The Balanced Sliding Window Protocol

Definitions

- Two processes, *p* and *q*, each sending an infinite array of words to the other

- <u>For Process</u> *p*:

  in_p: An infinite array of words to be sent to process q

  out_p: An infinite array of words being received from process q

  Initially for all i, $out_p[i] = udef$

  s_p: The lowest numbered word that *p* still expects to receive from *q*

  At any time, *p* has already written $out_p[0]$ through $out_p[\mathrm{s_p} - 1]$

Required Properties

Safe delivery:

- In every reachable configuration of the protocol

  $out_p[0 \ldots s_p - 1] = in_q[0 \ldots s_p - 1]$ and

  $out_q[0 \ldots s_q - 1] = in_p[0 \ldots s_q - 1]$

Eventual delivery:

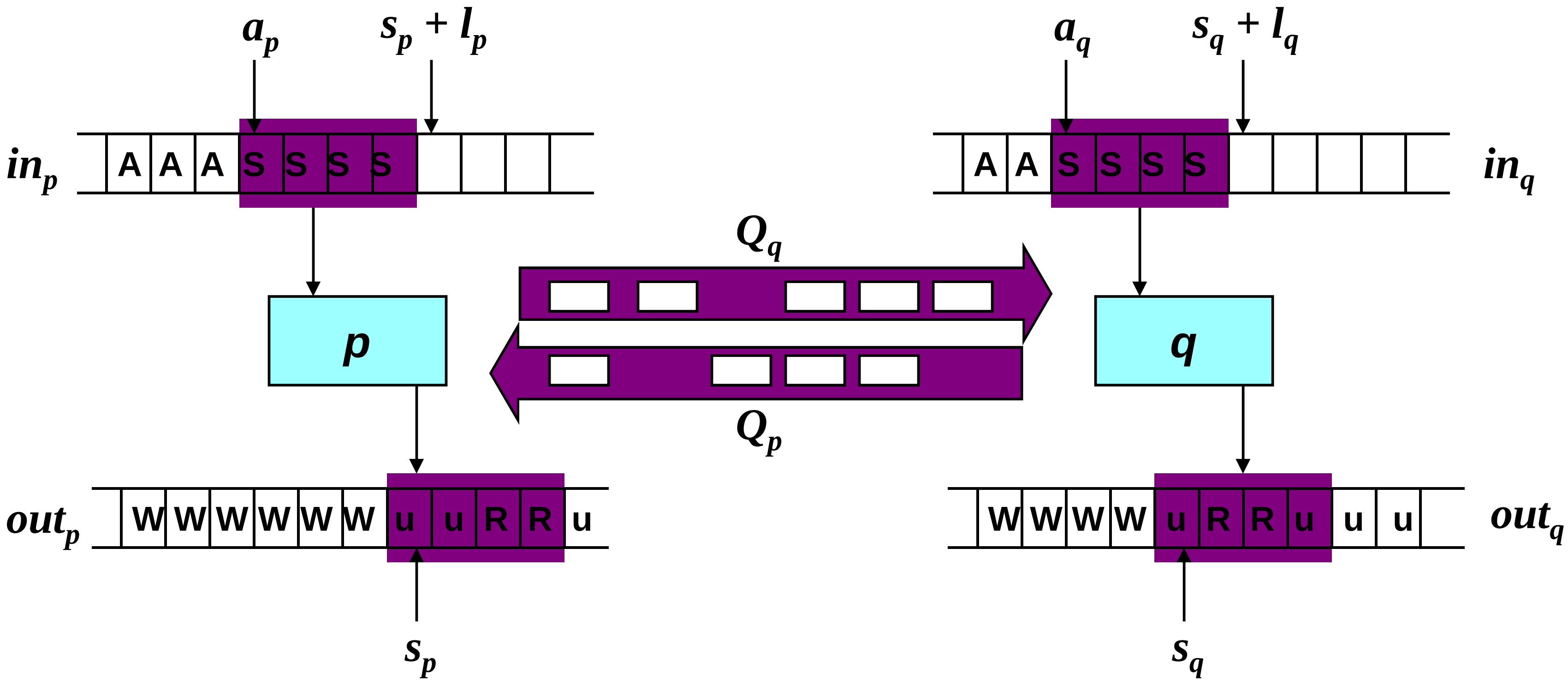
- For every integer $k \geq 0$, a configuration with $s_p \geq k$ and $s_q \geq k$ is eventually reached

The protocol

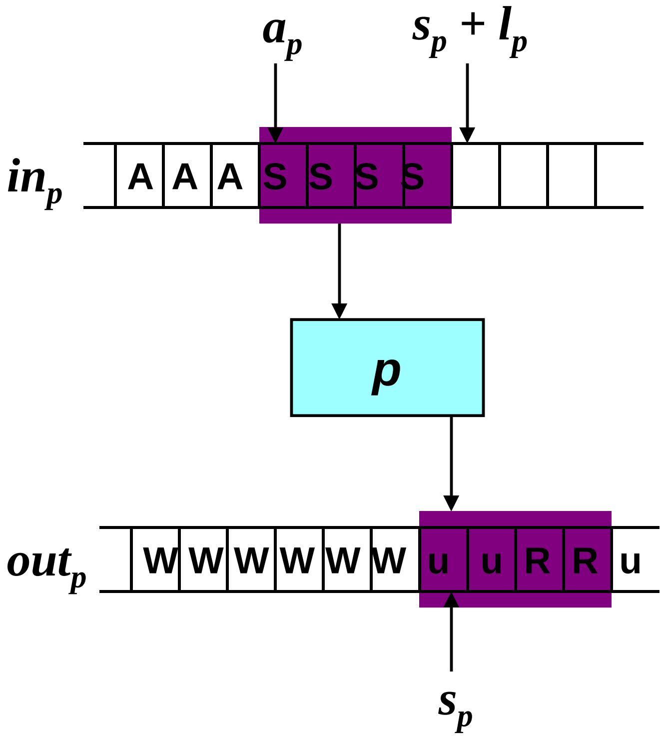
- The packet, < pack, w, i >, transmits the word $w = in_p[\ i\ ]$ to q.

- The processes use constants l_p and l_q as follows:
  - Process p can send the word $w = in_p[\ i\ ]$ (as the packet, < pack, w, i >) only after storing all the words $out_p[0]$ through $out_p[\ i - l_p\ ]$, that is, $i < s_p + l_p$.
  - When p receives < pack, w, i >, retransmission of words from $in_p[0]$ through $in_p[\ i - l_q\ ]$ is no longer necessary.

The Sliding Windows



The Protocol



S_p: { $a_p \le i < s_p + l_p$ }
begin send < pack, $in_p[i]$, i > to q end

R_p: { < pack, w, i > $\in Q_p$ }
begin receive < pack, w, i > ;
if $out_p[i] = udef$ then
begin $out_p[i] = w$;
$a_p = max\{ a_p, i - l_q + 1 \}$;
$s_p = min\{ j \mid out_p[j] = udef \}$
end
// else ignore – *retransmission*
end

L_p: { < pack, w, i > $\in Q_p$ }
begin $Q_p = Q_p \setminus \{$ < pack, w, i > $\}$ end

Protocol Invariant

$$
\begin{aligned}
P \equiv \quad & \forall i < s_p : out_p[i] \neq udef \\
\wedge\ & \forall i < s_q : out_q[i] \neq udef \\
\wedge\ & \langle \text{pack}, w, i \rangle \in Q_p \Rightarrow w = in_q[i] \wedge (i < s_q + l_q) \\
\wedge\ & \langle \text{pack}, w, i \rangle \in Q_q \Rightarrow w = in_p[i] \wedge (i < s_p + l_p) \\
\wedge\ & out_p[i] \neq udef \Rightarrow out_p[i] = in_q[i] \wedge (a_p > i - l_q) \\
\wedge\ & out_q[i] \neq udef \Rightarrow out_q[i] = in_p[i] \wedge (a_q > i - l_p) \\
\wedge\ & a_p \leq s_q \\
\wedge\ & a_q \leq s_p
\end{aligned}
$$

Results

<u>Safety</u>: The protocol satisfies the requirement of safe delivery

<u>Liveness</u>:

- P implies $s_p - l_q \leq a_p \leq s_q \leq a_q + l_p \leq s_p + l_p$
- P implies that the sending of <pack, $in_p[s_q]$, s_q> by *p* or the sending of <pack, $in_q[s_p]$, s_p> by *q* is applicable.
  - *Hence no deadlock is possible*

- The protocol satisfies the requirement of eventual delivery