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MODULE-2

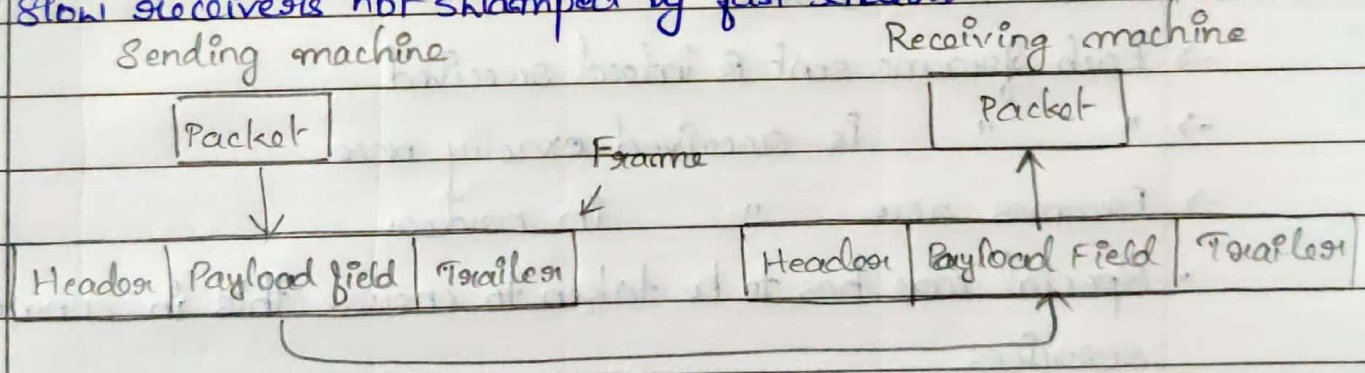
DLL Design Issues

- Services provided to the n/w layer
- Framing
- Error control
- Flow "

Funct^n's of DLL

- Provide service interface to n/w layer
- Dealing with txm errors
- Regulating data flow

→ Slow receivers not swamped by fast senders



Framing →

Types of Services Provided to N/w layer

- Unacknowledged Connect^n less service
- Acknowledged " "
- " Connect^n - Oriented service

Unacknowledged Connect^n less Service

- Losses are taken care of at Higher layers
- Used on reliable medium like coax. cables / optical fiber, where the error rate is low.

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- Appropriate for voice, where delay is worse than bad data.

Acknowledged Connectionless Service

- Useful on reliable medium like wireless
- Acknowledgement adds delays.
- Adding ack in DLL rather than in the NL is an optimization & not a requirement.
- On reliable channels, like fiber, the overhead associated with the ack is not justified.

Acknowledged Connection-Oriented Service

- Most reliable
- Guaranteed service

→ Each frame sent is indeed received

→ " " is received exactly once

→ Frames are " in order

- Special care has to be taken to ensure this in connectionless services

Framing

- Character count
- Flag bytes with byte stuffing
- " " " bit "

} Errors can be avoided using these techniques

Framing with Character Count

Sender

5	1	2	3	4	5	5	6	7	8	8	9	0	1	2	3	4	5	8	7	8	9	0	1	2	3

Frame 1: 5 characters | Frame 2: 5 characters | Frame 3: 8 characters | Frame 4: 8 characters

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Receiver

5	1	2	3	4	7	5	6	7	8	8	9	0	1	2	3	4	5	8	7	8	4	0	1	2	3

Frame 1 — 5 characters
Frame 2 (Wrong)
Non a character count

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- Problem with Framing with CC

→ What- if the count is garbled.

→ Even if with checksum, the receiver knows that the frame is bad there is no way to tell where the next frame starts.

→ Asking for re-txm doesn't help either because the start of the retransmitted frame is not known.

→ No longer used.

Framing with Byte Stuffing

FLAG	Header	Payload field	Trailer	FLAG

- Each frame starts & ends with special bytes called Flag bytes
- If the receiver loses synchronizatn, it just searches for the flag byte to determine the end of the frame.

Original chars				After stuffing					
A	FLAG	B	→	A	ESC	FLAG	B		
A	ESC	B	→	A	ESC	ESC	B		
A	ESC	FLAG	B	→	A	ESC	ESC	ESC	FLAG	B
A	ESC	ESC	B	→	A	ESC	ESC	ESC	ESC	B

ESC → Escape Sequence

- 2 consecutive flag bytes indicate end of 1 frame & start of next 1.

- Sender's DLL inserts a special esc. byte (ESC) just before each accidental flag byte in the data. This is known as byte stuffing or character stuffing.
- Problem:- Fixed char size: Assumes char size to be 16 bits (UNICODE): can't handle heterogeneous environment.

Framing with Bit Stuffing

- Each frame begins with a pattern 01111110
- Whenever sender's DLL encounters 5 consecutive 1's, it automatically stuffs a '0' bit into the bitstream.

Original data: 0110111111111111111110010

Data as they appear on the line: 01101111101111101111100010

(stuffed bits)

Data as they are stored in receiver's memory after destuffing: 0110111111111111111110010

Error Control

- +ve & -ve feedback
- Way to ensure successful txm of data
- Timers: What happens when a frame completely vanishes: receiver neither sends a +ack nor -ack. Then timer comes to help

→ It may result in a frame being sent more than once & received more than once.

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→ Soln: assign sequence nos to frames.

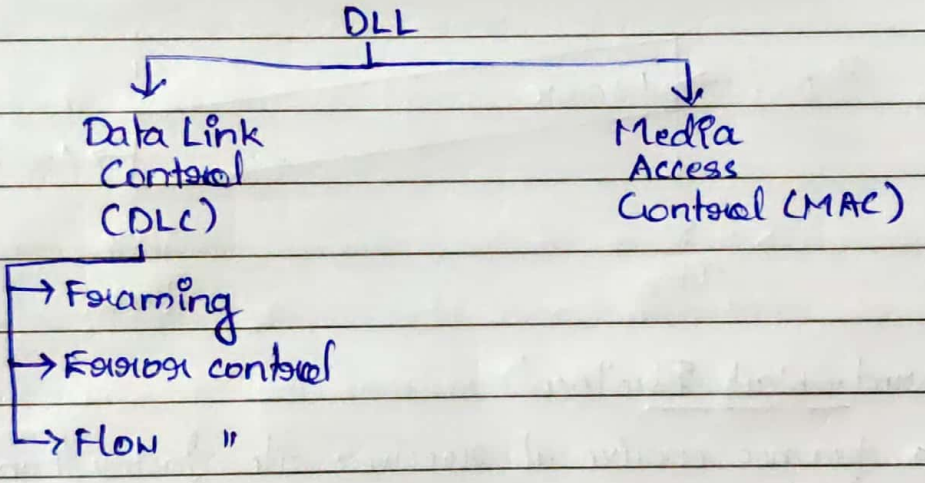
Flow Control

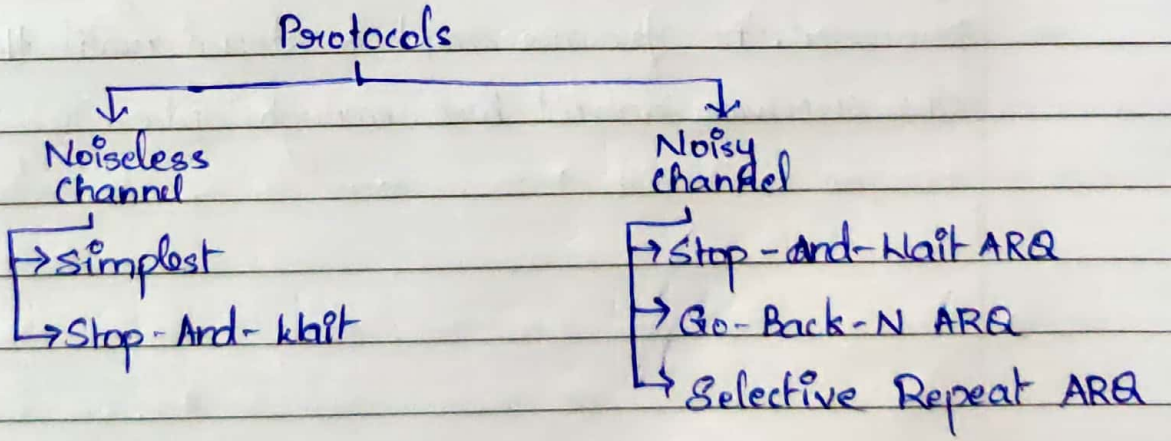
- Feedback-based flow control

→ Receiver sends back info to the sender giving it permission to send more data.

- Rate based flow control

→ The protocol has a built-in mechanism that limits the rate at which senders may transmit data, without using feedback from the receiver.





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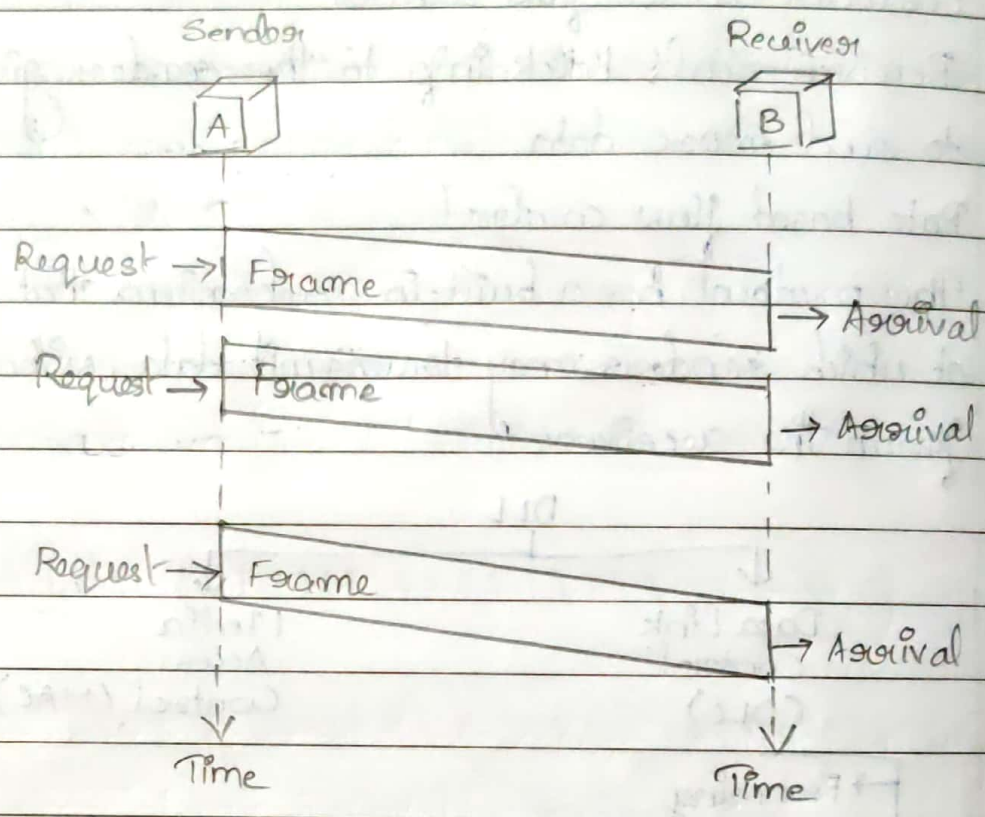
Noiseless Channels

- Simplest Protocol → has no flow or error control

→ Unidirectional protocol in which data frames are traveling in only

1 direct^{n} – from sender to receiver.

→ Receiver can never be filled out with incoming frames.



• Stop-and-Wait Protocol

→ If data frames arrive at receiver site faster than they can be processed, the frames must be stored until their use. Normally the receiver doesn't have enough space

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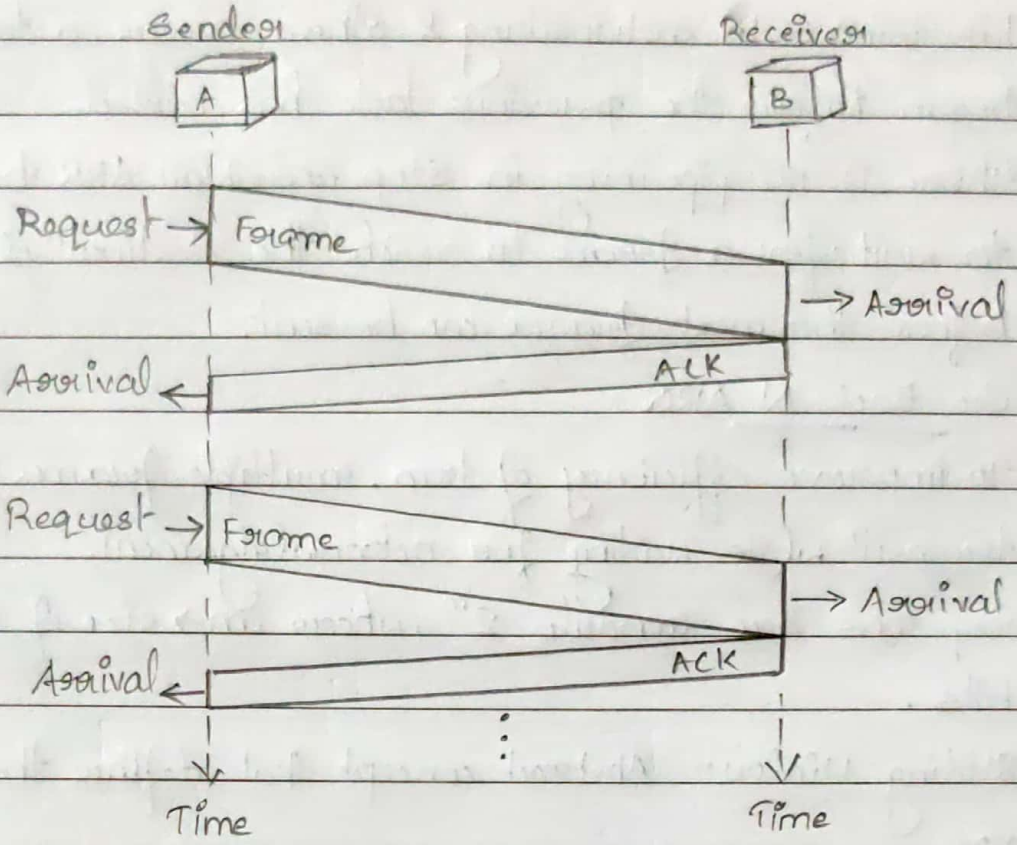

Noisy Channel

- Stop-and-Wait ARQ (Auto Repeat Request)

→ Error correct^n is done by keeping a copy of sent frame & re tx^m of frame when timer expires.

→ Use seq. nos to number frames. Seq. nos are based on modulo-2 arithmetic

→ Acknowledgement no. always announces the seq. no. of next frame expected.

→ Efficiency:- This protocol is inefficient if the channel has large bandwidth & long round trip time.

→ Round trip time:- It is the time required for a signal pulse or packet to travel from a specific source to a specific destinat^n & get back the acknowledge.

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→ Pipelining :- In networking & other areas, a task is often begun before the previous task has ended.

→ There is no pipelining in stop-and-wait ARQ because we need to wait for a frame to reach the destination & be acknowledged before the next frame can be sent.

• Go-Back-N ARQ

→ To improve efficiency of trm., multiple frames must be in transit while waiting for acknowledgement.

→ Seq. nos are modulo 2^m, where m → size of seq. no. field in bits.

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• Sliding Window :- Abstract concept that defines the range of seq nos

→ Send Window → It is an abstract concept defining an imaginary box of size $2^m - 1$ with 3 variables: S_f, S_n & S_{size}

S_f → Seq. no. of 1st (oldest) outstanding frame

S_n →

S_{size} →

→ Receive Window → It is an abstract concept defining an imaginary box of size 1 with 1 single variable R_n. The window slides when a correct frame has arrived; sliding occurs 1 slot at a time.

→ Timers :- This protocol uses only 1 timer. Timer for 1st outstanding frame always expires 1st; we send all outstanding frames when this timer expires.

→ Acknowledgement :- Receiver sends a +ve acknowledgement if a frame has arrived safe & sound in order.

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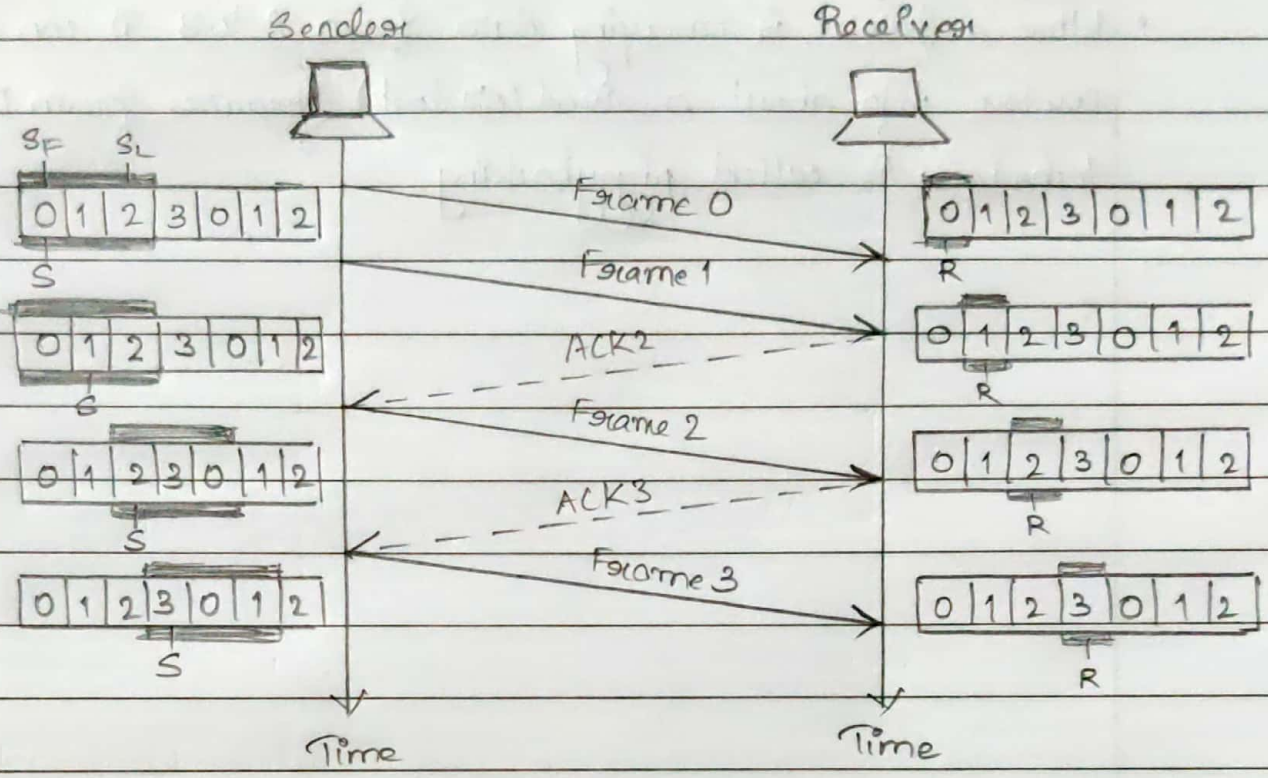
→ Sender keeps track of outstanding frames & updates the variables & windows as the ACKs arrive. (Normal operat^n)



→ If an ACK is damaged/lost, there can be 2 situat^n's:

(i) If next ACK arrives before expirat^n of any timer, there is no need for re-txm of frames because ACKs are cumulative in this protocol.

(ii) If next ACK arrives after expirat^n of timer, there is need for re-txm.

• Selective Repeat ARQ

→ Only damaged frame is resent. More bandwidth efficient but more complex processing at receiver.

→ It defines a -ve ACK (NAK) to request seq. no. of damaged frame before timer expires.

→ Size of sender & receiver windows must be at most 1 half of

2^m i.e. Window size = 2^{m-1}

Piggybacking

- When a frame is carrying data from A to B, it can also carry control info about arrived (or lost) frames from B; this technique is called piggybacking.

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High Level Data Link Control (HDLC)

- Bit oriented protocol
- For communicatn over point to point & multipoint links
- WAN communicatn

HDLC Statn Types

- 1° statn
  - → Controls operatn of link
  - → Issues commands (frames)
  - → Maintains separate logical link to each 2° statn.
- 2° statn
  - → Under control of 1° statn
  - → Issues responses (frames)
- Combined statn
  - → May issue commands & responses
  - → Combines features of 1° & 2° statns.

HDLC Link Configs

- Unbalanced
  - → 1 primary & 1 or more 2° statns
  - → Supports full duplex & ½ duplex
- Balanced.

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→ 2 combined stat^ns i.e.
→ Each stat^n can funct^n as 1° & 2°
→ Supports full duplex & 1/2 duplex.

HDLC Transfer Modes

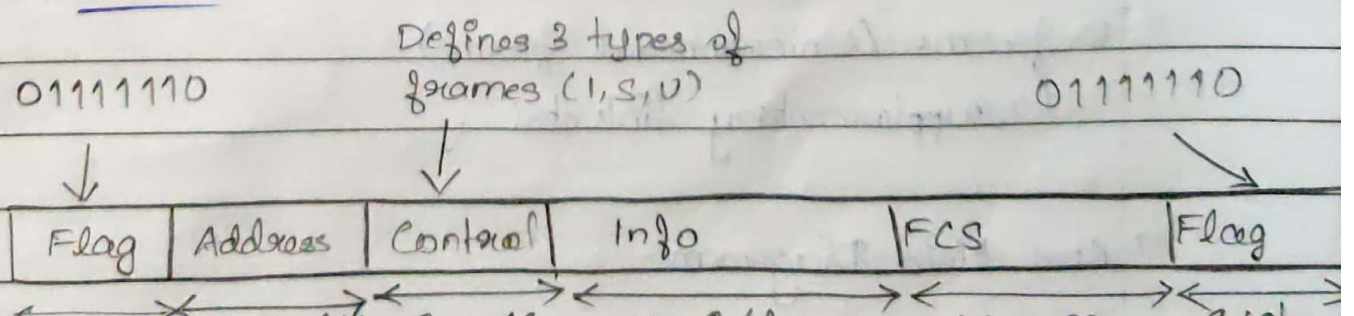
• Normal Response Mode (NRM)
→ Unbalanced config.
→ 1° can only initiate txm
→ 2° may only transmit data in response to cmd (poll) from 1°.
→ Used for both point-to-point & multi-point links.

• Asynchronous Balanced Mode (ABM)
→ Balanced config.
→ Link is point to point
→ Either stat^n can funct^n as a 1° & a 2°
→ Most widely used.

Frame

• 3 types of frames:
→ Info frame (I frame) → Transport user data & ctrl info relating to user data
→ Supervisory frames (S frames) → Transport ctrl info
→ Unnumbered " (U ") → Reserved for system manager

Frame Structure



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S frame →

Flag	Addr	Ctrl	FCS	Flag

U " →

Flag	Addr	Ctrl	Mgmt info	Flag

- Flag fields:-
→ Delimit frame at both ends
→ Used for synchronizatn
- Addr fields:-
→ Identifies 2° statn that sent or will receive frame
→ Usually 8 bits long
→ May be extended depending on the need of the n/w
  - LSB of each octet indicates that it is the last octet (1).
→ All ones (11111111) is broadcast
- Ctrl Field:-
→ Used for flow & error ctrl
→ Different for different frame type
- I-frame (Info frame)
  ↳ Data to be transmitted to user (next layer up)
- S-frame (Supervisory frame)
  ↳ Used for flow & error ctrl
- U-frame (Unnumbered frame)
  ↳ Supplementary link ctrl

→ Ctrl Field Diagram:-

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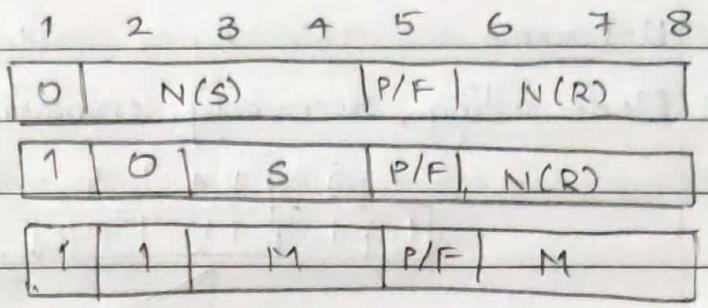


I-Frame

- Contains the seq. no. of transmitted frames & a piggybacked ACK.
- Poll / Final bit (P/F)

→ Use depends on context

→ Cmd frame

★ P-bit:- Used for poll from 1°

★ 1 to solicit (poll) response from peer

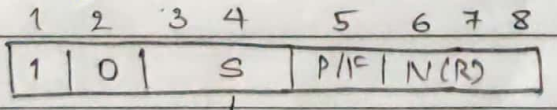
→ Response frame

★ F-bit:- Used for response from 2°

★ 1 indicates response to soliciting cmd.

S-Frame

- Used for flow & error ctrl.



RR → Receive Ready

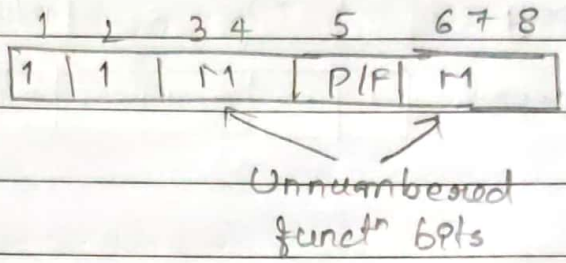
RNR → " Not "

REJ → Reject on frame N(R)

SREJ → Selective Reject on N(R)

U-Frame

- Mode setting, recovery, connect/disconnect



- Info Field :-

→ Users data from n/w layer or mgmt info

→ Variable length

- Frame Check Seq. (FCS) Field :-

→ FCS

→ Error detect

→ 16-bit CRC

→ Optional 32-bit CRC

HDLC Operat

- Exchange of info, supervisory & unnumbered frames
- 3 phases:

→ Initializat

→ Data transfer

→ Disconnect

Point to Point Protocol (PPP)

- DLL protocol
- Byte oriented protocol
- Used in WAN

→ Interconnect of small networks may be possible through

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dedicated or dial on demand WAN connect"

- Provides Services
→ Provides connect" over multiple links.
→ " n/w addr. config.
→ " multiple n/w layer services supporting a variety of n/w layer protocols
→ Define format of frame to be exchanged btw devices
→ Defines how n/w layer data are encapsulated in data link frame
- Not Provide Services like
→ Flow ctrl
→ Error "
→ Addressing mechanism to handle frames in a multipoint config
- Framing
→ It's a byte oriented protocol

Flag 1 byte	Addr 1 byte	Ctrl 1 byte	Protocol 2 bytes	Info (variable)	FCS 2 bytes (CRC)	Flag 1 byte
	↓ Always All 1s (11111111)	↓ Const value (00000011)				

→ Protocol Field:-
★ It specifies the kind of packet in data field i.e. what is being carried in data field.
→ Info:-
★ Info field:- From 0 bytes to MRU (Max. Receive. Unit)

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★ MRU default :- 1500 bytes. Different values may be negotiated
★ Padding :- May be added to fill the frame up to MRU. Treated as info data (checked by FCS). PPP not responsible of recognizing & delimiting it.

→ FCS field :-

★ It is either of 2 bytes or 4 bytes.
★ It contains the checksum

→ Byte stuffing :- Same as HDLC.

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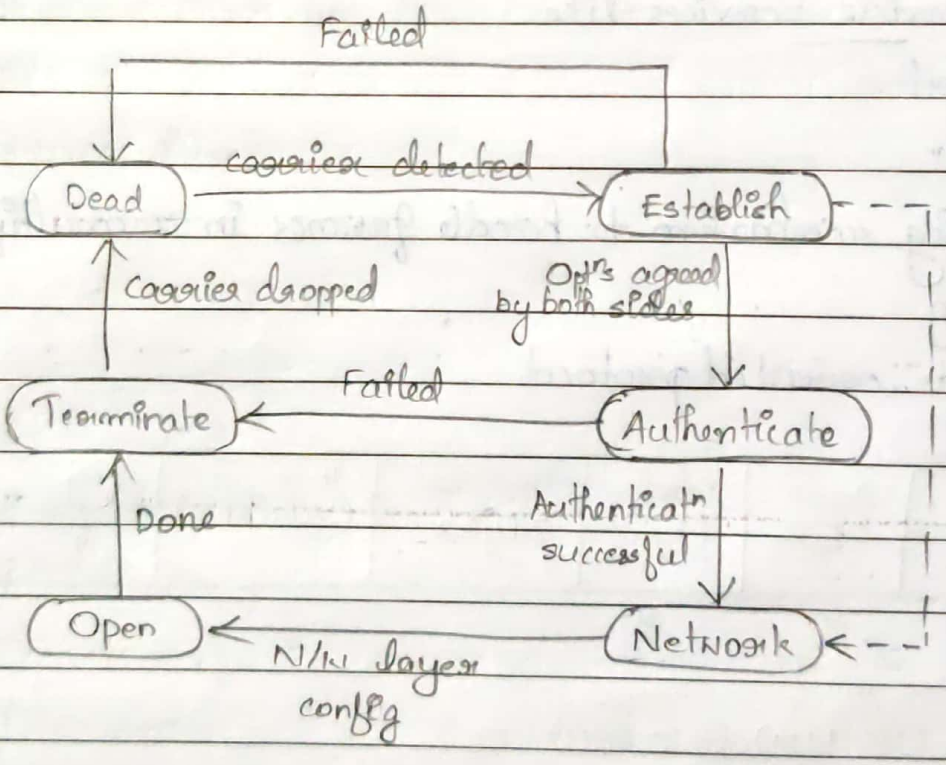
Transitn Phases



(i) Dead :- Here the link is not used. There is no active carrier & line is quiet.

(ii) Establish :- Connectn goes into this phase when 1 of the nodes start communicatn. In this phase, 2 parties negotiate the opt's. If it is successful, the system goes into authenticatn phase / directly to networking phase.

(iii) Authenticate:- It is optional. The 2 nodes may decide during establishment phase, not to skip this phase.

(iv) Network:- Here, negotiation for n/w layer protocols take place. PPP specifies that 2 nodes establish a n/w layer agreement before data at n/w layer can be exchanged.

(v) Open:- Here, data transfer takes place.

(vi) Terminate:- Here connection is terminated.

- 3 sets of protocols are defined to make PPP powerful:

(i) Link Control Protocol (LCP)

- Responsible for establishing, maintaining, configuring & terminating links.
- LCP - PDU Format:

Code	Identifier	Length	LCP info
1 byte	1 byte	2 bytes	0+variable

Flag	Addr	Ctrl	Protocol	Info	FCS	Flag

→ Code (1 byte) = type of LCP packet
→ Identifier (1 byte)
→ Length (2 bytes)
→ Data: variable

- Packet types

→ Link Config packets

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→ Link Termination packets
→ " Maintenance "
(ii) Authentication Protocol
• Authentication:- Validating the identity of a user who needs to access a set of resources.
• PPP has 2 protocols:
→ PAP (Password Authentication Protocol)
→ CHAP (Challenge Handshake Authentication Protocol)
→ PAP
★ 2 step process:
- The user who wants to access a system sends an authentication identification & password
-

→ CHAP
★ 3 way handshaking authentication protocol; greater security than PAP
★ System sends the user a challenge packet with a challenge value
★ User applies predefined func that takes challenge value & users password & create a result.
★ User sends result in response packet to system
★ System does the same
★ If both same, access granted

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(iii) Network Ctrl Protocol

- PPP can carry a n/w layer data packet from protocols defined by internet OSI, Xerox, Appletalk & so on.
- To do this, PPP has defined a specific NCP for each n/w protocol

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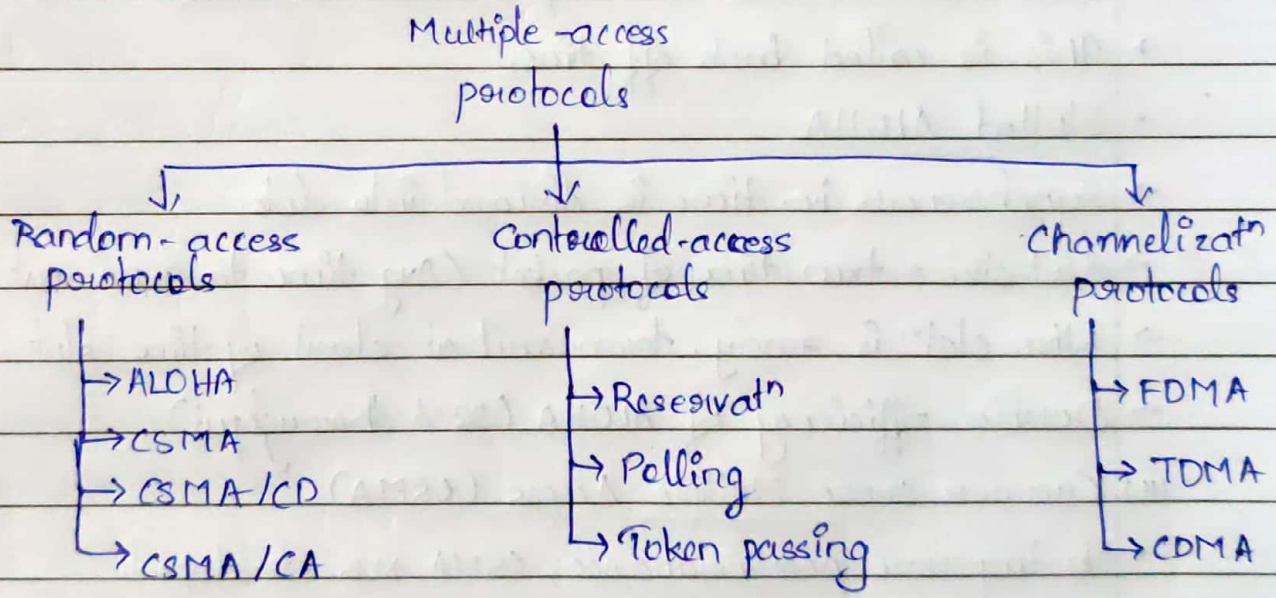
Media Access Sublayer

- When multiple nodes / stat'n are connected & use a common link, called a multipoint / broadcast link, we need multiple access protocols to coordinate access to the link.



Random Access

In random access, no stat'n is superior to another & none is assigned control over another. No stat'n permits, or doesn't permit, another stat'n to send. At each instance, a stat'n that has data to send uses a procedure defined by the protocol to make a decision on whether or not to send.

(i) ALOHA

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- Original ALOHA protocol is called pure ALOHA
- Pure ALOHA

→ If you have a packet, just send it.
→ " multiple people try it & so there is collision, then try resending it.
→ Theoretical analysis shows a throughput of only 18%.
→ If all stat^ns try to resend their frames after the time, each stat^n waits a random amount of time before resending its frame.
→ This randomness will help to avoid collision
→ This is called back off time.

- Slotted ALOHA

→ Synchronous i.e. time is divided into slots.
→ Slot size = txm time of packet (Avg. time to send out frame)
→ When stat^n is ready, transmit at start of time slot
→ Doubles efficiency of ALOHA (38% throughput)

(ii) Carrier Sense Multiple Access (CSMA)

- To improve performance, CSMA was developed.
- Chance of collision can be reduced if a stat^n senses the medium before trying to send.
- Listen to channel. If busy then wait for a random time & then listen again
- If not busy then transmit
- Collision may still happen.

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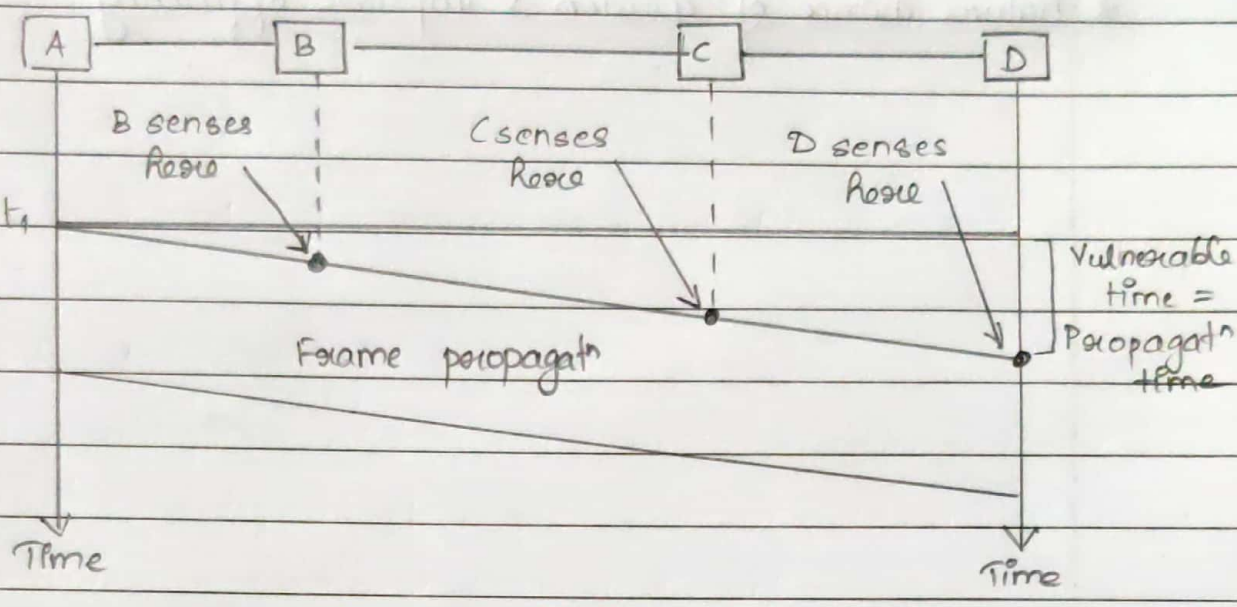

- Persistence Method

→ 1-Persistent :-

★ After the statn finds the line idle, it sends its frame immediately

★ This method has highest chance of collision

★ Bcoz 2 & or more statns may find the line idle & send their frames immediately.

→ Non-Persistent

★ A statn has a frame to send senses the channel.

★ If line idle, it sends immediately

★ If busy, it waits a random amount of time & then senses the line again.

★ Reduces chance of collision.

→ P-Persistent

★ It is used if channel has time slots with a slot durat^n equal to or > max. propagat^n time.

★ Combines advantages of others. 2

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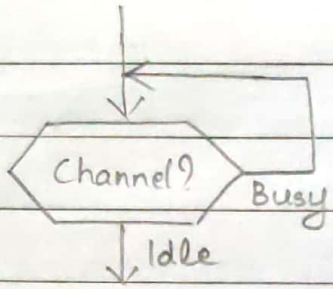
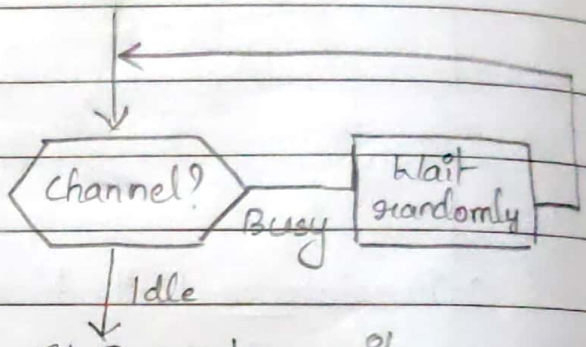
* Reduces chance of collision & improves efficiency
* When a transmitting stat^n has a frame to send & it senses a busy channel, it waits for end of tx^n & then transmits with a probability p.
* Since, it sends with a probability p, the name p-persistent CSMA is given.



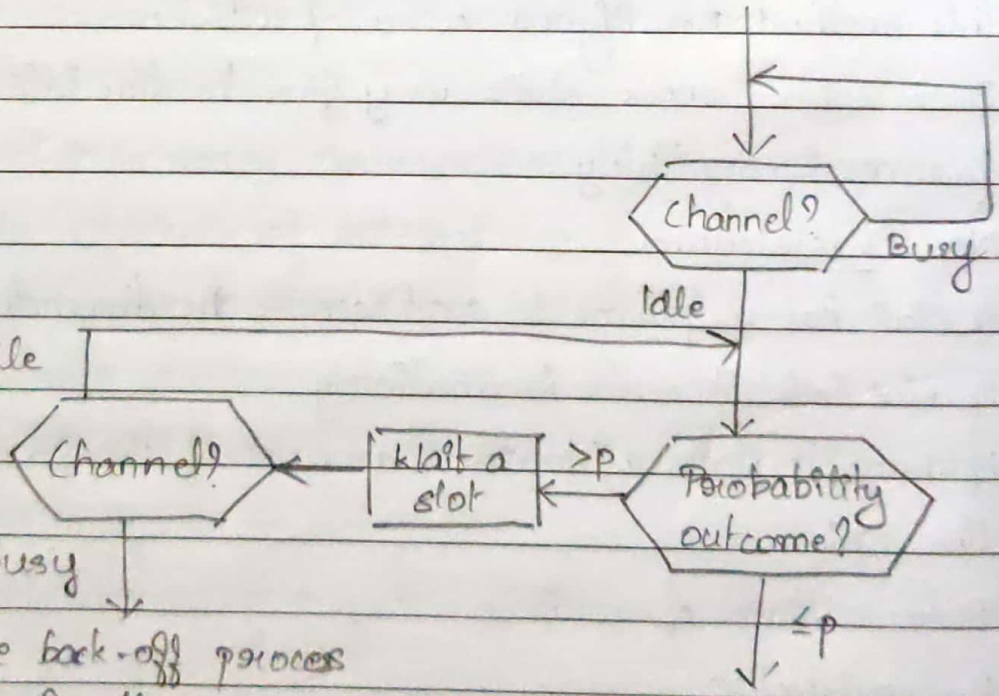
Stat^n can transmit

1-persistent



Stat^n can transmit

Non-persistent



Use back-off process as though collision occurred

Stat^n can transmit

p-persistent

(iii) CSMA/CD (Collision Detect^n)

- It is specified in the IEEE 802.3 standard.
- Each stat^n senses whether medium is idle & therefore available for use.
- If it is, the stat^n begins to transmit 1st frame.
- If another stat^n also tries to transmit at same time, a collision occurs & frames are discarded & then a jamming signal is sent throughout the n/w to notify all stat's of the collision.
- Each stat^n then waits for a random period of time & retries.
- If another collision occurs, the time intervals from which the random waiting time is selected are increased step by step. This is known as exponential back off. The stat's retry until successful txm of frame.

(iv) CSMA/CA (Collision Avoidance)

- Used in wireless n/w to avoid collision.
- Interframe Space

→ It can be used to define priority of stat^n / frame.

→ After finding idle channel it waits for a period of time.

- Content^n Window

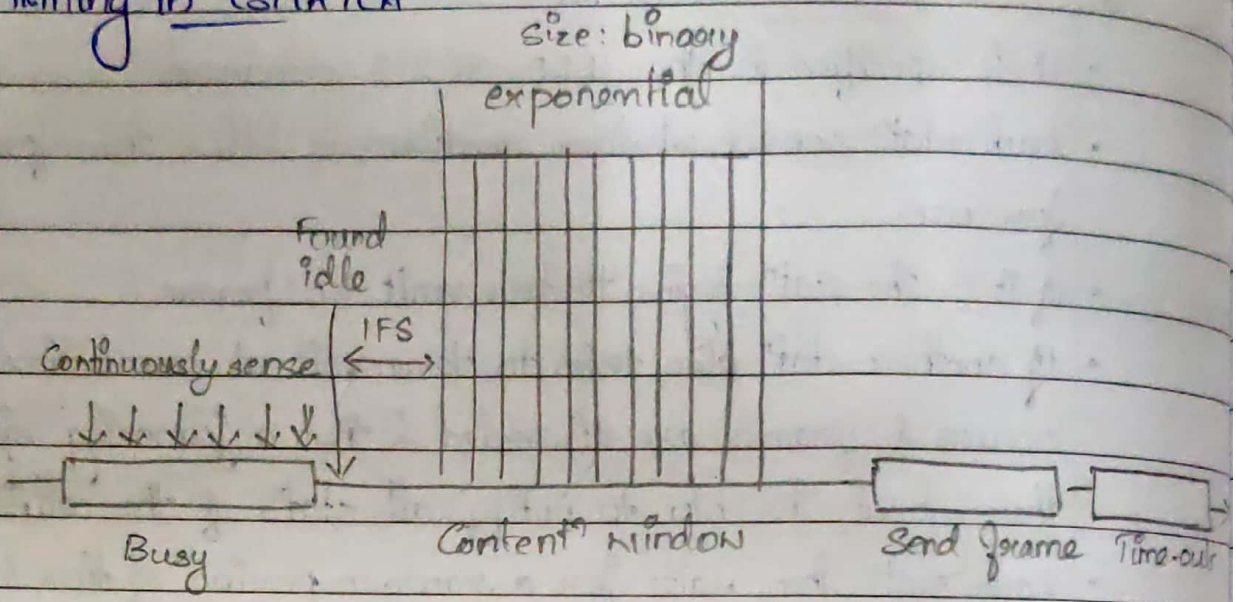
→ An amount of time divided into slots.

→ The no. of slots changes according to the binary exponential back-off strategy.

- Acknowledgement

→ A time out timer can help guarantee that the receiver has received the frame.

- Timing in CSMA/CA



Controlled Access

- Stat^n's consult 1 another to find which stat^n has the right to send. A stat^n cannot send unless it has been authorized by other stat^n's. 3 controlled access methods:

(i) Reservat^n

- A stat^n needs to make a reservat^n before sending data.
- Time is divided into intervals
- The stat^n's which have reserved their slots transfer their frames in order.
- If there are M stat^n's, the reservat^n interval is divided into M slots, & each stat^n has 1 slot.
- i^{th} stat^n may announce that it has a frame to send by inserting a 1 bit into the i^{th} slot.
- After all N slots have been checked, each stat^n knows which stat^n's wish to transmit.
- After data trans. period, next reservat^n interval begins.

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- Since everyone agrees on who goes next, there will never be any collisions.

(ii) Polling

- It works with topologies in which 1 device is considered as a 1° stat^n & the other devices are 2° stat^{n}s.
- All data exchanges must be made through the 1° device even when the ultimate destinat^n is a 2° device.
- 2 funct^{n}s:- Poll funct^n & Select funct^n

(iii) Token Passing

- The stat^{n}s in a n/w are organized in a logical ring.
- In other words, each stat^n has a predecessor (stat^n logically before the stat^n) & a successor (stat^n logically after the stat^n)

Channelizat^n

It is a multiple-access method in which the available bandwidth of a link is shared in time, freq., or through code, among different stat^{n}s.

3 protocols:- FDMA, TDMA & CDMA

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Ethernet 802.3

- LAN technology
- Topology used → bus
- MAC method → CSMA/CD
- Data rate: 10 Mbps, 100 Mbps, 1 Gbps, 10 Gbps
- Encoding techniques used: Manchester Encoding
- Ethernet addr: MAC addr.
- Baseband trm technique.

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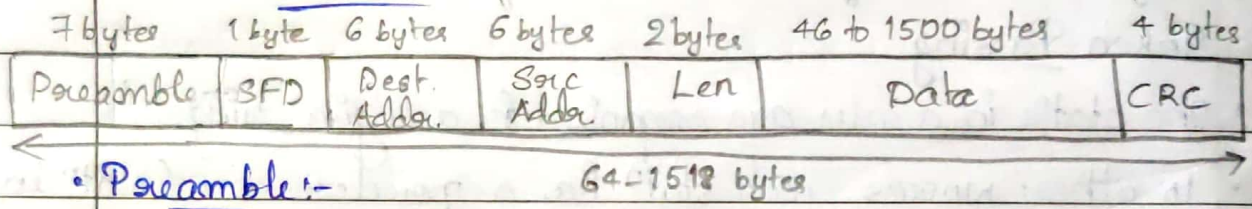
Ethernet Addr

- MAC addr is represented in Hexa Decimal format
  eg: 00:05:5D:FE:10:0A
- End notes are identified by their ethernet/MAC addresses which is a unique 6 byte addr.
- The 1st 3 bytes identify a vendor/prefix & last 3 bytes are unique for every host/device.

Ethernet Frame Structure



- **Preamble:-**
  → 7 bytes with pattern 10101010
  → Indicates start of frame & allow sender & receiver to establish bit synchronizat°.
- **SFD:-**
  → Start Frame Delimiter
  → Signals the beg. of the frame
  → 10101011
  → Alerts the receiver that the next field is the dest. addr.
- **Dest. Addr:-**
  → 6-byte field which contains MAC addr. of dest.
- **Src Addr:-**
  → 6-byte field which contains MAC addr. of src.
  → As src addr. is always an individual addr. (Unicast), the least significant bit of 1st byte is always 0.

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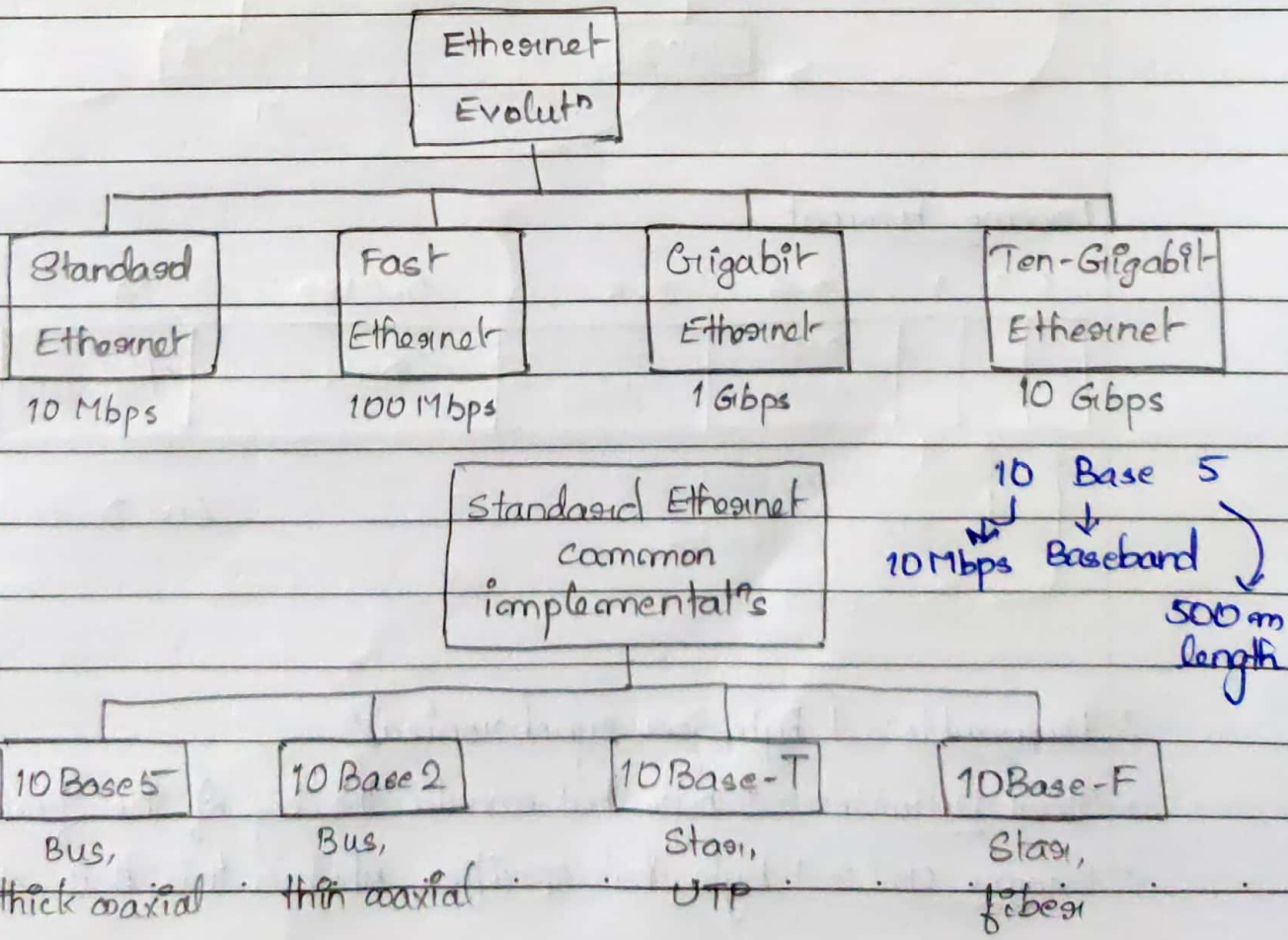
- **Length:-**
  - → 2-byte field which indicates the length of entire Ethernet frame.
  - → 16-bit field that can hold the length value btw 0 to 65534.
  - → Length cannot be larger than 1500 bcoz of some own limitat's of Ethernet.
- **Data:-**
  - → Place where actual data is inserted, also known as Payload.
  - → This field carries data encapsulated from upper layer protocol.
  - → Min. of 46 & max of 1500 bytes.
- **Cyclic Redundancy Check (CRC):-**
  - → Error detect^{n} info.



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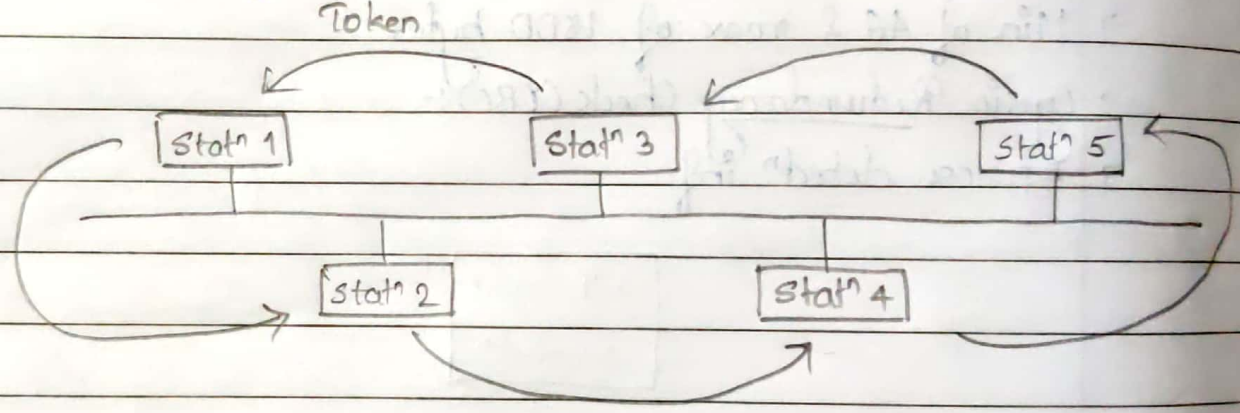
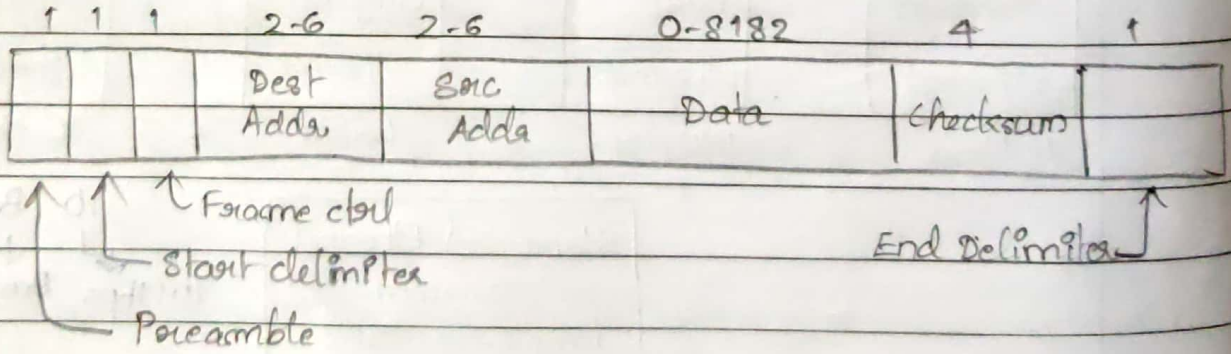
Token Bus (IEEE 802.4)

- It is a popular standard for token passing LANs
- Signal speeds in the range 1Mbps, 5Mbps & 10Mbps are achievable
- Cabling used is coax cable
- Is a broadband computer n/w.
- Physical topology is bus or tree & logical ring is created using coaxial cable.
- Token is passed from 1 user to another in a seq.
- A stat^n can only transmit data when it has the token.



Frame Format



- Preamble :- 1 byte for synchronizat^n
- Start Delimiter :- 1 byte that marks the beg of the frame
- Frame Ctrl :- 1 byte that specifies whether this is data/ctrl. frame

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- Dest Addr:- 2-6 bytes that specifies addr of dest stat^n
- Src Addr:- " " " " " " src "
- Payload:- A variable length field that carries