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: $0..(2^n - 1)$

$S_L < S_U, R_L < R_U$

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.

<table>
<thead>
<tr>
<th>$S_L$</th>
<th>$S_U$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 1 2 3</td>
<td>0 1 2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>$R_U$</th>
<th>$R_L$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 1 2 3</td>
<td>0 1 2</td>
</tr>
</tbody>
</table>