CS & IT ENGINEERING

COMPUTER NETWORKS

Flow Control

Lecture No-10

By- Ankit Doyla Sir

TOPICS TO BE COVERED

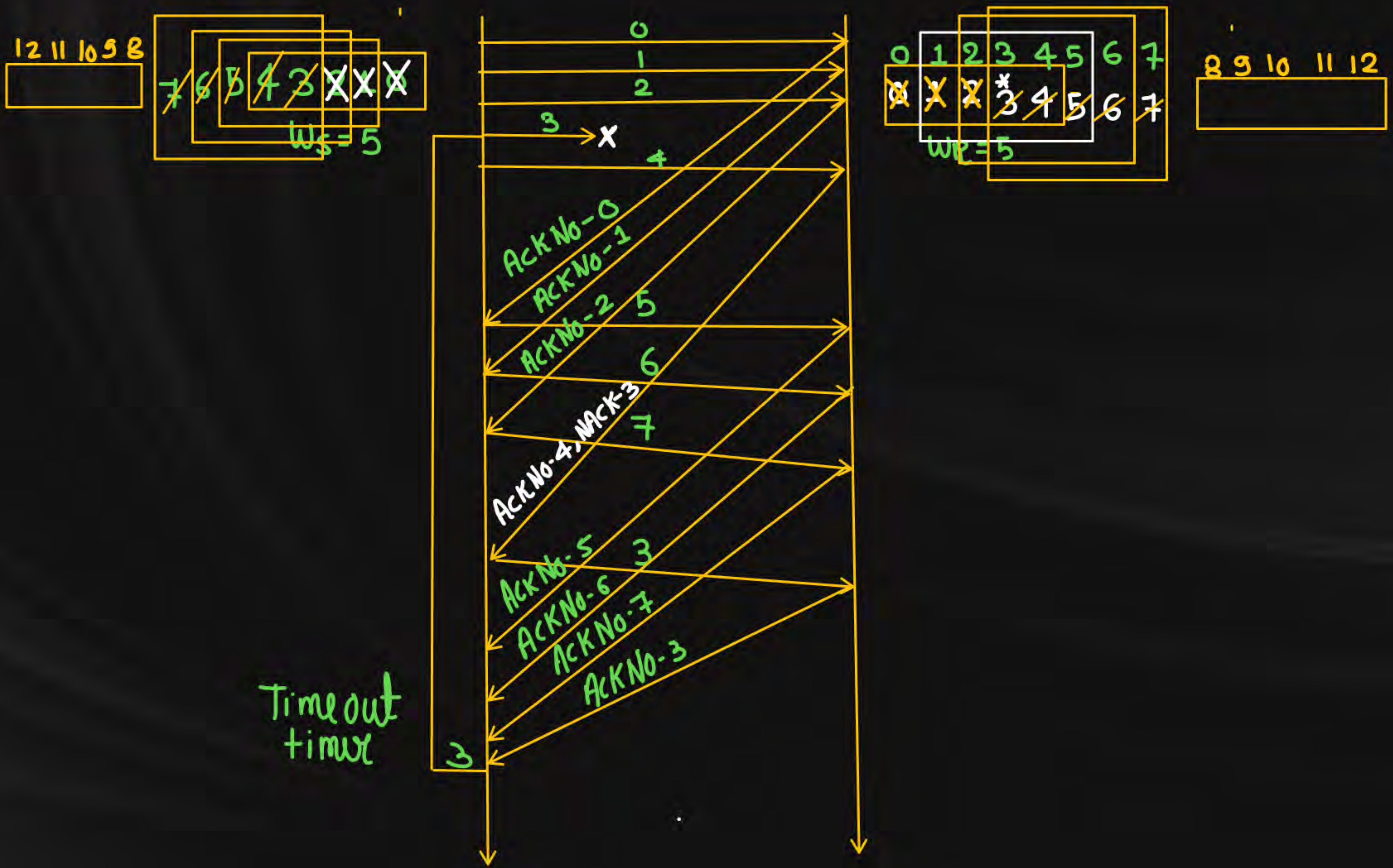
- Selective Repeat ARQ

Selective Repeat ARQ

Selective Repeat/ Selective Reject ARQ

$\boxed{W_S, W_R > 1}$

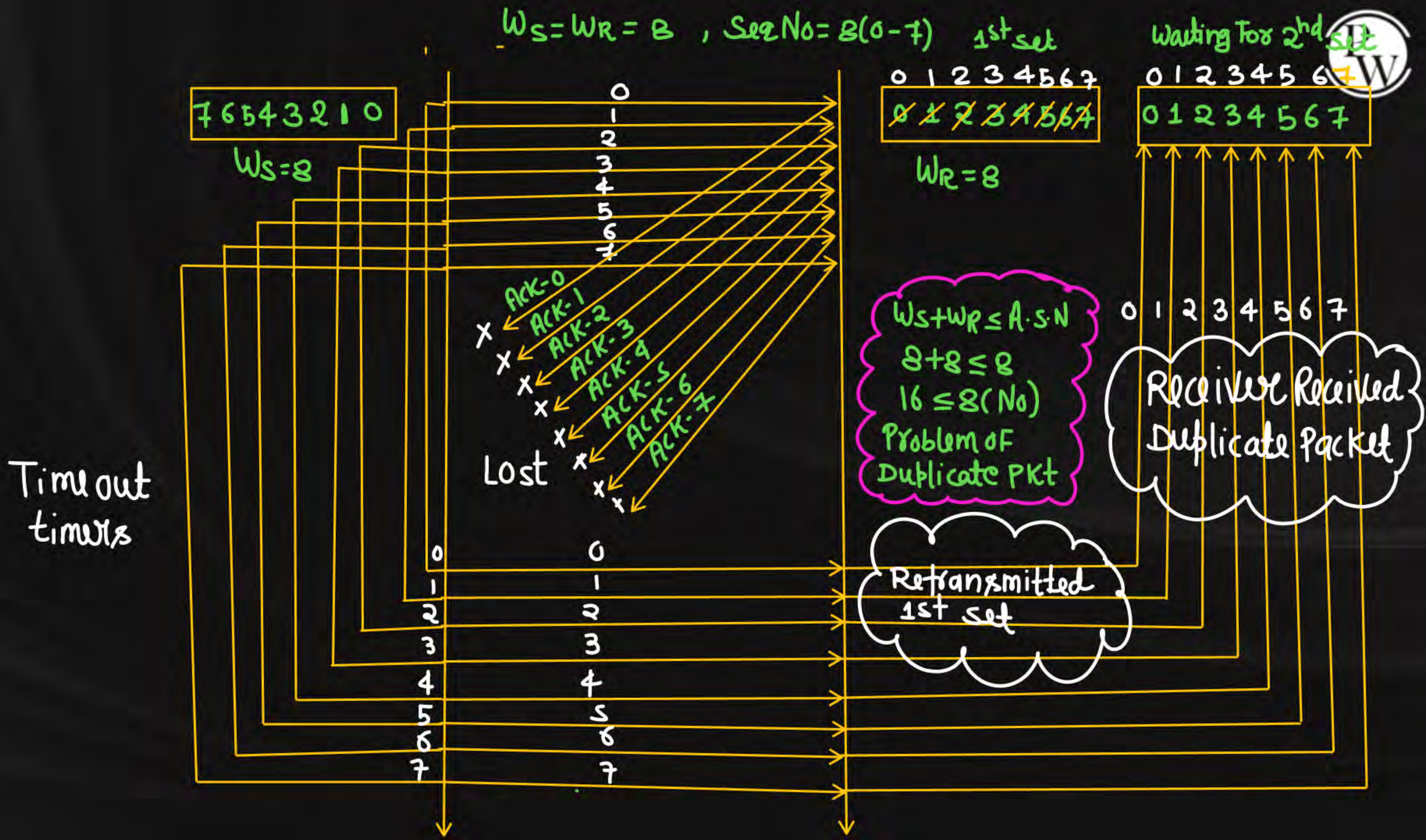
1. In SR Protocol window sender size is equal to window receiver size. $(W_S = W_R)$
2. SR Protocol uses independent acknowledgement, and acknowledgement number defines number of error free packet received
3. SR receiver can receive out of order packet but packets are delivered to upper layer in order.
4. In SR protocol searching and sorting logic is required. Searching is done by sender and sorting is done by receiver.
5. Timer is maintained for each and every frame in the window at sender side



12 11 10 9 8
7 6 5 4 3 2 1 0
Ws = 5
0
1
2
3
4
AckNo-0
AckNo-1
AckNo-2
5
6
AckNo-4, NACK-3
7
AckNo-5
3
AckNo-6
AckNo-7
AckNo-3
Timeout timer
3
0 1 2 3 4 5 6 7
WR = 5
8 9 10 11 12

1. For 1^{st} out of order delivery or if packet received is corrupted then NAK for respective packet is sent by receiver to sender.

2. When sender receive NAK 3 then it will search in the window for packet 3 & immediately packet 3 is retransmitted even though its timer is not expired.



Ws = WR = 8 , Seq No = 8(0-7)
1st set
Waiting for 2nd set
7 6 5 4 3 2 1 0
Ws=8
0 1 2 3 4 5 6 7
WR=8
ACK-0
ACK-1
ACK-2
ACK-3
ACK-4
ACK-5
ACK-6
ACK-7
Lost
Time out timers
Ws+WR ≤ A.S.N
8+8 ≤ 8
16 ≤ 8 (No)
Problem of Duplicate PKt
Receiver Received Duplicate Packet
Retransmitted 1st set

Note

1. Duplicate Packet Problem can be solved by Increasing the Sequence Number or decreasing the sender window size

2. Duplicate Packet Problem can be solved by using the Formula

$$\boxed{W_S + W_R \leq A.S.N}$$

Best 1. $W_S + W_R \leq A \cdot S \cdot N$

$4 + 4 \leq 8$ (yes)

2. $W_S + W_R \leq A \cdot S \cdot N$

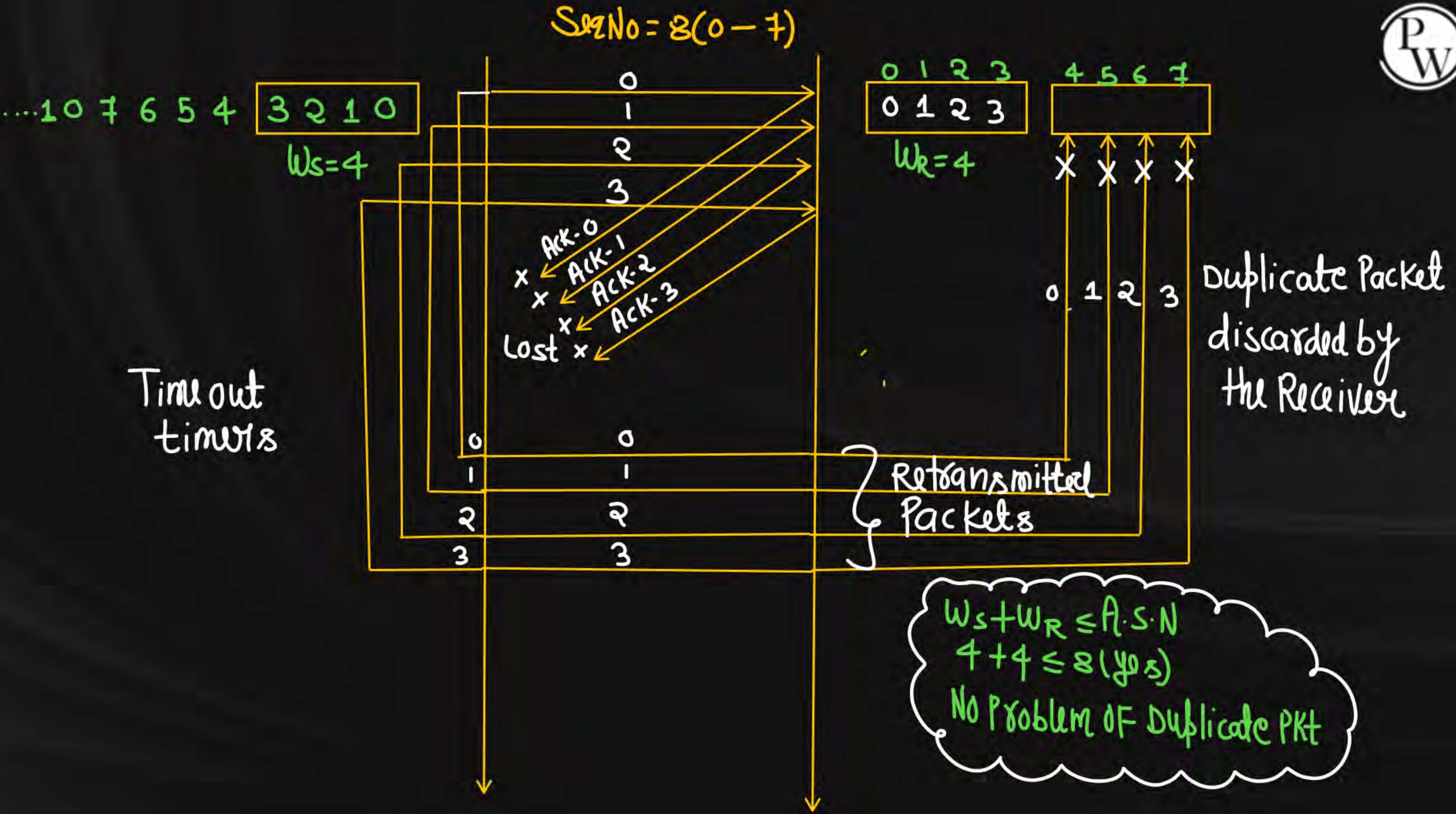
$5 + 3 \leq 8$ (yes)

3. $W_S + W_R \leq A \cdot S \cdot N$

No Meaning $3 + 5 \leq 8$ (yes)

Note

According to the Formula $W_S + W_R \leq A \cdot S \cdot N$ All the above 3 conditions are correct but 1st one is Best and their is no meaning For Last one.



$W_S + W_R \le A.S.N$

$4 + 4 \le 8$ (yes)

No Problem of Duplicate Pkt

1. Seq No = 8(0 − 7)

W_S	W_R
4	4

2. Seq No = 16(0 − 15)

W_S	W_R
8	8

3. Seq No = N(0 — N−1)

W_S	W_R
$\frac{N}{2}$	$\frac{N}{2}$

4. Seq. No = 3 bit

Total Sequence No = $2^3 = 8(0-7)$

W_S	W_R
$4\,[2^{3-1}]$	$4\,[2^{3-1}]$

5. Seq No = 4 bit

Total Sequence No. = $2^4 = 16\,(0-15)$

W_S	W_R
$8\,[2^{4-1}]$	$8\,(2^{4-1})$

6. Seq No = K bit

W_S	W_R
2^{K-1}	2^{K-1}

7.

W_S	W_R	min. Sequence No. Required
4	4	8
8	8	16
N	N	2N

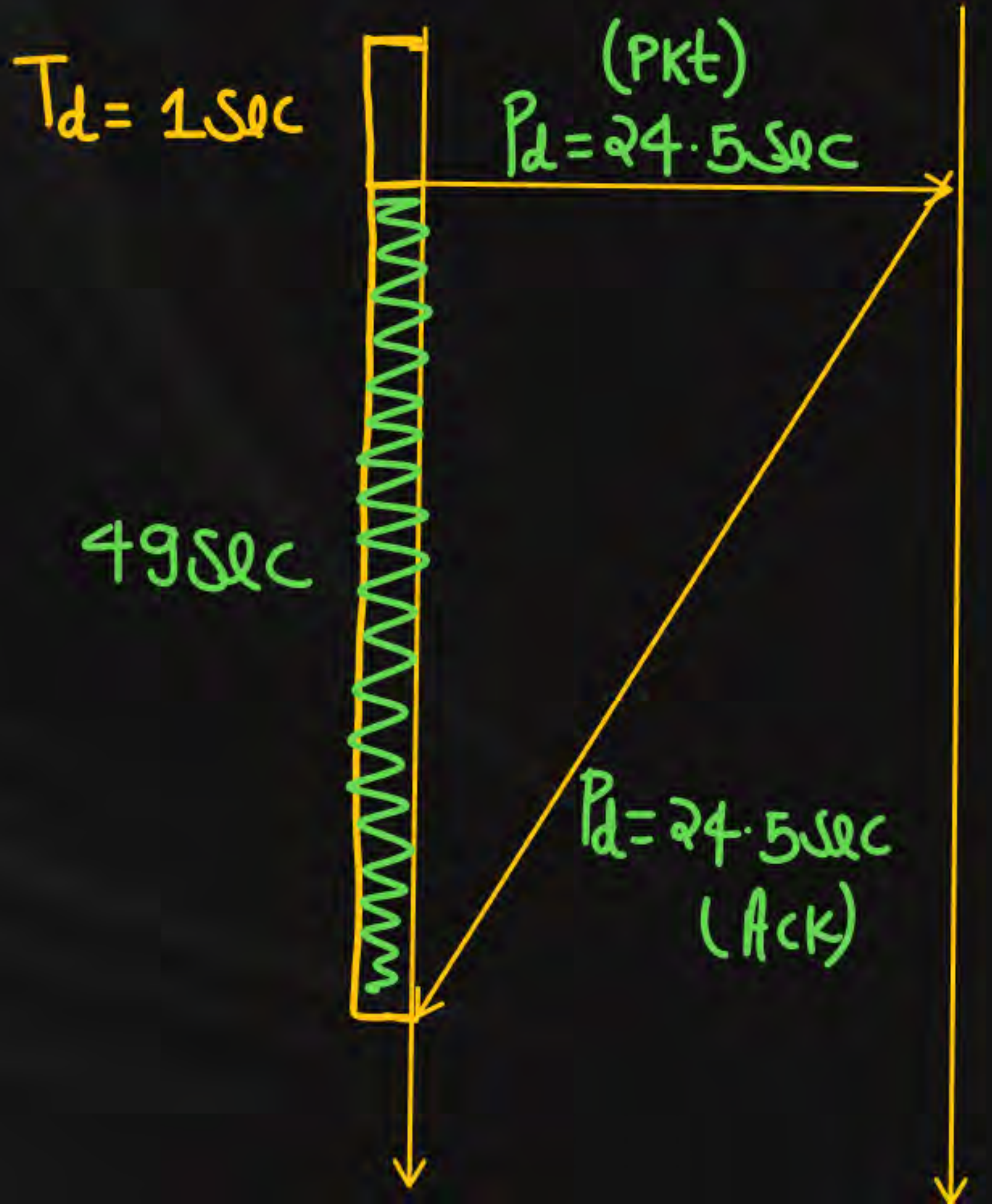
Seq No = 8 (0-7)

W_S	W_R		
4	4 ✓		
5	3 ✓		
3	5 ✓		
6	2 ✓		
1	2	X (No)	$W_S > 1$ in SR
1	1	X (No)	stop & wait

Q: $T_d = 1\,sec$, $P_d = 24.5\,sec$, $Q_d = 0$, $Pro_d = 0$, $T_d(Ack) = 0$, $W_s = 25$, $\eta = ?$

Maximum window size = (1+2a) Packet

$$= 1 + 2 * \frac{24.5}{1} = 50\,Pkt$$



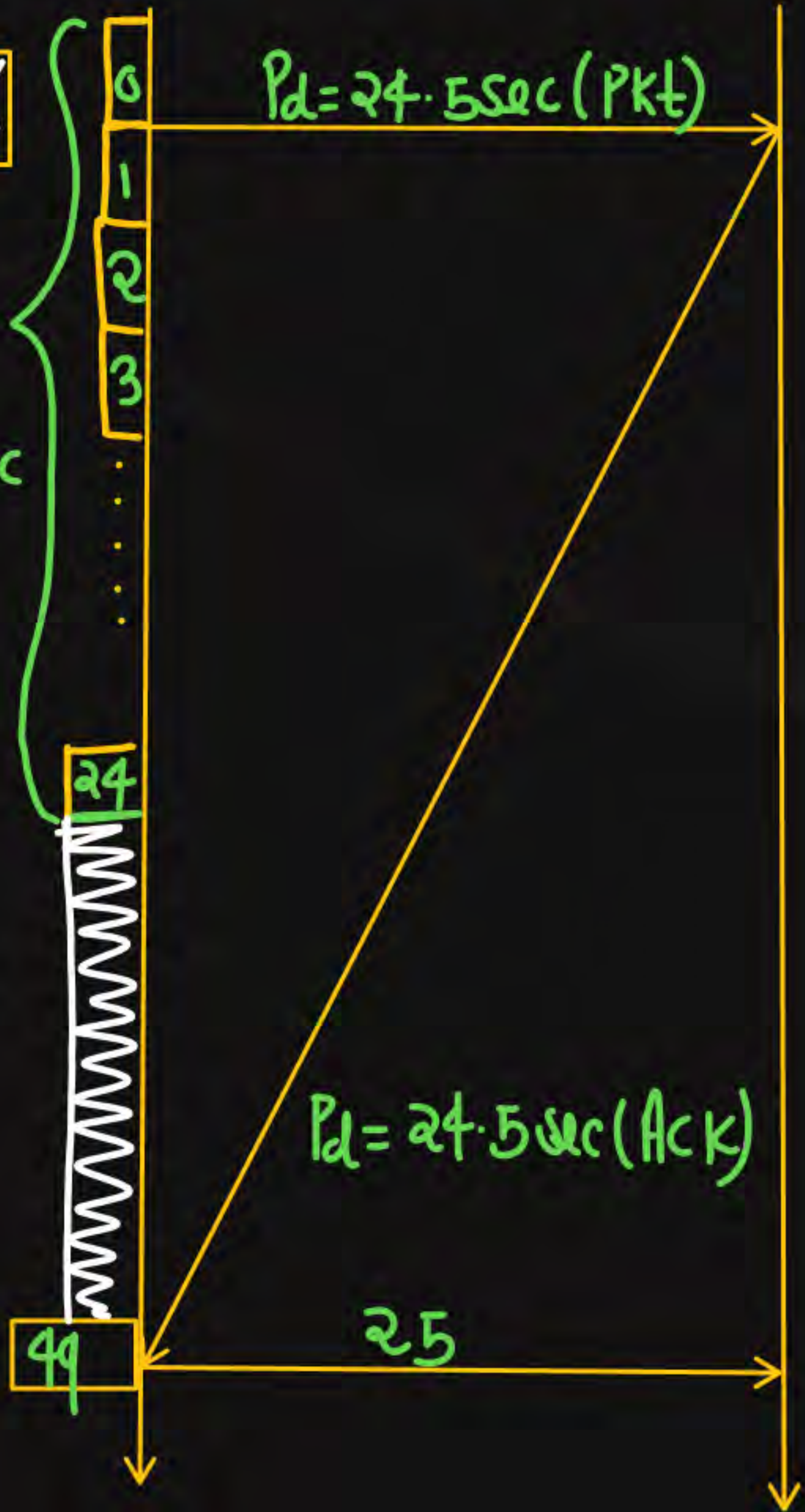
Seq No = 50 (0-49)

$\cdots 27\ 26\ \boxed{25\ \boxed{24 \cdots 3\ 2\ 1\ \cancel{0}}}$

$W_S = 25$

$W_R = 50$

Useful time ⇒ 25 sec



waiting time = 25 sec

$$\boxed{\text{efficiency} = \frac{25}{50} = \frac{1}{2} = 50\%}$$

$$\text{efficiency} = \frac{\text{useful time}}{\text{total time}}$$

$$\boxed{\text{efficiency} = \frac{W_s * T_d(\text{frame})}{T_d(\text{frame}) + 2 * P_d + Q_d + P_{rd} + T_d(\text{Ack})}}$$

$$\eta = \frac{25 * 1\,\text{sec}}{1\,\text{sec} + 2 * 24.5\,\text{sec} + 0 + 0 + 0}$$

$$\eta = \frac{\cancel{25}\,\cancel{\text{sec}}}{\cancel{50}\,\cancel{\text{sec}}}$$

$$\boxed{\eta = \frac{1}{2} = 50\,\%}$$

Q: $\eta = \frac{1}{2}$, Bandwidth = 40mbps, throughput = ?

$$\text{throughput} = \frac{1}{\cancel{2}} * \cancel{40}\text{mbps} = 20\text{mbps}$$

$$\boxed{\text{Throughput} = \text{efficiency} * \text{Bandwidth}}$$

OR

$$\boxed{\text{Throughput} = \frac{W_s * \text{Frame size}}{\text{Total time}}}$$

Comparison between stop & wait, GB-N and SR

① SR Protocal required more sequence Number in comparision of GBN

(i) SeqNo = 8 (0 - 7)

GB-N	$W_S = 7$	$W_R = 1$
SR	$W_S = 4$	$W_R = 4$

(ii)

			min. SeqNo required
GBN	$W_S = 7$	$W_R = 1$	8
SR	$W_S = 7$	$W_R = 7$	14

iii).

			min. SeqNo
GBN	$W_S = N$	$W_R = 1$	$N+1$
SR	$W_S = N$	$W_R = N$	$2N$

2. SR Protocal required more Buffer space in comparion of GB-N

	W_s	W_R	Buffer space
GB-N	N	1	N+1
SR	N	N	2N

3. Traffic is very High in SR Protocal because SR Protocal uses Independent Acknowledgement

	Stop & wait	GBN	SR
Total time = $T_d(\text{frame}) + 2 \times P_d + Q_d + Pr_d + T_d(\text{Ack})$			
Efficiency	$\eta = \frac{\text{useful time}}{\text{Total time}}$ or $\eta = \frac{T_d}{\text{Total time}}$	$\eta = \frac{\text{useful time}}{\text{Total time}}$ or $\eta = \frac{N * T_d}{\text{Total time}}$	$\eta = \frac{\text{useful time}}{\text{Total time}}$ or $\eta = \frac{W_S * T_d}{\text{Total time}}$
Throughput	$\frac{\text{Length of the frame}}{\text{Total time}}$ or $\boxed{\eta * B}$	$\frac{N * \text{Length of the frame}}{\text{Total time}}$ or $\boxed{\eta * B}$	$\frac{W_S * \text{Length of the frame}}{\text{Total time}}$ or $\boxed{\eta * B}$
Buffer	1 + 1	N + 1	N + N
Seq No.	2 (0 & 1)	N + 1 (0 - N)	2N (0 - 2N-1)
Seq. No. = K bit		$\frac{W_S}{2^K - 1}$ $\frac{W_R}{1}$	$\frac{W_S}{2^{K-1}}$ $\frac{W_R}{2^{K-1}}$

Problem Solving

on

SR Protocol

Q.1 The maximum window size for data transmission using the selective reject protocol with n-bit frame sequence numbers is:

GATE-2005

(A) 2^n

(B) $2^{(n-1)}$

(C) $2^{n}-1$

(D) $2^{(n-2)}$

SeqNo = K bits

$$\frac{W_S}{2^{K-1}} \qquad \frac{W_R}{2^{K-1}}$$

Q.2 If senders Window size(W_S) is 75. What will be sequence numbers required in Go-Back-N and SR protocol?

(A) 0 to 75 and 0 to 76

(B) 0 to 75 and 0 to 149

(C) 0 to 75 and 0 to 150

(D) 0 to 74 and 0 to 150

If Sender window size = N

min Seq. No required in GBN = N+1 (0 − N)

min seq. No required in SR = N+N = 2N (0 − 2N−1)

Sender window size = 75

min seq No required in GBN = 75+1 = 76 (0 − 75)

min. seq No required in SR = 2*75 = 150 (0-149)

Q.3 If 'N' is the maximum sequence number then window size in GB-N and SR is

SeqNo = 8 (0, 1, 2, 3, 4, 5, 6, 7) N

(A) $\frac{N}{2}$, N – 1

(B) N – 1, $\frac{N}{2}$

(C) N, $\frac{N+1}{2}$

(D) $\frac{N+1}{2}$, N

GBN

W_S	W_R
7	1
N	1

SR

W_S	W_R
4	4
$\frac{7+1}{2}$	$\frac{7+1}{2}$
$\frac{N+1}{2}$	$\frac{N+1}{2}$

Q.4

Suppose sliding window ARQ is used for flow control and optimal window size for maximum utilization of link is 5. If stop & wait ARQ is used instead of sliding window then the link utilization (in percent) is ____.

$\eta_{\text{sliding window}} = 1$, if $N = 5$ → window sender size

$$\boxed{\eta_{\text{sliding window}} = N * \eta_{\text{stop \& wait}}}$$

$$\eta_{\text{stop \& wait}} = \frac{1}{N} * \eta_{\text{sliding window}}$$

$$= \frac{1}{5} * 1 = 20\ \%$$

Q.5 Consider minimum number of bits required for sequence number field in selective repeat ARQ for maximum utilization are 4 then the efficiency of stop & wait ARQ (in percent) is ____.

N → sender window size

$$\eta_{\text{sliding window}} = N * \eta_{\text{stop \& wait}}$$

$$\eta_{\text{stop \& wait}} = \frac{1}{N} * \eta_{\text{sliding window}}$$

$$= \frac{1}{8} * 1$$

$$= 0.125$$

$$\eta_{\text{stop \& wait}} = 12.5\%$$

Seq No = 4 bit

W_S	W_R
2^{4-1}	2^{4-1}
2^3	2^3
8	8

Q.6 Assume we need to design selective repeat protocol for a network in which bandwidth is 1 Mbps and average distance between sender and receiver is 5000 Km. Assume that average packet size is 5000 bits. Propagation speed in the media is 2×10^8 m/sec. If window sender size is 8 and process delay is 0.5 Msec and queuing delay is 2msec then what is the efficiency.

(A) 99%

(B) 57%

(C) 87%

(D) 70% ✓

$B = 10^6$ bits/sec , $d = 5000$ km , $v = 2 * 10^8$ m/sec

Pkt size or Frame size = 5000 bits

$v = 2 * 10^5$ km/sec

$T_d(\text{Frame}) = \dfrac{\text{Frame size}}{\text{Bandwidth}} = \dfrac{5000 \text{ bits}}{10^6 \text{ bits/sec}} = 5 * 10^{-3} \text{ sec} = 5 \text{ msec}$

$P_d = \dfrac{d}{v} = \dfrac{5000 \text{ km}}{2 * 10^5 \text{ km/sec}} = 25 * 10^{-3} \text{ sec} = 25 \text{ msec}$

$W_s = 8$, $Q_d = 2$ msec, $Pr_d = 0.5$ msec

$$\eta = \frac{\text{usefultime}}{\text{totaltime}}$$

$$= \frac{W_s * T_d(\text{frame})}{T_d(\text{frame}) + 2*P_d + Q_d + Pr_d + \cancel{T_d(\text{Ack})}}$$

$T_d(\text{Ack}) \to 0$

$$= \frac{8*5}{5+2\times25+2+0.5}$$

$$= \frac{40}{57.5} = 0.6956 = 69.56\%$$

$\simeq 70\%$

Q.7

In selective repeat ARQ, packet size is 2000 bytes transmission time for one packet is 1ms. If distance between hosts is 10km and signal speed is 4ms per km (4ms/km) and frame sequence number are 6 bit long in frame format then the throughput (in Mbps) is 6.32 Mbps

$$\boxed{\text{Throughput} = \frac{W_s * \text{Frame size}}{\text{Total time}}}$$

OR

$$\boxed{\text{Throughput} = \eta * B}$$

SeqNo = 6 bit

SR Protocol

SeqNo = K bit

W_s	W_R
2^{K-1}	2^{K-1}
2^{6-1}	2^{6-1}
32	32

Q.8

Suppose you are designing a sliding window protocol for a 1-Mbps point to point link to the moon, which has a one way latency (delay) of 1.25 seconds. Assuming that each frame carries 1 KB of data, the minimum number of bits you need for the sequence number

(i) for RWS = 1 (GBN) and

(ii) for SWS = RWS (SR) is

(A) 6, 7

(B) 7, 8

(C) 8, 9

(D) 9, 10

$B = 10^6$ bits/sec, $P_d = 1.25$ sec

Frame size = 1 KB
= 1024 Byte
= 8 * 1024 bits
= 8192 bits

$T_d(\text{Frame}) = \frac{\text{Frame size}}{\text{Bandwidth}}$

$= \frac{8192 \text{ bits}}{10^6 \text{ bits/sec}}$

$8192 * 10^{-6}$ sec

$T_d(\text{Frame}) = 0.008192$ sec

$$\text{efficiency} = \frac{\text{useful time}}{\text{total time}}$$

$$1 = \frac{N * T_d(\text{frame})}{T_d(\text{Frame}) + 2 * P_d + \cancel{Q_d}^{0} + \cancel{P_{rd}}^{0} + \cancel{T_d(\text{Ack})}^{0}}$$

$$\frac{1}{1} = \frac{N * 0.008192}{0.008192 + 2 * 1.25}$$

$$\frac{306 * 0.008192}{0.008192 + 2 * 1.25} = 0.99$$

$$N = \frac{0.008192 + 2 * 1.25}{0.008192}$$

$N = 306.17$, $N = \lceil 306.17 \rceil = 307$ (sender window size)

Sliding window	GBN	SR
min SeqNo required in Sliding window = 307	min. SeqNo required in GB-N = 307 + 1 = 308	min. Sequence Number required in SR = 307 + 307 = 614
$2^K = 307$	$2^K = 308$	$2^K = 614$
$2^K = 2^9$	$2^K = 2^9$	$2^K = 2^{10}$
$\boxed{K = 9 \text{ bit}}$	$\boxed{K = 9 \text{ bit}}$	$\boxed{K = 10 \text{ bits}}$

Q.9

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 __4__.

GATE-2016-2M

$W_s = 5.68$

$W_s = \lceil 5.68 \rceil = 6$

Q.10 A 3000 km long trunk operating at 1.536 Mbps is used to transmit 64 bytes frames and uses SWP. If the propagation speed is 6 μsec/km, then the number of bits should the sequence numbers is

Sliding window Protocal

(A) 5

(B) 6

(C) 7

(D) 8

Q.11

Consider selective repeat ARQ is used for flow control, frame size is 4000 bits, data transfer rate of channel is 1 Mbps and one way propagation delay is 18 ms then minimum number of bits required for sequence number field for maximum utilization is ____ .

H·W

Q.12 Consider the sliding window flow-control protocol operating between a sender and a receiver over a full-duplex error-free link. Assume the following:

- The time taken for processing the data frame by the receiver is negligible.
- The time taken for processing the acknowledgement frame by the sender is negligible.
- The sender has infinite number of frames available for transmission.
- The size of the data frame is 2,000 bits and the size of the acknowledgement frame is 10 bits.
- The link data rate in each direction is 1 Mbps (= 10^6 bits per second).
- One way propagation delay of the link is 100 milliseconds.
- The minimum value of the sender's window size in terms of the number of frames, (rounded to the nearest integer) needed to achieve a link utilization of 50% is__________.

GATE-2021

Q.13

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

(A) 20

(B) 40

(C) 160

(D) 41

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AD steps to solve SWP Problem

1. Calculate RTT
2. Based on the given Bandwidth and RTT calculate No. of bits we are able to transfer with in RTT and Equate it as window in terms of bits (W_{bits}) = B*RTT
3. W_{pkt} or W_p $= \dfrac{W_{bits}}{\text{(Packet size) bits}}$
4. Minimum sequence No. required = W_p
5. $2^K = W_P$

   Where K = No. of bits required in the sequence number field

Q.14

Consider two node A and B round trip delay between these is 80 ms and bottle neck bandwidth of link between A and B is 512 KBps, the optimal window size (in packets) if the packet size is 64 Byte _____.

HW

IPv4 Header & Fragmentation → (4 days)