Chapter 3

Data Link Layer

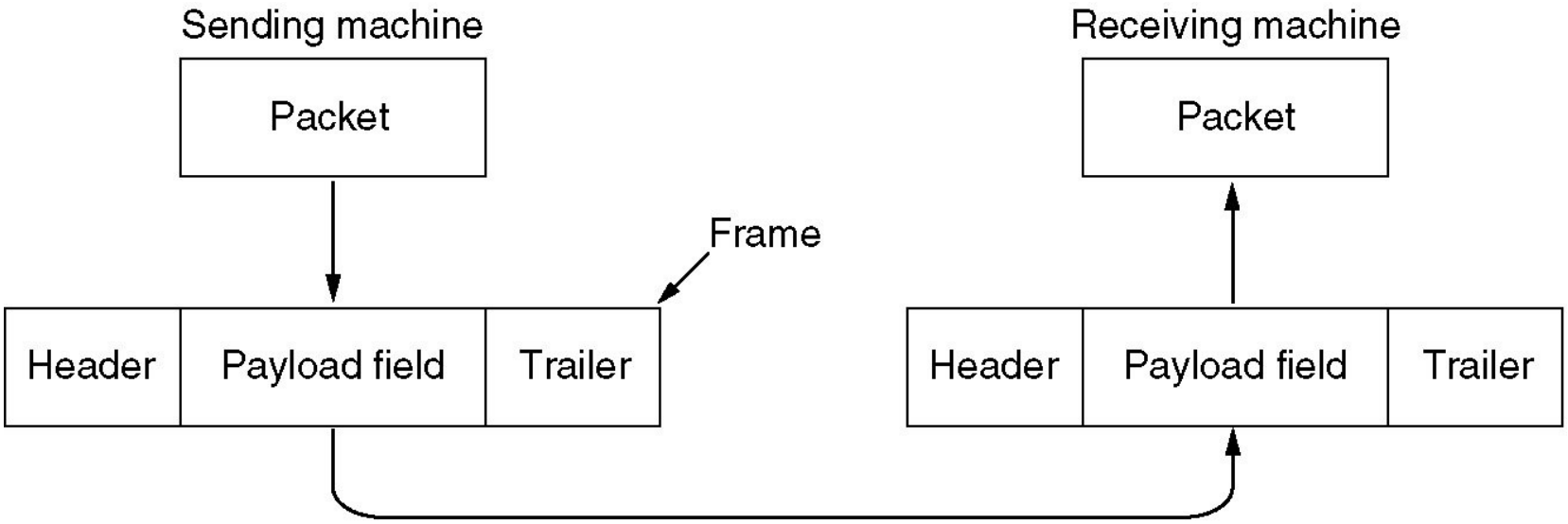
Data Link Layer Design Issues

- Services Provided to the Network Layer
- Framing
- Error Control
- Flow Control

Functions of the Data Link Layer

- Provide service interface to the network layer
- Dealing with transmission errors
- Regulating data flow
  - Slow receivers not swamped by fast senders

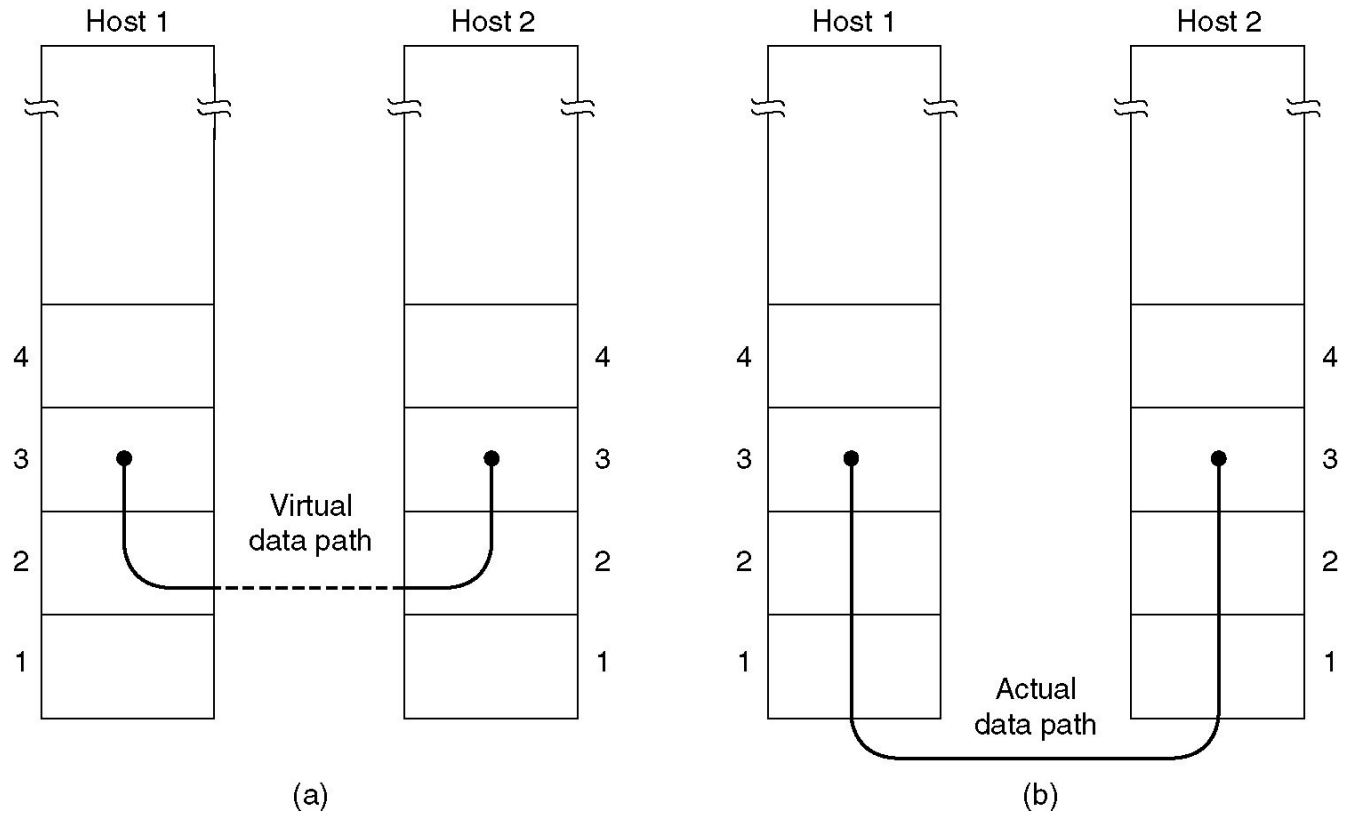
Relationship between packets and frames.



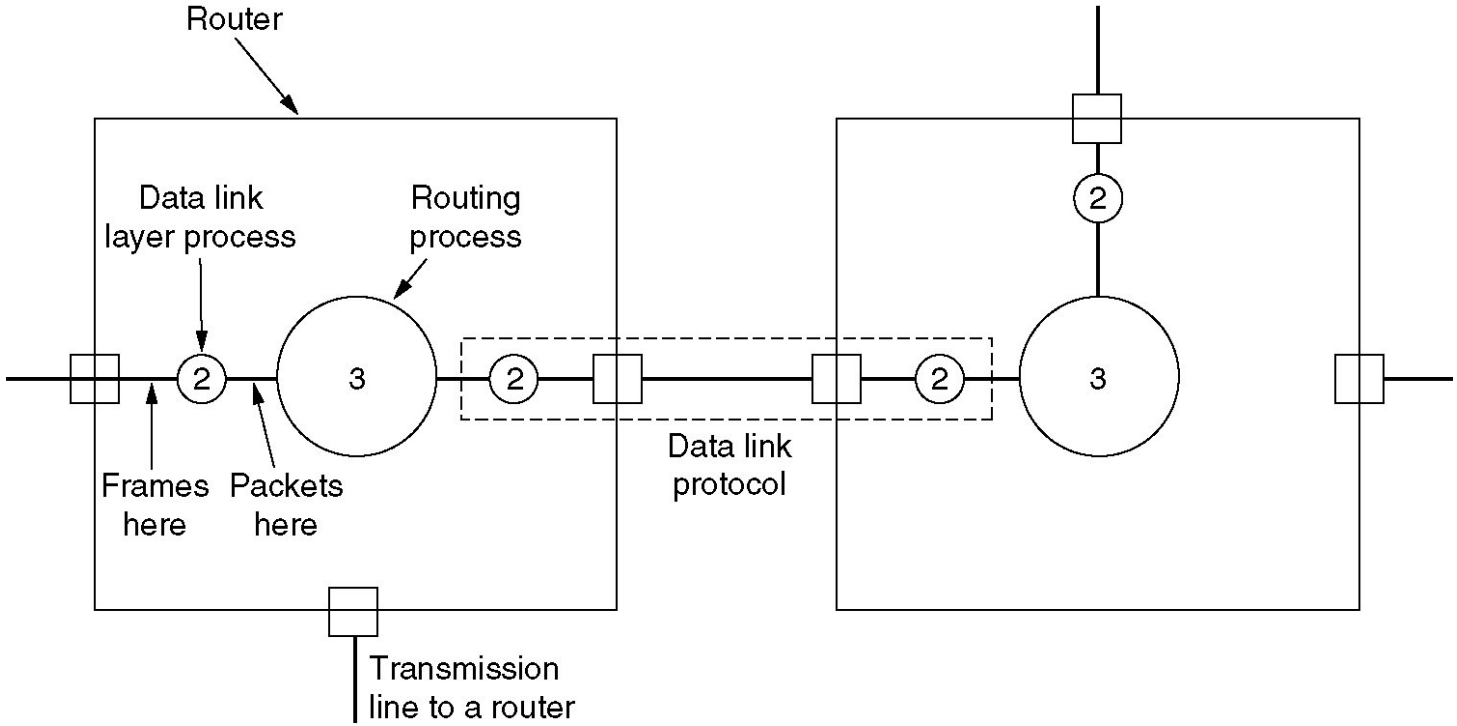
Service Provided to the Network Layer

- Transmission of network layer packets to destination
- Type of data transmission
  - No Ack No Connection
    - No reliability
  - Ack but No Connection
    - Reliable but duplication of packets
  - Ack and Connection
    - Reliable data transmission and the no duplication
    - Three phases of data transmission

(a) Virtual communication.
(b) Actual communication.



Placement of the data link protocol.



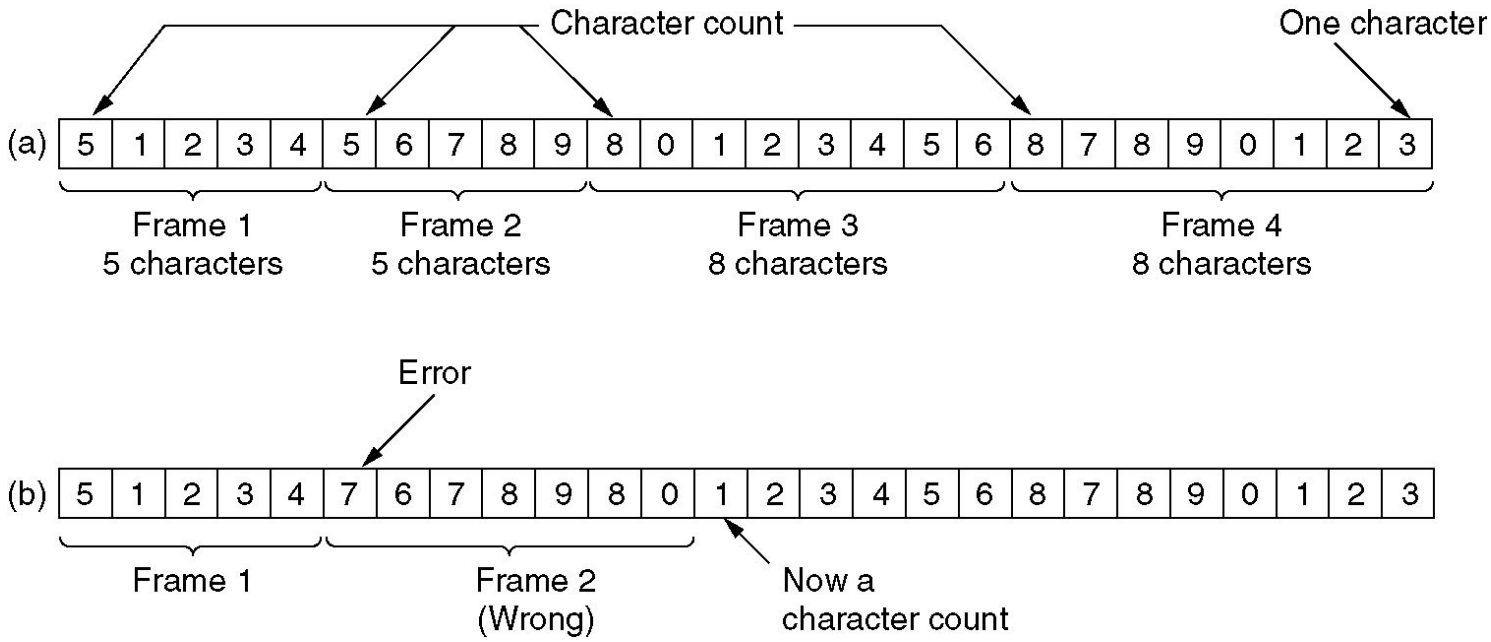
Framing

- Frame is the Basic unit of data streams
- Packets are broken into frames
- Frame size depends on the layer below DLL
- Checksum is computed and appended in the frame
- Generally used
  - Hybrid of Character count plus any one

End of Frame Detection

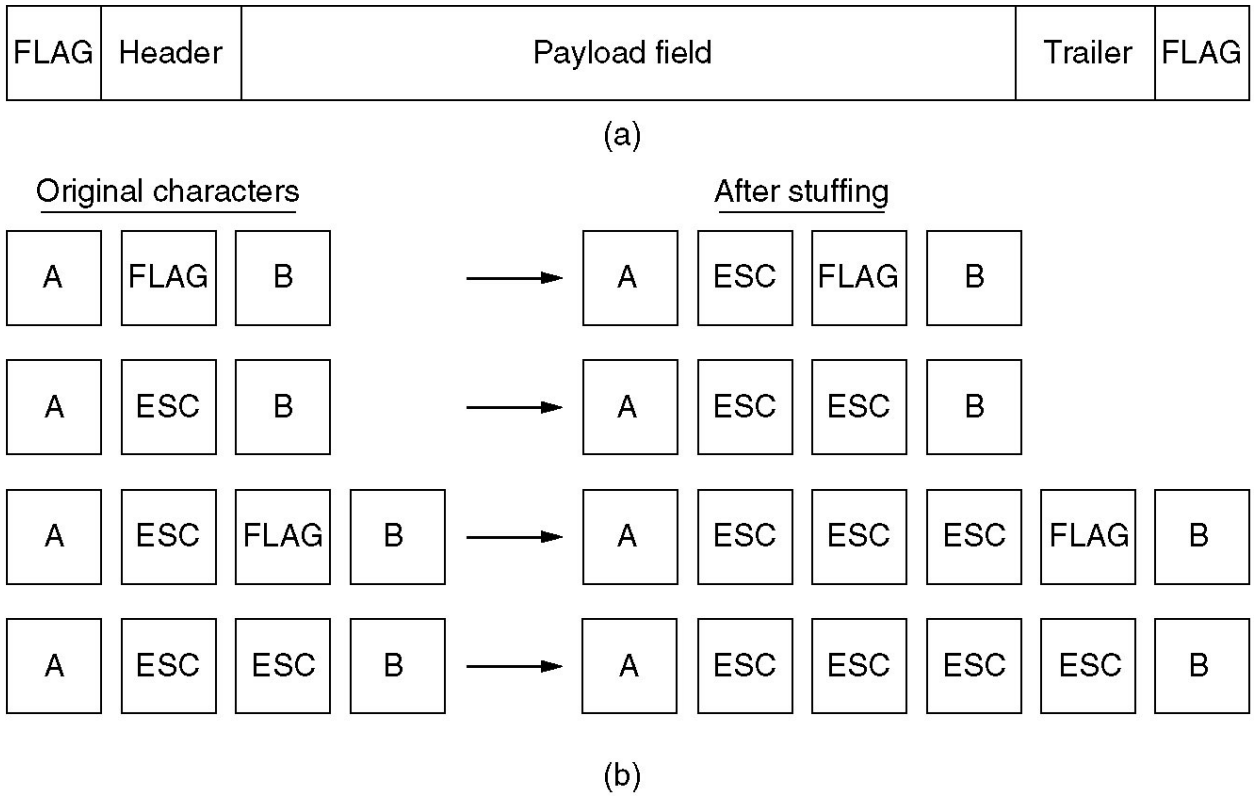
- Character count
  - Count can be garbled by a transmission error
- Starting and ending character with character stuffing
  - DLE STX for starting DLE ETX for ending
  - This sequences might be in floating point data
  - Character stuffing by two DLE for an actual DLE
- Starting and Ending flags, with bit stuffing
  - 01111110
  - When five 1s a 0 is stuffed
- Physical layer coding violations
  - Applicable when physical medium contains some redundancy

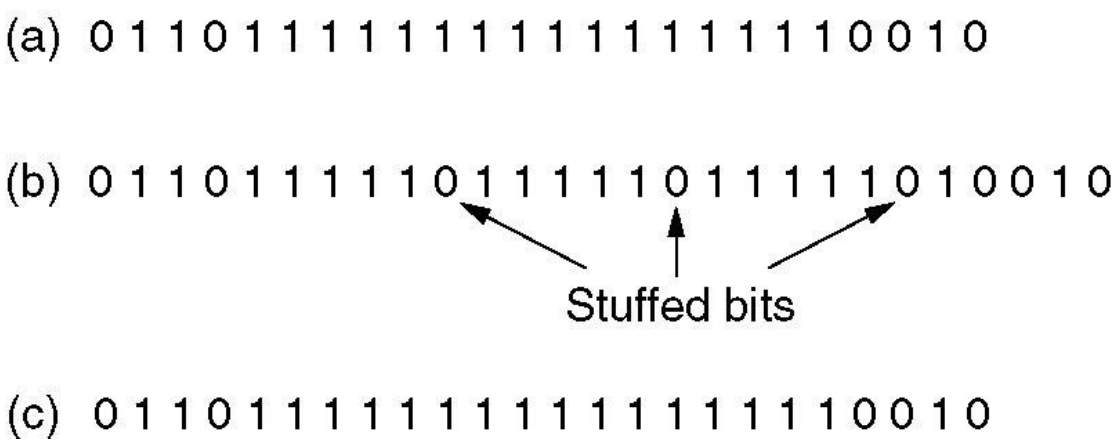
A character stream. (a) Without errors. (b) With one error.



(a) A frame delimited by flag bytes.

(b) Four examples of byte sequences before and after stuffing.





Bit stuffing

(a) The original data.

(b) The data as they appear on the line.

(c) The data as they are stored in receiver's memory after destuffing.

Error Control

- Ack is the solution
- A frame is sent and sender waits for Ack
- If Ack is not back within the deadline
  - Retransmission occurs
  - Not an infinite number of transmission
  - Detection of Receiver problem
- Sequence numbers for preventing duplications

Flow Control

- Sender is faster than Receiver
- Flow control to throttle the sender
- Sender must know whether the receiver is ready
- May be some receiver window of particular size

Error Detection and Correction

Hopefully Already Studied in other Courses

Elementary Data Link Protocols

- DLL accepts a packet from the network layer
- Frames are created
  - By adding header and trailer
  - Header : *frame_kind*, *seq_nr*, *ack*
- Frame is sent to the destination by calling *to_physical_layer*( )

Elementary Data Link Protocols

- *wait_for_event*( ) is waiting in the receiver of DLL for the frames
- *from_physical_layer* ( ) extracts the frame
- Checksum is computed
- The frame is sent to the Network layer of receiver
- An Ack is sent to the sender of DLL

Elementary Data Link Protocols

- Sender waits for Ack from receiver
- Retransmits the frame
  - If time out occurs
- The Seq number
  - 0 to MAX_SEQ (inclusive)
  - Incremented after each frame transmission

Sliding Window Protocols

- Features
  - Piggybacking
  - Sequence Number for each frame
  - Windows for sender and receiver
- Examples
  - A One-Bit Sliding Window Protocol
  - A Protocol Using Go Back N
  - A Protocol Using Selective Repeat

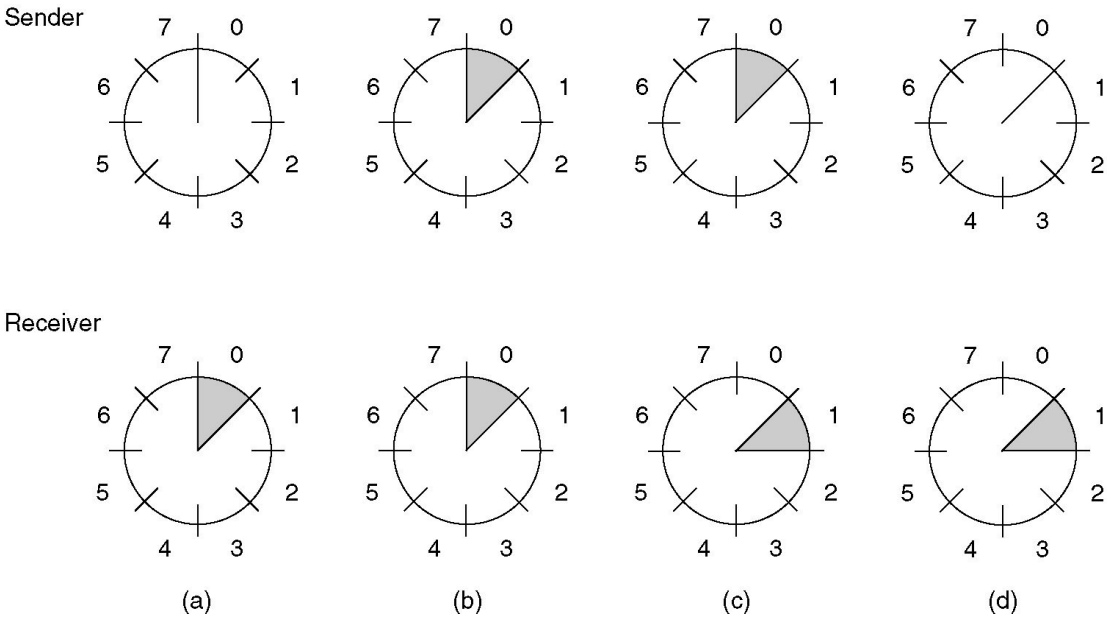
Piggybacking

- ACK frames consume lots of BW
- ACK frame gets a free ride on the data frames
- Takes time if receiver has no data frames
  - Causes lots of retransmission
  - Should not wait for free ride

Windows

- Seq number 0 to 2^n-1
- If n=1 then two Seq Number 0 and 1
  - Called Stop and Wait Protocol
- Sending Window
  - The frames are being sent
  - Needs buffer to hold frames
- Receiving Window
  - permitted frames to accept

Example of Sliding Window Protocols



A sliding window of size 1, with a 3-bit sequence number.

(a) Initially.

(b) After the first frame has been sent.

(c) After the first frame has been received.

(d) After the first acknowledgement has been received.

Why Window?

- Prevents Duplication of packets in the network Layer
- ACK can be destroyed
- Frames will be retransmitted
- The Receiver must discard those duplication

One Bit Sliding Window Protocol

- Stop and Wait Protocol
- Sender Window
  - *Next frame to send* (A variable)
  - Initially 0
- Receiver Window
  - *Frame expected* (A variable)
  - Initially 0

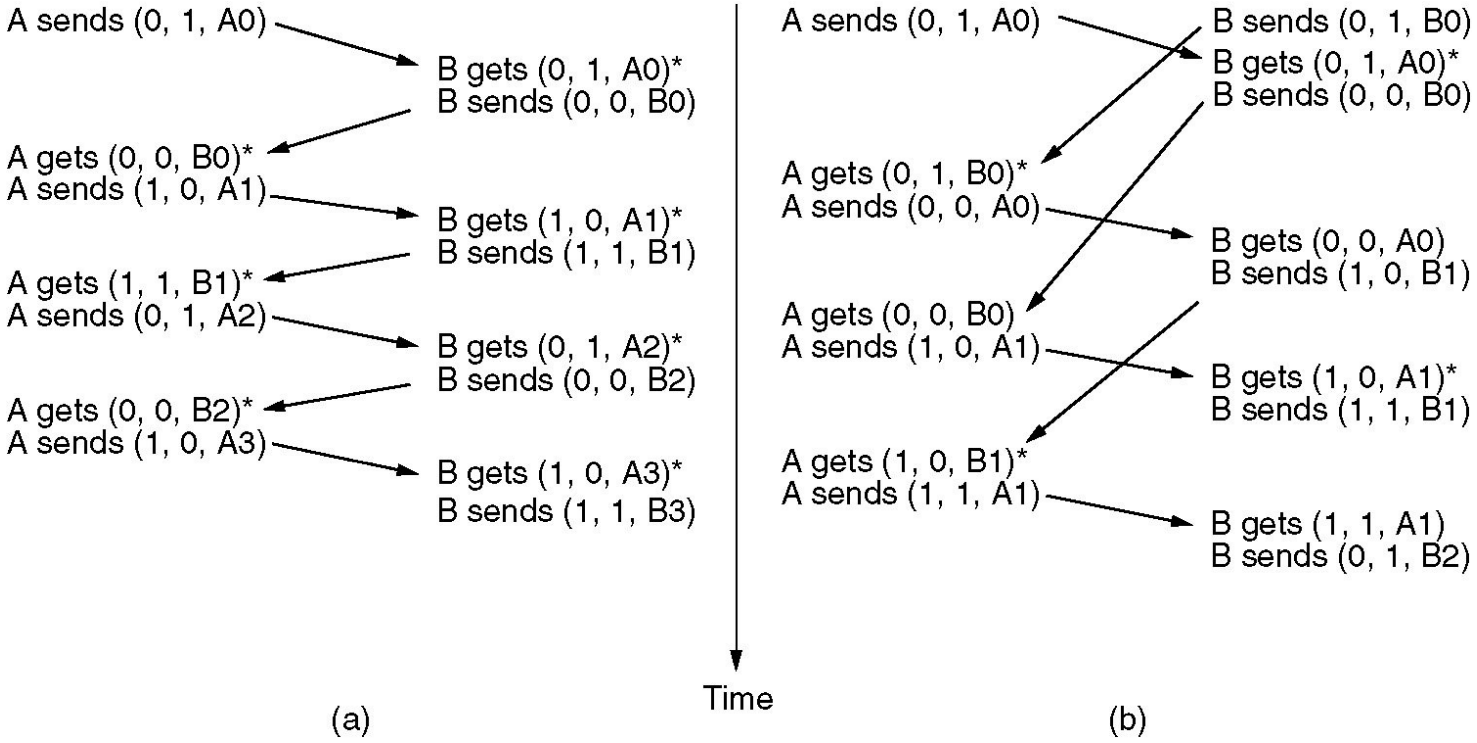
One Bit Sliding Window Protocol

- *Seq* = *Next_frame_to_send*
- *Ack* = *Inverse* (*frame_expected*), I.e., previous received frame without error
- incoming frame is accepted if
  - *Seq* = = *frame_expected*
  - *frame_expected* is incremented
- New Frame is Sent if
  - *Ack* = *Next_frame_to_send*
  - *Next_frame_to_send is incremented*
  - New frame is brought from Network Layer

Scenario of One Bit Sliding Window Protocol

- When Sender and Receiver starts simultaneously
  - Initially *seq*=0 and *ack* =1
- Peculiar situation if both side sends initial packet
  - Duplication of each frame
  - Does not make any disaster

Scenario One-Bit Sliding Window Protocol (2)



Two scenarios for protocol (a) Normal case. (b) Abnormal case. The notation is (seq, ack, packet number). An asterisk indicates where a network layer accepts a packet.

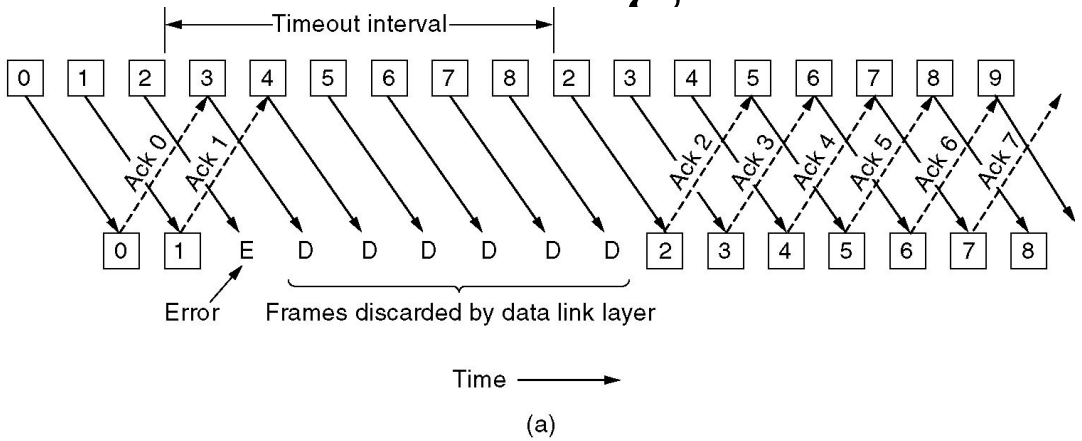
Larger Window Size

- One bit Sliding Window is costly
  - When large propagation delay
  - Sender window should be bigger
- Pipelining technology should be used
  - 50% efficiency can be achieved
  - 50% loss for Acks
  - Two Approaches when error occurs

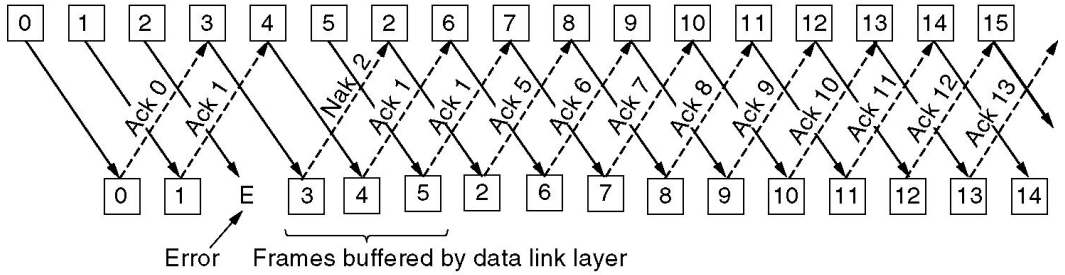
Go Back n

- Consecutive frames are discarded
- Timeout occurs
- Retransmission of all the frames from the lost frame
- Channel bandwidth is not utilized

A Protocol Using Go Back N



(a)



(b)

Pipelining and error recovery. Effect on an error when

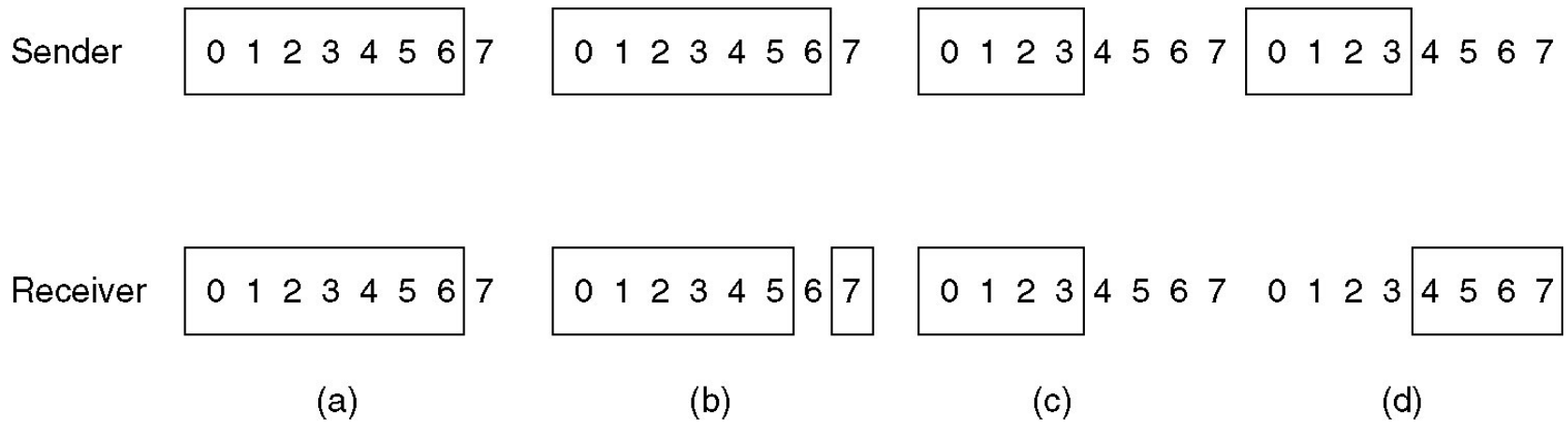
(a) Receiver's window size is 1.

(b) Receiver's window size is large.

Selective Repeat

- Only the corrupted frame is discarded
- Good frames are accepted and buffered but not sent to network layer
- Only the last frame accepted by Net Layer is Acknowledged
- Timeout and retransmission of the faulty packet only

Scenario of A Sliding Window Protocol Using Selective Repeat



(a) Initial situation with a window size seven.

(b) After seven frames sent and received, but not acknowledged.

(c) Initial situation with a window size of four.

(d) After four frames sent and received, but not acknowledged.

Problem in Selective Repeat

- Maximum window size: MAX_SEQ
- Seq Numbers : 0 to MAX_SEQ
- A Faulty Scenario
  - Sender send 0 to 7
  - Gets all Acks, Again sends 0 7
  - Gets an Ack of 7
  - Which 7 is it? Might be for the first batch if all frames are lost
- Should be from 0 to 6

More Problems

- Problems for Non Sequential Receipt of frames
  - Sender Sends 0 to 6
  - Receiver gets everything
  - Receiver is ready to get 7,0….5
  - All acks lost
  - Retransmission of 0 frame of first batch
  - Will be accepted as 0 frame of 2^{nd} batch

Solutions

- Should not be any overlapping
- Window Size (MAX_SEQ+1)/2
- Windows are
  - 0 to (MAX_SEQ+1)/2-1
  - (MAX_SEQ+1)/2 to MAX_SEQ

Negative Ack

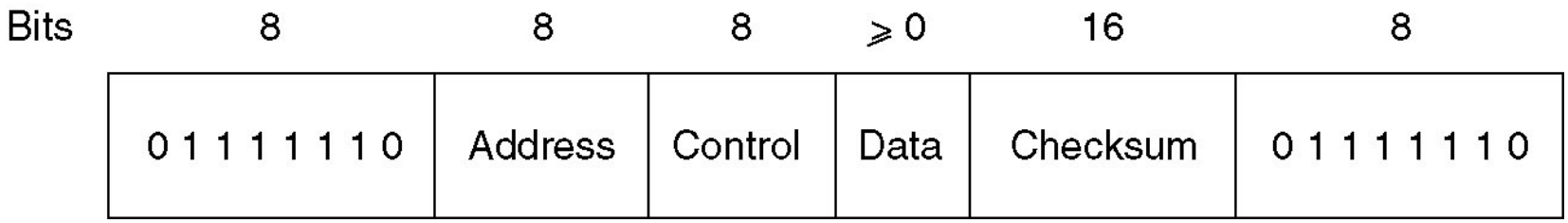
- Notifies the incorrect frames
- Retransmission if NO_ACK is received
- Saves Channel Bandwidth
  - As the sender does not wait for retransmission

Example Data Link Protocols

- HDLC – High-Level Data Link Control
- The Data Link Layer in the Internet
  - –PPP

High-Level Data Link Control

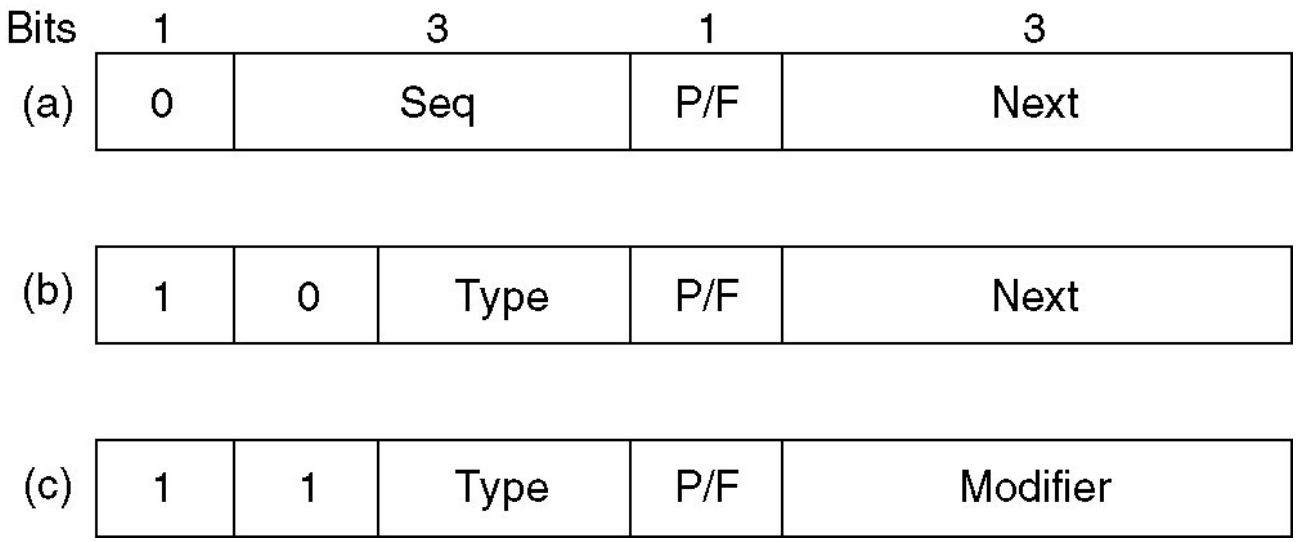
Frame format for bit-oriented protocols.



Fields of HDLC protocol

- The frame is started and delimited by 01111110.
  - Bit stuffing is used if the sequence is present in the payload
- Address field is not desired as it is a protocol between two single connected entities
  - Required when several terminals are connected with the server
- Control field
  - Seq number, type and ack
- Data field may contain any number of bytes
  - Large data means degraded performance of checksum (CRC coding)

Control Frame of HDLC



Control field of

(a) An information frame.

(b) A supervisory frame.

(c) An unnumbered frame.

Details of Control Fields

- Sequence number is 3 bit
- Next field is the acknowledgement
  - May be piggybacked or not
  - May be the last frame number received
  - Or, the frame expected
- P/F bit is for polling the other party for sending information
  - The computer is polling the terminal by setting P/F as P
  - The terminal will send back the required data
    - The terminal data frame will be with F set.
    - Other frames will contain P/F set as P.

Supervisory frame

- Use of P/F bit when the sender requires Ack
  - Receiver will not wait for reverse traffic
  - The receiver will send a supervisory frame
- 4 Types of Supervisory frame
  - Type 0, Ack frame without any data, Called Receive Ready
  - Type 1, negative Ack for transmission error
  - Type 2, Receive not ready, Acks all but not including Next.
    - Asks not to send any more frame
  - Type 3, Selective reject
    - Some frames have been discarded from buffer for sudden shortage of buffer

Unnumbered Frames

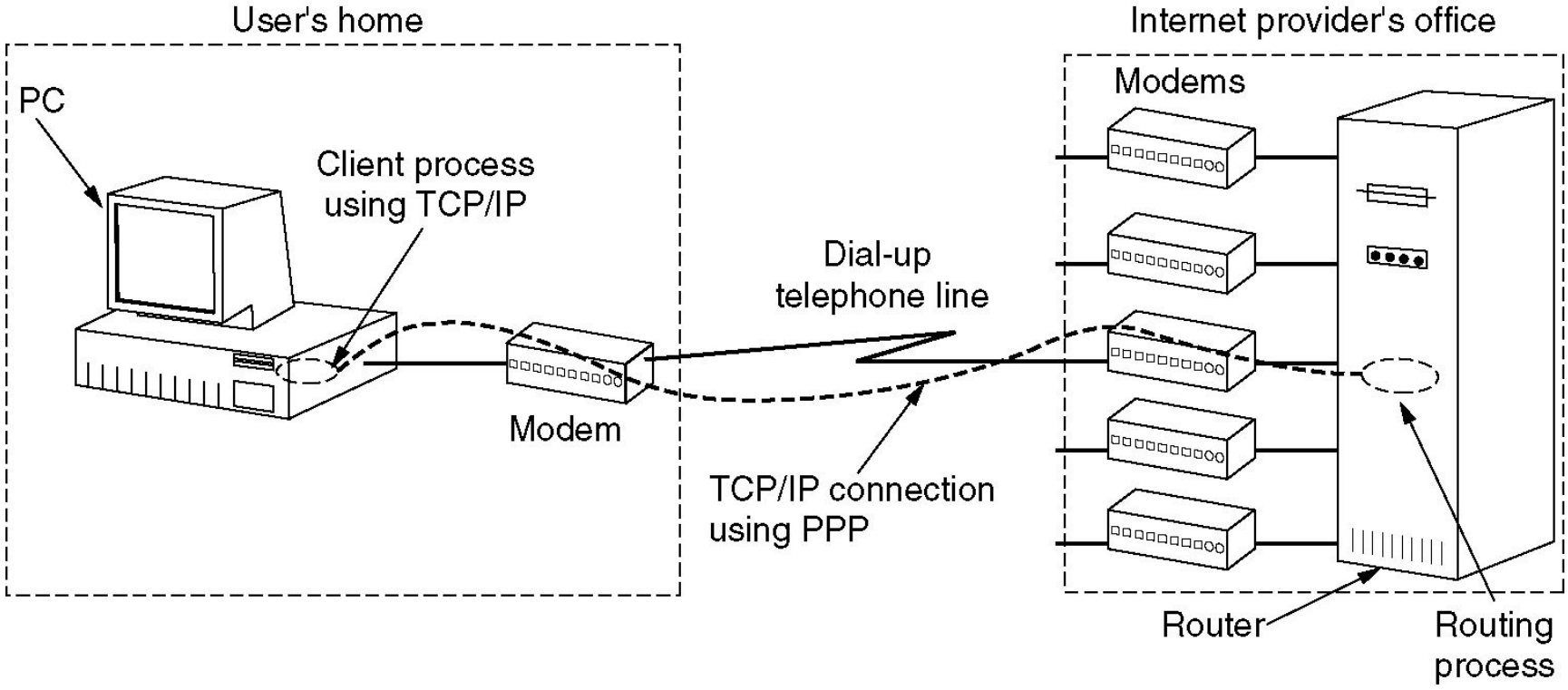
- Used for Control purpose
- Can carry data for unreliable connections
- 5 bits available, but not all are used
- Some of the examples are as follows
  - For allowing Disconnection
  - The notification for being live
  - Notification of frame rejection for unknown format
- Control frames can be lost
  - Ack is essential
  - No buffering

Motivation to Point to Point lines in the Internet

- Sometime the routers are interconnected by LAN, not PP
- Connection to the outside world
  - Through point to point leased lines
  - Communication subnet is built over the PP leased lines
- Dialing up the ISP for the Internet
  - Through modem

The Data Link Layer in the Internet

A home personal computer acting as an internet host.



Point to Point Protocol (PPP)

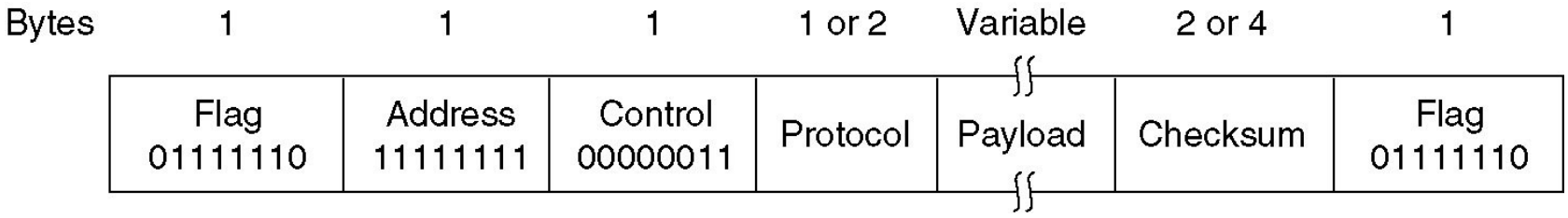
- Three features
  - Framing method
  - Link control protocol (LCP) for bringing lines
    - up
    - testing
    - Negotiating
    - Down
  - Way to negotiate network layer option
    - NCP (Network Control Protocol)
- The last two are the higher layer functionality

PPP scenario

- PC calls the providers router via modem
- Provider's modem answered and physical connection established
  - Exchanges of LCP packets
  - Selecting PPP parameters
- Now NCP packets are exchanged for setting IP addresses
  - The provider might have pool of IP adresses
- NCP tears down the connection and frees up IP address
- LCP shuts down the DLL connection
- Computer tells the modem to hang up.

PPP farme format

The PPP full frame format for unnumbered mode operation.



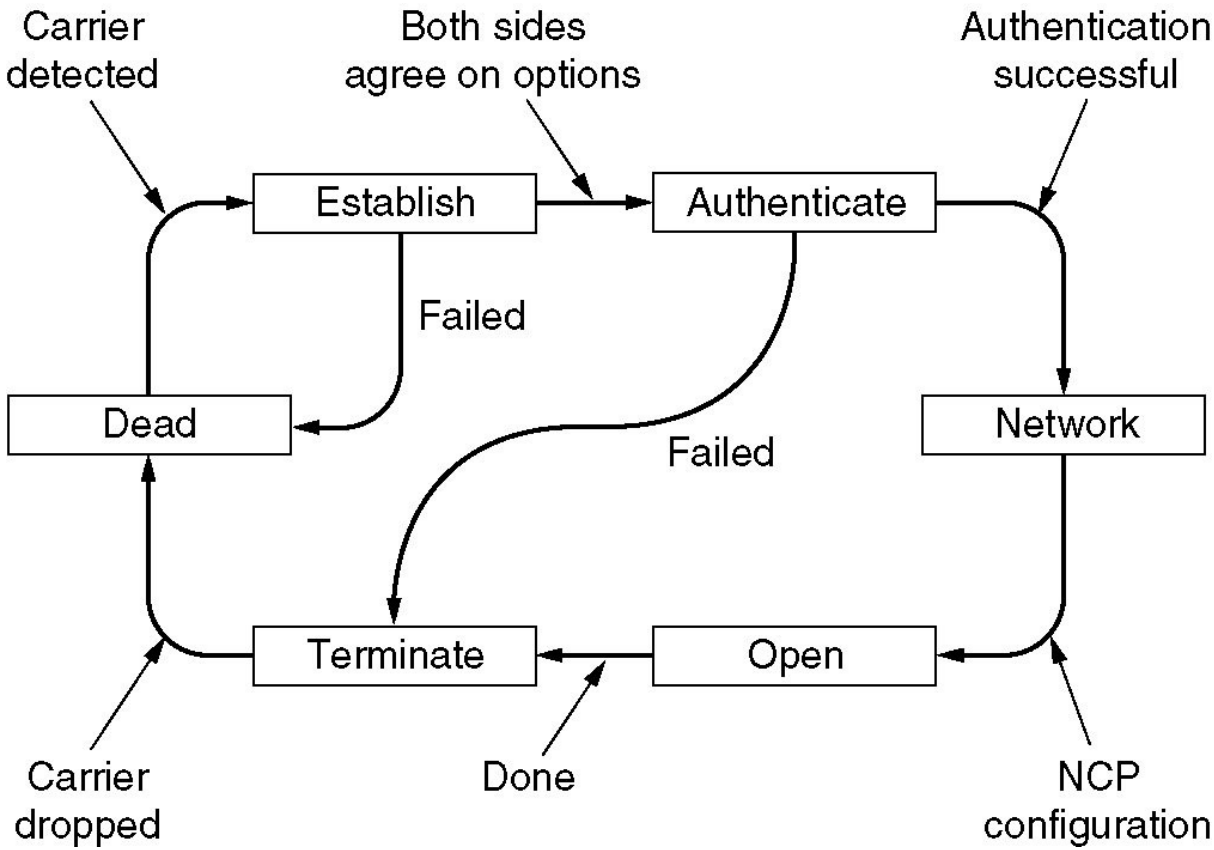
PPP frame details

- Little different from HDLC
  - Not bit oriented, character oriented
  - Byte stuffing if the starting and ending is in the data
  - Modem can send integral number of bytes
    - Fractional numbers are not allowed
- Address is always 1111111, this is for compatibility with HDLC
  - Indicates all stations will accept the data

PPP frame details (Cont.)

- Control field is the same as HDLC
  - But by default it is unnumbered, no reliable communication
  - For reliable transmission the same seq number and ack is used
- Protocol field specifies the type of payload
  - LCP, NCP, IP, IPX etc
- The length of Protocol and checksum can be negotiated down

PPP – Point to Point Protocol (2)



A simplified phase diagram for bring a line up and down.