- First three are the standards of the IEEE and are part of its project 802, whereas, FDDI is an ANSI standard. The classification of LAN is based on the transmission medium and it is given as:

  (i) Wired LAN, and

  (ii) Wireless LAN.

S. No	*LAN*	*IEEE standard*	*Access method*	*Topology*
1	Ethernet	802.3	CSMA/CD	Bus
2	Token bus	802.4	Token passing	Bus
3	Token ring	802.5	Token passing	Ring
4	FDDI	802.6	Token passing	Dual-ring

Table-8.1 MAC access methods

8.2 ETHERNET (IEEE 802.3): WIRED LANS

8.2.1. Introduction

- Ethernet is specified in a standard ***IEEE 802.3***. It was developed in the mid-1970s by Robert Metcalfe and David Boggs.
- *Ethernet is a popular **packet-switching** LAN technology that defines the way of connecting computers together in a local area network using physical and data link layers.*
- 10-Mbps Ethernet was standardized in ***1978***. *It is an extremely popular LAN technology used by several thousand local area networks around the world.*

Ethernet Generations:

Ethernet gone through four generations are,

(i) *Standard Ethernet (10 Mbps).*

(ii) *Fast Ethernet (100 Mbps).*

(iii) *Gigabit Ethernet (1 Gbps).*

(iv) *Ten-Gigabit Ethernet (10 Gbps).*

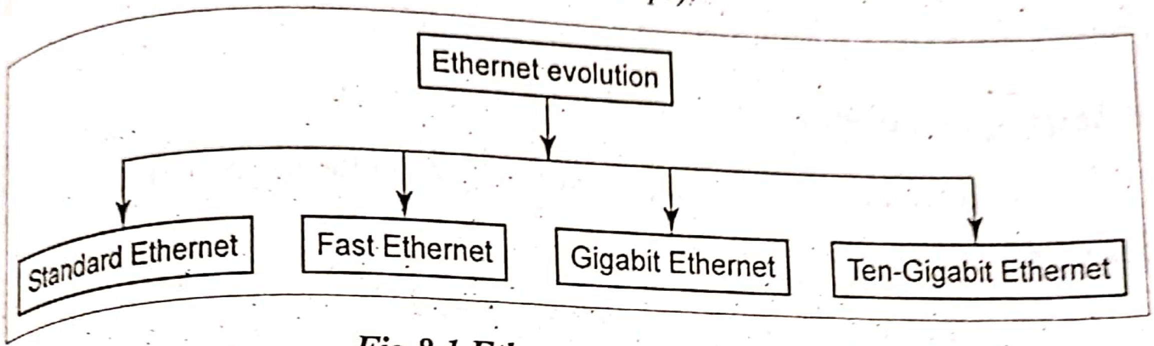


Fig 8.1 Ethernet generations

8.2.2 Standard Ethernet

The original Ethernet technology with the data rate of 10 Mbps is known as standard Ethernet.

(1) Frame Format

Preamble	Destination address	Source address	Frame type	Data and Padding	CRC
8 bytes	6 bytes	6 bytes	2 bytes	46 – 1500 bytes	4 bytes

← Minimum frame length: 512 bits (or) 64 bytes →

Maximum frame length: 12,144 bits (or) 1518 bytes

Fig 8.2 Ethernet MAC frame format

(a) Preamble

The preamble contains 64 bits (8 bytes) of alternating 0s and 1s (10101010) to help the receiving hosts to synchronize with the incoming frame. It is actually added at the physical layer but it is not (formally) the part of the frame.

(b) Destination Address (DA)

This 48 bits (6 bytes) contains the link-layer address of the destination station (or) the stations to receive the packet.

(c) Source Address (SA)

This 48 bits (6 bytes) contains the link-layer address of the sender station of the packet.

(d) Length / Type of PDU

This two bytes field indicate the number of bytes in the incoming Protocol Data Unit (PDU) *or* the type of PDU.

Minimum frame length: ***64 bytes (or) 512 bits.***

Maximum frame length: ***1518 bytes (or) 12,144 bits.***

(e) Frame Data (PDU)

This field contains the actual data of the frame, which can be of variable length, from ***46 to 1500 bytes*** long, depending on the type of frame and the length of the information field. The data length is given as,

Minimum data length: ***46 bytes***.

Maximum data length: ***1500 bytes***.

(f) Cyclic Redundancy Check (CRC)

- The last 2-bytes field in the 802.3 frame contains the error detection information. This CRC-32 bit field helps the destination station to detect the transmission errors.
- The sending station attaches the preamble and CRC before transmitting, and the receiving station will removes it.

(2) Addressing

- Each station of an Ethernet network has its own ***Adaptor (or) Network Interface Card (NIC)***. The NIC usually fits inside the station and provides the station with a unique ***six-byte physical address (or) hardware address*** that identifies a host uniquely.
- Normally, this address written in hexadecimal notation, separated by a colon between the bytes.

Example:

4A : 30 : 10 : 21 : 10 : 1A

6 bytes = 12 hex digits = 48 bits

- In human-readable representation:

  00001010 : 00110000 : 00010000 : 00100001 : 00010000 : 00011010

- Each frame transmitted on an Ethernet is received by every adaptor connected to that Ethernet and recognizes those frames addressed to its address and passes only those frames on to the host.

Types of Addresses

- An adaptor can be programmed to run in ***promiscuous mode****, in which it delivers all the received frames from the network to the host.*
- There are three different types of addresses:
  - (i) Unicast Address,
  - (ii) Multicast Address, and
  - (iii) Broadcast Address.
- *A unicast destination address defines only one recipient (one-to-one). A multicast destination address defines a group of addresses (one-to-many). It is used to send messages to some subset of the hosts on an Ethernet.*

(5) Implementation

(a) 10 Bases 5 (or) Thick Ethernet (or) Thick Net:

- 10 Base 5 is a ***bus topology LAN*** that uses baseband signaling and has a maximum ***segment length*** of ***500*** meters.

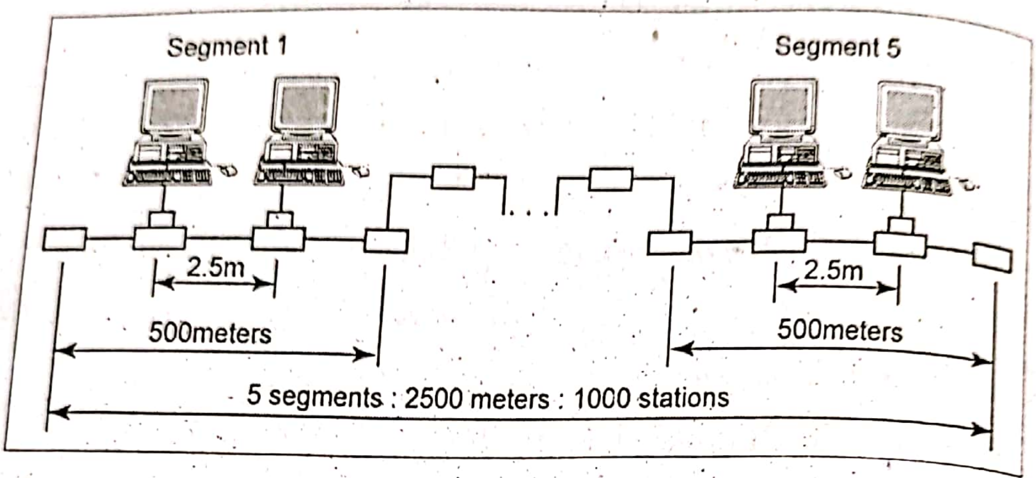
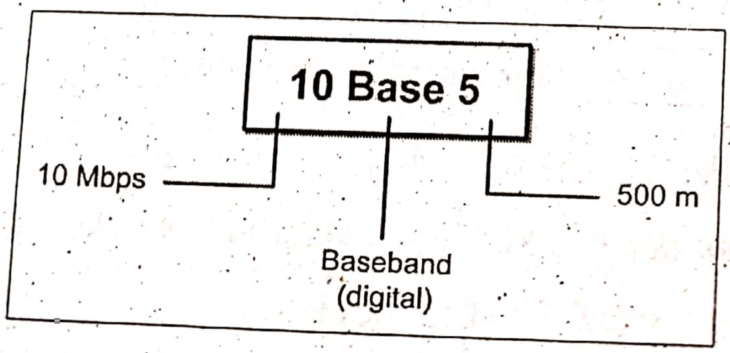


Fig 8.4 Ethernet segments

- In thick Ethernet, a local area network can be divided into segments by connecting the devices. An Ethernet segment uses a single ***coaxial cable*** as the transport ***medium*** and the length of each segment is limited to ***500 meters*** to ***reduce collisions.***

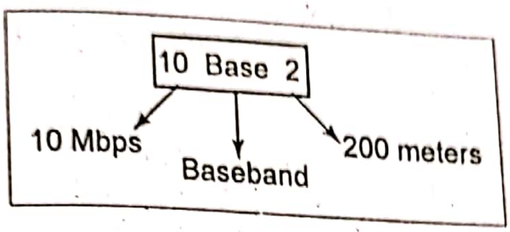
- All ***hosts*** in the Ethernet LAN ***connect*** to this ***cable***. The ***total length*** of the bus should not exceed ***2500*** meters (five segments).

- Here, the date rate is 10 Mbps, the word ***base*** indicates ***baseband transmission*** and specifies a ***digital signal*** with ***Manchester encoding***. Maximum cable length is 500 meters in a segment.



(b) 10 Base 2 (or) Thin Ethernet:

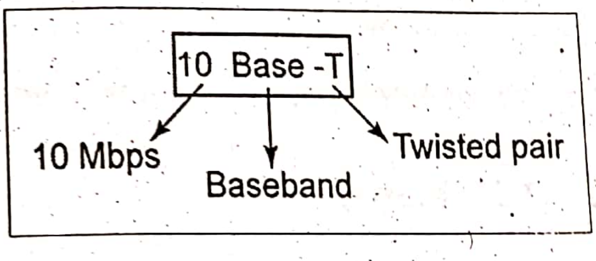
- 10 Base 2 provides an inexpensive alternative to 10 base 5 Ethernet with the same data rate.



- The length of each segment cannot exceed 185 m (close to 200 m) due to the high level of attenuation in thin coaxial cable.

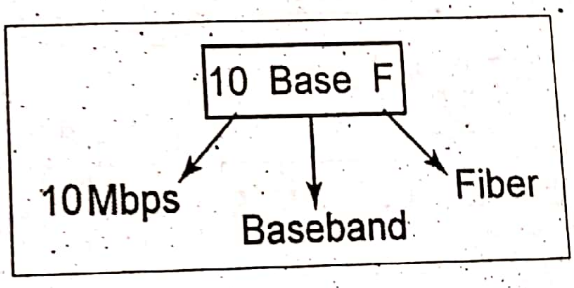
(c) 10 Base – T (or) Twisted – Pair Ethernet:

10 Base – T is a ***star-topology LAN*** which uses ***Unshielded Twisted Pair (UTP)***. It supports a data rate of ***10 Mbps*** and has a maximum length (hub to station) of ***100 meters***.



(d) 10 Base F (or) Fiber Ethernet:

10 Base-F uses a ***star topology*** to connect stations to a hub with the help of two fiber optic cables.



Manchester Encoding:

- The original Ethernet specifications used the Manchester encoding, in whic each bit period is divided into two equal intervals.

4) Both sender and receiver do a lot of waiting, it is just like teacher is giving one assignment question at a time. The student takes the question at home, works on it, brings it back to school, gives it to the teacher and waits for the next question.

2.6.3 Go-Back-N ARQ

- Go-Back-N uses the sliding window flow control protocol. If no errors occur the operations are identical to sliding window.
- A station may send multiple frames as allowed by the window size.
- Receiver sends a NAK i if frame i is in error. After that, the receiver discards all incoming frames until the frame in error was correctly retransmitted.
- If sender receives a NAK i it will retransmit frame I and all packets i+1, i+2,... which have been sent, but not been acknowledged.
- The need for a large window on the sending side occurs whenever the product of bandwidth x round-trip-delay is large. If the bandwidth is high, even for a moderate delay, the sender will exhaust its window quickly unless it has a large window.
- If the delay is high, the sender will exhaust its window even for a moderate bandwidth. The product of these two factors basically tells what the capacity of the pipe is and the sender needs the ability to fill it without stopping in order to operate at peak efficiency. This technique is known as **pipelining.**
- As in Stop-and-Wait protocol senders has to wait for every ACK then next frame is transmitted. But in Go-Back-N ARQ W frames can be transmitted without waiting for ACK. A copy of each transmitted frame is maintained until the respective ACK is received.

Additional features of Go-Back-N ARQ

1) **Sequence numbers :** Sequence numbers of transmitted frame are maintained in the header of each frame. If k is the number of bits for sequence number, then the numbering can range from 0 to $2^k - 1$ e.g. for k = 3. Sequence numbers are 0 to 7 $(2^3 - 1)$.

2) **Sender sliding window :** Window is a set of frames in buffer waiting for acknowledgment. This window keeps on sliding in forward direction. The window size is fixed. As the ACK is received, the respective frame goes out of window and new frame to sent come into window. Fig. 2.6.8 illustrates sliding of window for window size = 7.

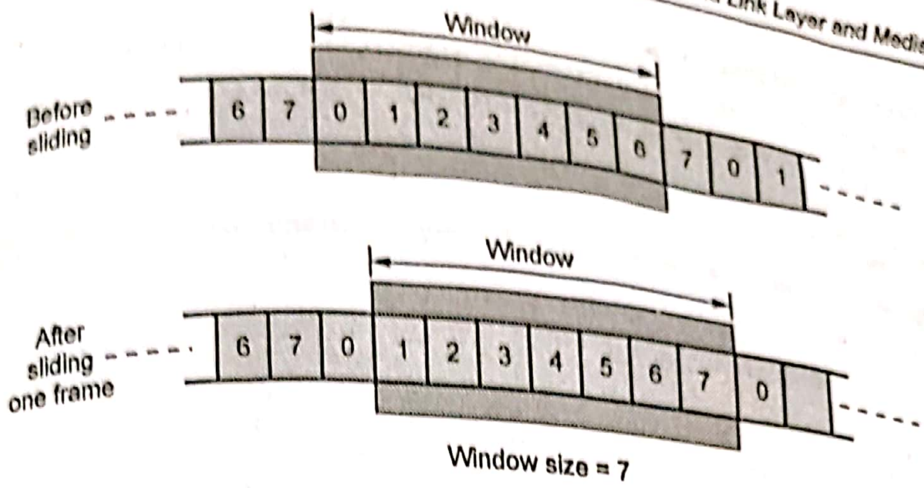


Fig. 2.6.8 Sender sliding window

3) Receiver sliding window : In the receiver side the size of the window is always one. The receiver is expecting to arrive frames in specific sequence. Any other frame received which is out of order is discarded. The receiver slides over after receiving the expected frame. Fig. 2.6.9 shows receiver sliding window.

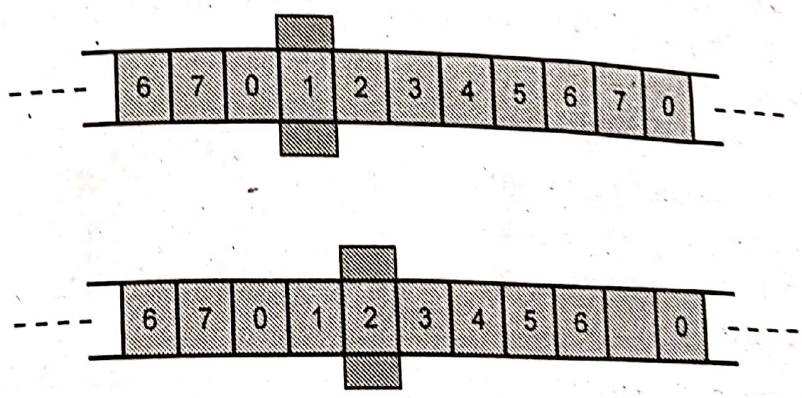


Fig. 2.6.9 Receiver sliding window

4) Control variables :

a) Sender variables

- The sender deals with three different variables.

$S \rightarrow$ Sequence number of recently sent frame.

$S_F \rightarrow$ Sequence number of first frame in window.

$S_L \rightarrow$ Sequence number of last frame in window.

$\therefore$ Window size $W = S_L - S_F + 1$

e.g. in previous feature, $W = 7 - 0 + 1 = 8$

b) **Receiver variable**

- The receiver deals with one variable only.
  R → Sequence number of frame expected
  If the number matches, then the frame is accepted otherwise not.

5) Timers

- The sender has a timer for each transmitted frame. The receiver don't have any timer.

6) Acknowledgment

- The receiver responds for frames arriving safely by positive acknowledgments. For damaged or lost frames receiver does not reply, the sender has to retransmit it when timer of that frame elapsed.
- The receiver may acknowledge once for several frames.

7) Resending of frames

- If the timer for any frame expires, the sender has to resend that frame and the subsequent frames also, hence the protocol is called Go-Back-N ARQ.

Operation

a) Normal operation

- The sender sends frames and update the control variables i.e. S_F, S, S_L and receiver updates variable R. Fig. 2.6.10 shows normal operation.

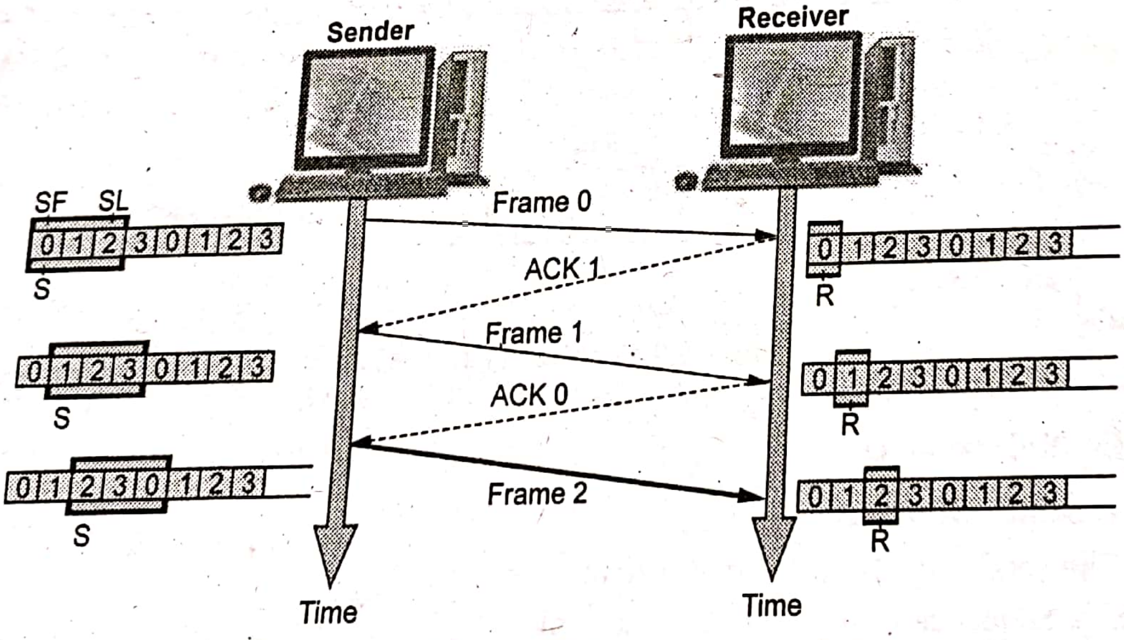


Fig. 2.6.10 Go-Back-N ARQ, normal operation

b) Damaged or lost frame

- Suppose frame 2 is damaged or lost and if receiver receives frame 3, it will be discarded since it is expecting frame 2. Sender retransmits frame 2 and frame 3. Fig. 2.6.11 shows this process.

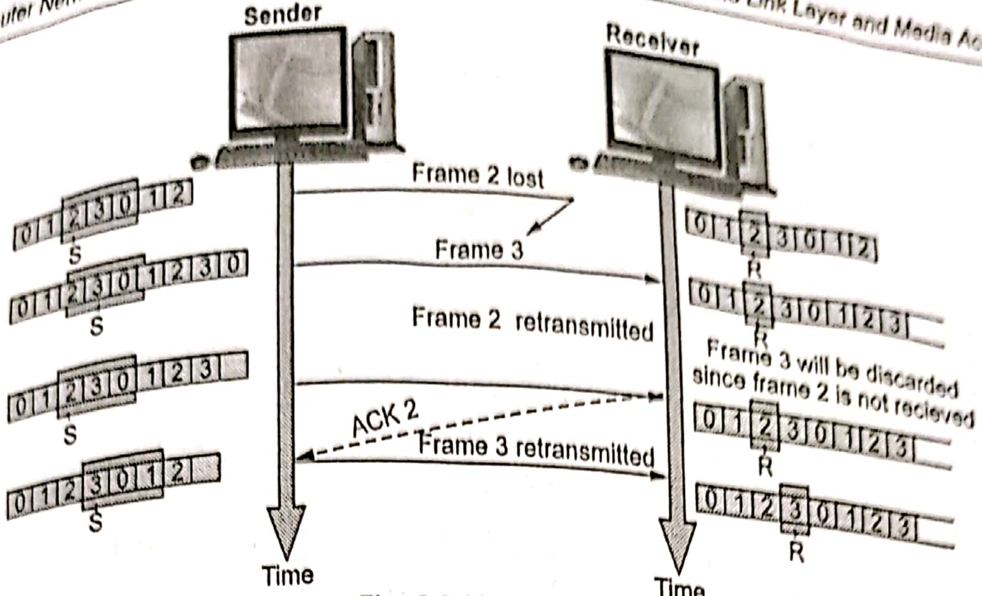


Fig. 2.6.11 Lost frame

2.6.4 Selective Repeat ARQ

- Selective repeat ARQ retransmitts only the damaged or lost frames instead of sending multiple frames. The selective retransmission increases the efficiency of transmission and is more suitable for noisy channel. The circuit complexities at the receiver side increases.
- The size of sender window is one half of 2^k. The receiver window size is of same length as that of sender. The receiver window includes the set of expected frames. The boundaries of receiver windows are defined by R_F and R_L. Fig. 2.6.12 shows the sender and receiver windows.
- Negative acknowledgement (NAK) is used for lost or damaged frames.

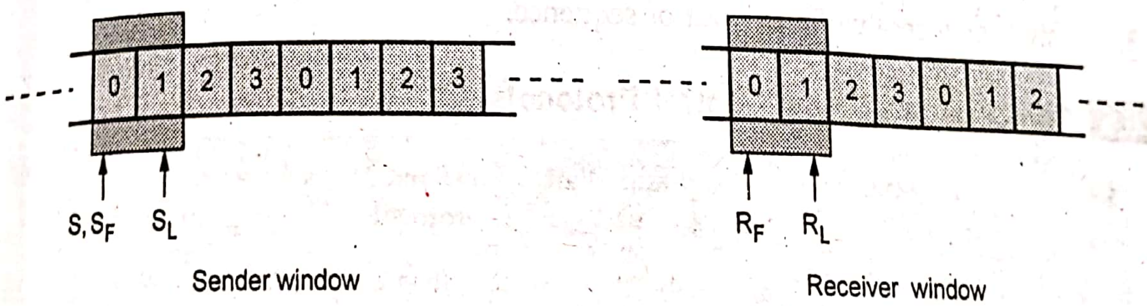


Fig. 2.6.12 Selective repeat windows

Operation

- In sequential transmission of frame 0, 1, 2, 3, suppose frame 2 is lost and the next frame 3 is already received then receiver sends NAK 2 frame to sender. Then sender retransmits frame 2 only. Fig. 2.6.13 shows operation of selective repeat ARQ.

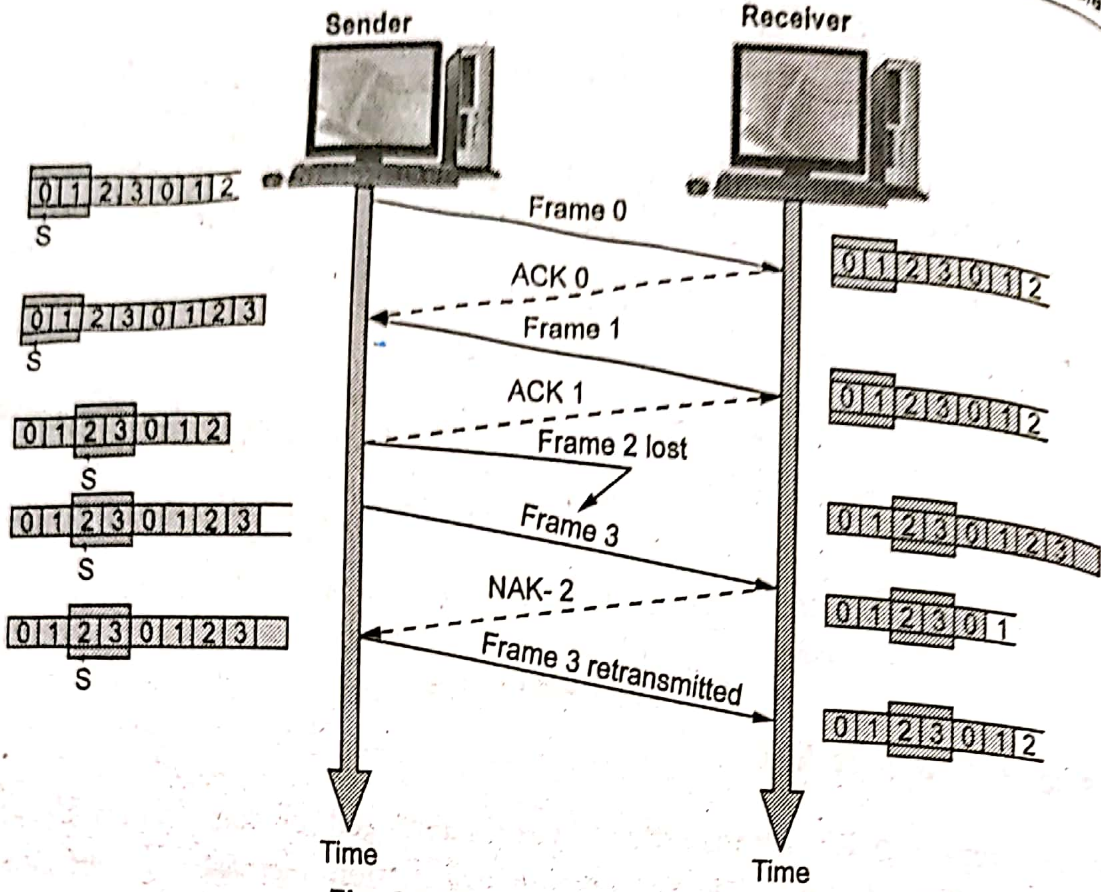


Fig. 2.6.13 Selective repeat ARQ

Advantage :

1) Fewer retransmissions.

Disadvantages :

1) More complexity at sender and receiver.
2) Each frame must be acknowledged individually (no cumulative acknowledgemen
3) Receiver may receive frames out of sequence.

2.6.5 Comparison of Flow Control Protocols

Sr. No.	Parameters	Stop-and-Wait protocol	Go-Back-N protocol	Selective repeat protocol
1.	Sending window size	One frame	Less than 2^k	Less than or equal to 2^k minus receiving window size
2.	Receiving window size	One frame	One frame	Less than or equal to 2^k minus sending window size

where k = Number of bits used for frame number.

Where $a = t_{prop} / t_{frame}$

$t_{prop} = 20$ ms

Solving this equation with respect to a

$a = 0.5[(1/U) - 1]$

For $U \geq 50\% = 0.5$, then $a \leq 0.5\left[(1/0.5)-1\right] \Rightarrow a \leq 0.5$

Since $a = t_{prop}/t_{frame}$ then $t_{prop}/t_{frame} \leq 0.5 \Rightarrow t_{frame} \geq 2t_{prop}$

But frame_size = t_{frame}/bit_duration =>

Frame_size $\geq 2t_{prop}$ / bit_duration $= 2 \times 20$ ms / 0.25 ms = 160

University Questions

1. *Explain the various flow control mechanics.* **AU : Dec.-15, Marks 16**
2. *Explain selective - repeat ARQ flow control method.* **AU : Dec.-16, Marks 8**
3. *Explain the algorithm used for reliable transmission and flow control.* **AU : Dec.-18, Marks 8**

2.7 DLL Protocols : HDLC - High-level Data link control.

AU : May- 16

- HDLC is the most important data link control protocol, also it is the basis for many other important data link control protocols, which use the same or similar formats and the same mechanisms as employed in HDLC.
- The HDLC protocol is an international standard that has been defined by ISO for use on both point-to-point and multipoint data links.
- It supports full duplex, transparent mode operation and is now extensively used in both multipoint and computer networks.
- Although the acronym HDLC is now widely accepted, a number of large manufacturers and other standards bodies still use their own acronyms. These include IBM's SDLC (Synchronous Data Link Control) and ADCCP (Advanced Data Communications Control Procedure), which is used by the American National Standards Institute (ANSI).
- To satisfy a variety of applications, HDLC defines three types of stations. These are,
  1) **Primary station :** Primary station has the responsibility for controlling the operation of the link. Frames issued by the primary are called command.
  2) **Secondary station :** Secondary station operates under the control of the primary station. Frames issued by a secondary are called responses. The primary maintains separate logical links with each secondary station of the line.

3) **Combined station :** It combines the features of primary and secondary combined station may issue both commands and responses.

- Since HDLC has been defined as a general purpose data link control protocol, stations can be configrated in different network configurations as
  - i) Point-to-point with single primary and secondary.
  - ii) Multipoint with single primary and multiple secondaries.
  - iii) Point-to-point with two primaries and two secondaries.

All above configurations are illustrated in Fig. 2.7.1 (a), 2.7.1 (b) and 2.7.1 (c).

i) Point-to-point with single primary and secondary

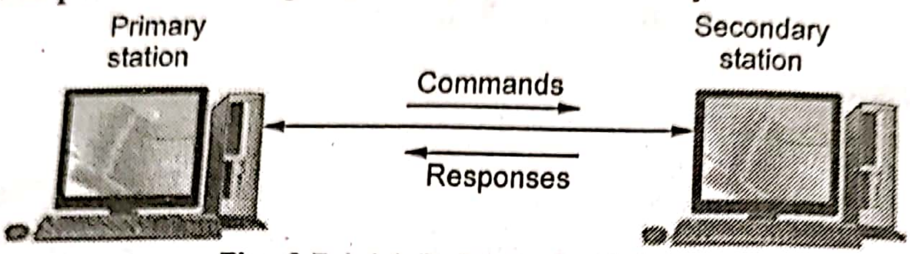


Fig. 2.7.1 (a) Point-to-point link

ii) Multipoint with single primary and multiple secondaries

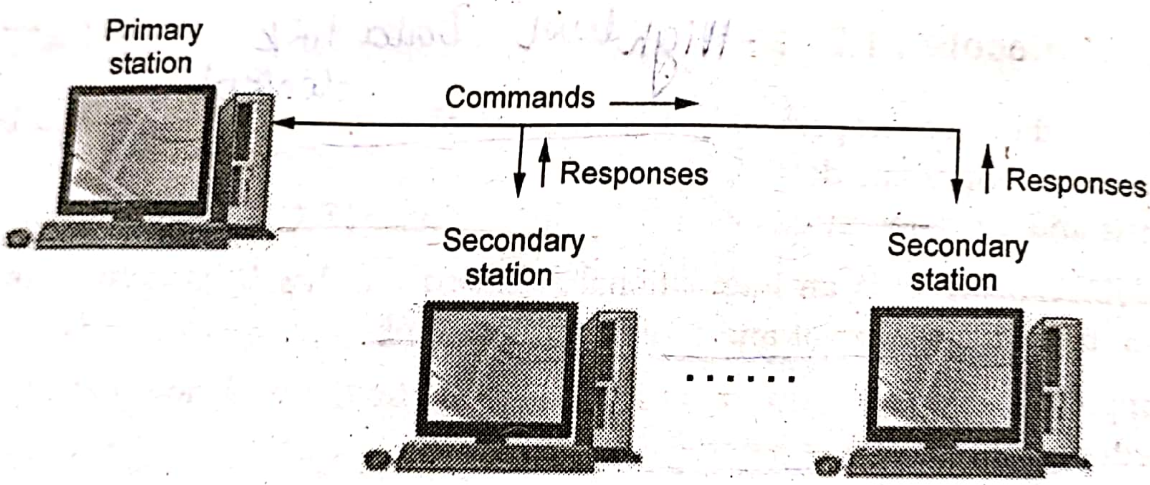


Fig. 2.7.1 (b) Multipoint link

iii) Point-to-point with two primaries and two secondaries

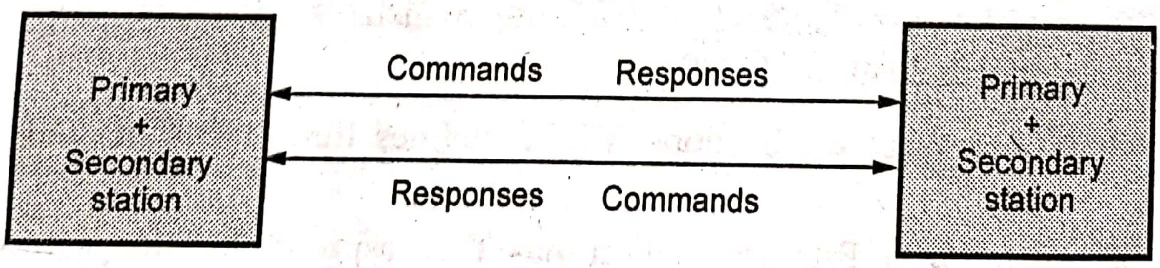


Fig. 2.7.1 (c) Point-to-point link between combined stations

- The frames sent by primary station to the secondary station are know **commands** and those from the secondary to the primary as **responses.**

- Two configurations shown in part (i) and (ii) have a single primary station are known as unbalanced configurations. Unbalanced configuration supports both full duplex and half duplex transmission.
- The configuration in part (iii) has two primary stations and is known as balanced configuration. Balanced configuration supports both full duplex and half duplex transmission. Since each station has both a primary and a secondary, they are also known as combined stations.

2.7.1 Operational Mode of HDLC

HDLC has following data transfer modes :

1) Normal Response Mode (NRM).

2) Asynchronous Balanced Mode (ABM).

1) Normal Response Mode (NRM)

- This is used in unbalanced configurations. There are one primary station and multiple secondary stations.
- A primary station can send commands; a secondary station can only respond.
- Fig. 2.7.2 shows a Normal Response Mode (NRM).

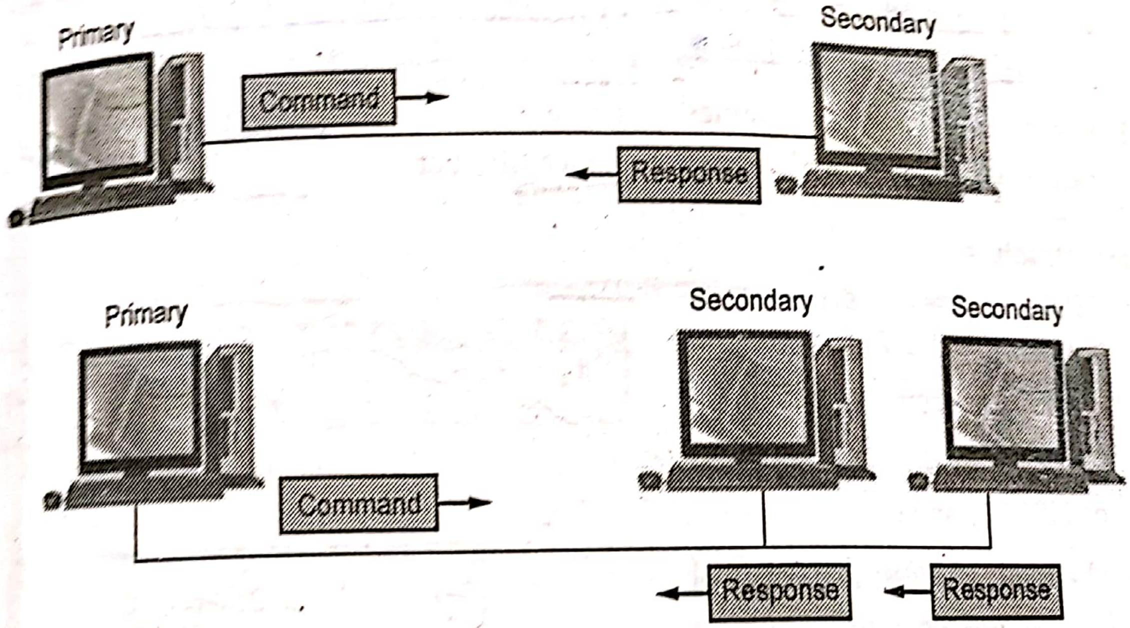


Fig. 2.7.2 NRM

- The NRM is used for both point-to-point and multipoint links.

2) Asynchronous Balanced Mode (ABM)

- In ABM, the configuration is balanced. The link is point to point and ea station can functions as a primary and a secondary.

- Fig. 2.7.3 shows the ABM.

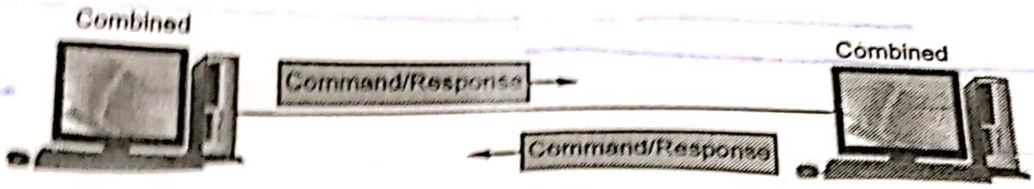


Fig. 2.7.3 ABM

- Either station can send data, control information or commands. This is typical in connections between two computers and in the X.25 interface standard.

2.7.2 Frames

In HDLC both data and control messages are carried in a standard format frame. Three classes of frame are used in HDLC.

1) **Unnumbered frames (U-frames) :** These are used for functions such as link setup and disconnection. The name derives from the fact that they do not contain any acknowledgment information, which is contained in sequence numbers.

2) **Information frames (I-frames) :** These carry the actual information or data and are normally referred to simply as I-frames. I-frames can be used to piggy back acknowledgment information relating to the flow of I-frames in the reverse direction when the link is being operated in ABM or ARM.

3) **Supervisory frames (S-frames) :** These are used for error and flow control and hence contain send and receive sequence numbers.

Frame structure

- HDLC uses synchronous transmission. All transmissions are in the forms of frames.
- Fig. 2.7.4 shows the structure of HDLC frame.
- The flag address and control bits before the information or data fields are known as a header. The FCS and flag fields following the data fields are referred as a trailer.
- **Flag fields :** It has a unique pattern at both the ends of the

Flag	Address	Control	User information	FCS	Flag

(a) I-frame

Flag	Address	Control	FCS	Flag

(b) S-frame

Flag	Address	Control	Management information	FCS	Flag

(c) U-frame

Fig. 2.7.4 HDLC frames

frame structure. It identifies the start of the frame and end of frame. The length of flag field is 8-bit.

- **Address fields :** Address field states the destination address. The address field is usually 8-bit long but can be extended.
- **Control fields :** Control fields contain frame numbers. Also it controls the acknowledgment of frames. Control field is 8 or 16 bits in length.
- **Information fields :** Data field contains the user data received from the network layer. It can be of variable length but in integral number of octets.
- **FCS (Frame Check Sequence) :** FCS is an error detecting code calculated from the remaining bits of the frame. FCS can be 16 bits or 32 bits long.

2.7.3 Control Field

Control field for I-frames

- I-frames are designed to carry user data from the network layer. This field also include flow and error control information.
- Fig. 2.7.5 shows the control field in I-frames.

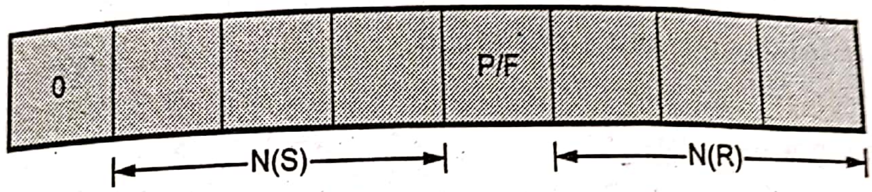


Fig. 2.7.5 Control field in I-frame

- The first bit defines the type. If it is 0, this means the frame is an I-frame.
- Next three bits define the sequence number (NCS). Sequence number range is in between 0 to 7.
- P/F field is 1-bit with dual purpose. This field is set when it is 1. It may be poll or final.
- Last 3-bit corresponds to the acknowledgement number when piggy backing is used.

Control field for S-frames

- S-frames do not have information fields. Fig. 2.7.6 shows the S-frame.

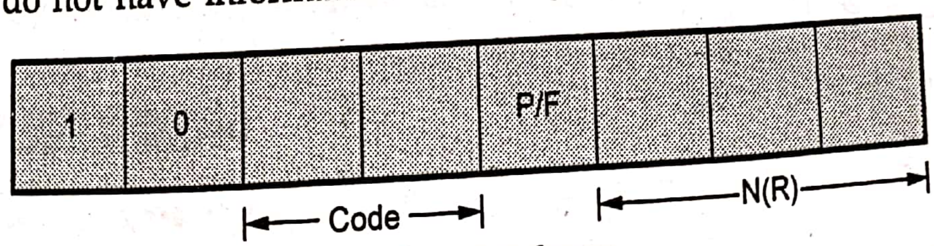


Fig. 2.7.6 S-frame