

## Reliable Broadcast

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**Exercise 1** What happens in the reliable broadcast and uniform reliable broadcast algorithms if the: (a) accuracy, (b) completeness property of the failure detector is violated?

**Solution**

**Reliable Broadcast.**

- a Suppose *accuracy* is violated. Then, the processes might be relaying messages when this is not really necessary. This wastes resources but does not impact correctness.
- b Suppose now *completeness* is violated. Then, the processes might not be relaying messages they should be relaying. This may violate *agreement*. For illustration, assume that only a single process  $p_1$  *bebDelivers* (and, hence *rbDelivers*) a message  $m$  from a crashed process  $p_2$ . If a failure detector (at  $p_1$ ) does not ever suspect  $p_2$  no other correct process will deliver  $m$  (i.e., *agreement* is violated).

**Uniform Reliable Broadcast.** Consider a system of three processes  $p_1$ ,  $p_2$  and  $p_3$ . Assume that  $p_1$  *urbBroadcasts* the message  $m$ .

- a First, suppose that *accuracy* is violated. Assume that  $p_1$  falsely suspects  $p_2$  and  $p_3$  to have crashed.  $p_1$  eventually *urbDelivers*  $m$ . Assume that  $p_1$  crashes afterwards. It may happen that  $p_2$  and  $p_3$  never *bebDeliver*  $m$  and have no knowledge about  $m$ : *uniform agreement* is violated.
- b Suppose now *completeness* is violated. Then,  $p_1$  might never *urbDeliver*  $m$  if either  $p_2$  or  $p_3$  crashes and  $p_1$  never detects their crash or *bebDelivers*  $m$  from  $p_2$  and  $p_3$ . Hence,  $p_1$  would wait indefinitely for  $p_2$  and  $p_3$  to relay  $m$ . In this case: *validity* property is violated.

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**Exercise 2** Implement a reliable broadcast algorithm without using any failure detector (i.e., using only *BestEffort-Broadcast* (beb)).

**Solution** We can circumvent the need for a failure detector in our reliable broadcast algorithm by adapting the following scheme: every process that gets a message relays it immediately. Recall that in the original algorithm, processes were relaying messages from a process  $p$  only if  $p$  crashes.

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**Exercise 3** Assume a majority of processes is correct. Modify the uniform reliable broadcast algorithm presented in the class, such that it *does not* use any failure detector.

**Solution** In the slide 35, substitute  $\langle \text{correct} \subset \text{ack}[m] \rangle$  with  $\langle |\text{ack}[m]| > N/2 \rangle$ , where  $N$  denotes the total number of processes.

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**Exercise 4** The reliable broadcast algorithm presented in the class has the processes continuously fill their different buffers without emptying them. Modify it to remove unnecessary messages from the buffers: (a) *from* $[p_i]$ , and (b) *delivered*.

**Solution**

- a The array *from* is used only to store messages that are relayed in the case of a failure. Therefore, messages from the array *from* can be removed as soon as they are relayed.
- b Messages from the buffer *delivered* cannot be removed. If a process crashes and its messages are retransmitted by two different processes, then a process might *rbDeliver* the same message twice if it empties the *delivered* buffer in the meantime. This would violate the *no duplication* property.