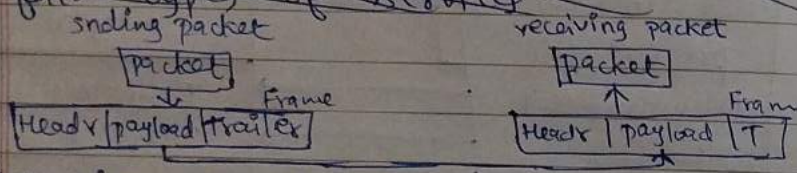
Module - 2

Data link Layer (DLL)

→ **DLC design issues =**

~~DLL can be designed to offer the follow types of services~~



I) **service provided to nlw layr:**

DLL can be designed to offer the follow types of services –

a) **Unacknowledge conne^{n}less service** consist of hving the source machine snd indepndnt frames to destn machine without hving the destn machine aknowledge thm.

b) **Acknowledge conn^{n}less service** also no logic conn^{n} used bt each frame snd is individually acknowledged. In this way, the sndr knows whethr a frame has arrived correctly / been lost.

c) **Acknowledge conn^{n} oriented service** Source & destn machines establish a conn^{n} bfre any dat a is transfered.

It is appropriate ovr long, unreliable links like satellite channel / long distnce telephn circuit.

* DLL of OSI model actually consist of 2 sublayrs –

a) LLC (logical link control)	(b) MAC (media Access control)
• upper sublayr that is responsible for flow & error control	lower sublayr that is mostly responsible for multiple access resoln. If the channel is dedicated, we do not need the lower sublayr.
• deals with procedures for commun b/w 2 adjacnt node – node to node commun	

II) **Data link control : (DLC)**

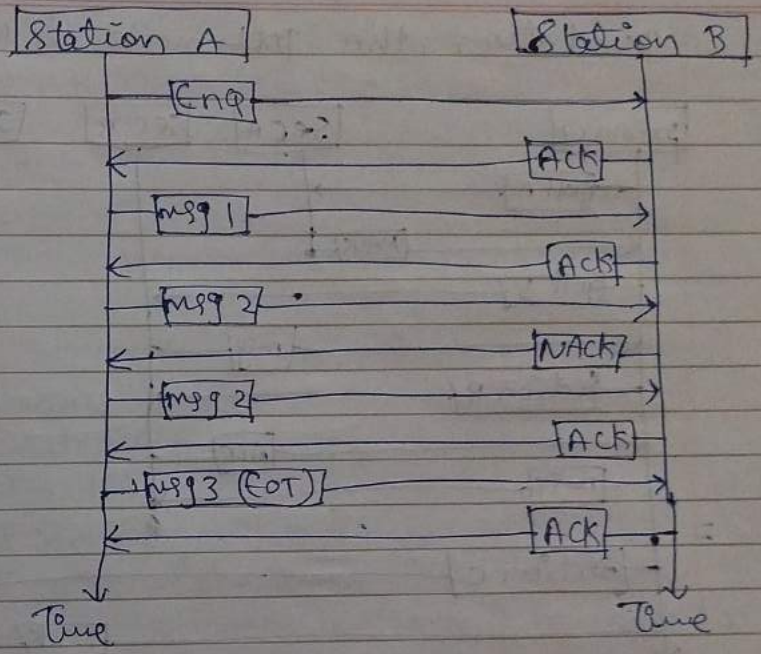
* It is the service provided by the DLL to provide reliable data transfer ovr the physical medium.
* The logic for DLC is provided by the LLC of DLL.
* data link () - nalities include –

a) Line Discipline:

* It is () of DLL. determines & identifies the (dir) of commun
* It is simply (f) of coordinating half-duplx trans. (i.e) data can be transmitted in both (dir) on n/w of data commun bt not same time.
* Also makes sure that whethr / not receiv is ready to accept / signal ender to start.
* Also used to determine which of device can transfer & whn it can trasfr data.
* L.D is accomblished in 2 ways—

i) ENQ/ACK. (enquiry / Acknowledgmnt):

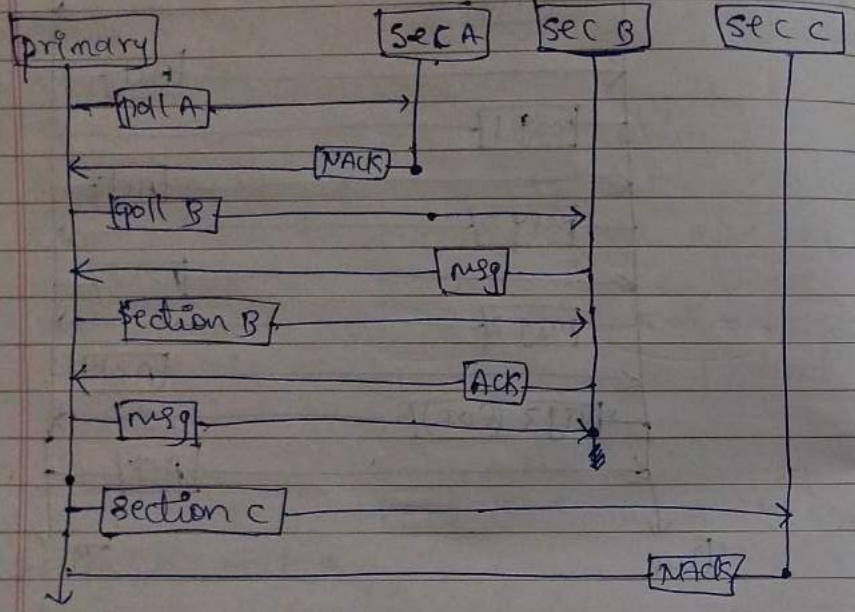
* It is a procedure of L.D that is generally used to determine that which of device on n/w is capable of initiating / starting trans. of data.
* Initiating device generally establishes session in both trans. - Full & hlf duplx
* Both of devices can send / transmit simultanously once session is established in full-duplx.



ii) poll / Select:

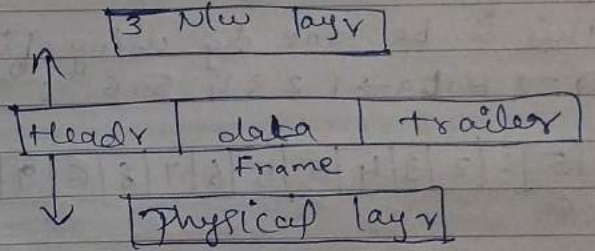
* Basically works with some topologies where 1 of devices is considered as primary station & othr device are considred as secondary station.
* whn p. station wants to transmit smthing to sec. station, then SELECT mode is used.
* To solicit transn frm s. station to

p. Station, then poll mode is used.



d) Framing : (F)

* frames are the units of digital trans. particularly in Comp n/w & telecommu.
* It is a point-to-point conn" b/t 2 Comp/devices consisting of a wire in which data is transmitted as a stream of bits.
* Ethernet, token ring, frame delay & other DLL technologies hve their own frame str.

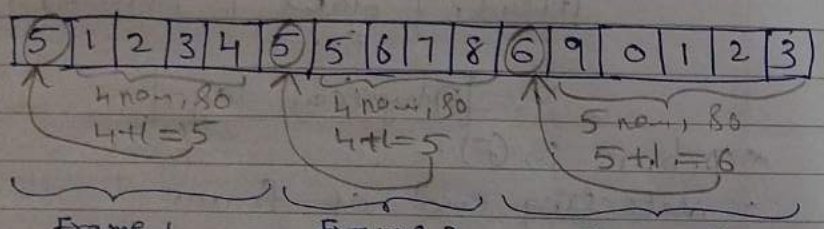


* prbms in (F) –
  - detecting end of frame
  - Handling errors.
  - Framing ovrhead
* Types → ① Fixed-Size (F) : The frame is of fixed size & there is no need to provide boundaries to the frame.
  ② Variable-Size (F) : there is a need to define the end of frame as well as the beginning of the nxt frame to distinguish.
  This can be done in 2 ways –
  a) Length field
  b) End Delimtr.
* 4 methods –

1) Character count :
   - This method is rarely used & is

generally required to count total nom of charactrs that are prsnt in frame

- This is be dne by using field in headr
- eg → data → 1 2 3 4 5 6 7 8 9 0 1 2 3.



2) Byte Stuffing :

* The flag (keyword) byte method gets around the prbm of resynchroniz^n after an error by hving each frame
* Here, an 8-bit Flag is added at the beginning & at the end of the frame.
* Every time a flag sequence is encountre it signifies the beginning / end of a frame.
* only 3 types of byte sequen us →
  flag, escape, data.

flag	data	flag

* The receivr would thn have to de-stuff the escape sequence in order to obtain original data.

3) Bit Stuffing :

* It is an alternative tool of 1 stuffing which uses framing at bit level so that frames can contain an arbitary nom of bits made up of units.
* It is the insertion of non info bits into data.
* The stuffed bits should not be confused with overhead bits (non data bits that are necessary for trans).
* eg → Suppose 01111110 is flag byte
  Now attach this flag byte to original data, (lets the data is 0100111111011111)

01111110	0100111111011111	01111110

starting flag — data — ending flag.
(original data → 5 flag bits same sequence receivr thinks that it is ending)
So it take only 010. So to overcome this we stuff,
after 5 consecutive one's, insert 0.

.data → 0100111110111111
ff data → 010011111010111110 1
ow add flag bits to original data —

| 01111110 0100111110101111101 01111110 |

at receivr side, it unstuff the data —

| 010011111011111 |

This data is snd to the n/w layr.

c) Error Control :
1) Transm error → Transm of time of [illegible] error.
2) types of error → ① Single bit error → [illegible] bit error [illegible]
→ burst error → more than 1 bit error.
eg → 1010110
11000101
→ 4.

3) Error detection :
* by receivr   * redundant bit
~~detection method~~: original bits [illegible] redundant bit add [illegible]

Sndr → Generator → msg & rb → transm → received info → Check func → msg received

~~* Single bit error~~
* Error detection Method:
1) Parity check: → Data bit + RB. & no. of 1's be evn.
2 types → odd & evn.
- 10100 → no. of 1's are 2 (evn) so add RB as 0
⇒ 101000 (evn RB), at receivr side it check no. of 1's & RB are same in sndr side.
- 10101 → no. of 1's are 3 (odd), so add RB as 1
⇒ 101011 (add RB).

2) CRC (Cyclic Redundancy check):
Databit + RB

eg, data → 1101011011
Sndr side: predetermined no. [illegible] → 10011
RB = n-1 = 5-1 = 4 (add 4 0s at last)

```
10011 | 11010110110000
        10011
using XOR(⊕)
discard → 01001 1
         10011
         00000
           10110
           10011
           00101
```

XOR method
0 0 → 0
1 0 → 1
0 1 → 1
1 1 → 0

```
discard
0 → 0 0 | 10100
          10011
discard
0 →  00 | 1110  → add this to OD.
```

```
10011 ) 11010110111110
        10011
        0 | 100111
            10011
            0.  10111
                10011
                00 | 10011
                     10011
                     0     → 0 → no error
```

3) LRC (Longitudinal redundancy check) :
* block of parity → RB. ie parity is calculated for each colmn. Displayed in rows & colm.

eg → data – 1100111, 1011101, 00111001, 10101001
arrange as rows & colm –

1	1	1	0	0	1	1	1
1	1	0	1	1	1	0	1
0	0	1	1	1	0	0	1
1	0	1	0	1	0	0	1
1	0	1	0	1	0	1	0

add by XOR → last row → LRC

in extra bit sender receiver in message, then it check whether it gets same no — (10101010) / not.
* LRC is an redundancy error scheme that uses parity to determine if an (tran) error has occured within a msg. sometimes it is → msg parity

4) Hamming code :
* can detect 2 bit error & can correct 1 bit error.
* error corrn steps :
1) cal no. of RB – ($2^r \geq m+r+1$)
2) positioning of RB.
3) cal value of each RB.
* eg → data = 1100 ∴ m = 1100.
$2^r \geq m+r+1 \Rightarrow 2^r \geq 4+r+1$.

① want to find r ?
$r = 2 \Rightarrow 2^2 \geq 4+2+1$ ✗ , $r = 3 \Rightarrow 2^3 \geq 4+2+1 = 8$ ✓
∴ r = 3 , total length = r + m = 3+4 = 7

② power of 2 – $2^0, 2^1, 2^2, 2^3$ → 1, 2, 4, 8.

D4	D3	D2	D1
1	1	0	0

→

r3	D4	D3	D2	r3	D1	r2	r1
8	7	6	5	4	3	2	1

→

1	1	0	r3	0	r2	r1
7	6	5	4	3	2	1
(111)	(110)	(101)	(100)	(011)	(010)	(001)

– binary no.

r_1 ? (binary non-zero LSB contain, if it is 1 take that num)

$r_1 = \{7, 5, 3, 1\} = (1, 0, 0, r_1)$

odd(0) so add 1 to

$\therefore r_1 = 1$

Same steps for r_2 & r_3

$r_2 = \{7, 6, 3, 2\} = \{1, 1, 0, r_2\}$

even (1)

$\therefore r_2 = 0$

(num of 1s check)

$r_3 = \{7, 6, 5, 4\} = (1, 1, 0, r_3)$

even(1)

$\therefore r_3 = 0$

This all is Sndr Side

Now receivr Side —

Sub r_1, r_2, r_3 in OD.

1	1	0	0	0	0	1

Suppose this num be 1101001 to receivr.

Same steps for r_1, r_2, r_3.

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

$r_1 = \{7, 5, 3, 1\} = \{1, 0, 0, 1\} \Rightarrow r_1 = 0$.

$r_2 = \{7, 6, 3, 2\} = \{1, 1, 0, 0\} \Rightarrow r_2 = 0$.

$r_3 = \{7, 6, 5, 4\} = \{1, 1, 0, 1\} = r_3 = 1$.

r_1	r_2	r_3
0	0	1

now reverse →

r_3	r_2	r_1
1	0	0

here r_3 is incrt (1)

error → (4)

* It is a set of error-correction codes that can be used to detect & crt. the errors that can occur when the data is moved / stored from Sndr to receivr.
* It is a technique developed by R.W. Hamming for error correction.
* Redundant Bits are extra binary bits that are generated & added to the info carrying bits of data transfr to ensure that no bits were lost during the data transfr.

• ~~2 types~~

c) Error control :

* used to ensure & confirm that all the ~~control~~ data frames (packets. (i.e) bit streams of data are transmitted from Sndr to receivr.
* It is basically (p) in DLL of detecting / identifying & re-transmitting data frames that might be lost / corrupted during trans~.

* Each & every time an error is detected during transm, particular data frame are retransmitted & this ϕ) → ARQ Automatic Repeat Requst).
* 3 versions of ARQ –

a) Stop-and-wait ARQ:
- Also called Alternating bit protocol.
- 1 of the simplest flow & error contro techniques. This mechanism is generally required in telecommun to transmit data b/w 2 connected devices.
- Receivr indicates its readiness to receive data for each frame.

b) Sliding window ARQ: Generally used for conti- transm error control.
2 categories –

1) Go-Back-N ARQ:
- It is a form of ARQ protocol in which transm ϕ) continues to snd / transmit total nom of frames
- It uses sliding w flow control protocol.
- If no errors, thn opr is identical to sliding window.

2) Selective-Repeat ARQ:
It is a form of ARQ protocol in which only suspended / damaged data frames are only retransmitted. more efficient than Go-back-N ARQ used less bcz of more complxity b/w sndr & receivr

2 ways of E-Control

Error detectn
* Simply means detectn of errors. This errors may occur due to noise during transm frm transmitter to the receivr in commun systm.

Error correctn
Simply means Correctn of errors. means reconstrun & rehabilitation of OD that is error free.

* Types of errors:

Single-Bit error
- Here, only 1 bit of a gvn data unit is changed frm 1 to 0 / frm 0 to 1.
- It is an isolated error condin that alters 1 bit bt does not affect nearby bits.
- Does not apper more in serial data transm mainly occurs in parallel data transm

Burst error
- means that 2 / more bits in the data unit hve changed frm 1 to 0 / frm 0 to 1:
- determined frm 1st corrupted bit to the last corrupted bit.
- Duration noise is more than S-b. err.

2 types of errors → ① Single-bit (E) : here, only 1 bit of a gvn data unit is changed frm 0 to 1 / 1 to 0.
② Burst (E) : means that 2 / more bits in the data unit hve changed frm 1 to 0 / frm 0 to 1.

→ Error Detection Codes :

I VRC (vertical Redundncy Checking) / parity check.

* refers to an err detection method where an extra bit is added to each data unit.
* provide Simple & efficient method for detecting err in data transn & storage
* 2 types of parity bits —

a) Evn P bit :
- Here, a gvn set of bits, the nos of 1's are counted. If that count is odd, P bit value is 1 othrwise 0 (evn).

b) odd P. Bit :
Here, a gvn set of bits, the nos of 1's are counted. If the count is evn, the P bit is 1 othrwise 0 (odd)

II CRC :

* CRC is based on binary nos.
* Here, a sequence of R bits are appnded to the end of data unit so that the resulting data unit becomes exactly divisible by a 2nd predetrmined binary no.
* At the destinatn, the incoming data unit is ÷ by the same no.
* A remaindr indicates that the data unit has been damaged in transmit & ; must be rejected.

III LRC :

* Also → 2-D parity check.
* here, data which the user want to snd is organised into tables of rows & colmns.
* A block of bits is ÷ into table / matrix of rows & colmns.
* In ordr to detect an err, a R bit is added to the whole block & this block is transmitted to receivr.

The receivr uses this redundnt row to detect ~~an~~ error.

* used to detect burst errors.

d) Flow Control :

* Technique for assuring that a sndr does not overwhelm a receivr with data frame at a rate which is faster than receivr can accept thm.

* Technique that generally observes the propr flow of data frm sndr to receivr.
* Essential bcz it is possible for sndr to transmit data at very fast rate & hnce receivr can receive this infor & (?) it.
* It tells the sndr hw much data should be snt to the receivr so that it is not lost. This mechanism makes the sndr waits for an ack bfre snding the nxt data.
* 2 ways to control the flow of data —

a) Stop and wait (P):
- Simplst flow control method. here snder will snd 1 frame at a time to the receivr.
- the sndr will stop & wait for the ack frm the receivr. whn the sndr gets ack then it will snd the nxt packet to receivr & waits for ack again & this (P) will continue.
- disadv → can snd only 1 packet at a time.

(b) Sliding window (P):
A window is a buffer where we store the frames. Each frame in a window is numbred.
A sndr can snd n frames at a time. whn the receivr snds the ack of the frame then we need not store that frame in our window as it has already been received by the receivr so, the window in the sndr side slides to the next frame.

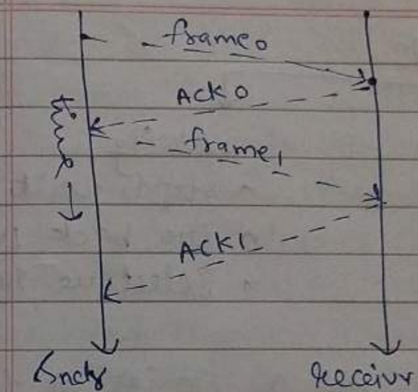


Fig: Stop and wait (P).

2 types of delays —
a) transm delay: time tkn by the sndr to snd all the bits of the frame onto the wire → T.D
$T_d = D/B$
b) propoga delay: time takn by the last bit of the frame to reach frm 1 side to othr side → P.D
$T_p = d/s$.

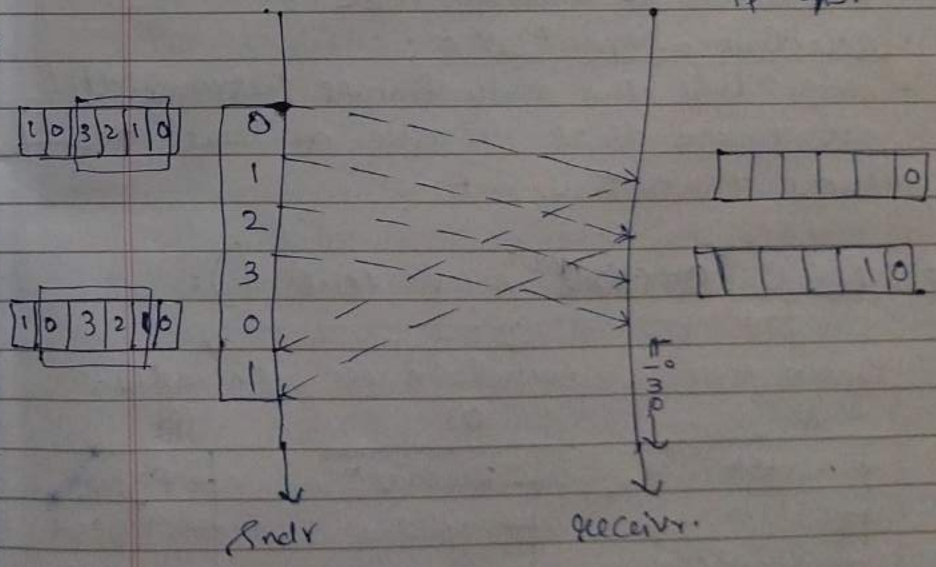


Fig: Sliding window (P)

DLL → Logical link control (LLC) → error control, flow control
DLL → MAC

* Protocols
  - Noiseless
    - Stop & wait
  - Noisy
    - Stop & wait ARQ
    - Go back N
    - Selective repeat

* Go-back-N ARQ:
- Here, a station may send a series of frames sequentially numbered some max value → window size.
- The nos of unack frames outstanding is determined by window size

* Selective-repeat ARQ:
- with this the only frames retransmitted are those that receive an -ve ack those that timeout.

=> MAC (Media Access control):
- Random Access
  - ALOHA
  - CSMA
  - CSMA/CD
  - CSMA/CA
- Controlled Access
  - Reserv^n
  - polling
  - Token passing
- Channelizan^n
  - FDMA
  - TDMA
  - CDMA

R.A.Ps are used in LANS & WANS.

I ALOHA:
Here, a node transmit whnevr data is available to snt.
If anthr node transmit on same time a collision occurs. & the frames that were transmitted are lost

1) pure aloha: Here, each station snd a frame whnevr it has a frame to snt it doesnot check whethr the channel is busy bfre transmitting. Since there is only 1 channel to share, there is a possibility of collision b/w frames.
2) Slotted aloha: Here, the time of shared channel is divided into discreate intervals → slots.
The stations can snd a frame only at the begining of the slot & only 1 frame is snt in each slot.

* (N) can be divided into 2 categories -
a) point-to-point conn^n is a unicast conn^n. There is a dedicated link b/w an individual pair of sndr & receivr. The capacity of entire channel is reserved only for the trans^n of packet b/w the sndr & receivr.
b) Broadcast channels is in contrast a commu^n channel that is shared by all the

machines in the (N).
In multipoint conn^{n}, a single link is shared by multiple devices.
So the channel capacity is shared temporarily by every device connecting to the link.

* Multiple Access control:

It is a dedicated link then the sndr & receivr than DLC layr is sufficient, however there is no dedicated link prsnt than multiple stations can access the channel simultaneously.

Multiple Access (P) —

I Random Access (P):

* Here, all stations hve same superiority that is no station has more priority than anthr station.
* Any station can snd data depnding on the medium's state (idle / busy)

2 featrs
- Has no fixed time for sndng data
- no fixed sequence of stations sndng data

* R.A (P) —

a) ALOHA: (Additive Links On-line Hawaii Area)

It was designed for wireless LAN bt is also applicable for shared medium. Here, multiple stations can transmit data at the same time & hence lead to collision & data being grabled (distorted).

(1) Pure ALOHA
- Any station can transmit data at any time
- * vulnerability time = 2x trasnission time
- * Time is continous & synchronised

(2) Slotted ALOHA.
- Any station can transmit data only at the beginning of slot.
- V.t = trans. time
- Time is discrete & synchronised.

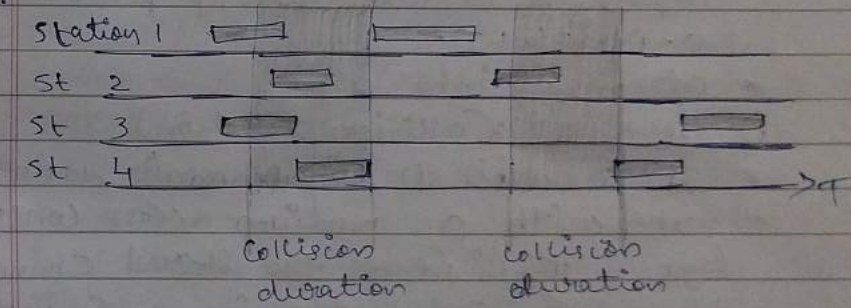


fig: pure ALOHA Frames

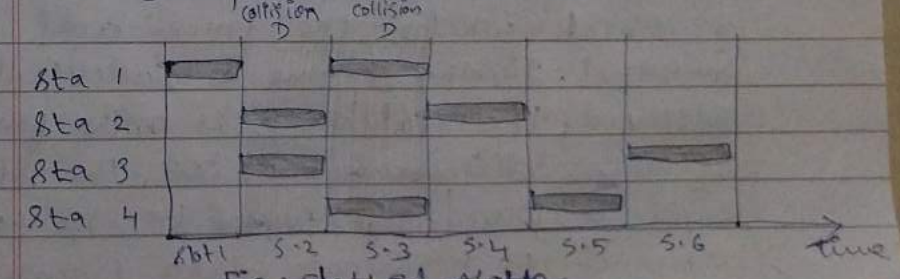


fig: slotted ALOHA

Vulnerable time of CSMA = T_p
(propagation time)

b) CSMA (Carrier Sense Multiple Access):
* It is a carrier sense multiple access based on media access ⓟ to sense the traffic on a channel (idle/busy) bfre transmitting the data.
* If the channel is idle, the station can snd data to the channel. otherwise, it must wait until the channel becomes idle. Hence, it reduces the chances of collision on a trans~ medium.
* CSMA access modes—
1-persistnt, non-persistnt, p-persistnt. & o-persistnt.
* categorized into 2 —

a) CSMA/CD: (collision detection)
* It is a (N) ⓟ to transmit data fram
* works with a medium access contrl layr.; it st senses the shared channel bfre broadcasting the frames & if the channel is idle, it transmits a frame to check whethr the trans~ was successful. If the frame is successfully received, the station snds anthr frame. If any collision is detected, the stati snds a jam/stop signal to shared channel to terminate data trans~

b) CSMA/CA (collision Avoidance):
* It is a (N) ⓟ for carrier trans~ of data frames.
* works with a medium access contrl layr. whn a data frame is snt to a channel, it receives an ack to check whethr the channel is clear.
If the station receives only a single ack that means the data frames has been successfully transmitted to the receivr.
But if it gets 2 signals, a collision of the frame occurs in the shared channel.
* To avoid collision we use 3 methods—
(a) Interframe space (b) Contention window
(c) Ack.

* 1-persistnt:
It is an aggressive trans~ (al). whn the transmitting node is ready to transmit its senses the trans~ medium for idle/busy
If idle, then it transmit immediatly.
If busy, then it senses the trans~ medium continously until it becomes idle. Then transmits the frame unconditionally.
* non-persistnt: It is a non-agressive trans~ medium.

when the transmitting node is ready to transmit data, it senses the transmedium idle/busy.
If idle it transmit immediately.
if it is busy it waits for a random amount of time.

* p-persistent:
If the channel is idle it transmits immediatly & if it is busy it senses the transmedium continously until it become idle. then transmit with probability 'p'.

II Controlled Access (CA) =

* Here, the stations seek (from one another) info frm 1 another to find which station has the right to snd.
* It allows only 1 node to snd at a time to avoid collision of msgs on shared medium.
* 3 methods -

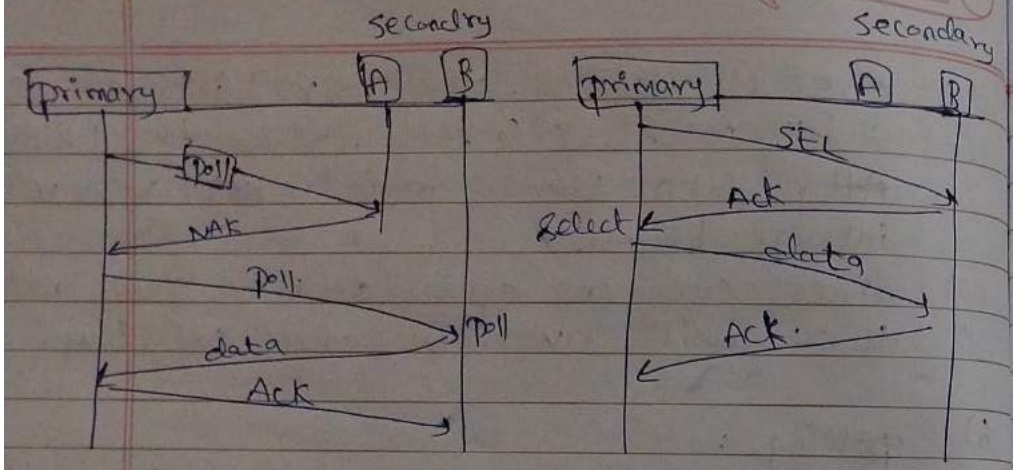
a) Reservation:
- Here, a station needs to make a reservation before sending data. If there are N stations, the resrv interval is ÷ into N slots & each station has 1 slot.
- After data trans- period, nxt resrv interval begins.
Since everyone agrees on who goes nxt, there will nver be any collisions.

b) Polling:
* Similar to roll-call performed in a clg.
* Here, 1 act as primary station (controller) & others are secondry stations.
All data exchanges must be made through the controller.
* The msg snt by the controller contains the add of the node being selected for granting access.
* If there is no data, usually "poll reject" (NAK) msg is snt back.
* Adv → Has max efficiency & bandwidth.
* dis → consume more time.

$$\text{Efficiency} = T_t / (T_t + T_{poll})$$

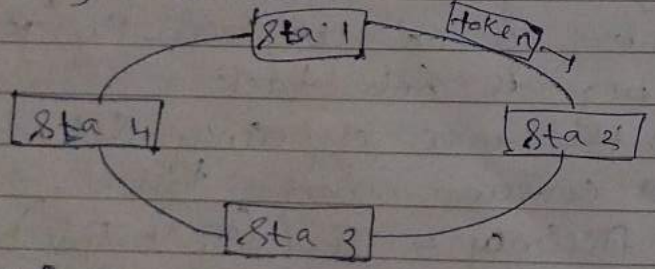
T_t → time required for trans of data.

T_{poll} → time for polling.



c) Token passing :

* Here, stations are connected logically to each othr inform of ring & acces to stations is governed by tokens.
* Here, token is passed from 1 station to anothr adjacent stations in the ring.



* performnce can be concluded by 2 paramtrs → Delay
  → Throughput.

=> wired LAN =

* LAN is a comp (N) that interconnects comp within a limited area like residnce, sch, office building.
* LAN may be wired, wireless / combin" of 2.
* 'wired' is the term that refers to any physical medium consisting of cables. Cables can be cu, twisted pair / ~~coaxial~~, fibre optic.
* Has seen several technologies such as ethrnt, token ring, token bus, FDDI, ATM LAN.

I IEEE Standards :

* In 1985, comp Society of IEEE (Institute of electrical & electronics engineers) started a project 802, to see standards to enable intercommu- among equipmnt frm a variety of manufacturers.
* objectives was to provide a way for specifying (1)s of physical layr & the data link layr of major LAN (N).

Standards are frm 802.1 to 802.20.

* The Services & protocols specified in IEEE 802 map to the lowr 2 layrs → DLL & physical (L). of 7 layr of OSI model.

a) IEEE 802.3 → Ethrnet:
4 Commcan Physical layr — 10Base5, 10Base2, 10Base-T & 10Base-F.

b) IEEE 802.11 → wireless LAN (wifi):
* wireless LANs are those LAN that use electromagnetic waves instead of cables for connecting the devices in LAN.
* Most wireless LANs are based upon the standard IEEE 802.11 / wifi.
* IEEE 802.11 is a part of IEEE 802 set of LAN protocols & specifies the set of MAC & physical (L) protocols for implemnting wireless LAN (WLAN).
* They are the world's most widely used wireless comp (N)-ing standards used in most home & office (N) to allow laptops, printrs, smartphns to talk to each othr & access intrnt without connecting wires.
* Access method → CSMA/CA.

(wifi → wireless Fidelity)

c) IEEE 802.15.1 → Bluetooth.
* It is a wireless technology standard for exchanging data b/w fixed & mob devices ovr short distances & building PANs.
* managed by the bluetooth sple intrst grp (SIG).
* Requires a low-cost tranceivr chip be included in each device.
* Also uses radio wave. The biggest diffnce b/w bluetooth & devices like FM radios & TV is distnce.
* It snds info within yr own personal space, which is → PAN at distnce up to 50m.

d) IEEE 802.16 → WiMAX
* wimax (wireless intr-operability for micro wave Access). covers all wimax series of products.
* It is optimized for 50km. It provides the services throughout the coverage area to enable continuous connectivity.
* Designed for long distnce / wide area.

* operates on freq of 2.4 GHz, 5 GHz.
* Bandwidths varies dynamically as per user requirmnt.

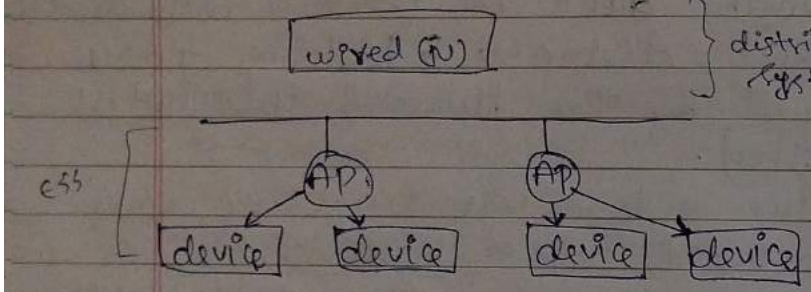


fig: wifi archi-

⇒ Mob (N) = / cellular (N).

* It is a commu- (N) where the last link is wireless.
* The (N) is distributed ovr land areas → cells, each served by at least 1 fixed-loc transceiver.
* A cell typically uses a diffrnt set of freq frm neighbouring cells to avoid interfrnce.
* used by the mob phn operator to achieve both coverage & capacity for their subscribers.
* Large geographic areas are split into smaller cells to avoid line-of-sight signal loss.
* All of the cell sites are connected to telephne exchanges which in turn connect to the public telephn (N).

I Evolution of Mob (N):

a) 1st generation (1G) - Analogue cellular (N): Main technological developmnt of 1G mob phns was the use of multiple cell sites.

b) 2nd generation (2G) - Digital c. (N): GTSM (global system for mob) is the most popular standard used in 2G. Speed upto 384 kbps. 2G introduced SMS, enabling txt msgs

c) 3G - High speed IP data (N): web brosing, email, vdeo downloading, picture sharing & othr smartphn technology were introduced. utilises a new technology UMTS (universal mob telecommu- system) as its core

(N) archi~
Speed upto 3.1 Mbps.

d) 4G - Curnt Standard :
Has improved data speeds (upto 1Gbps) for faster streaming & downloads., lower the cost of voice & data services, multimedia & intrnt over IP.
2 imp 4G standards - wimax & LTE (Long Term Evolution)

e) 5G - Coming Soon :
It is crntly undr development.
promises fastr data rates, highr coun^n density.
Also include device-to-device commu~

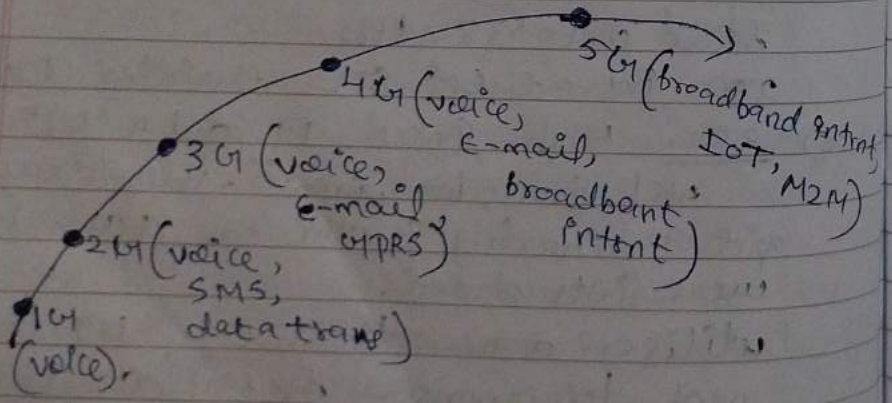


Fig : Evolution of Mob (N).

* IEEE 802.3 (ethrnet) : (wired LAN)

ethrnt → types → Standard · E
→ Fast · E
→ Gigabyte · E
→ Ten Gigabyte · E

Standard E → (4) :

(1) 10Base 5 (coaxial calele)
Max length - 500m
Max no. of Sta - 100
Bus (T).

(2) 10BaseT (twisted · C)
100 m
1024
Star(T)

3) 10Base 2 (coaxial calele)
185 m
30
Bus (T).

(4) 10BaseF (fibreoptic)
2000m
1024
Star(T).