CSC2/458 Parallel and Distributed Systems
Checkpointing and Recovery

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URCS

Outline

Checkpointing and Recovery

Independent Checkpointing

Coordinated Checkpointing

Message Logging

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Errors happen

- Errors happen
- How do we recover from them (say, for message loss)?
  - (before information theory): ?
  - (after information theory): ?

Checkpointing and Recovery

To checkpoint is to save the state of a computation so that you can "rollback" to it

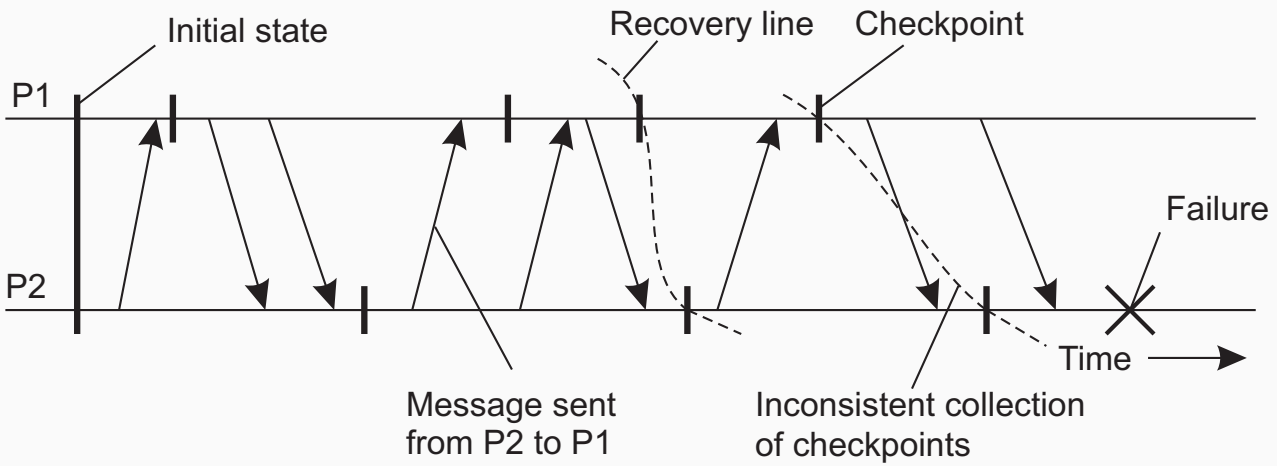
- Examples:
  - Save games
  - Virtual machine snapshots

Recovery is then "simply" restoring the checkpoint

Distributed Checkpointing: The Challenge

- Processes only know:
  - which messages they have received
  - which messages they have sent
  - what their local state is
- Checkpointing ideally should not require everybody to "pause"
  - Must run concurrently with computation

The Recovery Line



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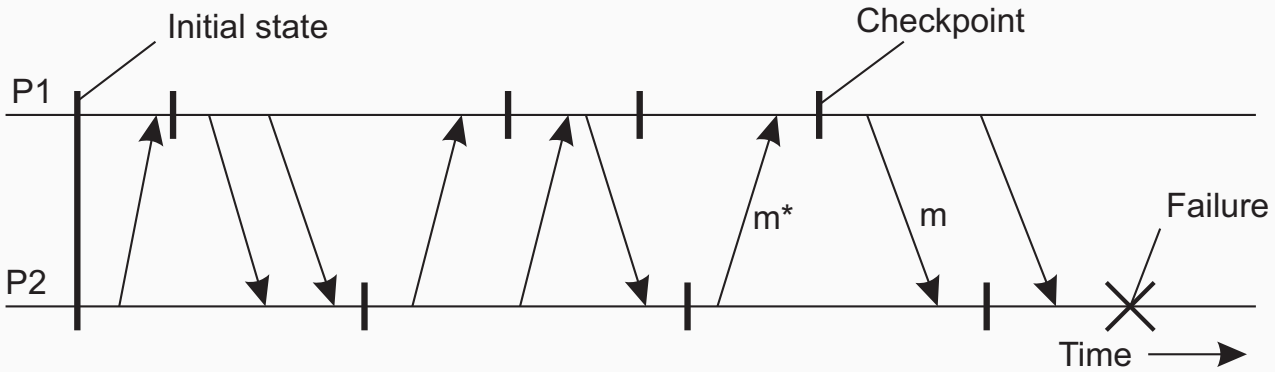
Algorithm

- A process records its local state independently
  - messages sent/received included
- A recovery for a process entails going back to its most recent checkpoint
  - Unfortunately, this can't be done independently

Rollbacks



Assume $P2$ fails. How far we do need to rollback to achieve a consistent worldview?

Detecting dependencies

- For a process P_i, let $INT_i(m)$ be the interval between the $m-1$ and m checkpoints.
- All messages sent in $INT_i(m)$ contain (i, m)
- When process P_j receives this message, it may be in $INT_j(n)$
  - records dependency $INT_i(m) \rightarrow INT_j(n)$
  - saves dependency with checkpoint

Rolling back: Consistency

- If P_i rolls back to checkpoint $m-1$, no messages from $INT_i(m)$ were ever sent
- All checkpoints dependent on $INT_i(m)$ are invalid
- Rollbacks need to continue until consistency is reached

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Algorithm

- Coordinator broadcasts CHECKPOINT-REQUEST message to all processes
- When this request is received,
  - Process checkpoints local state
  - Acknowledges to coordinator that it has taken checkpoint and waits
- When coordinator receives acknowledgements from all processes, it sends CHECKPOINT-DONE
  - Processes resume computation
- What about messages?

Message handling

- All incoming messages received after CHECKPOINT-REQUEST are not considered part of the checkpoint
- All outgoing messages are held back until CHECKPOINT-DONE is received
- This results in a "globally consistent state"
  - How?

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Basic idea

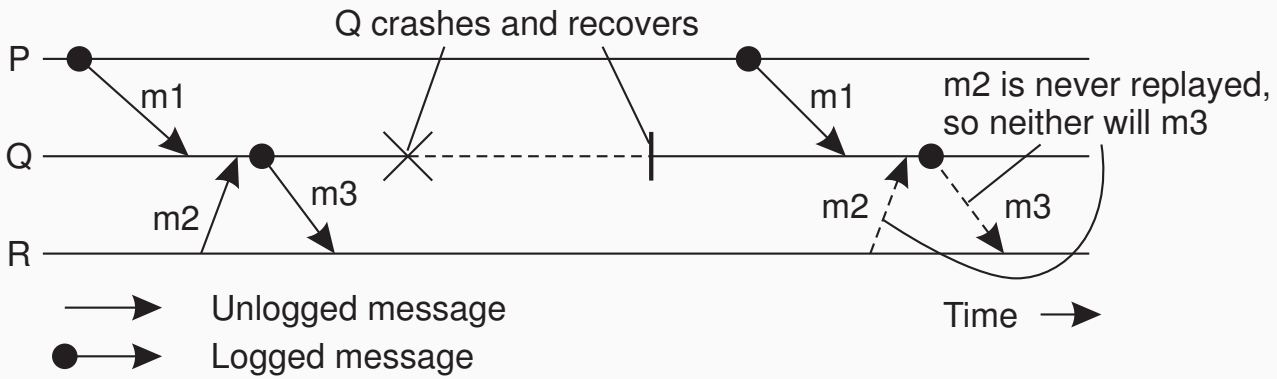
- Computations are deterministic and rely only on messages transmitted
- Save messages from a checkpoint and replay them during recovery

Piecewise deterministic execution

- A piecewise deterministic computation interval:
  - starts with a non-deterministic event (e.g. receipt of a message)
  - continues in a completely deterministic fashion
  - ends just before another non-deterministic event

This implies that only non-deterministic events need to be logged.

Who should save the messages?



Orphan processes

- Let $DEP(m)$ represent processes that depend on message m
- Let $COPY(m)$ represent processes that contain a copy of m
  - but may not have logged it
- Note, m contains all details necessary to retransmit it

A process Q is orphaned if and only if:

- Q depends on m (i.e. $Q \in DEP(m)$)
- All processes in $COPY(m)$ have failed
- So m cannot be played back

Pessimistically avoiding orphan processes

- Orphan processes can be avoided by ensuring that
  - A non-deterministic message is sent only to one process
  - That process cannot send another message without logging m

Further reading

Chandy and Lamport, “Distributed Snapshots: Determining Global States of Distributed Systems”, ACM TOCS 1985

Acknowledgments

All figures from Van Steen and Tanenbaum, Distributed Systems, 3rd Edition, Chapter 8.