TCP

Complete Course on Computer Networks - Part I

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EFFICIENCY

$$\text{Efficiency}(\eta) = \frac{\text{Useful time}}{\text{Total cycle time}}$$

$$\boxed{\eta = \frac{Tt}{Tt + 2Tp}}$$

$$\eta = \frac{1}{1 + \frac{2Tp}{Tt}} \qquad a = \frac{Tp}{Tt}$$

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

THROUGHPUT

Effective bandwidth
Or
Throughput $= \dfrac{L}{Tt + 2Tp}$
Or
Bandwidth utilization

$$= \frac{L/B}{Tt + 2Tp} \times B$$

$$= \frac{Tt}{Tt + 2Tp} \times B$$

$$= \eta \times B$$

$$\boxed{\text{Throughput} = \text{Efficiency } (\eta) \times \text{Bandwidth(B)}}$$

REVISION OF THE FORMULAE

1.) $Tt = \dfrac{\text{Length of data (bits)}}{\text{Bandwidth(bps)}} = \dfrac{L}{B}$

2.) $Tp = \dfrac{\text{distance of the link (d)}}{\text{Velocity(v)}}$

STOP AND WAIT

3.) $\eta = \dfrac{1}{1 + 2a}$

$a = \dfrac{Tp}{Tt}$

4.) Throughput $=$ Efficiency (η) x Bandwidth(B)

5.) Round Trip Time (RTT) = 2 X Tp

REMEMBER

Whenever data has **K**,
K= 1024

Whenever data has **M**,
M=1024 X 1024

Whenever data has **G**,
G=1024 X 1024 X 1024

Whenever Bandwidth has **K**,
K= 1000 = 10^3

Whenever Bandwidth has **M**,
M= 10^6

Whenever Bandwidth has **G**,
G= 10^9

Problems on Stop and wait

1.) Tt = 1ms Tp = 1ms

$$\eta = \frac{1}{1 + 2a} = \frac{1}{3} = 0.33 \text{ or } 30\%$$

2.) Tt = 2ms Tp = 1ms

$$\eta = \frac{1}{1 + 2a} = \frac{1}{2} = 0.5 \text{ or } 50\%$$

Problems on Stop and wait

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2.) Tt = 2ms Tp = 1ms

$$\eta = \frac{1}{1+2a} = \frac{1}{2} = 0.5 \text{ or } 50\%$$

So, if we want the efficiency to be atleast 50 % then,

$\eta >= 0.5$

$$\frac{Tt}{Tt + 2Tp} >= \frac{1}{2}$$

2Tt >=Tt+2Tp

$\boxed{Tt>=2Tp}$

Or we can say that,

$$\frac{L}{B} >= 2Tp$$

$\boxed{L>=2Tp * B}$

Question:

Given, bandwidth = 4 Mbps, Tp = 1ms, What is the length of the packet so as to achieve at least 50% efficiency?

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L >= 2Tp * B

L >= $2*10^{-3}*4*10^{6}$

L >= $8*10^{3}$ bits

Therefore, Length of packet must be at least 8000 bits so as to achieve at least 50 % efficiency.

SOMETHINGS THAT CAN BE SAID ABOUT EFFICIENCY

$$\eta = \frac{1}{1 + \frac{2Tp}{Tt}}$$

$$\eta = \frac{1}{1 + \frac{2(d/v)}{(L/B)}}$$

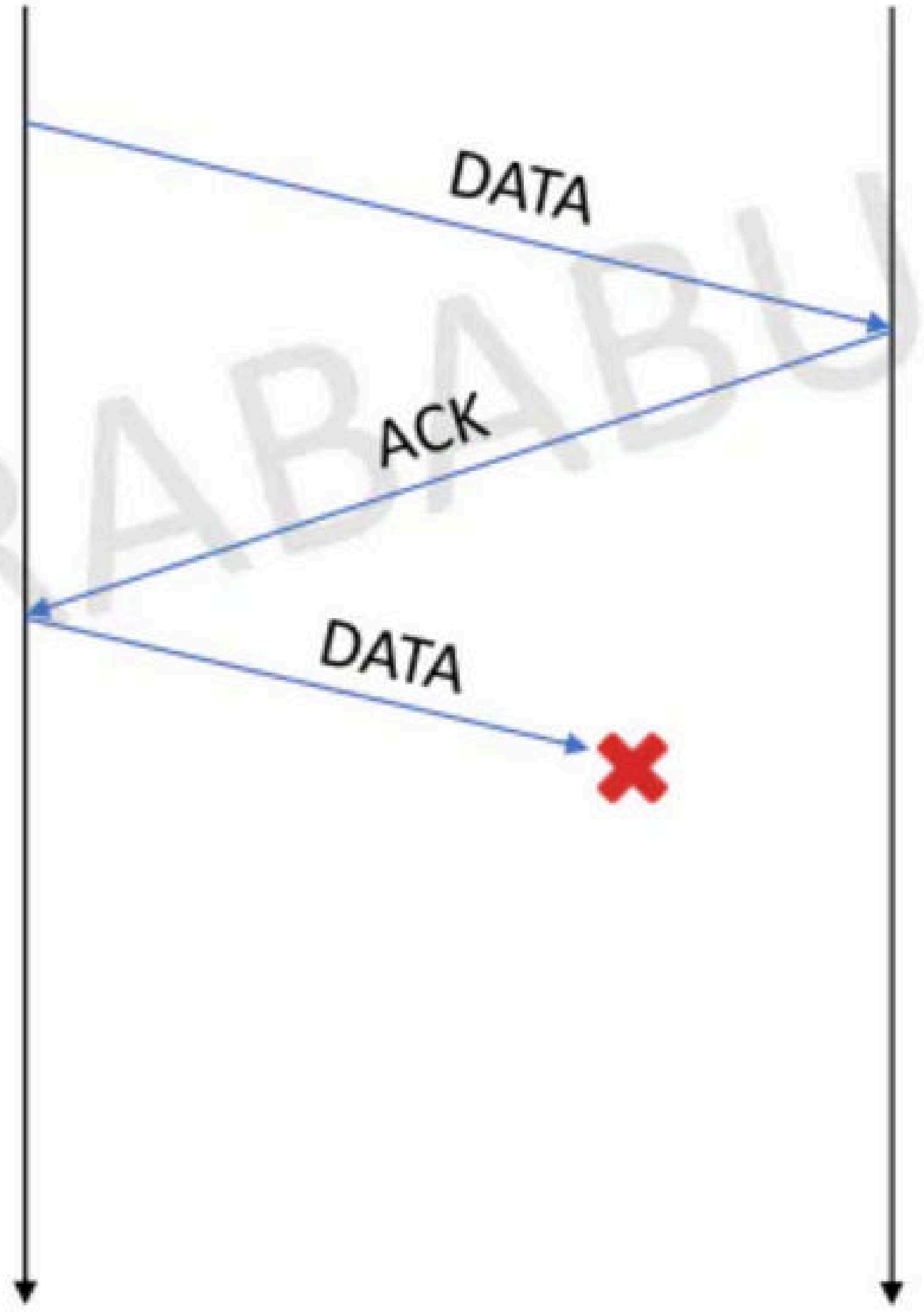
As we can see that,

$d \uparrow \quad \eta \downarrow$ So, Stop and Wait is good for LANs

$L \uparrow \quad \eta \uparrow$ Good for big packets

PROBLEMS WITH STOP AND WAIT

PROBLEM 1: Data packet lost

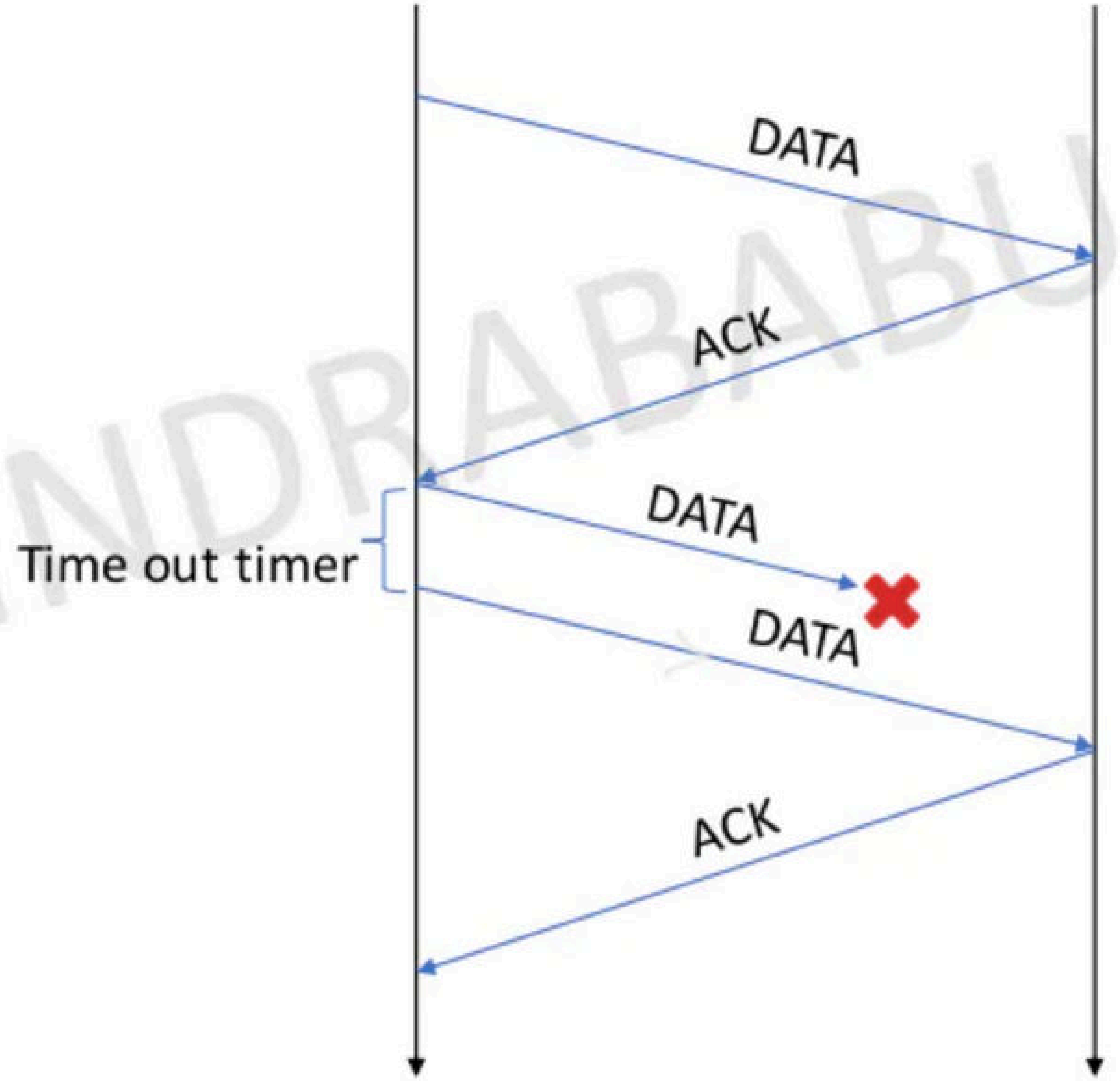


SENDER THINKS THAT RECEIVER IS BUSY

RECEIVER THINKS SENDER DID NOT SEND THE DATA

PROBLEMS WITH STOP AND WAIT

PROBLEM 1: Data packet lost



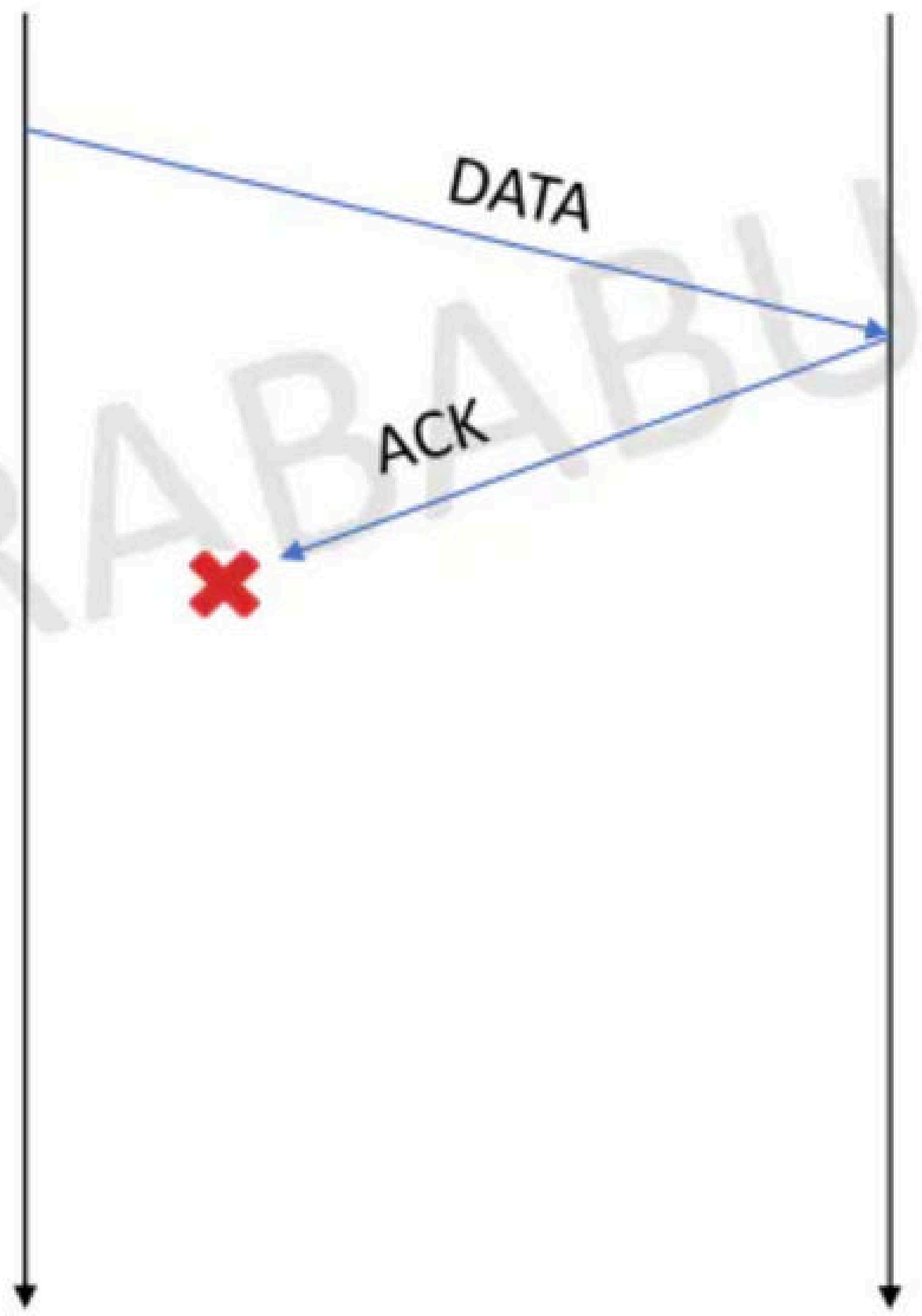
SOLUTION

So, to solve this issue the sender
Waits for time known as **Time out Timer**
And resends the packet.

This is stop and wait + timeout timer
Which is known as **"Stop and wait ARQ"**
ARQ stands for Automatic Repeat Request

PROBLEMS WITH STOP AND WAIT

PROBLEM 2: Acknowledgement lost

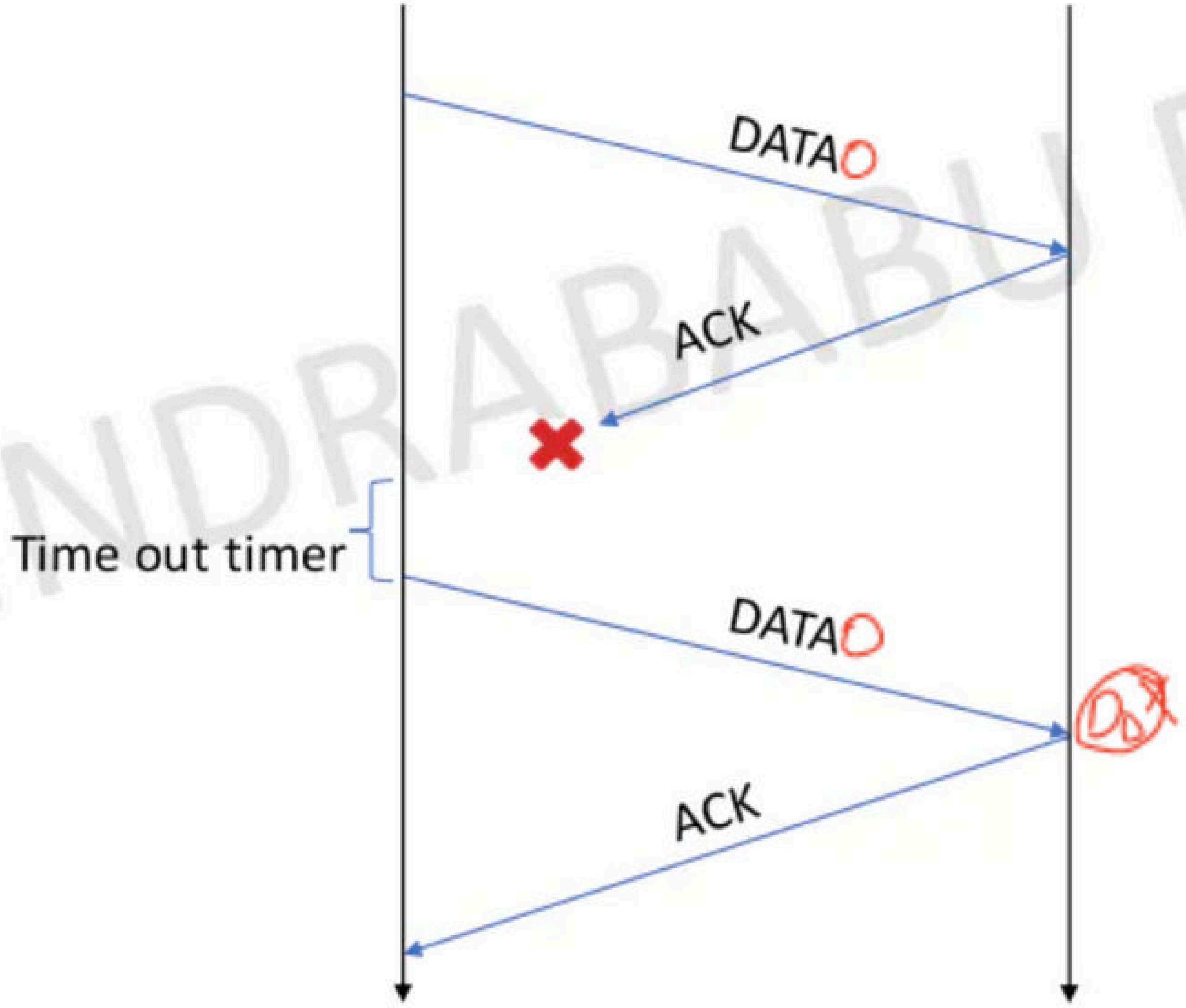


SENDER THINKS THAT
RECEIVER HAS NOT RECEIVED THE PACKET

RECEIVER THINKS SENDER HAS RECEIVED ACK

PROBLEMS WITH STOP AND WAIT

PROBLEM 2: Acknowledgement lost



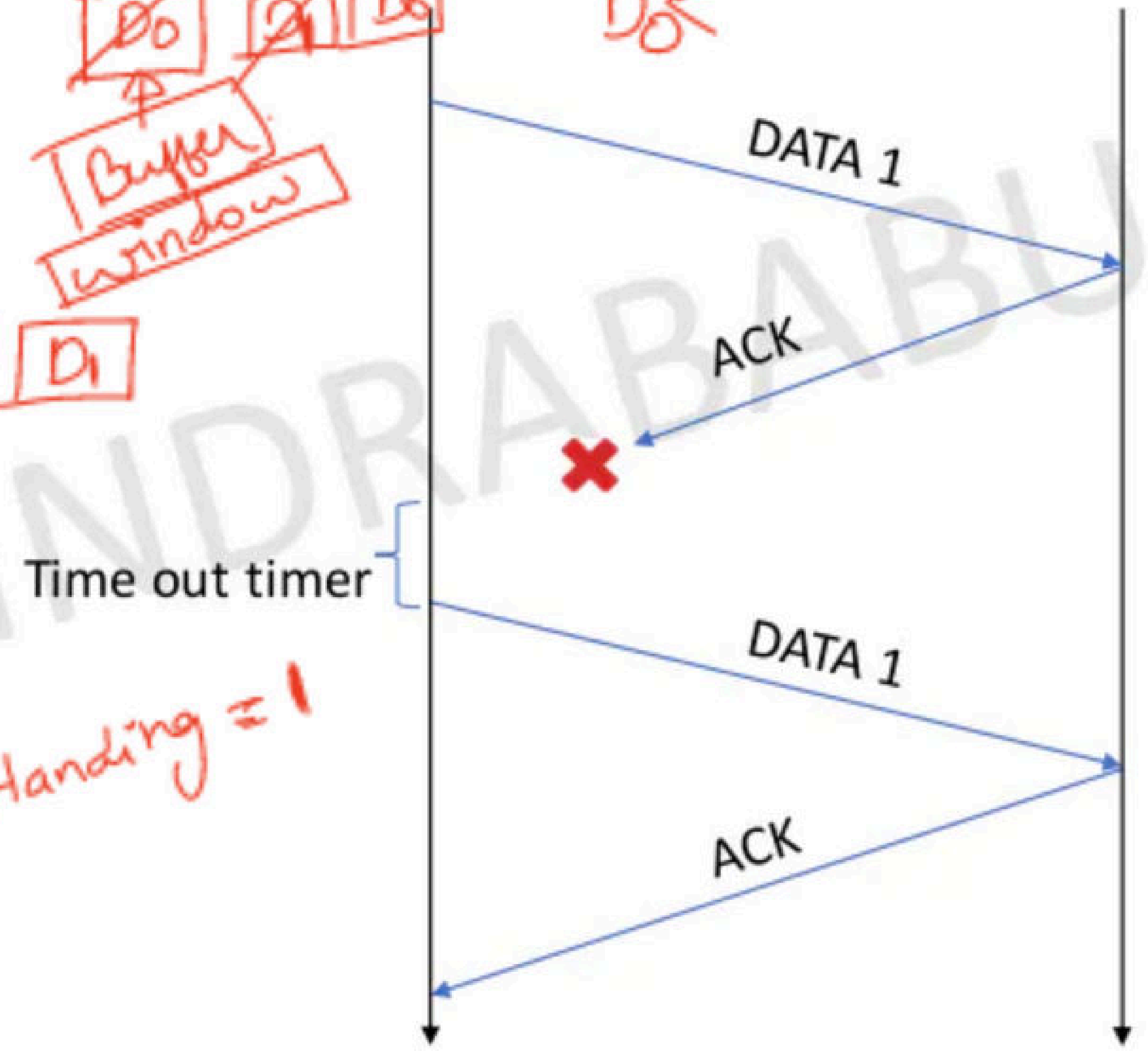
SENDER WAITS FOR TIMEOUT TIMER AND RESENDS THE PACKET

RECEIVER THINKS SENDER HAS SENT NEW DATA PACKET.

THIS IS **DUPLICATE PACKET PROBLEM**

PROBLEMS WITH STOP AND WAIT

PROBLEM 2: Acknowledgement lost



data | header

0101

Seq number is binary.

D0 D1 D2 D3 D4 D5 ...... D1024

10 bit

Seq = 1 bit

0, 1

Buffer

window

S&W

Out standing = 1

SOLUTION :

SENDER SENDS DATA PACKET WITH **SEQUENCE NUMBERS**

STOP AND WAIT + TO TIMER + SEQ NUMBER

D0 D1 D0 D1 D0 D1

SW

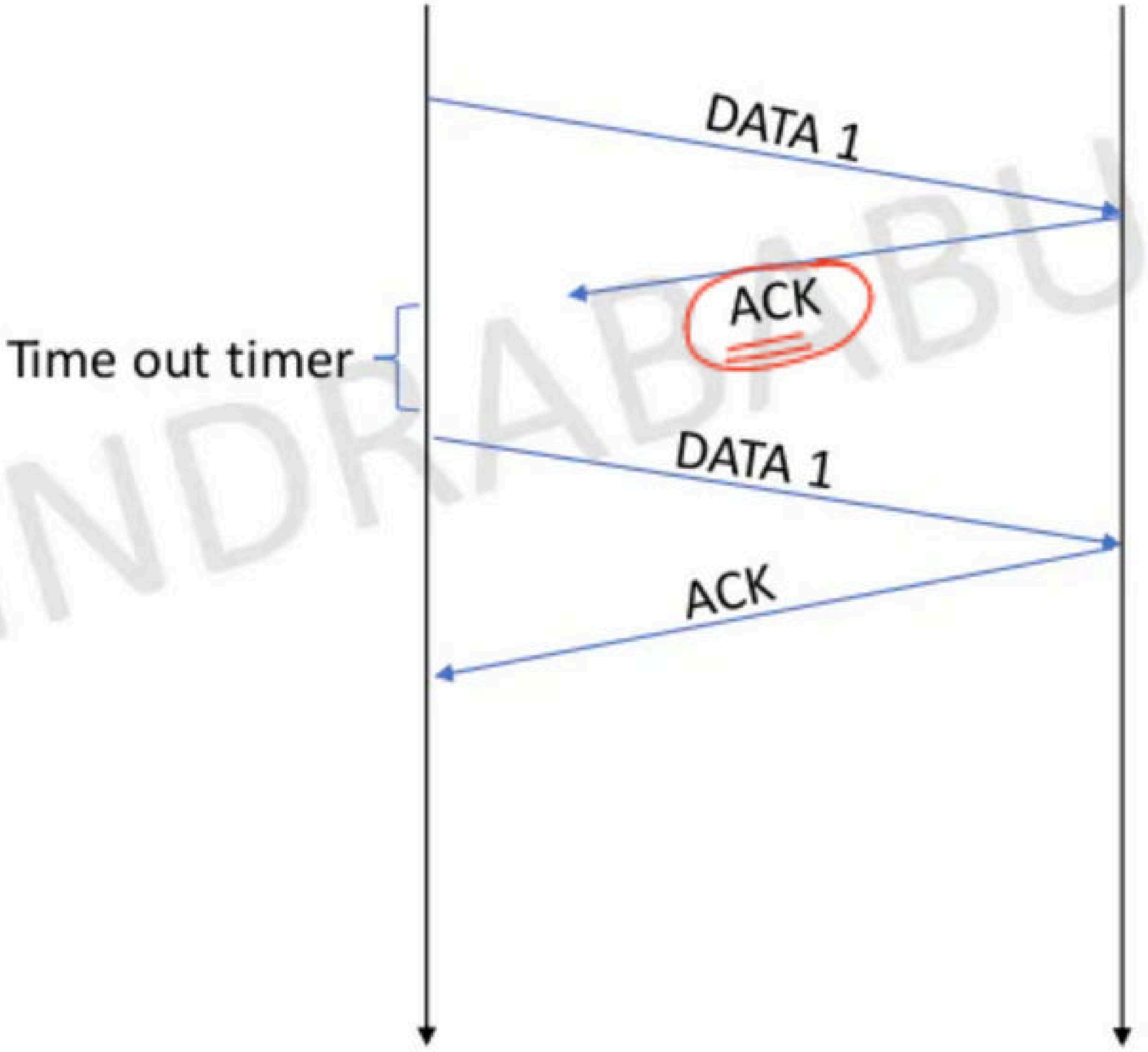
RW

S&W

Doubts
S/W
GBN SR
Seq

PROBLEMS WITH STOP AND WAIT

PROBLEM 3: Acknowledgement Delayed

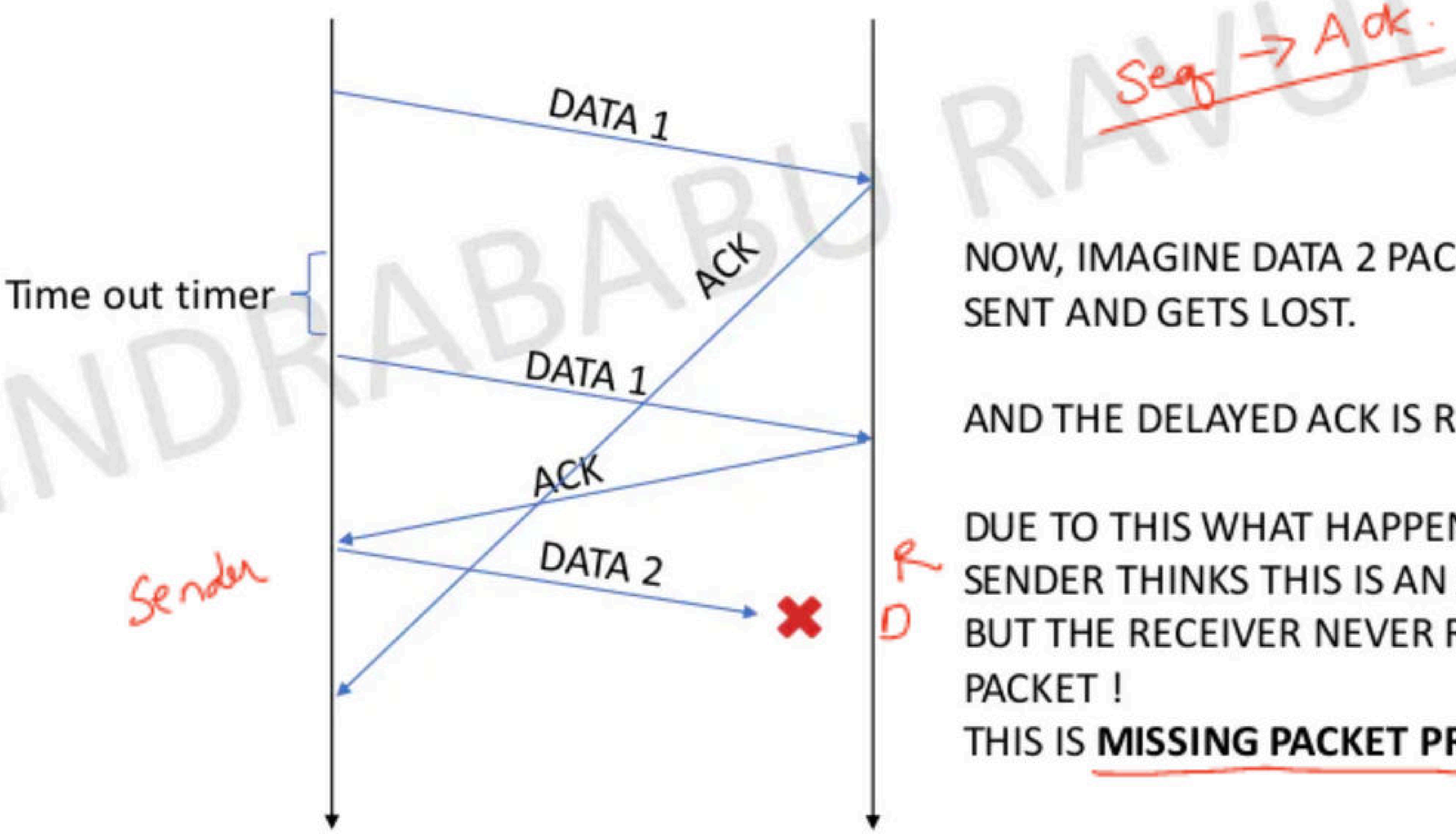


ACKNOWLEDGEMENT IS DELAYED FOR DATA 1 AND THE PACKET IS RESENT BY THE SENDER BY WAITING FOR TO TIMER

RECEIVER SENDS THE ACK FOR THE RESENT DATA 1 PACKET

PROBLEMS WITH STOP AND WAIT

PROBLEM 3: Acknowledgement Delayed



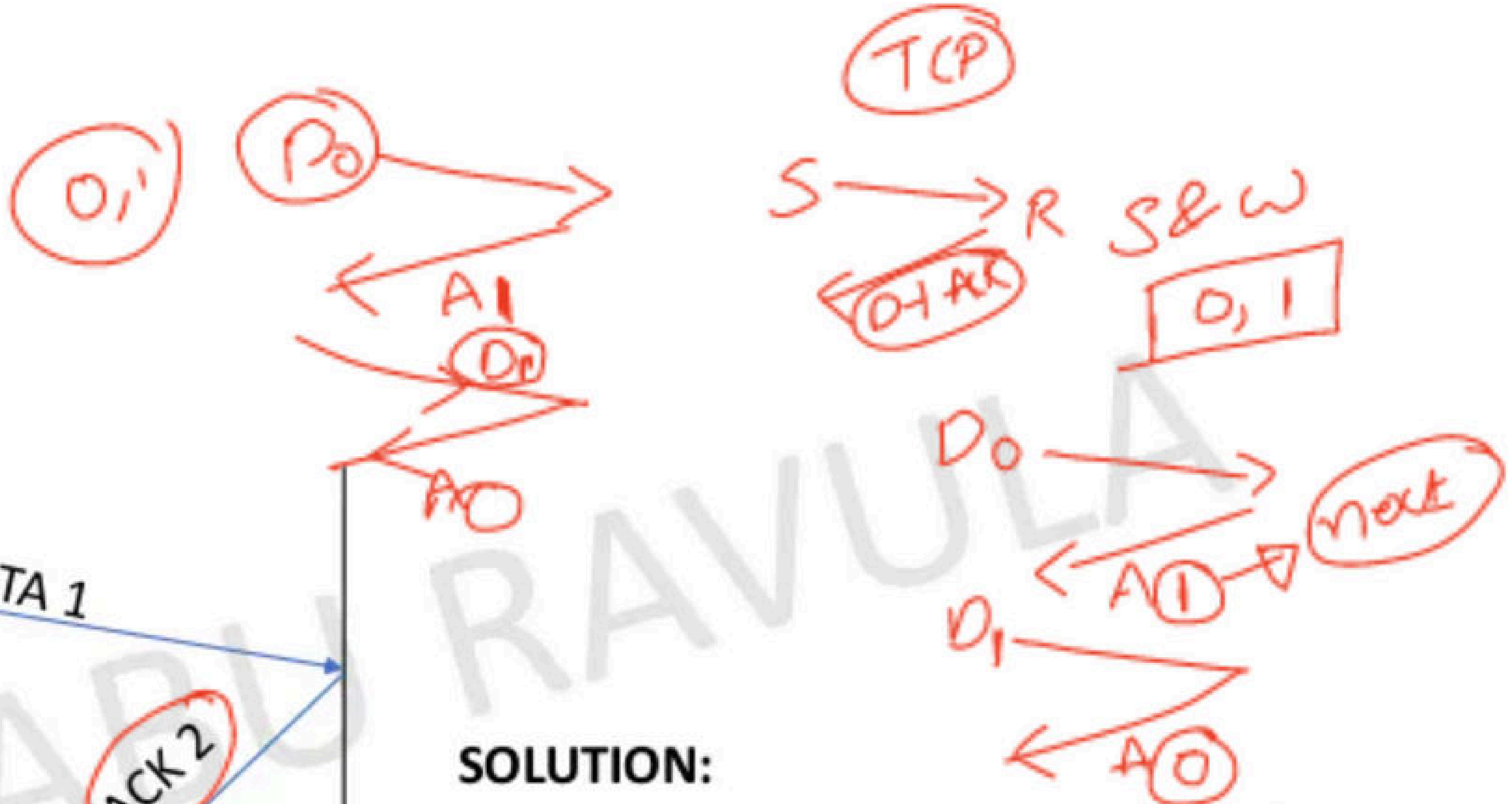
NOW, IMAGINE DATA 2 PACKET IS SENT AND GETS LOST.

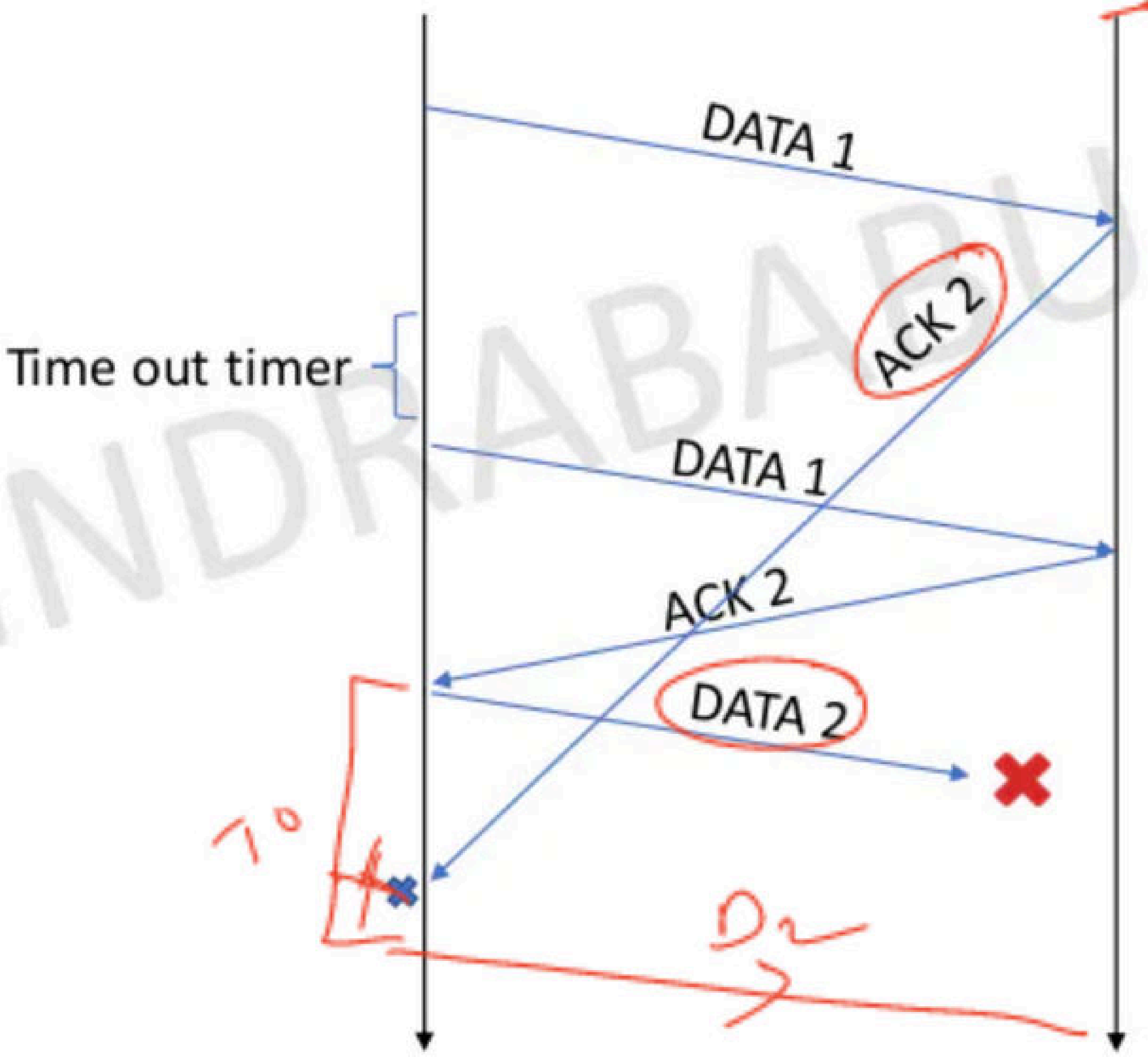
AND THE DELAYED ACK IS RECEIVED NOW

DUE TO THIS WHAT HAPPENS IS,
SENDER THINKS THIS IS AN ACK FOR DATA 2
BUT THE RECEIVER NEVER RECEIVED DATA 2 PACKET !
THIS IS **MISSING PACKET PROBEM**

PROBLEMS WITH STOP AND WAIT

PROBLEM 3: Acknowledgement Delayed





SOLUTION:

ACK NUMBER WILL BE SENT BY RECEIVER

ACK NUMBER = SEQUENCE NO + 1

1 1

S A

$\boxed{\text{TO + Seq + Seq ack}}$

S&W

QUESTION : Suppose sender wants to send 10 packets to receiver and every 4^{th} packet is lost
How many packets will be sent in total?

SOLUTION:

10 →

13

Packets to be sent : 1 2 3 4 5 6 7 8 9 10

As per the given scenario :1 2 3 4 4 5 6 7 7 8 9 10 10

4, 7, 10 → two times.

Total transmissions = 13

Question:

Suppose while sending packets to destination there is error probability of 0.2 .
If we are sending 400 packets over this channel. How many Packets would be sent?

$\frac{2}{100}$

$(100) + 2\left(\frac{2}{100}\right)$

Packets sent would be :
400+400(0.2) +80(0.2)…..

If we are sending n packets with p error probability, then,
Packets sent would be,

$= (n+np+np^{2\ldots\ldots\ldots})$

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

$=n(1/1-p)$

$n \quad p$

$n + np + np^2 + np^3 + np^4 + \cdots$

$n(\underbrace{1 + p + p^2 + p^3 + \cdots}_{GP})$

$= n\left(\frac{1}{1-p}\right) = \quad 400\left(\frac{1}{1-0.2}\right) = 400\left(\frac{1}{0.8}\right)$

$= 500$

Computer Networks

Practice Problems and PYQs on Stop and Wait

Problem-01:

If the bandwidth of the line is 1.5 Mbps, RTT is 45 msec and packet size is 1 KB, then find the link utilization in stop and wait.

Solution-

Given-
Bandwidth = 1.5 Mbps
RTT = 45 msec
Packet size = 1 KB

$LU = \eta \times BW$

Calculating Transmission Delay Tt-

Transmission delay (T_t)
= Packet size / Bandwidth
= 1 KB / 1.5 Mbps
= (2^{10} x 8 bits) / (1.5 x 10^6 bits per sec)
= 5.461 msec

Calculating Propagation Delay Tp-

Propagation delay (T_p)
= Round Trip Time / 2
= 45 msec / 2
= 22.5 msec

Calculating Value Of ‘a’-

$a = T_p / T_t$
a = 22.5 msec / 5.461 msec
a = 4.12

Calculating Link Utilization-

Link Utilization or Efficiency (η)
= 1 / 1+2a
= 1 / (1 + 2 x 4.12)
= 1 / 9.24
= 0.108
= 10.8 %

Problem-02: GATE IT 2005

A channel has a bit rate of 4 Kbps and one way propagation delay of 20 msec. The channel uses stop and wait protocol. The transmission time of the acknowledgement frame is negligible. To get a channel efficiency of at least 50%, the minimum frame size should be-

1.80 bytes
2.80 bits
3.160 bytes
4.160 bits

Solution-

Given-

- Bandwidth = 4 Kbps
- Propagation delay (T_p) = 20 msec
- Efficiency >= 50%

Calculating Transmission Delay-

Transmission delay (T_t)
= Packet size / Bandwidth
= L bits / 4 Kbps

Calculating Value Of 'a'-

$a = T_p / T_t$
a = 20 msec / (L bits / 4 Kbps)
a = (20 msec x 4 Kbps) / L bits

Condition For Efficiency To Be At least 50%-

For efficiency to be at least 50%, we must have-

$$1 / 1+2a >= 1/2$$
$$a <= 1/2$$

Substituting the value of 'a', we get-
(20 msec x 4 Kbps) / L bits <= 1/2
L bits >= (20 msec x 4 Kbps) x 2
L bits >= (20×10^{-3} sec x 4 x 10^3 bits per sec) x 2
L bits >= 20 x 4 bits x 2
L >= 160

Similar in Class

From here, frame size must be at least 160 bits. → Bytes
Thus, Correct Option is (D).

Problem-03: GATE CS 2016

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 (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.

(A) 2500

(B) 2000

(C) 1500

(D) 500

$$\frac{T_{td}}{T_{td}+T_p+T_{ta}+T_p}$$

Problem-03: GATE CS 2016

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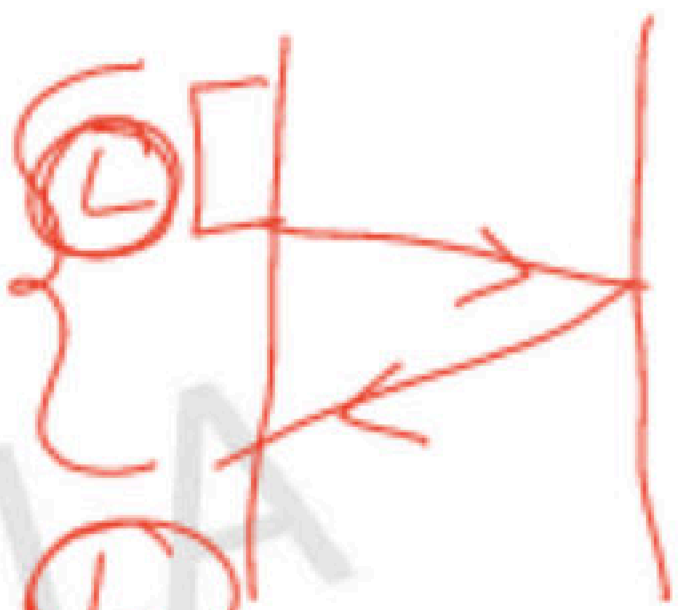
(B) 2000
(C) 1500
(D) 500

Solution:

Total time = Transmission-Time + 2* Propagation-Delay + Ack-Time. Trans. time
= (1000*8)/80*1000 = 0.1 sec 2*Prop-Delay = 2*100ms
= 0.2 sec Ack time = 100*8/8*1000 = 0.1 sec. Total Time
= 0.1 + 0.2 + 0.1 = 0.4 sec.
Throughput = ((L/B)/Total time) * B,
L = data packet to be sent and B = BW of sender.
Throughput = L/Total Time = 1000/0.4 = 2500 bytes/sec.

$$Thro = \frac{\;}{sec}$$

$$Thu = \frac{bits}{sec}$$



$$Th = \frac{bits}{sec}$$

$$Th = \frac{L}{T_t + 2T_p}$$

$$= \left(\frac{(L/B)}{T_t + 2T_p}\right) * B$$

$$\boxed{Th = \eta * B} = \left(\frac{T_t}{T_t + 2*T_p}\right) * B$$

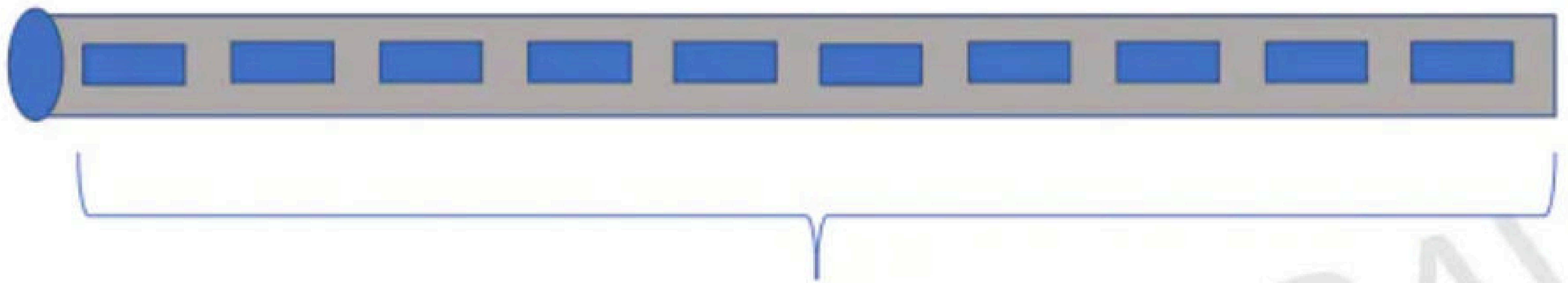
$$= \left(\frac{1}{1 + 2a}\right) * B$$

$$\eta$$

$$\boxed{Th = \eta * B}$$

Computer Networks

Capacity of Pipe, Pipelining, Sliding Window



The wire is carrying bits a much as it can, this is what is the **capacity of link**

Capacity of the link depends on 2 parameters:

1.) Bandwidth

2.)Propagation Delay (Tp)

CAPACITY = BANDWIDTH x PROPAGATION DELAY In case of half duplex

CAPACITY = 2 x BANDWIDTH x PROPAGATION DELAY In case of half duplex

$\eta = 1 / 1 + 2\ Tt/Tp$

$\eta = 1 / 1 + 2Tp * B/L$

This is capacity

We can see as the capacity increases, efficiency decreases.

We can increase the efficiency by the method called as **Pipelining.**

PIPELINING

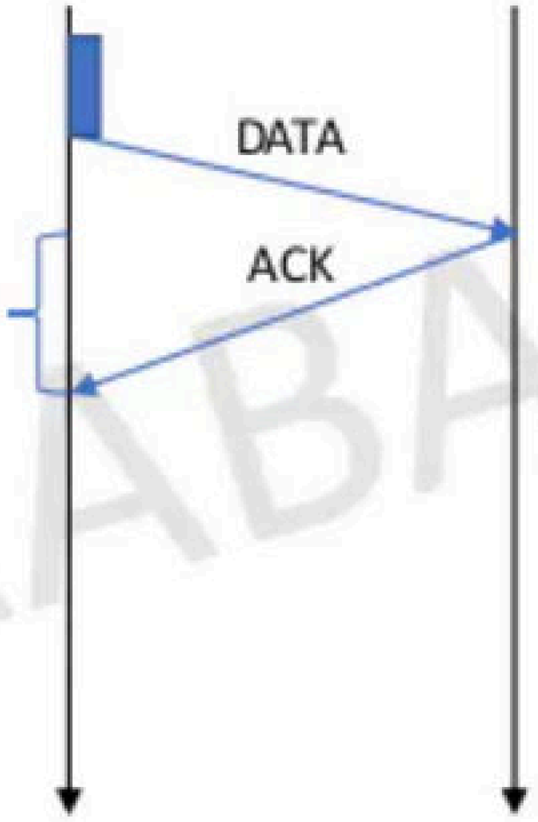
Tt ---------> 1 Packet sent

1 Sec -------> 1/Tp Packets sent

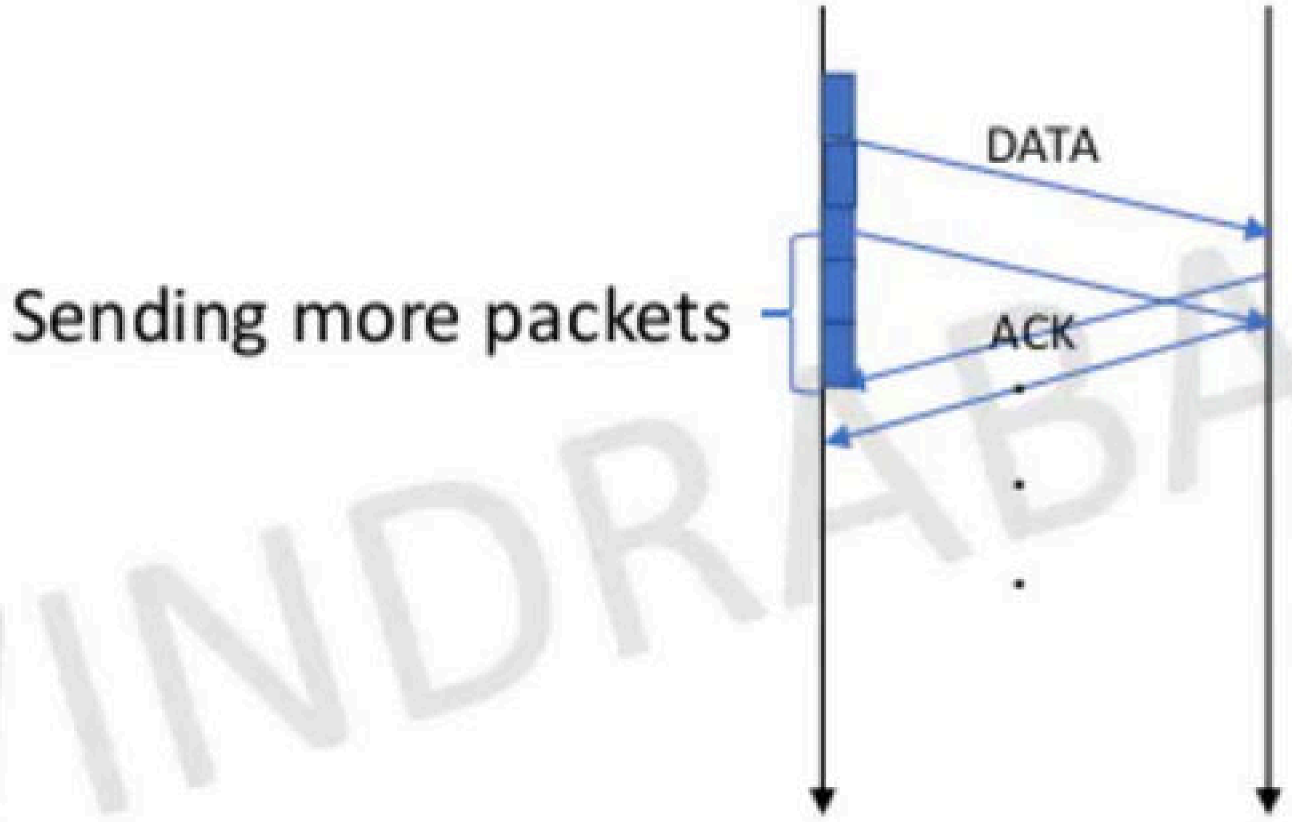
Tt + 2Tp-----> Tt + 2Tp/Tt
-----> 1+2a sent

Basically in Stop and Wait, we need to transfer more number of packets,
In order to increase the efficiency.

In this remaining time
Sender is not sending
any packet and just waiting



So to make more utilization of the available channel and increase efficiency
We can transmit more packets in that particular period of time.

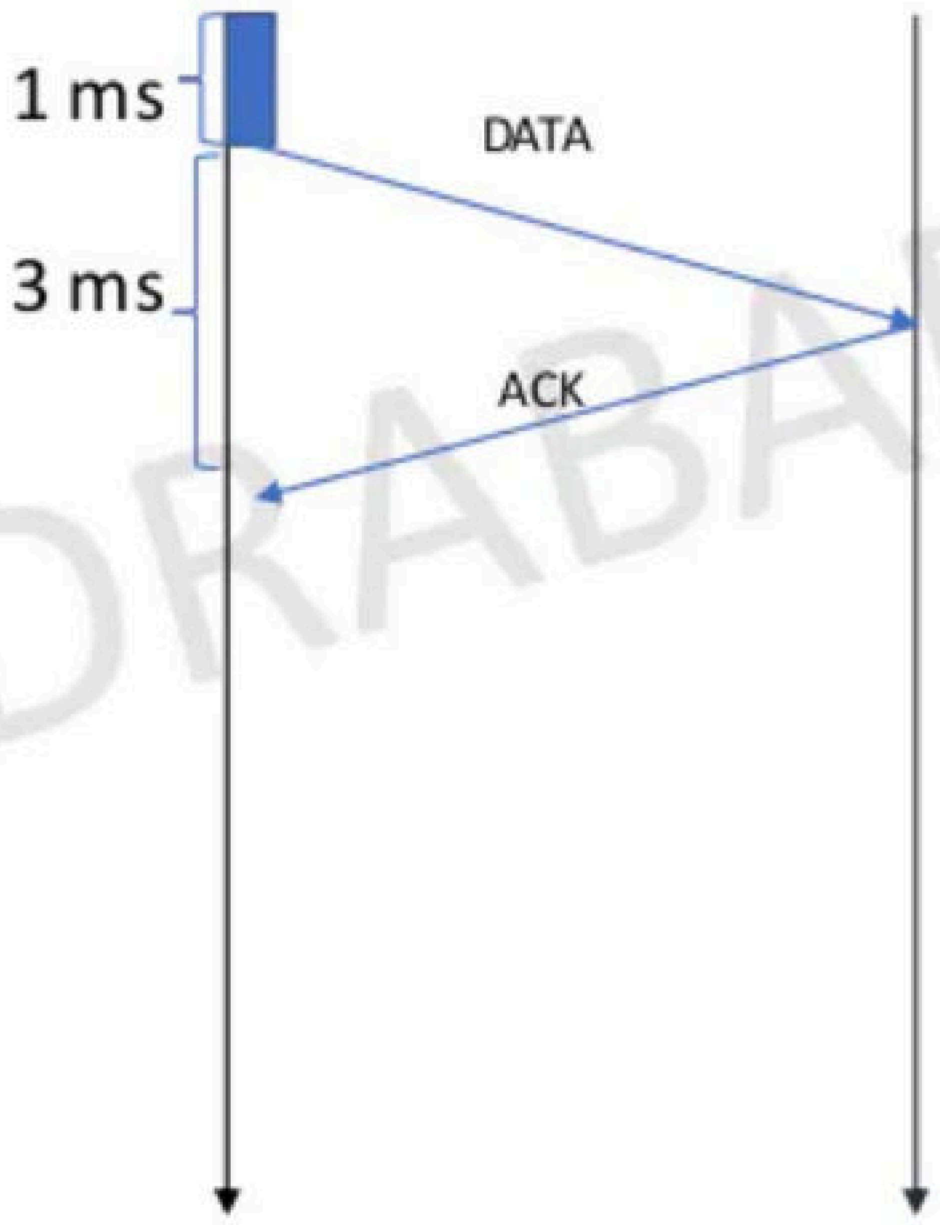


So to make more utilization of the available channel and increase efficiency
We can transmit more packets in that particular period of time.

LET'S SEE ONE EXAMPLE

Given that, Tt =1 ms and Tp=1.5 ms

Therefore, $\eta = \frac{1}{1+2*1.5} = 1/4$



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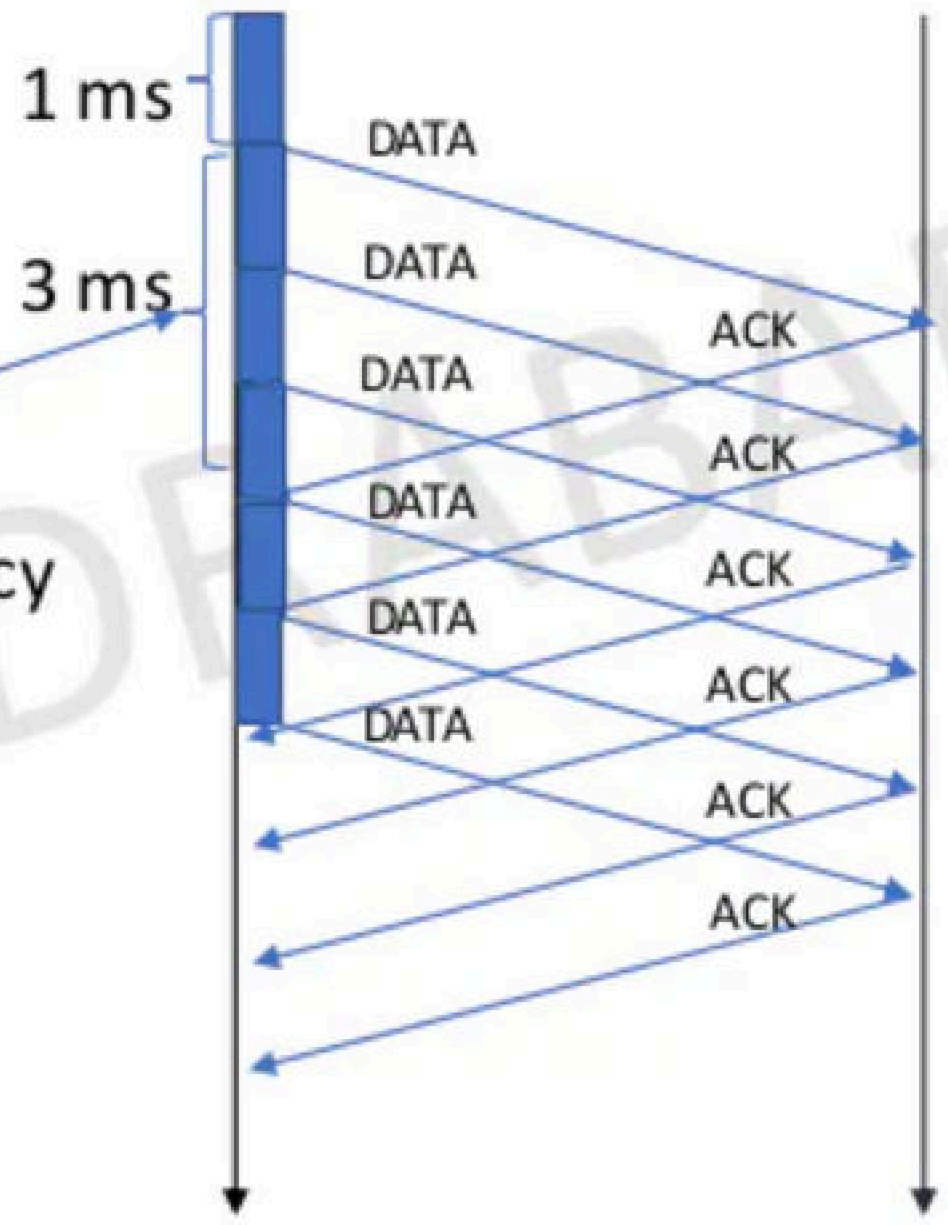
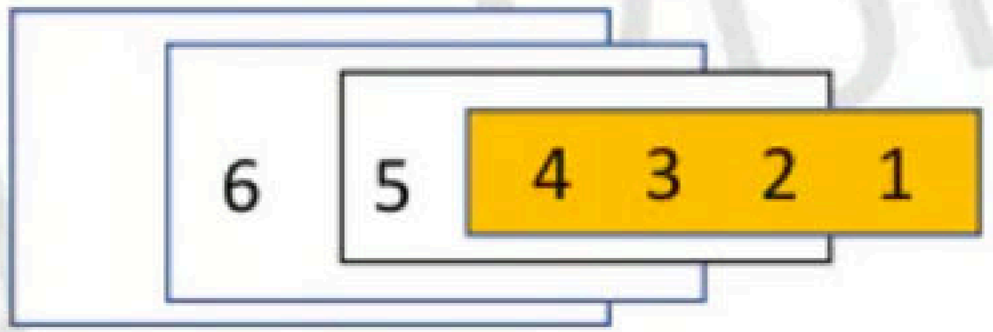


We can increase the efficiency by increasing the number of packets sent here



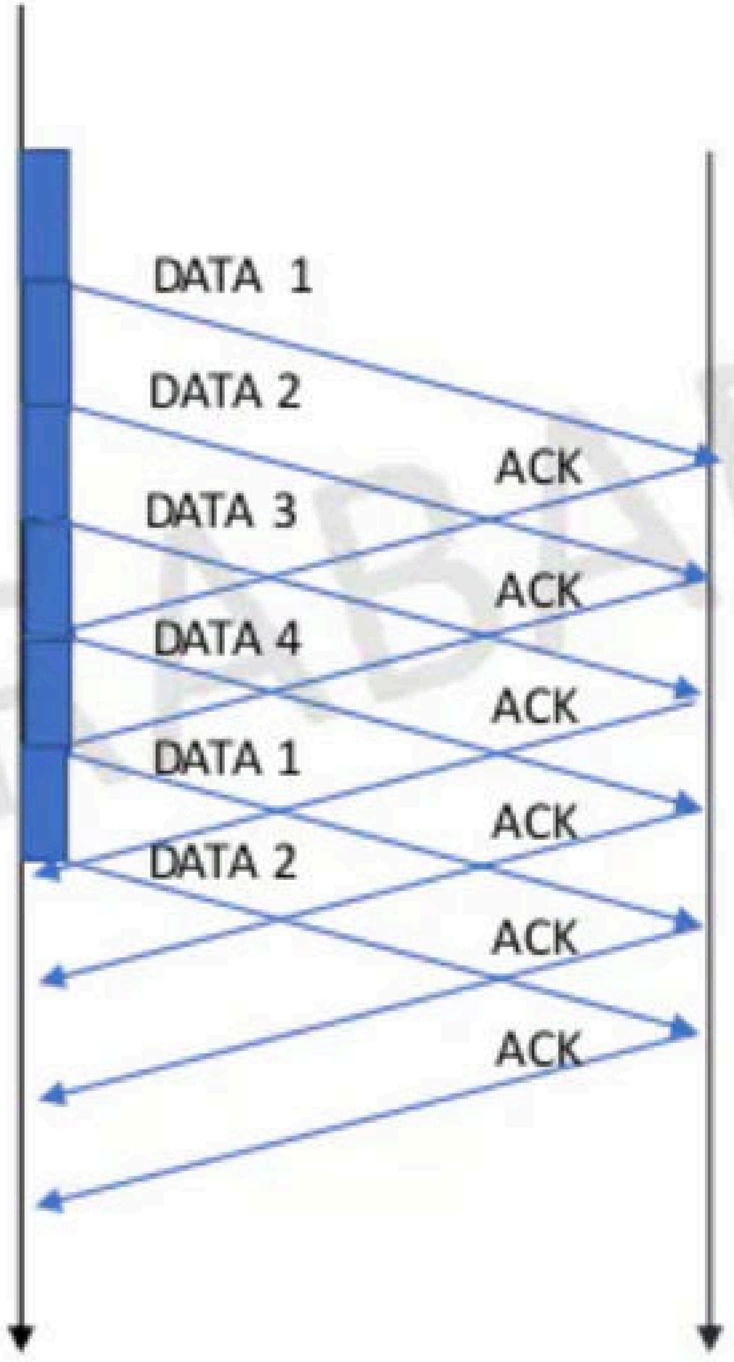
This is buffer which is holding packets
This is also known as **Sliding Window Protocol**

Ws = 1+2a

Window size in case of Sliding window protocol

LET'S SEE HOW MANY SEQUENCE NOS AND BITS ARE REQUIRED

Given that, $T_t = 1$ ms and $T_p = 1.5$ ms



$W_s = 1+2a$

Nos used = 1 2 3 4

Minimum sequence nos required = $1+2a$

Bits in sequence no field = $\lceil \log_2 (1+2a) \rceil$

QUESTION:

T_t = 1 ms   Tp=49.5 ms

Ws = ?

Sequence no =?

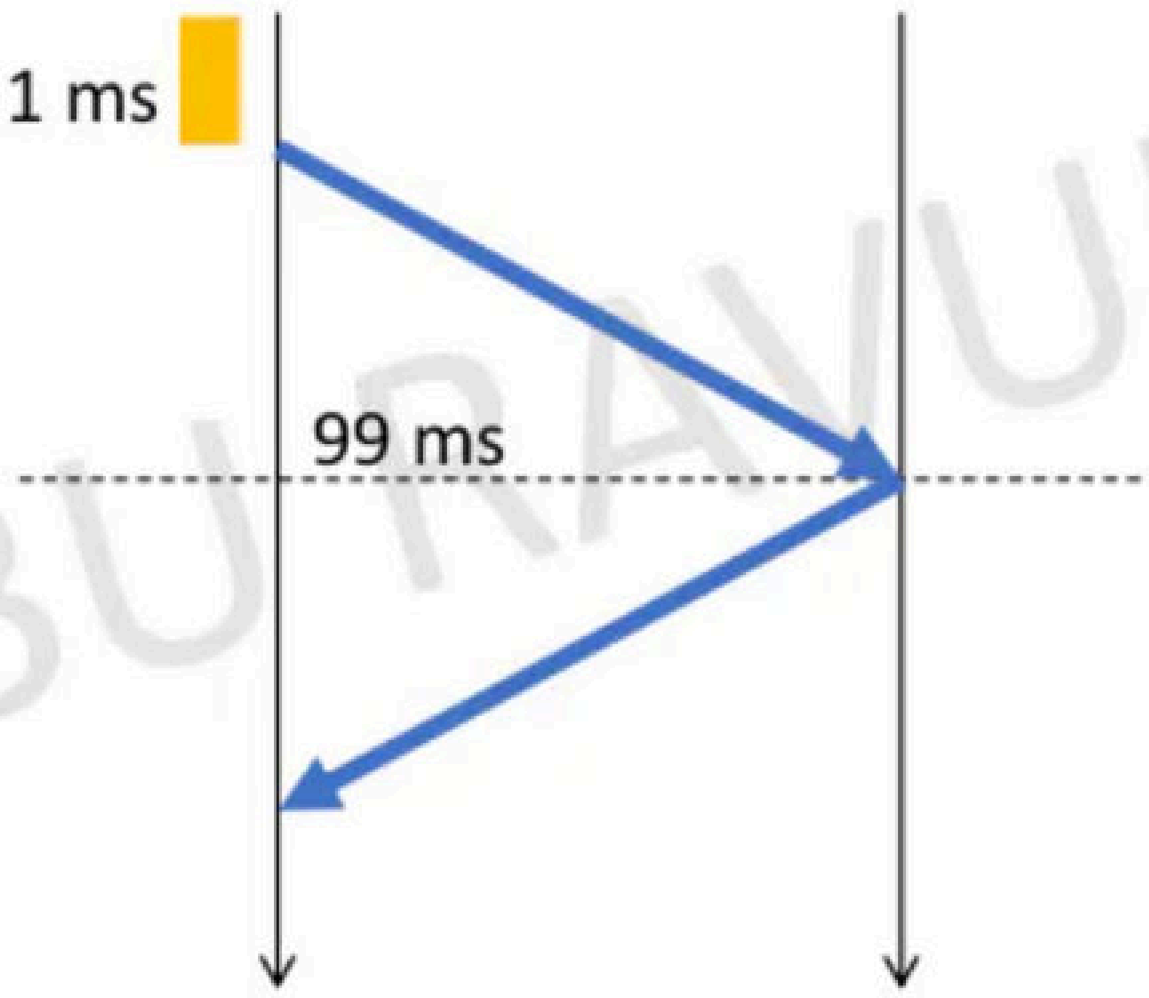
Minimum no of bits in seq no field= ?

SOLUTION:

Ws = 1+2a = 100

Sequence no = 1+2a = 100

Minimum no of bits in seq no field= $\lceil og_2(100) \rceil$ = 6.8 = 7



NOTE:

Sometimes, the minimum no of bits in sequence no field (n) is already given in such cases:

$$Ws = \min (1+2a\ ,\ 2^n)$$