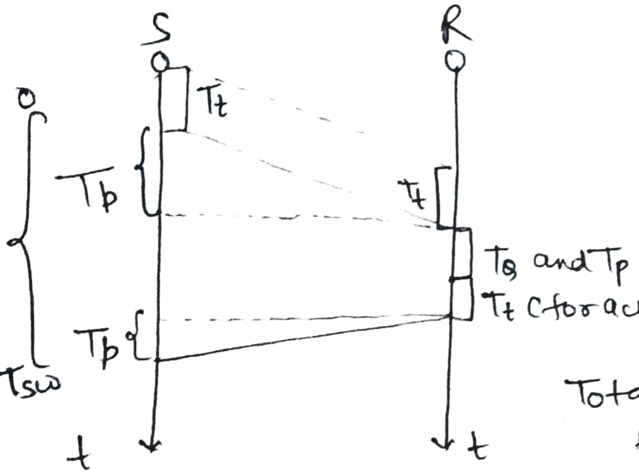
Flow Control (stop and wait)

Sometimes receiver is not consuming the data with the same rate as sender send data.

Buffer used to save data to process on its turn.

So, sender needs to send the data according to receiver's buffer, also called closure loop protocol.

Sender should send a packet and wait for receivers acknowledge when receiver demands another then send next packet called stop and wait.



$T_t \rightarrow$ transmission delay
$T_p \rightarrow$ propagation delay
$T_q \rightarrow$ Queuing delay
$T_p \rightarrow$ Processing delay.

Considering 0

Total time to sent a single packet = $(T_t)_{data} + T_p + \cancel{T_q} + \cancel{T_p} + (T_t)_{acknowledgement} + T_p(\text{acknowledge})$

→ T_p is same for both data and acknowledgement

Total time = $(T_t)_{data} + 2(T_p) + (T_t)_{acknowledgement}$

Generally $(T_t)_{acknowledge} << (T_t)_{data}$ so neglect.

Total time = $(T_t)_{data} + 2(T_p)$ — ①

But some time $(T_t)_{acknowledge} = (T_t)_{data}$

So, Total time = $2(T_t + T_p)$ — ②

Both ① and ② can be use situationally.

T_{sw} in figure is time of stop and wait.

Efficiency = $\frac{\text{Total time (useful)}}{\text{Total cycle time}} = \frac{T_t}{T_t + 2 * T_p}$

↓

Stop & wait Protocol

$$\boxed{\eta = \frac{1}{1 + 2(T_p/T_t)}} = \boxed{\frac{1}{1+2a} \quad \forall\ a = \frac{T_p}{T_t}}$$

Imp

Throughput :- It have different definition in case of OS, CN and COA.

for CN :- $\frac{\text{No. of bits}}{\text{sends per sec}}$

⇒ 1 Packet sends in $T_t + 2 * T_p$

So, Throughput = $\frac{L}{T_t + 2 * T_p}$ ∵ L = size of packet in bits.

$$\Rightarrow \frac{(L/B) \times B}{T_t + 2 * T_p} = \boxed{\frac{T_t}{T_t + 2 * T_p} * B}$$

$\boxed{B \longrightarrow \text{Bandwidth}}$

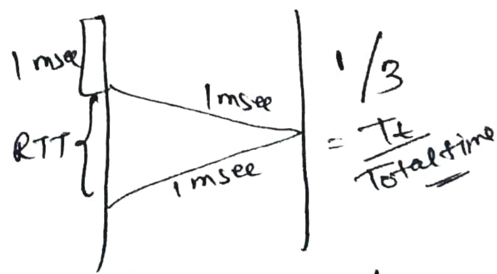
So, Throughput = $\left(\frac{1}{1+2a}\right) * B = \boxed{\eta * B}$ Imp

→ Throughput also called as effective Bandwidth and Bandwidth Utilization.

$$\boxed{\text{Throughput} = \text{Efficiency} * \text{Bandwidth}}$$

Q Given, $T_t = 1ms$, $T_p = 1m\,sec$ find η?

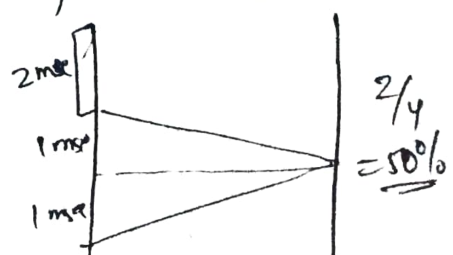
$\boxed{a = \frac{T_p}{T_t} = 1}$ $\quad \eta = \frac{1}{1+2a} = \frac{1}{3} = \underline{33.3\%}$



$\boxed{\text{Round trip time} = 2 * T_p}$

(2) $T_t = 2ms$ $\quad T_p = 1ms$

$\eta = \frac{1}{1+2a} = \frac{1}{1 + 2 \times 1/2} = \frac{1}{2} = \underline{50\%}$



Q If $\eta \geq 0.5$ then find the relation between T_t and T_p.

Sol^n $\frac{T_t}{T_t + 2*T_p} \geq 0.5 \Rightarrow \boxed{T_t \geq 2*T_p}$

$$\frac{L}{B} \geq 2*T_p$$

$$\Rightarrow \boxed{L \geq 2*T_p*\underbrace{\text{Bandwidth}}_{}}$$

grop

⇒ If size of packet is equals to twice of product of propagation time and Bandwidth then we get 50% efficiency.

factors effecting efficieny :-

→ $\boxed{\text{Effective Bandwith} \leq \text{Bandwidth}}$

$$\eta = \frac{1}{1+2\left(\frac{T_p}{T_t}\right)} = \frac{1}{1+2\left(\frac{d}{v}\right)\left(B/L\right)}.$$

⇒ After setting up a network the 'v' and 'B' will be fix(constant)

① If $d\uparrow \longrightarrow \eta\downarrow$

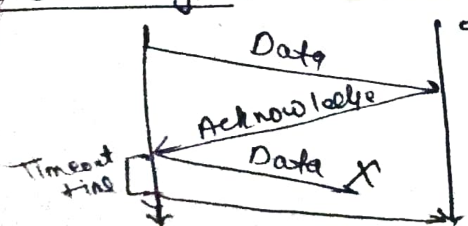
⇒ So, stop and wait is better for optimizing 'small areas (LAN).'

② If $L\uparrow \longrightarrow \eta\uparrow$

If length (size) of packet increase increase efficieny

⇒ So, stop and wait is useful in case of 'larger packets.'

Disadvantage :- ① Data Packet Lost



⇒ If sender sends the data and it gets miss then sends will think data packet reaches to receiver end and it doesn't send acknowledge but receiver will think no data packet has come

⇒ Sender will wait for acknowledge and receiver will wait for data packet and both will comes in 'deadlock'.

Solution → Wait for sometime (Timeout time) and if sender doesn't get acknowledgement then send the data again.

So, (Stop & wait) + (Timeout Timer)
= ARQ (Automatic Repeat Request)

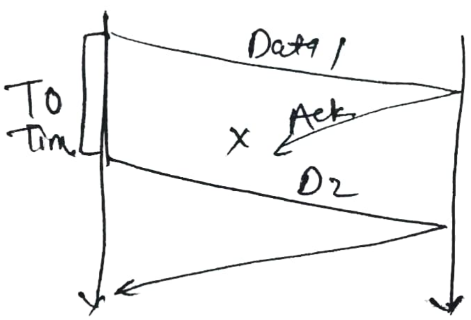
Problem

② Acknowledgement could be lost.

In this case assume that data is lost and send the same data packet again to be safe.

→ Also called as duplicate packet problem.

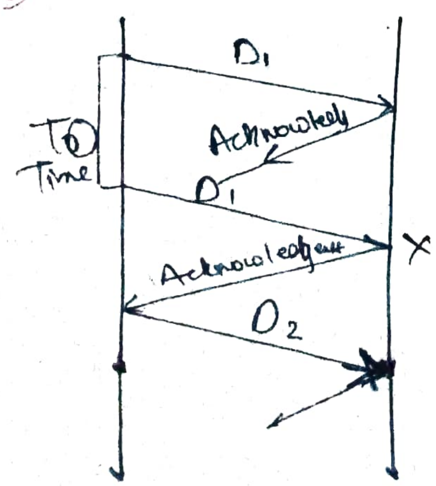
To optimize this problem send some numbers with data.



Receiver will think that acknowledge might have lost so he send the data packet second time.

⇒ (Stop & wait) + (TO Time) + Sequence number
↳ We can say packet is duplicate.

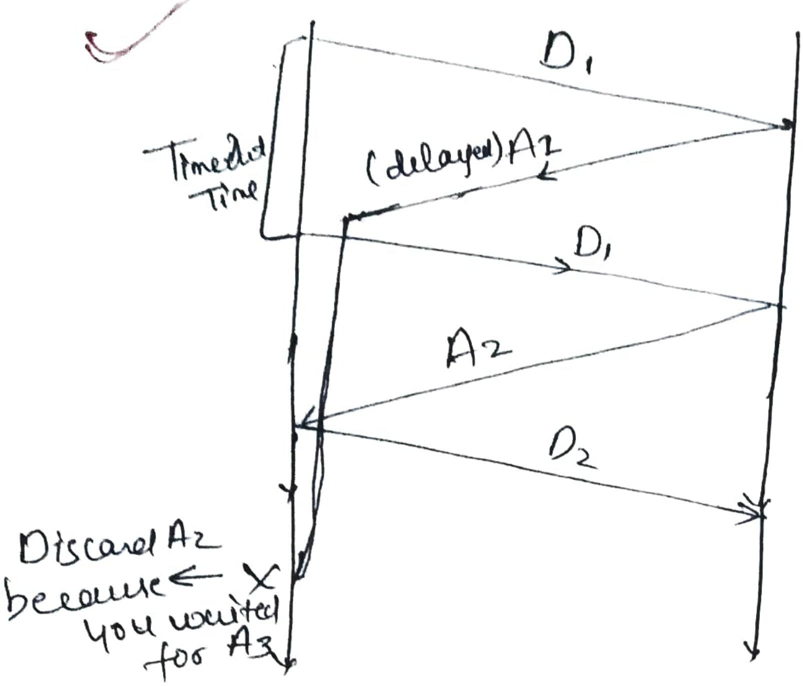
Problem ③ Delayed Acknowledgement (Missing Packet Problem)



After sending D1 the acknowledge get delayed then sender send the same packet again and receiver discard it and send another acknowledgement. After this sender sends packet D2 and suddenly the delayed acknowledgement comes, receiver will think that this is for D2 but its an dilema and send D3

⟶ Problem Statement

Solution → Send numbers on Acknowledge too.



A_2 → I am demanding packet 2.

(Stop and wait
+
Timeout time
+
sequence number on both Data and Acknowledge)

↓

Complete solution

Imp Q. we send 10 packet to destination from source and every 4th packet is going to lost. How many packets we send

Sol^n

1 2 3 4 4 5 6 7 7 8 9 10 10

(4th, 4th, 4th)

lost so send again — lost so send again — lost so send again

No of packet send = 10 + 3 = 13

packet retransmitted = 4, 7, 10.

Imp Q. (S) ——→ (R) Send 400 packets and probability of lost a packet is 0.2 then how many packet get retransmitted

⇒ 400 + 400(0.2) = 400 + 80

⇒ 80 packet retransmitted.] wrong ✗

Correct

$400 + 400(0.2) + 80(0.2) + \cdots$

Because we will also lost some packet in next 80.

So, $400 + 400(0.2) + 80(0.2) + \cdots$

Infinite GP $\leftarrow n + np + np^2 - -$

$= n(1 + p + p^2 + \cdots)$

$= \boxed{n\left(\frac{1}{1-p}\right)}$ Imp

↳ for stop and wait

$\Rightarrow \frac{400}{0.8} = 500$ total packet send.

Packet Retransmitted = $500 - 400 = \underline{100}$

Q Gate 2015

$n \geq 50\% \geq \frac{1}{1+2a}$

$\frac{50}{100} \leq \frac{1}{1+2a}$

$\Rightarrow a \leq 1/2$

$\frac{T_p * B}{L} \leq 1/2$

$L \geq 2 * T_p * B$ — $B \to 64 \times 10^3$, $T_p \to 20 \times 10^{-3}$

$\boxed{L \geq 320}$

↳ Answer demanded in bytes

→ Do this question while practice too.

⇒ Capacity of Pipe (Channel) and Pipelining
↳ wire

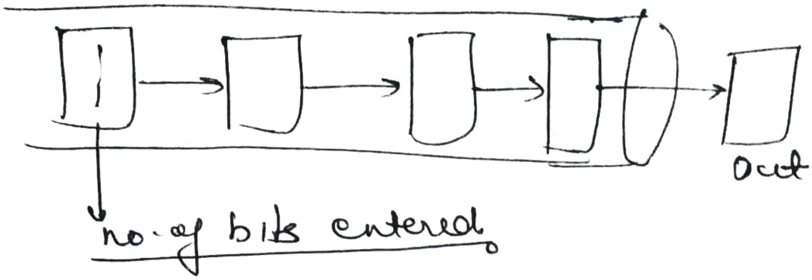
→ Link / Wire / Channel

→ Full Duplex Link (Data can transmit in both direction without collision)

Link is completely filled and you count no. of bits inside → capacity.

⇒ If entire speed is 1 bps so capacity equals to time in which first bit came out of link.

$$\boxed{\text{Capacity} = \text{Bandwidth} \times T_p} \longrightarrow \text{Half Duplex}$$



In case of full Duplex

$$\boxed{\text{Capacity} = 2 * (\text{Capacity})_{\text{Half Duplex}}}$$

⇒ Thick channels are channel or pipes with high Capacity.

Thick channels are not for stop & wait (Thin pipe)

Thick pipe ⟶ $\eta \downarrow$ (stop and wait)

Thin pipe ⟶ $\eta \uparrow$,,

$$\eta = \frac{1}{1+2a} = \frac{1}{1 + \frac{\boxed{2 * T_p * B}}{L}}$$

Capacity

$$\Rightarrow \boxed{\frac{1}{1 + \text{Capacity}/L}}$$

Pipelining

In T_t sec ⟶ 1 packet transmit

1 sec ⟶ $\frac{1}{T_t}$ packet transmit

In order to send 1 packet in stop & wait

$$\text{Time} = T_t + 2T_p$$

In time $(T_t + 2T_p)$ how many packets can be send.

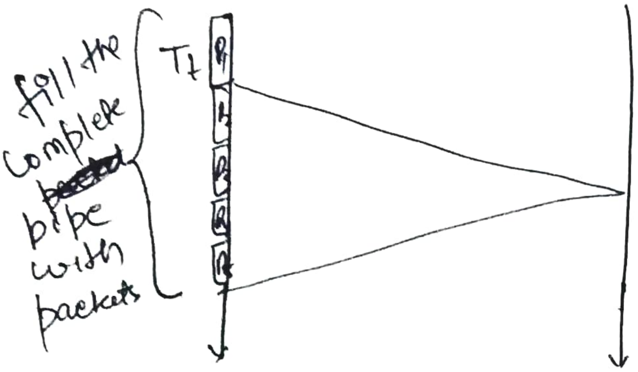
No. of packets $= \dfrac{T_t + 2 * T_p}{T_t}$

$= (1+2a)$ packets.

We can transmit $(1+2a)$ packet but we transmit only 1 packet, so

$$\boxed{\eta = \frac{1}{1+2a}}$$

→ To increase efficiency of stop & wait we have to send $(1+2a)$ packets (100%).

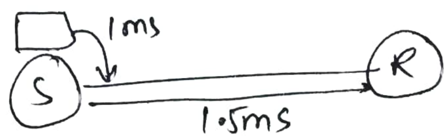


Collection of packet

↳ window

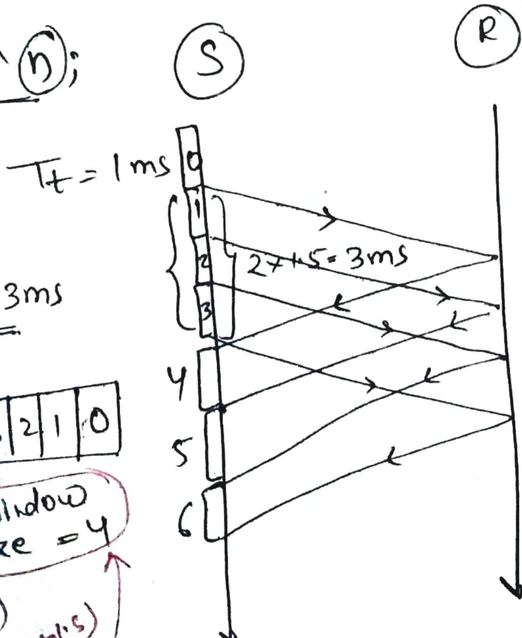
Ex → $T_t = 1ms$

$T_p = 1.5\ ms$



for stop and wait $\eta = \dfrac{1}{1+2a} = \dfrac{1}{4} = 25\%$

To ↑ (η);



Roundtrip time = 3ms

Window

3	2	1	0

min window size = 4

$(1+2a)$

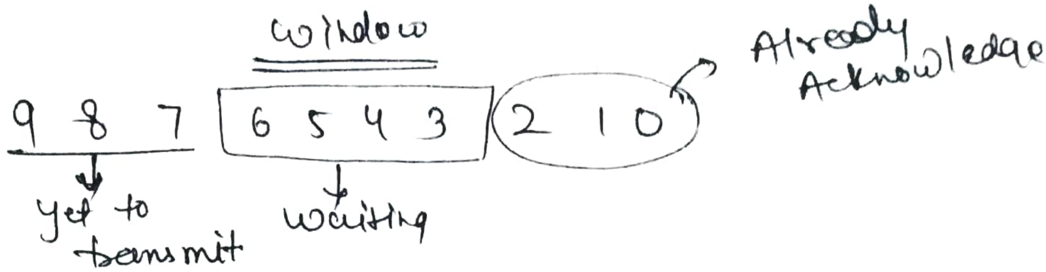
$= (1 + 2 \times 1.5)$

$= 4$

we are waiting for 3ms to ↑ efficiency in 3ms transmit 3 more packets in that time. After getting acknowledgement, remove '0' from window and make space for '4' Also send packet '1' so that with acknowledge of '1' you ~~get~~ send packet 2 and packet 4 should be inside the window. and go so on.

→ You can remove packet from window after getting acknowledgement

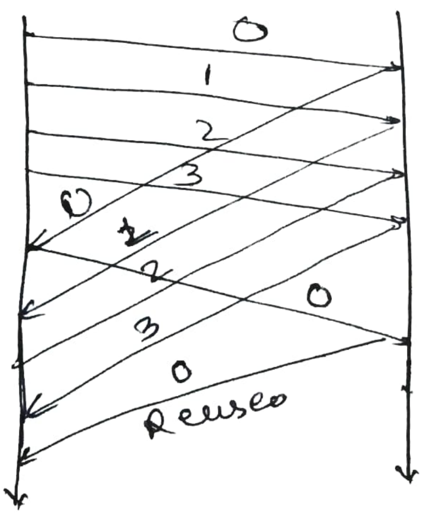
→ Also called as sliding window Protocols

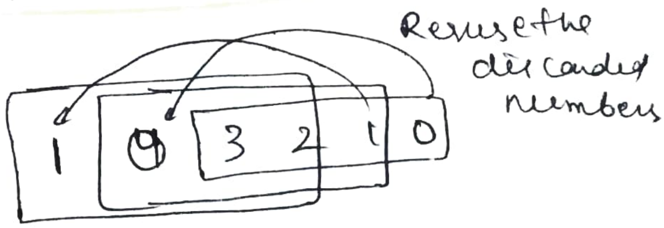


→ So for maximum utilisation no. of packets in window $= (1+2a)$

$T_t = 1\,ms$ No. of sequence number required.
$T_p = 1.5\,ms$

→ for liberty we can take sequence number upto ∞ but head pointer size should be minimum.





Instead of 4 we can use 0 because its free so we can use minimum sequence numbers

→ we can send all the packet using 2 bits only.

→ To get max. efficiency -

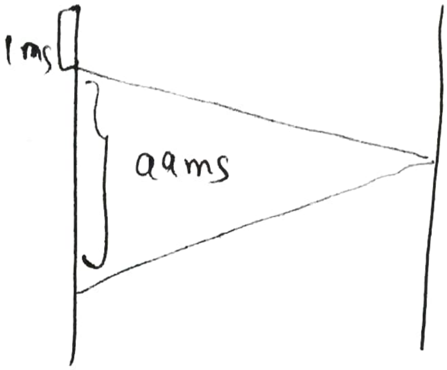
$(W_s) \rightarrow (1+2a)$ window size

min No. of (number sequence required in) $\rightarrow (1+2a)$

No. of bits required $= \boxed{\log_2(1+2a)}$

~~floor~~ ceil function or → $\lceil \log_2(1+2a) \rceil$

Q $T_t = 1ms$ $T_p = 49.5ms$ find out sender window size to get max efficiency.



$ws = 1 + 2a$
$= \underline{100 \text{ packets}}$.

min. seq. number $= 100$

min. no. of bits $= \log_2 (10)^2$

$= \lceil 2 \log_2 2^3 \rceil$

$= \lceil 2 \cdot 3 \cdots \rceil$

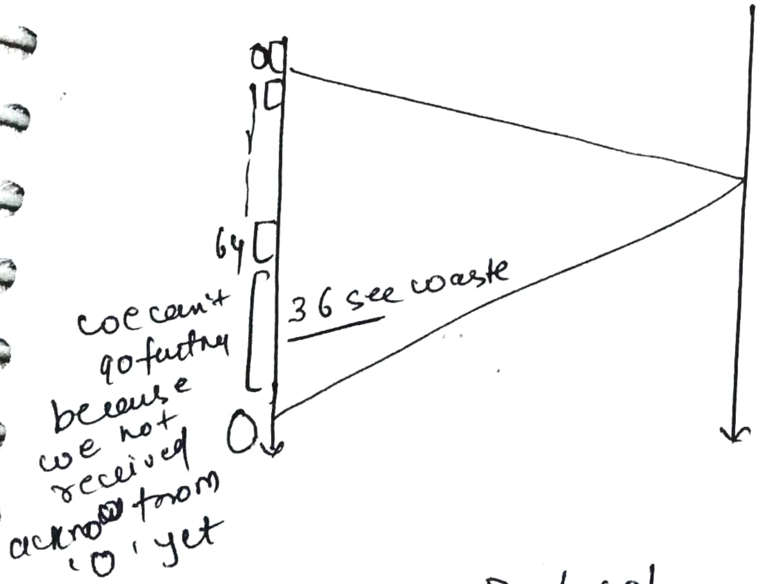
$= \lceil 6 \cdots \rceil = \underline{7 \text{ bits}}$

→ $2^7 \rightarrow 128$ sequence number possible

Q ~~If~~ in above question it is given that no. of bits in sequence no. field = 6 (Predefined) then what is the max. efficiency

no. of sequence no. possible $= 2^6 = 64$

then $\max(\eta) = \dfrac{64}{100} = \underline{64\%}$



Sliding Window Protocol

→ It is the theoretical concept. we can say about sender window not about receiver window.

But it can be implement practically in two ways—

① GBN (Go Back N) Protocol

② SR (Selective Repeat) Protocol

GBN

① Sender window size is N itself.

Ex Go Back 10
sender window size = 10

⇒ N > 1 Always

Example —On RHS→

Ex → T_t = 1ms T_p = 49.5msec
find 'η' in case of GB(10)

Max packet can send = 1+2a
= 100

N = 10

η = 10/100 = 10%

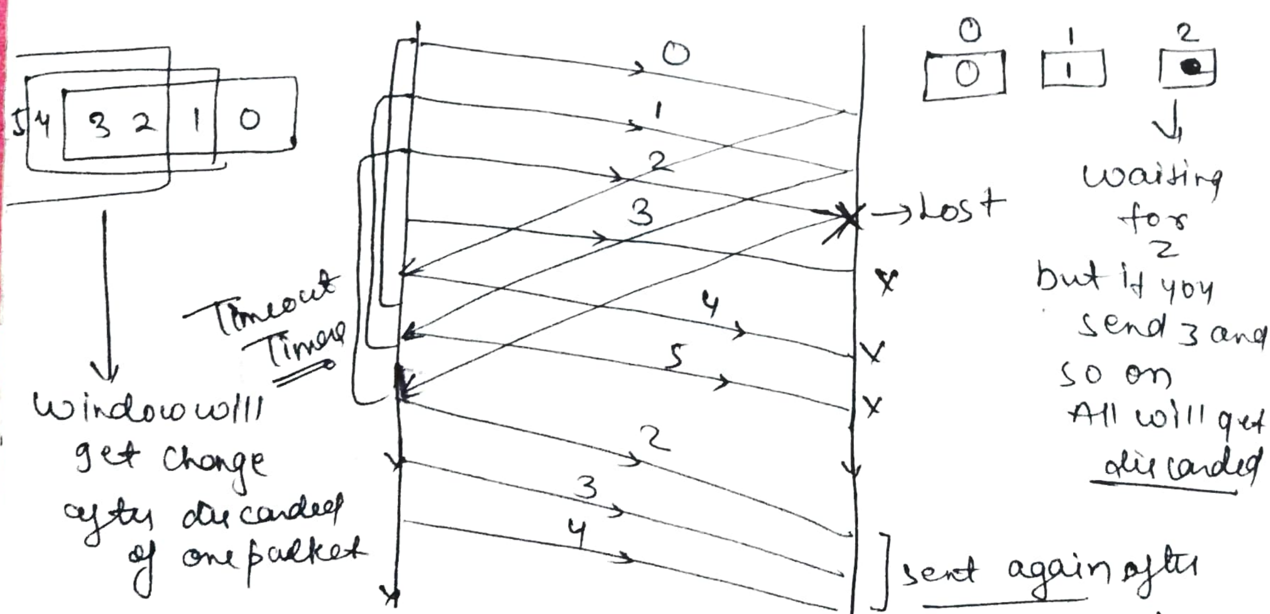
Bandwidth = 40mbps find throughput

Throughput = $\frac{10}{100}$ × 40mbps

= 4 mbps

② Receiver window size is always 1.

Ex → sender window size = 4
Receiver —————— = 1



If one packet is lost all other packet discarded and send again that is why called Go back N

Means go back and send N packets again

Imp

$\boxed{5\ 4\ 3\ 2}\ 1\ 0$

Go back to 2.

Q In GB3, if every 5th packet is being ~~discarded~~ transmitted is lost and 10 packets send. How many transmission are required.

→ 1 2 3 4 5 6 7 8 9 10

first lost

Retransmitted

$\boxed{5\ 6\ 7}$ 5 6 $\boxed{7\ 8\ 9}$ ~~10~~ 7 8 $\boxed{9\ 10}$ 9 10

5th

next lost

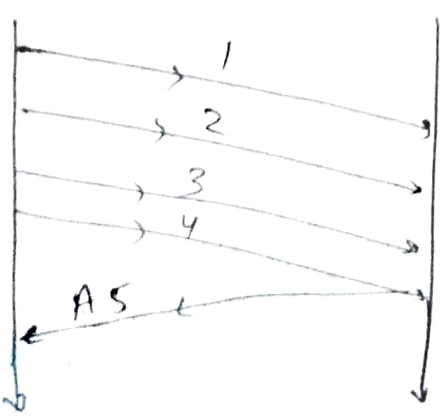
nextlost packet

Discarded packets, $\boxed{5, 6, 7, 8, 9, 10}$] 10 + $\boxed{5\ 6\ 7}$ $\boxed{7\ 8\ 9}$ $\boxed{9, 10}$

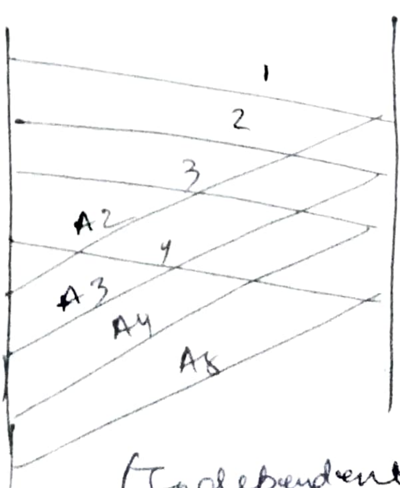
~~t~~ → Two times

Ans - 18 Imp Question

(3) point in 'Goback N' (About Acknowledgement)



Cummulative Acknowledgment (Single Acknowledgement for all packets)



(Independent Acknowledgement)

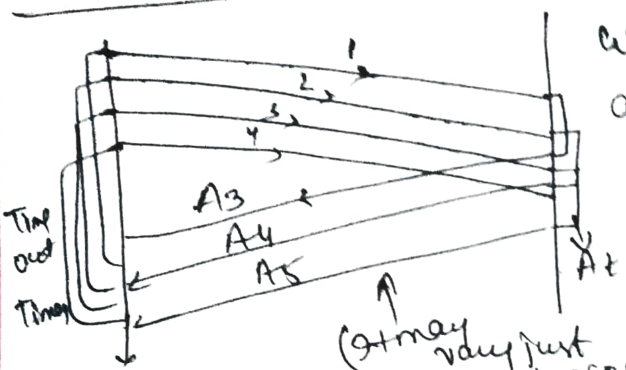
Cummulative

1) Less Traffic
2) If one acknowledge is loss means all packet is loss
→ Less Reliable

Independent

1) More reliable than cummulative
2) More Traffic

Go Back N uses Cummulative Acknowledgement



We can send a single acknowledgement for K-packets then what should be the value of K.

At → Acknowledgement time.
We have a an acknowledgement timer on receivers end. No. of packets came in particular acknowledge time will acknowledge to sender.

In (At), 1 and 2 reaches so we send A3 request for packet 3.

As max as (At) more the packet will cover but it should be less than timeout timer.

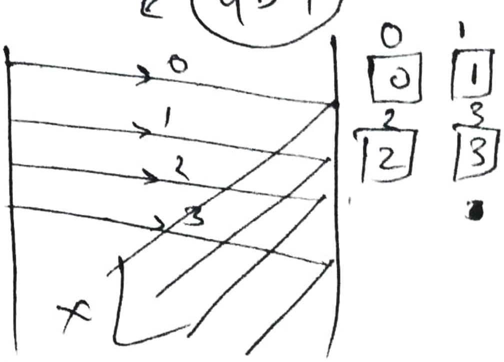
Timeout timer > Acknowledgement Timer

Relation between window size and sequence number in case of GBN

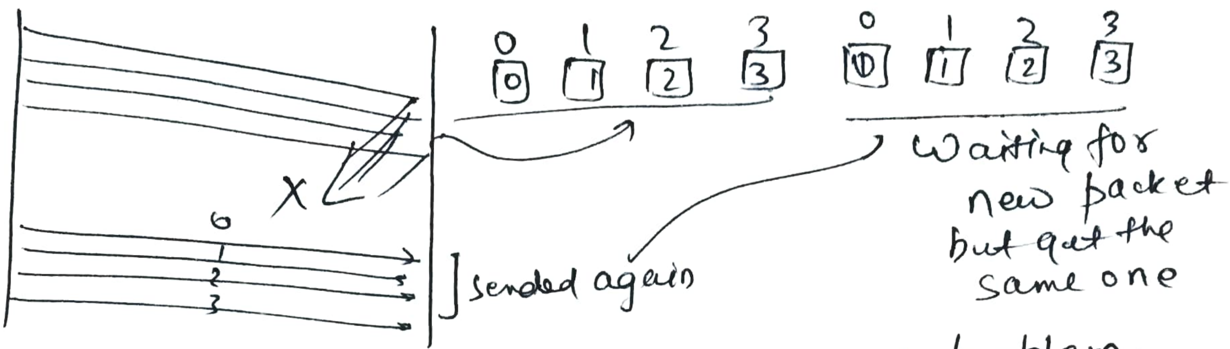
Ex: Let sender Ws = 4
Receiver Ws = 4

3 2 1 0

Let sequence number = 4

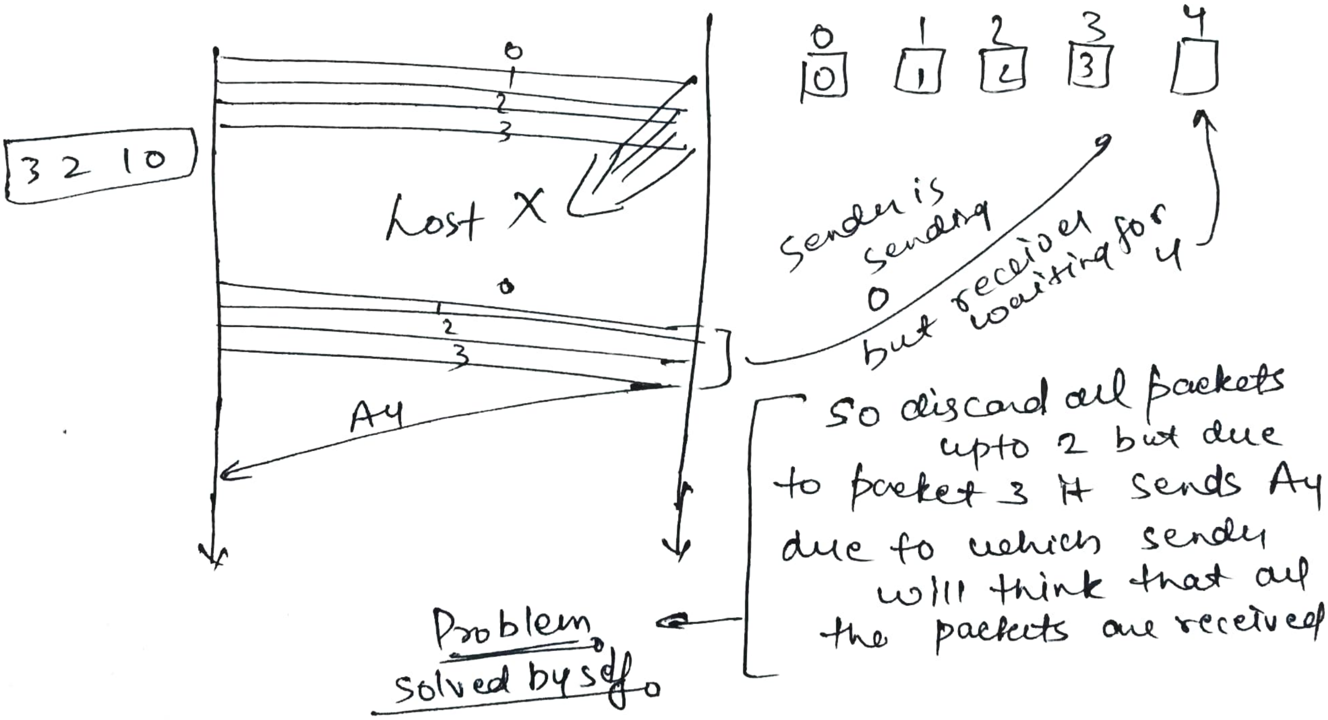


If all the acknowledge are lost sender will send all packet again from 0, but receiver is waiting for next set of 0 because of GB ④



⇒ It is called as duplicate packet problem.

⇒ It will create problem as if n=5 instead of 4



If ~~you~~ the size of sender widow is N then take sequence number = (N+1) → In above Problem.

To detect duplicate packet problem → sequence number should be $\geq (W_S + W_R)$

W_S → Sender window

W_R → Receiver window

No. of bits needs in sequence no. field. $= \lceil \log_2 (N+1) \rceil$

If sequence number is fixed

$W_S = N$

$W_R = 1$

as

$\underline{seq = N}$

Number sequence $= N+1$

No. of bits $= \lceil \log_2 (N+1) \rceil$

max W_S = ?

max W_R = ?

$\boxed{\begin{array}{l} W_S = N-1 \\ W_R = 1 \end{array}}$ ← solution

Ex

If seq no = 4

$W_S = 3$

$W_R = 1$

Always

$\boxed{W_R < W_S}$

No. of bits available are K.

$\Rightarrow$ seq number $= 2^K$

$\Rightarrow \boxed{\begin{array}{l} W_S = 2^K - 1 \\ W_R = 1 \end{array}}$

$\boxed{W_R + W_S \leq \text{Available Sequence Number}}$

S/R Protocols.

① Sender window size > 1

Ex $T_t = 1ms$, $T_p = 49.5ms$, $W_S = 50$ find efficiency in SR.

Max $W_S = (1+2a) = 100$

But $W_S = 50$

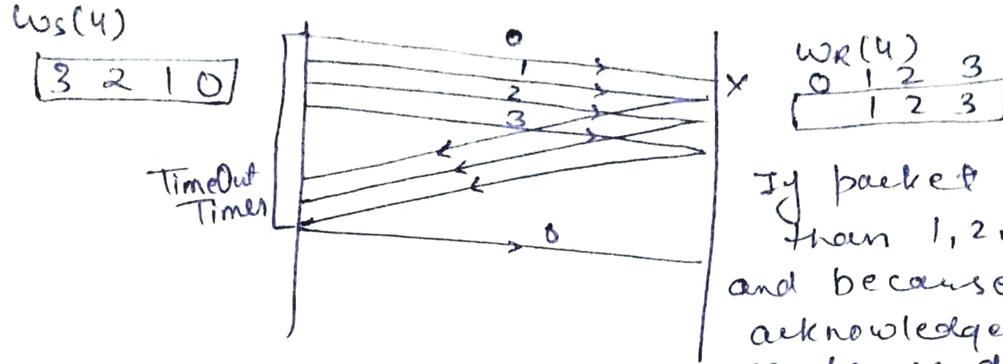
$\eta = \frac{50}{100} = \underline{50\%}$

If Bandwidth = 4mbps find throughput (T)

$T = 4mbps \times 1/2$

$= \underline{2mbps}$

② W_R (Receiver window size) = W_s



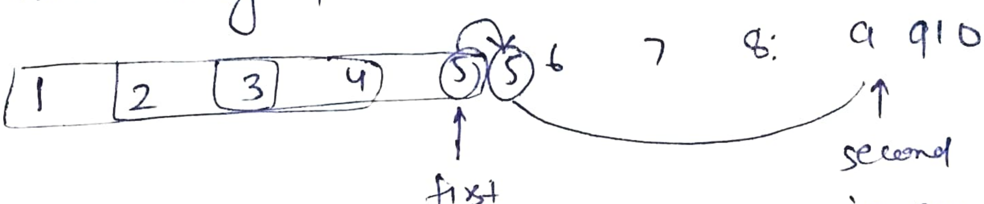
If packet 0 is lost then 1, 2, 3 will accept. and because of no acknowledgement for 0 sender send it again

→ So this process is called selective-repeat (SR).

→ Like GBN we are transmitting the complete window.

Ex: $W_s = 3$, 10 packets send, every 5^{th} packet is lost. How many packet will send in SR protocol.

Soln:



Here no need to consider W_s bcoz in any case we will send on a single packet that lost.

So, number of retransmission = 2 (5, 9)

Total packet sends = 12.

→ In case of Efficiency SR is similar to GBN and in terms of SR is similar to stop and wait.

→ ~~SR~~ is superior to another protocols.

3) ~~Acknowledgements are independent here.~~
~~Here~~ if a packet is lost then packet will retransmitt after Time Out.

→ In GBN if packet recived in corrupt then it discarded all the upcoming packets but in SR receiver send a negative acknowoledge for that so we can send the packet before TimeOut.

→ No need of Acknowledgement timer at receiver end in SR protocols because it sends independent acknowledgement.

Comparison

	Stop & Wait	GBN	SR
Efficiency	$1/1+2a$	$N/1+2a$	$N/1+2a$
Buffers	1 at sender and 1 at receiver (2)	N → sender (N+1) 1 - Receiver	(N+N) = 2N sender → Receiver
Seq. numbers	(1+1) = 2	$W_s + W_R$ = (N+1)	N+N = 2N
No. of Retransmission if (1 packet lost)	1	N (W_s)	1
Bandwidth (Required / Consume)	Low	High	Moderate
CPU	Low	Moderate	High
Implementation	Low	Moderate	Complex

→ Buffer is require to save the packet until we get the acknowledgements.

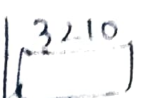
→ Seq. Number = $W_s + W_R$

→ High Bandwidth required if retransmission are more.

→ CPU Utilisation

on SR

If any packet is lost then search to retransmit

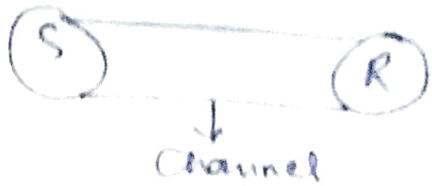


Need to sort bcoz packet can arrive in any order

→ Due to searching and sorting CPU used in SR is high instead of other too

→ Order of superiority :-
It can be change according to various parameters.

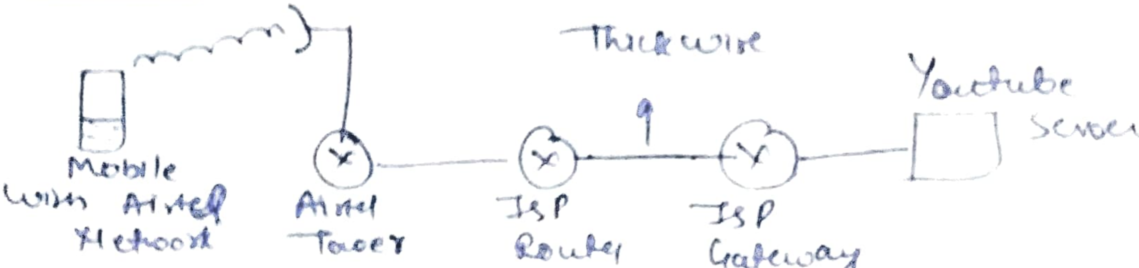
Ex:-



Bandwidth → Sufficient
CPU → Moderate / Less
Buffer → Moderate / Less

→ In this case we use 'Go Back N'

Scenario



Thick wire → High Bandwidth → Less Error

Q Gate 2016 (S/R Protocol) [Solve while Practice]

Sol^n $\eta = 100\%$

$100\% \geq \frac{w}{1+2a}$, $a = \frac{T_p}{T_t}$ [w = Window Size]

or (1)

$w \leq 1+2a$

$\leq 1 + 2\left[\frac{150\times10^3}{(1024\times8)/128\times10^3}\right]$

$\leq 5.68 \Rightarrow 5$

Available sequence number $\geq w_s + w_R$

$\geq$ ~~w_s~~ $5 + 5$ [$w_s = w_R$ in case of SR]

≥ 10

Min. No of bits required = 4 (B)

Gate Ques.

Q The max. window size for data transmission using the selective-repeat with n bit frame sequence number is —

Sol^n $w_s + w_R \leq$ sequence number (2^n for n bit)

$2|w| \leq 2^n$

$\boxed{|w| \leq 2^{n-1}}$.

Ex → Client Server Architecture (Day-3)

Internet chat
E-mail
web - Browsing

Ping is not a client-server

Gate-2003 [Must do solve Question from book]

$L = 1000$ bytes $= 8000$ bits

$T_t = 50\mu s$ $T_p = 200\mu s$

$(W_S, W_R) = 5$

$$\eta = \frac{N}{1+2a} = \frac{5}{9}$$

throughput $= \eta \times B$

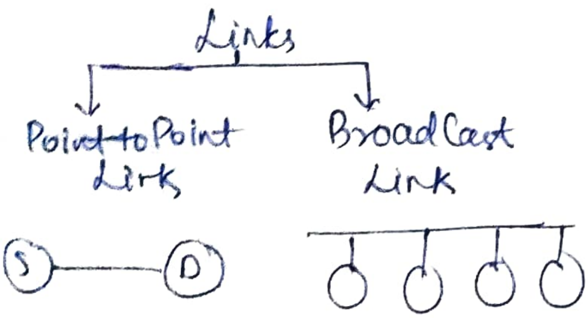
$= \frac{5}{9} \times 8 \times 10^9/5$

$= \frac{40}{9} \times 10^9/5$

$= 11.11 \times 10^6$ bps

Gate-2006 [Given as video Solve it from PYQ first and then watch if required)

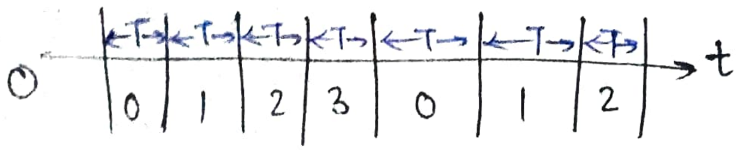
Introduction to access Control Methods



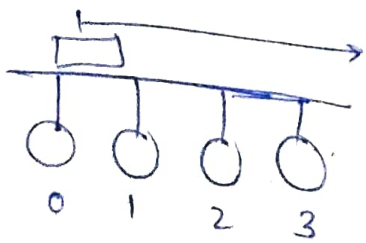
We have no issue with duplex link incase of Point to Point, but we have issues with broadcast.

(*) To achieve data transmission using duplex in case of broadcast without collision we need access control methods.

TDM :- (Time Division Multiplexing)



→ Dividing timeline into slots.



Since we are assuming that T_t is same for all 4 stations and T_p is different and we given $T = T_t + T_p$ to all slots to perform operation

$$\text{Efficiency} = \frac{\text{Useful Time}}{\text{Cycle Time}} = \frac{T_t}{T_t + T_p} = \boxed{\frac{1}{1+a}}$$

Q1 $T_t = T_p = 1\,msec$ find η of TDM.

$$\Rightarrow \eta = \frac{1}{1+a} = \frac{1}{2} = 50\%$$

If BW. 4 mbps then what is the effective BW of throughput $\frac{1}{2} \times 4 = 2$ mbps.

Q If N-station are connected in TDM and each station needs 2 kbps BW. How many max. station can be connected to the network?

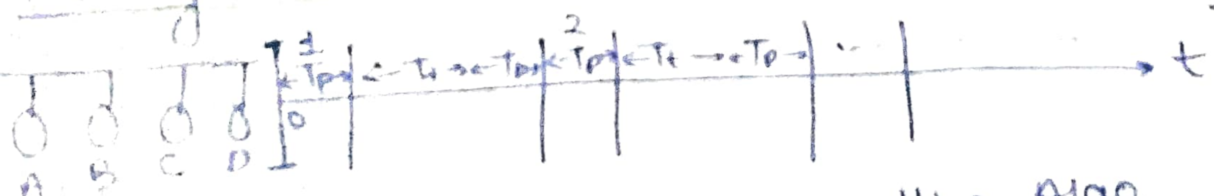
$$N \times 2\,kbps = 2\,mbps$$

$$\boxed{N = 1000}$$

Disadvantages of TDM :-

On reserving a slot for station it might possible that station doesn't have any data to transmit means that slot is going waste.

Polling → we give slot if station ask for it.



- To select a station we use polling Algo.
- T_p - Time taken in polling.
- This way no slot is wasting.

Disadvantage
→ It might possible that same station get the slot again.

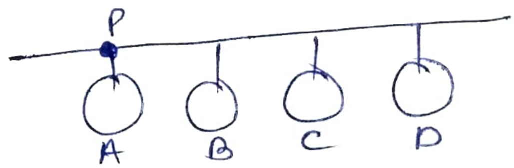
$$\eta = \frac{\text{Useful time}}{\text{Cycle time}} = \boxed{\frac{T_t}{T_{polling} + T_t + T_p}}$$

→ In case of LAN T_p is very small so we can neglect it if not given in question.

→ We waste sometime in polling (T_p / $T_{polling}$).

CSMA / CD :- [Carrier sensing Multiple Access / Collision Detection]

CSMA
- Career Sensing [CS]
- Multiple Access [MA]



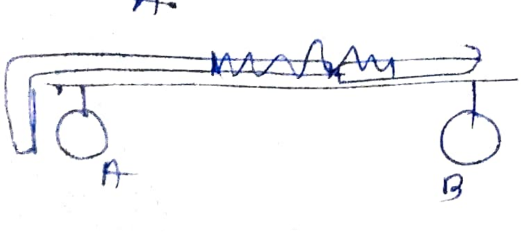
→ Multiple access also called as broadcast channel

→ Carrier sensing means send the data if carrier is free.

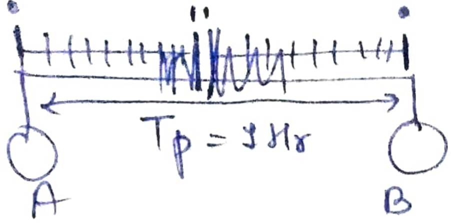
→ It is difficult that by seeing point P to find out that anyone other is sending data or not.

→ If two station transmit data at same time the collision may occur. Then now two station will verify that data got corrupted and they need to send again without any acknowledgement [Both packet get corrupted]

You can identify that the collision signal achieved at A is due to data packet of A.

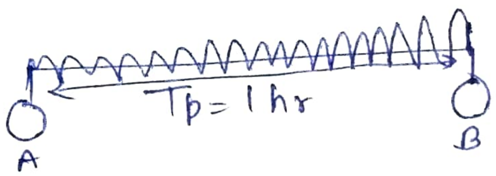


अगर data packet का size इतना हो कि पूरा Data send होने से पहले ही Collision Signal आने लगे तो A can identify that signal is due to packet ...



$t = 10$ AM   A and B starts transmitting
$t = 10:30$ Both reaches at half and collide.
$t = 11:00$ Collision signal reaches to A and B

So, if $\boxed{T_t > T_p}$ then we can identify that collision signal is due to my data.



Worst Case

→ 10 : AM 'A' started
→ 10:59:59 ≈ 11 AM first bit of A about to reach B and at this time B start transmitting
→ then collision signal will reaches at A : 12:00AM
So, if A has to detect the collision it needs

$\boxed{T_t \geq 2 * T_p}$

① So, condition for collision detection

② How much data we should have so that we can transmit upto $2 * T_p$

So, $T_t \geq 2 T_p$

$L/B \geq 2 T_p$

$\boxed{L \geq 2 * T_p * B}$ ← size of packet (minimum)

Imp

Q Given d, v, B, find size of packet to detect collison.

$T_p = \frac{d}{v}$ and $\boxed{L \geq 2 * T_p * B}$.

Q T_p = 1 msec, BW = 1 mbps L = ?

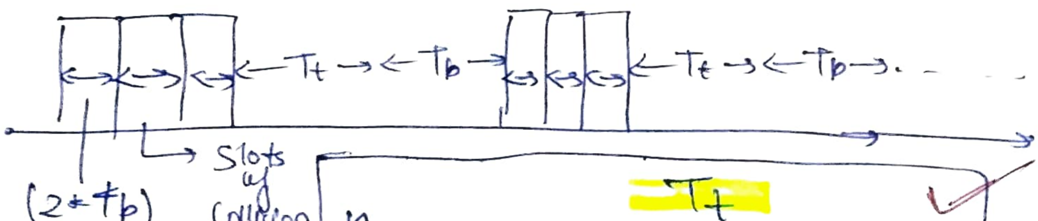
$L \geq 2 \times 10^{-3} \times 10^{6} \geq$ 2000 bits (min.)

→ If you have less than 2000 that must add the remain bit to packets

Efficiency (η) of CSMA/CD or Ethernet :-

There may lot of collision before a successful propagation or transmission

If a collision occurs than min $2 * T_p$ (worst cases) time get wasted.



$$\boxed{\eta = \frac{T_t}{c(2 * T_p) + T_t + T_p}}$$

c → no. of collision slots.

To calculate c, assume

1) n stations connected
2) 'p' ↔ probability of sending data
3) Probability of success when only one station transmits the data.

$$P_{success} = \underline{nC_1 * p * (1-p)^{n-1}}$$

for $(P_{success})_{max} = \frac{d(P_{success})}{dp} = 0$

$\Rightarrow \boxed{p = 1/n}$ for $(P_{success})_{max}$

$$(P_{success})_{max} = n * 1/n \, (1 - 1/n)^{n-1}$$

$$= \underline{(1 - 1/n)^{n-1}}$$

$$\lim_{n \to \infty} (P_{success})_{max} = 1/e = P_{max}$$

(4) How many times we try to get first successful transmission.

According to poison distribution [Probability]

No. of times we should try before getting first success $\rightarrow 1/P_{max}$

$= e$

So, $\boxed{\eta = \dfrac{T_t}{2 * T_p * e + T_t + T_p}}$ $[\because C = e]$

→ Remember this formula

$\Downarrow$

$\boxed{\eta = \dfrac{1}{1 + 6.44a}}$ $\left[a = \dfrac{T_p}{T_t}\right]$

$$\Rightarrow \frac{1}{1 + 6.44 \left(\frac{d}{v}\right)\left(\frac{B}{L}\right)}$$

(1) If $d \uparrow \longleftrightarrow \eta \downarrow$ [Not suitable for WAN's but useful for LAN's]

(2) $L \uparrow \longrightarrow \eta \uparrow$ [As large packet sent you get better efficiency]

(3) v and B are generally constant for particular questions.

Gate 2015 (CSMA/CD) | Read the question from P/Q and try to solve first.

$\rightarrow T_t \geq 2 * T_p$

$L/B \geq 2 * d/v$

$\dfrac{1250 * 8}{10^{6}} \geq 2 * 1/v$

$\rightarrow v \geq 20000 \text{ km/s}$