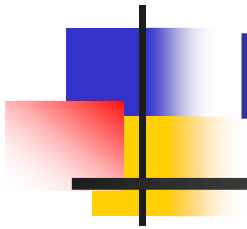

EC 554
Data Communications

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Syllabus

- Tentatively

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Data Link Control and Protocols

11.1 Flow and Error Control

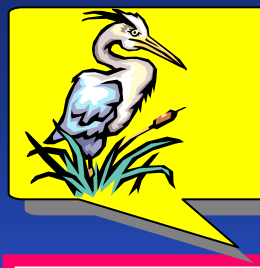
Flow Control

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.

- ensure sending entity does not overwhelm receiving entity
  - by preventing buffer overflow
- influenced by:
  - transmission time
    - time taken to emit all bits into medium
  - propagation time
    - time for a bit to traverse the link
- assume here no errors but varying delays



Note:

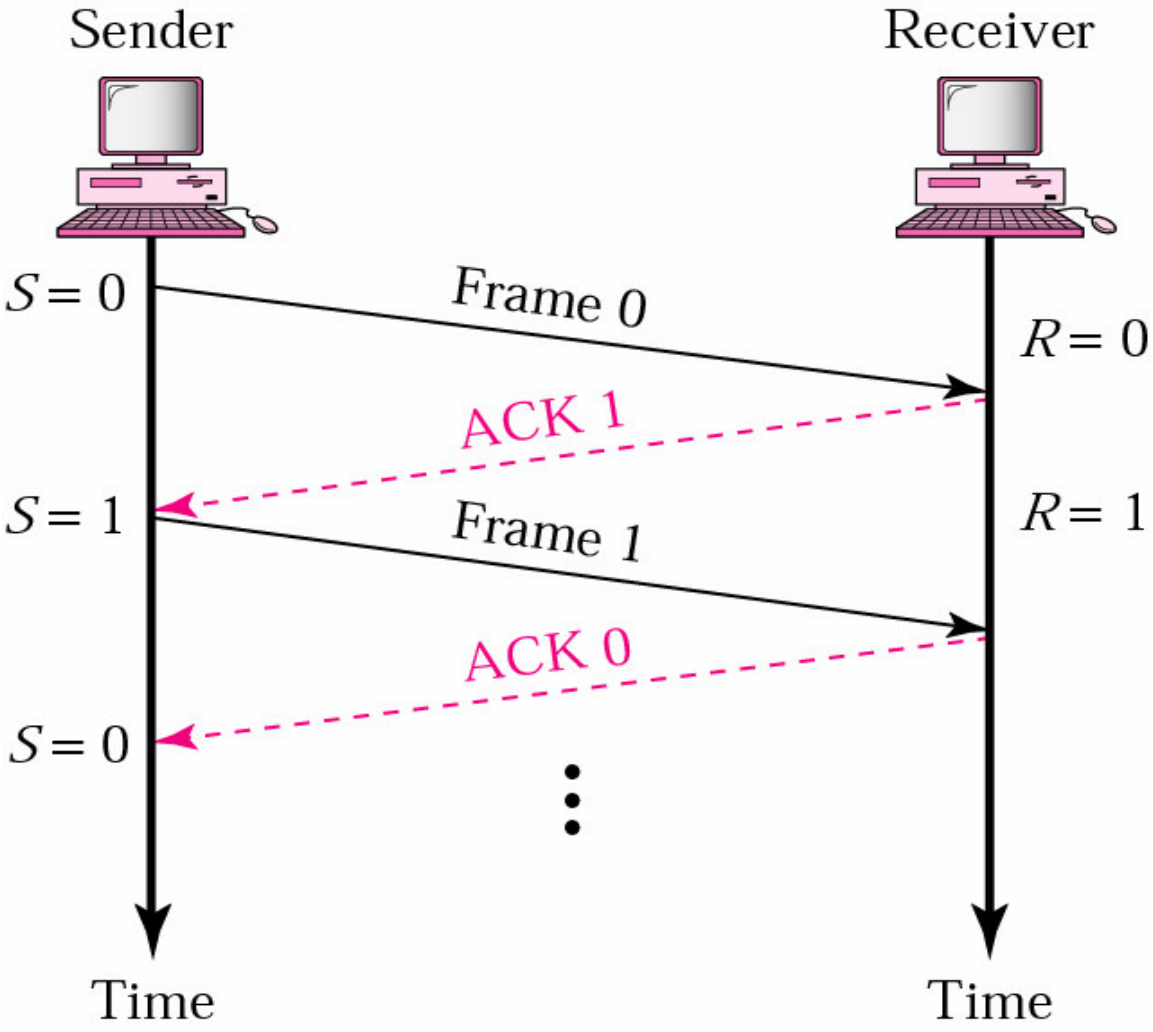
Error control in the data link layer is based on automatic repeat request, which is the retransmission of data.

- detection and correction of errors such as:
  - lost frames
  - damaged frames
- common techniques use:
  - error detection
  - positive acknowledgment
  - retransmission after timeout
  - negative acknowledgement & retransmission

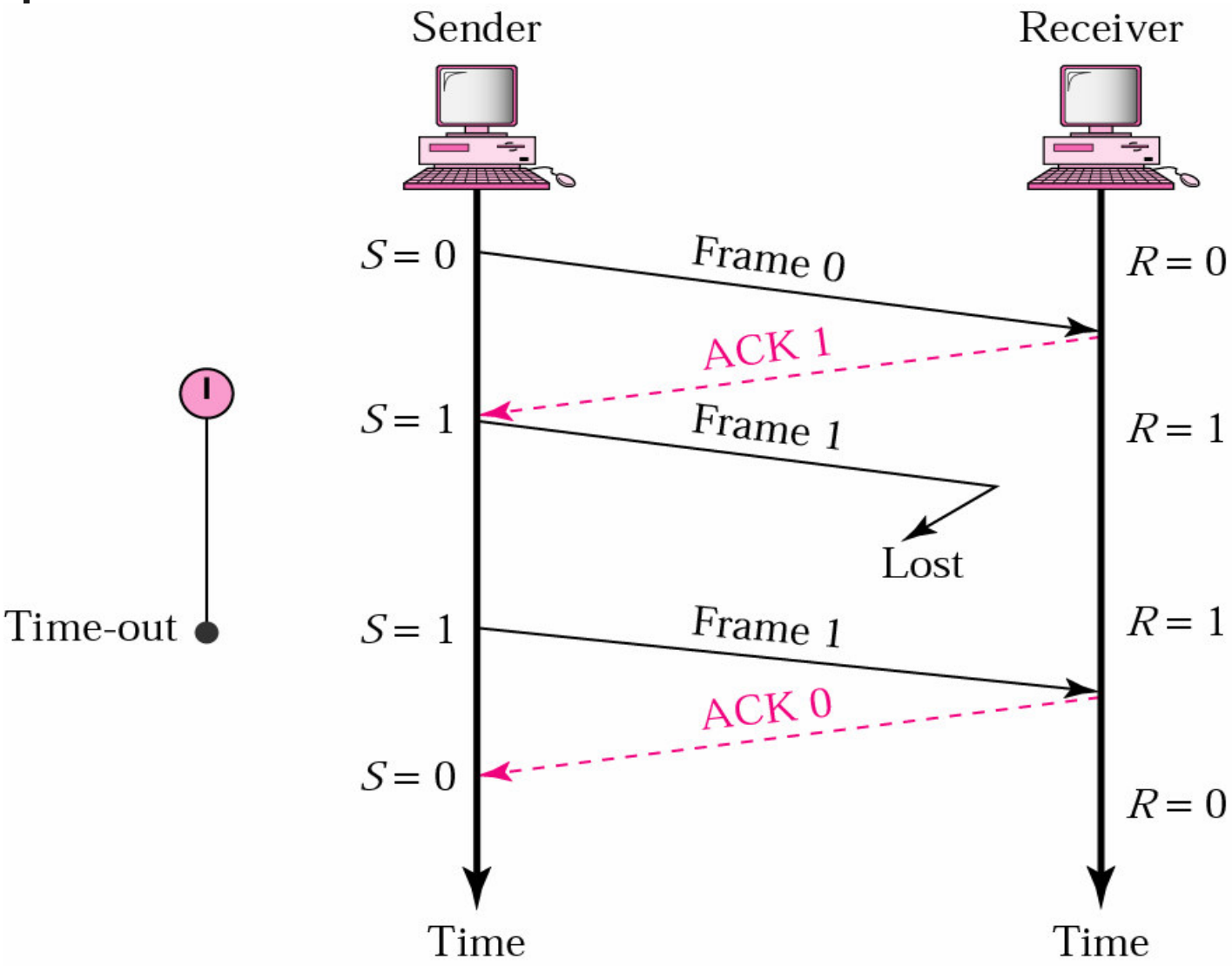
11.2 Stop-and-Wait ARQ

- source transmits frame
- destination receives frame and replies with acknowledgement (ACK)
- source waits for ACK before sending next
- destination can stop flow by not send ACK
- works well for a few large frames
- Stop and wait becomes inadequate if large block of data is split into small frames

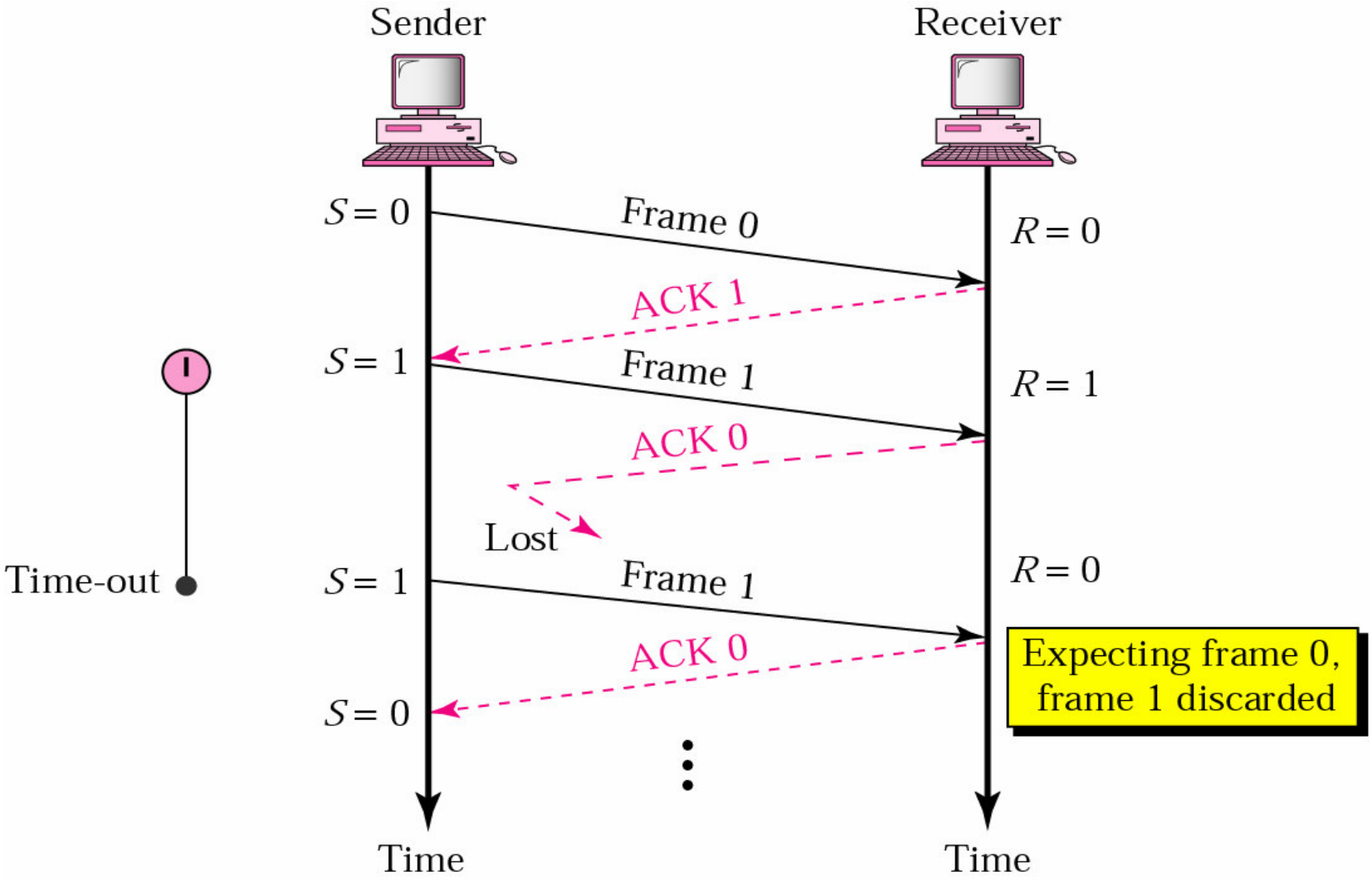
11.1 Normal operation



11.2 Stop-and-Wait ARQ, lost frame



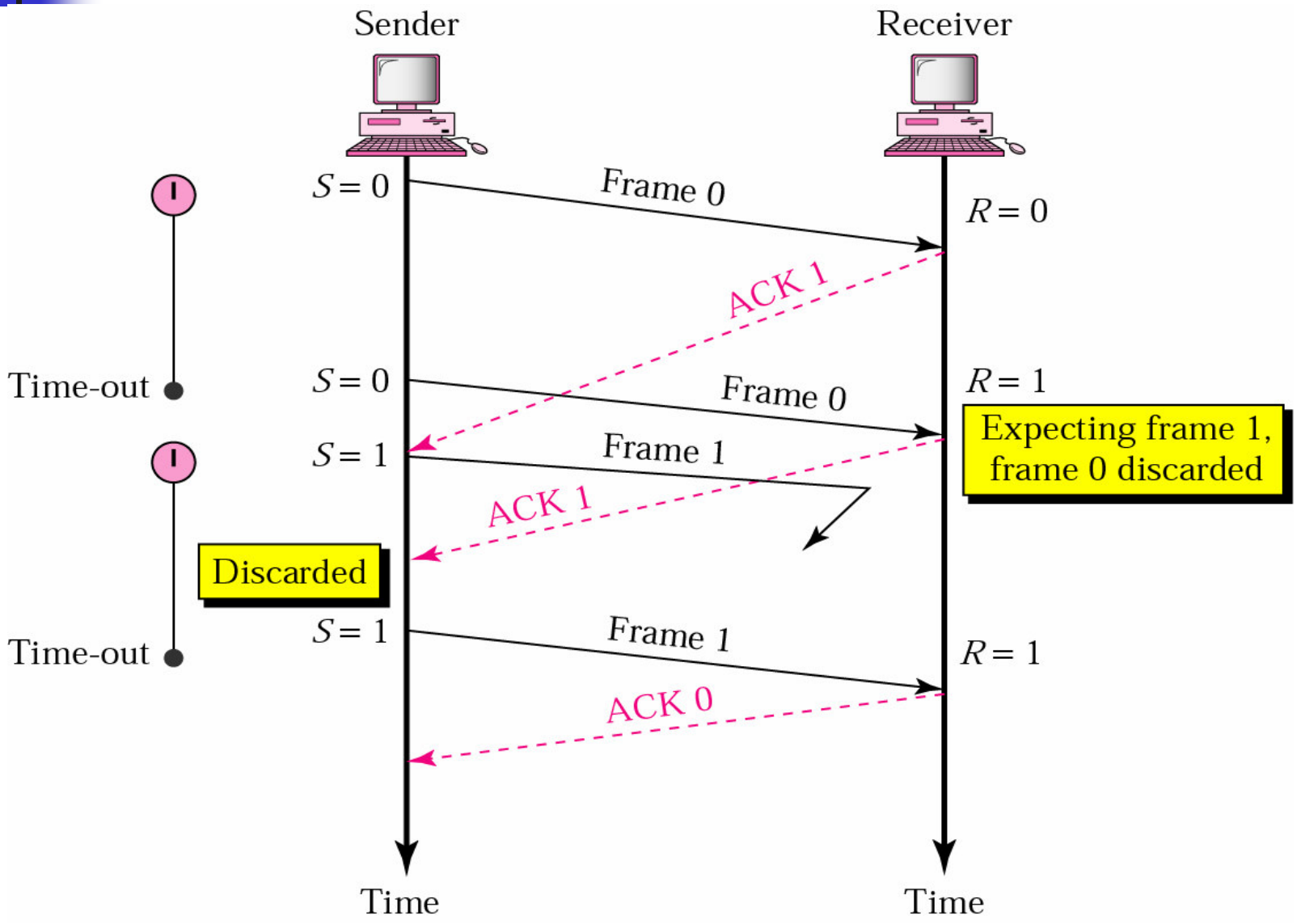
11.3 Stop-and-Wait ARQ, lost ACK frame



Note:

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

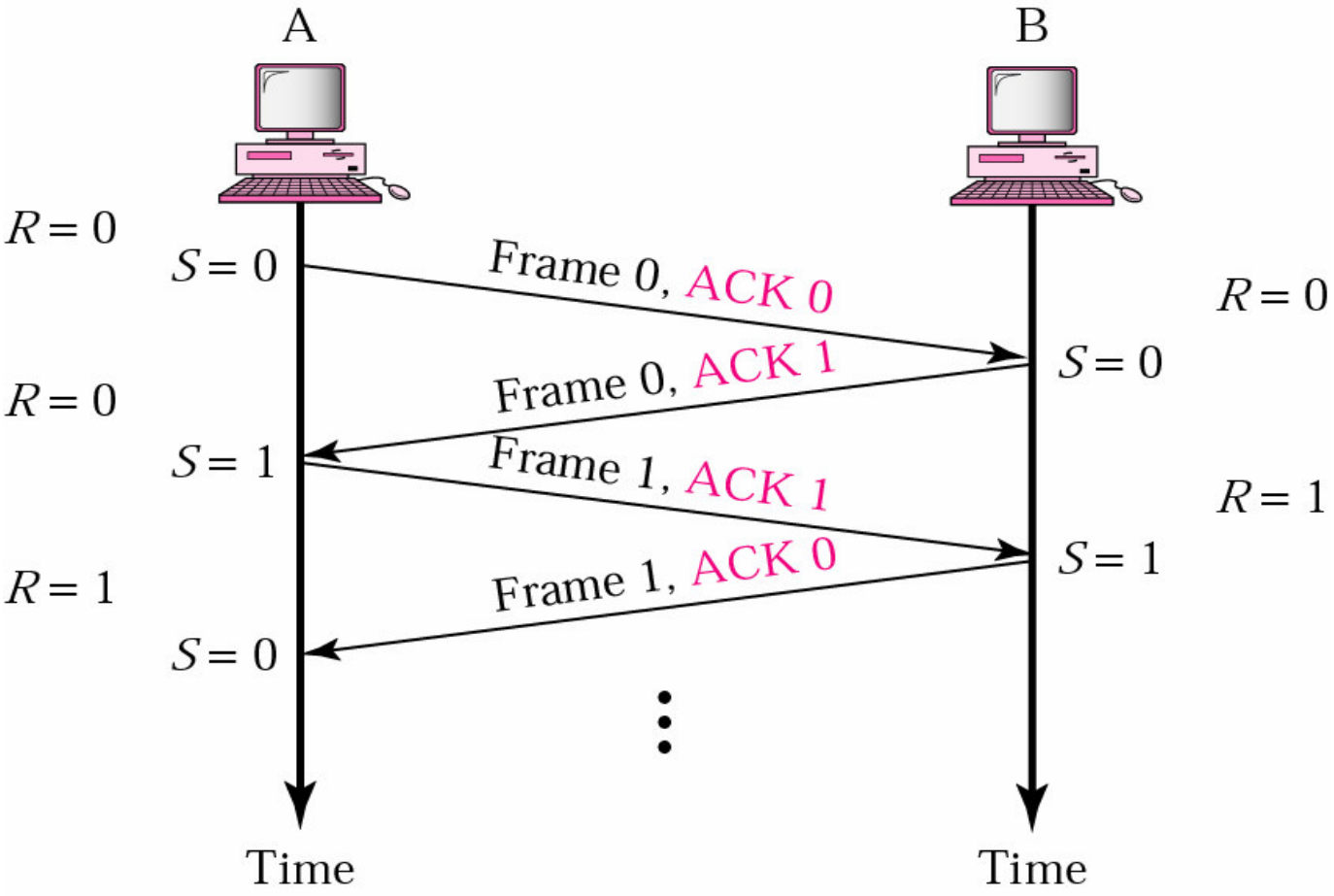
11.4 Stop-and-Wait ARQ, delayed ACK



Note:

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

11.5 Piggybacking



Sliding Windows Flow Control

- allows multiple numbered frames to be in transit
- receiver has buffer W long
- transmitter sends up to W frames without ACK
- ACK includes number of next frame expected
- sequence number is bounded by size of field (k)
  - frames are numbered modulo 2^k
  - giving max window size of up to $2^k - 1$
- receiver can ack frames without permitting further transmission (Receive Not Ready)
- must send a normal acknowledge to resume
- if have full-duplex link, can piggyback ACKs

11.3 Go-Back-N ARQ

Sequence Number

Sender and Receiver Sliding Window

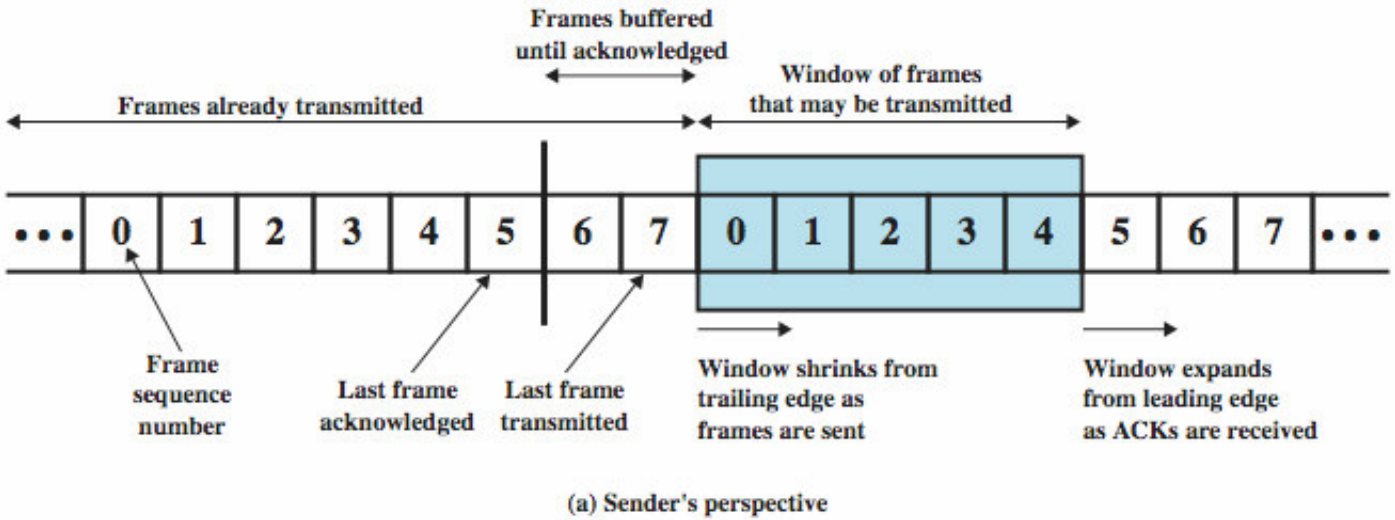
Control Variables and Timers

Acknowledgment

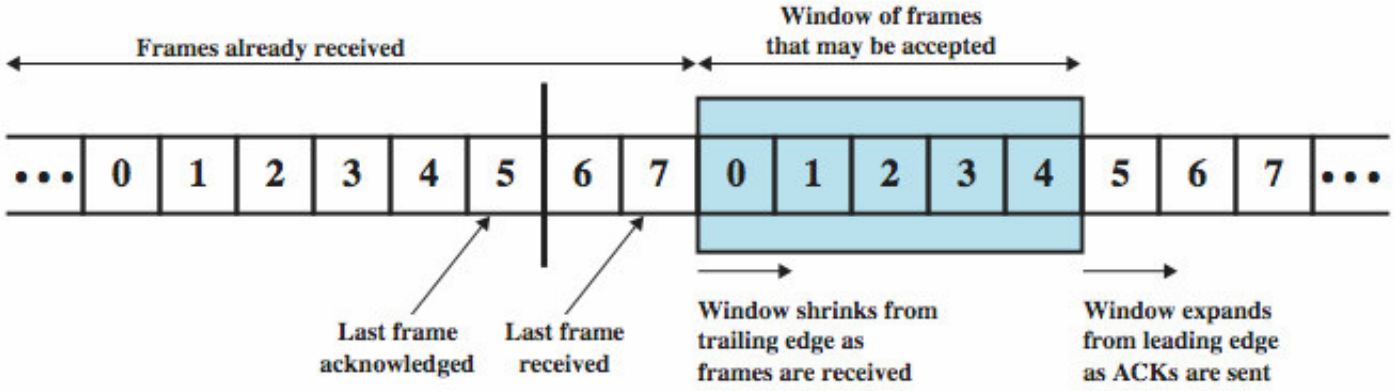
Resending Frames

Operation

Sliding Window Diagram

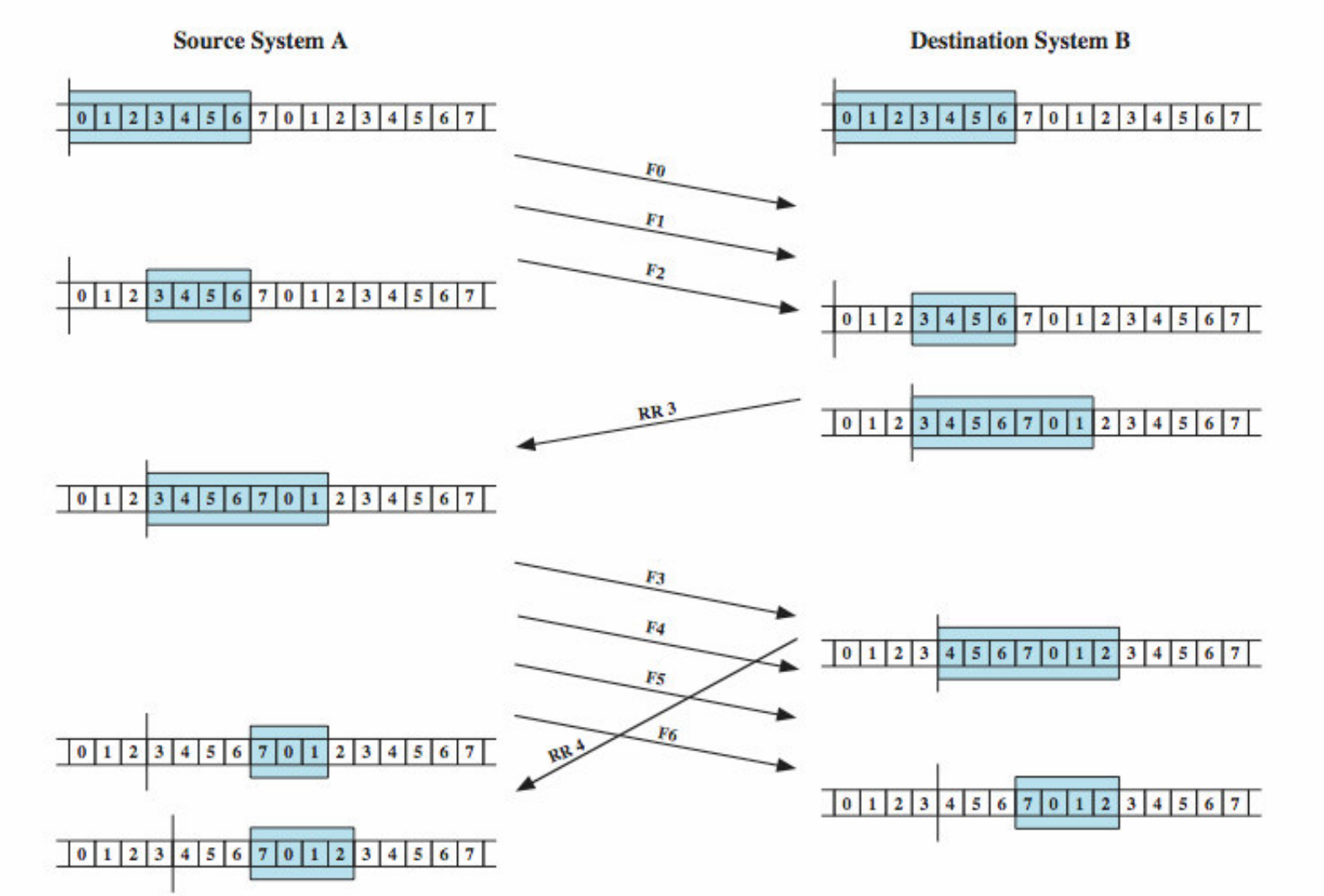


(a) Sender's perspective

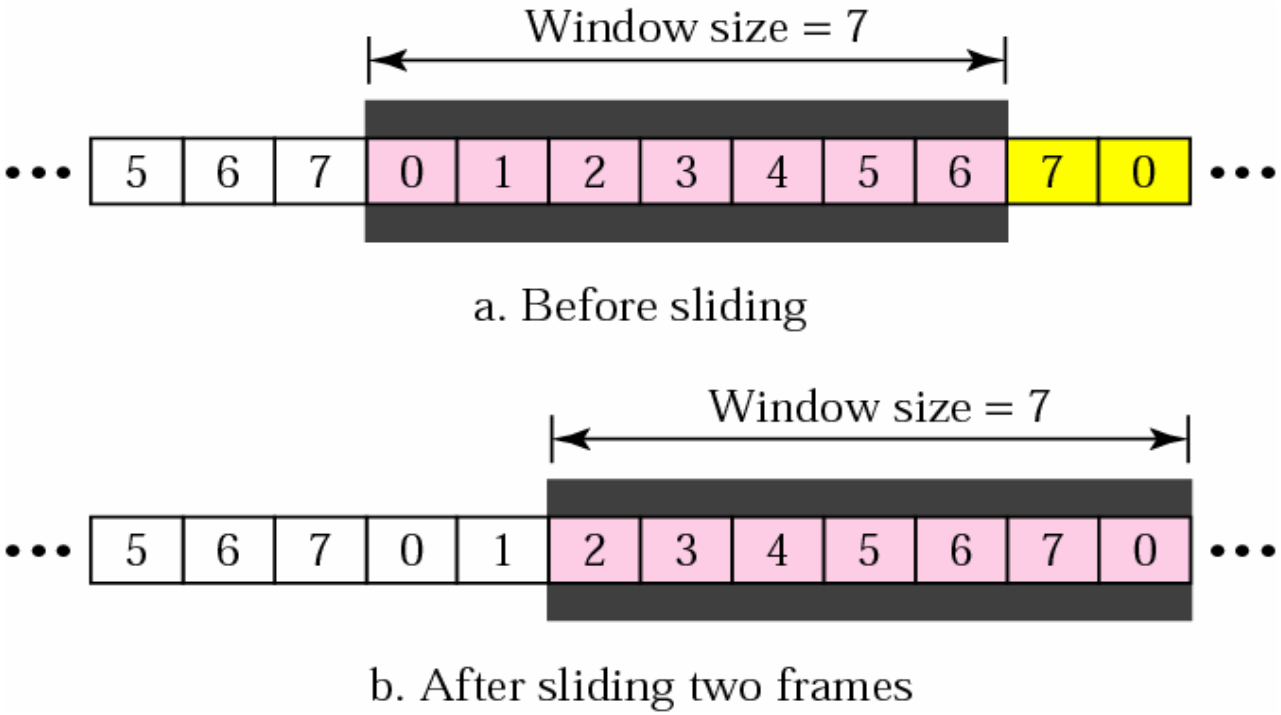


(b) Receiver's perspective

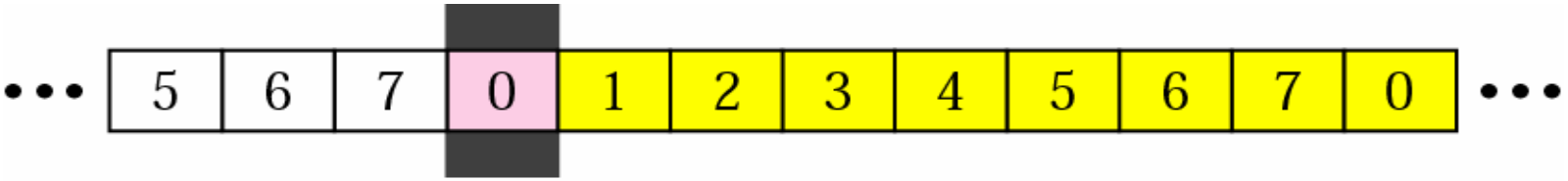
Sliding Window Example



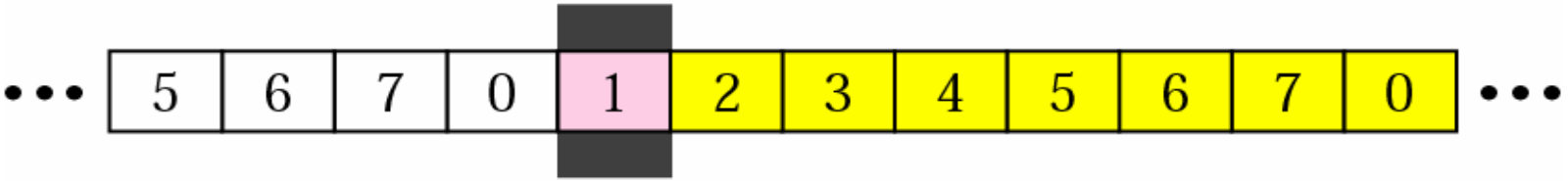
11.6 Sender sliding window



11.7 Receiver sliding window

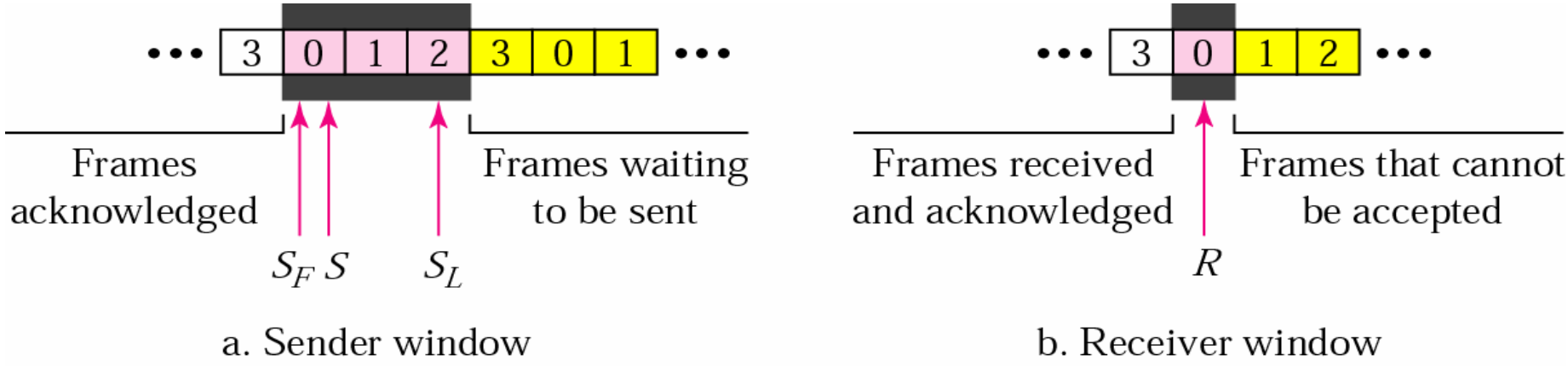


a. Before sliding

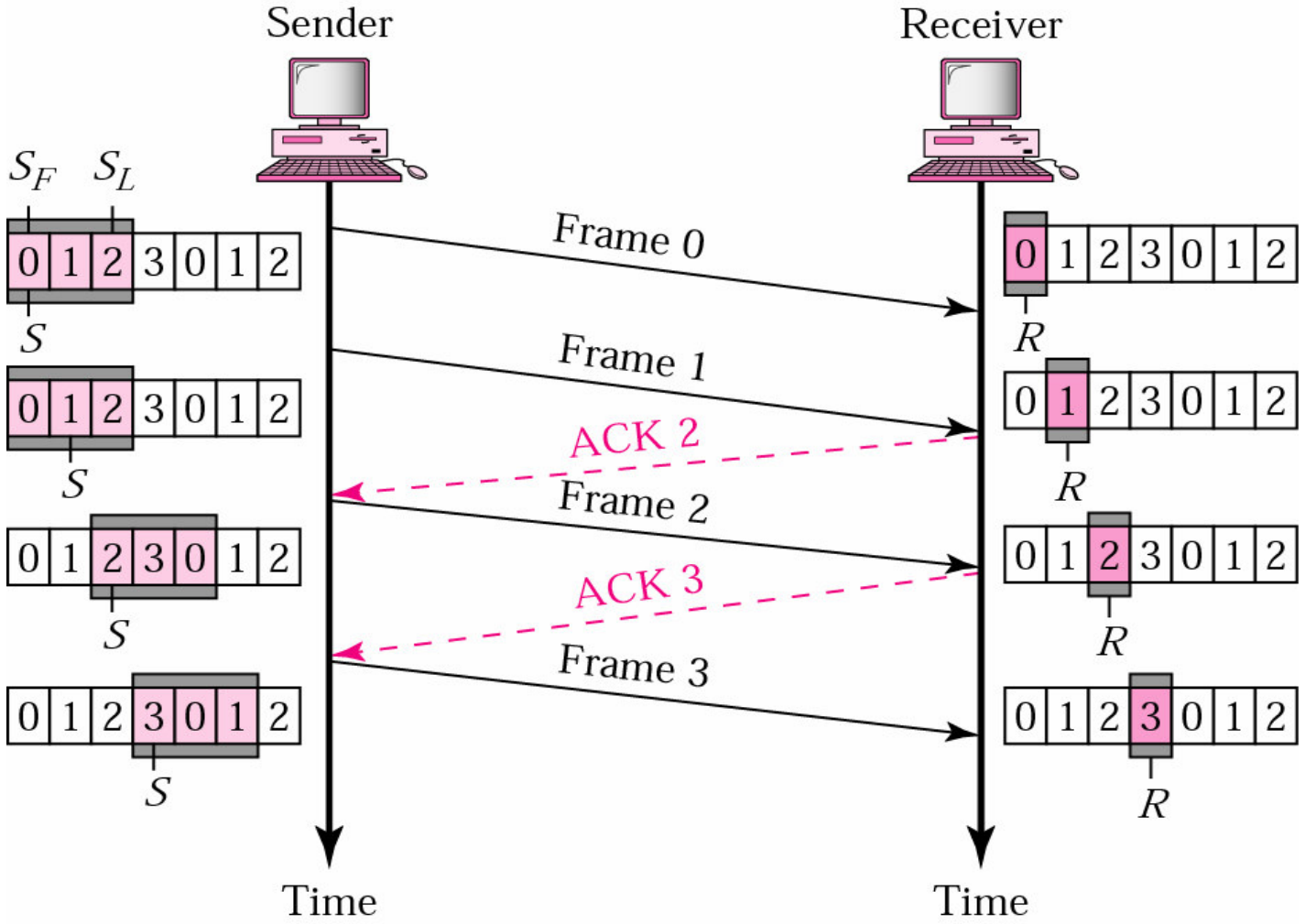


b. After sliding

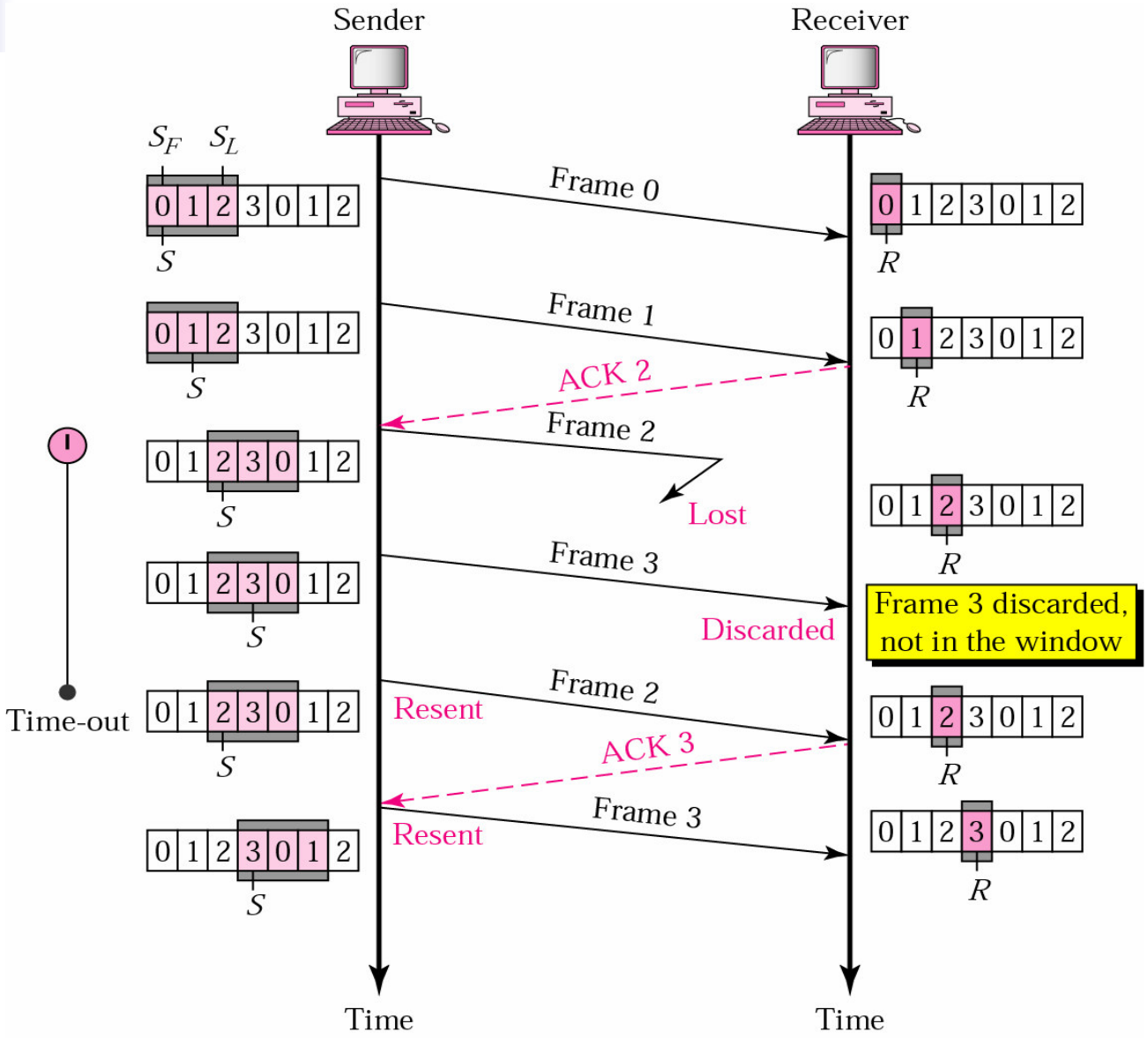
11.8 Control variables



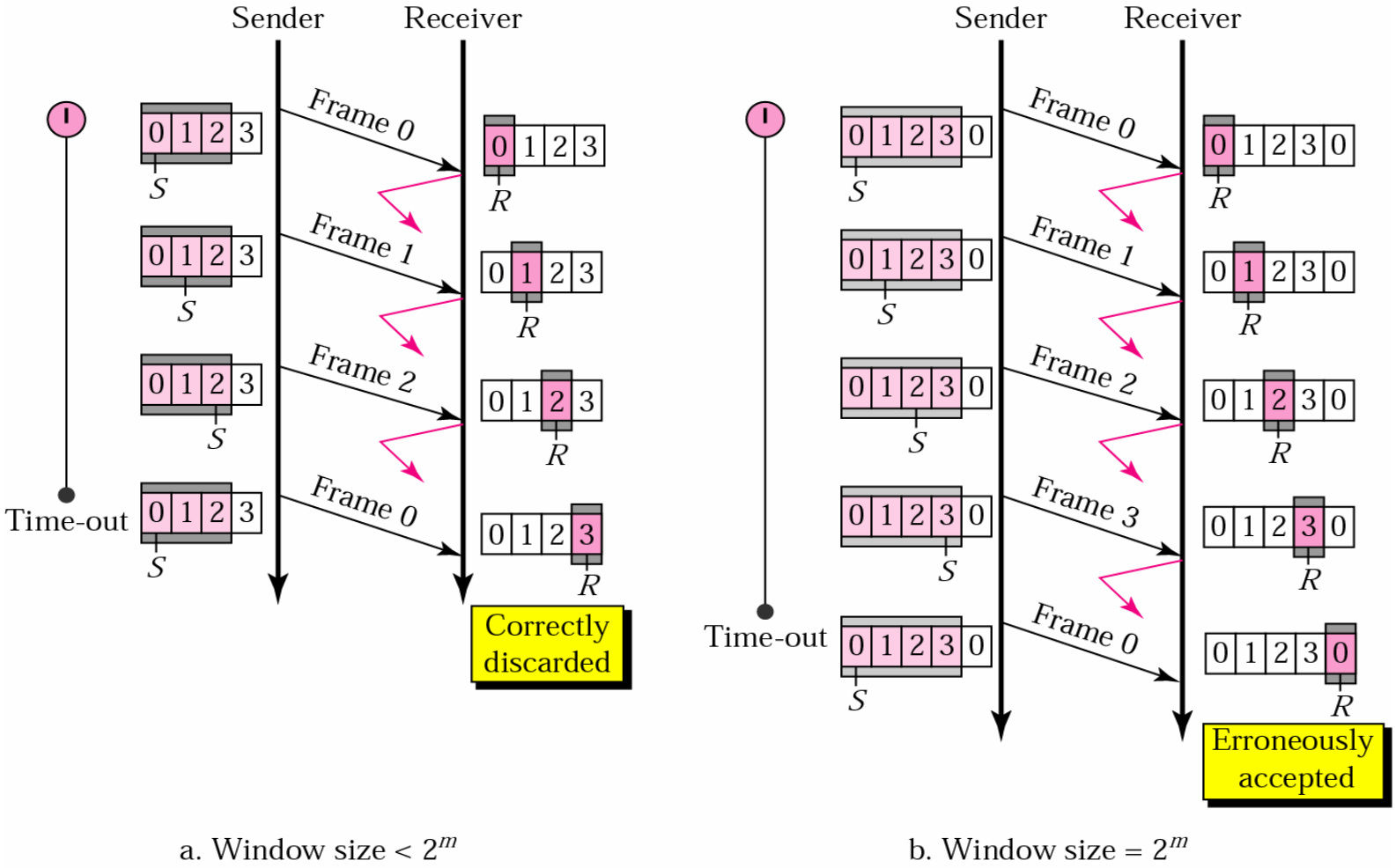
11.9 Go-Back-N ARQ, normal operation



11.10 Go-Back-N ARQ, lost frame



11.11 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.

11.4 Selective-Repeat ARQ

Sender and Receiver Windows

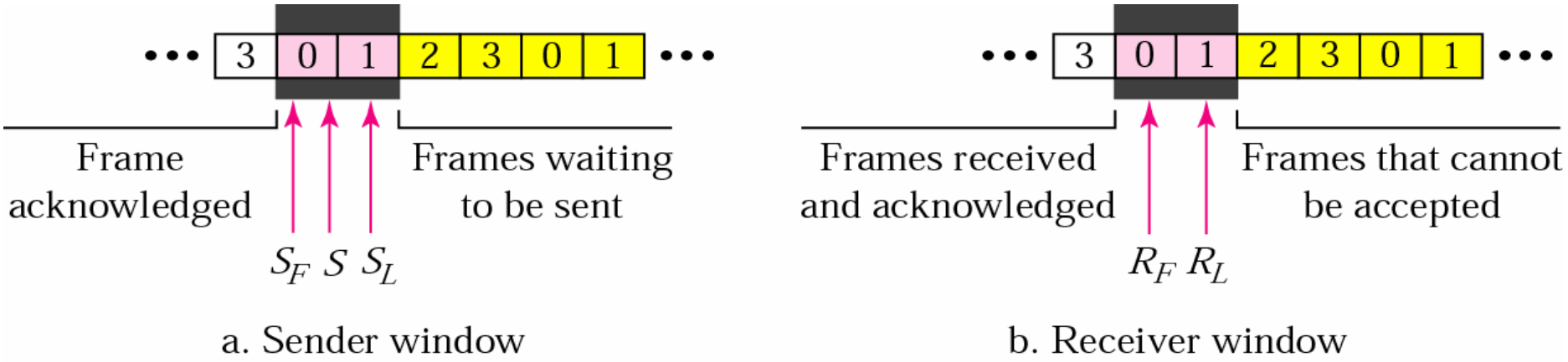
Operation

Sender Window Size

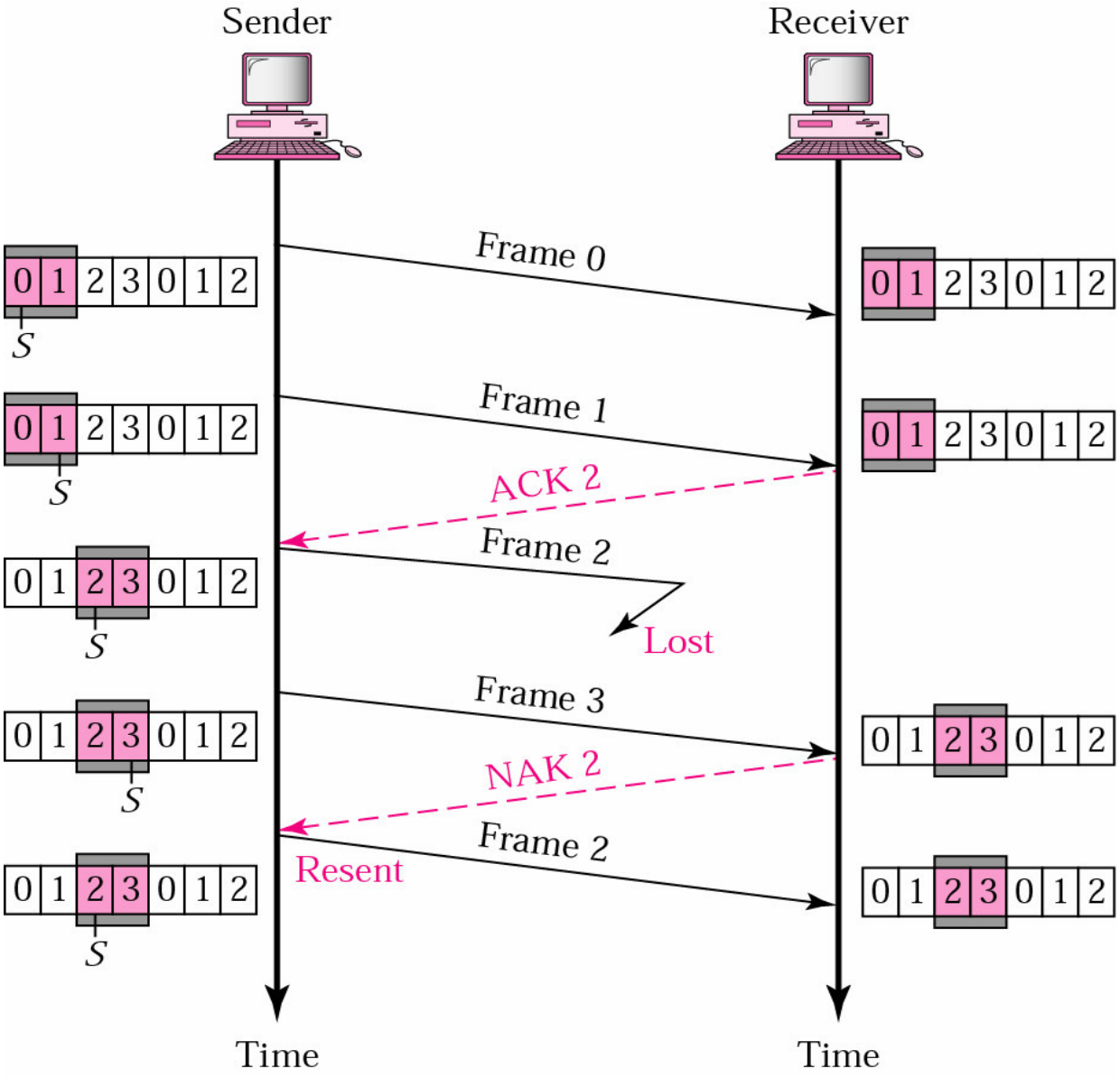
Bidirectional Transmission

Pipelining

11.12 Selective Repeat ARQ, sender and receiver windows



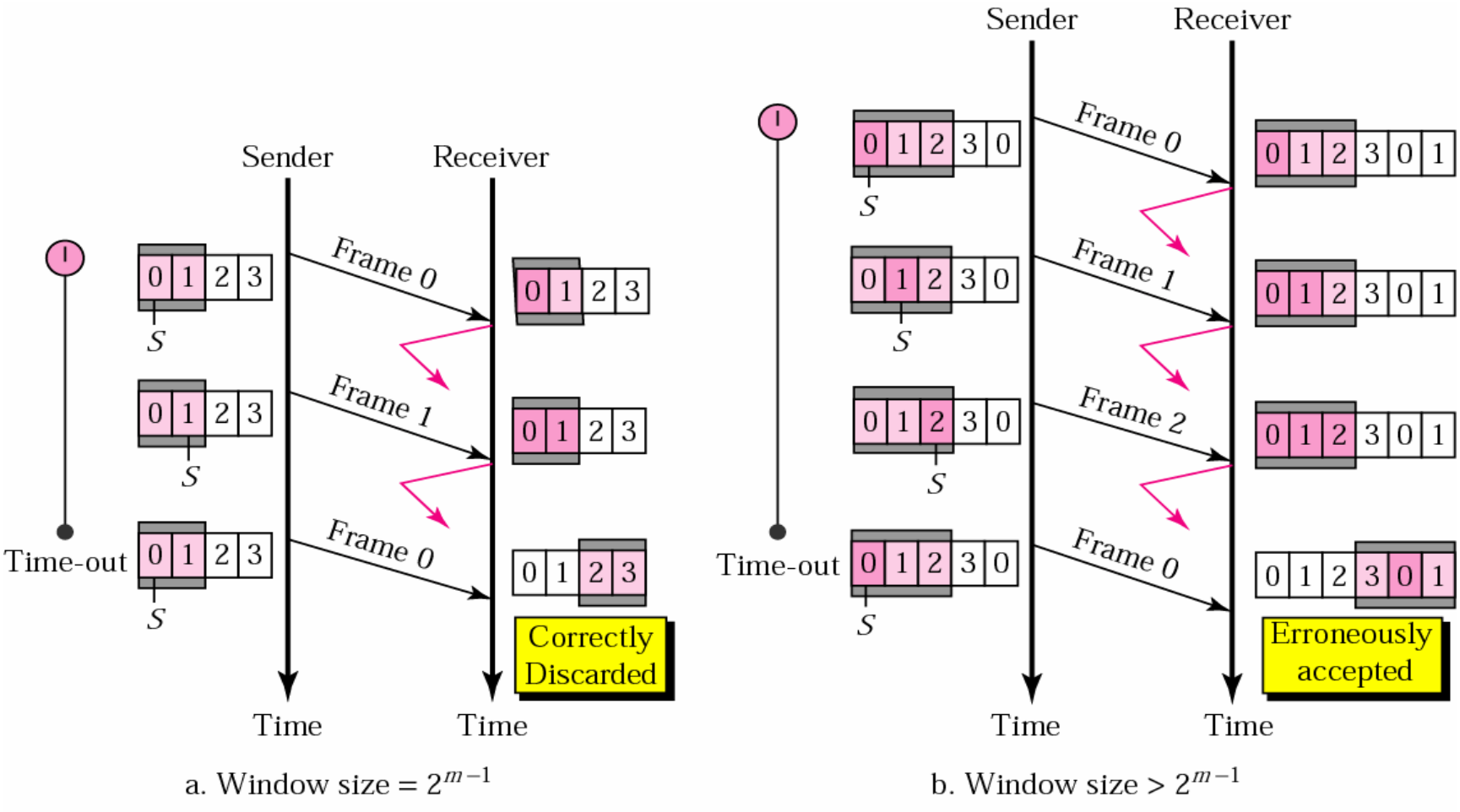
11.13 Selective Repeat ARQ, lost frame



Note:

In Selective Repeat ARQ, the size of the sender and receiver window must be at most one-half of 2^m.

11.14 Selective Repeat ARQ, sender window size



Example 1

In a Stop-and-Wait ARQ system, the bandwidth of the line is 1 Mbps, and 1 bit takes 20 ms to make a round trip. What is the bandwidth-delay product? If the system data frames are 1000 bits in length, what is the utilization percentage of the link?

Solution

The bandwidth-delay product is

$$1 \times 10^6 \times 20 \times 10^{-3} = 20{,}000 \text{ bits}$$

The system can send 20,000 bits during the time it takes for the data to go from the sender to the receiver and then back again. However, the system sends only 1000 bits. We can say that the link utilization is only 1000/20,000, or 5%. For this reason, for a link with high bandwidth or long delay, use of Stop-and-Wait ARQ wastes the capacity of the link.

Example 2

What is the utilization percentage of the link in Example 1 if the link uses Go-Back-N ARQ with a 15-frame sequence?

Solution

The bandwidth-delay product is still 20,000. The system can send up to 15 frames or 15,000 bits during a round trip. This means the utilization is 15,000/20,000, or 75 percent. Of course, if there are damaged frames, the utilization percentage is much less because frames have to be resent.