Lecture 18 &19 Roadmap

Understand the Following Topics:

- Flow and Error Control
- Stop and Wait
- Sliding window
- Stop and Wait ARQ
- Go Back N ARQ
- Selective Reject ARQ

Flow and Error Control

Flow Control

Error Control

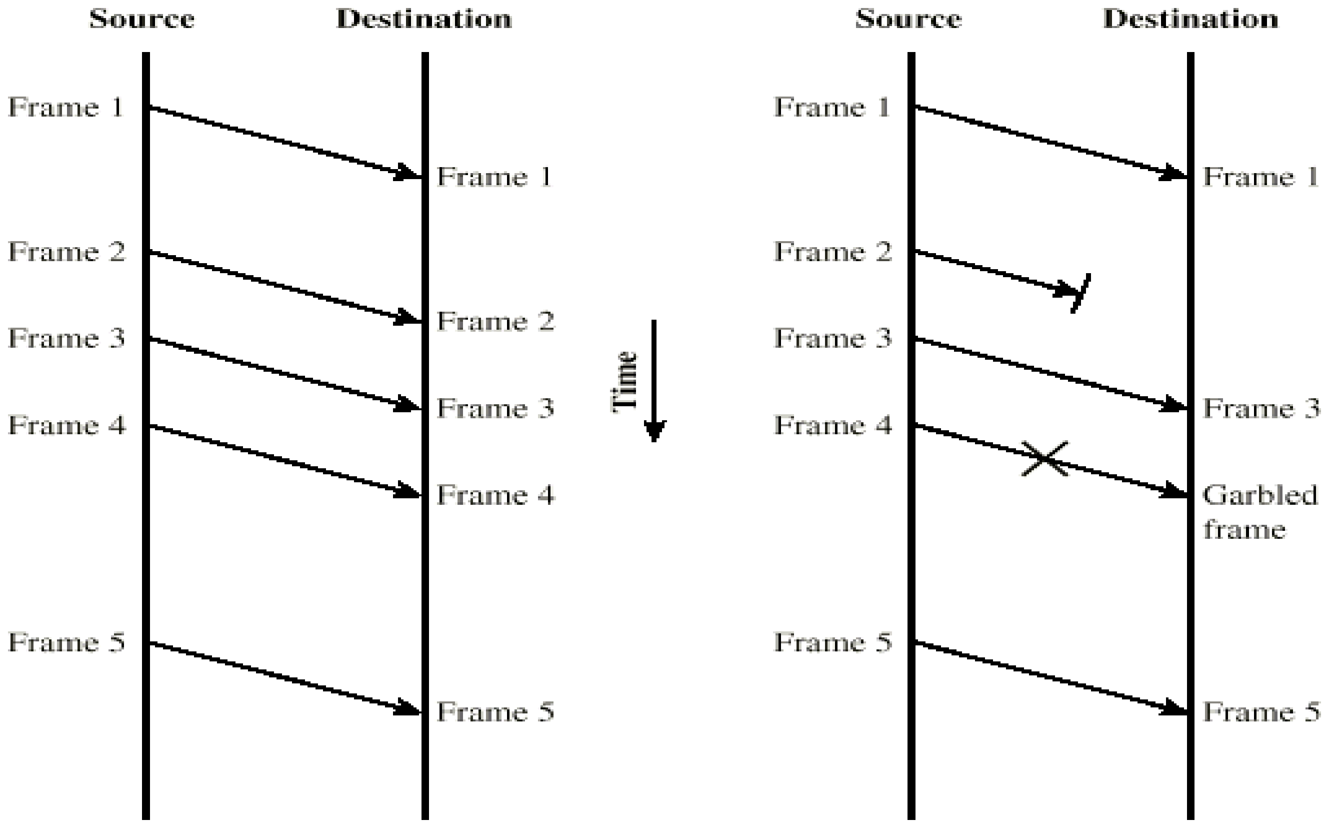
Note:

Flow control refers to a set of procedures used to restrict the amount of data that the sender can send before waiting for acknowledgment.

Flow Control

- Limits the amount or rate of data that is sent
- Reasons:
  - Source may send frames faster than destination can process headers
  - Higher-level protocol user at destination may be slow in retrieving data
  - Destination may need to limit incoming flow to match outgoing flow for retransmission

Model of Frame Transmission



(a) Error-free transmission

(b) Transmission with losses and errors

Stop and Wait

- Source transmits frame
- Destination receives frame and replies with acknowledgement
- Source waits for ACK before sending next frame
- Destination can stop flow by not send ACK
- Works well for a few large frames

Fragmentation

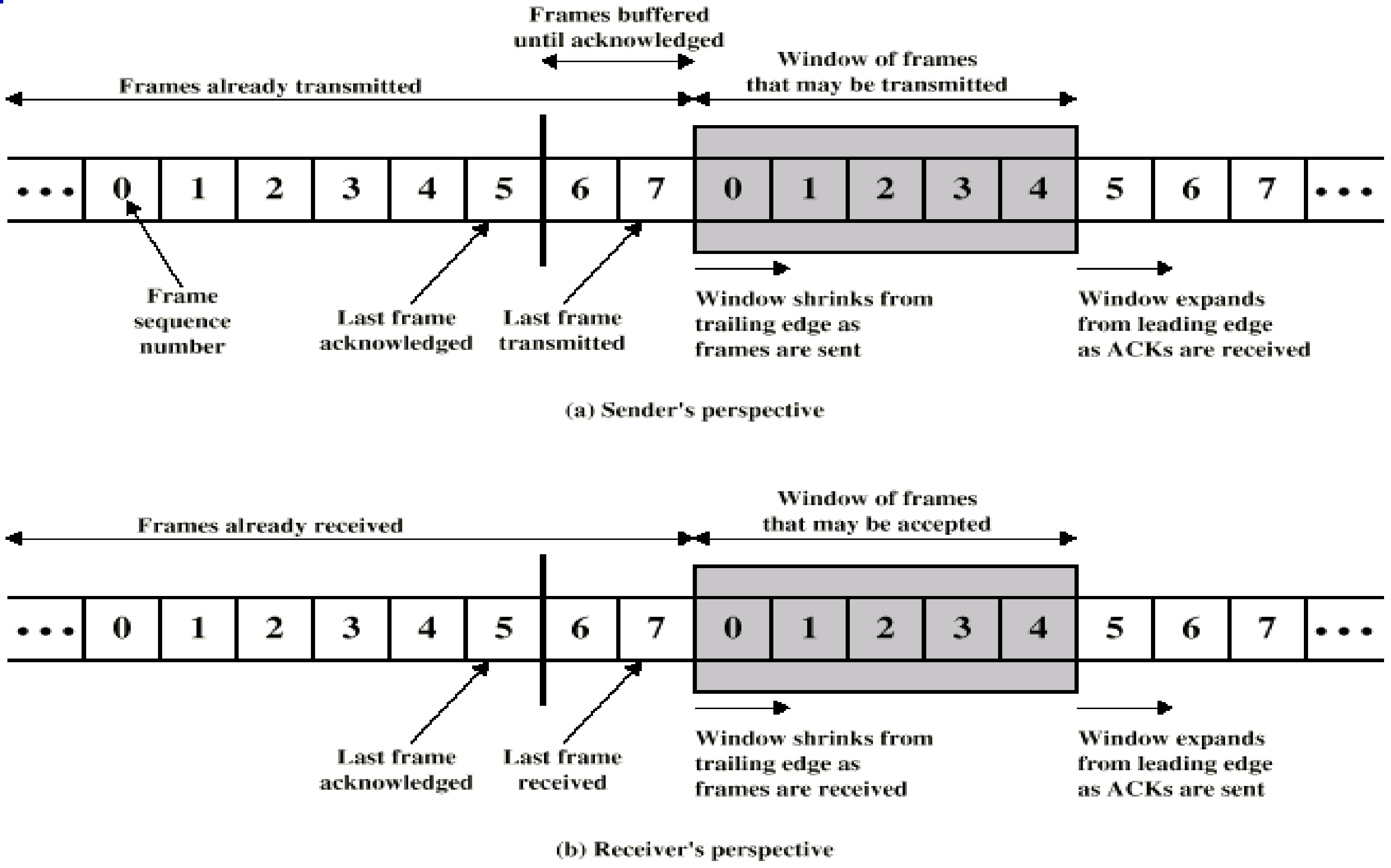
- Large block of data may be split into small frames
  - Limited buffer size
  - Errors detected sooner (when whole frame received)
  - On error, retransmission of smaller frames is needed
  - Prevents one station occupying medium for long periods
- Stop and wait becomes inadequate

Sliding Window

Sliding window:

- Allow multiple frames to be in transit
- Receiver has buffer W long
- Transmitter can send up to W frames without ACK
- Each frame is numbered (sequence number)
- ACK includes number of next frame expected

Sliding Window


Frames buffered until acknowledged
Window of frames that may be transmitted
Frames already transmitted
• • • 0 1 2 3 4 5 6 7 0 1 2 3 4 5 6 7 • • •
Frame sequence number
Last frame acknowledged
Last frame transmitted
Window shrinks from trailing edge as frames are sent
Window expands from leading edge as ACKs are received
(a) Sender's perspective
Window of frames that may be accepted
Frames already received
• • • 0 1 2 3 4 5 6 7 0 1 2 3 4 5 6 7 • • •
Last frame acknowledged
Last frame received
Window shrinks from trailing edge as frames are received
Window expands from leading edge as ACKs are sent
(b) Receiver's perspective

Example Sliding Window

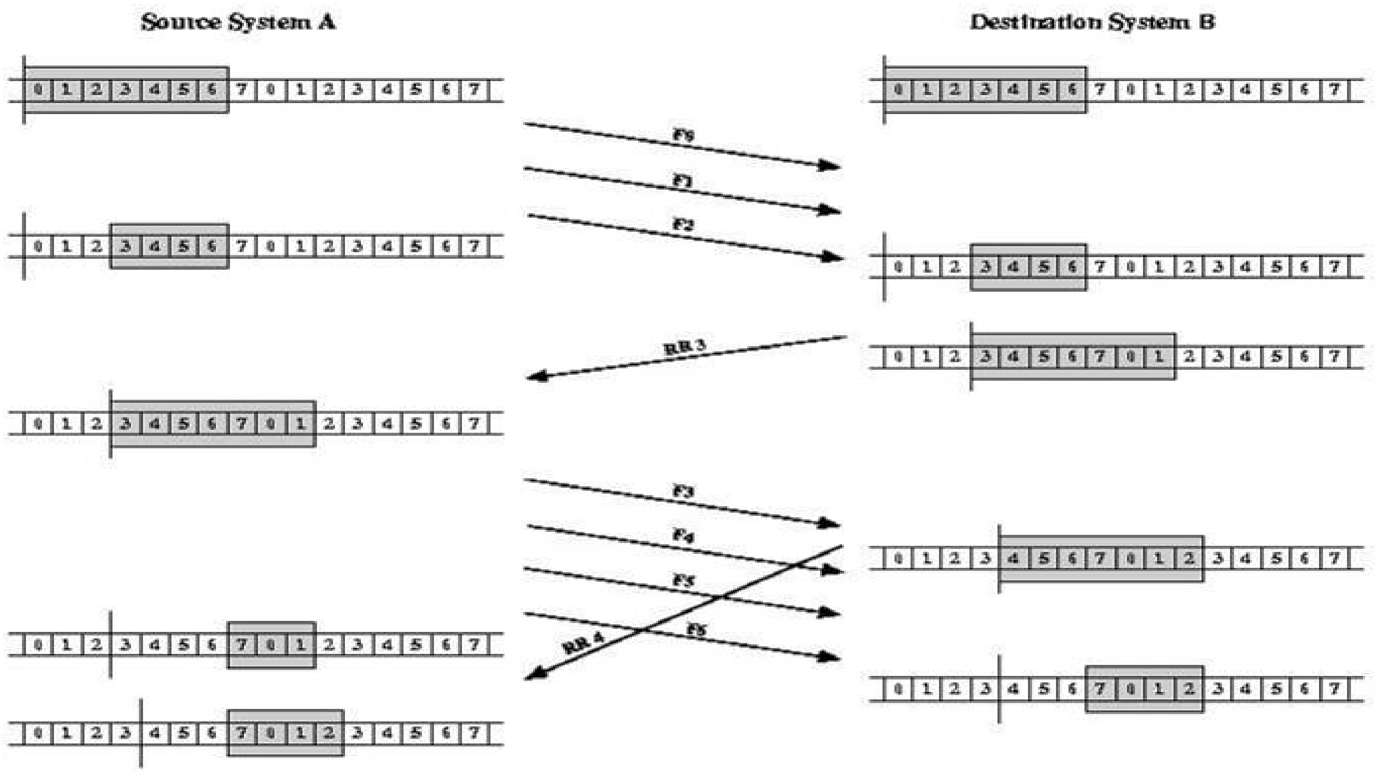


Figure 11.6 Example of a Sliding-Window Protocol

Sliding Window Enhancements

- Receiver can acknowledge frames without permitting further transmission (receive not ready)
- Must send a normal acknowledge to resume
- If duplex, use piggybacking
  - If no data to send, use acknowledgement frame
  - If data but no acknowledgement to send, send last acknowledgement number again, or have ACK valid flag (TCP)

Error Control

Note:

Error control in the data link layer is based on automatic repeat request, which is the retransmission of data.

Error Control

- Used to recover lost or damaged PDUs
- Involves error detection and PDU retransmission
- Implemented together with flow control in a single mechanism
- Performed at various protocol levels

Error Control

- Error recovery
  - Re-transmission
  - ARQ (automatic repeat request) primarily based on sliding window mechanism
    - Stop and wait
    - Go back N
    - Selective reject (selective retransmission)

Assume 2 end systems connected by direct Link

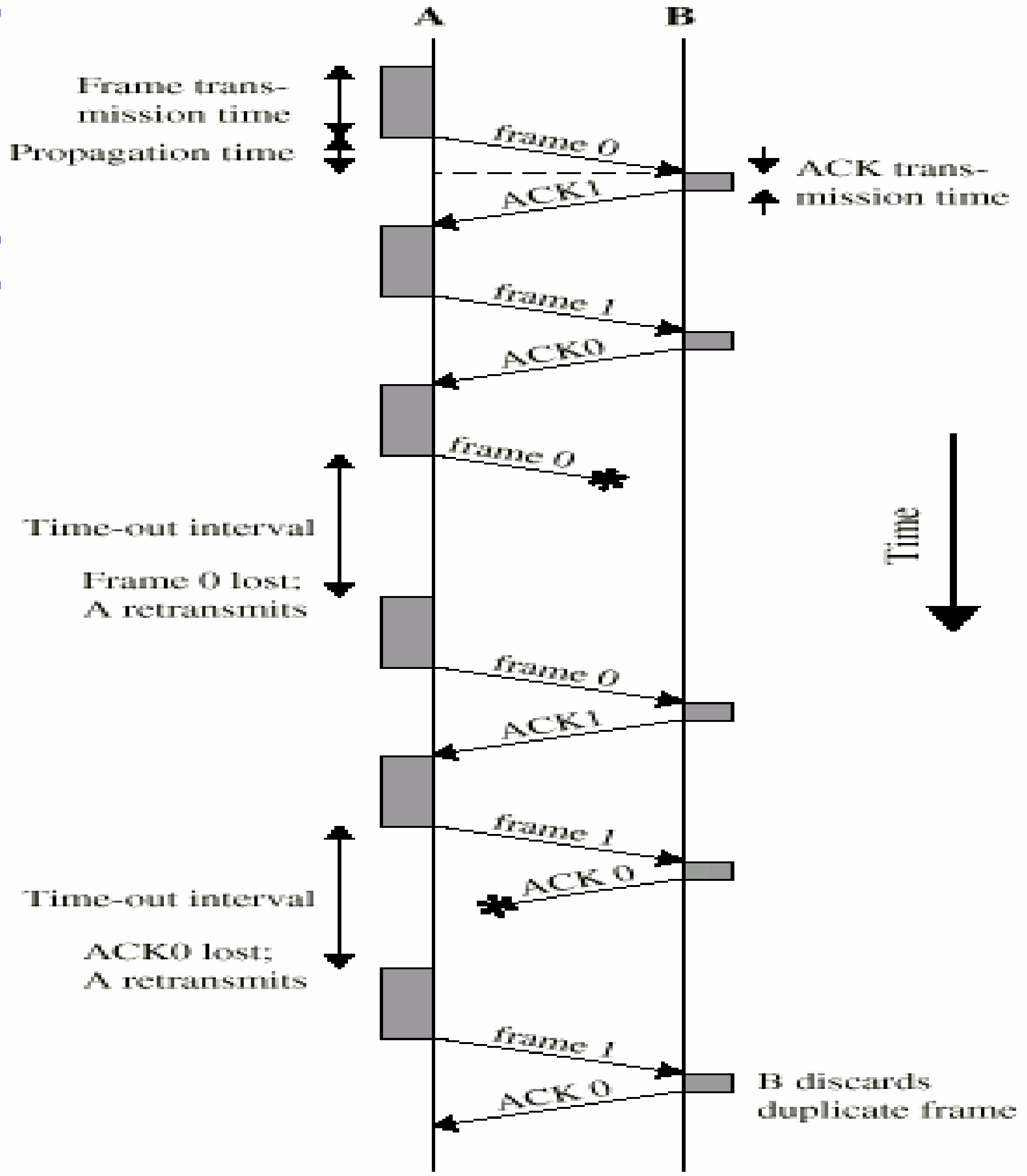
Automatic Repeat Request (ARQ)

- Automatic repeat request
  - Error detection
  - Positive acknowledgment
  - Retransmission after timeout
  - Negative acknowledgement and retransmission
- **Stop and wait ARQ**
- **Sliding window ARQ**
  - Go back N
  - Selective reject (selective retransmission)

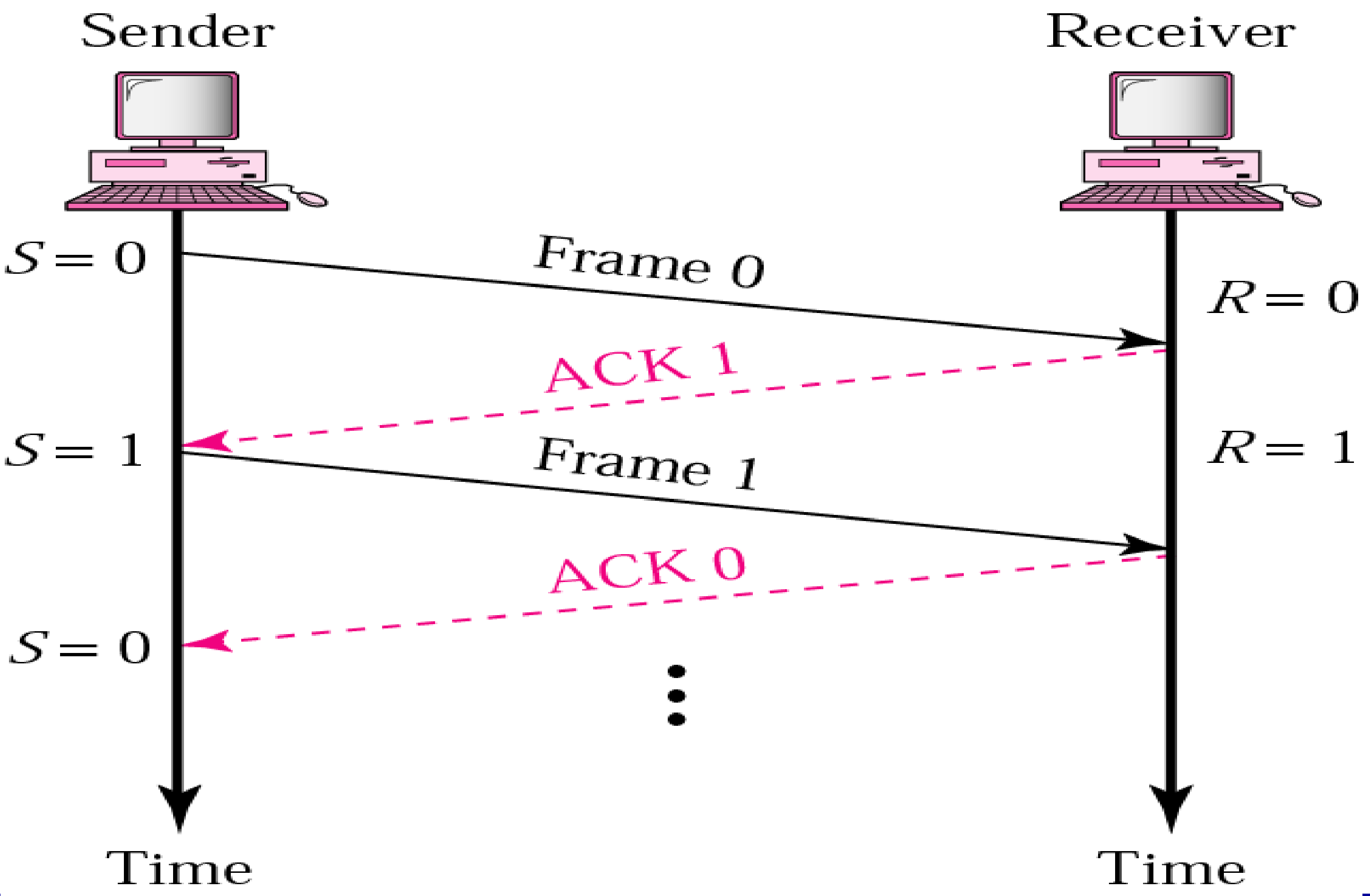
Stop and Wait

- Source transmits single frame
- Wait for ACK
- If received frame damaged, discard it
  - Transmitter has timeout
  - If no ACK within timeout, retransmit
- If ACK damaged, transmitter will not recognize it
  - Transmitter will retransmit
  - Receive gets two copies of frame
  - Use ACK0 and ACK1

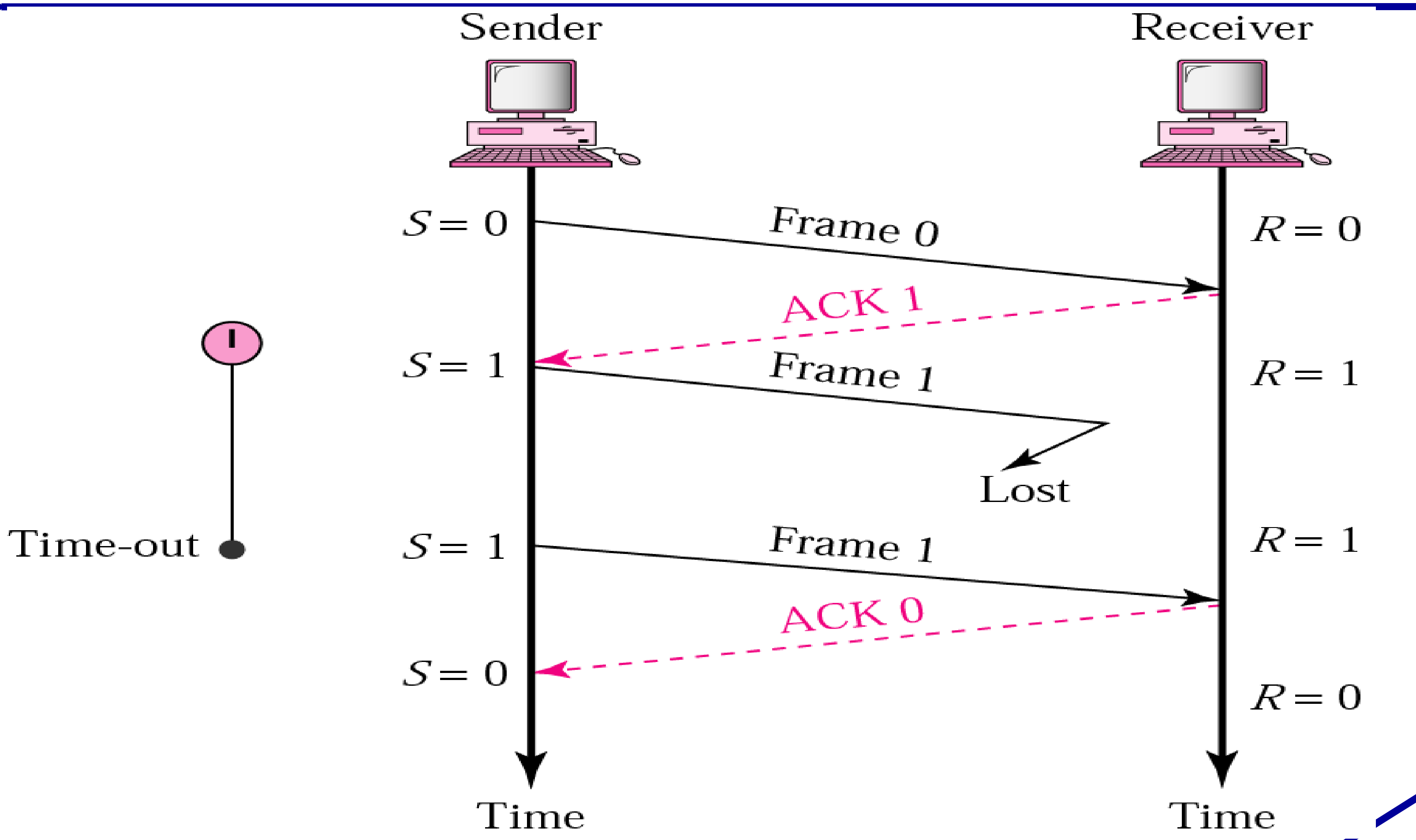
Stop and Wait -Diagram



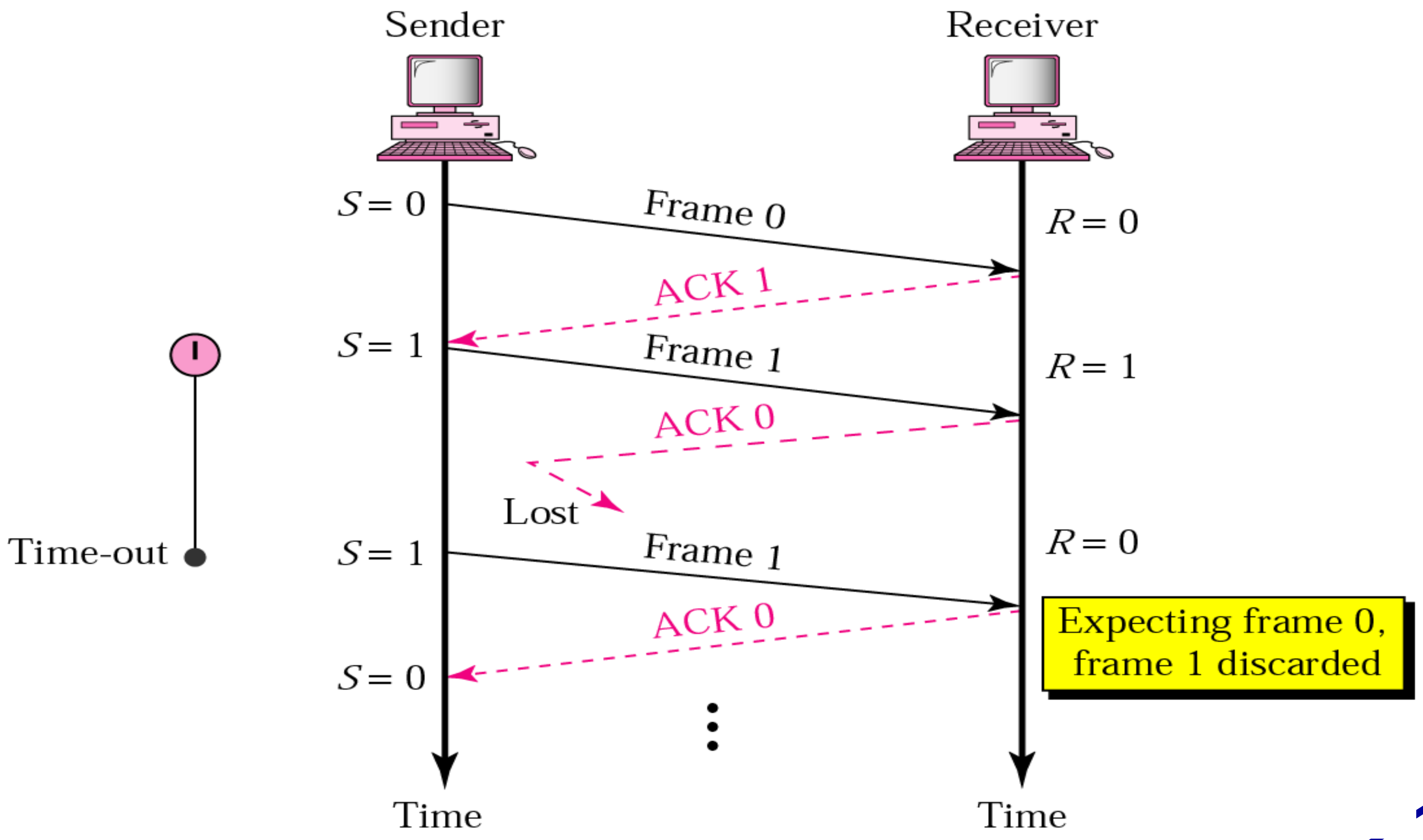
Stop and Wait ARQ Normal Operation



Stop-and-Wait ARQ, lost frame



Stop-and-Wait ARQ, lost ACK frame



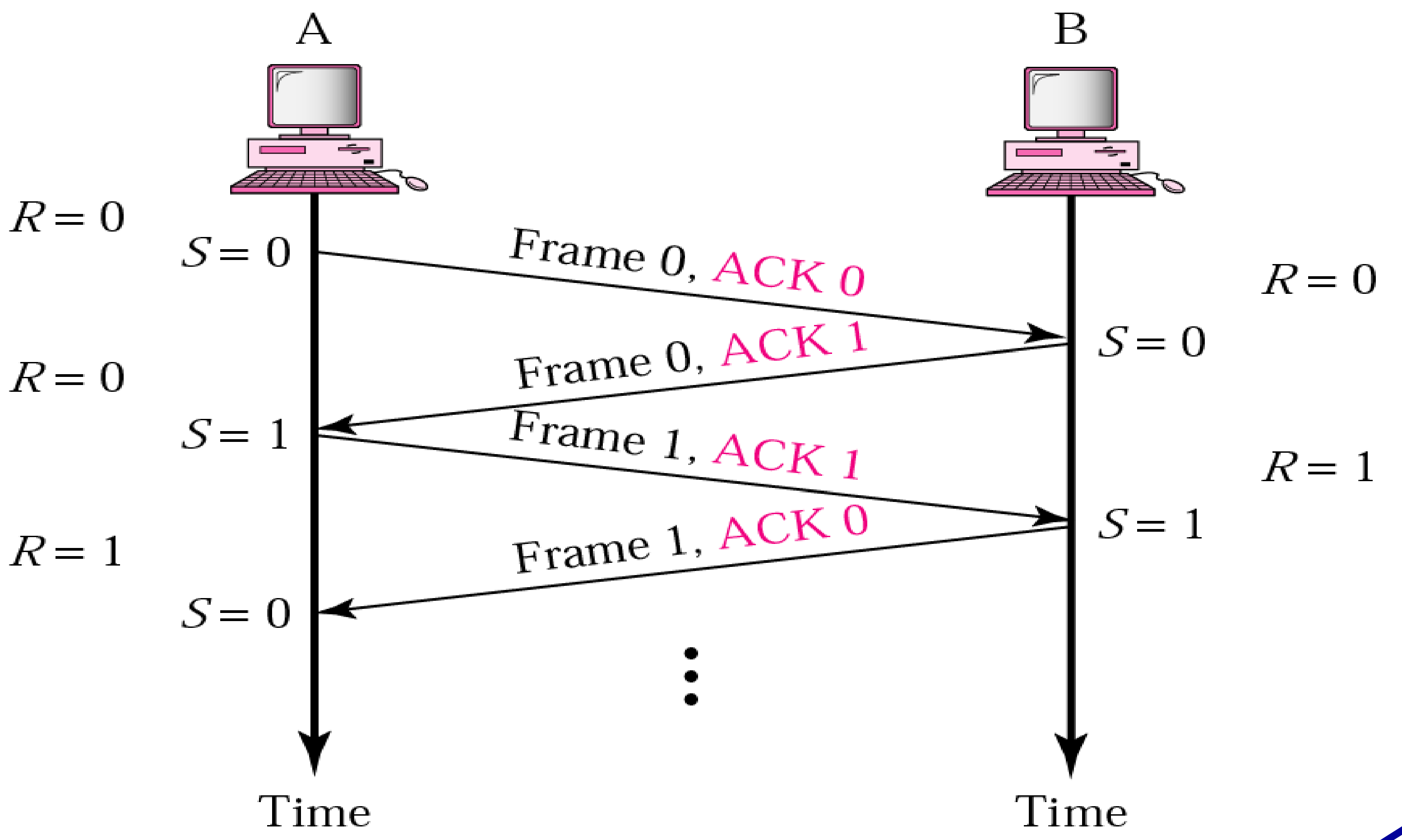
Note:

In Stop-and-Wait ARQ, numbering frames prevents the retaining of duplicate frames.

Note:

Numbered acknowledgments are needed if an acknowledgment is delayed and the next frame is lost.

Piggybacking



Go-Back-N ARQ

Sequence Number

Sender and Receiver Sliding Window

Control Variables and Timers

Acknowledgment

Resending Frames

Operation

Go-back-n ARQ

- Based on sliding window
- If no error, ACK as usual with next frame expected
- Use window to control number of outstanding frames
- If error, reply with rejection
  - Discard that frame and all future frames until error frame received correctly
  - Transmitter must go back and retransmit that frame and all subsequent frames

Go-back-n ARQ

- Damaged frame
  - Receiver detects error in frame *i*
  - Receiver sends rejection-*i*
  - Transmitter gets rejection-*i*
  - Transmitter retransmits frame *i* and all subsequent
- Lost frame
  - Frame *i* lost
  - Transmitter sends *i+1*
  - Receiver gets frame *i+1* out of sequence
  - Receiver send reject *i*
  - Transmitter goes back to frame *i* and retransmits

Go-back-n ARQ

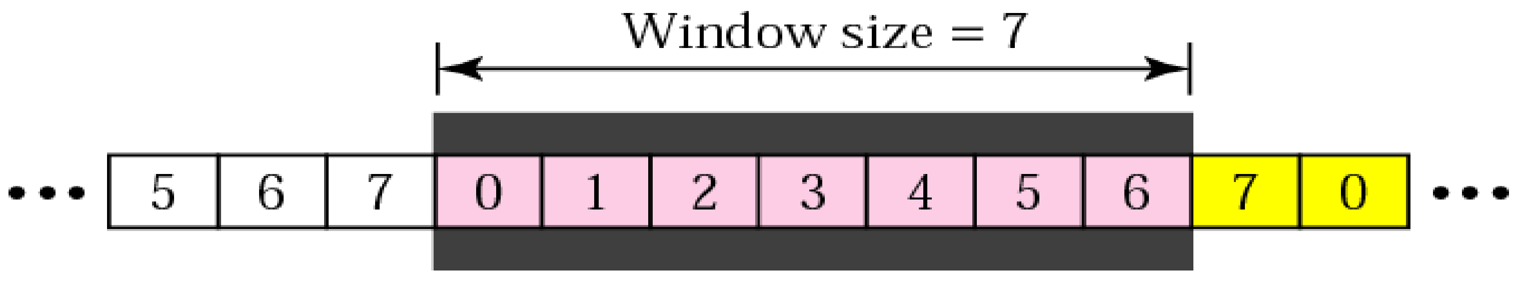
Lost frame

- Frame *i* lost and no additional frame sent
  - Receiver gets nothing and returns neither acknowledgement nor rejection
  - Transmitter times out and sends acknowledgement frame with P bit set to 1
  - Receiver interprets this as command which it acknowledges with the number of the next frame it expects (frame *i*)
  - Transmitter then retransmits frame *i*

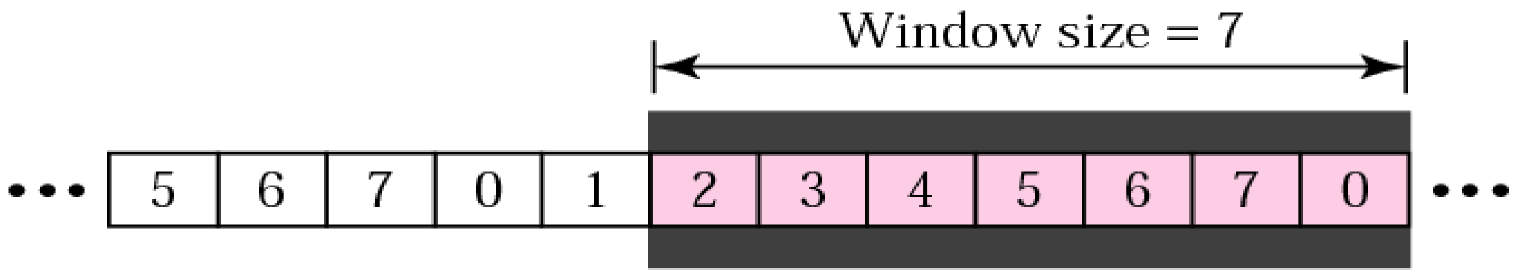
Go-back-n ARQ

- **Damaged acknowledgement**
  - Receiver gets frame *i* and send acknowledgement (*i*+*1*) which is lost
  - Acknowledgements are cumulative, so next acknowledgement (*i*+*n*) may arrive before transmitter times out on frame *i*
  - If transmitter times out, it sends acknowledgement with P bit set as before
  - This can be repeated a number of times before a reset procedure is initiated
- **Damaged rejection**
  - As for lost frame

Sender sliding window

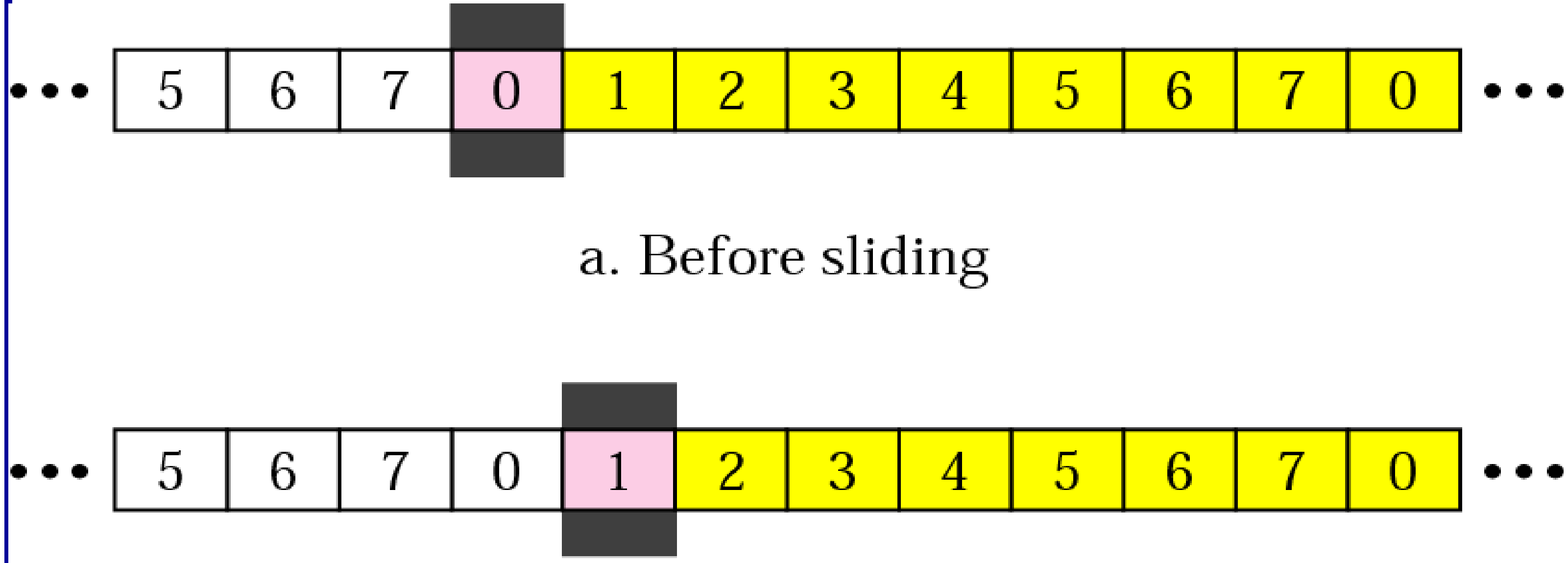


a. Before sliding



b. After sliding two frames

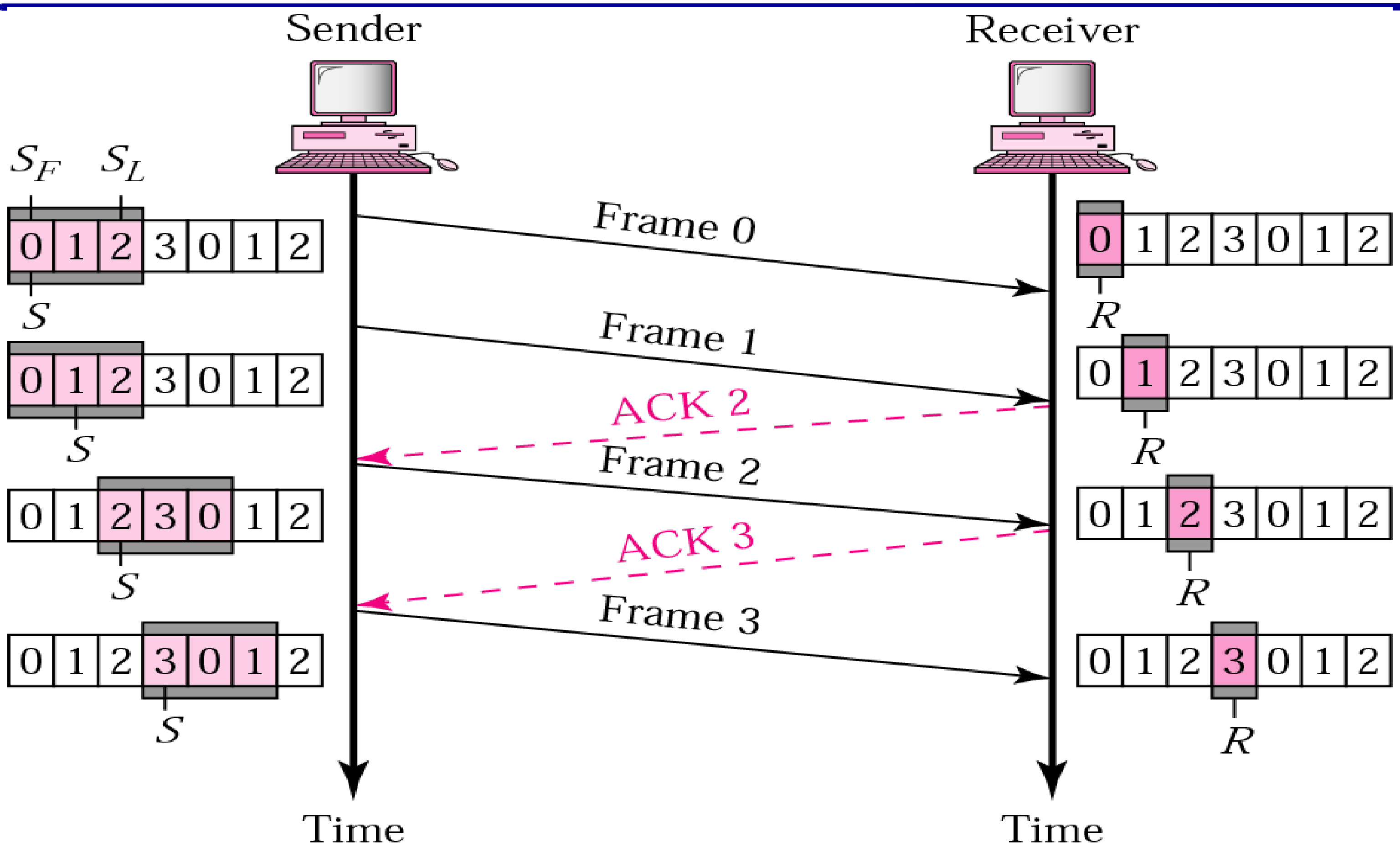
Receiver sliding window



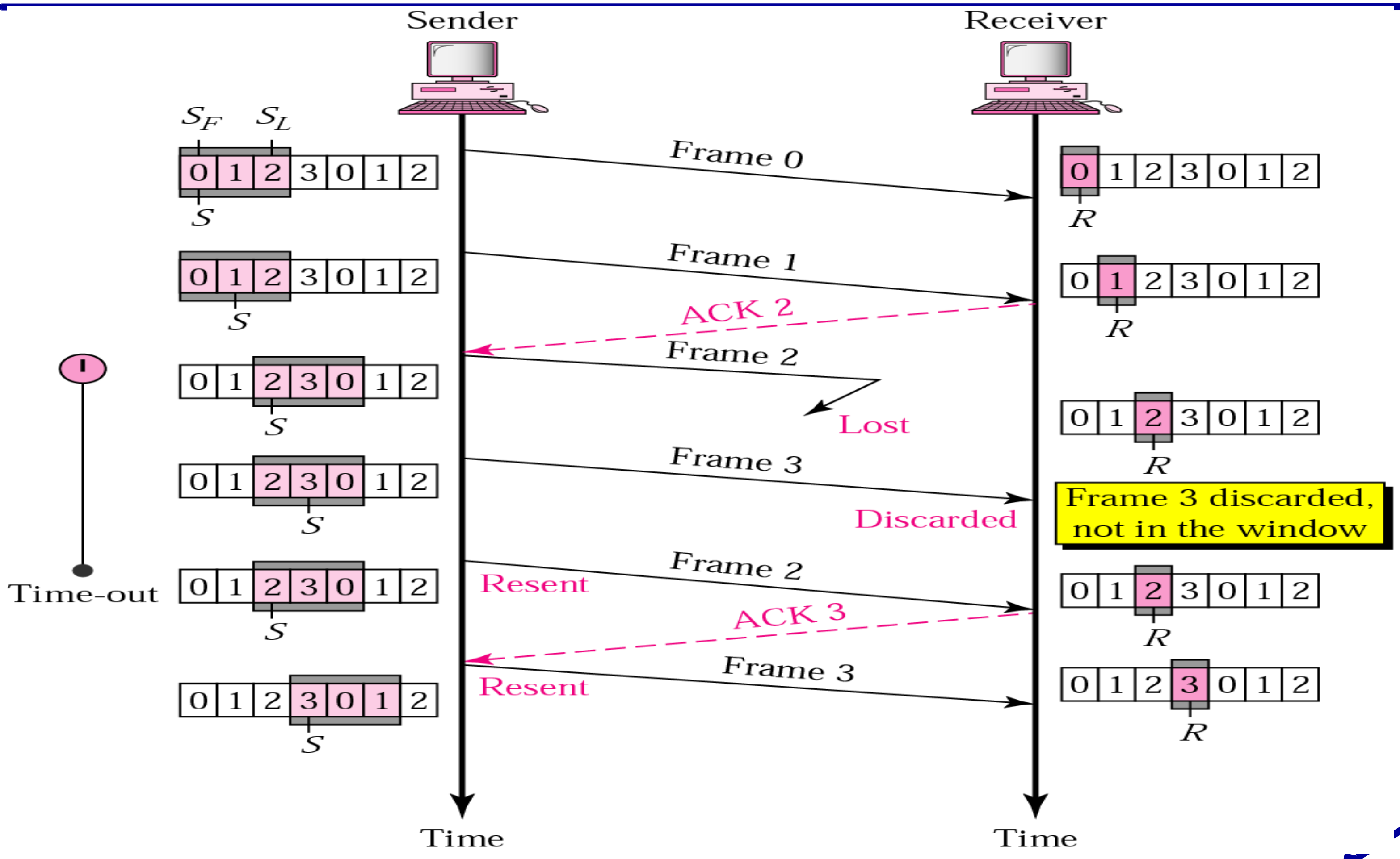
a. Before sliding

b. After sliding

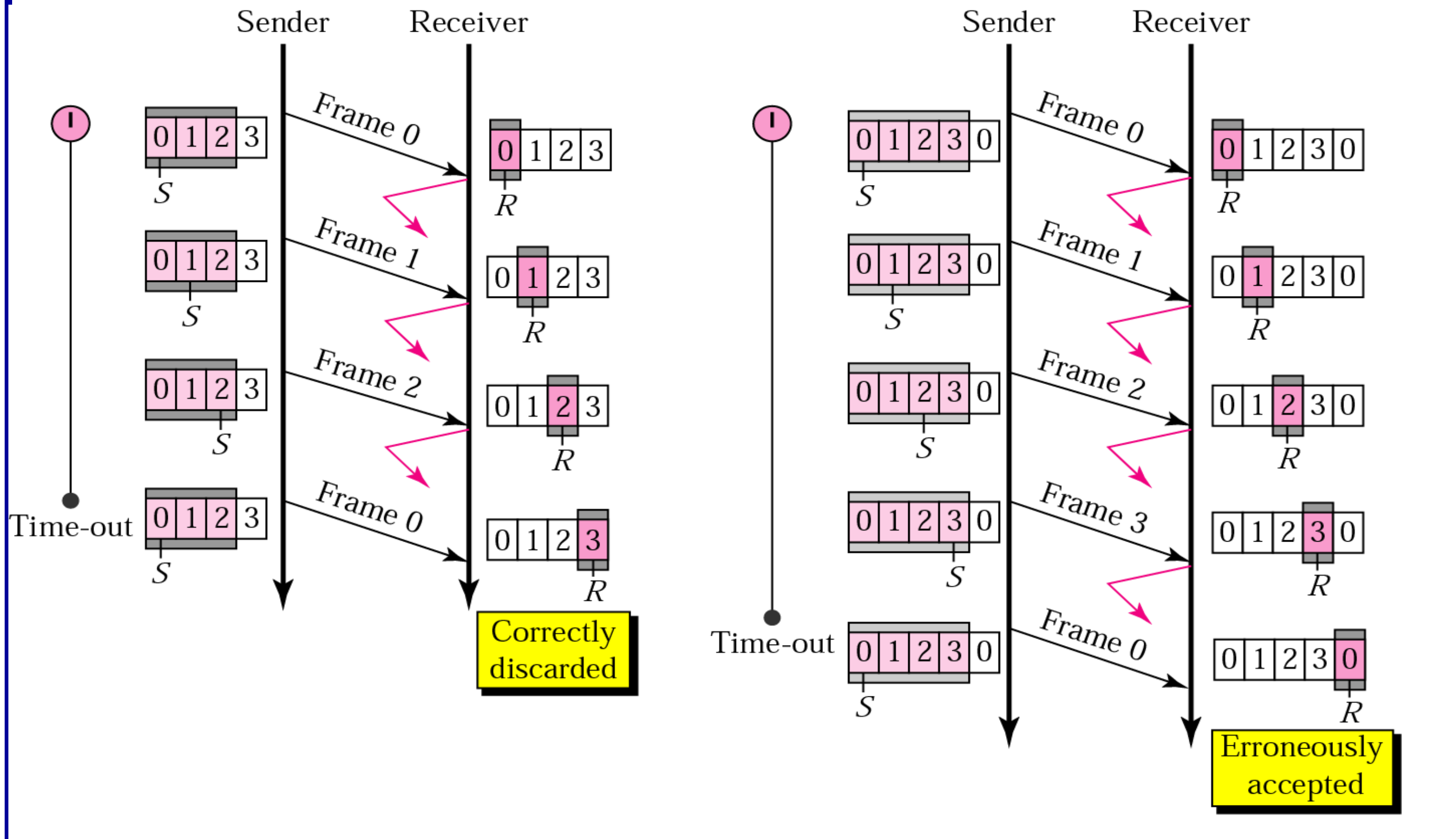
Go-Back-N ARQ, normal operation



Go-Back-N ARQ, lost frame



Go-Back-N ARQ: sender window size



a. Window size < 2^m

b. Window size = 2^m

Note:

In Go-Back-N ARQ, the size of the sender window must be less than 2m; the size of the receiver window is always 1.

Selective Reject

- Also called selective retransmission
- Only rejected frames are retransmitted
- Subsequent frames are accepted by the receiver and buffered
- Minimizes retransmission
- Receiver must maintain large enough buffer
- More complex logic in transmitter

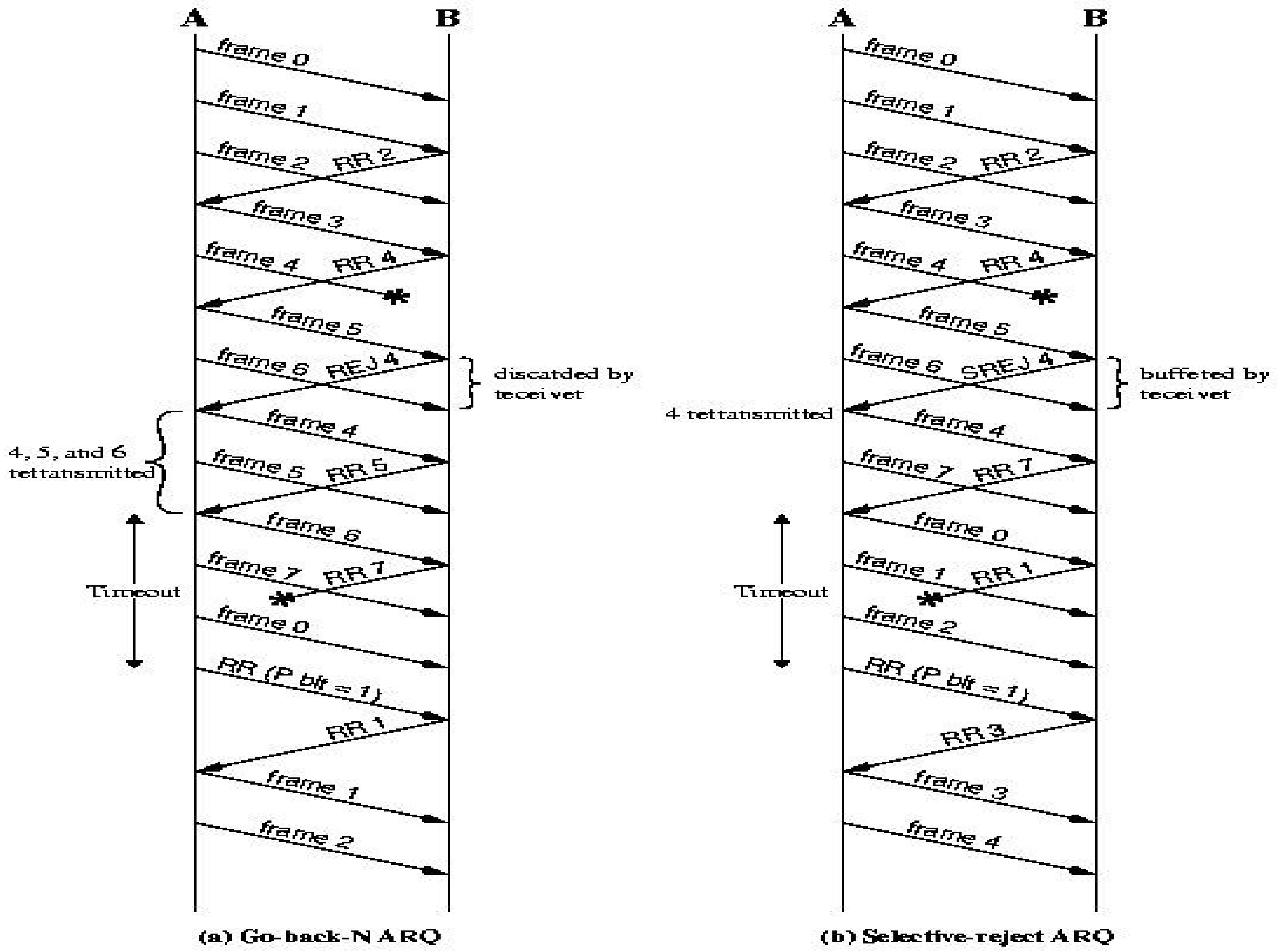


Figure 11.7 Sliding-Window ARQ Protocols