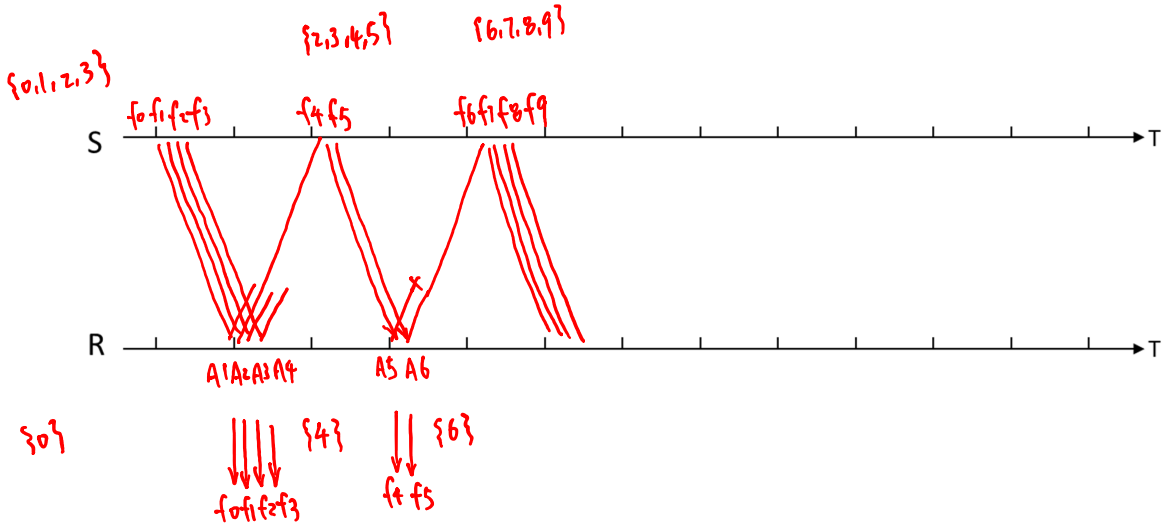
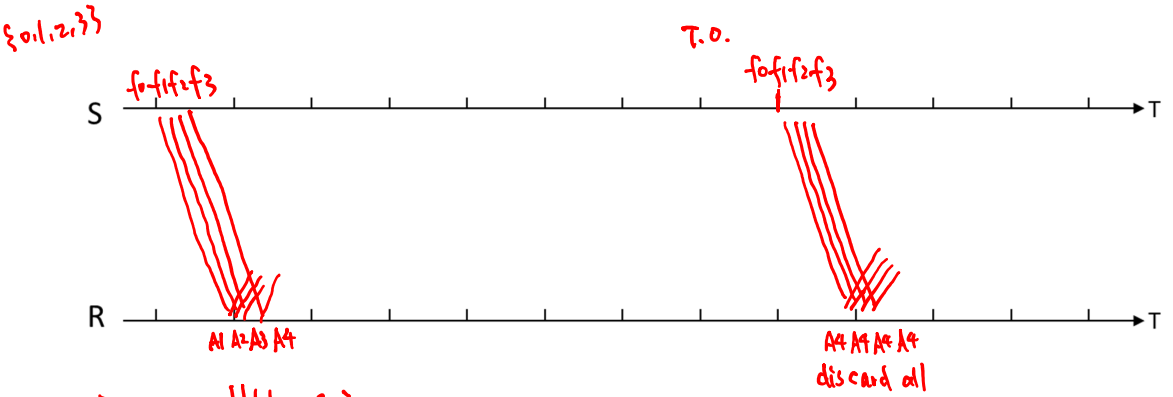
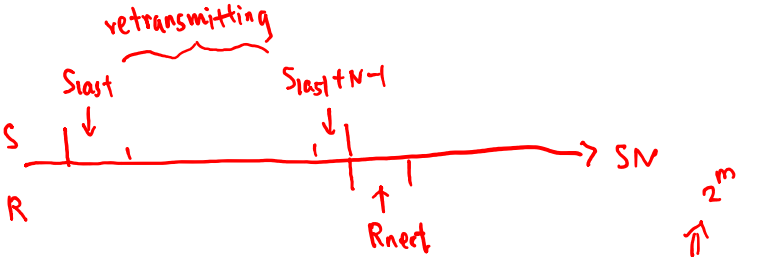
GB4



GBN: - good at dealing with ACK losses
- not good at dealing with data losses

GB4



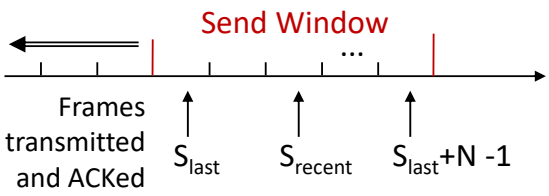


at least N+1 unique seq. $\Rightarrow \lceil \log_2(N+1) \rceil$ = m bits in SN field

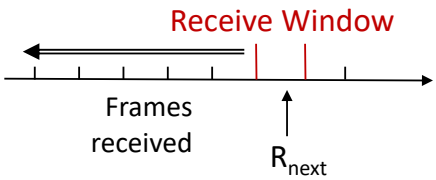
GBN Protocol

- *Essential Components:* ACK, timeout, sequence numbering
  - ACK acknowledges reception of all prior frames implicitly
- Upon timeout:
  - Frame in error and all subsequent frames are retransmitted
- Needs m-bit sequence numbering to remove ambiguities
  - What is the minimum value for m?
    - $\lceil \log2 (N + 1) \rceil$

GBN Transmitter & Receiver



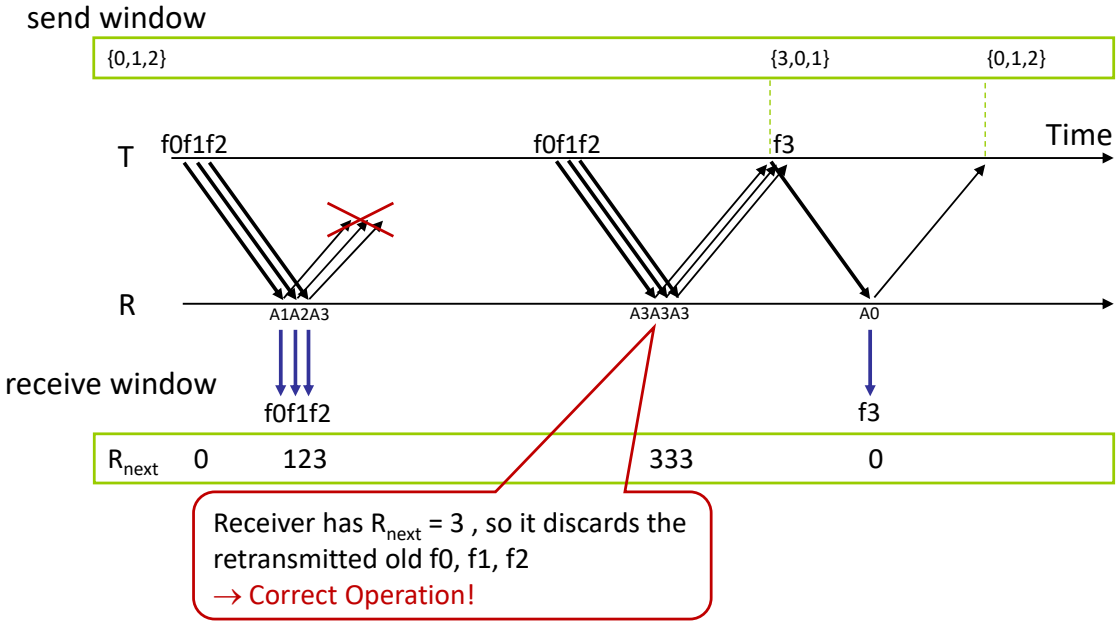
1. Transmitter waits for error-free ACK with: $R_{next} \in [S_{last}, S_{recent}+1]$
2. When such ACK arrives, send window slides forward: $S_{last} = R_{next}$
3. When timer expires for S_{last}, transmitter go-back-N to retransmit S_{last} and all subsequent frames



1. Receiver only accepts error-free frame with sequence number R_{next}
2. When such frame arrives, R_{next} is incremented by one, meaning that receive window slides forward by 1: $R_{next} = R_{next} + 1$
3. Erroneous frames and error-free frames with sequence number $\neq R_{next}$ are discarded
4. ACK is sent for each error-free frame received

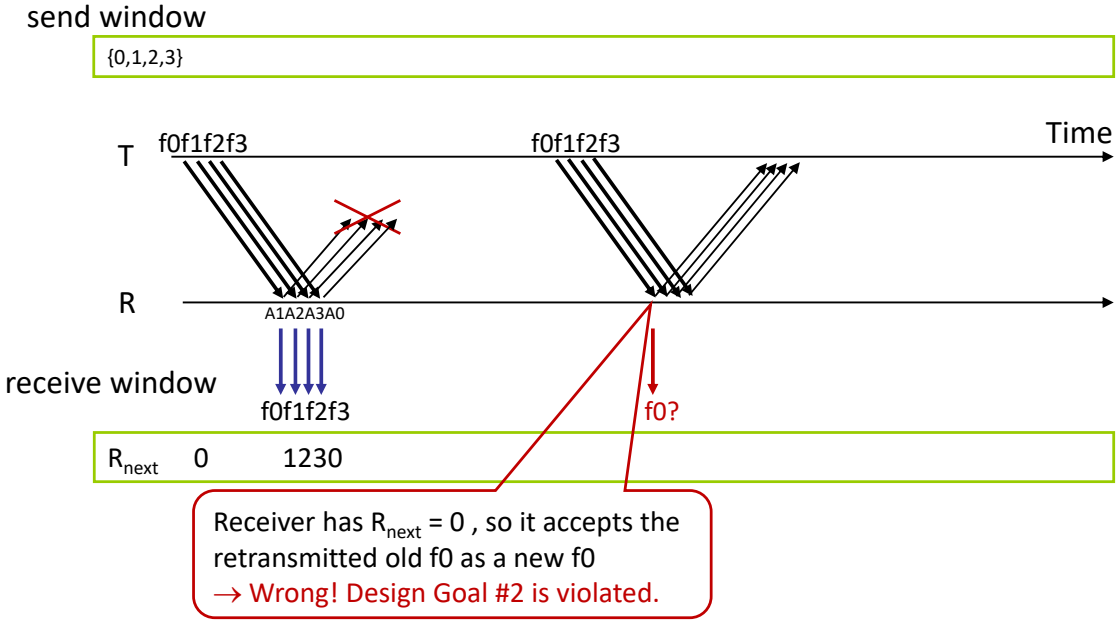
$N + 1 \leq 2^m$

- Example: 2-bit (m = 2) sequence numbering suffices for Go-Back-3 (N = 3) ARQ



$N + 1 \leq 2^m$

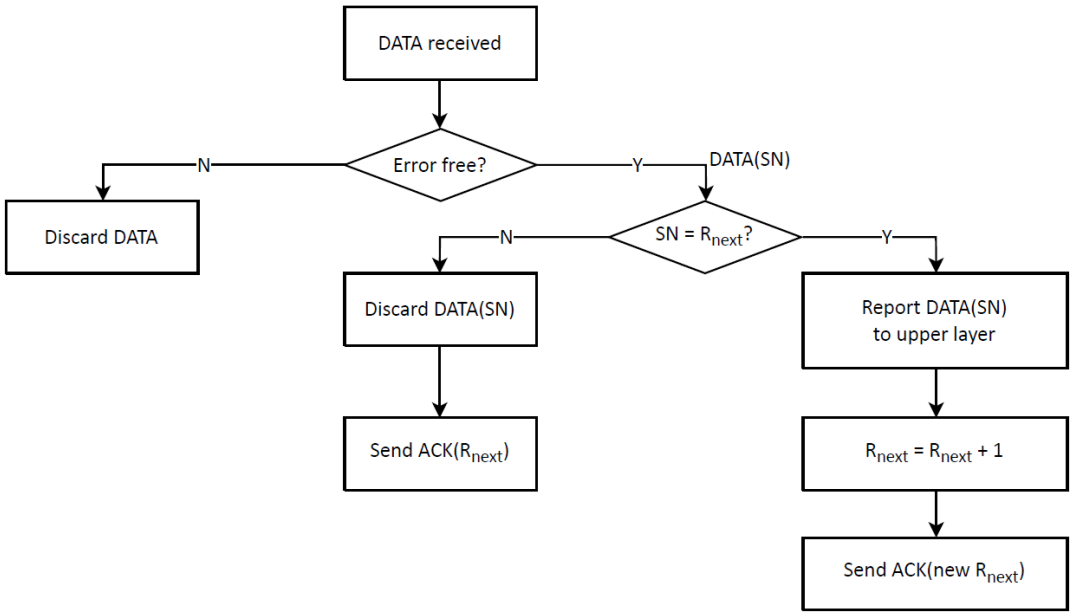
- Example: 2-bit (m = 2) sequence numbering is inadequate for Go-Back-4 (N = 4) ARQ

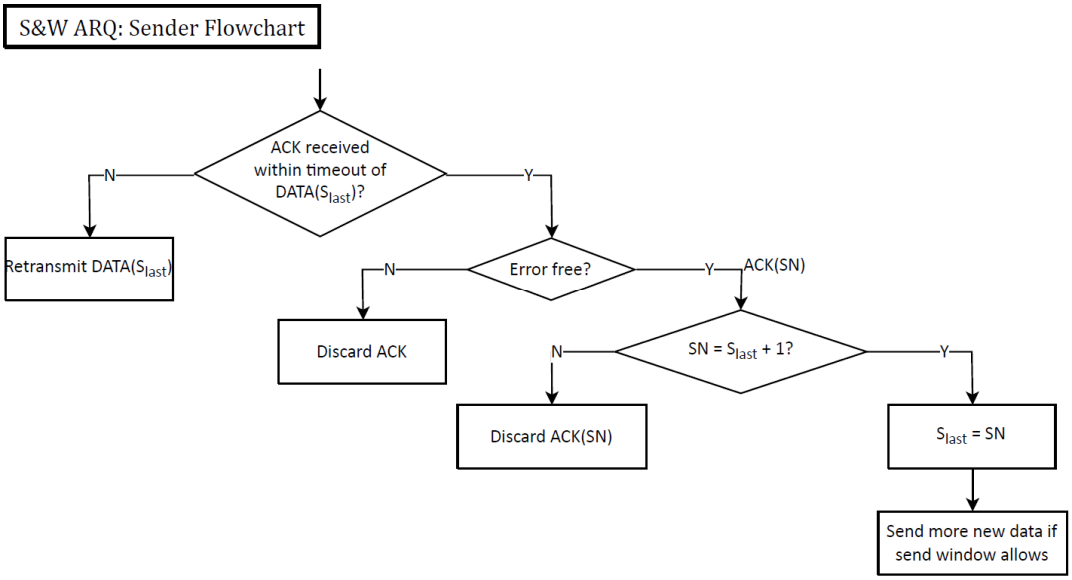


2. Stop-and-Wait ARQ (S&W)

- The transmitter and receiver work on the delivery of one frame at a time through alternation of actions
  - Special version of GBN: S&W = GB1
  - *Essential Components:* ACK, timeout, sequence numbering
    - ACK acknowledges reception of a frame
    - Needs 1-bit sequence numbering to remove ambiguities

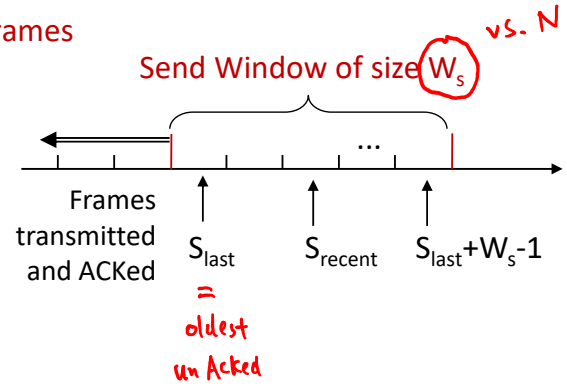
S&W ARQ: Receiver Flowchart



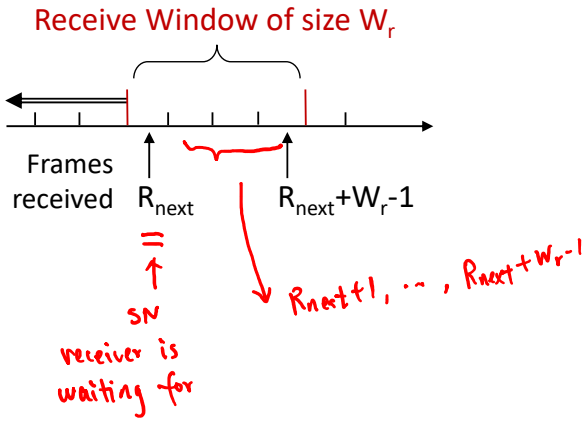


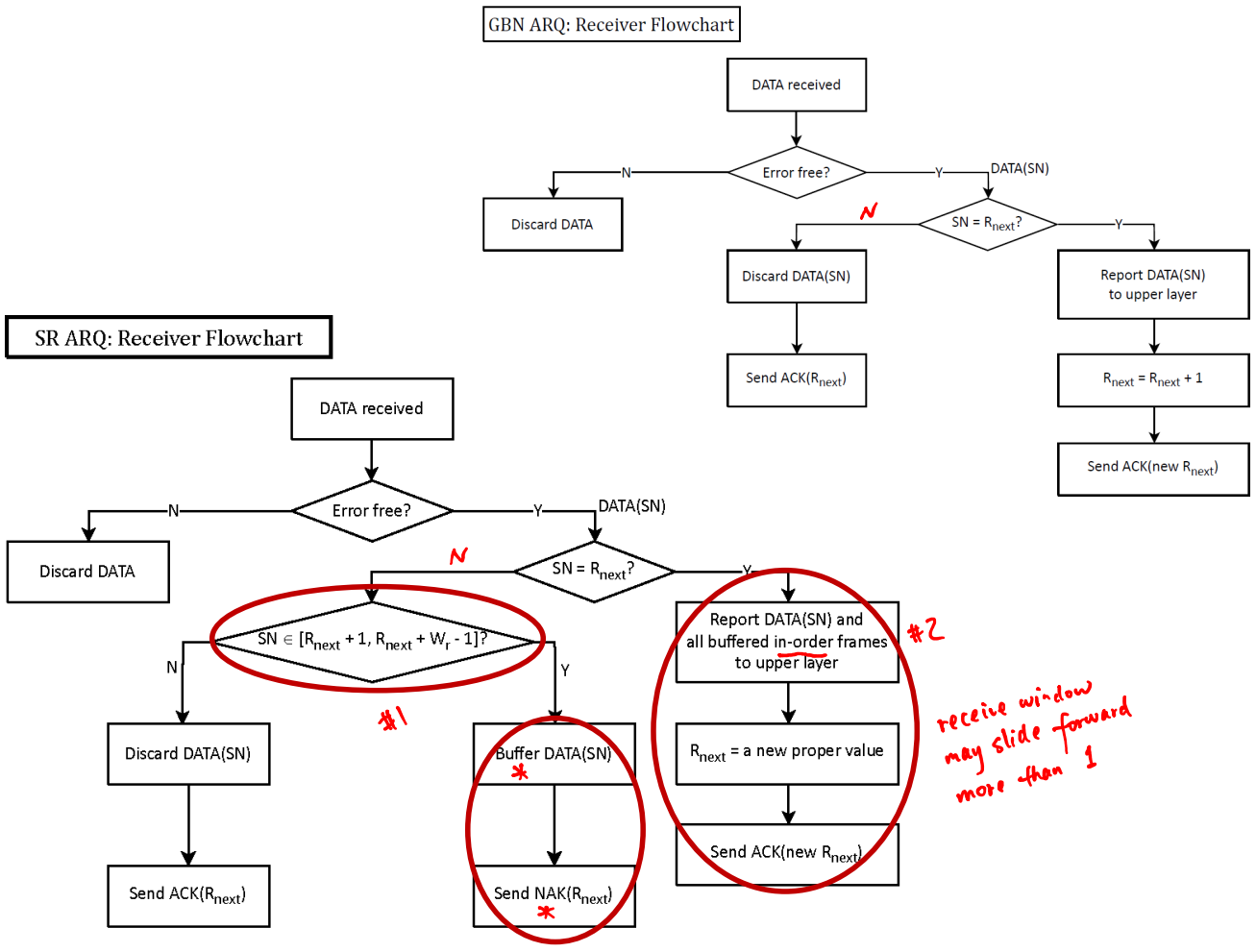
3. Selective Repeat ARQ (SR)

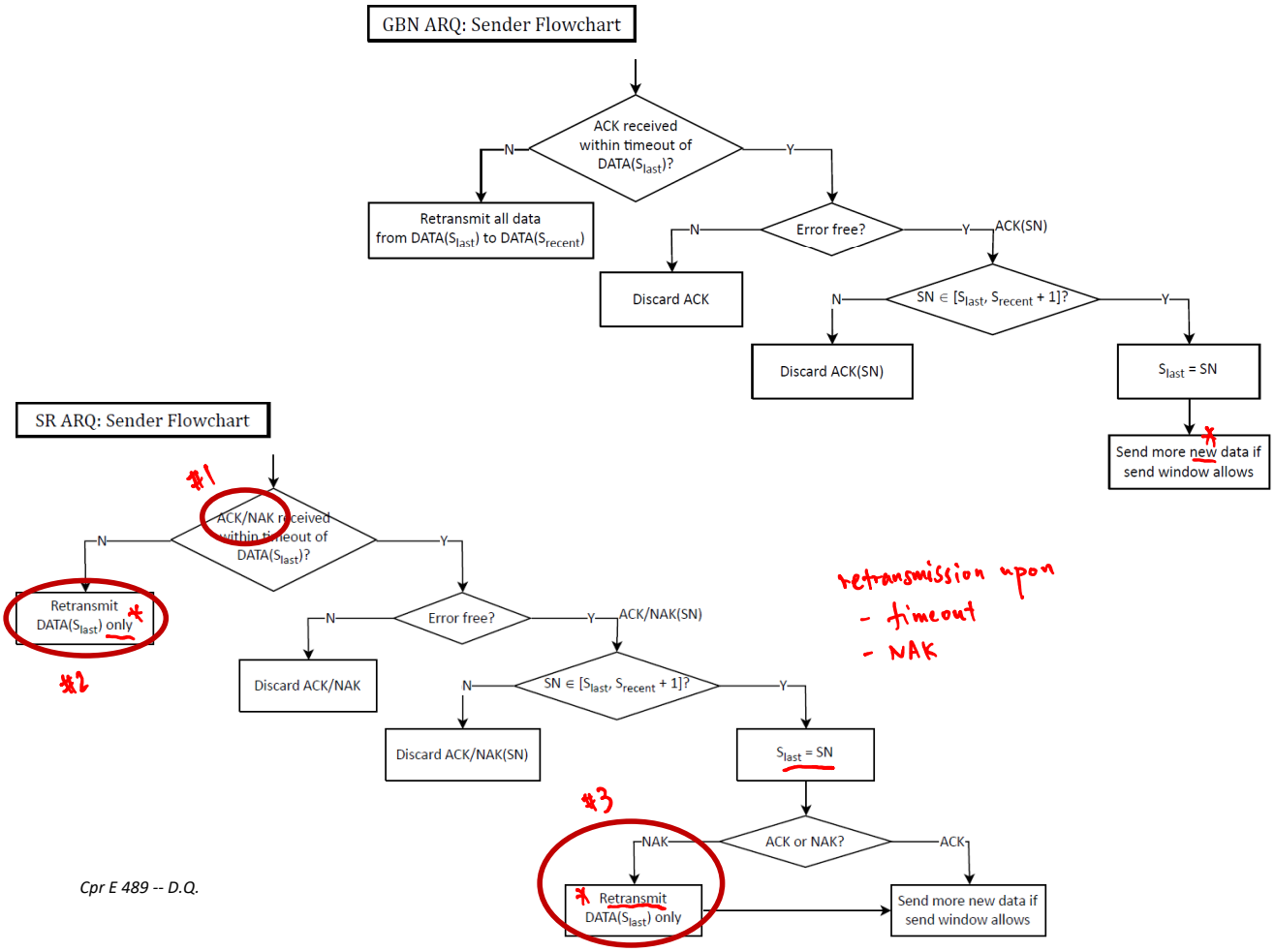
- SR improves upon GBN by buffering at the receiver side
  - Allow up to W_s outstanding frames

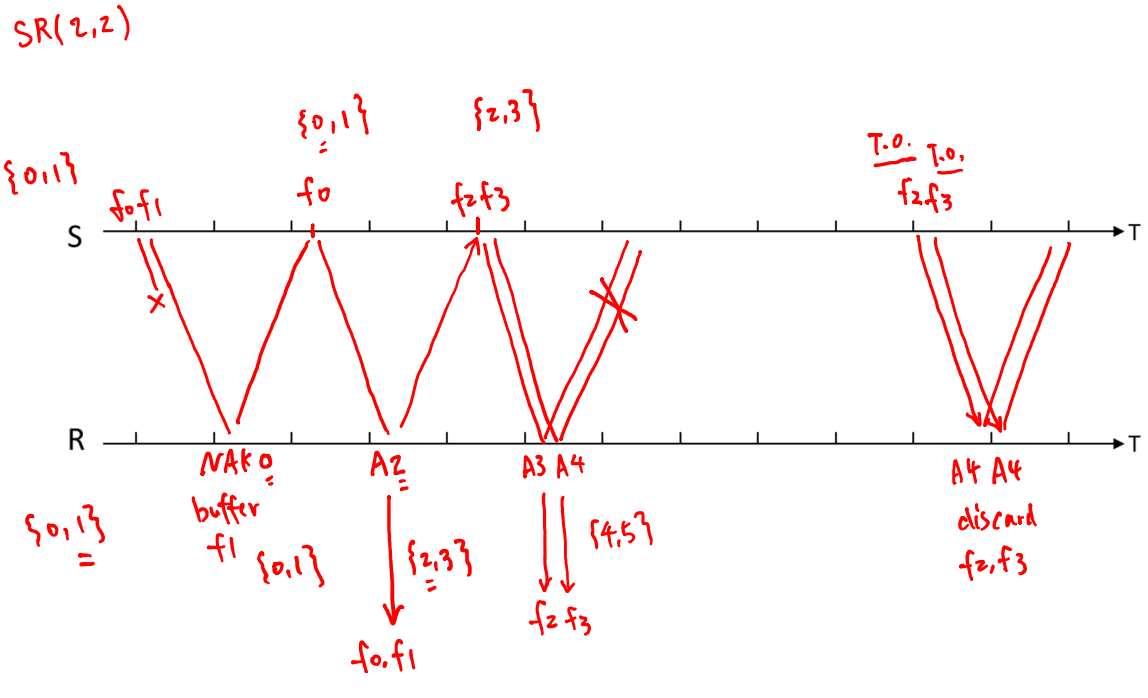


- SR improves upon GBN by buffering at the receiver side
  - Allow a receive window of size W_r (>1)
    - Receiver buffers the error-free frames with sequence number $\in [R_{next}+1, R_{next}+W_r-1]$ *






GBN ARQ: Sender Flowchart
ACK received within timeout of DATA(S_last)?
N
Y
Retransmit all data from DATA(S_last) to DATA(S_recent)
Error free?
N
Y
ACK(SN)
Discard ACK
SN ∈ [S_last, S_recent + 1]?
N
Y
Discard ACK(SN)
S_last = SN
Send more new data if send window allows
SR ARQ: Sender Flowchart
#1
ACK/NAK received within timeout of DATA(S_last)?
N
Y
Retransmit DATA(S_last) only
#2
Error free?
N
Y
ACK/NAK(SN)
Discard ACK/NAK
SN ∈ [S_last, S_recent + 1]?
N
Y
Discard ACK/NAK(SN)
S_last = SN
#3
ACK or NAK?
NAK
ACK
Retransmit DATA(S_last) only
Send more new data if send window allows
retransmission upon
- timeout
- NAK


SR(2,2)
{0,1}
{0,1}
{2,3}
T.O.
T.O.
f0f1
f0
f2f3
f2f3
S
T
R
T
NAK 0
buffer
f1
{0,1}
A2
{2,3}
A3 A4
{4,5}
A4 A4
discard
f2,f3
{0,1}
f0,f1
f2 f3