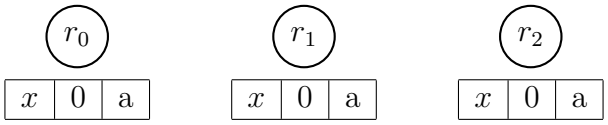
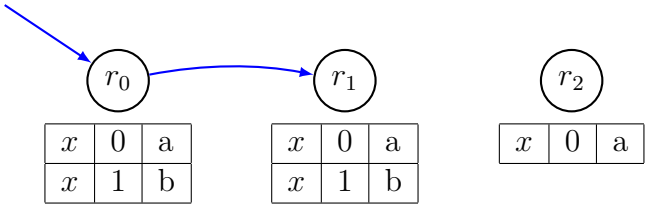
# CRAQ Garbage Collection Bug

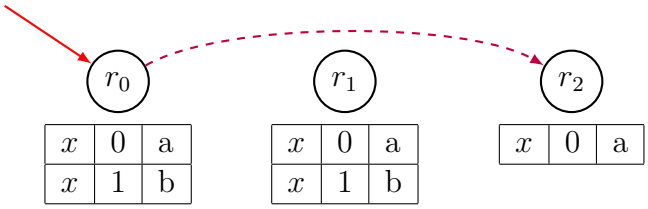
We describe a very minor bug in CRAQ's garbage collection. Consider the CRAQ deployment with three replicas shown below, where $r_0$ is the head and $r_2$ is the tail. Initially, all three replicas store a single version (i.e. version 0) of object $x$, which has value a.



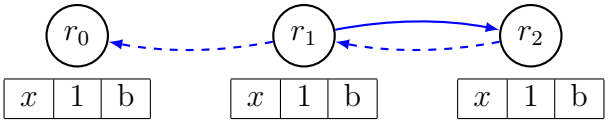

A client sends a write request with value b to the head, $r_0$. $r_0$ creates a new version of $x$ and forwards the write request to $r_1$, which also creates a new version of $x$.




Then, a client sends a read request of value $x$ to the head. $r_0$ has more than one version of $x$, so it cannot perform the read locally. Instead, it sends a version request to the tail $r_2$. When $r_2$ receives the version request, it queries to find that its version of $x$ is 0. It sends 0 back to $r_0$, but this message is delayed in network and is not yet received by $r_0$.




Next, $r_1$ forwards the write request to the tail, and the tail successfully propagates write acknowledgements backwards through the chain. When $r_0$ and $r_1$ receive the acknowledgement, they garbage collect version 0 of $x$, as described in the CRAQ paper: "When an acknowledgment message for an object version arrives at a node, the node marks the object version as clean. The node can then delete all prior versions of the object."




Finally, $r_0$ receives the delayed message, which includes version 0, from $r_2$. $r_0$ then attempts to read version 0 of $x$. The CRAQ paper says "by construction, the node is guaranteed to be storing this version of the object", but this is not true. $r_0$ does not have this version (actually, no node has this version), and is stuck.