Module 3 : Data Link Layer

Department of COMPUTER ENGINEERING

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Module 3	Topics	Hrs	CO Covered
3.1 3.2	DLL Design Issues (Services, Framing, Error Control, Flow Control), Error Detection and Correction(Hamming Code, CRC, Checksum) , Elementary Data Link protocols , Stop and Wait, Sliding Window(Go Back N, Selective Repeat) **Medium Access Control sublayer** Channel Allocation problem, Multiple access Protocol(Aloha, Carrier Sense Multiple Access (CSMA/CD)	8	CO-2

Module 3 :

Course Outcome Covered : CO2 : Explore different design issues at data link layer.

DLL Design Issues

- DLL Design Issues (Services, Framing, Error Control, Flow Control)
- **Design issues with data link layer are :**

1. **Services provided to the network layer:** The data link layer act as a service interface to the network layer. The principal service is transferring data from network layer on sending machine to the network layer on destination machine. This transfer also takes place via DLL (Data link-layer).
2. **Frame Synchronization :** The source machine sends data in the form of blocks called **frames** to the destination machine. The starting and ending of each frame **should be identified** so that the frame can be recognized by the destination machine

DLL Design Issues

Flow control : Flow control is done to **prevent** the **flow** of data frame at the receiver end. The source machine **must not** send data frames at a rate faster than the capacity of destination machine to accept them.

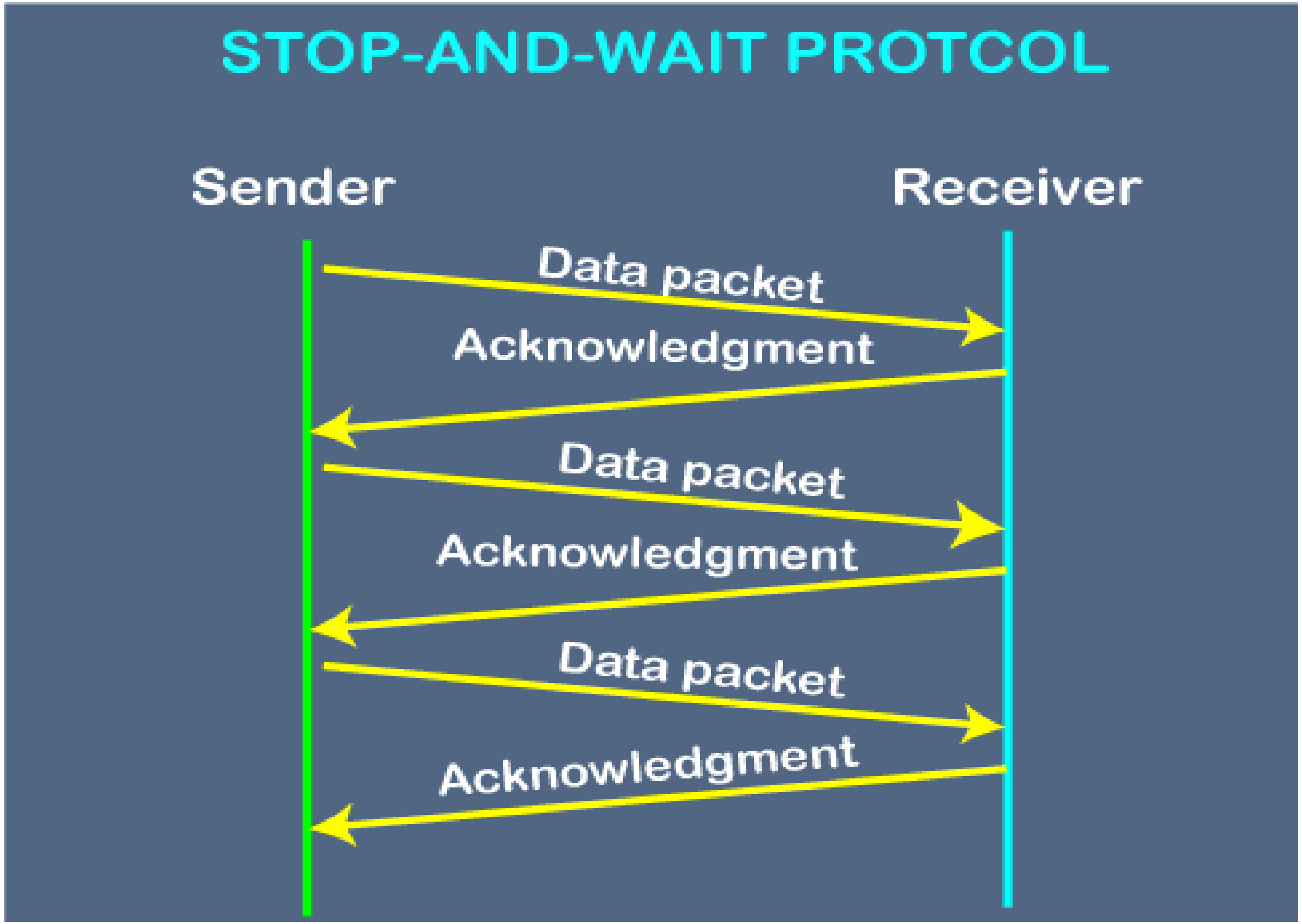
Error control : Error control is done to **prevent duplication** of frames. The errors introduced during transmission from source to destination machines must be detected and corrected at the destination machine.

Elementary Datalink Protocols

- **Stop & Wait Protocol:**
- stop and wait means, whatever the data that sender wants to send, he sends the data to the receiver.
- After sending the data, he stops and waits until he receives the acknowledgment from the receiver.
- The stop and wait protocol is a flow control protocol where flow control is one of the services of the data link layer.

- **Sender side**
- **Rule 1:** Sender sends one data packet at a time.
- **Rule 2:** Sender sends the next packet only when it receives the acknowledgment of the previous packet.
- Therefore, the idea of stop and wait protocol in the sender's side is very simple, i.e., send one packet at a time, and do not send another packet before receiving the acknowledgment.

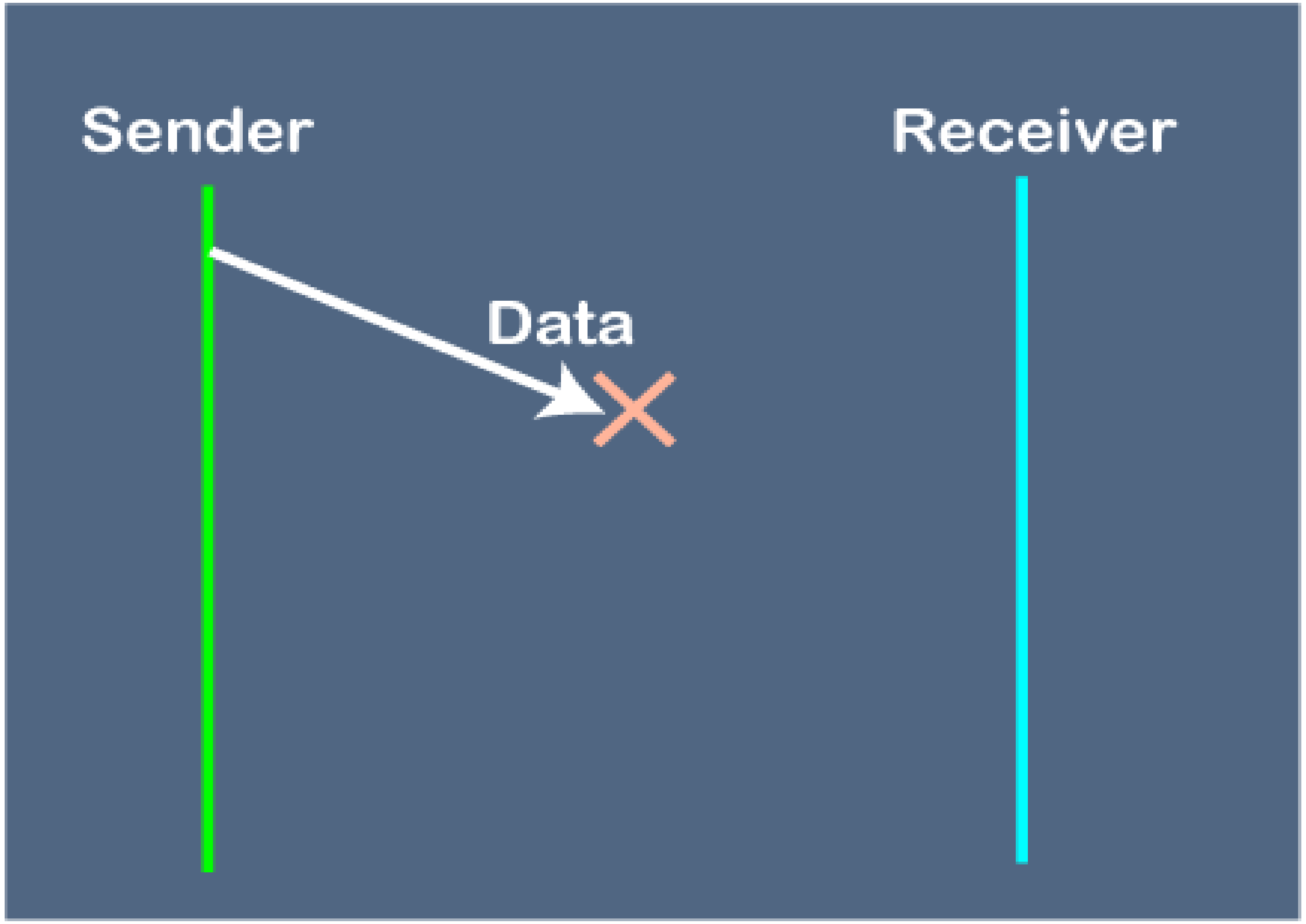
- Receiver side
- **Rule 1:** Receive and then consume the data packet.
- **Rule 2:** When the data packet is consumed, receiver sends the acknowledgment to the sender.
- Therefore, the idea of stop and wait protocol in the receiver's side is also very simple, i.e., consume the packet, and once the packet is consumed, the acknowledgment is sent. This is known as a flow control mechanism.


STOP-AND-WAIT PROTCOL
Sender
Receiver
Data packet
Acknowledgment
Data packet
Acknowledgment
Data packet
Acknowledgment

- **Working :**
- If there is a sender and receiver, then sender sends the packet, and that packet is known as a data packet.
- The sender will not send the second packet without receiving the acknowledgment of the first packet.
- The receiver sends the acknowledgment for the data packet that it has received.
- Once the acknowledgment is received, the sender sends the next packet. This process continues until all the packet are not sent.

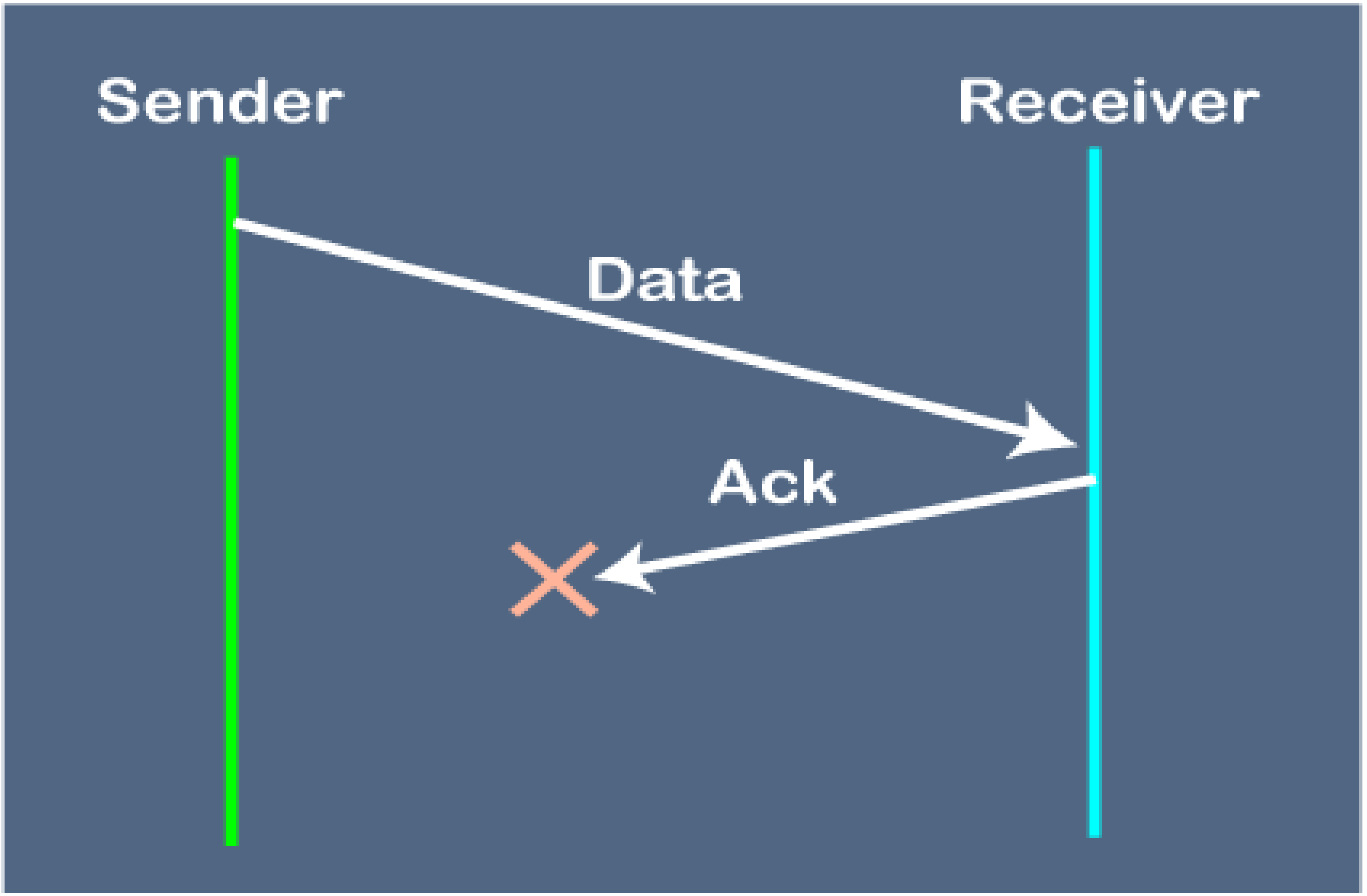
- **Advantages & Disadvantages :**
- The main advantage of this protocol is its simplicity, but it has some disadvantages also.
- For example, if there are 1000 data packets to be sent, then all the 1000 packets cannot be sent at a time as in Stop and Wait protocol, one packet is sent at a time.

- **1. Problems occur due to lost data :**



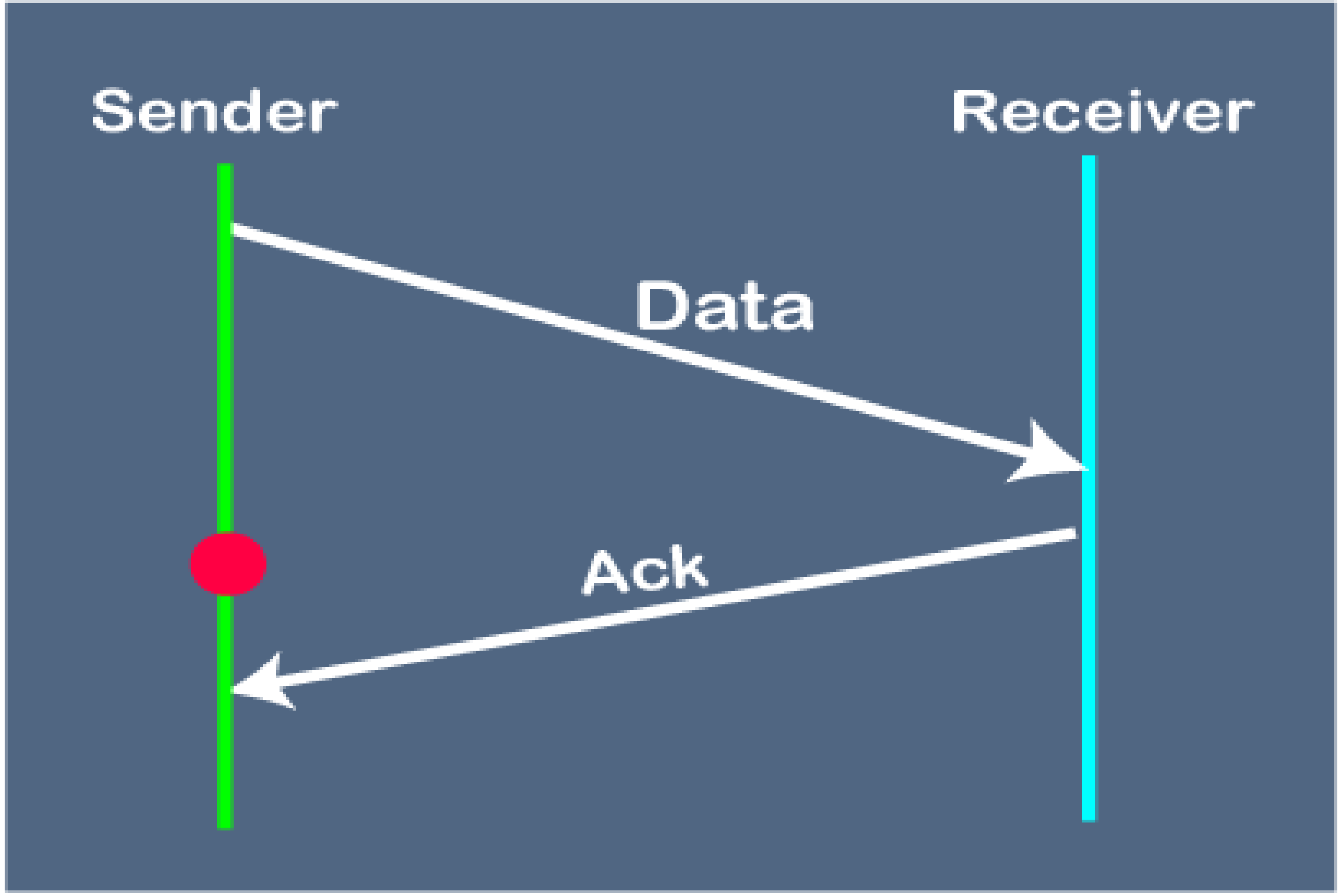
- Suppose the sender sends the data and the data is lost. The receiver is waiting for the data for a long time.
- Since the data is not received by the receiver, so it does not send any acknowledgment.
- Since the sender does not receive any acknowledgment so it will not send the next packet.
- This problem occurs due to the lost data.

- **2. Problems occur due to lost acknowledgment**



- Sender sends the data, and it has also been received by the receiver. On receiving the packet, the receiver sends the acknowledgment.
- In this case, the acknowledgment is lost in a network, so there is no chance for the sender to receive the acknowledgment.
- There is also no chance for the sender to send the next packet as in stop and wait protocol, the next packet cannot be sent until the acknowledgment of the previous packet is received.

- **3. Problem due to the delayed data or acknowledgment**



- The sender sends the data, and it has also been received by the receiver.
- The receiver then sends the acknowledgment, but the acknowledgment is received after the timeout period on the sender's side.
- As the acknowledgment is received late, so acknowledgment can be wrongly considered as the acknowledgment of some other data packet.

Sliding Window Protocol

- Sliding Window Protocol :
- The sliding window is a technique for sending multiple frames at a time. It controls the data packets between the two devices where reliable and gradual delivery of data frames is needed.
- In this technique, each frame has sent from the sequence number. The sequence numbers are used to find the missing data in the receiver end. The purpose of the sliding window technique is to avoid duplicate data, so it uses the sequence number.

- Types of Sliding Window Protocol
- Sliding window protocol has two types:

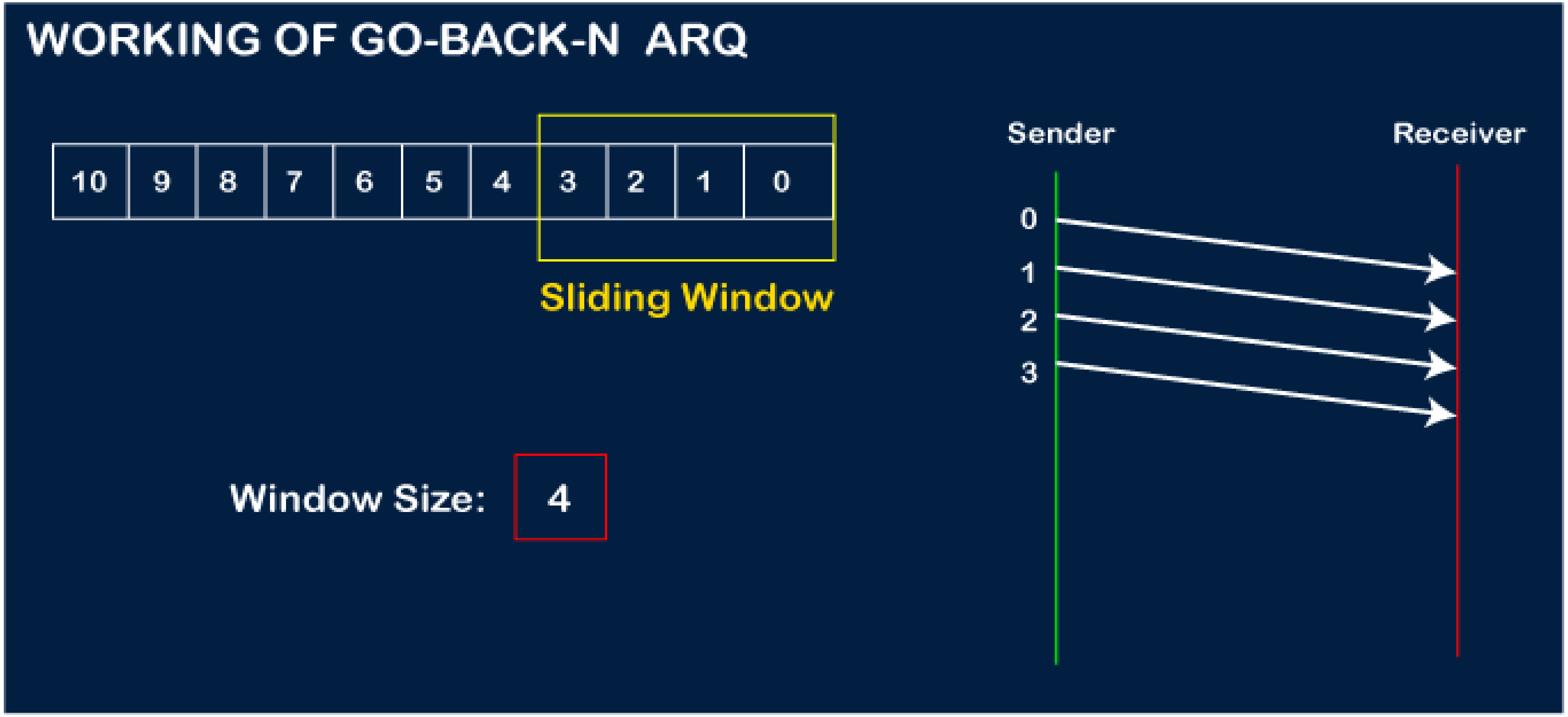
1. Go-Back-N ARQ
2. Selective Repeat ARQ

- **Go-Back-N ARQ**
- In Go-Back-N ARQ, **N** is the sender's window size. Suppose we say that Go-Back-3, which means that the three frames can be sent at a time before expecting the acknowledgment from the receiver.
- It uses the principle of protocol pipelining in which the multiple frames can be sent before receiving the acknowledgment of the first frame.
- If we have five frames and the concept is Go-Back-3, which means that the three frames can be sent, i.e., frame no 1, frame no 2, frame no 3 can be sent before expecting the acknowledgment of frame no 1.

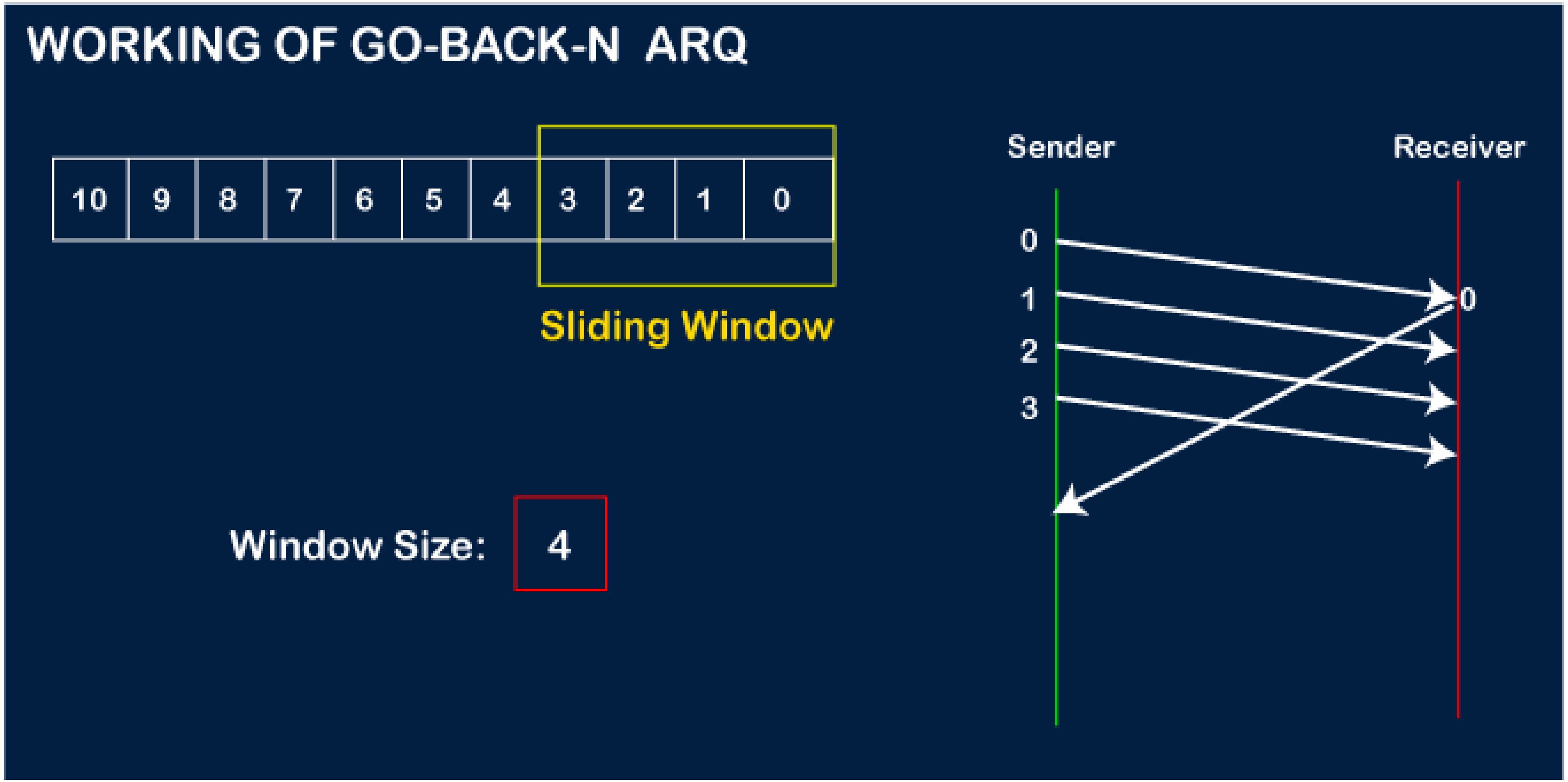
- The number of frames that can be sent at a time totally depends on the size of the sender's window. So, we can say that 'N' is the number of frames that can be sent at a time before receiving the acknowledgment from the receiver.
- If the acknowledgment of a frame is not received within an agreed-upon time period, then all the frames available in the current window will be retransmitted.
- Suppose we have sent the frame no 5, but we didn't receive the acknowledgment of frame no 5, and the current window is holding three frames, then these three frames will be retransmitted.

- **Working of Go-Back-N ARQ**
- Suppose there are a sender and a receiver, and let's assume that there are 11 frames to be sent.
- These frames are represented as 0,1,2,3,4,5,6,7,8,9,10, and these are the sequence numbers of the frames. Mainly, the sequence number is decided by the sender's window size.
- But, for the better understanding, we took the running sequence numbers, i.e., 0,1,2,3,4,5,6,7,8,9,10. Let's consider the window size as 4, which means that the four frames can be sent at a time before expecting the acknowledgment of the first frame.

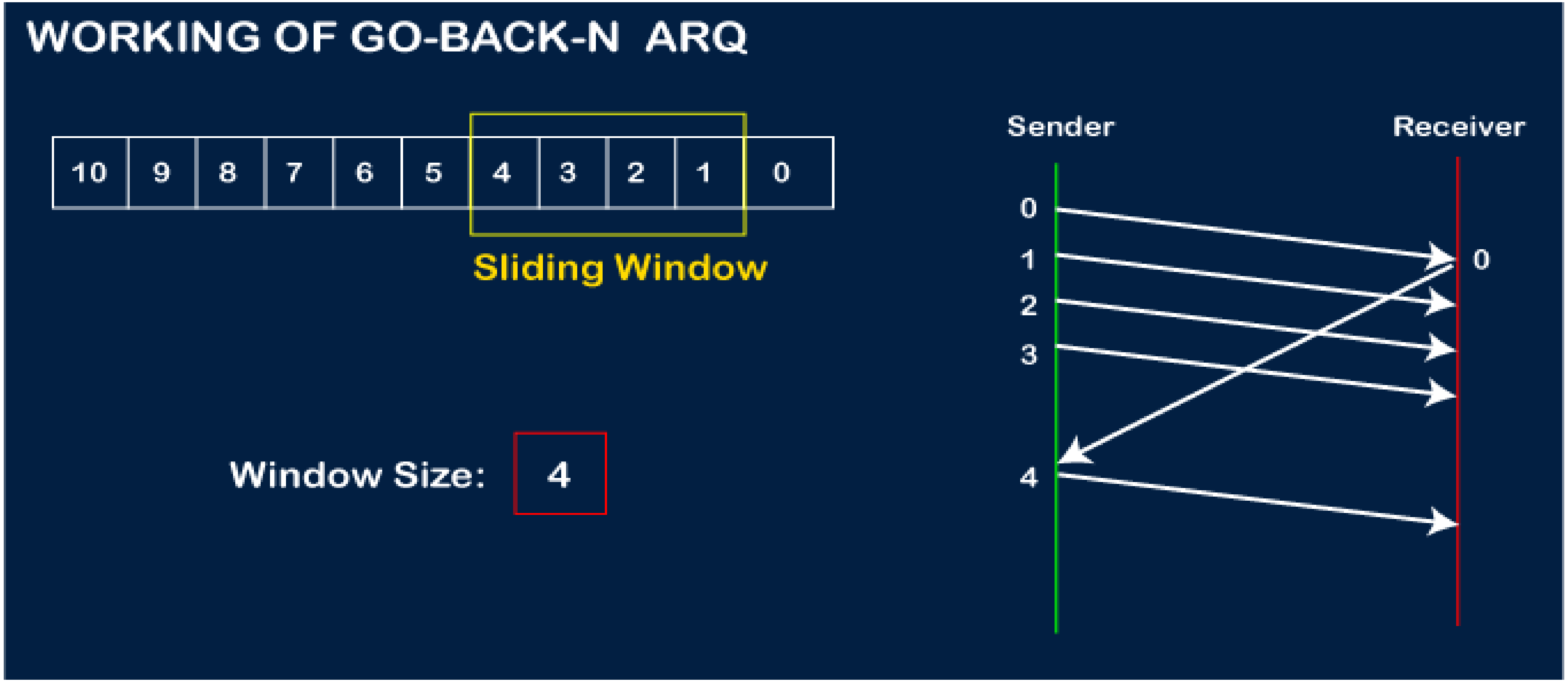
- **Step 1:** Firstly, the sender will send the first four frames to the receiver, i.e., 0,1,2,3, and now the sender is expected to receive the acknowledgment of the 0^{th} frame.



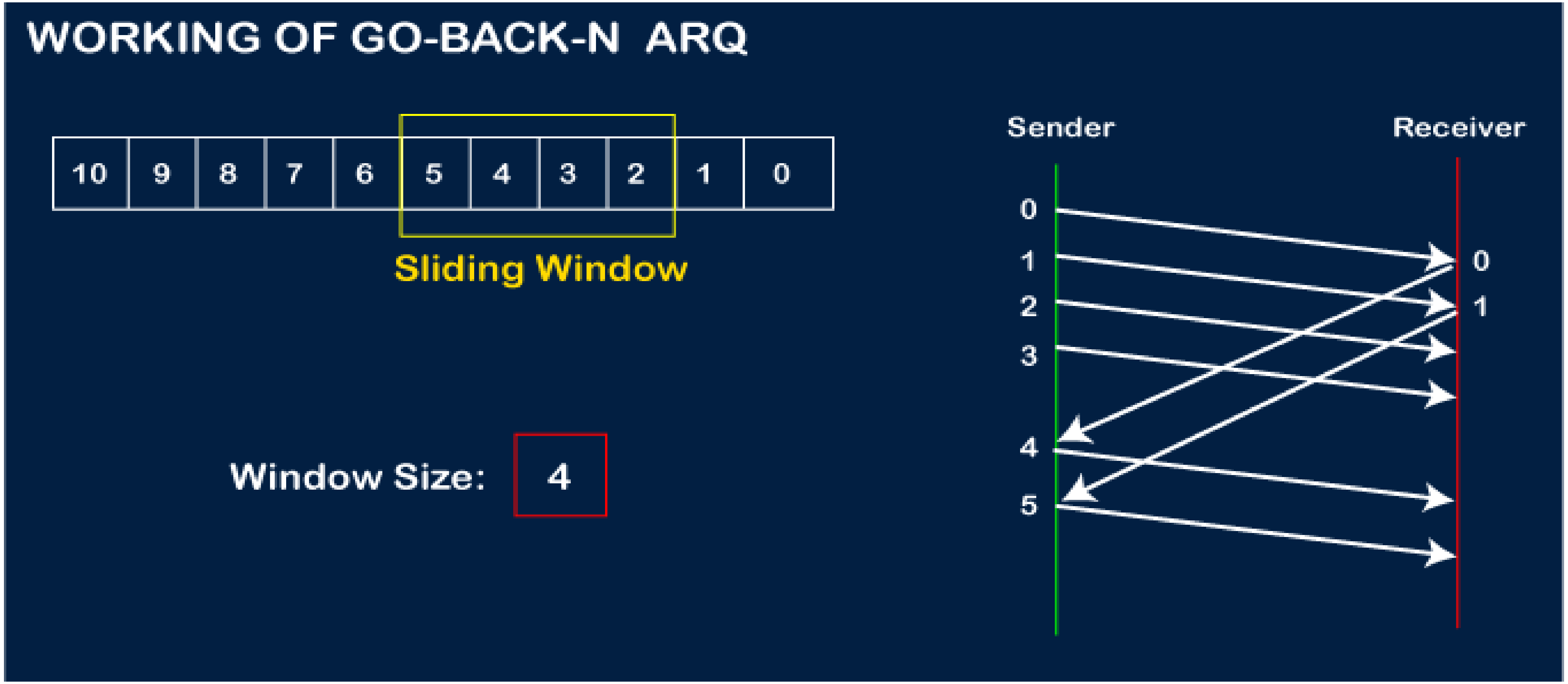
Let's assume that the receiver has sent the acknowledgment for the 0 frame, and the receiver has successfully received it.



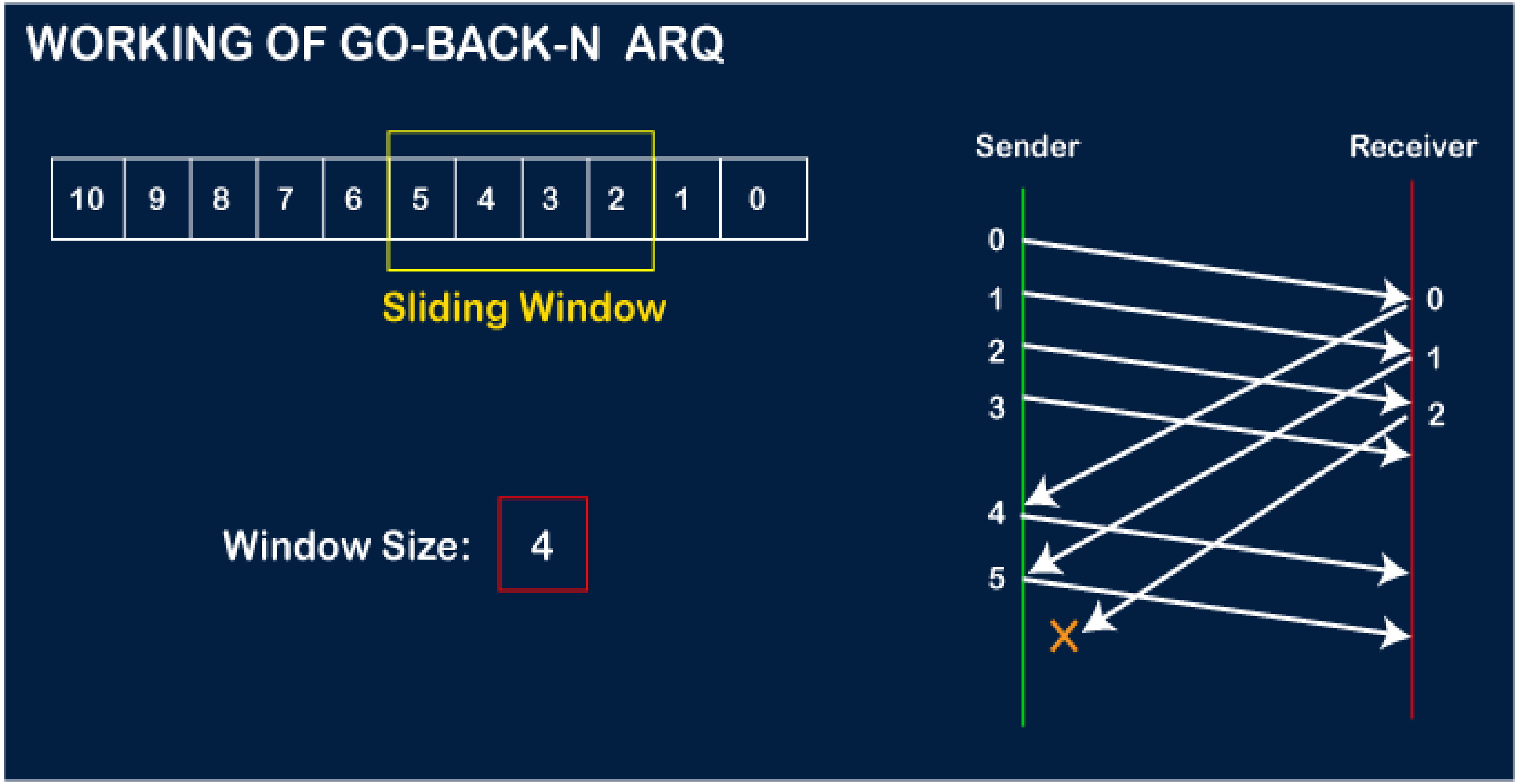
- The sender will then send the next frame, i.e., 4, and the window slides containing four frames (1,2,3,4).



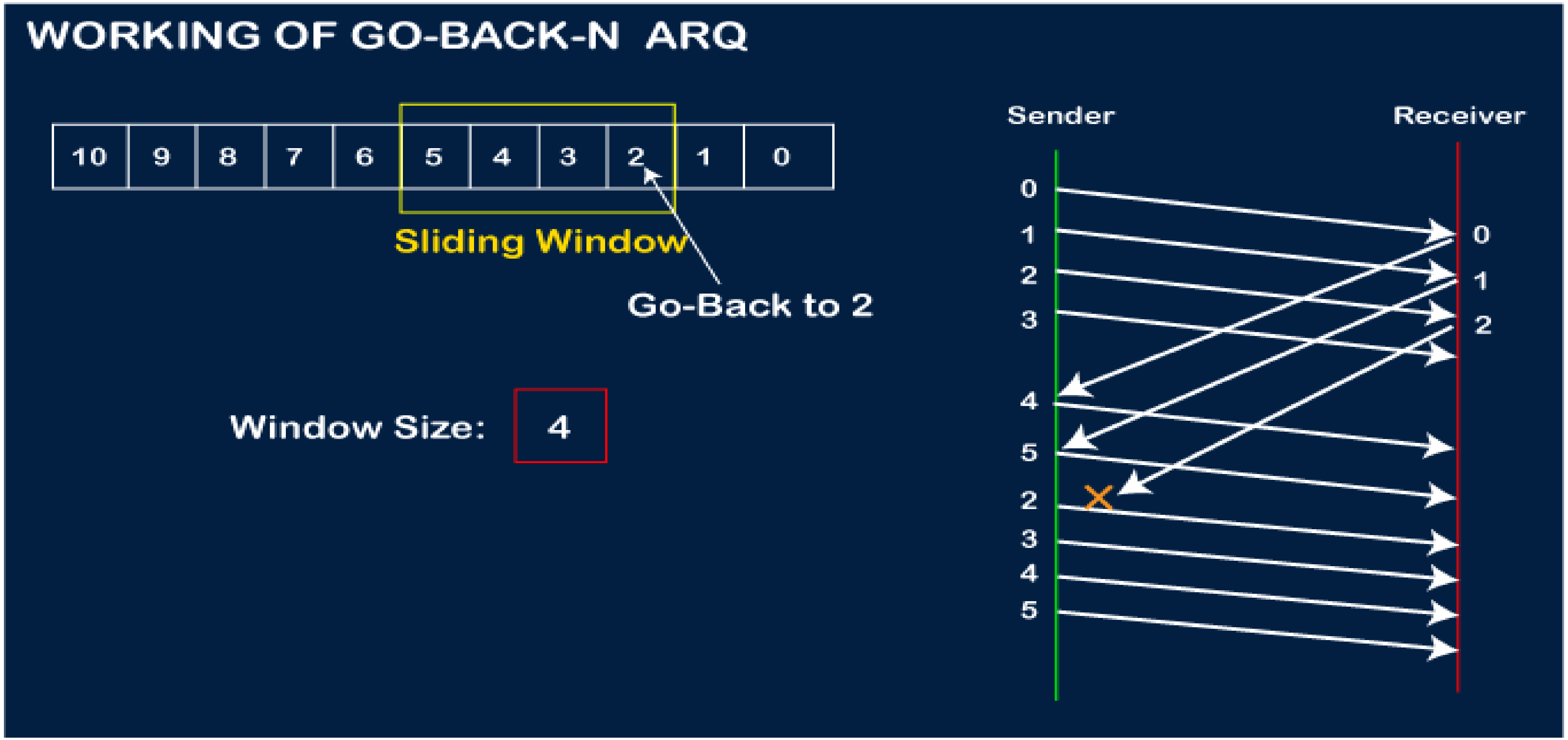
- The receiver will then send the acknowledgment for the frame no 1. After receiving the acknowledgment, the sender will send the next frame, i.e., frame no 5, and the window will slide having four frames (2,3,4,5).



- let's assume that the receiver is not acknowledging the frame no 2, either the frame is lost, or the acknowledgment is lost.



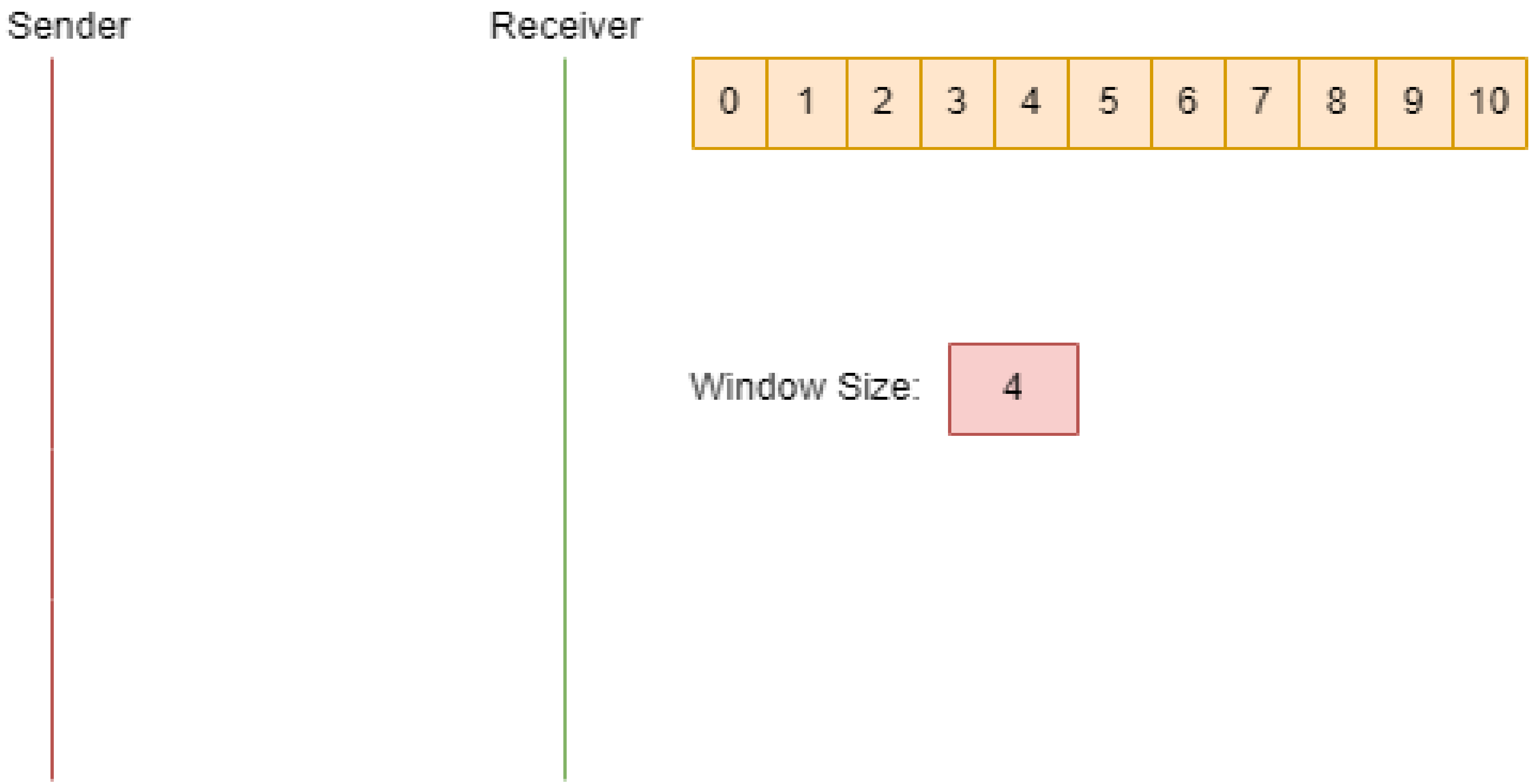
- Instead of sending the frame no 6, the sender Go-Back to 2, which is the first frame of the current window, retransmits all the frames in the current window, i.e., 2,3,4,5.

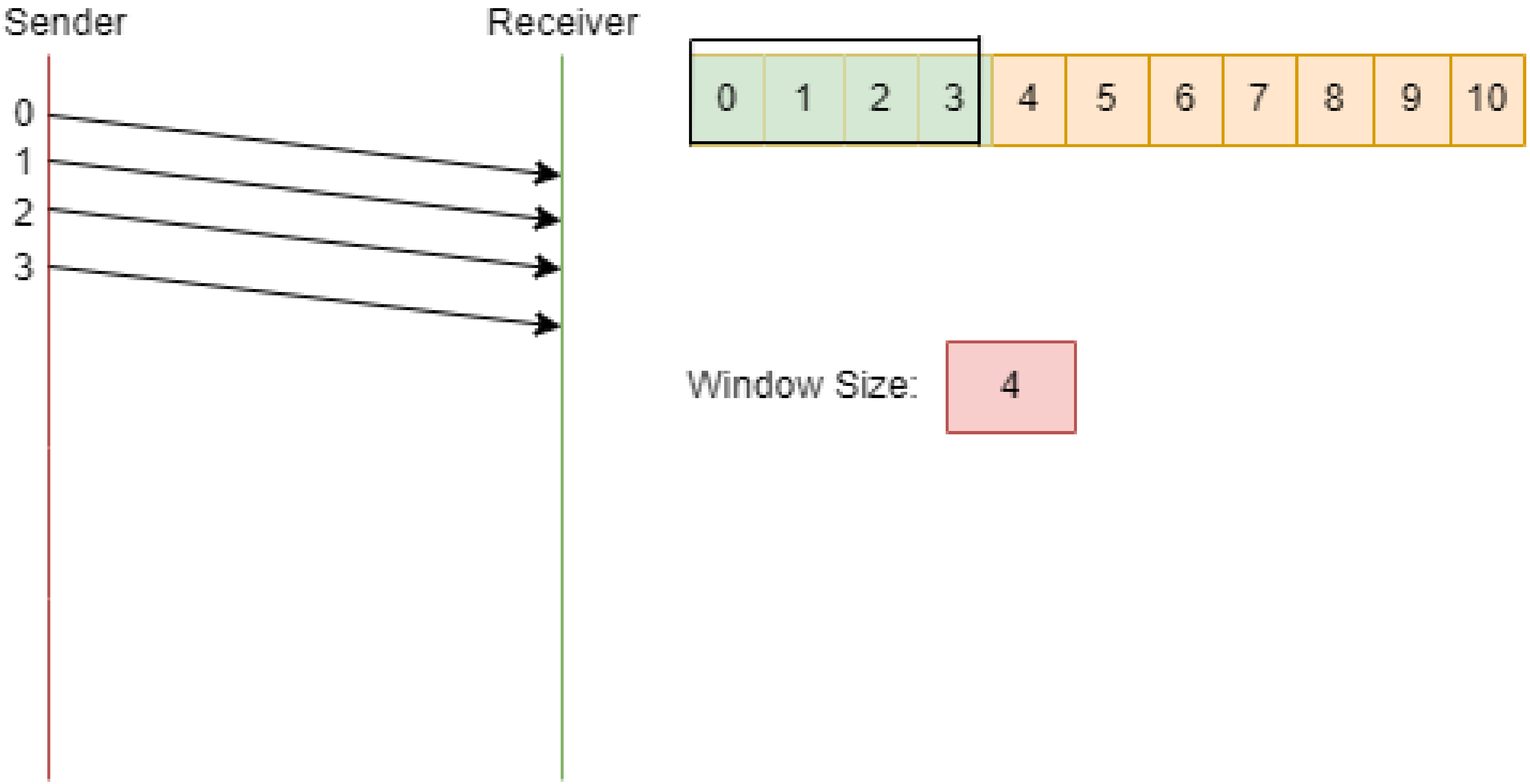


- Selective repeat protocol, also known as **Selective Repeat Automatic Repeat Request** (ARQ), is a data link layer protocol that uses the sliding window technique for reliable data frame delivery.
- Only erroneous or lost frames are retransmitted in this case, while good frames are received and buffered.
- **Selective Repeat ARQ** is used in the data link layer for error detection and control. The sender sends several frames specified by a window size in the selective repeat without waiting for individual acknowledgement from the receiver as in Go-Back-N ARQ.

- **Working of Selective Repeat ARQ**
- In Selective Repeat ARQ, only the erroneous or lost frames are retransmitted, while correct frames are received and buffered.
- While keeping track of sequence numbers, the receiver buffers the frames in memory and sends **NACK** (negative acknowledgement) for only the missing or damaged frame.
- The sender will send/retransmit the packet for which NACK (negative acknowledgement) is received.

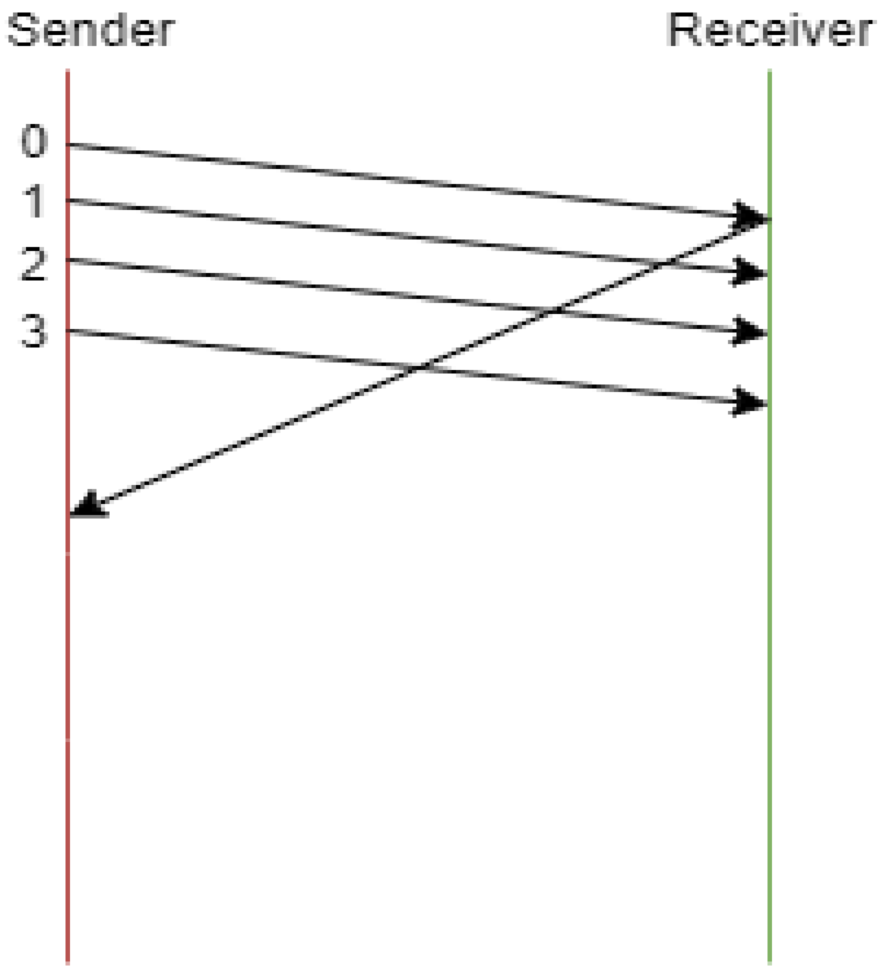
- Suppose there is a sender and a receiver. There are 11 frames to be sent, and the frames are numbered as 0,1,2,3,4,5,6,7,8,9,10.
- The sequence number of the frames is decided by the size of the window N. For better understanding, we have taken the running numbers.
- Let's take the sender's window size to be 4, which means the sender can send 4 frames before expecting any acknowledgement from the first frame, which is 0.

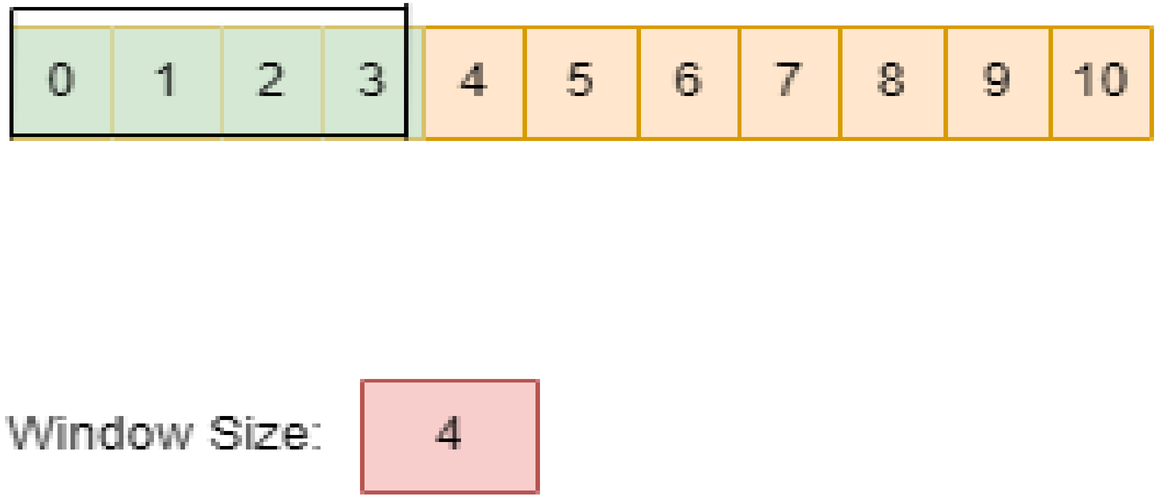

Sender
Receiver
0
1
2
3
4
5
6
7
8
9
10
Window Size:
4



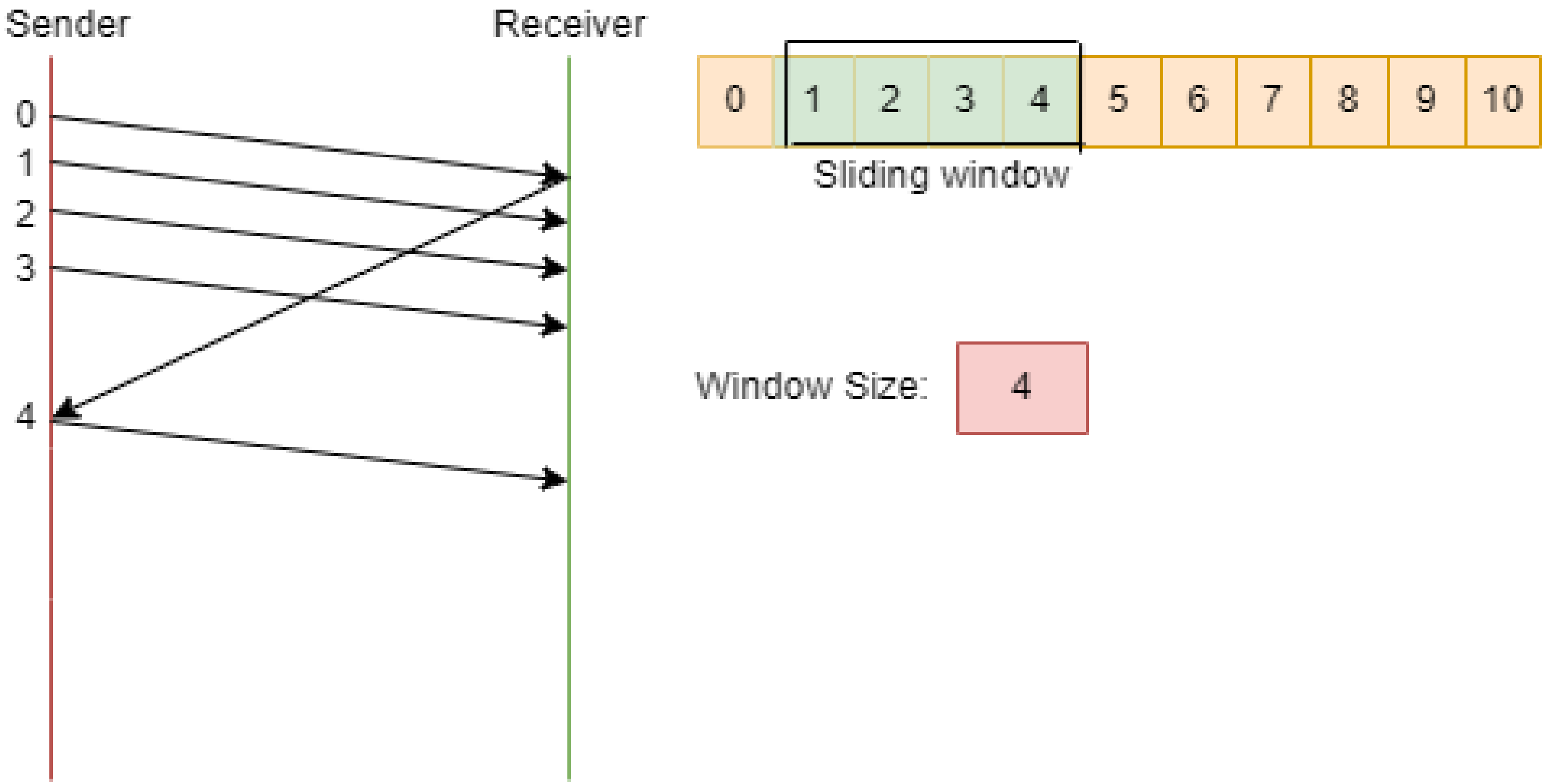
Sender
Receiver
0
1
2
3
0
1
2
3
4
5
6
7
8
9
10
Window Size:
4

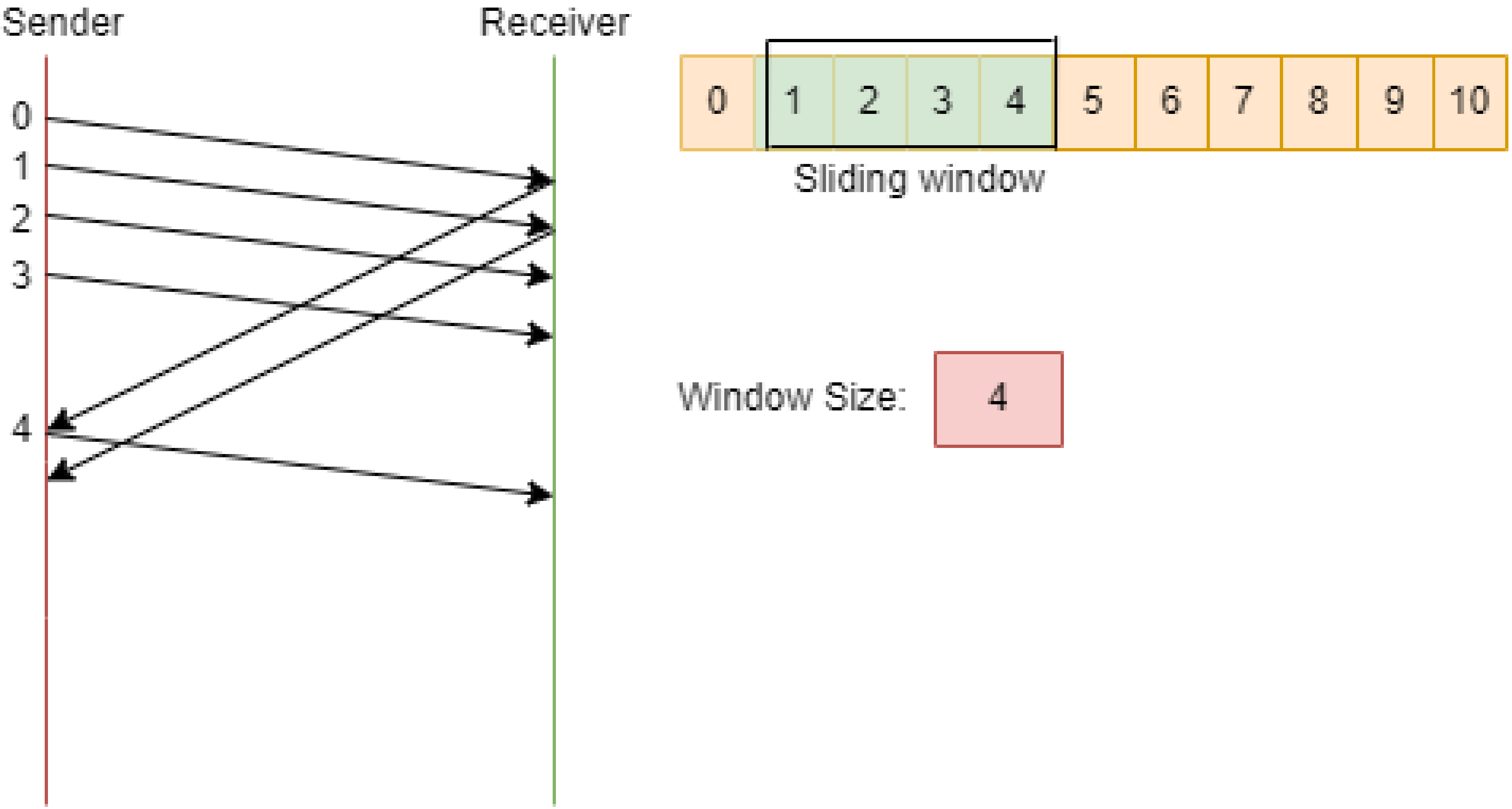
The sender is expected to receive an acknowledgement from the receiver. Let's assume the sender received an acknowledgement for frame 0 from the receiver.



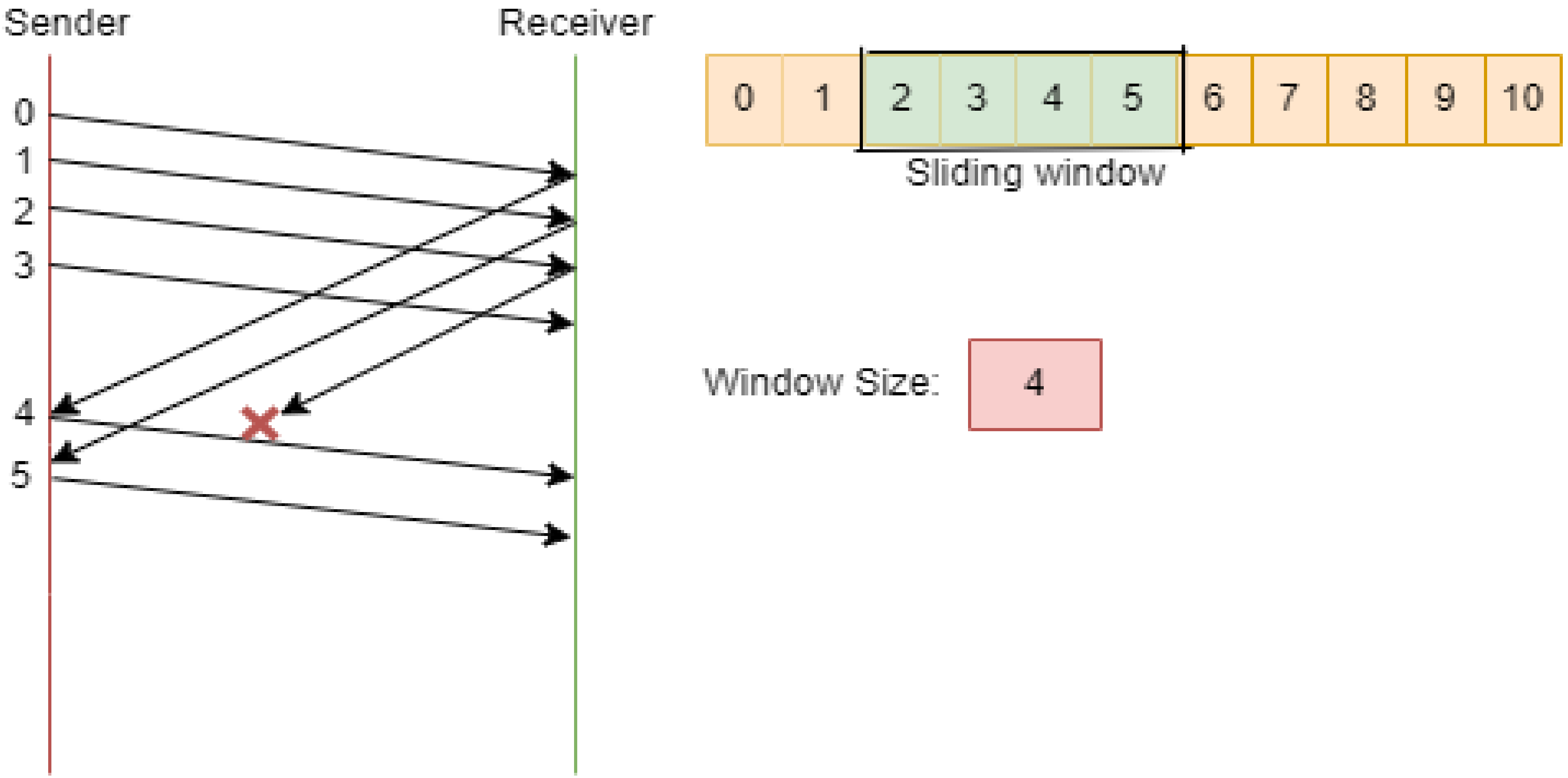


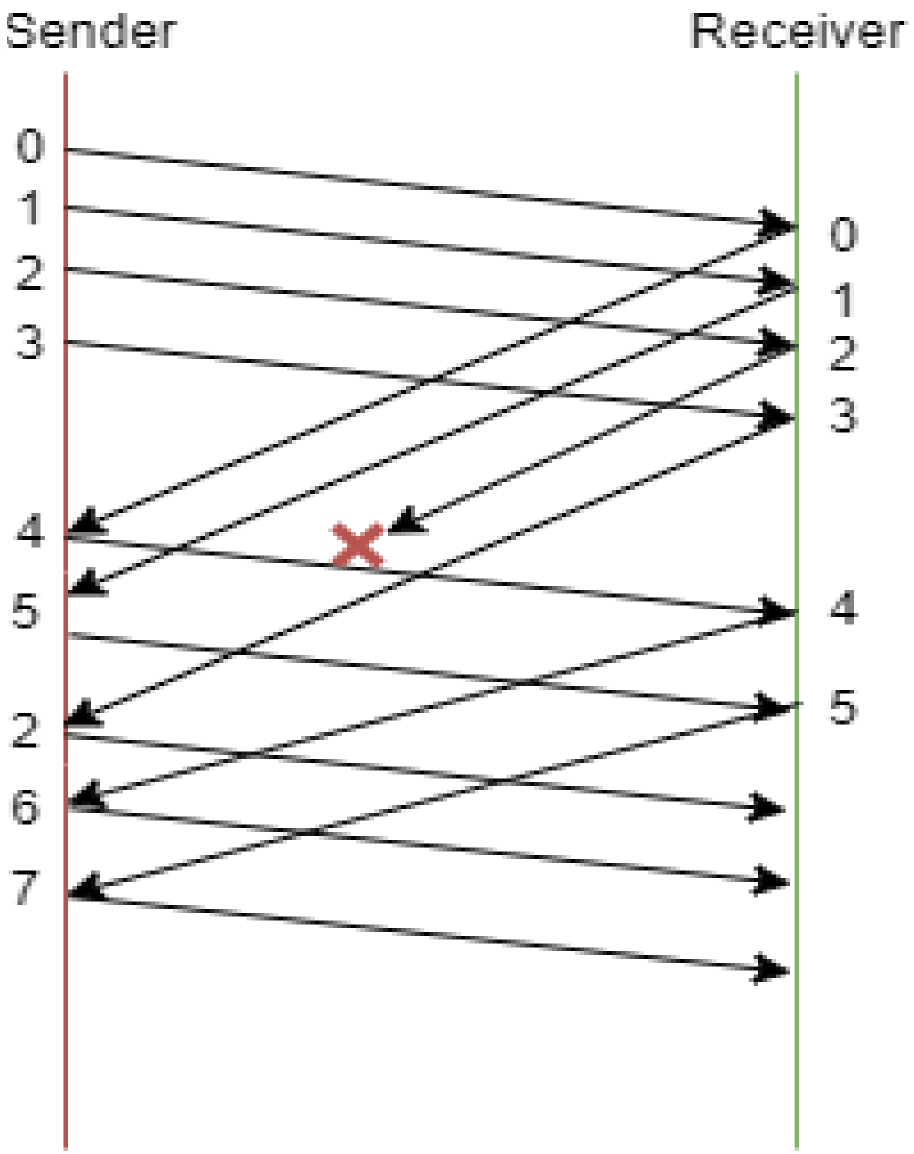
Frame 0 is sent and acknowledged. The current window size is 3; the sender will send the next frame from the buffer, which is 4, and the window slides.

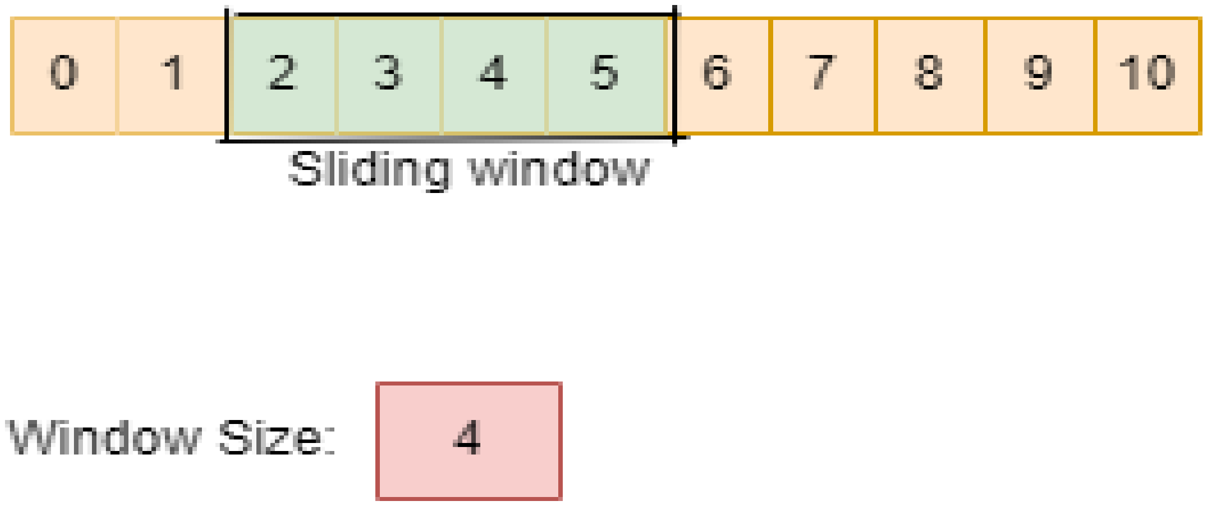



Sender
Receiver
0
1
2
3
4
0
1
2
3
4
5
6
7
8
9
10
Sliding window
Window Size:
4

The window slides and the sender will send the next frame in the buffer, which is 5, and the window slides. Let's assume that the sender is not acknowledging frame number 2 because either the frame is lost or the acknowledgement is lost.




Sender
Receiver
0
1
2
3
4
5
2
6
7
0
1
2
3
4
5


0
1
2
3
4
5
6
7
8
9
10
Sliding window
Window Size:
4

- **Advantage :**
- In the Selective-Repeat ARQ protocol, we avoid unnecessary transmission by sending only the damaged or missing frames.

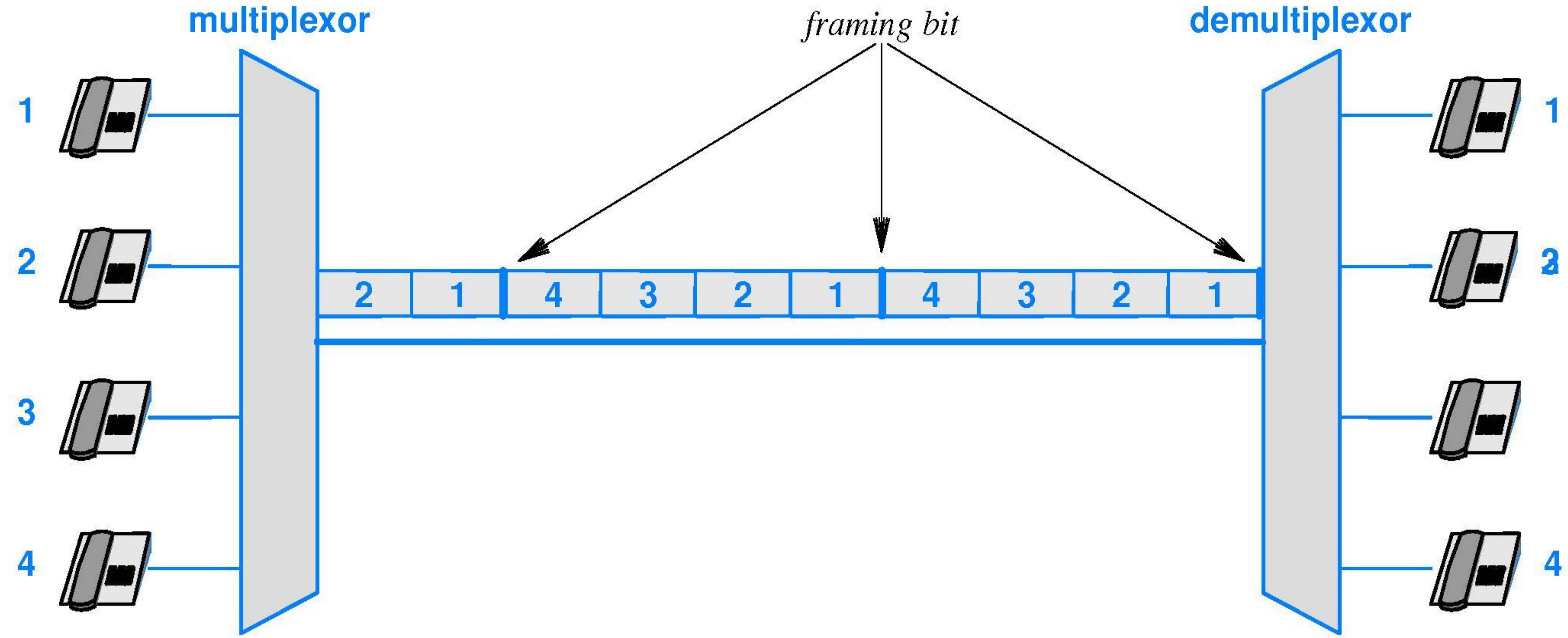
- **Medium Access Control sublayer**
- Channel Allocation problem, Multiple access Protocol (Aloha, Carrier Sense Multiple Access (CSMA/CD)

- **Channel Allocation problem :**
- In a broadcast network, the single broadcast channel is to be allocated to one transmitting user at a time.
- When multiple users use a shared network and want to access the same network. Then channel allocation problem in computer networks occurs.
- So, to allocate the same channel between multiple users, techniques are used, which are called channel allocation techniques in computer networks.

- **Channel Allocation Techniques :**
- For the efficient use of frequencies, time-slots and bandwidth channel allocation techniques are used.
- There are three types of channel allocation techniques that you can use to resolve channel allocation problem in computer networks as follows:
- Static channel allocation
- Dynamic channel allocation
- Hybrid channel allocation.

- **Static Channel Allocation**
- The traditional way of allocating a single channel between multiple users is called static channel allocation.
- Static channel allocation is also called fixed channel allocation. Such as a telephone channel among many users is a real-life example of static channel allocation.

- The frequency division multiplexing (FDM) and time-division multiplexing (TDM) are two examples of static channel allocation.
- In these methods, either a fixed frequency or fixed time slot is allotted to each user.


multiplexor
framing bit
demultiplexor
1
2
3
4
2 1 4 3 2 1 4 3 2 1
1
2
4

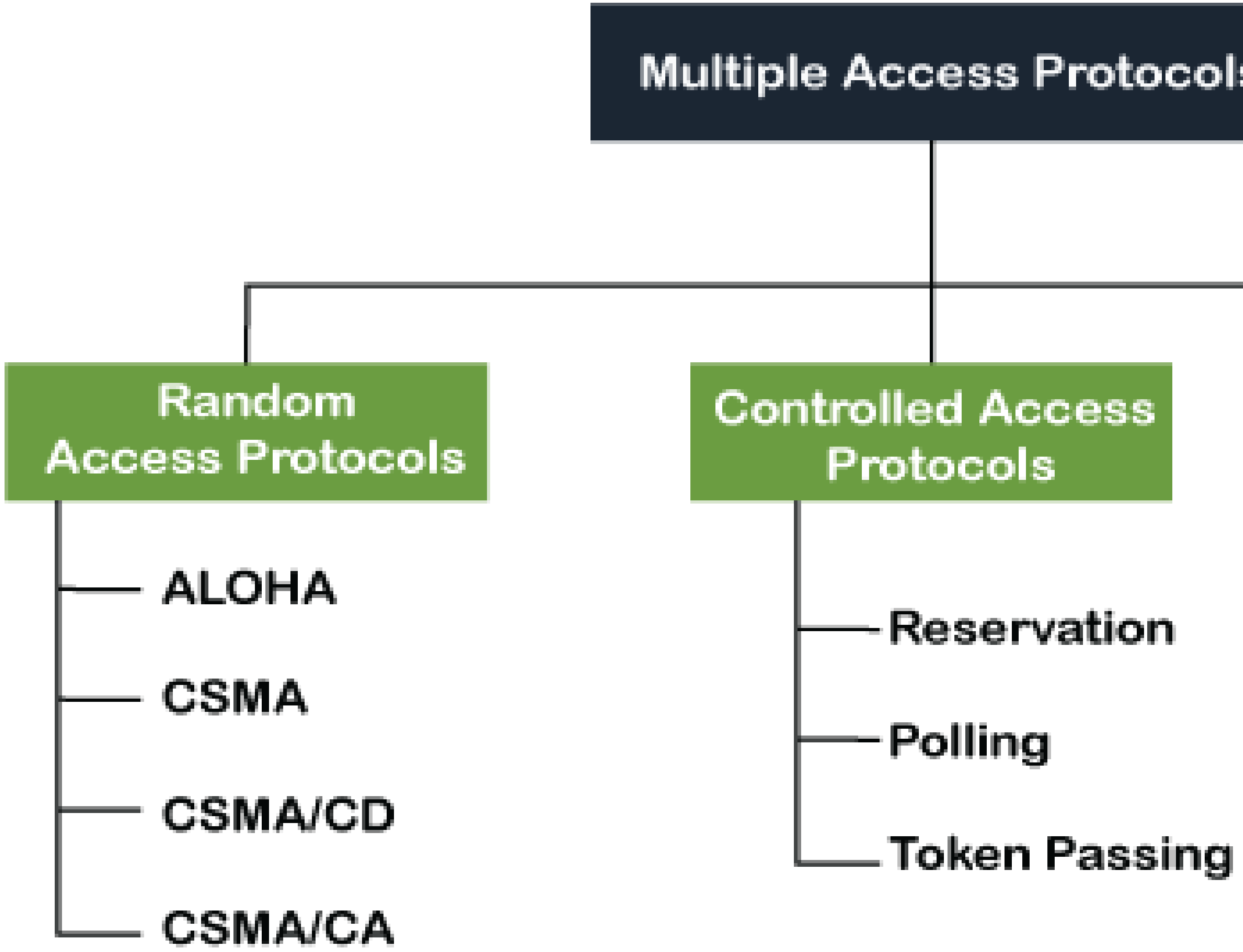
- Dynamic Channel Allocation :
- The technique in which channels are not permanently allocated to the users is called dynamic channel allocation. In this technique, no fixed frequency or fixed time slot is allotted to the user.
- The allocation depends upon the traffic. If the traffic increases, more channels are allocated, otherwise fewer channels are allocated to the users.
- This technique optimizes bandwidth usage and provides fast data transmission. Dynamic channel allocation is further categorized into two parts as follows:

- **Centralized dynamic channel allocation**
- **Distributed dynamic channel allocation**
- The following are the assumptions in dynamic channel allocation:
- **Station Model:** Comprises N independent stations with a program for transmission.
- **Single Channel:** A single channel is available for all communication.

- **Collision:** If frames are transmitted at the same time by two or more stations, then the collision occurs.
- **Carrier or no carrier sense:** Stations sense the channel before transmission.

- **Hybrid Channel Allocation**
- The mixture of fixed channel allocation and dynamic channel allocation is called hybrid channel allocation. The total channels are divided into two sets, fixed and dynamic sets.
- First, a fixed set of channels is used when the user makes a call. If all fixed sets are busy, then dynamic sets are used. When there is heavy traffic in a network, then hybrid channel allocation is used.

- **Multiple access protocol :**
- When a sender and receiver have a dedicated link to transmit data packets, the data link control is enough to handle the channel.
- Suppose there is no dedicated path to communicate or transfer the data between two devices. In that case, multiple stations access the channel and simultaneously transmits the data over the channel.
- It may create collision and cross talk. Hence, the multiple access protocol is required to reduce the collision and avoid crosstalk between the channels.

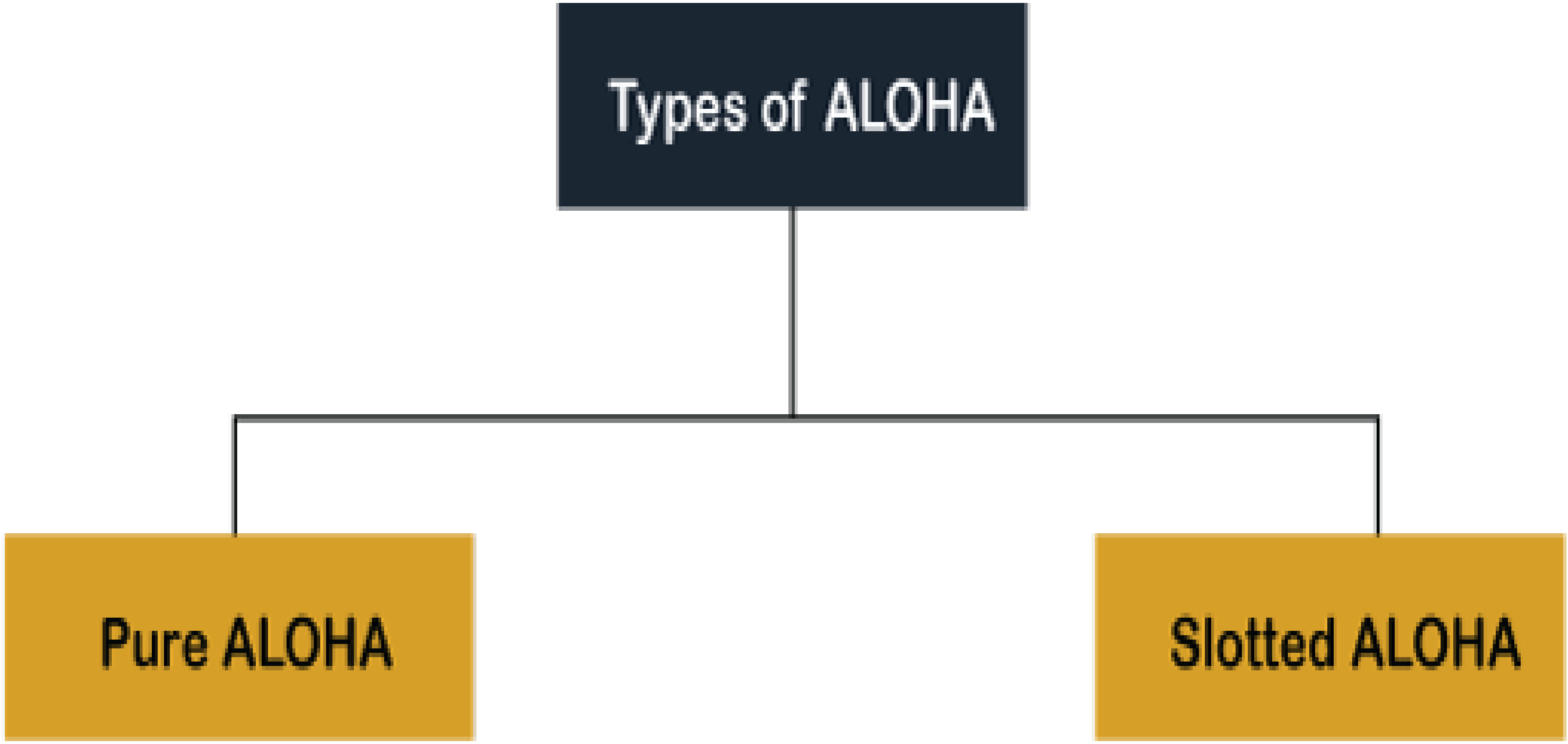

Multiple Access Protocols
Random Access Protocols
Controlled Access Protocols
Channelization Protocols
ALOHA
CSMA
CSMA/CD
CSMA/CA
Reservation
Polling
Token Passing
FDMA
TDMA
CDMA

- **Random Access Protocol**
- In this protocol, all the station has the equal priority to send the data over a channel. In random access protocol, one or more stations cannot depend on another station, nor any station control another station.
- Depending on the channel's state (idle or busy), each station transmits the data frame.
- However, if more than one station sends the data over a channel, there may be a collision or data conflict.
- Due to the collision, the data frame packets may be lost or changed. And hence, it does not receive by the receiver end.

- Following are the different methods of random-access protocols for broadcasting frames on the channel.
- Aloha
- CSMA
- CSMA/CD
- CSMA/CA

- **ALOHA Random Access Protocol**
- It is designed for wireless LAN (Local Area Network) but can also be used in a shared medium to transmit data. Using this method, any station can transmit data across a network simultaneously when a data frameset is available for transmission.
- **Aloha Rules**

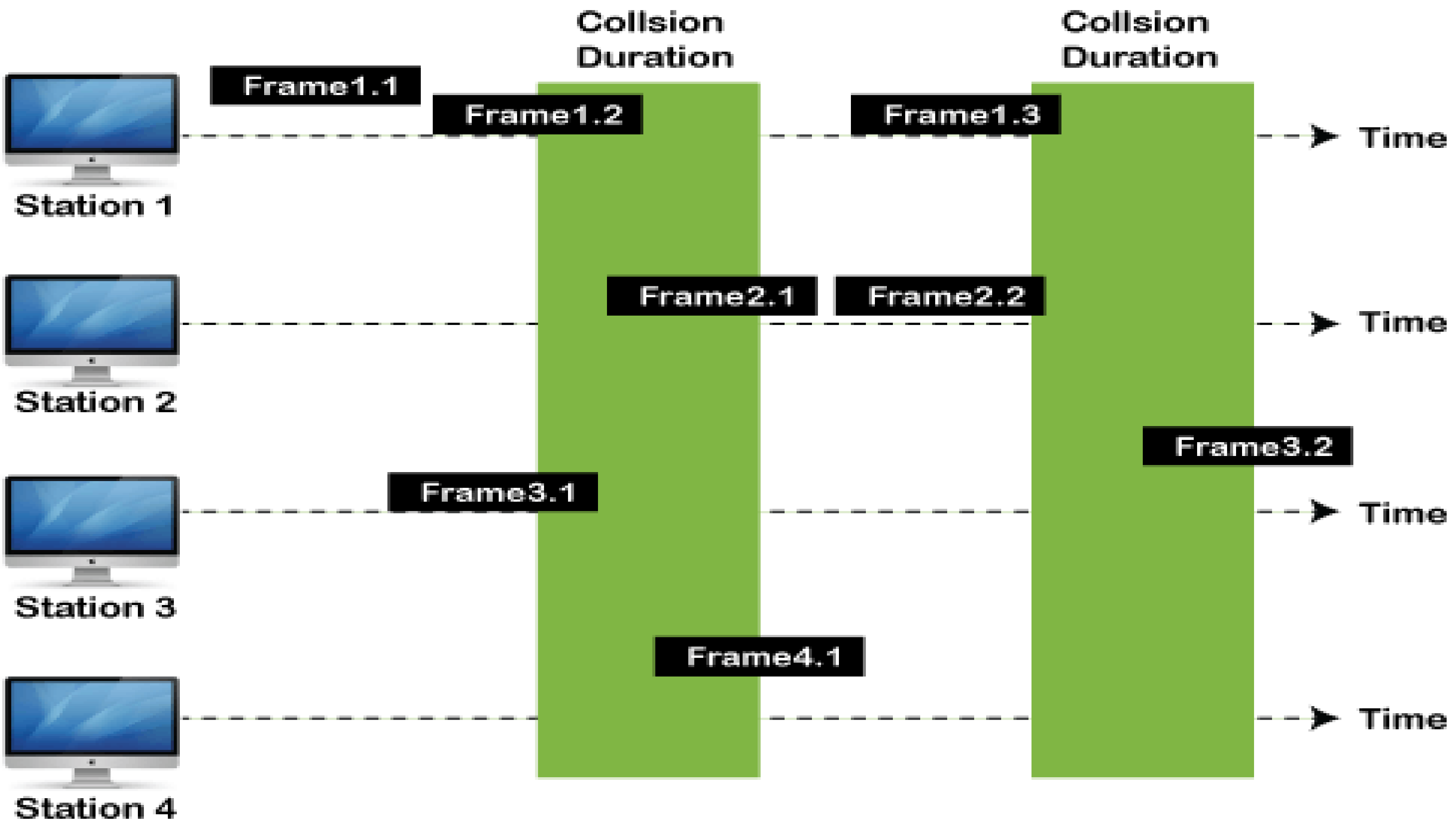
1. Any station can transmit data to a channel at any time.
2. It does not require any carrier sensing.
3. Collision and data frames may be lost during the transmission of data through multiple stations.
4. Acknowledgment of the frames exists in Aloha. Hence, there is no collision detection.
5. It requires retransmission of data after some random amount of time.


Types of ALOHA
Pure ALOHA
Slotted ALOHA

- **Pure Aloha**
- Whenever data is available for sending over a channel at stations, we use Pure Aloha.
- In pure Aloha, when each station transmits data to a channel without checking whether the channel is idle or not, the chances of collision may occur, and the data frame can be lost.
- When any station transmits the data frame to a channel, the pure Aloha waits for the receiver's acknowledgment.

- If it does not acknowledge the receiver end within the specified time, the station waits for a random amount of time, called the backoff time (Tb).
- And the station may assume the frame has been lost or destroyed.
- Therefore, it retransmits the frame until all the data are successfully transmitted to the receiver.

1. The total vulnerable time of pure Aloha is 2 * Tfr.
2. Maximum throughput occurs when G = 1/ 2 that is 18.4%.
3. Successful transmission of data frame is S = G * e ^ - 2 G.



Frames in Pure ALOHA

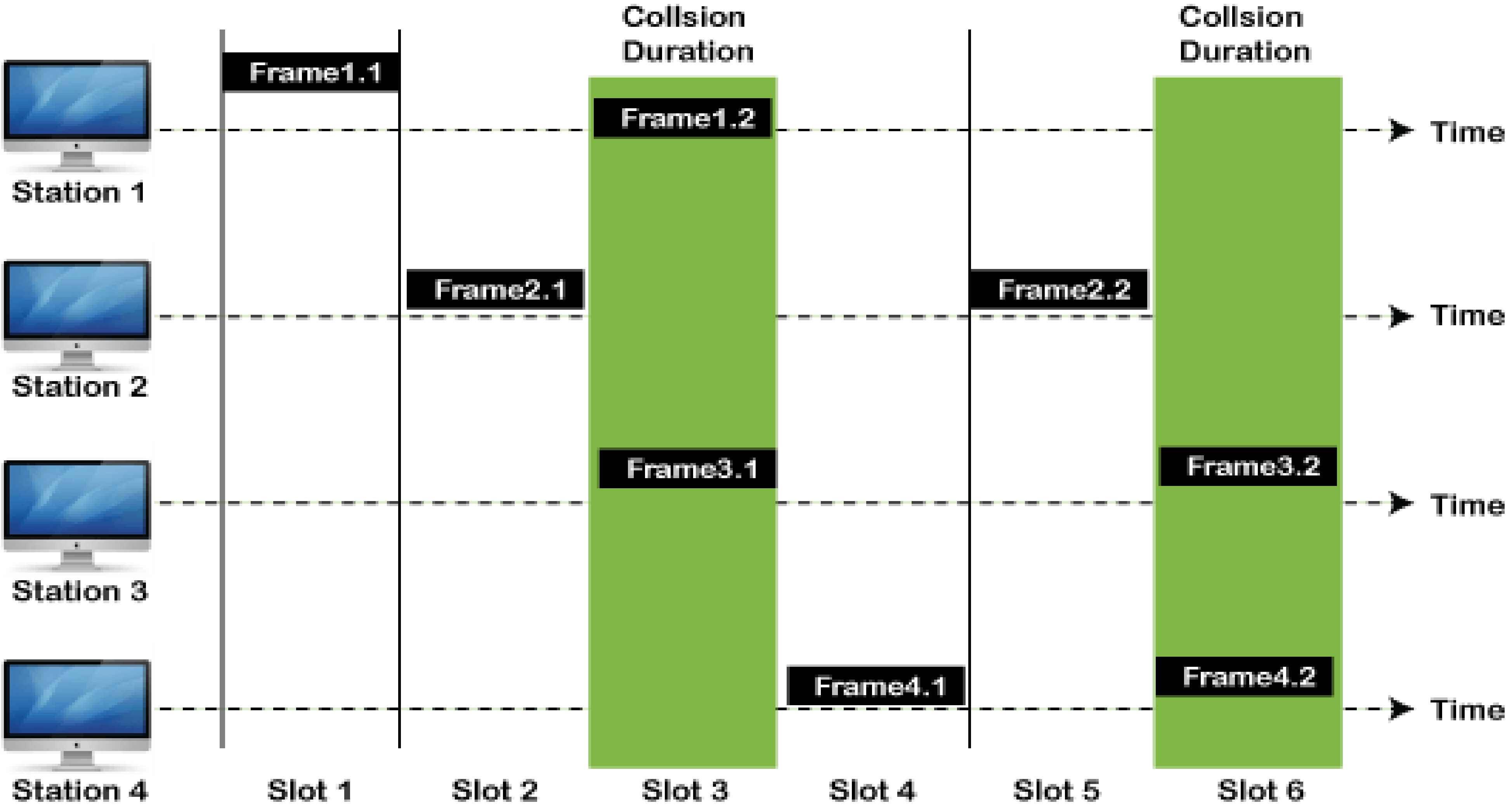
- As we can see in the figure above, there are four stations for accessing a shared channel and transmitting data frames.
- Some frames collide because most stations send their frames at the same time.
- Only two frames, frame 1.1 and frame 2.2, are successfully transmitted to the receiver end. At the same time, other frames are lost or destroyed.
- Whenever two frames fall on a shared channel simultaneously, collisions can occur, and both will suffer damage.

- If the new frame's first bit enters the channel before finishing the last bit of the second frame. Both frames are finished, and both stations must retransmit the data frame.
- **Advantages :**
- The main advantage of pure aloha is its simplicity in implementation.
- Superior to fixed assignment when there are large number of bursty stations.

- **Disadvantages :**
- Theoretically proven throughput maximum of 18.4%.
- Requires queuing buffers for retransmission of packets.

- **Slotted Aloha**
- The slotted Aloha is designed to overcome the pure Aloha's efficiency because pure Aloha has a very high possibility of frame hitting.
- In slotted Aloha, the shared channel is divided into a fixed time interval called **slots**.
- So that, if a station wants to send a frame to a shared channel, the frame can only be sent at the beginning of the slot, and only one frame is allowed to be sent to each slot.
- And if the stations are unable to send data to the beginning of the slot, the station will have to wait until the beginning of the slot for the next time.

- However, the possibility of a collision remains when trying to send a frame at the beginning of two or more station time slot.
- Maximum throughput occurs in the slotted Aloha when G = 1 that is 37%.
- The probability of successfully transmitting the data frame in the slotted Aloha is S = G * e ^ - 2 G.
- The total vulnerable time required in slotted Aloha is Tfr.



Frames in Slotted ALOHA