Data Link Control Protocols

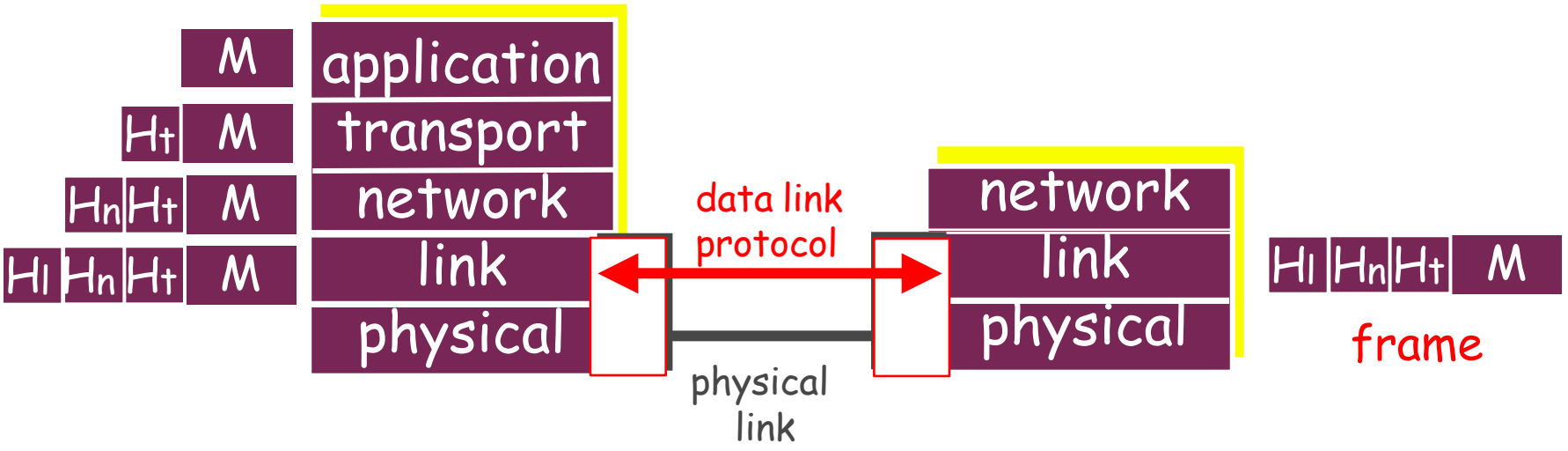
EE450: Introduction to Computer Networks

Professor A. Zahid

Data Link Layer

- Two physically connected devices:
  - Host-Router, Router-Router, Router-Host

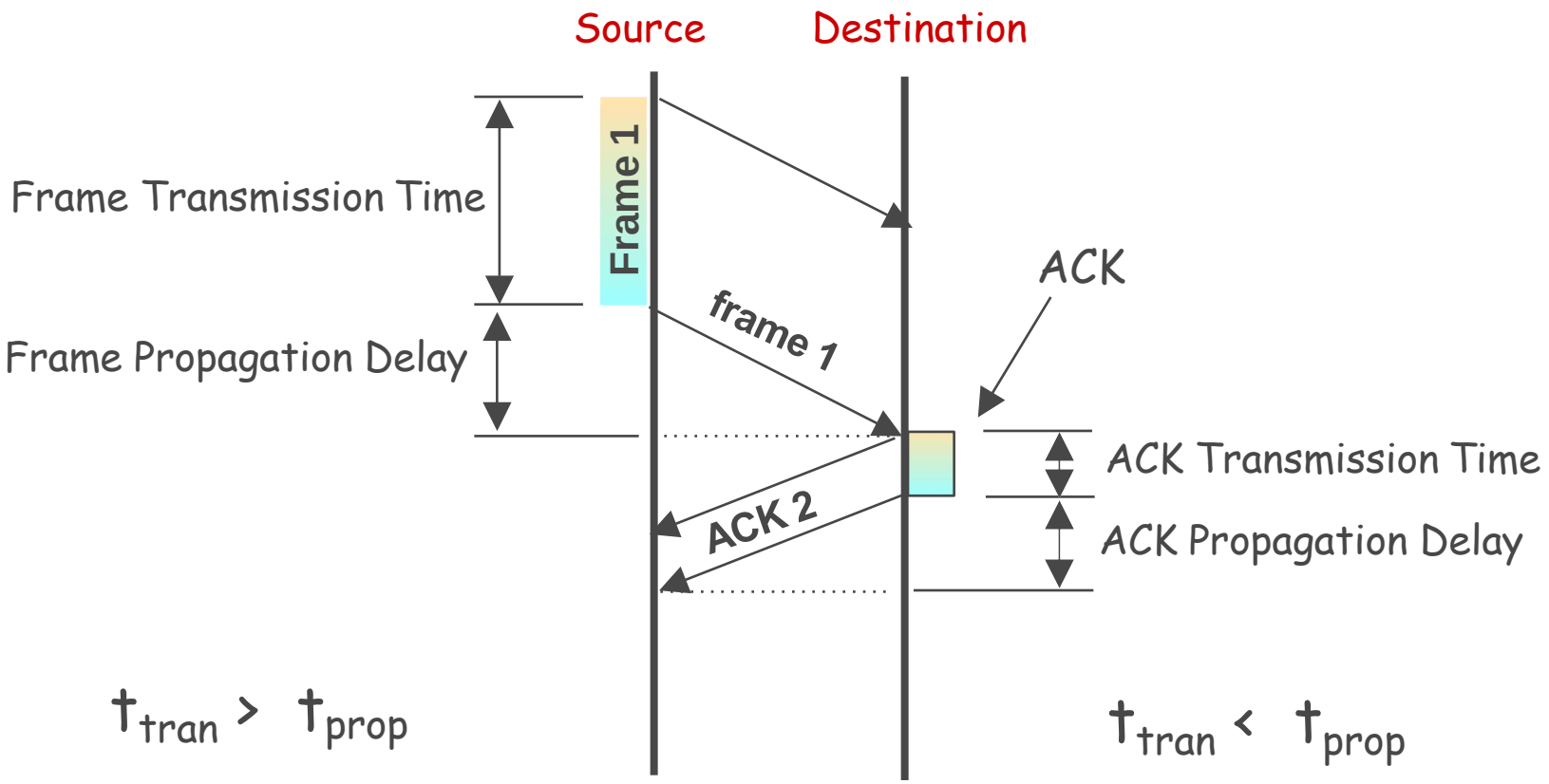
- Unit of data: frame



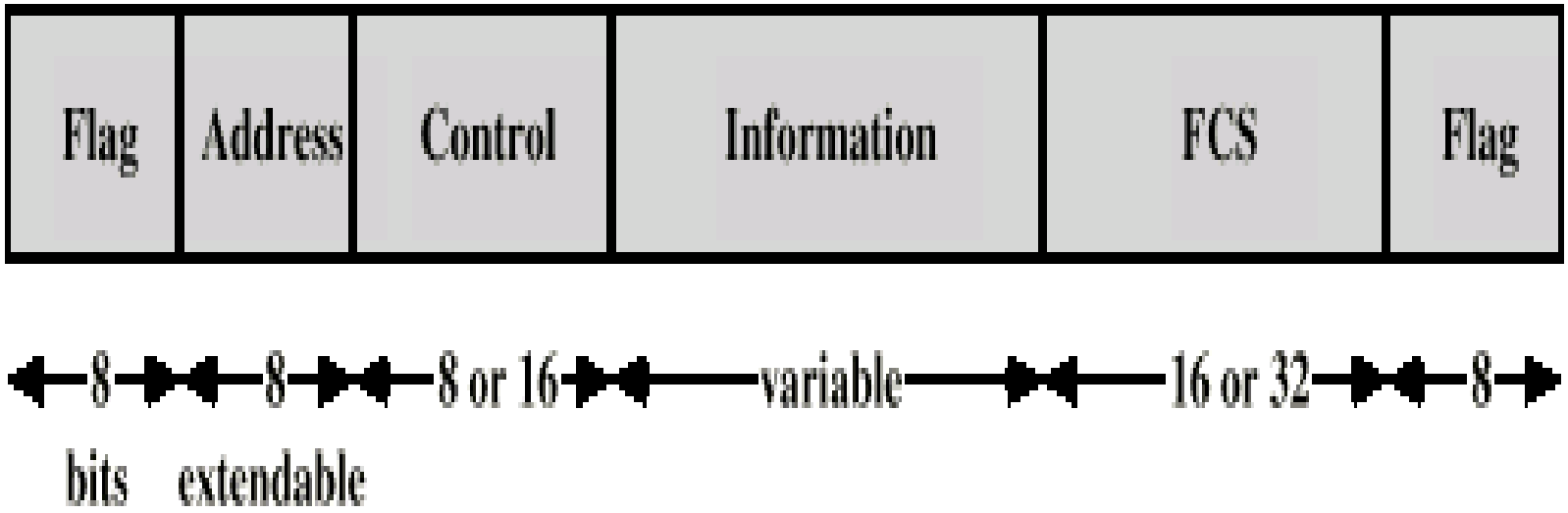
Data Link Layer Services

- Framing
  - Encapsulate packet into frame, adding header/trailer
  - Establish frame synchronization
- Error Detection & Control
  - Errors caused by signal attenuation, noise.
  - Receiver detects presence of errors:
    - Receiver drops frame
    - Receiver requests retransmission (ARQ)
- Flow Control
  - Ensuring the sender does not overwhelm the receiver (i.e., preventing buffer overflow)

Frame Transmission Model



Typical Frame Structure

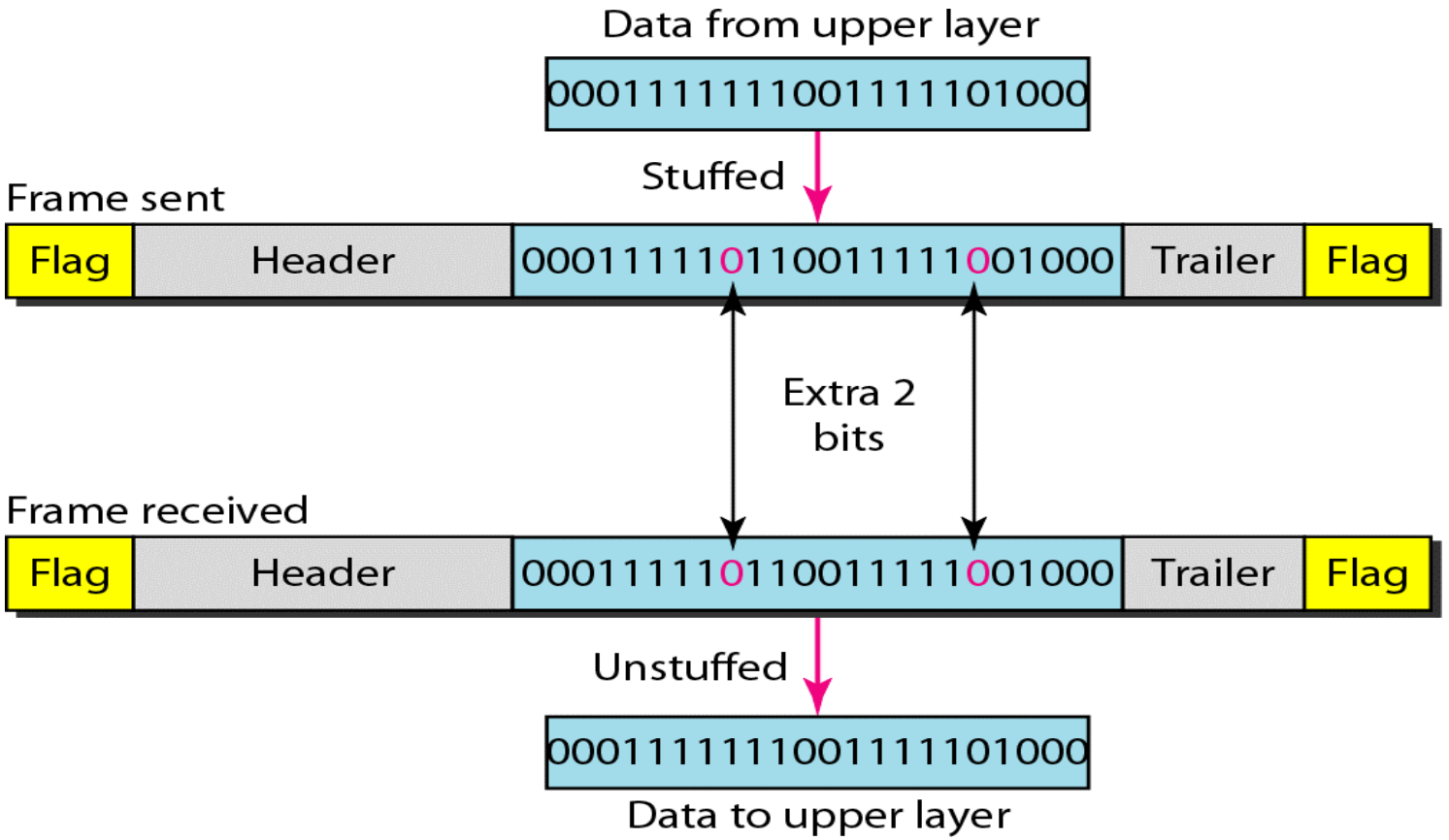


We shall see that the above structure does not work in a Multipoint link (like in LANs)

Frame Synchronization

- A special pattern, called a Flag (01111110) appears at the beginning and the end of the frame
- Receiver hunts for flag sequence to synchronize
- **Bit stuffing** used to avoid confusion with data containing 01111110
  - 0 inserted after every sequence of five 1s
  - If receiver detects five 1s it checks next bit
  - If 0, it is deleted
  - If 1 and seventh bit is 0, accept as flag
  - If sixth and seventh bits 1, sender is indicating abort

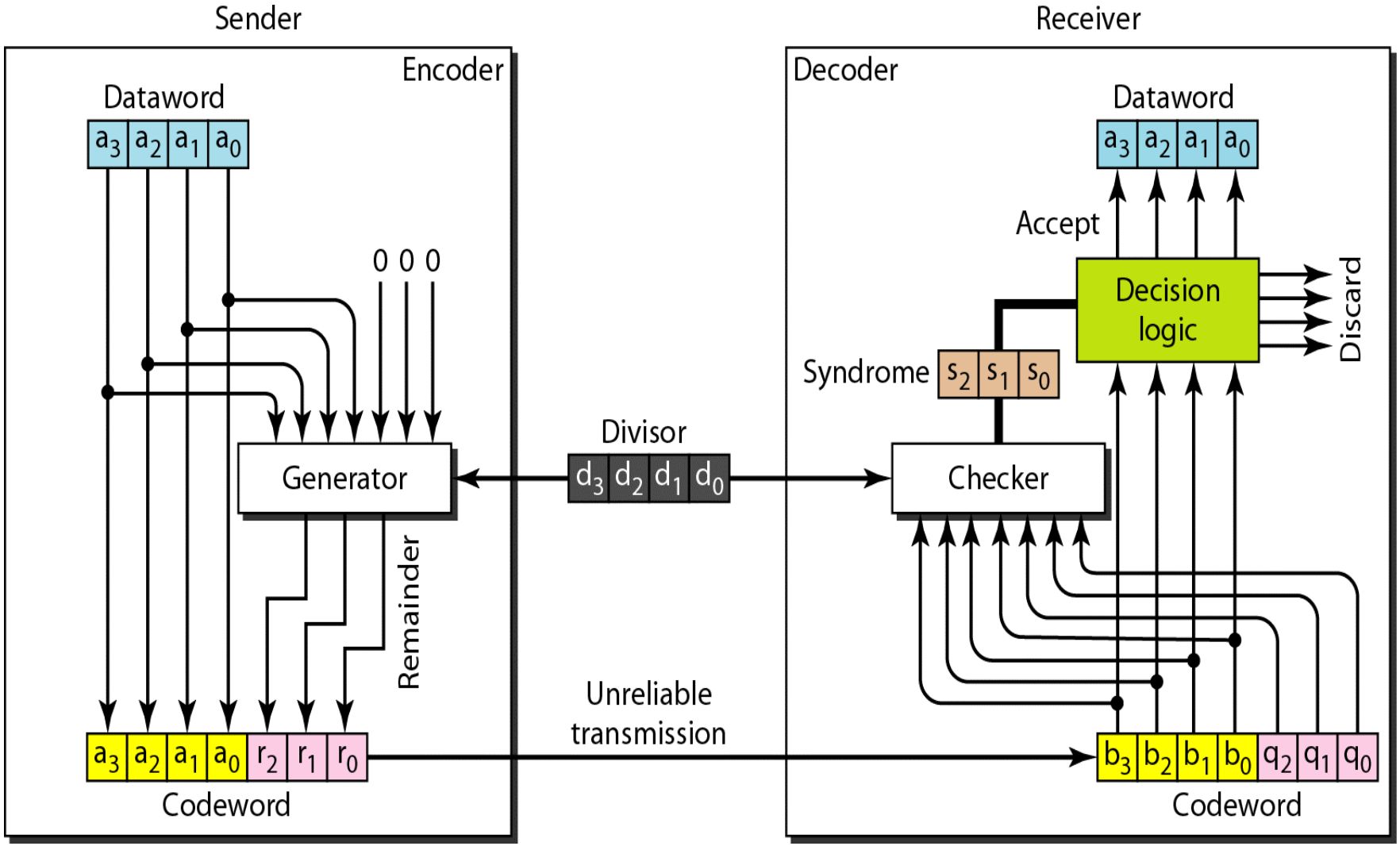
Bit Stuffing and un-Stuffing



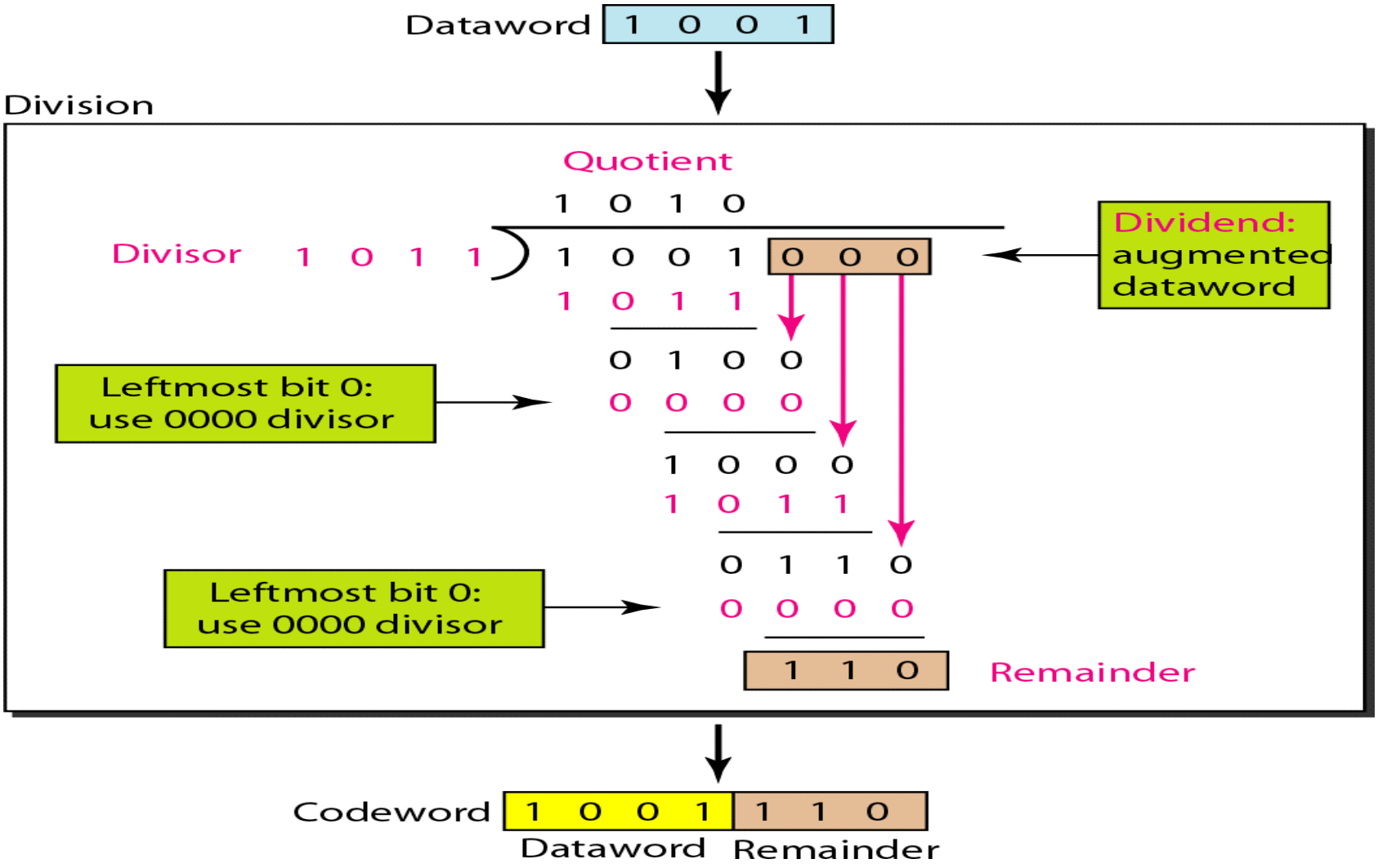
Error Detection: Frame Check Sequence

- Additional bits added by transmitter for error detection purposes at receiver
- For every block of k bits, transmitter generates n bit sequence
- Transmit k+n bits which is exactly divisible by some number
- Receive divides frame by that number
  - If no remainder, assume no error
  - If reminder, an error is detected

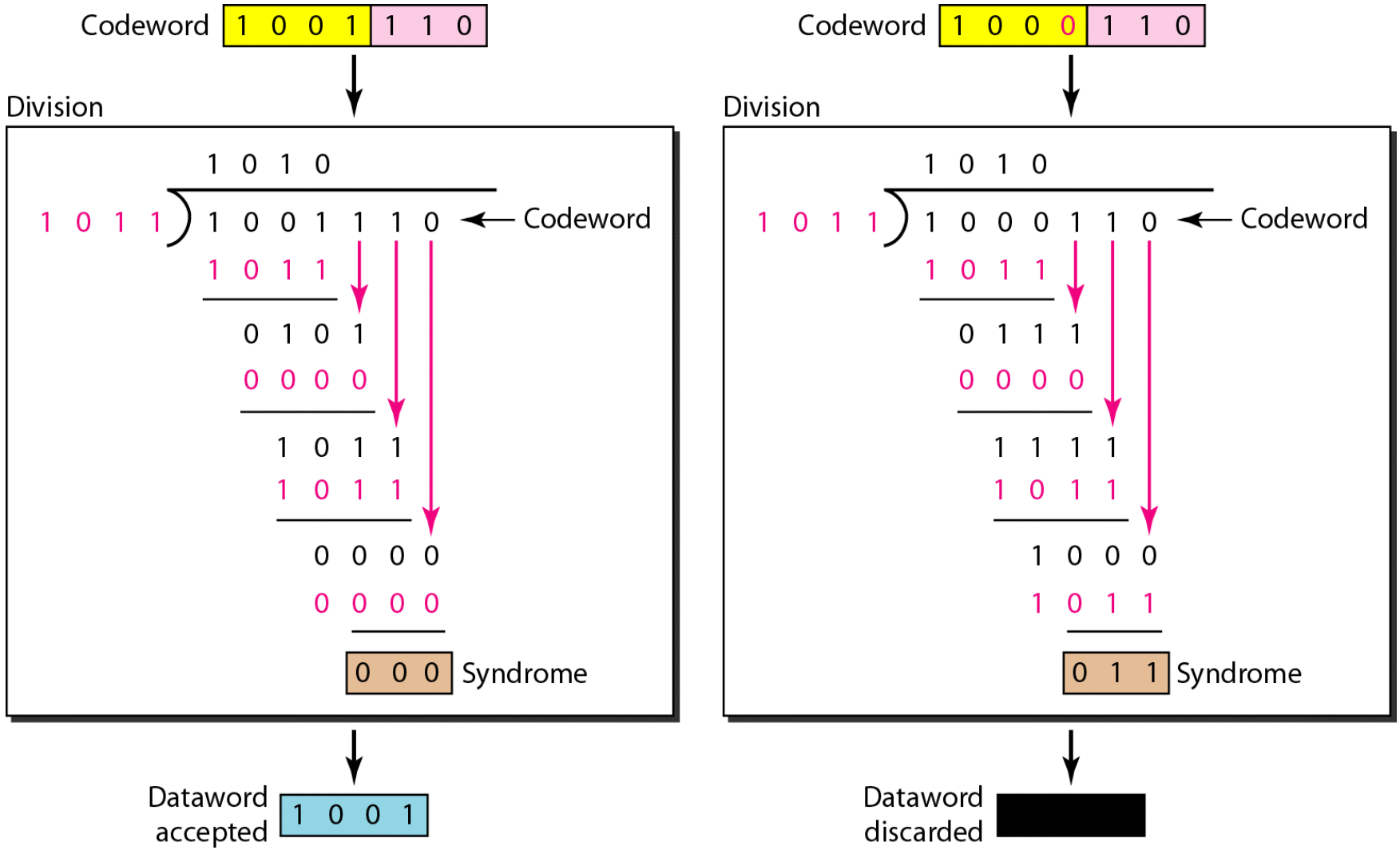
FCS Structure



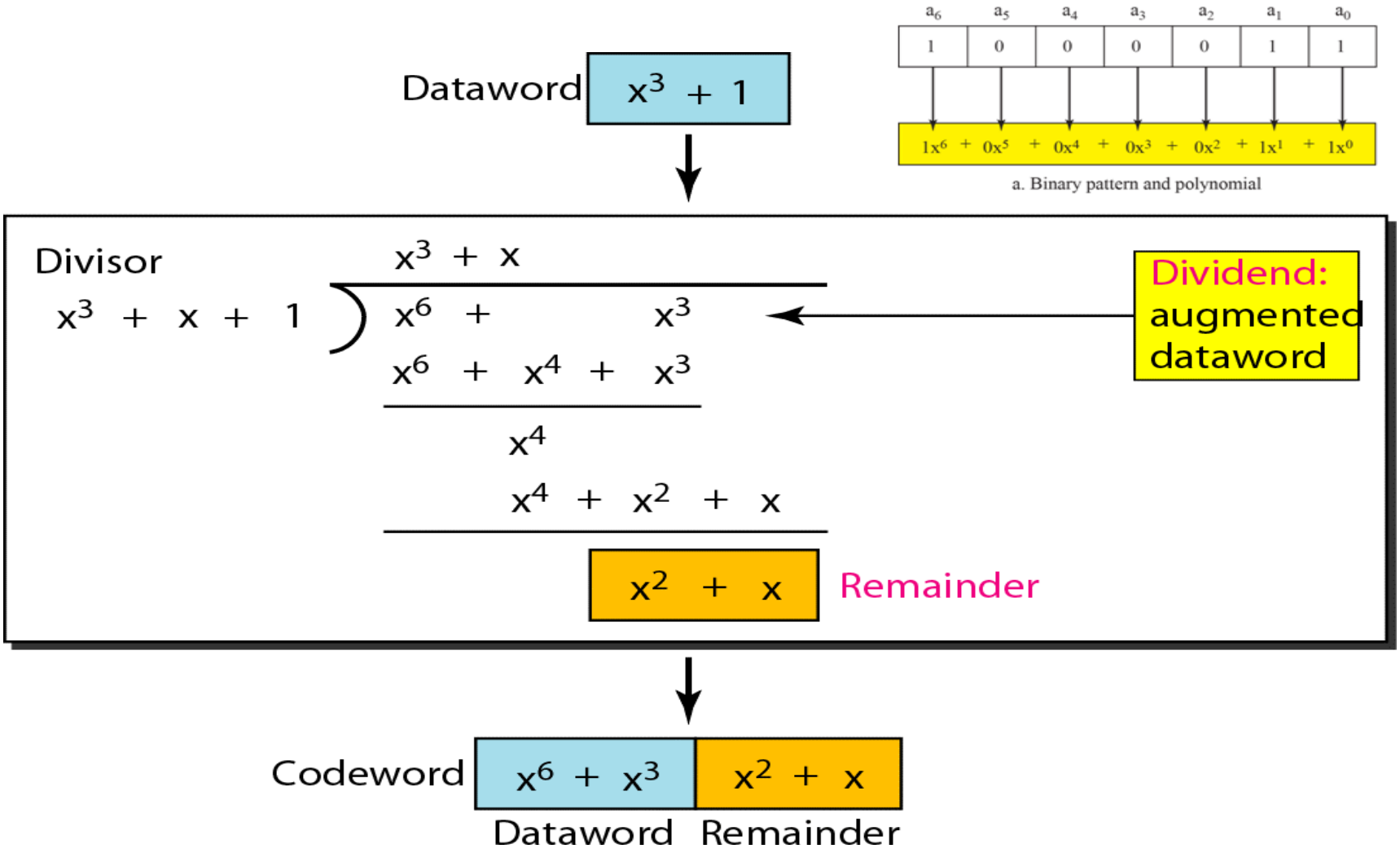
Example of FCS (CRC)



FCS (error-free and w/errors)



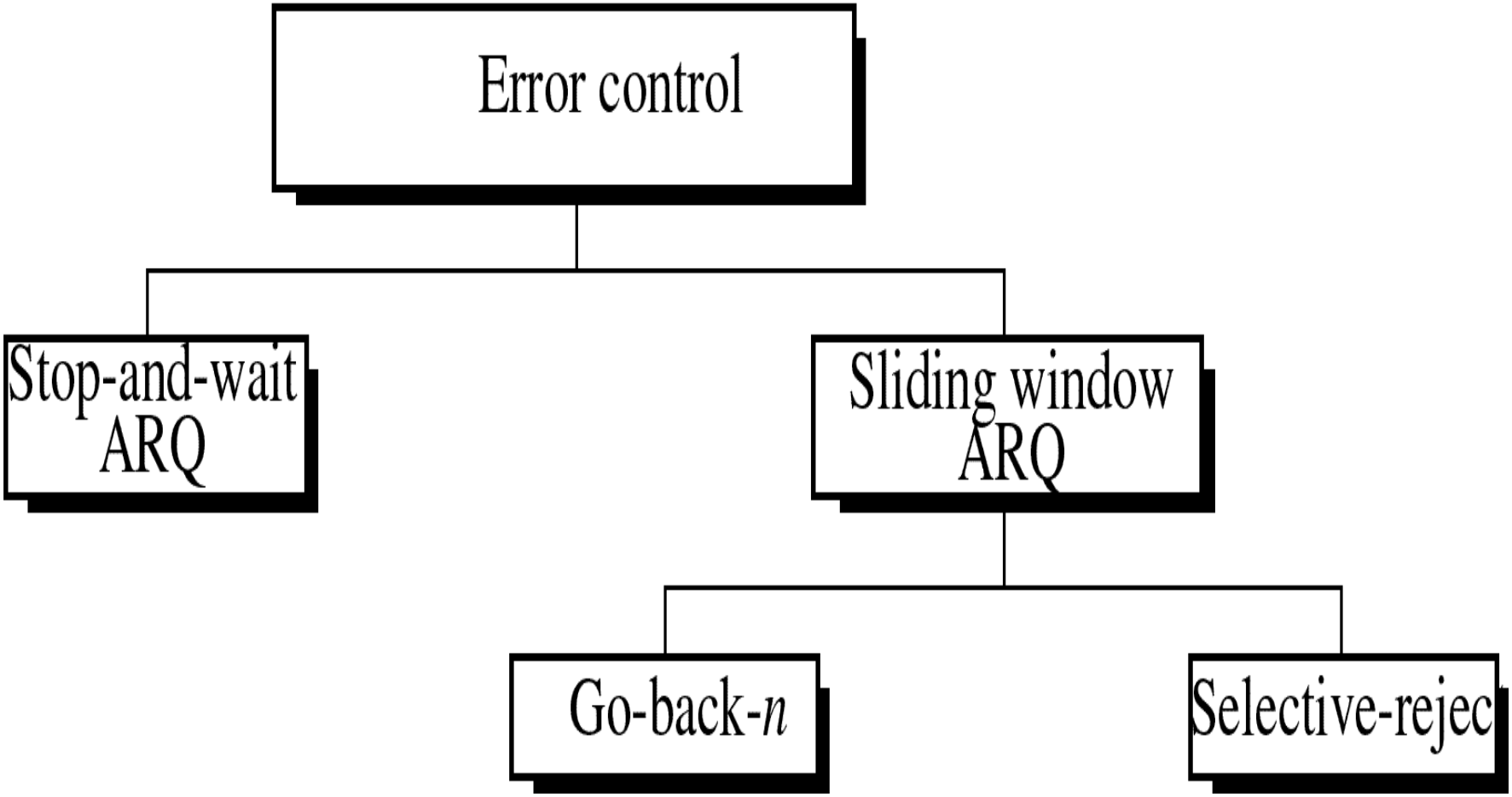
FCS using Polynomials



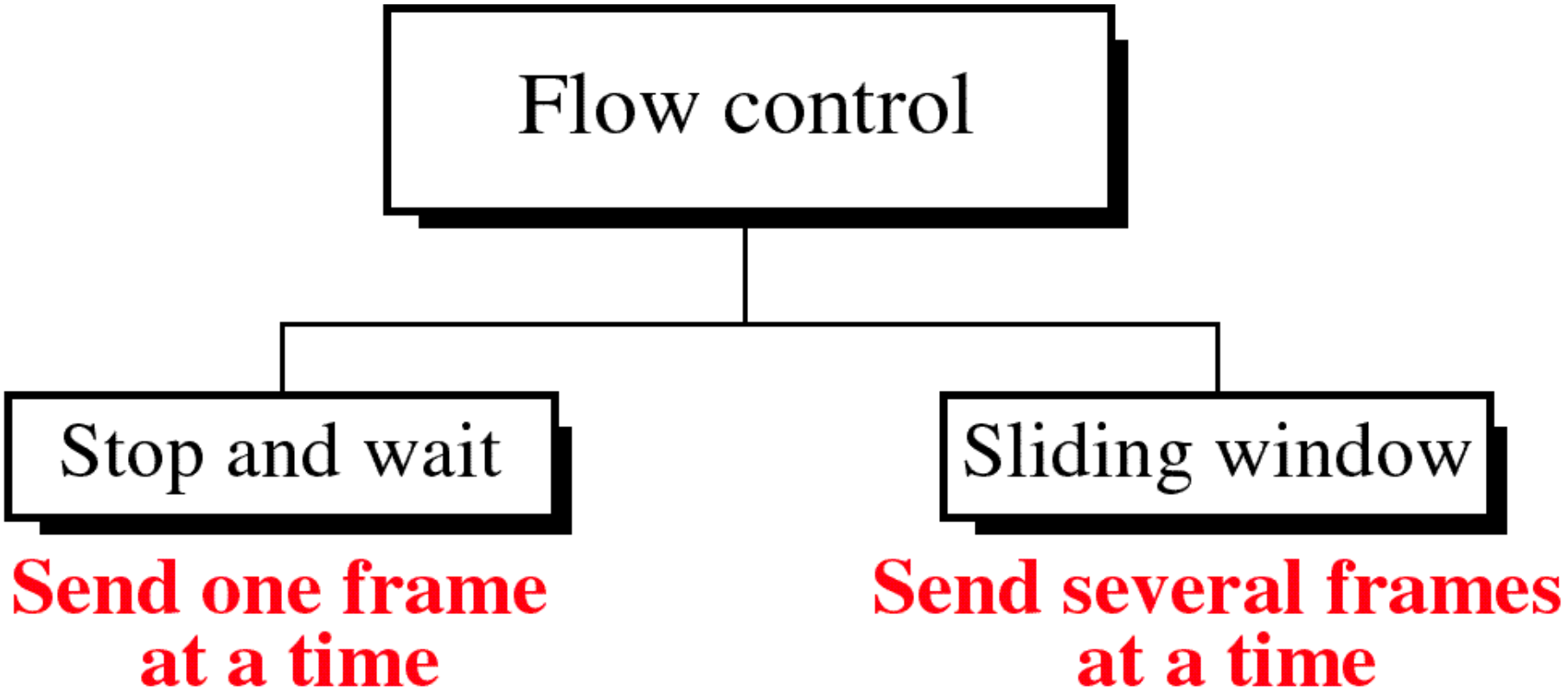
Receiver Rules

- If the reminder is not zero, then one or more bits are corrupted and the frame is rejected
- If the remainder is 0, then
  - No bits are corrupted or
  - Some bits are corrupted but the FCS decoder failed to detect them

Error Control Procedures



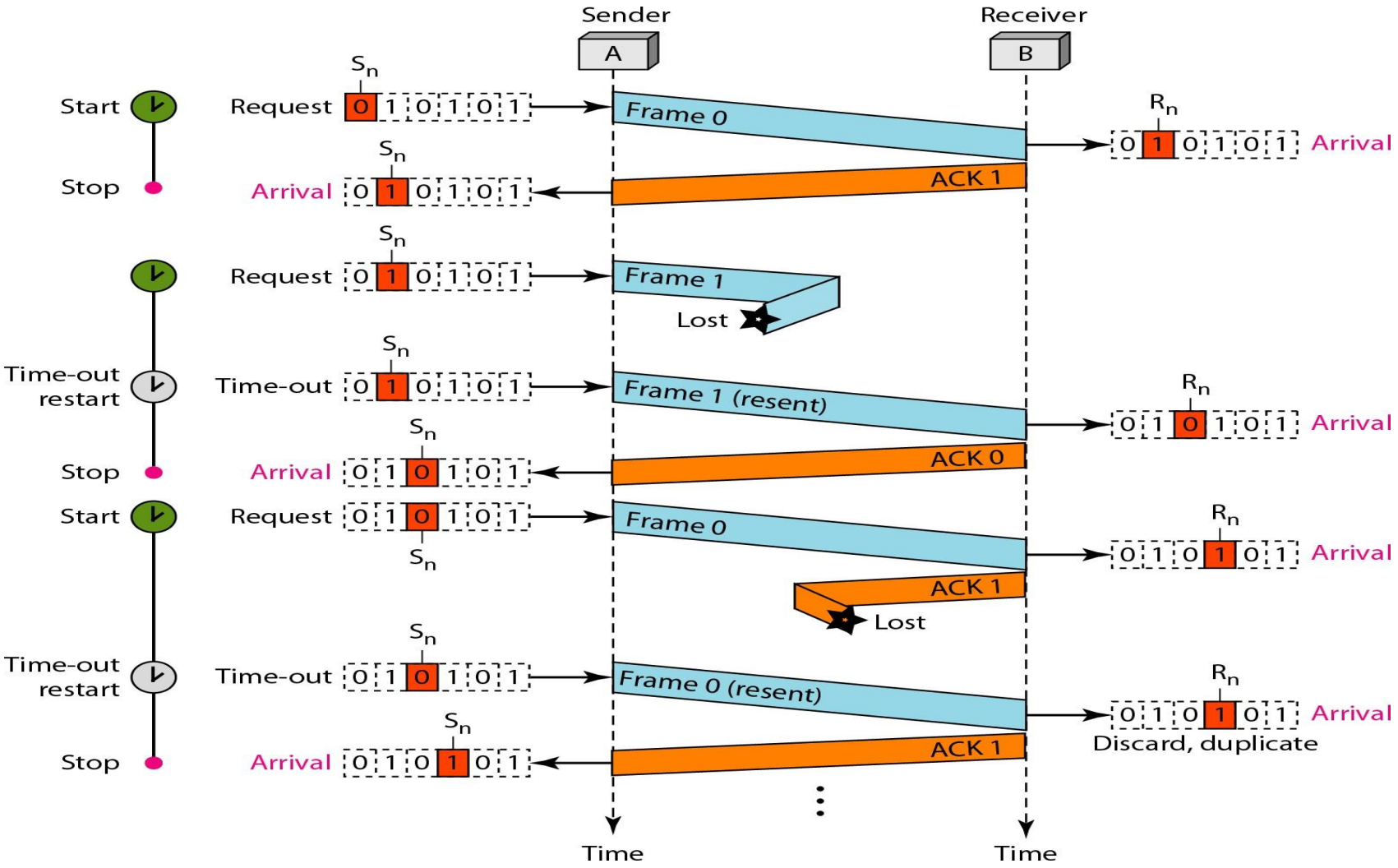
Flow Control Procedures



Stop and Wait ARQ

- Source transmits a single frame at a time
- Wait for ACK
- If received frame damaged, discard it
  - Transmitter has timeout timer
  - If no ACK within t_{out} = timeout, retransmit frame
  - Transmitter buffers copy of frame until ACK is received
- If ACK damaged, transmitter will not recognize it
  - Transmitter will retransmit
  - Receiver gets two copies of frame and discards one.
  - Use ACK_0 (recv'd frame 1) and ACK_1 (recv'd frame 0)

Stop & Wait ARQ



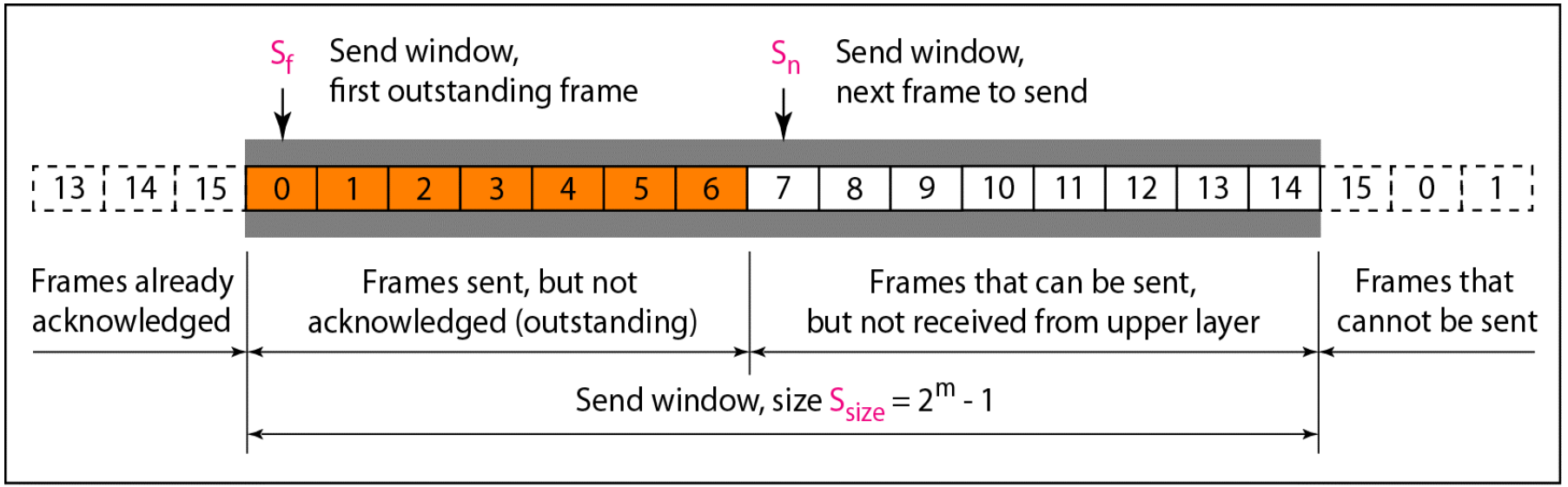
Link Utilization is Stop & Wait ARQ

- Link Bandwidth: 1 Mbps
- RTT: 20 msec
- Frame Length: 1000 bits
- BW x Delay Product = 20000 bits = 20 frames
- Sender can ONLY send 1 frame during RTT
- Hence Link Utilization is 5%
- Really Bad!

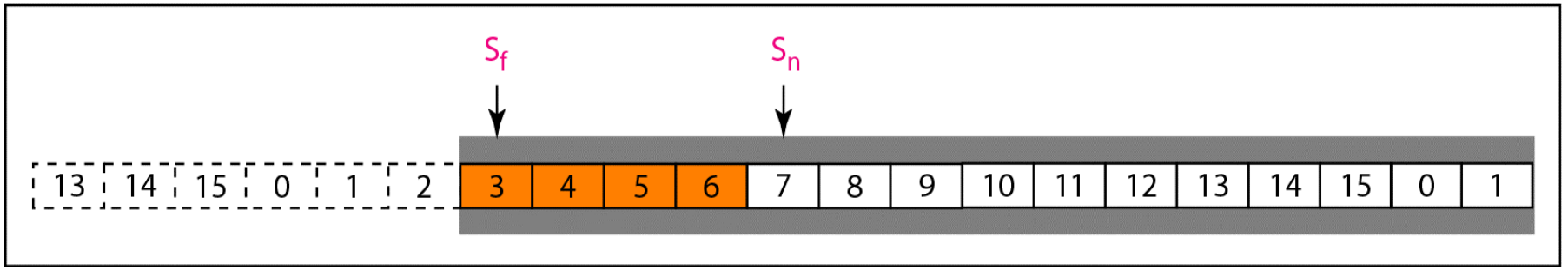
Go-Back-N ARQ

- Based on sliding window Protocol
- 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

Sending Window in Go-Back-N ARQ

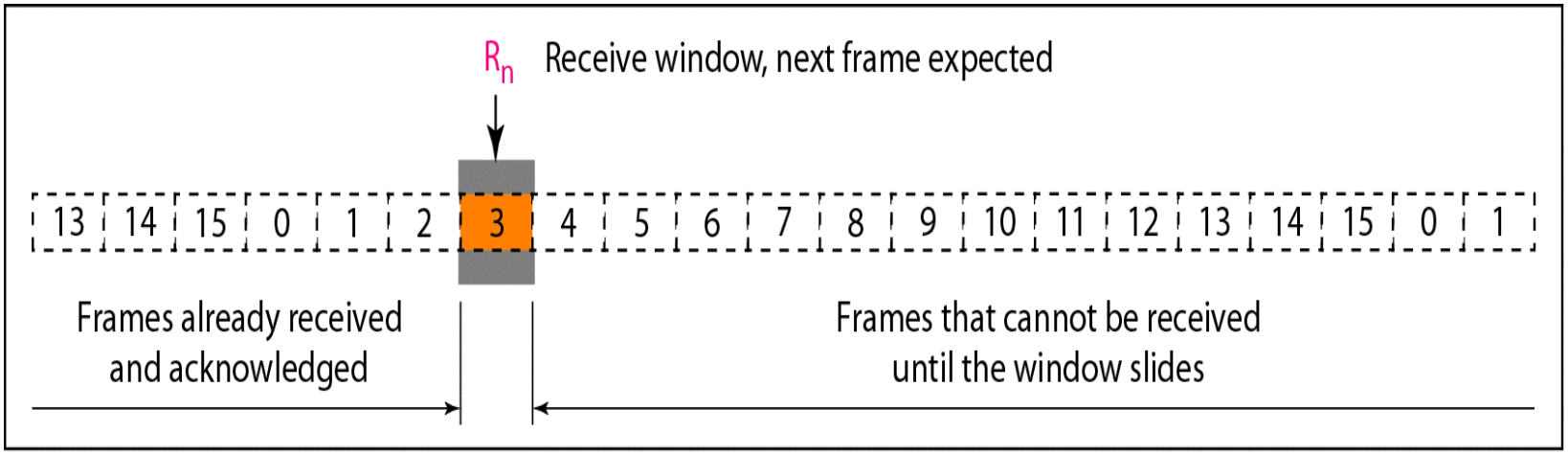


a. Send window before sliding

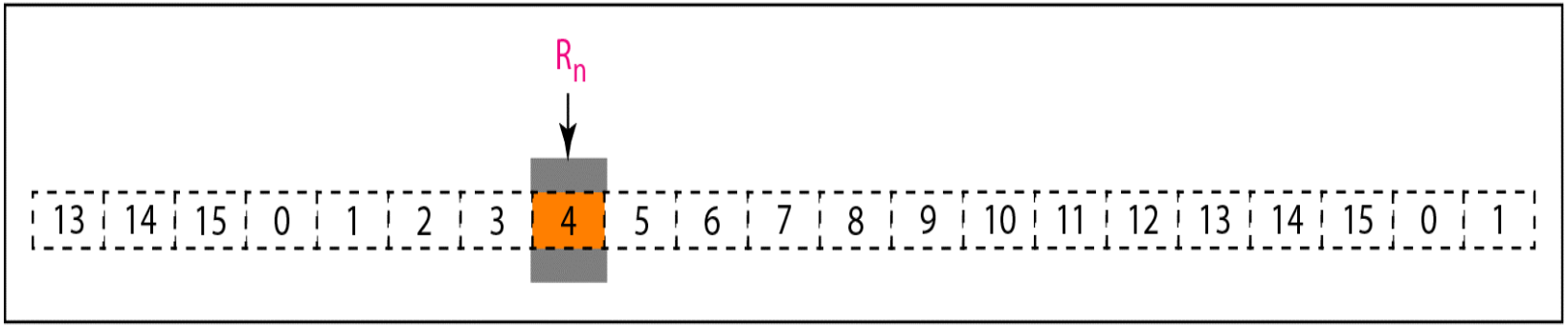


b. Send window after sliding

Receiver Window in Go-Back-N ARQ

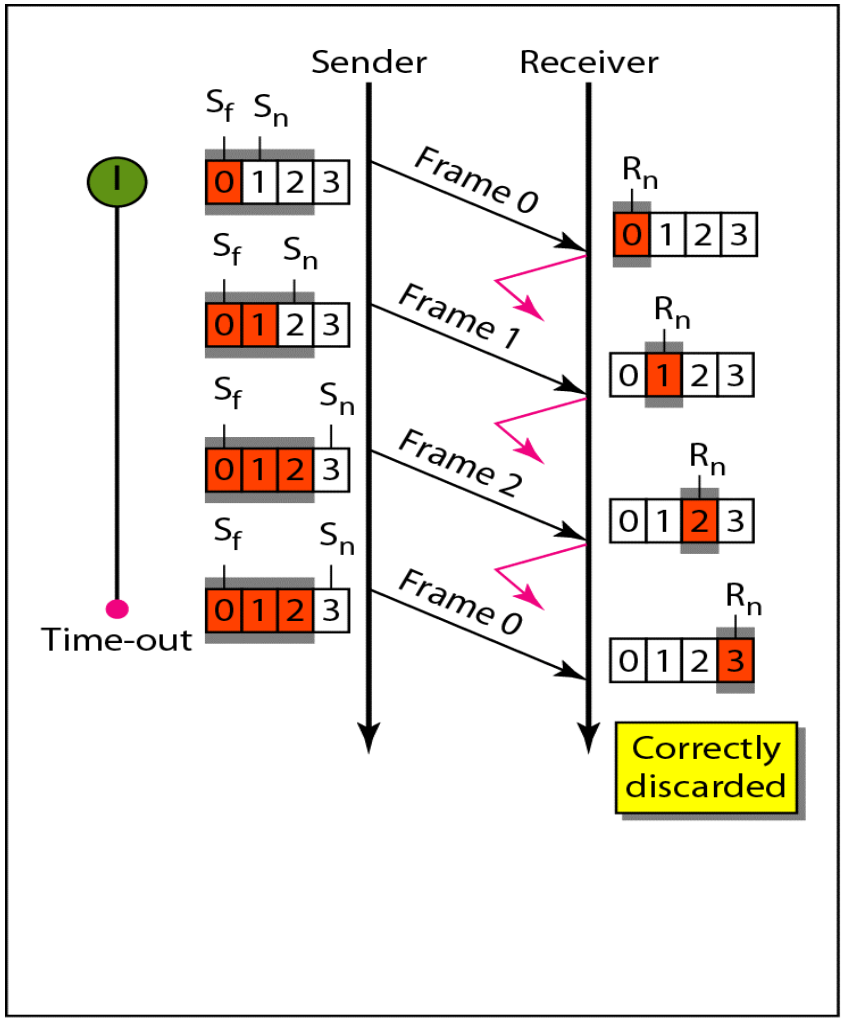


a. Receive window

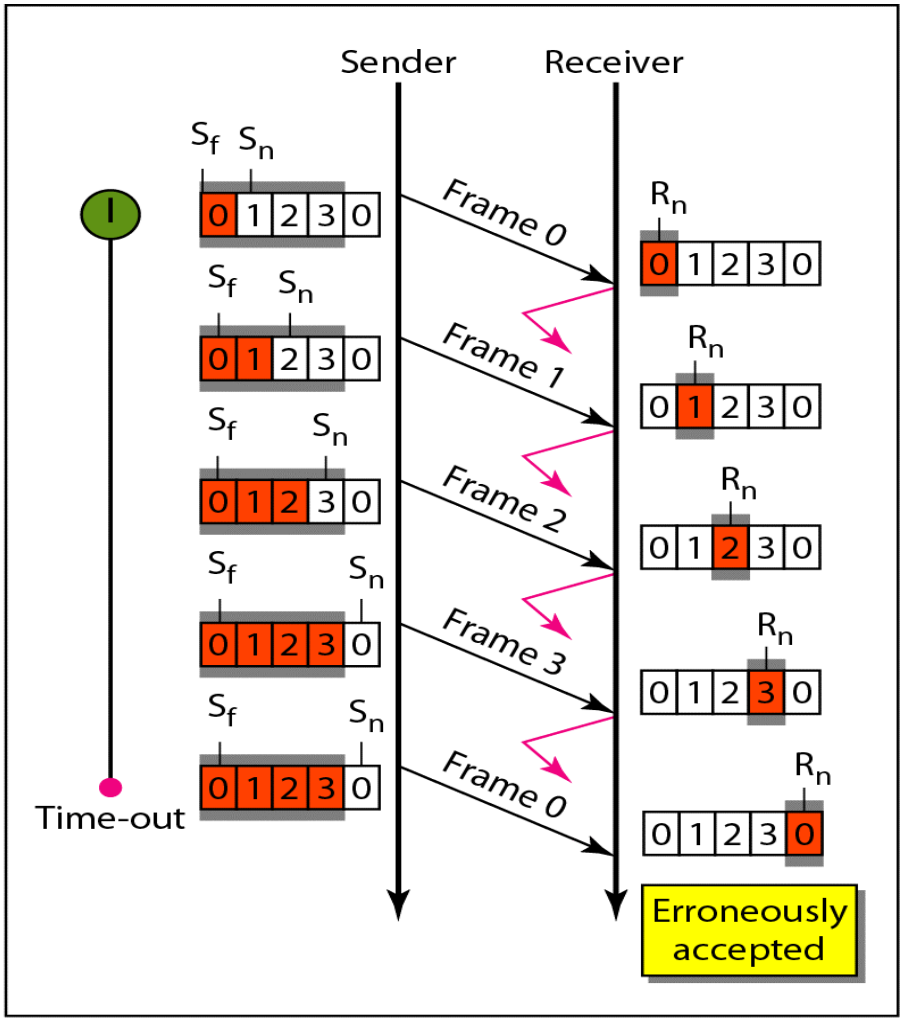


b. Window after sliding

Window Size in Go-Back-N ARQ



a. Window size $< 2^m$

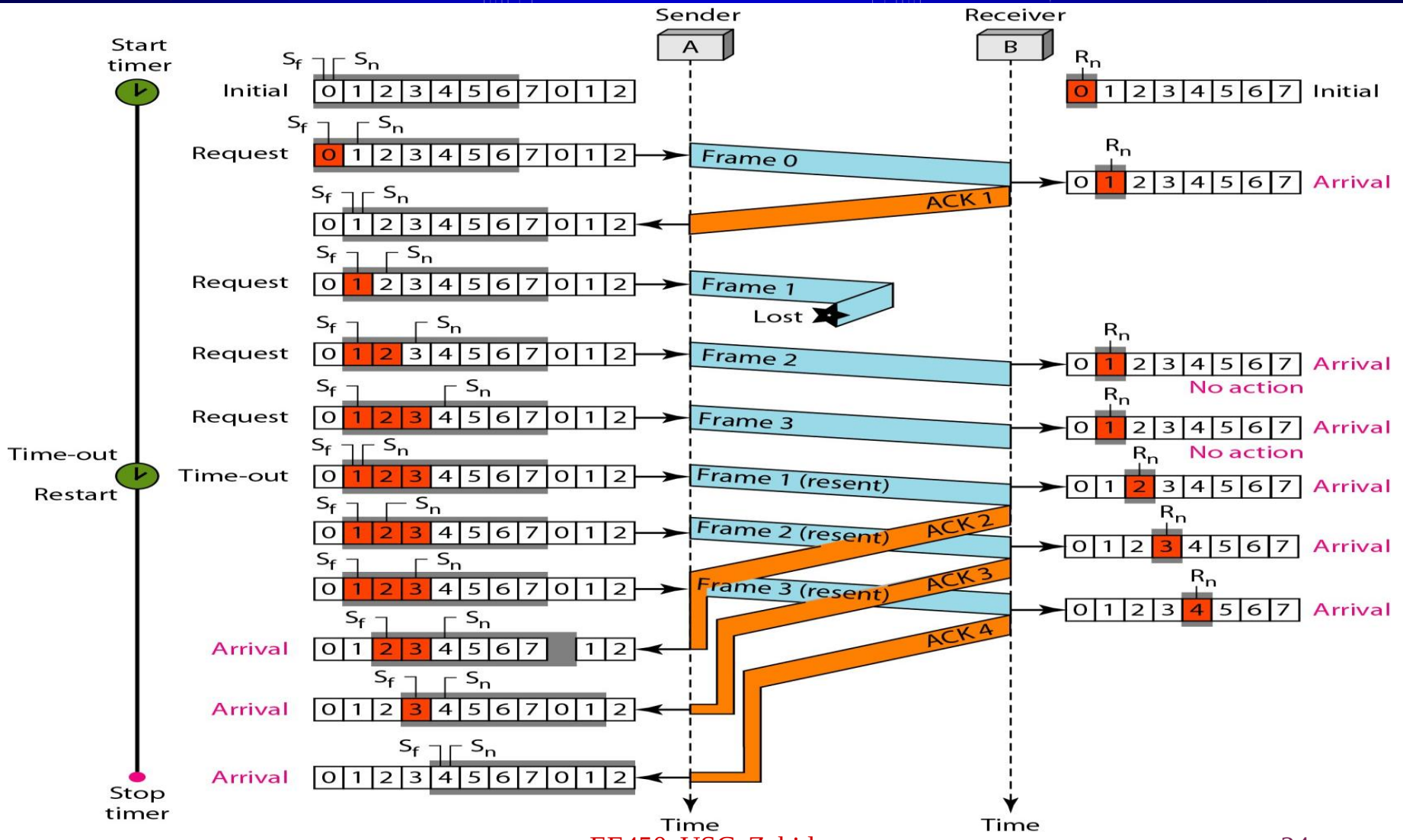


b. Window size $= 2^m$

Summary Notes for Go-Back-N ARQ

- In the Go-Back-N Protocol, the sequence numbers are modulo 2^m, where m is the size of the sequence number field in bits.
- The send window can slide one or more slots when a valid acknowledgment arrives.
- In Go-Back-N ARQ, the size of the send window must be less than 2^m; the size of the receiver window is always 1.
- The receive window of size 1. The window slides when a frame with no detected errors arrive; i.e. sliding occurs one slot at a time. Receiver will drop any out-of-order frames

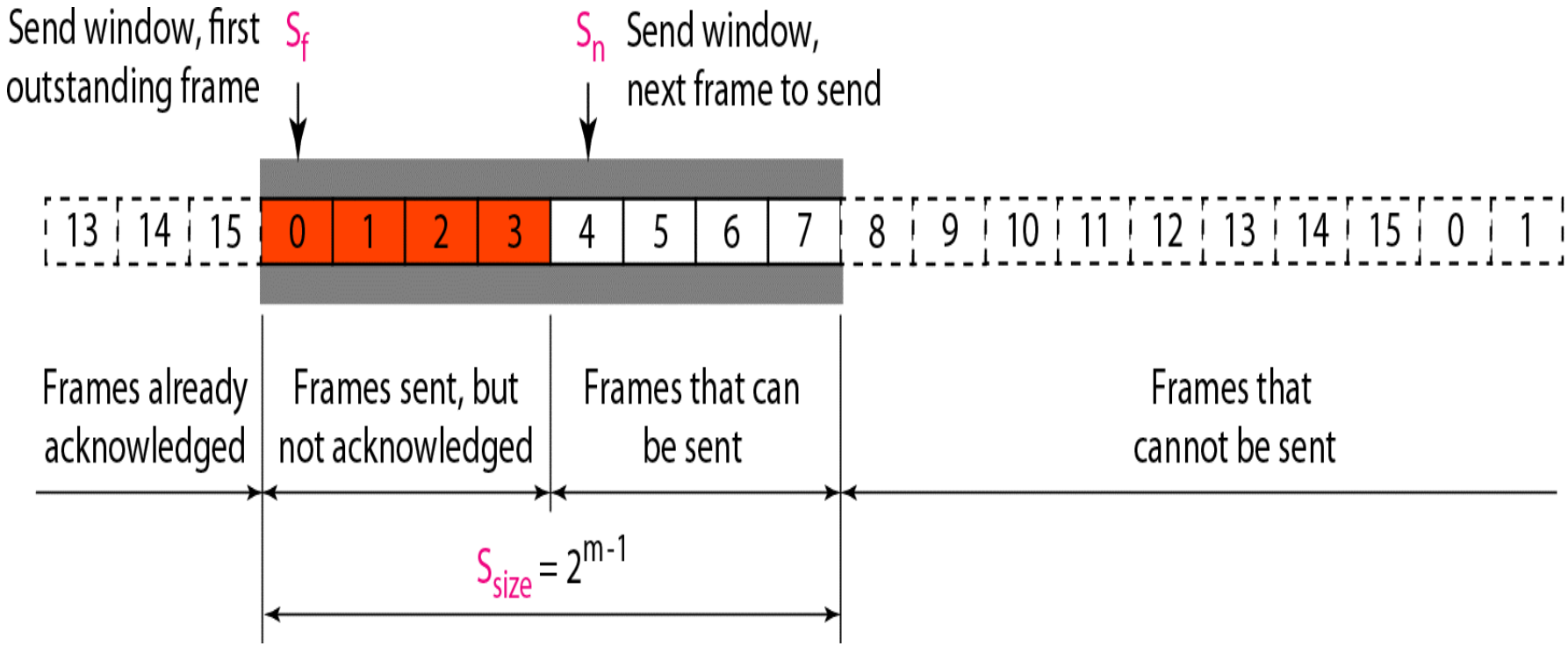
Example: Un-reliable Channel



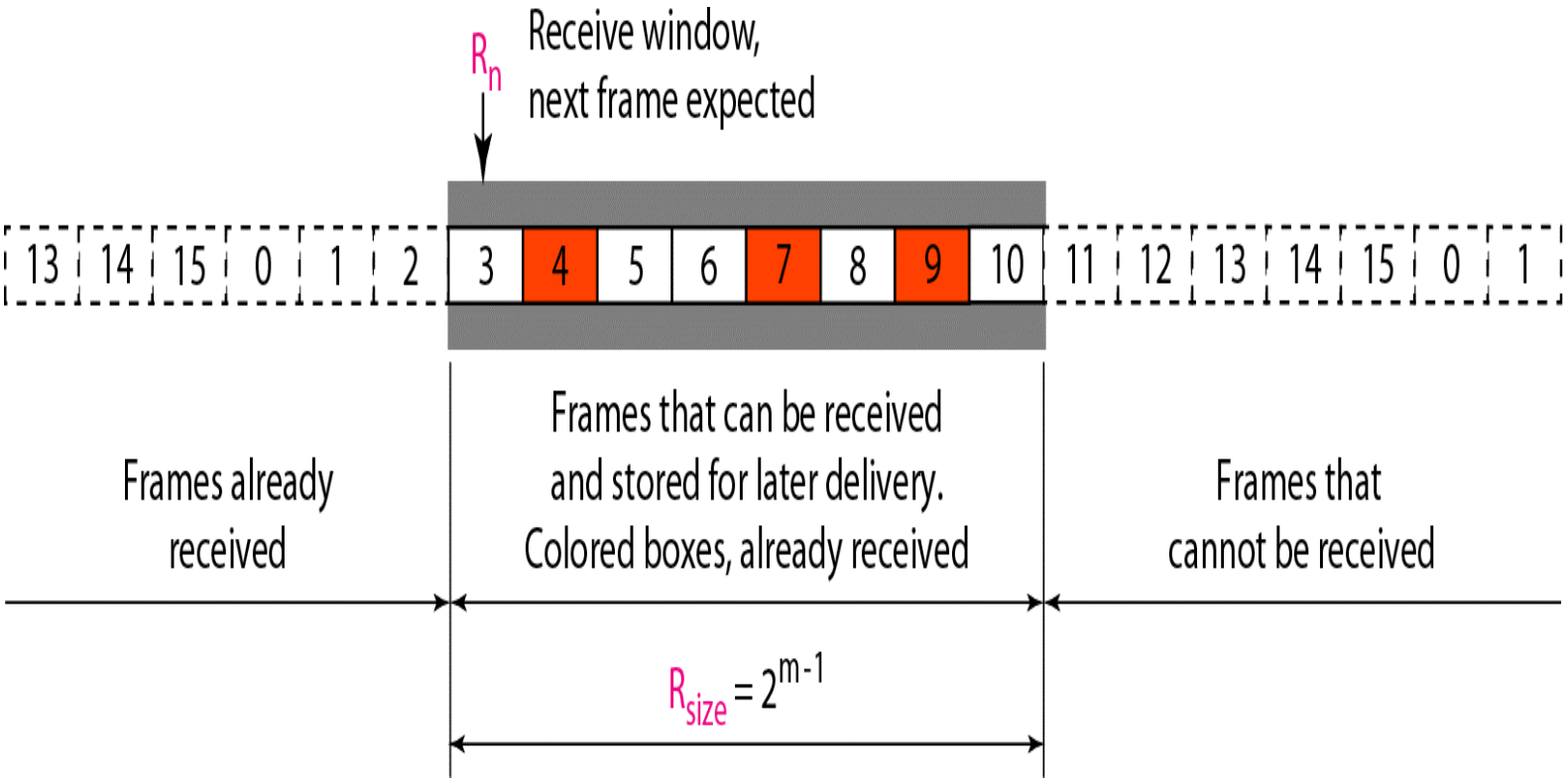
Selective Repeat (Reject) ARQ

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

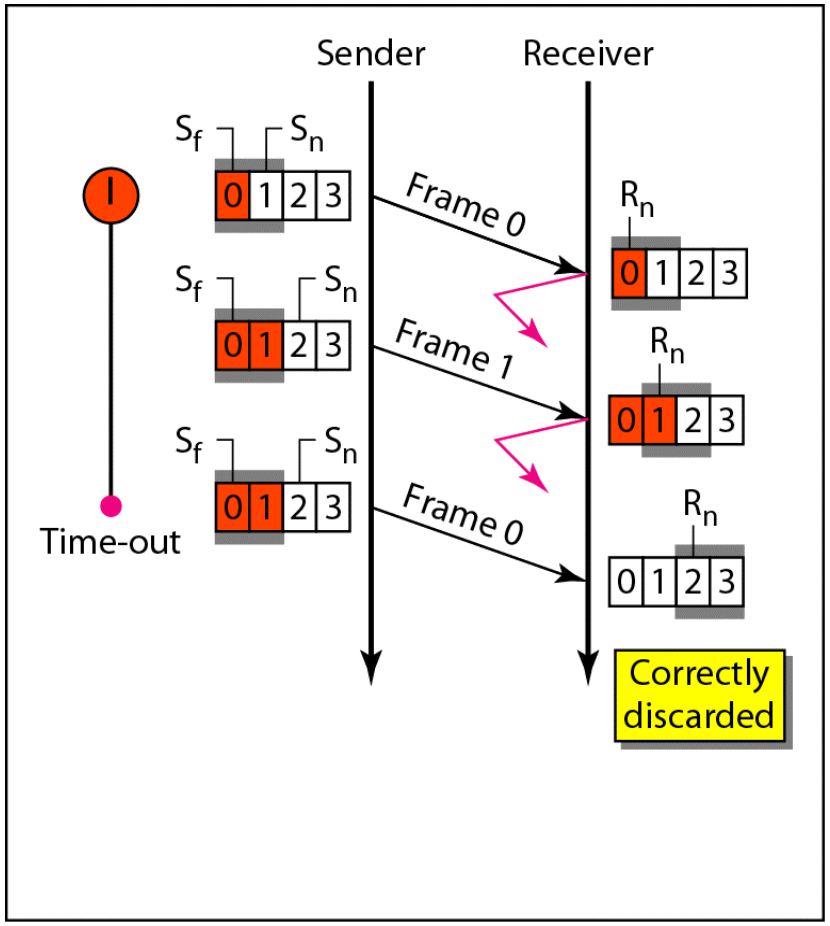
Sender Window fo SR ARQ



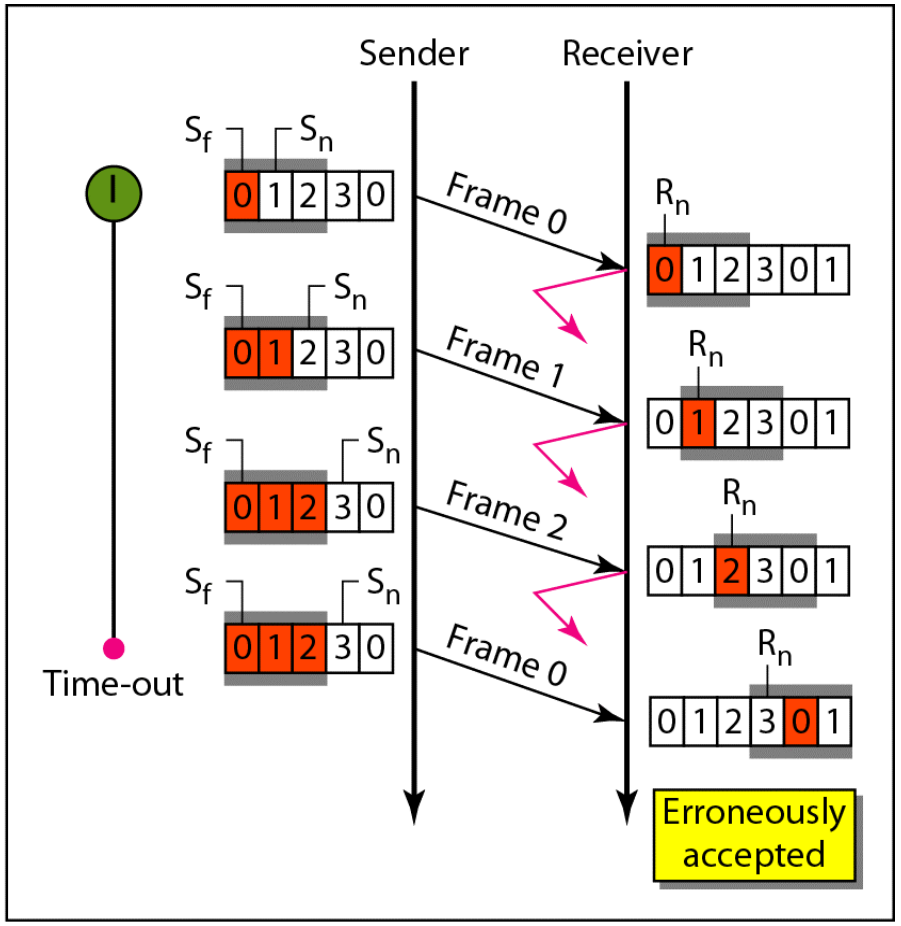
Receive Window for SR ARQ



SR ARQ Window Size



a. Window size = 2^{m-1}



b. Window size > 2^{m-1}

Summary Notes for SR ARQ

- In Selective Repeat ARQ, the size of the send window must be at most 2^{m-1}; the size of the receiver window is usually (but not necessarily) the same as that of the sender window. Receiver will buffer any out-of-order frames

- Receiver can acknowledge frames that are out of sequence but it can't pass them to the network layer. The sequence number of the ACK corresponds to the sequence number of the frame being acknowledged

Example of SR ARQ