Snapshots

A snapshot of an execution of a distributed algorithm should return a configuration of an execution *in the same computation*.

Snapshots can be used for:

- Restarting after a failure.
- Debugging.
- Off-line determination of stable properties,
  which remain true as soon as they have become true.

  Examples: deadlock, garbage.

Challenge: Take a snapshot without (temporarily) freezing the execution.

Snapshots

We distinguish basic messages of the underlying distributed algorithm and control messages of the snapshot algorithm.

A snapshot of a (basic) execution consists of:

- a local snapshot of the (basic) state of each process, and
- the channel state of (basic) messages in transit for each channel.

A snapshot is meaningful if it is a configuration of an execution in the same computation as the actual execution.

Snapshots

We need to avoid the following situations.

1. Process p takes a local snapshot, and then sends a message m to process q, where:
   - q takes a local snapshot after the receipt of m,
   - or m is included in the channel state of pq.

2. p sends m to q, and then takes a local snapshot, where:
   - q takes a local snapshot before the receipt of m,
   - and m is not included in the channel state of pq.

Chandy-Lamport algorithm

Consider a directed network with *FIFO* channels.

Initiators take a local snapshot of their state, and send a control message $\langle$**marker**$\rangle$ to their neighbors.

When a process that hasn't yet taken a snapshot receives $\langle$**marker**$\rangle$, it

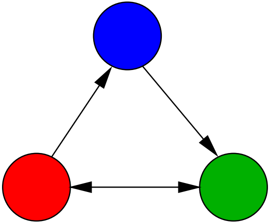
- takes a local snapshot of its state, and
- sends $\langle$**marker**$\rangle$ to all its neighbors.

Process q computes as channel state of pq the messages it receives via pq after taking its local snapshot and before receiving $\langle$**marker**$\rangle$ from p.

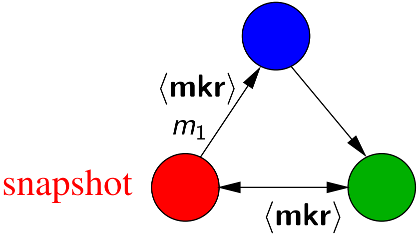
If channels are FIFO, this produces a meaningful snapshot.

Message complexity: $\Theta(E)$ (with E the number of edges)
Worst-case time complexity: $O(D)$ (with D the diameter)

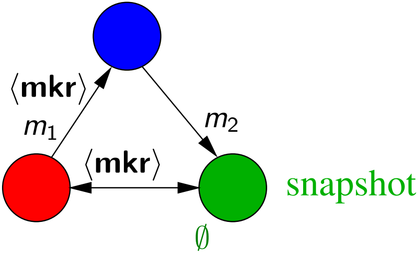
Chandy-Lamport algorithm - Example



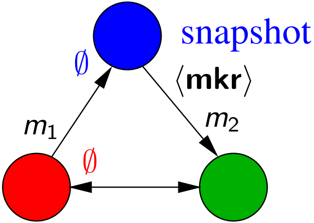
Chandy-Lamport algorithm - Example



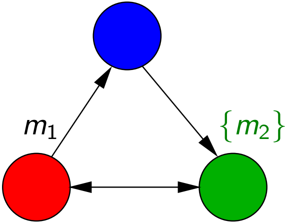
Chandy-Lamport algorithm - Example



Chandy-Lamport algorithm - Example



Chandy-Lamport algorithm - Example



The snapshot (processes red/blue/green, channels $\emptyset, \emptyset, \emptyset, \{m_2\}$) isn't a configuration in the actual execution.

The send of m_1 isn't causally before the send of m_2.

So the snapshot is a configuration of an execution that is in the same computation as the actual execution.

Chandy-Lamport algorithm - Correctness

Claim: If a post-snapshot event e is causally before an event f, then f is also post-snapshot.

This implies that the snapshot is a configuration of an execution that is in the same *computation* as the actual execution.

Proof: The case that e and f occur at the same process is trivial.

Let e be a send and f the corresponding receive event.

Let e occur at p and f at q.

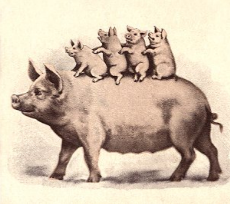
e is post-snapshot at p, so p sent $\langle$**marker**$\rangle$ to q before e.

Channels are FIFO, so q receives this $\langle$**marker**$\rangle$ before f.

Hence f is post-snapshot at q.

Lai-Yang algorithm

Suppose channels are *non-FIFO*. We use piggybacking.



Initiators take a local snapshot of their state.

When a process has taken its local snapshot, it appends *true* to each outgoing basic message.

When a process that hasn't yet taken a snapshot receives a message with *true* or a *control message* (see next slide) for the first time, it takes a local snapshot of its state *before reception of this message*.

Process q computes as channel state of pq the basic messages without the tag *true* that it receives via pq after its local snapshot.

Lai-Yang algorithm - Control messages

Question: How does q know when it can determine the channel state of pq?

Answer: p sends a control message to q, informing q how many basic messages without the tag *true* p sent into pq.

These control messages also ensure that all processes eventually take a local snapshot.

Lai-Yang algorithm - Multiple snapshots

Question: How can multiple subsequent snapshots be supported ?

Answer: Each snapshot is provided with a sequence number.

Basic message carry the sequence number of the last snapshot at the sender (instead of *true*).

Control messages carry the sequence number of their snapshot.