Global state

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KTH

HT15

Global state

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

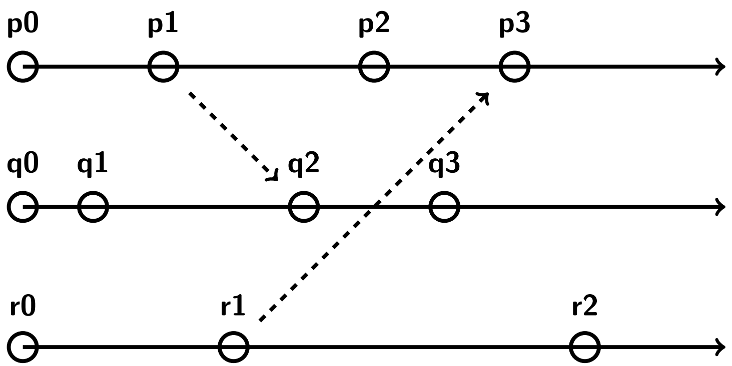
If we cannot agree on a time, how should we agree on a global state?

Global state is important:

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

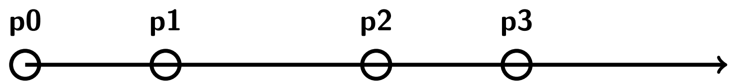
Global state

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



History and state

The *history* of a process is a sequence of events: <p0, p1, ..pn>



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

Global state

Is the state of a process the history of events?

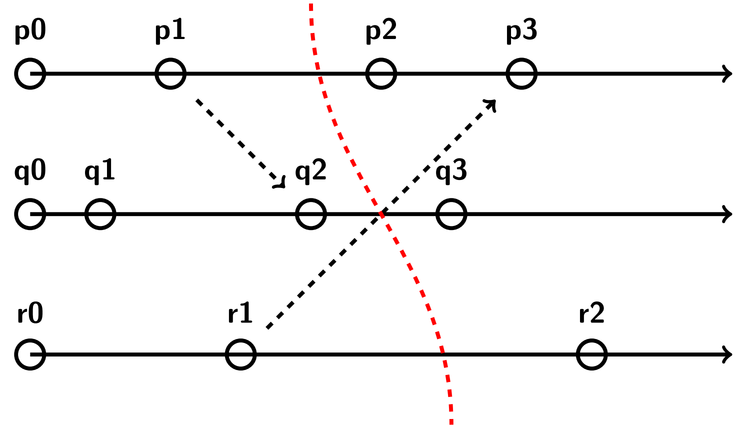
What is the *global state* of a distributed system?

The union of histories of all processes?

Do all unions make sense?

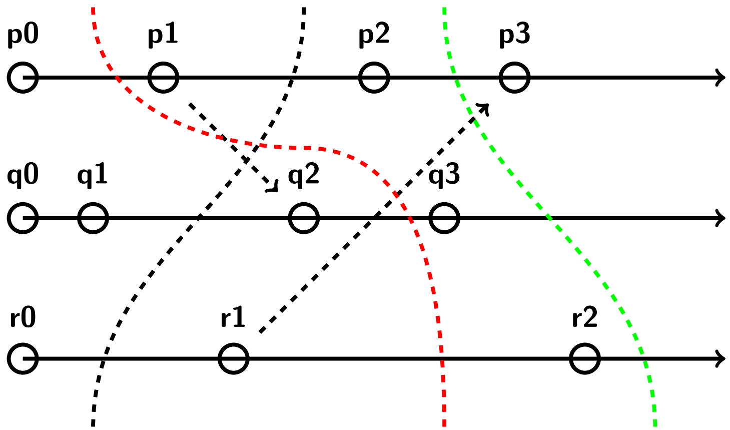
Global history and cut

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

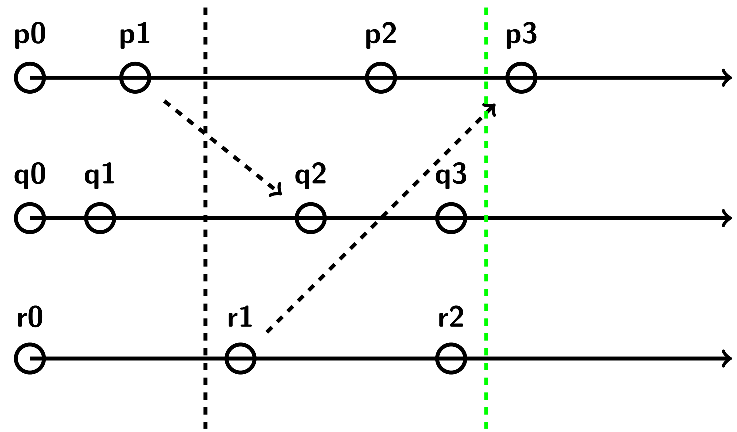


An event is *in the cut* if it belongs to the events of a history up to the specific

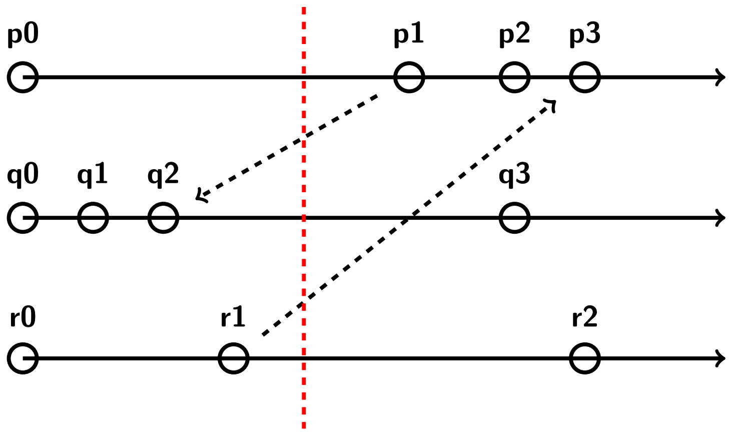
All cuts are equal, but ...



..some are more equal ..



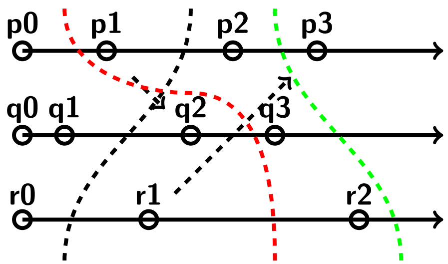
.. than others



Consistent cuts

For each event *e* in the cut:

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

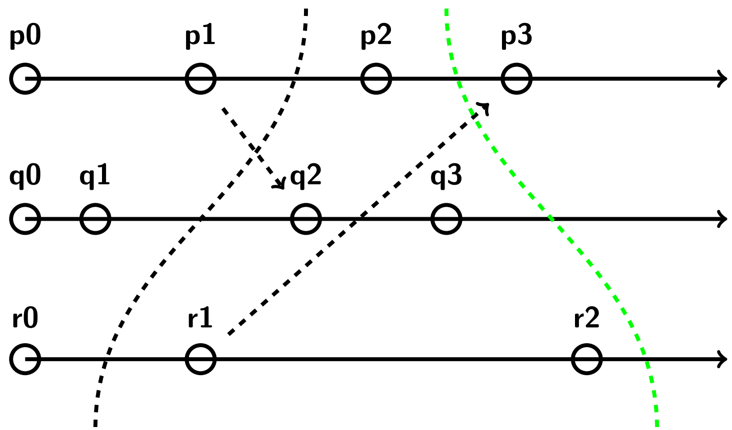


Consistent global state

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

Consistent, but not actual states

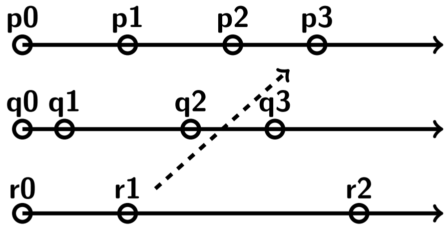


All *real time cuts* are *consistent*, but who knows the real time?

Linearization

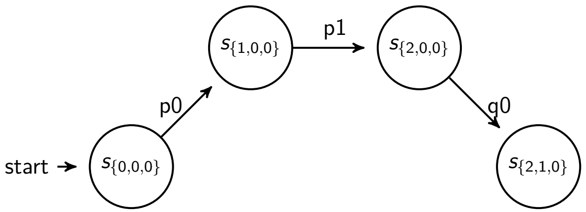
- A *run* is a total ordering of all events in a global history that is consistent with each local history.
- A *linearization* or *consistent run* is a run that describes transitions between consistent global states.
- A state *S'* is *reachable* from state *S* if there is a linearization from S to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

Linearization



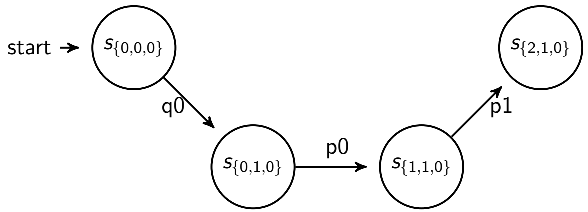
Possible state transitions

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

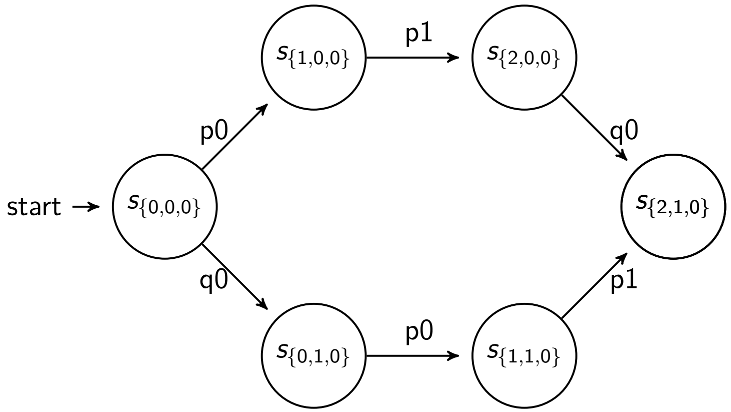


Possible state transitions

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



Possible paths



Each path is a consistent run, a linearization, one of which 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?

Global state predicate

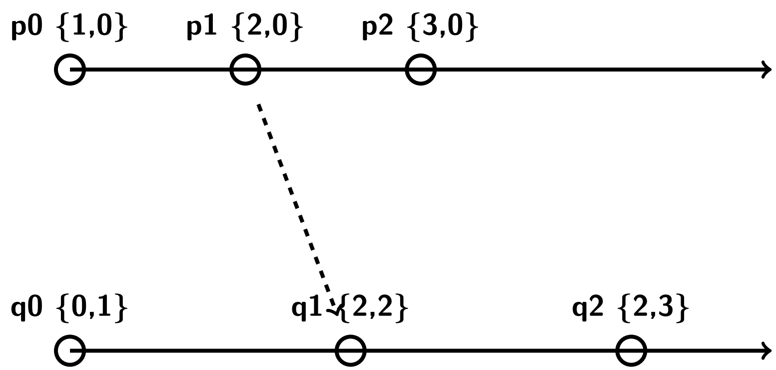
A global state predicate is a property that is true or false for a global state.

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

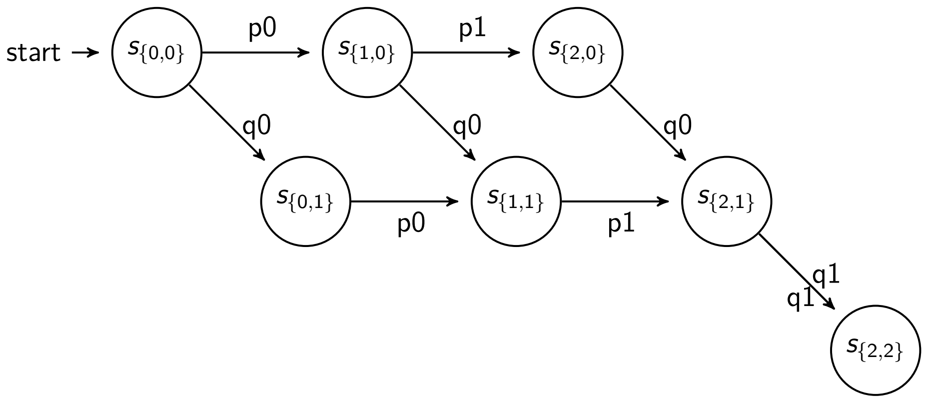
How do we determine if a property holds in an execution?

let's capture all linearizations

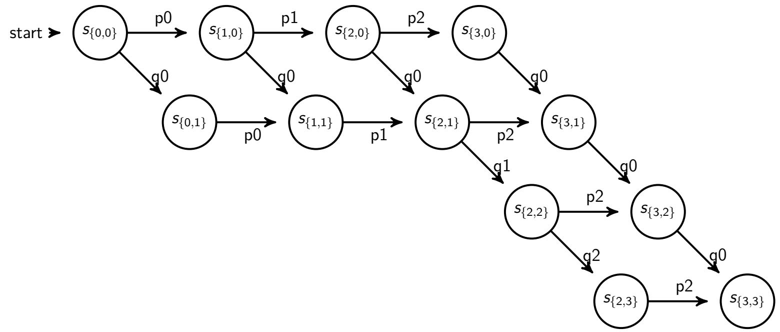
Idéa - use vector clocks, collect all events of the execution.



construct all linearizations



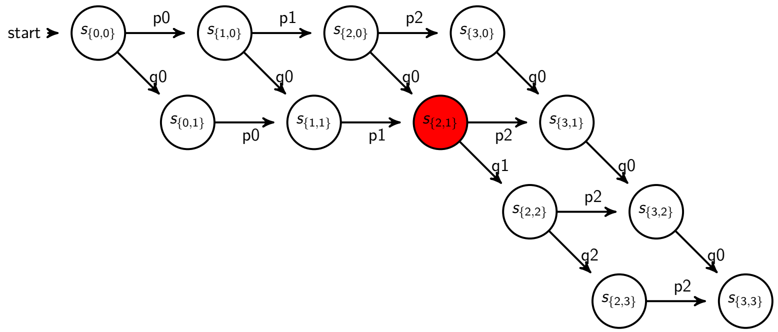
an execution latice



Any path is a linearization.

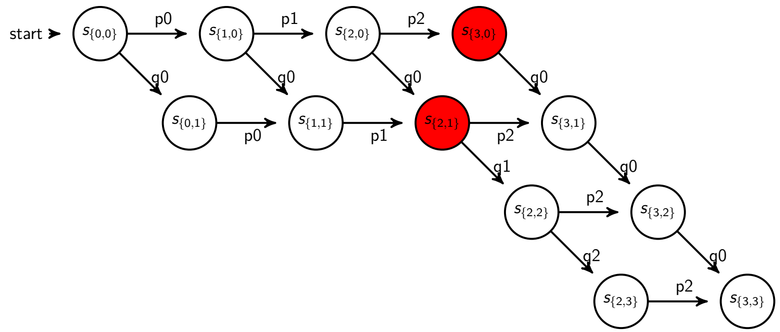
The actual execution took one path.

Possibly true



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

Definitely true



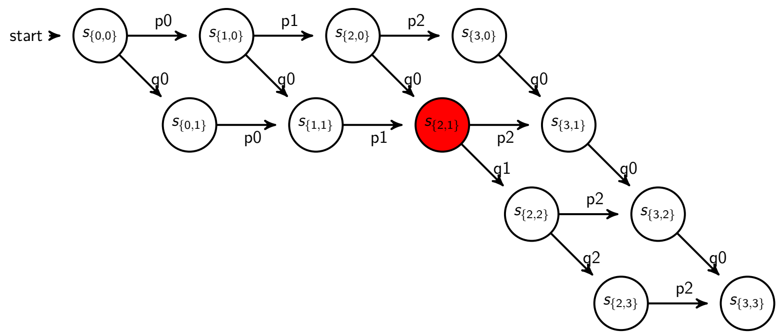
If we cannot find a path from the initial state to the final state without reaching a state for which a predicate is true then the predicate is *definitely true* during the execution.

Stable and non-stable

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

Stable is good



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

let's capture a possible state

Idéa : 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?

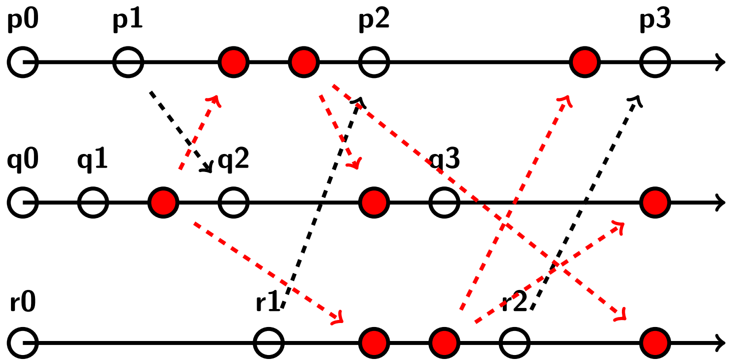
Snapshot - Chandy and Lamport

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.

Snapshot markers



What messages are collected by which node?

Snapshot

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

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**.