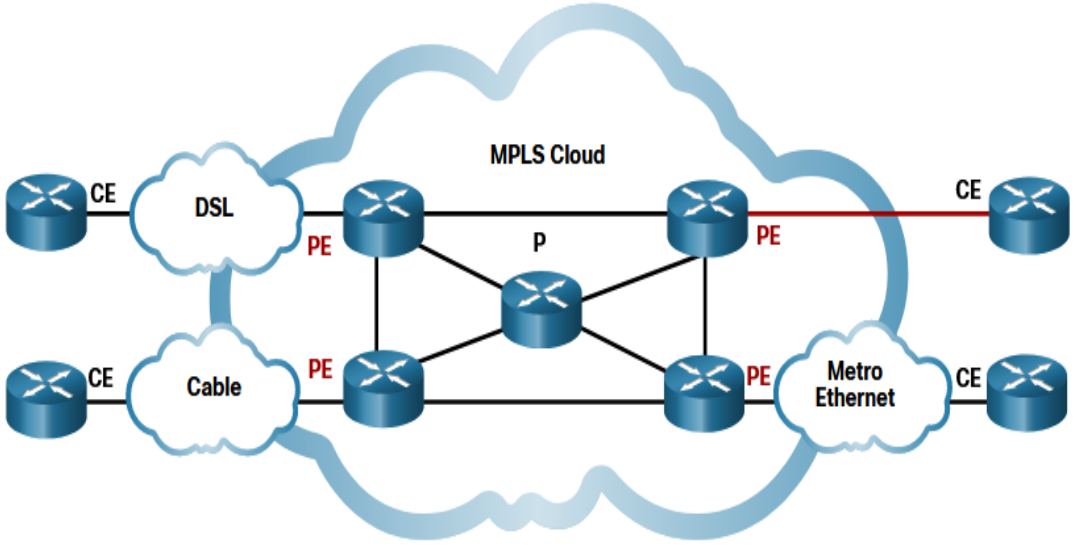



Note: Ethernet WANs have gained in popularity and are now commonly being used to replace the traditional serial point-to-point, Frame Relay and ATM WAN links.

# MPLS

Multiprotocol Label Switching (**MPLS**) is a high-performance service provider WAN routing technology to interconnect clients without regard to access method or payload.

- MPLS supports a variety of client access methods (e.g., Ethernet, DSL, Cable, Frame Relay).
- MPLS can encapsulate all types of protocols including IPv4 and IPv6 traffic.
- An MPLS router can be a customer edge (**CE**) router, a provider edge (**PE**) router, or an internal provider (**P**) router.
- MPLS routers are label switched routers (**LSRs**). They attach labels to packets that are then used by other MPLS routers to forward traffic.
- MPLS also provides services for QoS support, traffic engineering, redundancy, and VPNs.



# Internet-Based Connectivity

Internet-based broadband connectivity is an alternative to using dedicated WAN options.

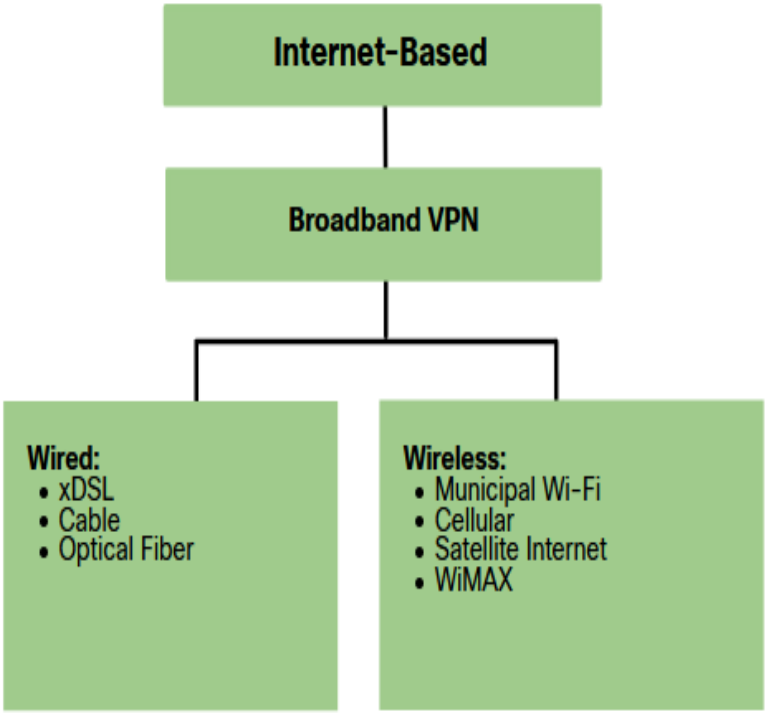
Internet-based connectivity can be divided into wired and wireless options.

Wired Options

- Wired options use permanent cabling (e.g., copper or fiber) to provide consistent bandwidth, and reduce error rates and latency. Examples: DSL, cable connections, and optical fiber networks.

Wireless Options

- Wireless options are less expensive to implement compared to other WAN connectivity options because they use radio waves instead of wired media to transmit data. Examples: cellular 3G/4G/5G or satellite internet services.
- Wireless signals can be negatively affected by factors such as distance from radio towers, interference from other sources and weather.



# Wireless Internet-Based Broadband

Wireless technology uses the unlicensed radio spectrum to send and receive data.

- **Municipal Wi-Fi** - Municipal wireless networks are available in many cities providing high-speed internet access for free, or for substantially less than the price of other broadband services.
- **Cellular** – Increasingly used to connect devices to the internet using radio waves to communicate through a nearby mobile phone tower. 3G/4G/5G and Long-Term Evolution (LTE) are cellular technologies.
- **Satellite Internet** - Typically used by rural users or in remote locations where cable and DSL are not available. A router connects to a satellite dish which is pointed to a service provider satellite in Geosynchronous orbit. Trees and heavy rains can impact the satellite signal.
- **WiMAX** - Worldwide Interoperability for Microwave Access (WiMAX) is described in the IEEE standard 802.16 Provides high-speed broadband service with wireless access and provides broad coverage like a cell phone network rather than through small Wi-Fi hotspots

# Optical Fiber

Many municipalities, cities, and providers install fiber-optic cable to the user location. This is commonly referred to as Fiber to the x (**FTTx**) and includes the following:

- Fiber to the Home (**FTTH**) - Fiber reaches the boundary of the residence.
- Fiber to the Building (**FTTB**) - Fiber reaches the boundary of the building with the final connection to the individual living space being made via alternative means.
- Fiber to the Node/Neighborhood (**FTTN**) – Optical cabling reaches an optical node that converts optical signals to a format acceptable for twisted pair or coaxial cable to the premise.

**Note**: FTTx can deliver the highest bandwidth of all broadband options

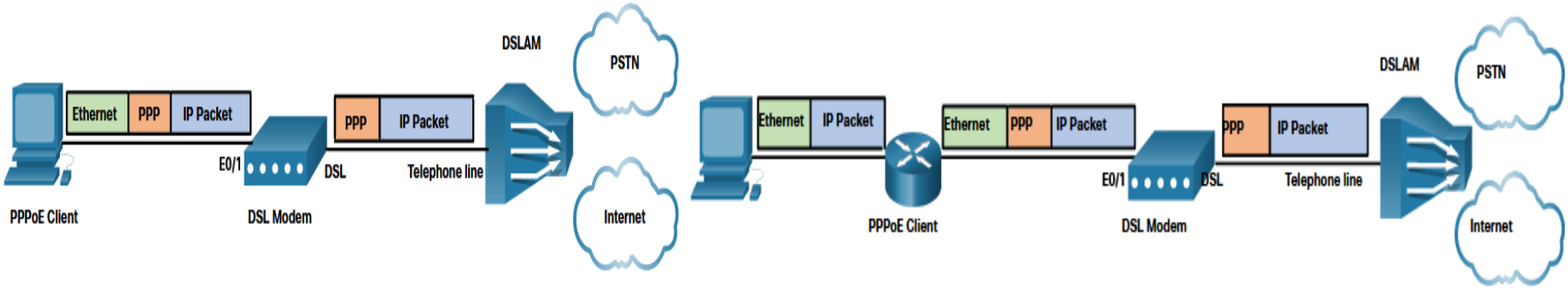
# DSL and PPP

ISPs use PPP as the Layer 2 protocol for broadband DSL connections.

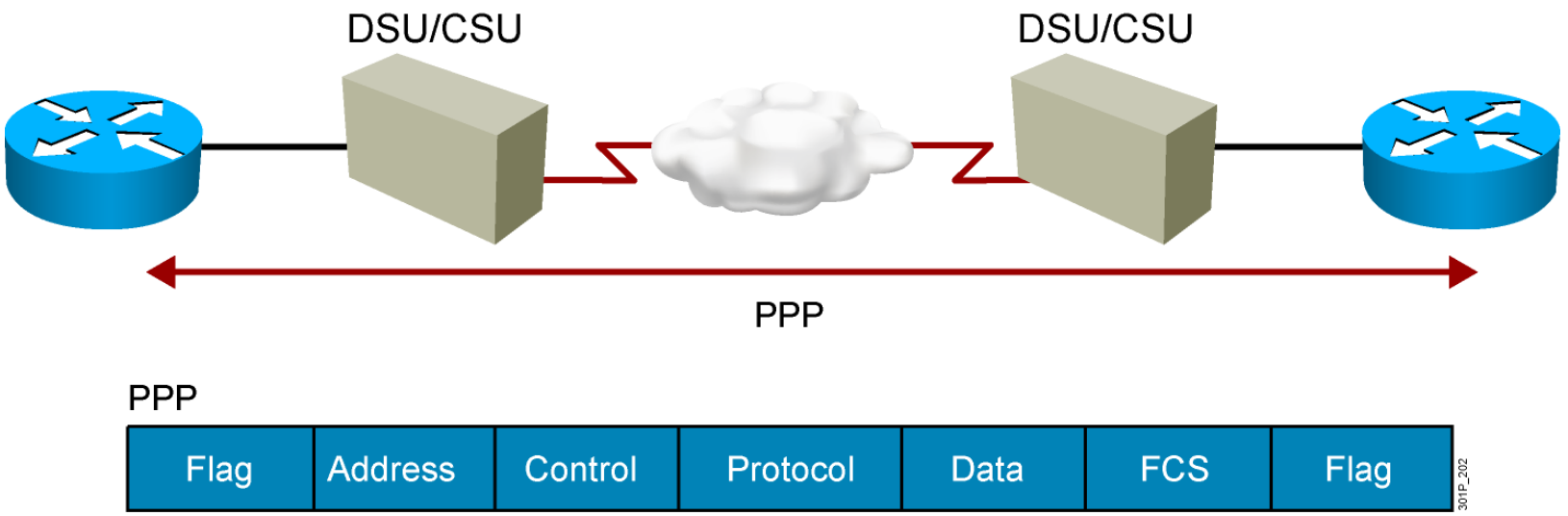
- PPP can be used to authenticate the subscriber.
- PPP can assign a public IPv4 address to the subscriber.
- PPP provides link-quality management features.

There are two ways PPP over Ethernet (PPPoE) can be deployed:

- Host with PPoE Client - The PPPoE client software communicates with the DSL modem using PPPoE and the modem communicates with the ISP using PPP.
- Router PPPoE Client - The router is the PPPoE client and obtains its configuration from the provider.



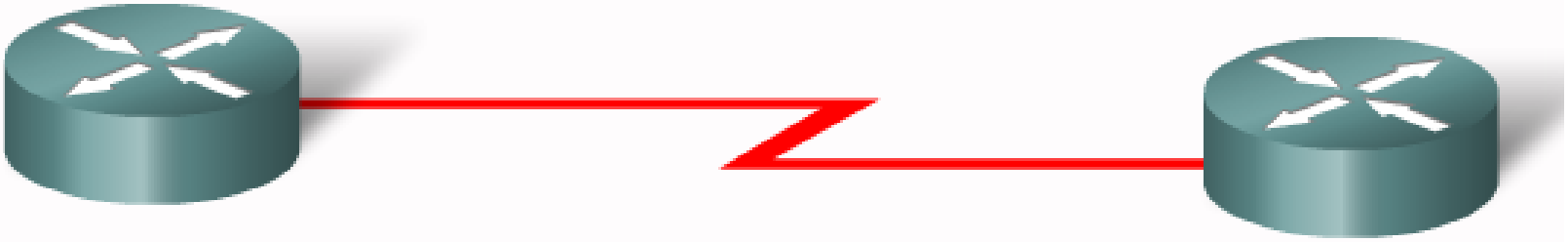
# An Overview of PPP



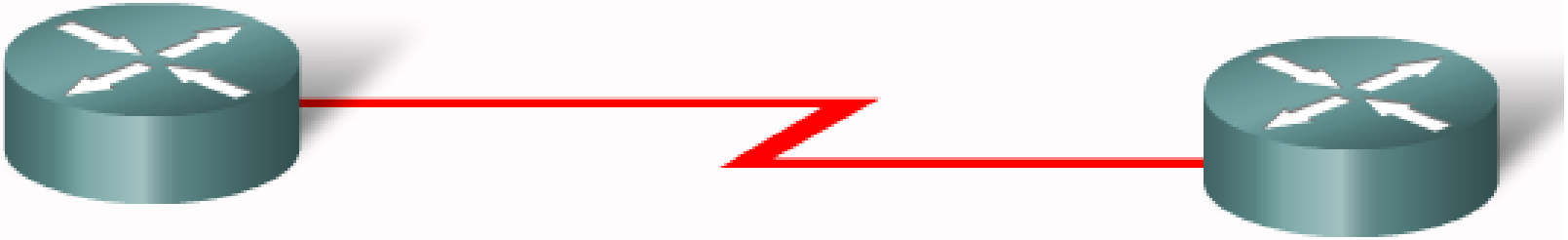

- PPP can carry packets from several protocol suites using NCP.
- PPP controls the setup of several link options using LCP.

# PPP

What is PPP?

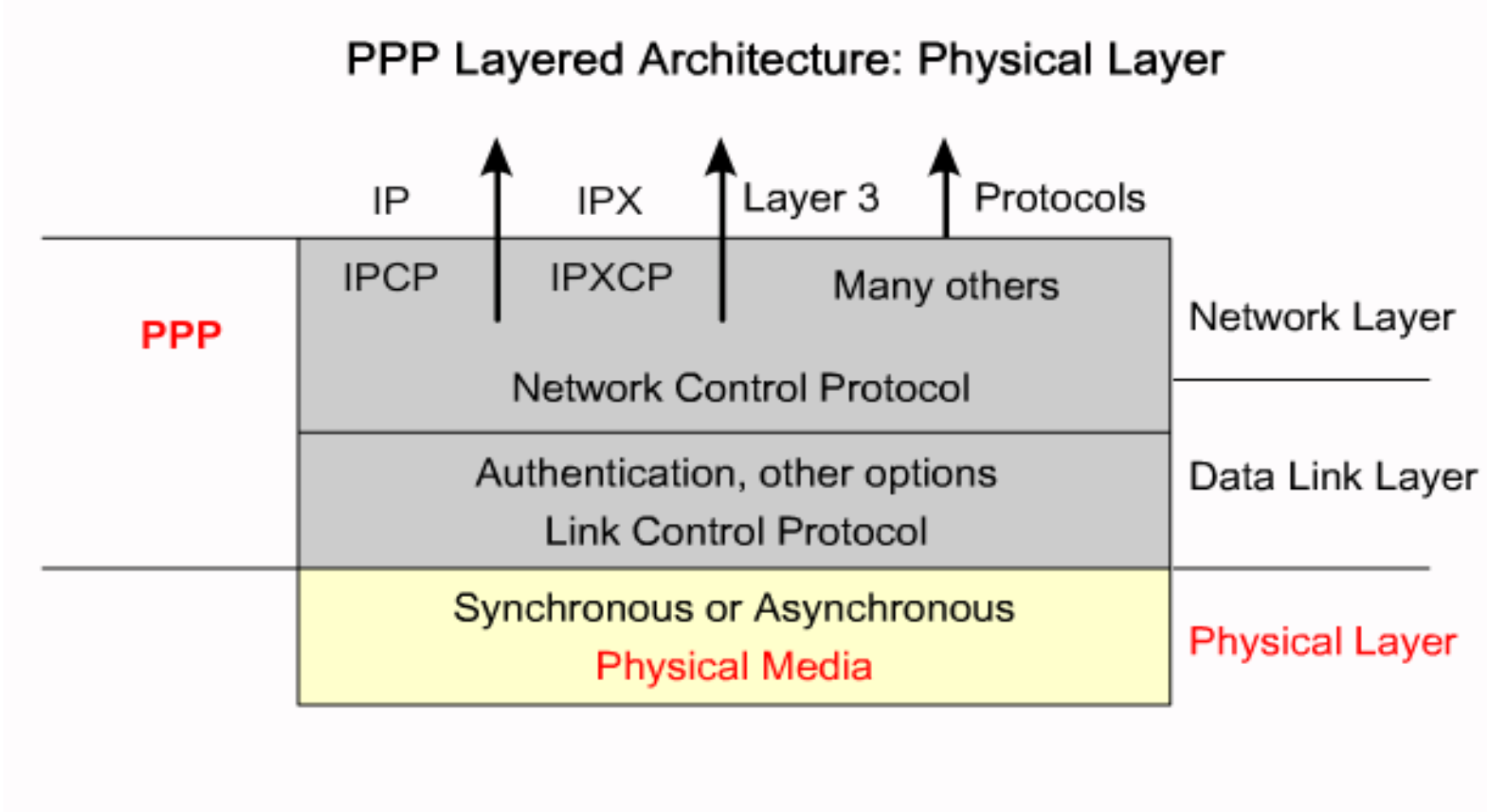


HDLC is the default encapsulation method between Cisco routers.

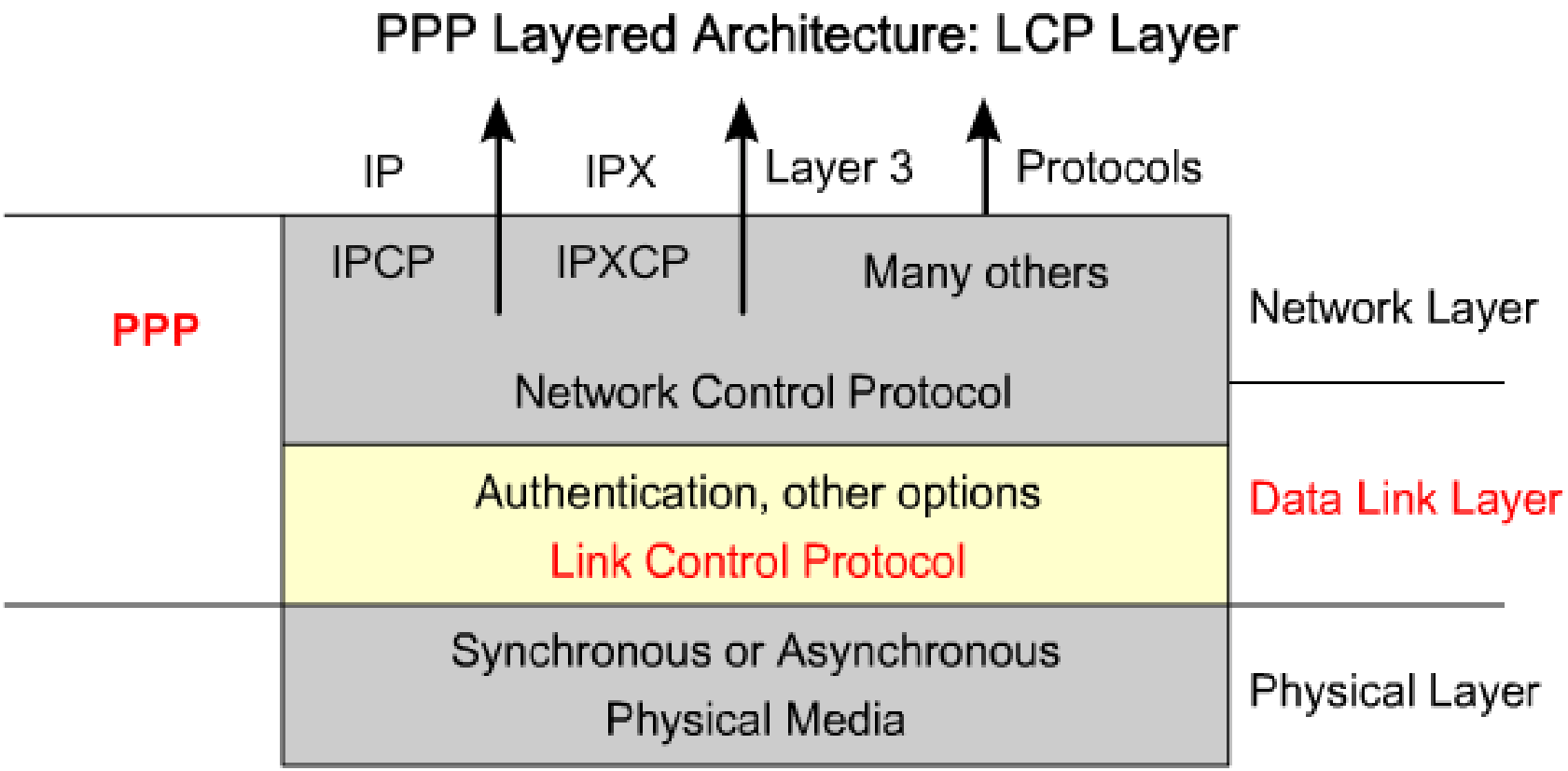


Use PPP encapsulation to connect to a non-Cisco router.

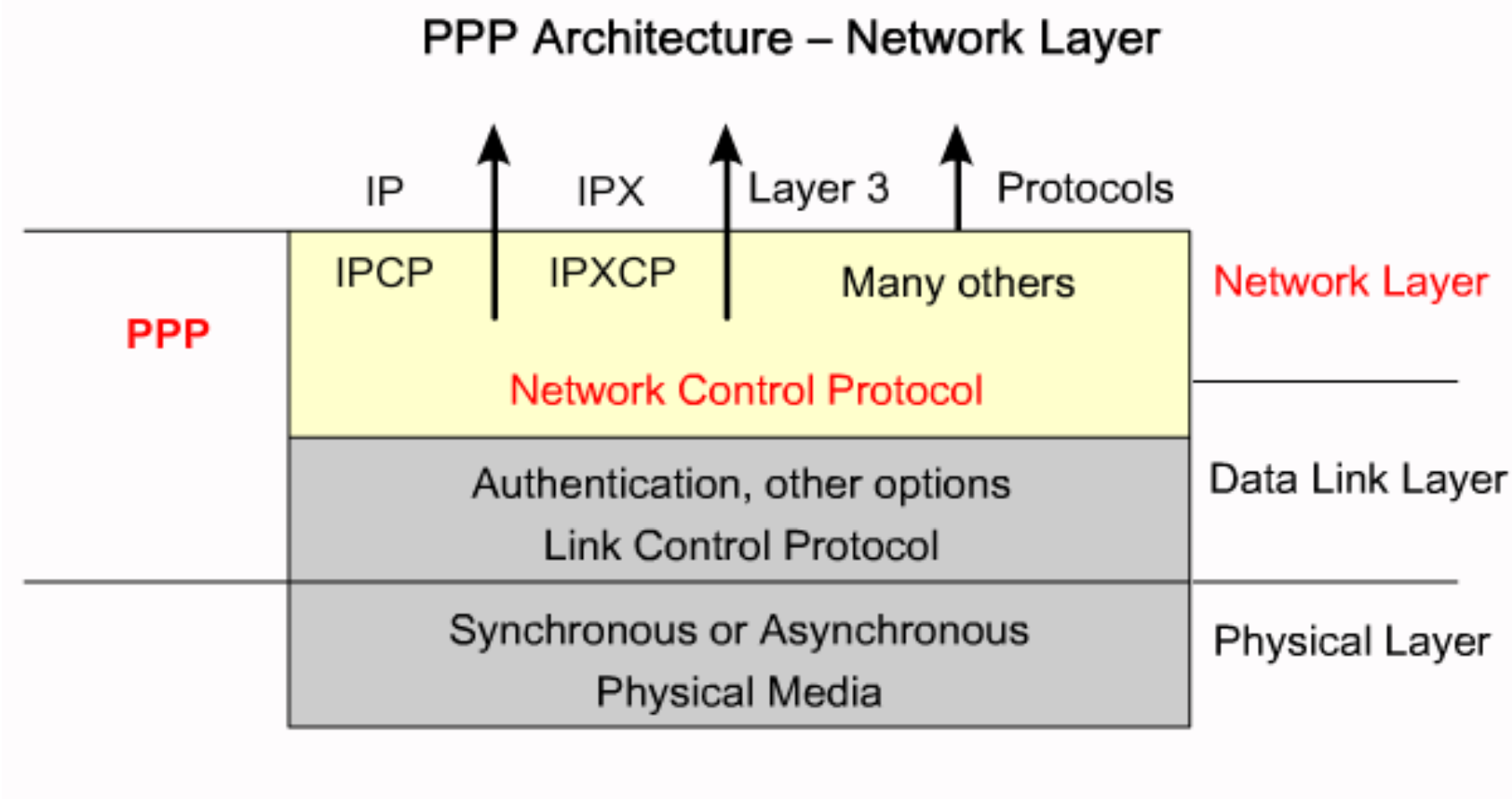
# PPP PHYSICAL LAYER



# LCP


PPP Layered Architecture: LCP Layer
IP
IPX
Layer 3
Protocols
IPCP
IPXCP
Many others
PPP
Network Layer
Network Control Protocol
Authentication, other options
Link Control Protocol
Data Link Layer
Synchronous or Asynchronous
Physical Media
Physical Layer

# NCP


PPP Architecture – Network Layer
IP
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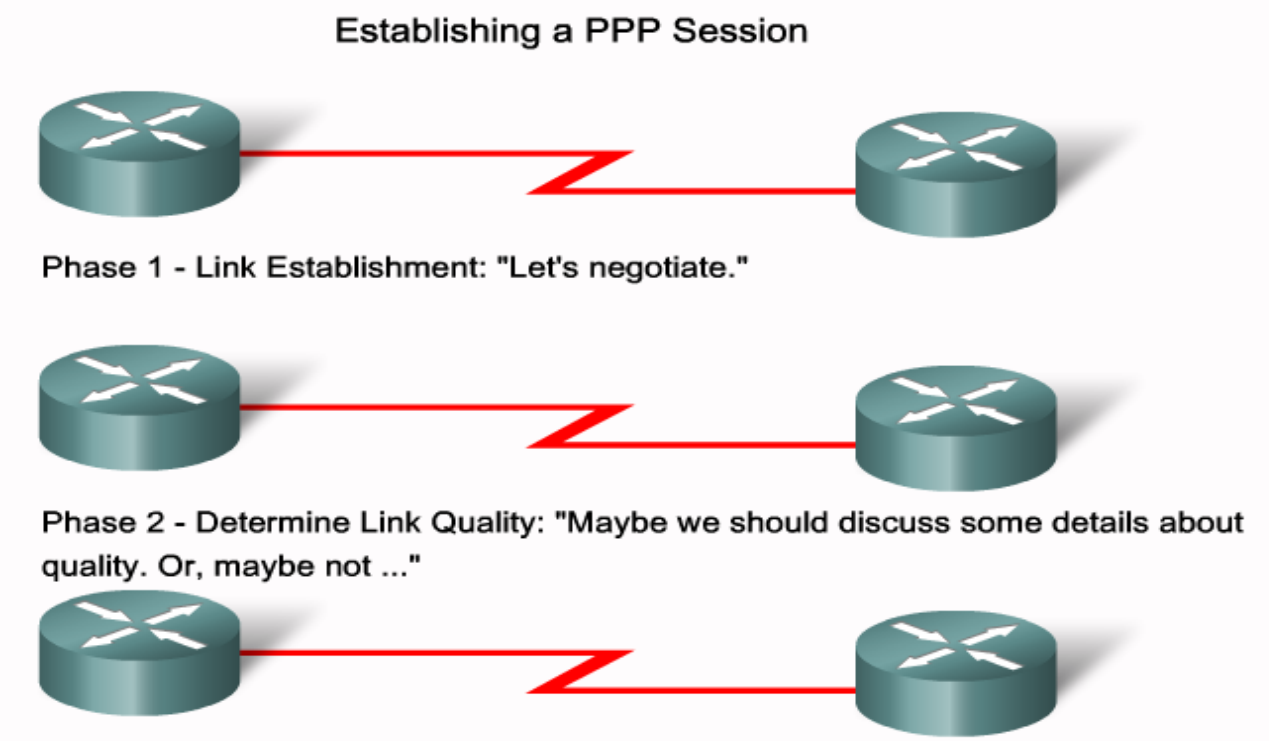
IPXCP
Many others
Network Layer
PPP
Network Control Protocol
Authentication, other options
Link Control Protocol
Data Link Layer
Synchronous or Asynchronous
Physical Media
Physical Layer

# Establishing a PPP Session



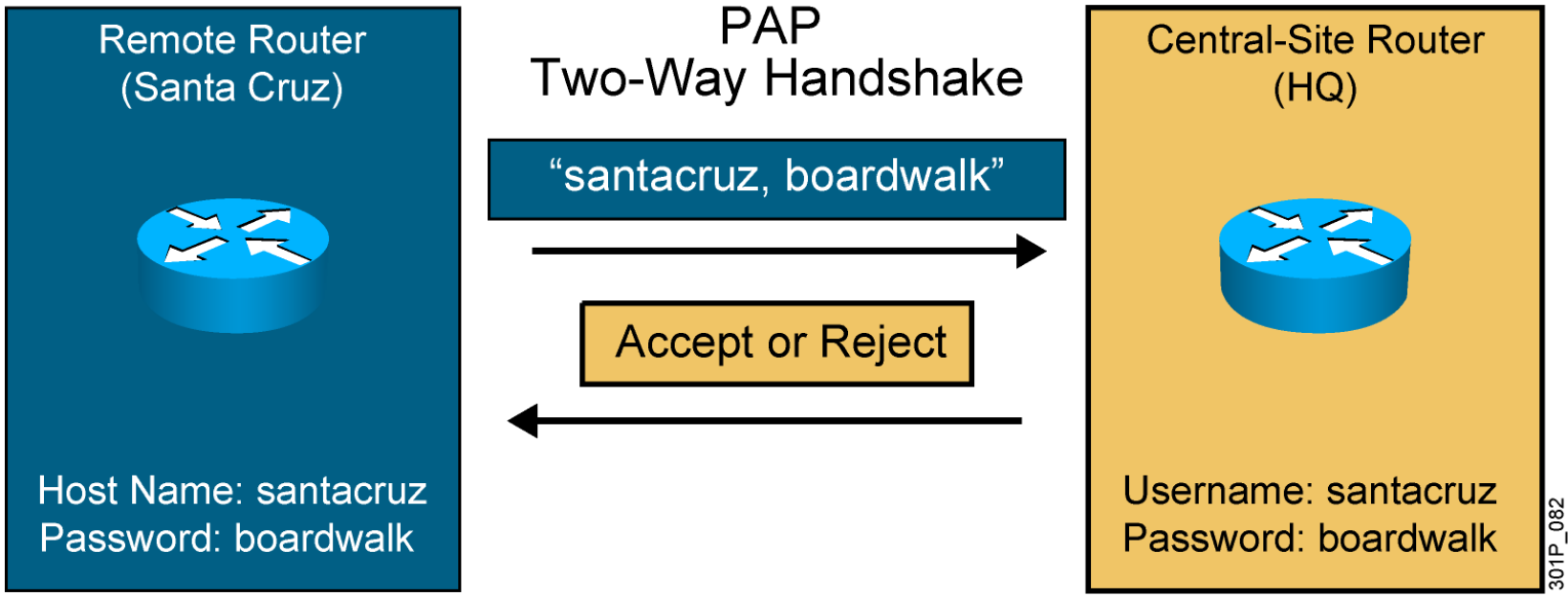
# Authentication

**Authentication means to put a username and password before accessing the network.**

**There is two authentication protocols:**

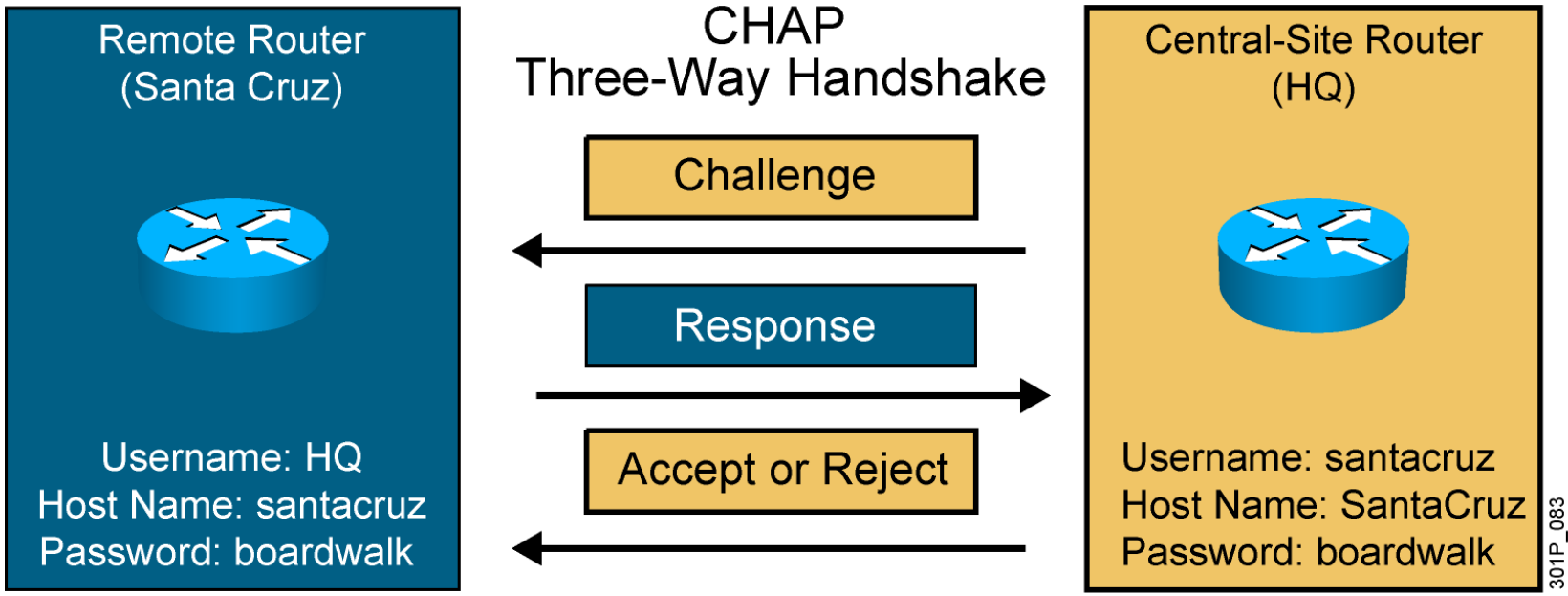
- PAP (Password Authentication Protocol).
- CHAP (Challenge Handshake Authentication Protocol).

# PPP Authentication Protocols: PAP




- Passwords sent in plaintext
- Peer in control of attempts

# PPP Authentication Protocols: CHAP



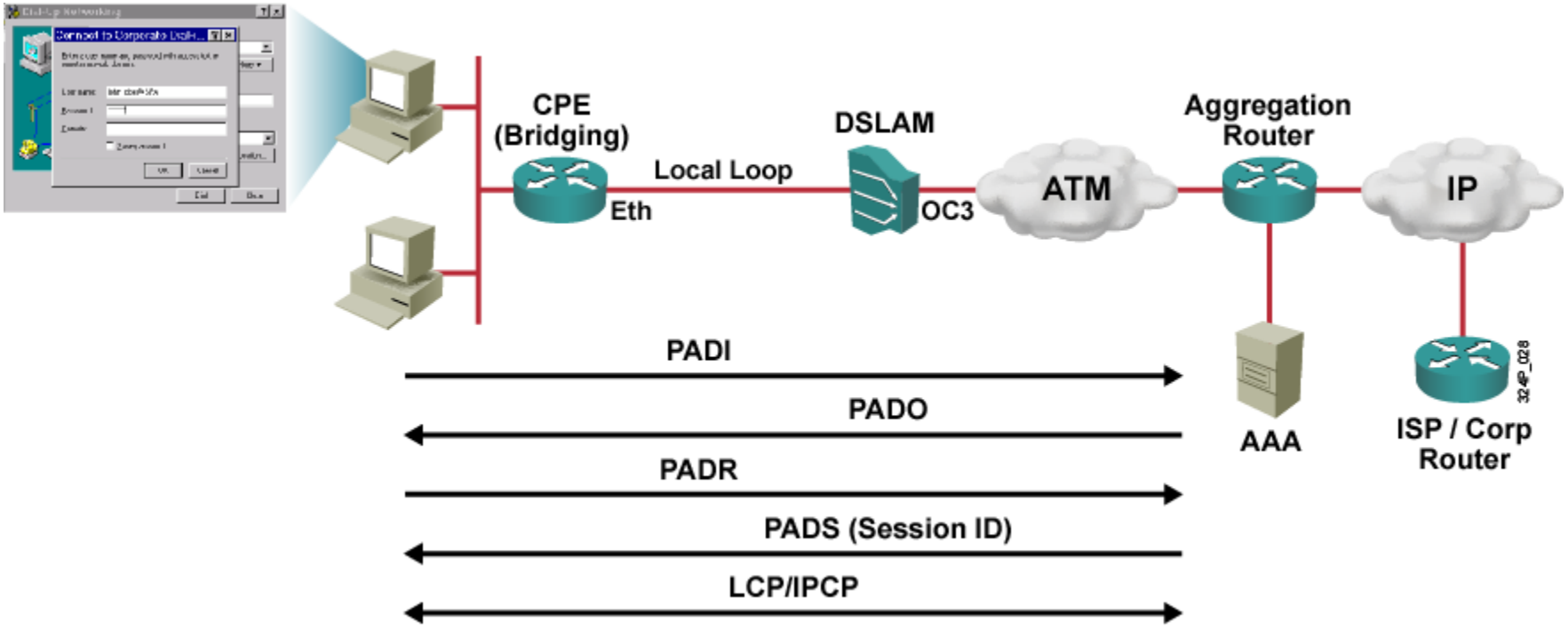

- This is an example of the Santa Cruz router authenticating to the HQ router.
- Hash values, not actual passwords, are sent across the link.
- The local router or external server is in control of authentication attempts.

# PPPoE

# PPP over Ethernet

- **Ethernet frame carrying PPP frame**
- **Service provider end:**
  - DSLAM for DSL connection termination
  - Aggregation router for PPP session termination
- **Subscriber end:**
  - DSL modem for DSL connection termination
  - PPPoE client for PPP session termination
- **The client device is the PC or the router at the CPE**

# PPPoE Session Establishment




- **PPP session is from PPPoE client to the aggregation router.**
- **Subscriber IP address is assigned by the aggregation router via IPCP.**

# PPPoE Client Configuration

## PPPoE Client:

```
Client(config)#interface dialer 0
Client(config-if)#encapsulation ppp
Client(config-if)#ip address negotiated
Client(config-if)#ppp pap sent-username user1 password cisco
Client(config-if)#dialer pool 1

Client(config)#interface g1
Client(config-if)#pppoe-client dial-pool-number 1
```

# PPPoE Verification

**Ping successfully:**

```
Client#ping 8.8.8.8

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 8.8.8.8, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 12/20/30 ms
```

# PPPoE Verification

```
Client#show pppoe session
     1 client session

Uniq ID   PPPoE   RemMAC           Port                 VT   VA          State
            SID   LocMAC                                     VA-st
    N/A      18   000c.297c.c044   G1                   Di0  Vi1         UP
                  000c.297c.d19e                             UP
```


CISCO