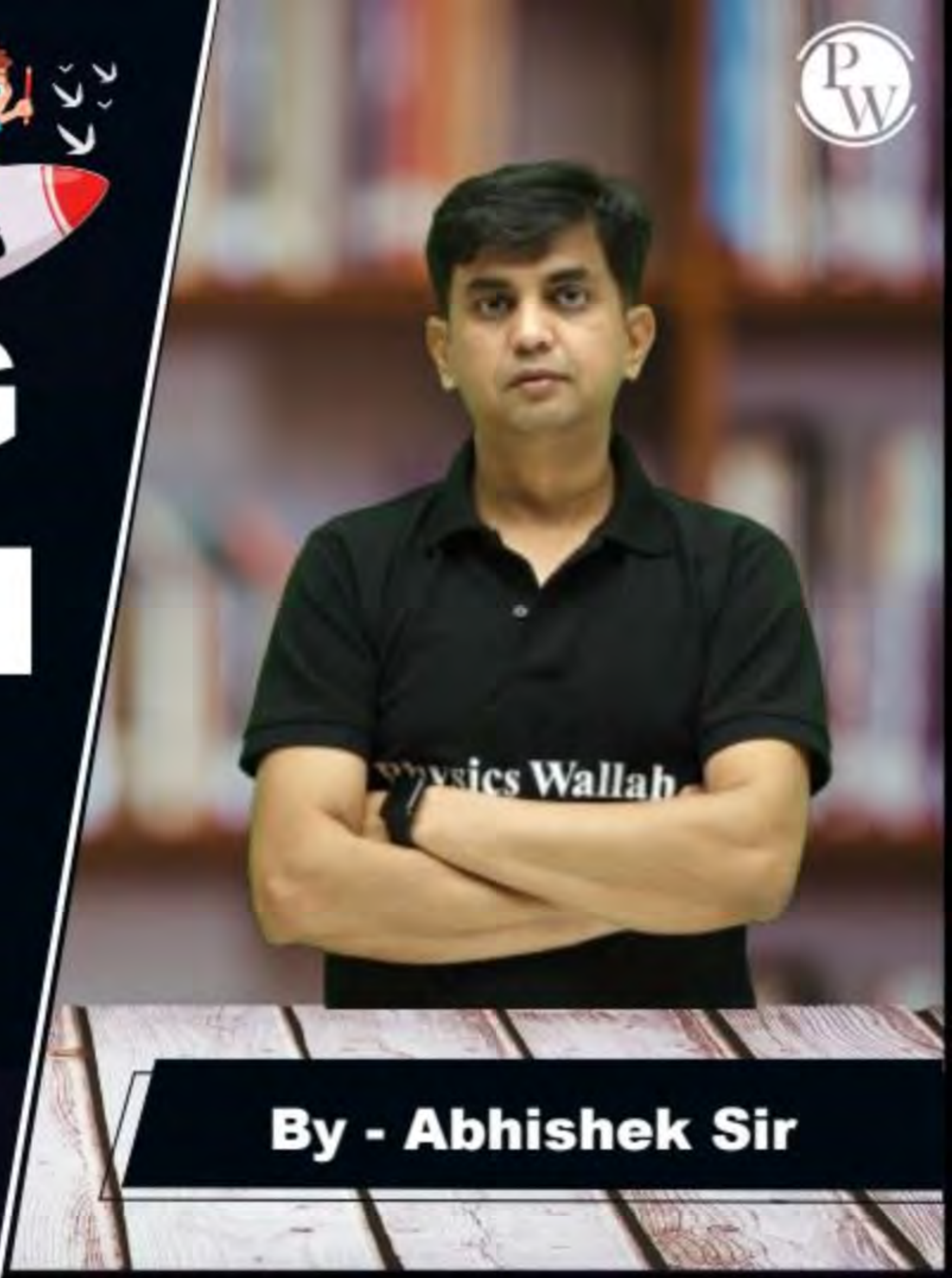
CS & IT ENGINEERING

Computer Network

Flow Control

Lecture No. - 03



By - Abhishek Sir

Recap of Previous Lecture

Topic Stop-and-Wait Protocol

Topic Stop-and-Wait ARQ

Topics to be Covered

Topic	Sliding Window Protocol
Topic	Go Back N ARQ

ABOUT ME

Hello, I'm Abhishek

- GATE CS AIR - 96
- M.Tech (CS) - IIT Kharagpur
- 12 years of GATE CS teaching experience

Telegram Link : https://t.me/abhisheksirCS_PW

@ABHISHEKSIRCS_PW

[MCQ] [GATE-2025] [2 Mark]

#Q. Suppose we are transmitting frames between two nodes using Stop-and-Wait protocol. The frame size is 3000 bits. The transmission rate of the channel is 2000 bps (bits/second) and the propagation delay between the two nodes is 100 milliseconds. Assume that the processing times at the source and destination are negligible. Also, assume that the size of the acknowledgment packet is negligible. Which ONE of the following most accurately gives the channel utilization for the above scenario in percentage?

Efficiency

(A) 88.23

(B) 93.75

(C) 85.44

(D) 66.67

Ans: A

Solution:-

Frame Size = $\boxed{3000 \text{ bits}}$

Bandwidth = $\boxed{2000 \text{ bits / sec}}$

$$t_x = \frac{\text{Packet Size}}{\text{Bandwidth}} = \frac{3000 \text{ bits}}{2000 \text{ bits / sec}} = 1.5 \text{ Sec}$$

$$t_p = 100 \text{ ms} = 0.1 \text{ Sec}$$

$$\text{Cycle time} = (t_x + 2 * t_p) = 1.7 \text{ Sec}$$

For Stop-and-Wait ARQ :

$$\text{Efficiency } (\eta) = \frac{\text{Transmission delay}}{\text{Cycle Time}} = \frac{1.5 \text{ Sec}}{1.7 \text{ Sec}}$$

$$= 0.8823$$

$$= 0.8823 * 100 \%$$

$$= \boxed{88.23 \%}$$

[NAT] [GATE-2015][2 Mark]

#Q. A link has a transmission speed of $\boxed{10^6 \text{ bits/sec}}$. It uses data packets of size 1000 bytes each. Assume that the acknowledgment has negligible transmission delay, and 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-and-wait" protocol in this setup is exactly 25%. The value of the one-way propagation delay (in milliseconds) is ________.

Solution:-

Packet Size = $\boxed{1000 \text{ bytes}}$ = $\boxed{8 * 10^3 \text{ bits}}$

Bandwidth = $\boxed{10^6 \text{ bits / sec}}$

$$t_x = \frac{\text{Packet Size}}{\text{Bandwidth}} = \frac{8 * 10^3 \ \cancel{\text{bits}}}{10^6 \ \cancel{\text{bits}} / \text{sec}} = \boxed{8 \text{ ms}}$$

To achieve ~~50%~~ 25% utilization in Stop-and-Wait ARQ.

$$\boxed{\text{Cycle time} = 4 * t_x}$$

$$(t_x + 2 * t_p) = 4 * t_x$$

$$t_p = (3 * t_x / 2)$$

$$= (3 * 8\text{ ms} / 2)$$

$$= \boxed{12\text{ ms}}$$

$$\boxed{\text{Ans} = 12}$$

[NAT] [GATE-2017][2 Mark]

#Q. The values of parameters for the Stop-and–Wait ARQ protocol are as given below.

Bit rate of the transmission channel = $\boxed{1 \text{ Mbps}}$

Propagation delay from sender to receiver = 0.75 ms

Time to process a frame = $\boxed{0.25 \text{ ms}}$

Number of bytes in the information frame = $\boxed{1980}$

Number of bytes in the acknowledge frame = $\boxed{20}$

Number of overhead bytes in the information frame = $\boxed{20}$

Assume that there are no transmission errors. Then the transmission efficiency (expressed in percentage) of the Stop-and–Wait ARQ protocol for the above parameters is ________ (correct to 2 decimal place).

IIT-R Ans: 86.5 to 89.5

Solution:-

Packet Size = $\boxed{1980 \text{ bytes}}$

Bandwidth = $\boxed{1 \text{ Mbps}}$ = 10^6 bits / sec

$$t_x = \frac{\text{Packet Size}}{\text{Bandwidth}} = \frac{1980 \text{ bytes}}{10^6 \text{ bits / sec}} = 15.84 \text{ ms}$$

Packet Size = (20 + 1980) bytes = $\boxed{2000 \text{ bytes}}$ = $16 * 10^3$ bits

$$t_x = \frac{\text{Packet Size}}{\text{Bandwidth}} = \frac{16 * 10^3 \text{ bits}}{10^6 \text{ bits / sec}} = 16 \text{ ms}$$

ACK Size = $\boxed{20 \text{ bytes}}$ = 160 bits

Bandwidth = 1 Mbps = 10^6 bits / sec

$$t_{xA} = \frac{\text{ACK Size}}{\text{Bandwidth}} = \frac{160 \text{ bits}}{10^6 \text{ bits / sec}} = 0.16 \text{ ms}$$

t_p = 0.75 ms

Processing Delay = 0.25 ms

$$\boxed{t_x = 15.84 \text{ ms}}$$

Cycle time $= (t_x + t_p) + \text{Processing Delay} + (t_{xA} + t_p)$

$= (15.84 + 0.75) + 0.25 + (0.16 + 0.75)$ ms

$= 17.75$ ms

For Stop-and-Wait ARQ :

$$\text{Efficiency}(\eta) = \frac{\text{Transmission delay}}{\text{Cycle Time}} * 100\% = \frac{15.84}{17.75} * 100\%$$

$= 89.23\%$

$\boxed{t_x = 16 \text{ ms}}$

$$\text{Cycle time} = (t_x + t_p) + \text{Processing Delay} + (t_{xA} + t_p)$$
$$= (16 + 0.75) + 0.25 + (0.16 + 0.75)$$
$$= 17.91 \text{ ms}$$

For Stop-and-Wait ARQ :

$$\text{Efficiency} = \frac{\text{Transmission delay}}{\text{Cycle Time}} * 100\% = \frac{16 \text{ ms}}{17.91 \text{ ms}} * 100\%$$
$$= 89.33\%$$

Topic : Channel Utilization

→ $\underbrace{\text{Link Utilization}}$ or $\underbrace{\text{Throughput}}$ ⟹ [in bytes per sec]

$$\boxed{\text{Throughput} = \frac{[\text{Packet Size}]}{[\text{Cycle Time}]}}$$

$$\boxed{\text{Throughput} <= \text{Bandwidth}}$$

$$= \frac{\left(\frac{\text{Packet Size}}{\text{Bandwidth}}\right)}{\text{Cycle time}} * \text{Bandwidth}$$

$$\boxed{\text{Throughput} = \underbrace{\text{Efficiency}} * \underbrace{\text{Data Transfer Rate at sender}}}$$

Example 7 :-

#Q. Consider two hosts A and B directly connected through point to point link using stop and wait ARQ for flow control. Suppose packet size is 50 bytes, link bandwidth is 2 Kbps and one-way propagation delay is 100 millisecond, the sender throughput is ________ bytes/second ?

$\boxed{Ans = 125}$

Solution 7 :-

$\underbrace{\text{Packet Size}}$ = $\boxed{\text{50 bytes}}$ = $\boxed{\text{400 bits}}$

Bandwidth = $\boxed{\text{2 Kbps}}$ = $\boxed{2 * 10^3 \text{ bits / sec}}$

$$t_x = \frac{\text{Packet Size}}{\text{Bandwidth}} = \frac{400 \ \cancel{\text{bits}}}{2 * 10^3 \ \cancel{\text{bits}} / \text{sec}} = 200 \text{ ms}$$

$$\boxed{t_p = 100 \text{ ms}}$$

$$\text{Cycle time} = (t_x + t_p) + (t_{xA} + t_p) = (200 + 100) + (0 + 100) \text{ ms}$$

$$= 400 \text{ ms}$$

$$\text{Throughput} = \frac{\text{Packet Size}}{\text{Cycle Time}} = \frac{50 \text{ byte}}{400 \text{ ms}}$$

$$= \frac{50 \text{ byte}}{400 * 10^{-3} \text{ sec}} = \frac{1000}{8} \text{ bytes/sec}$$

$$= 125 \text{ bytes/sec}$$

$$\eta = \frac{t_x}{\text{cycle time}} = \frac{200 \text{ms}}{400 \text{ms}} = \frac{1}{2}$$

$$\text{Throughput} = \eta * \text{Bandwidth}$$

$$= \frac{1}{2} * 2 \text{ Kbps} = 1 \text{ Kbps}$$

$$= 10^3 \text{ bits/sec} = \frac{10^3}{8} \text{ bytes/sec}$$

$$= 125 \text{ bytes/sec}$$

[NAT] IISC, H.W. [GATE-2016][2 Mark]

#Q. A sender uses the $\boxed{\text{Stop-and-Wait ARQ}}$ protocol for reliable transmission of frames. Frames are of size 1000 bytes and the transmission rate at the sender is 80 Kbps (1Kbps = 1000 bits/second). Size of an acknowledgement is 100 bytes and the transmission rate at the receiver is 8 Kbps. The one-way propagation delay is 100 milliseconds. Assuming no frame is lost, the sender throughput is ________ bytes/second.

Topic : Sliding Window Protocol

- → Transmitter's transmitting window size = $\boxed{N}$ [N>1]
- → Transmitter's can transmit N frames in a cycle [without any ACK]
- → Overlapping, unlike Stop-and-Wait Protocol [To increase utilization]

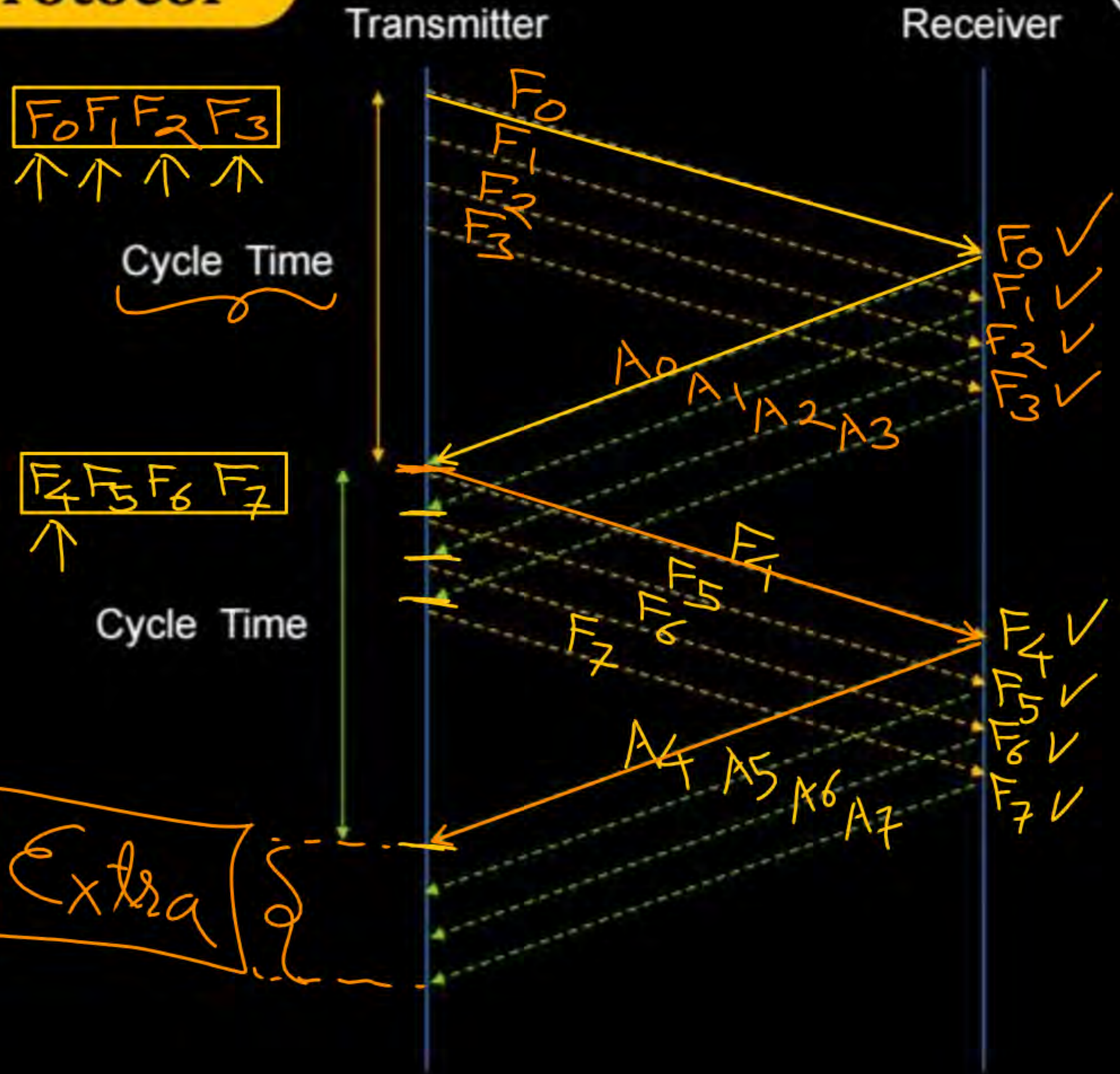
Topic : Sliding Window Protocol

$$\text{Efficiency} = \frac{[\text{Window Size} * \text{Packet transmission time}]}{\text{Cycle Time (RTT)}}$$

$$\eta = \frac{N * t_x}{\text{cycle time}}$$

Topic : Sliding Window Protocol

$[N = 4]$



$[(N-1) * t_{XA}]$ (Ignore)

Extra

Topic : Optimal Window Size

Optimal Window Size =
For maximum channel utilization,
minimum transmitter's transmitting window size.

$$\text{Optimal Window Size (N)} = \left\lceil \frac{\text{Cycle Time (RTT)}}{\text{Frame transmission time}} \right\rceil = \left\lceil \frac{\text{cycle time}}{t_x} \right\rceil$$

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

[GATE 2006]

IIT-KGP

A. 20

B. 40

C. 160

D. 320

$\boxed{\text{Ans: B}}$

Solution:-

Packet Size = $\boxed{32 \text{ bytes}}$ = $\boxed{2^8 \text{ bits}}$

Bandwidth = $\boxed{128 \text{ Kbps}}$ = $\boxed{2^7 * 10^3 \text{ bits / sec}}$

$$t_x = \frac{\text{Packet Size}}{\text{Bandwidth}} = \frac{2^8 \ \cancel{\text{bits}}}{2^7 * 10^3 \ \cancel{\text{bits}} / \text{sec}} = \boxed{2 \text{ ms}}$$

RTT (Cycle Time) = $\boxed{80 \text{ ms}}$

For Sliding Window Protocol :

$$\text{Optimal Window Size} = \left\lceil \frac{\text{Cycle Time (RTT)}}{\text{Transmission delay}} \right\rceil = \left\lceil \frac{80\,ms}{2\,ms} \right\rceil$$

$$= 40$$

Cycle time = 20 sec

$t_x = 2$ sec

optimal window size (N) = ?

$$= \left\lceil \frac{20\ sec}{2\ sec} \right\rceil = 10$$

Cycle time = 20 sec

$t_x = 3$ sec

optimal W.S. (N) = ?

$$= \left\lceil \frac{20\ sec}{3\ sec} \right\rceil = 7$$

Cycle time = 20 sec

$t_x = 2$ sec

Transmit W.S. (N) = 11

Efficiency (N) = ?

= 100%

Topic : Sliding Window Protocol

→ Transmitter's transmitting window size = $\boxed{N}$ [N>1]

→ Receiver's receiving window size = $\boxed{N}$

Topic : Sliding Window Protocol

→ Total number of sequences = $\boxed{N}$ [0 to (N-1)]

Total number of sequences
= Transmitter's transmitting window size

Sequence number ← (Frame number) mod (N)

Topic : Sliding Window Protocol

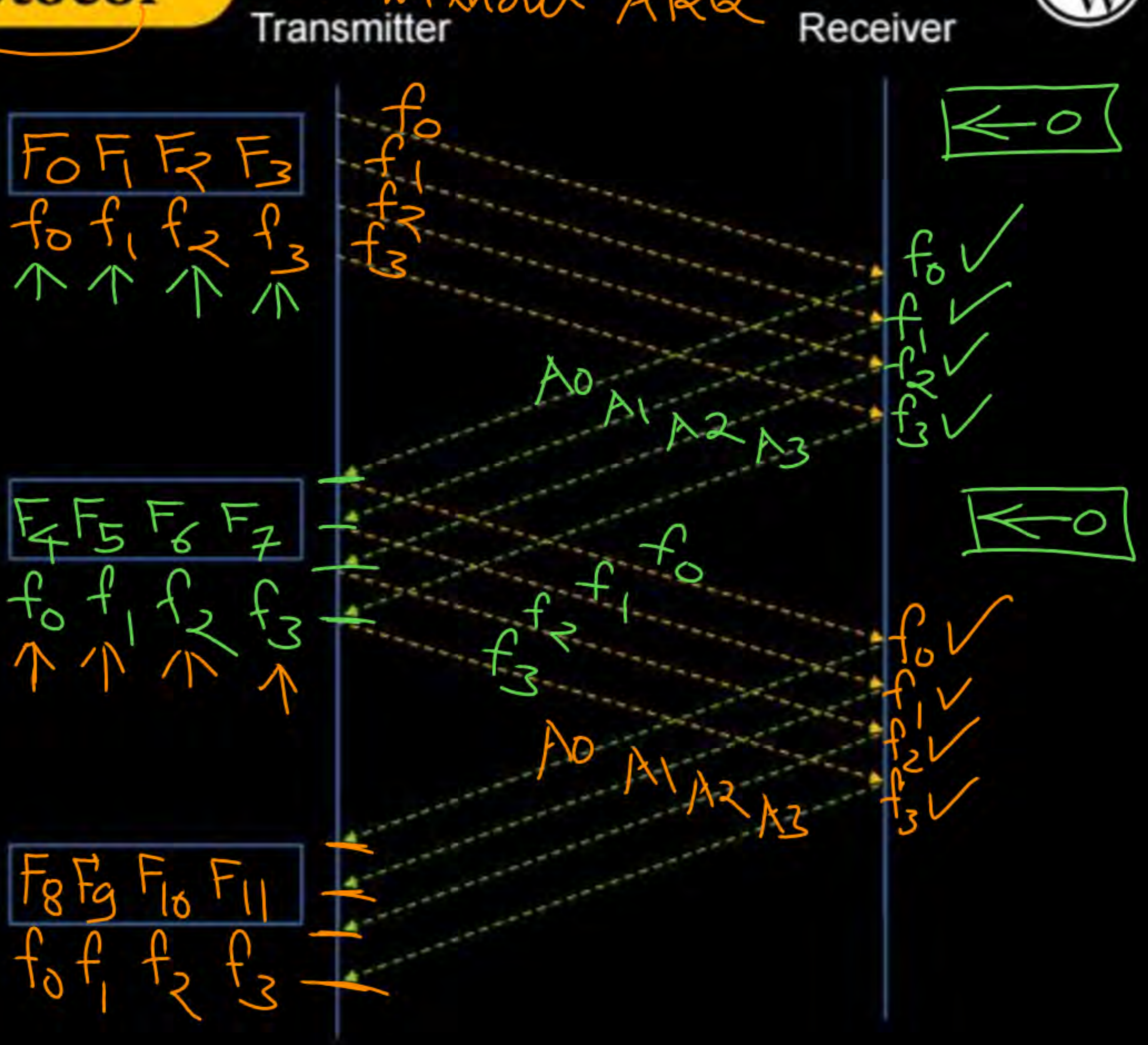
⇒ Noiseless channel without ARQ

Suppose N = 4

Sequence Number = 0 to 3

F_0	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	F_{11}	F_{12}

⇒ Mod 4



Topic : Sliding Window Protocol

⟹ Noisy channel with ARQ

→ In case of, Noisy Channel

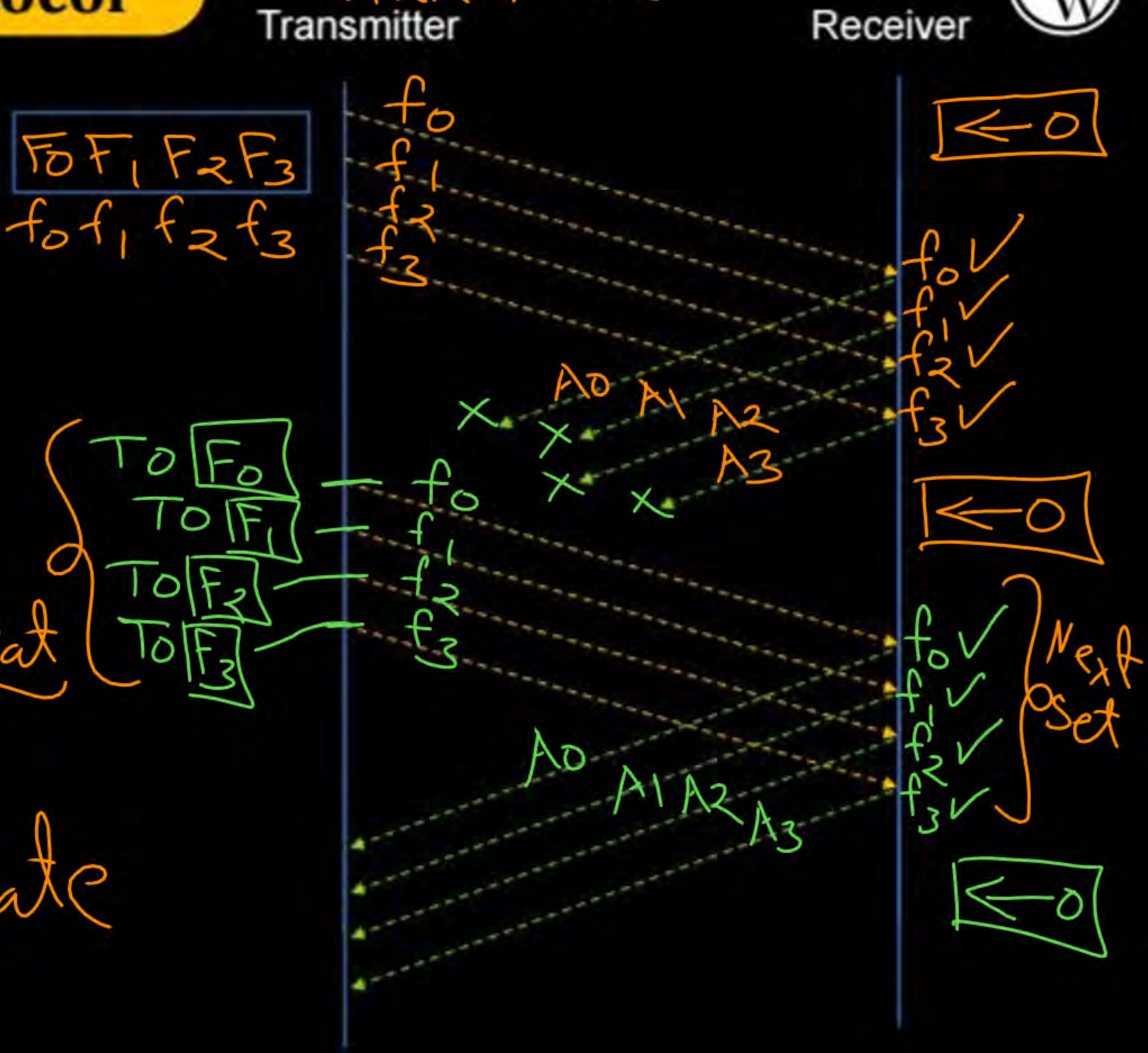
* ARQ

Suppose N = 4

Sequence Number = $\boxed{0 \text{ to } 3}$

→ Mod 4

⟹ Receiver may not able to recognize duplicate frame set!



Topic : Sequence Number

Minimum number of bits required for sequence number field (in frame header)

$$= \left\lceil \log_2 [\underbrace{\text{Total number of sequences}}] \right\rceil \text{ bits}$$

#Q. The distance between two stations M and N is L kilometers. All frames are K bits long. The propagation delay per kilometer is t seconds. Let R bits/second be the channel capacity. Assuming that processing delay is negligible, the minimum number of bits for the sequence number field in a frame for maximum utilization, when the sliding window is used, is

[GATE 2007]

IIT-K, H.W.

Topic : Channel Utilization

→ Link utilization or Throughput [in bits or bytes per sec]

→ Total number of bytes (or bits) transmitted in Cycle time (RTT)

$$\text{Throughput} = \frac{[\text{Transmitter Window Size} * \text{Packet Size}]}{\text{Cycle Time (RTT)}}$$

$$\text{Throughput} = \text{Efficiency} * \text{Data transfer rate at transmitter}$$

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

[GATE 2003]

IIT-M, H.W.

(A) $7.69 * 10^6$ bytes per sec

(B) $11.11 * 10^6$ bytes per sec

(C) $12.33 * 10^6$ bytes per sec

(D) $15.00 * 10^6$ bytes per sec

Example 8 :- [H.W.]

#Q. Consider two hosts A and B directly connected through point-to-point link using 'sliding window protocol' for flow control where transmit window size is 20 and acknowledgments are always piggybacked. Each packet transmission time is 2 seconds and one-way propagation delay of the link is 24 seconds. After transmitting all 20 frames in a cycle, what is the minimum time the sender will have to wait before starting transmission of the next frame ? (Ignore the processing and queuing delays at both the end.)

2 mins Summary

Topic Sliding Window Protocol

Topic ~~Go Back N ARQ~~

THANK - YOU

@ABHISHEKSIRCS_PW