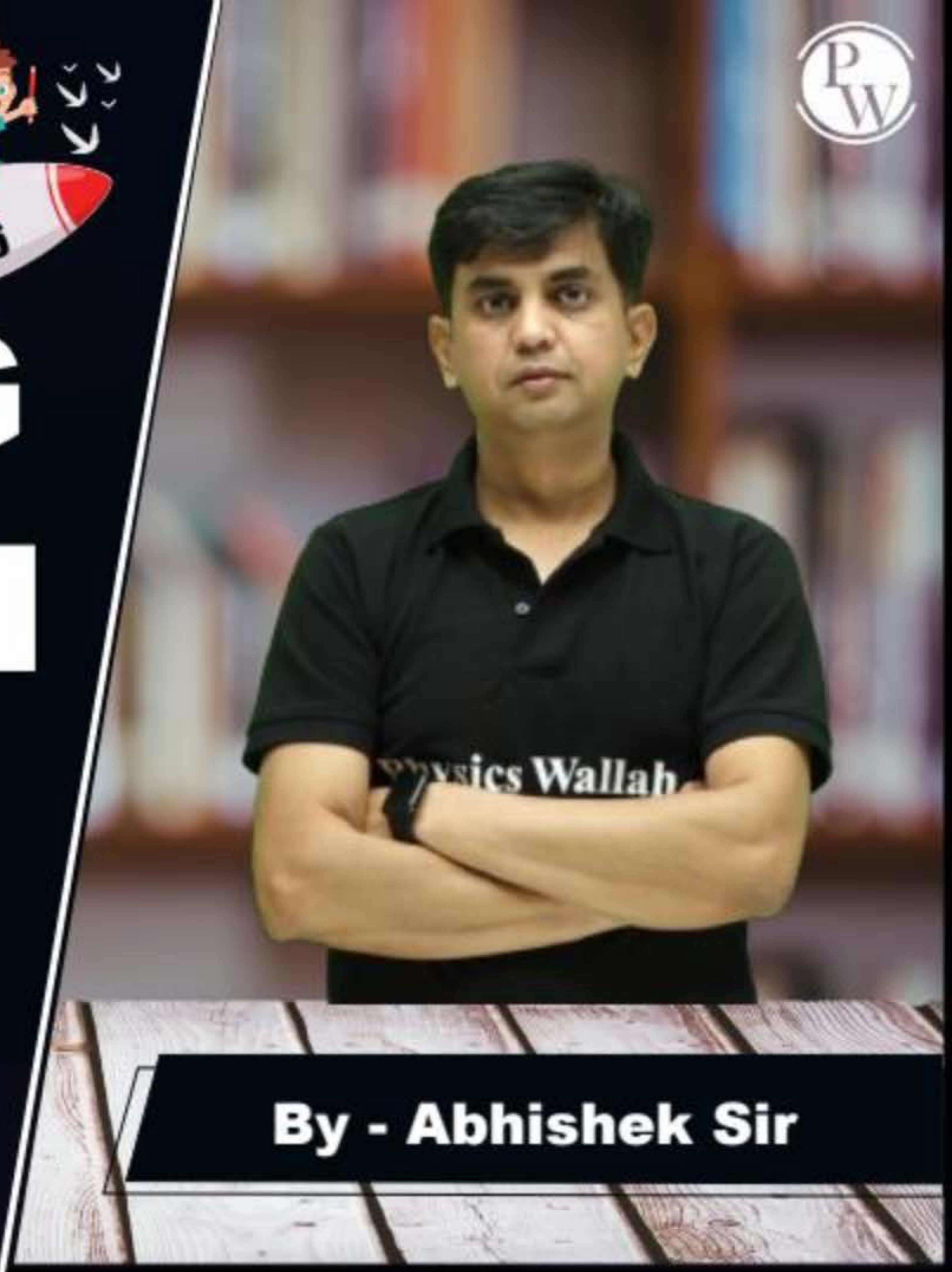
CS & IT ENGINEERING

Computer Network

Flow Control

Lecture No. - 06



By - Abhishek Sir

Recap of Previous Lecture

Topic — Go Back N ARQ

Topic — Selective Repeat ARQ

Topics to be Covered

Topic — Store-and-Forward Delay

Topic — End-to-End Delay

Topic — Bit Error Probability

#Q. Station A needs to send a message consisting of 9 packets to Station B using a sliding window (window size 3) and go-back-n flow 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?

[GATE 2006]

A) 12

B) 14

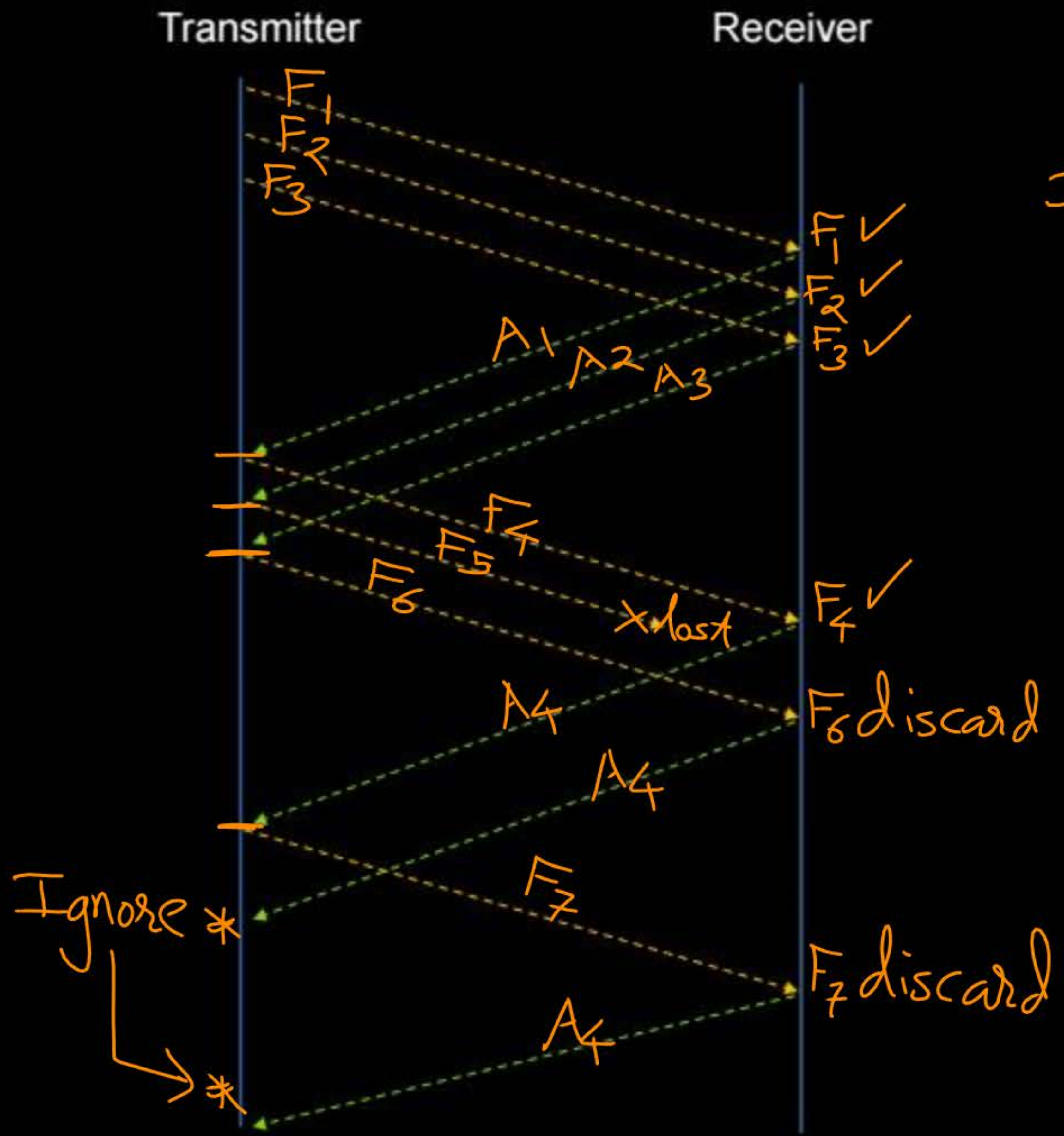
C) 16

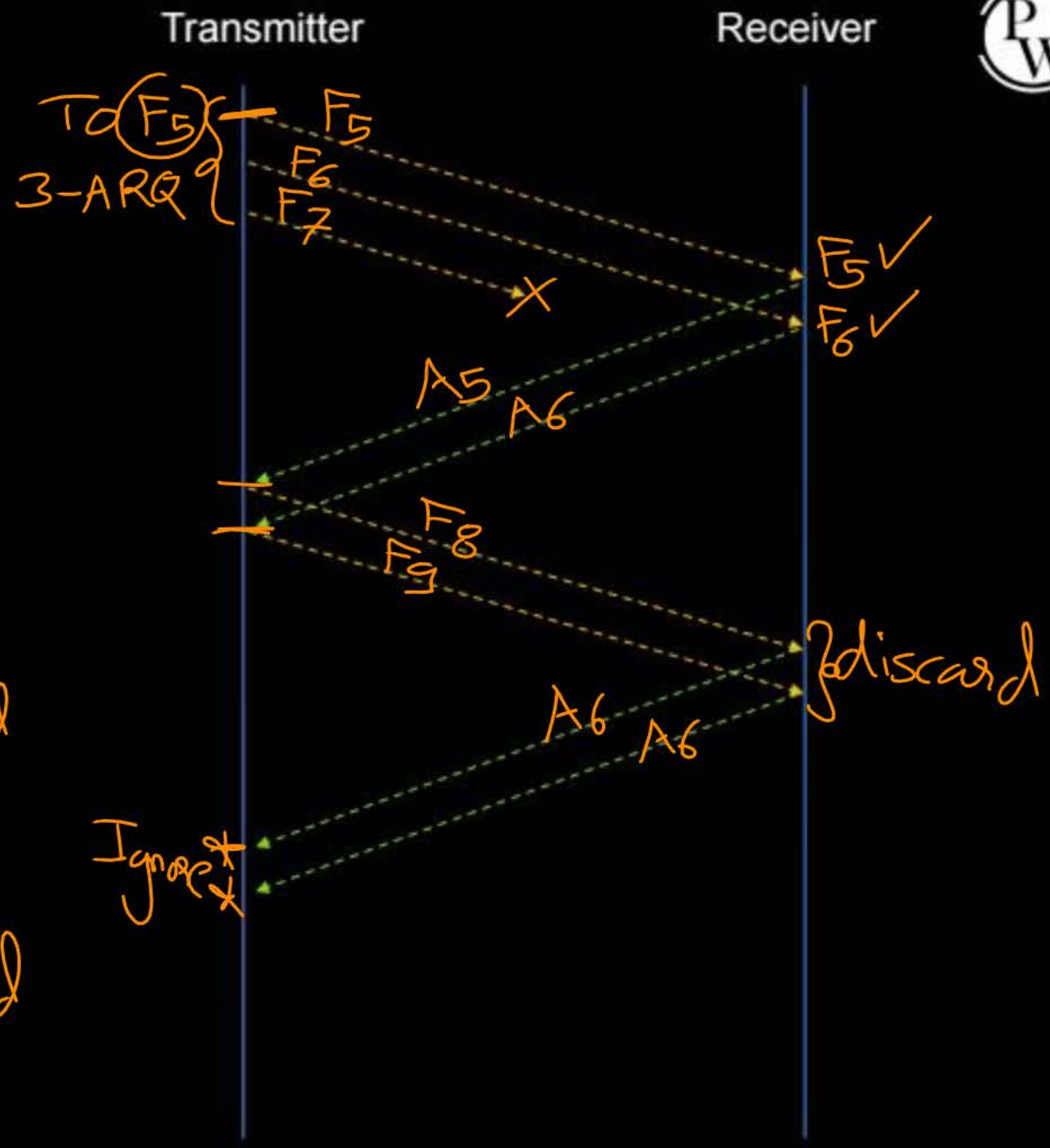
D) 18

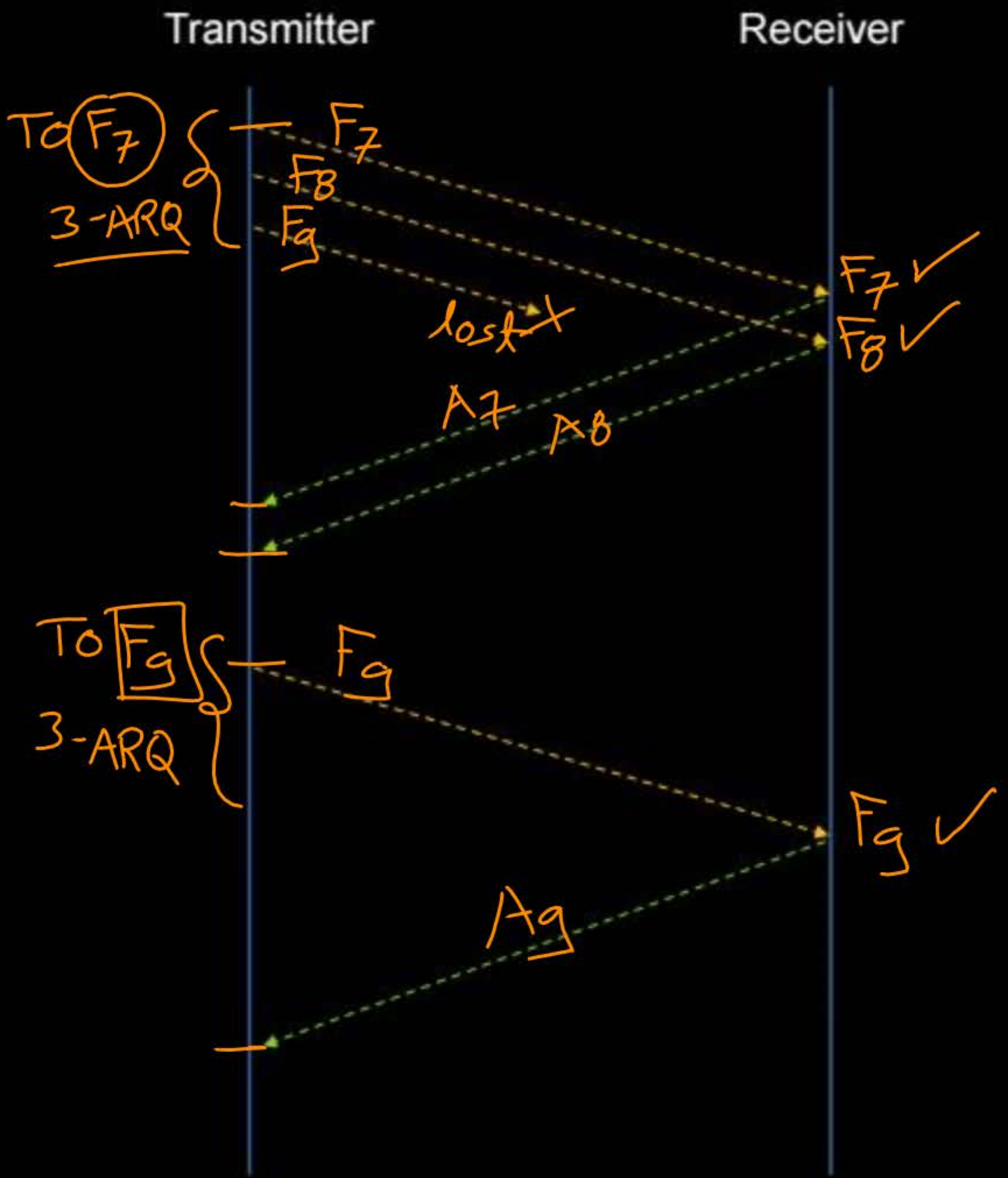
1 ✓ 2 ✓ 3 ✓ 4 ✓ 5 Lost $\underbrace{6\ 7}_{\text{discard}}$

TO 5 ✓ 6 ✓ 7 Lost $\underbrace{8\ 9}_{\text{discard}}$ | TO 7 ✓ 8 ✓ 9 Lost | TO 9 ✓

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


Transmitter
Receiver
F1
F2
F3
F1 ✓
F2 ✓
F3 ✓
A1
A2
A3
F4
F5
F6
lost
F4 ✓
F6 discard
A4
A4
F7
F7 discard
Ignore
A4


Transmitter
Receiver
T0 F5
3-ARQ
F5
F6
F7
F5 ✓
F6 ✓
A5
A6
F8
F9
discard
A6
A6
Ignore


Transmitter
Receiver
TO F7
3-ARQ
F7
F8
F9
lost
F7 ✓
F8 ✓
A7
A8
TO F9
3-ARQ
F9
F9 ✓
A9

#Q. Consider a network connecting two systems located 8000 kilometers apart. The bandwidth of the network is 500×10^6 bits per second. The propagation speed of the media is 4×10^6 meters 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 ______.

[GATE 2015, Set-3, 2-Mark]

Solution:-

$\underbrace{\text{Packet Size}}$ = $\boxed{10^7 \text{ bits}}$

$\underbrace{\text{Bandwidth}}$ = $\boxed{500 * 10^6 \text{ bits / sec}}$

$$t_x = \frac{\text{Packet Size}}{\text{Bandwidth}} = \frac{10^7 \ \cancel{\text{bits}}}{500 * 10^6 \ \cancel{\text{bits}} \text{ / sec}} = \frac{1}{50} \text{ sec}$$

$\underbrace{\text{Distance}} = \boxed{8000 \text{ Km}} = \boxed{8 * 10^6 \text{ m}}$

$\underbrace{\text{Signal Speed}} = \boxed{4 \times 10^6 \text{ m/s}}$

$$t_p = \frac{\text{Distance}}{\text{Signal Speed}} = \frac{8 * \cancel{10^6} \cancel{\text{m}}}{4 \times \cancel{10^6} \cancel{\text{m}}/s} = 2 \text{ sec}$$

$$\text{Cycle Time} = (t_x + 2 * t_p) = \left(\frac{1}{50} + 2 * 2\right) \text{sec}$$

$$= \left(\frac{201}{50}\right) \text{sec}$$

$$\text{Optimal Window Size (N)} = \left\lceil \frac{\text{Cycle Time (RTT)}}{\text{Transmission delay}} \right\rceil = \left\lceil \frac{(201/50)\,sec}{(1/50)\,sec} \right\rceil$$

$$= 201$$

For Go Back N ARQ :

$$\text{Total number of sequences} = \boxed{(N+1)} = 202$$

Minimum number of bits required for sequence number field

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

$$= \lceil \log_2 (202) \rceil \text{ bits} = 8 \text{ bits}$$

$$\boxed{Ans = 8}$$

#Q. 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 kilobyte. Neglect the transmission time of acknowledgment. The minimum number of bits required for the sequence number field to achieve 100% utilization is ________.

[GATE-2016, Set-2, 2-Mark]

Solution:-

Packet Size $= \boxed{1\ \text{KB}} = \boxed{2^{13}\ \text{bits}}$

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

$$t_x = \frac{\text{Packet Size}}{\text{Bandwidth}} = \frac{2^{13}\ \cancel{\text{bits}}}{2^{7} * 10^{3}\ \cancel{\text{bits}} / \text{sec}} = \boxed{64\ \text{ms}}$$

$$\boxed{t_p = 150\ \text{ms}}$$

Cycle time $= (t_x + 2 * t_p) = \boxed{364\ \text{ms}}$

$$\text{Optimal Window Size (N)} = \left\lceil \frac{\text{Cycle Time (RTT)}}{\text{Transmission delay}} \right\rceil = \left\lceil \frac{364\ ms}{64\ ms} \right\rceil = 6$$

For Selective Repeat ARQ :

Total number of sequences = (N + N) = 2 * N = 12

Minimum number of bits required for sequence number field

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

$$= \lceil \log_2 (12) \rceil \text{ bits} = 4 \text{ bits}$$

$$\boxed{\text{Ans} = 4}$$

#Q. 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 ______.

[GATE-2014, Set-1, 2-Mark]

Solution:-

Packet Size = $\boxed{1 \text{ KB}}$ = $\boxed{2^{13} \text{ bits}}$

Bandwidth = $\boxed{1.5 \text{ Mbps}}$ = $\boxed{1.5 * 10^6 \text{ bits / sec}}$

$$t_x = \frac{\text{Packet Size}}{\text{Bandwidth}} = \frac{2^{13} \text{ bits}}{1.5 * 10^6 \text{ bits / sec}} = \boxed{5.461 \text{ ms}}$$

$$\boxed{t_p = 50 \text{ ms}}$$

$$\text{Cycle time} = (t_x + 2 * t_p) = \boxed{105.461 \text{ ms}}$$

To achieve 60% utilization ($\eta = 3/5$) in Selective Repeat ARQ

$$\text{Efficiency } (\eta) = \frac{N * \text{Transmission delay}}{\text{Cycle Time}}$$

$$N = \left\lceil \frac{3 * \text{Cycle Time}}{5 * \text{Transmission delay}} \right\rceil$$

$$= \left\lceil \frac{3 * 105.461 \text{ ms}}{5 * 5.461 \text{ ms}} \right\rceil$$

$$= 12$$

For Selective Repeat ARQ :

Total number of sequences = $(N + N)$ = $2 * N = 24$

Minimum number of bits required for sequence number field

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

$$= \lceil \log_2 (24) \rceil \text{ bits} = 5 \text{ bits}$$

$$\boxed{\text{Ans} = 5}$$

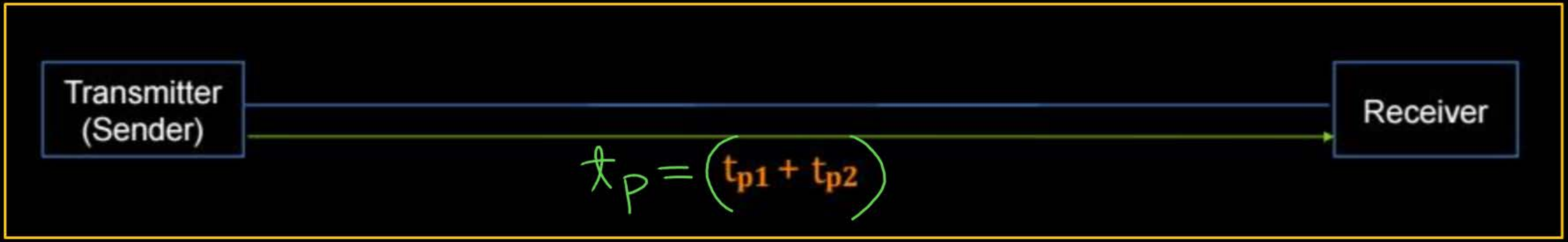
Topic : Store-and-Forward Device

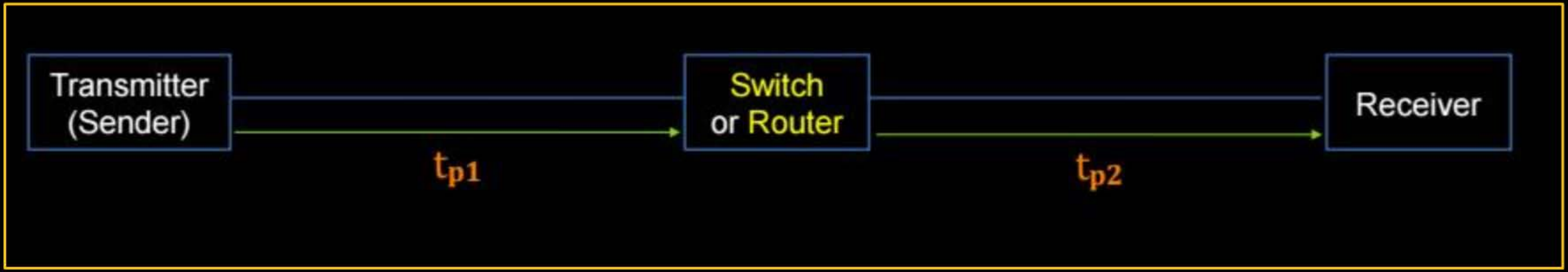
→ Layer-2 device : 'Bridge' or 'Switch'

→ Layer-3 device : 'Router'
['L3 – Switch' or 'Packet Switch']

→ Switch and Router : Store-and-Forward device
[Store, Process and Forward]

Topic : Store-and-Forward Device





Topic : End-to-End Delay

→ Total time required for a packet to be transmitted from Transmitter to Receiver

→ With no any 'Store-and-Forward device'

End-to-end delay = Transmission delay + Propagation delay for first link + Propagation delay for second link

$$= t_x + (t_{p_1} + t_{p_2})$$

$$= t_x + t_p$$

Topic : End-to-End Delay

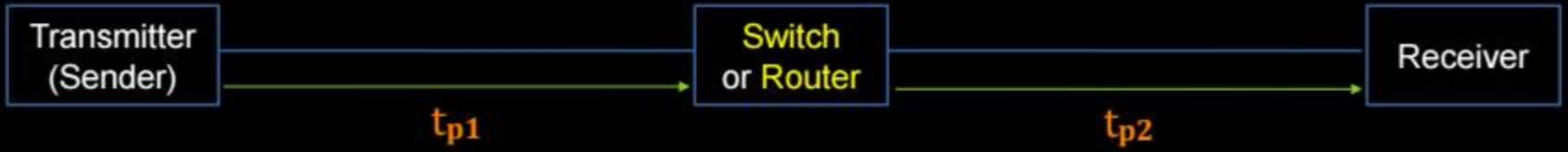
→ Total time required for a packet to be transmitted from Transmitter to Receiver

→ With one 'Store-and-Forward device'

End-to-end delay = Transmission delay + Propagation delay for first link
+ Store-and-Forward delay
+ Propagation delay for second link

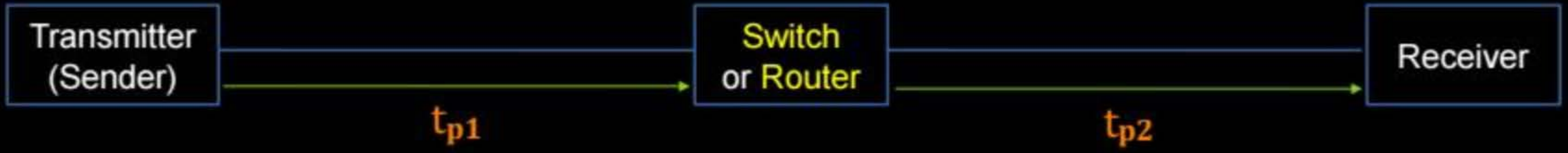
Topic : Store and Forward Delay

⇒ Transmission delay



Store-and-Forward delay = Queuing delay at device + Processing delay by device + Transmission delay

Topic : End-to-End Delay ⇒ one-way

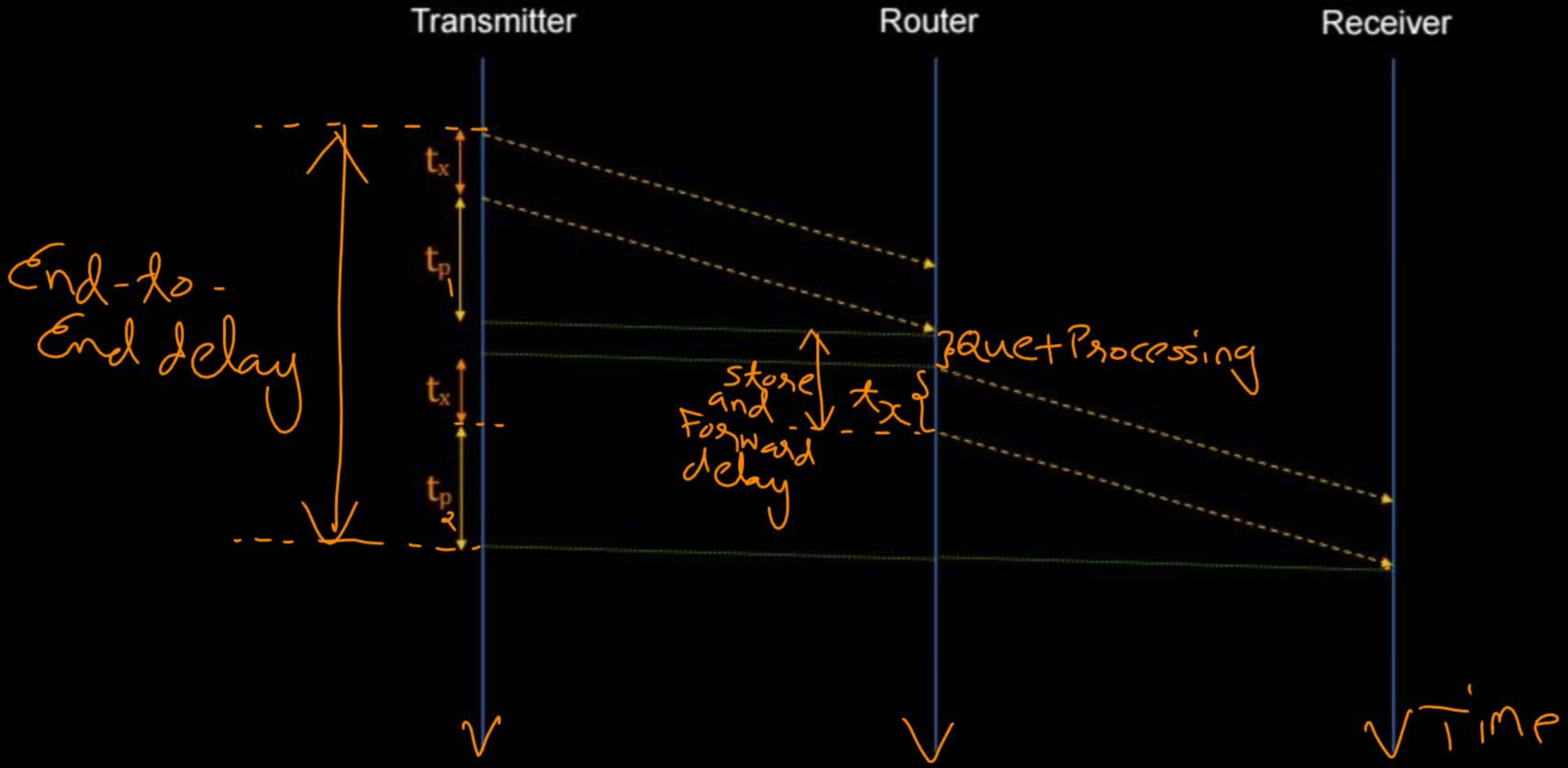


→ Suppose each link have same bandwidth

→ Total time required for a packet to be transmitted from Transmitter to Receiver

End-to-end delay = [Transmission delay + Propagation delay for first link]
+ [Queuing delay at device + Processing delay by device]
+ [Transmission delay + Propagation delay for second link]

Topic : End-to-End Delay



Example 10 :-

#Q. Consider two hosts A and B are connected through one router (router takes negligible processing delay). Suppose each link bandwidth is 1 Kbps and each link propagation delay is $\boxed{\text{200 milliseconds.}}$ Calculate amount of time required (in milliseconds) to transmit one 10 byte packet from hosts A to B ?

Solution 10 :-

Packet Size = $\boxed{10 \text{ bytes}}$ = $\boxed{80 \text{ bits}}$

Bandwidth = $\boxed{1 \text{ Kbps}}$ = $\boxed{10^3 \text{ bits / sec}}$

$$t_x = \frac{\text{Packet Size}}{\text{Bandwidth}} = \frac{80 \text{ bits}}{10^3 \text{ bits / sec}} = 80 \text{ ms}$$

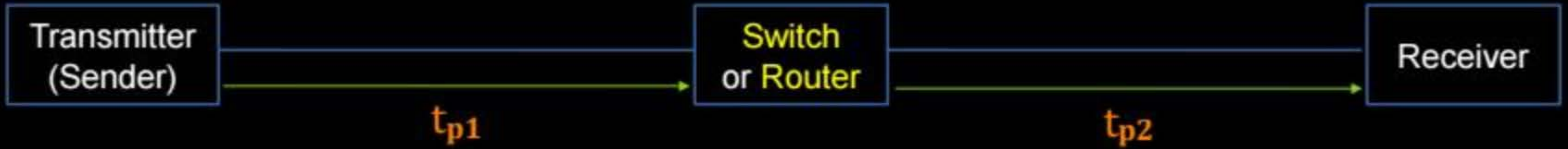
$$\boxed{t_{p_1} = 200 \text{ ms} = t_{p_2}}$$

End-to-end delay $= (t_x + t_{p_1}) + (t_x + t_{p_2})$

$= (80+200)+(80+200) \text{ ms} = 560 \text{ ms}$

$\boxed{\text{Ans} = 560}$

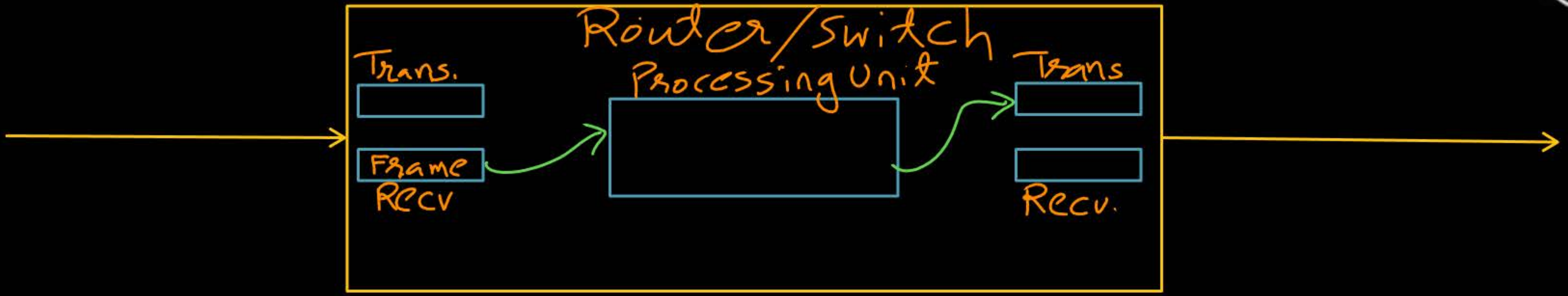
Topic : End-to-End Delay



→ Suppose each link have same bandwidth

→ Total time required for N packets to be transmitted from Transmitter to Receiver

End-to-end delay = (N * Transmission delay) + Propagation delay for first link
+ Queuing delay at device + Processing delay by device
+ Transmission delay + Propagation delay for second link



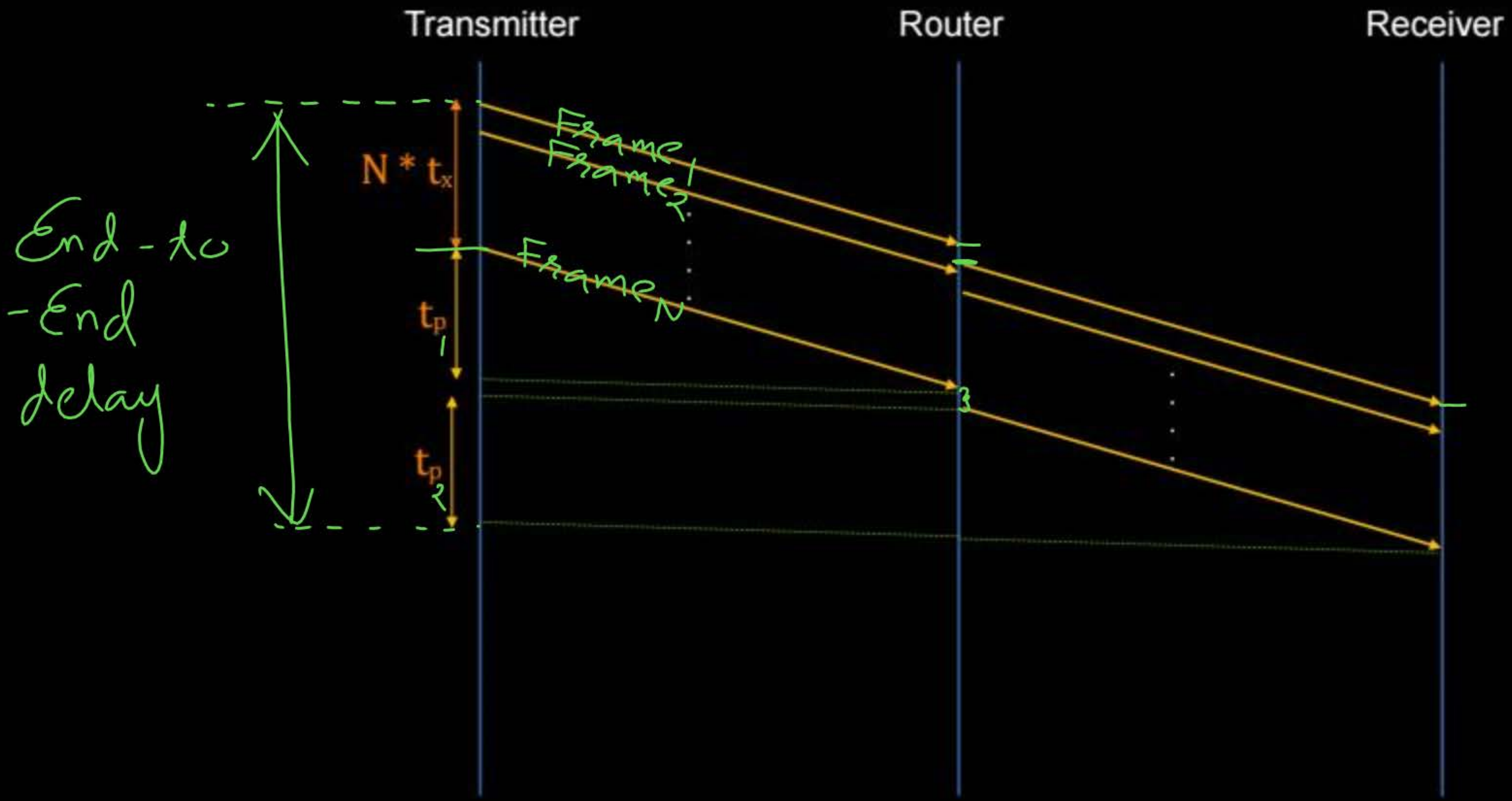
F_3 F_2 F_1

F_N $F_{(N-1)}$ $F_{(N-2)}$

F_N $F_{(N-1)}$

F_N

Topic : End-to-End Delay



Example 11 :-

#Q. Consider two hosts A and B are connected through one router (router takes negligible processing delay). Suppose packet size is 20 bytes, each link bandwidth is 2 Mbps and each link propagation delay is 500 microseconds. Calculate amount of time required (in microseconds) to transmit a file of 100 bytes from hosts A to B ?

Solution 11 :-

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

$\underbrace{\text{Bandwidth}} = \boxed{2 \text{ Mbps}} = \boxed{2 * 10^6 \text{ bits / sec}}$

$$t_x = \frac{\text{Packet Size}}{\text{Bandwidth}} = \frac{160 \text{ b}\cancel{\text{i}}\text{ts}}{2 * \underline{10^6} \text{ b}\cancel{\text{i}}\text{ts / } \underline{\text{sec}}} = 80 \mu s$$

$$\boxed{t_{p_1} = 500 \underline{\mu s} = t_{p_2}}$$

File Size = 100 bytes

Packet Size = $\boxed{\text{20 bytes}}$

$$\text{Number of packets } (N) = \frac{\text{File Size}}{\text{Packet Size}} = \frac{100 \text{ bytes}}{20 \text{ bytes}} = 5$$

$$\text{End-to-end delay} = (N * t_x + t_p) + (t_x + t_p)$$

$$= (5 * 80 + 500) + (80 + 500)\ \mu s$$

$$= 1480\ \mu s$$

$\boxed{\text{Ans} = 1480}$

#Q. Two hosts are connected via a packet switch with 10^7 bits per second links. Each link has a propagation delay of 20 microseconds. The switch begins forwarding a packet 35 microseconds 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 ______. IIT-K, H.W.

[GATE 2015, Set-2, 2-Mark]

#Q. Consider a source computer (S) transmitting a file of size 10^6 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 meters per second. Assume that the link bandwidth on each link is 1Mbps. 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 file from S to D.

IIT-D, H.W.

[GATE 2012, 2-Mark]

(A) 1005 ms (B) 1010 ms

(C) 3000 ms (D) 3003 ms

(CS-24)
(CS-14)

if $(BW_1 < BW_2)$

$t_{x_1} > t_{x_2}$

if $(BW_1 > BW_2)$

$t_{x_1} < t_{x_2}$

Topic : Bit Error Rate

=> Bit Error Rate (BER)

→ Number of bit errors per unit time

=> Bit Error Ratio or Bit Error Probability $\boxed{(P_b)}$

→ Probability that a bit is corrupted

Example 1:-

#Q. Consider source and destination hosts are directly connected through a point-to-point $\boxed{\text{noisy communication link.}}$ A frame of length L bits is transmitted into the channel and the probability that a bit of the frame gets flipped during transmission (bit error probability) is $\boxed{P_b.}$ What is the probability that the frame is delivered error-free to the destination host ?

A) $(P_b)^L$

B) $(1 - P_b)^L$

C) $P_b * (1 - P_b)^{(L-1)}$

D) $1 - (1 - P_b)^L$

Frame length = L bits
Bit Error Prob. = P_b

Ans = $(1-P_b) * (1-P_b) * \ldots\ldots * (1-P_b)$

$= (1-P_b)^L$

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

[NAT] IIT-R [GATE-2025, Set-1] [2 Mark]

#Q. Suppose a 5-bit message is transmitted from a source to a destination through a noisy channel. The probability that a bit of the message gets flipped during transmission is 0.01. Flipping of each bit is independent of one another. The probability that the message is delivered error-free to the destination is _____. (rounded off to three decimal places)

$L = 5$ bits

$P_b = 0.01$

$$\text{Ans} = (1 - P_b)^L$$
$$= (1 - 0.01)^5$$
$$= 0.9509$$

IIT-R Ans = 0.949 to 0.952

#Q. In a communication network, a packet of length L bits takes link L1 with a probability of p_1 or link L2 with a probability of p_2. Link L1 and L2 have bit error probability of b_1 and b_2 respectively. The probability that the packet will be received without error via either L1 or L2 is

[GATE 2005]

A. $(1 - b_1)^L p_1 + (1 - b_2)^L p_2$

B. $[1 - (b_1 + b_2)^L] p_1 p_2$

C. $(1 - b_1)^L (1 - b_2)^L p_1 p_2$

D. $1 - (b_1^l p_1 + b_2^l p_2)$

Ans =

$$P_1 * (1-b_1)^L$$
$$+$$
$$P_2 * (1-b_2)^L$$

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

Example 2:-

#Q. Consider source and destination hosts are directly connected through a point-to-point noisy communication link. A frame of length L bits is transmitted into the channel and the probability that a bit of the frame gets flipped during transmission (bit error probability) is P_b. What is the probability that the frame is delivered to the destination host $\underbrace{\text{contains some error(s)}}_{\text{Any type of error}}$?

A. $(P_b)^L$

B. $(1 - P_b)^L$

C. $P_b * (1 - P_b)^{(L-1)}$

D. $1 - (1 - P_b)^L$

$$[\text{Ans} = 1 - (\text{Ans of Example 1})]$$

$$= 1 - (1 - P_b)^L$$

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

Topic : Packet Error Probability

=> Packet Error Probability (P_p)

→ Probability that a packet is corrupted

[Packet contains corrupted bits] → Some error

Suppose P_b = bit error probability

and Frame Length = L bits

Packet error probability (P_p) = $\boxed{1 - (1 - P_b)^L}$

#Q. On a wireless link, the probability of packet error is 0.2. A stop-and-wait protocol is used to transfer data across the link. The channel condition is assumed to be independent from transmission to transmission. What is the average number of transmission attempts required to transfer 100 packets?

[GATE 2006]

IIT-KGP, H.W.

A 100

B 125

C 150

D 200

2 mins Summary

Topic Store-and-Forward Delay

Topic End-to-End Delay

Topic Bit Error Probability

* Optimum Packet Size

⇒ MAC Sublayer

THANK - YOU

@ABHISHEKSIRCS_PW