

FLOW CONTROL

- ★ Speed matching mechanism.
- ★ Flow control coordinates the amount of data that can be sent before receiving an acknowledgment.
- ★ Flow control is a set of procedures that tells the sender how much data it can transmit before it must wait for an acknowledgement from the receiver.
- ★ Receiver has a limited speed at which it can process incoming data and a limited amount of memory in which to store incoming data.
- ★ Receiver must inform the sender before the limits are reached and request that the transmitter to send fewer frames or stop temporarily.



FLOW CONTROL

Protocols

Noiseless Channels

- ★ Simplest
- ★ Stop-and-wait

Noisy Channels

- ★ Stop-and-wait ARQ
- ★ Go-Back-N-ARQ
- ★ Selective Repeat ARQ

STOP-AND-WAIT PROTOCOL

- ★ Stop - and - Wait protocol is data link layer protocol for transmission of frames over noiseless channels.
- ★ It provides unidirectional data transmission with flow control facilities but without error control facilities.
- ★ The idea of stop-and-wait protocol is straightforward.
- ★ After transmitting one frame, the sender waits for an acknowledgement before transmitting the next frame.

PRIMITIVES OF STOP-AND-WAIT PROTOCOL

Sender side

Rule 1 : Send one data packet at a time.

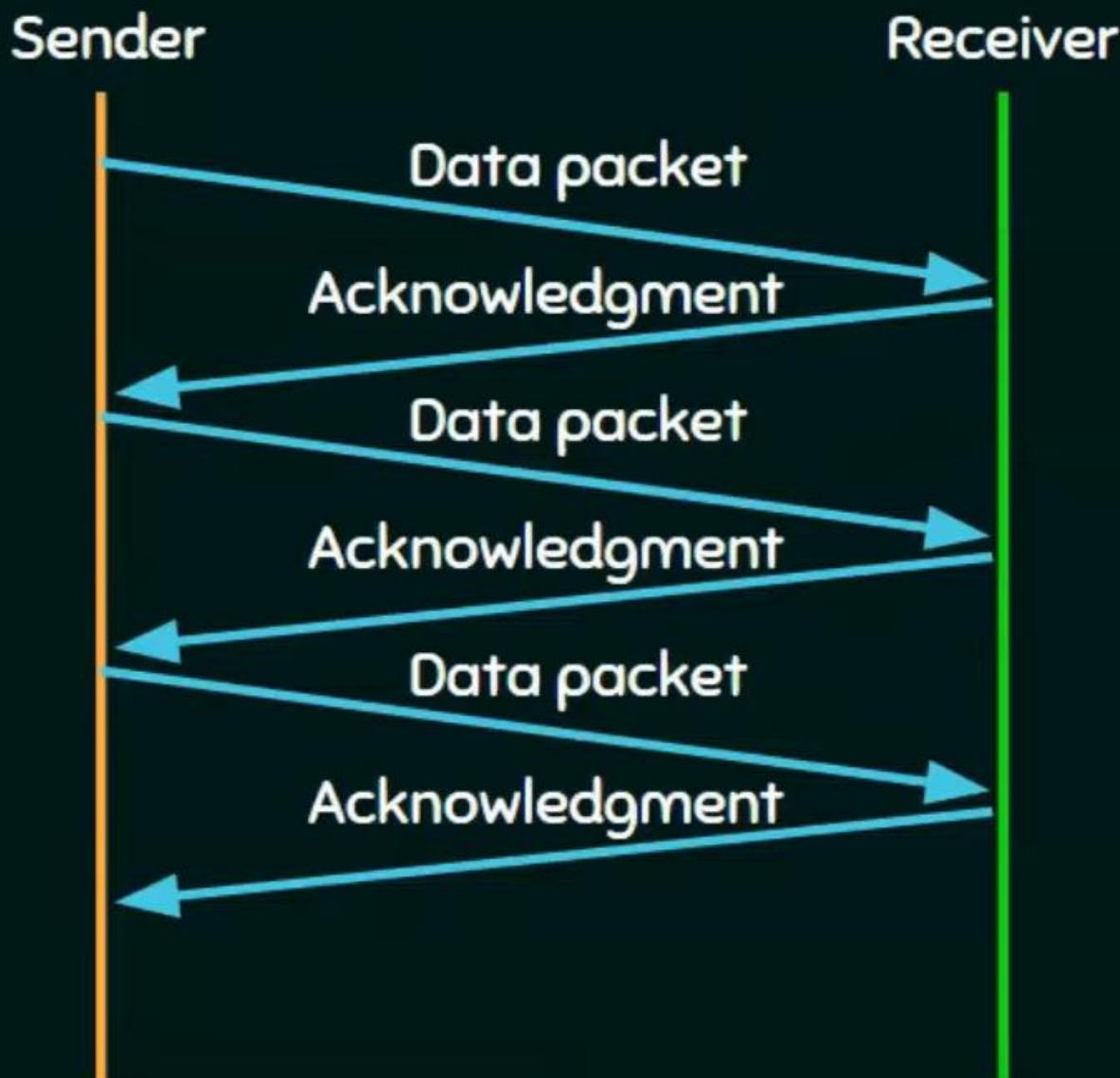
Rule 2 : Send the next packet only after receiving ACK for the previous.

Receiver side

Rule 1 : Receive and consume data packet.

Rule 2 : After consuming packet, ACK need to be sent (Flow Control).

STOP-AND-WAIT PROTOCOL



PROBLEMS OF STOP-AND-WAIT PROTOCOL

1. Problems due to lost data.

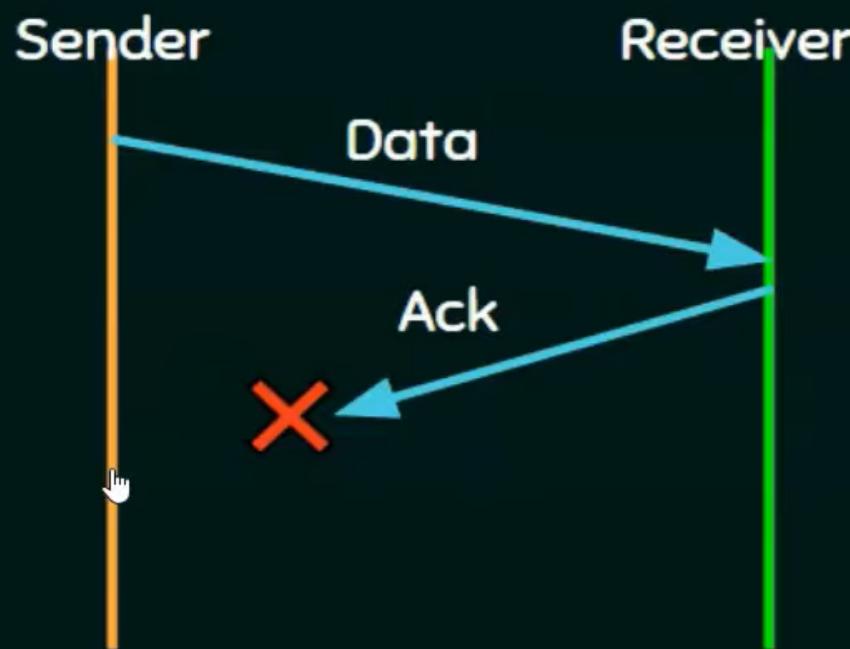
- ★ Sender waits for ack for an infinite amount of time.
- ★ Receiver waits for data an infinite amount of time.



PROBLEMS OF STOP-AND-WAIT PROTOCOL

2. Problems due to lost ACK.

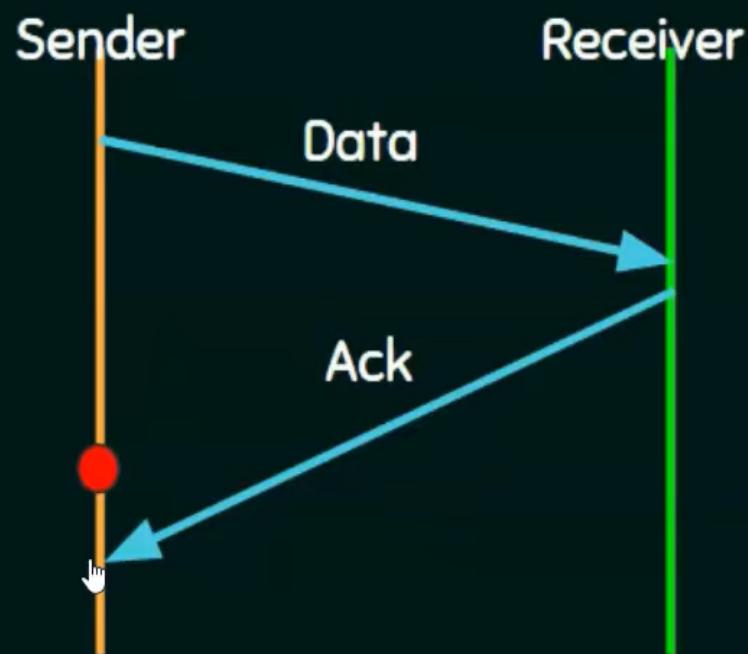
- ★ Sender waits for an infinite amount of time for ack.



PROBLEMS OF STOP-AND-WAIT PROTOCOL

3. Problems due to delayed ACK/data.

- ★ After timeout on sender side, a delayed ack might be wrongly considered as ack of some other data packet.



PROBLEMS OF STOP-AND-WAIT PROTOCOL

1. Problems due to lost data.

Sender waits for ack for an infinite amount of time.

Receiver waits for data an infinite amount of time.

2. Problems due to lost ACK.

Sender waits for an infinite amount of time for ack.

3. Problems due to delayed ACK/data.

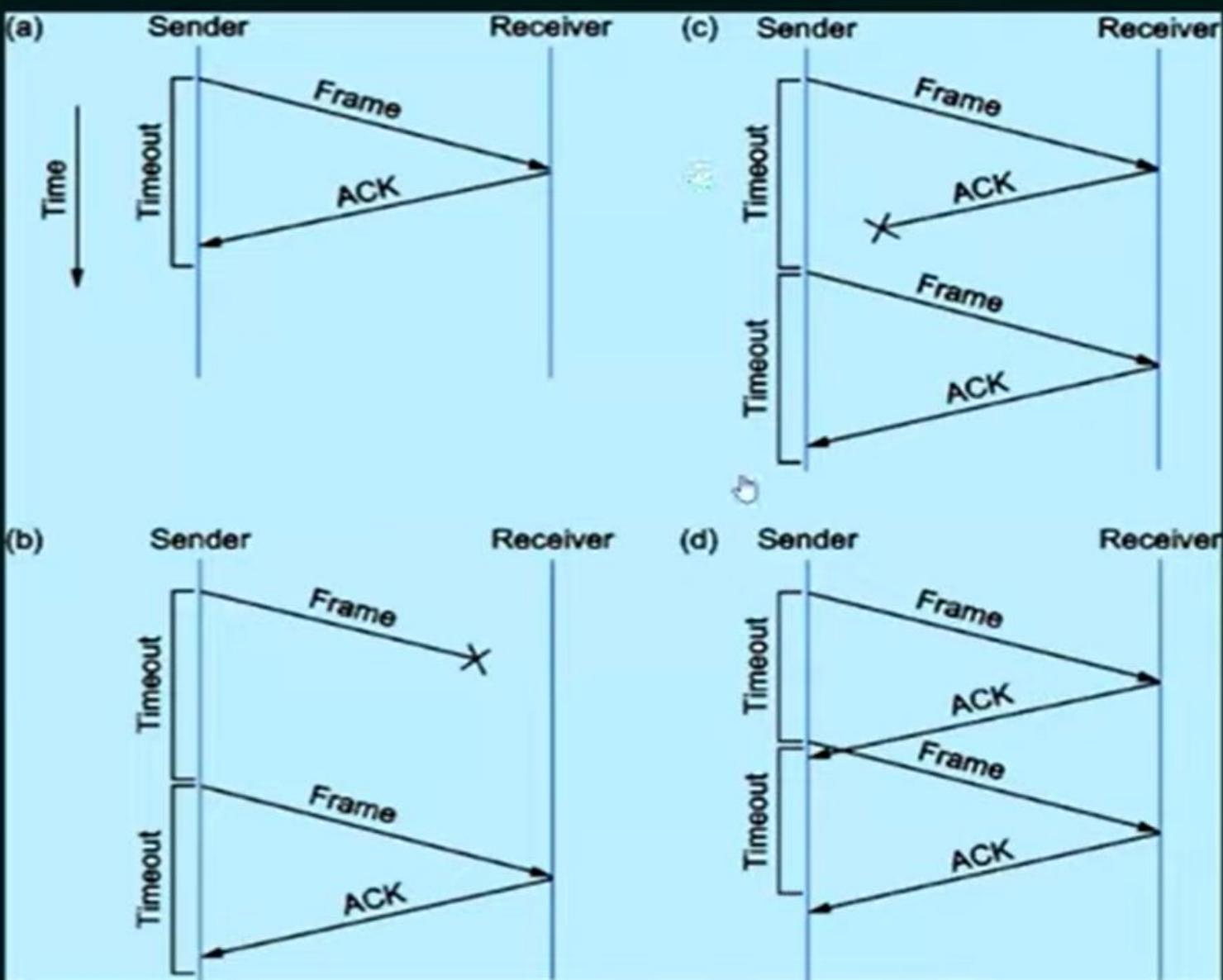


After timeout on sender side, a delayed ack might be wrongly considered as ack of some other data packet.

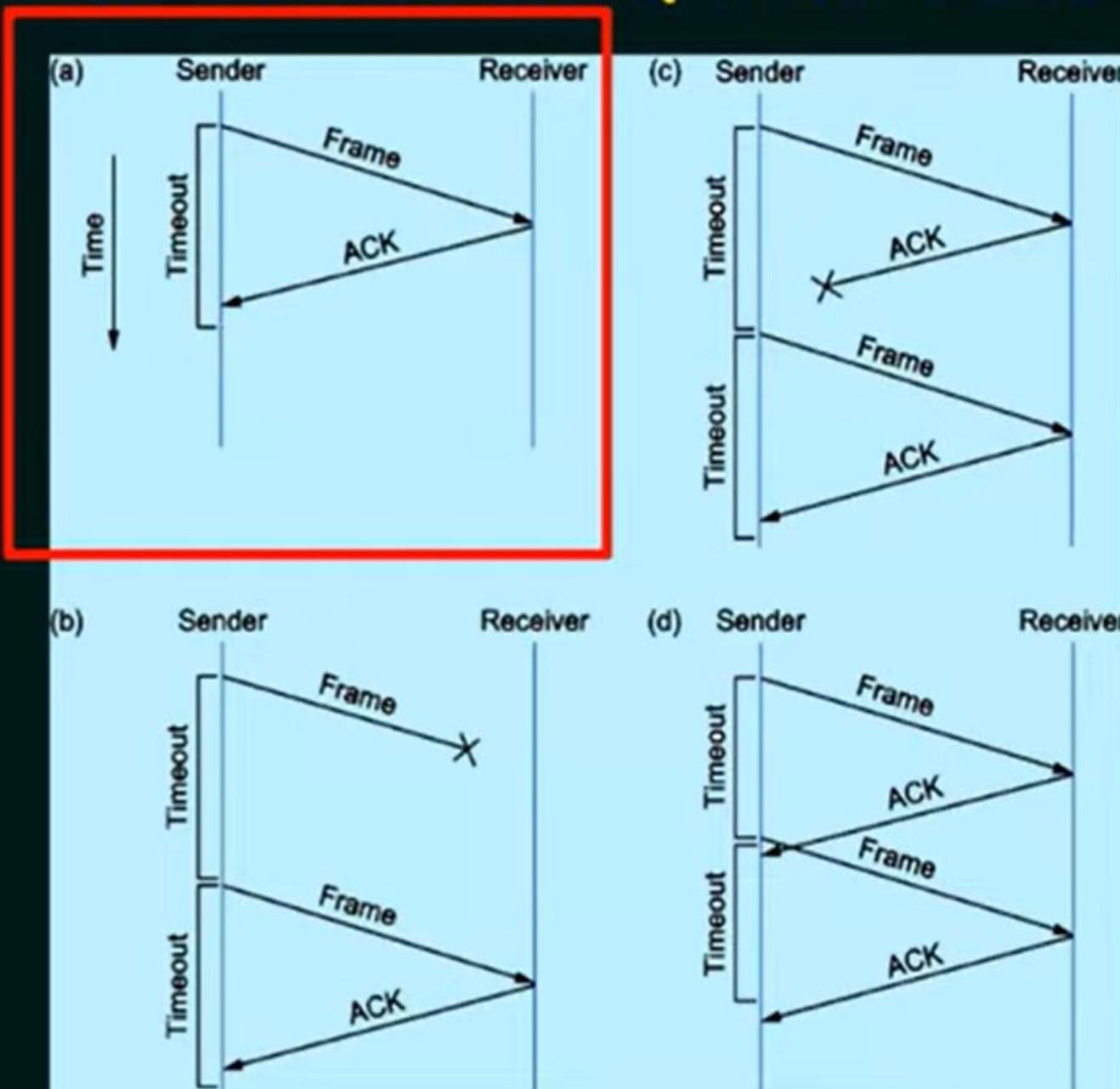
STOP-AND-WAIT ARQ PROTOCOL

- ★ Idea of stop-and-wait protocol is straightforward.
- ★ After transmitting one frame, the sender waits for an acknowledgement before transmitting the next frame.
- ★ If the acknowledgement does not arrive after a certain period of time, the sender times out and retransmits the original frame.
- ★ Stop-and-Wait ARQ = Stop-and-Wait + Timeout Timer + Sequence number

STOP-AND-WAIT ARQ PROTOCOL

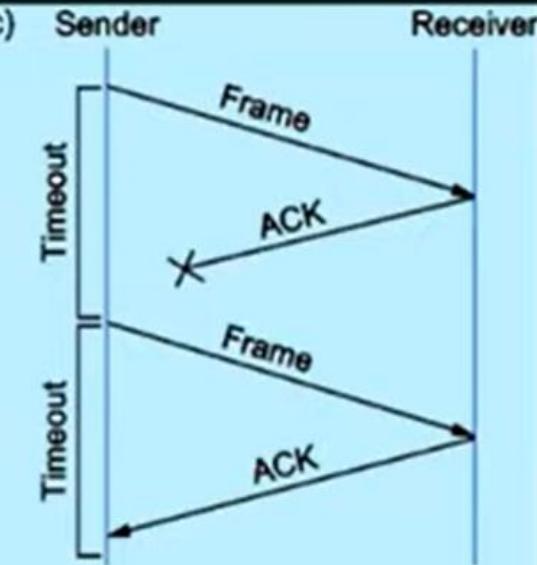
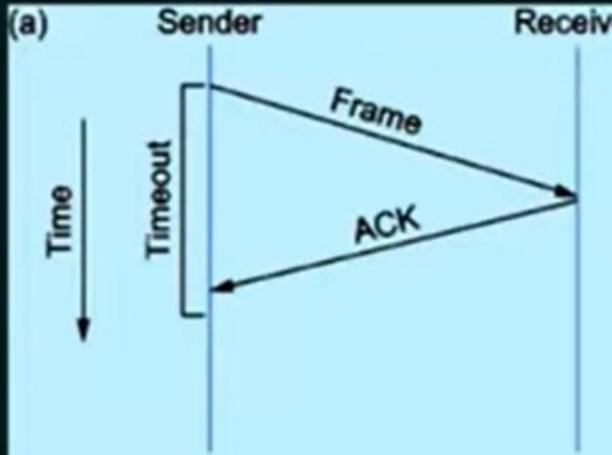


STOP-AND-WAIT ARQ PROTOCOL

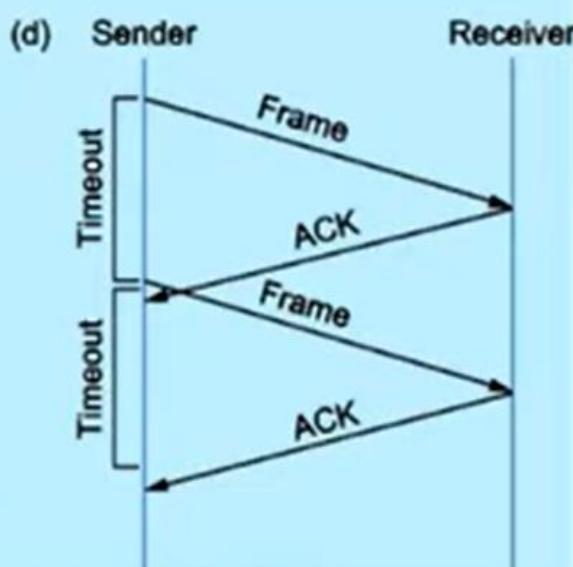
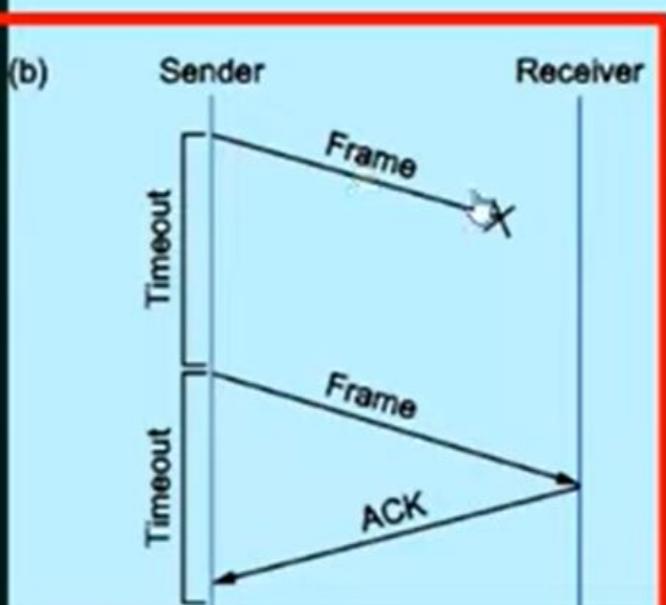


(a) The ACK is received before the timer expires;

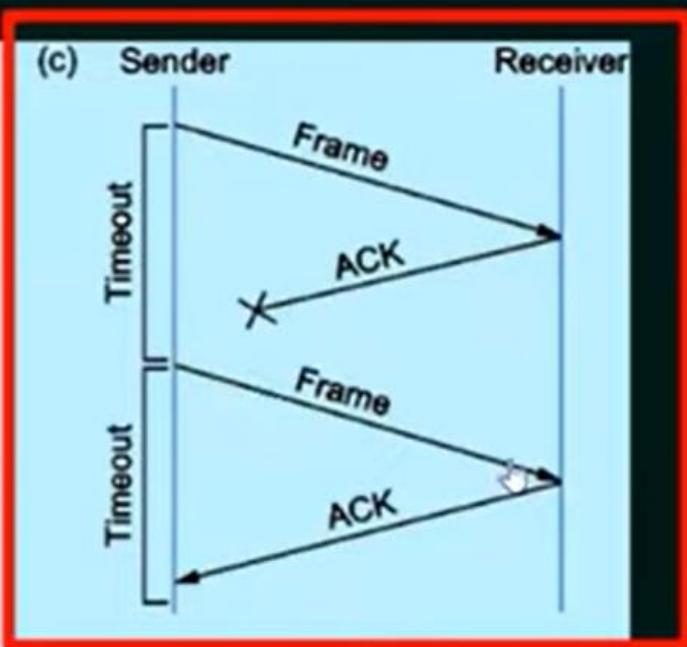
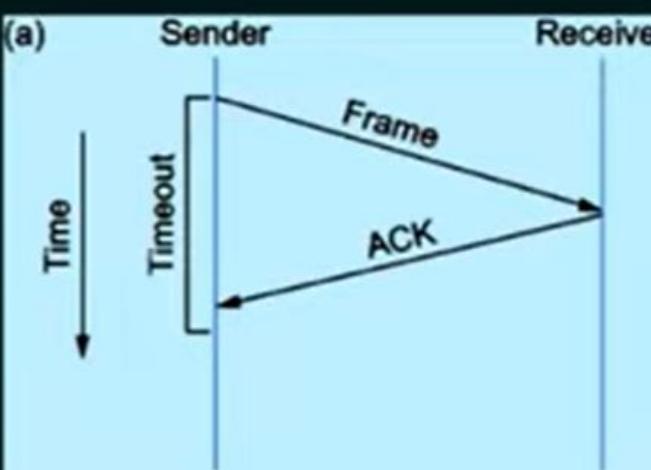
STOP-AND-WAIT ARQ PROTOCOL



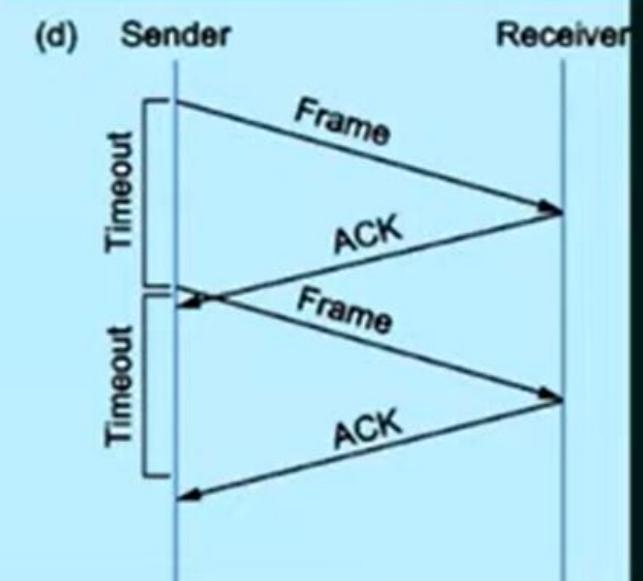
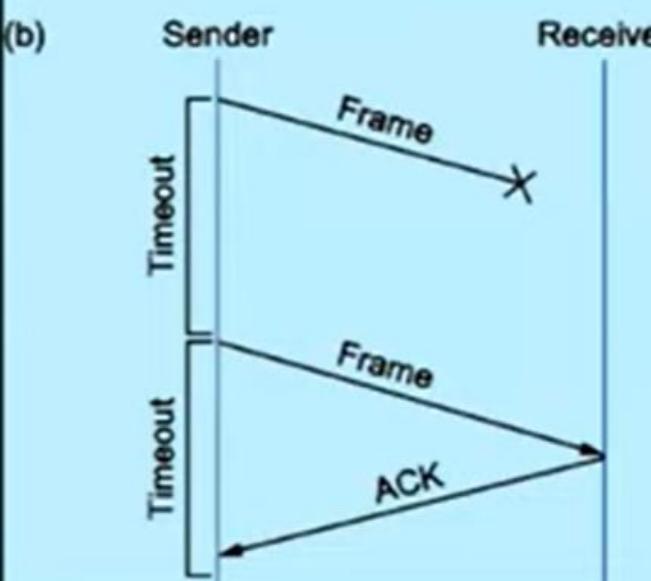
(b) The original frame is lost



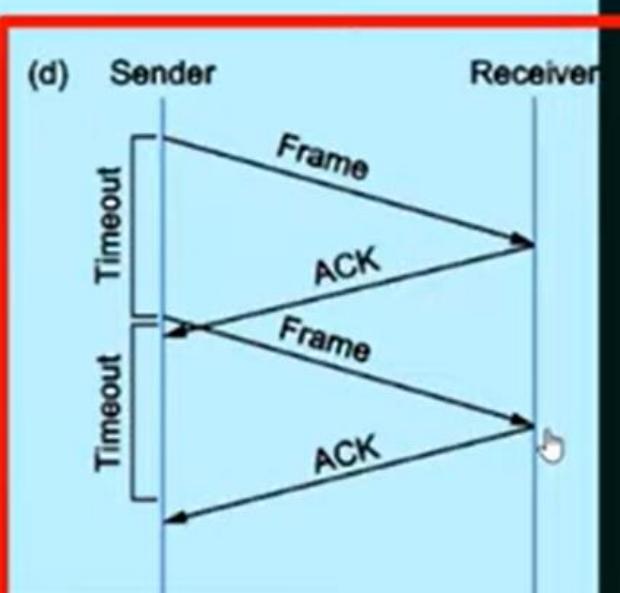
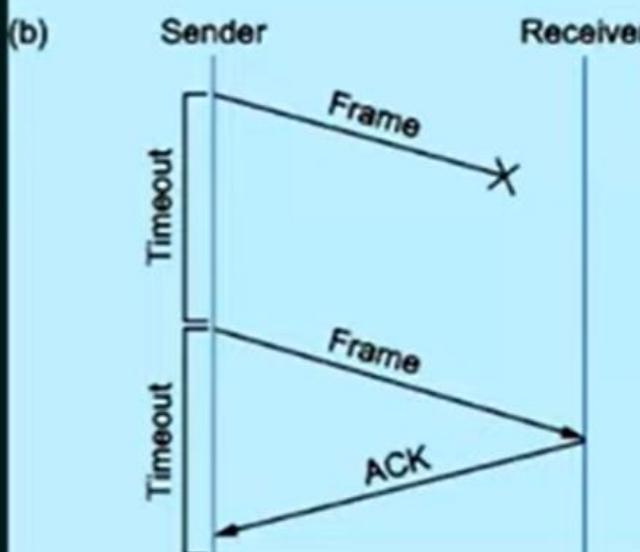
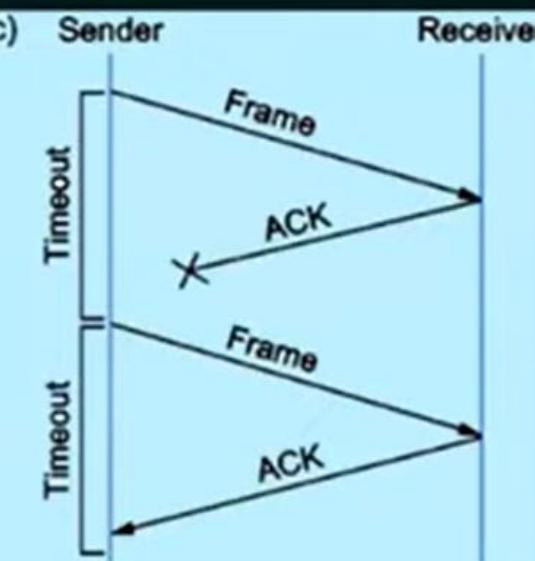
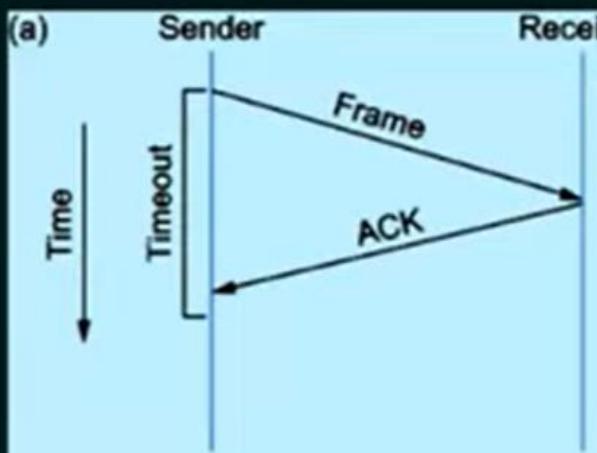
STOP-AND-WAIT ARQ PROTOCOL



(c) The ACK is lost



STOP-AND-WAIT ARQ PROTOCOL



(d) The timeout fires too soon

STOP-AND-WAIT ARQ – DRAWBACKS

- ★ One frame at a time.
- ★ Poor utilization of bandwidth.
- ★ Poor Performance

FLOW CONTROL

Protocols

Noiseless Channels

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- ★ Stop-and-wait

Noisy Channels

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- ★ Go-Back-N-ARQ
- ★ Selective Repeat ARQ

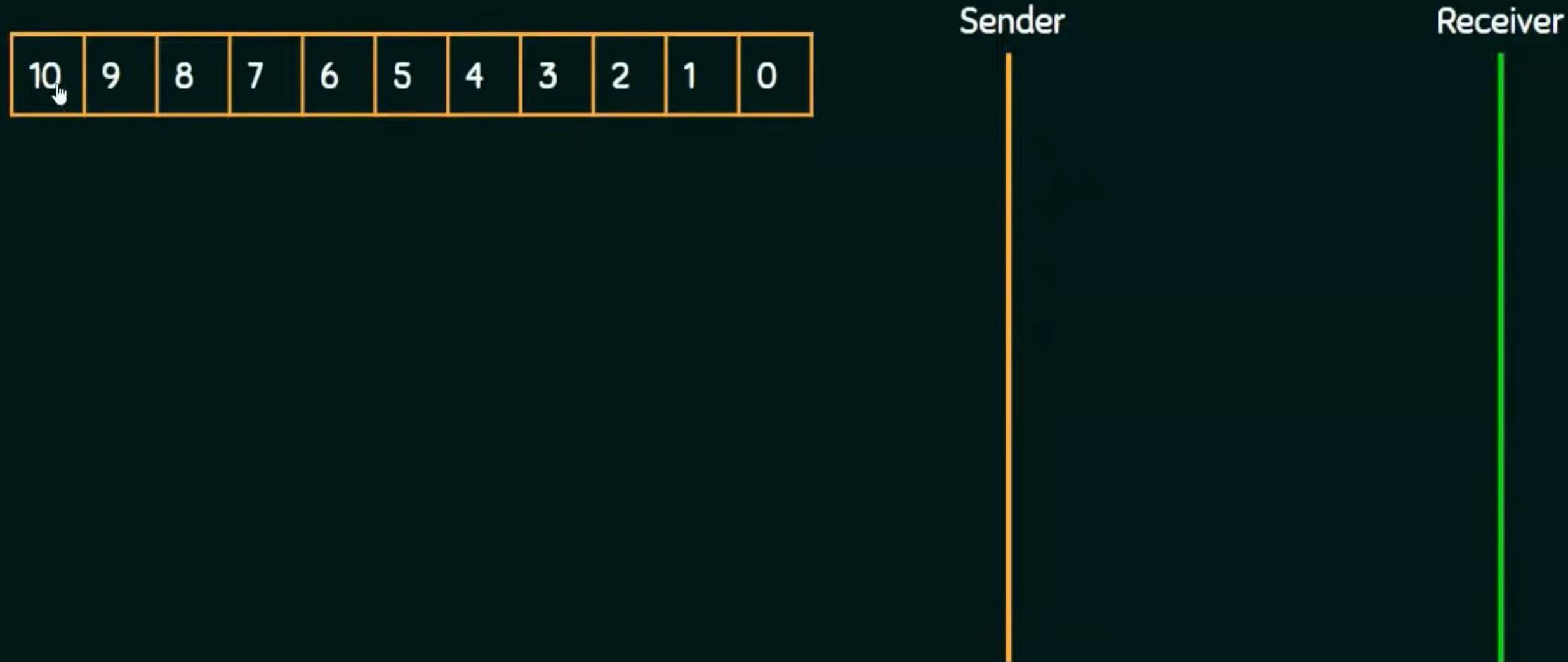
Sliding Window
Protocols

SLIDING WINDOW PROTOCOL

- ★ Send multiple frames at a time.
- ★ Number of frames to be sent is based on Window size.
- ★ Each frame is numbered -> Sequence number.



WORKING OF SLIDING WINDOW PROTOCOL



WORKING OF SLIDING WINDOW PROTOCOL

10	9	8	7	6	5	4	3	2	1	0
----	---	---	---	---	---	---	---	---	---	---

Window Size: 4

Sender

Receiver

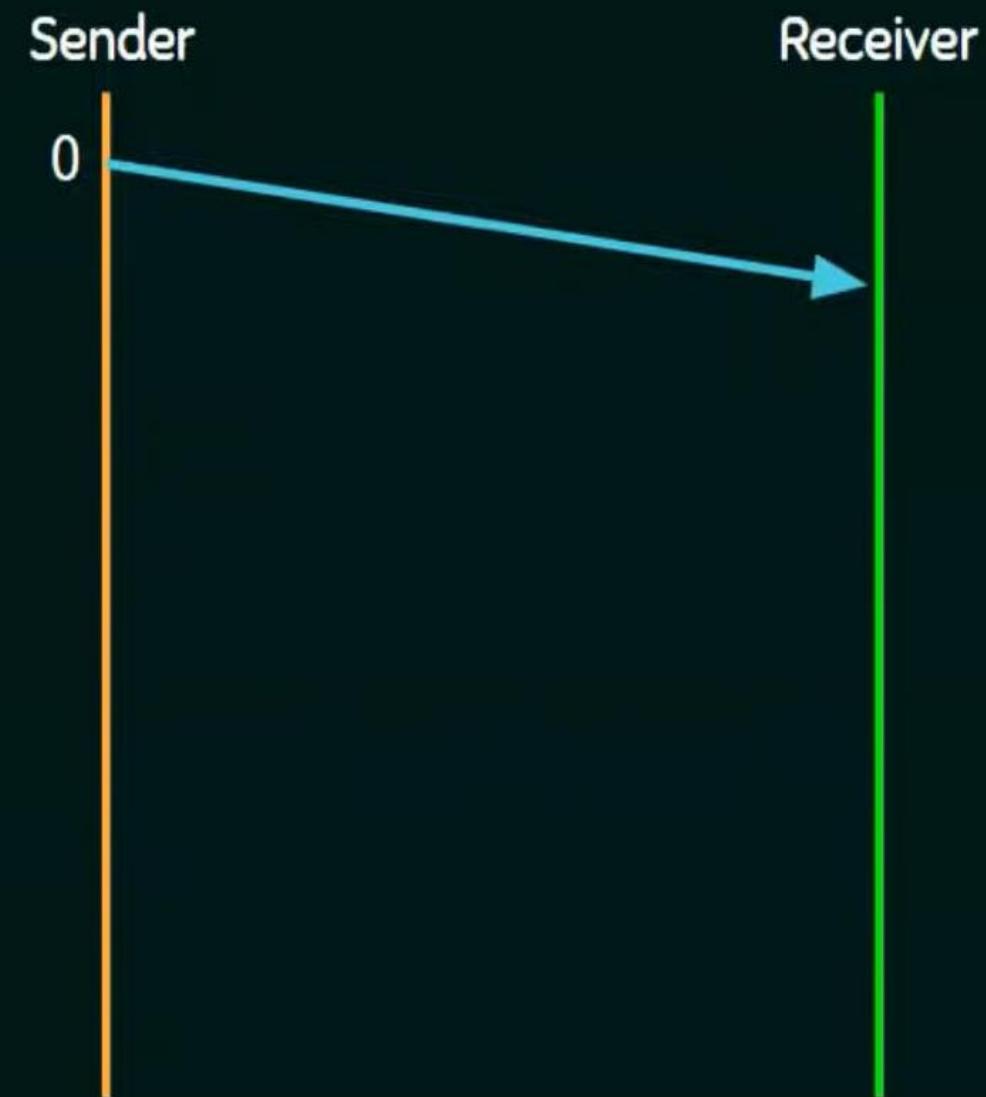


WORKING OF SLIDING WINDOW PROTOCOL



Sliding Window

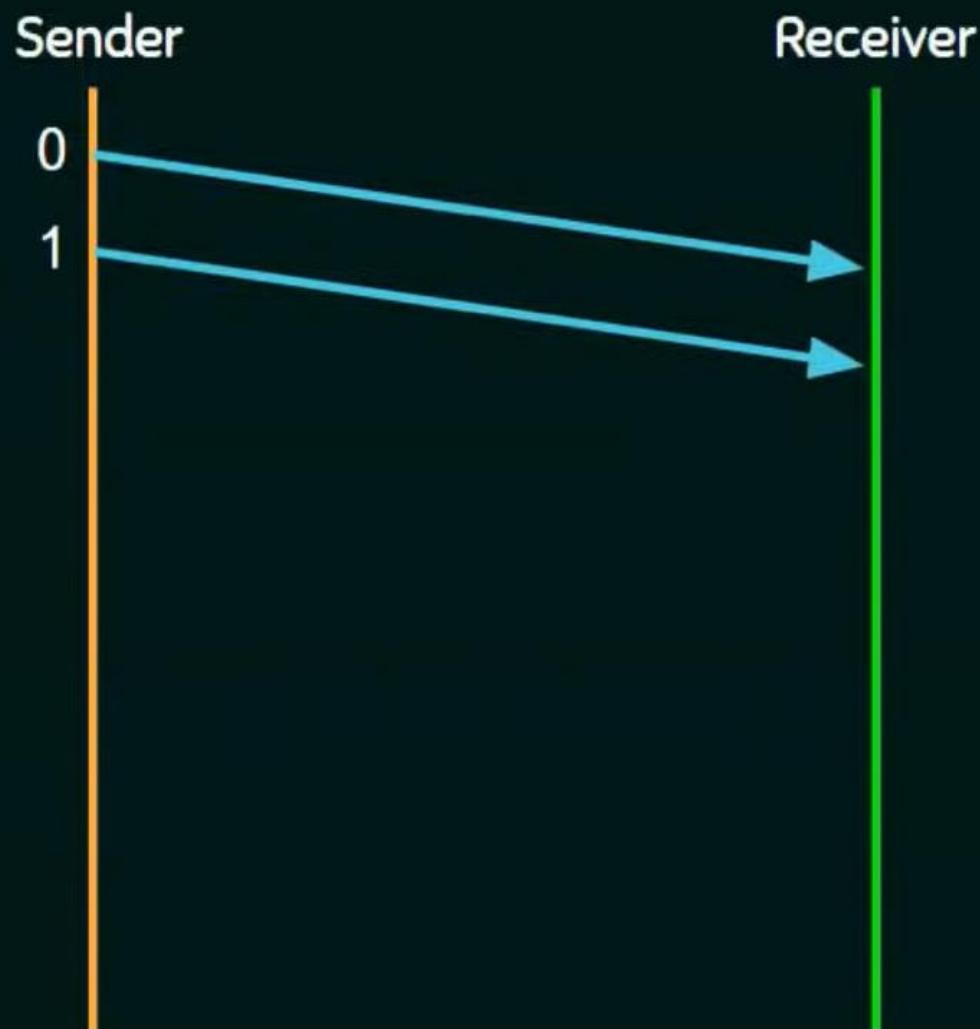
Window Size: 4



WORKING OF SLIDING WINDOW PROTOCOL



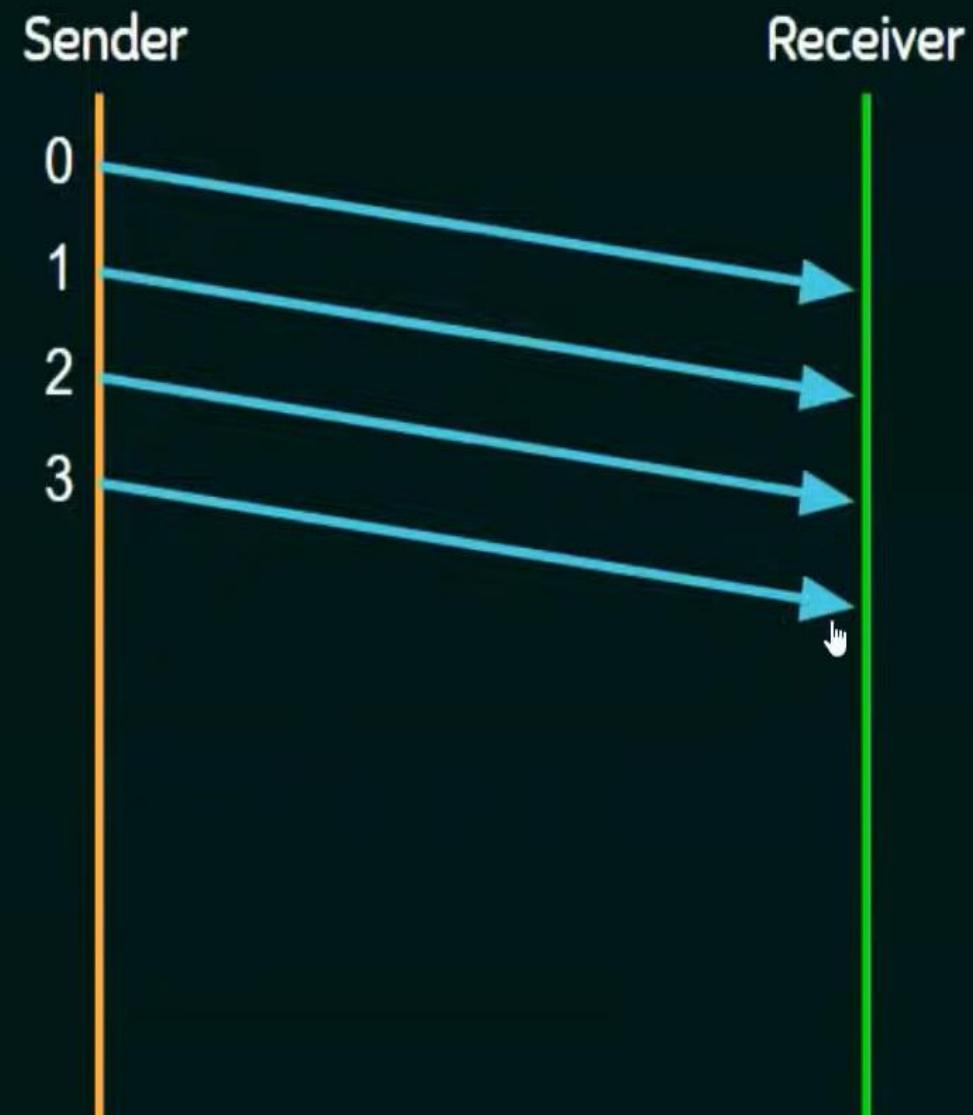
Window Size: 4



WORKING OF SLIDING WINDOW PROTOCOL



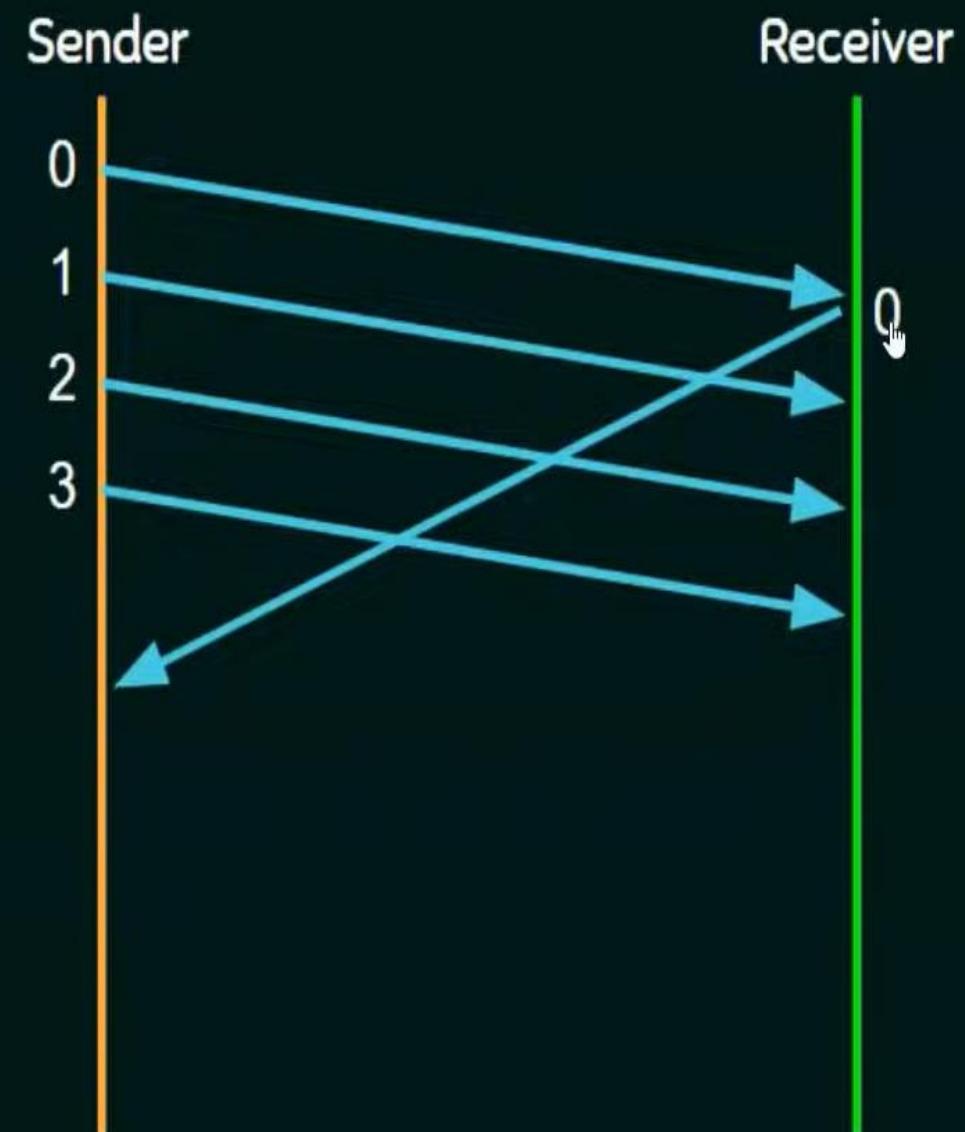
Window Size: 4



WORKING OF SLIDING WINDOW PROTOCOL



Window Size: 4



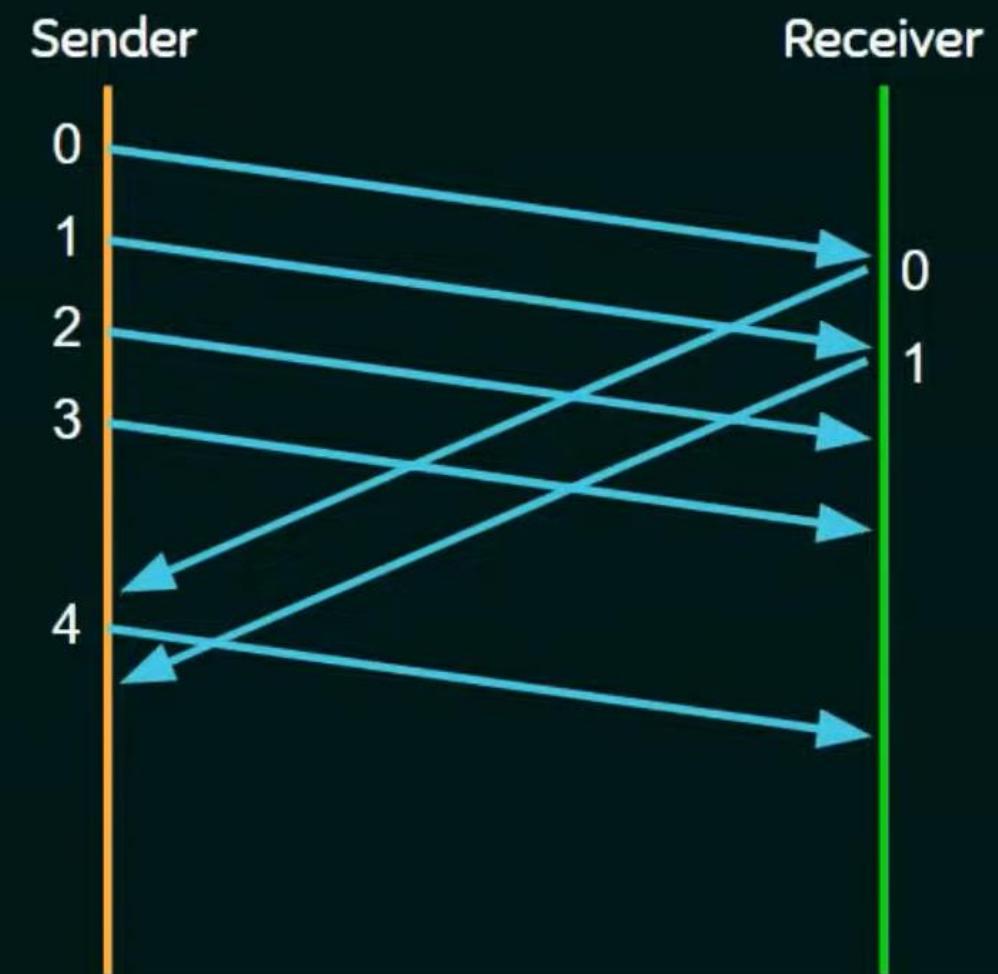
WORKING OF SLIDING WINDOW PROTOCOL



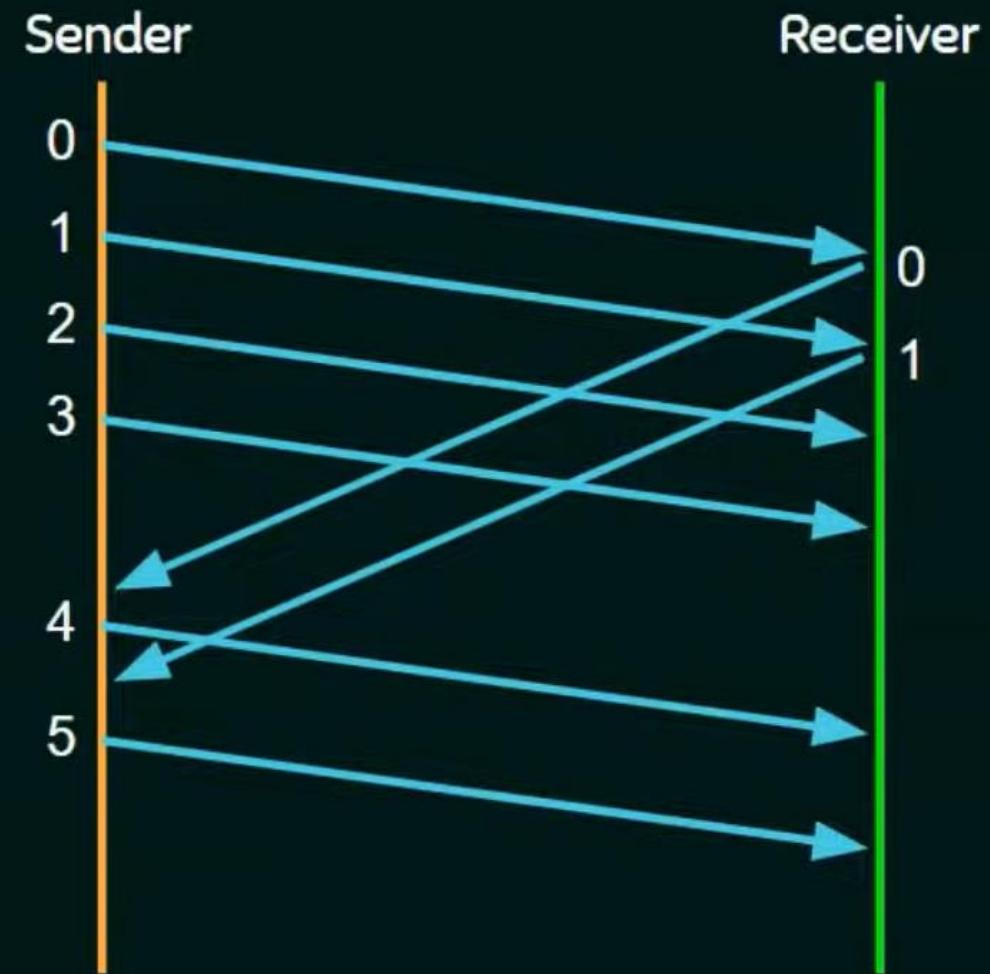
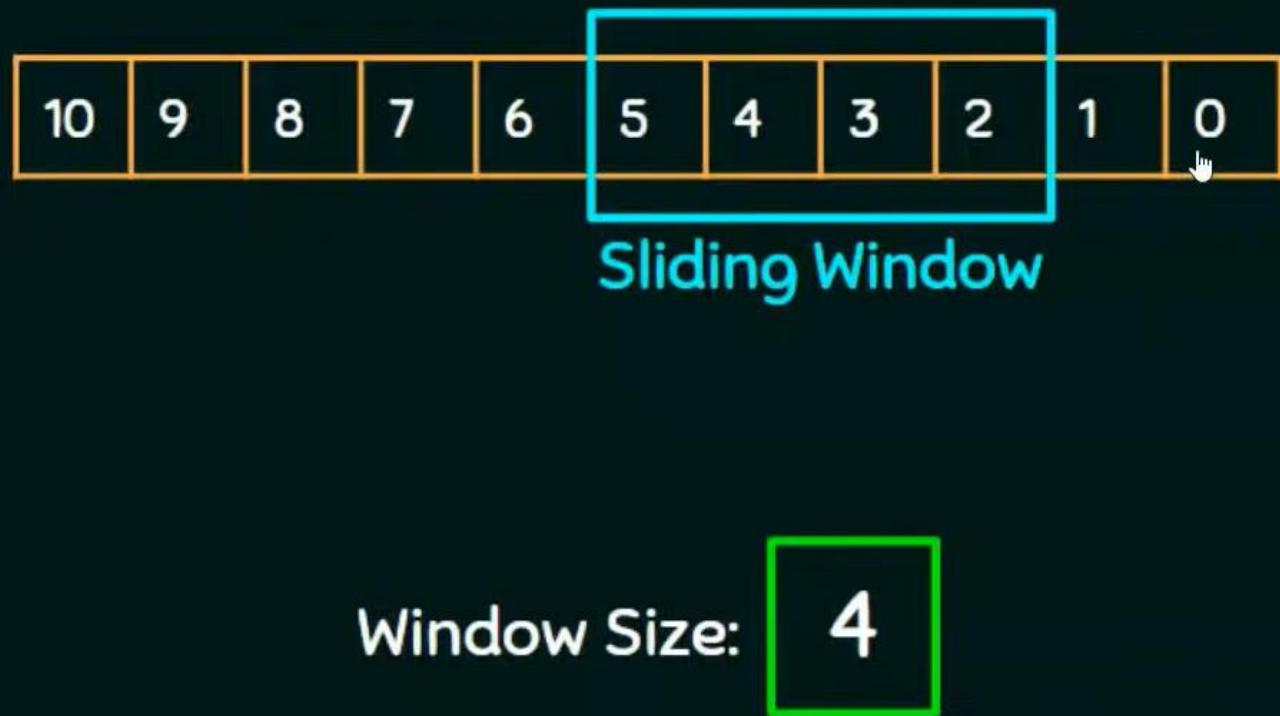
Window Size: 4



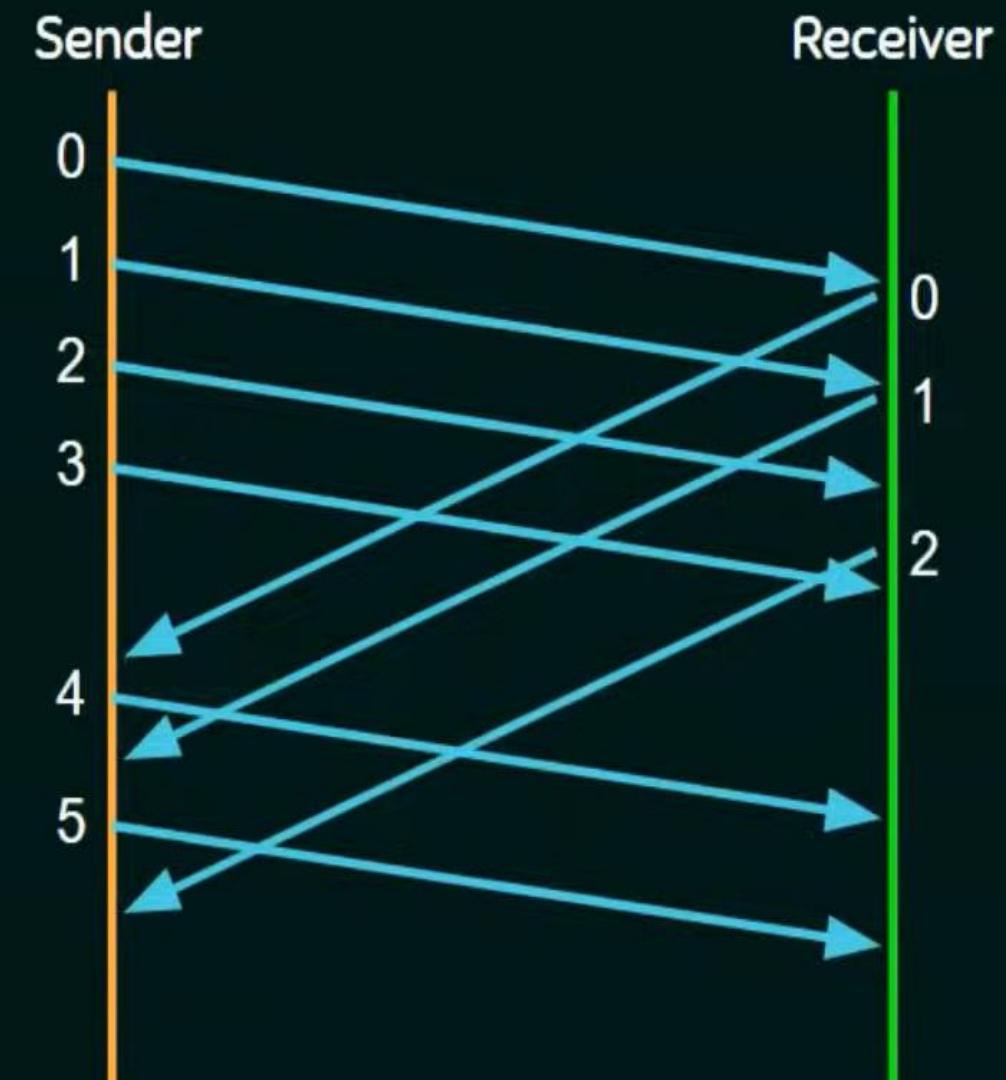
WORKING OF SLIDING WINDOW PROTOCOL



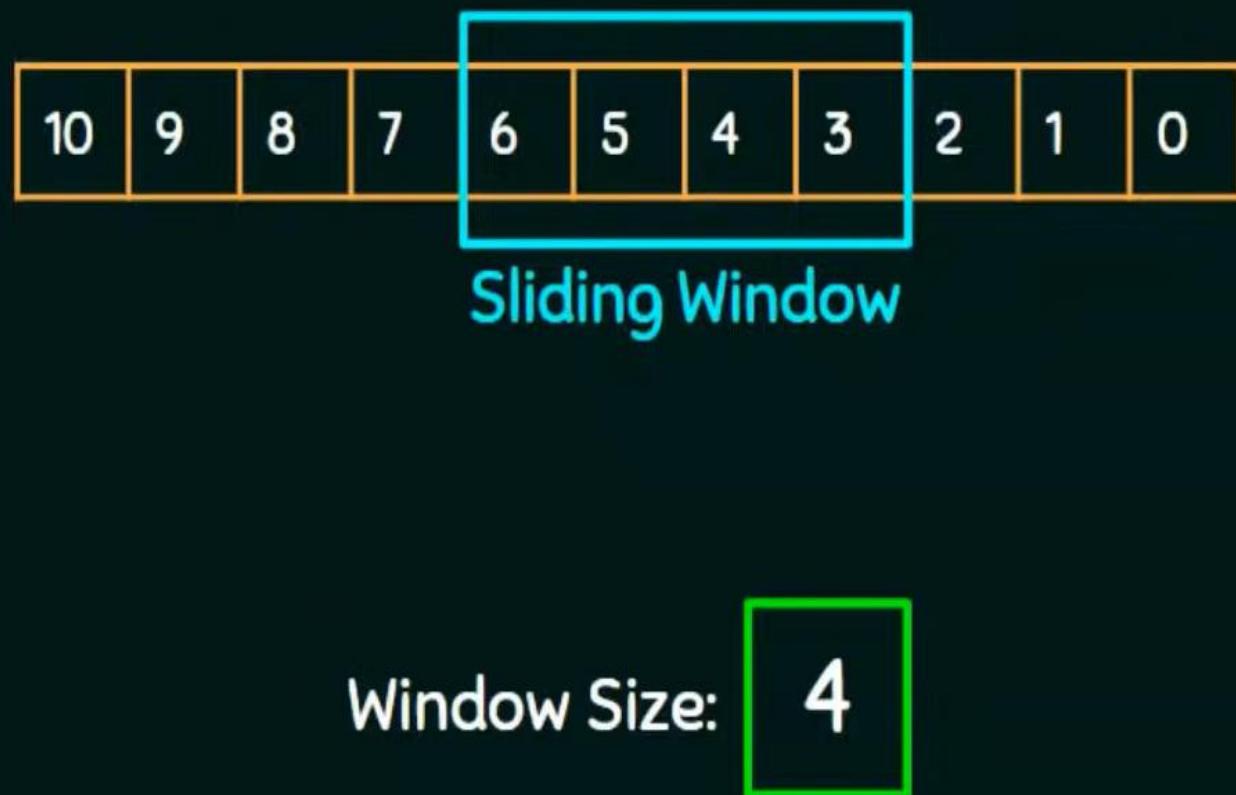
WORKING OF SLIDING WINDOW PROTOCOL



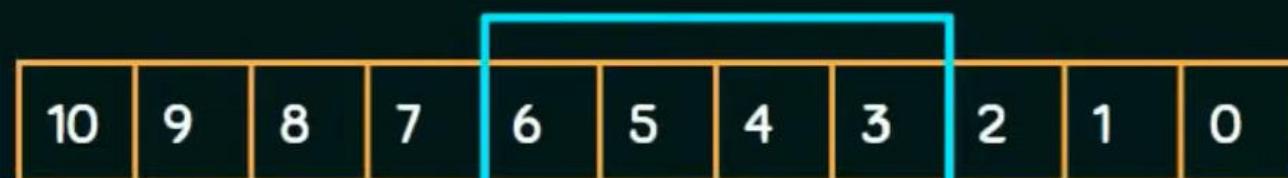
WORKING OF SLIDING WINDOW PROTOCOL



WORKING OF SLIDING WINDOW PROTOCOL

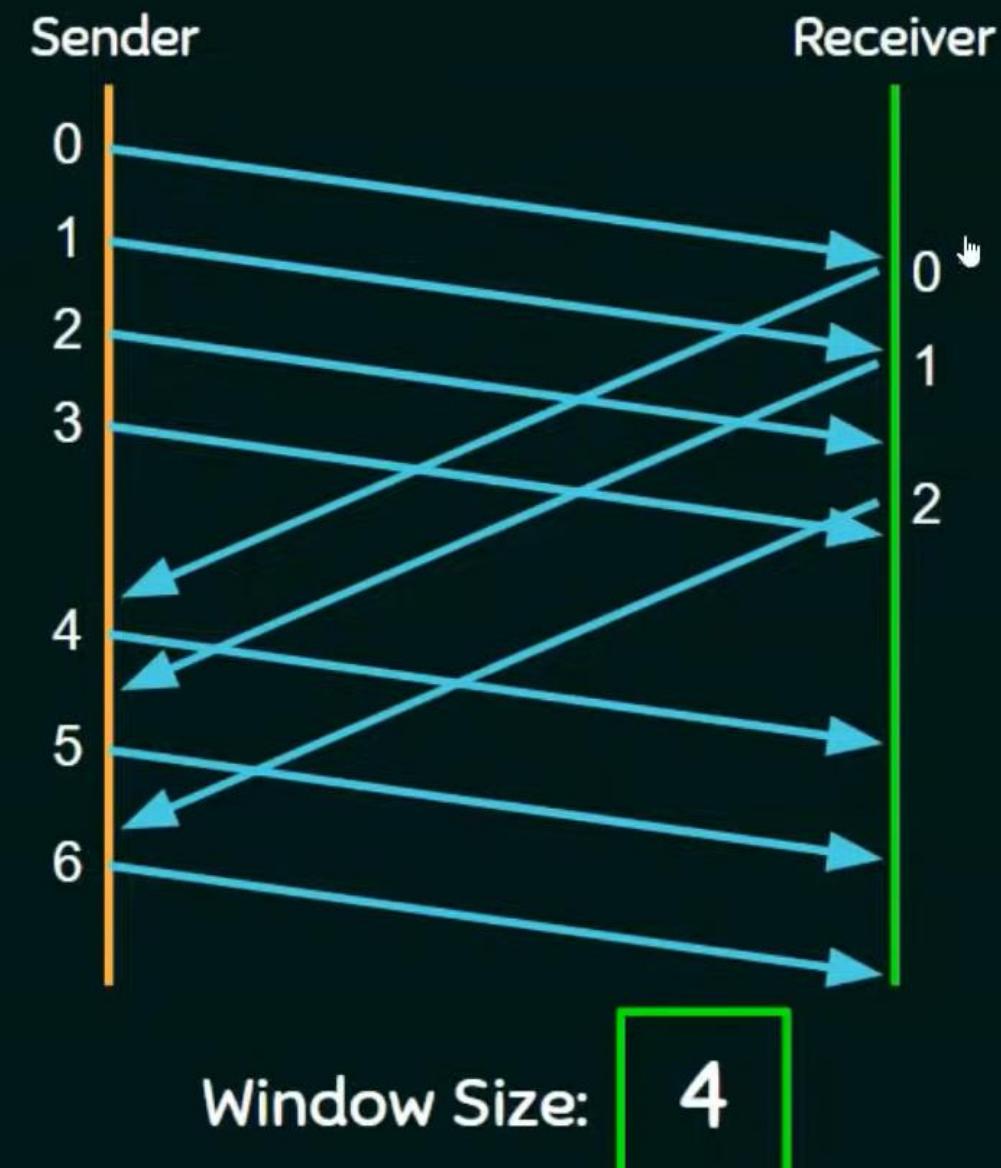


WORKING OF SLIDING WINDOW PROTOCOL

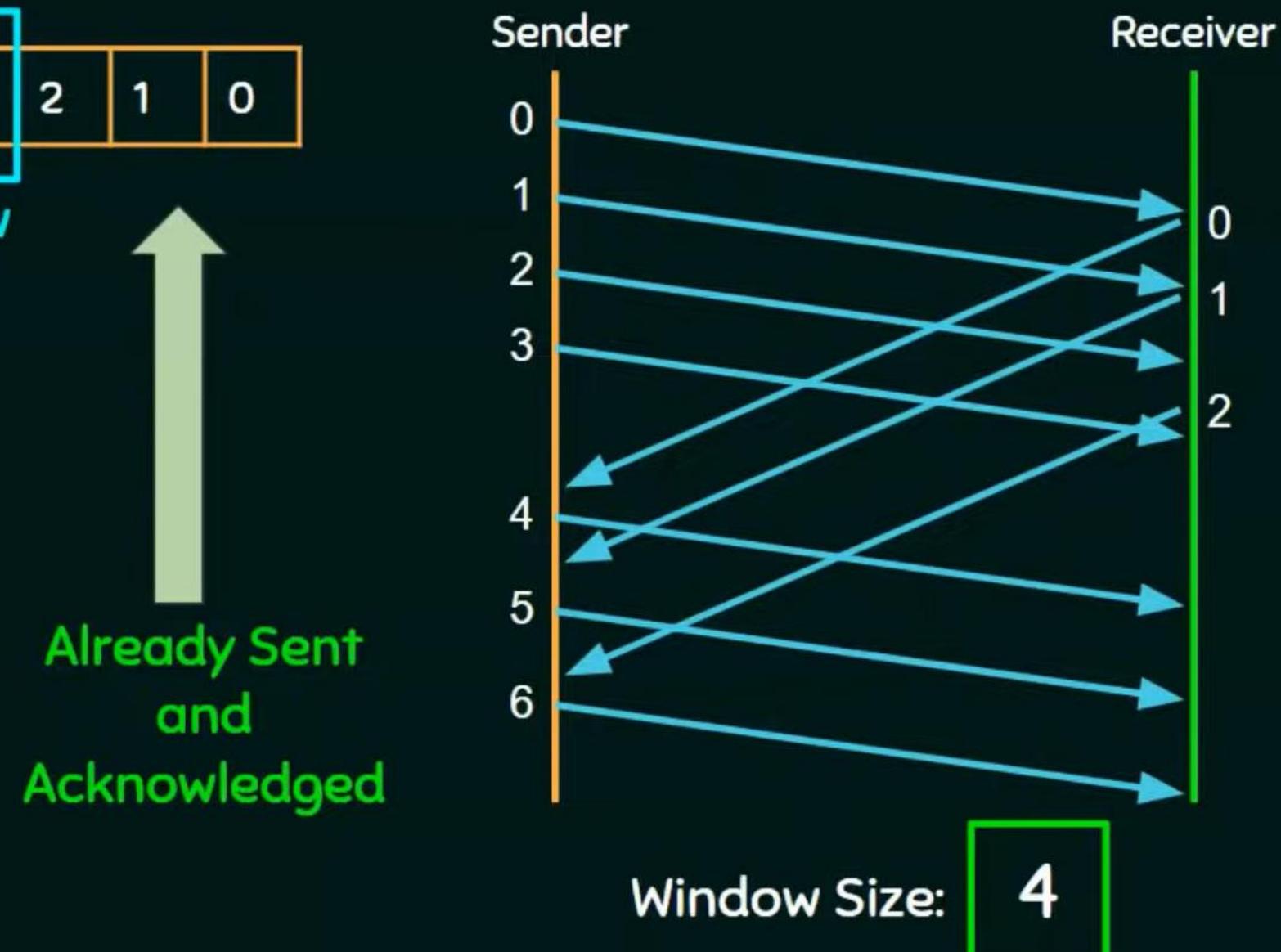
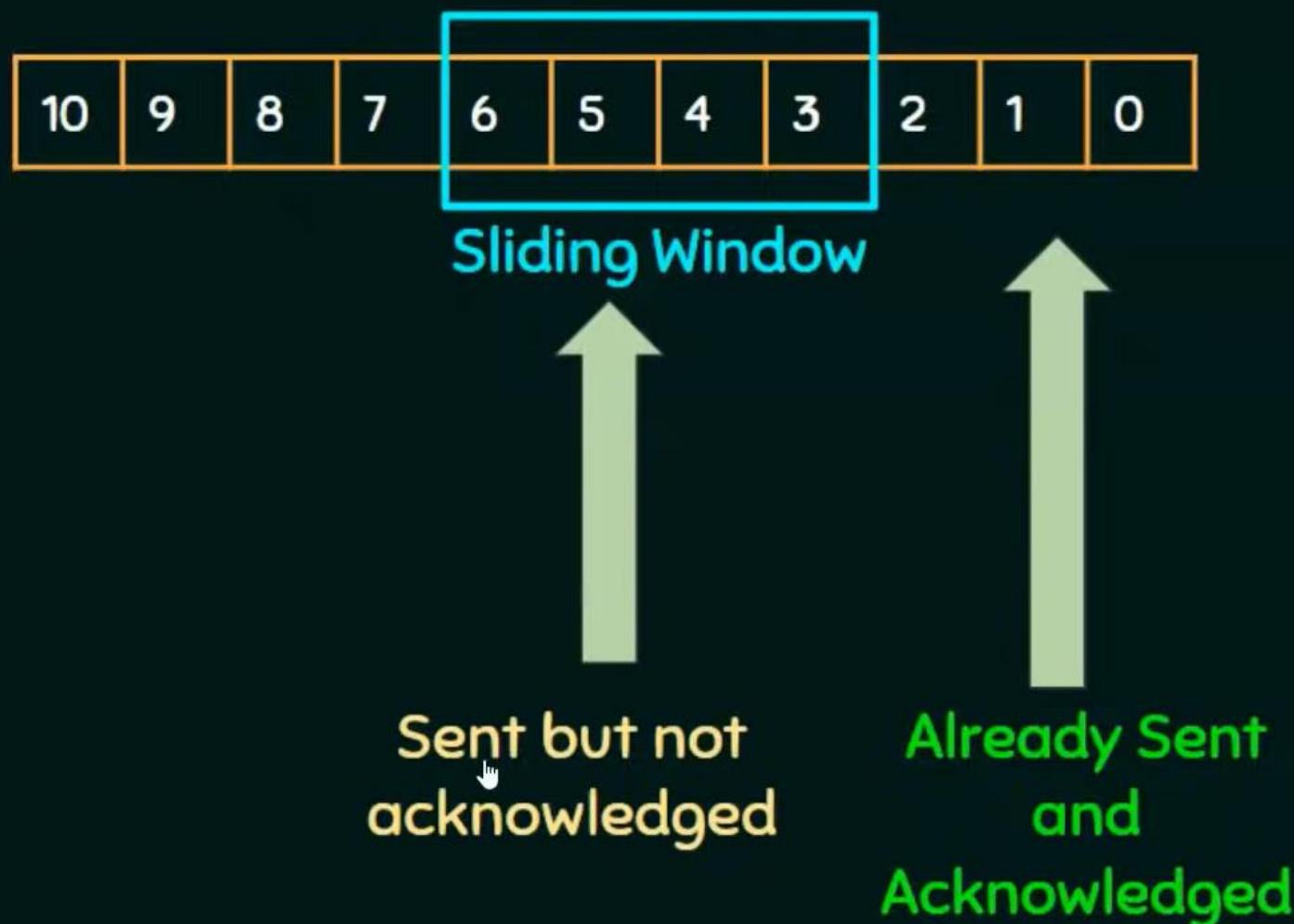


Sliding Window

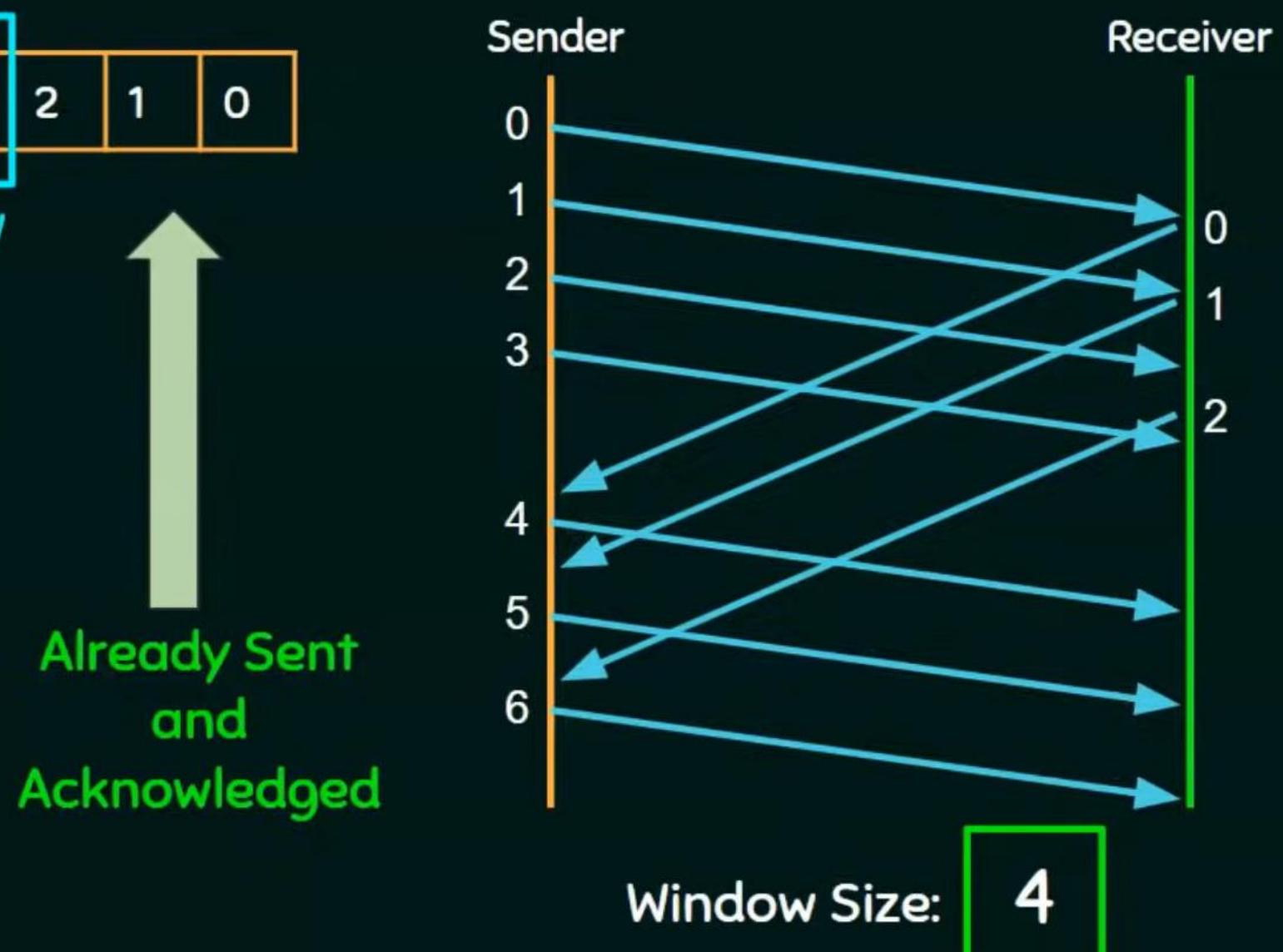
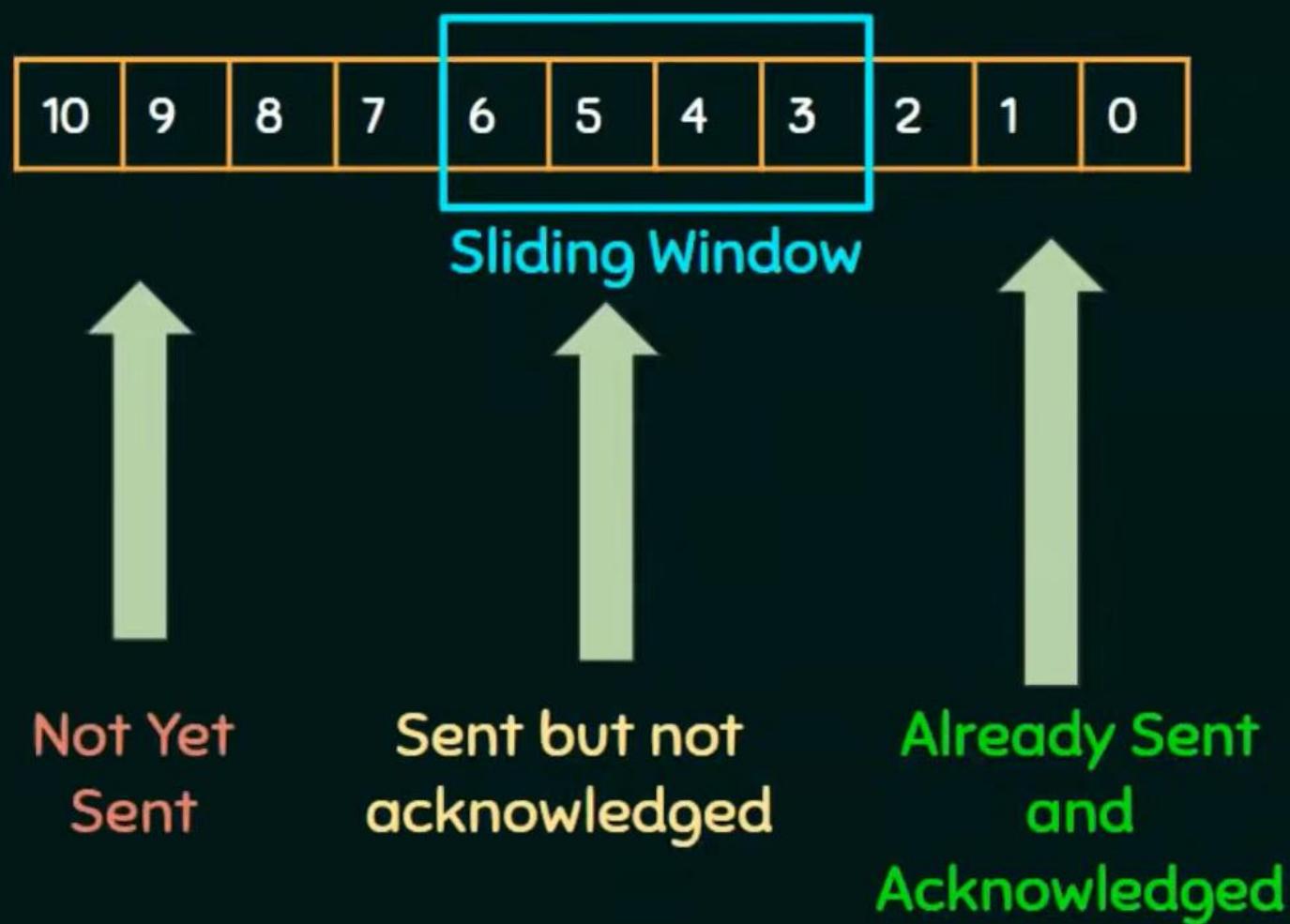
Already Sent
and
Acknowledged



WORKING OF SLIDING WINDOW PROTOCOL



WORKING OF SLIDING WINDOW PROTOCOL



Go-BACK-N ARQ

- ★ Go - Back - N ARQ uses the concept of protocol pipelining i.e. the sender can send multiple frames before receiving the acknowledgment for the first frame.
- ★ There are finite number of frames and the frames are numbered in a sequential manner.
- ★ The number of frames that can be sent depends on the window size of the sender.
- ★ If the acknowledgment of a frame is not received within an agreed upon time period, all frames in the current window are transmitted.

Go-BACK-N ARQ

- ★ The size of the sending window determines the sequence number of the outbound frames.

Go-BACK-N ARQ

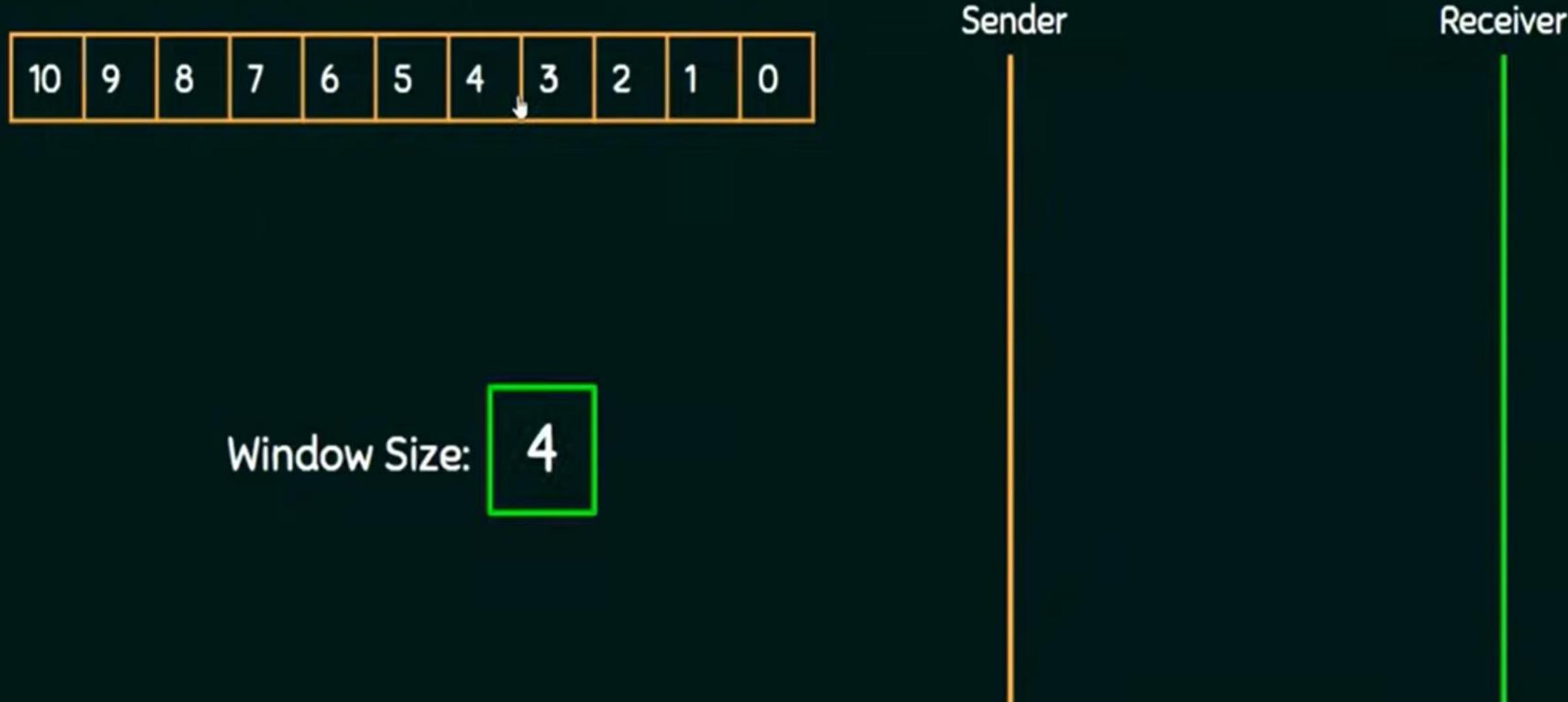


'N' is the sender window size.

Go-BACK-N ARQ

- ★ N - Sender's Window Size.
- ★ For example, if the sending window size is 4 (2^2), then the sequence numbers will be 0, 1, 2, 3, 0, 1, 2, 3, 0, 1, and so on.
- ★ The number of bits in the sequence number is 2 to generate the binary sequence 00, 01, 10, 11.

WORKING OF Go-BACK-N ARQ

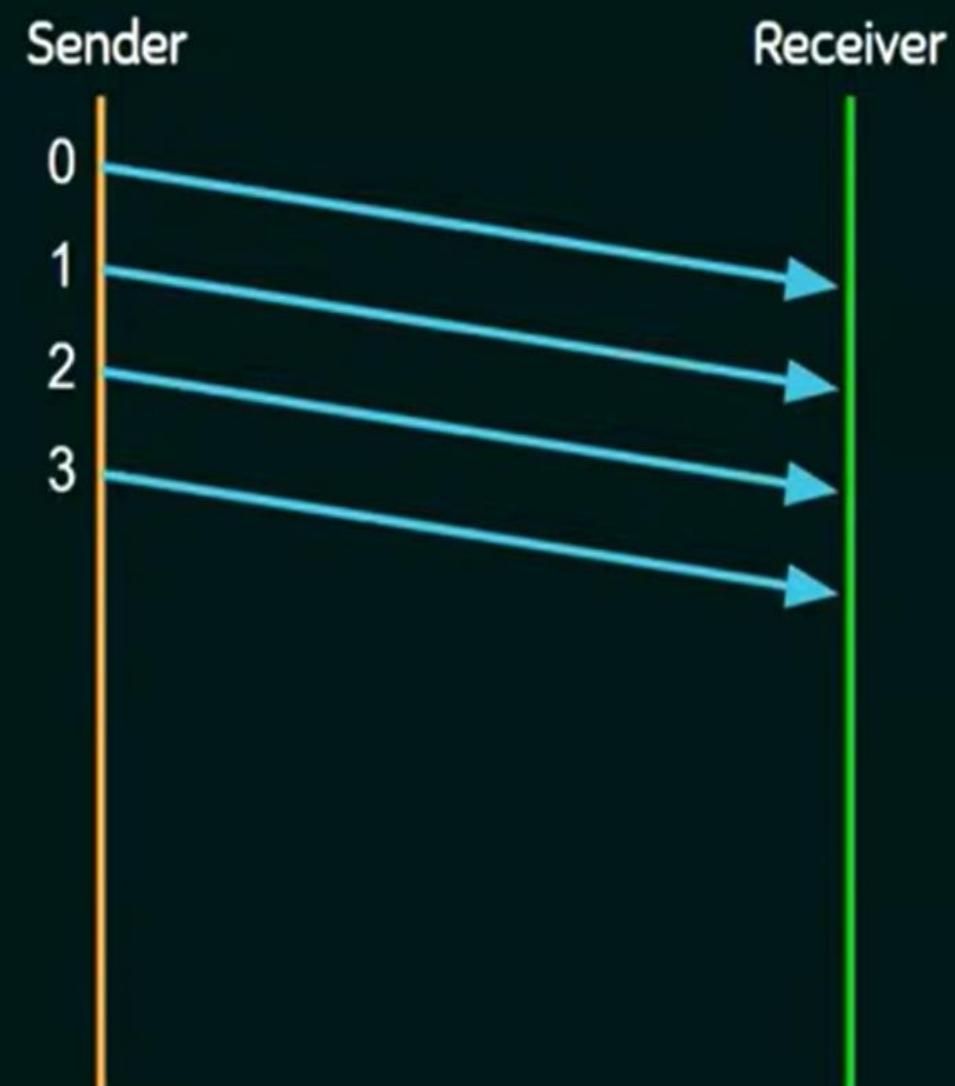


WORKING OF Go-BACK-N ARQ

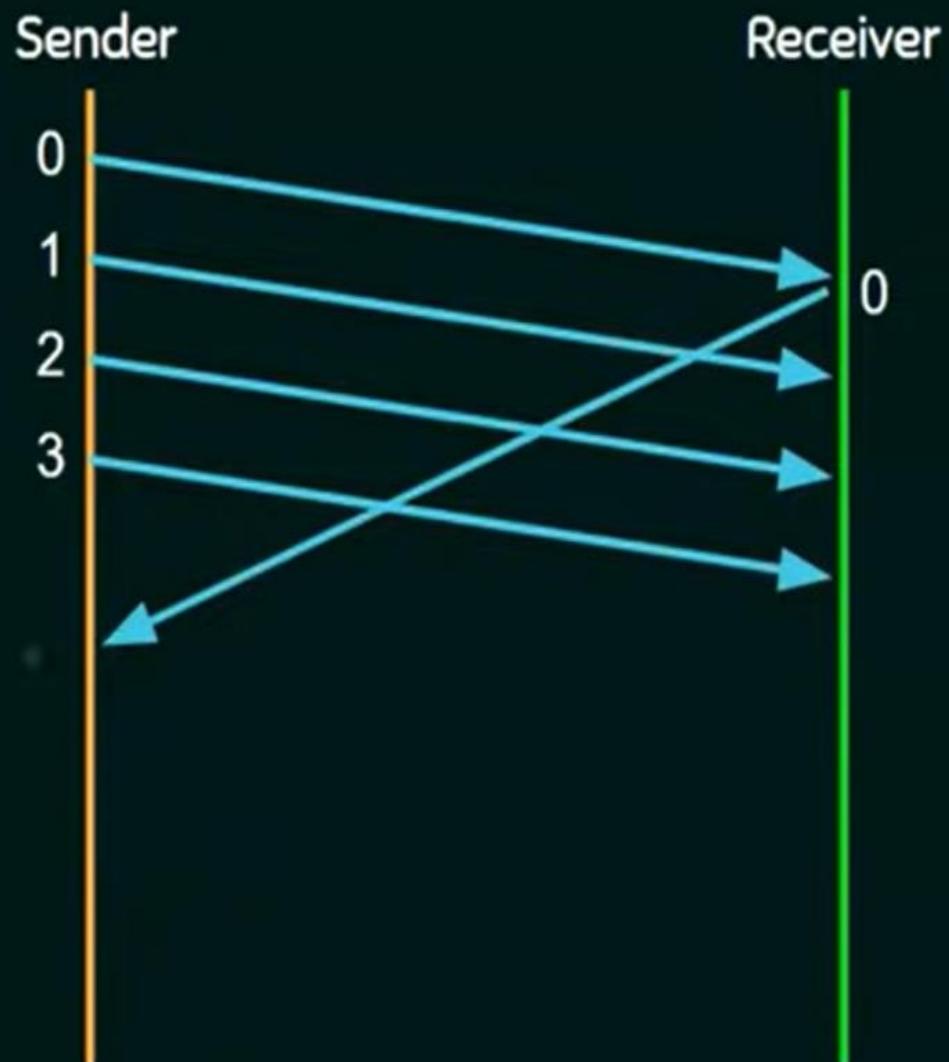
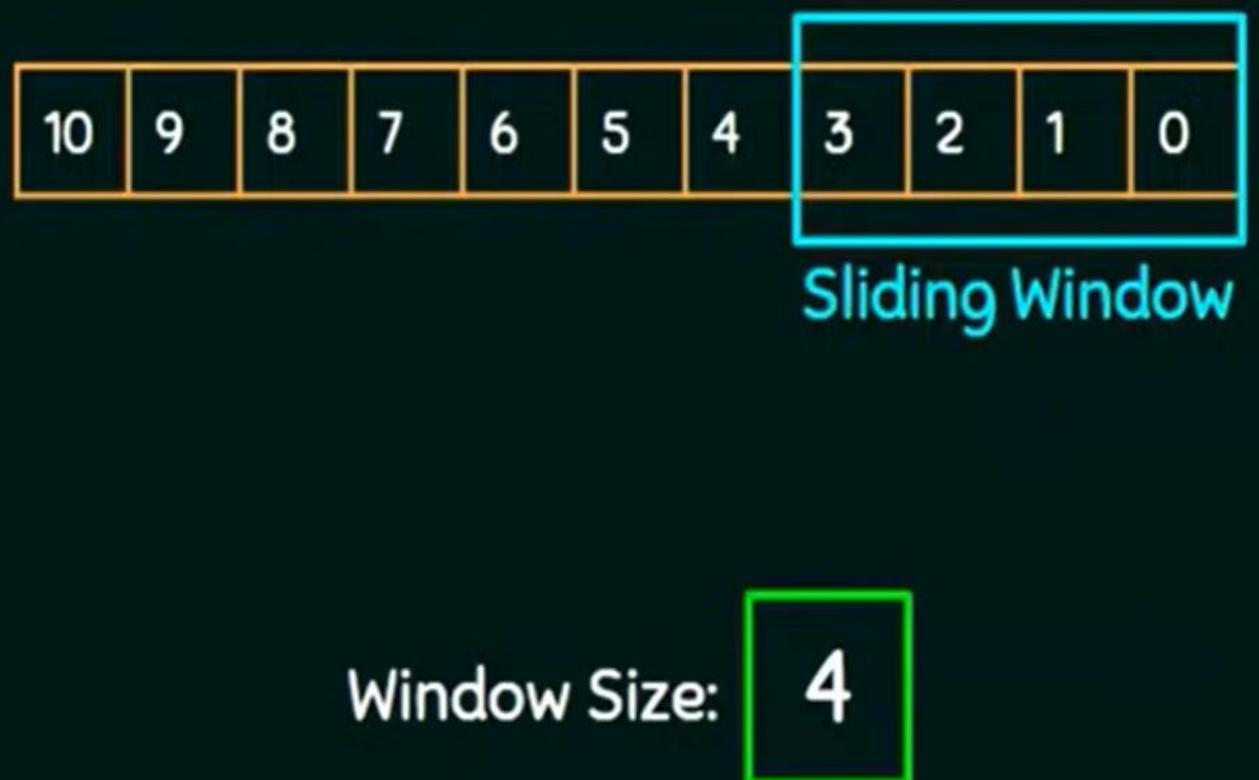


Sliding Window

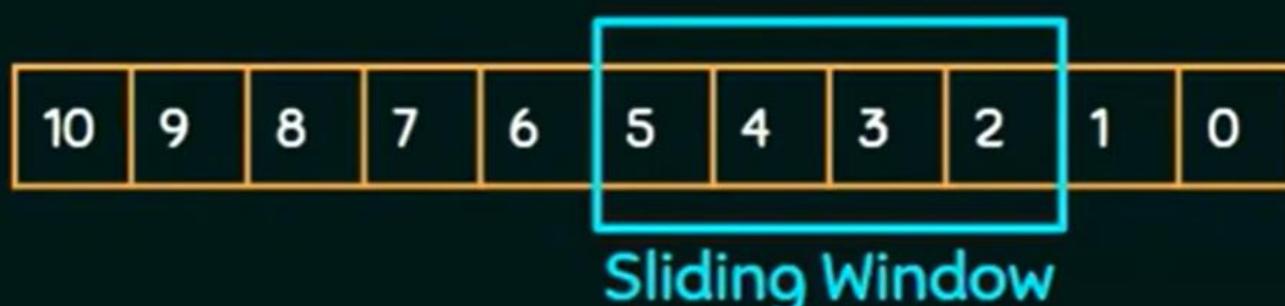
Window Size: 4



WORKING OF Go-BACK-N ARQ

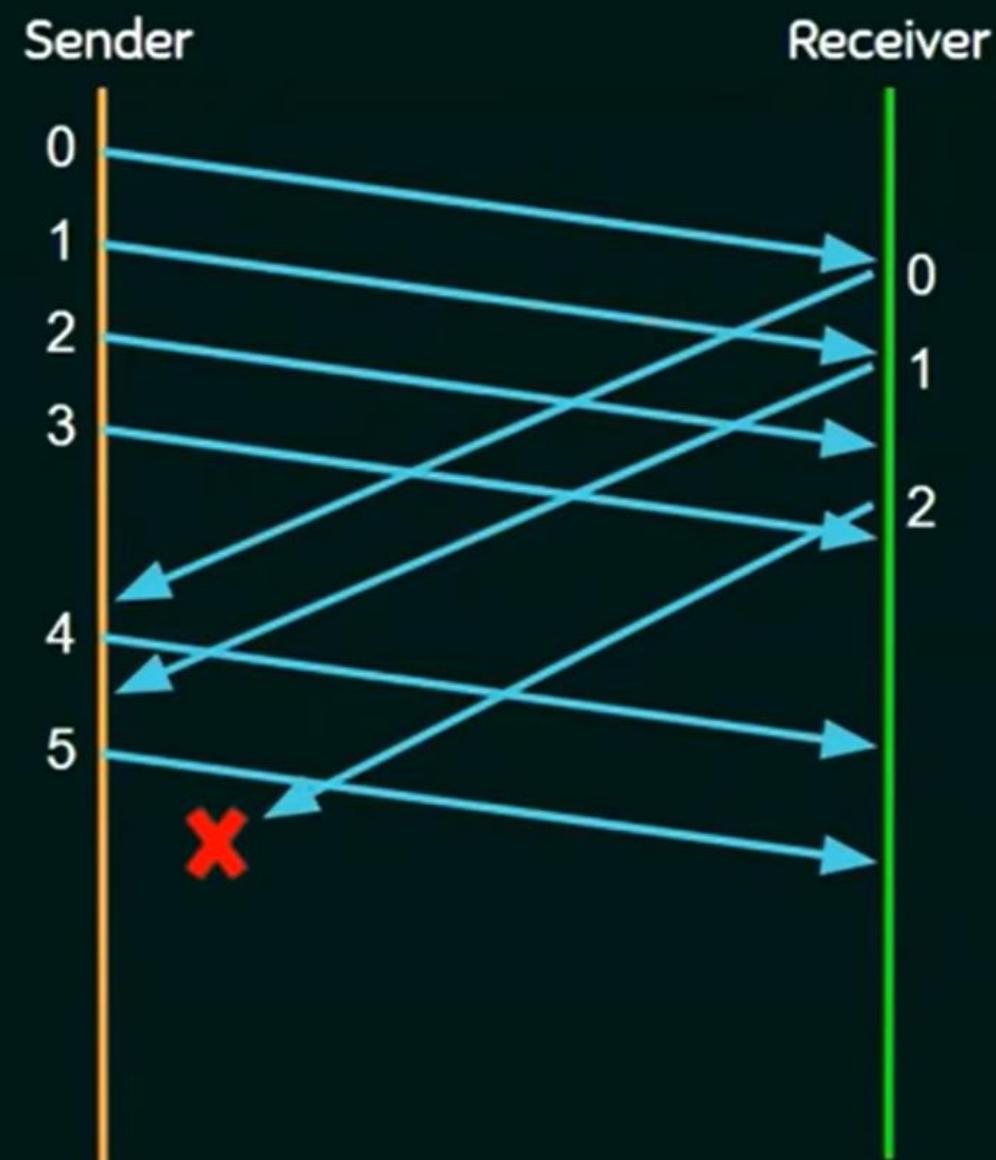


WORKING OF Go-BACK-N ARQ

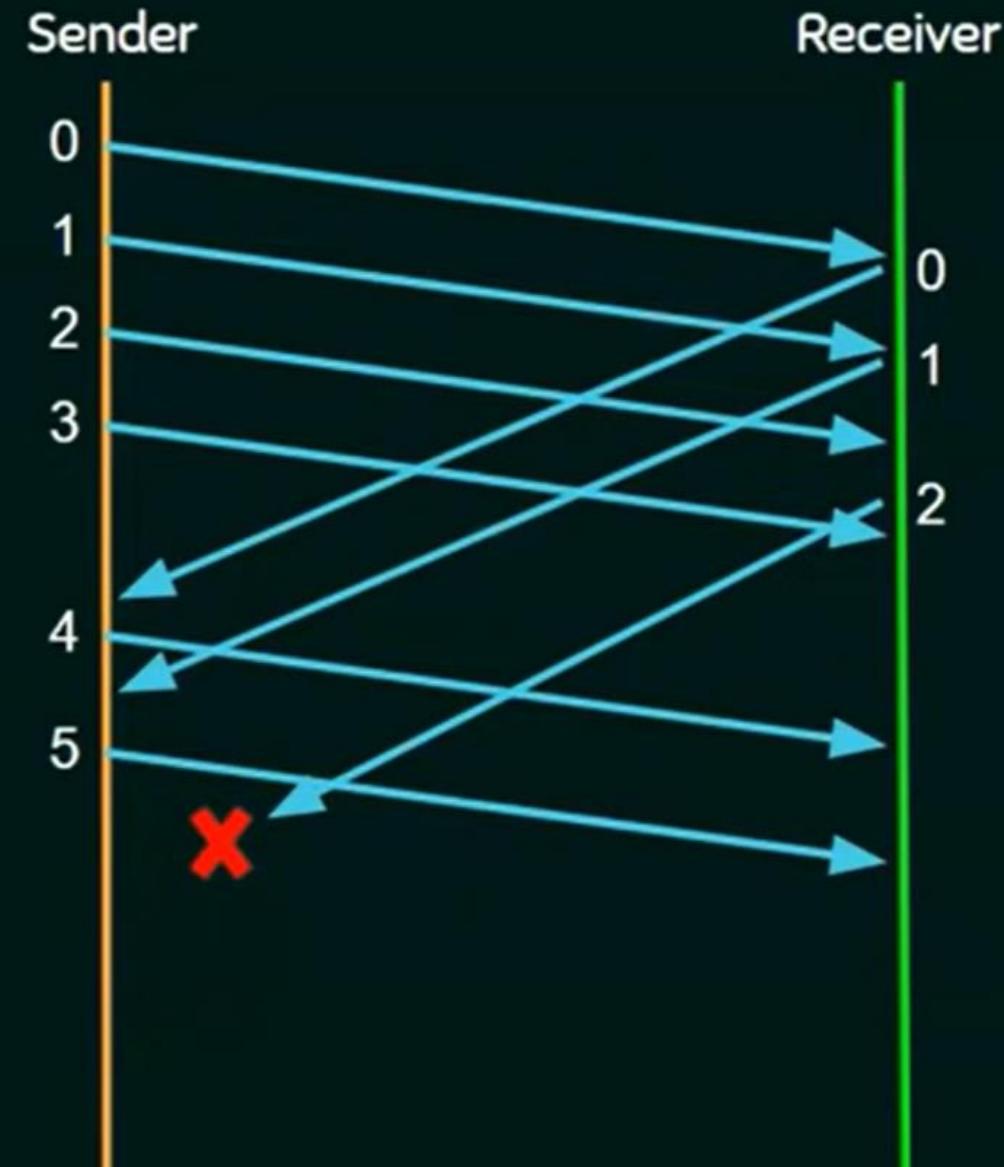
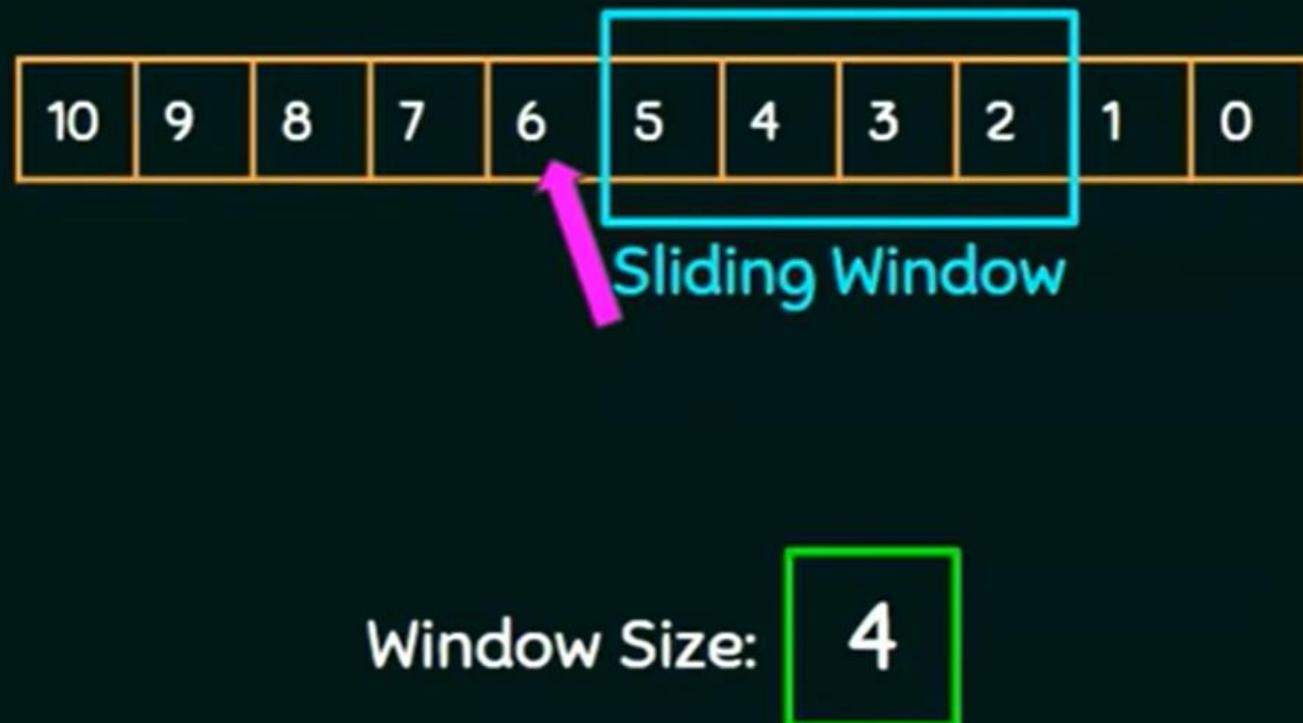


Window Size: 4

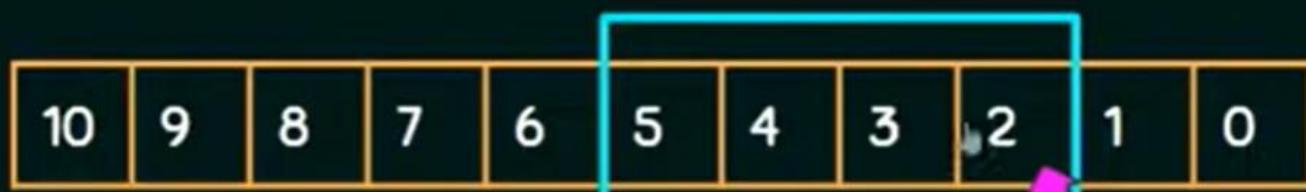
ACK not received in time. So
Sender times out.



WORKING OF Go-BACK-N ARQ

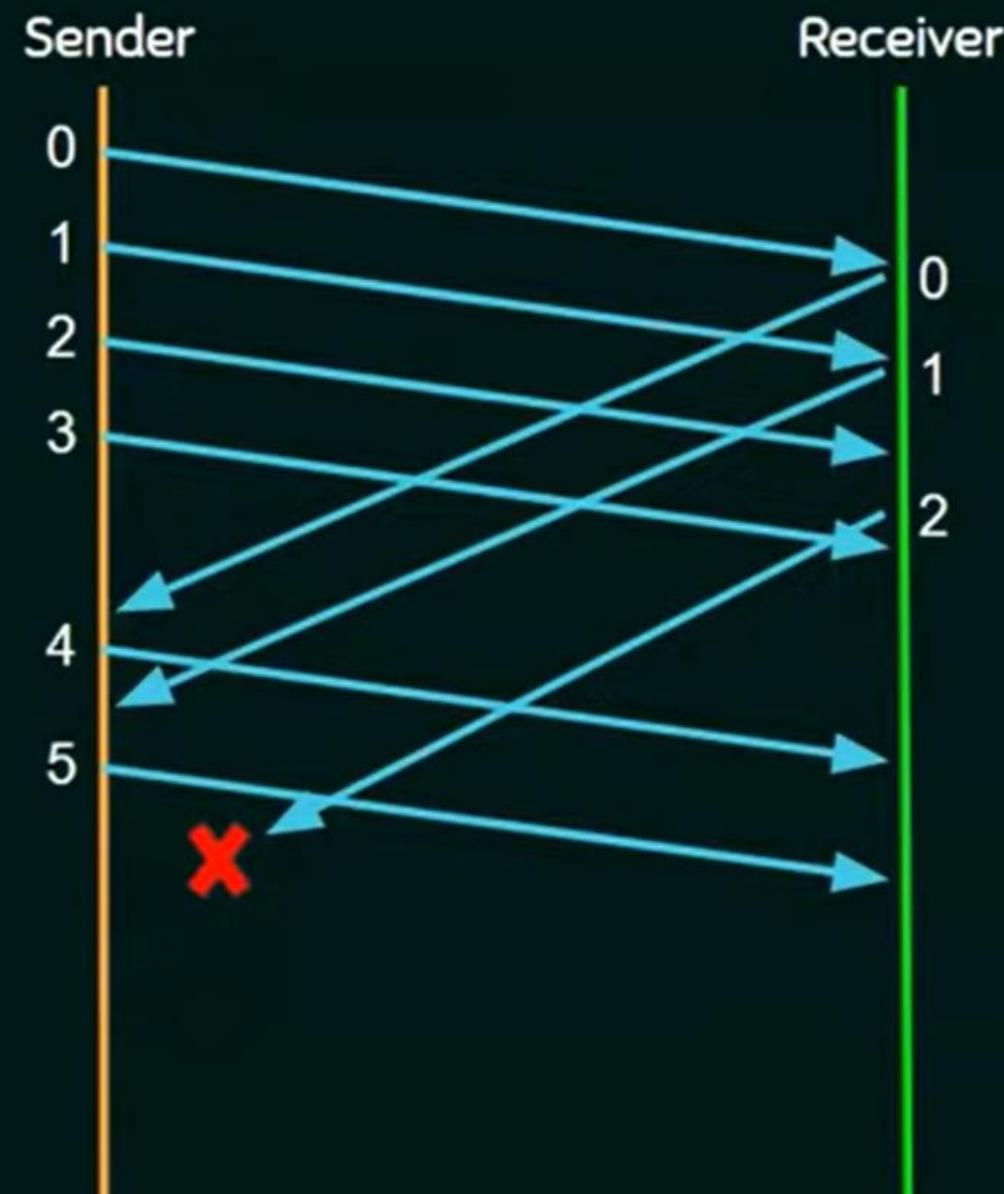


WORKING OF Go-BACK-N ARQ



Sliding Window

Window Size: 4

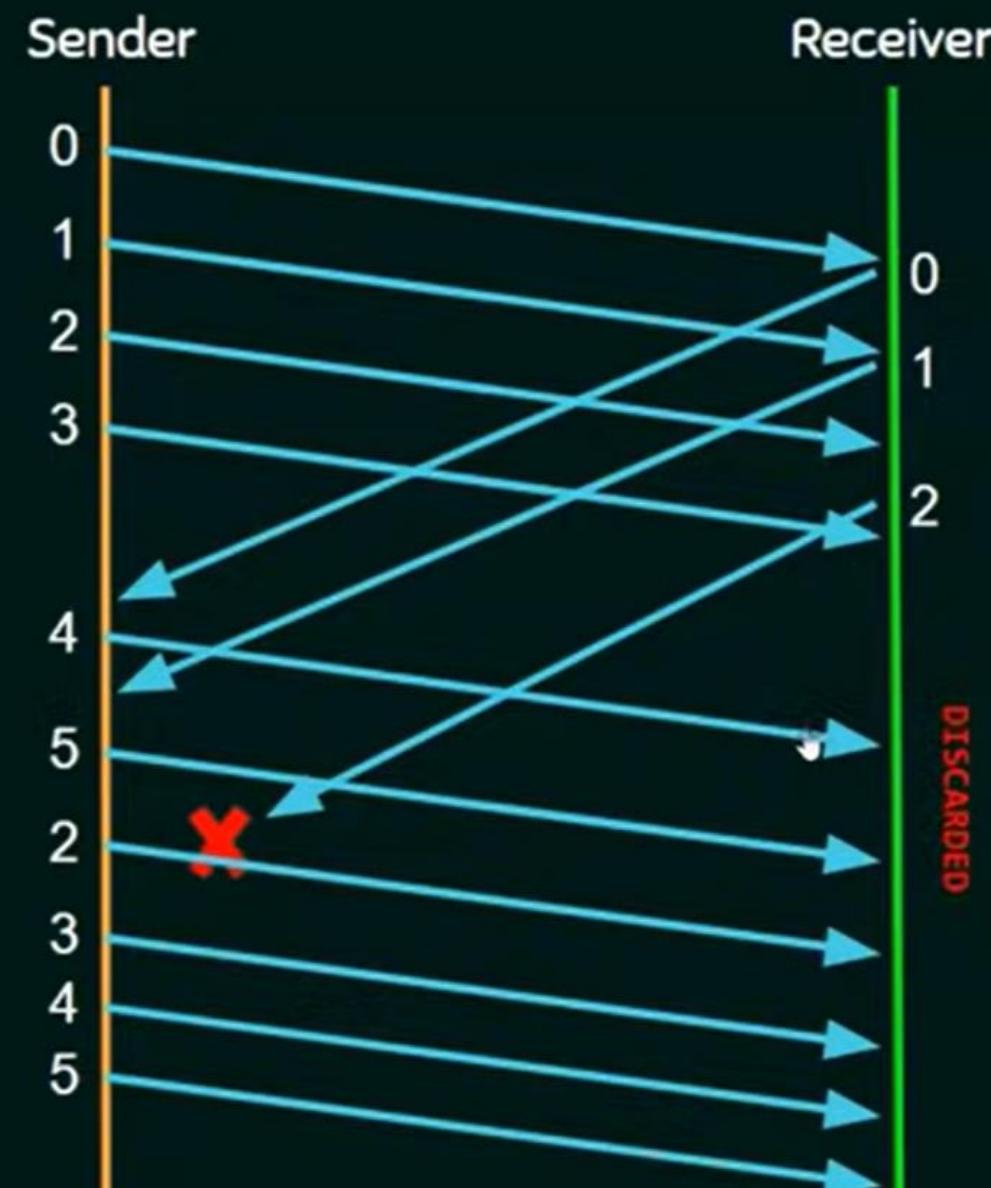


WORKING OF Go-BACK-N ARQ



Go-Back to 2

Window Size: 4



QUESTION

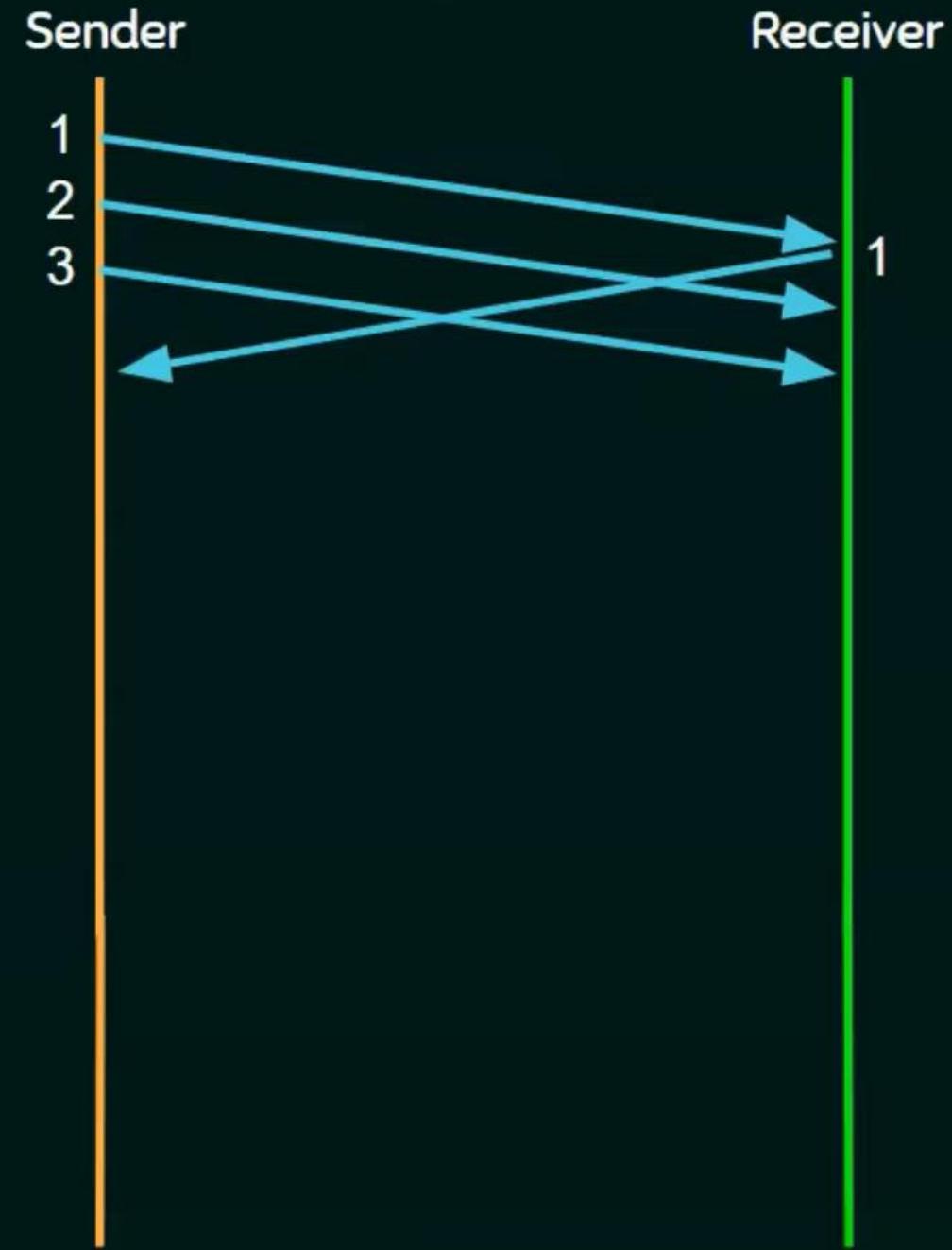
Station A needs to send a message consisting of 9 packets to station B using a sliding window (window size 3) and go-back-n error control strategy. All packets are ready and immediately available for transmission. If every 5th packet that A transmits gets lost (but no ACKs from B ever get lost), then what is the number of packets that A will transmit for sending the message to B?

- (A) 12
- (B) 14
- (C) 16
- (D) 18

SOLUTION



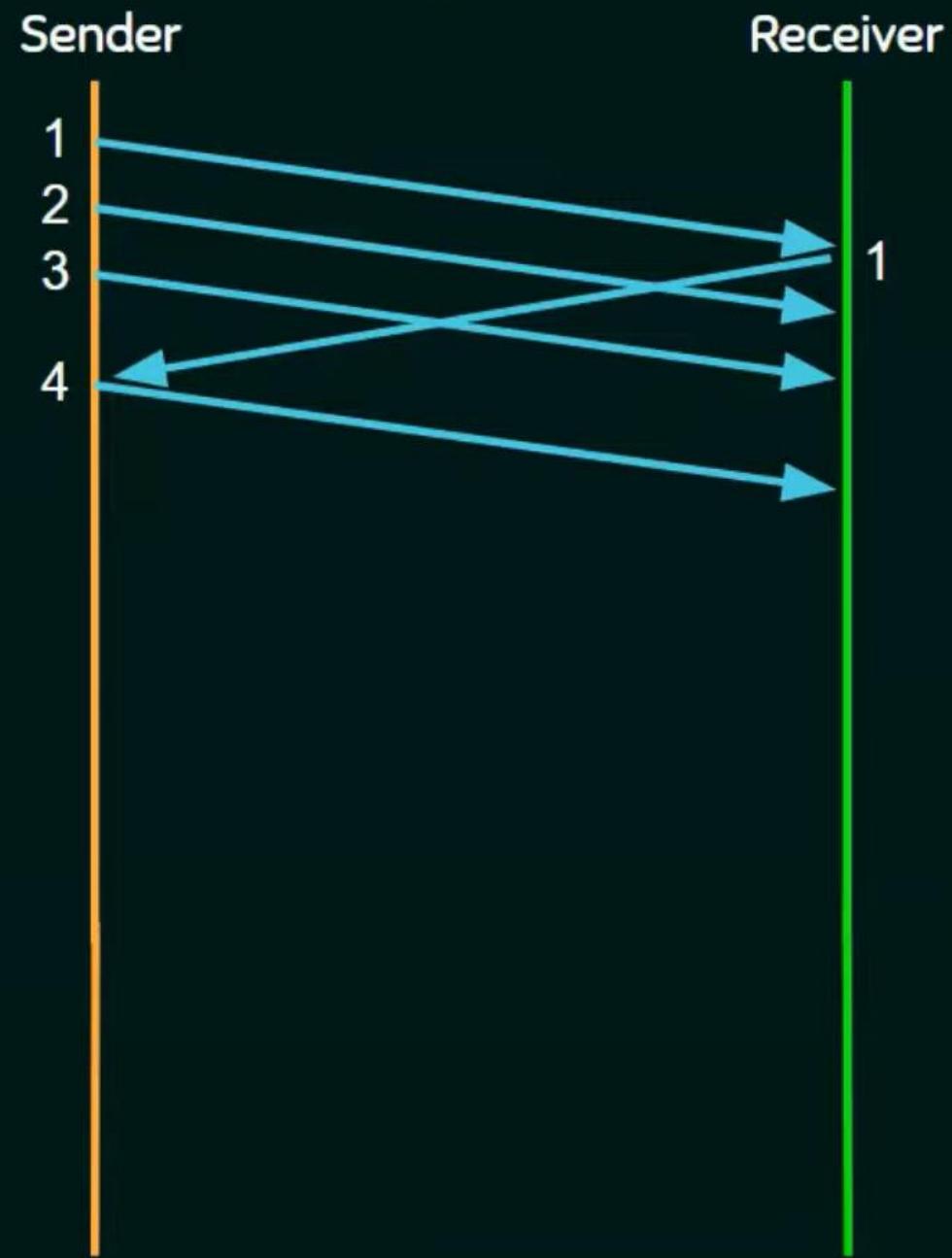
Window Size: 3



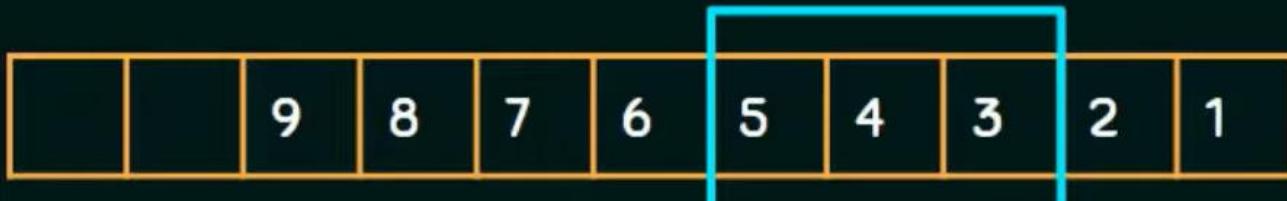
SOLUTION



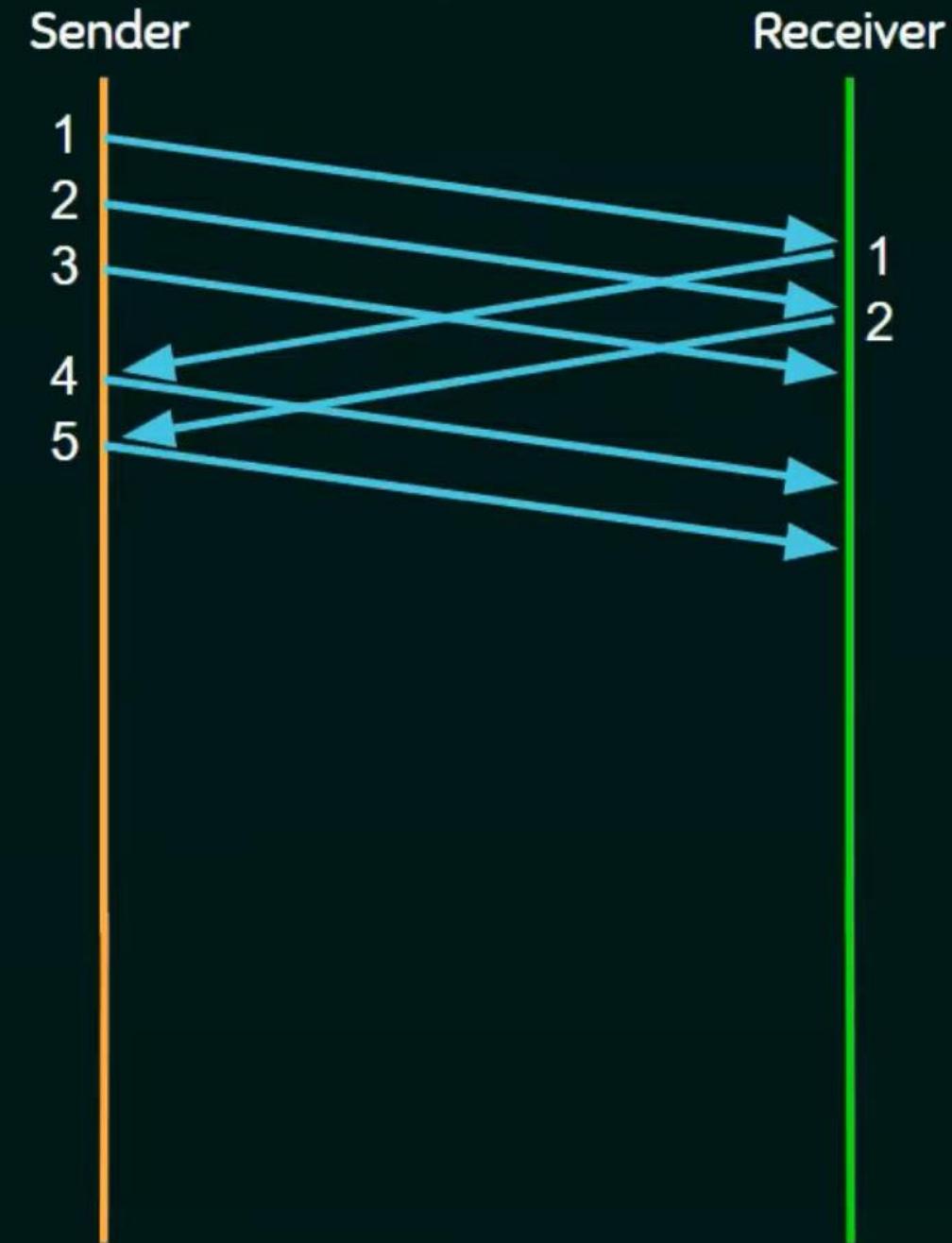
Window Size: 3



SOLUTION



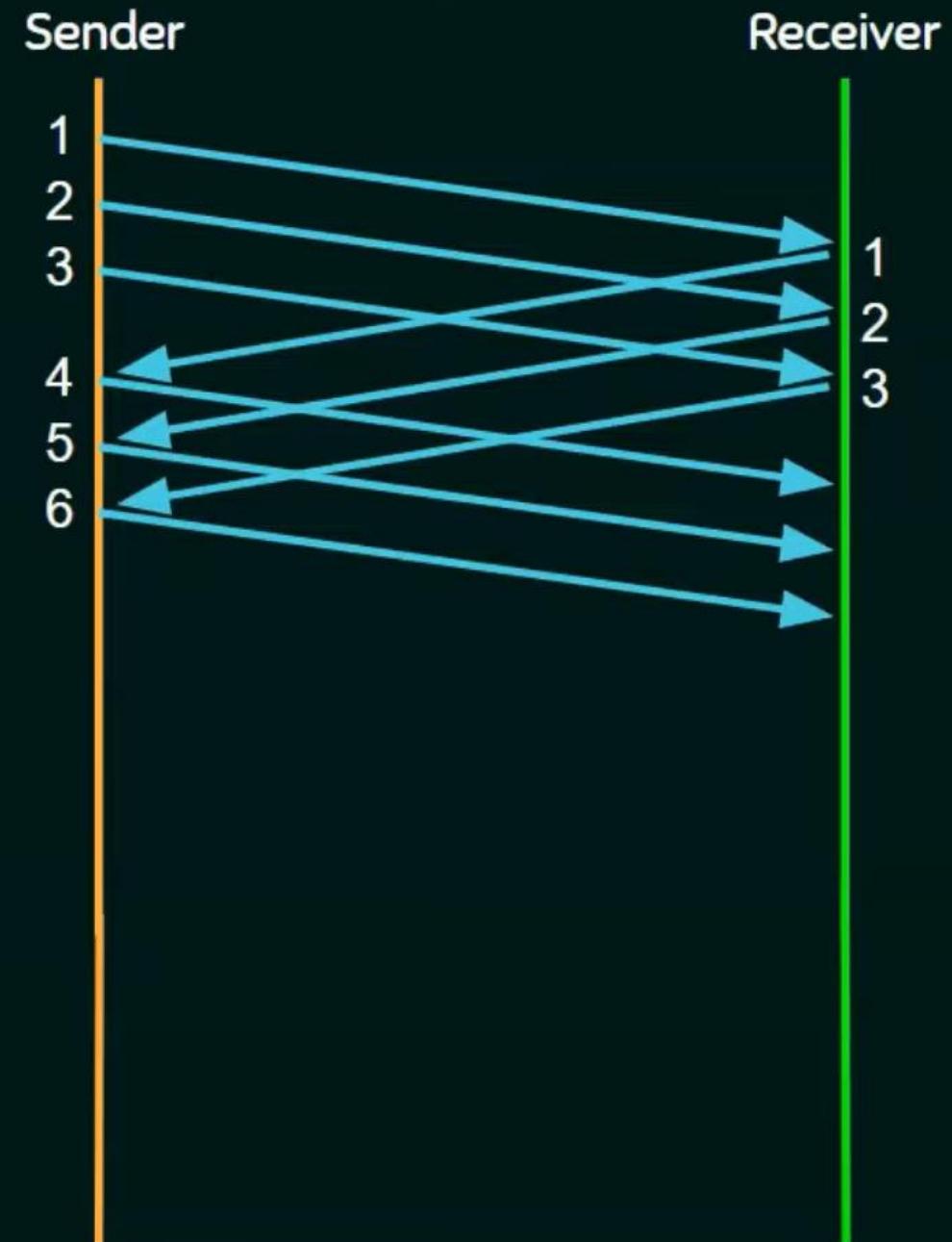
Window Size: 3



SOLUTION



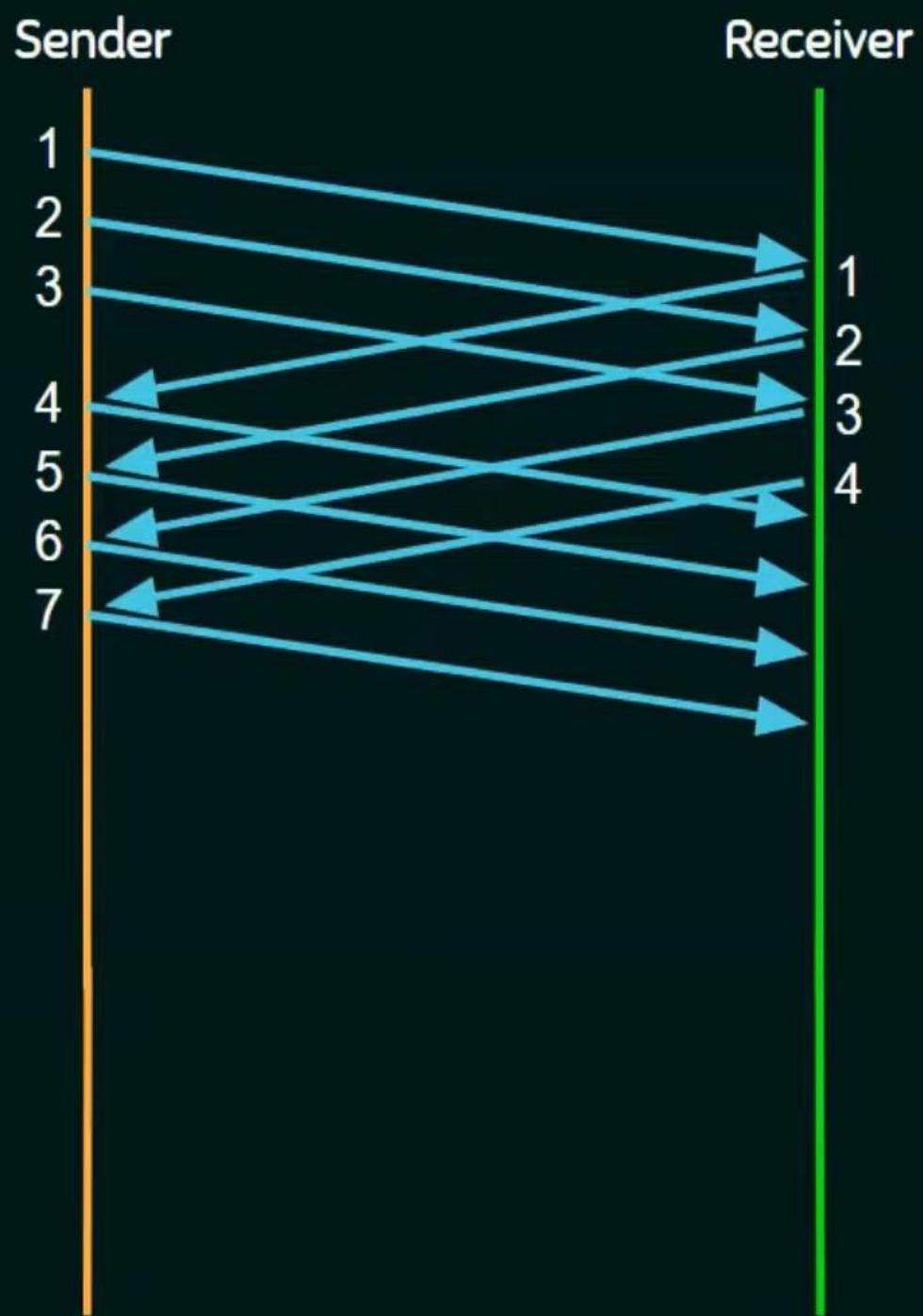
Window Size: 3



SOLUTION



Window Size: 3



SOLUTION



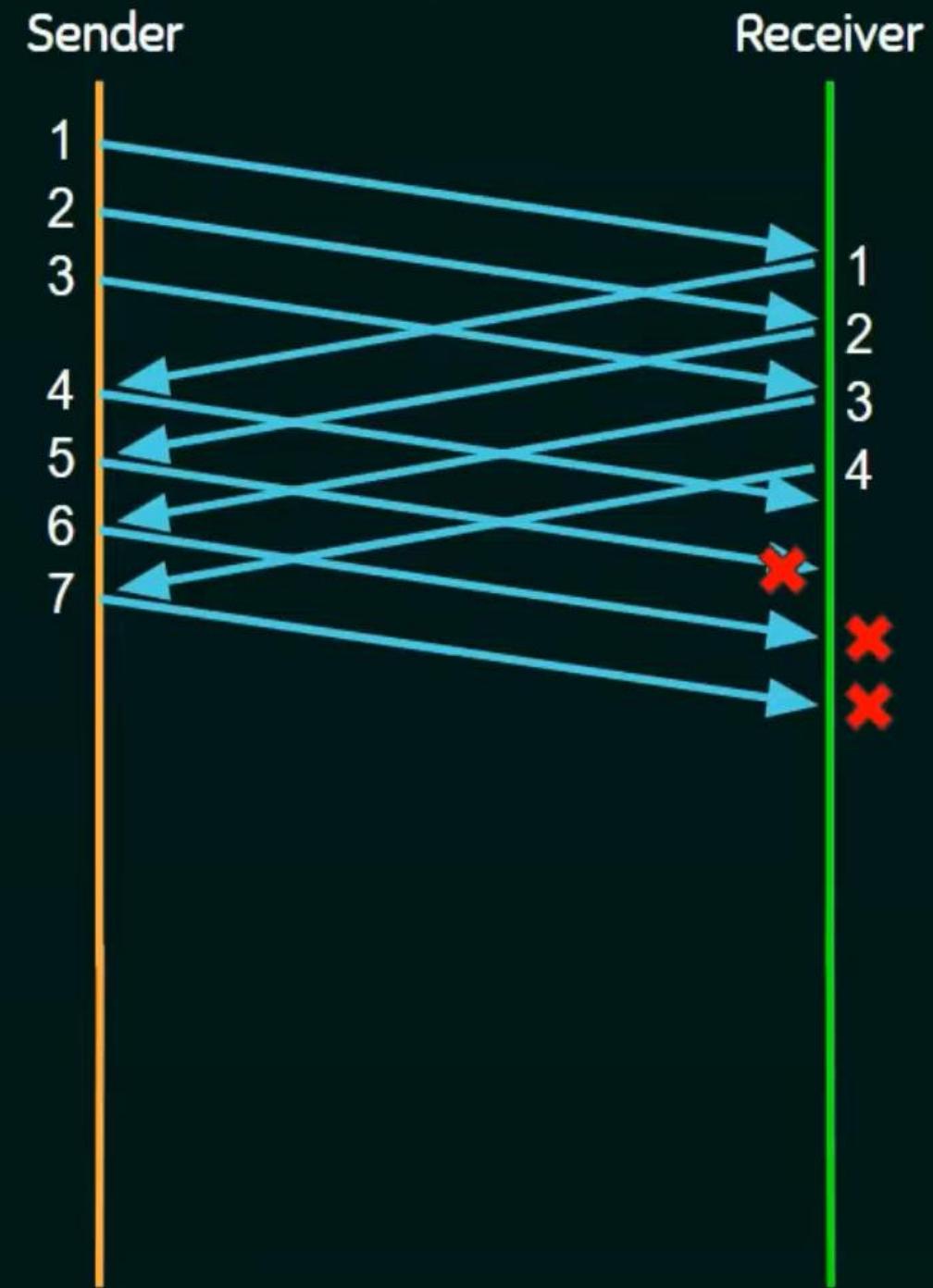
Window Size: 3



SOLUTION



Window Size: 3



SOLUTION



Window Size: 3



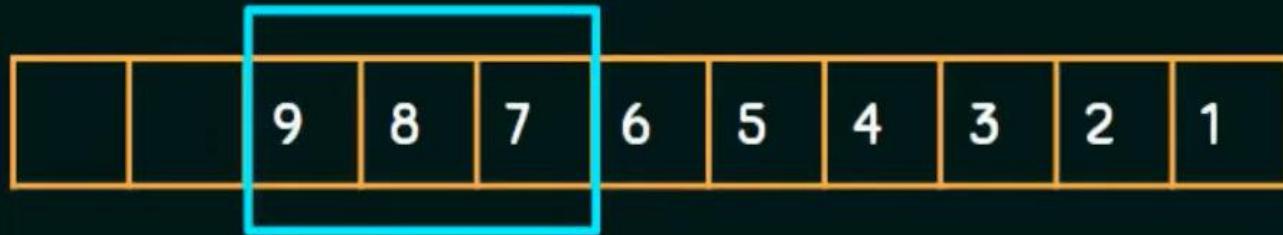
SOLUTION



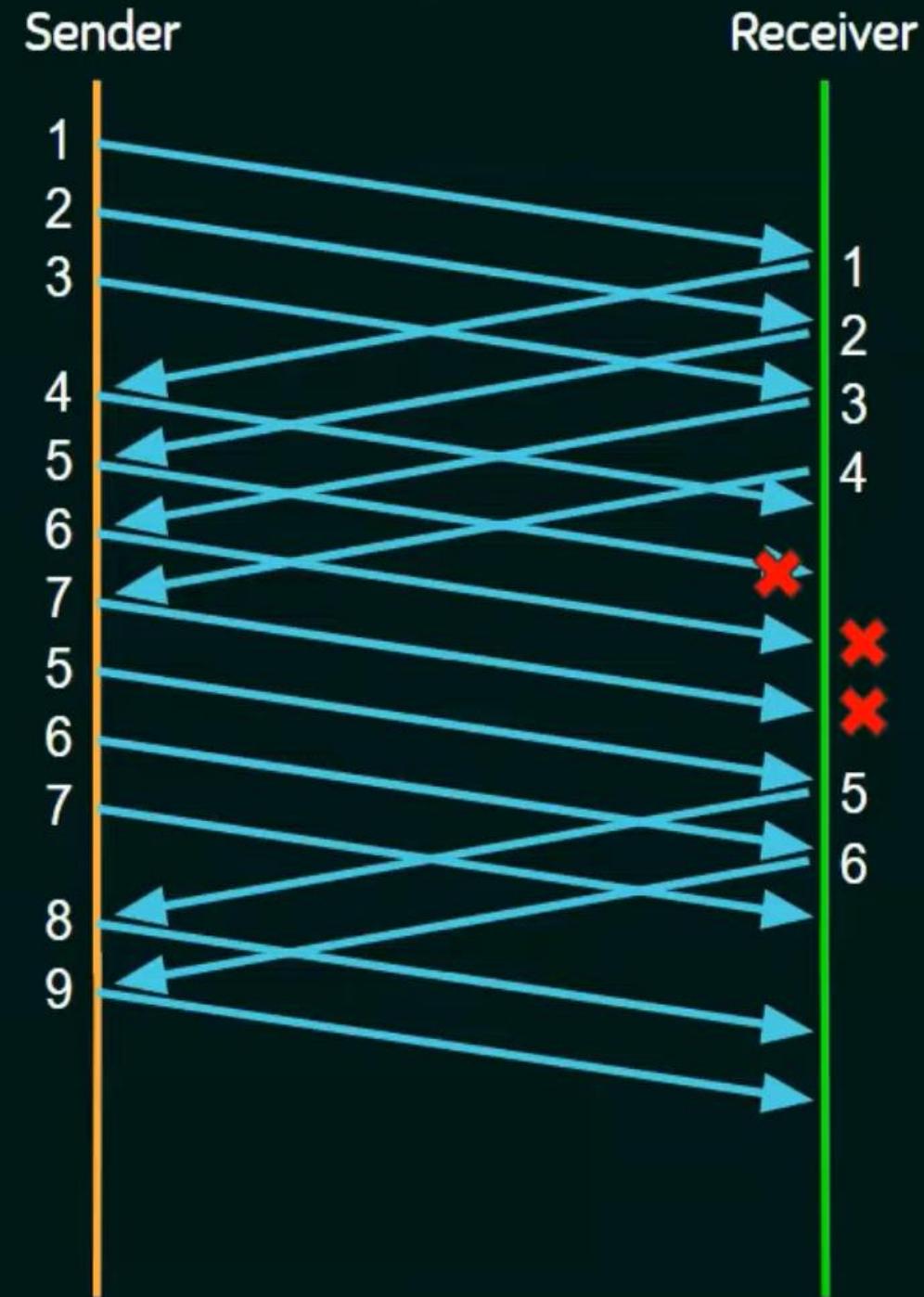
Window Size: 3



SOLUTION



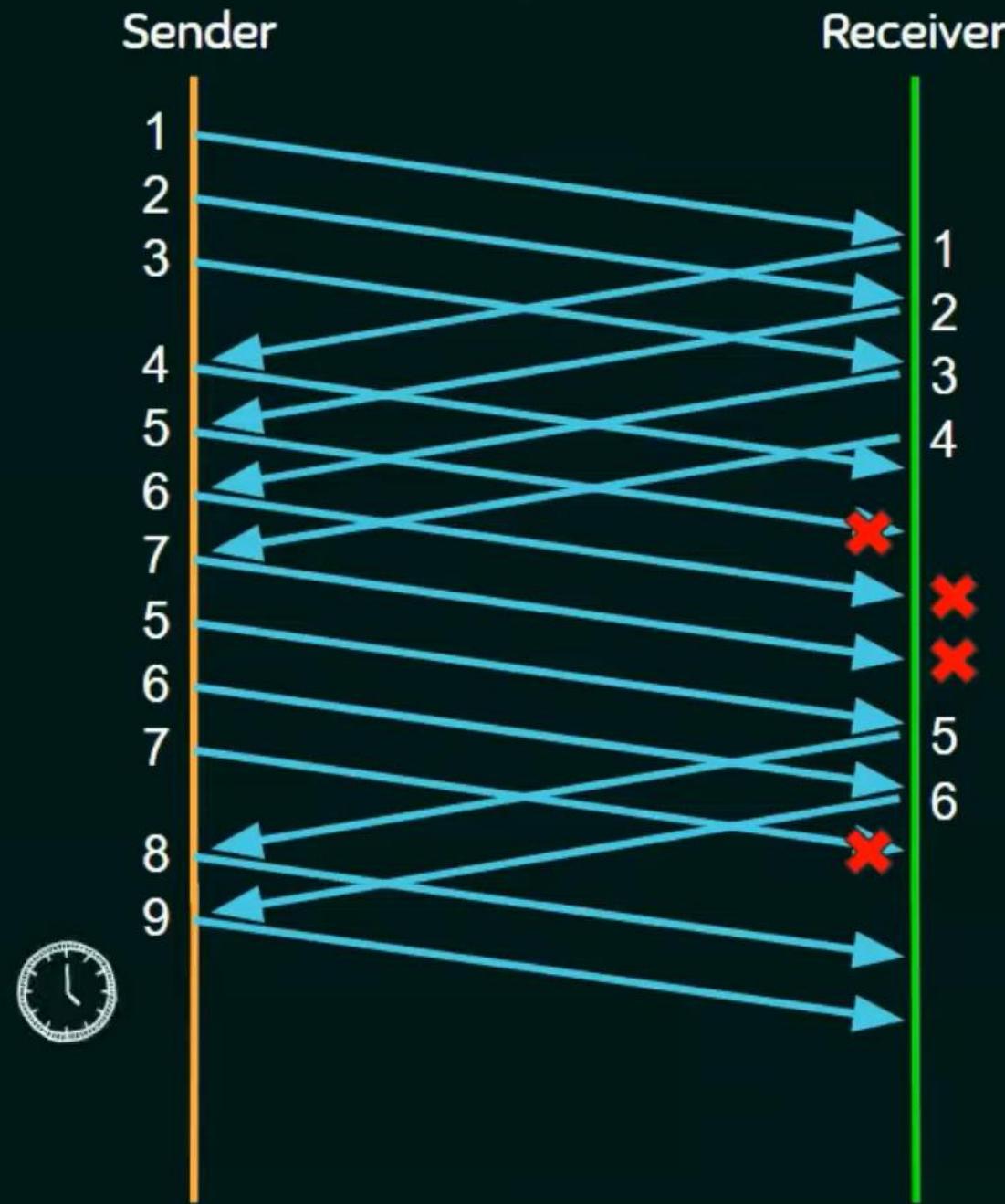
Window Size: 3



SOLUTION



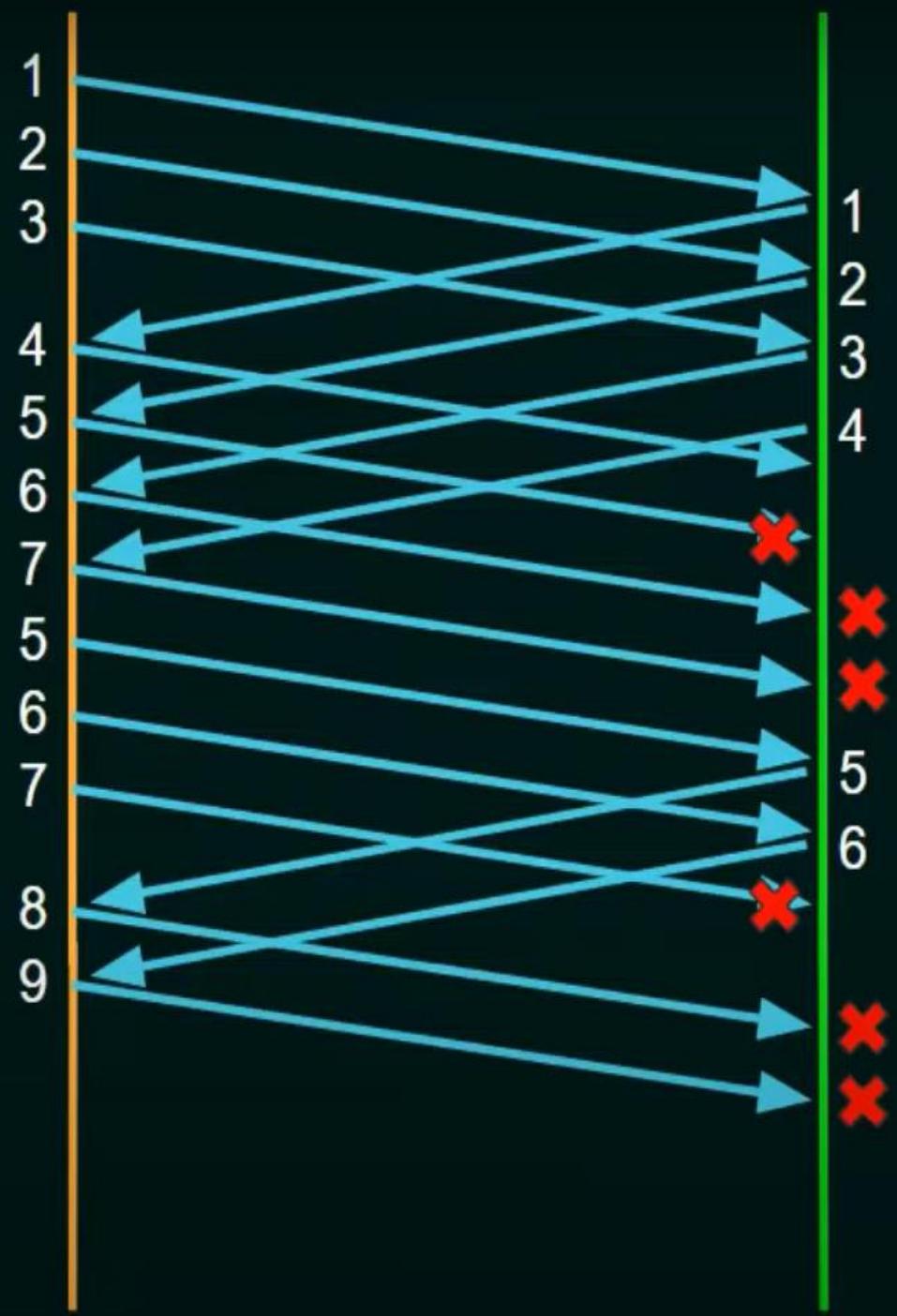
Window Size: 3



SOLUTION



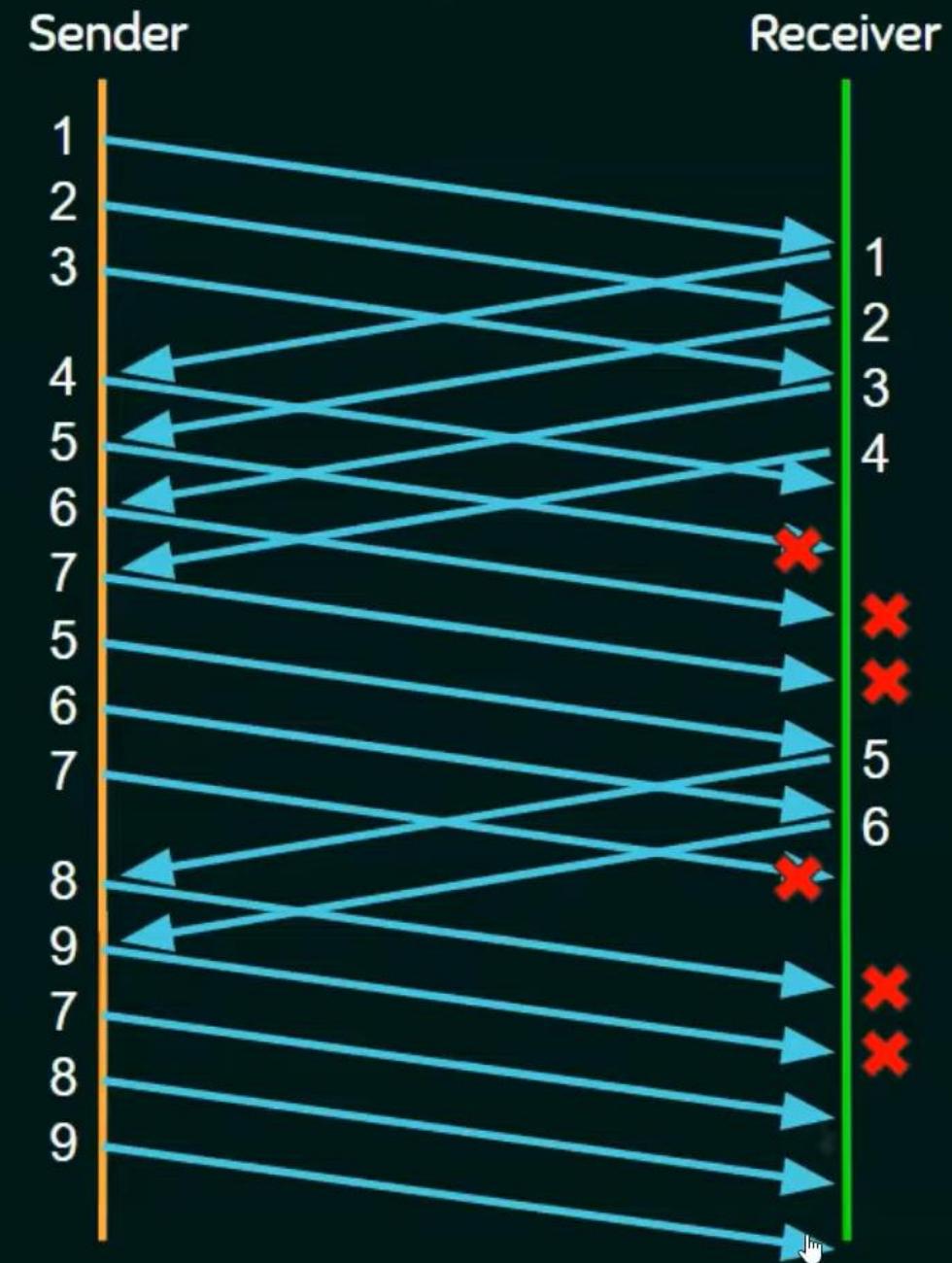
Window Size: 3



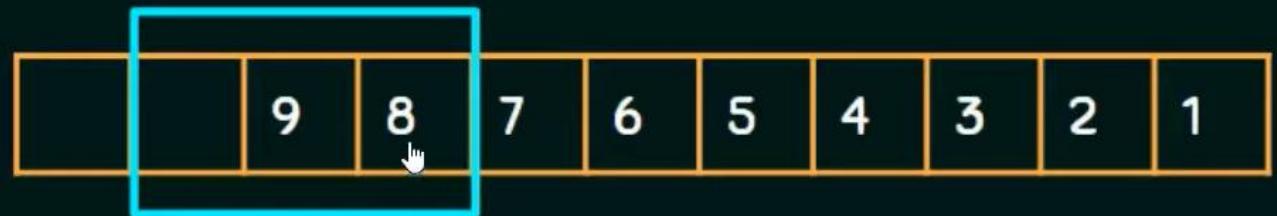
SOLUTION



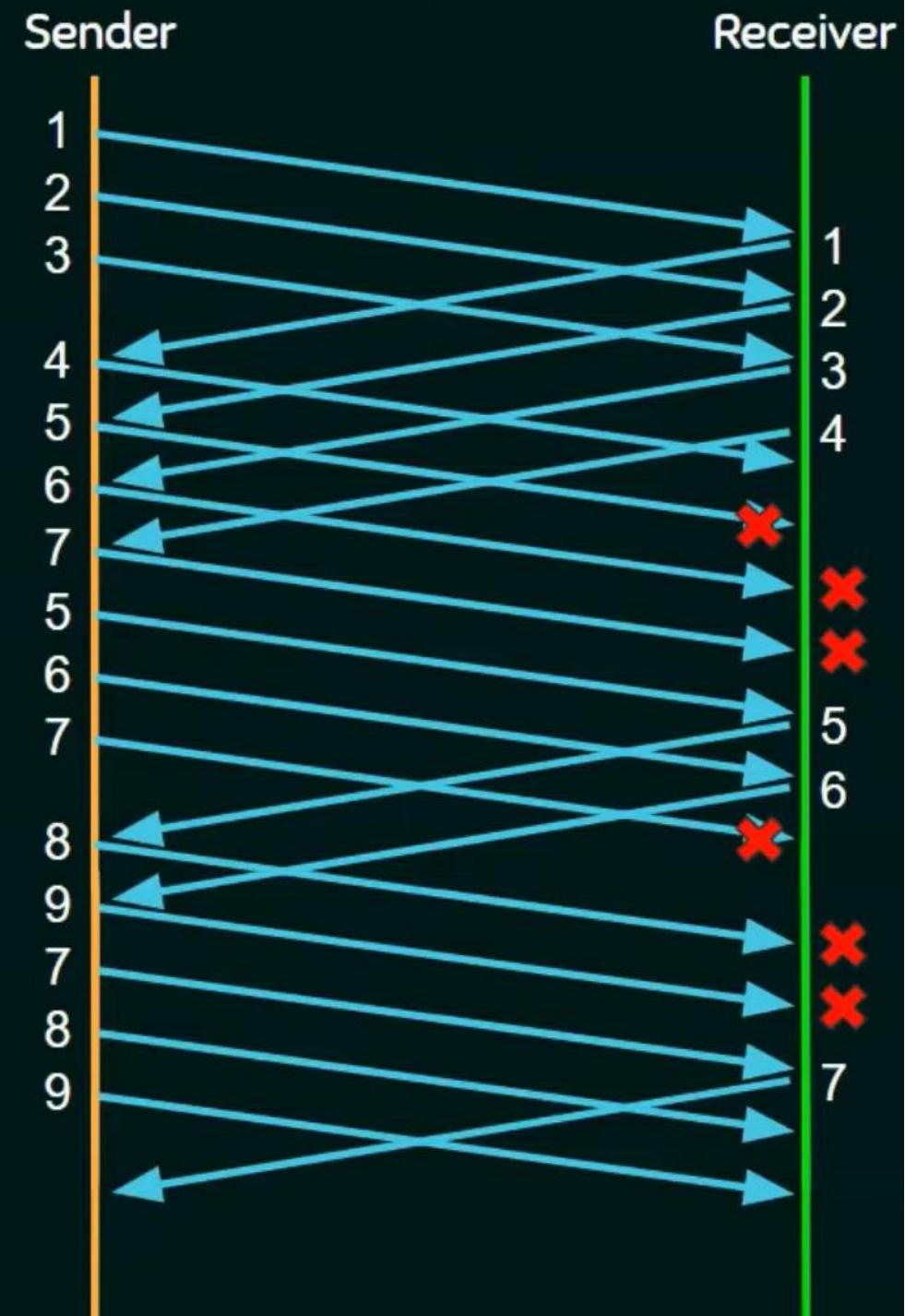
Window Size: 3



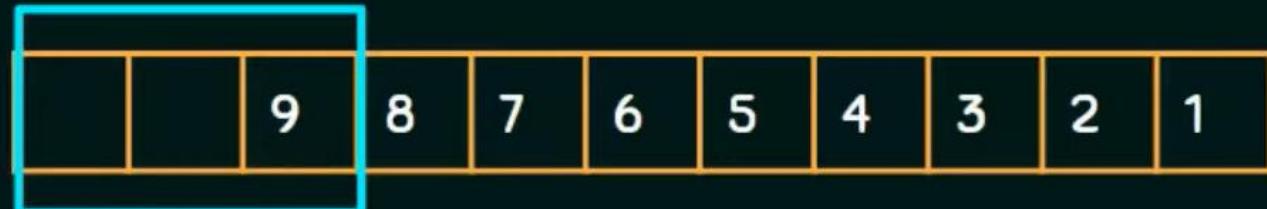
SOLUTION



Window Size: 3



SOLUTION



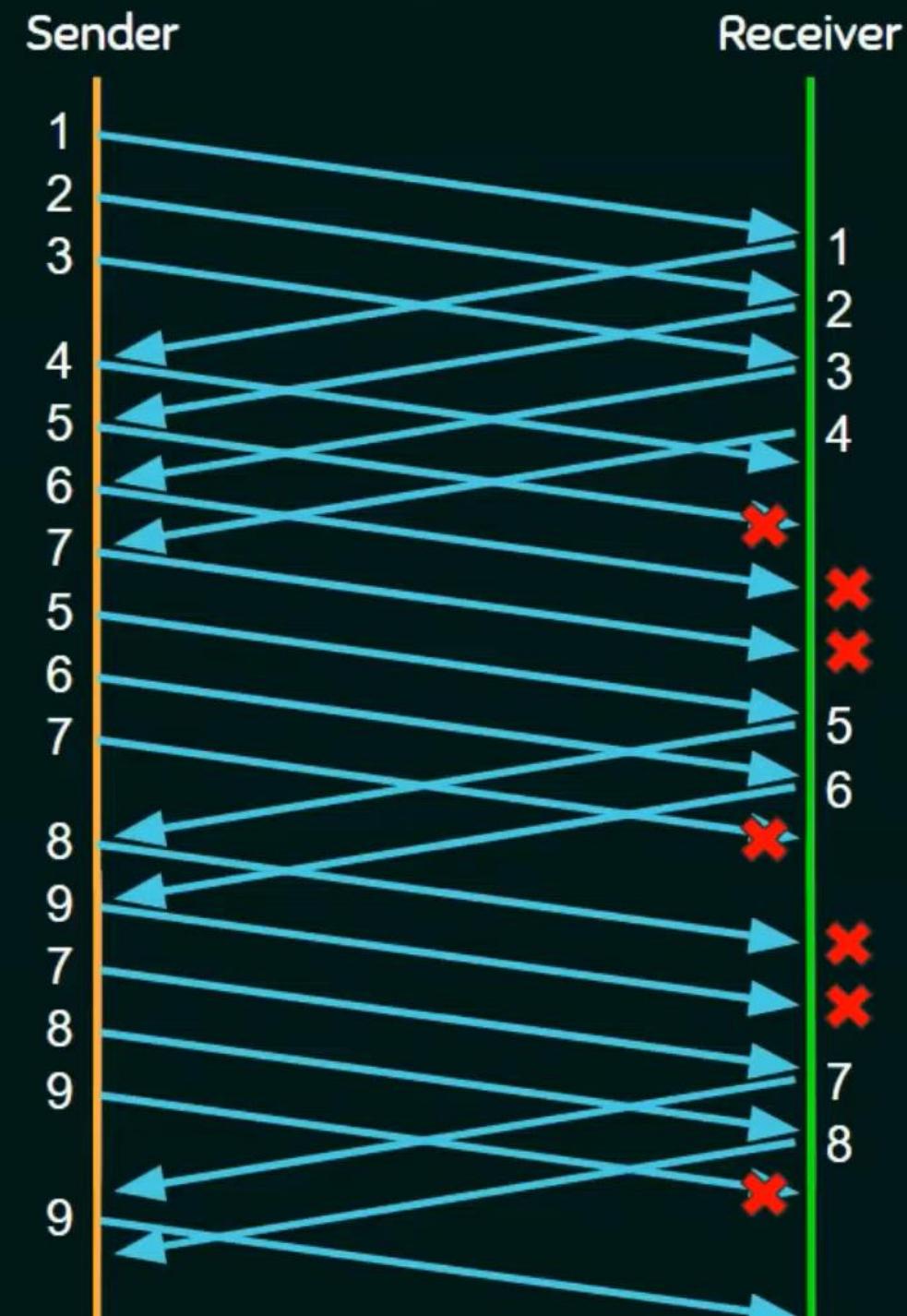
Window Size: 3



SOLUTION



Window Size: 3



SELECTIVE REPEAT/ SELECTIVE REJECT ARQ

- (1) In SR Protocol window sender size is equal to window receiver size ($WS = WR$).
- (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 sorted 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.

SELECTIVE REPEAT ARQ

- ★ In Selective Repeat ARQ, only the erroneous or lost frames are retransmitted, while correct frames are received and buffered.
- ★ The receiver while keeping track of sequence numbers, buffers the frames in memory and sends NACK for only frame which is missing or damaged.



- (6) For 1st out of order delivery or if packet received is corrupted then Negative acknowledgment (NACK) for respective packet is sent by receiver to sender.
- (7) When sender receive NACK 3 then it will search in the window for packet 3 & immediately packet 3 is retransmitted even though its timer is not expired.

	Stop & wait	GBN	SR
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 $\eta * B$	$\frac{N * \text{Length of the frame}}{\text{Total time}}$ or $\eta * B$	$\frac{W_S * \text{Length of the frame}}{\text{Total time}}$ or $\eta * B$
Buffer	1 + 1	N + 1	N + N
Sequence No.	2	N + 1	2N
Seq. No. = K bit		$\frac{W_S}{2^K - 1}$ $\frac{W_R}{1}$	$\frac{W_S}{2^{K-1}}$ $\frac{W_R}{2^{K-1}}$

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

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 ____.

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 2 msec then what is the efficiency.