* Data Transmission time $= \frac{\text{Length}}{\text{Bandwidth}}$

$\boxed{\text{Propagation time} = \frac{\text{Distance}}{\text{Speed}}}$

* Round trip time = 2x Propagation Delay

* Go Back N ARQ

$\boxed{W_S = 2^n - 1}$, $\boxed{W_R = 1}$

$n \rightarrow$ Sequence no.

* Selective Repeat ARQ

$\boxed{W_S = W_R} = \frac{2^n}{2} = 2^{n-1}$

Some Important Formula:

1. $$\text{Efficiency} = \frac{\text{Throughput}}{\text{Bandwidth}}$$

2. $$\text{Efficiency} = \frac{\text{Data Transmission Time}}{\text{Total Time}}$$

3. $$\text{Data Transmission Time} = \frac{\text{Length}}{\text{Bandwidth}}$$

   $$PT = \frac{\text{Distance}}{\text{Speed}}$$

4. $$\text{Round Trip Time} = 2 \times \text{Propagation Delay}$$

5. $$\text{Total Time} = TT(\text{DATA}) + TT(\text{ACK}) + RTT$$

6. $$TT(\text{ACK}) = \frac{\text{Length}}{\text{Bandwidth}}$$

7. Transmission Efficiency $= \dfrac{\text{Transmission time for useful data}}{\text{Total transmission time}}$

8. Total Time = TT (DATA) + TT (ACK) + RTT + Time to process frame

Time to process data frame
+
Time to process ack frame

9. Efficiency $= \dfrac{\text{Window size} \times \text{Transmission Time}}{\text{Total time}}$

10. Efficiency $= \dfrac{\text{Transmitted Data Size}}{\text{Packet size} + \text{RTT} \times \text{Bandwidth}}$

11. Efficiency $= \dfrac{\text{Window size}}{1 + \frac{2T_p}{T_t}}$

12. Goodput $= \dfrac{\text{Successfully Data delivered}}{\text{Time}}$

GATE-15

(26.) A link has a transmission speed of 10^6 bits/sec. It uses data packets of size 1000 bytes each. Assume that the acknowledgement has negligible transmission delay, that its propagation delay is the same as the data propagation delay. Also assume that the processing delays at nodes are negligible. The efficiency of the STOP & WAIT protocol in this setup is exactly 25%. The value of the one-way propagation delay (in msec) is

Given,

~~Speed~~ (Bandwidth) $= 10^6$ bits/sec

Length $= 1000$ bytes
$= 8000$ bits

Efficiency $= 25\% = 0.25$

* TT (Data) $= \dfrac{\text{Length}}{\text{Bandwidth}}$

$$\boxed{\text{Efficiency} = \frac{\text{Data transmission time}}{\text{Total time taken}}}$$

* Total Time $=$ TT(Data) $+$ TT(ack) $+$ RTT

$\rightarrow$ $TT(\text{Data}) = \frac{8000}{10^6} = 0.008 \text{ sec} = 8 \text{ msec}$

$\rightarrow$ $\text{Total time} = TT(\text{Data}) + \cancel{TT(\text{ack})}^{0} + RTT$

$= 8 + RTT$

$$\text{Efficiency} = \frac{8}{8 + RTT}$$

$$0.25 = \frac{8}{8 + RTT} \Rightarrow \frac{\cancel{25}}{\cancel{100}_{4}} = \frac{8}{8 + RTT}$$

$$32 = 8 + RTT$$

$$\boxed{RTT = 24 \text{ msec}}$$

$$RTT = 2 \times PD$$

$$24 = 2 \times PD \Rightarrow \boxed{PD = 12 \text{ msec}}$$

GATE-16

(21.) A sender uses the stop and Wait ARQ protocol for reliable transmission of frames. Frames are of size 1000 bytes and the transmission rate at the sender is 80 kbps. Size of an acknowledgement is 100 bytes and the transmission rate at the receiver is 8 kbps. The one-way propagation delay is 100 msec. Assuming No frame is lost, the sender throughput is ______ bytes/second.

Given,

Frame size = 1000 bytes

Ack size = 100 bytes

Transmission rate at sender = 80 kbps

Transmission rate at receiver = 8 kbps

One way propagation delay = 100 msec

To find : Sender throughput : ?

* Throughput = Efficiency x Bandwidth
* Efficiency of sender = $\frac{\text{Data Transmission time}}{\text{Total time}}$

* Data Trasmission time = $\frac{\text{Length}}{\text{Bandwidth}} = \frac{1000 \times 8}{80 \times 1000} = 0.1$ sec

* Total time = TT(DATA) + TT(ACK) + RTT
  = 0.1 + 0.1 + 0.2 = 0.4 sec

* TT (Ack) = $\frac{\text{Length}}{\text{Bandwidth}} = \frac{100 \times 8}{8 \times 1000} = 0.1$ sec

* RTT = 2 x Propagation Delay = 2x100 m sec
  = 200 msec
  = 0.2 sec

* Efficiency
  $= \frac{0.1}{0.4}$
  $= 0.25$

* Throughput
  $= 0.25 \times 80 \times 1000$
  $= 20000$

GATE-16

(19.) Consider a 128×10^3 bits/second satellite communication link with one way propagation delay of 150 milliseconds. Selective retransmission (repeat) protocol is used on this link to send data with a frame size of 1 KB. Neglect the transmission time of acknowledgement. The minimum number of bits required for the sequence number field to achieve 100% utilization is

Sender data bhejte jaaega jb tk ack na mile

Given, Efficiency = 100% = 1

* Data transmission time $= \dfrac{\text{Length}}{\text{Bandwidth}} = \dfrac{10^3 \times 8}{128 \times 10^3} = 0.0625 \text{ sec}$

$= 62.5 \text{ msec}$

* Round Trip time = 2 × Propagation Delay

$= 2 \times 150$

$= 300 \text{ msec}$

itni देर तक भेजते Jaaega!

* Total time = TT + RTT = 362.5 msec

✲ No. of frames $= \frac{362.5}{62.5} = 5.8 \approx 6$

window size must be atleast 6

✲ In Selective Repeat ARQ :

$W_S = W_R$

→ Total Sequence no. $= 6 \times 2$
$= 12$

✲ To represent 12 seq. no अपने को कम से कम 4 bit lagenge!

GATE-15

20. Consider a network connecting two systems located 8000 km apart. The bandwidth of the network is 500×10^6 bits per second. The propagation speed of the media is 4×10^6 m per second. It is needed to design a Go-Back-N sliding window protocol for this network. The average packet size is 10^7 bits. The network is to be used to its full capacity. Assume that processing delays at nodes are negligible. Then, the minimum size in bits of the sequence number field has to be

→ Sender sends data until the first ack comes!

→ Efficiency = 100% = 1

$$TT = \frac{\text{Length}}{\text{Bandwidth}} = \frac{10^7}{500 \times 10^6} = 0.02 \text{ sec}$$

$$PT = \frac{\text{Distance}}{\text{Speed}} = \frac{8000 \times 10^3}{4 \times 10^6} = 2 \text{ sec}$$

✱ RTT = 2 × PT = 2 × 2 = 4 sec

↳ itni der tak data bhejte rhega!

✱ No. of frames $= \dfrac{4}{0.02} = 200$ → window size of sender side must be at least 200

Now, Window size = 200 + 1

= 201

→ 201 Sequence no. ko represent karne ke liye kam se kam 8 bits lagenge!

GATE-17

(22.) The values of parameters for the stop and Wait ARQ Protocol are as given below:

→ Bit rate of the transmission channel = 1 Mbps

→ Propagation delay from sender to receiver = 0.75 ms

→ Time to process a frame = 0.25 ms

→ No. of bytes in the information frame = 1980

→ No. of bytes in the acknowlege frame = 20

→ No. of overhead bytes in the information frame = 20

Assume that there are no transmission errors. Then, the transmission efficiency (in percentage) of the STOP and WAIT ARQ protocol for the above parameters is ______ (Correct to 2 decimal place)

$$\text{Transmission Efficiency} = \frac{\text{Transmission time for useful data}}{\text{Total transmission time}}$$

→ Kitna Useful data h = 1980 − 20 = 1960 bytes

→ TT for useful data = $\frac{\text{Length}}{\text{Bandwidth}} = \frac{1960 \times 8}{10^6} = 0.01568$ sec

Total Transmission Timee = TT(DATA) + TT(ACK) + RTT + Time to process fram

→ TT(DATA) = $\frac{1980 \times 8}{10^6} = 0.1584$ sec

→ TT(ACK) = $\frac{20 \times 8}{10^6} = 0.00016$ sec

Transmission Efficiency $= \frac{15.68}{18}$

$= 0.8711$

$\approx 87.11\%$

→ RTT $= 2 \times$ propagation delay

$= 2 \times 0.75$

$= 1.5$ msec

→ Time to process frames = Time to process inf frame + Time to process ack frame

$= 0.25 + 0.25$

$= 0.5$ msec

→ Total Time for transmission time $= 15.84 + 0.16 + 1.5 + 0.5$

$= 18$ m sec

→ TT for useful data $= 0.01568$ sec $= 15.68$ m sec

GATE-14

27. Consider a selective repeat sliding window protocol that uses a frame size of 1 KB to send data on a 1.5 Mbps link with a one-way latency of 50 msec. To achieve a link utilization of 60%, the minimum number of bits required to represent the sequence number field is

Given. Length = ~~1 KB~~ 1 KB , $T_p = 50$ msec

$$\boxed{\text{Efficiency} = \frac{\text{Window Size}}{1 + \frac{2T_p}{T_t}}}$$

= 1000 Byte

= 1000 x 8 bits

= 8000 bits

Bandwith = 1.5 Mbps

$= 1.5 \times 10^6$

$$0.6 = \frac{\text{window size}}{1 + \frac{2 \times 50}{5.33}}$$

$$T_t = \frac{\text{length}}{\text{Bandwidth}} = \frac{8000}{1.5 \times 10^6} = 5.33 \text{ msec}$$

window size = 11.8

$\approx$ 12

T_p = 50 msec

∴ Total window size

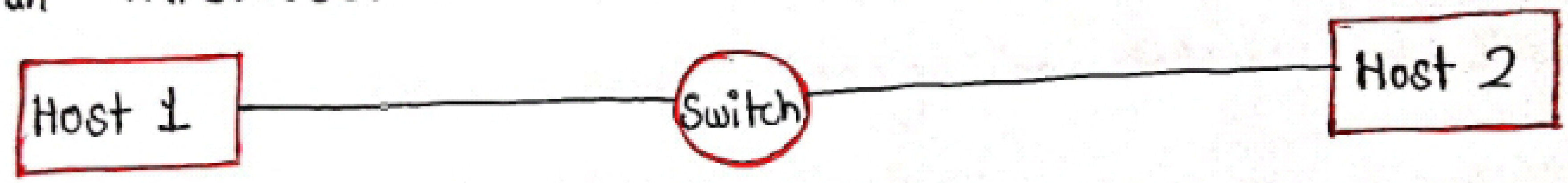
= 12 + 12

= 24

मतलब 5 bit lagega km se k

GATE-15

Q. Two hosts are connected via a packet switch with 10^7 bits per second links. Each link has a propagation delay of 20 μsec. The switch begins forwarding a packet 35 μsec after it receives the same. If 10000 bits of data are to be transmitted between the two hosts using a packet size of 5000 bits, the time elapsed between the transmission of the first bit of data and the reception of the last bit of the data in microseconds is ______.



Given, Bandwidth = 10^7 bps

Propagation delay = 20 μsec

Total data = 10000 bits

Packet size = 5000 bits

$\therefore$ No. of packets $= \dfrac{\cancel{10000}^{2}}{\cancel{5000}} = 2$

★ Transmission Time

$= \dfrac{\text{Length}}{\text{Bandwidth}}$

$= \dfrac{5000}{10^7}$

$= 0.0005$ sec

$= 500$ μsec

Packet - 1 :

Time to reach Host 2 = $500 + 20 + 35 + 500 + 20 = 1075\ \mu sec$

Packet - 2 :

Time to reach Host 2 = $500 + 1075 = 1575\ \mu sec$

GATE-12

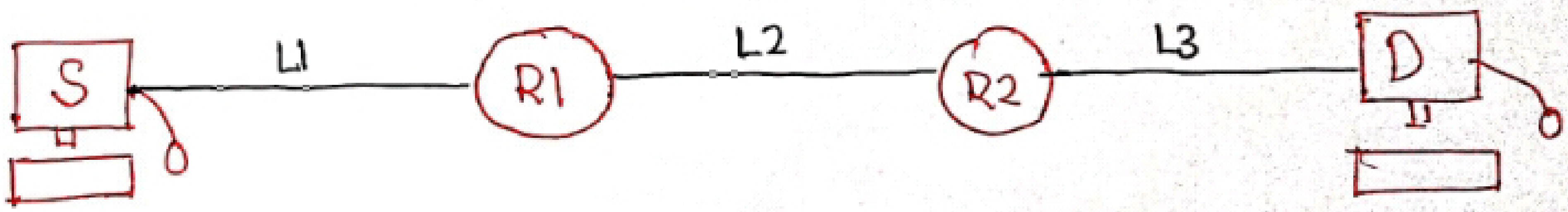
Q. Consider a source computer (S) transmitting a file of size 10[illegible] bits to a destination computer (D) over a network of two routers (R1 and R2) and three links (L1, L2 and L3). L1 connects S to R1; L2 connects R1 to R2; and L3 connects R2 to D. Let each link be of length 100 km. Assume signals travel over each link at a speed of 10^8 metres per second. Assume that the link bandwidth on each link is 1 Mbps. Let the file be broken down into 1000 packets each of size 1000 bits. Find the total sum of transmission and propagation delays in transmitting the files from S to D?

(a) 1005 ms

(b) 1010 ms

(c) 3000 ms

(d) 3003 ms



<u>Given</u>, Length of each link = 100 km

Speed over each link = 10^8 m/s

Bandwidth = 1 Mbps

Packet size = 1000 bits

Number of packets = 1000

* Transmission Time $= \dfrac{\text{Length}}{\text{Bandwidth}} = \dfrac{1000}{10^6} = 10^{-3}$ sec $= 1$ msec

* Propagation Time $= \dfrac{\text{Distance}}{\text{Speed}} = \dfrac{10^5}{10^8} = 10^{-3}$ sec $= 1$ msec

Packet - 1 :

Time to reach to D $= \underbrace{1+1}_{\text{S to R1}} + \underbrace{1+1}_{\text{R1 to R2}} + \underbrace{1+1}_{\text{R2 to D}} = 6$ msec

Packet - 2 :

Time to reach to D $= 1 + 6 = 7$ msec

Packet - 3 :

Time to reach to D $= 1 + 7 = 8$ msec

Packet - 1000 :

Time to reach to D $= 999 + 6 = 1005$ msec

GATE-05

Q. The maximum window size for data transmission using the selective repeat protocol with n-bit frame sequence no is :

A. 2^n

B. 2^{n-1}

C. $2^n - 1$

D. 2^{n-2}

* In selective repeat protocol,

Maximum window size $= \frac{2^n}{2} = 2^{n-1}$

* In Go-back-n,

Maximum window size $= 2^n - 1$

GATE-06

Q. Station A uses 32 byte packet to transmit messages to station B using a sliding window protocol. The round trip delay between A and B is 80 msec and the bottleneck bandwidth on the path between A and B is 128 kbps. What is the optimal window size that A should use?

A. 20 B. 40 C. 160 D. 320

D. $TT = \frac{\cancel{32} \times 8}{\cancel{128} \times 10^3} = 2\ ms$

$TT = 2 + 80$
$= 82\ ms$

No. of frames $= \frac{82}{2}$

$= 41$

GATE-04

Q. Suppose that the maximum transmit window size for a TCP connection is 12000 bytes. Each packet consists of 2000 bytes. At some point in time, the connection is in slow-start phase with a current transmit window of 4000 bytes. Subsequently, the transmitter receives two acknowledgments. Assume that no packets are lost and there are no time outs. What is the maximum possible value of the current transmit window?

A. 4000 bytes

B. 8000 bytes

C. 10000 bytes

D. 12000 bytes

→ In slow start phase,

हर ek ACK में sender increases transmit window by MSS.

→ Ques. में दिया है packet consists of 2000 bytes
↓
MSS

→ After two ACKs,

current transmit window

$= 4000 + 2000 + 2000$

$= 8000$

GATE-06

Q. Suppose that it takes 1 unit of time to transmit a packet (of fixed size) on a communication link. The link layer uses a window flow control protocol with a window size of N packets. Each packet causes an ack or a nak to be generated by the receiver and ack/nak transmission times are negligible. Further, RTT on the link is equal to N units. Consider time $i > N$. If only acks have been received till time i (no nacks), then the goodput evaluated at the transmitter at time i (in packets per unit time) is

A. $1 - \frac{N}{i}$

B. $\frac{i}{N+i}$

C. 1

D. $1 - e^{i/N}$

→ At time 'i' → 'i' packet nikal gye

→ $(i-N)$ → itno ~~को~~ ack करना है।

→ RTT = N → M|tb no waiting for sender

→ $\boxed{\text{Goodput} = \frac{\text{Successfully Data delivered}}{\text{Time}}}$

$= \frac{i-N}{i}$

$= 1 - \frac{N}{i}$

GATE-06

Q. Station A needs to send a message consisting of 9 packets using a sliding window of size 3 and go back n error control strategy. All packets are ready and immediately available for transmission. If every 5^{th} packet that A transmits gets lost (but no acks from B ever get lost), then what is the number of packets that A will transmit for sending the message to B?

A. 12

B. 14

C. 16

D. 18

1 2 3 4 $\boxed{5 \quad 6 \quad 7}$

5 6 $\boxed{7 \quad 8 \quad 9}$ 7 8 $\boxed{9}$ 9

→ 16 packets

GATE-07

Q. The distance between two stations M and N is L km. All fram

bits long. The propagation delay per km is t seconds. Let R bits/second be the channel capacity. Assuming that the processing delay is neglible the minimum no. of bits for the sequence no. field in a frame for maximum utilization, when the sliding window protocol is used is

A. $\log_2 \frac{2LtR+2K}{K}$

B. $\log_2 \frac{2LtR}{K}$

C. $\log_2 \frac{2LtR+K}{K}$

D. $\log_2 \frac{2LtR+2K}{2K}$

→ Transmission Time = $\frac{K}{R}$

→ RTT = $2tL$

→ Total time = $\frac{K}{R} + 2tL = \frac{K+2tRL}{R}$

→ No. of frames = $\frac{K+2tRL}{\cancel{R}} \cdot \frac{\cancel{R}}{K} = \frac{K+2tRL}{K}$

$$2^n = \frac{K+2tRL}{K}$$

$$\boxed{n = \log_2 \frac{K+2LtR}{K}}$$

GATE-08

Q. A 1 Mbps satellite link connects two ground stations. The altitude of the satellite is 36,504 km and speed of the signal is 3×10^8 m/s. What should be the packet size for a channel utilization of 25%. for a satellite link using go-back-127 sliding window protocol? Assume that the acknowledgement packets are negligible in size and that there are no errors during communication.

A. 120 bytes

B. 60 bytes

C. 240 bytes

D. 90 bytes

$$\ast \text{ Efficiency} = \frac{\text{Transmitted Data Size}}{\text{Packet Size} + RTT \times \text{Bandwidth}}$$

→ Distance from Station A to satellite

$$= 36504 \times 10^3 \text{ m}$$

→ Time to reach satellite $= \dfrac{36504 \times 10^3}{3 \times 10^8} = 0.12168\,s$

→ RTT = 4 × Time to reach satellite

(S1 → satellite, satellite → S2, S2 → satellite, Satellite → S1)

GATE-04

Q. In a sliding window ARQ scheme, the transmitter's window size is N and the receiver's window size is M. The minimum no. of distinct sequence numbers required to ensure correct operation of the ARQ scheme is

A. min(M,N)

B. max(M,N)

C. M+N

D. MN

→ $W_s + W_r \le$ Sequence nos.

→ Maximum no. of unacknowledged packets at sender will be W_s and at the receiver it will be W_r.

∴ M+N

GATE-04

Q. A 20 Kbps satellite link has a propagation delay of of 400 ms. The transmitter employs the "go back n ARQ" scheme with n set to 10. Assume that each frame is 100 byte long, what is the maximum data rate possible?

$$\text{Efficiency} = \frac{\text{Window size} \times \text{Transmission Time}}{\text{Total time}}$$

$$D.T.T = \frac{100 \times 8}{20 \times 10^3} = 40ms$$

$P.D = 400ms \Rightarrow RTT = 800\ ms$

$\text{Total Time} = 40 + 800 = 840\ ms$

$$= \frac{10 \times \cancel{40}}{\cancel{840}_{21}} = 0.476$$

$$E = \frac{T}{B}$$

$$0.476 = \frac{T}{20\ Kbps}$$

$T = 9.52\ Kbps$

GATE-03

unacademy

Q. Host A is sending data to host B over a full duplex link. A & B are using the sliding window protocol for flow control. The send & receive window sizes are 5 packets each. Data packets (sent only from A to B) are all 1000 bytes long & the transmission time for such packet is 50 μs. Acknowledgement packets (sent only from B to A) are very small & require negligible transmission time. The propagation delay over the link is 200 μs. What is the maximum achievable throughput in this communication?

A. 7.69×10^6 Bps

B. 11.11×10^6 Bps

C. 12.33×10^6 Bps

D. 15.00×10^6 Bps

→ Maximum throughput mtlb Apne jitna ho ske utna Data bhejna है।

→ Maximum packet that can be sent $= 1 + 2a = 1 + \frac{2T_p}{T_t}$

$= 1 + 2 \times \frac{\cancel{200}^{4}}{\cancel{50}} = 9$

↓

for 100% efficiency

→ But Apne पास तो window size = 5 packet है

→ Bandwidth $= \frac{L}{T_t}$

$= \frac{1000}{50 \times 10^{-6}}$

$= 20 \times 10^6$ bps

∴ Efficiency $= \frac{5}{9} = \frac{\text{Throughput}}{\text{Bandwidth}}$

~~window si~~

$\frac{5}{9} = \frac{\text{Throughput}}{20 \times 10^6} \Rightarrow \boxed{\text{Throughput} = 11.11 \times 10^6 \text{ bps}}$

GATE-09

ISRO-16

Q. Frames of 1000 bits are sent over a 10^6 bps duplex link between two hosts. The propagation time is 25 ms. Frames are to be transmitted into this link to maximally pack them in transit (within the link). What is the minimum no. of bits (I) that will be required to represent the sequence no. distinctly assuming that no time gap needs to be given between transmission of two frames.

& Let I be the minimum no. of bits (I) that will be required to represent the sequence no. distintly assuming that no time gap needs to be given between transmission of two frames.

Suppose that the sliding window protocol is used with the sender window size of 2^I, where I is the no. of bits as mentioned earlier and acknowledgements are always piggy backed. After sending 2^I frames, what is the minimum time the sender will have to wait before starting transmission of the next frame?

A. 16 ms B. 18 ms C. 20ms D. 22ms

$\because$ Efficiency $= \dfrac{\text{Transmitted data size}}{\text{Packet size} + \text{RTT} \times \text{Bandwidth}}$

$$0.25 = \frac{127 \times X}{X + 4 \times 0.12168 \times 10^{6}}$$

[$\because$ Bandwidth $= 1$ Mbps $= 10^{6}$ bps]

$X = 9.6 \times 10^{-4} \times 10^{6}$

$X = 960$ bits $= 120$ bytes

$\boxed{X = 120 \text{ bytes}}$

GATE-14

Q. Consider a selective repeat sliding window protocol that uses a frame size of 1Kb to send data on a 1.5 Mbps link with a one way latency of 50msec. To achieve a link utilization of 60%, the minimum no. of bits required to represent the sequence no. field is ______.

→ $P.D = 50msec \Rightarrow RTT = 2 \times P.D = 100msec$

→ Length = 1Kb

→ Bandwidth = 1.5 Mbps

→ Efficiency = 60% = 0.6

$* \; TT = \frac{L}{B} = \frac{10^3 \times 8}{1.5 \times 10^6} = \frac{2}{3} \times 8 \times 10^{-3}$

$= \frac{16}{3} ms$

$$\text{Efficiency} = \frac{\text{window size}}{1 + 2\frac{T_p}{T_t}}$$

$$0.6 = \frac{N}{1 + \cancel{2} \times \frac{\cancel{50}^{25} \times 3}{\cancel{16}\,\cancel{8}_{4}}} \Rightarrow \boxed{N = 11.85}$$

↓

$W_S + W_R \leq 2 \times 11.85$

≤ 23.7

$\leq 24 \rightarrow \log_2 24 = 5$

→ Propagation time = 25 ms

→ Bandwidth = 10^6 bps

→ पूरी Tarike se channel का utilization तब होगा जब, we send 10^6 bits in a second → जो ki diya है

1000 frames in 1 sec. ⇒ 1000 bits

→ Propagation time = 25 ms
↓
iska mtlb agr pura pack krna है link को तो we need to send at least = $1000 \times 25 \times 10^{-3}$ = 25 frames.
⇓
$\log_2 25 = 5$ bits.

$I = 5$, $2^I = 32$ frames are sent.

→ Transmission time = $\frac{1000}{10^6}$ = 1 ms

∴ TT for 32 frames = 32 ms.

→ RTT = PT(frame) + TT(frame) + PT(Ack) + TT(Ack)
= 25 + 1 + 25 + 1
= 52 ms

∴ Waiting time = 52 − 32 = 20 ms

SI-15

Q. Stations A & B are connected through a line of bandwidth 64 kbps. Station A uses 16 byte packets to transmit message to B using a sliding window protocol. The round trip propagation delay between A and B is 50 m sec. Determine the window size A should use to maximize the line utilization. Assume that the ack frame is of negligible size & processing delay may be ignored.

Given. Bandwidth = 64 kbps = 64000 bps

Length = 16 Byte = 16 x 8 bits

RTT = 50 msec = 0.05 sec

Transmission time (T_f) = ~~Size of~~ $\frac{\text{Length}}{\text{Bandwidth}} = \frac{16 \times 8}{64000} = 0.02 \text{ sec}$

★ For maximum utilization in sliding window protocol,

size of sender's window $= 1 + \frac{2 T_p}{T_f} = 1 + \frac{RTT}{T_f} = 1 + \frac{0.05}{0.002}$

$= 26$

ISI-17

Q. Station A is sending data to station B over a full duplex error free channel. A packets sliding window protocol is being used for flow control. The send & receive window size is being used for flow control. The send and receive window sizes are 6 frames each. Each frame is 1200 bytes long and the transmission time for such a frame is 70 microsec. Acknowledgement frames sent by B to A are very small and require negligible transmission time. The propagation delay over the link is 300 μsec. What is the maximum achievable throughput in this communication?

→ ∵ window size is 6, the sender can send maximum of 6 frames till first frame is acknowledged.

→ Time taken by first frame to get acknowledged

$= TT(\text{frame}) + PD(S \text{ to } R) + TT(\text{Ack}) + PD(R \text{ to } S)$

$= 70 + 300 + 0 + 300$

$= 670\ \mu sec$

→ Data sent during this time = 6 frames = 6× 1200 = 7200 bytes

→ Throughput $= \dfrac{7200 \text{ byte}}{670\ \mu sec} = 85.97$ Mbps