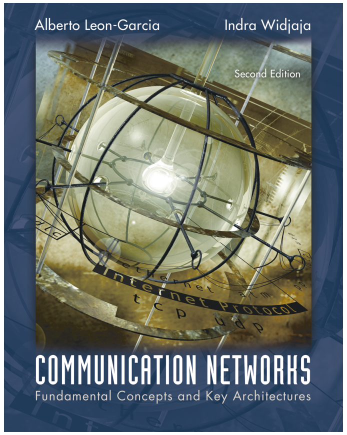
Chapter 5
Peer-to-Peer Protocols and Data Link Layer



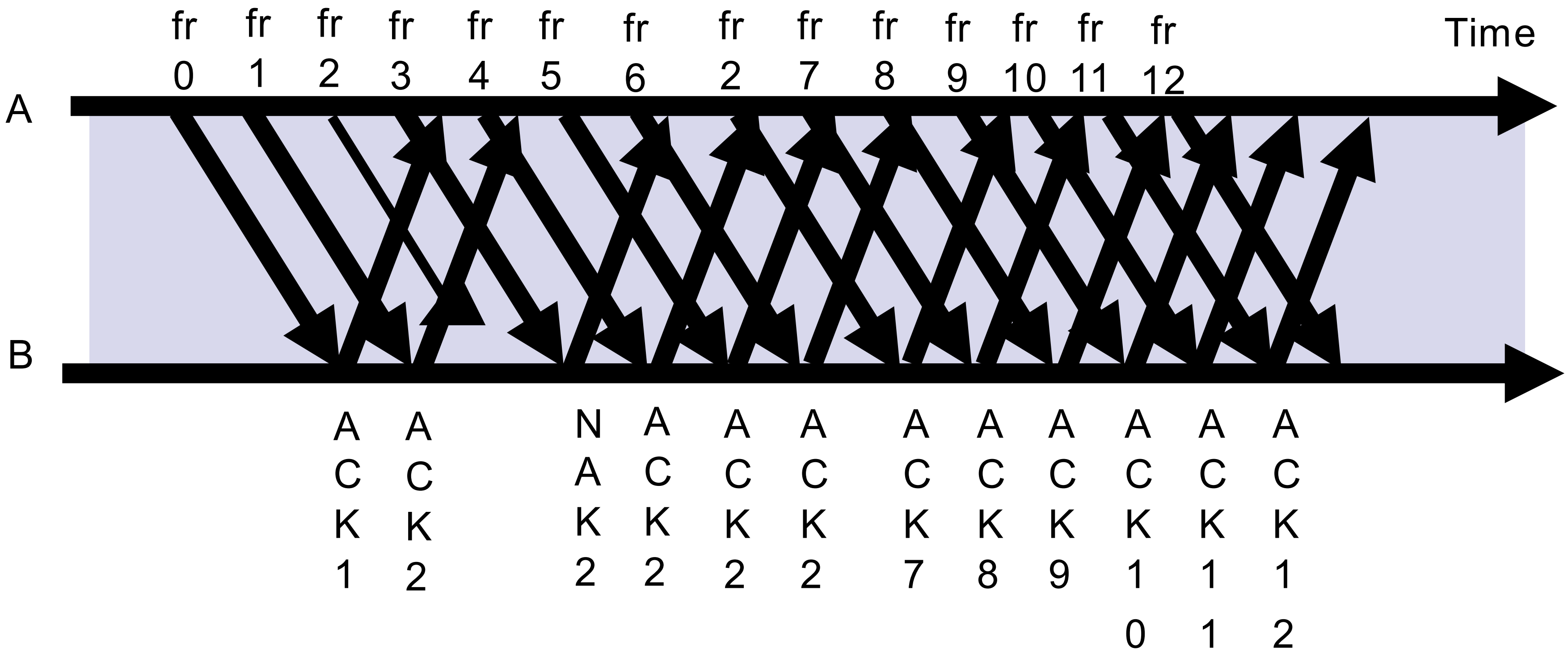
PART I: Peer-to-Peer Protocols

ARQ Protocols and Reliable Data Transfer

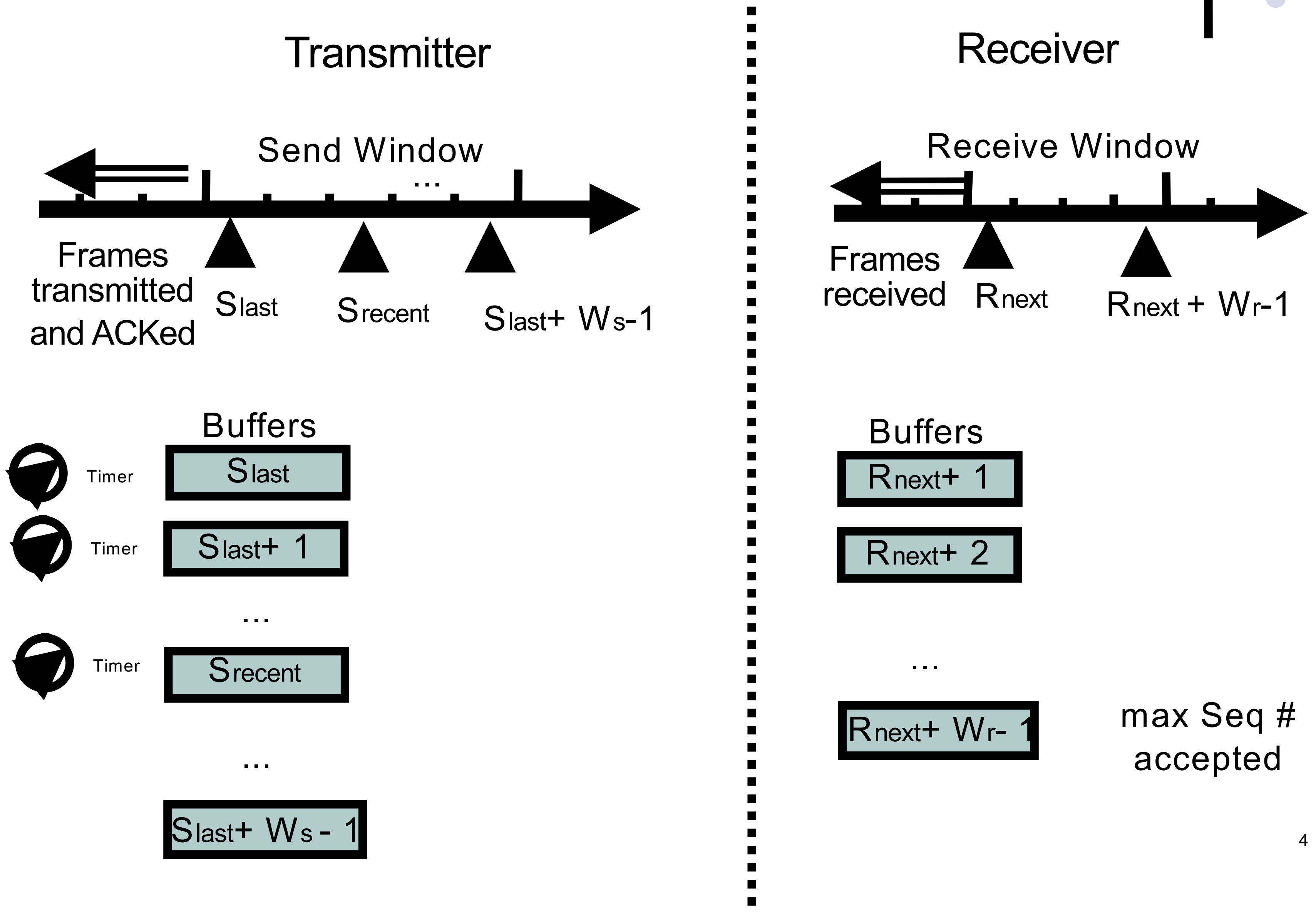
Selective Repeat ARQ

- Go-Back-N ARQ inefficient because *multiple* frames are resent when errors or losses occur
- Selective Repeat retransmits *only an individual frame*
  - Timeout causes individual corresponding frame to be resent
  - NAK causes retransmission of oldest un-acked frame
- Receiver maintains a *receive window* of sequence numbers that can be accepted
  - Error-free, but out-of-sequence frames with sequence numbers within the receive window are buffered
  - Arrival of frame with R_{next} causes window to slide forward by 1 or more

Selective Repeat ARQ

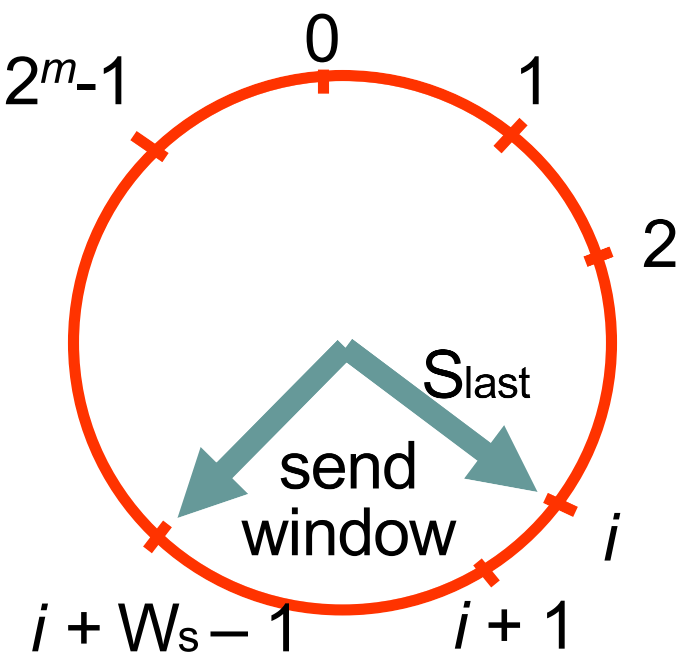


Selective Repeat ARQ

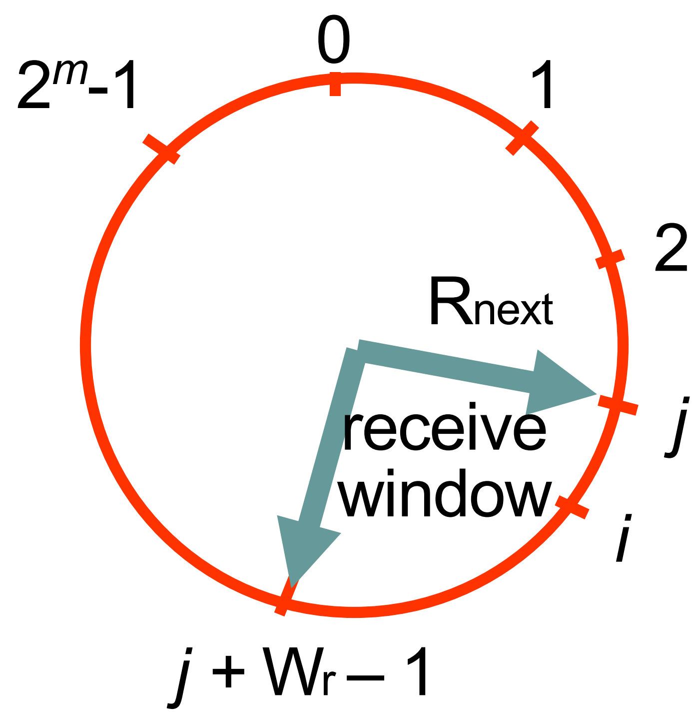


Send & Receive Windows

Transmitter



Receiver



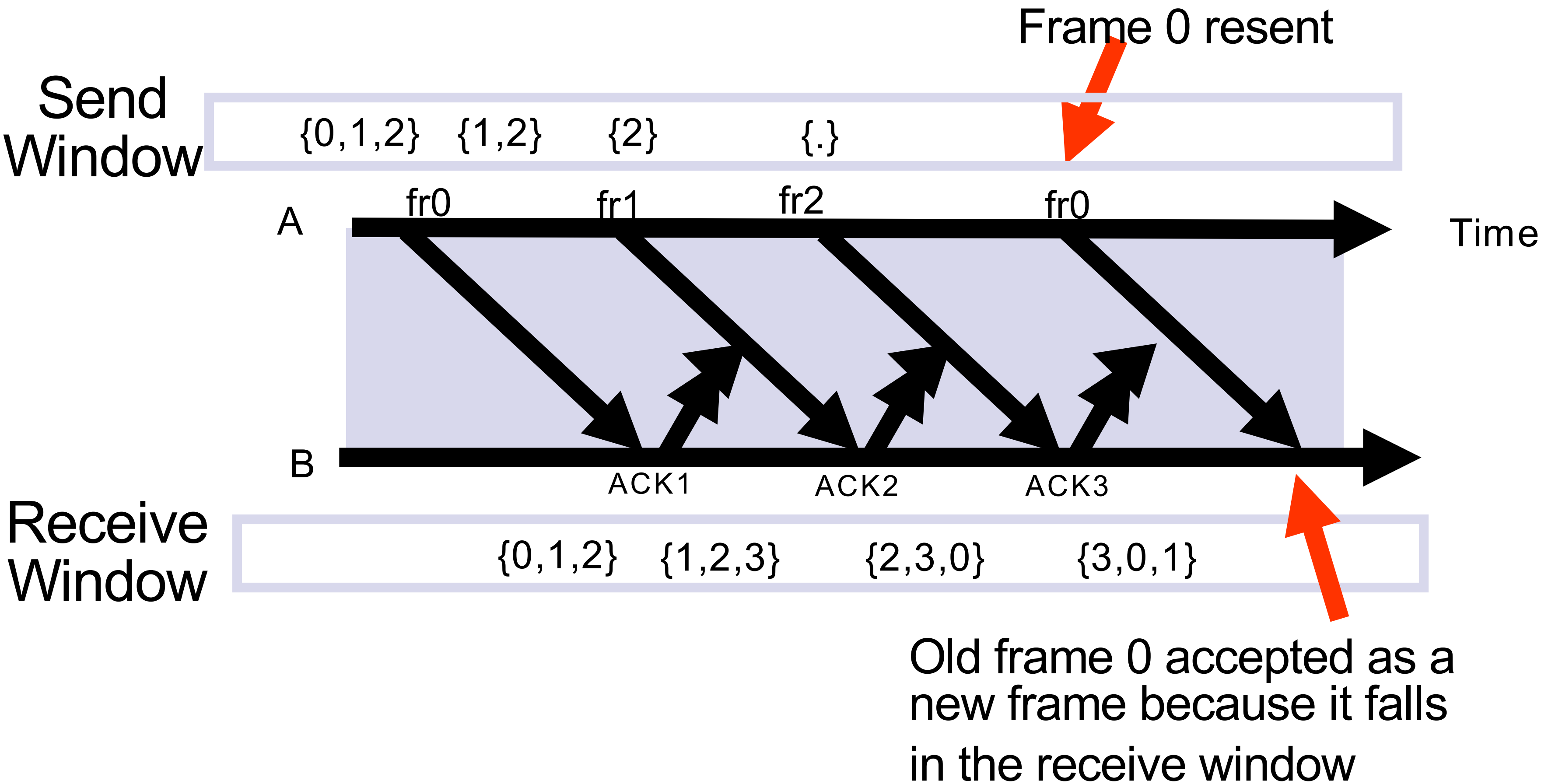
Moves k forward when ACK arrives with $R_{next} = S_{last} + k$

$k = 1, \ldots, W_s-1$

Moves forward by 1 or more when frame arrives with Seq. # = R_{next}

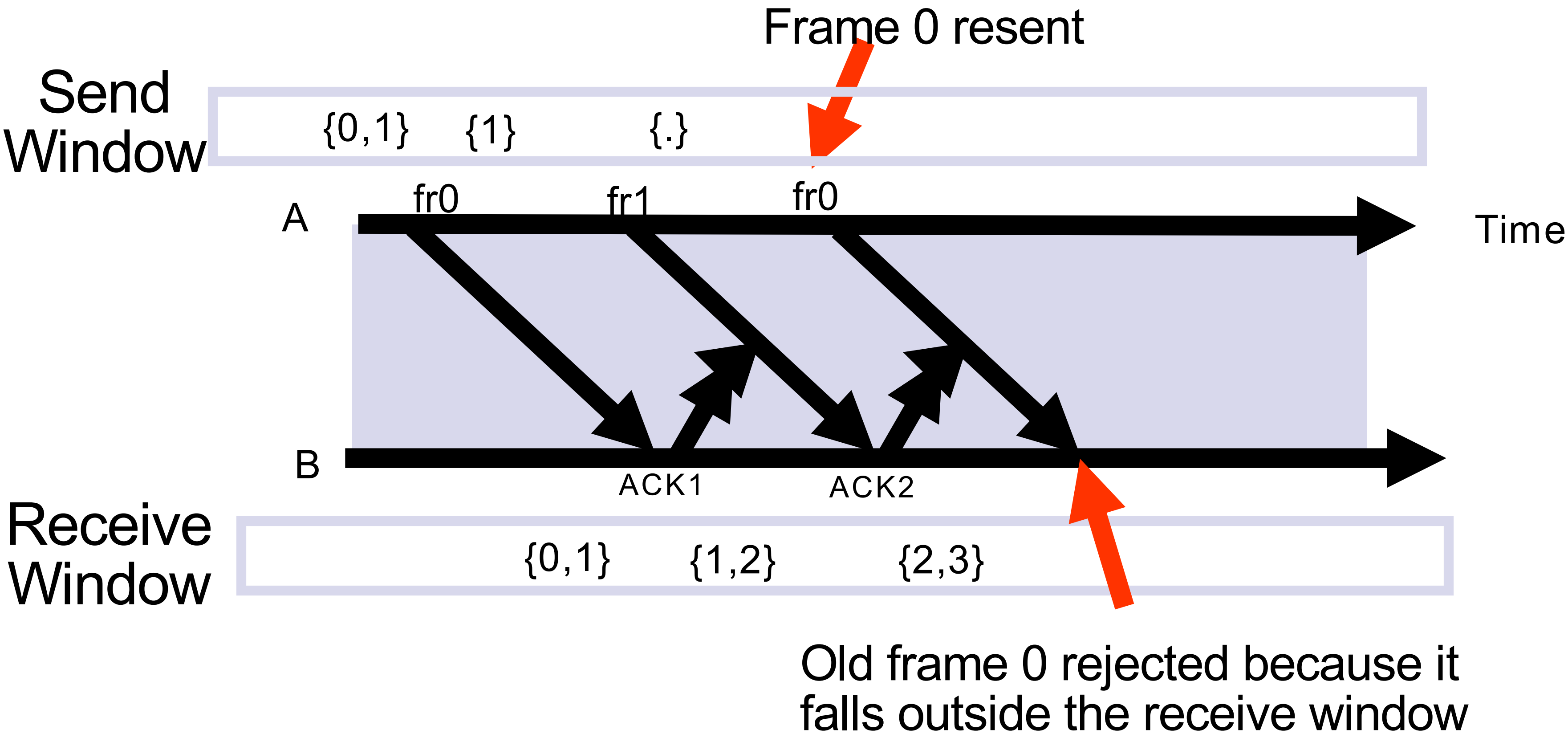
What size W_s and W_r allowed?

- Example: $M=2^2=4$, $W_s=3$, $W_r=3$



$W_s + W_r = 2^m$ is maximum allowed

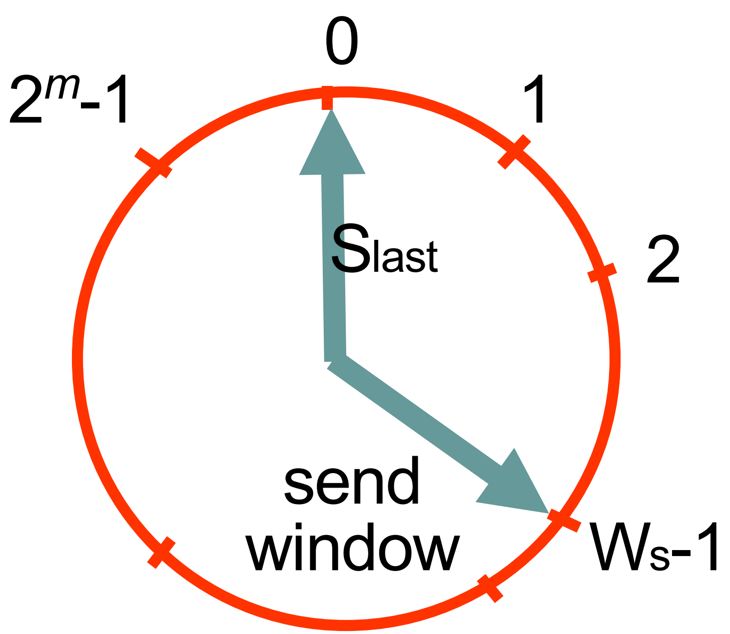
- Example: $M=2^2=4$, $W_s=2$, $W_r=2$

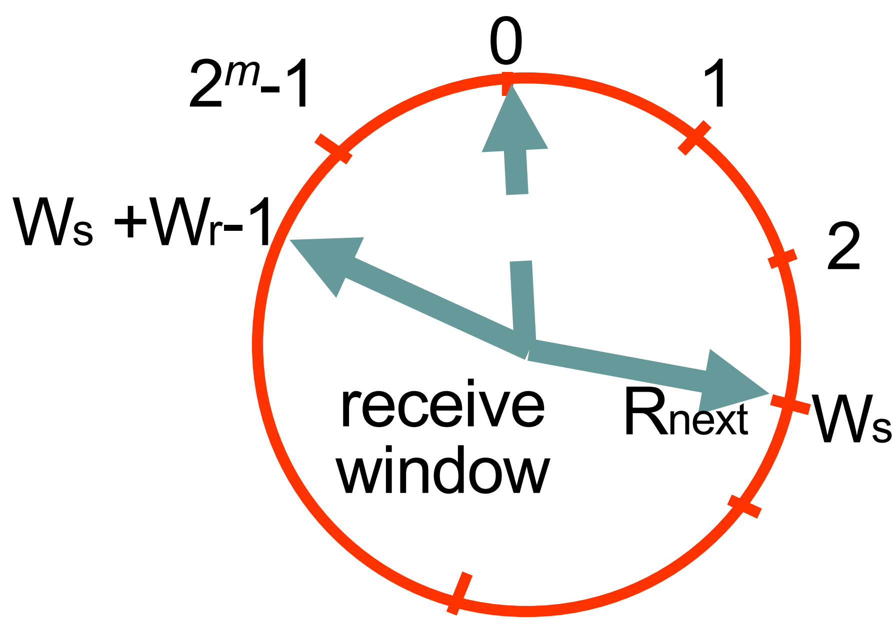


Why $W_s + W_r = 2^m$ works

- Transmitter sends frames 0 to Ws-1; send window empty
- All arrive at receiver
- All ACKs lost
- Transmitter resends frame 0

- Receiver window starts at {0, …, W_r}
- Window slides forward to {W_s,…,W_s+W_r-1}
- Receiver rejects frame 0 because it is outside receive window





Applications of Selective Repeat ARQ

- *TCP* (Transmission Control Protocol): transport layer protocol uses variation of selective repeat to provide reliable stream service
- *Service Specific Connection Oriented Protocol*: error control for signaling messages in ATM networks

Efficiency of Selective Repeat

- Assume P_f frame loss probability, then number of transmissions required to deliver a frame is:
  - $t_f / (1-P_f)$

$$\eta_{SR} = \frac{\dfrac{n_f - n_o}{t_f/(1-P_f)}}{R} = (1-\frac{n_o}{n_f})(1-P_f)$$

Example: Impact Bit Error Rate on Selective Repeat

n_f=1250 bytes = 10000 bits, n_a=n_o=25 bytes = 200 bits

Compare S&W, GBN & SR efficiency for random bit errors with p=0, 10^{-6}, 10^{-5}, 10^{-4} and R= 1 Mbps & 100 ms

Efficiency	0	10^{-6}	10^{-5}	10^{-4}
S&W	8.9%	8.8%	8.0%	3.3%
GBN	98%	88.2%	45.4%	4.9%
SR	98%	97%	89%	36%

- *Selective Repeat outperforms GBN and S&W, but efficiency drops as error rate increases*

Comparison of ARQ Efficiencies

Assume n_a and n_o are negligible relative to n_f, and
$L = 2(t_{prop}+t_{proc})R/n_f = (W_s-1)$, then

Selective-Repeat:

$$\eta_{SR} = (1-P_f)(1-\frac{n_o}{n_f}) \approx (1-P_f)$$

Go-Back-N:

For $P_f \approx 0$, SR & GBN same

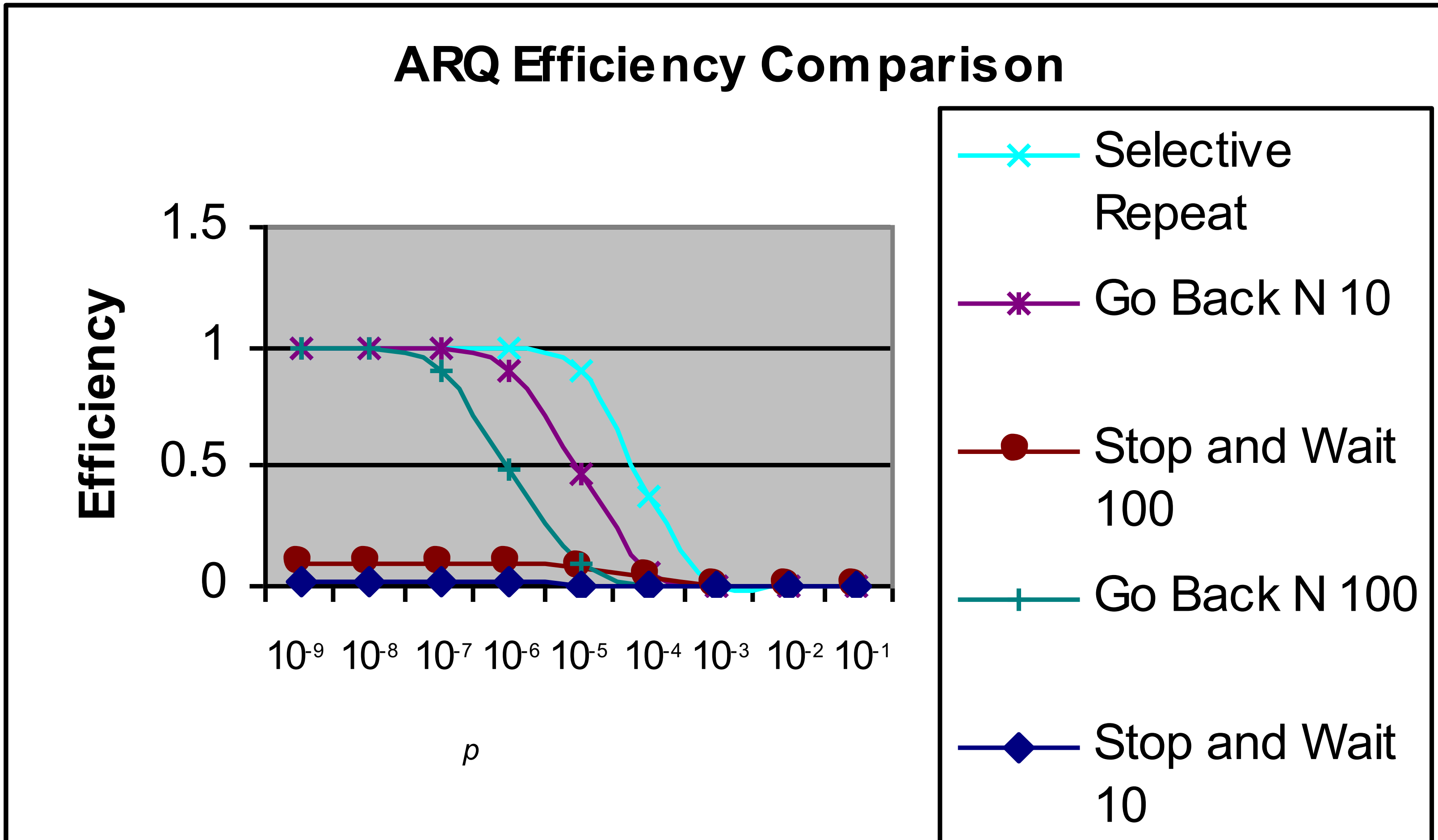
$$\eta_{GBN} = \frac{1-P_f}{1+(W_S-1)P_f} = \frac{1-P_f}{1+LP_f}$$

For $P_f \rightarrow 1$, GBN & SW same

Stop-and-Wait:

$$\eta_{SW} = \frac{(1-P_f)}{1+\frac{n_a}{n_f}+\frac{2(t_{prop}+t_{proc})R}{n_f}} \approx \frac{1-P_f}{1+L}$$

ARQ Efficiencies



Delay-Bandwidth product = 10, 100