

Global state

Global state

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Time is very much related to the notion of global state.

If we cannot agree on a time, how should we agree on a global state?

Global state is important:

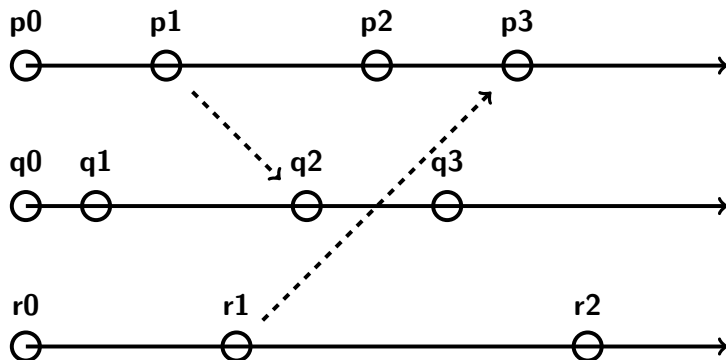
- garbage collection
- dead-lock detection
- termination
- debugging

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Global state

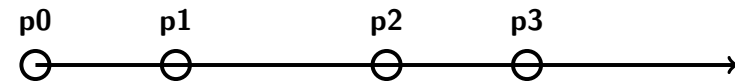
Given a partial order of events, can we say anything about the state of the system?



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History and state

The *history* of a process is a sequence of events: $\langle p_0, p_1, \dots, p_n \rangle$



The state of a process, is a description of the process after an event.

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Global state

Is the state of a process the history of events?

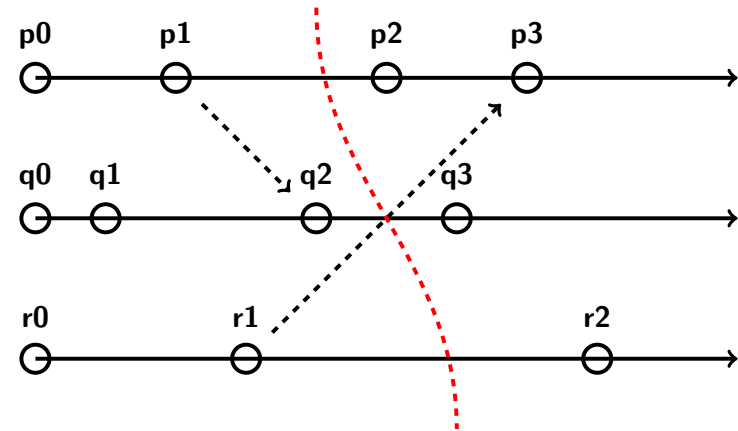
What is the *global state* of a distributed system?

The union of histories of all processes?

Do all unions make sense?

Global history and cut

A cut is the global history up to a specific event in each history.



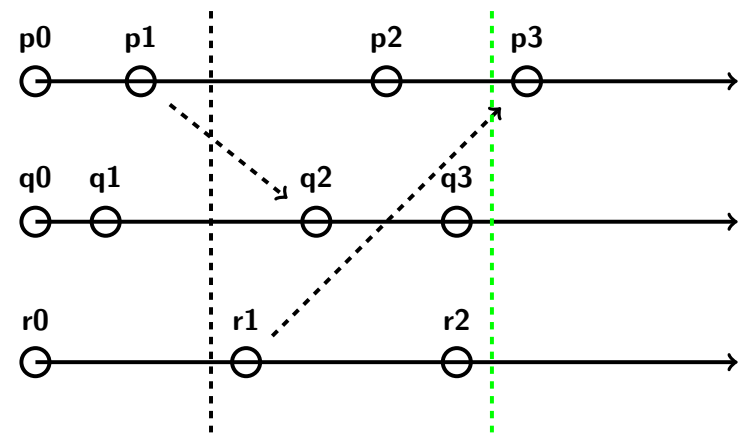
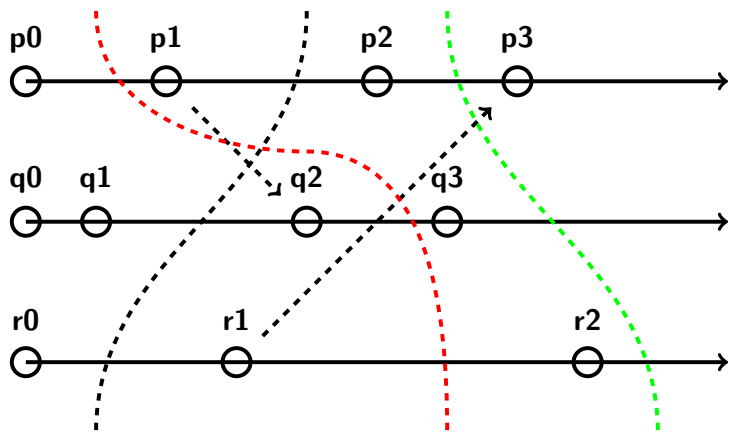
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An event is *in the cut* if it belongs to the events of a history up to the specific

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All cuts are equal, but ...

..some are more equal ..

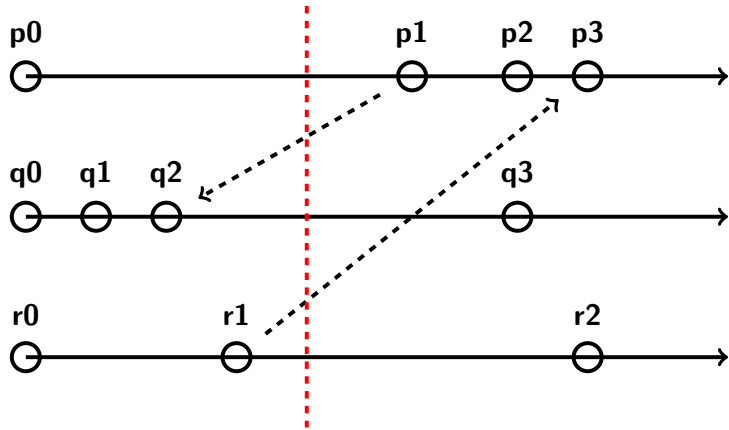


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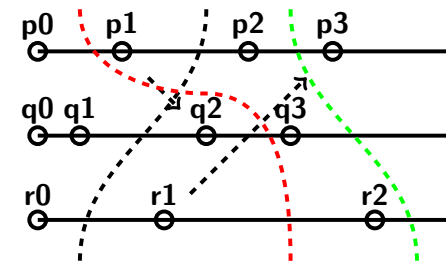
.. than others

Consistent cuts



For each event e in the cut:

- if f happened before e then
- f is also in the cut.



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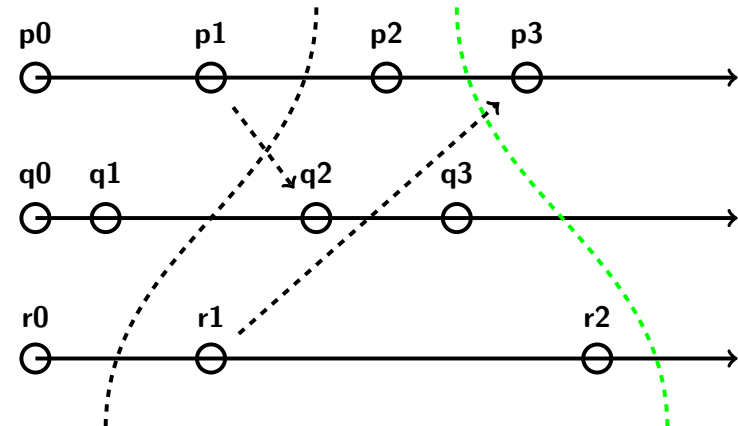
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Consistent global state

Consistent, but not actual states

A *consistent cut* corresponds to a *consistent global state*.

- it is a possible state without contradictions
- the actual execution might not have passed through the state



All *real time cuts* are *consistent*, but who knows the real time?

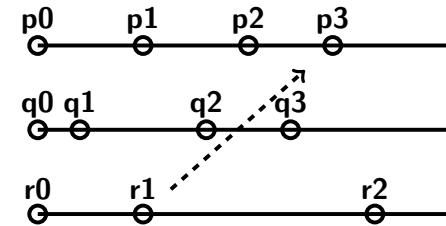
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Linearization

- A *run* is a total ordering of all events in a global history that is consistent with each local history.
- A *linearization* or *consistent run* is a run that describes transitions between consistent global states.
- A state S' is *reachable* from state S if there is a linearization from S to S' .

Linearization

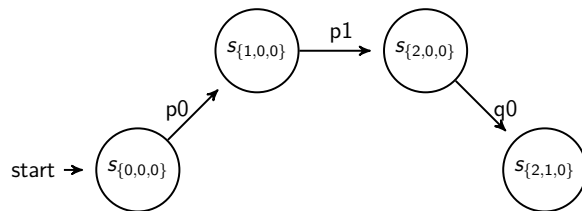


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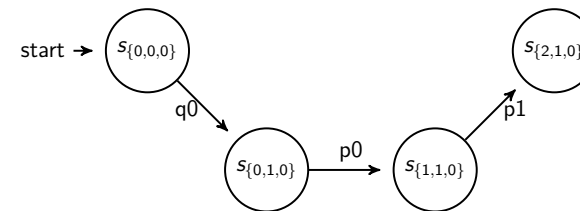
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Possible state transitions

[p0, p1, q0, r0, q1, r1, p2, p3, q2, r2, q3]



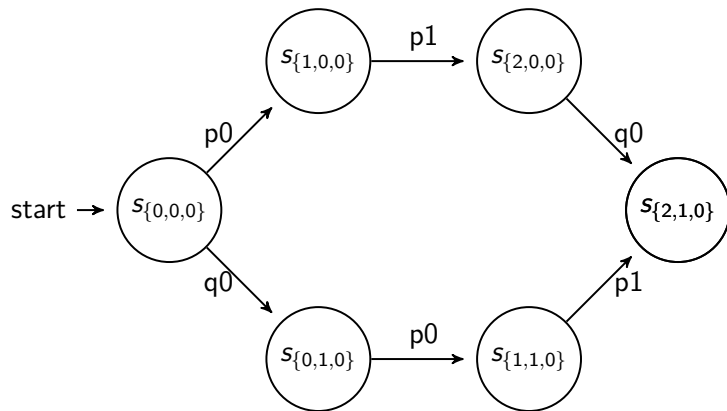
[q0, p0, p1, r0, q1, r1, p2, p3, q2, r2, q3]



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Possible paths



Each path is a consistent run, a linearization, a path that the execution actually took.

Why is this important?

- If we can collect all events and know the happened before order, then we can construct all possible linearizations.
- We know that the actual execution took one of these paths.
- Can we say something about the execution even though we do not know which path that was taken?

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Global state predicate

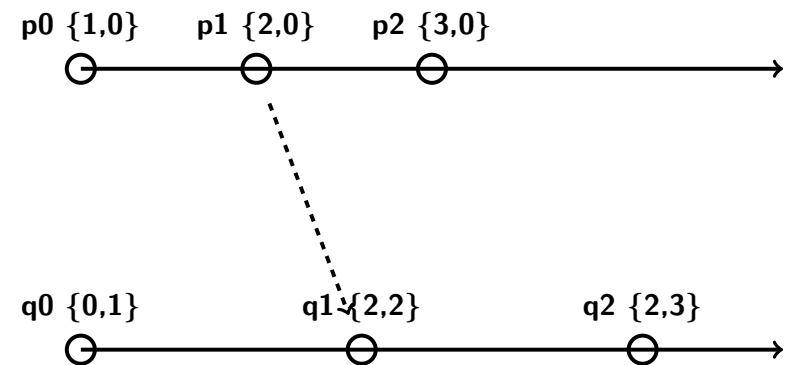
A global state predicate is a property that is true or false for a global state.

- **Safety** - a predicate is never true in any state.
- **Liveness** - a predicate that eventually evaluates to true.

How do we determine if a property holds in an execution?

let's capture all linearizations

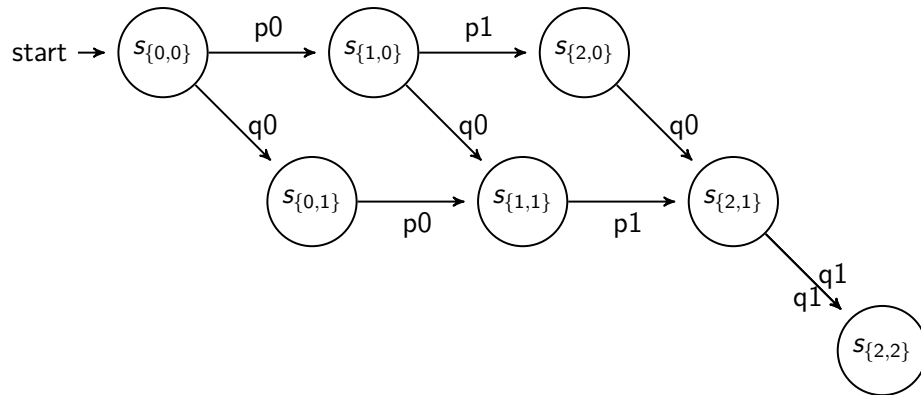
Idée - use vector clocks, collect all events of the execution.



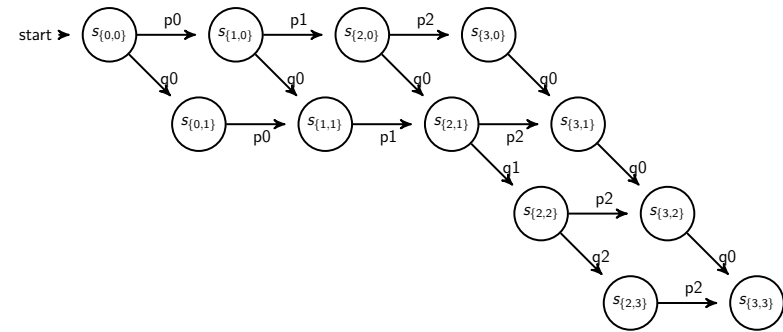
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construct all linearizations



an execution lattice



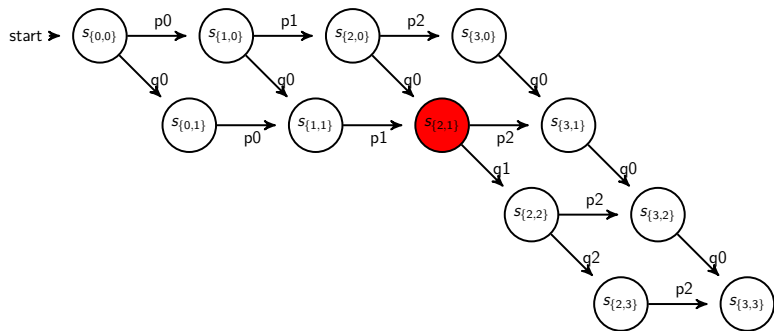
Any path is a linearization.

The actual execution took one path.

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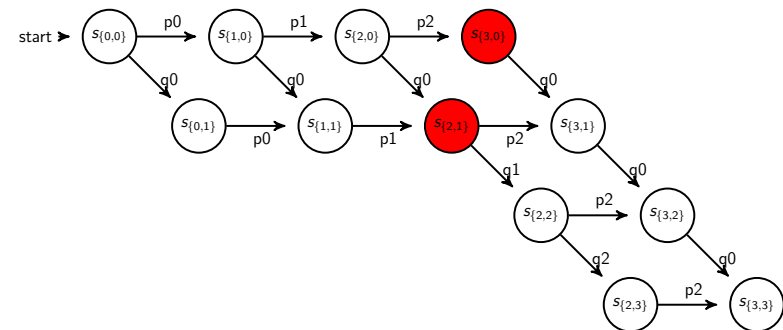
Possibly true



If a predicate is true in a consistent global state of the lattice, then it is *possibly true* in the execution.

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Definitely true

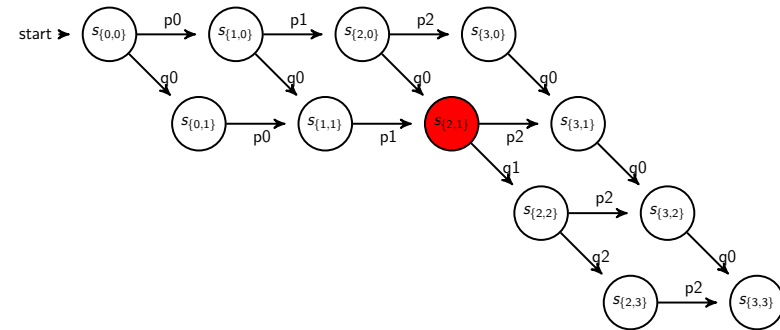


If we cannot find a path from the initial state to the final state without reaching a state for which a predicate is true then the predicate is *definitely true* during the execution.

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We differentiate between:

- **Stable:** if a predicate is true it remains true for all reachable states
- **Non-stable:** if a predicate can become true and then later become false



What do I know is a stable predicate is true for state $S_{2,1}$?

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Idée : capture a consistent global state that was possibly true in the execution.
If a stable predicate is true for this state - then it is true in the actual execution.

How do we capture a state?

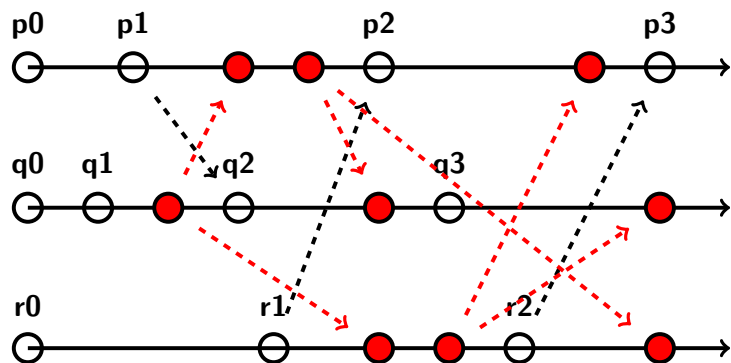
A node initiate a snapshot when it receives a *marker*.

- Record the local state and
- send a *marker* on all out going channels.
- Record all incoming messages on each channel, ..
- until you receive a marker.
- When the last channel is closed you have a local and a set of messages.

Ask one node to initiate the snapshot, collect all local states and messages and construct a global state.

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- Allows us to collect a global state during execution.
- Only allows us to determine stable predicates.

What messages are collected by which node?

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Summary

The happened before order gives us *consistent cuts* or *consistent global states*.

Using vector clocks we can time stamp states, *construct all possible linearizations* and evaluate if predicates hold true in the execution.

A snapshot can record a consistent state that can be used to evaluate **stable predicates**.

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