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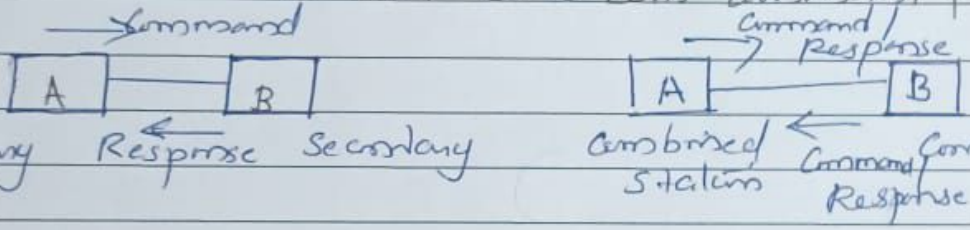
Secondary station – Secondary station operates under the control of a primary station.
- The frame sent by the secondary station are called response.

Combined station :- A combined station can act as a primary as well as secondary station.
- It can issue both command & Response.



* HDLC provides two common transfer modes that can be used in different configurations.
1) Normal response mode (NRM)
2) Asynchronous balanced mode (ABM)

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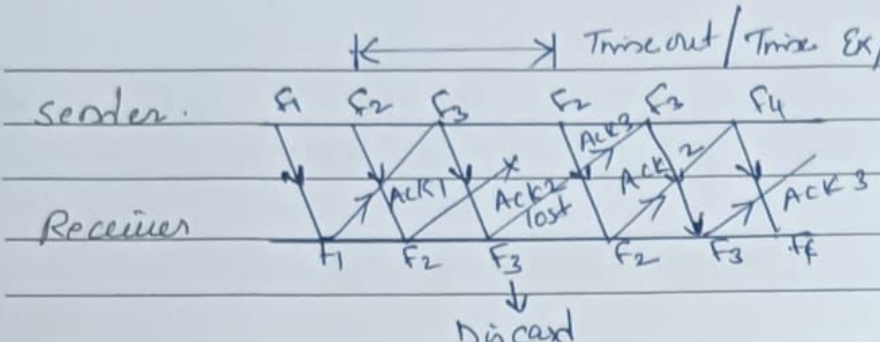
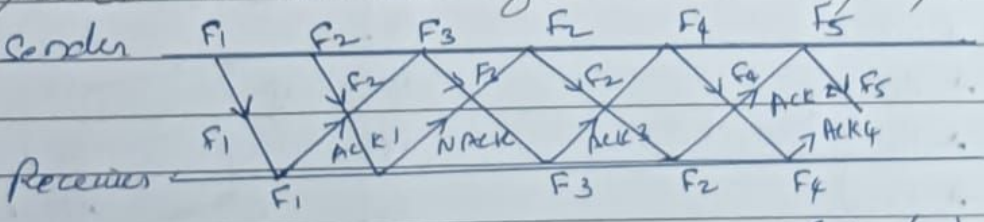


Selective Repeat ARQ.

The selective repeat ARQ scheme retransmit only those for which NAKs are received or for which timer has expired.

- Most efficient among ARQ scheme
- More complex (It can send-out of order frame also received)
- The receiver also must have storage space to store the post NAK frames and processing power to reinsert frames in proper order.



Note:

For Noiseless channel ← Simplest Stop and wait

For Noisy channel ← Stop-and-wait ARQ
Go-back-N ARQ
Selective Repeat ARQ

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Data link Protocols.

Widely used data link protocols.

- HDLC (High level - data link control)
- PPPC (Point - to point protocol)

HDLC (High level Data link control)

1st Development Flow chart (generation chart)

SDLC (IBM) (Synchronous Datalink protocol) → ADCCP (ANSI) (IInd) (Advanced Data Communication control procedure)

(Link Access procedure) LAP (CCITT) (IVth) ← HDLC (ISO) (IIIrd)

- High level - Data link control (HDLC) is a bit-oriented protocol for communication over point-to-point and multipoint links.
- HDLC developed by ISO.
- It offers a high level of flexibility, adaptability, reliability and efficiency of operation.

Note :-
* Bit-oriented Protocol is a communn protocol, that sees the transmitted data as stream of bits.

- Three types of stations have been defined in HDLC,
  1) Primary Station 2) Secondary station 3) Combined station

Primary Station - The primary station has a responsibility of connecting and disconnecting the data link.

- The frames sent by a primary station are called commands.

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Piggy Backing.

The three protocols (stop-and-wait, Go-back-N & selective repeat are all unidirectional

- Data frame flow in only one direction although control information such as Ack and NAck frames are travel in other direction (Full duplex).
- In real life, data frames are normally flowing in both directions.
- A technique called piggy backing is used to improve the efficiency of bidirectional protocols.
- Full duplex transmission can achieve by using separate two channel this will waste the bandwidth, here is the importance of piggy backing.
- When data frame arrives, the receiver waits & doesn't send control (acknowledgement) frame back immediately.

The receiver waits until its network layer passes data on information to data link layer. The acknowledgment is then attached to this outgoing data frame.

- This technique in which the outgoing acknowledgment is delayed temporarily is called piggy backing.
- In Go-back-N ARQ, each node have two windows.
  - One send window & One receive window
  - Both need to use a timer.

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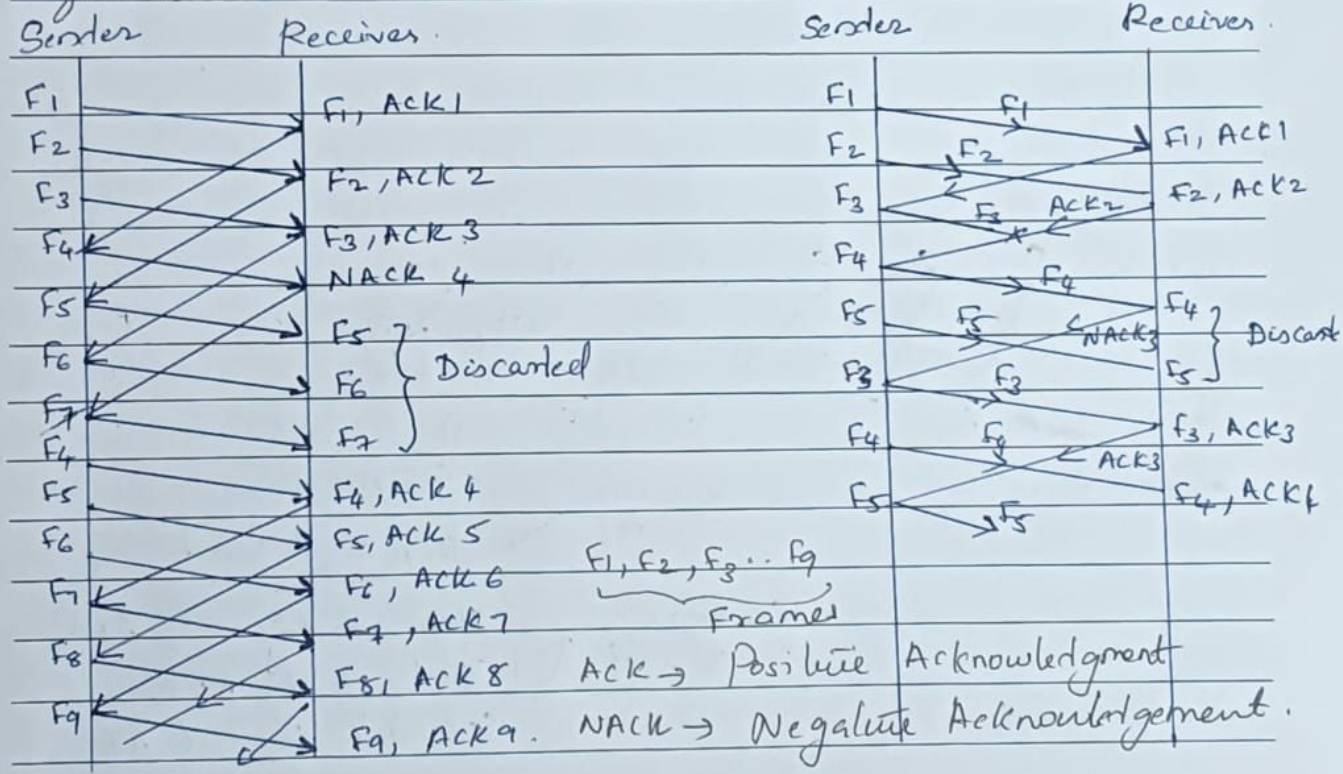
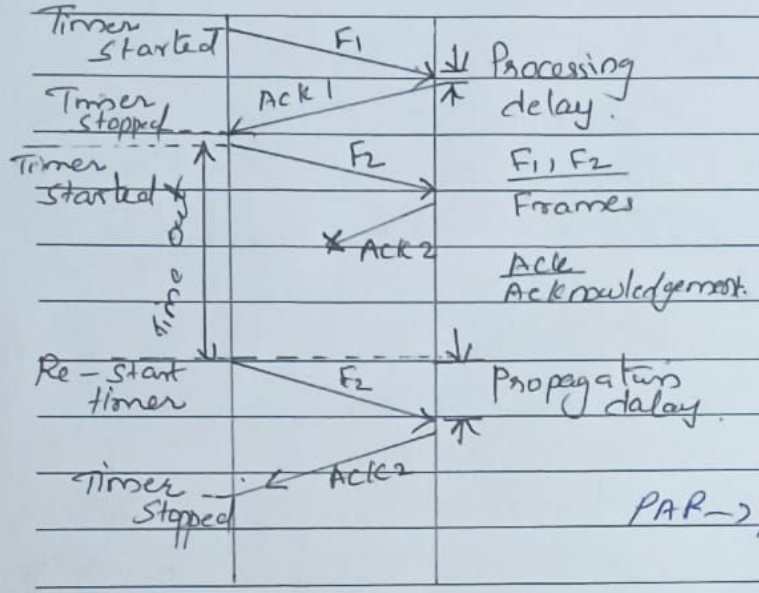
- When the sender receives a NACK, it retransmitting the corresponding frame plus all the succeeding frames.
- Receiver discards the duplicate frames.
- The sender keeps a copy of sent frame, at the same time it starts a timer.
  - If ACK lost or NACK lost, timer expires the frame is resent corresponding to the time out plus all succeeding frames.
- The copy is held and timer restarts for corresponding frames.





- Error correction in stop & wait ARQ is done by keeping a copy of sent frame and retransmitting of the frame when the timer expires.

Note:- ARQ (Automatic repeat request) is sometimes called PAR.

PAR → Positive Acknowledgment with retransmission.

- NACK is received by the transmitter receiver before timer expires / time out the old frame is sent & timer restarted.

Go-back-N-ARQ

- Most Popular ARQ protocol is go-back-N-ARQ
- sender / transmitter sends frame continuously without waiting acknowledgement.
- It is also called Continuous ARQ.
- we keep a copy of frames, ~~It keep sending Acks or NACKs~~ until the acknowledgement arrive.
- As the receiver receives the frame, It keep sending ACKs or NACKs.

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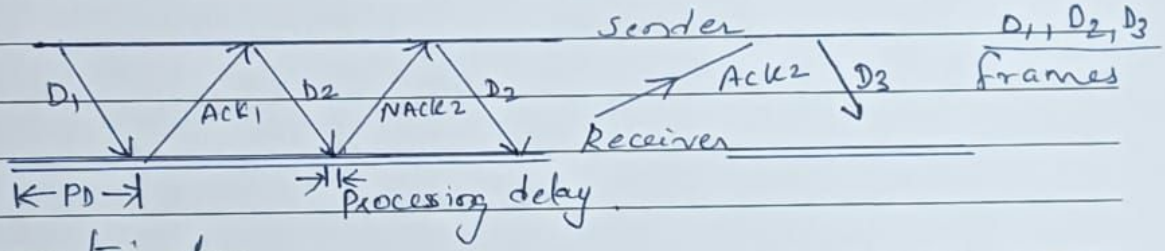
Stop-and-wait ARQ Go-back-n

Error control < sliding window ARQ < selective-repeat.

Stop and wait ARQ.

- Simplest among all protocols.
- A sender transmit a frame and then waits till it receives positive acknowledgement (ACK) or negative acknowledgement (NACK) from the receiver.
- Receiver sends an ACK, if the frame is received correctly, otherwise it sends NACK.
- sender receives Ack: send new frame
- sender receive NACK: re-transmit old frame



PD - Propagation day

- In stop & wait ARQ, the sender keeps a copy of sent frame.

At the same time, it starts a timer.

- If Ack or NAck lost, timer expires, the frame is resent, the copy is held and timer re-started.
- Frame number is help to avoid duplicate frame.

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Note:-

The receiver window is an abstract concept defining an imaginary box of size 1 with one single variable 'R0' the window slides when a correct frame has arrived.

- Sliding occurs one slot at a time

Link utilization in case of sliding window Protocol

$U = N/(1+2a)$ for $N<2a+1$

where N = the window size

a = propagation time / transmission time

ARQ (Automatic - Repeat - Request)

- Error control is both error detection and error correction.
- It allows the receiver to inform the sender of any frame lost or damaged in transmission and co-ordinates the retransmission of those frame by the sender.
- In the data link layer, the term Error control refers primarily error detection and retransmission.
- Any time an error is detected in an exchange, specified frame are re-transmitted.
- This process is called automatic repeat request.

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- link utilization is strongly dependent on the ratio of the propogation time to the transmission time.
- propagation time is small (LAN environment) the link utilization is good.
- Long propagation delay (satellite communication) the link utilization is poor.

Sliding Window.

- To improve the link utilization, we can use sliding window protocol instead of using stop & wait protocol.
- Sliding window is an abstract concept that defines the range of sequence number that is the concern of sender and receiver.
- The range of sequence number concern of the sender is called sender sliding window
- Sequence number is used to keep track the frames.
- Sender station sends sequentially numbered frames, sequence number occupies a field in limited size.
- If the header of the frame allows k bits, the sequence number range from 0 to $2^k - 1$.
- Sender maintains a list of sequence number that it is allowed to send (Sliding window),

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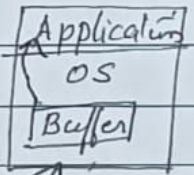
the size of sliding window (sender) is at most $2^k - 1$.
- Sender provided with a buffer equal to the window size.
- Receiver also acknowledges a frame by sending an ACK frame, that includes the sequence number of next frame expected
- TCP, Internets stream transfer protocols are used sliding window algorithm.

Note: -

A sliding window algorithm places a buffer between the application program and the network data flow (TCP)
- Data received from the network is stored in the buffer, from where the application can read at its own place.
- Application reades data, buffer space is freed up to accept more input from the network.



- The window is the amount of data that can be "read ahead" - size of buffer.

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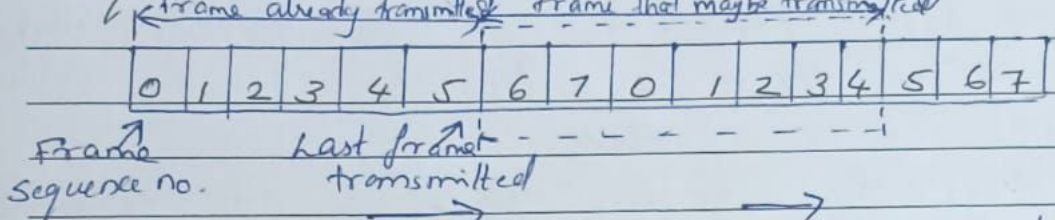
- window announcement are used to inform the remote host of the current window size.

Sender sliding window.

- The sender is permitted to send frames with sequence numbers in a certain range.



Receiver sliding window:

- The receiver always maintains window of size 1
- The receiver window make sure that the correct data frames are received and that the correct acknowledgment are sent.

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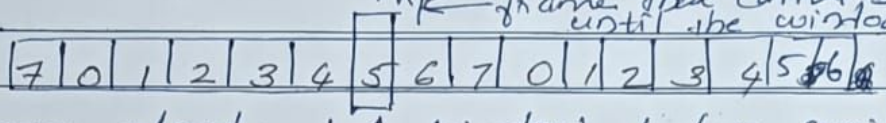
- The receiver is always looking for the arrival of a specific frame, any frame arriving out of order is discarded and need to be resent.
- The receiver acknowledges a frame by sending Ack frame that includes the sequence number of the next frame expected.



- If the window size is larger than the packet size, the multiple packets can be outstanding in the network, since the sender knows that buffer space available on the receiver to hold all of them.
- Each new window announcements is received by the sender from receiver, more packets (frames) are transmitted. As application reads data from the buffer, more window announcement are generated.
- Keeping a series of data frame is transmitting ensure the efficient use of network resource.

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- A small processing delay may be introduced between reception of the last byte of a data PDU & generation of the corresponding Ack.
- Major drawback of Stop-and-wait flow control is that only one frame can be transmit at a time. This leads to inefficiency if propagation delay is much longer than the transmission delay.

Link utilization of Stop & wait:

Transmission time:- The time take for a station to transmit a frame (normalized to a value of 1)

Propogation time/delay:- The time takes for a bit to travel from sender to receiver (expressed as 'a')

* $a < 1$: The frame is sufficiently long such that the first bits of the frame arrive at destination before the source has completed transmission of the frame.
* $a > 1$: Sender completes transmission of entire frame before the leading bits of the frame arrive at the receiver.

∴ the link utilization $u = 1/(1+2a)$

$a = \frac{\text{propagation time}}{\text{transmission time}}$.

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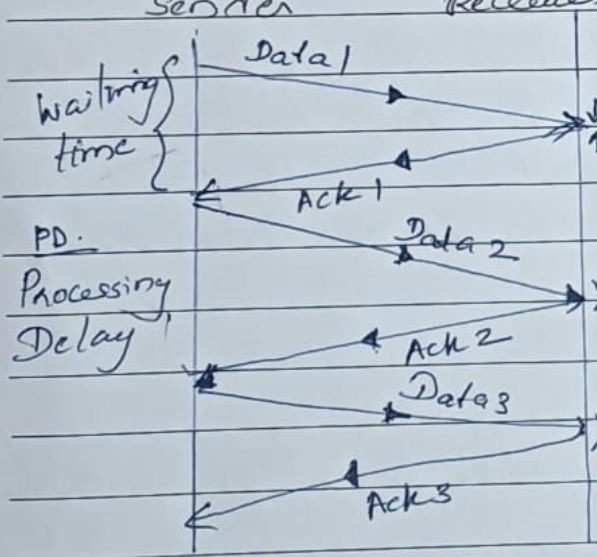
Stop and wait (Request/reply)

- Simplest form of flow control.
- After receiving the frame, the receiver indicates its willingness to accept another frame by sending back an Ack frame (acknowledgement) just received.
- The sender must wait until it receives ack frame before sending the next data frame.
- This is sometimes referred to as ping-pong behaviour.
- Advantage :- Simple to understand, easy to implement
- Disadvantage - Not very efficient.
- Efficient in LAN architecture.
- Difficult in WAN links (need more time for Ack)



Data 1, Data 2, Data 3 are the data frame passing from sender to receiver.

Ack 1, Ack 2, Ack 3 are return frames acknowledging the successful transmission.

Data: Sender to Receiver
Ack: Receiver to Sender.

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for the frame to reach the destination machine and acknowledged back. If the frame or acknowledgement is lost, the timer will go off.
- Transmit frame again
- Retransmit creates the problem of receiving multiple times. To prevent this generally assign a sequence number to outgoing frame; so that the receiver can distinguish retransmitted frame.

Flow control:
- Flow control is a set of procedures that tells the sender how much data can transmit before it must wait for an acknowledgement from the receiver.
- Flow of data should not be overload to the receiver.
- Receiver should also be able to inform the transmitter before its limits (This limits may be amount of memory used to store the incoming data or the processing power of receiver).

Flow control :- 2 Methods
1) Stop & wait
2) Sliding-Window.
- Stop & wait is also known as Request/Reply sometimes.

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Starting and ending flag with bit stuffing.

- The new technique allows data frames to contain and arbitrary (undetermined) number of bits and allows character code with arbitrary number of bit per character, use starting and ending flag with bit stuffing.
- Each frame begins and ends with a special bit pattern 01111110, called a flag byte.
- Whenever the sender's data link layer encounters five consecutive ones in the data, it automatically stuffs a '0' bit into the outgoing stream. - which is called bit stuffing
- Receiving machine destuffs the '0' bit

(3) Error Control

- Make sure all frames are eventually delivered to the network layer at the destination in proper order.
- Ensure reliable delivery by providing the sender with feedback about what is happening at other end of line.
- When a sender transmit a frame, it generally starts a timer. The timer is set to go off after an interval long enough for the

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Acknowledged connection-oriented service:
- The source and destination machines establish a connection before any data are transferred.
- Frame is sent over the established connection.
- Data link layer guarantees that each frame that sent is received.
- When connection oriented service is used, transfer have three distinct phases.

Phase 1- connection is established by having both sides initializing variable and counter need to keep track of which frame have been received and which one is not.

Phase 2- one or more frames are actually transmitted.

Phase 3 - The connection is released, freeing up the variables, buffers and other resources used to maintain the connection.

(2) Framing.

Physical layer accept the bit stream and attempt to deliver it to the destination. This bit stream is not guaranteed to be error free. Its upto the data link layer to detect and if necessary correct the errors.

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- The usual approach is for data link layer to break the bit streams up into discrete frames and compute the checksum.

For each frame, when the frames arrived at the destination, the checksum is re-computed, If newly calculated checksum is different from old one - error detection.

* There are four methods for breaking the bit streams into frames.

1) character count
2) Starting and ending character stuffing
3) Starting and ending flag with bit stuffing
4) Physical layer coding violations.

Characters count:

- Use a field in header to specify the number of characters in the frame.
- The data link layer at the destination sees the character count, it knows how many characters follow.

problem- count can possible be misrepresented by transmission errors.

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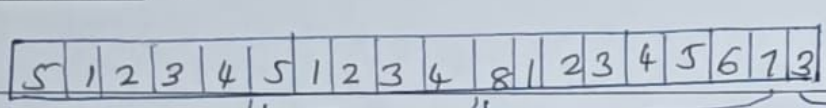
A character stream without errors.

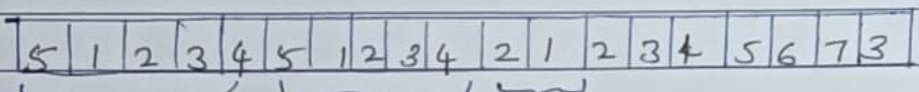


frame 1 — 5 → character count

frame 2 — 5 → character count

frame 3 — 8 → character count

frame 4 — 3 → character count



frame 1 frame 2 frame 3

A character stream with errors.

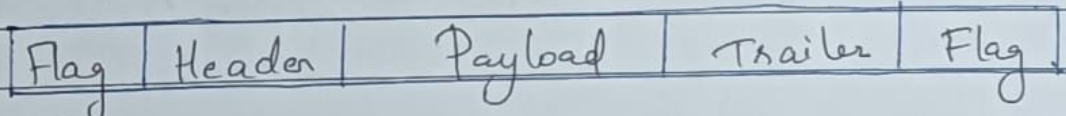
Starting and ending character stuffing.

→ This is about the problem of re synchronization after an errors.

→ Re synchronization by having each frame start and end with special bytes

Eg: Frame start with ASCII character DCE STX and end with sequence DLE ETX

— In the past starting and ending by two where different, but in recent years, most of the protocols use same byte called flag byte



Problems:

chances of occurrence of flag bit pattern in data.

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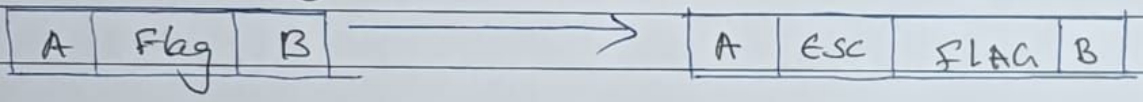
→ To solve this,
at senders data link layer, insert DLE (escape byte) just before each accidental flag byte in data
- on the receiver machine, remove them before data to network layer.
- This method is called character stuffing.

Original msg → Stuffed msg.



- Two consecutive flag byte indicate the end of one frame and start of the next one.
- By character stuffing or byte stuffing, a framing flag byte can be distinguished from one in the data by absence or presence of an escape byte before it,

DLE - Data link Escape.
STX → Data link start of text
ETX → End of text.

- If an escape byte occurs in the middle of data, a double the escape byte before the flag and which indicate that a single escape occured naturally in the data.

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Common Services,
→ Un acknowledged connectionless service
→ Acknowledged connectionless service
→ Acknowledged connection oriented service.

Un acknowledged connectionless service.
→ It is having source machine sends independent frames to destination machine without sending ack.
→ no connection is established before or after
→ good channel have low error rate.
→ no attempt is made to detect or recover the lost data due to noise on the line in the data link layer.
Eg: Real-time traffic such as voice.

Acknowledged connectionless service.
→ No connection establishment before or after.
→ Each frame send its acknowledgement individually, this way, the sender knows whether or not a frame has arrived safely.
→ If acknowledgement is not arrived within a specified time interval, it can be send again.
Eg: Good for unreliable channels, such as wireless.

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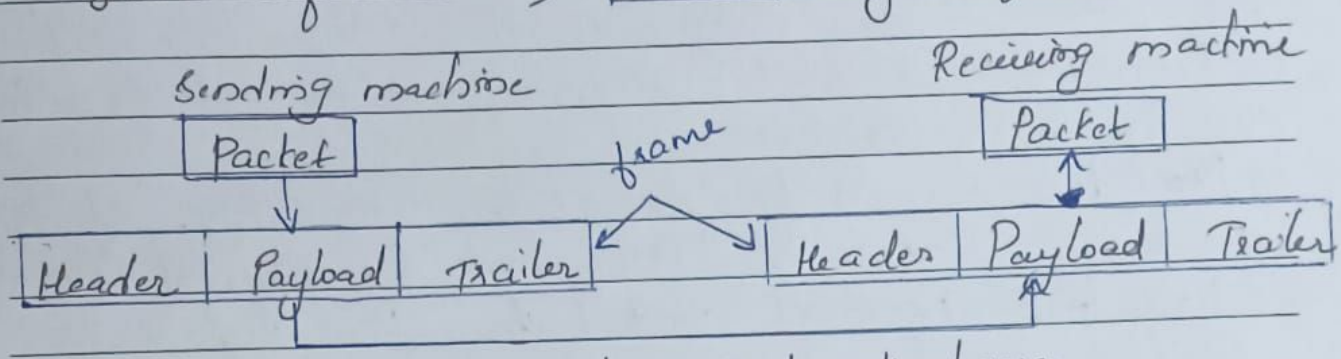
information for handling of the data block (or just make its ends.

Frame format → | Header | Payload field | Trailer |



Service Provided to the Network Layer.

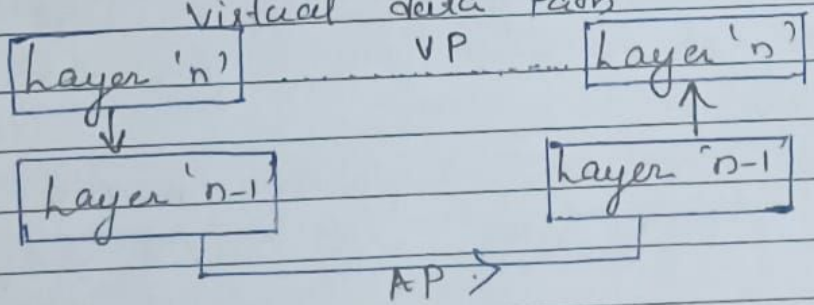
N/w layer of Src → N/w layer of Destination

The job of data link layer is to transmit the bits to the destination machine.

→ Bits can be handover to the network layer of destination by,

Actual Path

Virtual data Path



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Second module :-

Data link Layer.

Data link layer design Issues.

The data link layer has number of specific functions. It can carry out these functions like,

→ Providing a well defined service interface to the network layer.

→ Provide services for reliable interchange of data across a data link established by physical layer.

→ Data link protocols control the flows of data, dealing with transmission errors and supervise data errors recovery.

→ Recovery from abnormal conditions.

→ Regulating the flow of data so that slow receivers are not swamped by fast sender. Flow control.

To accomplish these goals, the data link layer takes the packet from the network layer and encapsulate them into frame for transmission.

Packets → frames.

* Each frame contains a frame header, a payload field for holding the packet & a frame trailer.

Trailer — supplement data placed at the end of a block of data transmitted, which may contain