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

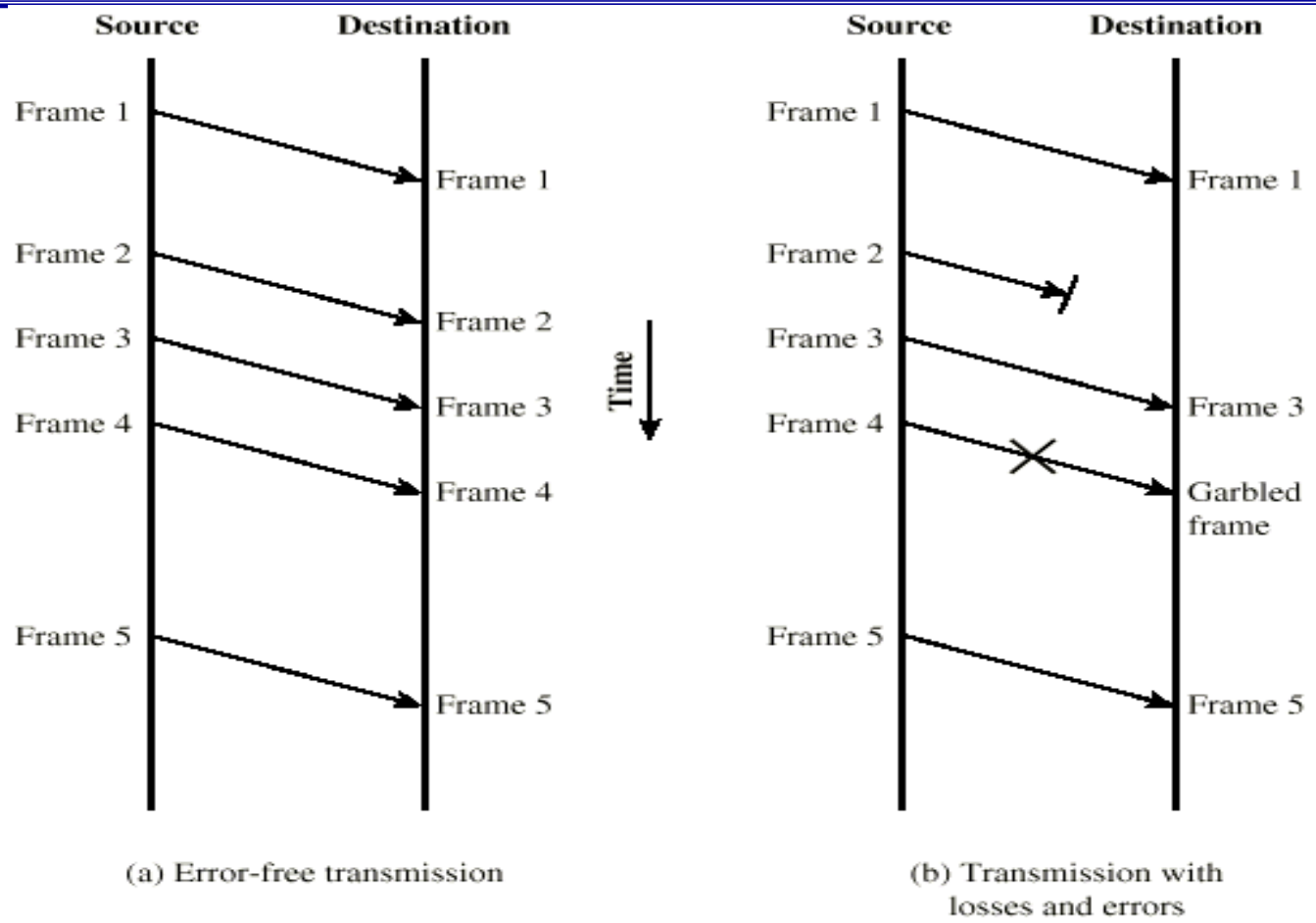
Note:

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

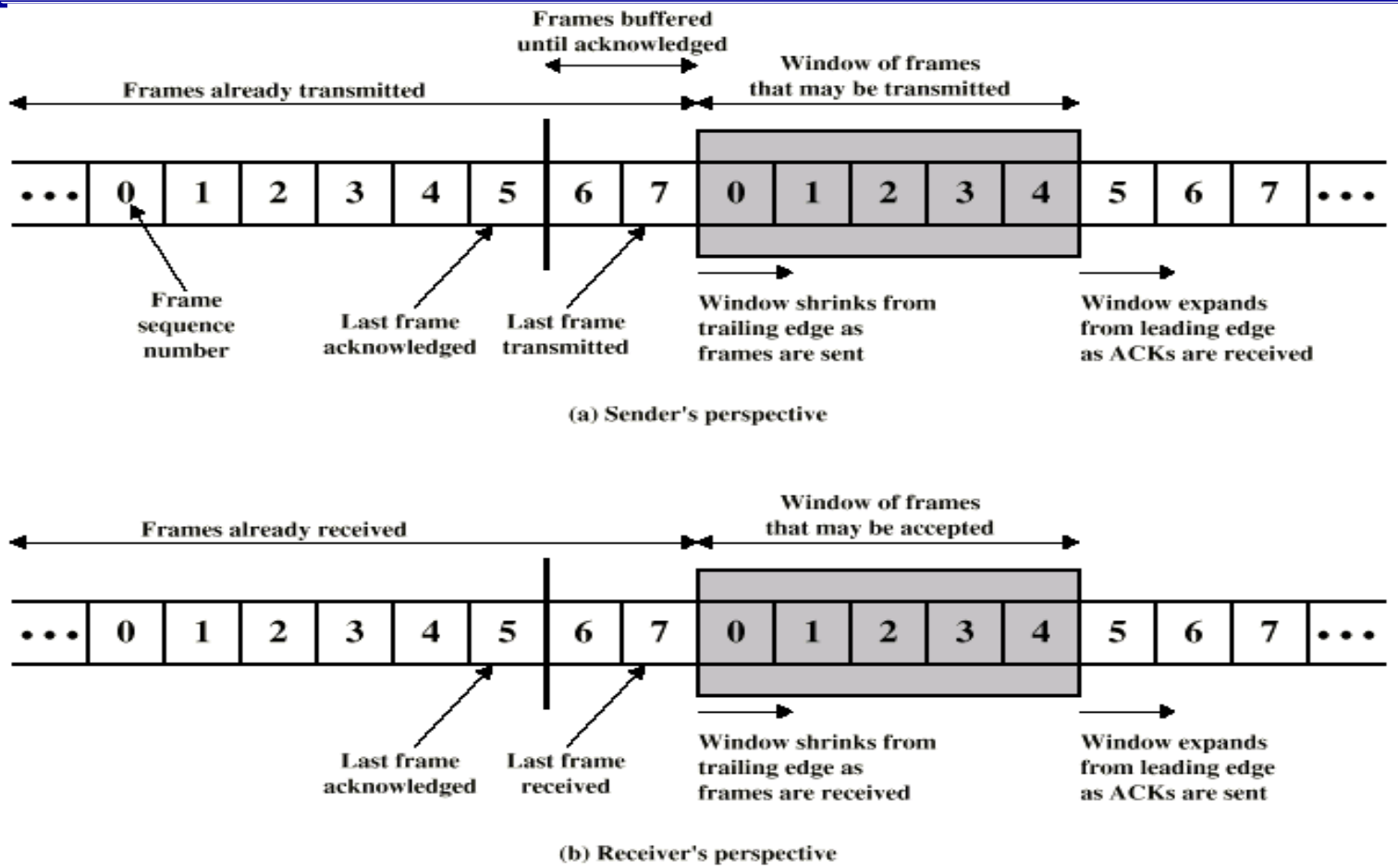
- Large block of data may be split into small frames
  - Limited buffer size
  - Errors detected sooner (when whole frame received)
  - On error, retransmission of smaller frames is needed
  - Prevents one station occupying medium for long periods
- Stop and wait becomes inadequate

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



Example Sliding Window

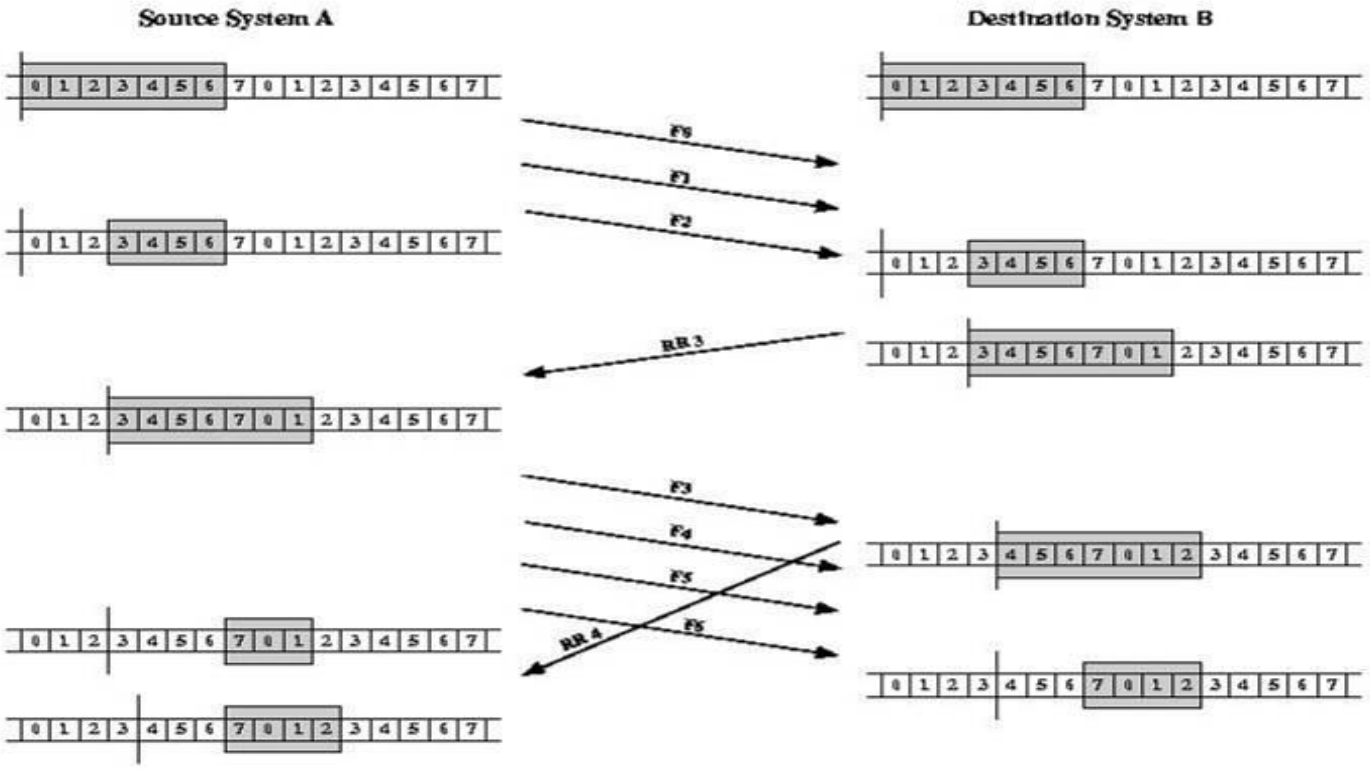


Figure 11.6 Example of a Sliding-Window Protocol

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

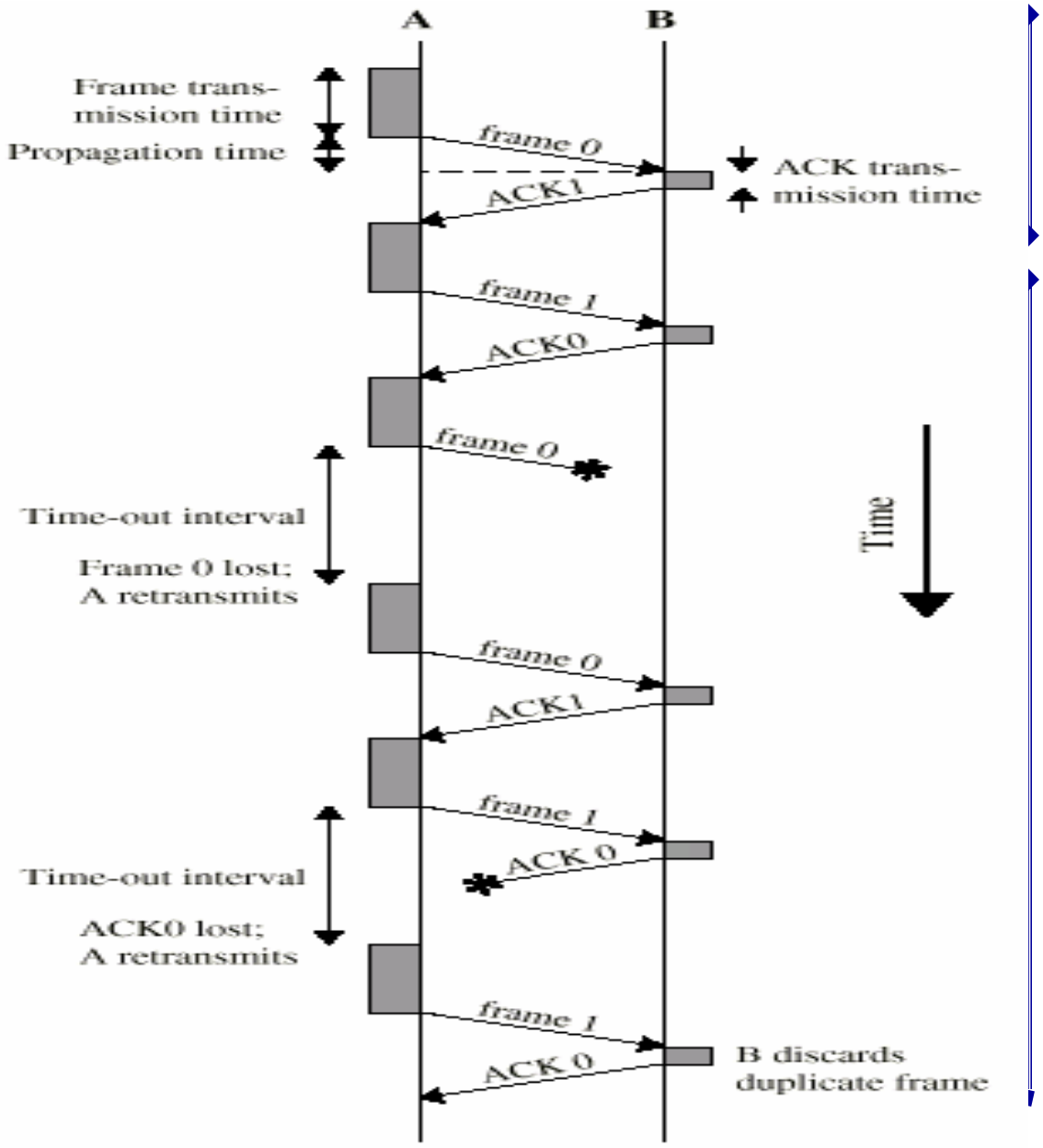
Automatic Repeat Request (ARQ)

- 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)

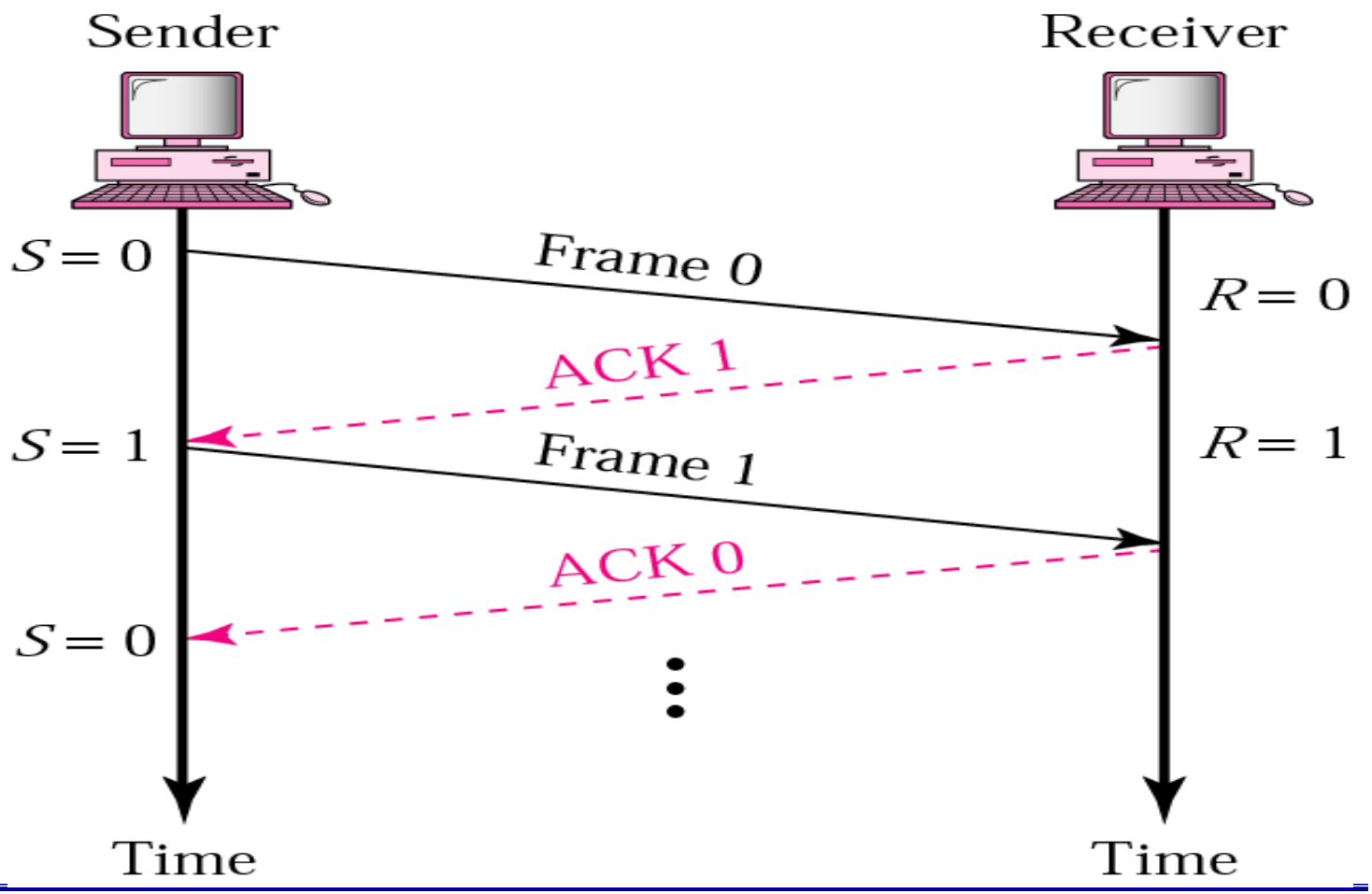
Stop and Wait

- 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

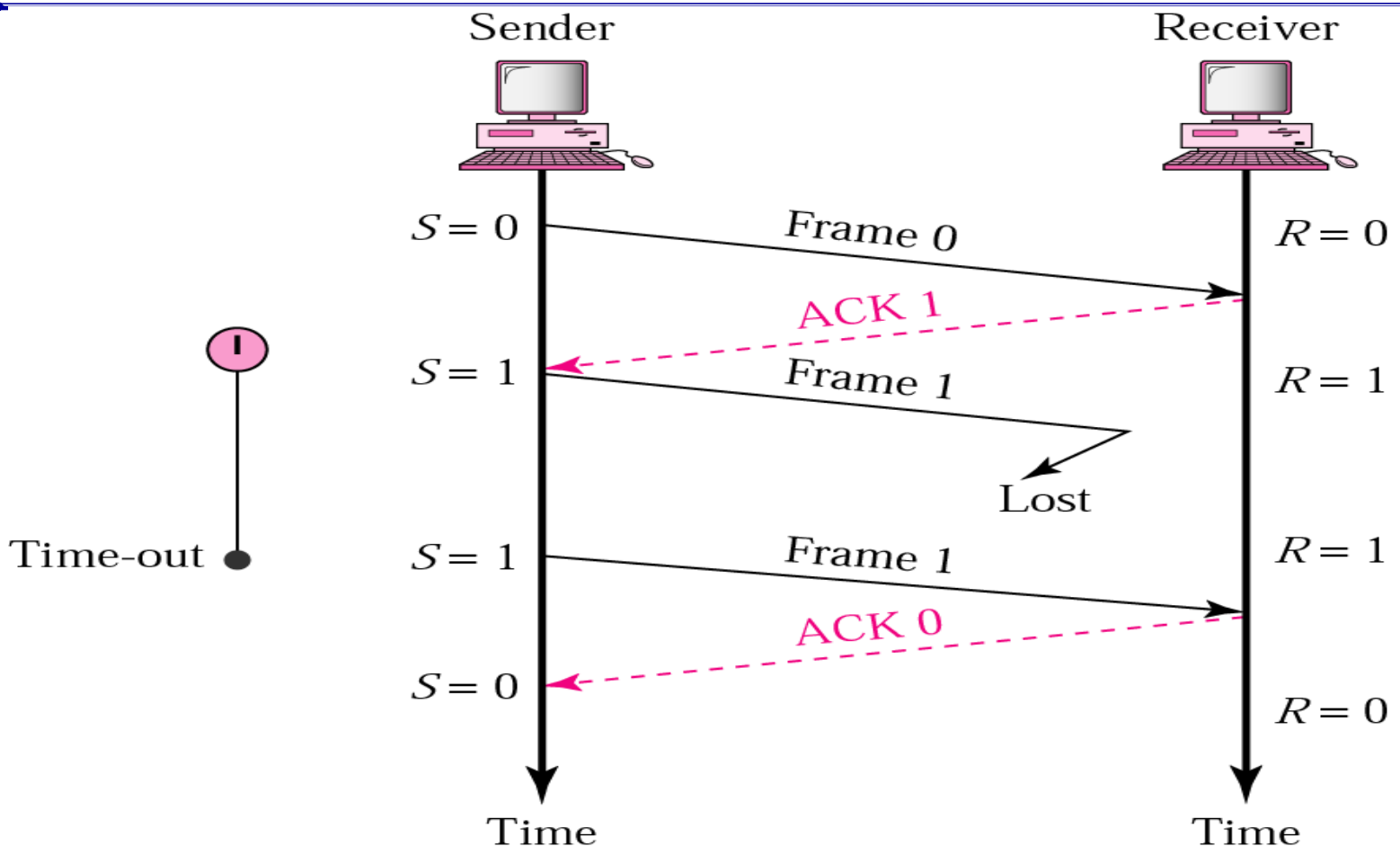
Stop and Wait - Diagram



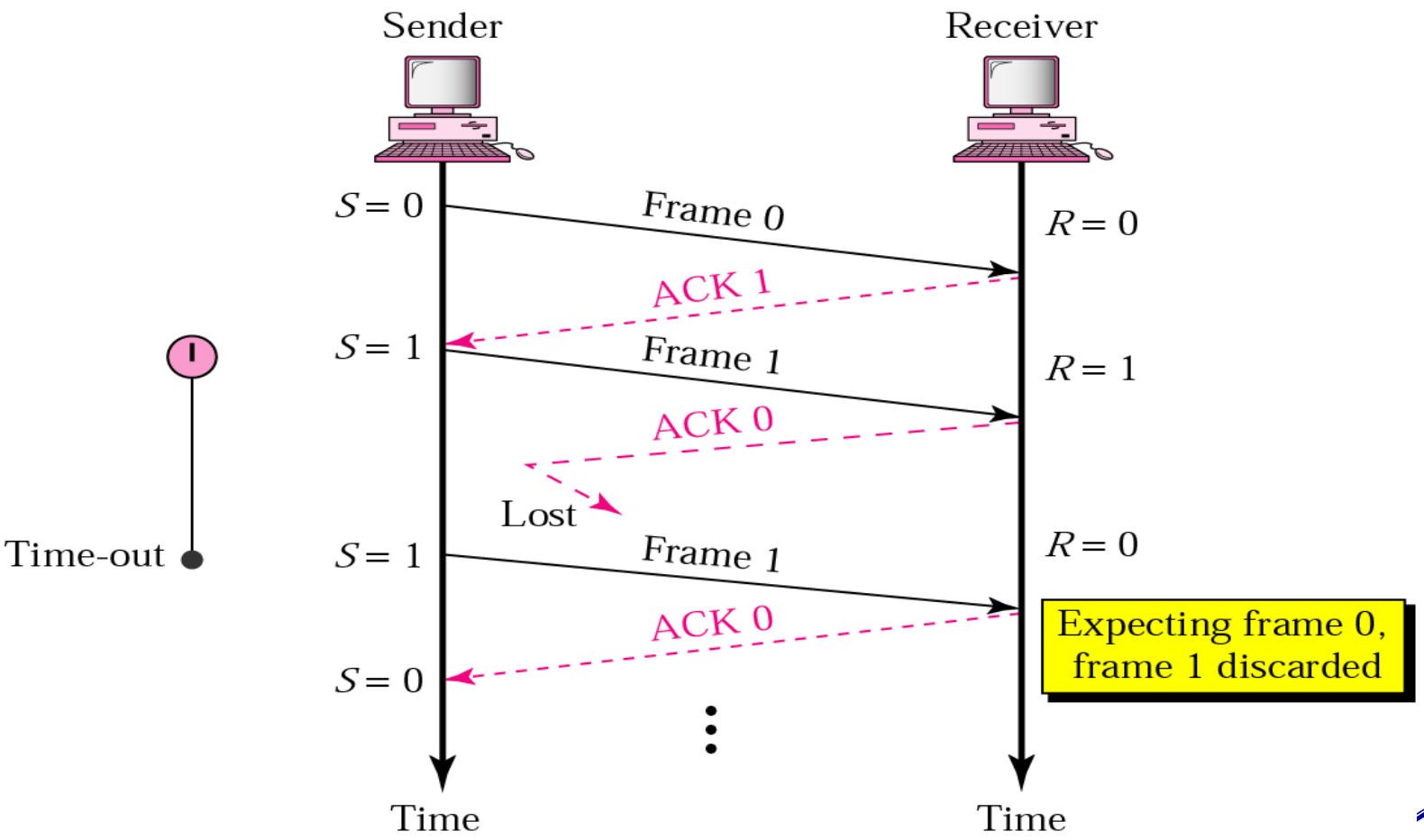
Stop and Wait ARQ Normal Operation



Stop-and-Wait ARQ, lost frame



Stop-and-Wait ARQ, lost ACK frame



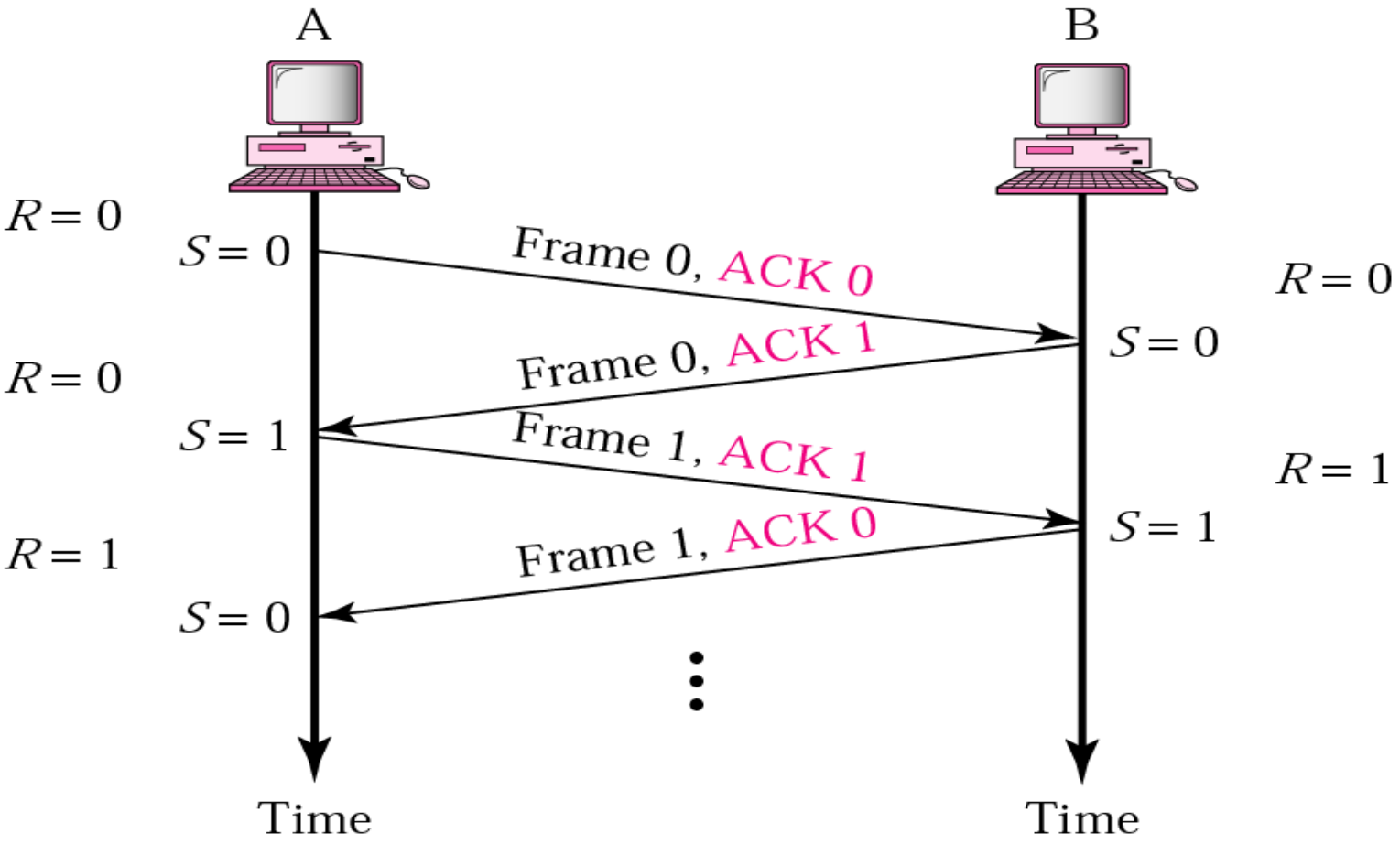
Note:

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

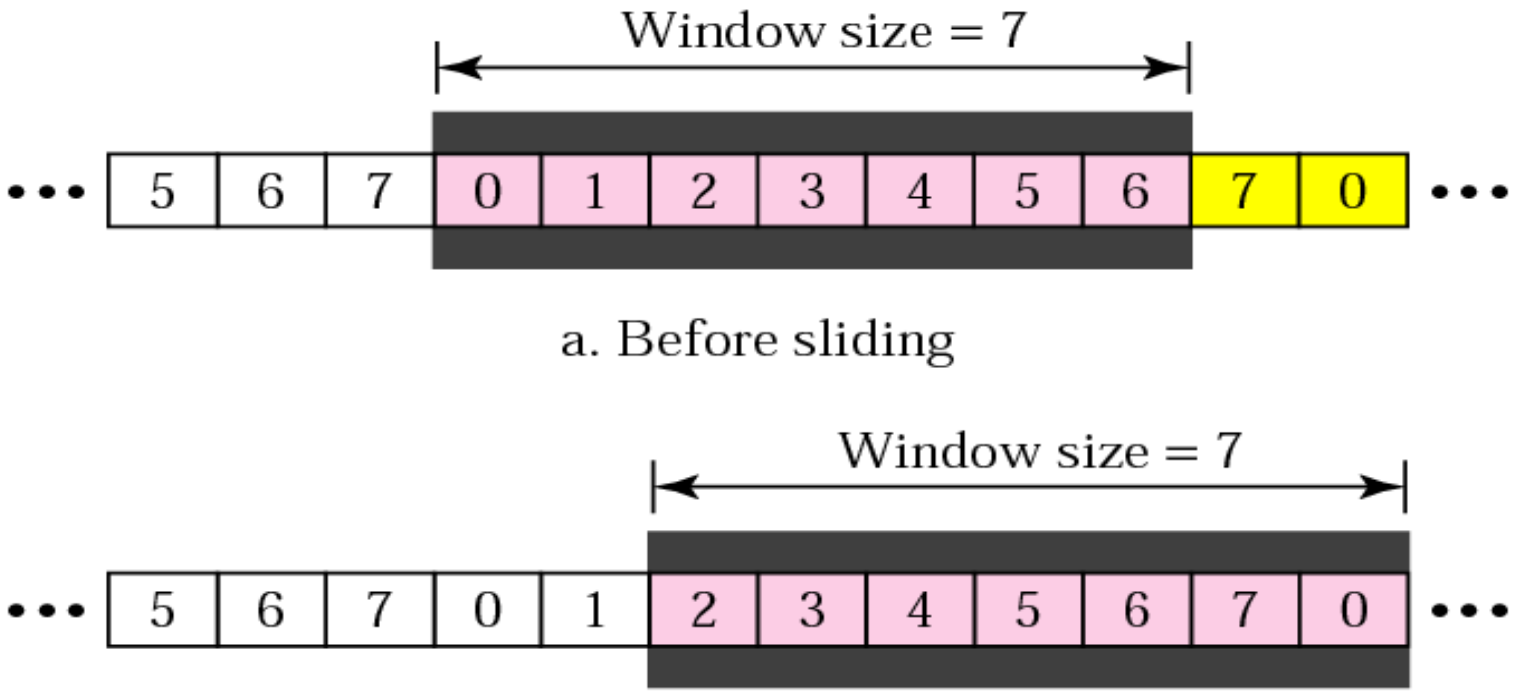
Lost frame

- 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*

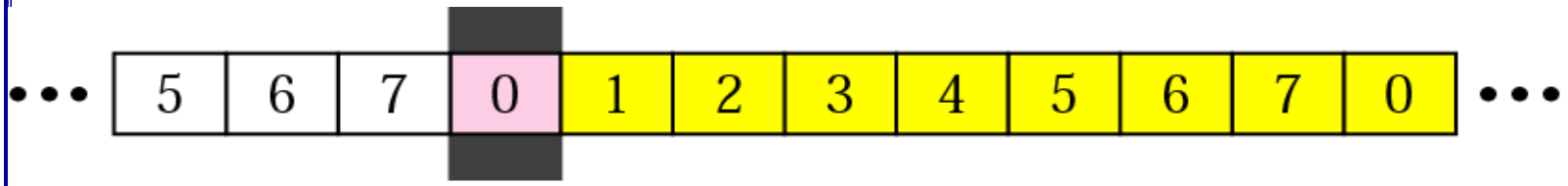
Go-back-n ARQ

- **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

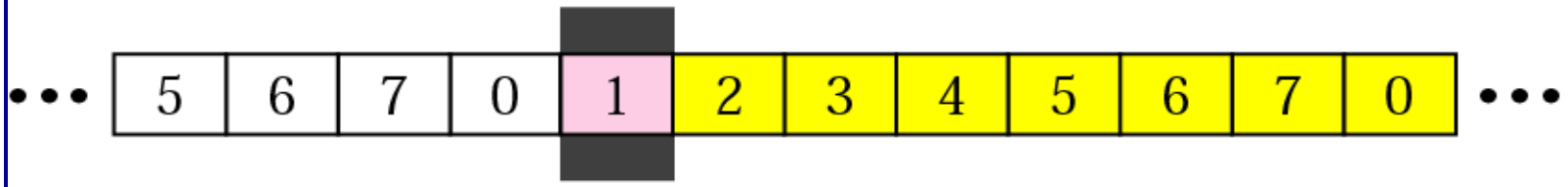
Sender sliding window



Receiver sliding window

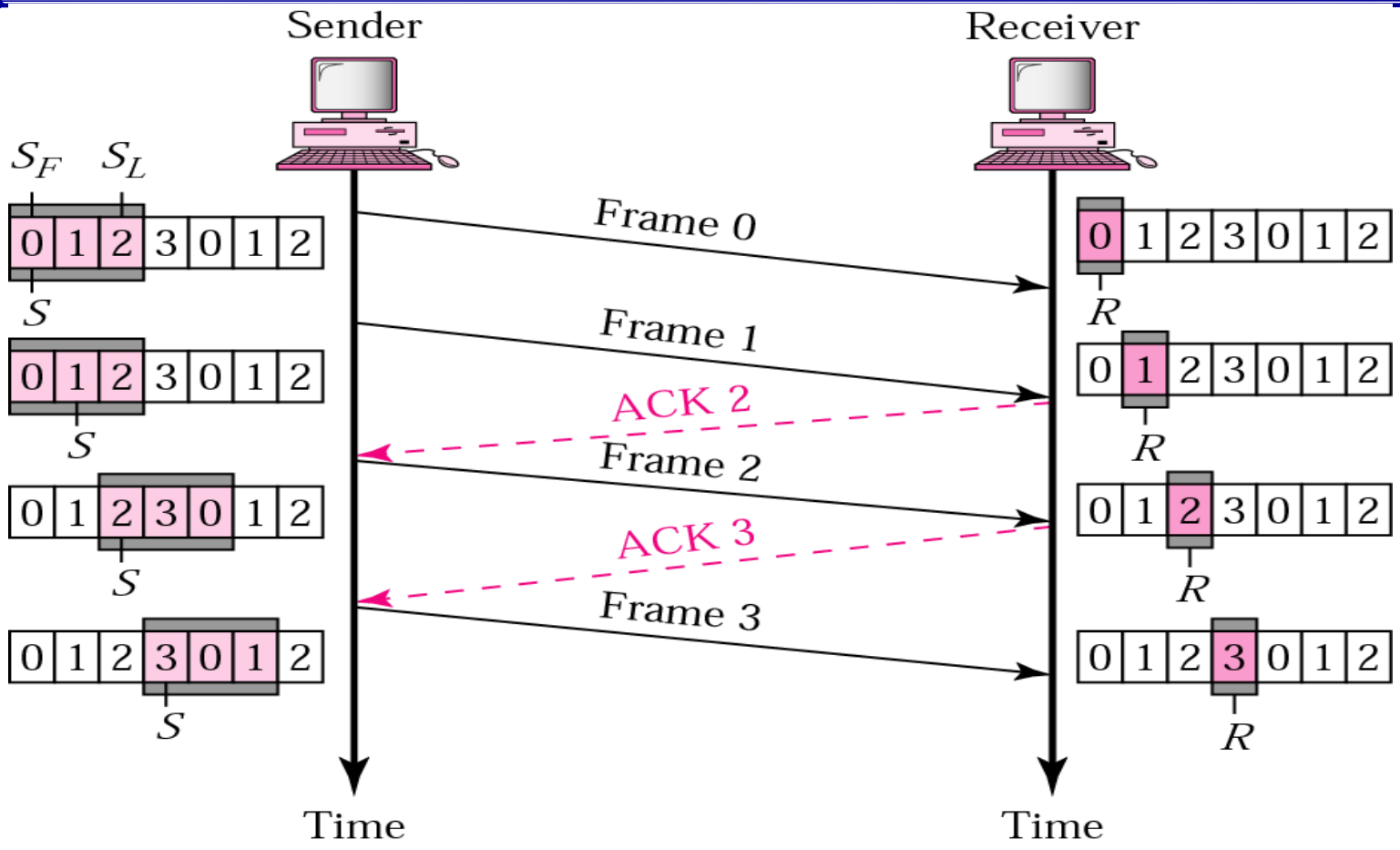


a. Before sliding

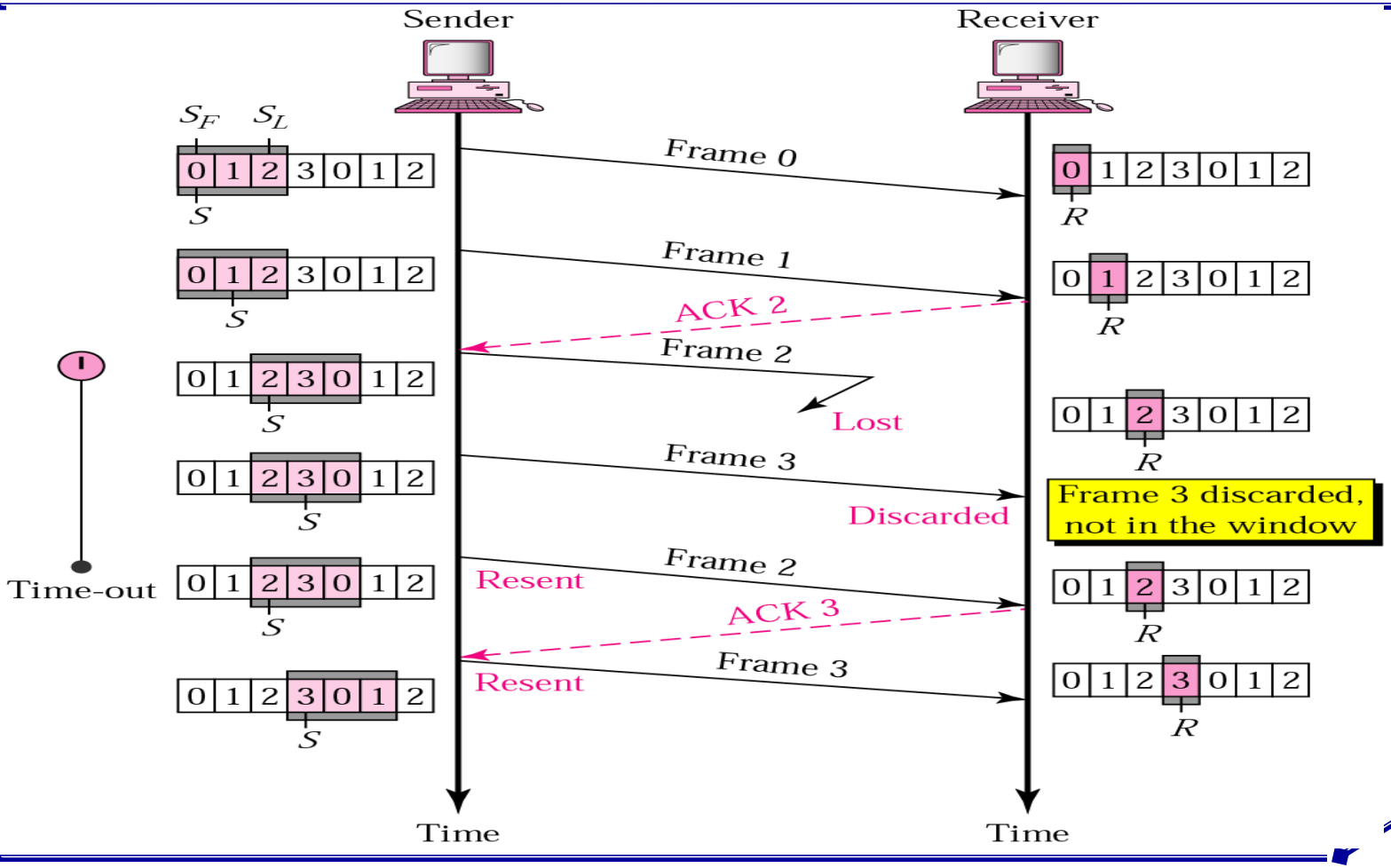


b. After sliding

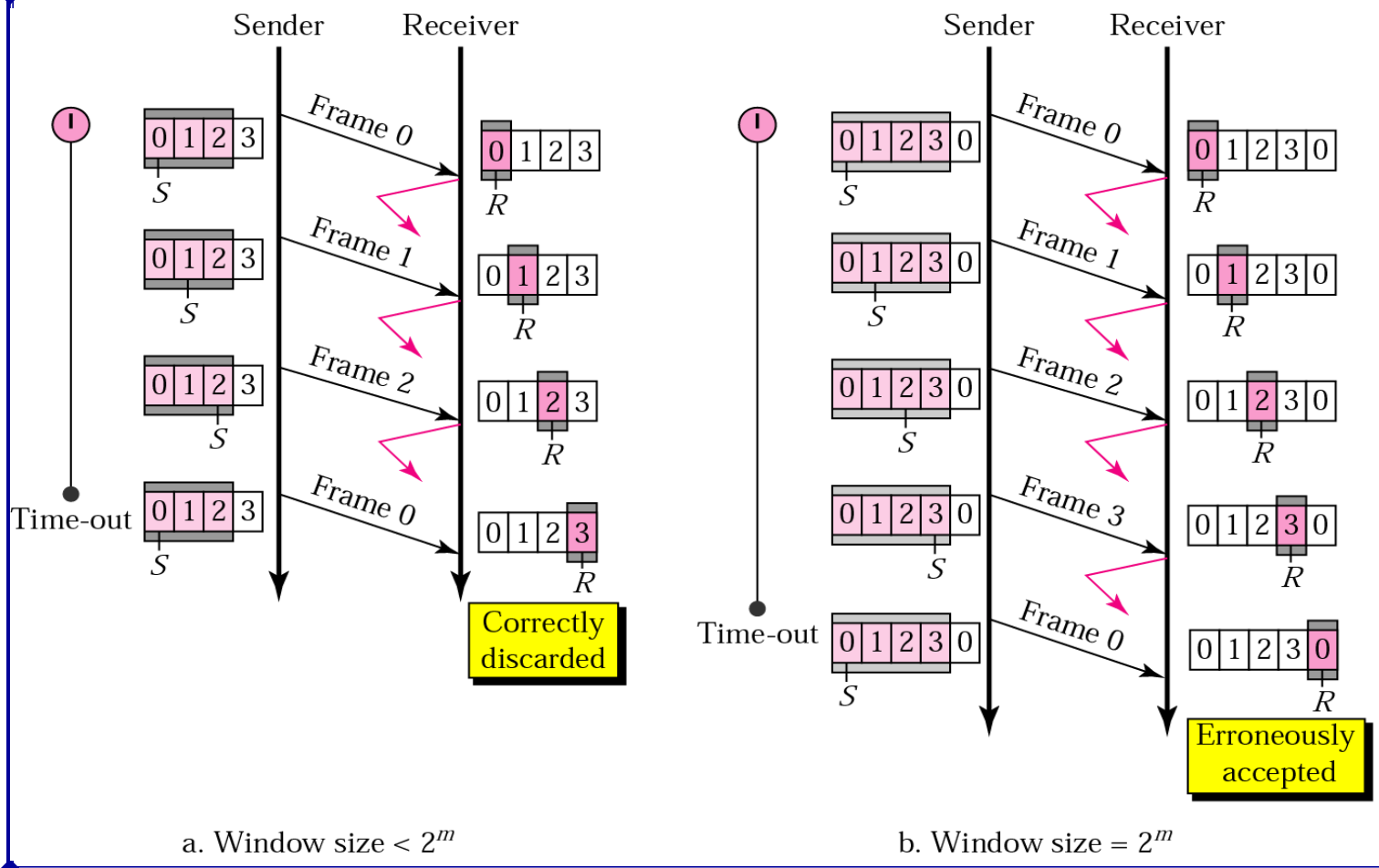
Go-Back-N ARQ, normal operation



Go-Back-N ARQ, lost frame



Go-Back-N ARQ: sender window size



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

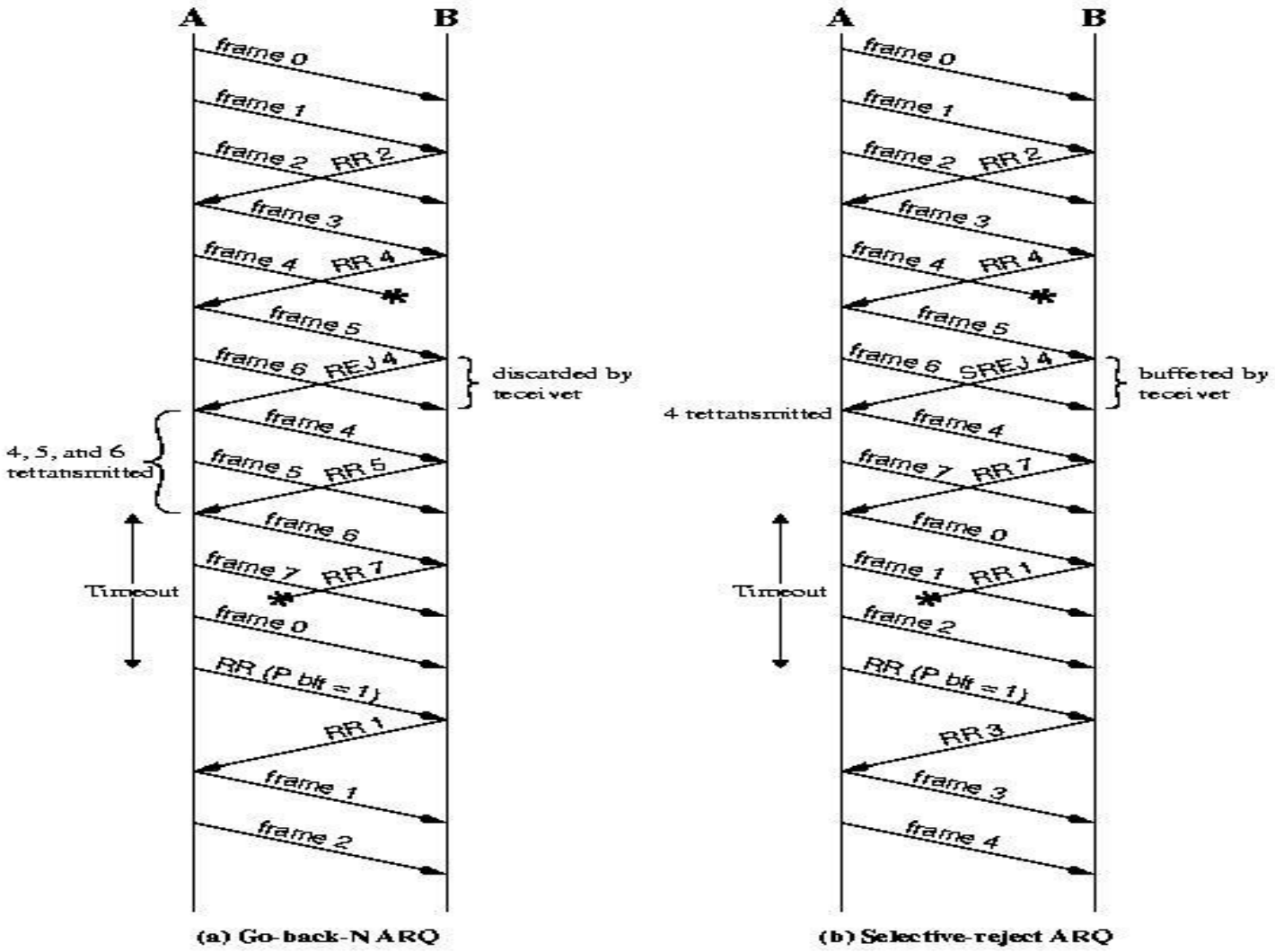


Figure 11.7 Sliding-Window ARQ Protocols