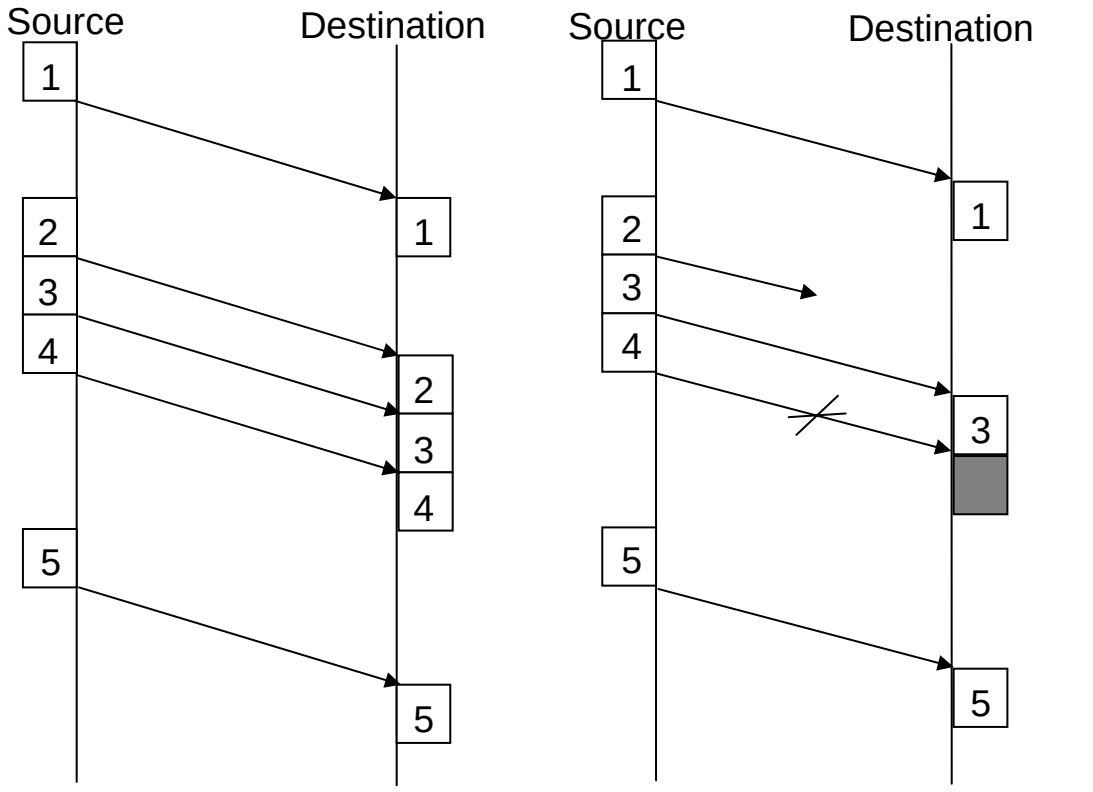
Chapter 3_2

The Data Link Layer

Error control techniques

Error control = mechanism to detect and correct errors that occur in the transmission of frames



(a) Error-free transmission

(b) Transmission with errors and losses

Error control techniques

- Error detection
- Positive acknowledgment
- Retransmission after time-out
- Negative acknowledgment

Collectively all are referred to as ***automatic repeat request*** (ARC).

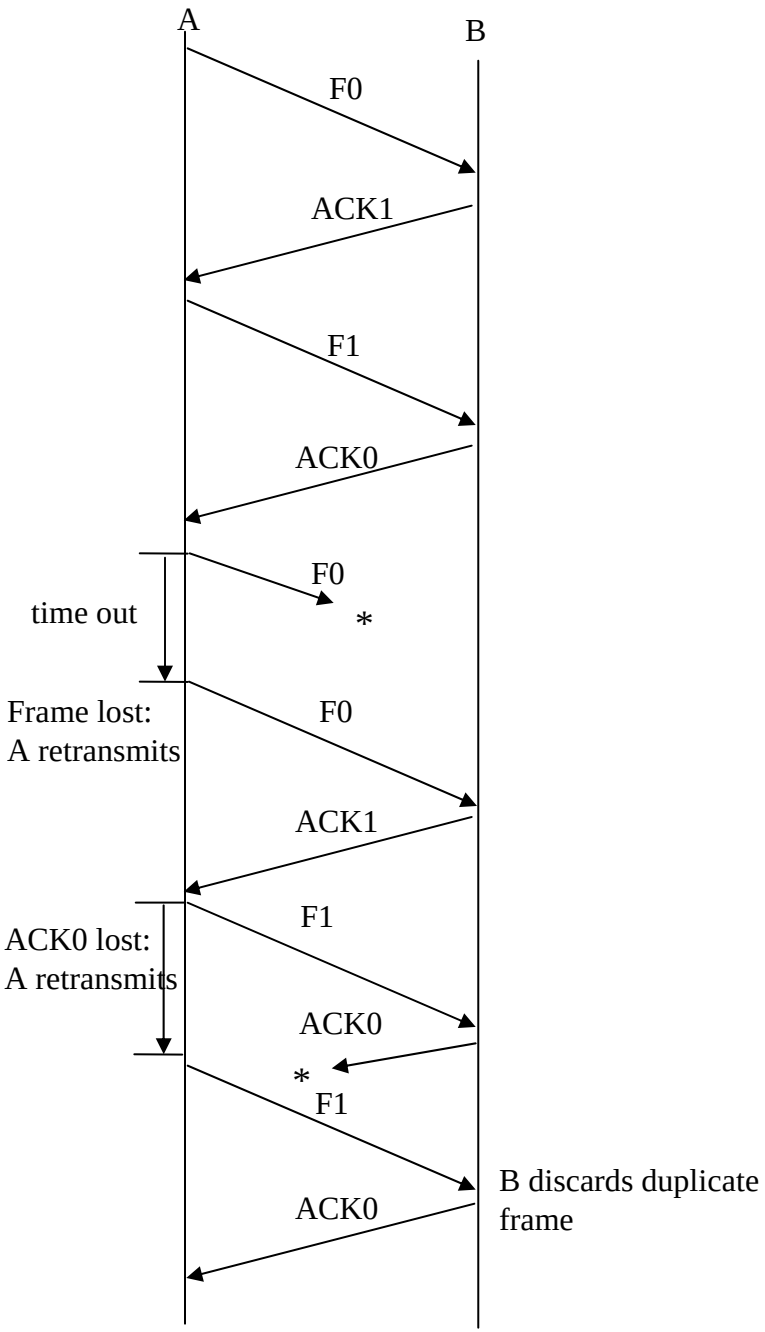
The effect of ARQ is to turn an unreliable data link into a reliable one.

Three versions of ARQ:

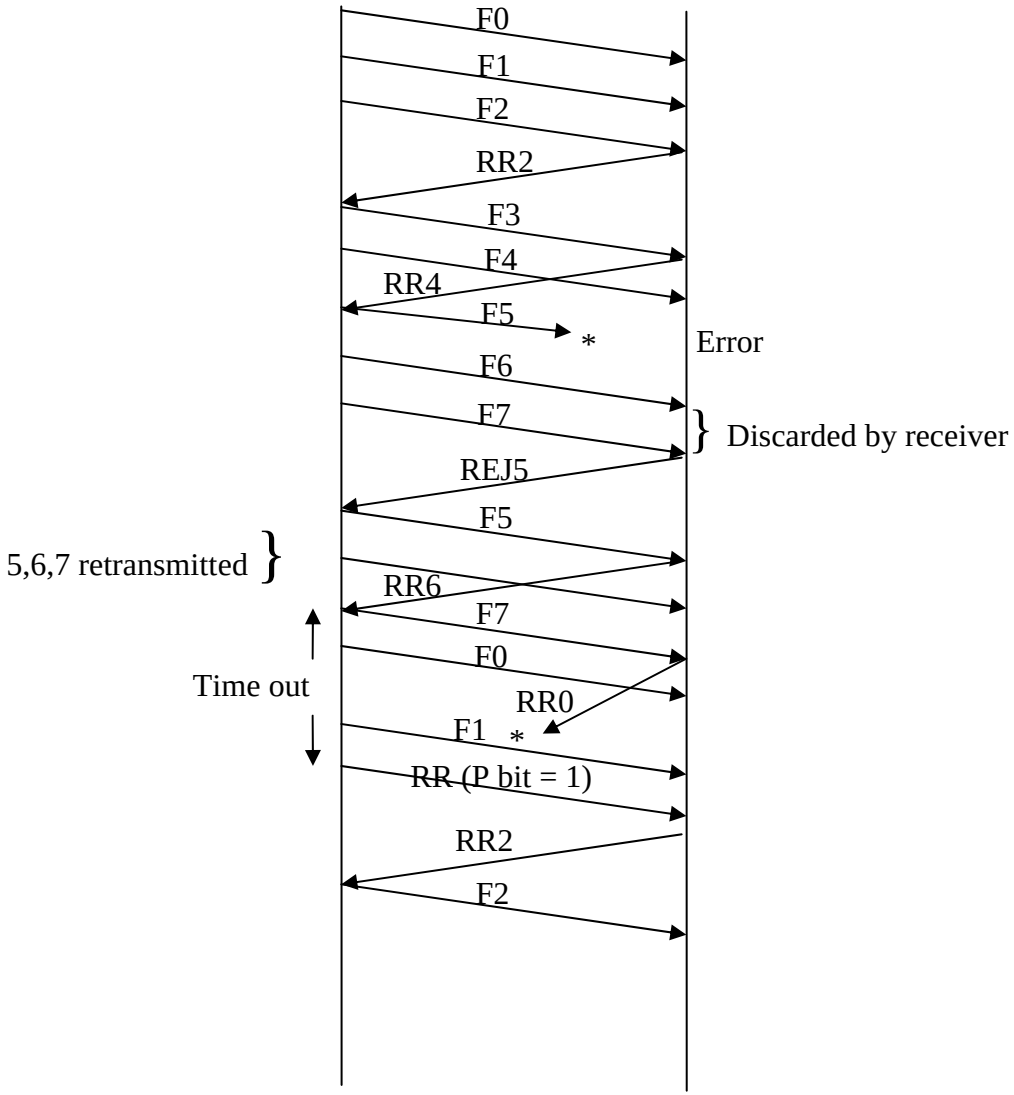
- Stop – and – wait ARQ
- Go – back – N ARQ
- Selective – reject ARQ

All are based on the flow control techniques discussed previously

Error control techniques- Stop – and – wait ARQ



Error control techniques- Go - back - N ARQ



Error control techniques- Go - back - N ARQ

Damaged frames

a) ***Receiver detects error in frame i***

- A transmit frame i
- B detects an error and has previously successfully received frame (i-1)
- B sends REJ i
- when A receives the REJ it must retransmit frame i and all subsequent that it has transmitted since the original transmission of frame i

b) ***Receiver sends rejection - i***

- frame i is lost in transit. A sends frame (i+1), B receives frame (i+1) out of order and sends REJ i. A must retransmit frame i and all subsequent frames.

c) ***Transmitter gets rejection-i***

- frame i is lost in transit and A does not soon send additional frames
- B receives nothing and returns neither an RR nor an REJ
- when A's timer expires, it transmit an RR frame that includes a bit known as the P bit which is set to 1
- B interprets the RR frame with a P bit of 1 as a command that must be ack. by sending an RR including the next frame that it expects
- when A receives the RR, it retransmits frame i.

Error control techniques- Go - back - N ARQ

Damaged RR

- a) – b receives frame i and sends RR (i+1) which is lost in transit
- b) if A's timer expires it retransmit an RR command as in the case 1c. It sets another timer, called the P bit timer. If B fails to respond to the RR command, or if its response is damaged, the A's P bit will expire.
- A will try again by issuing a new RR command and restarting the P-bit timer. This procedure is tried for a no of iterations.
- If a fails to obtain an ack after some maximum no of attemps it initiate a RESET PROCEDURE

DAMAGED REJ

If an REJ is lost this is equivalent to case 1c.

The transmitter must keep a copy of all unacknowledged frames.

Error control techniques- Selective – reject- ARQ

OBS

- the only frames retransmitted are those that:
  - receive a negative ack – called SREJ;
  - or that time-out.
- more efficient than go-back-N: it minimizes the retransmissions;
- the receiver must maintain a buffer large enough to save post - SREJ frames until the frame error is retransmitted; It must contain logic for reinserting that frame in the proper sequence.

High- Level Data Link Control (HDLC)

HDLC - ISO 33009, ISO 4335

- basis for other important data link protocols
  - same or similar format
  - same mechanisms

Basic characteristics

Stations types:

- primary station:
  - controls the operation of the link
  - frames issued are called commands
- second station:
  - operates under the control of primary station
  - frames issued are called responses
  - primary maintains a separate logical link with each secondary station on the line;

High- Level Data Link Control (HDLC)

- combined station:
  - combines the features of primary and secondary;
  - may issues both commands and responses;

Link configurations:

- unbalanced configuration:
  - one primary and one or more secondary stations
  - supports both: full-duple and half-duplex transmission
- balanced configuration:
  - 2 combined stations and supports both: full-duple and half-duplex

Data transfer modes:

- Normal response mode (NRM)
- Asynchronous transfer mode (ABM)
- Asynchronous response mode (ARM)

High- Level Data Link Control (HDLC)

NRM - used with an unbalanced configuration

- the primary may initiate data transfer to a secondary
- secondary may only transmit data in the response to a command

NRM used:

- on multidrop lines
- on point-to-point links: particularly if the link connect a terminal or other peripheral to a computer

ABM - used with a balanced configuration;

- either combined stations may initiate transmission without receiving permission from the other combined station;
- most widely used
- makes more efficient use of a full-duplex point-to-point link

High- Level Data Link Control (HDLC)

ARM

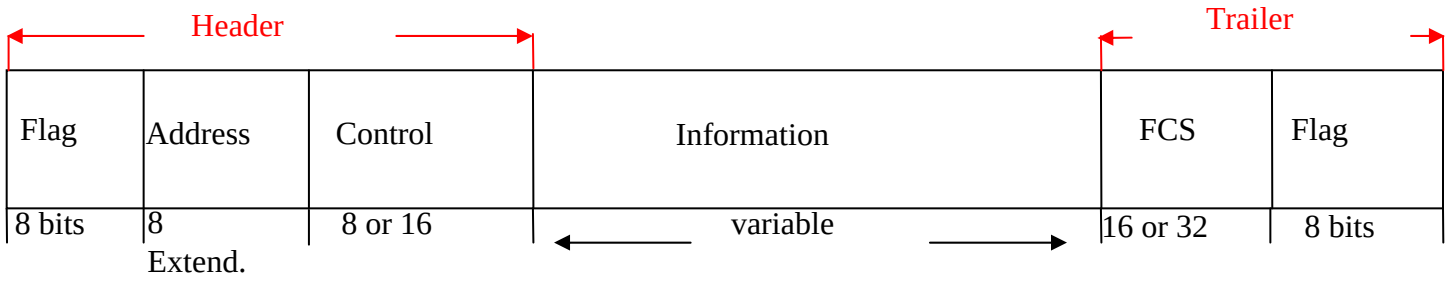
- used with an unbalanced configuration
- the secondary may initiate transmission without explicit permission of the primary
- the primary still retains responsibility for the line, including:
  - initialization
  - error recovery
  - logical disconnection
- rarely used: applicable to some special situations in which a secondary may need to initiate transmission

High- Level Data Link Control (HDLC)

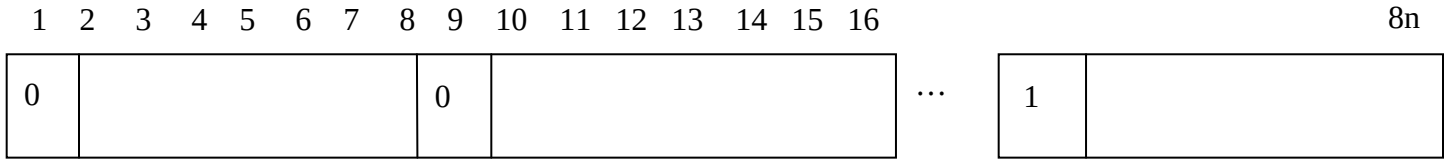
Frame structure

HDLC: uses synchronous transmissions

- all transmissions are in the form of frames
- a single frame format for all types of data and control exchanges

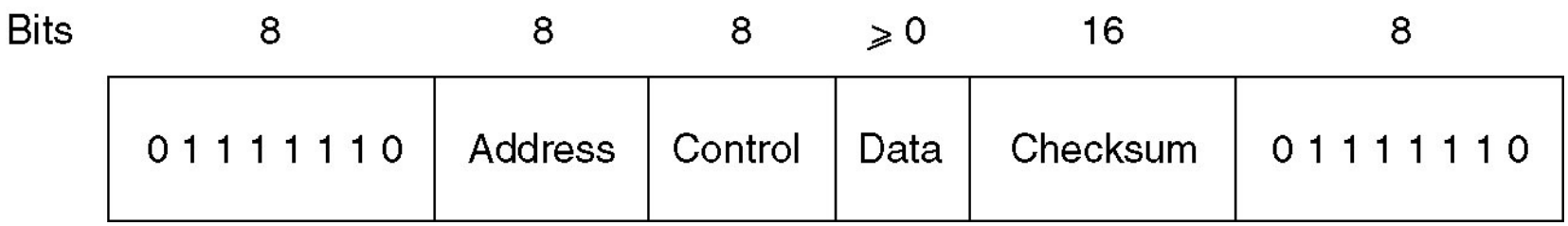


(a) Frame format



(b) Extended address field

High-Level Data Link Control



Frame format for bit-oriented protocols.

High- Level Data Link Control (HDLC)

Flag fields

- delimits the frame at both ends: 01111110
- a single flag may be used as the closing flag for one frame and the opening for the next
- synchronize of receivers at both sides
- bit stuffing procedure – arbitrary bit patterns inserted in the data field – data transparency

Original pattern

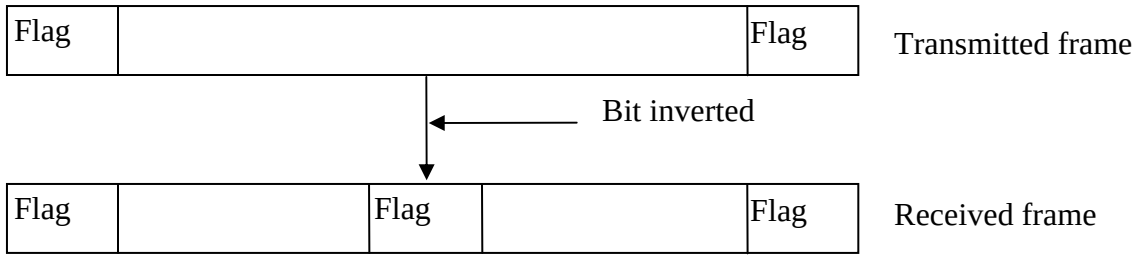
111111111111011111101111110

After bit - stuffing

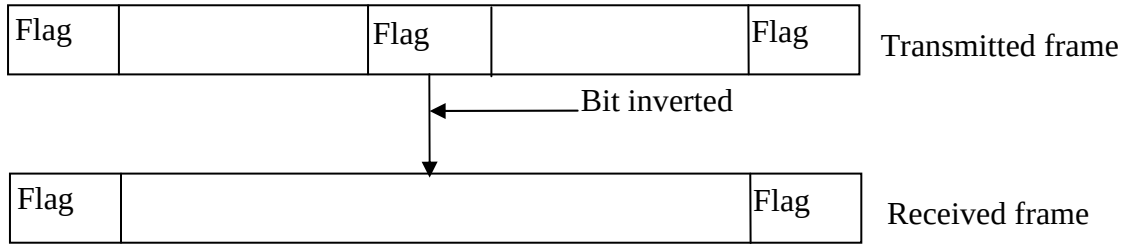
1111101111110110111110101111010

(a) Example

High- Level Data Link Control (HDLC)



(b) An inverted bit splits a frame in two



(c) An inverted bit merges two frames

Address field

- identifies the secondary station that transmitted or is to receive the frame;
- not needed for point-to-point link
- usually of 8 bits long – extended format: multiple of 7 bits
- the least significant bit
  - = 1: it is the last octet of the address field
  - = 0: it is not the last octet of the address field
- the single octet address: 11111111 = the all stations address in both classic and extended format – *Used to allow the primary to broadcast a frame for reception by all secondaries.*

High- Level Data Link Control (HDLC)

Control field

Information frames (I - frames)

- carry the data;
- flow and error control – ARQ;

Supervisory frames (S – frames)

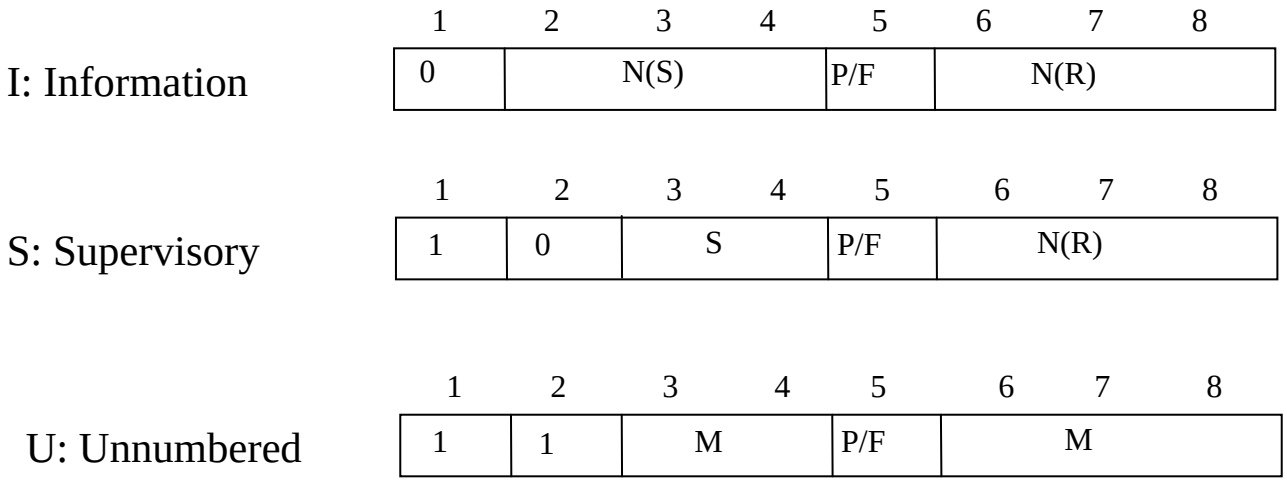
- provide the ARQ mechanism when piggybacking is not used;

Unnumbered frames (U -frames)

- provide supplemental link control functions
- bits to identify the frame type
- subfields

Note
- the basis control field for S- and I- frames uses a 3 - bit sequence numbers; extended control field format: 7 – bit sequence numbers
- U – frames always contain an 8 – bit control field

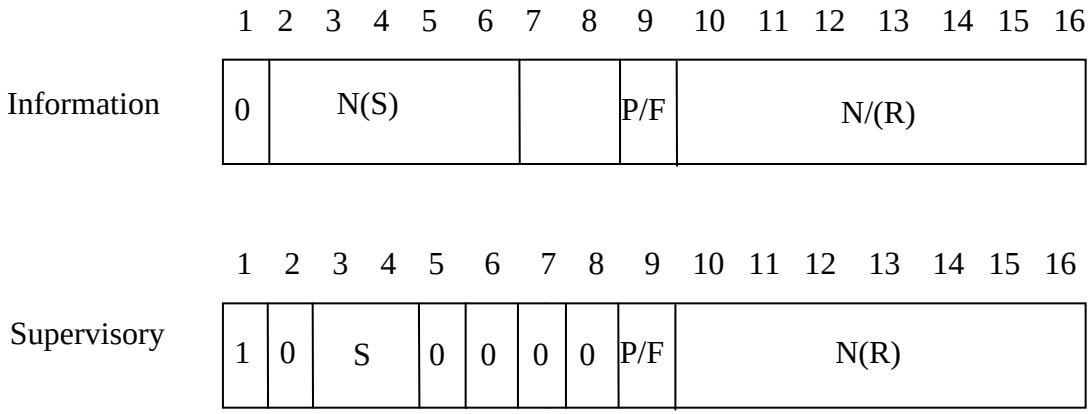
High-Level Data Link Control (2)



c) 8-bit control field format

Legend:
N(S) = Send sequence number
N(R) = Receive sequence number
S = Supervisory function bit
M = Unnumbered function bits
P/F = Poll/final bit

High-Level Data Link Control (2)



(d) 16 – bit control field format

High- Level Data Link Control (HDLC)

Information field

Present in:

- Information frames
- Some U - frames
- integral number of octets

Frame – Check Sequence field

FCS – is an error detecting code calculated from the remaining bits of the frame, exclusive of flags

- the normal code – 16-bits CRC-CCITT;

HDLC Operation

- consists of the exchange of I – frames, S – frames, and U – frames between 2 stations;
- involves 3 phases:
  - initializing of the data link; agreement regarding the options that are to be used;

High- Level Data Link Control (HDLC)

HDLC Operation

- consists of the exchange of I – frames, S – frames, and U – frames between 2 stations;
- involves 3 phases:
  - initialization of the data link; agreement regarding the options that are to be used;
  - exchanges of users data and control information
  - termination of the operation

Initialization – 6 set - mode commands

Purposes:

- It signals the other side that initialization is requested;
- It specifies which of 3 modes (NRM, ABM, ARM) is requested;
- It specifies whether 3 - or 7 – bit sequence no are to be used.

Responses

- unnumbered ACK (UA);
- disconnect mode (DM).

Name	Command/ response	Description
Information (I)	C/R	Exchange user data
Supervisory (S)		
Receive ready (RR)	C/R	Positive acknowledgment; ready to receive I-frame
Receive not ready (RNR)	C/R	Positive acknowledgment; not ready to receive
Reject (REJ)	C/R	Negative acknowledgment; go back N
Selective reject (SREJ)	C/R	Negative acknowledgment; selective reject
Unnumbered (U)		
Set normal response/extended mode (SNRM/SNRME)	C	Set mode; extended = 7-bit sequence numbers
Set asynchronous response/extended mode (SARM/SARME)	C	Set mode; extended = 7-bit sequence numbers
Set asynchronous balanced/extended mode (SABM, SABME)	C	Set mode; extended = 7-bit sequence numbers
Set initialization mode (SIM)	C	Initialize link control functions in addressed station
Disconnect (DISC)	C	Terminate logical link connection
Unnumbered acknowledgment (UA)	R	Acknowledge acceptance of one of the set-mode commands
Disconnected mode (DM)	C	Terminate logical link connection
Request disconnect (RD)	R	Request for DISC command
Request initialization mode (RIM)	R	Initialization needed; request for SIM command
Unnumbered information (UI)	C/R	Used to exchange control information
Unnumbered poll (UP)	C	Used to solicit control information
Reset (RSET)	C	Used for recovery; resets N(R), N(S)
Exchange identification (XID)	C/R	Used to request/report status
Test (TEST)	C/R	Exchange identical information fields for testing
Frame reject (FRMR)	R	Reports receipt of unacceptable frame

High- Level Data Link Control (HDLC)

Data transfer

I - frames

- N(S) and N(R) seq no that support flow and error control
- numbered sequentially – modulo 8 or 128
- N(R) – acknowledgment for I – frames received – indicates which no I - frame is expected next

S – frames

- also used for flow and error control
  - RR (Receive ready) - frame
  - RNR (Receive not ready) - frame
  - REJ – frame initiate the go – back – N – ARQ
  - SREJ – frame initiate retransmission of just a single frame

Disconnect

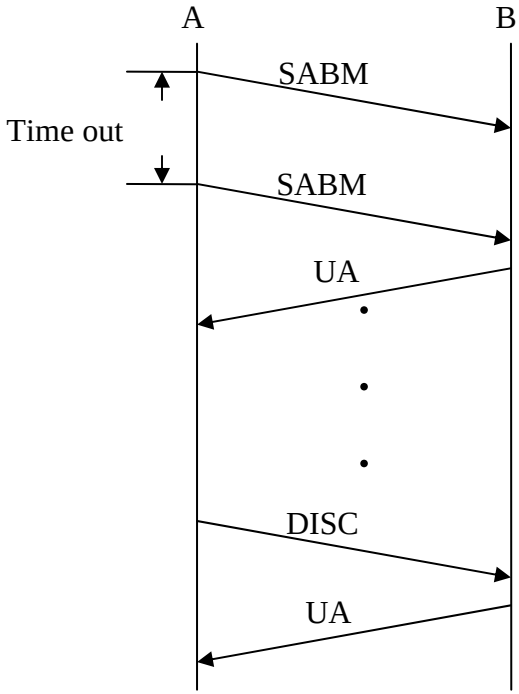
Initiated - on its own when there is a sort of fault

- at the request of the higher- level user
  - DISC – frame

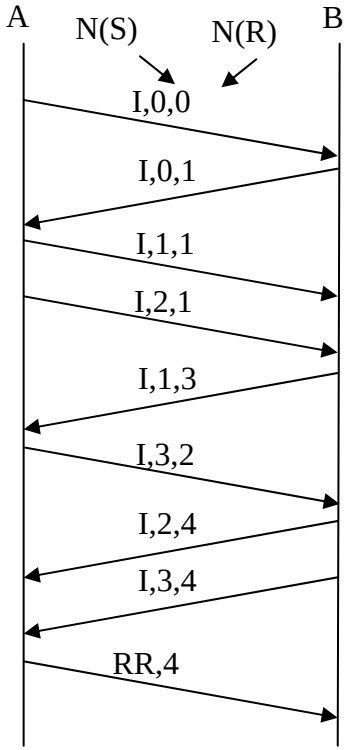
Response: - UA

High- Level Data Link Control (HDLC)

Examples of Operation



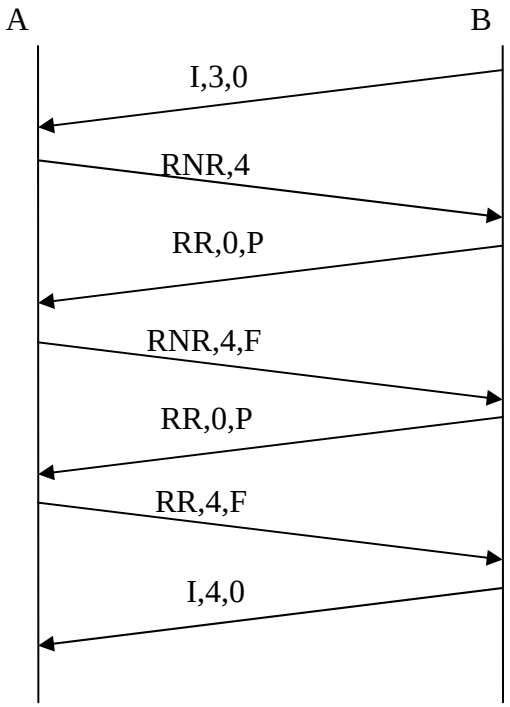
(a) Link setup and disconnect



(b) Two- way data exchange

High- Level Data Link Control (HDLC)

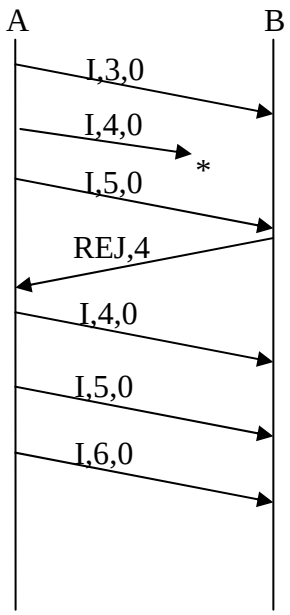
Examples of Operation



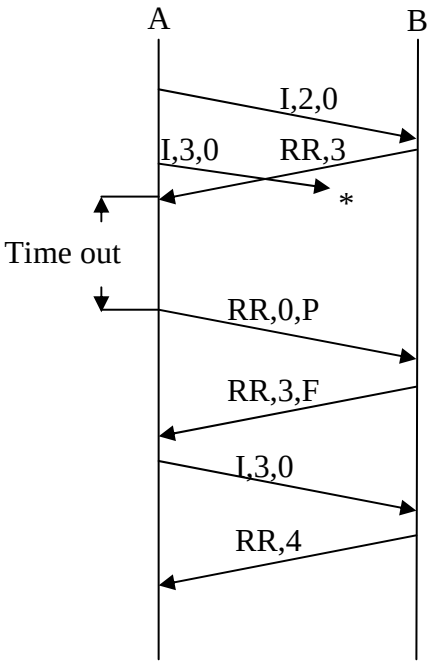
(c) Busy condition

High- Level Data Link Control (HDLC)

Examples of Operation



(d) Reject recovery



(e) Timeout recovery

Others Data Link control protocols

LAPB(Link Access Procedure Balanced)

- issued by ITU - T as part of its X25;
- a subset of HDLC that provides only the asynchronous balanced mode (ABM);
- designed for the point – to - point link between a user system and a packet-switching network node;

LAPD (Link Access Procedure, D- Channel)

- issued by ITU-T as part of its set of recommendations on ISDN;
- provides data link control over D – channel, which is a logical channel at the user – ISDN interface
- differences between LAPD and HDLC:
  - LAPD restricted to ABM
  - 7 - bit sequence no
  - 3 – bit sequence no not allowed
  - the FCS for LAPD is always the 16-bit CRC
  - the address field: contains 2 sub-addresses

Data link control frames format

Flag	Address	Control	Information	FCS	Flag
8	8n	8 or 16	Variable	16 or 32	8

(a) HDLC, LAPB

Flag	Address	Control	Information	FCS	Flag
8	8n	16*	Variable	16	8

(b) LAPD

* = 16 bit control field(7-bit sequence numbers) for I- and S-frames; 8 bit for U frames

Others Data Link control protocols

LLC(Logical Link Control)

- part of the IEEE 802 family of standards for controlling operation over a local a LAN;
- difference between LLC and HDLC:
  - in the frame format;
  - link control functions are divided in 2 layers:
    - a medium access control (MAC)
    - the LLC which operates on the top of the MAC layer

LLC offers 3 forms of service:

- the connection – mode service; the same as the ABM(HDLC)
- unacknowledged connectionless
- acknowledged connectionless

Data link control frames format

MAC control	Dest. MAC address	Source MAC address	DSAP	SSAP	LLC control	Information	FCS
Variable	16 or 48	16 or 48	8	8	16*	Variable	32

(c) LLC/MAC

Others Data Link control protocols

Frame Relay

- provides a streamlined capability for use over high-speed switched networks;

- used in place of X.25;

- the data link control defined for FRAME RELAY is LAPF(LINK ACCES PROCEDURE for FRAME-Mode Bearer Services);

- a control protocol;

- a core protocol- a subset of control protocol;

Differences :: HDLC

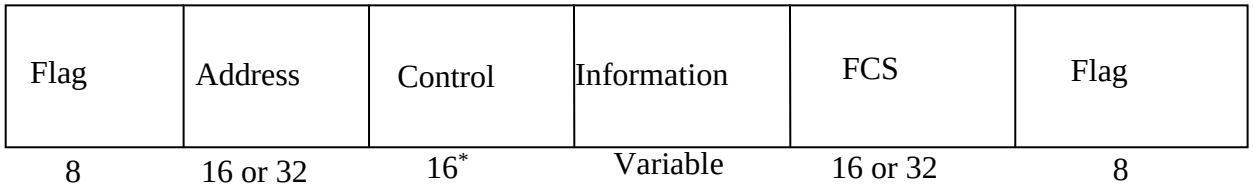
- LAPF restricted to ABM

- DLCI (Data link control identifier)

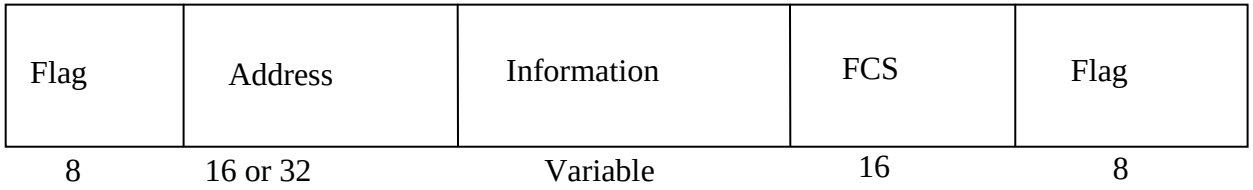
- identifies a logical connection between a source and a destination system

- the address field contains some control bits that are useful for flow control purposes

Data link control frames format



(d) LAPF (control)

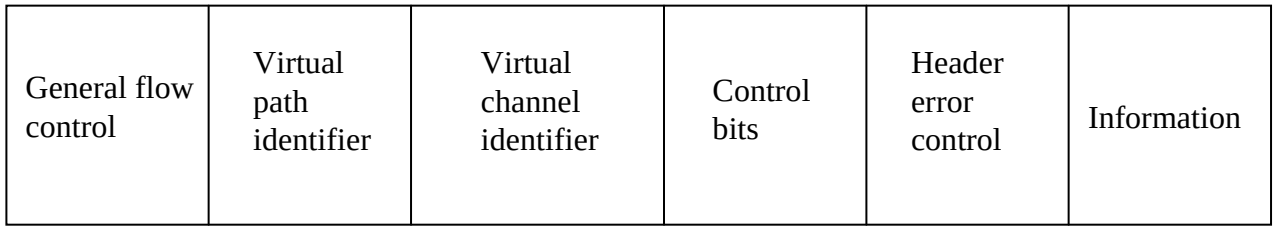


(e) LAPF (core)

* = 16 bit control field(7-bit sequence numbers) for I- and S-frames; 8 bit for U frames

Asynchronous Transfer Mode (ATM)

- provides a streamlined capability for use over high-speed networks;
- is not based on HDLC;
- a new frame format known as a cell that provides minimum processing overhead;
- the cell has a fixed length of 53 octets or 424 bits.



(f) ATM

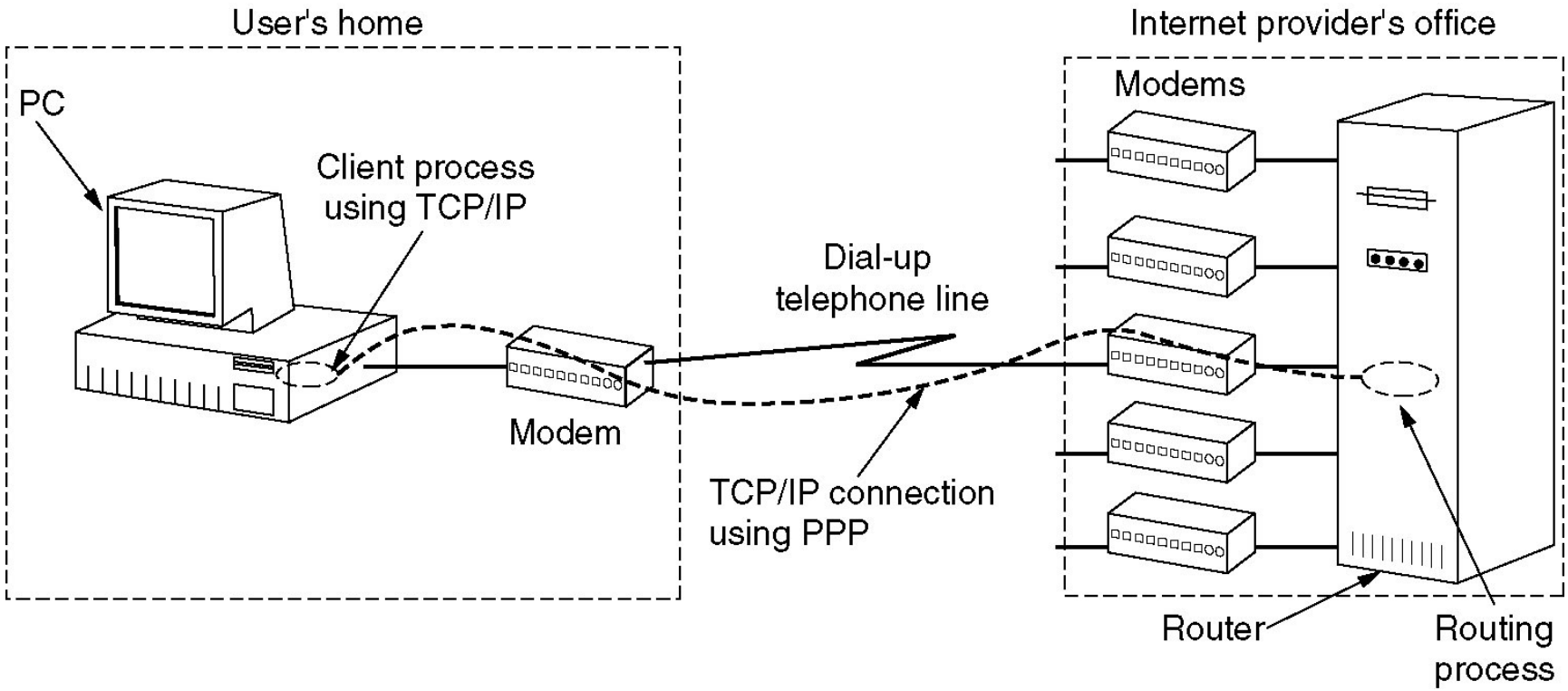
The Data Link Layer in the Internet

The wide area infrastructure is built up from point – to - point leased lines.

Point – to – point communication

- to connect subnets (router to router)
- connections to the Internet of individuals using modems and dial-up telephones lines

The Data Link Layer in the Internet



A home personal computer acting as an internet host.

PPP – Point to Point Protocol

PPP protocol defined in RFC 1661 and further elaborated in RFCs(1662,1663);

- supports multiple protocols;
- handles error detection;
- ***allows IP addresses to be negotiated at connection time***
- permits authentification

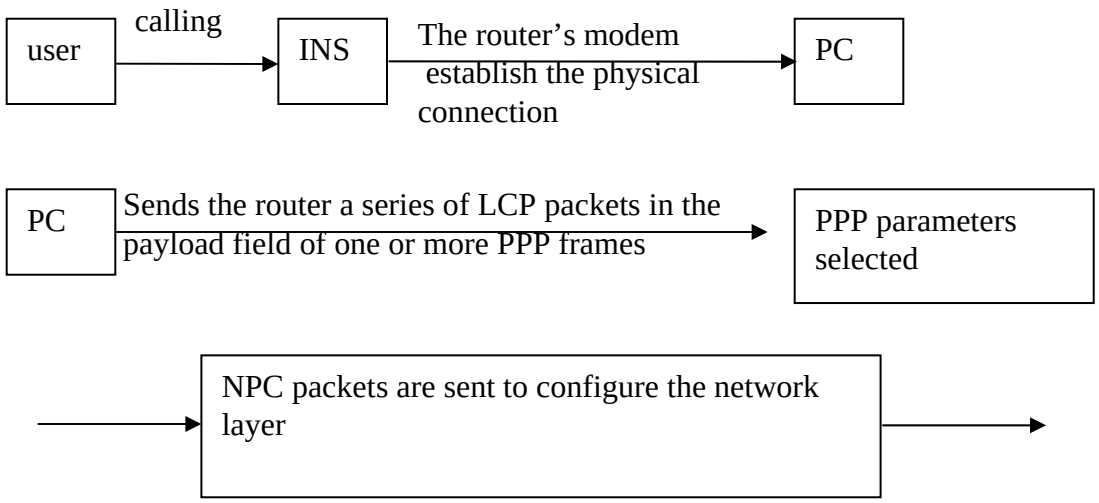
PPP provides 3 features:

1. a framing method that unambiguously delineates the end of one frame and the start of the next one;
2. a link control protocol (LCP) for:
   - bringing links up;
   - testing them, negotiating options;
   - bringing them down;
   - supports:
     - synchronous and asynchronous circuits;
     - byte – oriented and bit – oriented encodings

PPP – Point to Point Protocol (2)

PPP provides 3 features:

3. a way to negotiate network layer options in a way that is independent of the network layer protocol to be used – NCP- Network Control Protocol different for each network layer supported;

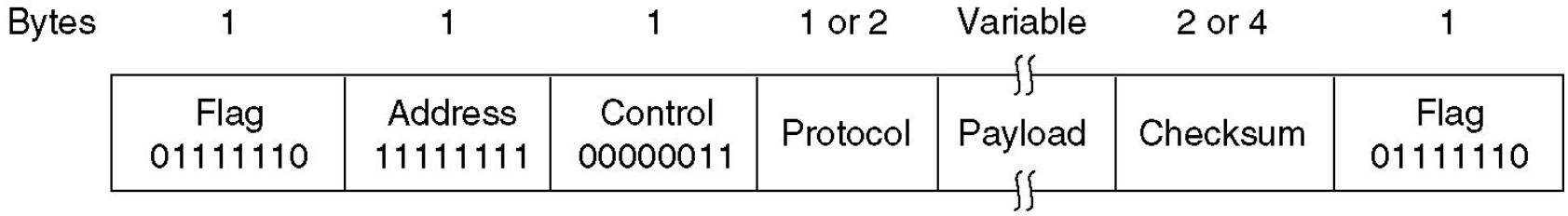


PPP – Point to Point Protocol (3)

- The PPP frame format closely resemble the HDLC frame format
- PPP is character oriented rather than bit oriented
- uses bit stuffing on dial-up modem lines,
- all frames are integral number of bytes

Can be sent over

- dial-up telephone lines
- SONET
- true bit-oriented HDLC lines (e.g. router - router connection)



The PPP full frame format for unnumbered mode operation.

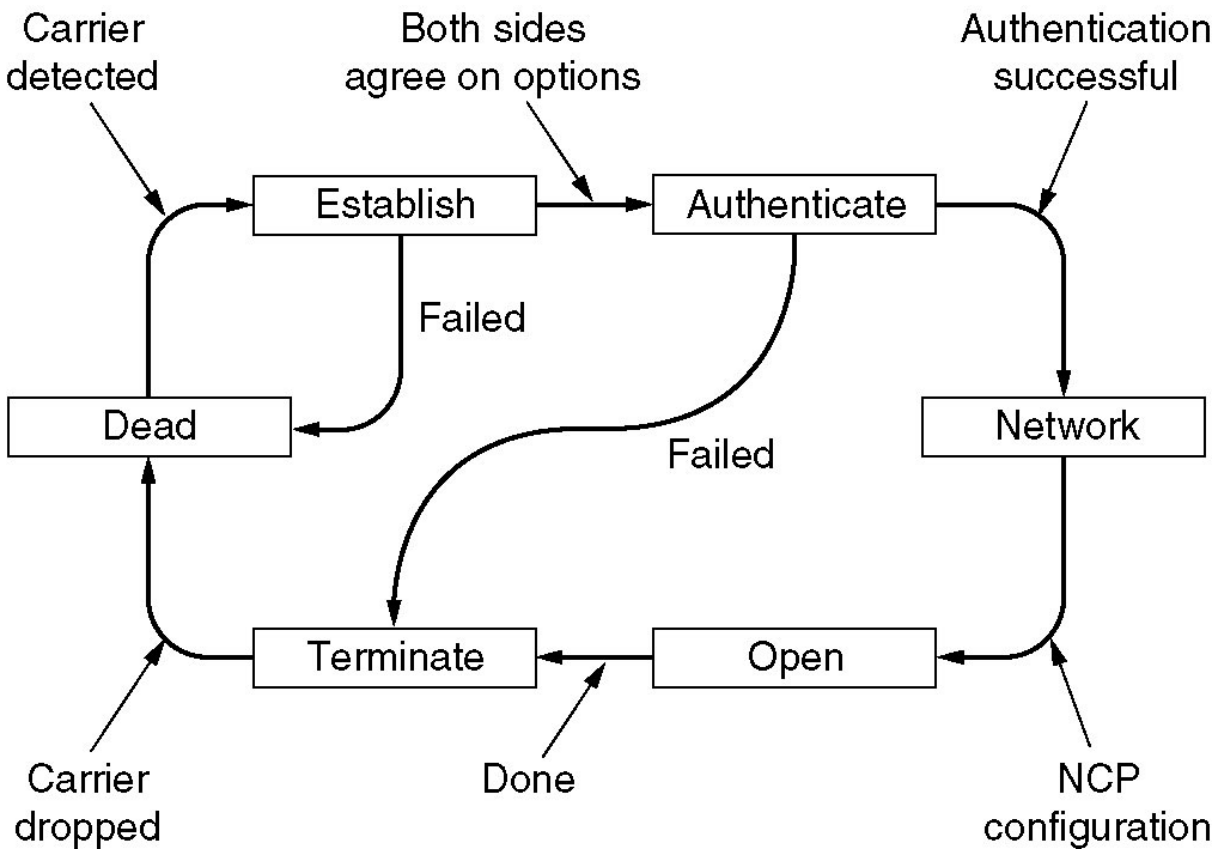
PPP – Point to Point Protocol (4)

Protocol field: what kind of packet is in the Payload field

- protocols starting with a 0 bit: network layer protocols: IP, IPX, OSI, XNS…
- protocols starting with a 1 bit: used to negotiate other protocols: LCP and a different NCP for each layer
- default size: 2 bytes

Payload field: variable length up to some negotiated maximum (default size- 1500bytes)

PPP – Point to Point Protocol (5)



A simplified phase diagram for bring a line up and down

PPP – Point to Point Protocol (6)

Name	Direction	Description
Configure-request	I → R	List of proposed options and values
Configure-ack	I ← R	All options are accepted
Configure-nak	I ← R	Some options are not accepted
Configure-reject	I ← R	Some options are not negotiable
Terminate-request	I → R	Request to shut the line down
Terminate-ack	I ← R	OK, line shut down
Code-reject	I ← R	Unknown request received
Protocol-reject	I ← R	Unknown protocol requested
Echo-request	I → R	Please send this frame back
Echo-reply	I ← R	Here is the frame back
Discard-request	I → R	Just discard this frame (for testing)

The LCP frame types