Computer Networks I

Data Link Control Protocols

(Flow Control)

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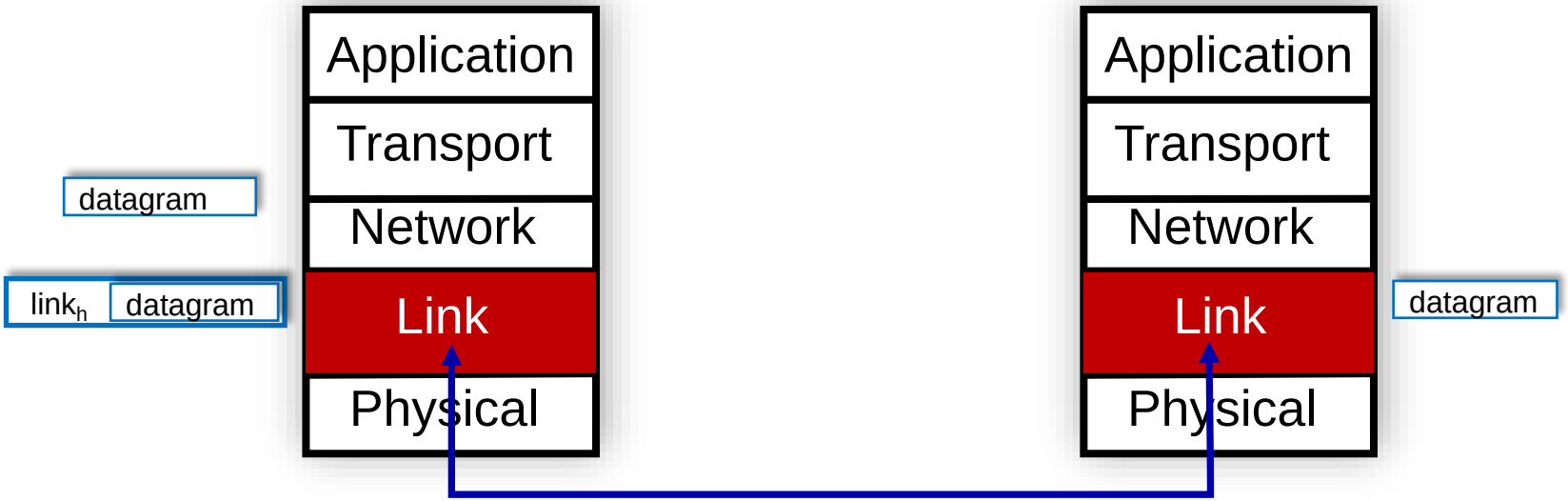
Data Link Layer

- Data link layer has responsibility of transferring datagram from one node to physically adjacent node over a link
  - Framing
    - Encapsulate datagram into frame, adding header, trailer
  - Reliable delivery between adjacent nodes
    - Flow control and error control
  - Channel access if shared medium

Data Link Layer



Sending side:

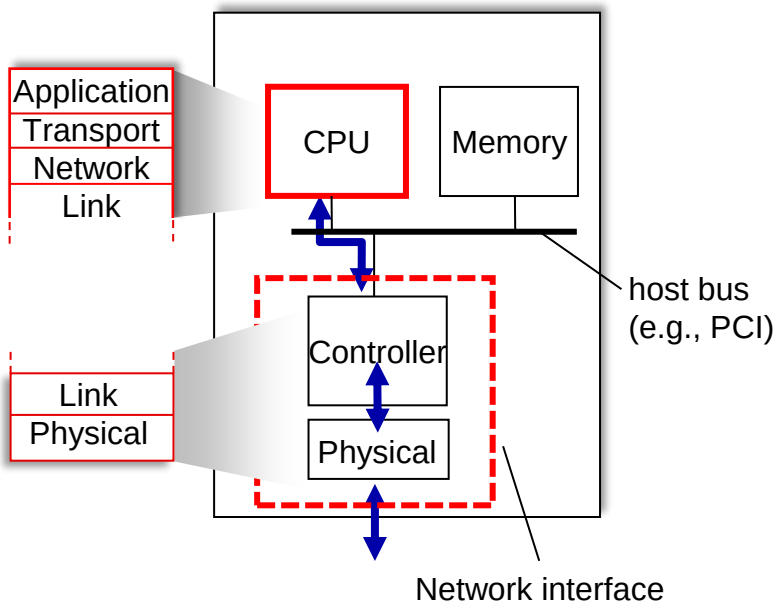
- Encapsulates datagram in frame
- Adds error checking bits, reliable data transfer, flow control, etc.

Receiving side:

- Looks for errors, reliable data transfer, flow control, etc.
- Extracts datagram, passes to upper layer at receiving side

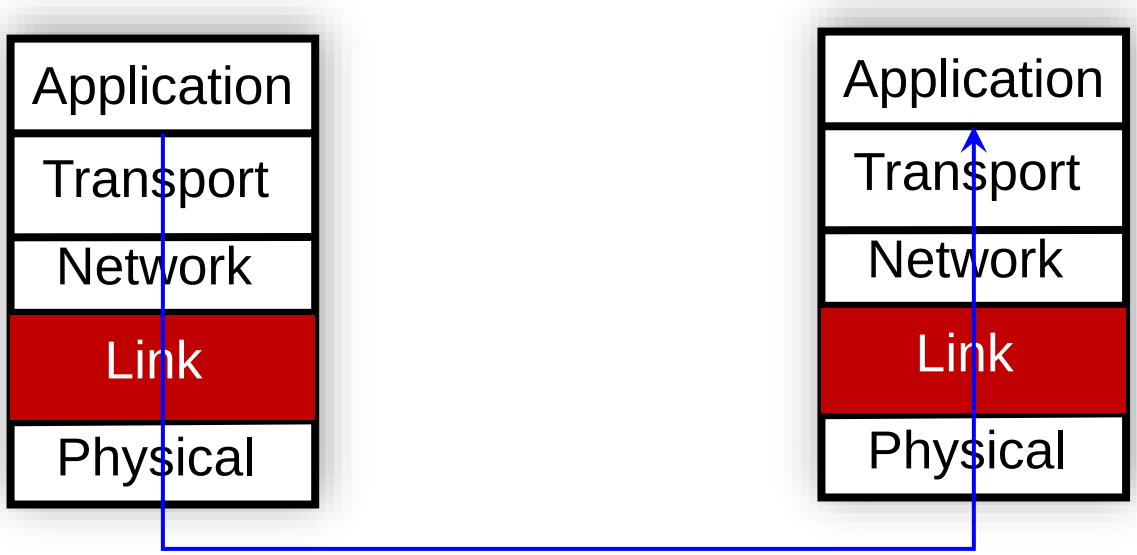
Data Link Layer

- Link layer implemented on-chip or in network interface card (NIC)
  - Implements link, physical layer
  - Attaches into host's system buses
- Combination of hardware, software, firmware



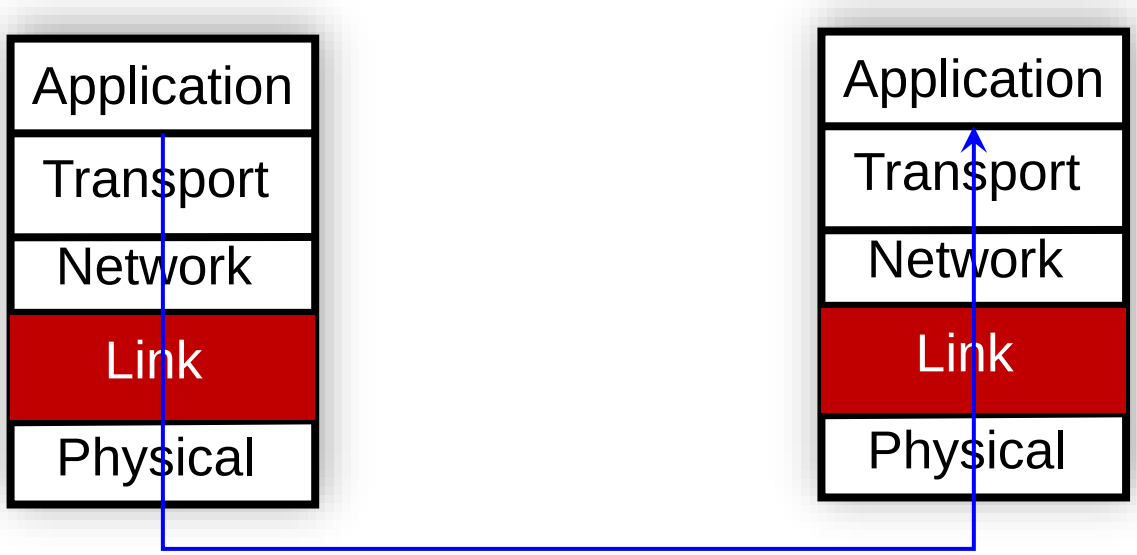
Flow Control

Flow Control



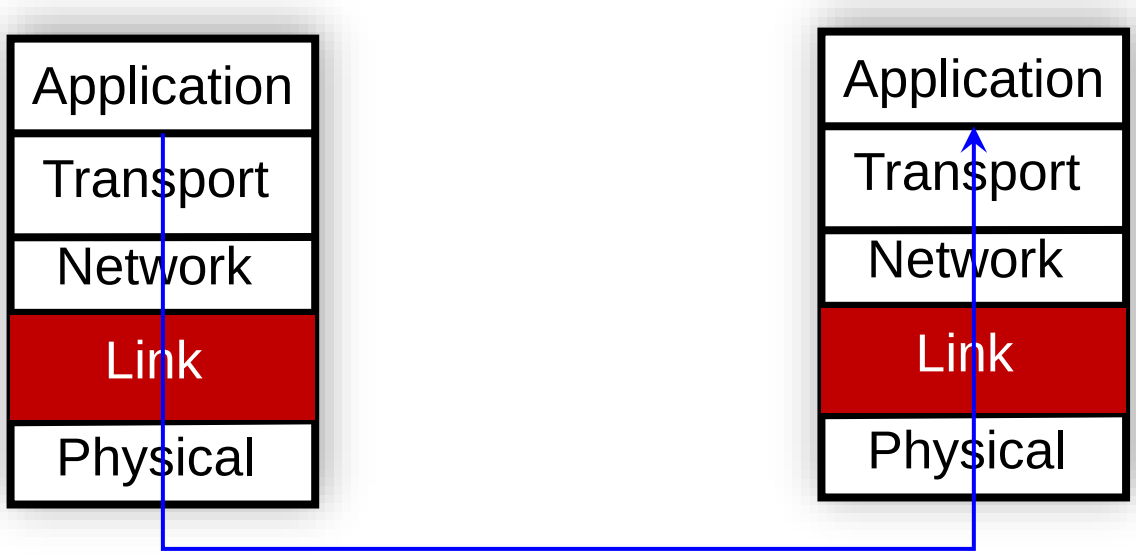
- Flow control assures that a transmitting entity does not overwhelm a receiving entity with data
  - If the transmitter transmits too fast, then the receiver buffer may overflow
    - This may lead to data loss, retransmission, and performance reduction

Flow Control



- Flow control assures that a transmitting entity does not overwhelm a receiving entity with data
  - Assumptions:
    - No frames loss or error, all transmitted frames are successfully received
    - Transmitted frames suffers from an arbitrary and variable amount of delay

Flow Control



- Flow control:
  - Stop and Wait Flow Control
  - Sliding Window Flow Control

Stop-and-Wait Flow Control

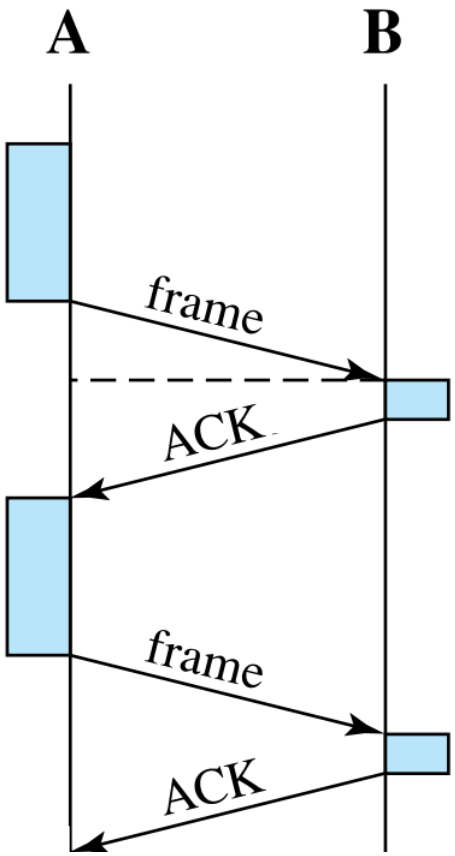
Stop and Wait Flow Control

❑Source:

- Source transmits a DATA frame
- Source waits for ACK frame before sending next DATA frame

❑Destination:

- Destination receives DATA frame → replies back with an ACK if ready to accept more data
- Destination can stop flow of data by withholding ACK

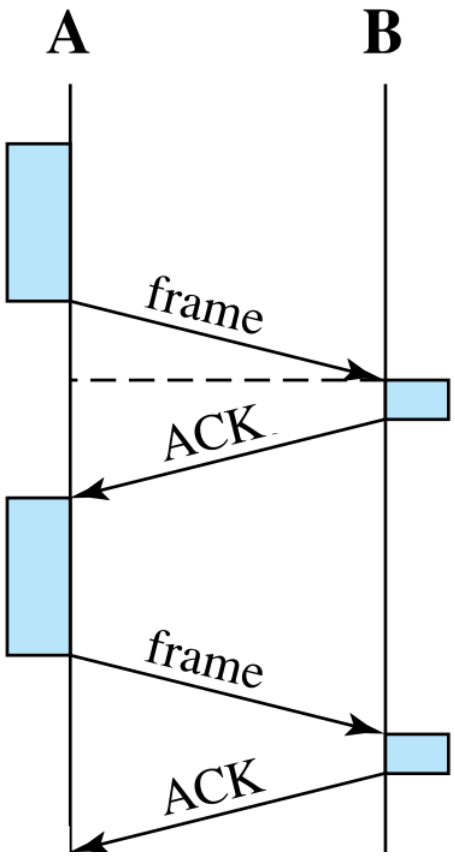


Efficiency Calculation

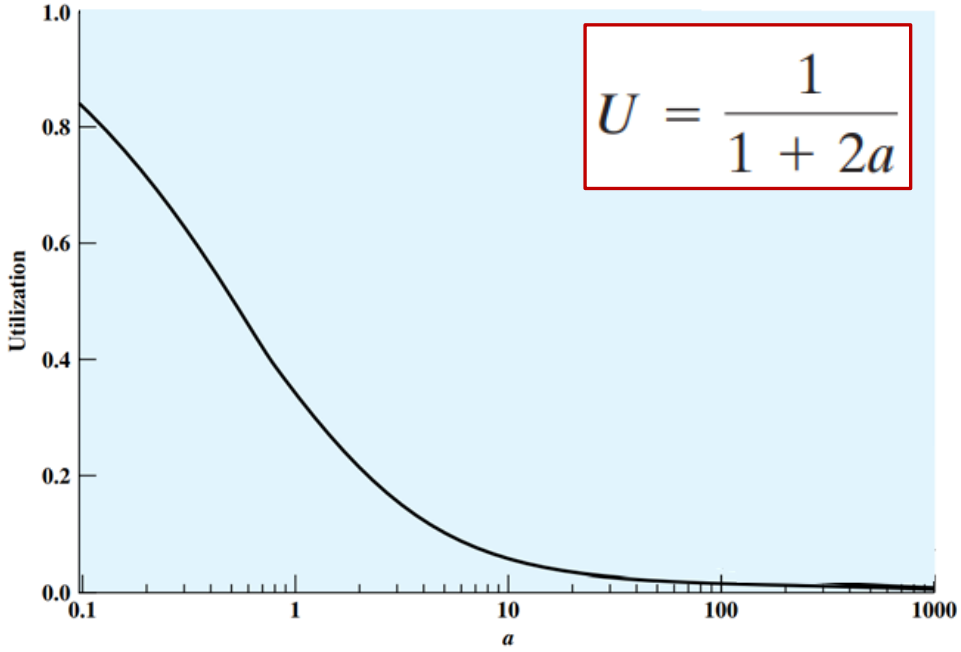
$$U = \frac{t_{frame}}{t_{frame} + t_{ack} + 2 \times t_{prop}}$$

$$a = \frac{\text{Propagation time}}{\text{Transmission time}} = \frac{t_{prop}}{t_{frame}}$$

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



Efficiency Calculation



- Stop-and-wait allows only 1 frame to be in transit at a time
  - Leads to serious inefficiencies especially when the frame size is small
  - Efficiency can be greatly improved by allowing multiple frames to be in transit at a time → which is the idea of Sliding-window flow control

Sliding Window Flow Control

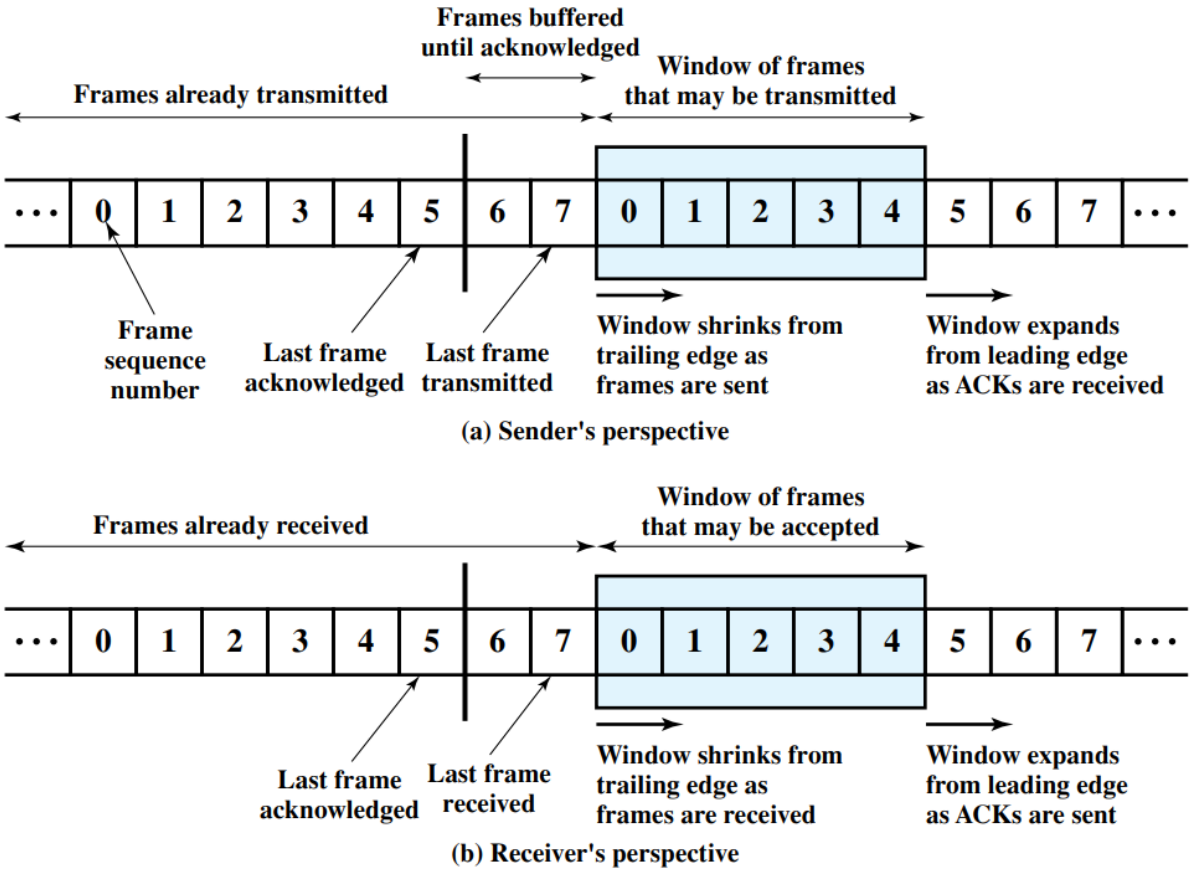
Sliding Window Flow Control

- Receiver allocates a buffer space of W frames
- Sender can send up to W frames without waiting for an ACK

- Each frame is labeled with a k-bit sequence number
  - Frames are numbered modulo 2^k
  - Giving max window size of up to $2^k - 1$ (will learn during error control)

- Receiver acknowledges a frame by sending an ACK (or Receiver Ready, RR)
- ACK includes the sequence number of the next frame expected
  - ACK also implicitly says that the receiver can receive the next W frames

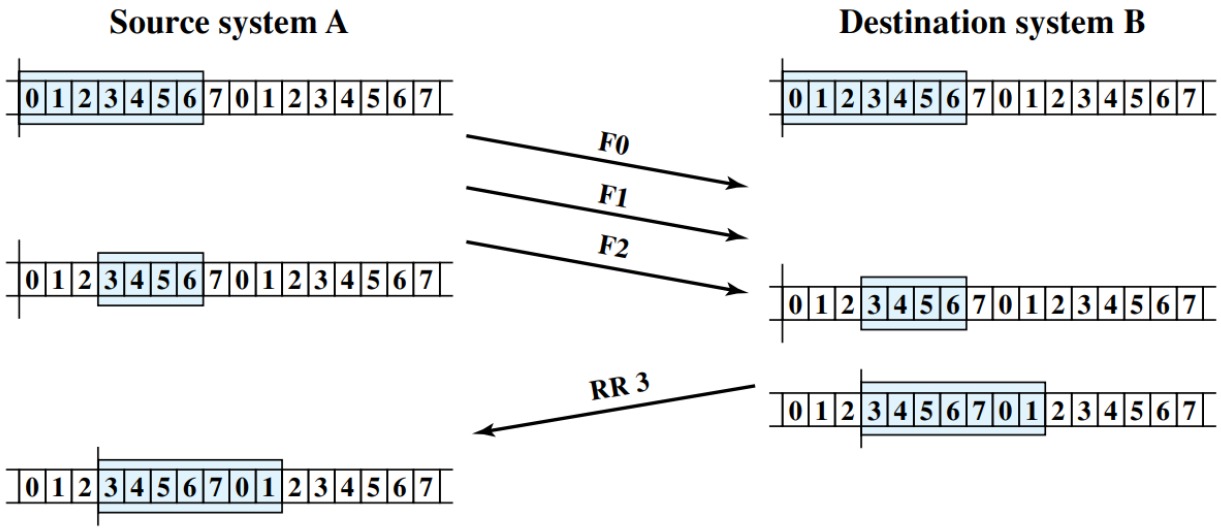
Sliding Window Flow Control



Sliding Window Flow Control

- Sender and Receiver record:
  - Last frame acknowledged
  - Last frame transmitted (in case of sender) or received (in case of receiver)
  - Window of frames that may be transmitted (in case of sender) or received (in case of receiver)

Sliding Window Flow Control: Example



Sliding Window Flow Control

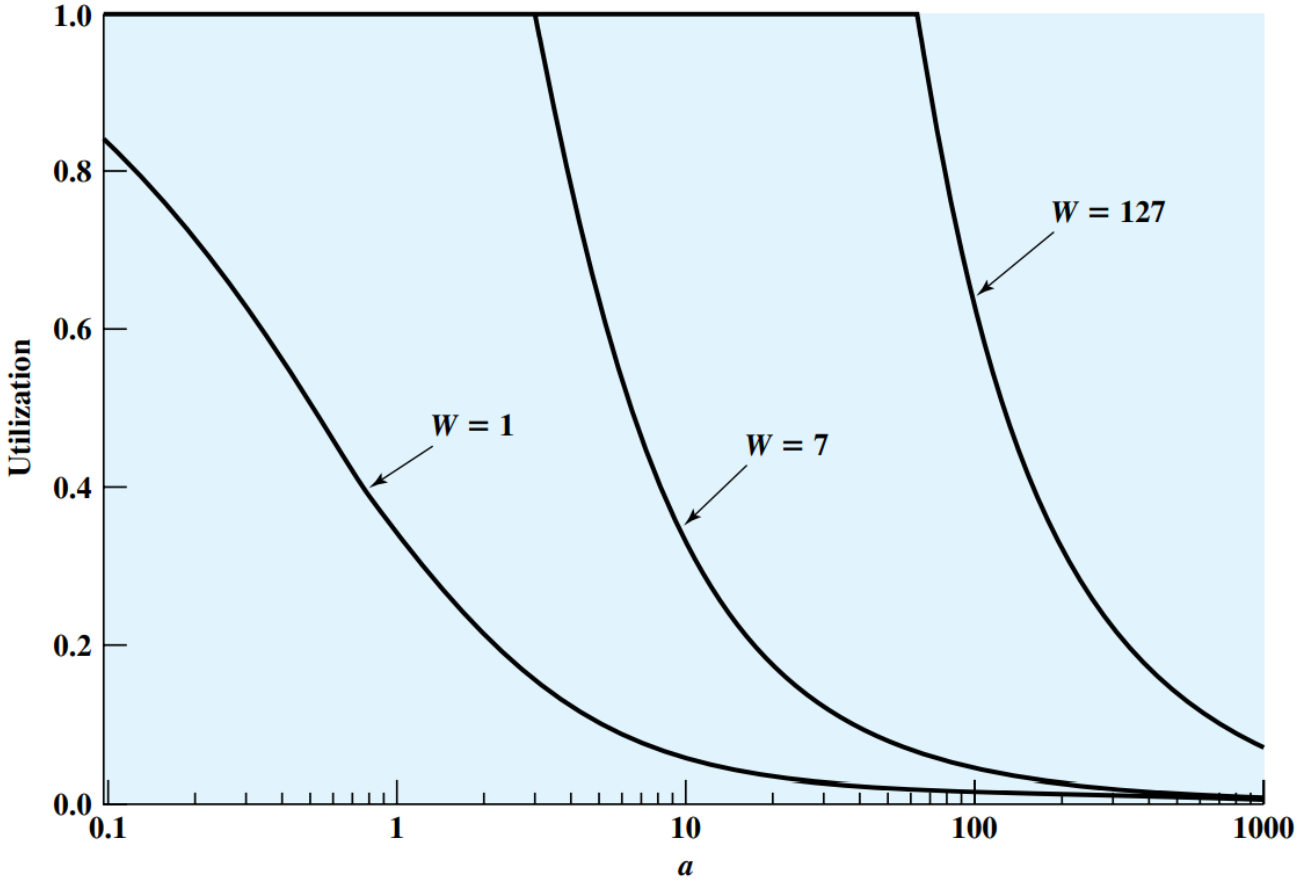
❑Additional features:

- Receive Not Ready (RNR): Receiver can ACK frames without permitting further transmission
- RNR 5: received frames up to 4, but unable to accept any more
- Must send a normal acknowledge to resume

- Piggybacking: If a station has a DATA and ACK to send, it sends both together → saves communication capacity
- DATA frame includes sequence number of the frame and sequence number used for ACK (i.e. next expected frame number)
- If the station has an ACK but no DATA to send, it sends normal ACK (RR or RNR)
- If the station has DATA to send but no new ACK → repeats the last ACK seq. no.

Sliding Window Flow Control

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



Summary

- Link layer services
- Flow control in Link Layer:
  - Stop and wait
  - Sliding window