Data Link Layer Protocols

This module covers data link layer issues, such as point-to-point links, Ethernet, and the Point-to-Point Protocol (PPP).

PPP Components (Encapsulation, LCP, NCP

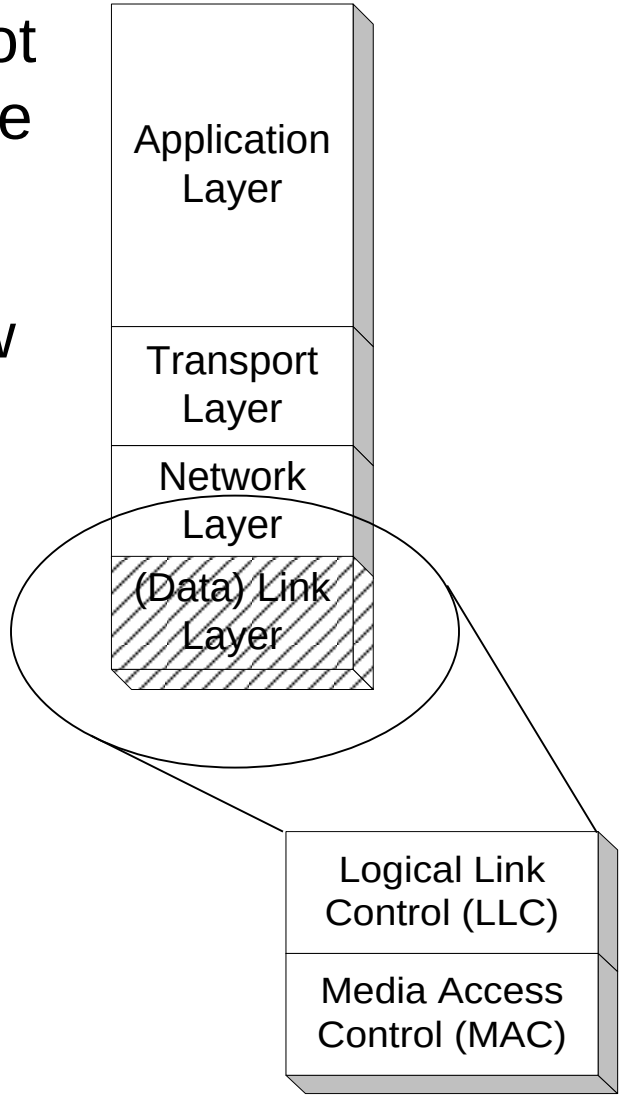
PPP Frame Format

SLIP vs. PPP

TCP/IP Suite and OSI Reference Model

- The TCP/IP protocol stack does not define the lower layers of a complete protocol stack

- In this lecture, we will address how the TCP/IP protocol stacks interfaces with the data link layer

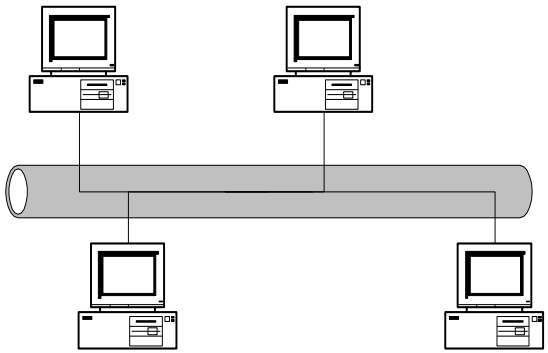


Data Link Layer

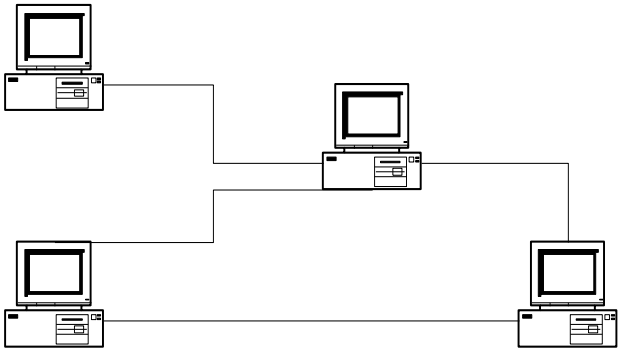
- The main tasks of the data link layer are:
  - Transfer data from the network layer of one machine to the network layer of another machine
  - Convert the raw bit stream of the physical layer into groups of bits (“frames”)

Two types of networks at the data link layer

- Broadcast Networks: All stations share a single communication channel
- Point-to-Point Networks: Pairs of hosts (or routers) are directly connected



Broadcast Network

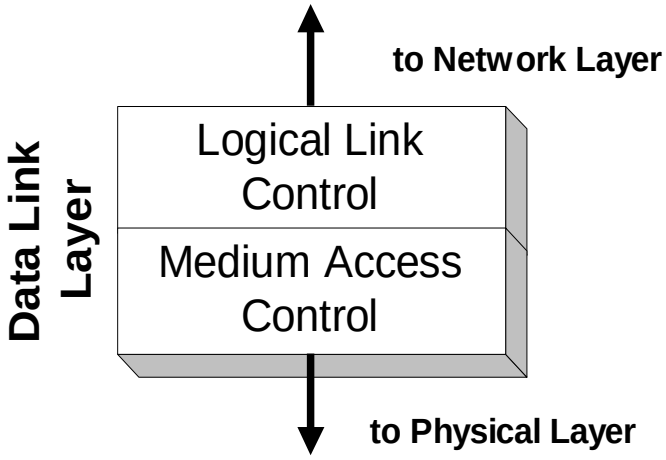


Point-to-Point Network

- Typically, local area networks (LANs) are broadcast and wide area networks (WANs) are point-to-point

MAC and LLC

- In any broadcast network, the stations must ensure that only one station transmits at a time on the shared communication channel
- The protocol that determines who can transmit on a broadcast channel are called Medium Access Control (MAC) protocol
- The MAC protocol are implemented in the MAC sublayer which is the lower sublayer of the data link layer
- The higher portion of the data link layer is often called Logical Link Control (LLC)



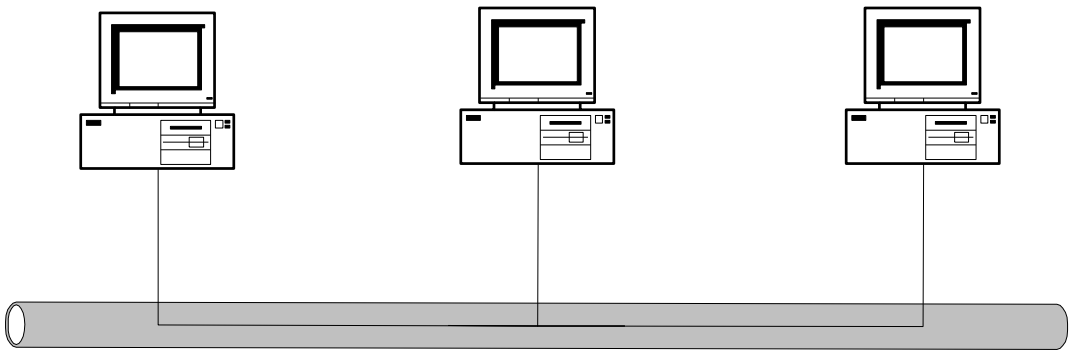
Ethernet

- Speed: 10Mbps -10 Gbps
- Standard: 802.3, Ethernet II (DIX)

- Most popular physical layers for Ethernet:
  - 10Base5 **Thick Ethernet:** 10 Mbps coax cable
  - 10Base2 **Thin Ethernet:** 10 Mbps coax cable
  - 10Base-T 10 Mbps Twisted Pair
  - 100Base-TX 100 Mbps over Category 5 twisted pair
  - 100Base-FX 100 Mbps over Fiber Optics
  - 1000Base-FX 1Gbps over Fiber Optics
  - 10000Base-FX 1Gbps over Fiber Optics (for wide area links)

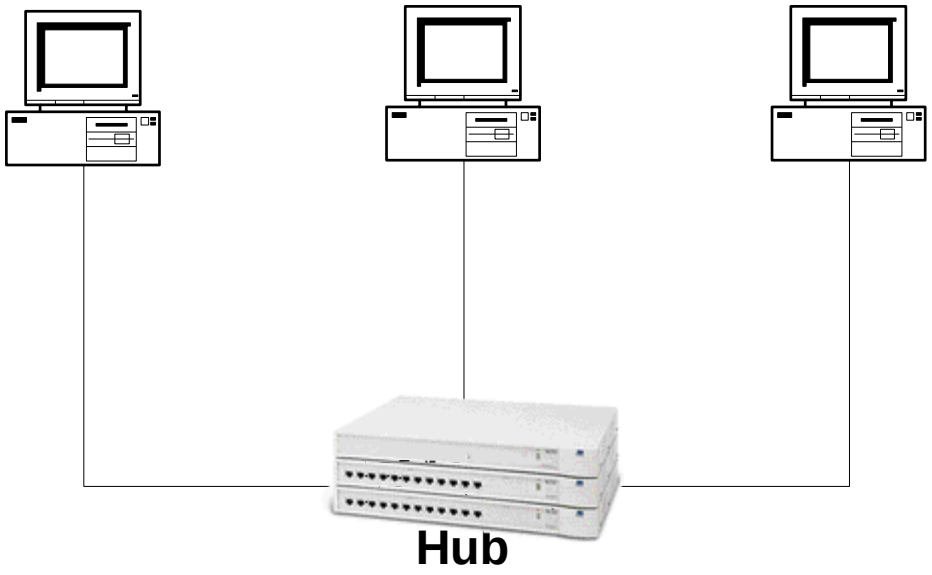
Bus Topology

- 10Base5 and 10Base2 Ethernets has a bus topology



Star Topology

- Starting with 10Base-T, stations are connected to a hub in a star configuration



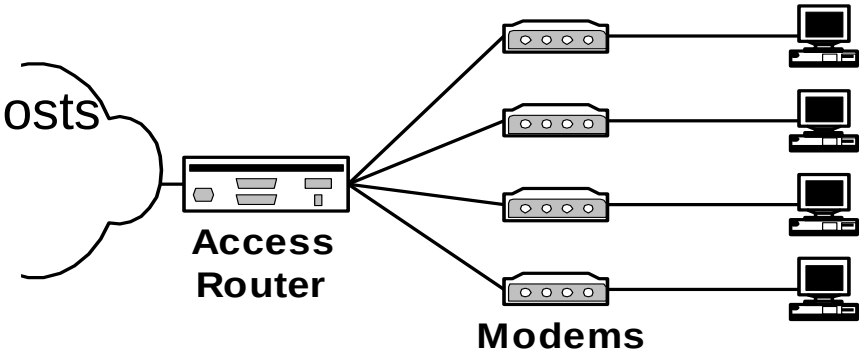
Ethernet and IEEE 802.3: Any Difference?

- There are two types of Ethernet frames in use, with subtle differences:
- ***"Ethernet" (Ethernet II, DIX)***
  - An industry standards from 1982 that is based on the first implementation of CSMA/CD by Xerox.
  - Predominant version of CSMA/CD in the US.
- **802.3:**
  - IEEE's version of CSMA/CD from 1985.
  - Interoperates with 802.2 (LLC) as higher layer.

- **Difference for our purposes:** Ethernet and 802.3 use different methods to encapsulate an IP datagram.

Point-to-Point (serial) links

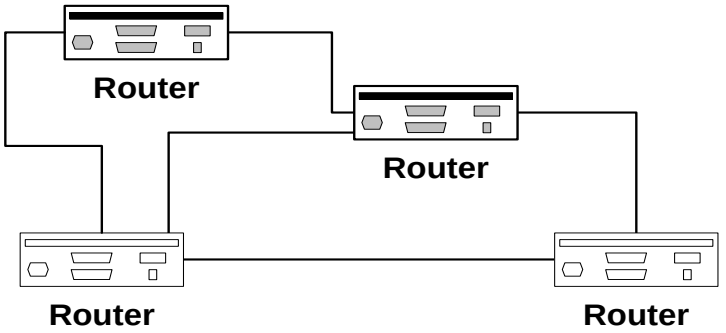
- Many data link connections are point-to-point serial links:
  - Dial-in or DSL access connects hosts to access routers
  - Routers are connected by high-speed point-to-point links



Dial-Up Access

- Here, IP hosts and routers are connected by a serial cable

- Data link layer protocols for point-to-point links are simple:
  - Main role is encapsulation of IP datagrams
  - No media access control needed



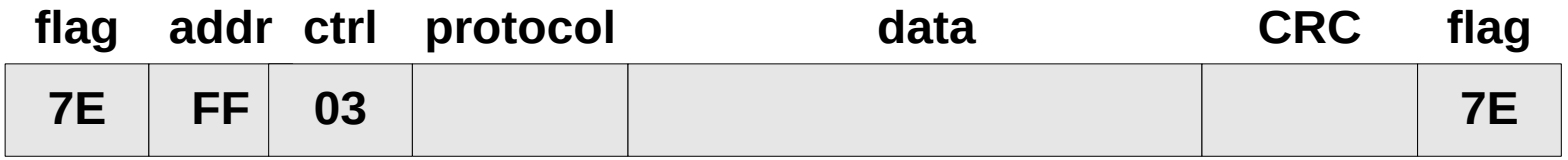
Point-to-Point Links

Data Link Protocols for Point-to-Point links

- **SLIP (Serial Line IP)**
  - First protocol for sending IP datagrams over dial-up links (from 1988)
  - Encapsulation, not much else
- **PPP (Point-to-Point Protocol):**
  - Successor to SLIP (1992), with added functionality
  - Used for dial-in and for high-speed routers
- **HDLC (High-Level Data Link) :**
  - Widely used and influential standard (1979)
  - Default protocol for serial links on Cisco routers
  - Actually, PPP is based on a variant of HDLC

PPP - IP encapsulation

- The frame format of PPP is similar to HDLC and the 802.2 LLC frame format:



0021	IP datagram

C021	link control data

8021	network control data

- PPP assumes a duplex circuit
- Note: PPP does not use addresses
- Usual maximum frame size is 1500

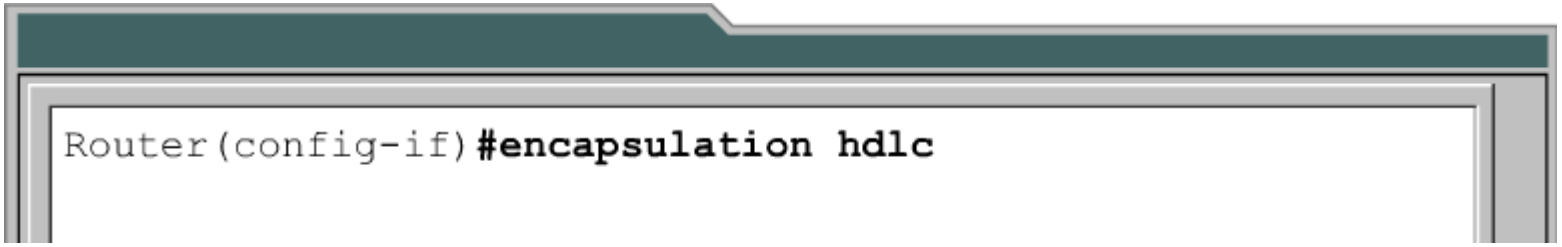
HDLC Encapsulation

HDLC ISO frame					
Flag	Address	Control	Data (Payload)	FCS	Flag
1 byte	1 byte	1 or 2 bytes	1500 bytes	2 (or 4) bytes	1 byte

PPP frame						
Flag	Address	Control	Protocol	Data (Payload)	FCS	Flag
1 byte	1 byte	1 byte	1 or 2 bytes	Up to 1500 bytes	2 (or 4) bytes	1 byte

- **Standard HDLC does not inherently support multiple protocols on a single link**, as it does not have a way to indicate which protocol is being carried.
- Cisco offers a proprietary version of HDLC.
- The **Cisco HDLC** frame uses a proprietary 'type' field that acts as a protocol field.
- HDLC is the default Layer 2 protocol for Cisco router serial interfaces.
- PPP actually uses HDLC as a basis for encapsulating datagrams.

Configuring HDLC



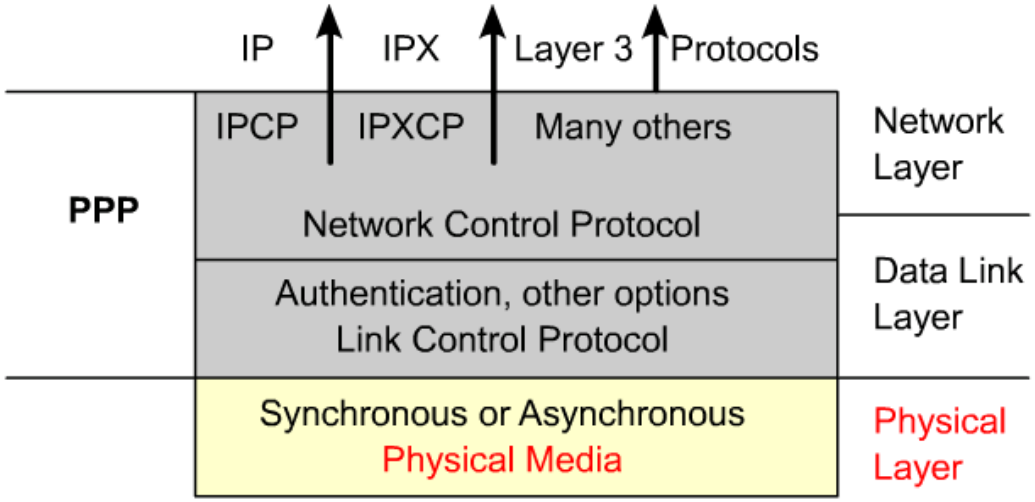
- The default encapsulation method used by Cisco devices on synchronous serial lines is Cisco HDLC.
- Cisco HDLC is a point-to-point protocol that can be used on leased lines between two Cisco devices.
- When communicating with a non-Cisco device, PPP is a more viable option.

Additional PPP functionality

- In addition to encapsulation, PPP supports:
  - multiple network layer protocols (protocol multiplexing)
  - Link configuration
  - Link quality testing
  - Error detection
  - Option negotiation
  - Address notification
  - Authentication

- The above functions are supported by helper protocols:
  - LCP
  - PAP, CHAP
  - NCP

PPP layered architecture



- PPP contains two sub-protocols:
  - **Link Control Protocol (LCP)** – Used for establishing the point-to-point link.
    - Negotiate and setup control options on the WAN data link.
  - **Network Control Protocol (NCP)** – Used for configuring the various network layer protocols.
    - Encapsulate and negotiate options for multiple network layer protocols.
    - The LCP sits on top of the physical layer and is used to establish, configure, and test the data-link connection

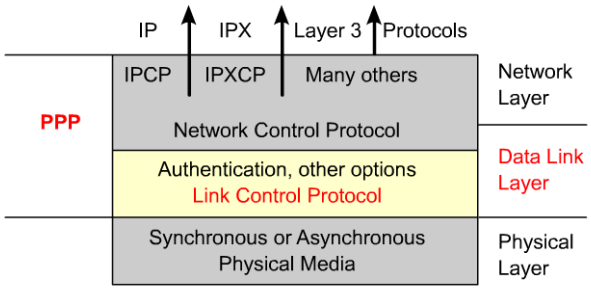
PPP Support protocols

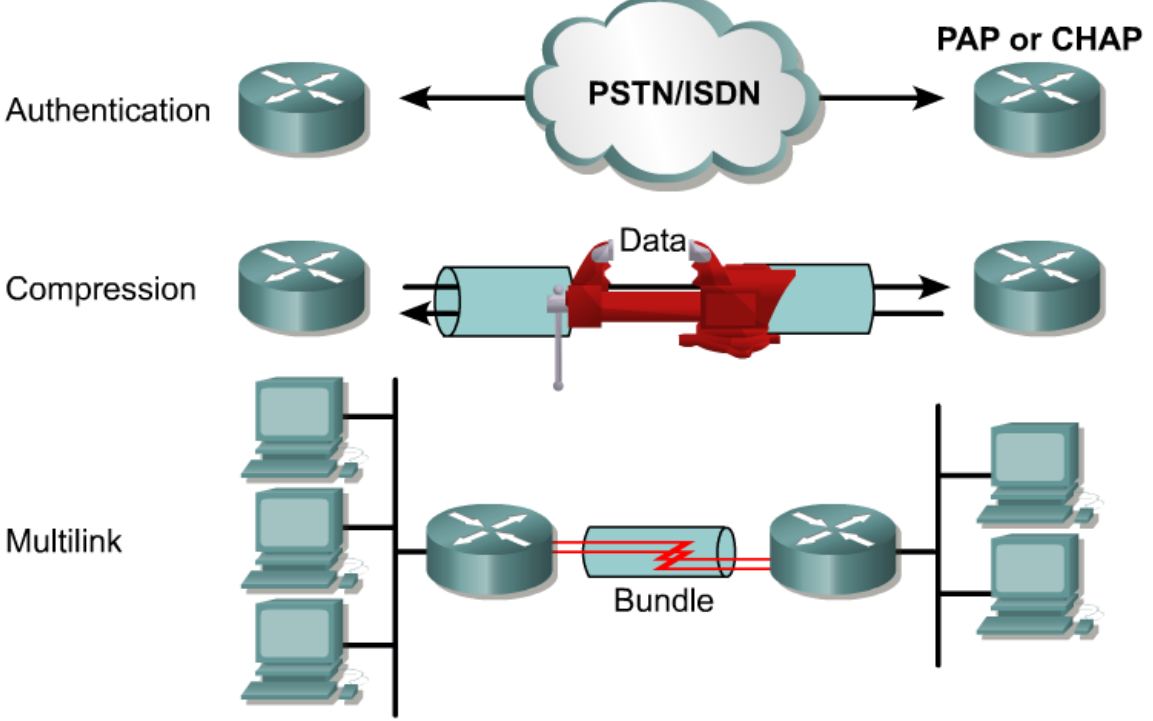
- **Link management:** The link control protocol (LCP) is responsible for establishing, configuring, and negotiating a data-link connection. LCP also monitors the link quality and is used to terminate the link.

- **Authentication:** Authentication is optional. PPP supports two authentication protocols: Password Authentication Protocol (PAP) and Challenge Handshake Authentication Protocol (CHAP).

- **Network protocol configuration:** PPP has network control protocols (NCPs) for numerous network layer protocols. The IP control protocol (IPCP) negotiates IP address assignments and other parameters when IP is used as network layer.

LCP





Features	How It Operates	Protocol
Authentication	Require a password and perform challenge handshake	PAP CHAP
Compression	Compress data at source and reproduce data at destination	Stacker, Predictor, TCP Header, or MPPC
Error Detection	Monitor data dropped on link Avoid frame looping	Quality Magic Number
Multilink	Load balancing across multiple links	Multilink Protocol (MP)

•Also: PPP callback

- **LCP** is used to automatically agree upon encapsulation format options.

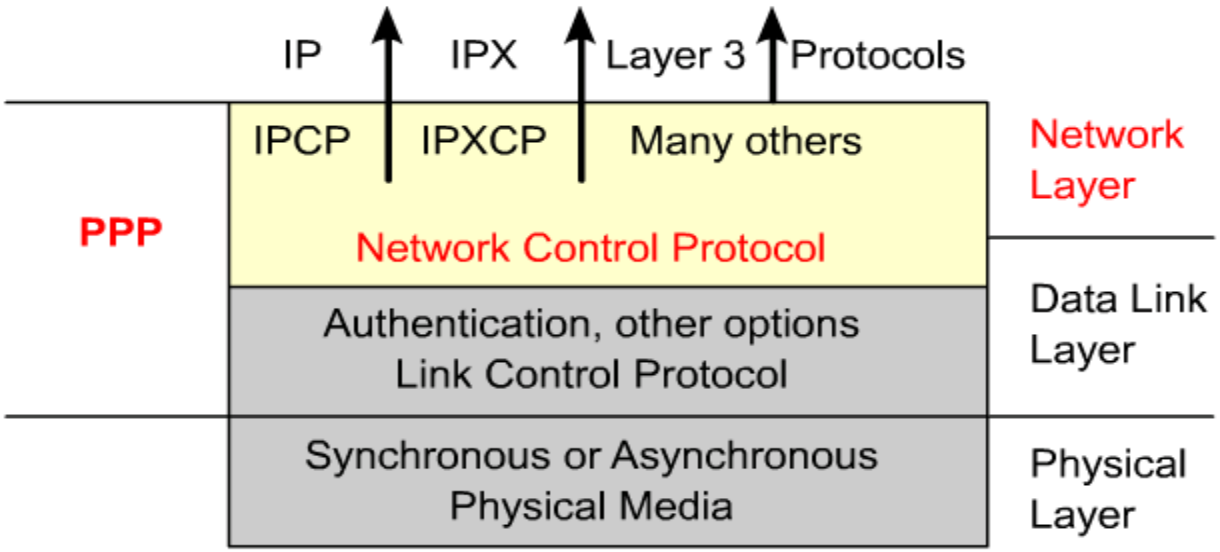
LCP

- LCP will also do the following:
  - Handle varying limits on packet size
  - Detect common misconfiguration errors
  - Terminate the link
  - Determine when a link is functioning properly or when it is failing

PPP Session Establishment

```
Router#configure terminal
Router(config)#interface serial 0/0
Router(config-if)#encapsulation ppp
```

Network Layer Protocol Phase

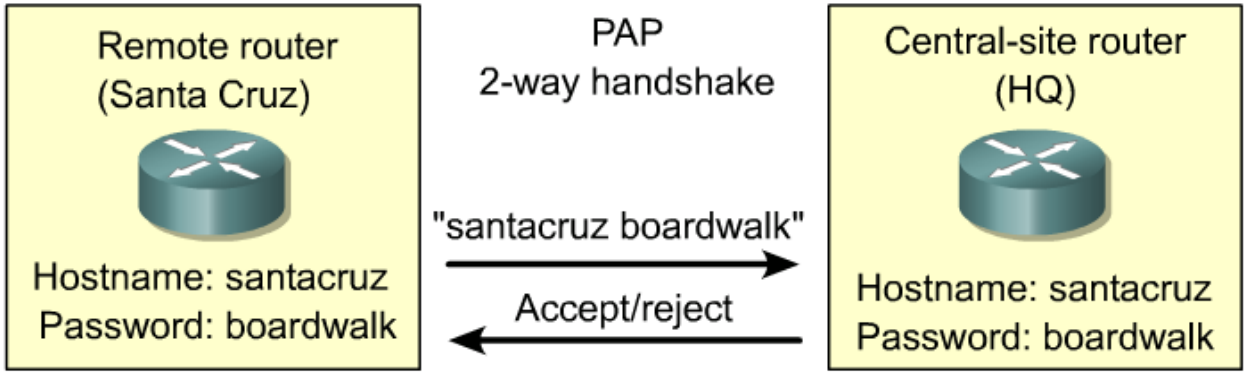


•In this phase the PPP devices send NCP packets to choose and configure one or more network layer protocols, such as IP.

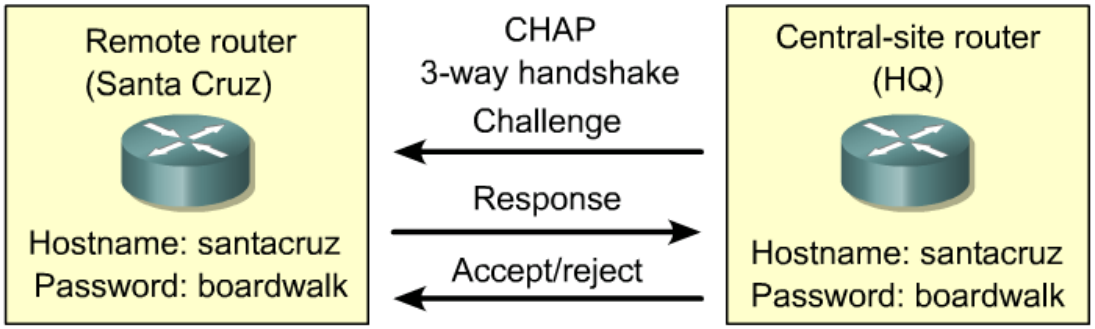
•Once each of the chosen network layer protocols has been configured, packets from each network layer protocol can be sent over the link.

•If LCP closes the link, it informs the network layer protocols so that they can take appropriate action.

Configuring Authentication (PAP or CHAP)



- Password sent in clear text
- Peer in control of attempts



•Encrypted password
Repeated challenges

- Peer routers exchange authentication messages.
- Two alternatives are:
  - Password Authentication Protocol (PAP)
  - Challenge Handshake Authentication Protocol (CHAP)
- In general, CHAP is the preferred protocol but PAP is still very common.

SLIP vs PPP

- SLIP (Serial Line Internet Protocol) and PPP (Point-to-Point Protocol) are two protocols that are used in interconnecting two points in order to facilitate the transmission of data to and fro
- 1.SLIP is obsolete and has been replaced by PPP in most applications.
  2.PPP can auto-configure settings while SLIP cannot.
  3.PPP provides error detection and recovery while SLIP doesn't.
  4.SLIP has very minimal overhead compared to PPP.
- Although SLIP is obsolete and is no longer used in most computer systems, it still enjoys some use in certain systems like microcontrollers. This is because of the relatively small amount of overhead that it adds

Switched networks

Data link layer technologies:

- Switched Ethernet
- ATM (Asynchronous Transfer Mode)
- Frame Relay
- Multiprotocol Label Switching (MPLS)

- Some switched networks are intended for enterprise networks (Switched Ethernet), wide area networks (MPLS, Frame Relay), or both (ATM)

- Some switched networks have a complete protocol suite.