Computer Networks I

Data Link Control Protocols

(Error Control)

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Error Control

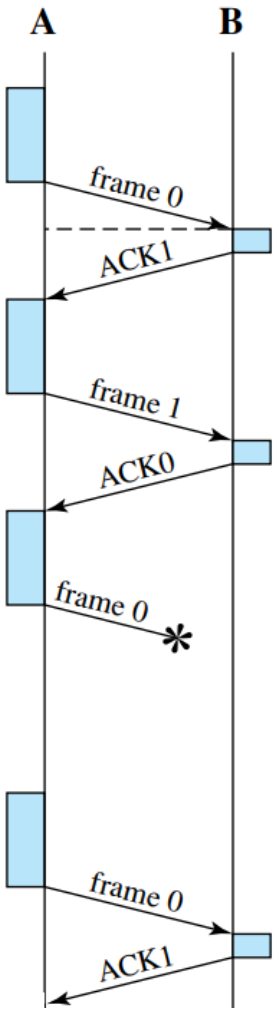
- Two types of error
  - Lost frame: A frame fails to arrive at the other end
  - Damaged frame: A frame arrives at the destination, but few bits are damaged

- Automatic Repeat Request (ARQ):
  - Stop-and-wait ARQ
  - Go-back-N ARQ
  - Selective-reject ARQ

Stop-and-Wait ARQ

Stop-and-Wait ARQ

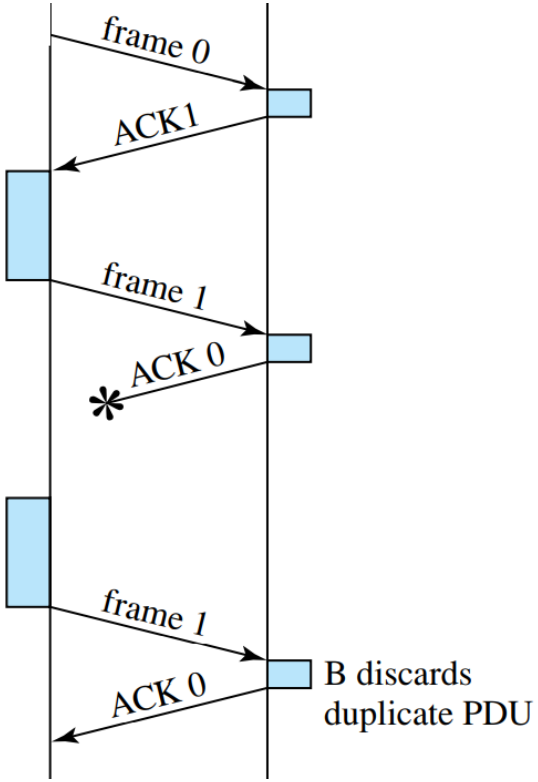
- Based on Stop-and-Wait flow control
- Source:
  - Source transmits single frame, waits for an ACK
  - It also starts a timer and maintains the copy
  - If ACK received, stop timer and transmit next frame
  - Sender has timeout → if no ACK within timeout, retransmit
- Destination:
  - Destination sends ACK if frame received correctly (with no errors)
  - If frame received is damaged, discard it



Stop-and-Wait ARQ

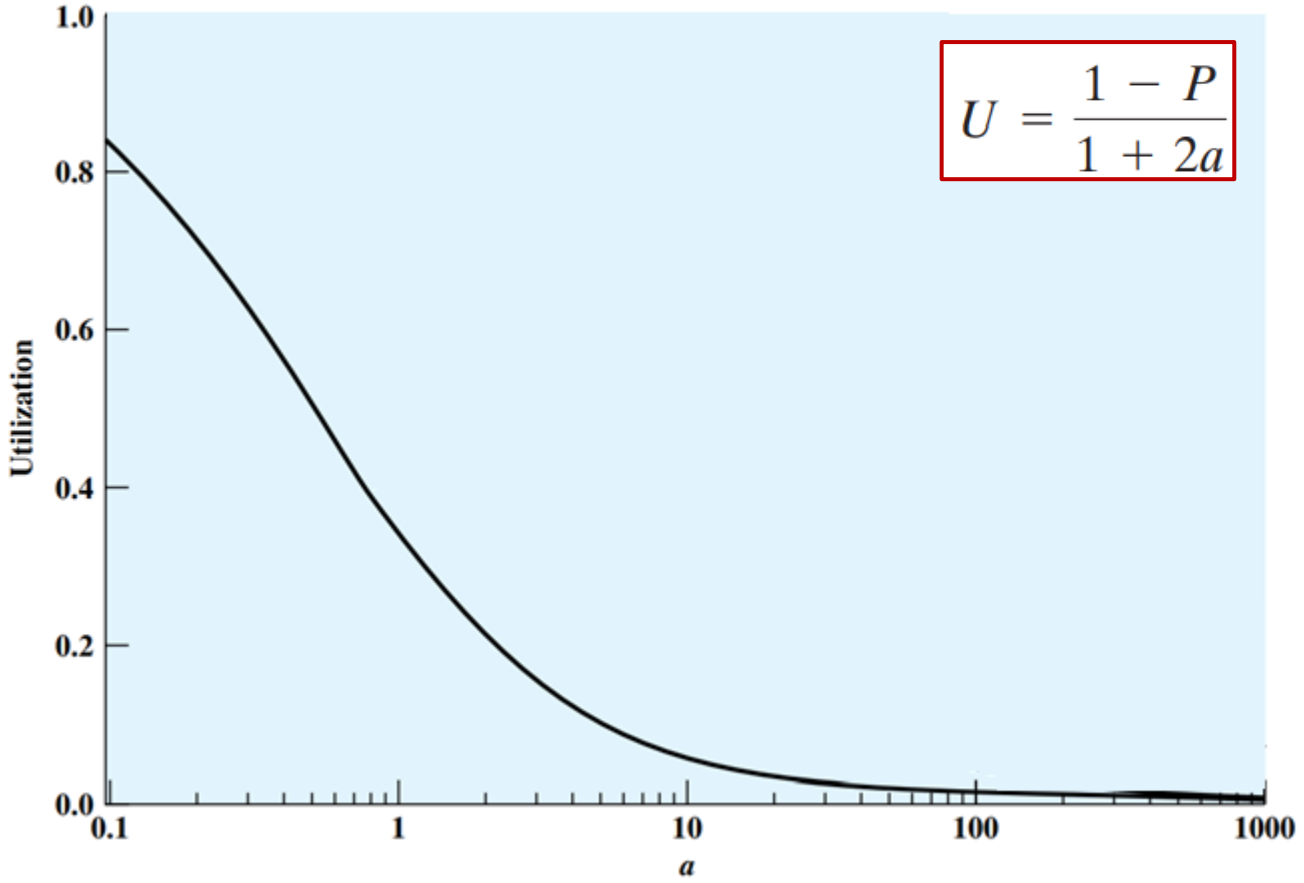
- If ACK is damaged, transmitter will not recognize
  - Transmitter will retransmit after the timeout
  - Receiver gets two copies of frame
  - Solution: use 1-bit frame SEQ number and ACK0 / ACK1

- Stop-and-Wait ARQ is simple, but inefficient



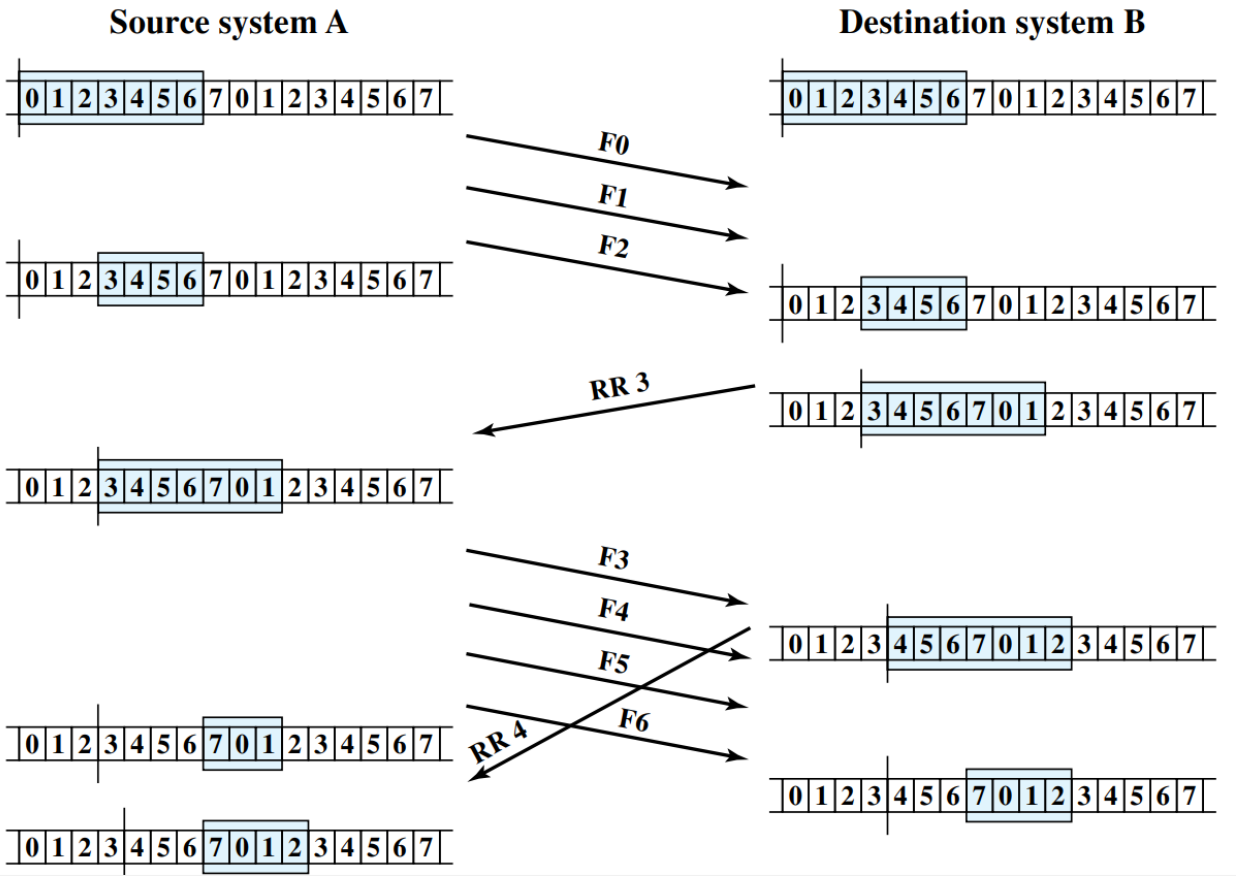
Stop-and-Wait ARQ

$$a = \frac{t_{prop}}{t_{frame}}$$



Go-Back-N ARQ

Sliding Window Flow Control: Example



Go-Back-N ARQ

- Based on Sliding Window flow control → Most commonly used error control

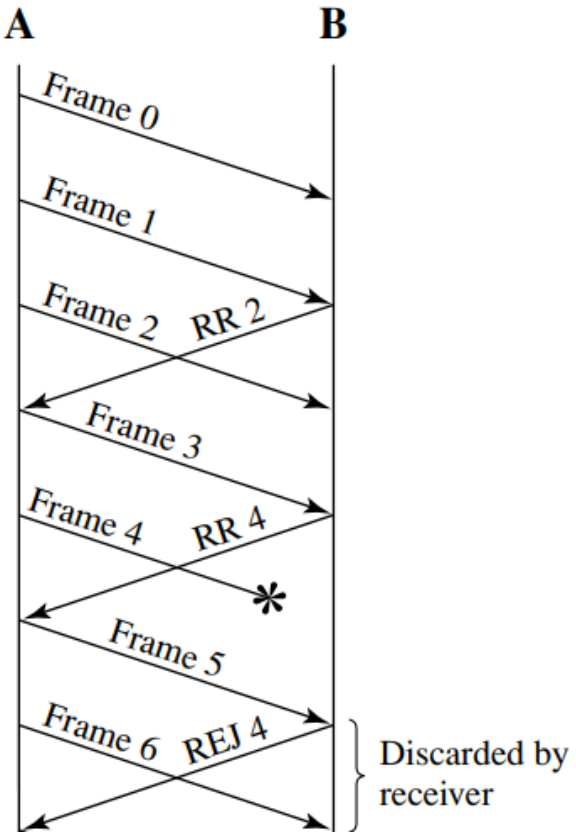
Source:

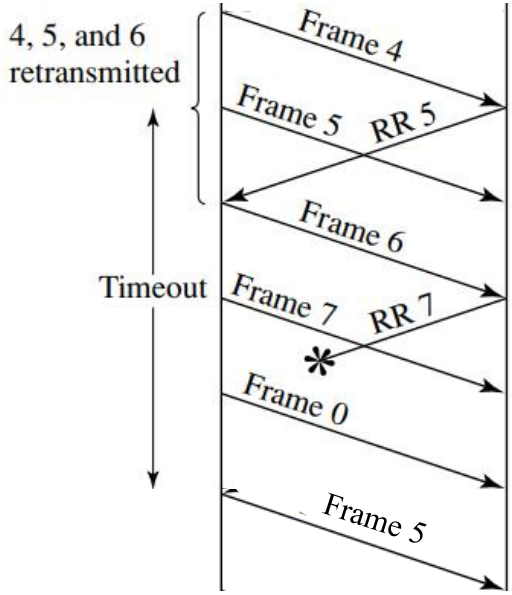
- Sender must go back and retransmit that frame and all subsequent frames
- If no ACK received from Destination after timeout, the Source can retransmit the previous frame asked by the receiver

Destination:

- If no error, the destination will ACK incoming frames as in sliding window
  - RR=receive ready, or piggybacked acknowledgment with sequence number of next expected frame
- If the destination station detects an error in a frame, it may send a negative acknowledgment
  - REJ=reject with sequence number of next expected frame
- Destination will discard that frame and all future frames until the frame in error is received correctly

Go-Back-N ARQ


A
B
Frame 0
Frame 1
Frame 2
RR 2
Frame 3
Frame 4
RR 4
*
Frame 5
Frame 6
REJ 4
Discarded by receiver


4, 5, and 6 retransmitted
Timeout
Frame 4
Frame 5
RR 5
Frame 6
Frame 7
RR 7
*
Frame 0
Frame 5

Go-Back-N ARQ

- A k-bit sequence number provides a sequence number range of 2^k
  - However the maximum window size is limited to $2^k - 1$
- As a case of 3-bit sequence number (i.e. sequence number space is 8)
- Suppose sender sends frame 0 and gets back an RR 1
- Then sends frames 1, 2, 3, 4, 5, 6, 7, 0 and gets another RR 1
- This could mean that all eight frames were received correctly and the RR 1 is a cumulative acknowledgment
- It could also mean that all eight frames were damaged or lost in transit, and the receiving station is repeating its previous RR 1
- The problem is avoided if the maximum window size is limited to 7, i.e. $2^3 - 1$
- Max window size = $2^k - 1$ (for a k-bit sequence number)

Selective Reject ARQ

Selective Reject ARQ

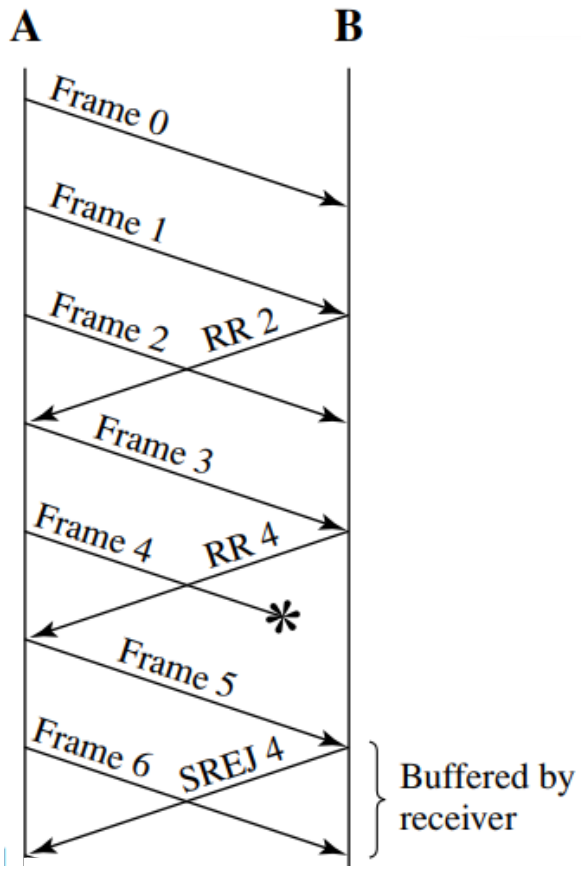
- Also called selective retransmission
- Only rejected or timeout frames are retransmitted
- Subsequent frames are accepted by the receiver and buffered

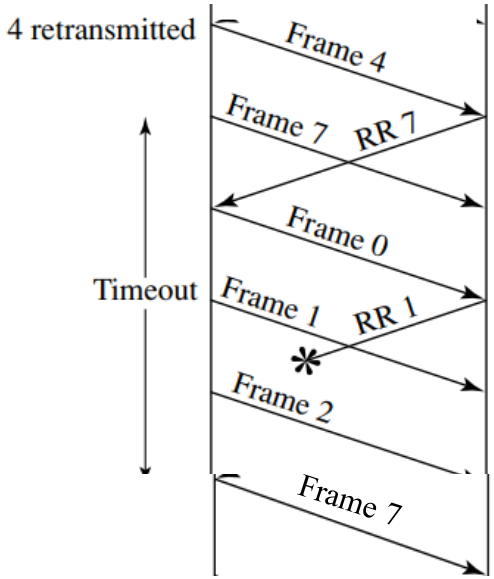
- Pros:
  - Minimizes retransmission

- Cons:
  - Receiver must maintain large enough buffer to store out-of-order frames
  - More complex logic in transmitter

- Less widely used
- Useful for satellite links with long propagation delays

Selective Reject ARQ





Selective Reject ARQ

- Window size is more restrictive for selective-reject than for go-back-N
- Consider the case of a 3-bit sequence number size for selective-reject
  - Sender sends frames 0 through 6
  - Receiver receives all seven frames and cumulatively acknowledges with RR 7
  - Because of a noise burst, the RR 7 is lost
  - Sender times out and retransmits frame 0
  - Receiver has already advanced its receive window to accept frames 7, 0, 1, 2, 3, 4, and 5
  - It assumes that frame 7 has been lost and that this is a new frame 0, which it accepts
- The problem is that there is an overlap in between the sending and receiving window
  - To overcome the problem, the maximum window size should be no more than half the range of sequence numbers
- Max window size = 2^{k-1} (for a k-bit sequence number)

Comparison

Flow control

$$U = \frac{1}{1 + 2a}$$

Stop and Wait

$$U = \begin{cases} 1 & W \geq 2a + 1 \\ \dfrac{W}{2a + 1} & W < 2a + 1 \end{cases}$$

Sliding Window

Error control

$$U = \frac{1 - P}{1 + 2a}$$

Stop and Wait

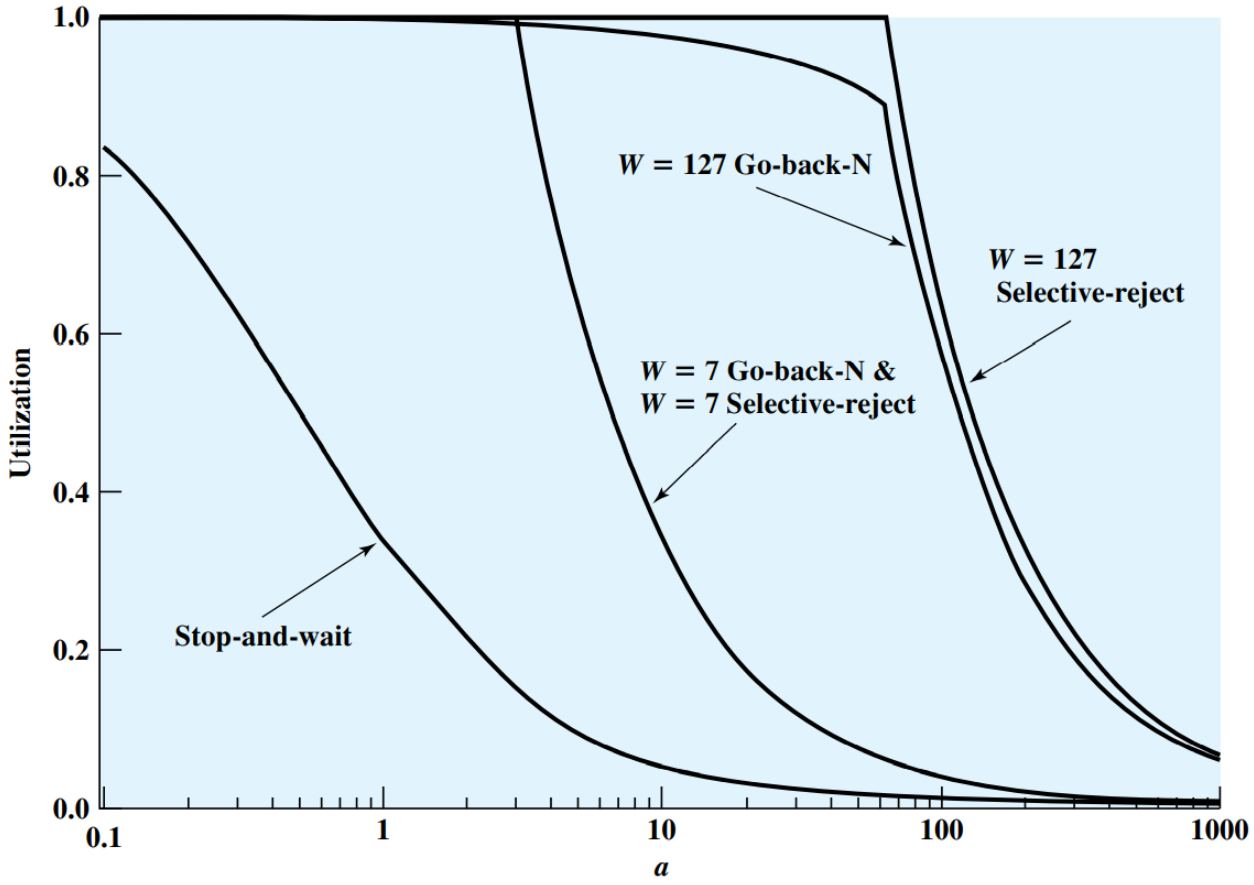
$$U = \begin{cases} 1 - P & W \geq 2a + 1 \\ \dfrac{W(1 - P)}{2a + 1} & W < 2a + 1 \end{cases}$$

Selective Reject

$$U = \begin{cases} \dfrac{1 - P}{1 + 2aP} & W \geq 2a + 1 \\ \dfrac{W(1 - P)}{(2a + 1)(1 - P + WP)} & W < 2a + 1 \end{cases}$$

Go-back N

Comparison


1.0
0.8
0.6
0.4
0.2
0.0
Utilization
0.1
1
10
100
1000
a
W = 127 Go-back-N
W = 127
Selective-reject
W = 7 Go-back-N &
W = 7 Selective-reject
Stop-and-wait

Summary

- Error control in Link Layer:
  - Stop and wait
  - Selective reject
  - Go-back N