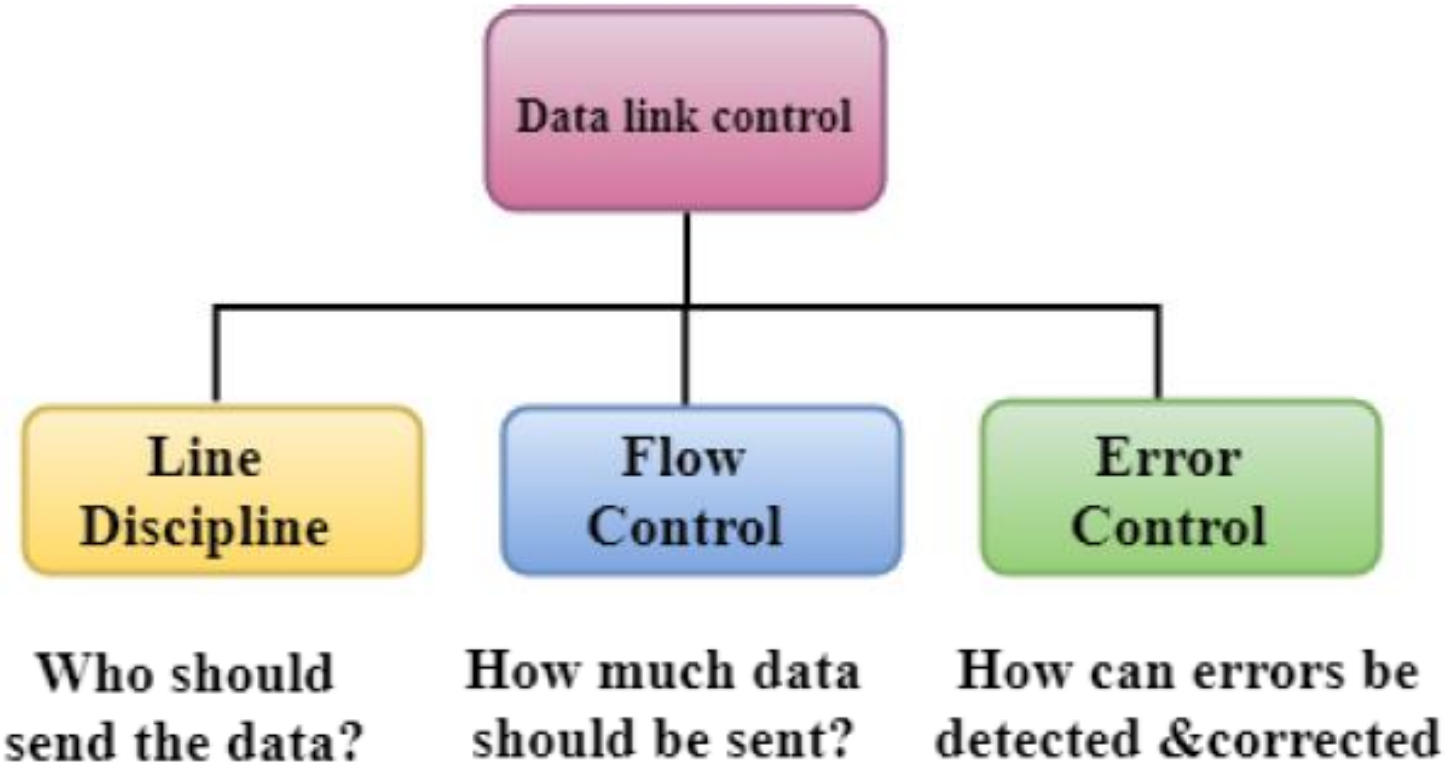
Data Link Control

Overview


Data link control
Line Discipline
Flow Control
Error Control
Who should send the data?
How much data should be sent?
How can errors be detected &corrected

Line Discipline

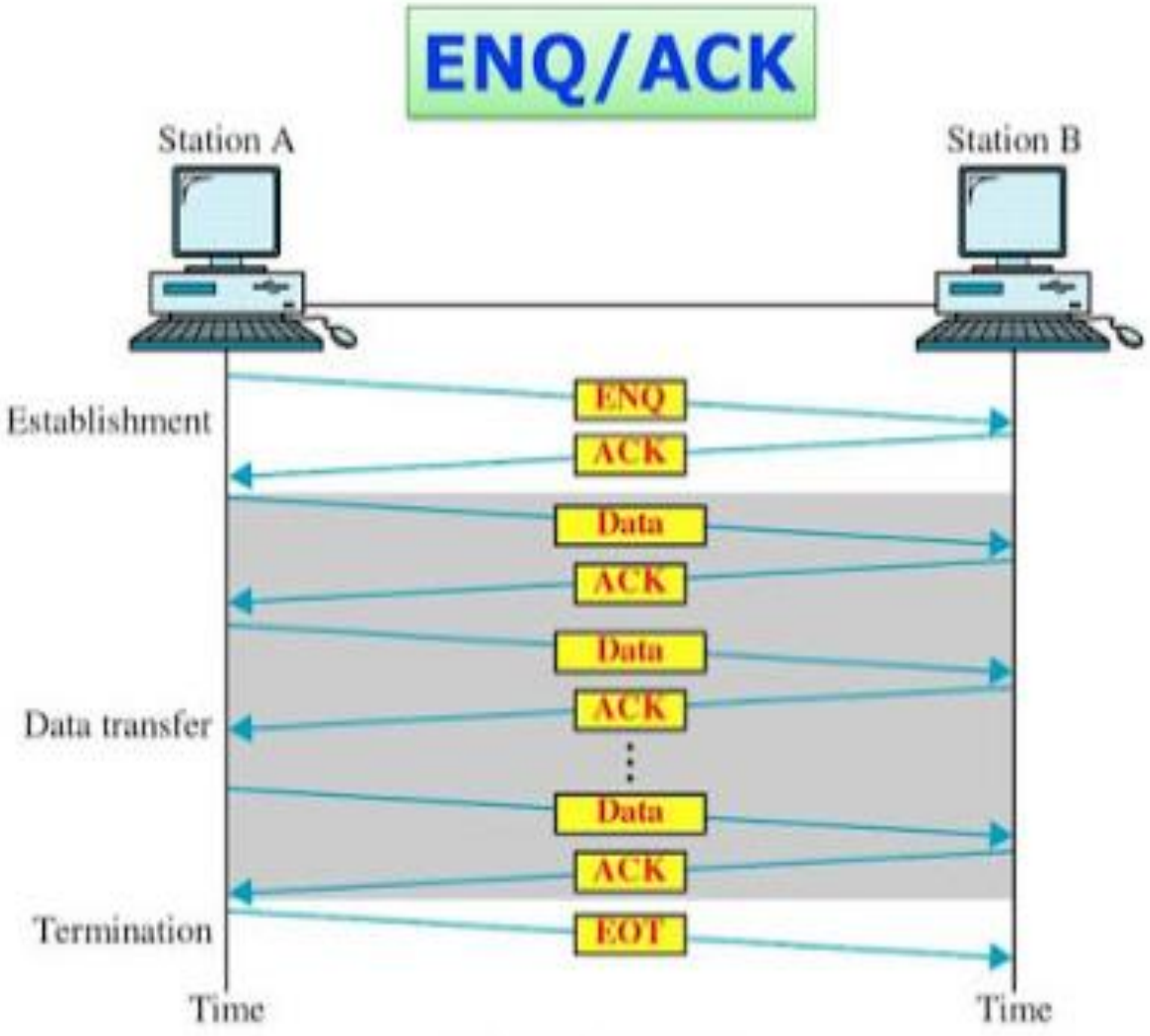
- Line Discipline can be achieved in two ways:
  - ENQ/ACK
  - Poll/select
- ENQ/ACK stands for Enquiry/Acknowledgement.

- ENQ/ACK coordinates which device will start the transmission and whether the recipient is ready or not.

Working of ENQ/ACK

- The transmitter transmits the frame called an Enquiry (ENQ) asking whether the receiver is available to receive the data or not.
- The receiver responses either with the positive acknowledgement (ACK) or with the negative acknowledgement (NACK) where positive acknowledgement means that the receiver is ready to receive the transmission and negative acknowledgement means that the receiver is unable to accept the transmission.

Working of ENQ/ACK



Poll/Select

- The Poll/Select method of line discipline works with those topologies where one device is designated as a primary station, and other devices are secondary stations.

Working of Poll/Select

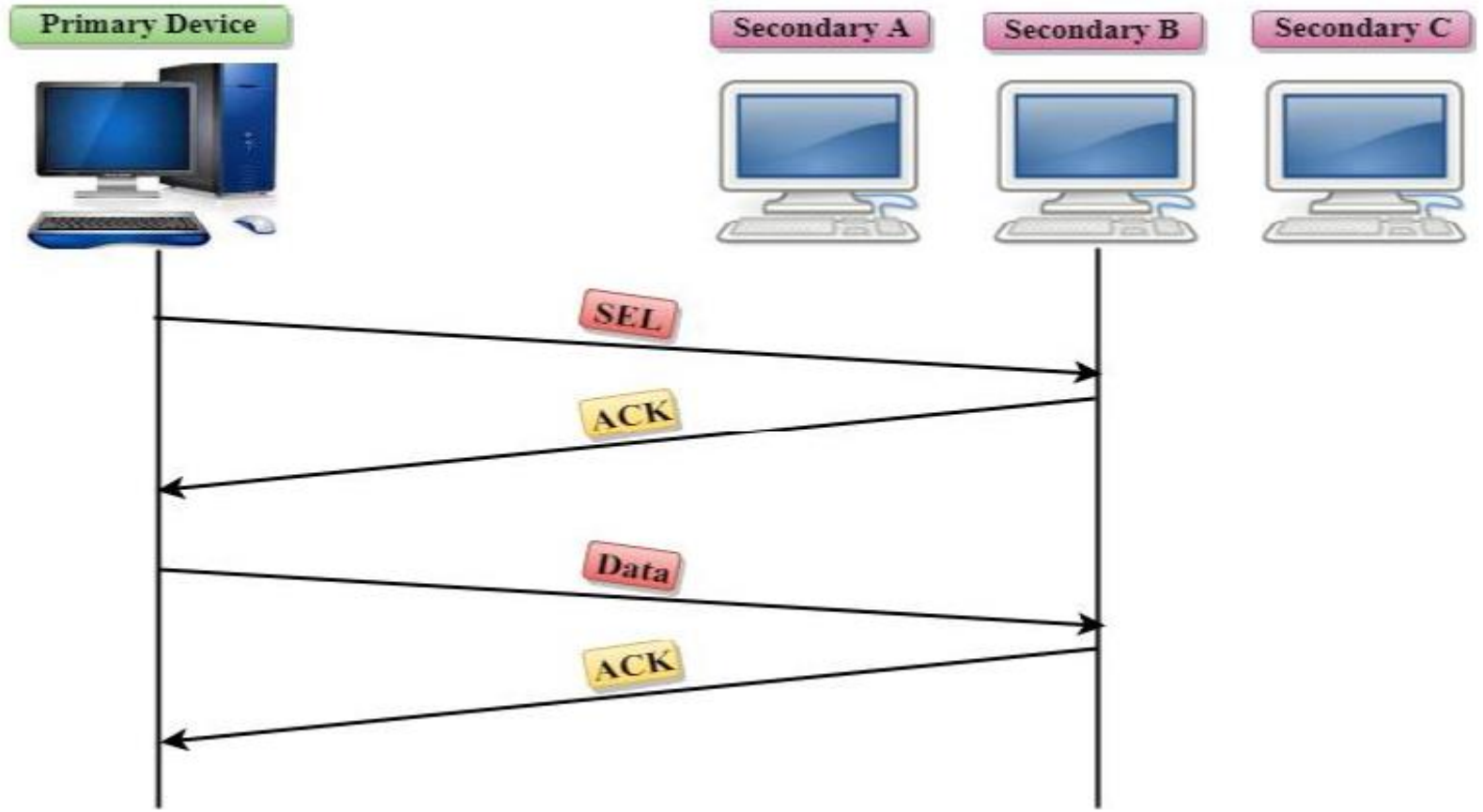
- In this, the primary device and multiple secondary devices consist of a single transmission line, and all the exchanges are made through the primary device even though the destination is a secondary device.
- The primary device has control over the communication link, and the secondary device follows the instructions of the primary device.
- The primary device determines which device is allowed to use the communication channel. Therefore, we can say that it is an initiator of the session.

Working of Poll/Select

- If the primary device wants to receive the data from the secondary device, it asks the secondary device that they anything to send, this process is known as **polling**.
- If the primary device wants to send some data to the secondary device, then it tells the target secondary to get ready to receive the data, this process is known as **selecting**.

Select

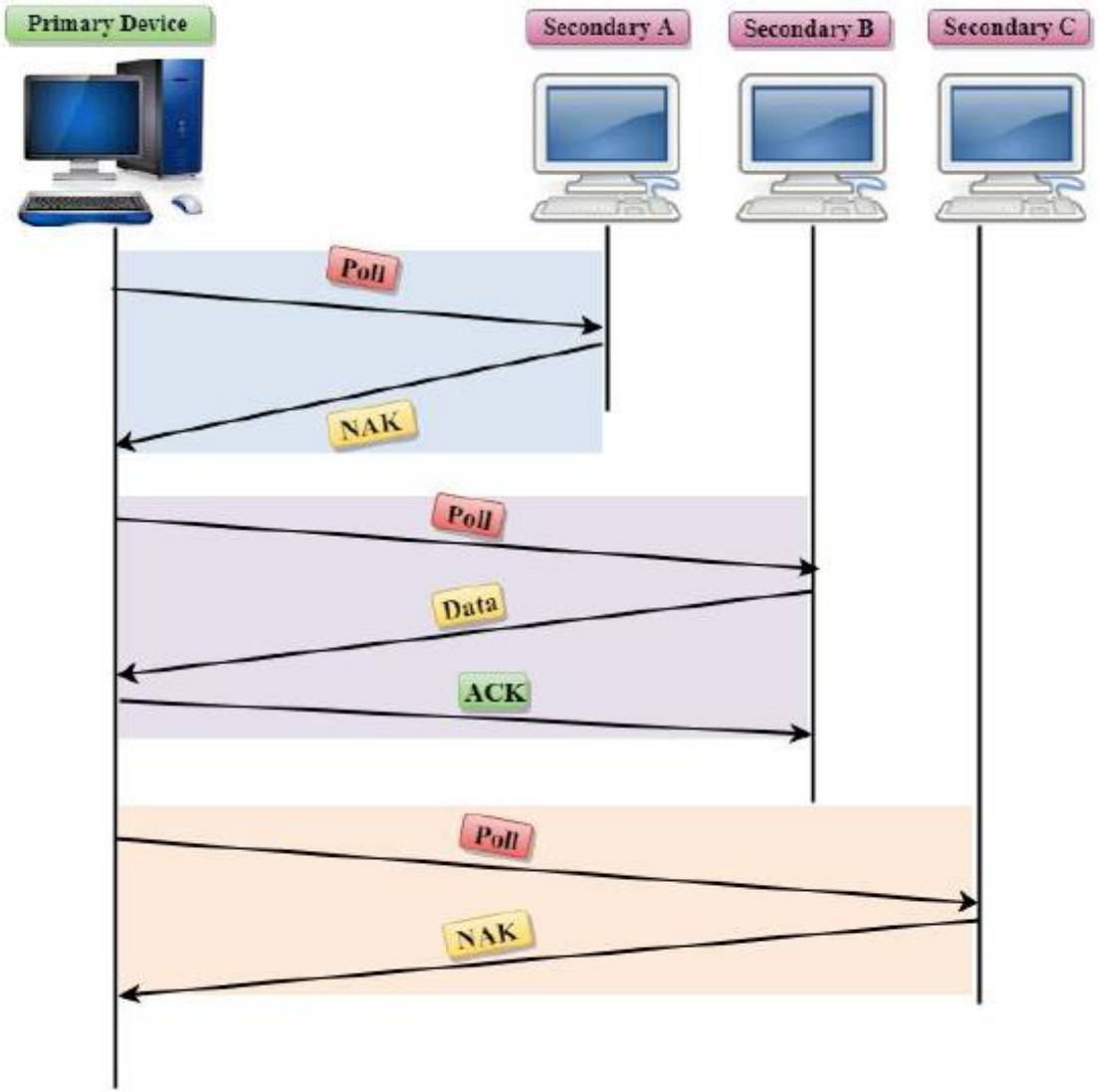
- The select mode is used when the primary device has something to send.



Poll

- The Poll mode is used when the primary device wants to receive some data from the secondary device.
- When a primary device wants to receive the data, then it asks each device whether it has anything to send.

Poll


Primary Device
Secondary A
Secondary B
Secondary C
Poll
NAK
Poll
Data
ACK
Poll
NAK

Flow Control

- Flow Control is a technique for speed-matching of transmitter and receiver. Flow control ensures that a transmitting station does not overflow a receiving station with data
- We will discuss two protocols for flow control:
  - —Stop-and-Wait
  - —Sliding Window
- For the time being, we assume that we have a perfect channel (**no errors)**

Stop-and-Wait Flow Control

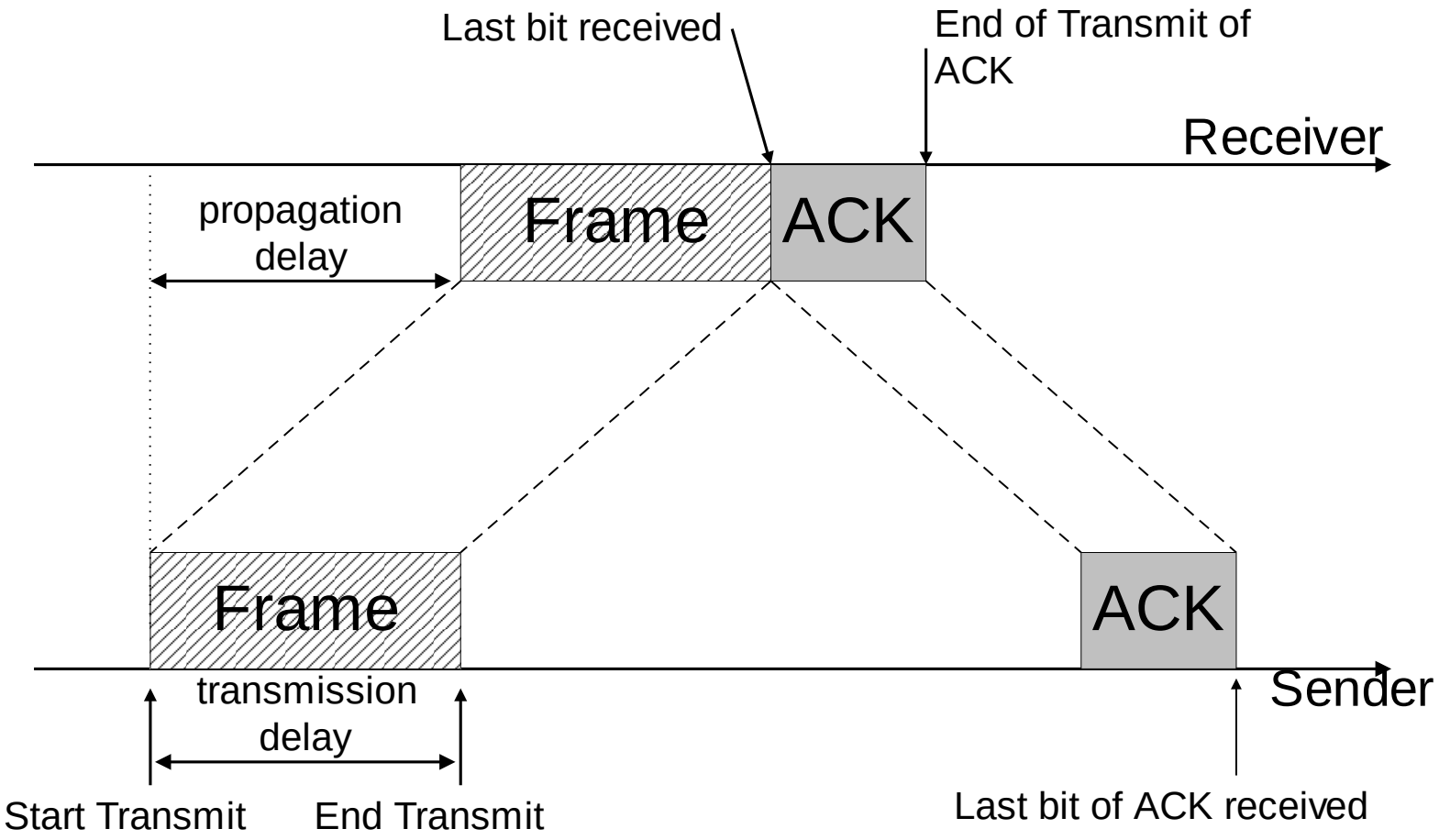
- Simplest form of flow control
- In Stop-and-Wait flow control, the receiver indicates its readiness to receive data for each frame
- **Operations:**

  1. **Sender:** Transmit a single frame

  2. **Receiver:** Transmit acknowledgment (ACK)

  3. Goto 1.

Analysis of Stop-and-Wait

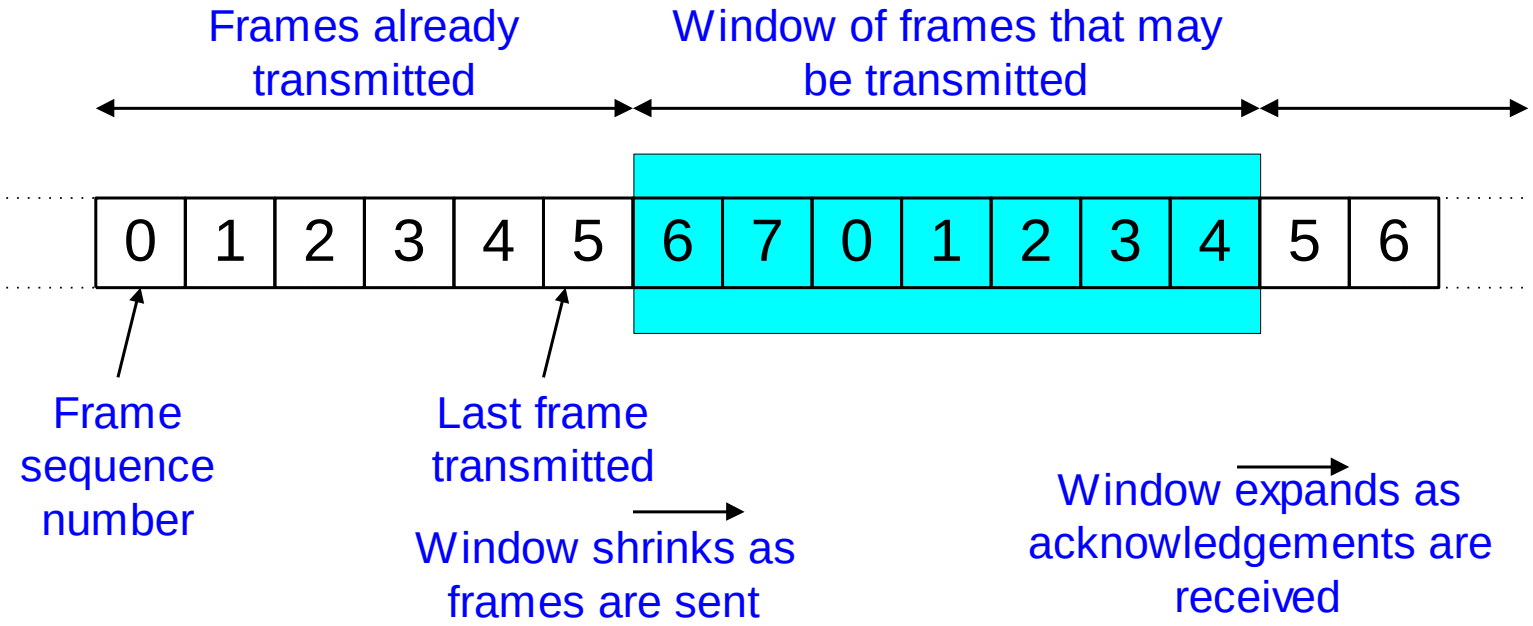


Sliding Window Flow Control

- **Major Drawback of Stop-and-Wait Flow Control:**
  - —Only one frame can be in transmission at a time
  - —This leads to inefficiency if propagation delay is much longer than the transmission delay
- **Sliding Window Flow Control**
  - —Allows transmission of multiple frames
  - —Assigns each frame a k-bit sequence number
  - —Range of sequence number is $[0..2^k-1]$, i.e., frames are counted modulo 2^k

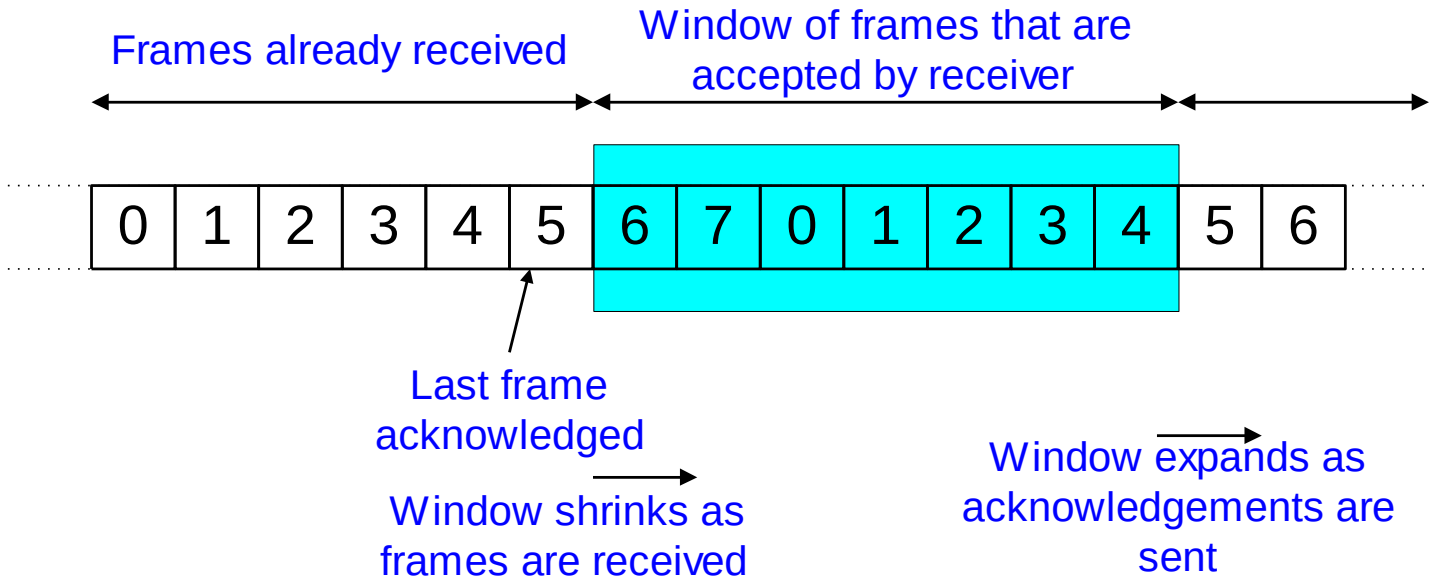
Operation of Sliding Window

- **Sending Window:**
  - —At any instant, the sender is permitted to send frames with sequence numbers in a certain range (the *sending window*)



Operation of Sliding Window

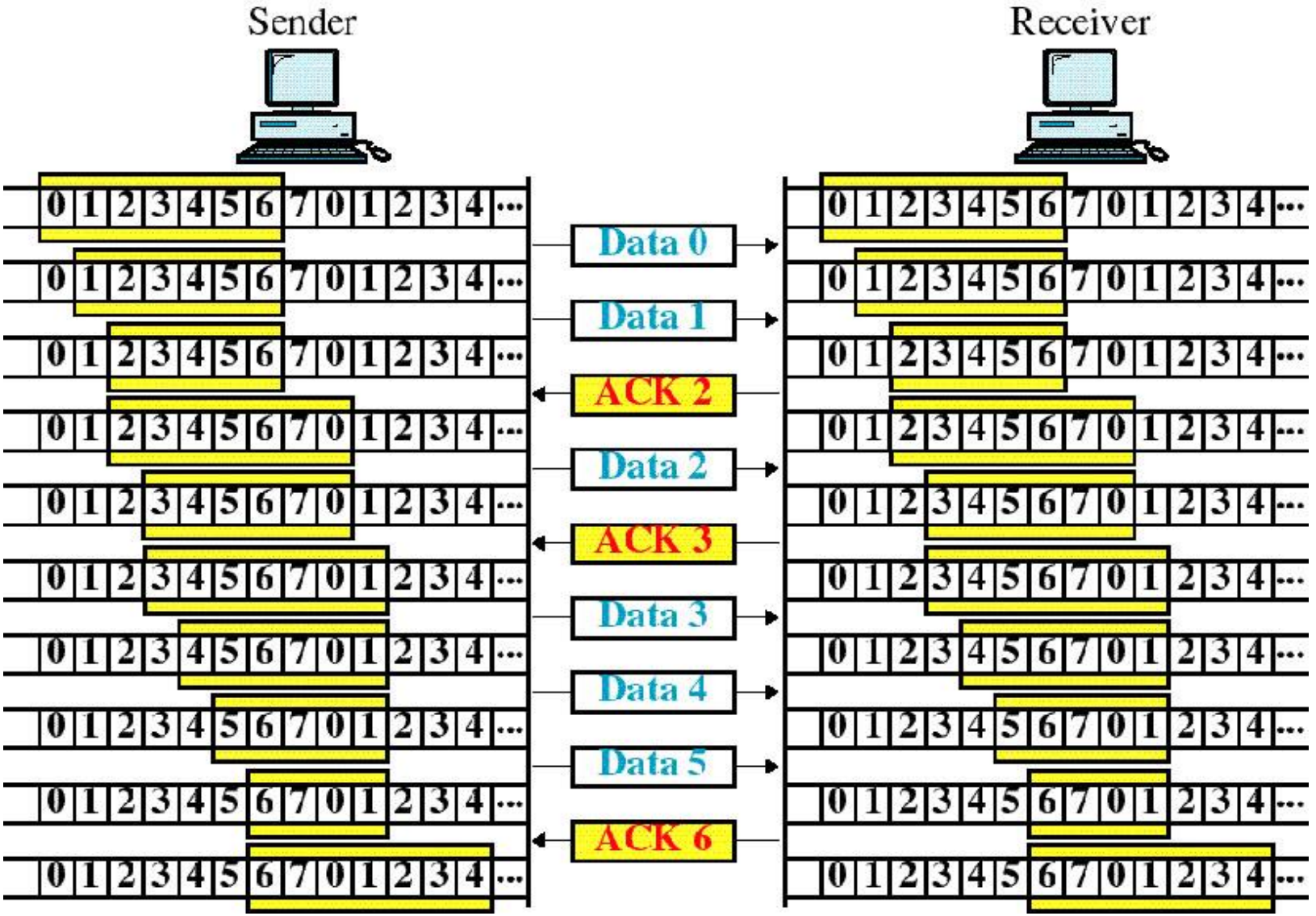
- **Receiving Window:**
  - —The receiver maintains a *receiving window* corresponding to the sequence numbers of frames that are accepted



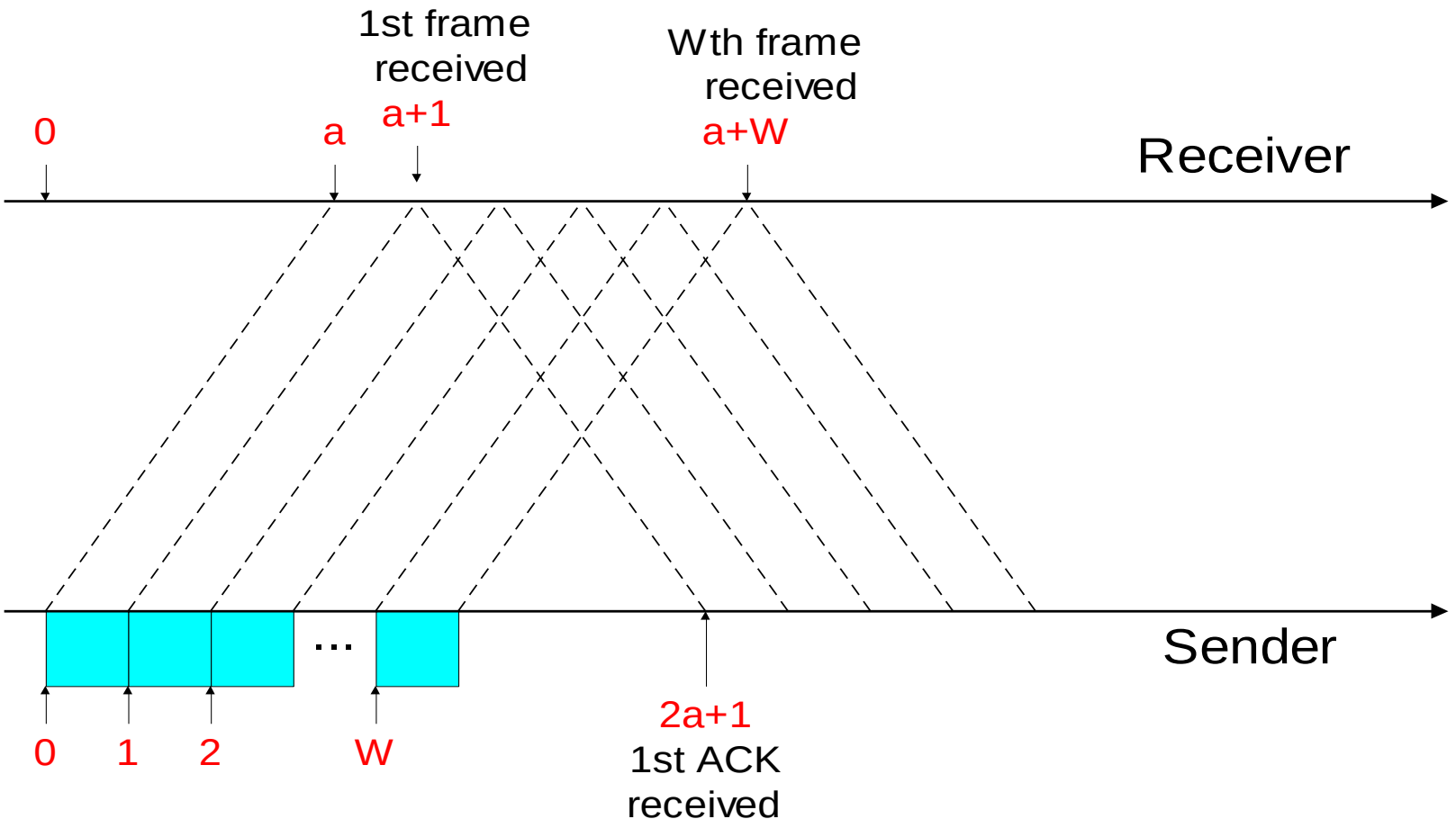
Operation of Sliding Window

- **How is "flow control" achieved?**
  - Receiver can control the size of the sending window
  - By limiting the size of the sending window data flow from sender to receiver can be limited
- **Interpretation of *ACK N* message:**
  - Receiver acknowledges all packets until (but not including) sequence number N

Example


Sender
Receiver
Data 0
Data 1
ACK 2
Data 2
ACK 3
Data 3
Data 4
Data 5
ACK 6

Analysis of Sliding Windows



Analysis of Sliding Windows

- If the window size is sufficiently large the sender can continuously transmit packets:
- **W** $\geq$ **2a+1**: Sender can transmit continuously

$$normalized efficiency = 1$$

- **W** $<$ **2a+1**: Sender can transmit *W* frames every *2a+1* time units

$$normalized efficiency = \frac{W}{1+2a}$$

ARQ Error Control

- **Types of errors:** Lost frames, damaged frames
- Most Error Control techniques are based on (1) Error Detection Scheme (e.g., Parity checks, CRC), and (2) Retransmission Scheme
- Error control schemes that involve error detection and retransmission of lost or corrupted frames are referred to as ***Automatic Repeat Request (ARQ)*** error control

ARQ Schemes

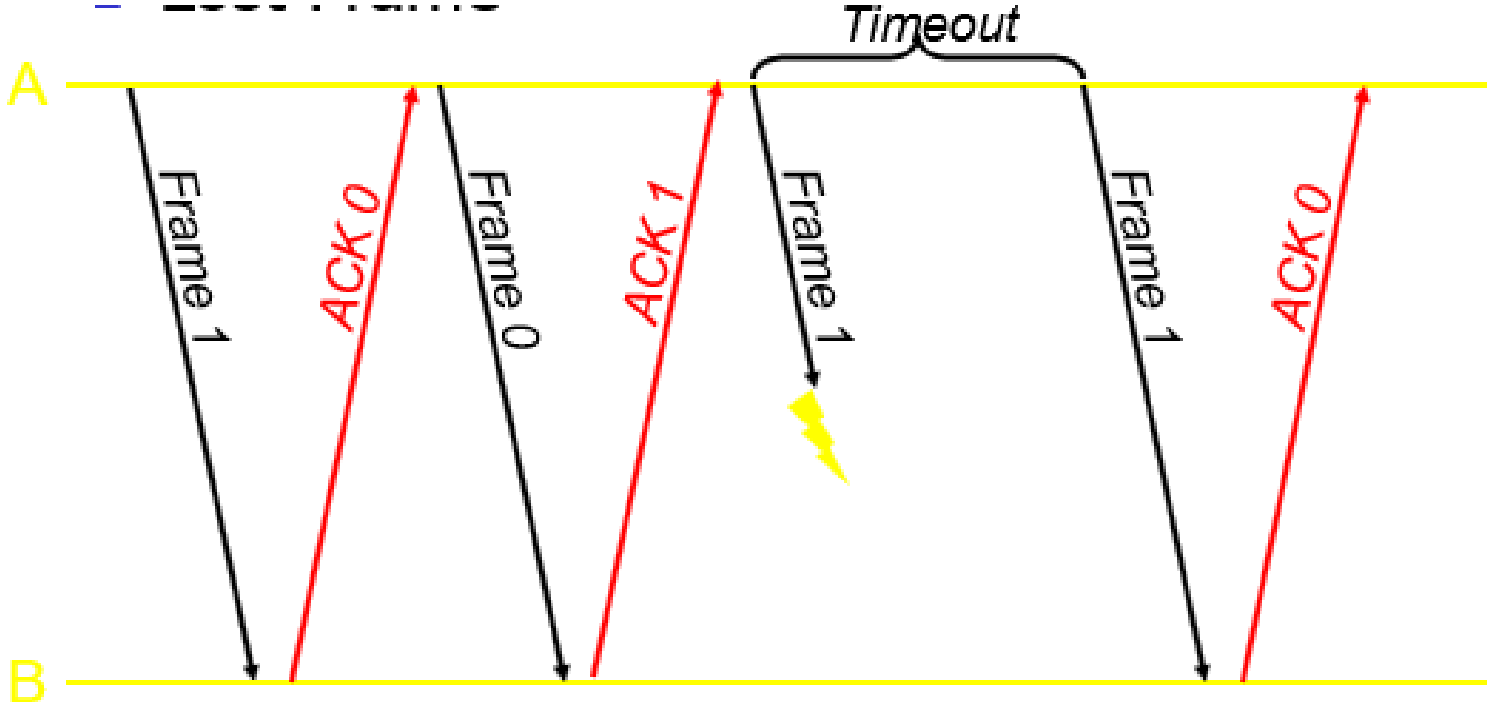
- The most common ARQ retransmission schemes:
  - Stop-and-Wait ARQ
  - Go-Back-N ARQ
  - Selective Repeat ARQ
- The protocol for sending ACKs in all ARQ protocols are based on the sliding window flow control scheme

Stop-and-Wait ARQ

- **Stop-and-Wait ARQ** is an addition to the Stop-and-Wait flow control protocol:
- Frames have 1-bit sequence numbers (*SN* = 0 or 1)
- Receiver sends an *ACK (1-SN)* if frame *SN* is correctly received
- Sender waits for an *ACK (1-SN)* before transmitting the next frame with sequence number *1-SN*
- If sender does not receive anything before a timeout value expires, it retransmits frame SN

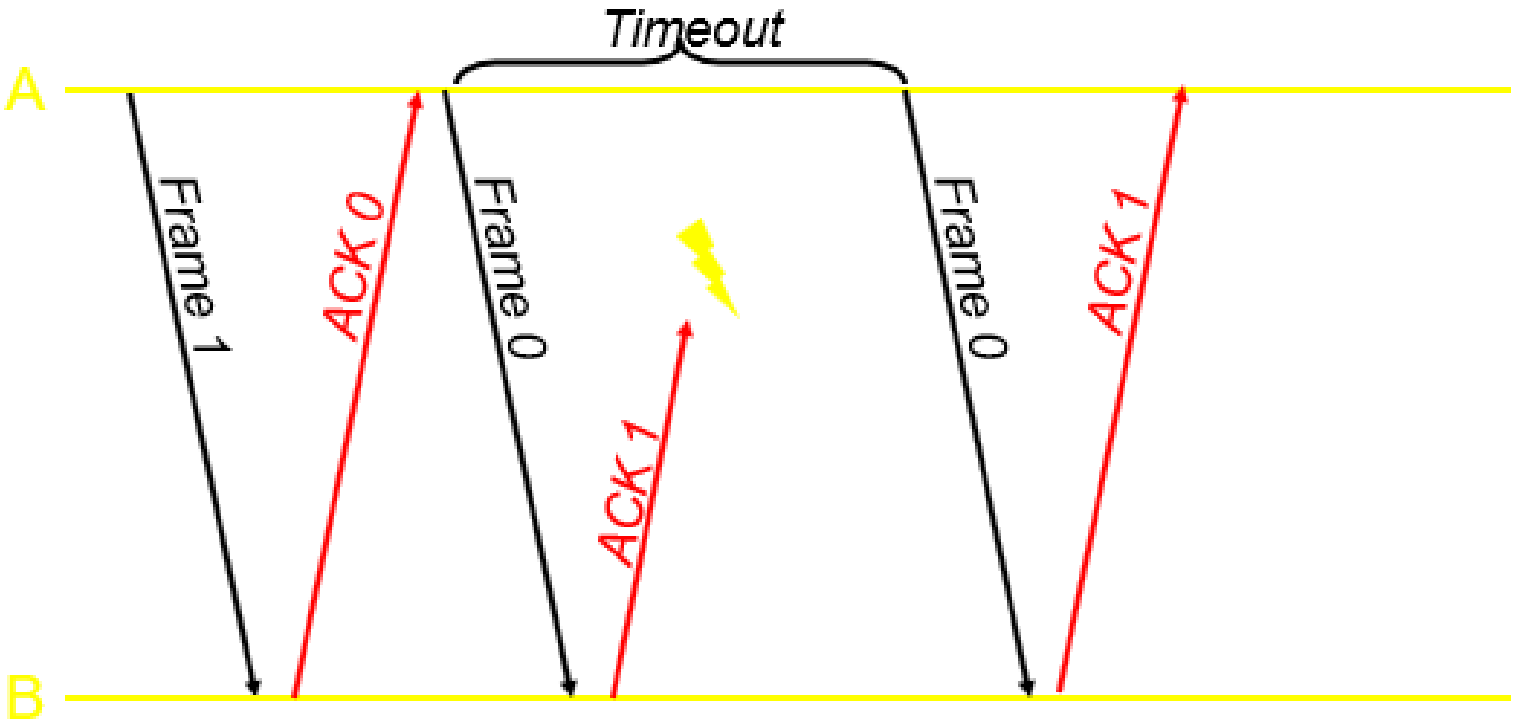
Stop-and-Wait ARQ

- Lost Frame



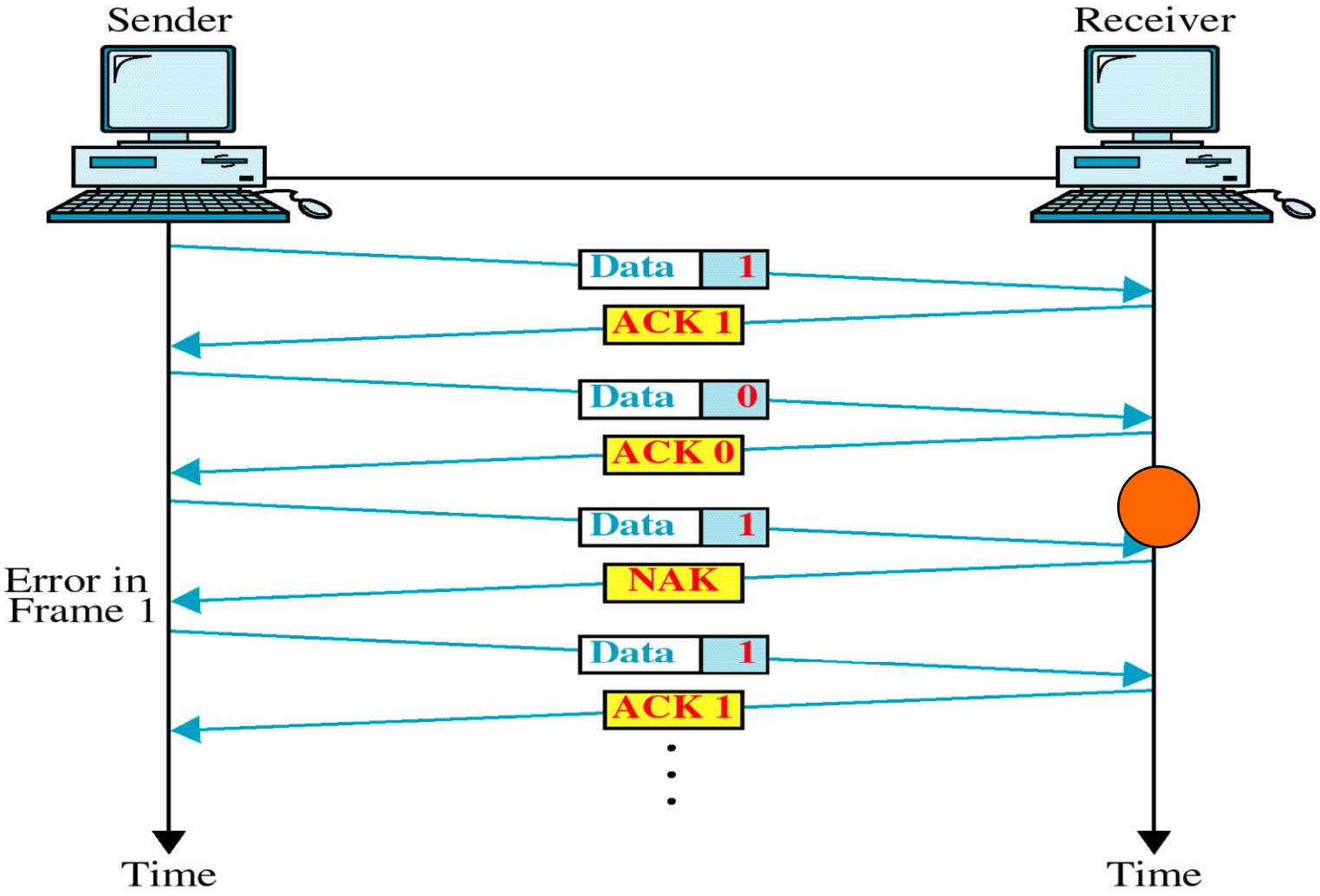
Stop-and-Wait ARQ

- Lost ACK



Stop-and-Wait ARQ

- Damaged Frame



Go-Back-N ARQ

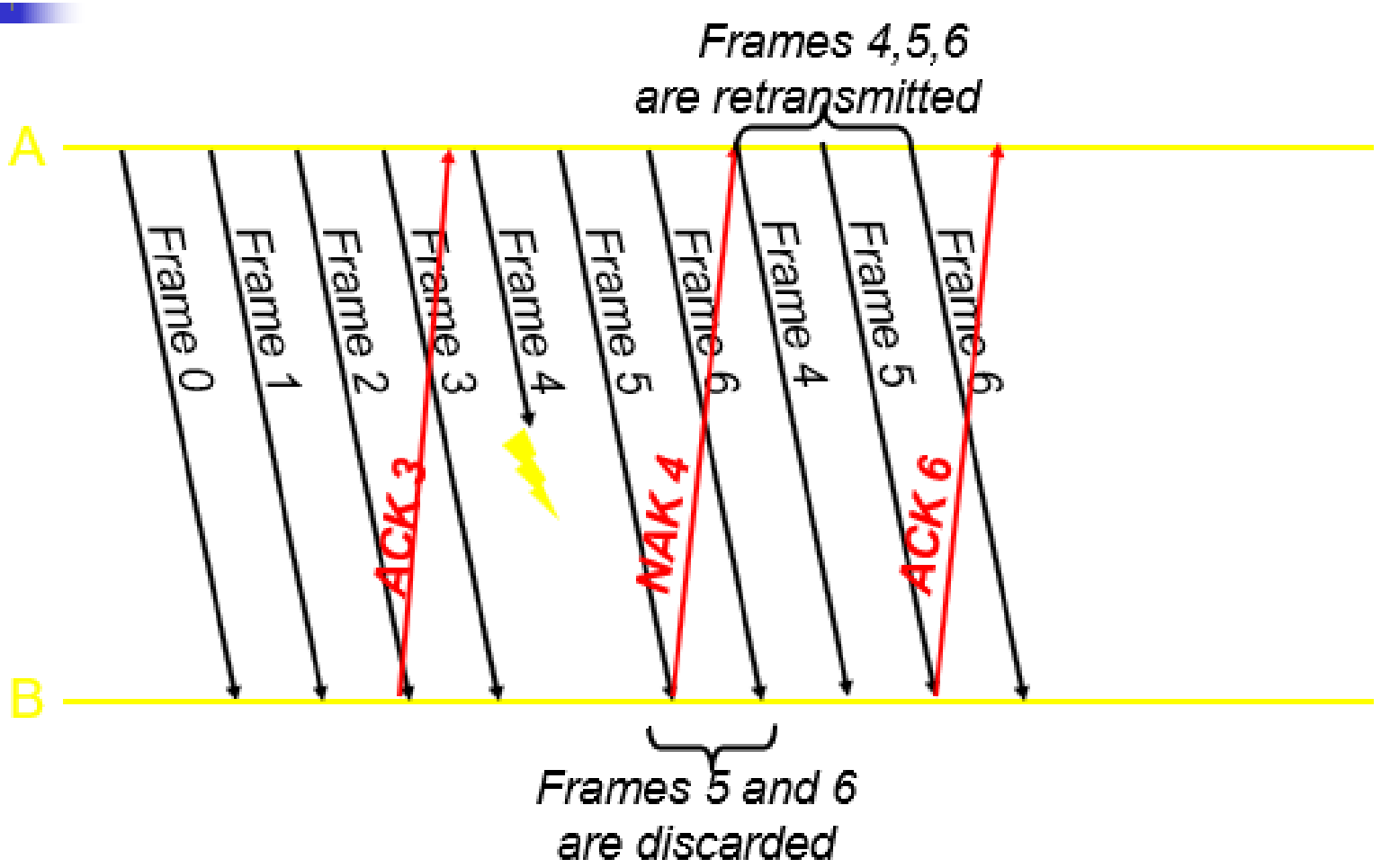
- Go-Back-N uses the sliding window flow control protocol. If no errors occur the operations are identical to Sliding Window

Go-Back-N ARQ

- **Operations:**
  - A station may send multiple frames as allowed by the window size
  - Receiver sends a ***NAK i*** if frame ***i*** is in error. *After that, the receiver discards all incoming frames until the frame in error was correctly retransmitted*
  - *If sender receives a **NAK i** it will retransmit frame **i** and all packets **i+1, i+2,...** which have been sent, but not been acknowledged*

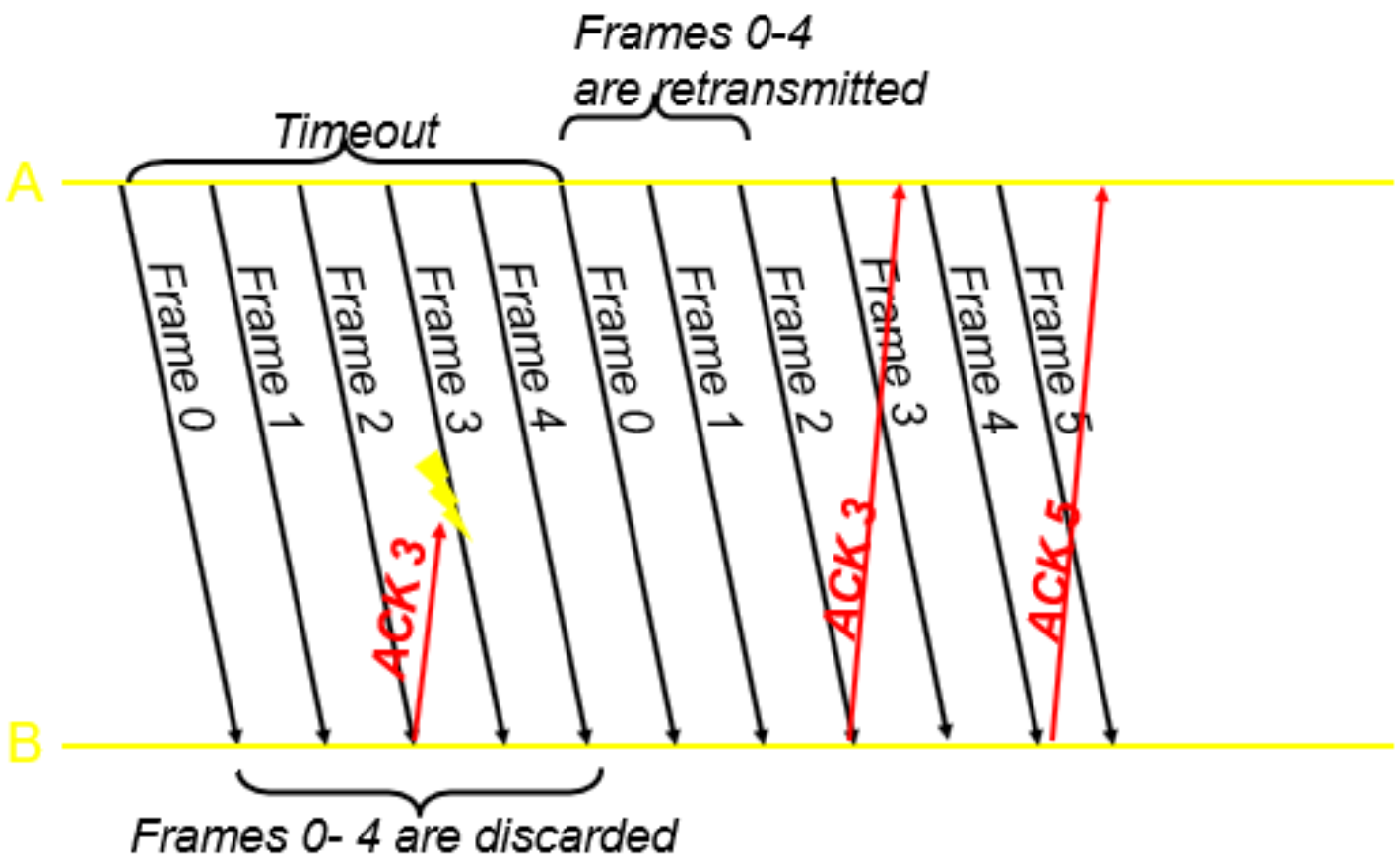
Go-Back-N ARQ

- Lost Frame



Go-Back-N ARQ

- Lost ACK

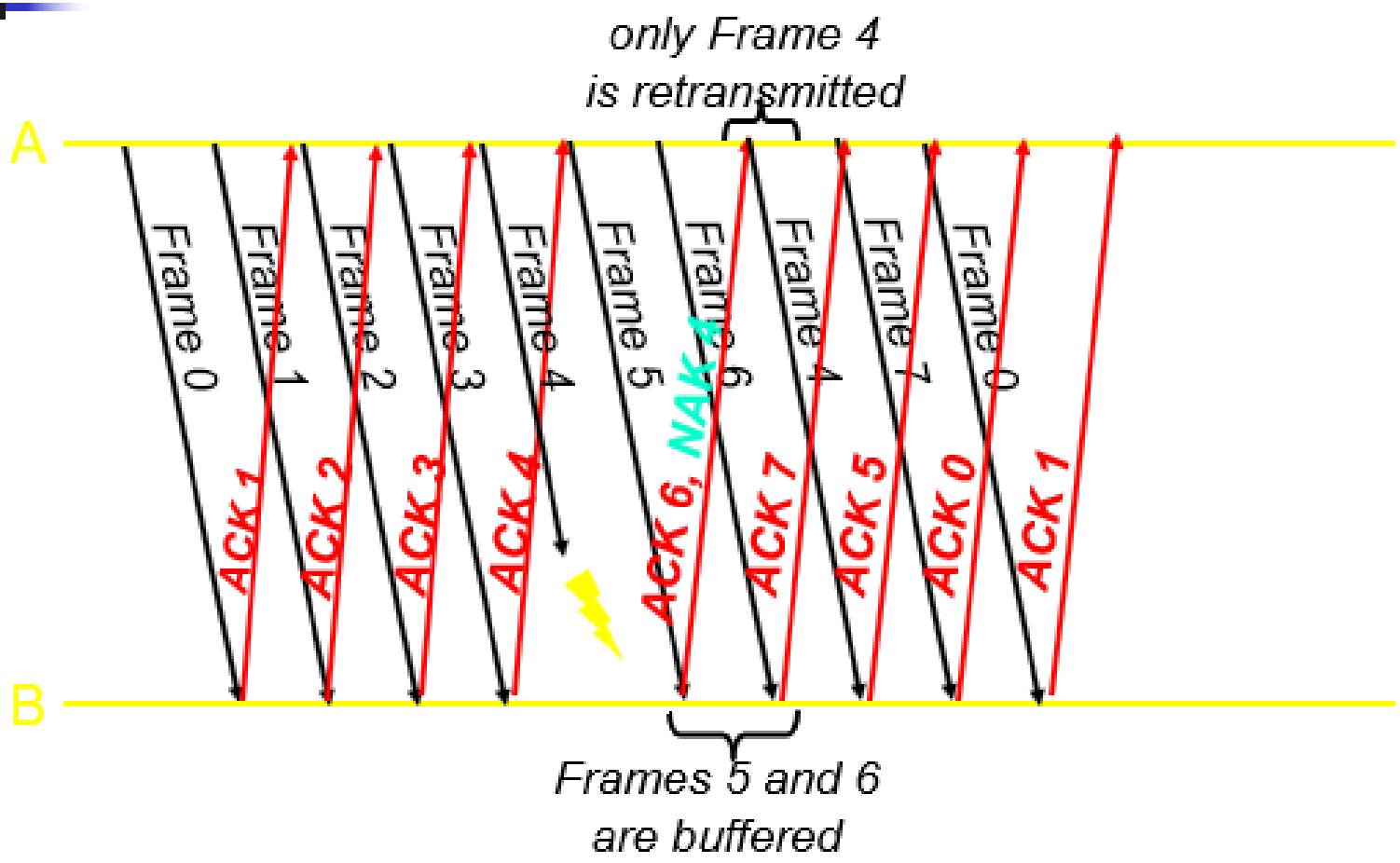


Selective-Repeat ARQ

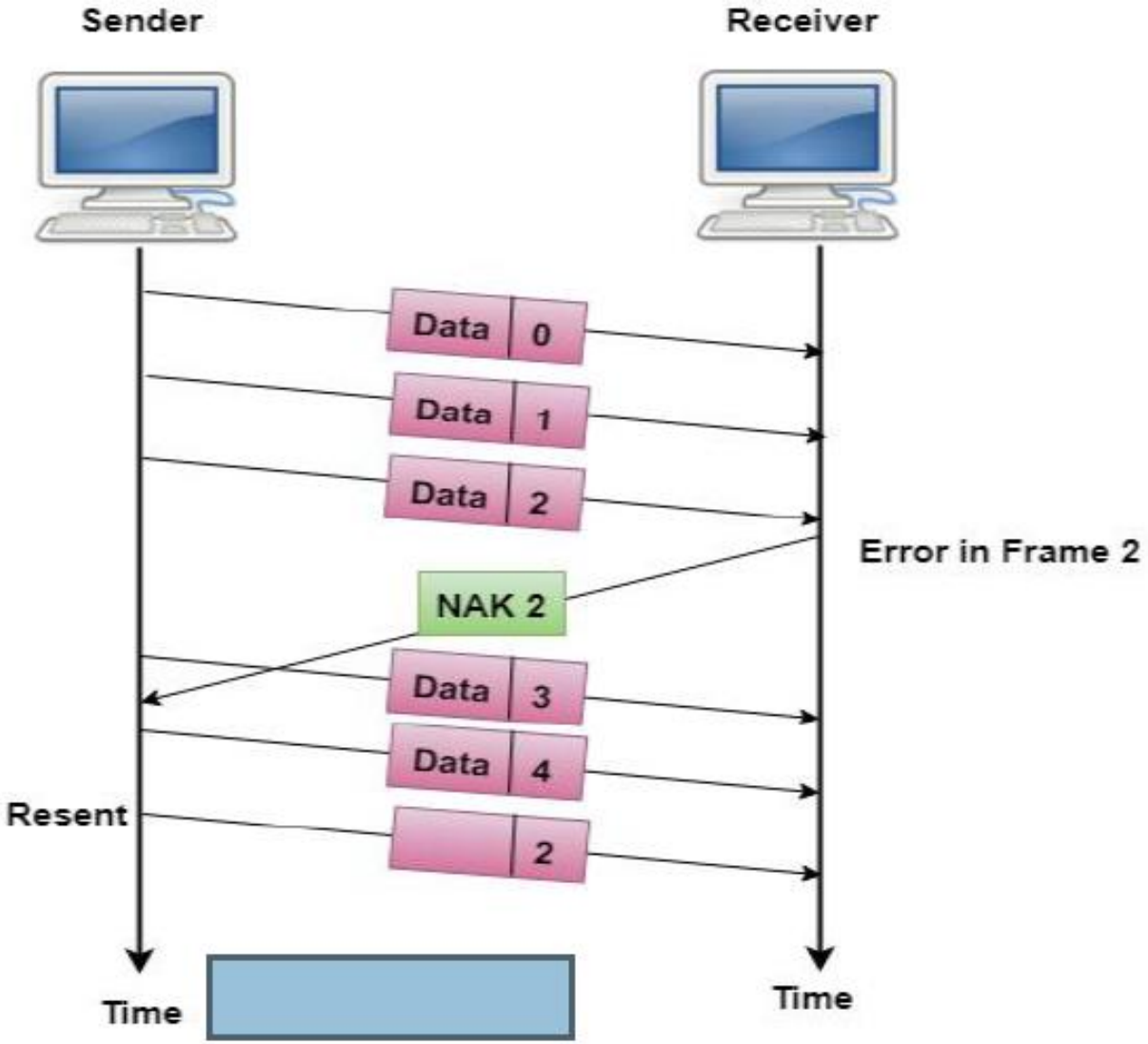
- Similar to Go-Back-N ARQ. However, the sender only retransmits frames for which a **NAK** is received
- **Advantage over Go-Back-N:**
  - —Fewer Retransmissions.
- **Disadvantages:**
  - —More complexity at sender and receiver
  - —Each frame must be acknowledged individually (no cumulative acknowledgements)
  - —Receiver may receive frames out of sequence

Selective-Repeat ARQ

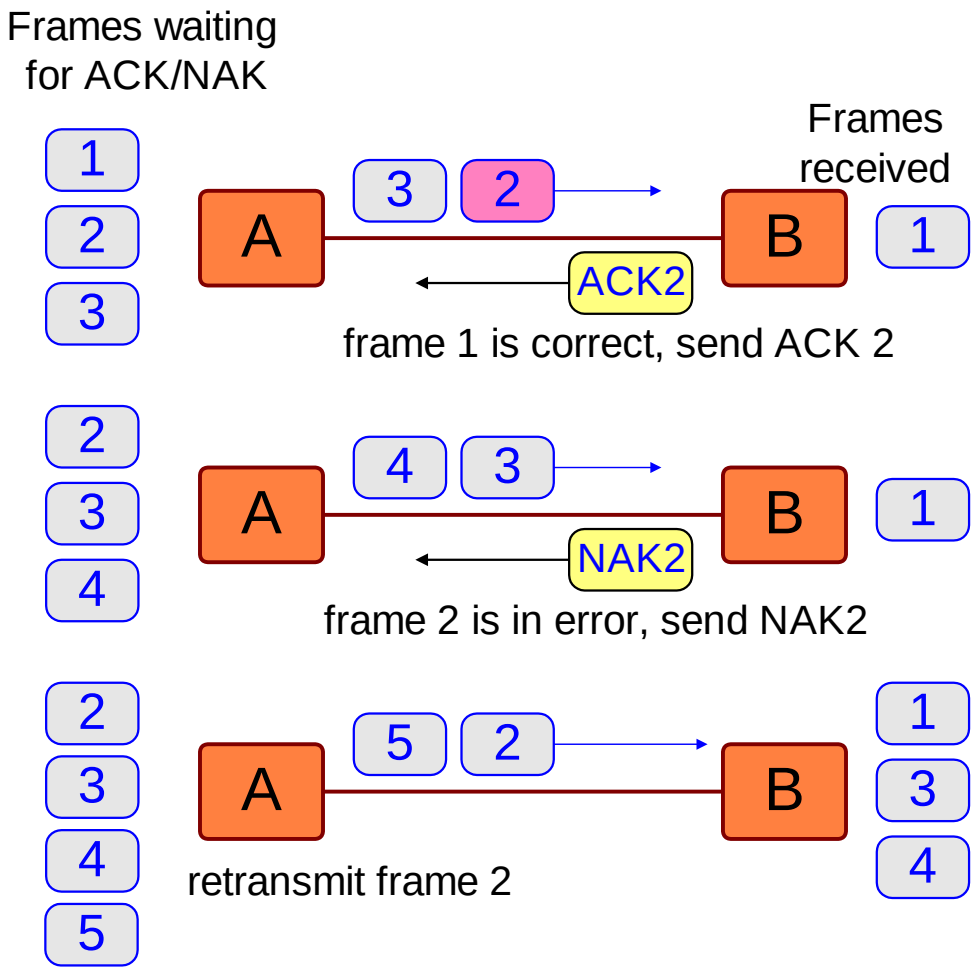
- Lost Frame



Selective-Repeat ARQ



Example of Selective-Repeat ARQ



Receiver must keep track of `holes' in the sequence of delivered frames

Sender must maintain one timer per outstanding packet