# The Balanced Sliding Window Protocol

## CS60002: Distributed Systems

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# Definitions

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

- For Process $p$:

  $in_p$: 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 $out_p[i]$

# Required Properties

***Safe delivery***:

- In every reachable configuration of the protocol

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

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

***Eventual delivery***:

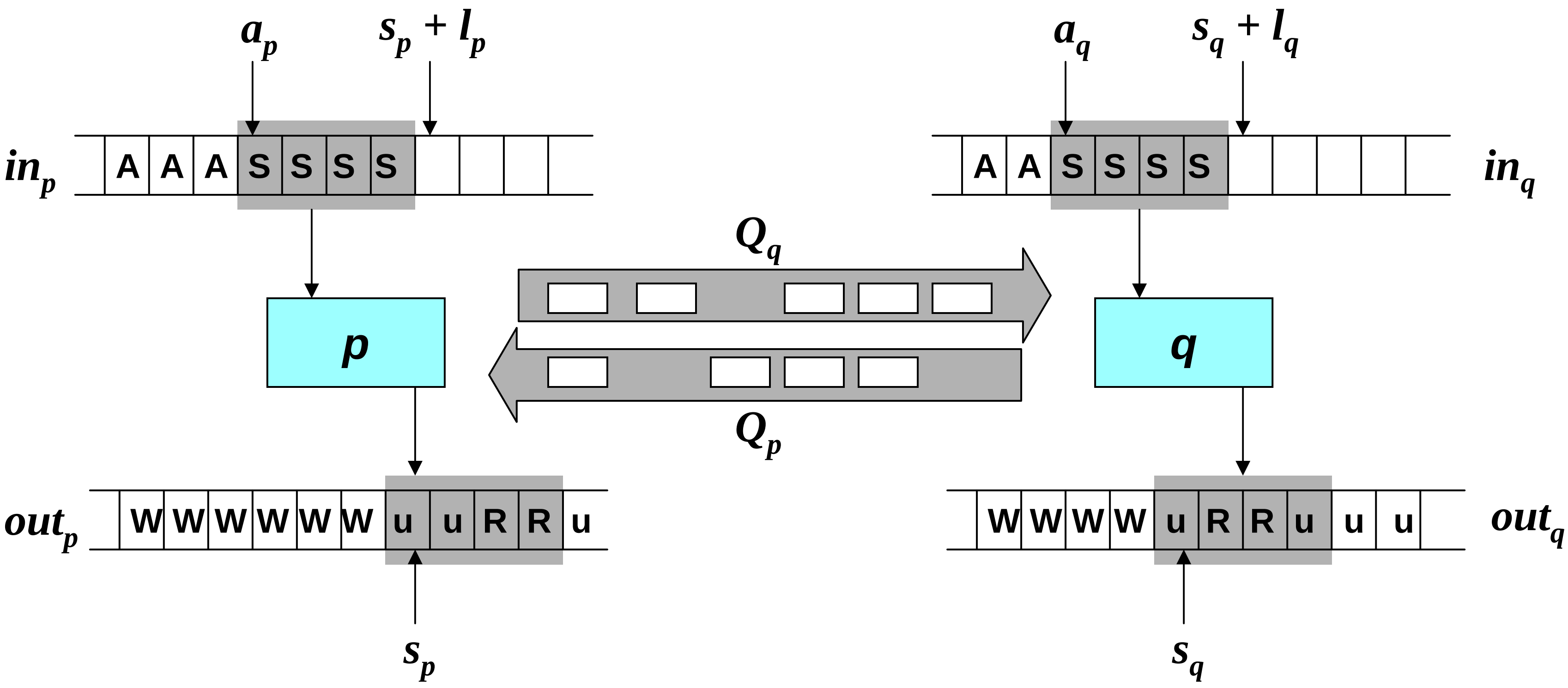
- For every integer $k \geq 0$, a configuration with $s_p \geq k$ and $s_q \geq k$ is eventually reached

# The protocol

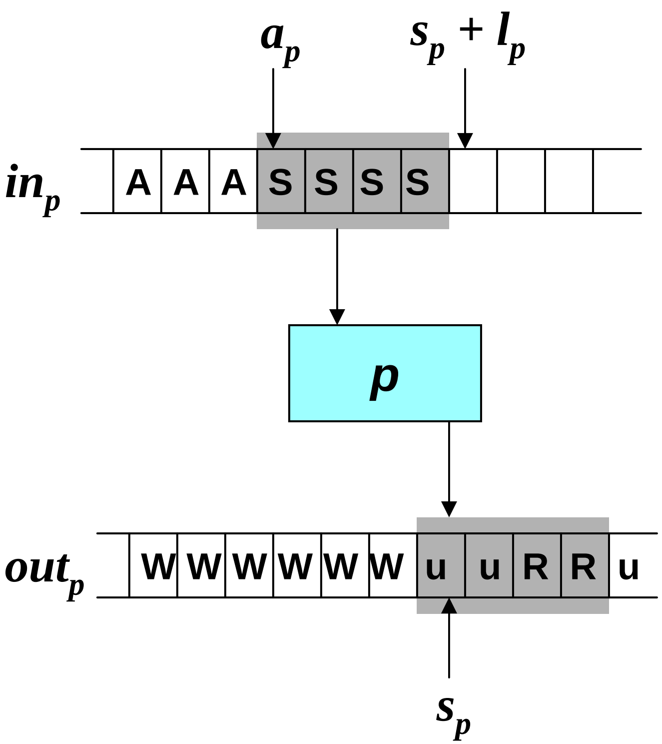
- The packet, $< pack, w, i >$ , transmits the word $w = in_p[\ i\ ]$ to $q$.

- 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$_p$:** $\{ a_p \leq i < s_p + l_p \}$

**begin** send $<$ pack, $in_p[i]$, $i >$ to $q$ **end**

**R$_p$:** $\{ <$ pack, $w$, $i > \in \mathrm{Q_p} \}$

**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, $w$, $i > \in \mathrm{Q_p} \}$

**begin** $\mathrm{Q_p} = \mathrm{Q_p} \setminus \{ <$ pack, $w$, $i > \}$ **end**

# Protocol Invariant

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

# Results

**Safety**: The protocol satisfies the requirement of safe delivery

**Liveness**:

- 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