Sliding Window Protocols

- Frames are numbered.
- Lost frames can be retransmitted.
- Duplicate frames can be deleted.
- Out of order frames can be reordered.

The sender maintains two variables:

- $S_L =$ the number of the “oldest” frame sent, but not ACK’ed.
- $S_U =$ the number of the next frame to send that has not ever been sent.
- $S_U - S_L =$ the size of the sender’s window (the number of sending buffers needed)

The receiver maintains two variables:

- $R_L =$ lowest numbered frame the receiver is willing to accept
- $R_U =$ one more than the highest numbered frame the receiver is willing to accept.
- $R_U - R_L =$ size of receiver’s window.

Algorithm

Rough algorithm of the sliding window protocols:

1. Transmit all frames in the sender’s window (no more than from $S_L$ to $S_U-1$)
2. Whenever the receiver gets a frame in its window:
   
   (a) it generates an ACK for the highest frame correctly received (same as the frame for protocol 5).
   
   (b) if the frame $R_L$ has been received it passes $R_L$ to the host and bumps $R_L$ and $R_U$ (advances the window).
3. Whenever the receiver gets a damaged frame or a frame not within its window it generates a NAK for one less than the frame expected ($R_L - 1$) (only for protocol 6).
4. Whenever the sender receives an ACK for a frame within its window, it marks that frame as having been correctly sent and received. If \( S_L \) is ACKed then increment \( S_L \) and \( S_U \) (advance the sender’s window) and transmit \( S_{U-1} \) (last previously unsent frame).

5. Whenever a timer goes off, retransmit the corresponding frame.

**Relationships**

Sequence numbers: \( 0 \ldots (2^n - 1) \)

\[
S_L < S_U, \quad R_L < R_U
\]

Steady state condition: \( R_L \leq S_U \)

Interval of active frames: \([S_L, R_U)\)

So \( R_U - S_L \leq 2^n \) and \((R_U - R_L) + (S_U - S_L) \leq 2^n\)

where \( n \) is the number of bits in the sequence number Two cases:

1. Receiver window size of one (protocol 5):
   \[
   R_U - R_L = 1 \\
   (S_U - S_L) + 1 \leq 2^n \\
   (S_U - S_L) \leq 2^n - 1
   \]

2. Receiver and sender have equal window sizes (protocol 6):
   \[
   R_U - R_L = S_U - S_L = W \\
   2W \leq 2^n \\
   W \leq 2^{n-1}
   \]

**Protocol 6 Example**

Situation:

1. Sender sends sequence numbers 0-3.

2. Receiver has ACKed 0-3 (advancing window), but sender has not received the ACKs.

\[
\begin{align*}
\text{SL} & \quad \text{SU} \\
0 & \quad 1 & \quad 2 & \quad 3 & \quad 4 & \quad 5 & \quad 6 & \quad 7 \\
\text{RU} & \quad \text{RL} \\
0 & \quad 1 & \quad 2 & \quad 3 & \quad 4 & \quad 5 & \quad 6 & \quad 7
\end{align*}
\]