Problem on IP Addressing

Complete Course on Computer Networks - Part I

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GBN SR SWP S&W → SW=1 RW=1

SW, η, Th, seq, no. bits

1 line/pages

filter

Computer Networks

Prac.

Sliding Window Protocol - Go Back N ← SWP Th

(i) Sender

(ii) Re

(iii) Seq

Sliding Window

Go Back N(GBN)

Selective Repeat(SR)

Go Back N

$GB\boxed{N} \rightarrow$ Sender window size.

Point 1 : Sender Window Size in GBN is N

Ex– If we say GB10 then sender window size is 10

Note : N must be greater than 1 (N>1)

$GB\boxed{10} \Rightarrow \boxed{W_S = 10}$

Example – Tt =1ms Tp=49.5ms BW =40Mbps. What is the efficiency(η) in case of GB10 ad also calculate throughput?

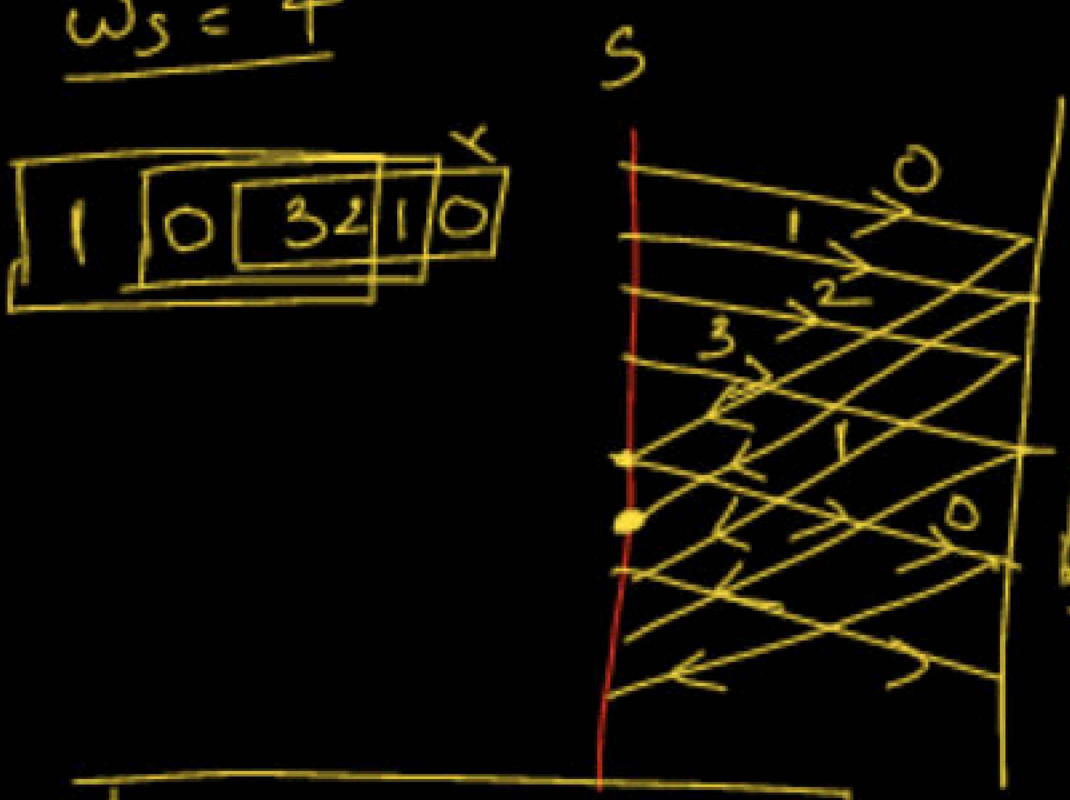
$$\boxed{\eta = \frac{\text{sender window size}}{1+2a}} = \frac{10}{100} = 10\ \%$$

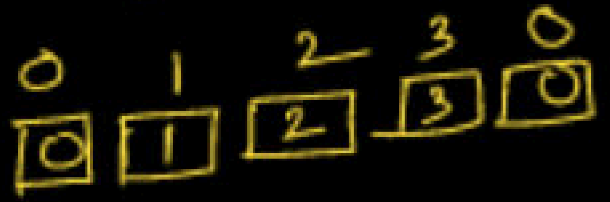
$$\text{Throughput} = \eta * BW = \frac{10}{100} * 40 = 4\ \text{Mbps}$$

$$\eta = \frac{W_S}{1+2a} = \frac{10}{100} = 10\%.$$

$$Th = \eta * BW = \frac{10}{100} \times 40 = 4\ \text{mbps}.$$

$w_S = 4$ $w_R = 1$

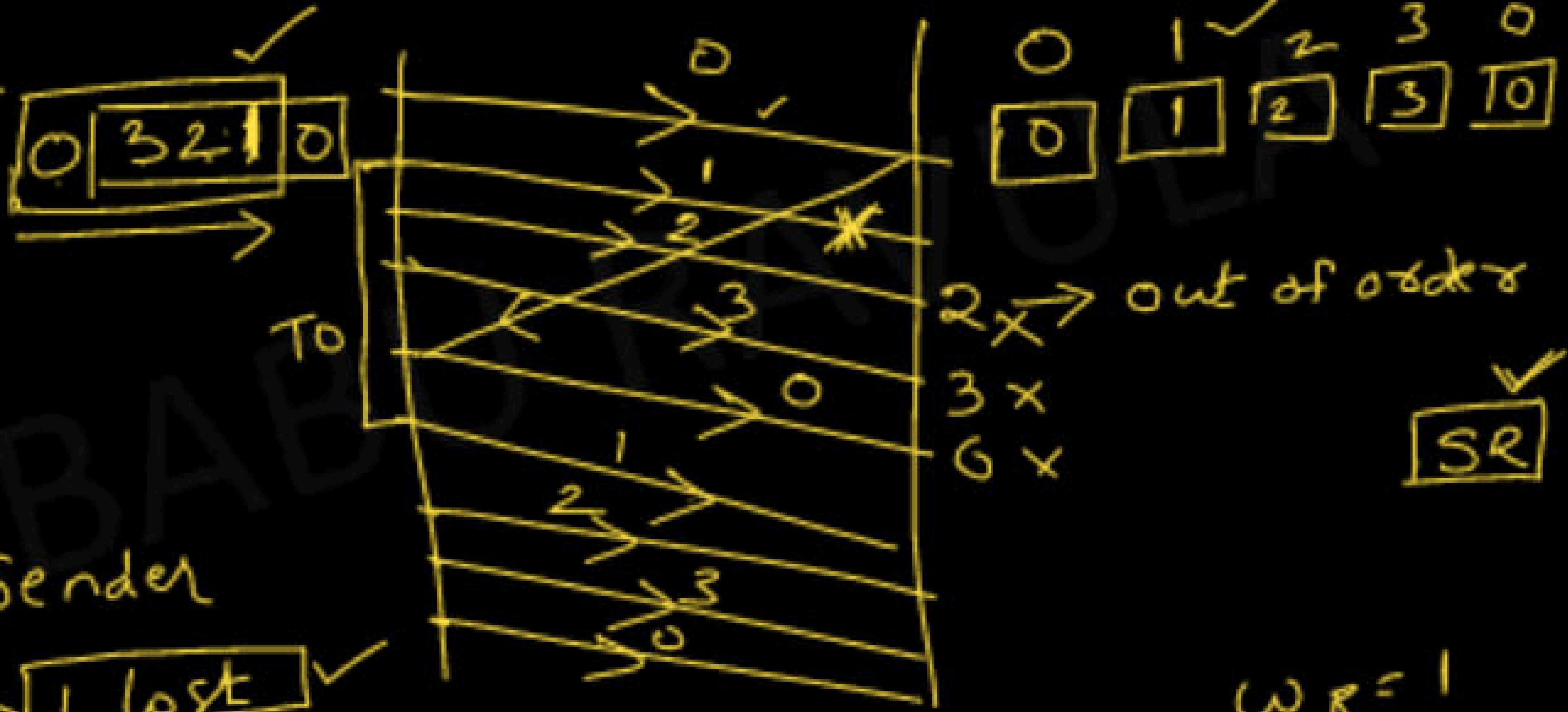




$w_S > 1$

$w_R = 1$

GBN ✓



SR ✓

1 packet is lost
entire is retrans.

Sender
- 1 lost ✓
- later packets are discarded
- retransmit all the out standing packets.

$w_R = 1$

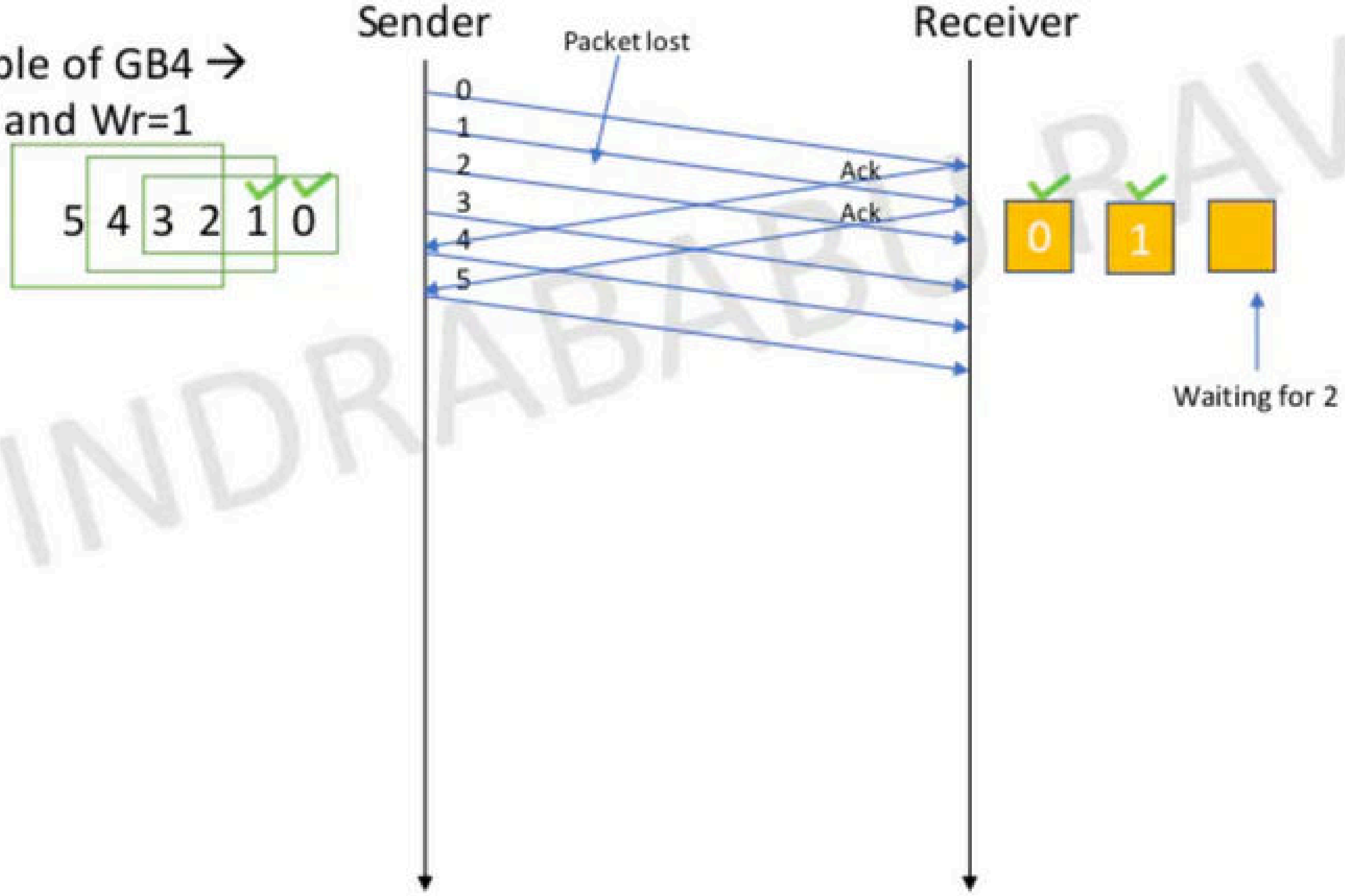
Rec → In order

GBN

Go Back N

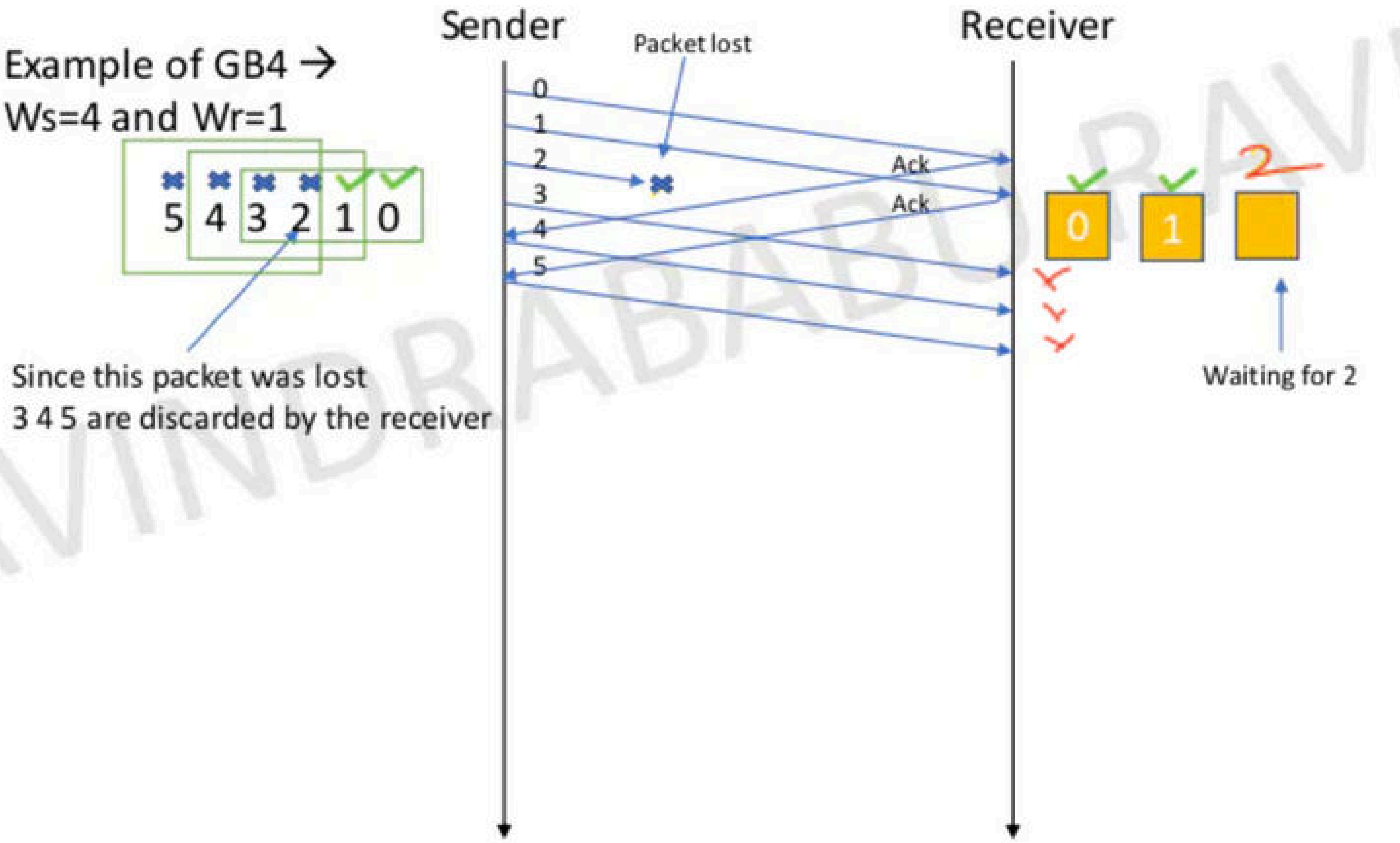
Point 2 : Receiver Window Size is 1

Example of GB4 →
Ws=4 and Wr=1



Go Back N

Point 2 : Receiver Window Size is 1 <u>Suppose packet 2 is lost</u>

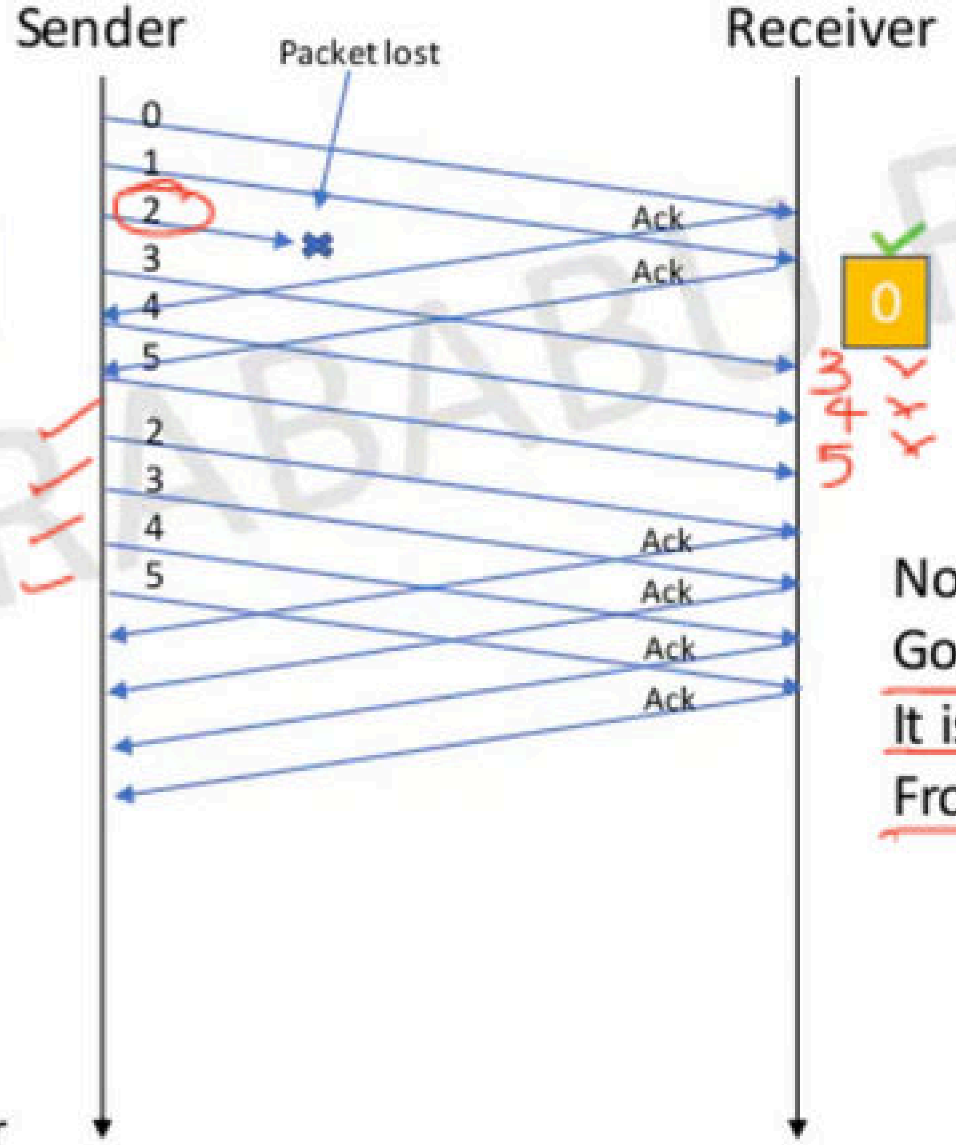


Go Back N

Point 2 : Receiver Window Size is 1

Example of GB4 →
Ws=4 and Wr=1

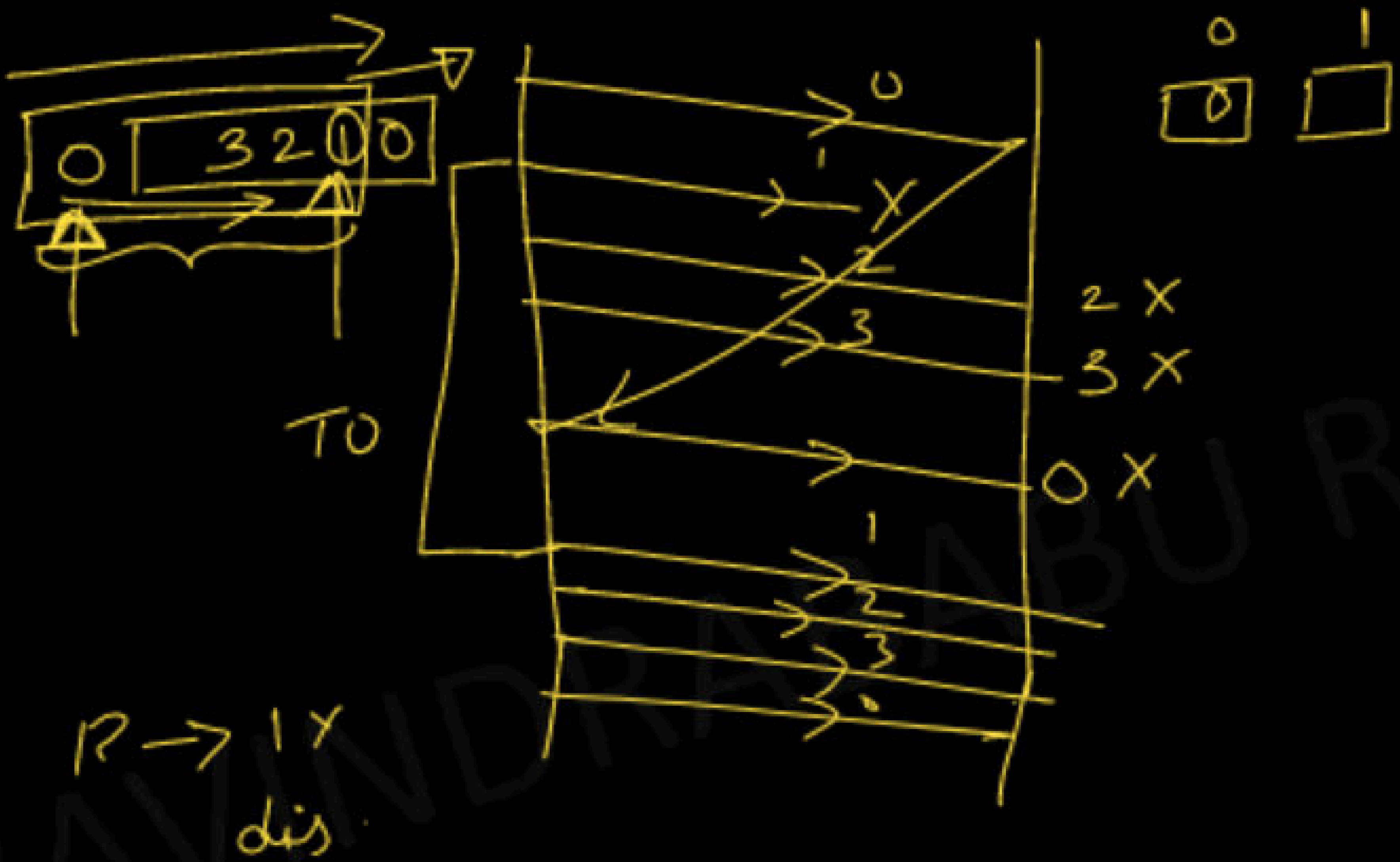
Since this packet was lost
2 3 4 5 were resent



Note:
Go back N is not going back from the lost
It is going back N from the last
From the example,

Go back 4

Note: The acknowledgement sent
By the receiver is not as shown,
it is just for the sake of understanding
this point, We will see the actual Ack point later



lost → N

last → N

GBN

$w_s = N$

$w_R = 1$

(1) Rec → out of order

Example: In GB4, from the 10 packets to be transmitted if every 6^{th} packet is lost. How many transmissions are required?

Solution:

$\boxed{1\ 2\ 3\ 4}$ 5 6 7 8 9 10

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$\boxed{1\ 2\ 3\ 4}\ 5\ 6\ 7\ 8\ 9\ 10$

$1\ \boxed{2\ 3\ 4\ 5}\ 6\ 7\ 8\ 9\ 10$

$1\ 2\ \boxed{3\ 4\ 5\ 6}\ 7\ 8\ 9\ 10$

$1\ 2\ 3\ \boxed{4\ 5\ 6\ 7}\ 8\ 9\ 10$

Example: In GB4, from the 10 packets to be transmitted if every 6^{th} packet is lost. How many transmissions are required?

Solution:

1 2 3 4 5 6 7 8 9 10

1 **2 3 4 5** 6 7 8 9 10

1 2 **3 4 5 6** 7 8 9 10

1 2 3 **4 5 6 7** 8 9 10

1 2 3 4 **5 6 7 8** 9 10

Example: In GB4, from the 10 packets to be transmitted if every 6th packet is lost. How many transmissions are required?

Solution:

1 2 3 4 5 6 7 8 9 10

1 2 3 4 5 6 7 8 9 10

1 2 3 4 5 6 7 8 9 10

1 2 3 4 5 6 7 8 9 10

1 2 3 4 5 6 7 8 9 10

1 2 3 4 5 6 7 8 9 10

1 2 3 4 5 6 7 8 9 6 7 8 9 10

Retransmitted

Window will go on sliding,

1 2 3 4 5 6 7 8 9 6 7 8 9 10

This is the 6th packet

GB4 $W_s = 4$

Example: In GB4, from the 10 packets to be transmitted if every 6th packet is lost. How many transmissions are required?

GB3

Solution:

1 2 3 4 5 6 7 8 9 10

1 **2 3 4 5** 6 7 8 9 10

1 2 **3 4 5 6** 7 8 9 10

1 2 3 **4 5 6 7** 8 9 10

1 2 3 4 **5 6 7 8** 9 10

1 2 3 4 5 **6 7 8 9** 10

1 2 3 4 5 **6 7 8 9** 6 7 8 9 10

Retransmitted

Window will go on sliding,

1 2 3 4 5 6 7 8 9 6 7 **8 9 10**

This is the 6th packet

1 2 3 4 5 6 7 8 9 6 7 **8 9 10** 8 9 10

Retransmitted

Answer: 17 transmissions

7 1

S&W 1U 6th
1 I → many

$S\&W = \frac{1}{1+2a}$

$GB4 = \frac{4}{1+2a}$ 4X

RT GBN > SW

Transmissions → 15

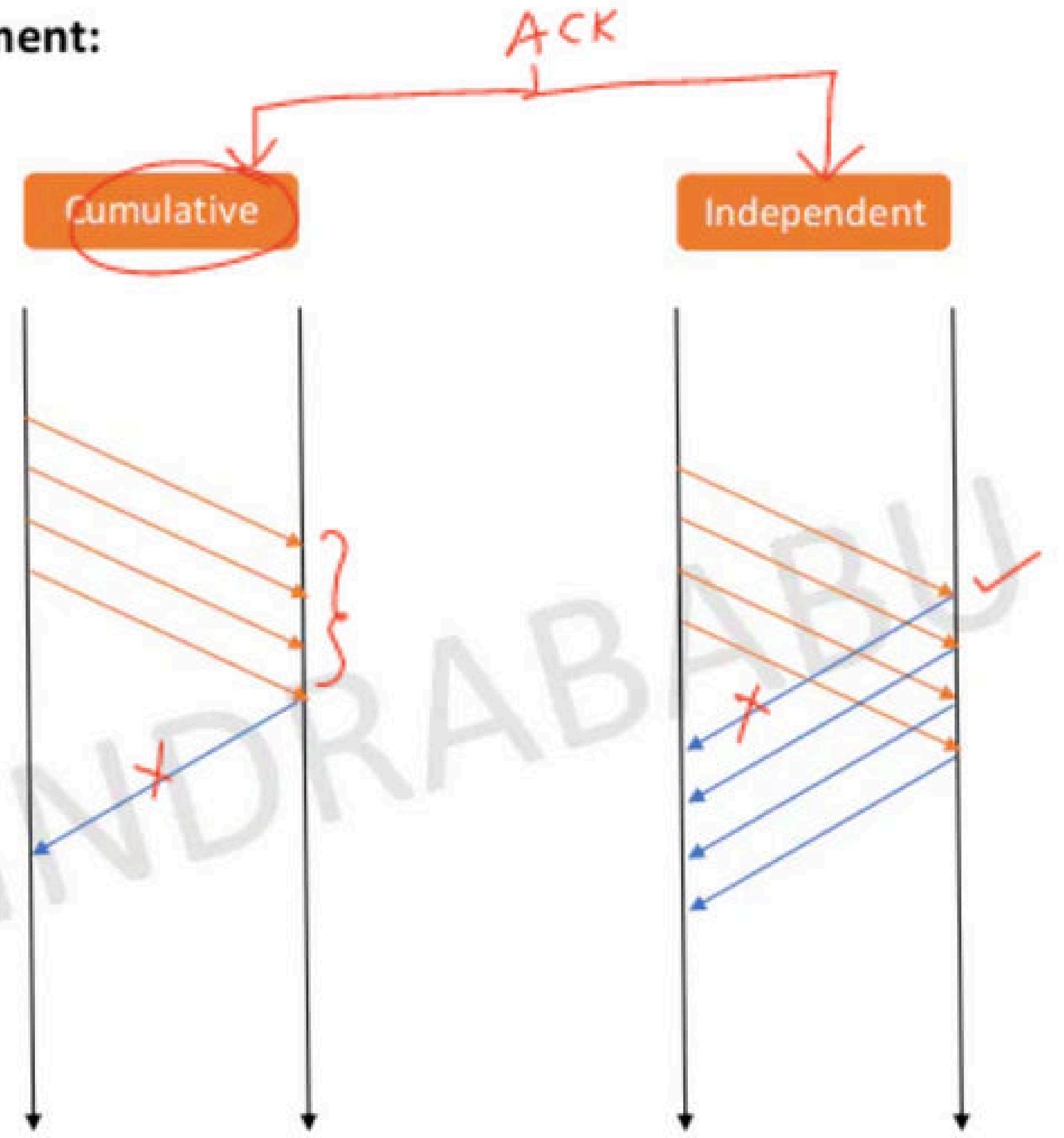
10 GB4

17

S&W → R

GBN → eff.

Types of Acknowledgement:



Advantage:
Less Traffic

Disadvantage:
Less Reliable

Advantage:
High Reliable

Disadvantage:
High Traffic

1 2 3 4 5 $\boxed{6\ 7\ 8}$ 6 7 8 $\boxed{9\ 10}$ 9 10 → 15

15 − 10 = 5

GBS

$\boxed{W_S = 5}$

A) 18 B) 19 C) 21 D) sleeping

1 2 3 4 5 $\boxed{6\ 7\ 8\ 9\ 10}$ 6 $\boxed{7\ 8\ 9\ 10}$ 7 8 $\boxed{9\ 10}$ 9 10

$W_S = 5$ ✓
21

η ↑

RT ↑

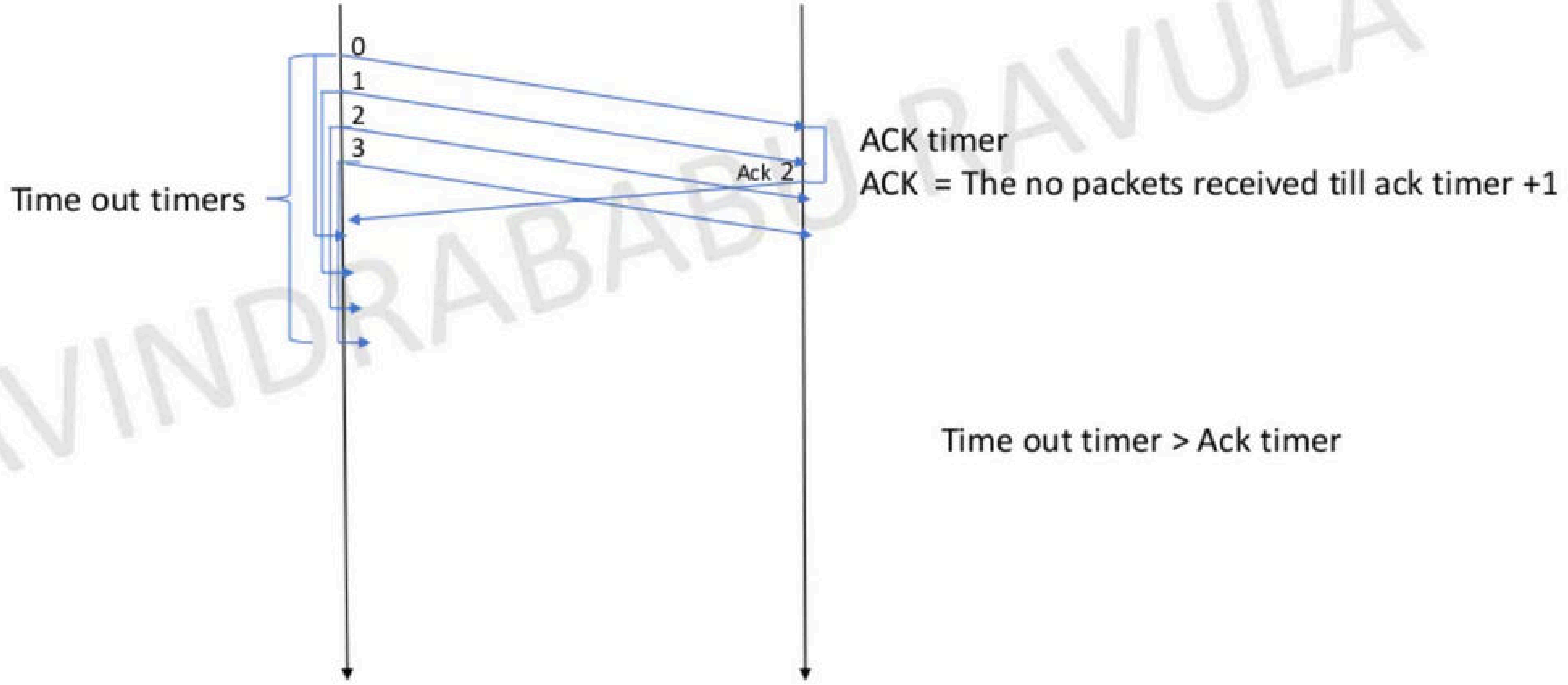
$W_S = 4$ ✓
17

$W_S = 3$ ✓
15

$W_S = 1$ ✓
11

Go Back N

Point 3 : Cumulative Acknowledgement in GBN

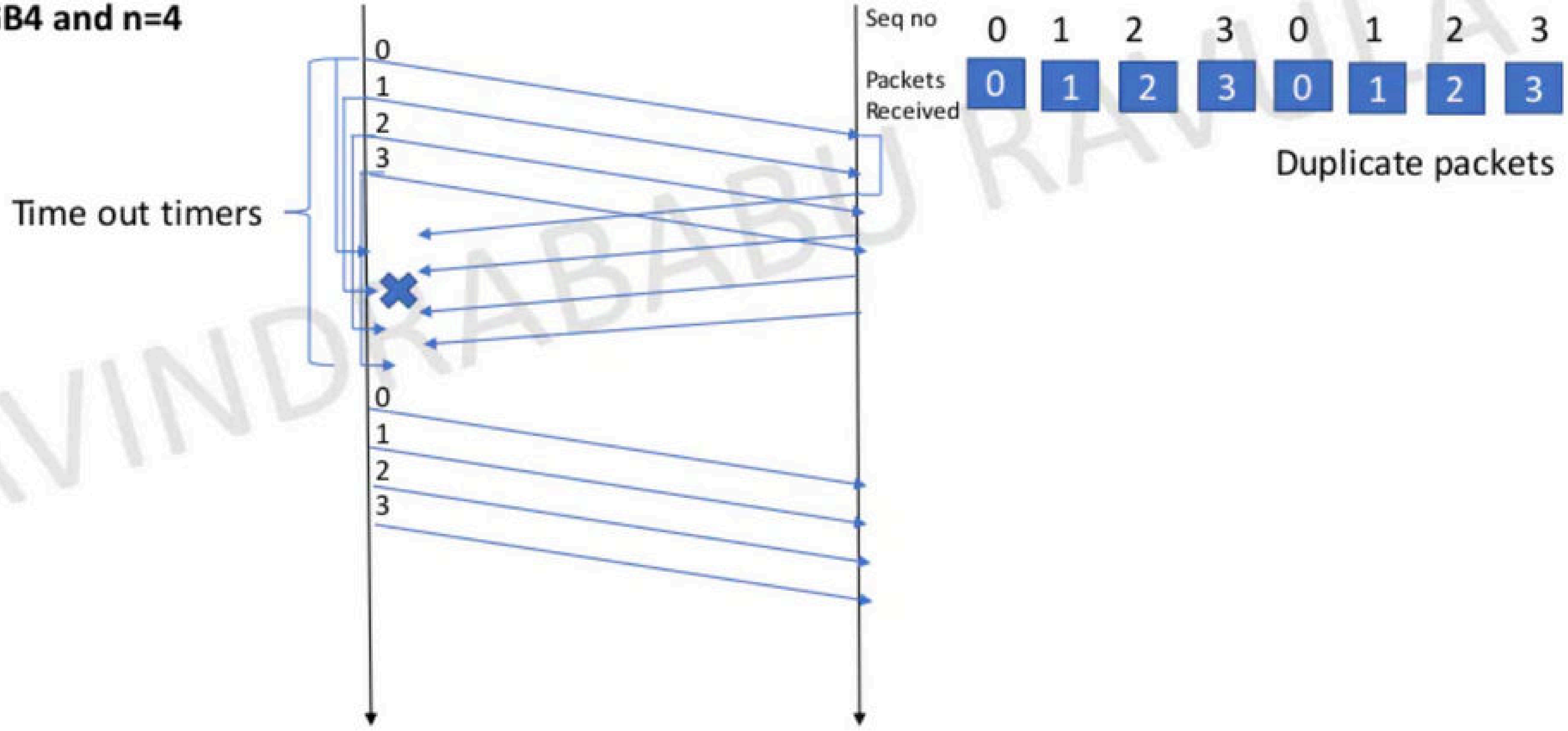


Time out timer > Ack timer

Relation between Window Size and Sequence Nos

Let us consider few scenarios

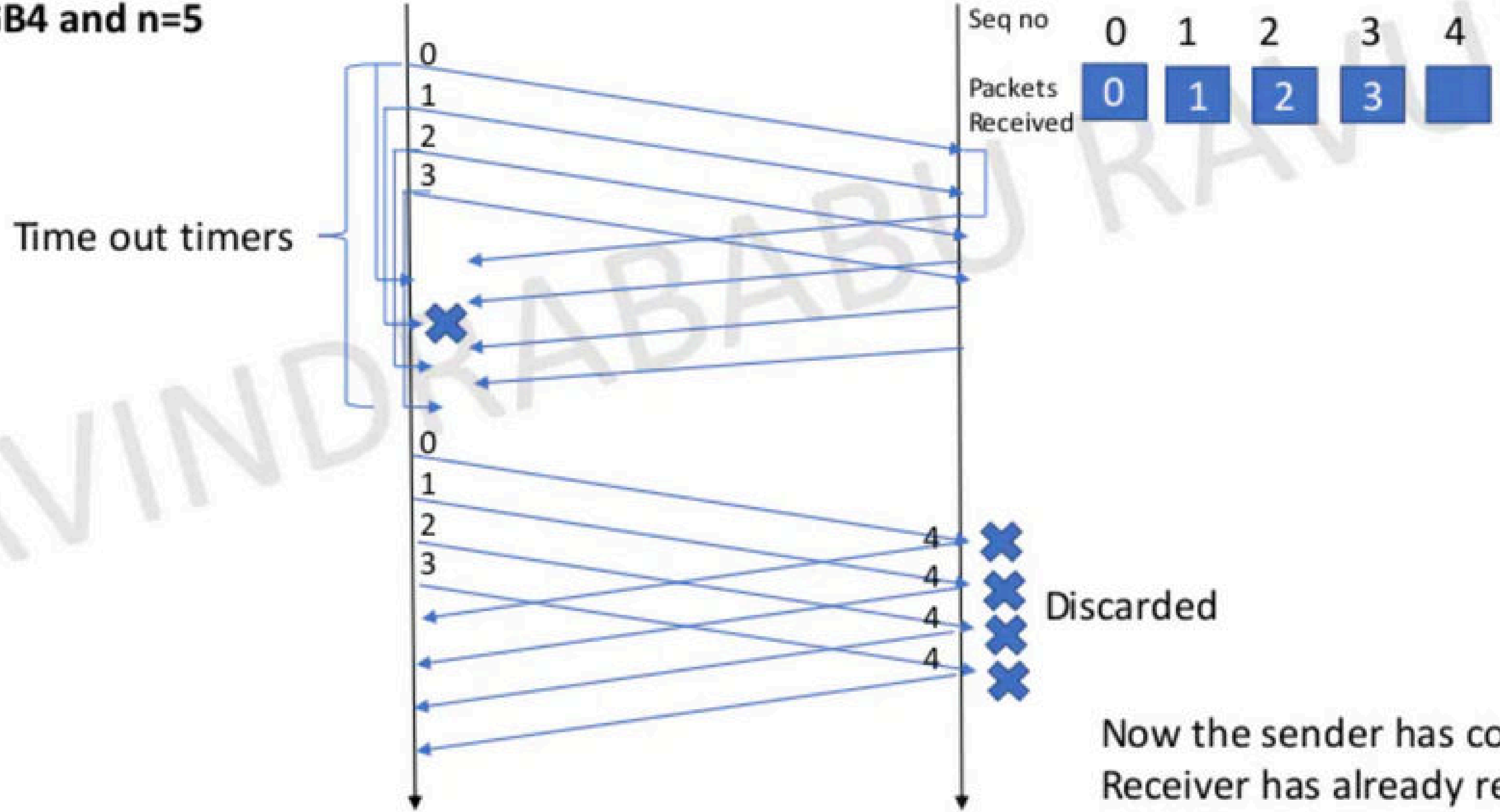
1.) GB4 and n=4



Relation between Window Size and Sequence Nos

Let us consider few scenarios

2.) GB4 and n=5

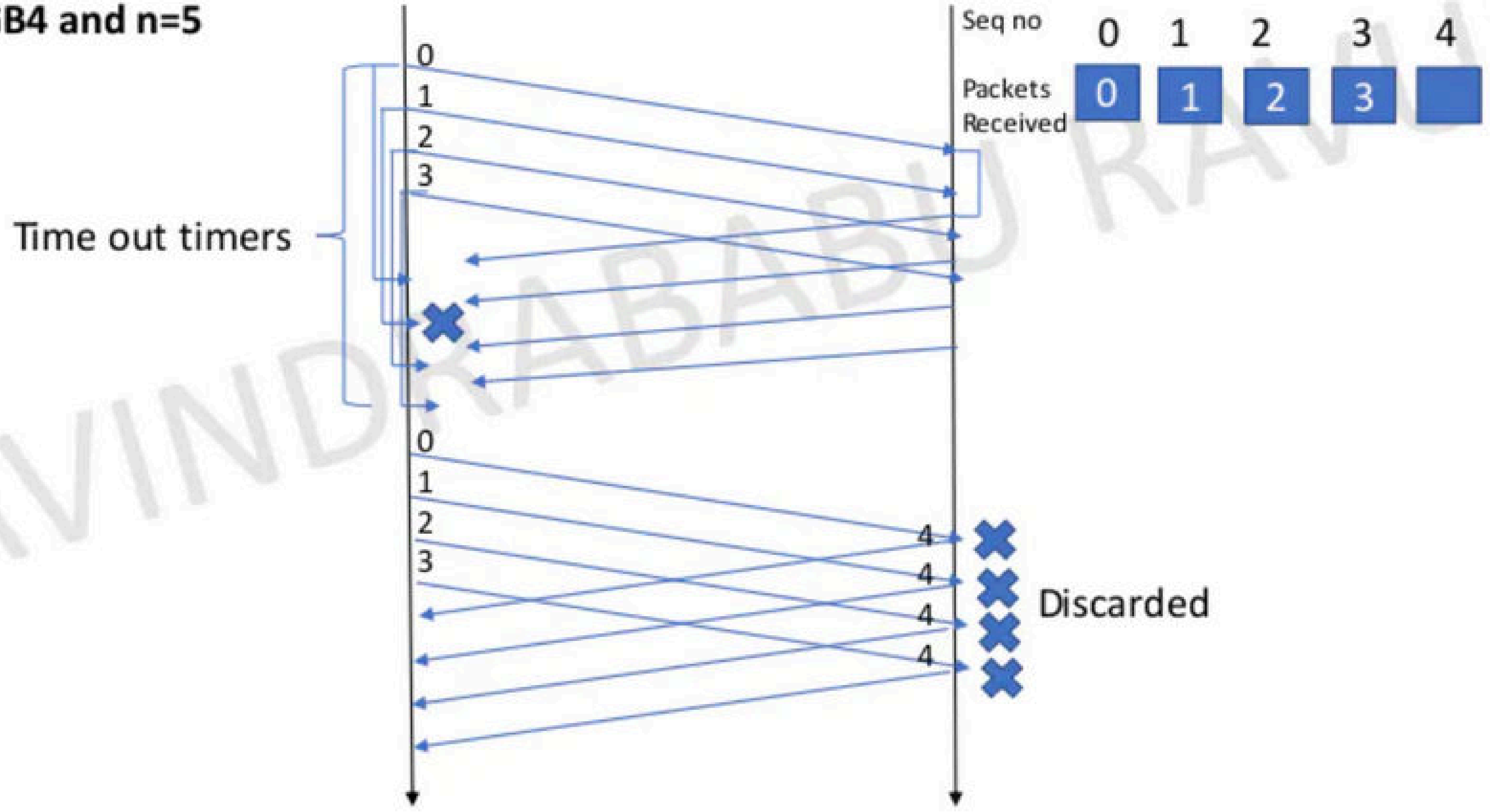


Now the sender has come to know that Receiver has already received 0,1,2,3

Relation between Window Size and Sequence Nos

Let us consider few scenarios

2.) GB4 and n=5



From the 2 examples, we can say that,

Available seq nos. >= Sender window size + Receiver window size

Number of bits required in the sequence no field = $\lceil \log_2 (N+1) \rceil$

We can say that, If

1.)Ws= N Wr=1 $\boxed{\begin{array}{l}\text{Sequence no= N+1} \\ \text{Bits} = \lceil \log_2 (N+1) \rceil\end{array}}$

2.)Sequence no=N $\boxed{\text{Ws = N-1} \quad \text{Wr=1}}$

3.)Bits required in seq no field = k $\boxed{\text{Seq no} = 2^k \quad \text{Ws} = 2^k - 1 \quad \text{Wr=1}}$

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Sliding Window protocol – Selective Repeat, Comparisons of Flow Control Protocols

Selective Repeat

Point 1:Ws>1

Example – Tt =1ms Tp=49.5ms Ws=50 BW= 4Mbps. What is the efficiency(η) in case of SR ad also calculate throughput?

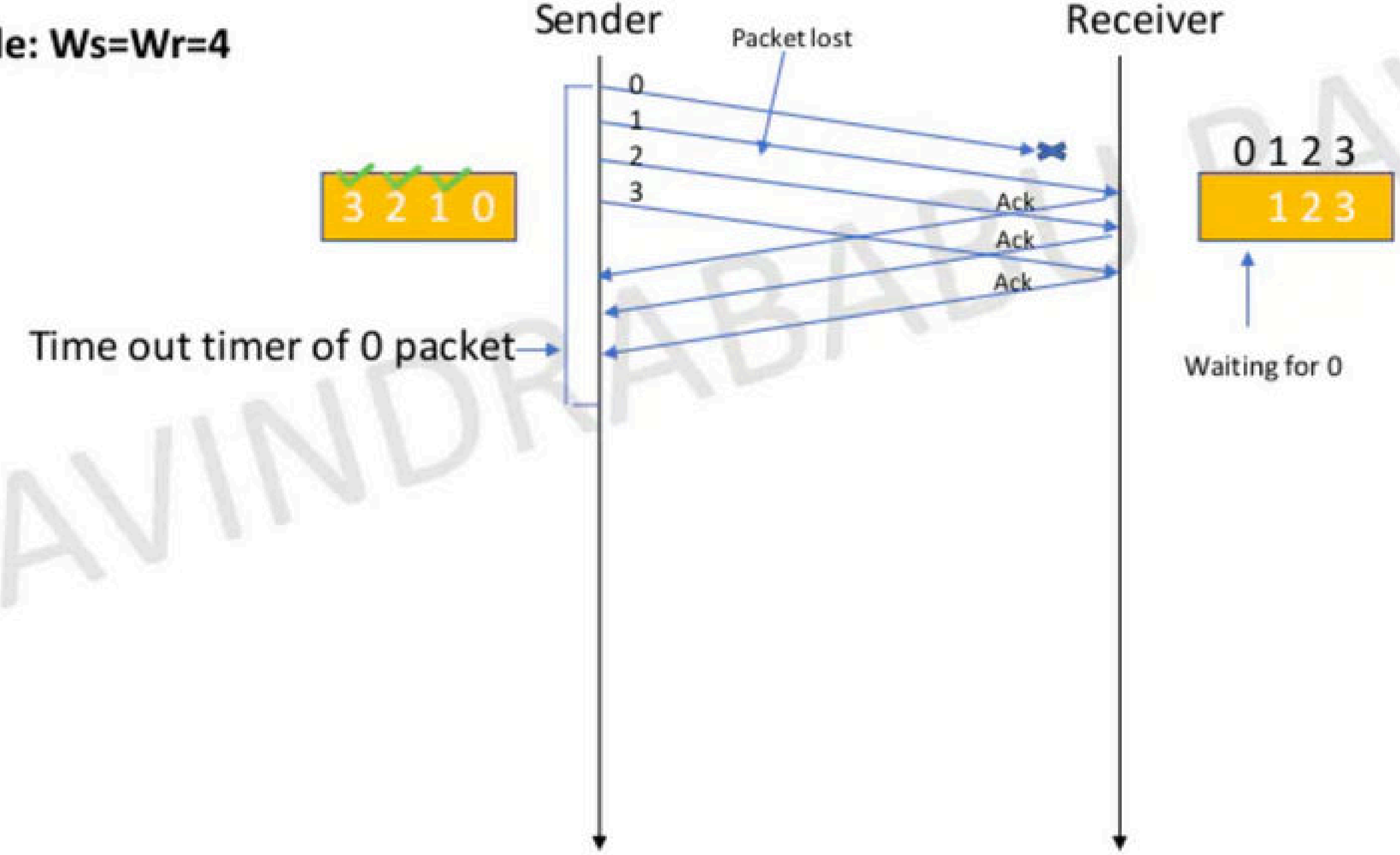
$$\eta = \frac{\text{sender window size}}{1+2a} = \frac{50}{100} = 50\ \%$$

$$\text{Throughput} = \eta * BW = \frac{50}{100} * 4 = 2\ \text{Mbps}$$

Selective Repeat

Point 2: Ws = Wr

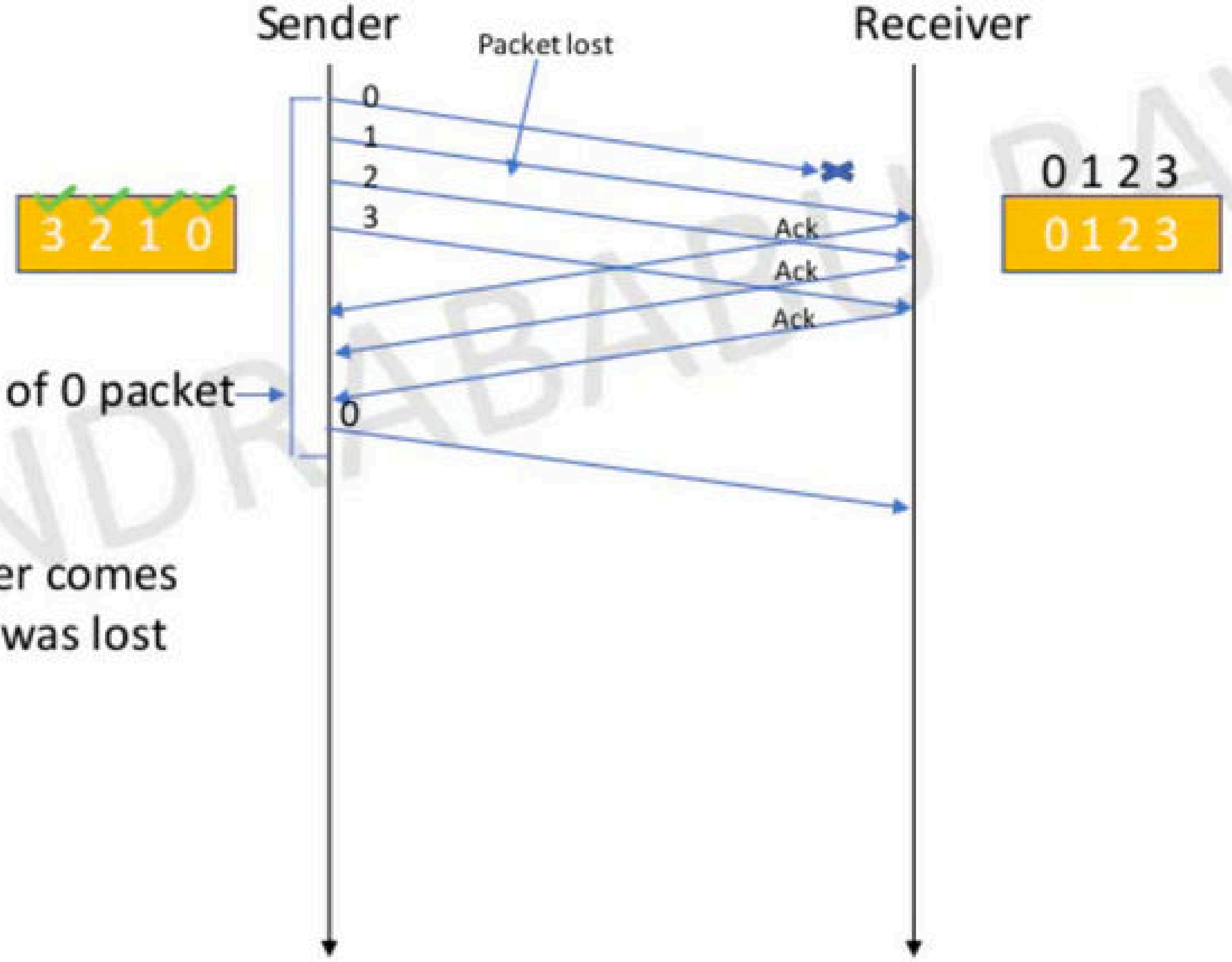
Example: Ws=Wr=4



Selective Repeat

Point 2: Ws = Wr

Example: Ws=Wr=4



Thus, the sender comes
to know that 0 was lost
And is resent

Example: In SR, from the 10 packets to be transmitted if every 5th packet is lost.
How many transmissions are required?

Solution:

1 2 3 4 5 6 7 8 9 10

1 2 3 4 5 $\boxed{5}$ 6 7 8 9 10
resent

1 2 3 4 5 5 6 7 8 9 $\boxed{9}$ 10
resent

Therefore, 12 transmissions are required

Selective Repeat

Point 3: About Acknowledgement

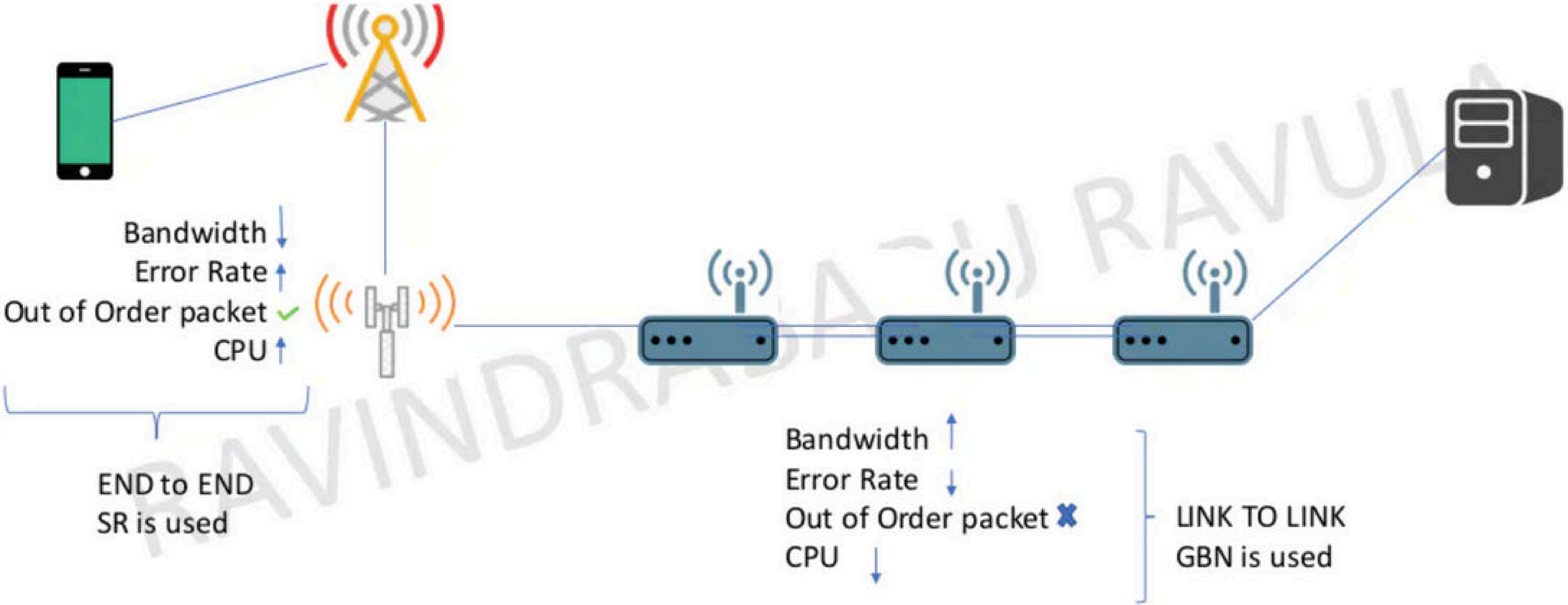
In GBN,

The ack was cumulative and the receiver silently discards the out of order packets
Also in case of the corrupted packet, the receiver silently discards the packet without notifying the sender about it.
In both the cases, the sender waits for time out timer and then resends the entire window of packets.

In SR, The ack is **independent**.
If the Receiver does not receive any packet,
The sender sends that packet after time out timer.

If the receiver receives a corrupted packet then Receiver sends a **Negative Acknowledgement** to the sender of that packet

	Stop and Wait ARQ	Go back N	Selective Repeat	Remarks
Efficiency	1 / (1+2a)	N / (1+2a)	N / (1+2a)	Go back N and Selective Repeat gives better efficiency than Stop and Wait ARQ.
Window Size	Sender Window Size = 1 Receiver Window Size = 1	Sender Window Size = N Receiver Window Size = 1	Sender Window Size = N Receiver Window Size = N	Buffer requirement in Selective Repeat is very large. If the system does not have lots of memory, then it is better to choose Go back N.
Minimum number of sequence numbers required	2	N+1	2 x N	Selective Repeat requires large number of bits in sequence number field.
Retransmissions required if a packet is lost	Only the lost packet is retransmitted	The entire window is retransmitted	Only the lost packet is retransmitted	Selective Repeat is far better than Go back N in terms of retransmissions required.
Bandwidth Requirement	Bandwidth requirement is Low	Bandwidth requirement is high because even if a single packet is lost, entire window has to be retransmitted. Thus, if error rate is high, it wastes a lot of bandwidth.	Bandwidth requirement is moderate	Selective Repeat is better than Go back N in terms of bandwidth requirement.
CPU usage	Low	Moderate	High due to searching and sorting required at sender and receiver side	Go back N is better than Selective Repeat in terms of CPU usage.
Acknowledgements	Uses independent acknowledgement for each packet	Uses cumulative acknowledgements (but may use independent acknowledgements as well)	Uses independent acknowledgement for each packet	Sending cumulative acknowledgements reduces the traffic in the network but if it is lost, then the ACKs for all the corresponding packets are lost.


Bandwidth ↓
Error Rate ↑
Out of Order packet ✓
CPU ↑
END to END
SR is used
Bandwidth ↑
Error Rate ↓
Out of Order packet ✗
CPU ↓
LINK TO LINK
GBN is used

Computer Networks

Practice problems on Sliding Window protocol – GBN and SR and GATE PYQ

Problem-01:

A 3000 km long trunk operates at 1.536 Mbps and is used to transmit 64 byte frames and uses sliding window protocol. If the propagation speed is 6 μsec / km, how many bits should the sequence number field be?

Solution-

Given-

- Distance = 3000 km
- Bandwidth = 1.536 Mbps
- Packet size = 64 bytes
- Propagation speed = 6 μsec / km

Calculating Transmission Delay-

Transmission delay (T_t)
= Packet size / Bandwidth
= 64 bytes / 1.536 Mbps
= (64 x 8 bits) / (1.536 x 10^6 bits per sec)

= 333.33 μsec

Calculating Propagation Delay-

For 1 km, propagation delay = 6 μsec
For 3000 km, propagation delay = 3000 x 6 μsec = 18000 μsec

Calculating Value Of 'a'-

a = T_p / T_t
a = 18000 μsec / 333.33 μsec
a = 54

Calculating Bits Required in Sequence Number Field-

Bits required in sequence number field

$= \lceil \log_2(1+2a) \rceil$

$= \lceil \log_2(1 + 2 \times 54) \rceil$

$= \lceil \log_2(109) \rceil$

$= \lceil 6.76 \rceil$

= 7 bits

Thus,

- Minimum number of bits required in sequence number field = 7
- With 7 bits, number of sequence numbers possible = 128
- We use only (1+2a) = 109 sequence numbers and rest remains unused.

Problem-02: GATE 2004(IT)

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

Solution-

Given-
- Bandwidth = 20 Kbps
- Propagation delay (T_p) = 400 ms
- Frame size = 100 bytes
- Go back N is used where N = 10

Calculating Transmission Delay-

Transmission delay (T_t)
= Frame size / Bandwidth
= 100 bytes / 20 Kbps

= (100 x 8 bits) / (20 x 10^3 bits per sec)
= 0.04 sec
= 40 msec

Calculating Value Of 'a'-

$a = T_p / T_t$
a = 400 msec / 40 msec
a = 10

Calculating Efficiency-

Efficiency (η)
= N / (1+2a)
= 10 / (1 + 2 x 10)
= 10 / 21
= 0.476
= 47.6 %

Calculating Maximum Data Rate Possible-

Maximum data rate possible or Throughput
= Efficiency x Bandwidth
= 0.476 x 20 Kbps
= 9.52 Kbps
≅ 10 Kbps

Thus, Correct Option is (B)

Problem-03:GATE 2008(IT)

A 1 Mbps satellite link connects two ground stations. The altitude of the satellite is 36504 km and speed of the signal is 3 x 10^8 m/sec. What should be the packet size for a channel utilization of 25% for a satellite link using go back 127 sliding window protocol?

1. 120 bytes
2. 60 bytes
3. 240 bytes
4. 90 bytes

Solution-

Given-

- Bandwidth = 1 Mbps
- Distance = 2 x 36504 km = 73008 km
- Propagation speed = 3 x 10^8 m/sec
- Efficiency = 25% = 1/4
- Go back N is used where N = 127

Calculating Transmission Delay-

Transmission delay (T_t)
= Packet size / Bandwidth
= L bits / 1 Mbps
= L μsec

Calculating Propagation Delay-

Propagation delay (T_p)
= Distance / Speed
= $(73008 \times 10^3$ m) / (3×10^8 m/sec)
= 24336×10^{-5} sec
= 243360 μsec

Calculating Value of 'a'-

$a = T_p / T_t$
a = 243360 μsec / L μsec
a = 243360 / L

Calculating Packet Size-

Efficiency (η) = N / (1+2a)
Substituting the values, we get-
1/4 = 127 / (1 + 2 x 243360 / L)
1/4 = 127 x L / (L + 486720)
L + 486720 = 508 x L
507 x L = 486720
L = 960

From here, packet size = 960 bits or 120 bytes.
Thus, Correct Option is (A).

Problem-04:GATE 2016(CS)

Consider a 128×10^3 bits/sec satellited communication link with one way propagation delay of 150 msec. 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 ________ .

Solution-

Given-

- Bandwidth = 128×10^3 bits/sec
- Propagation delay (T_p) = 150 msec
- Frame size = 1 KB

Now,

- To achieve 100% utilization, efficiency must be 100%.
- Efficiency is 100% when sender window size is optimal i.e. 1+2a

Calculating Transmission Delay-

Transmission delay (T_t)
= Frame size / Bandwidth
= 1 KB / (128 x 10^3 bits per sec)
= (1 x 2^{10} x 8 bits) / (128 x 10^3 bits per sec)
= 64 msec

Calculating Value of 'a'-

$a = T_p / T_t$
a = 150 msec / 64 msec
a = 2.34

Calculating Optimal Sender Window Size-

Optimal sender window size
= 1 + 2a
= 1 + 2 x 2.34
= $\lceil 5.68 \rceil$
= 6

Calculating Number Of Sequence Numbers Required-

In SR Protocol, sender window size and receiver window size are same.

So, sender window size = receiver window size = 6

Now,

For any sliding window protocol, minimum number of sequence numbers required

= Sender window size + Receiver window size

= 6 + 6

= 12

Calculating Bits Required in Sequence Number Field-

To have 12 sequence numbers,

Minimum number of bits required in sequence number field

= $[\log_2(12)]$

= 4

Thus,

- Minimum number of bits required in sequence number field = 4
- With 4 bits, number of sequence numbers possible = 16
- We use only 12 sequence numbers and rest 4 remains unused.

Computer Networks

Access Control Methods

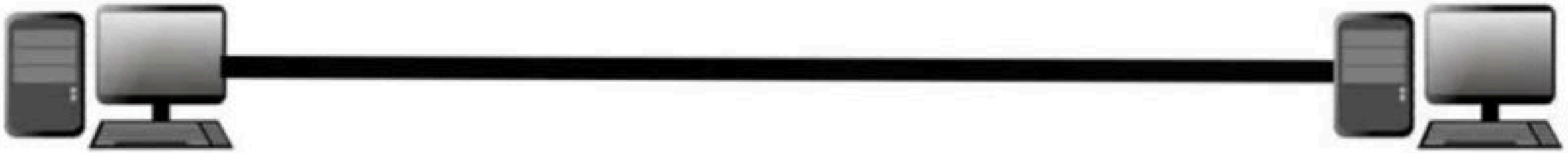
Links

Broadcast Links

Point to Point Links

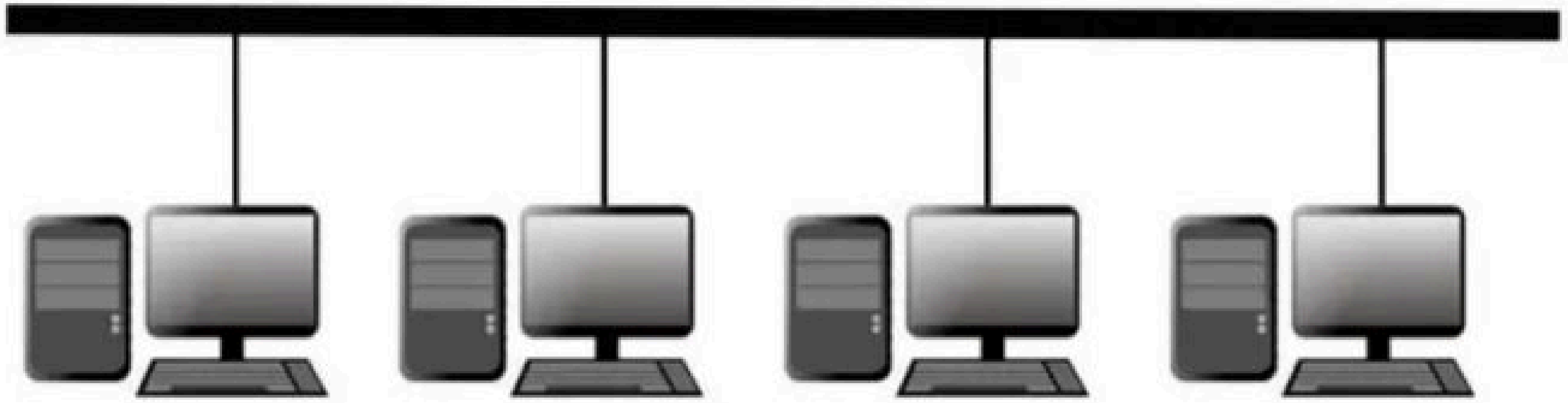
1. Point to Point Link-

- Point to Point link is a dedicated link that exists between the two stations.
- The entire capacity of the link is used for transmission between the two connected stations only.



2. Broadcast Link-

- Broadcast link is a common link to which multiple stations are connected.
- The capacity of the link is shared among the connected stations for transmission.

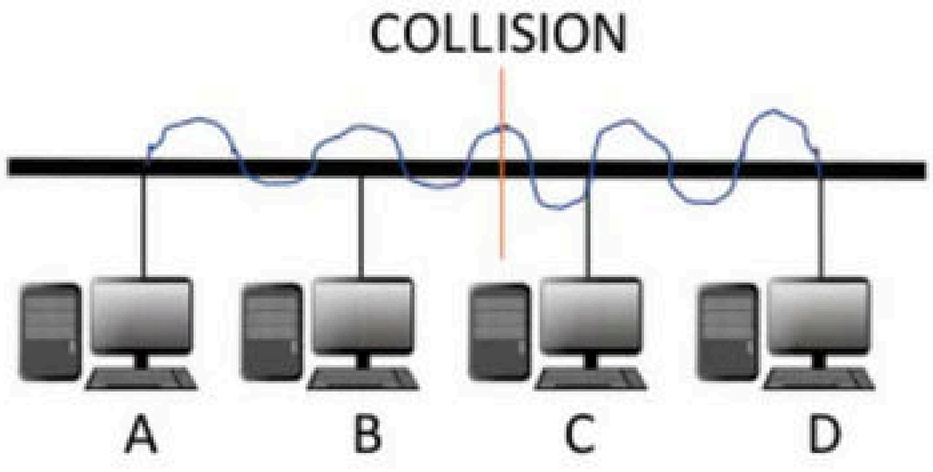


Access Control

Access Control is a mechanism that controls the access of stations to the transmission link.

Broadcast links require the access control.
This is because the link is shared among several stations.

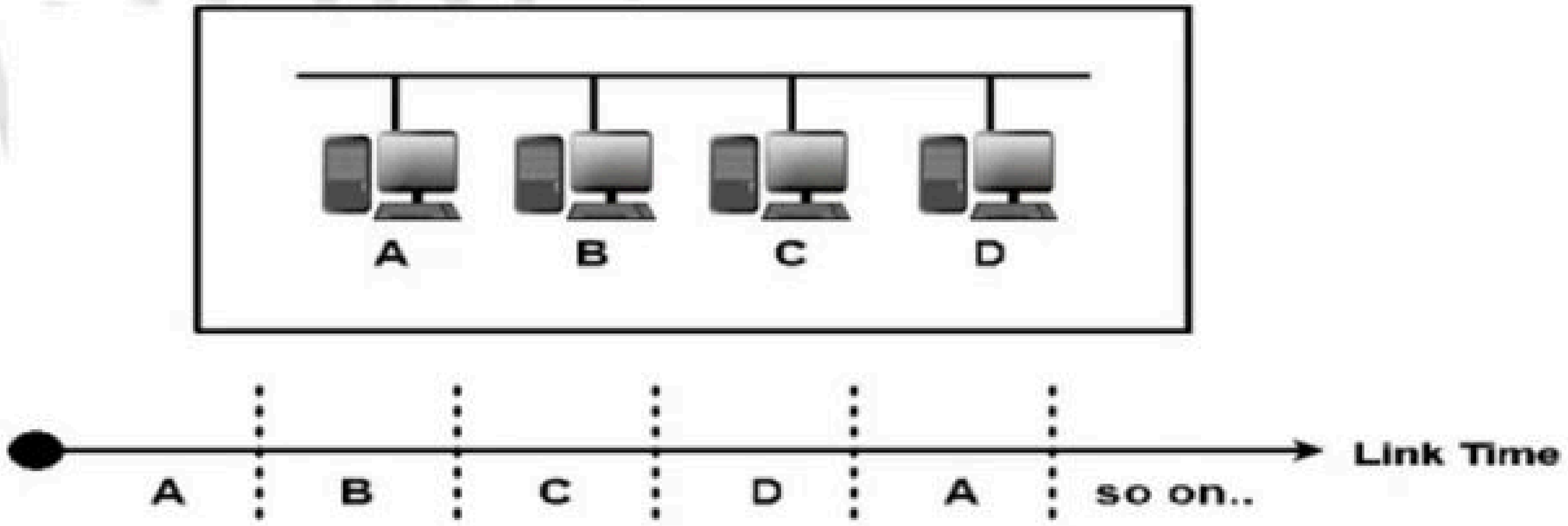
Example:
Two stations A and D starts transmitting their data packets simultaneously.
This situation gives rise to a collision between the data packets transmitted by them.
Thus, to prevent the collision or to deal with it, access control is needed



Access Control Methods

1.)Time Division Multiplexing-

In Time Division Multiplexing (TDM),
•Time of the link is divided into fixed size intervals called as **time slots** or **time slices**.
•Time slots are allocated to the stations in **Round Robin** manner.
•Each station transmit its data during the time slot allocated to it.
•In case, station does not have any data to send, its time slot goes waste.



Time Division Multiplexing

Size Of Time Slots-

The size of each time slot is kept such that each station gets sufficient time for the following tasks-

- To put its data packet on to the transmission link
- Last bit of the packet is able to get out of the transmission link

$$\text{Size of each time slot} = T_t + T_p$$

NOTE-

To keep the size of time slots constant,

- We have assumed that all the stations want to send the packets of same size.
- This keeps T_t constant for all the stations.
- We have considered the worst case when both the stations are present at the two extreme ends.
- This ensures T_p will be maximum and all the stations will get sufficient time to propagate their data.

Efficiency-

Efficiency (η) = Useful Time / Total Time

- Useful time = Transmission delay of data packet = T_t
- Useless time = Propagation delay of data packet = T_p

$$\boxed{\text{Efficiency } (\eta) = \frac{T_t}{T_t + T_p}}$$

OR

$$\boxed{\text{Efficiency } (\eta) = \frac{1}{1 + a} \quad \text{where } a = \frac{T_p}{T_t}}$$

Important Formulas-

- Size of each time slot in Time Division Multiplexing = $T_t + T_p$
- Efficiency (η) = $1 / (1+a)$ where $a = T_p / T_t$
- Effective Bandwidth / Bandwidth Utilization / Throughput = Efficiency(η) x Bandwidth
- Maximum Available Effective Bandwidth = Total number of stations x Bandwidth requirement of 1 station

Disadvantage-

- If any station does not have the data to send during its time slot, then its time slot goes waste.
- This reduces the efficiency.
- This time slot could have been allotted to some other station willing to send data.

Problem-

If transmission delay and propagation delay of a packet in Time Division Multiplexing is 1 msec each at 4 Mbps bandwidth, then-

1. Find the efficiency.
2. Find the effective bandwidth.
3. How many maximum stations can be connected to the network if each station requires 2 Kbps bandwidth?

Solution-

Given-

- Transmission delay (T_t) = 1msec
- Propagation delay (T_p) = 1msec
- Bandwidth = 4 Mbps

For a TDM Network,

$$\text{Efficiency } (\eta) = 1 / 1+a \text{ where } a = T_p / T_t$$

Calculating Value Of ‘a’-

$a = T_p / T_t$
$a = 1 \text{ msec} / 1 \text{ msec}$
$a = 1$

Calculating Efficiency-

Efficiency (η)
$= 1 / (1+a)$
$= 1 / (1 + 1)$
$= 1 / 2$
$= 0.5$
$= 50\%$

Effective Bandwidth = Efficiency (η) x Bandwidth

= 0.5 x 4 Mbps

= 2 Mbps

Maximum Effective Bandwidth=Total number of stations x Bandwidth requirement of 1 station

Let the total number of stations that can be connected be N.

Then, we have-

2 Mbps = N x 2 Kbps

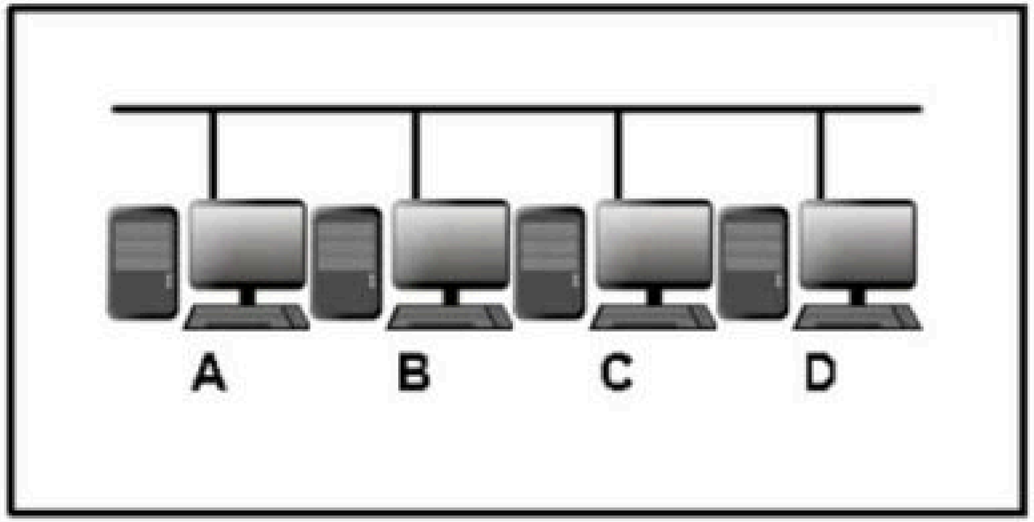
N = 1000

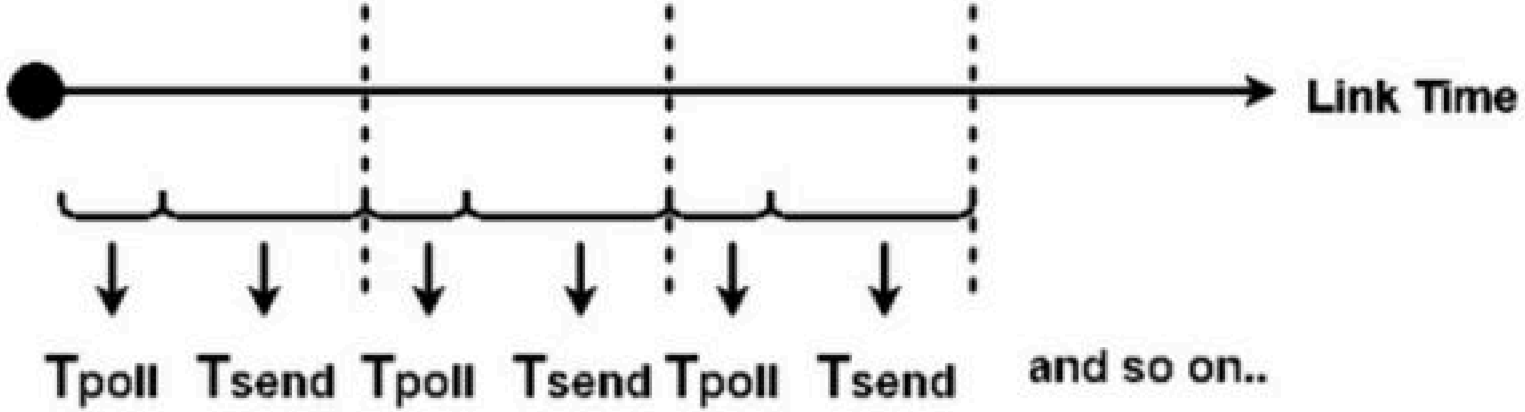
Thus, maximum 1000 stations can be connected.

2.)Polling-

In this access control method,

- A polling is conducted in which all the stations willing to send data participates.
- The polling algorithm chooses one of the stations to send the data.
- The chosen station sends the data to the destination.
- After the chosen station has sent the data, the cycle repeats.





Polling Access Control Method

Here-

- T_{poll} = Time taken for polling
- T_{send} = Time taken for sending the data = Transmission delay + Propagation delay = $T_t + T_p$

Efficiency-

Efficiency (η) = Useful Time / Total Time

- Useful time = Transmission delay of data packet = T_t
- Useless time = Time wasted during polling + Propagation delay of data packet = $T_{poll} + T_p$

$$\boxed{\text{Efficiency } (\eta) = \frac{T_t}{T_{poll} + T_t + T_p}}$$

Advantages-

- Unlike in Time Division Multiplexing, no slot is ever wasted.
- It leads to maximum efficiency and bandwidth utilization.

Disadvantages-

- Time is wasted during polling.
- Link sharing is not fair since each station has the equal probability of winning in each round.
- Few stations might starve for sending the data.

Important Formulas-

- Efficiency (η) = $T_t / (T_{poll} + T_t + T_p)$
- Effective Bandwidth / Bandwidth Utilization / Throughput = Efficiency(η) x Bandwidth
- Maximum Available Effective Bandwidth = Total number of stations x Bandwidth requirement of 1 station

3.) CSMA / CD

CSMA / CD stands for Carrier Sense Multiple Access / Collision Detection.

This access control method works as follows-

Step-01: Sensing the Carrier-

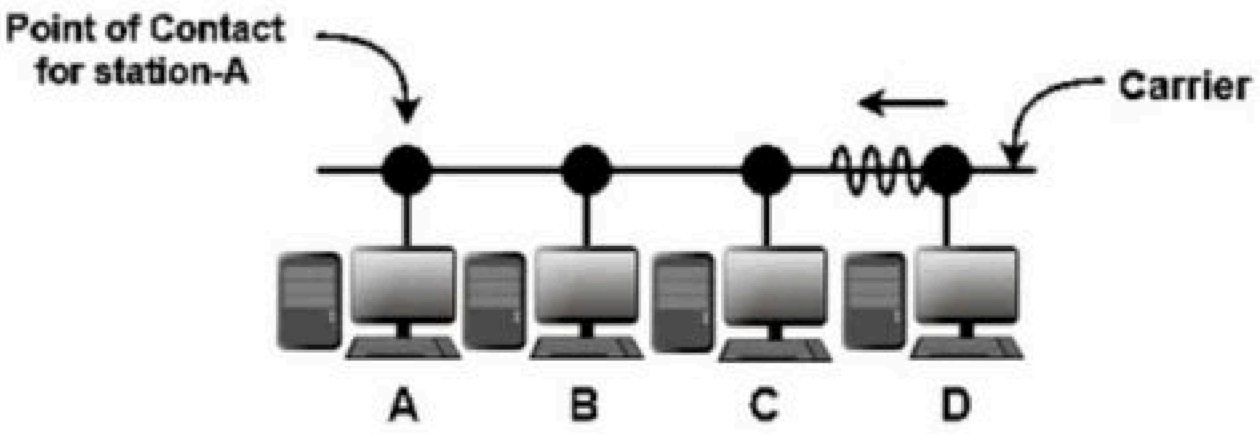
- Any station willing to transmit the data senses the carrier.
- If it finds the carrier free, it starts transmitting its data packet otherwise not.

How?

- Each station can sense the carrier only at its point of contact with the carrier.
- It is not possible for any station to sense the entire carrier.
- Thus, there is a huge possibility that a station might sense the carrier free even when it is actually not.

Example-

Consider the following scenario-



(Bus Topology)

At the current instance,

•If station A senses the carrier at its point of contact, then it will find the carrier free.

•But the carrier is actually not free because station D is already transmitting its data.

•If station A starts transmitting its data now, then it might lead to a collision with the data transmitted by station D.

Step-02: Detecting the Collision-

In CSMA / CD,

- It is the responsibility of the transmitting station to detect the collision.
- For detecting the collision, CSMA / CD implements the following condition.
- This condition is followed by each station-

Transmission delay >= 2 x Propagation delay

Meaning-

According to this condition,

- Each station must transmit the data packet of size whose transmission delay is at least twice its propagation delay.
- If the size of data packet is smaller, then collision detection would not be possible.

Length Of Data Packet-

We know-

- Transmission delay = Length of data packet (L) / Bandwidth (B)
- Propagation delay = Distance between the two stations (D) / Propagation speed (V)

Substituting values in the above condition, we get-

$$L / B >= 2 \times D / V$$

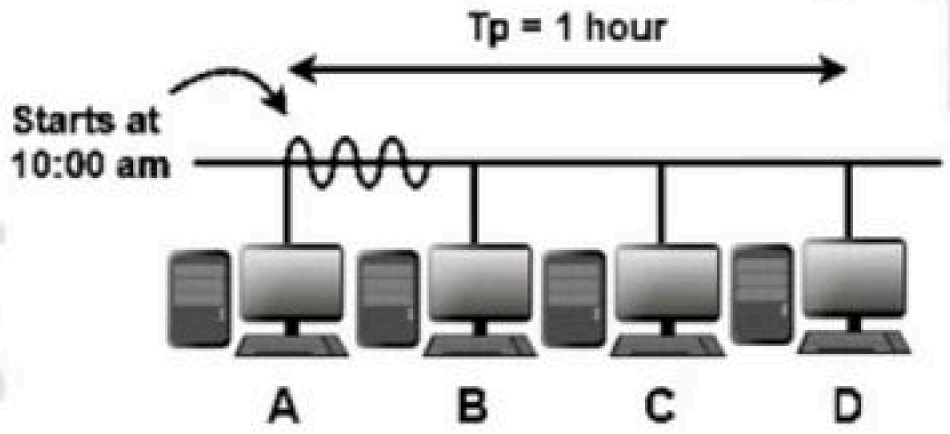
Thus,

$$L >= 2 \times B \times D / V$$

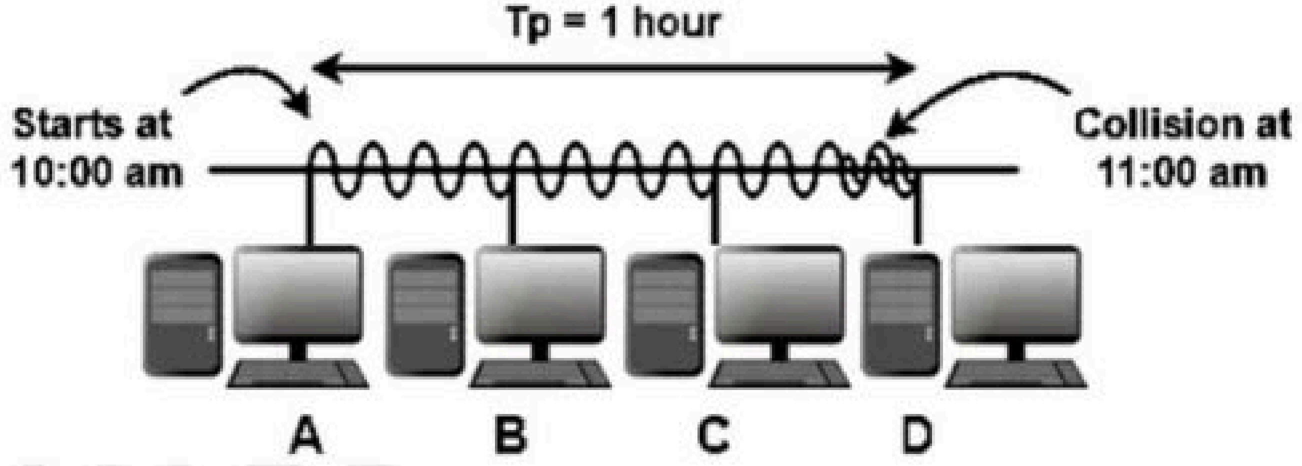
Understanding the Condition To Detect Collision With Example

- Consider at time 10:00 am, station A senses the carrier.
- It finds the carrier free and starts transmitting its data packet to station D.
- Let the propagation delay be 1 hour.

(We are considering station D for the worst case)



- Let us consider the scenario at time 10:59:59:59 when the packet is about to reach the station D.
- At this time, station D senses the carrier.
- It finds the carrier free and starts transmitting its data packet.
- Now, as soon as station D starts transmitting its data packet, a collision occurs with the data packet of station A at time 11:00 am.



- After collision occurs, the collided signal starts travelling in the backward direction.
- The collided signal takes 1 hour to reach the station A after the collision has occurred.
- For station A to detect the collided signal, it must be still transmitting the data.
- So, transmission delay of station A must be >= 1 hour + 1 hour >= 2 hours to detect the collision.
- That is why, for detecting the collision, condition is $T_t >= 2T_p$.

Two cases are possible-

Case-01:

If no collided signal comes back during the transmission,
- It indicates that no collision has occurred.
- The data packet is transmitted successfully.

Case-02:

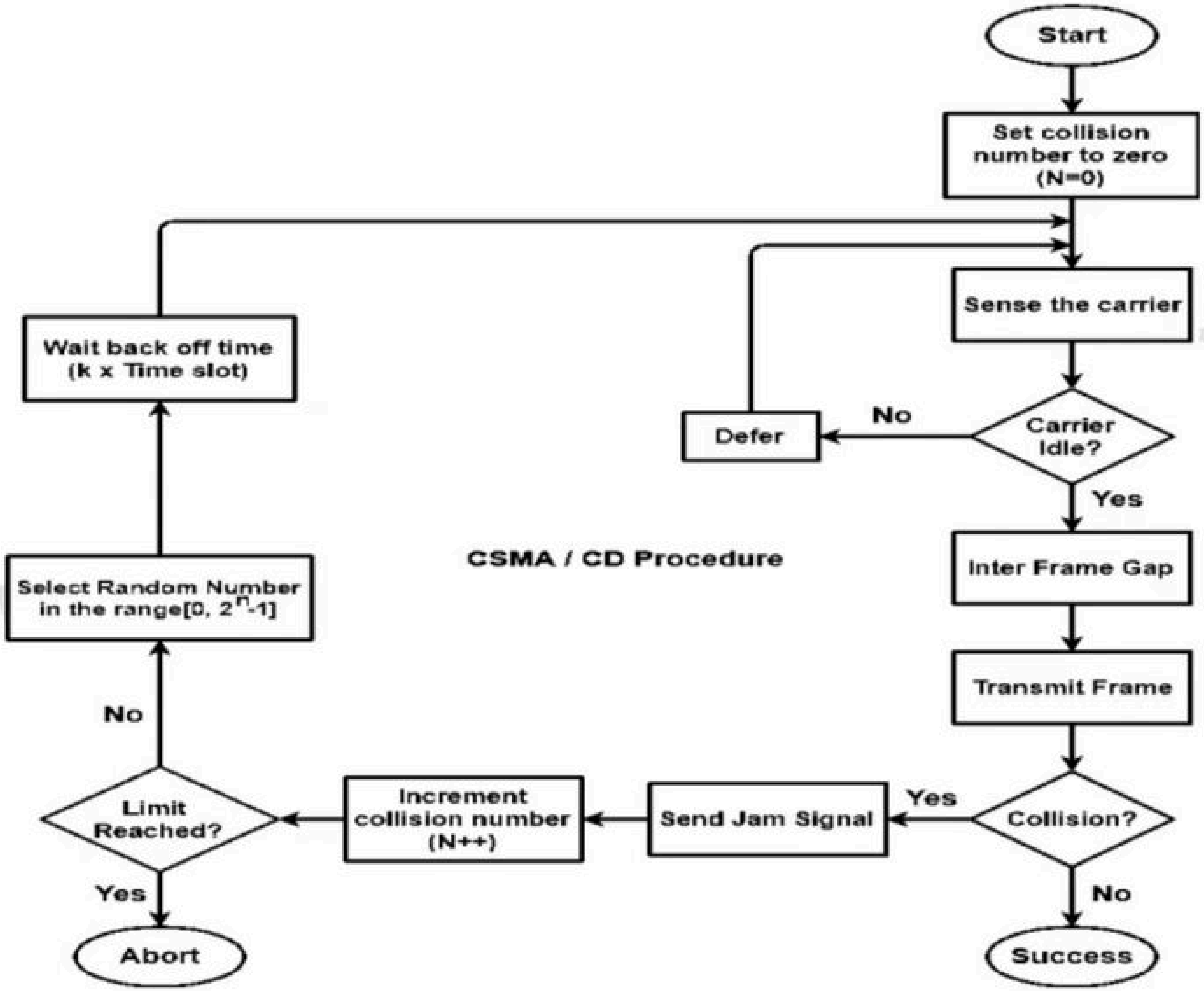
If the collided signal comes back during the transmission,
- It indicates that the collision has occurred.
- The data packet is not transmitted successfully.
- Step-03 is followed.

Step-03: Releasing Jam Signal-

- Jam signal is a 48 bit signal.
- It is released by the transmitting stations as soon as they detect a collision.
- It alerts the other stations not to transmit their data immediately after the collision.
- Otherwise, there is a possibility of collision again with the same data packet.
- Ethernet sends the jam signal at a frequency other than the frequency of data signals.
- This ensures that jam signal does not collide with the data signals undergone collision.

Step-04: Waiting For Back Off Time-

- After the collision, the transmitting station waits for some random amount of time called as **back off time**.
- After back off time, it tries transmitting the data packet again.
- If again the collision occurs, then station again waits for some random back off time and then tries again.
- The station keeps trying until the back off time reaches its limit.
- After the limit is reached, station aborts the transmission.
- Back off time is calculated using **Back Off Algorithm**.


Start
Set collision number to zero (N=0)
Sense the carrier
Carrier Idle?
No
Defer
Yes
Inter Frame Gap
Transmit Frame
Collision?
Yes
Send Jam Signal
Increment collision number (N++)
Limit Reached?
No
Select Random Number in the range[0, 2^n-1]
Wait back off time (k x Time slot)
Yes
Abort
No
Success
CSMA / CD Procedure

Efficiency (η) = Useful Time / Total Time

Before a successful transmission,

- There may occur many number of collisions.
- $2 \times T_p$ time is wasted during each collision.

Thus,

- Useful time = Transmission delay of data packet = T_t
- Useless time = Time wasted during collisions + Propagation delay of data packet = $c \times 2 \times T_p + T_p$
- Here, c = Number of contention slots / collision slots.

$$\boxed{\textbf{Efficiency } (\eta) = \frac{T_t}{c \times 2 \times T_p + T_t + T_p}}$$

Here,

- c is a variable.
- This is because number of collisions that might occur before a successful transmission are variable.

Probabilistic Analysis shows-

Average number of collisions before a successful transmission = e

$$\text{Efficiency } (\eta) = \frac{T_t}{e \times 2 \times T_p + T_t + T_p}$$

OR

$$\text{Efficiency } (\eta) = \frac{T_t}{T_t + 6.44 \times T_p}$$

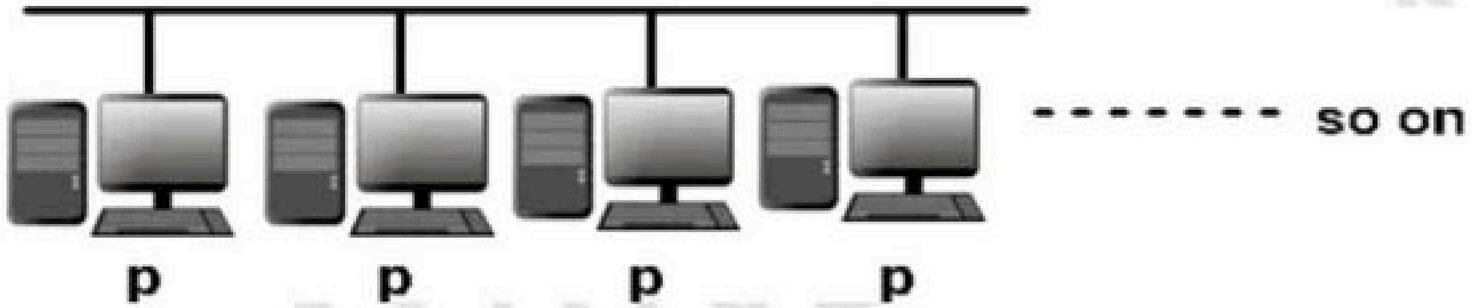
OR

$$\text{Efficiency } (\eta) = \frac{1}{1 + 6.44 \times a}, \text{ where } a = T_p / T_t$$

Probabilistic Analysis-

Let us perform the probabilistic analysis to find the average number of collisions before a successful transmission.

Consider-
- Number of stations connected to a CSMA / CD network = n
- Probability of each station to transmit the data = p



Transmission will be successful only when-
- One station transmits the data
- Other (n-1) stations do not transmit the data.

Thus, Probability of successful transmission is given by-

$$P_{\text{successful transmission}} = {}^{n}C_{1} \times p \times (1-p)^{n-1}$$

Now, let us find the maximum value of $P_{\text{successful transmission}}$.
For maximum value, we put-

$$\boxed{\frac{dP_{\text{successful transmission}}}{dp} = 0}$$

On solving,

At $p = 1/n$, we get the maximum value of $P_{\text{successful transmission}}$

Thus,
$(P_{\text{successful transmission}})_{max}$
$= {}^{n}C_{1} \times 1/n \times (1 - 1/n)^{n-1}$
$= n \times 1/n \times (1 - 1/n)^{n-1}$
$= (1 - 1/n)^{n-1}$

$$(P_{\text{successful transmission}})_{max} = (1 - 1/n)^{n-1}$$

If there are sufficiently large number of stations i.e. $n \to \infty$, then we have-

$$\lim_{n\to\infty} \left(P_{\text{successful transmission}}\right)_{max} = \lim_{n\to\infty} \left(1 - \frac{1}{n}\right)^{n-1}$$

$$= \frac{1}{e}$$

Number of times a station must try before successfully transmitting the data packet

$= 1 / P_{max}$ (Using Poisson's distribution)

$= 1 / (1/e)$

$= e$

Average number of collisions that might occur before a successful transmission = e

Important Notes-

Note-01:

- CSMA / CD is used in wired LANs.
- CSMA / CD is standardized in IEEE 802.3

Note-02:

- CSMA / CD only minimizes the recovery time.
- It does not take any steps to prevent the collision until it has taken place.

Important Formulas-

- Condition to detect collision: Transmission delay >= 2 x Propagation delay
- Minimum length of data packets in CSMA / CD = 2 x Bandwidth x Distance / Speed
- Efficiency of CSMA / CD = 1 / (1 + 6.44 x a) where $a = T_p / T_t$
- Probability of successful transmission = ${}^nC_1 \times p \times (1-p)^{n-1}$
- Average number of collisions before a successful transmission = e

Back off algorithm for CSMA/CD

Back Off Time-

In CSMA / CD protocol,

- After the occurrence of collision, station waits for some random back off time and then retransmits.
- This waiting time for which the station waits before retransmitting the data is called as **back off time**.
- Back Off Algorithm is used for calculating the back off time.

Back Off Algorithm-

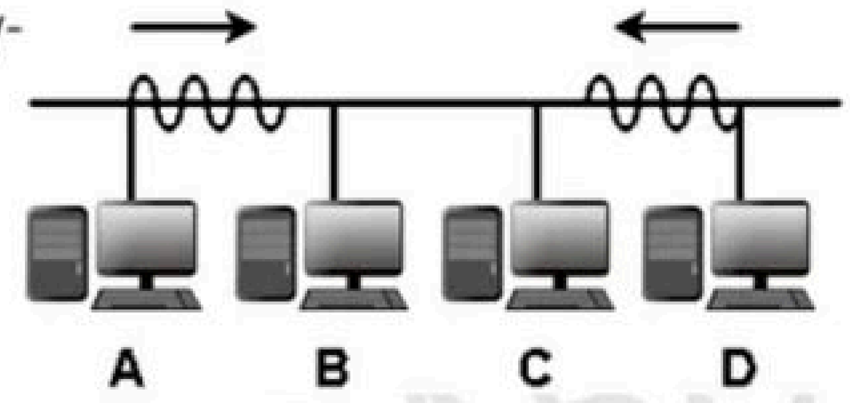
After undergoing the collision,

- Transmitting station chooses a random number in the range $[0, 2^n-1]$ if the packet is undergoing collision for the n^{th} time.
- If station chooses a number k, then-

Back off time = k x Time slot

Example-

Consider the following scenario where stations A and D start transmitting their data simultaneously-



For simplicity,

- We consider the value of time slot = 1 unit.
- Thus, back off time = K units.

Scene-01: For 1st Data Packet Of Both Stations-

- Both the stations start transmitting their 1st data packet simultaneously.
- This leads to a collision.
- Clearly, the collision on both the packets is occurring for the 1st time.
- So, collision number for the 1st data packet of both the stations = 1.

At Station A-

After detecting the collision,

- Station A randomly chooses a number in the range $[0, 2^1-1]$ = $[0,1]$.
- If station A chooses the number K_A, then back off time = K_A units.

At Station D-

After detecting the collision,

- Station D randomly chooses a number in the range $[0, 2^1-1]$ = $[0,1]$.
- If station D chooses the number K_D, then back off time = K_D units.

K_A	K_D	Remarks
0	0	•In this case, both the stations start retransmitting their data immediately. •This case leads to a collision again.
0	1	•In this case, station A starts retransmitting its data immediately while station D waits for 1 unit of time. •This case leads to A successfully retransmitting its data after the 1st collision.
1	0	•In this case, station A waits for 1 unit of time while station D starts retransmitting its data immediately. •This case leads to D successfully retransmitting its data after the 1st collision.
1	1	•In this case, both the stations wait for 1 unit of time and then starts retransmitting their data simultaneously. •This case leads to a collision again.

From here,

- Probability of station A to successfully retransmit its data after the 1st collision = 1 / 4
- Probability of station D to successfully retransmit its data after the 1st collision = 1 / 4
- Probability of occurrence of collision again after the 1st collision = 2 / 4 = 1 / 2

Now,

- Consider case-02 occurs.
- This causes station A to successfully retransmit its 1st packet after the 1st collision.

Scene-02: For 2nd Data Packet Of Station A And 1st Data Packet Of Station D-

Consider after some time,

- Station A starts transmitting its 2nd data packet and station D starts retransmitting its 1st data packet simultaneously.
- This leads to a collision.

At Station A-

- The 2nd data packet of station A undergoes collision for the 1st time.
- So, collision number for the 2nd data packet of station A = 1.
- Now, station A randomly chooses a number in the range $[0, 2^1-1] = [0,1]$.
- If station A chooses the number K_A, then back off time = K_A units.

At Station D-

- The 1st data packet of station D undergoes collision for the 2nd time.
- So, collision number for the 1st data packet of station D = 2.
- Now, station D randomly chooses a number in the range $[0, 2^2-1] = [0,3]$.
- If station D chooses the number K_D, then back off time = K_D units.

K_A	K_D	Remarks
0	0	•In this case, both the stations start retransmitting their data immediately. •This case leads to a collision again.
0	1	•In this case, station A starts retransmitting its data immediately while station D waits for 1 unit of time. •This case leads to A successfully retransmitting its data after the 2nd collision.
0	2	•In this case, station A starts retransmitting its data immediately while station D waits for 2 unit of time. •This case leads to A successfully retransmitting its data after the 2nd collision.
0	3	•In this case, station A starts retransmitting its data immediately while station D waits for 3 unit of time. •This case leads to A successfully retransmitting its data after the 2nd collision.
1	0	•In this case, station A waits for 1 unit of time while station D starts retransmitting its data immediately. •This case leads to D successfully retransmitting its data after the 2nd collision.
1	1	•In this case, both the stations wait for 1 unit of time and then starts retransmitting their data simultaneously. •This case leads to a collision again.
1	2	•In this case, station A waits for 1 unit of time while station D waits for 2 unit of time. •This case leads to A successfully retransmitting its data after the 2nd collision.
1	3	•In this case, station A waits for 1 unit of time while station D waits for 3 unit of time. •This case leads to A successfully retransmitting its data after the 2nd collision.

From here,

- Probability of station A to successfully retransmit its data after the 2nd collision = 5 / 8
- Probability of station D to successfully retransmit its data after the 2nd collision = 1 / 8
- Probability of occurrence of collision again after the 2nd collision = 2 / 8 = 1 / 4

Now,

- Consider case-03 occurs.
- This causes station A to successfully retransmit its 2nd packet after the 2nd collision.

Scene-03: For 3rd Data Packet Of Station A And 1st Data Packet Of Station D-

Consider after some time,

- Station A starts transmitting its 3rd data packet and station D starts retransmitting its 1st data packet simultaneously.
- This leads to a collision.

At Station A-

- The 3rd data packet of station A undergoes collision for the 1st time.
- So, collision number for the 3rd data packet of station A = 1.
- Now, station A randomly chooses a number in the range $[0, 2^1-1] = [0,1]$.
- If station A chooses the number K_A, then back off time = K_A unit.

At Station D-

- The 1st data packet of station D undergoes collision for the 3rd time.
- So, collision number for the 1st data packet of station D = 3.
- Now, station D randomly chooses a number in the range $[0, 2^3-1] = [0,7]$.
- If station D chooses the number K_D, then back off time = K_D unit.

K_A	K_D	Remarks
0	0	•In this case, both the stations start retransmitting their data immediately. •This case leads to a collision again.
0	1	•In this case, station A starts retransmitting its data immediately while station D waits for 1 unit of time. •This case leads to A successfully retransmitting its data after the 3rd collision.
0	2	•In this case, station A starts retransmitting its data immediately while station D waits for 2 unit of time. •This case leads to A successfully retransmitting its data after the 3rd collision.
0	3	•In this case, station A starts retransmitting its data immediately while station D waits for 3 unit of time. •This case leads to A successfully retransmitting its data after the 3rd collision.
0	4	•In this case, station A starts retransmitting its data immediately while station D waits for 4 unit of time. •This case leads to A successfully retransmitting its data after the 3rd collision.
0	5	•In this case, station A starts retransmitting its data immediately while station D waits for 5 unit of time. •This case leads to A successfully retransmitting its data after the 3rd collision.
0	6	•In this case, station A starts retransmitting its data immediately while station D waits for 6 unit of time. •This case leads to A successfully retransmitting its data after the 3rd collision.
0	7	•In this case, station A starts retransmitting its data immediately while station D waits for 7 unit of time. •This case leads to A successfully retransmitting its data after the 3rd collision.
1	0	•In this case, station A waits for 1 unit of time while station D starts retransmitting its data immediately. •This case leads to D successfully retransmitting its data after the 3rd collision.

1	1	•In this case, both the stations wait for 1 unit of time and then starts retransmitting their data simultaneously. •This case leads to a collision again.
1	2	•In this case, station A waits for 1 unit of time while station D waits for 2 unit of time. •This case leads to A successfully retransmitting its data after the 3rd collision.
1	3	•In this case, station A waits for 1 unit of time while station D waits for 3 unit of time. •This case leads to A successfully retransmitting its data after the 3rd collision.
1	4	•In this case, station A waits for 1 unit of time while station D waits for 4 unit of time. •This case leads to A successfully retransmitting its data after the 3rd collision.
1	5	•In this case, station A waits for 1 unit of time while station D waits for 5 unit of time. •This case leads to A successfully retransmitting its data after the 3rd collision.
1	6	•In this case, station A waits for 1 unit of time while station D waits for 6 unit of time. •This case leads to A successfully retransmitting its data after the 3rd collision.
1	7	•In this case, station A waits for 1 unit of time while station D waits for 7 unit of time. •This case leads to A successfully retransmitting its data after the 3rd collision.

From here,

- Probability of station A to successfully retransmit its data after the 3^{rd} collision = 13 / 16
- Probability of station D to successfully retransmit its data after the 3^{rd} collision = 1 / 16
- Probability of occurrence of collision again after the 3^{rd} collision = 1 / 16

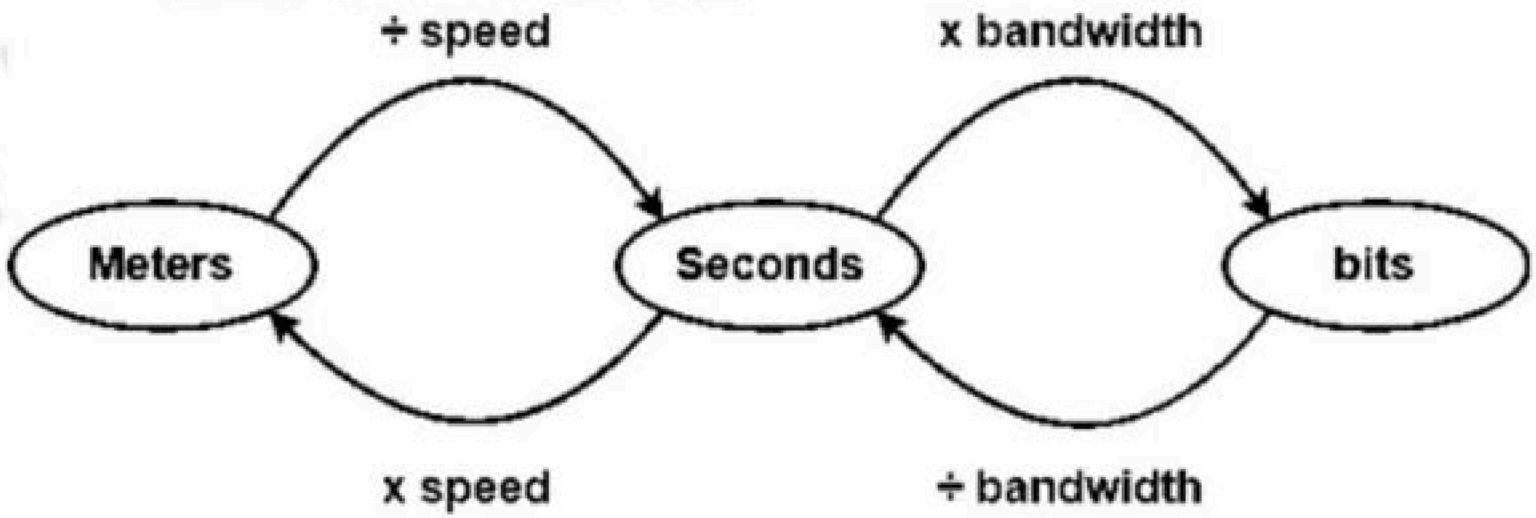
In the similar manner, the procedure continues.

Before discussing Token Passing, let us discuss few important concepts required for the discussion.

<u>Time Conversions-</u>

In token passing,

- Time may be expressed in seconds, bits or meters.
- To convert the time from one unit to another, we use the following conversion chart-



Token Passing Terminology-

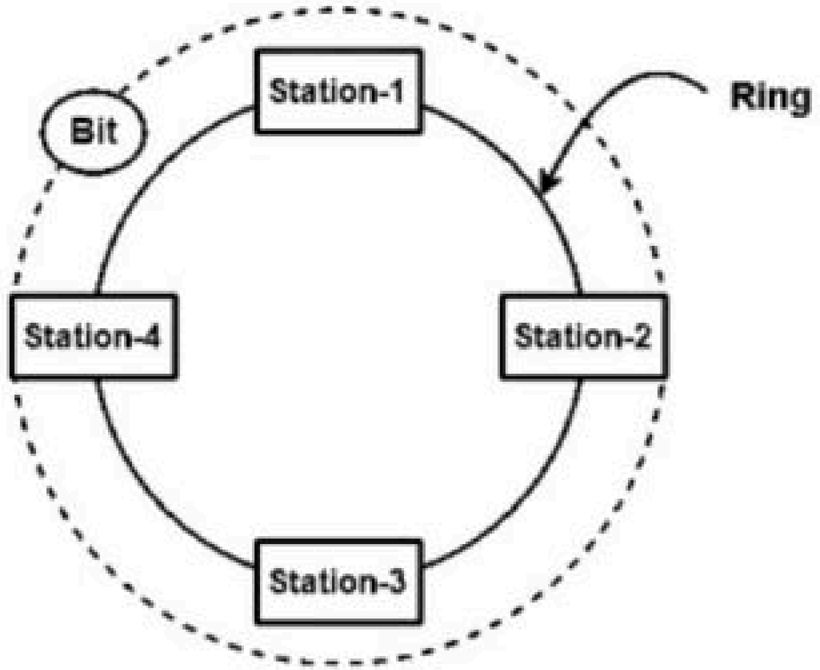
The following terms are frequently used-
1.Token
2.Ring Latency
3.Cycle Time

1. Token-

•A token is a small message composed of a special bit pattern.
•It represents the permission to send the data packet.
•A station is allowed to transmit a data packet if and only if it possess the token otherwise not.

2. Ring Latency-

Time taken by a bit to complete one revolution of the ring is called as **ring latency**.



Let us derive the expression for ring latency.

If-

- Length of the ring = d
- Speed of the bit = v
- Number of stations = N
- Bit delay at each station = b

(Bit delay is the time for which a station holds the bit before transmitting to the other side)

$$\text{Ring Latency} = \underbrace{\frac{d}{v}}_{\text{This time is taken by the bit to traverse the ring}} + \underbrace{N \times b}_{\text{This time is taken by the stations to hold the bit}}$$

Notes-

- d / v is the propagation delay (T_p) expressed in seconds.
- Generally, bit delay is expressed in bits.
- So, both the terms (d / v and N x b) have different units.
- While calculating the ring latency, both the terms are brought into the same unit.
- The above conversion chart is used for conversion.

After conversion, we have-

$$\text{Ring Latency} = \left(\frac{d}{v} + \frac{N \times b}{B}\right) \text{ sec}$$

$$= \left(T_p + \frac{N \times b}{B}\right) \text{ sec}$$

OR

$$\text{Ring Latency} = \left(\frac{d \times B}{v} + N \times b\right) \text{ bits}$$

$$= (T_p \times B + N \times b) \text{ bits}$$

3. Cycle Time-

Time taken by the token to complete one revolution of the ring is called as **cycle time**.

If-

- Length of the ring = d
- Speed of the bit = v
- Number of stations = N
- Token Holding Time = THT

(Token Holding Time is the time for which a station holds the token before transmitting to the other side)

Then-

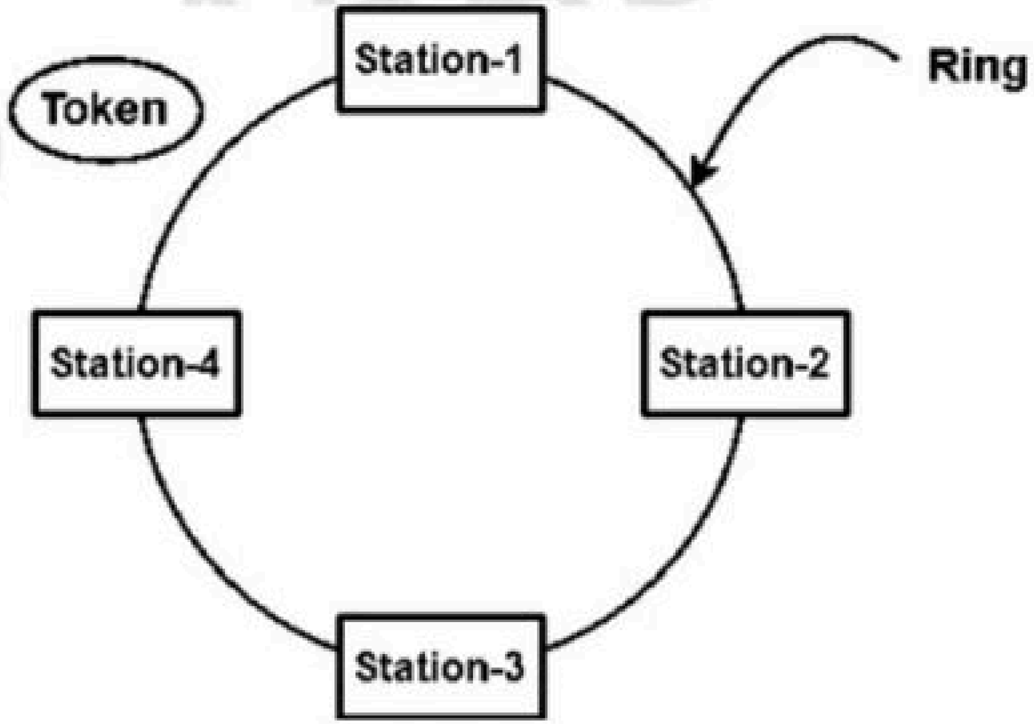
$$\text{Cycle Time} = \frac{d}{v} + N \times THT$$

$$= T_p + N \times THT$$

Token Passing-

In this access control method,

- All the stations are logically connected to each other in the form of a ring.
- The access of stations to the transmission link is governed by a token.
- A station is allowed to transmit a data packet if and only if it possess the token otherwise not.
- Each station passes the token to its neighboring station either clockwise or anti-clockwise.



Assumptions-

Token passing method assumes-
- Each station in the ring has the data to send.
- Each station sends exactly one data packet after acquiring the token.

Efficiency-

Efficiency (η) = Useful Time / Total Time

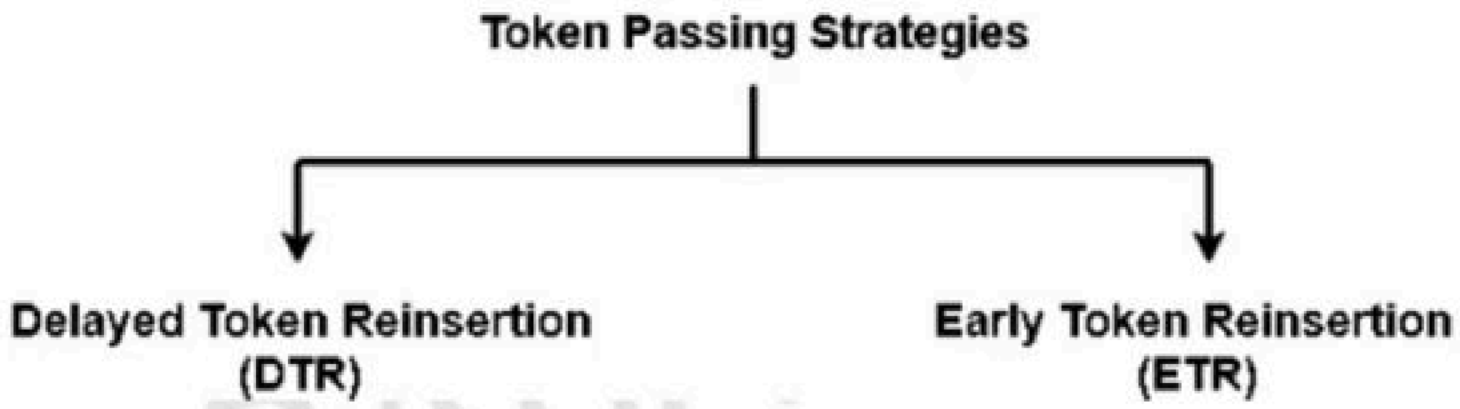
In one cycle,
- Useful time = Sum of transmission delay of N stations since each station sends 1 data packet = $N \times T_t$
- Total Time = Cycle time = $T_p + N \times THT$

Thus,

$$\boxed{\text{Efficiency } (\eta) = \frac{N \times T_t}{T_p + N \times THT}}$$

Token Passing Strategies-

The following 2 strategies are used in token passing-



1. Delayed Token Reinsertion-

In this strategy,

•Station keeps holding the token until the last bit of the data packet transmitted by it takes the complete revolution of the ring and comes back to it.

Working-

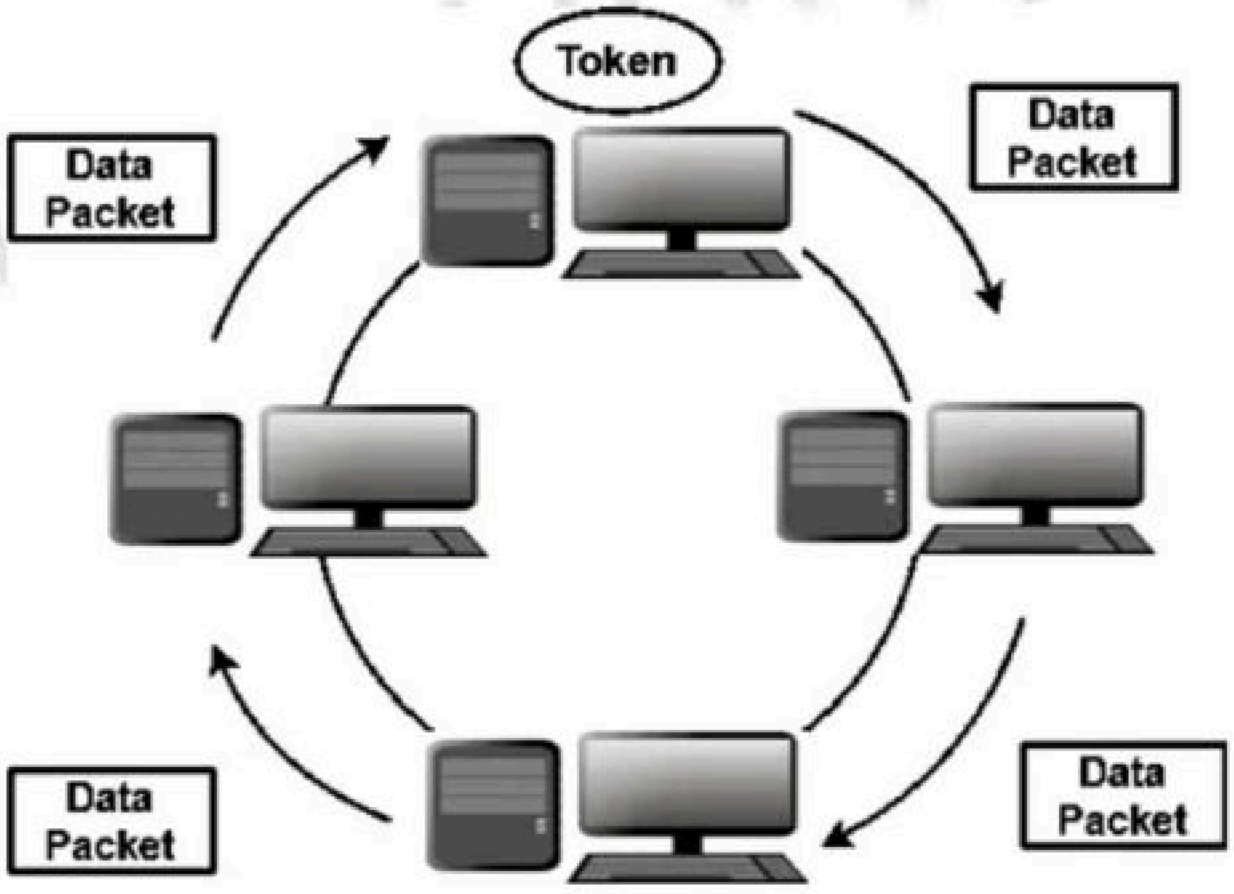
After a station acquires the token,

•It transmits its data packet.

•It holds the token until the data packet reaches back to it.

•After data packet reaches to it, it discards its data packet as its journey is completed.

•It releases the token.



Delayed Token Reinsertion Token Passing

Token Holding Time-

Token Holding Time (THT) = Transmission delay + Ring Latency

We know,

- Ring Latency = T_p + N x bit delay
- Assuming bit delay = 0 (in most cases), we get-

Token Holding Time = $T_t + T_p$

Efficiency-

Substituting THT = $T_t + T_p$ in the efficiency expression, we get-

$$\text{Efficiency } (\eta) = \frac{N \times T_t}{T_p + N \times (T_t + T_p)}$$

OR

$$\text{Efficiency } (\eta) = \frac{1}{\frac{a}{N} + (1 + a)}$$

OR

$$\text{Efficiency } (\eta) = \frac{1}{1 + \left(1 + \frac{1}{N}\right) a}$$

OR

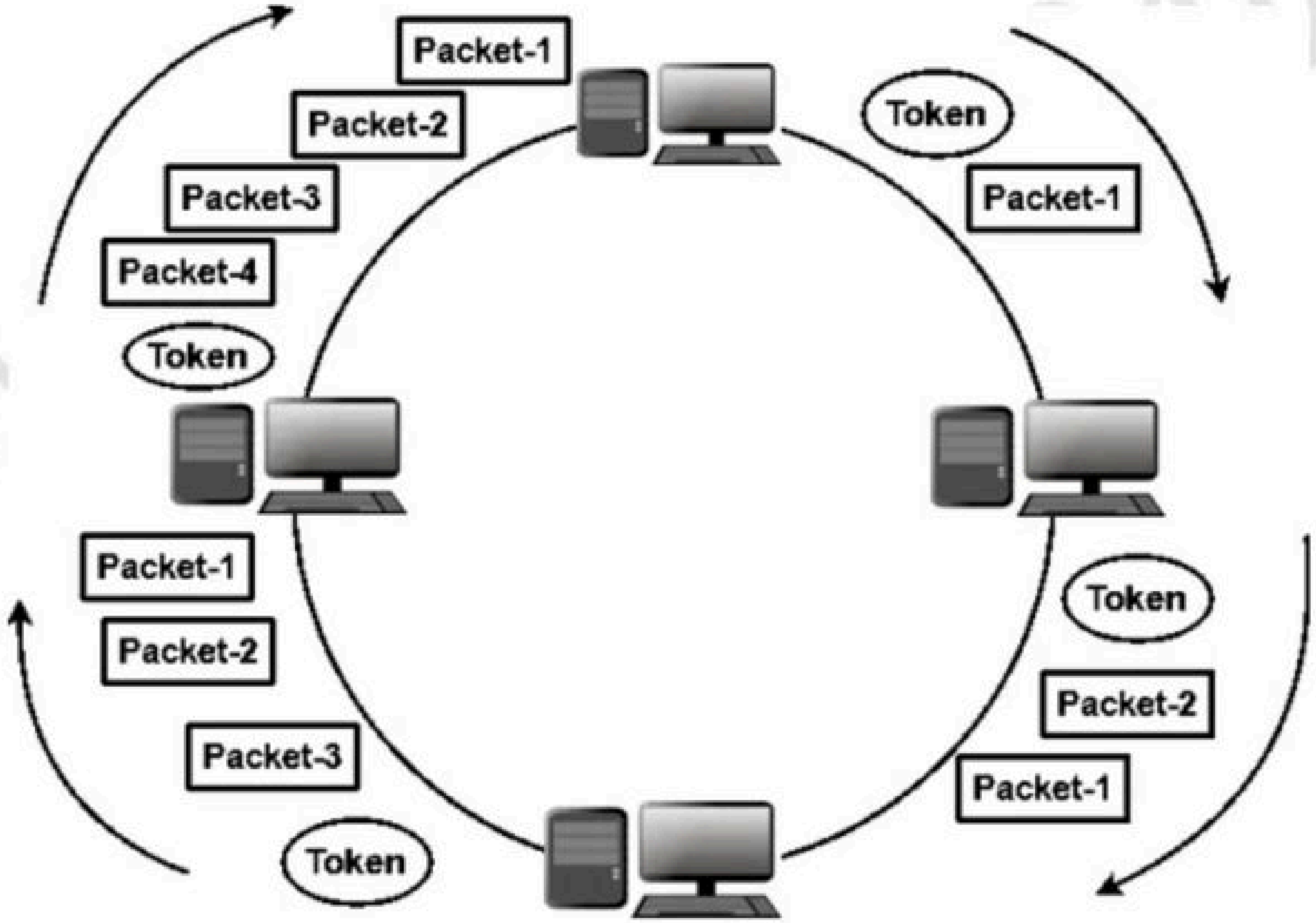
$$\text{Efficiency } (\eta) = \frac{1}{1 + \left(\frac{N + 1}{N}\right) a}$$

2. Early Token Reinsertion-

In this strategy,

•Station releases the token immediately after putting its data packet to be transmitted on the ring.

Working-



Step-01: At Station-1:

Station-1
•Acquires the token
•Transmits packet-1
•Releases the token

Step-02: At Station-2:

Station-2
•Receives packet-1
•Transmits packet-1
•Acquires the token
•Transmits packet-2
•Releases the token

Step-03: At Station-3:

Station-3
•Receives packet-1
•Transmits packet-1
•Receives packet-2
•Transmits packet-2
•Acquires the token
•Transmits packet-3
•Releases the token

Step-04: At Station-4:

Station-4
•Receives packet-1
•Transmits packet-1
•Receives packet-2
•Transmits packet-2
•Receives packet-3
•Transmits packet-3
•Acquires the token
•Transmits packet-4
•Releases the token

Step-05: At Station-1:

•Receives packet-1
•Discards packet-1 (as its journey is completed)
•Receives packet-2
•Transmits packet-2
•Receives packet-3
•Transmits packet-3
•Receives packet-4
•Transmits packet-4
•Acquires the token
•Transmits packet-1 (new)
•Releases the token

In this manner, the cycle continues.

Token Holding Time-

Token Holding Time (THT) = Transmission delay of data packet = T_t

Efficiency-

Substituting THT = T_t in the efficiency expression, we get-

$$\boxed{\text{Efficiency } (\eta) = \frac{N \times T_t}{T_p + N \times T_t}}$$

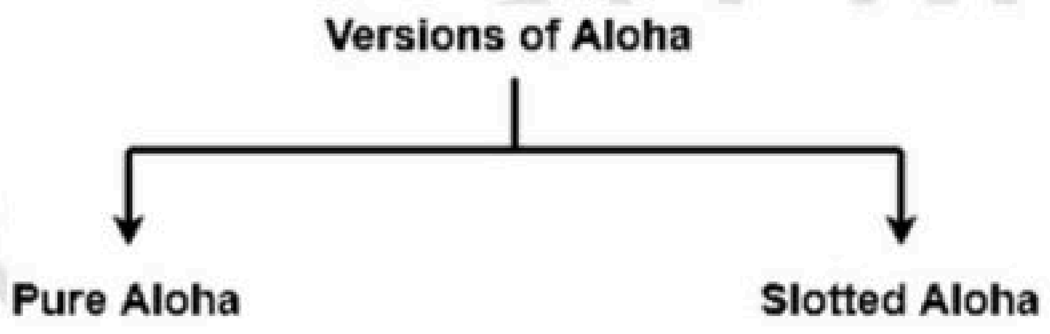
OR

$$\boxed{\text{Efficiency } (\eta) = \frac{1}{1 + \frac{a}{N}}}$$

Delay Token Retransmission (DTR)	Early Token Retransmission (ETR)
Each station holds the token until its data packet reaches back to it.	Each station releases the token immediately after putting its data packet on the ring.
There exists only one data packet on the ring at any given instance.	There exists more than one data packet on the ring at any given instance.
It is more reliable than ETR.	It is less reliable than DTR.
It has low efficiency as compared to ETR.	It has high efficiency as compared to ETR.

Aloha-

There are two different versions of Aloha-



1. Pure Aloha-

- It allows the stations to transmit data at any time whenever they want.
- After transmitting the data packet, station waits for some time.

Then, following 2 cases are possible-

Case-01:

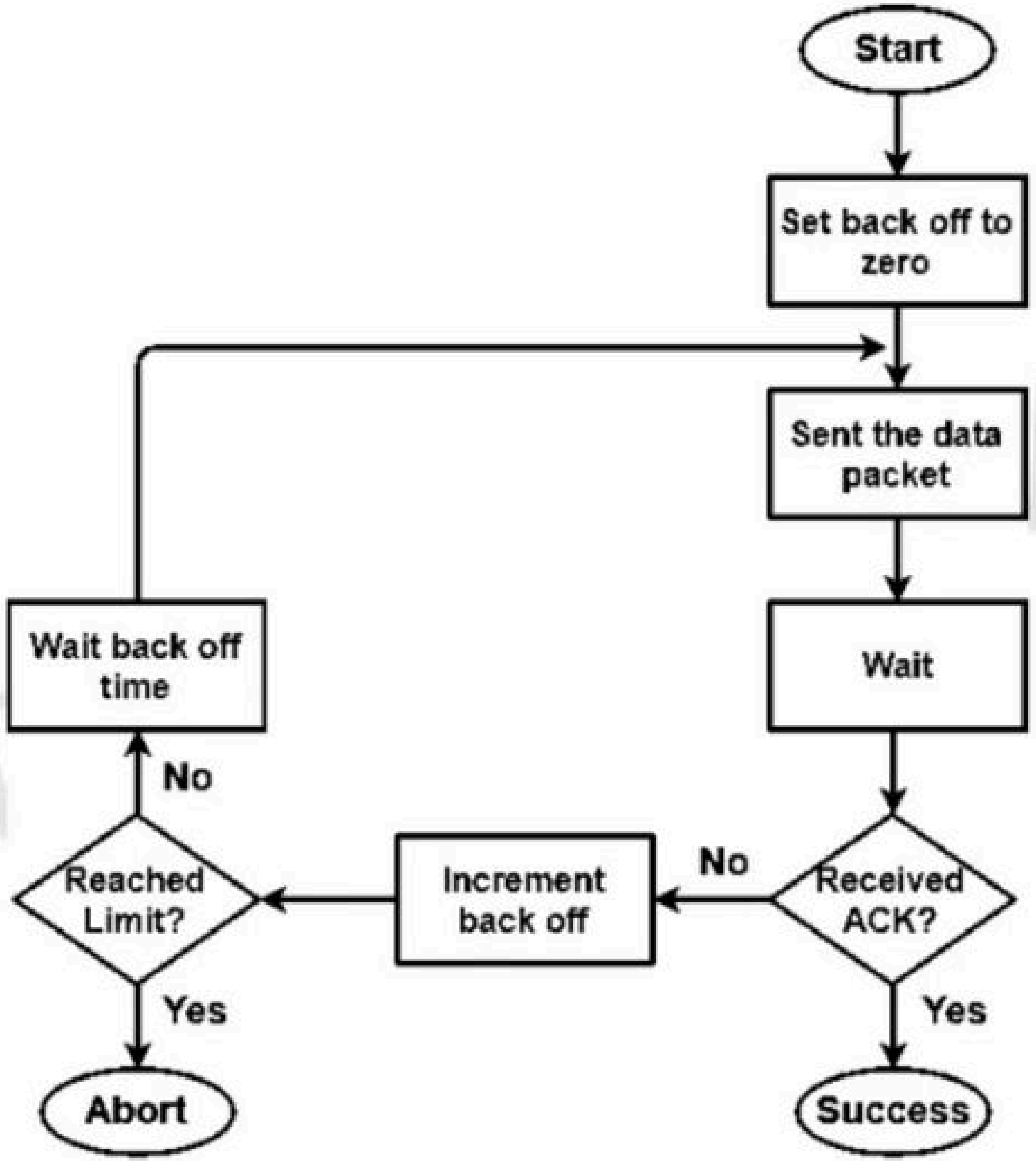
- Transmitting station receives an acknowledgement from the receiving station.
- In this case, transmitting station assumes that the transmission is successful.

Case-02:

- Transmitting station does not receive any acknowledgement within specified time from the receiving station.
- In this case, transmitting station assumes that the transmission is unsuccessful.

Then,

- Transmitting station uses a **Back Off Strategy** and waits for some random amount of time.
- After back off time, it transmits the data packet again.
- It keeps trying until the back off limit is reached after which it aborts the transmission.



Flowchart for Pure Aloha

Efficiency-

$$\text{Efficiency of Pure Aloha } (\eta) = G \times e^{-2G}$$

where G = Number of stations willing to transmit data

Maximum Efficiency-

For maximum efficiency,

- We put $d\eta / dG = 0$
- Maximum value of η occurs at $G = 1/2$
- Substituting $G = 1/2$ in the above expression, we get-

Maximum efficiency of Pure Aloha

$= 1/2 \times e^{-2 \times 1/2}$

$= 1 / 2e$

$= 0.184$

$= 18.4\%$

Thus, Maximum Efficiency of Pure Aloha (η) = 18.4%

2. Slotted Aloha-

- Slotted Aloha divides the time of shared channel into discrete intervals called as **time slots**.
- Any station can transmit its data in any time slot.
- The only condition is that station must start its transmission from the beginning of the time slot.
- If the beginning of the slot is missed, then station has to wait until the beginning of the next time slot.
- A collision may occur if two or more stations try to transmit data at the beginning of the same time slot.

Efficiency-

Efficiency of Slotted Aloha (η) = $G \times e^{-G}$

where G = Number of stations willing to transmit data at the beginning of the same time slot

Maximum Efficiency-

For maximum efficiency,

- We put $d\eta / dG = 0$
- Maximum value of η occurs at $G = 1$
- Substituting $G = 1$ in the above expression, we get-

Maximum efficiency of Slotted Aloha

$= 1 \times e^{-1}$

$= 1 / e$

$= 0.368$

$= 36.8\%$

Thus,

Maximum Efficiency of Slotted Aloha (η) = 36.8%

Pure Aloha	Slotted Aloha
Any station can transmit the data at any time.	Any station can transmit the data at the beginning of any time slot.
The time is continuous and not globally synchronized.	The time is discrete and globally synchronized.
Vulnerable time in which collision may occur $= 2 \times T_t$	Vulnerable time in which collision may occur $= T_t$
Probability of successful transmission of data packet $= G \times e^{-2G}$	Probability of successful transmission of data packet $= G \times e^{-G}$
Maximum efficiency = 18.4% (Occurs at G = 1/2)	Maximum efficiency = 36.8% (Occurs at G = 1)
The main advantage of pure aloha is its simplicity in implementation.	The main advantage of slotted aloha is that it reduces the number of collisions to half and doubles the efficiency of pure aloha.