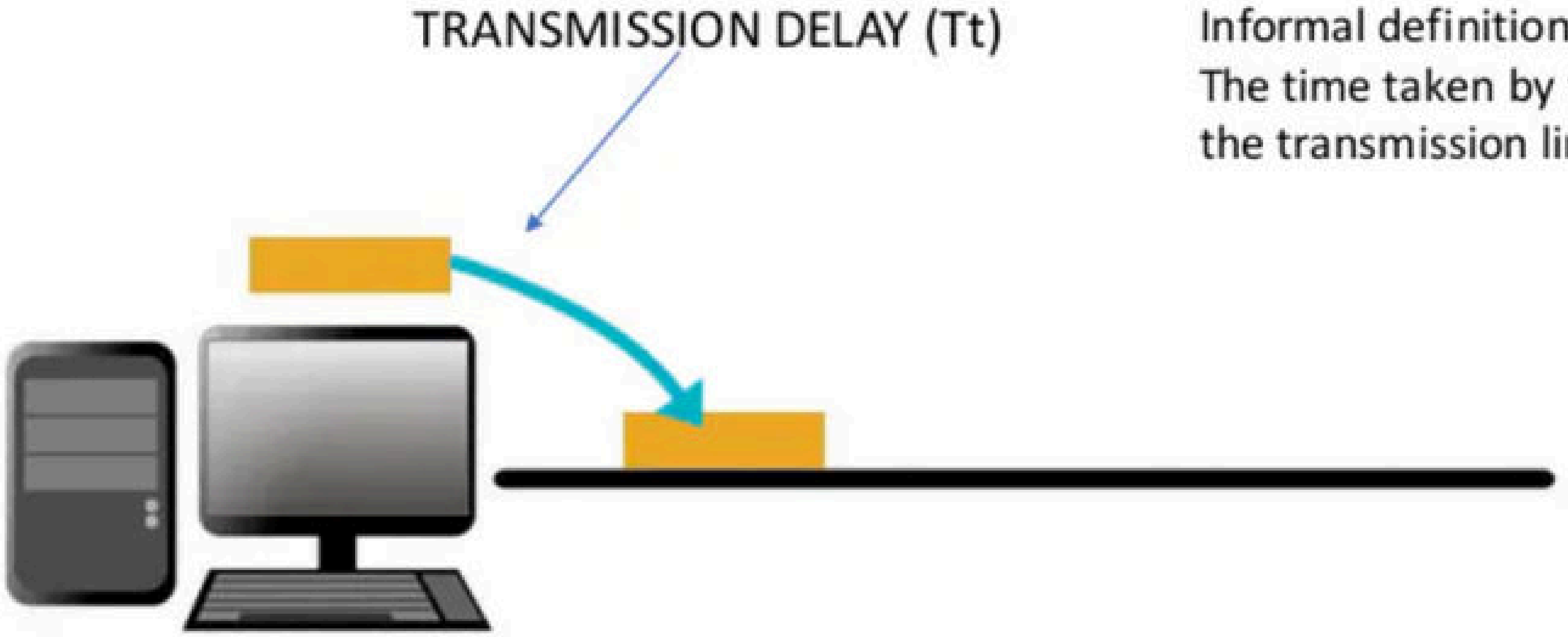
Application Protocol

Complete Course on Computer Networks - Part I

Ravindrababu RAVULA • Lesson 15 • Feb 3, 2021

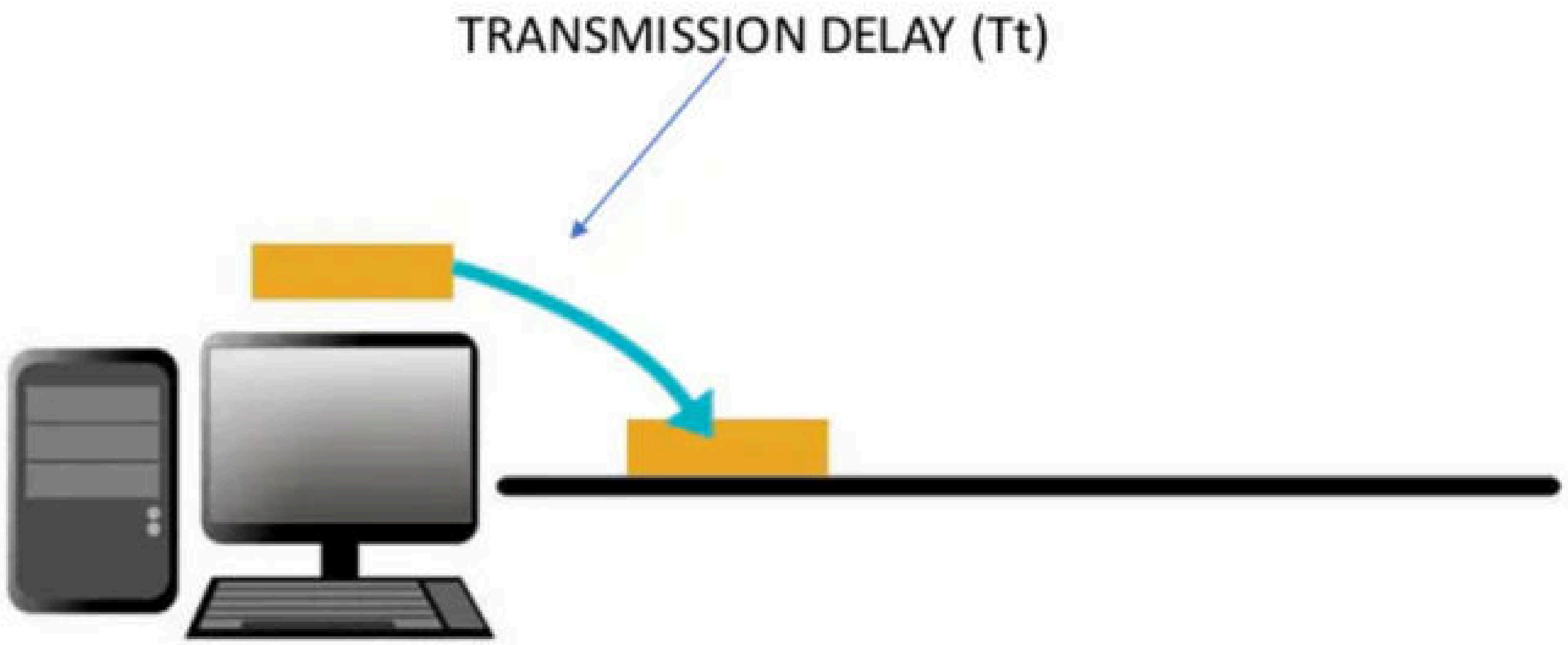
Computer Networks

Delays in Computer Networks



Informal definition:

The time taken by the host to put the data packet into the transmission link is called Transmission Delay



If Bandwidth is 1 bps
And data to be sent is 10 bits
The Tt would be 10 sec

So, in general we can say that,

$$Tt = \frac{\text{Length of data (bits)}}{\text{Bandwidth(bps)}} = \frac{L}{B} \text{ sec}$$

Consider these 2 examples

Example 1 : If L = 1000 bits and BW = 1 Kbps

Then

$$Tt = \frac{L}{B} = \frac{1000}{1000} = 1 \text{ sec}$$

Example 2 : If L = 1 KB and BW = 1 Kbps

Then

$$Tt = \frac{L}{B} = \frac{1024}{1000} = 1.024 \text{ sec}$$

Consider these 2 examples

Example 1 : If L = 1000 bits and BW = 1 Kbps
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Example 2 : If L = 1 KB and BW = 1 Kbps
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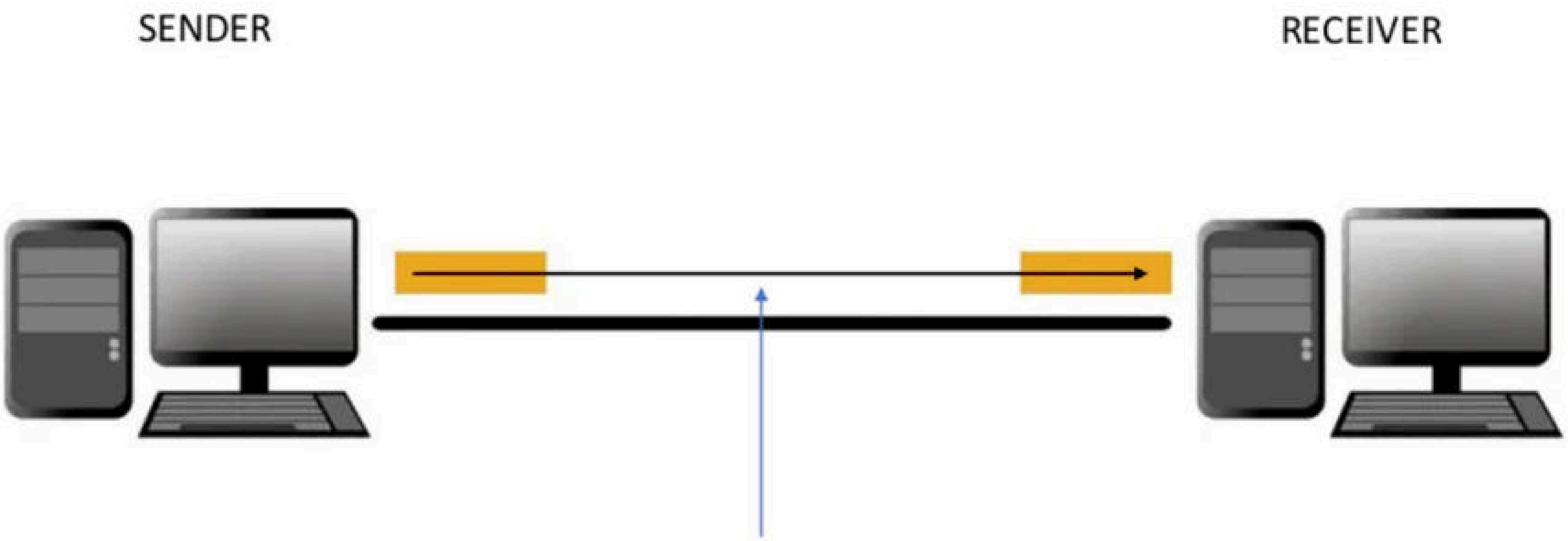
$$Tt = \frac{L}{B} = \frac{1024}{1000} = 1.024 \text{ sec}$$

REMEMBER

Whenever data has **K**, K= 1024	Whenever Bandwidth has **K**, K= 1000 = 10^3
Whenever data has **M**, M=1024 X 1024	Whenever Bandwidth has **M**, M= 10^6
Whenever data has **G**, G=1024 X 1024 X 1024	Whenever Bandwidth has **G**, G= 10^9



Time taken for one bit to travel from sender to receiver end of the link is called as propagation delay.

$$Tp = \frac{\text{distance of the link (d)}}{\text{Velocity(v)}} \text{ seconds}$$

Generally the link nowadays is optical fibre and
We know that the speed at which the light travels
is 3×10^8 m/s.

In optical fibre the light travels with 70% of the original speed of light(3×10^8 m/s)
=>$v = 0.7 \times 3 \times 10^8$ m/s = $\underline{2.1 \times 10^8 \text{ m/s}}$

Generally the velocity will be given in the question but, in questions where velocity is not given, we need to take it as 2.1×10^8 m/s

Example: d = 2.1 km and v = 2.1×10^8 m/s

$$T_p = \frac{\text{distance of the link (d)}}{\text{Velocity(v)}}$$

$$T_p = \frac{2.1}{2.1 \times 10^8}$$

$$= \frac{2.1 \times 1000}{2.1 \times 10^8}$$

$$T_p = 10^{-5} \text{ sec}$$

Converting 10^{-5} sec to µsec

We know that µ is 10^{-6}

Step 1 :Divide and multiply by 10^{-6}

$$10^{-5} \times \frac{10^{-6}}{10^{-6}}$$

Step 2 :Combine

$$10^{-5} \times \frac{10^{-6}}{10^{-6}} = 1 \times 10^{-6}$$

= 1 µsec

Time taken by the processor to process the data packet is called as **processing delay**

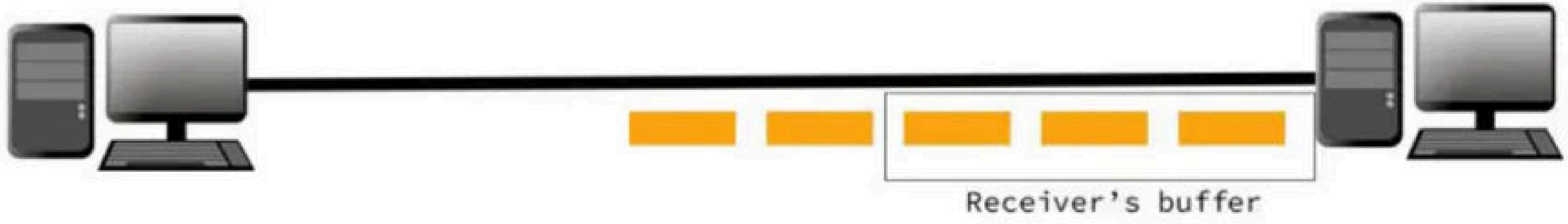
Time spent by the data packet waiting in the queue before it is taken for execution is called as **queuing delay**.

NOTE :THESE TWO DELAYS DEPEND UPON THE TYPE OF PROCESSOR USED AND CANNOT BE EVALUATED AND THEREFORE ARE CONSIDERED AS ZERO IN ALMOST ALL NUMERICALS

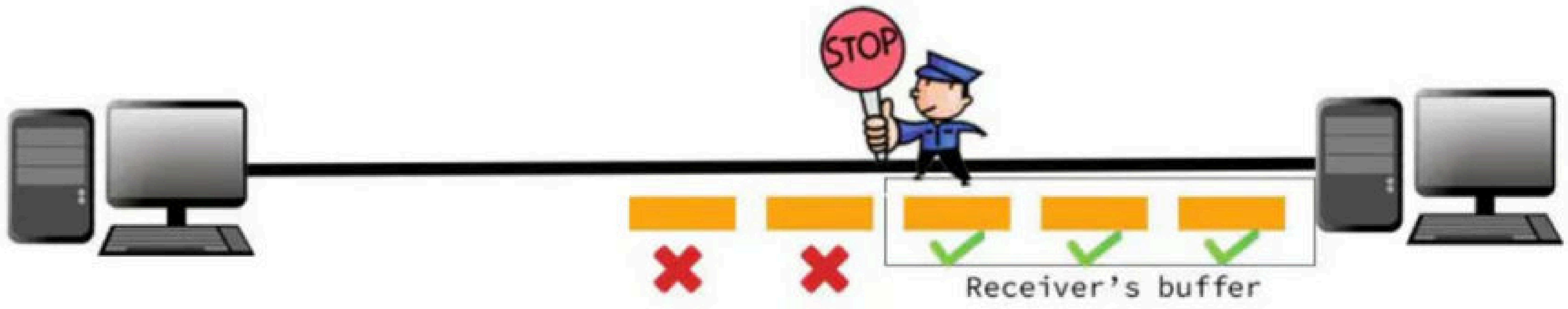
Computer Networks

Flow Control Methods- Stop and Wait

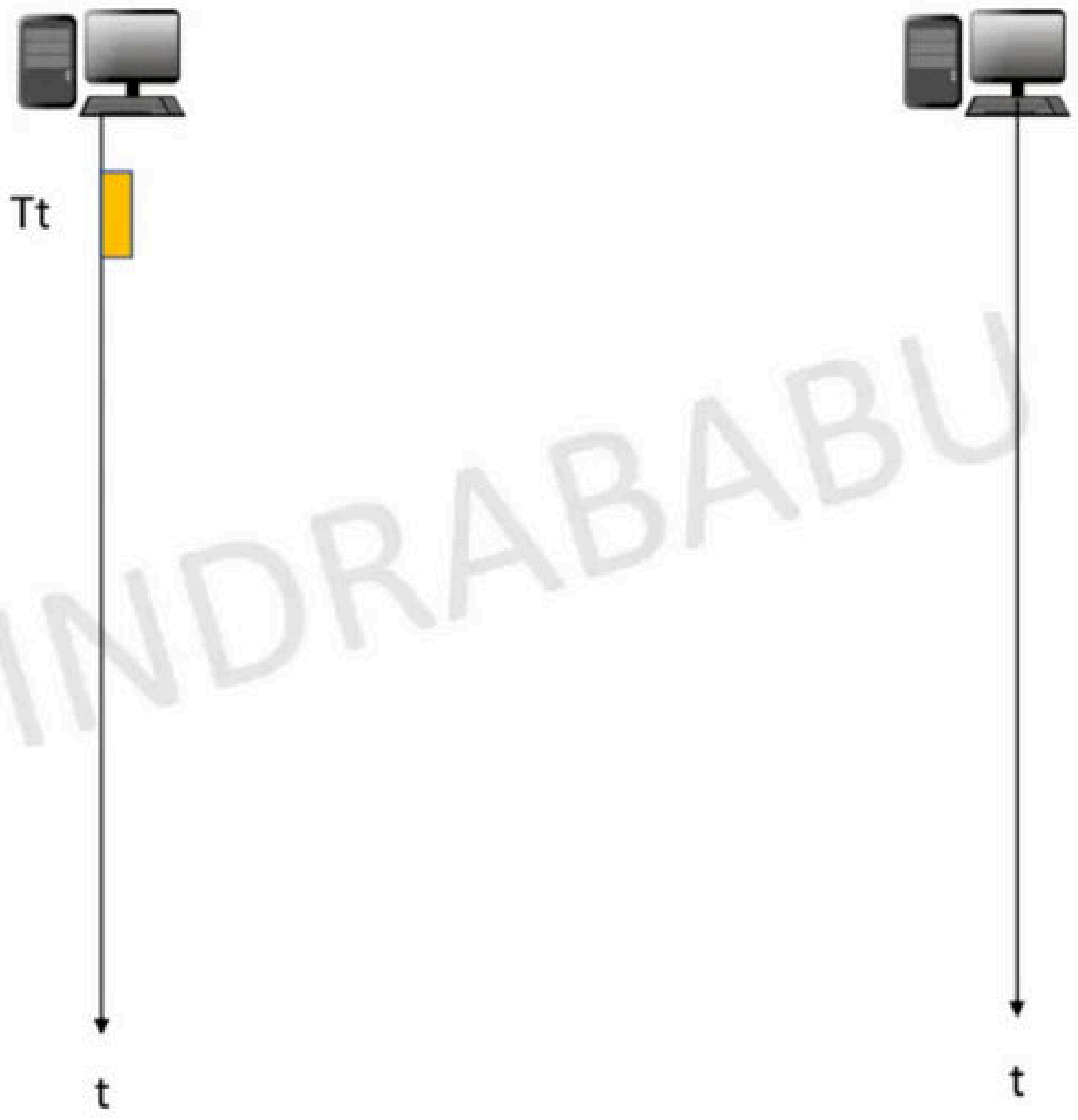
WHY FLOW CONTROL IS REQUIRED?

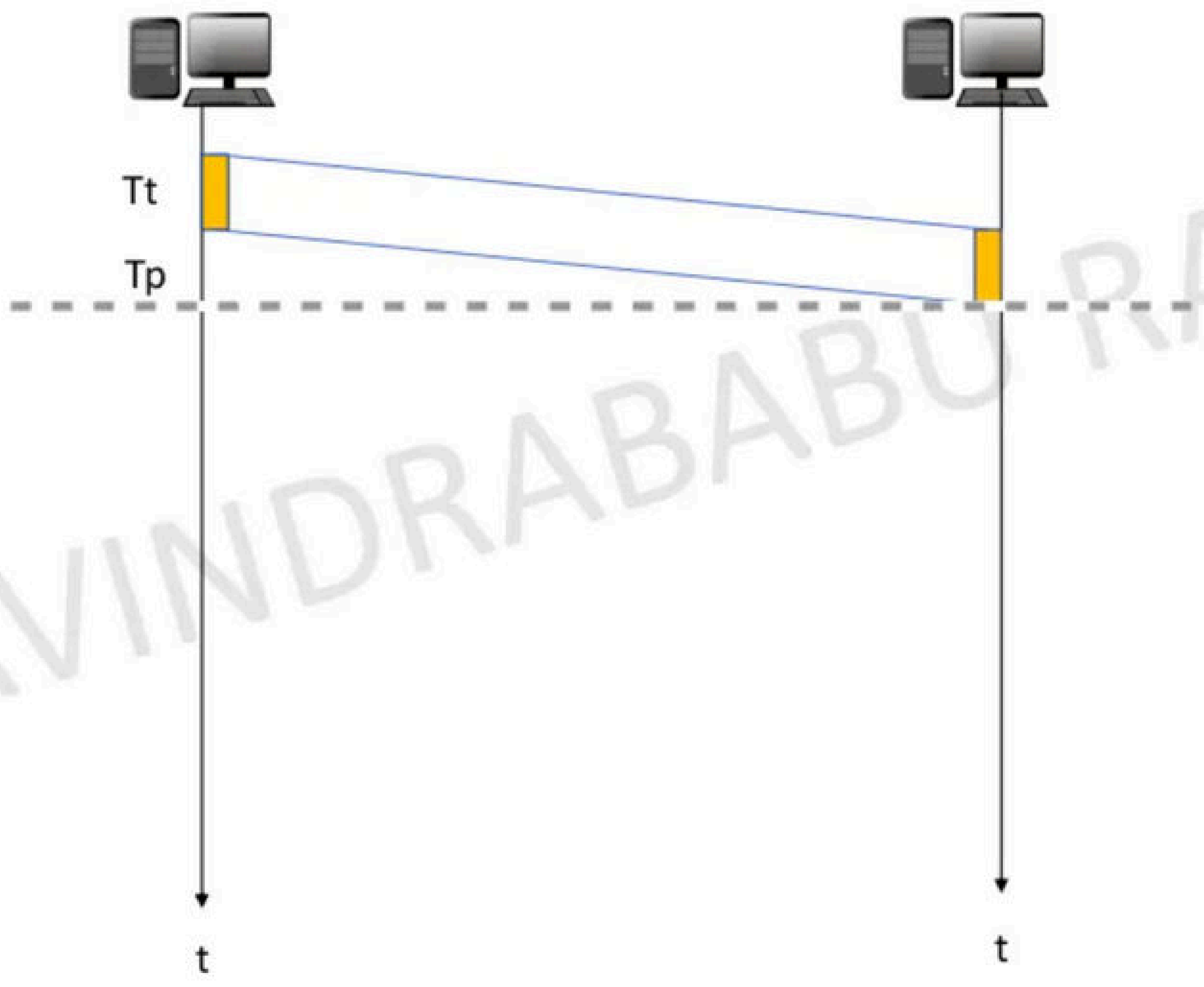


WHY FLOW CONTROL IS REQUIRED?

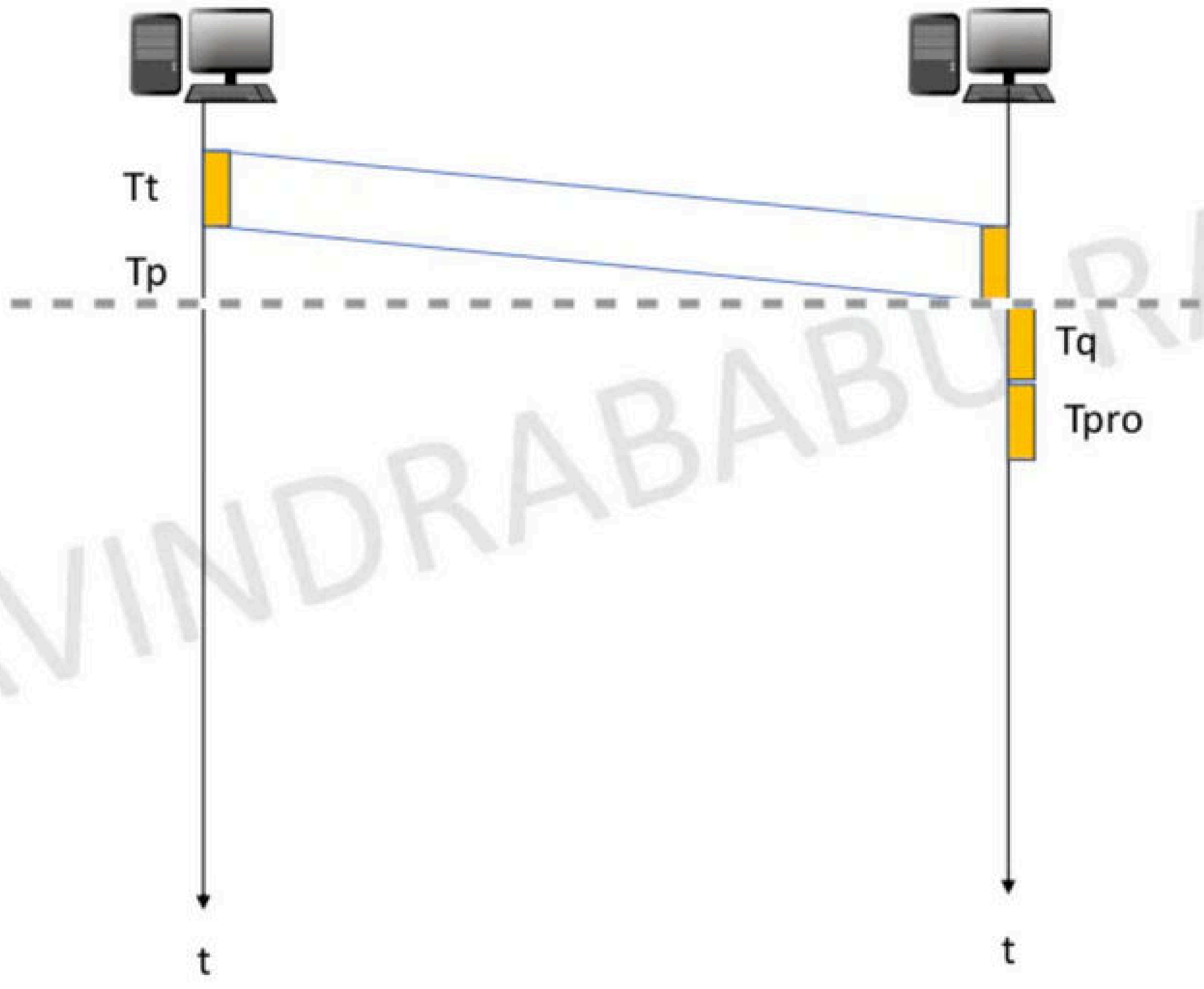


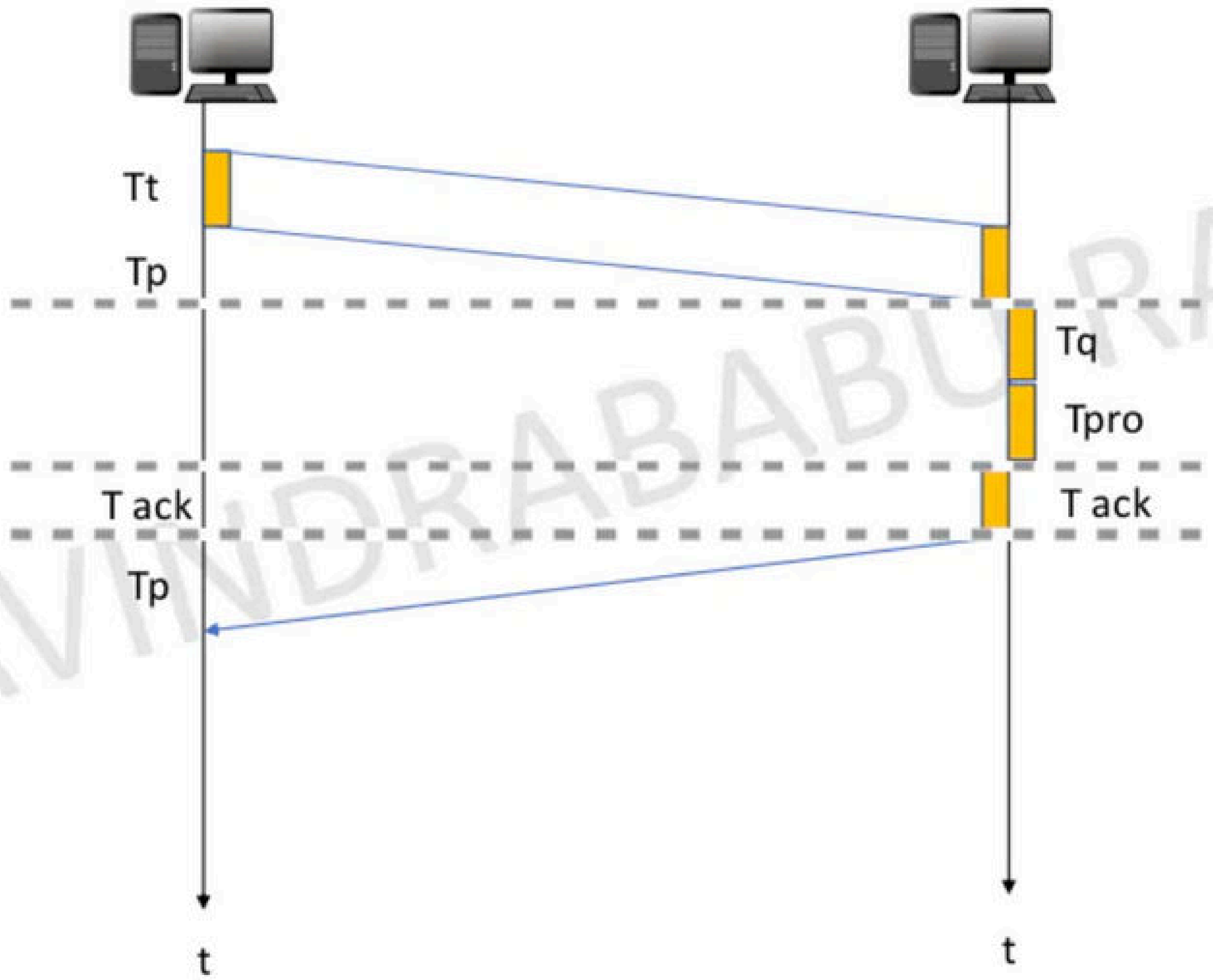
Buffer size of receiver was 3, so other 2 packets got discarded
Therefore, The sender must send the packets in the rate at which the receiver can receive it.
Here is where **Flow control** comes in picture.

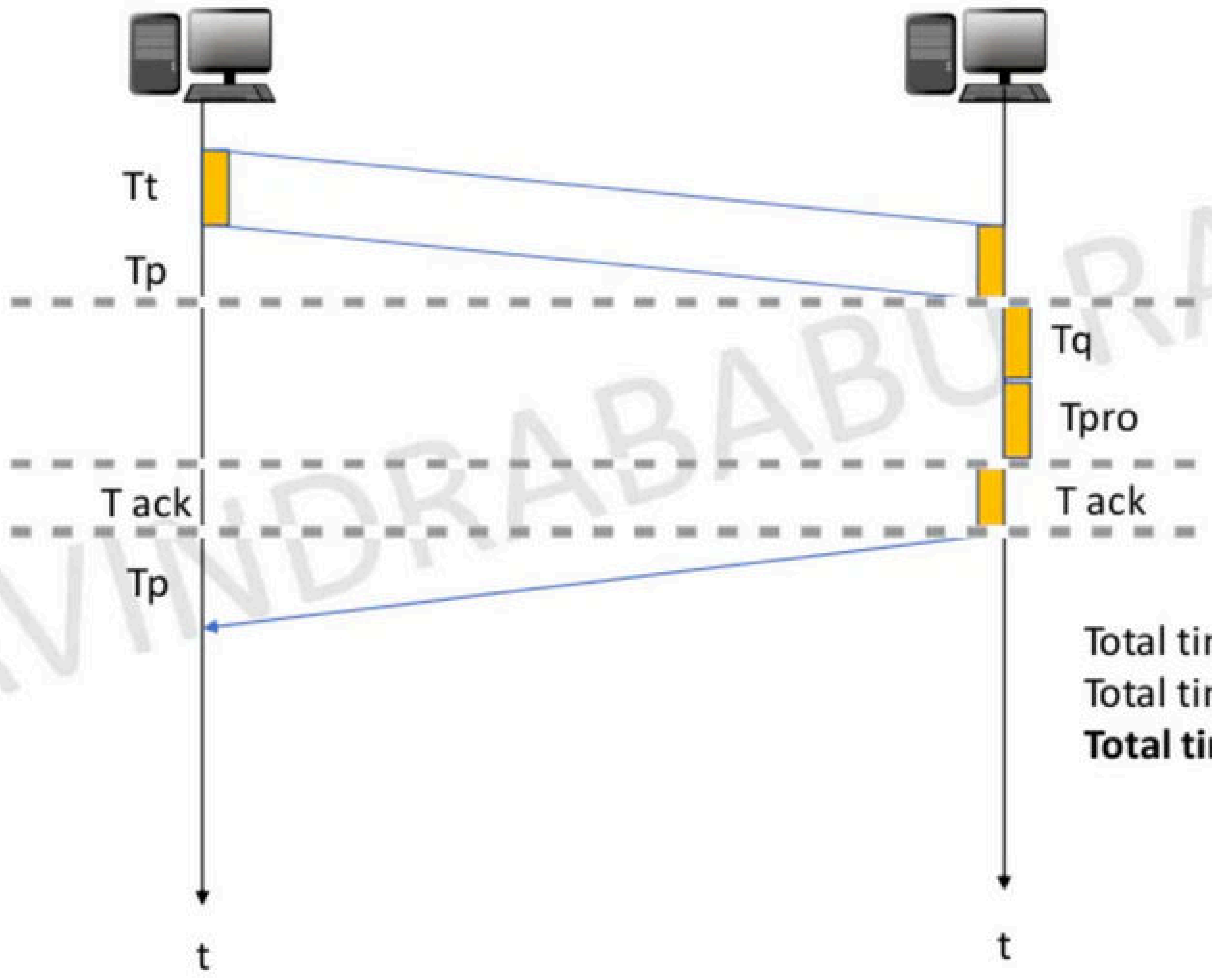

Tt
t
t



Tt
Tp
t
t


Tt
Tp
Tq
Tpro
t
t

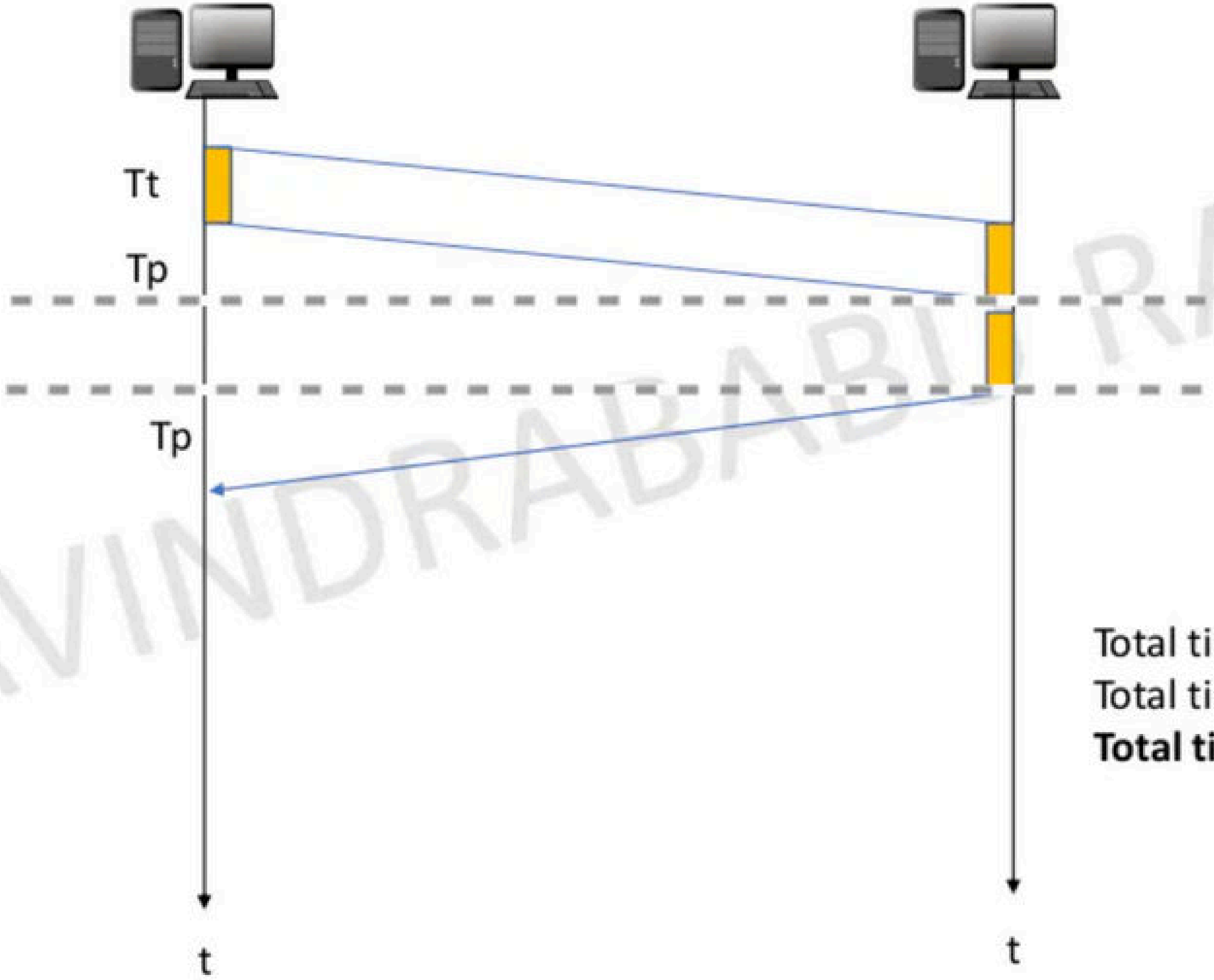

Tt
Tp
Tq
Tpro
T ack
T ack
Tp
t
t



$$\text{Total time} = T_t + T_p + \overset{0}{T_q} + \overset{0}{T_{pro}} + \overset{0}{T_{ack}} + T_p$$

$$\text{Total time} = T_t + T_p + T_p$$

$$\textbf{Total time} = \mathbf{T_t + 2T_p}$$



$$\text{Total time} = T_t + T_p + \underbrace{T_q}_{0} + \underbrace{T_{pro}}_{0} + \underbrace{T_{ack}}_{0} + T_p$$

Total time= Tt + Tp + Tp

Total time= Tt + 2Tp

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
Or
Bandwidth utilization

$$= \frac{L}{Tt + 2Tp}$$

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

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

$$= \eta \times B$$

Throughput = Efficiency (η) x 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

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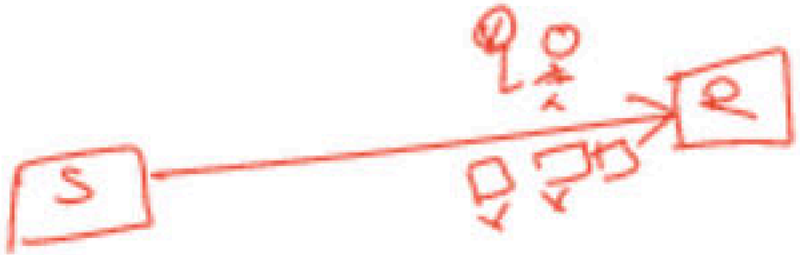
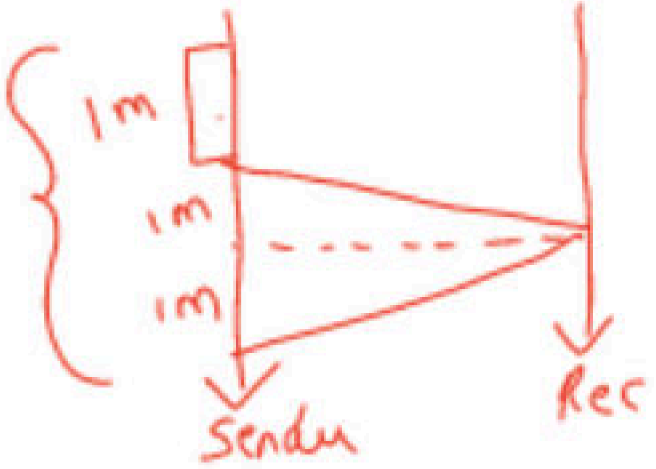


Problems on Stop and wait

1.) Tt = 1ms Tp = 1ms η

$$\eta = \frac{1}{1+2a} = \frac{1}{3} = 0.33 \text{ or } 33\%$$



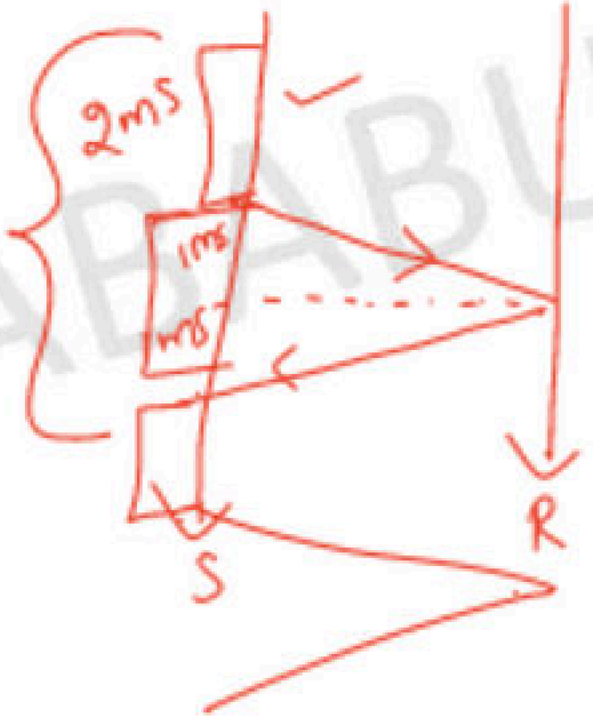
$\frac{1}{3}$

$T_{tack} \to 0$
$T_{pro} \to 0$
$T_{que} \to 0$

$\frac{T_t}{T_p}$

2.) Tt = 2ms Tp = 1ms

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



$\frac{1}{2 \text{ packets}} = 50\%$

$a = \frac{T_p}{T_t} = \frac{1ms}{2ms}$

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

If efficiency has to be 50% atleast $\longrightarrow$ $\boxed{T_t, T_p}$ in S&W

$$\boxed{\eta = \frac{T_t}{T_t + 2T_p} \geq \frac{1}{2}}$$

$\frac{50}{100} = \frac{1}{2}$

$$2T_t \geq T_t + 2T_p$$

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

If eff has to be 50% atleast, then what is the min packet size?

$$T_t \geq 2 * T_p$$

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

$$\Rightarrow \boxed{L \geq 2 * T_p * B}$$

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

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

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?

$$L \geq B \times 2T_p = 4 \times 10^6 \times 2 \times 10^{-3}$$

$$\geq \boxed{8000 \text{ bits}} \Rightarrow \boxed{1000}$$

Question:

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

$L >= 2Tp * B$

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

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

$$\eta = \frac{1}{1+2a} = \frac{1}{1+2*\frac{T_p}{T_t}}$$

8 mB

8 mb

BW = b/s

B/s

$$\eta = \frac{1}{1+2*\frac{d}{V}*\frac{B}{L}}$$

V -> const

B -> const

$d\uparrow \Rightarrow \eta\downarrow \Rightarrow$

$d\downarrow \Rightarrow \eta\uparrow \Rightarrow$ S&W -> LAN's × WAN's

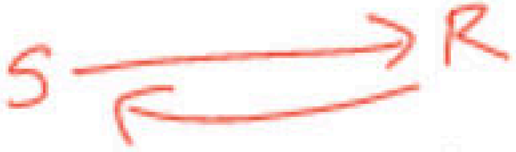
$L\uparrow \Rightarrow \eta\uparrow \Rightarrow$ S&W is eff for big packets

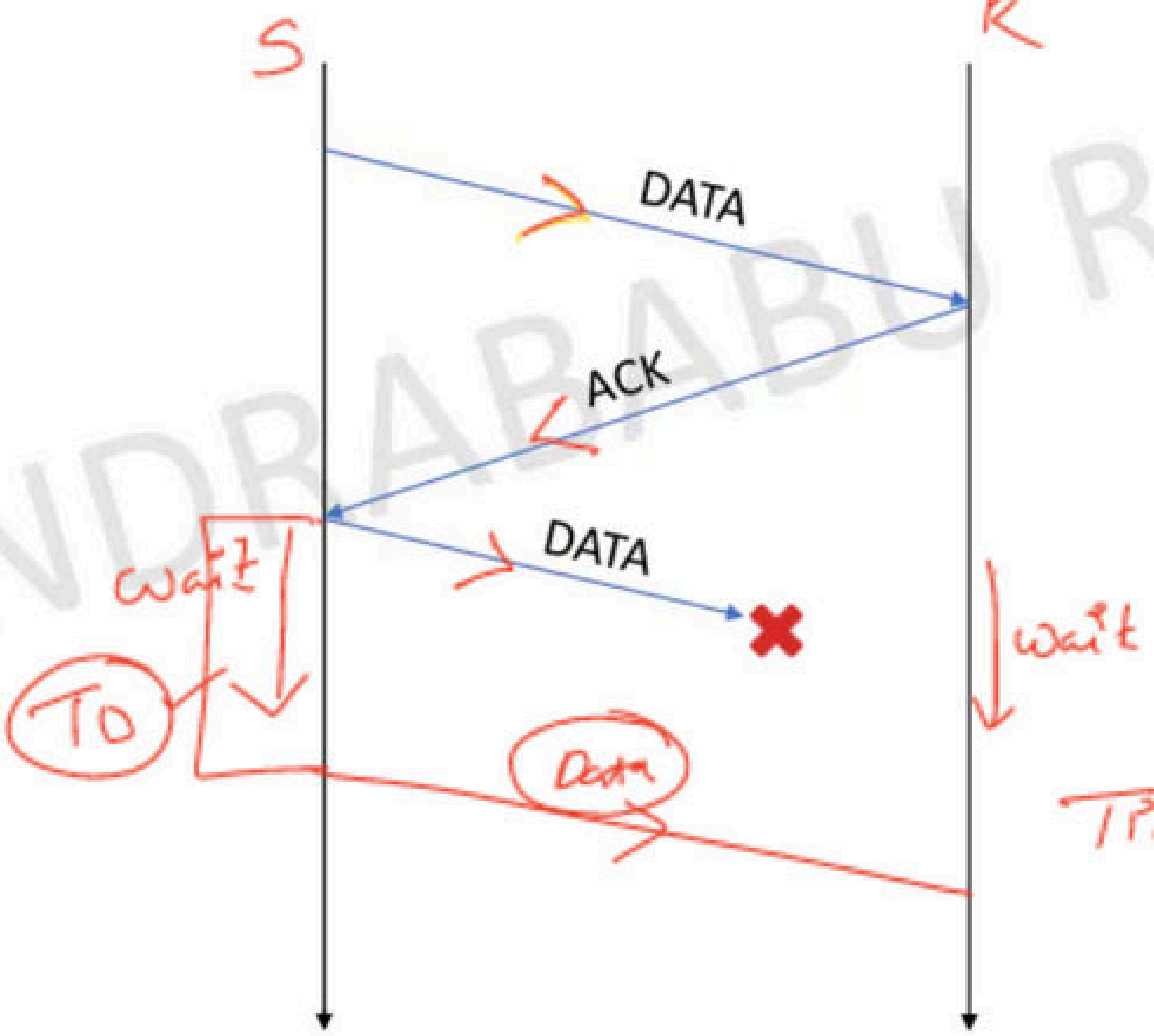
× small packets.

$L\downarrow \Rightarrow \eta\downarrow \Rightarrow$

PROBLEMS WITH STOP AND WAIT

PROBLEM 1: Data packet lost

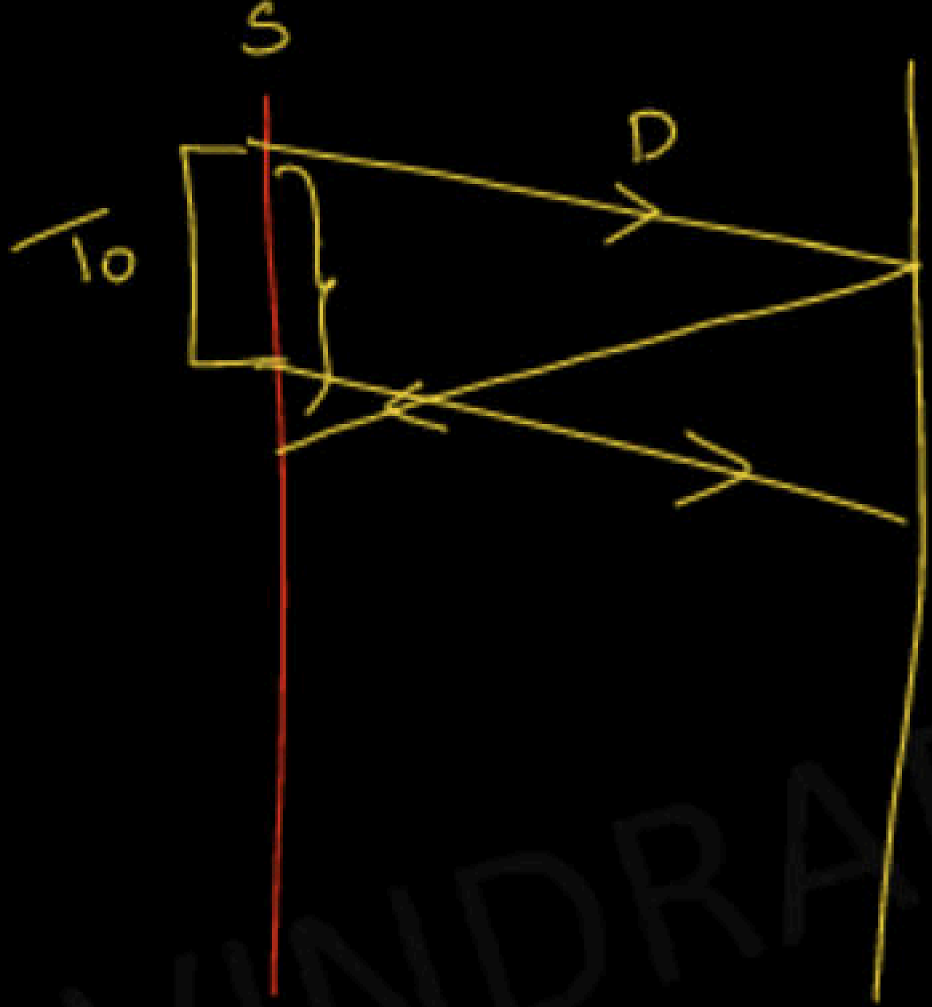


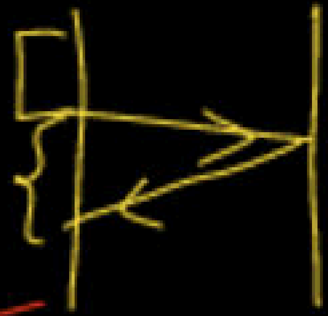


SENDER THINKS THAT RECEIVER IS BUSY

RECEIVER THINKS SENDER DID NOT SEND THE DATA

Timeout timer



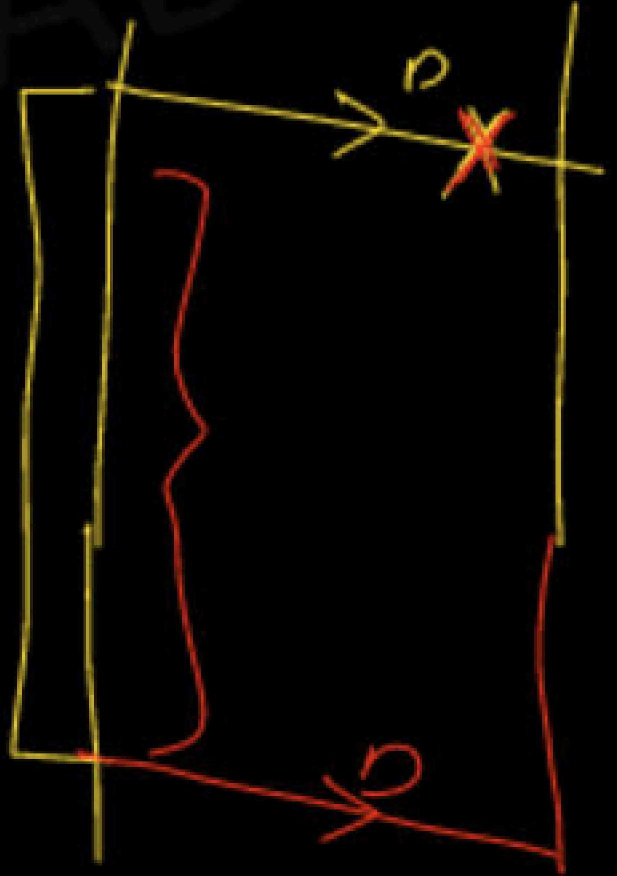


$T_0 \geq 2T_b$

T_0 too small → unnec retrans

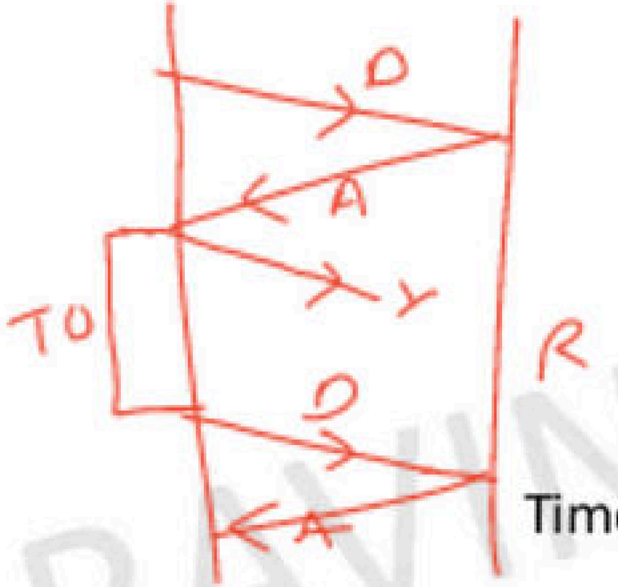
TCP

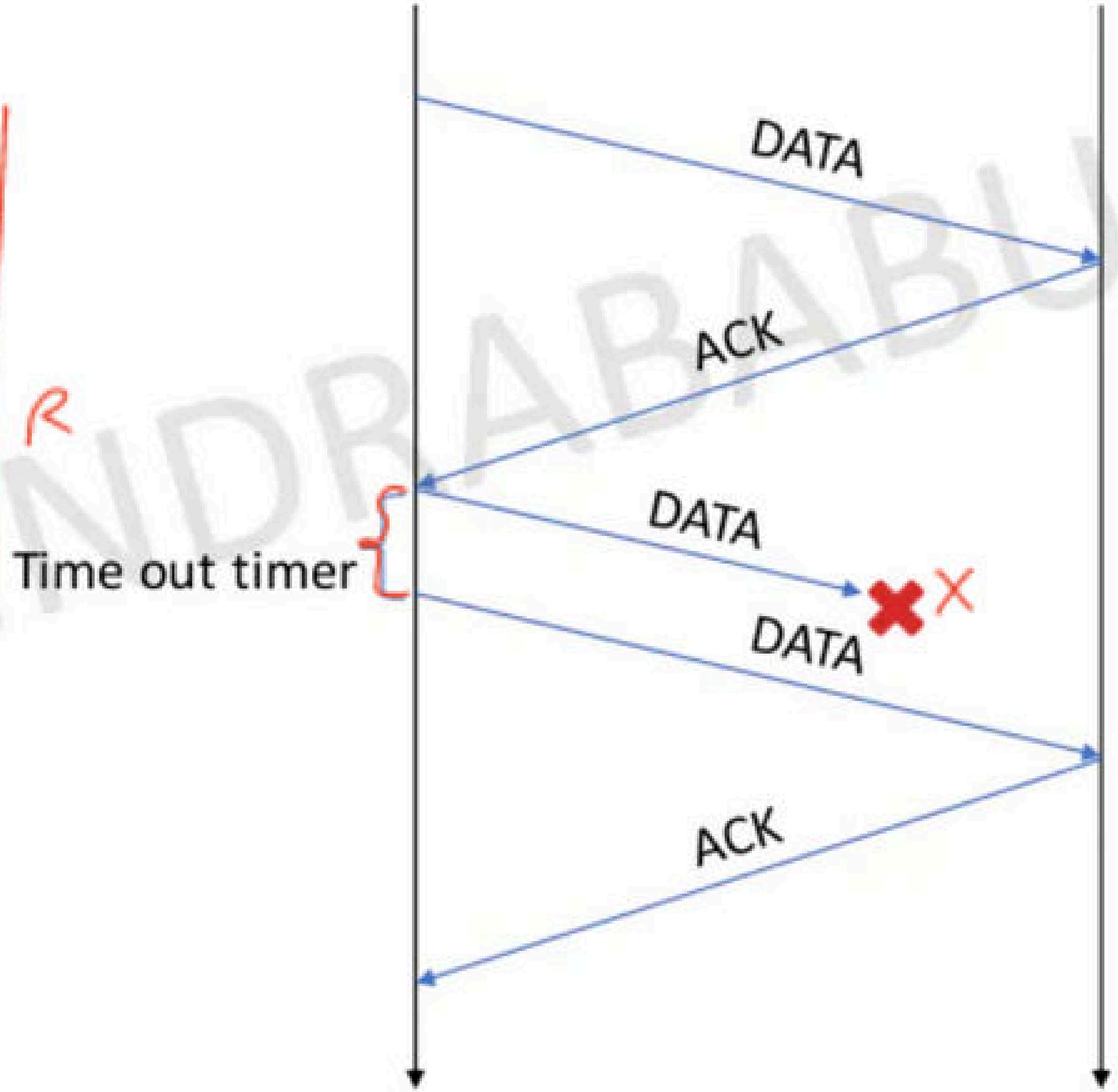
T_0 too large →



PROBLEMS WITH STOP AND WAIT

PROBLEM 1: Data packet lost





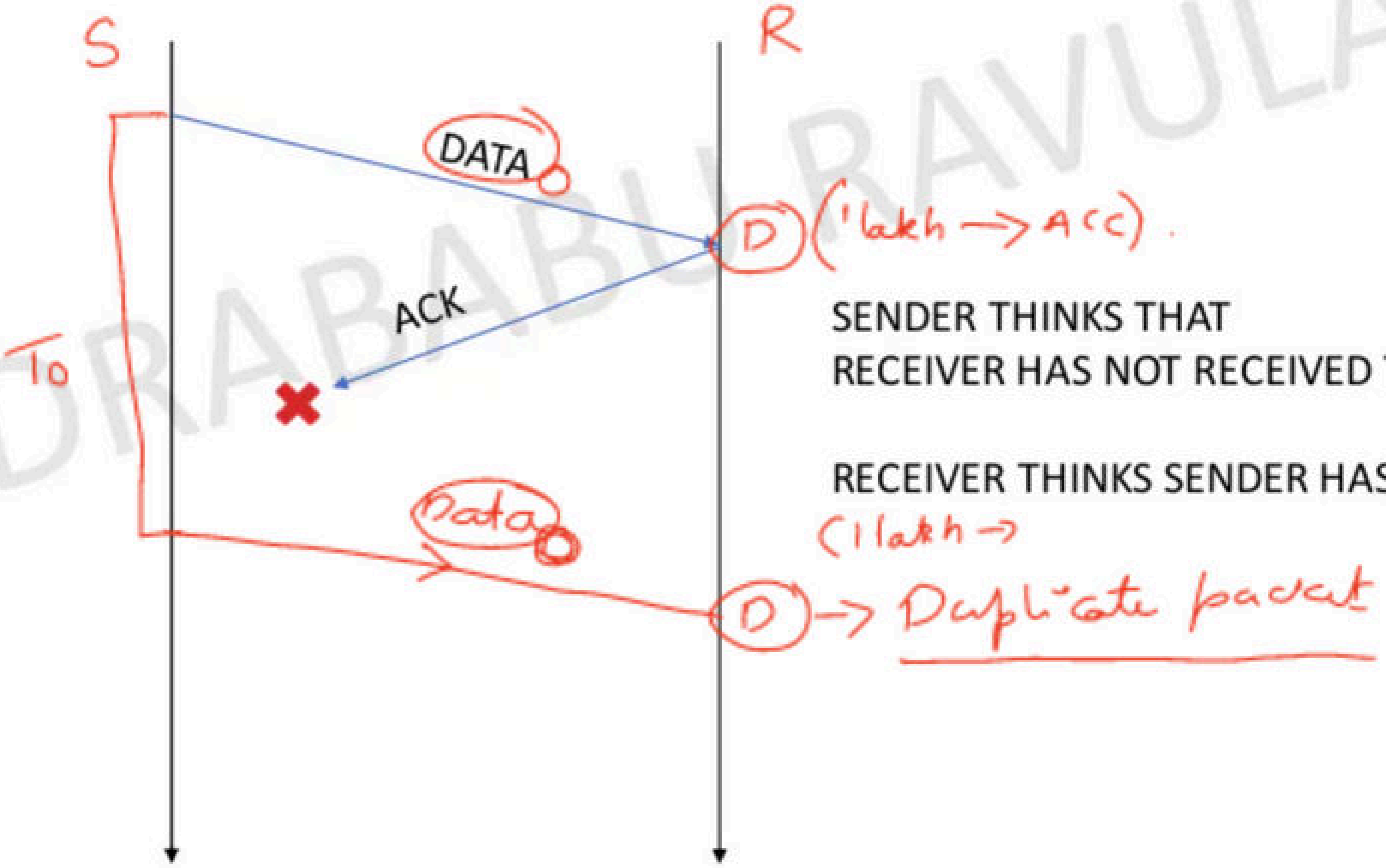
SOLUTION

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

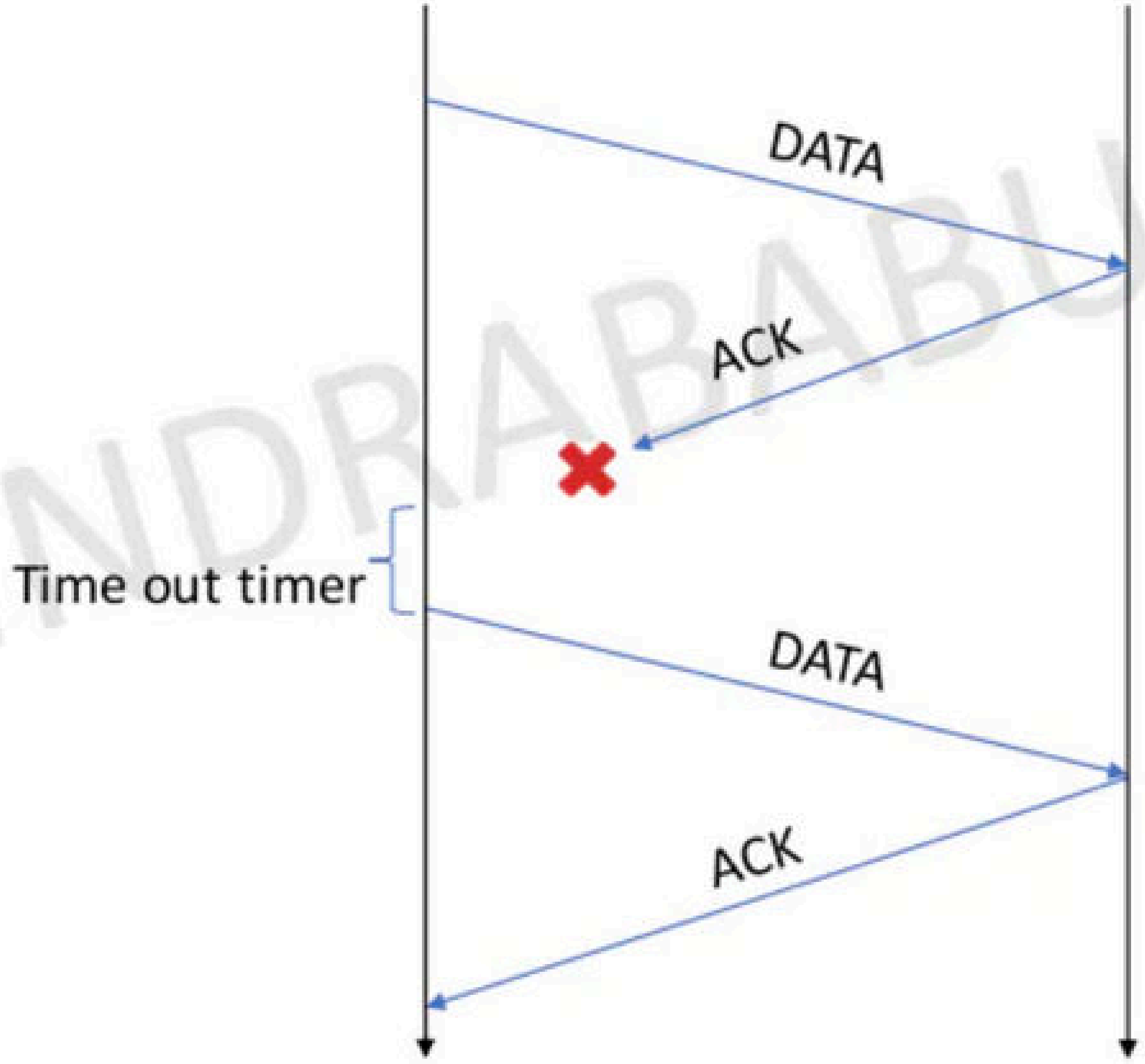


SENDER THINKS THAT
RECEIVER HAS NOT RECEIVED THE PACKET

RECEIVER THINKS SENDER HAS RECEIVED ACK

PROBLEMS WITH STOP AND WAIT

PROBLEM 2: Acknowledgement lost



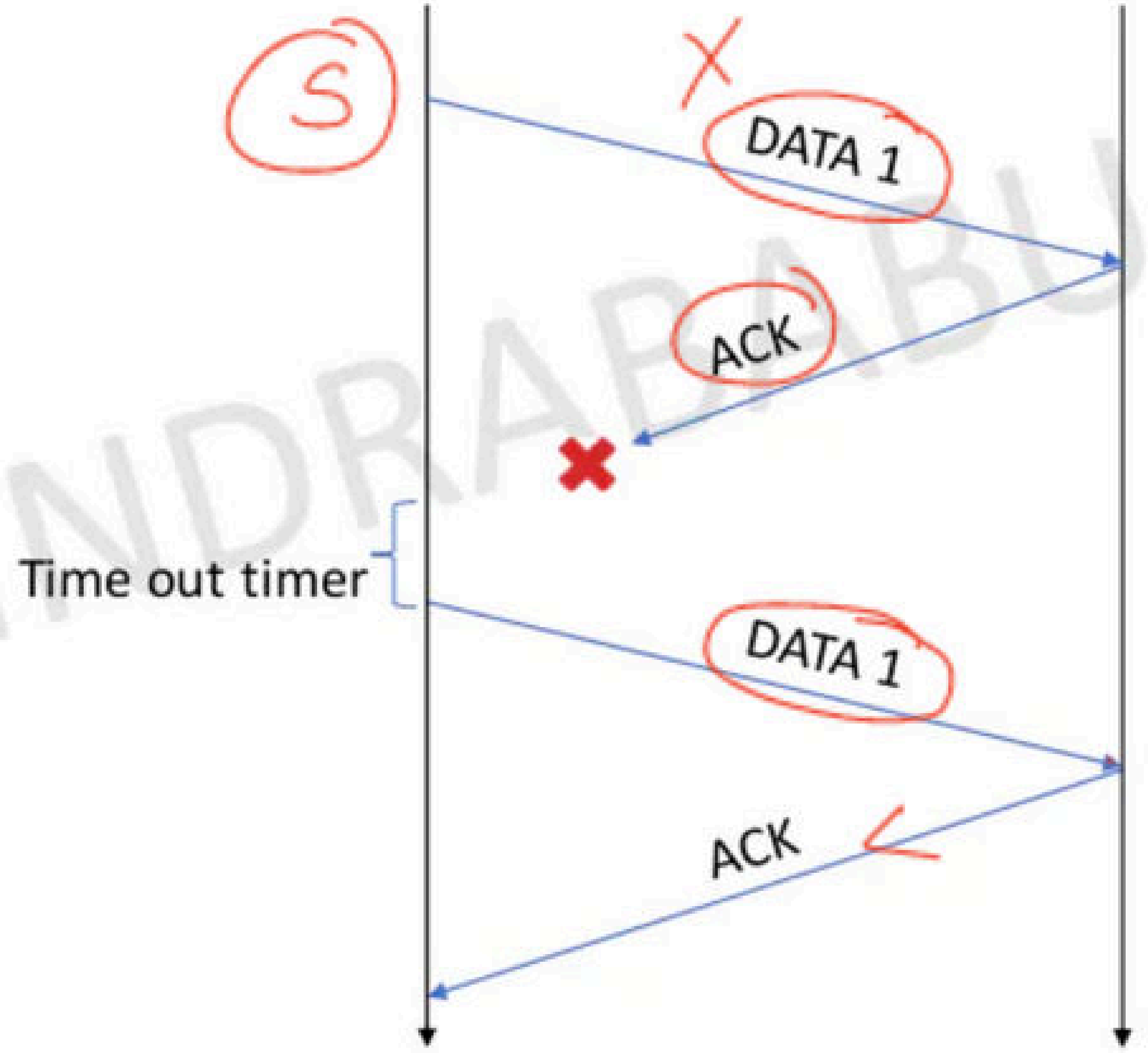
SENDER WAITS FOR TIMEOUT TIMER AND RESENDS THE PACKET

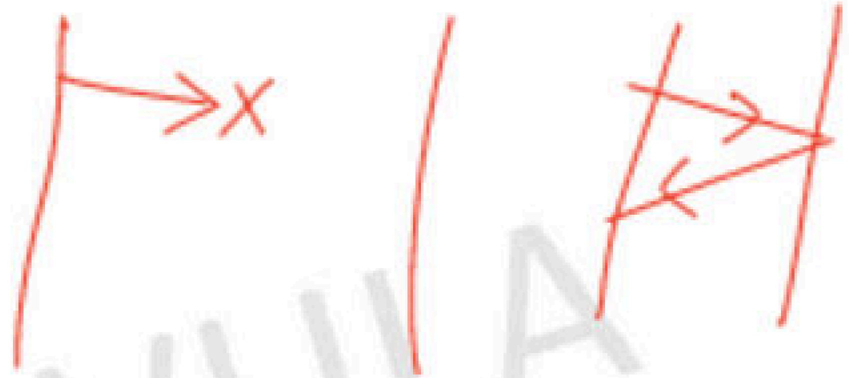
RECEIVER THINKS SENDER HAS SENT NEW DATA PACKET.

THIS IS **DUPLICATE PACKET PROBLEM**

PROBLEMS WITH STOP AND WAIT

PROBLEM 2: Acknowledgement lost





SOLUTION :

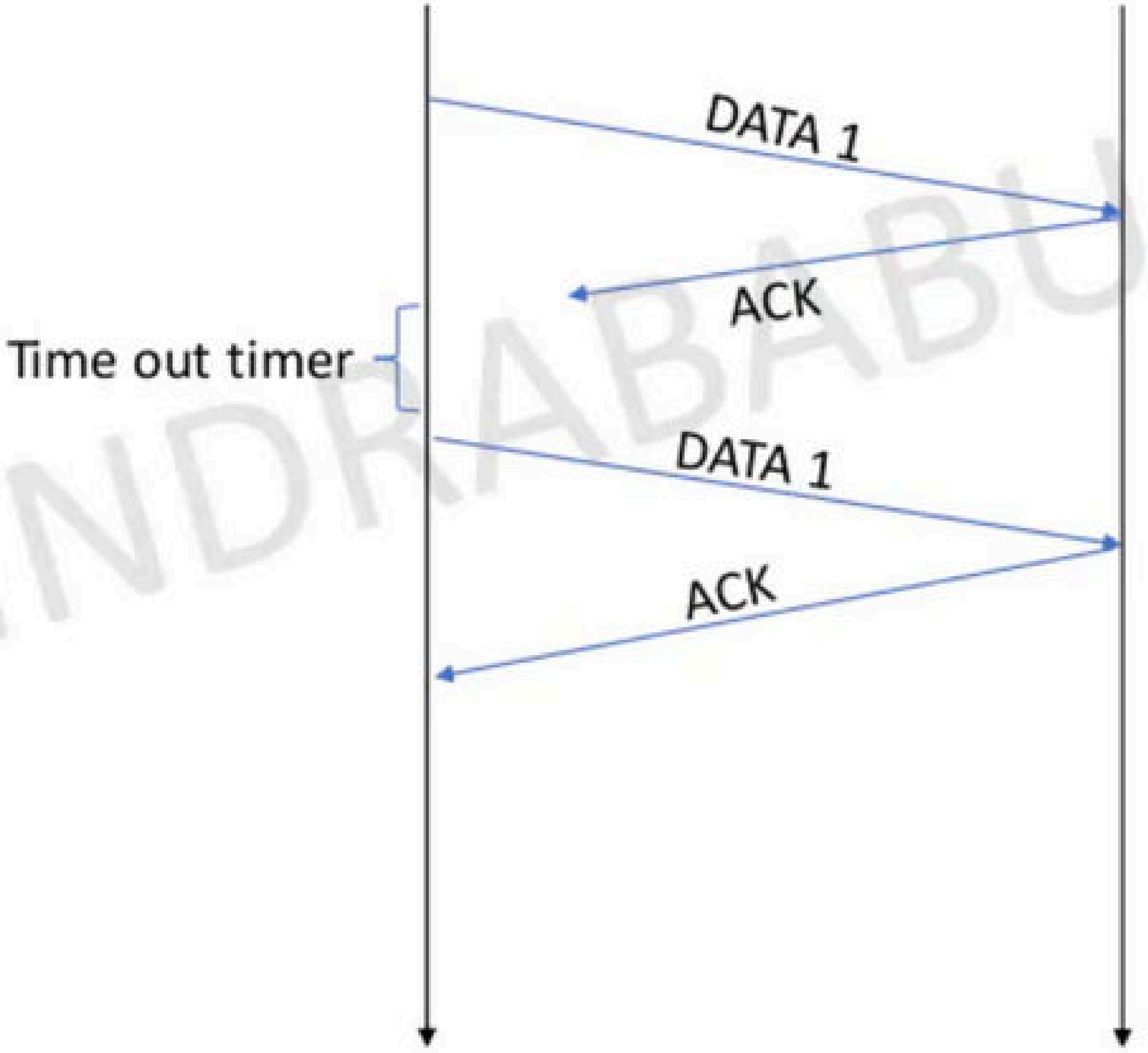
SENDER SENDS DATA PACKET WITH **SEQUENCE NUMBERS**

STOP AND WAIT + TO TIMER + SEQ NUMBER

Seq.

PROBLEMS WITH STOP AND WAIT

PROBLEM 3: Acknowledgement Delayed

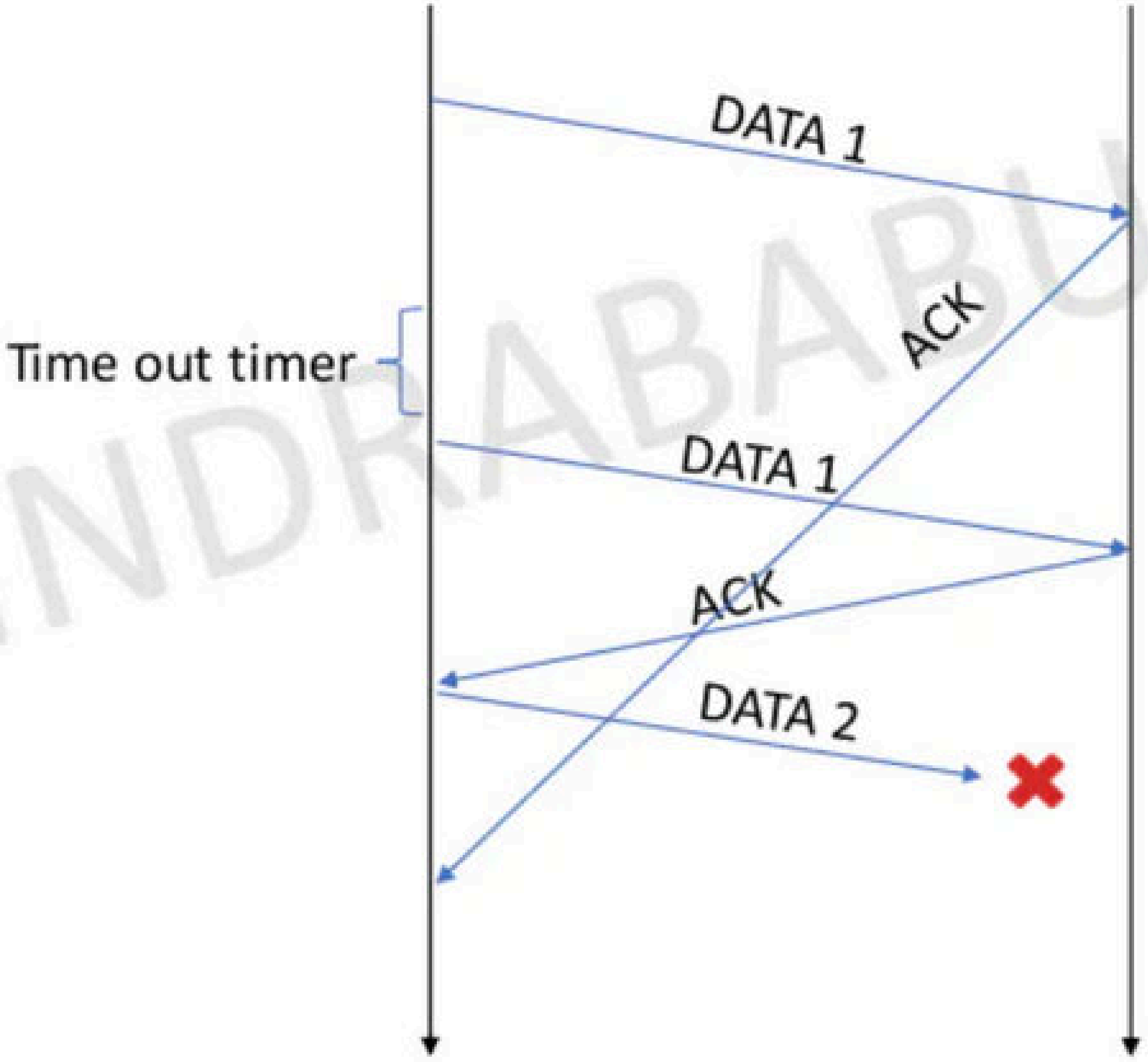


ACKNOWLEDGEMENT IS DELAYED
FOR DATA 1 AND THE PACKET IS RESENT
BY THE SENDER BY WAITING FOR TO TIMER

RECEIVER SENDS THE ACK FOR THE RESENT
DATA 1 PACKET

PROBLEMS WITH STOP AND WAIT

PROBLEM 3: Acknowledgement Delayed



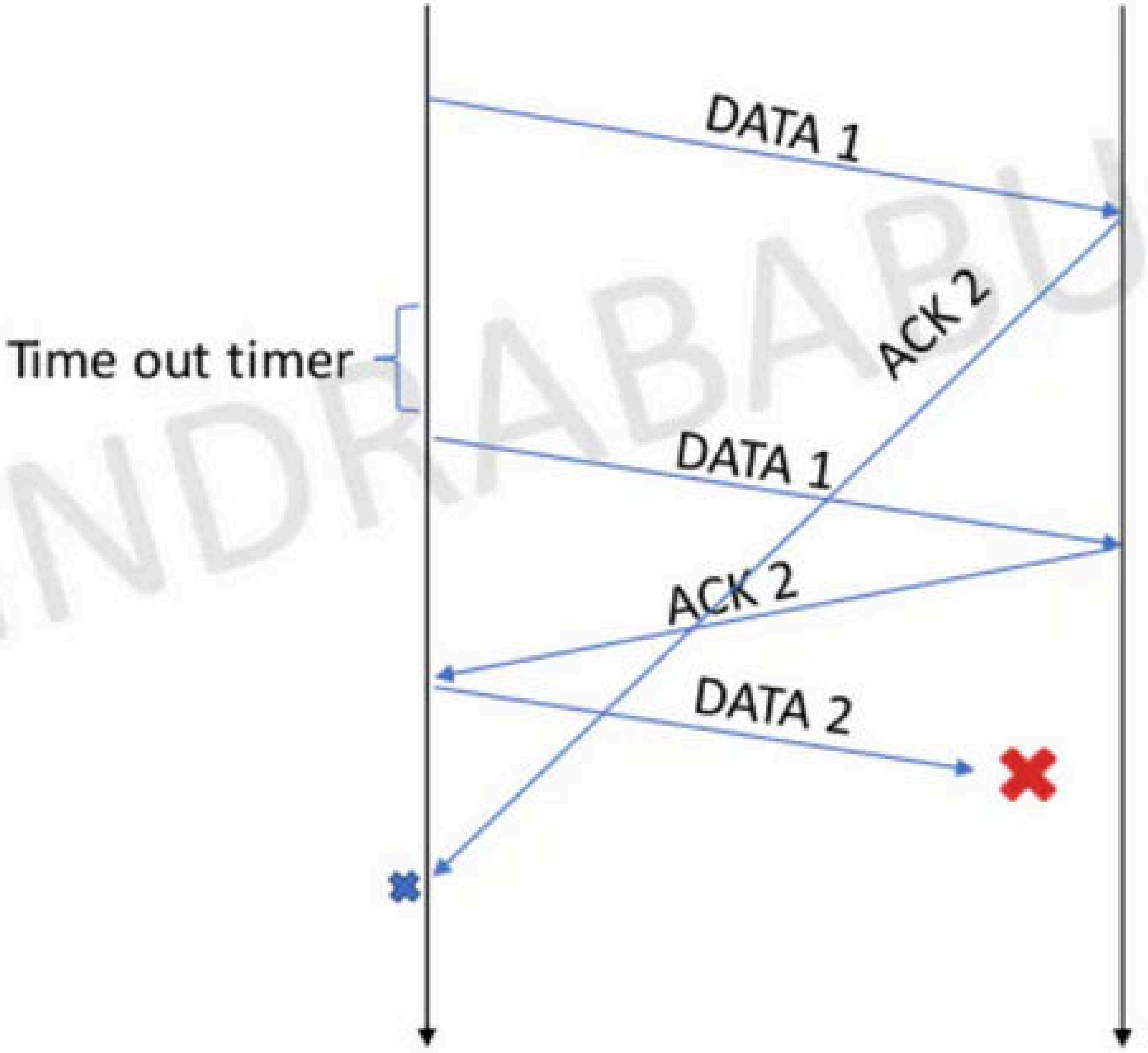
NOW, IMAGINE DATA 2 PACKET IS SENT AND GETS LOST.

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

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:

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

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?

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,

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

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

$=n(1/1-p)$

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

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 x 10^{-3} sec x 4 x 10^3 bits per sec) x 2
L bits >= 20 x 4 bits x 2
L >= 160

From here, frame size must be at least 160 bits.
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

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(A) 2500
(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.