

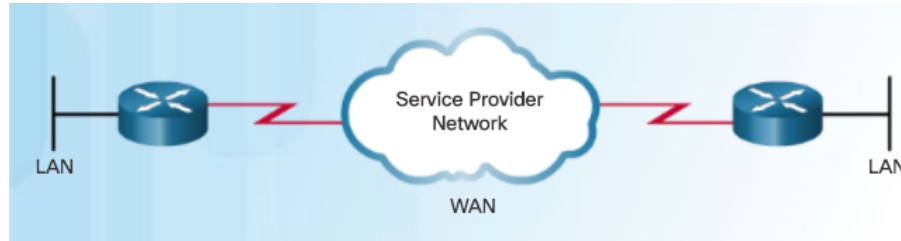
WAN Connectivity

CCNA Routing and Switching
Connecting Networks v6.0



Point-to-Point Communication Links

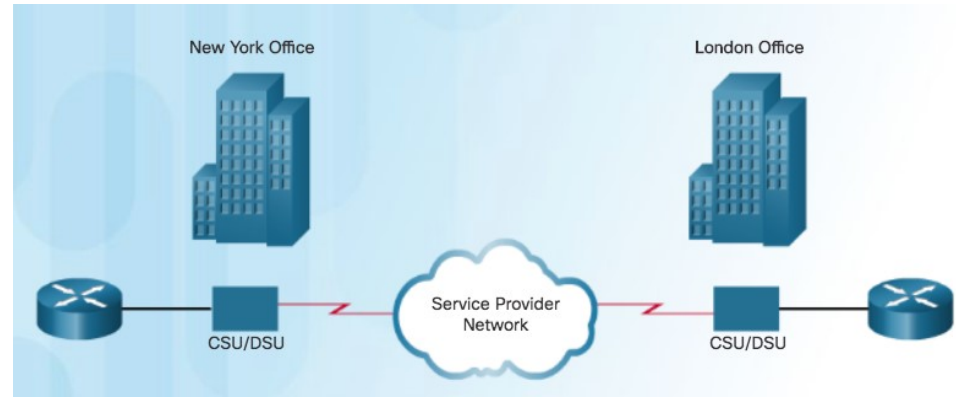
- A WAN is owned by a service provider and a LAN is typically owned by an organization.
- Point-to-point connections connect LANs to service provider WANs and connect LAN segments.
- A LAN-to-WAN point-to-point connection is also referred to as a serial connection or leased-line connection.
- Lines are leased from a carrier.
- Companies pay for a continuous connection between two remote sites, and the line is continuously active and available.



Serial Point-to-Point Connection

Point-to-Point Communication Links

- Point-to-point link
 - Used when permanent dedicated connections are required
 - Provides a single, pre-established WAN communications path
 - Path goes from the customer premises, through the provider network, to a remote destination, as shown in the figure
 - Can connect two geographically distant sites, such as a corporate office in New York and a regional office in London
 - Not limited to connections that cross land (undersea fiber-optics)
 - Usually more expensive than shared services
 - Constant availability is essential for some applications such as VoIP or video over IP.



Serial Communications

Serial Bandwidth

- Bandwidth
 - Refers to the rate at which data is transferred over the communication link.
 - Carrier technology will dictate how much bandwidth is available.
 - North American (T-carrier) specification
 - European (E-carrier) system
 - U.S. Optical Carrier (OC) bandwidth points
 - OC transmission rates are a set of standardized specifications for the transmission of digital signals carried on SONET fiber-optic networks.

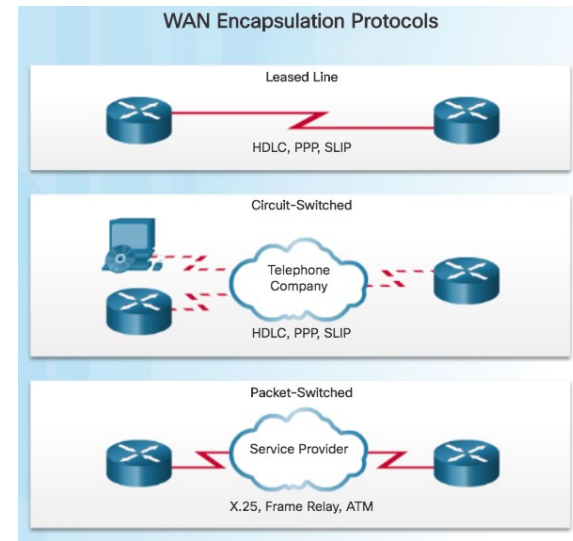
Carrier Transmission Rates

Line Type	Bit Rate Capacity
56	56 kb/s
64	64 kb/s
T1	1.544 Mb/s
E1	2.048 Mb/s
J1	1.544 Mb/s
E3	34.368 Mb/s
T3	44.736 Mb/s
OC-1	51.84 Mb/s
OC-3	155.52 Mb/s
OC-9	466.56 Mb/s
OC-12	622.08 Mb/s
OC-18	933.12 Mb/s
OC-24	1.244 Gb/s
OC-36	1.866 Gb/s
OC-48	2.488 Gb/s
OC-96	4.976 Gb/s
OC-192	9.954 Gb/s
OC-768	39.813 Gb/s

- In North America, expressed as a digital signal level number (DS0, DS1, etc.), which refers to the rate and format of the signal.
 - Most fundamental line speed is 64 kb/s, or DS0.
 - 24 DS0s can be bundled to get a DS1 line (T1 line).
 - 28 DS1s can be bundled to get a DS3 line (T3 line).

WAN Encapsulation Protocols

- Data is encapsulated into frames before crossing the WAN link and must be configured for the appropriate Layer 2 protocol.
- Choice of protocol depends on the WAN technology and the communicating equipment.
- WAN protocols:
 - HDLC - Default encapsulation on point-to-point connections, dedicated links, and circuit-switched connections when the link uses two Cisco devices.
 - PPP - Provides router-to-router and host-to-network connections over synchronous and asynchronous circuits. Has built-in security mechanisms such as PAP and CHAP.

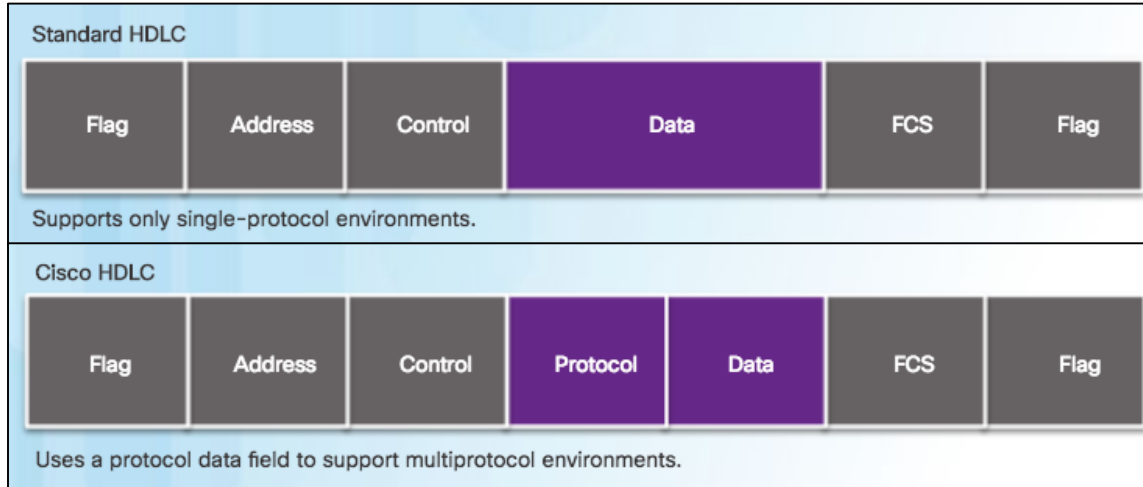


- Serial Line Internet Protocol (SLIP) - Displaced by PPP.
- X.25/Link Access Procedure, Balanced (LAPB) - Predecessor to Frame Relay.
- Frame Relay - Data link layer protocol that handles multiple virtual circuits. After X.25.
- ATM - International standard for cell relay in which devices send multiple service types, such as voice, video, or data, in fixed-length (53-byte) cells. Takes advantage of high-speed transmission media such as E3, SONET, and T3.

HDLC Encapsulation

HDLC Encapsulation

The figure compares standard HDLC to Cisco HDLC.



Uses a frame delimiter, or flag, to mark beginning and end of each frame.

With an added protocol type field, Cisco HDLC can only work with other Cisco devices.

- HDLC is a synchronous data link layer protocol developed by the International Organization for Standardization (ISO).
- HDLC defines a Layer 2 framing structure that allows flow and error control through acknowledgments.
 - Default serial encapsulation method when connecting two Cisco routers.
 - Cisco's HDLC is a point-to-point protocol that can be used on leased lines between two Cisco devices.
 - Protocol field makes it possible for a single serial link to accommodate multiple network-layer protocols.

Configuring HDLC Encapsulation

```
Router(config)# interface s0/0/0
Router(config-if)# encapsulation hdlc
```

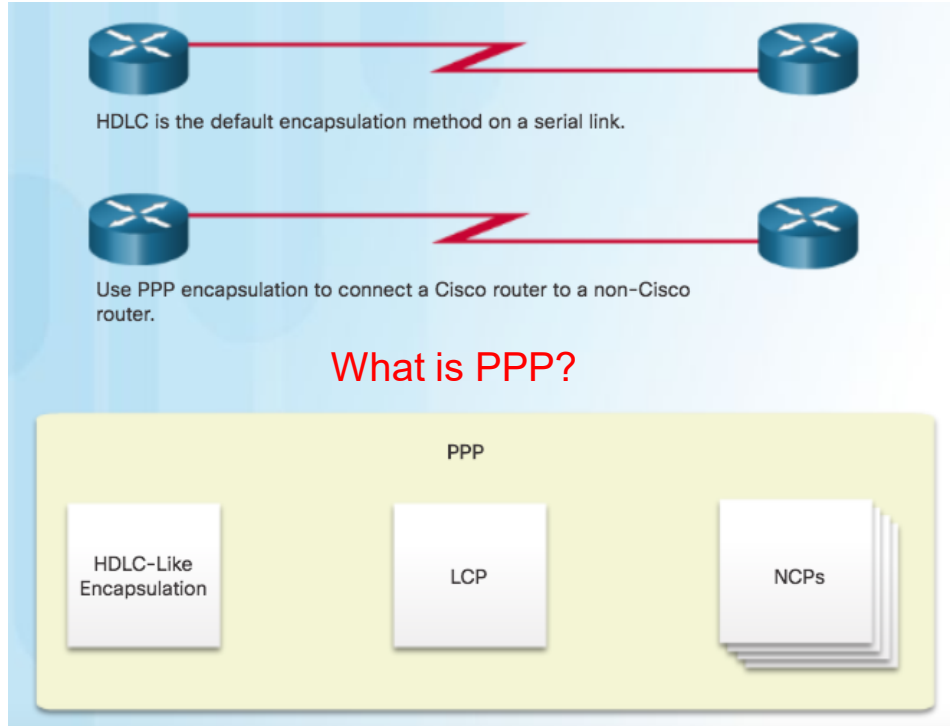
- Enable HDLC encapsulation
- HDLC is the default encapsulation on synchronous serial interfaces

- Use Cisco HDLC as a point-to-point protocol on leased lines between two Cisco devices.
- If connecting non-Cisco devices, use synchronous PPP.
- If the default encapsulation method has been changed, use the **encapsulation hdlc** command in interface configuration mode to re-enable HDLC.

PPP Operation

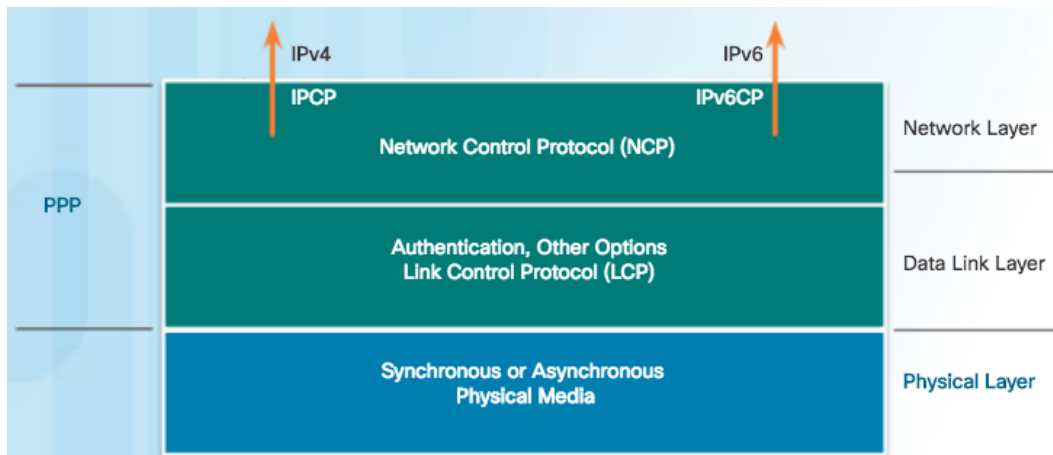
Benefits of PPP

Introducing PPP



- PPP encapsulation should be used when there is a need to connect to a non-Cisco router.
- PPP encapsulates data frames for transmission over Layer 2 physical links.
- PPP establishes a direct connection using serial cables, phone lines, trunk lines, cellular telephones, specialized radio links, or fiber-optic links.
- PPP contains three main components:
 - HDLC-like framing for transporting multiprotocol packets over point-to-point links.
 - Extensible Link Control Protocol (LCP) for establishing, configuring, and testing the data-link connection.
 - Network Control Protocols (NCPs) for establishing and configuring different network layer protocols (IPv4 and IPv6 Control Protocol).

PPP Layered Architecture

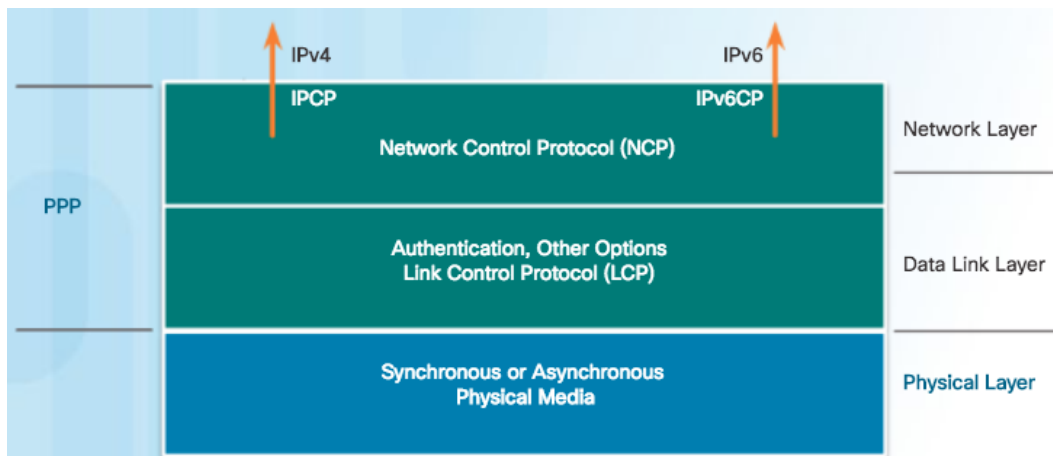


At the Physical Layer PPP Can Use

- Synchronous physical media, such as leased line services
- Asynchronous physical media, such as those that use basic telephone service for modem dialup connections

- The figure maps the layered architecture of PPP against the Open System Interconnection (OSI) model.
- PPP and OSI share the same physical layer, but PPP distributes the functions of LCP and NCP differently.
- PPP requires a full-duplex circuit, either dedicated or switched, that can operate in an asynchronous or synchronous bit-serial mode.
- Most of the work done by PPP happens at the data link and network layers, by LCP and NCPs.

PPP – Link Control Protocol (LCP)

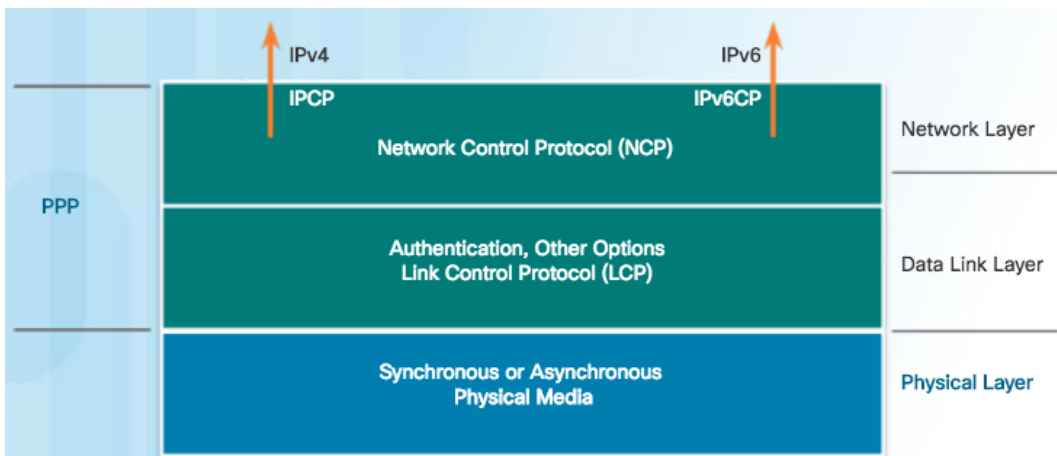


At the Physical Layer PPP Can Use

- Synchronous physical media, such as leased line services
- Asynchronous physical media, such as those that use basic telephone service for modem dialup connections

- LCP functions within the data link layer and has a role in establishing, configuring, and testing the data-link connection.
- LCP establishes the point-to-point link.
- LCP also negotiates and sets up control options on the WAN data link, which are handled by the NCPs.
- After the link is established, PPP also uses LCP to agree automatically on encapsulation formats such as authentication, compression, and error detection.

PPP – Network Control Protocol (NCP)



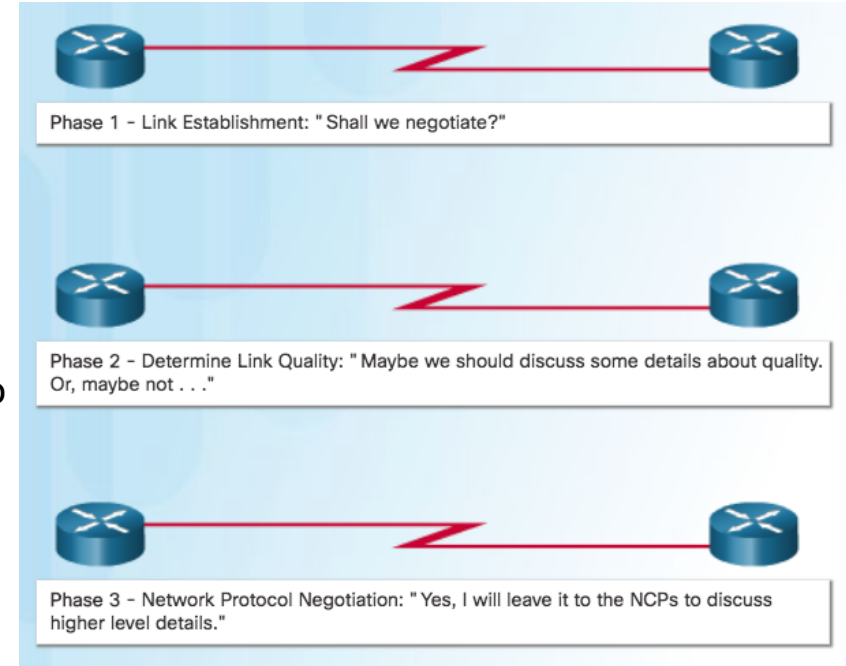
At the Physical Layer PPP Can Use

- Synchronous physical media, such as leased line services
- Asynchronous physical media, such as those that use basic telephone service for modem dialup connections

- PPP permits multiple network layer protocols to operate on the same communications link.
- For every network layer protocol used, PPP uses a separate NCP, as shown in the figure. IPv4 uses IP Control Protocol and IPv6 uses IPv6 Control Protocol.
- NCPs include functional fields containing standardized codes to indicate the network layer protocol that PPP encapsulates.
 - Value 8021 = IPCP
 - Value 8057 = IPv6CP

Establishing a PPP Session

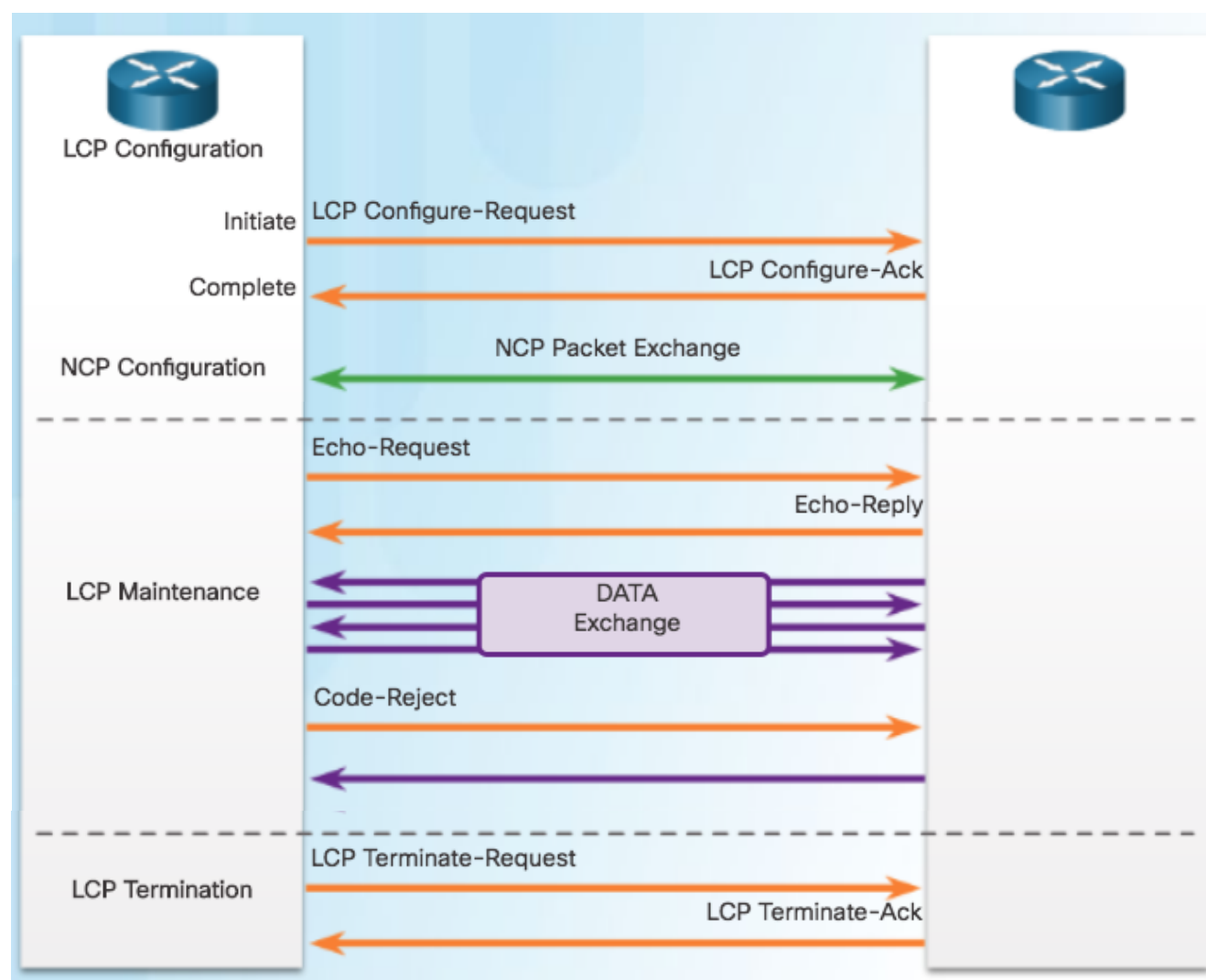
- **Phase 1: Link establishment and configuration negotiation** - Before PPP exchanges any network layer datagrams, such as IP, the LCP must first open the connection and negotiate configuration options. This phase is complete when the receiving router sends a configuration-acknowledgment frame back to the router initiating the connection.
- **Phase 2: Link quality determination (optional)** - The LCP tests the link to determine whether the link quality is sufficient to bring up network layer protocols.
- **Phase 3: Network layer protocol configuration negotiation** - After the LCP has finished Phase 2, the appropriate NCP can separately configure the network layer protocols, and bring them up and take them down at any time. If the LCP closes the link, it informs the network layer protocols so that they can take appropriate action.



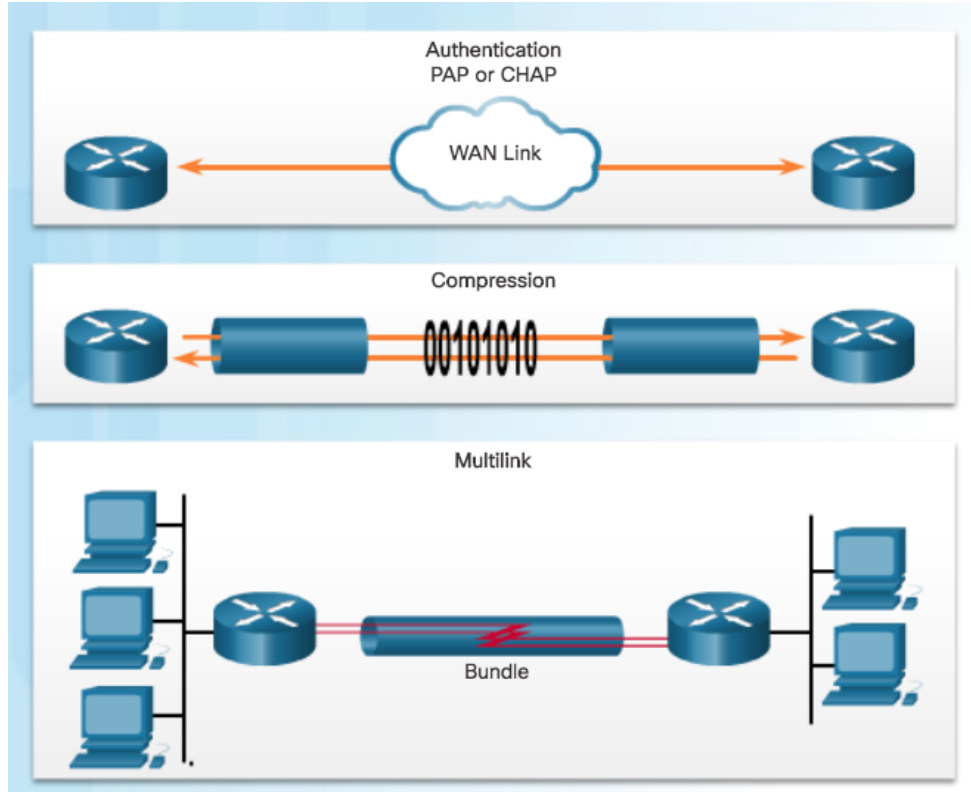
PPP Sessions

LCP Operation

- LCP operation includes provisions for 3 classes of LCP frames:
 - Link-establishment frames
 - Link-maintenance frames
 - Link-termination frames



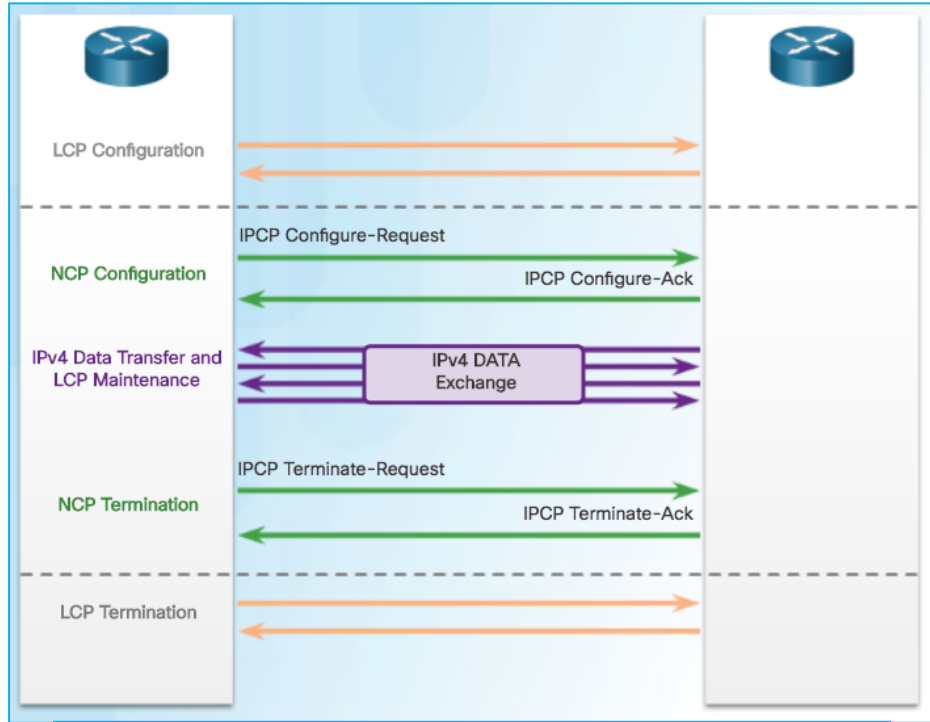
PPP Configuration Options



- Authentication using either PAP or CHAP
- Compression using either Stacker or Predictor
- Multilink that combines two or more channels to increase the WAN bandwidth

PPP Sessions

NCP Explained



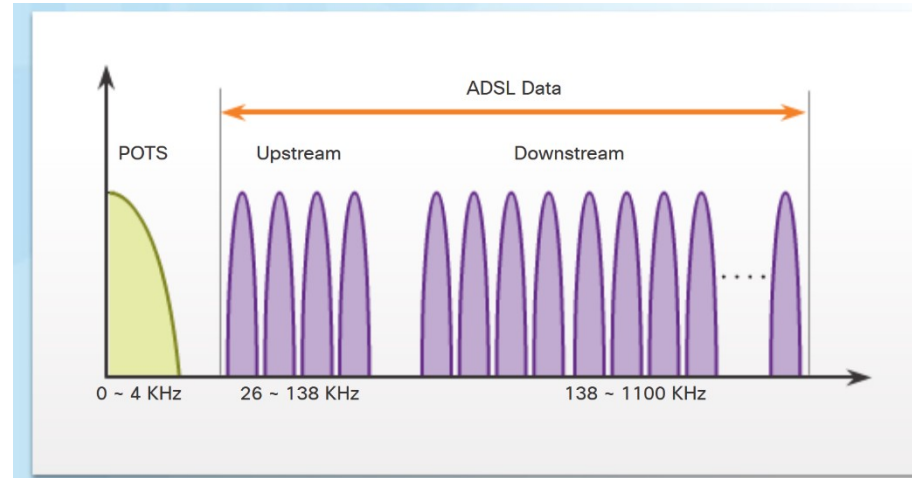
When data transfer is complete, NCP terminates the protocol link and LCP terminates the PPP connection.

- After LCP has established the link, the routers exchange IPCP messages, negotiating options specific to IPv4.
- IPCP is responsible for configuring, enabling, and disabling the IPv4 modules on both ends of the link.
- IPCP negotiates two options:
 - Compression - Allows devices to negotiate an algorithm to compress TCP and IP headers and save bandwidth.
 - IPv4-Address - Allows the initiating device to specify an IPv4 address to use for routing IP over the PPP link, or to request an IPv4 address for the responder.
- After the NCP process is complete, the link goes into the open state and LCP takes over again in a link maintenance phase.

Remote Access Connections

What is DSL?

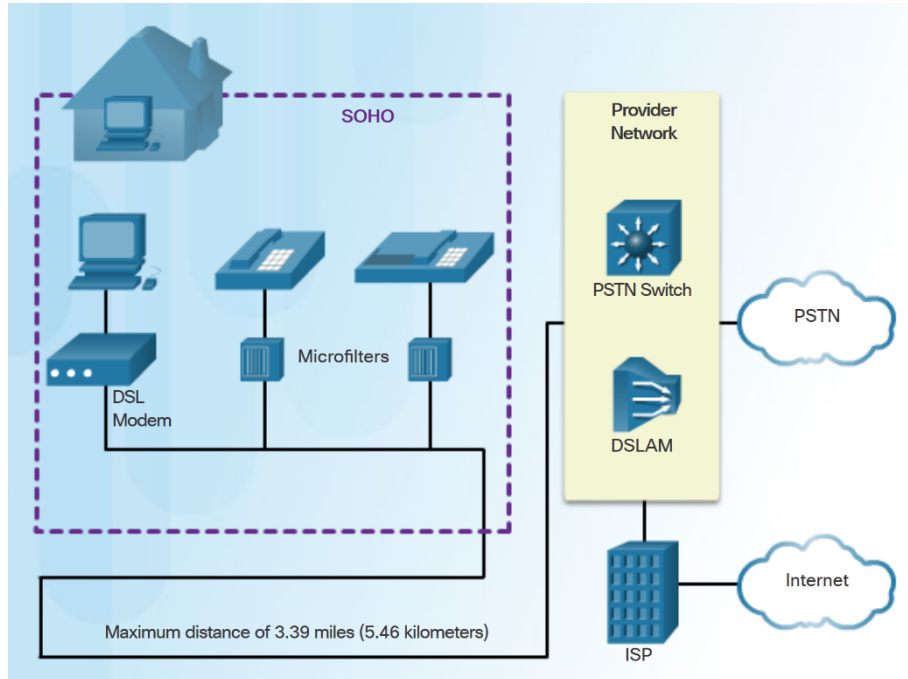
- Digital Subscriber Line (DSL) is a means of providing high-speed connections over installed copper wires.
- Asymmetric DSL (ADSL) provides higher downstream bandwidth to the user than upload bandwidth.
- Symmetric DSL (SDSL) provides the same capacity in both directions.
- For satisfactory ADSL service, the local loop length must be less than 3.39 miles (5.46 km).



The figure shows a representation of bandwidth space allocation on a copper wire for ADSL. POTS (Plain Old Telephone System) identifies the frequency range used by the voice-grade telephone service. The area labeled ADSL represents the frequency space used by the upstream and downstream DSL signals.

Broadband Connections

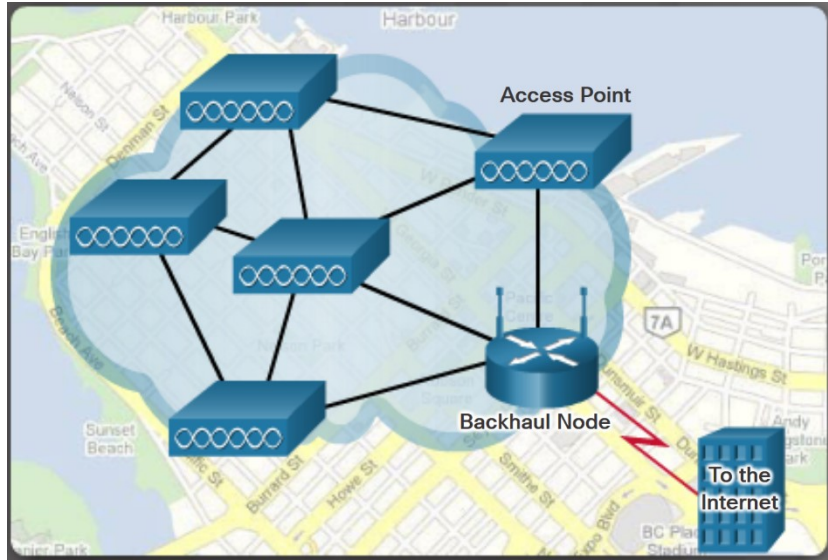
DSL Connections



- The DSL connection is set up between the customer premises equipment (CPE) and the DSL access multiplexer (DSLAM) device located at the Central Office (CO).
- Key components in the DSL connection:
 - Transceiver - Usually a modem in a router which connects the computer of the teleworker to the DSL.
 - DSLAM - Located at the CO of the carrier, it combines individual DSL connections from users into one high-capacity link to an ISP.
- Advantage of DSL over cable technology is that DSL is not a shared medium. Each user has a separate direct connection to the DSLAM.

Broadband Connections

Wireless Connection



- Three main broadband wireless technologies:
 - **Municipal Wi-Fi** - Most municipal wireless networks use a mesh of interconnected access points as shown in figure.
 - **Cellular/mobile** - Mobile phones use radio waves to communicate through nearby cell towers. Cellular speeds continue to increase. LTE Category 10 supports up to 450 Mb/s download and 100 Mb/s upload.
 - **Satellite Internet** - Used in locations where land-based Internet access is not available. Primary installation requirement is for the antenna to have a clear view toward the equator.

Note: WiMAX has largely been replaced by LTE for mobile access, and cable or DSL for fixed access.

Comparing Broadband Solutions

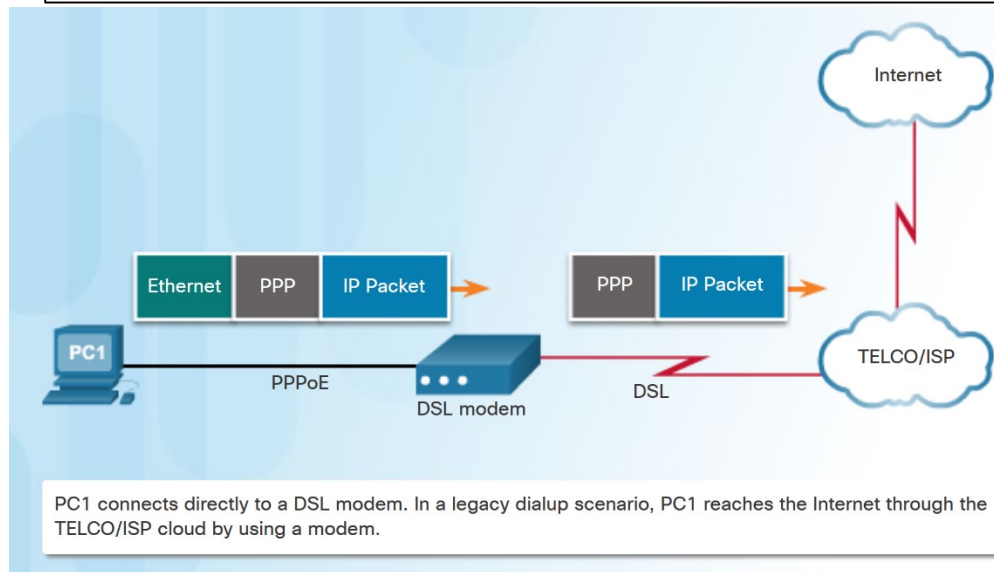
- Factors to consider in selecting a broadband solution:
 - **Cable** - Bandwidth shared by many users, slow data rates during high-usage hours.
 - **DSL** - Limited bandwidth that is distance sensitive (in relation to the ISP's central office).
 - **Fiber-to-the-Home** - Requires fiber installation directly to the home.
 - **Cellular/Mobile** - Coverage is often an issue.
 - **Wi-Fi Mesh** - Most municipalities do not have a mesh network deployed.
 - **Satellite** - Expensive, limited capacity per subscriber



PPPoE Motivation

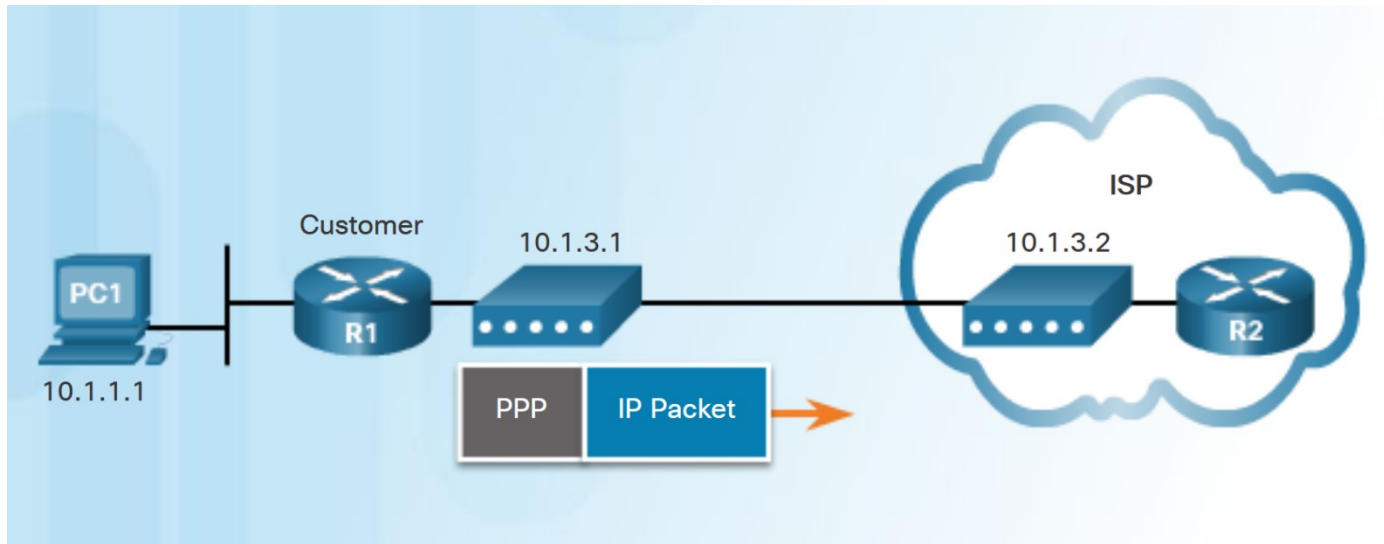
- PPP can be used on all serial links including those links created with dial-up analog and ISDN modems.
- ISPs often use PPP as the data link protocol over broadband connections.
 - ISPs can use PPP to assign each customer one public IPv4 address.
 - PPP supports CHAP authentication.
- Ethernet links do not natively support PPP.
 - PPP over Ethernet (PPPoE) provides a solution to this problem.

PPP Frames Over An Ethernet Connection



PPPoE Concepts

- PPPoE creates a PPP tunnel over an Ethernet connection.
- This allows PPP frames to be sent across the Ethernet cable to the ISP from the customer's router.

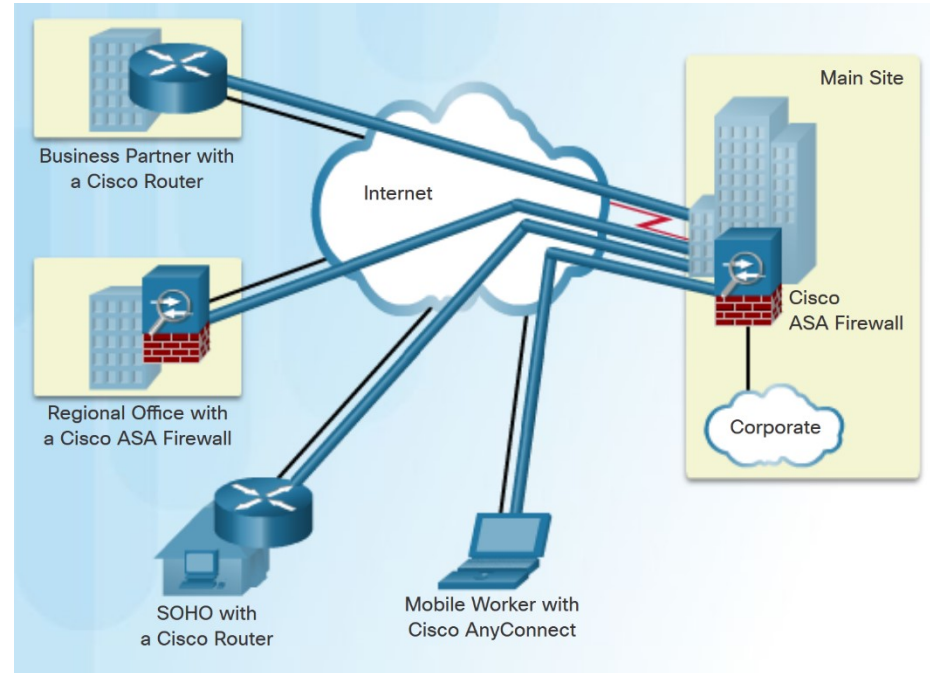


VPNs

Fundamentals of VPNs

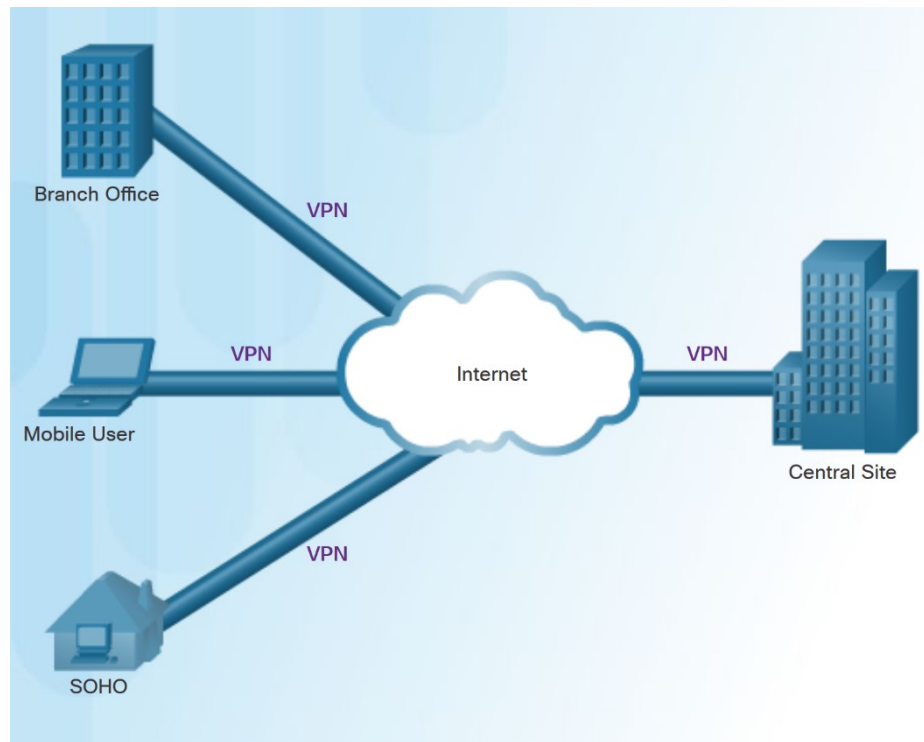
Introducing VPNs

- A VPN is a private network created via tunneling over a public network, usually the Internet.
- A secure implementation of VPN with encryption, such as IPsec VPNs, is what is usually meant by virtual private networking.
- To implement VPNs, a VPN gateway is necessary - could be a router, a firewall, or a Cisco Adaptive Security Appliance (ASA).



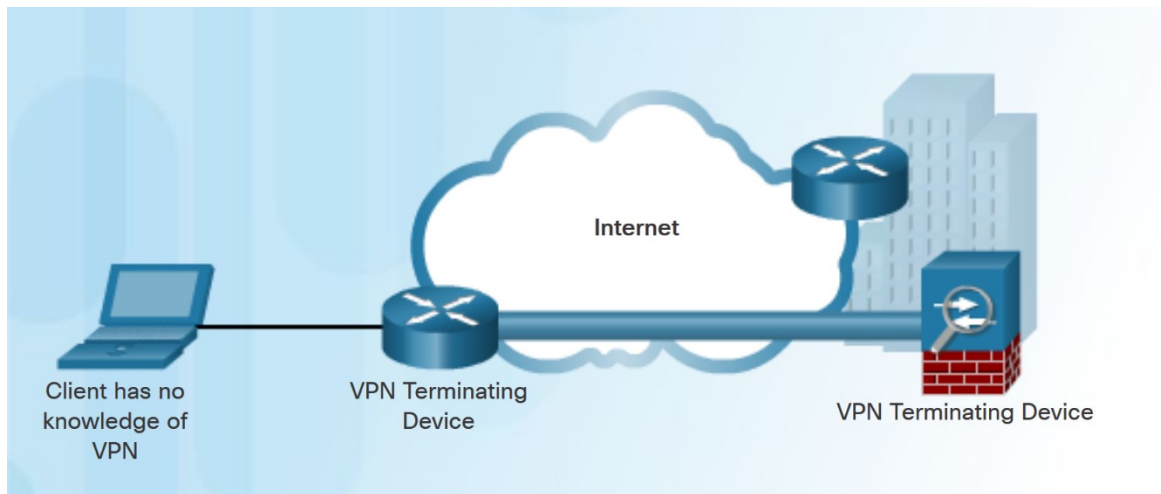
Benefits of VPNs

- The benefits of a VPN include the following:
 - **Cost savings** - VPNs enable organizations to use cost-effective, high-bandwidth technologies, such as DSL to connect remote offices and remote users to the main site.
 - **Scalability** - Organizations are able to add large amounts of capacity without adding significant infrastructure.
 - **Compatibility with broadband technology** - Allow mobile workers and telecommuters to take advantage of high-speed, broadband connectivity.
 - **Security** - VPNs can use advanced encryption and authentication protocols.



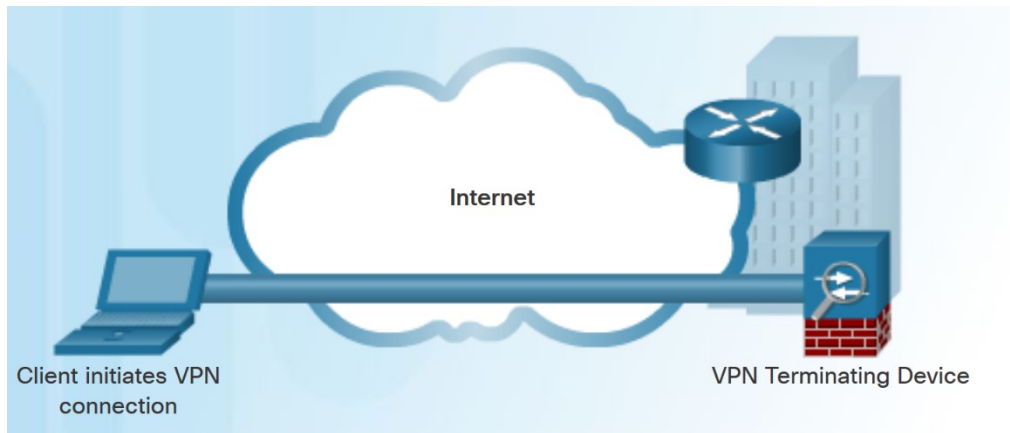
Site-to-Site VPNs

- Site-to-site VPNs connect entire networks to each other, for example, connecting a branch office network to a company headquarters network.
- In a site-to-site VPN, end hosts send and receive normal TCP/IP traffic through a VPN “gateway”.
- The VPN gateway is responsible for encapsulating and encrypting outbound traffic.



Remote Access VPNs

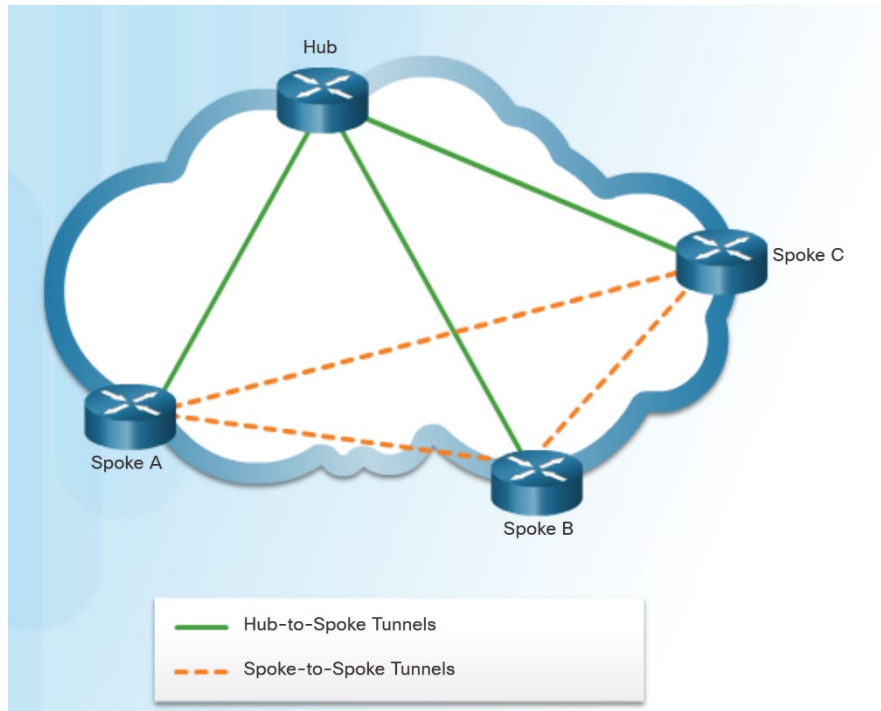
- A remote-access VPN supports the needs of telecommuters, mobile users, and extranet traffic.
- Allows for dynamically changing information, and can be enabled and disabled.
- Used to connect individual hosts that must access their company network securely over the Internet.
- VPN client software may need to be installed on the mobile user's end device.



Types of VPNs

DMVPN

- Dynamic Multipoint VPN (DMVPN) is a Cisco software solution for building multiple VPNs.
- DMVPN is built using the following technologies:
 - **Next Hop Resolution Protocol (NHRP)** - NHRP creates a distributed mapping database of public IP addresses for all tunnel spokes.
 - **Multipoint Generic Routing Encapsulation (mGRE) tunnels** - An mGRE tunnel interface allows a single GRE interface to support multiple IPsec tunnels.
 - **IP Security (IPsec) encryption** - provides secure transport of private information over public networks.



Lab - Researching Broadband Internet Access Technologies



Cisco Networking Academy®

Mind Wide Open™

Lab – Researching Broadband Internet Access Technologies

Objectives

Part 1: Investigate Broadband Distribution

Part 2: Research Broadband Access Options for Specific Scenarios

Background / Scenario

Although broadband Internet access options have increased dramatically in recent years, broadband access varies greatly depending on location. In this lab, you will investigate current broadband distribution and research broadband access options for specific scenarios.

Required Resources

Device with Internet access

Part 1: Investigate Broadband Distribution

In Part 1, you will research broadband distribution in a geographical location.

Step 1: Research broadband distribution.

Use the Internet to research the following questions:

- For the country in which you reside, what percentage of the population has broadband Internet subscriptions?
- What percentage of the population is without broadband Internet options?

Step 2: Research broadband distribution in the United States.

Navigate to the website www.broadbandmap.gov. The National Broadband Map allows users to search and map broadband availability across the United States.

Note: For access options and ISPs for locations outside the United States, perform an Internet search using the keywords "broadband access XYZ, where XYZ is the name of the country.

- Enter your zip code, city and country that you would like to explore and click **Find Broadband**. List the zip code or city in the space provided.
- Click **Show Wired** and **Expand All**. What, if any, wired broadband Internet connections are available at this location? Complete the table below.

ISP	Connection Type	Download Speed