Analyzing time constrained MSGs

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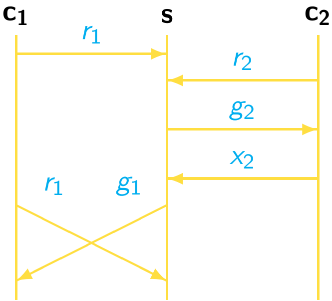
Joint work with P Gastin, Madhavan Mukund

Chennai, 30 January 2009

Message Sequence Charts

Two clients and a server



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Can we extend the analysis techniques to the timed setting?

Unfortunately, most of the results are negative.

MSCs

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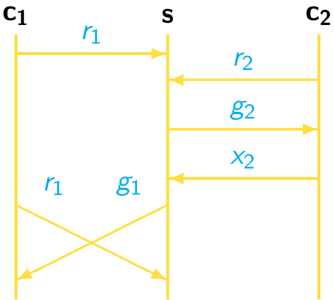

MSCs as Partial Orders

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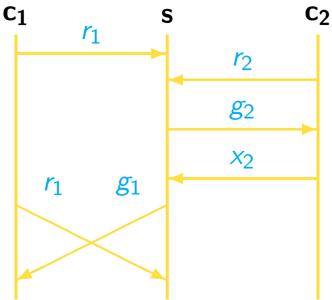

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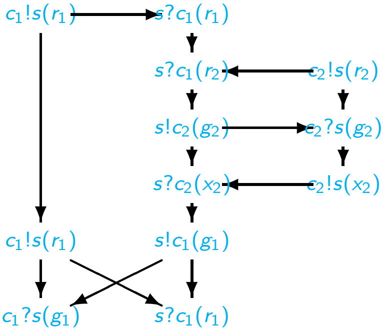

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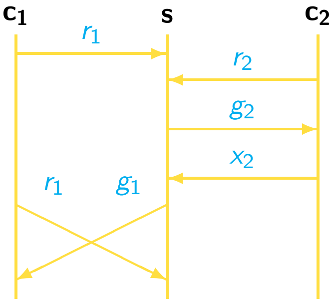

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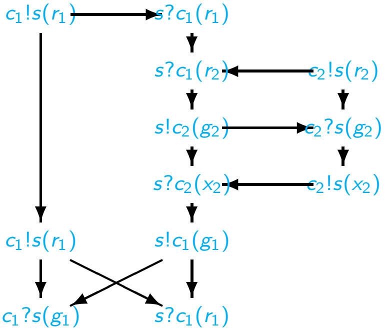

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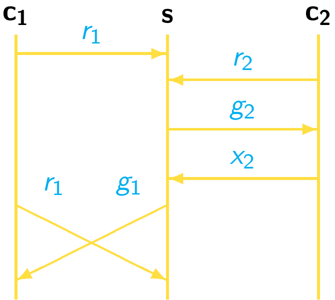

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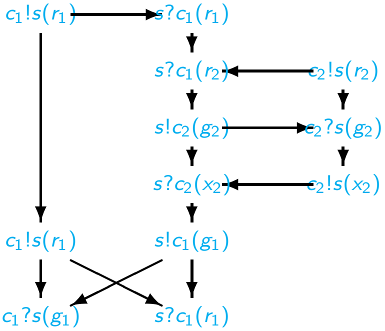
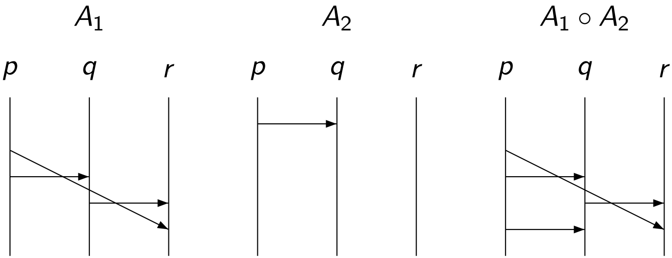


- All channels are assumed to be FIFO.
- An MSC can be regenerated from any one sequentialization.

Concatenation of MSCs



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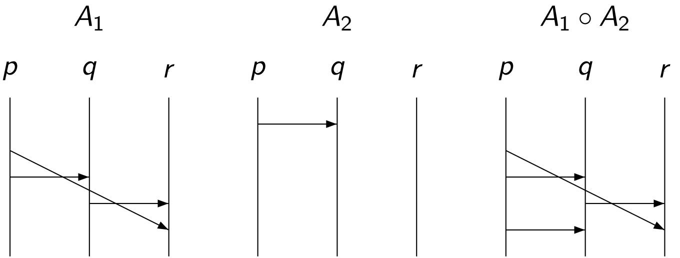

p!r p!q q?p q!r r?q p!q q?p r?p

is a sequentialization of of $A_1 \circ A_2$.

Message Sequence Graphs

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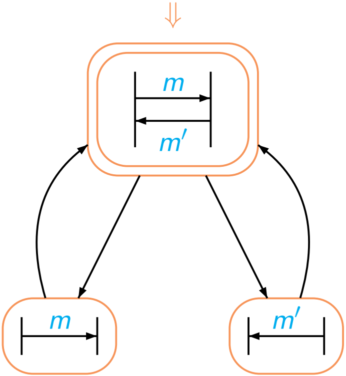

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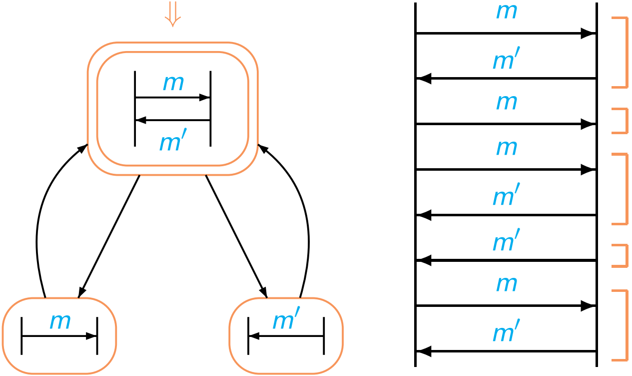

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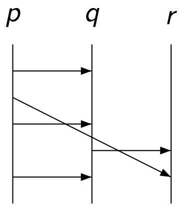

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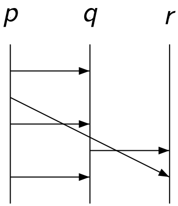

The linearization

p!q q?p p!r p!q q?p q!r r?q p!q q?p r?p

is 1-bounded while the linearization

p!q p!r p!q p!q q?p q?p p!r q?p r?q r?p

is 3-bounded.

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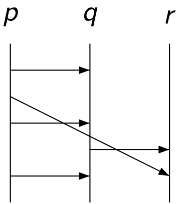

An existentially 1-bounded and universally 3-bounded MSC.

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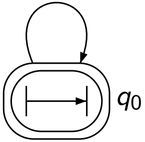

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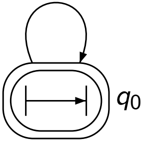

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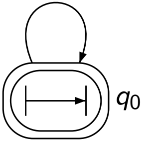

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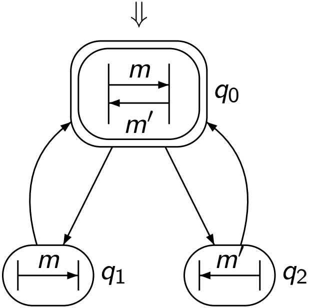
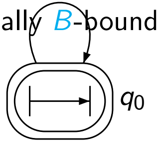
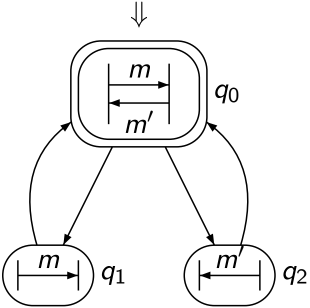


Boundedness ...

An MSG is existentially bounded if there exists a B such that every MSC it generates is existentially B-bounded.



An MSG is universally bounded if there exists a B such that every MSC it generates is B-bounded.



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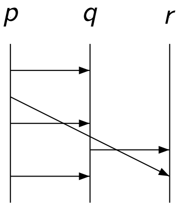
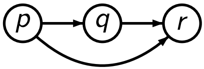
- Checking whether an MSG is bounded is decidable.

Communication graph of an MSC

Nodes are the processes. An edge from p to q if there is a message from p to q.





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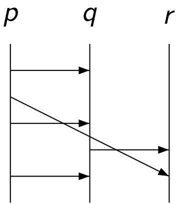

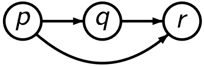

An MSG is bounded if and only if every the MSC generated by every loop has a communication graph that is a disjoint union of SCCs.

Adding time to scenarios

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  - MSCs with timing constraints between events

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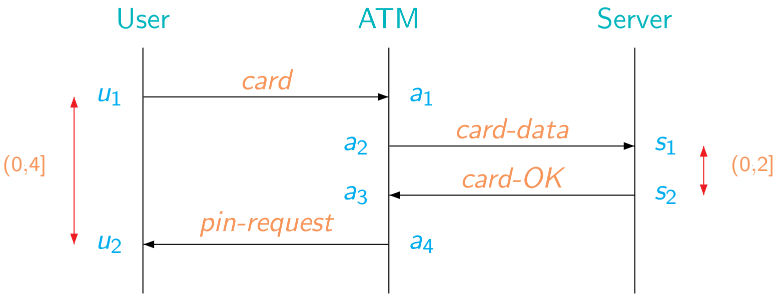
  - MSCs with timing constraints between events
- Time constrained Message Sequence Graphs
  - Generate infinite families of time constrained MSCs

MSCs with time constraints



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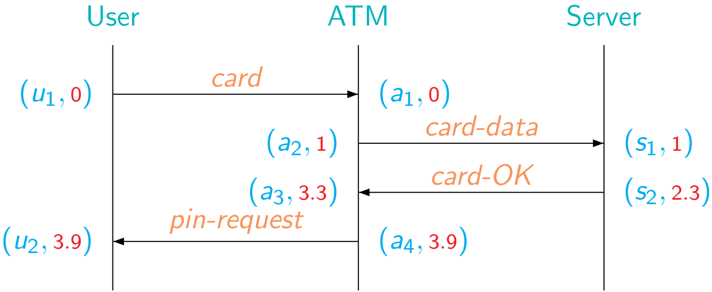
    - e is $p!q(m)$ and e' is corresponding receive $q?p(m)$

A timed behaviour



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- TC-MSC $T \Rightarrow L(T)$, set of timed MSCs that cover T

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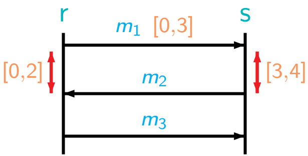

TC-MSCs and Timed MSCs

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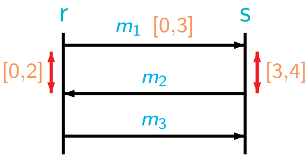
- A TC-MSC is said to be realizable if it is covered by atleast one timed MSC.



Time Constrained Message Sequence Graphs

- States labelled by time constrained MSCs
- Local constraints for each process along edges
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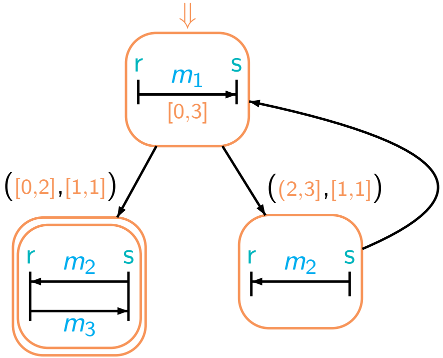

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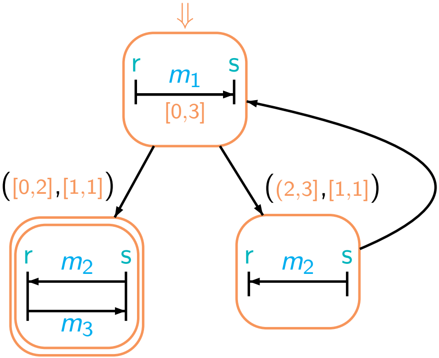

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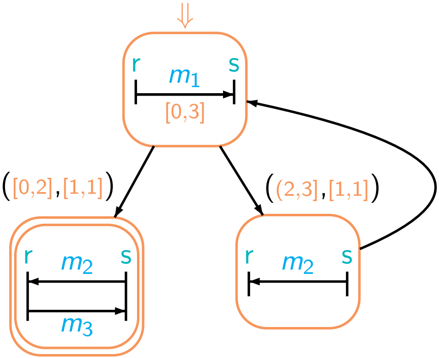

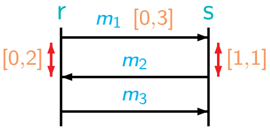

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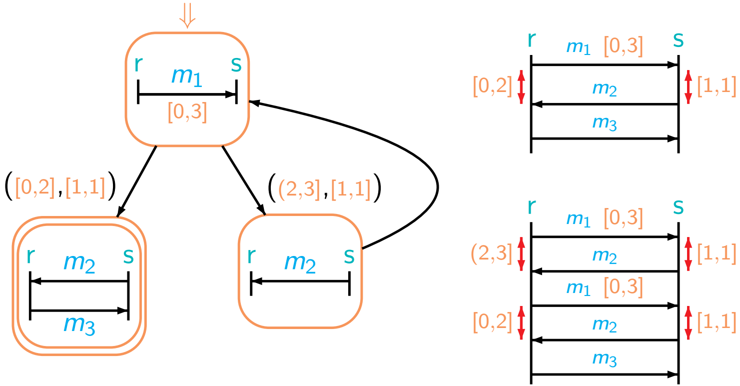

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This problem is trivial for ordinary MSGs.

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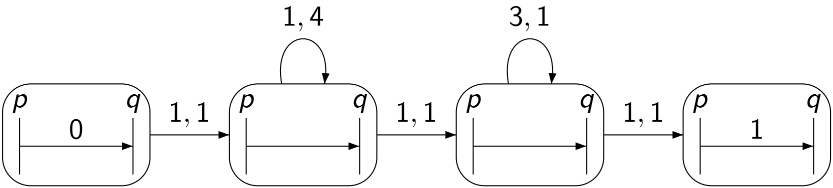

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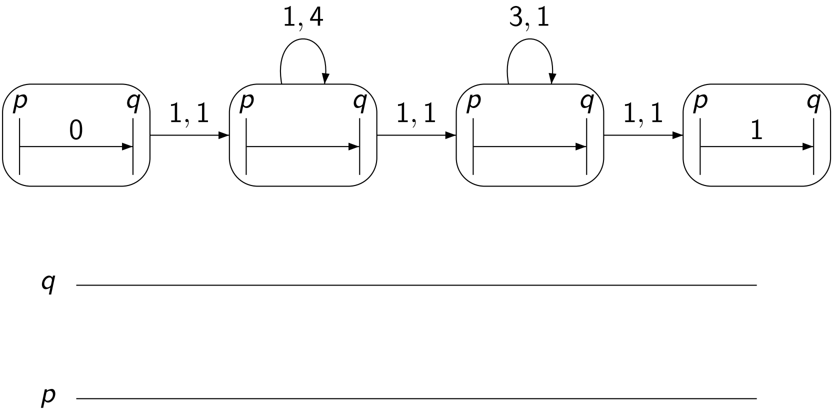

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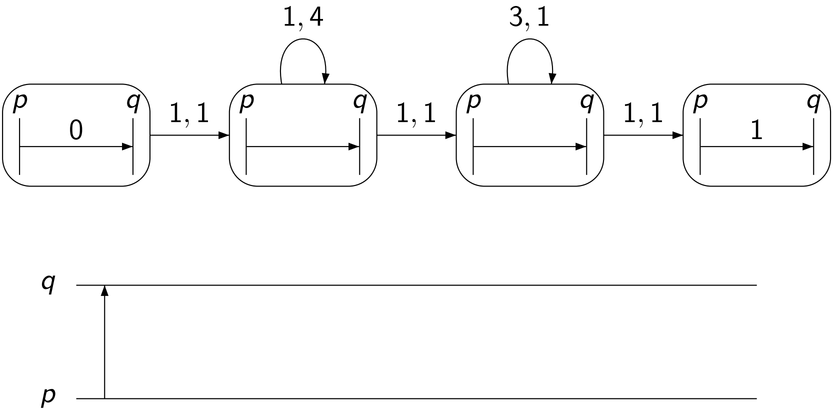

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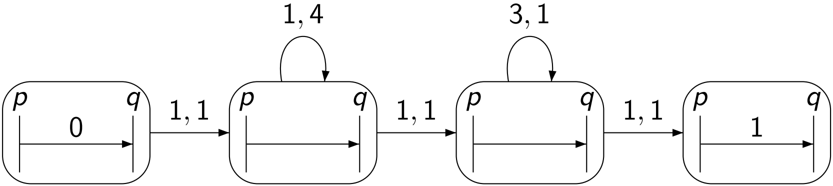

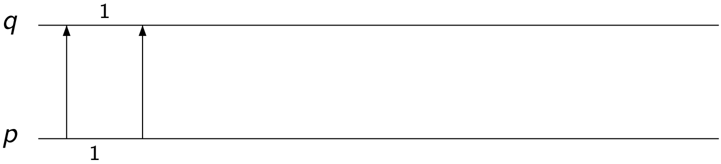

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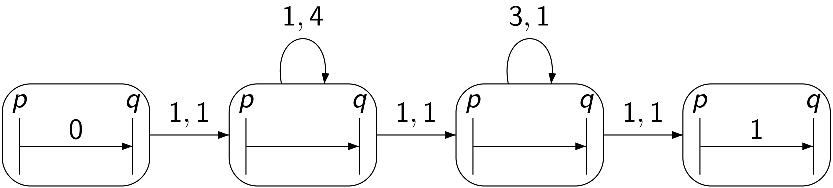

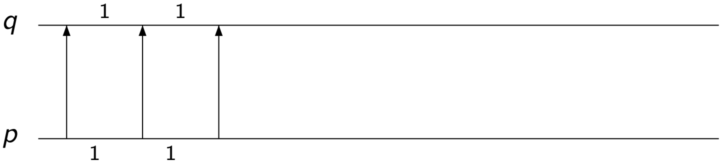

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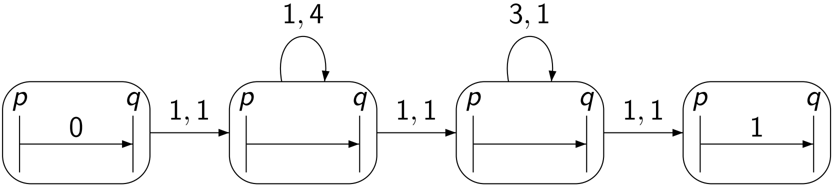

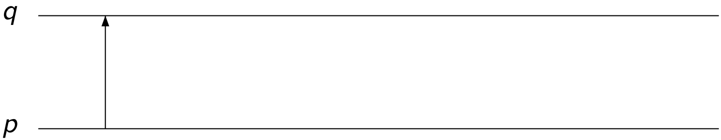

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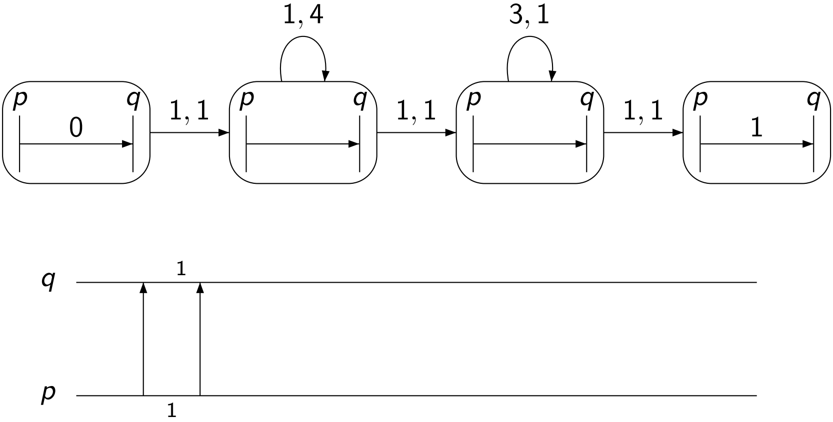

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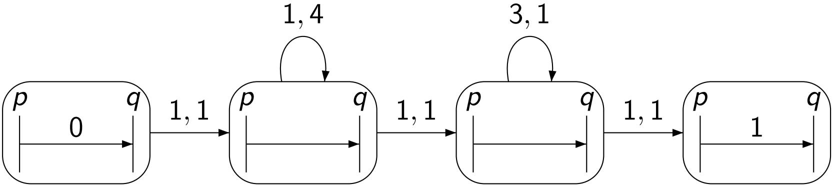

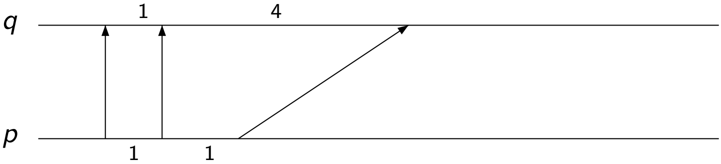

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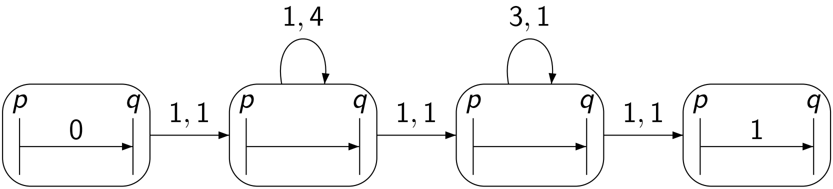

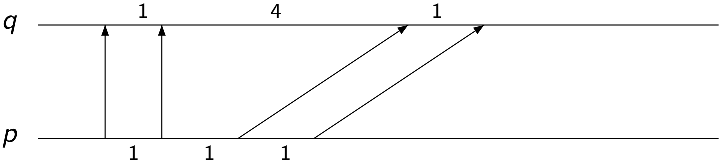

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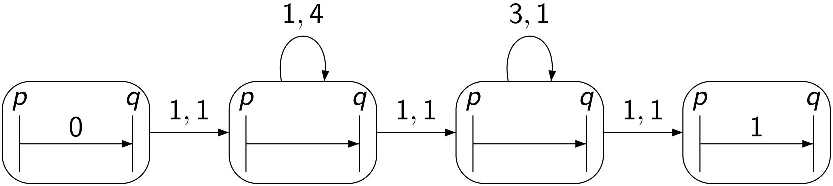

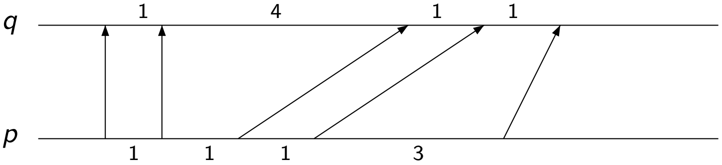

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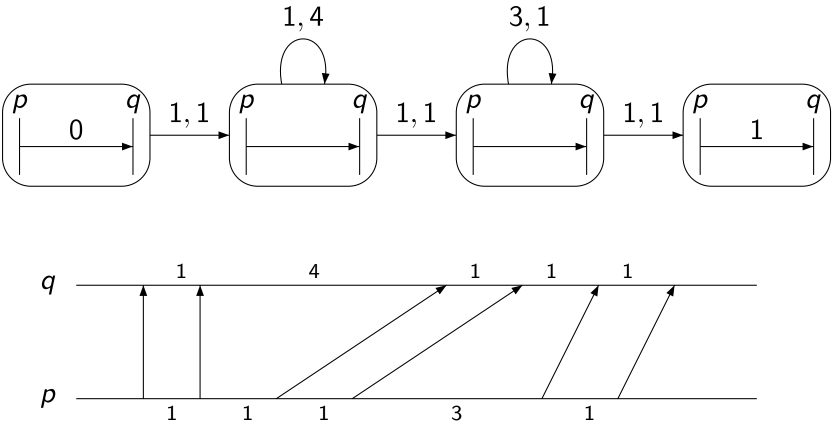

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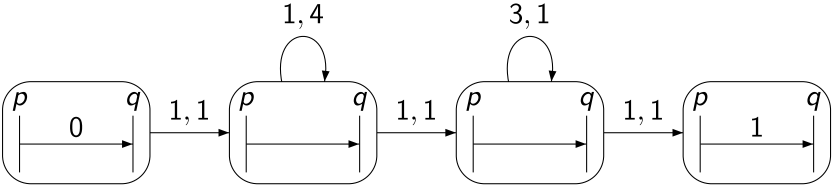

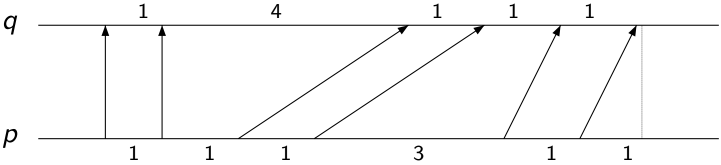

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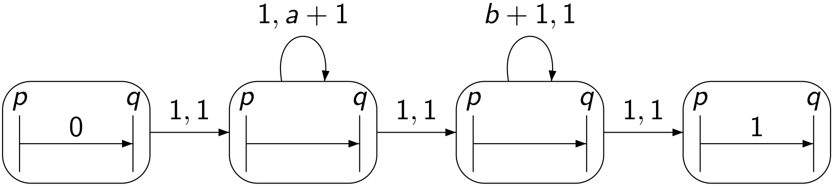

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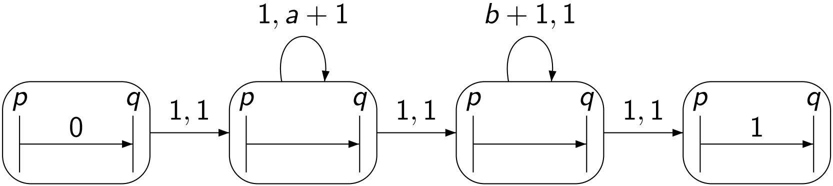

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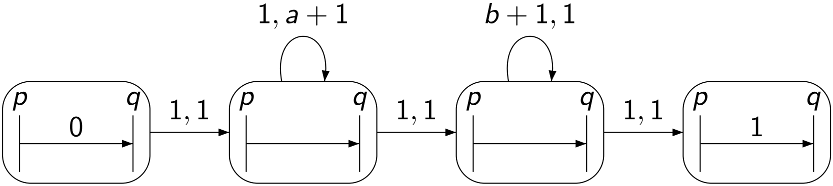

- The first loop is to be executed k times and the second one l times such that $a.k - b.l = 1$.
- Simple paths may not be realizable while those with loops may be.

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Time constraints may ensure boundedness.

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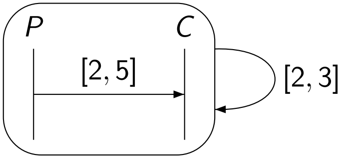

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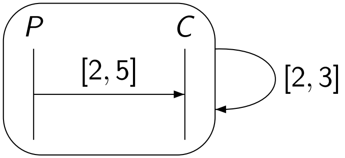

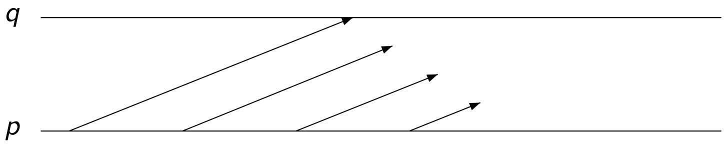

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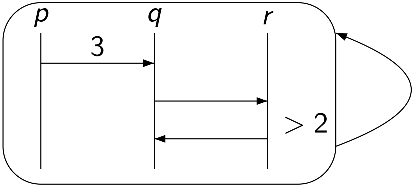

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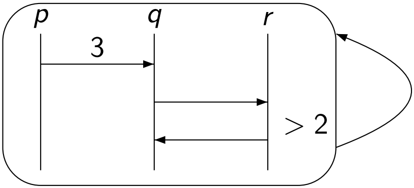

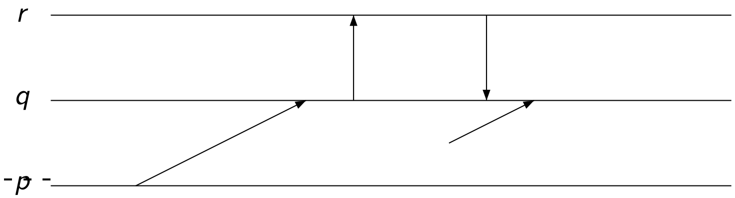

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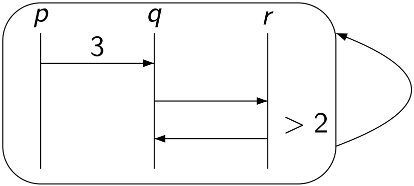

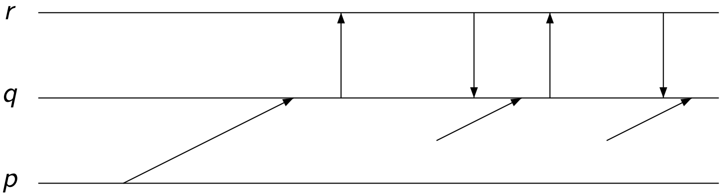

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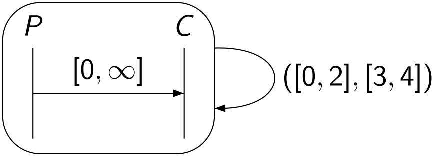

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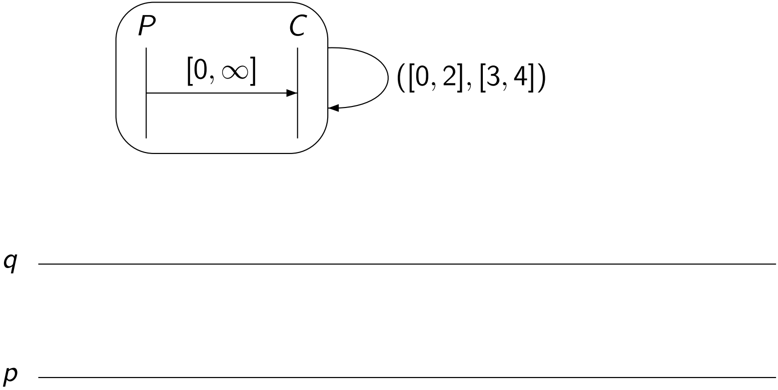

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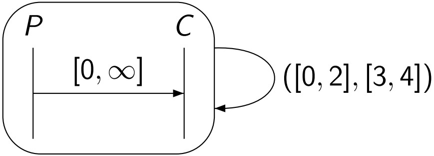

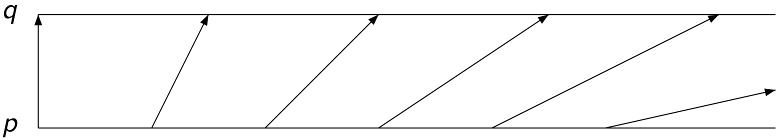

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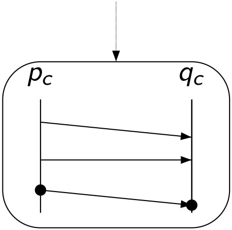
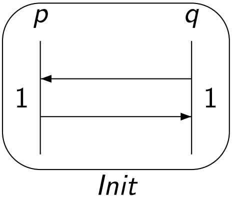


The reduction

- Initialization of the counter value to 0



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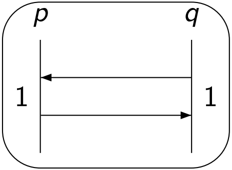

Init

- Keep counter values as it is (Freeze).

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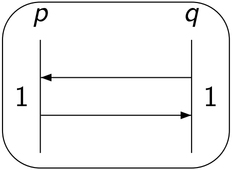

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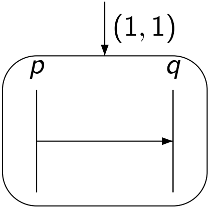

Freeze

The Reduction ...

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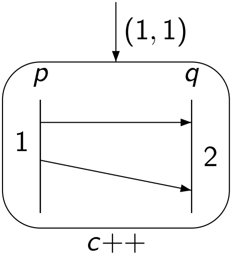

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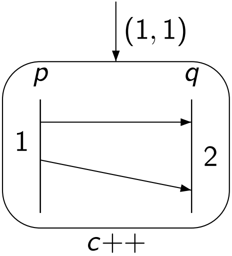

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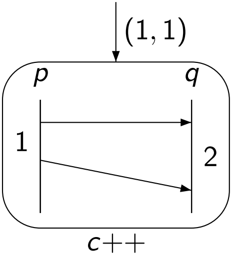

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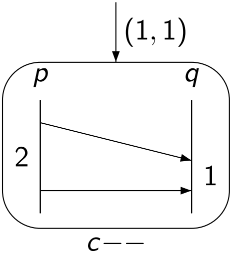

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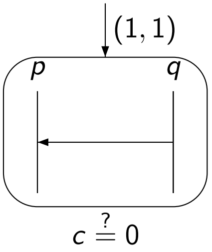

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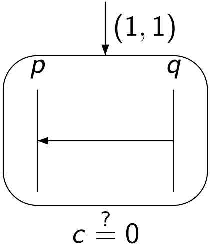

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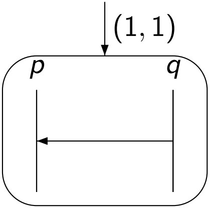

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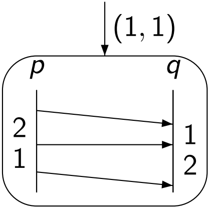

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The (language) emptiness problem for TC-MSGs is undecidable.

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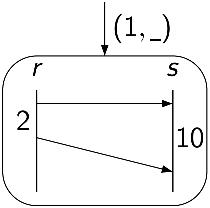

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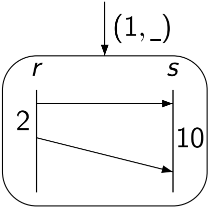

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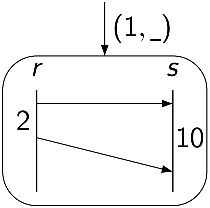

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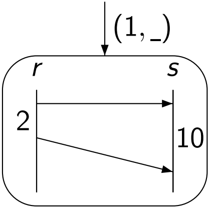

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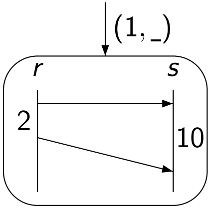

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Checking boundedness for TC-MSGs is undecidable

More Undecidability – 1

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- The value of $p_u - q_u$ is used to check for 0.

Open Intervals ...

Initialize the counter to 0.

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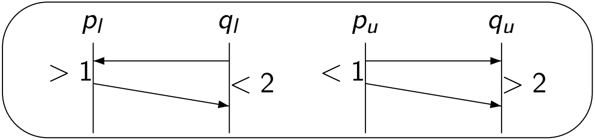

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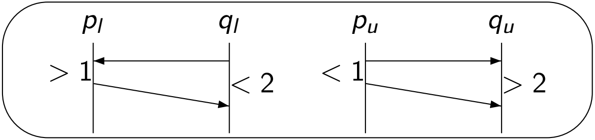
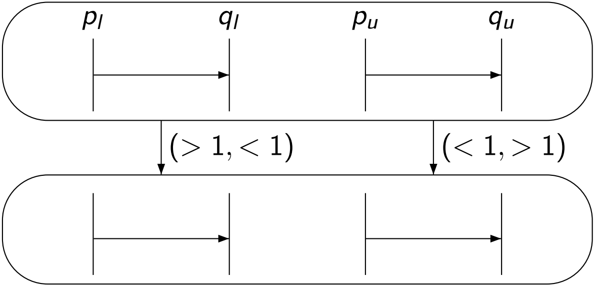


Composition between Nodes



Open intervals ...

The decrement instruction

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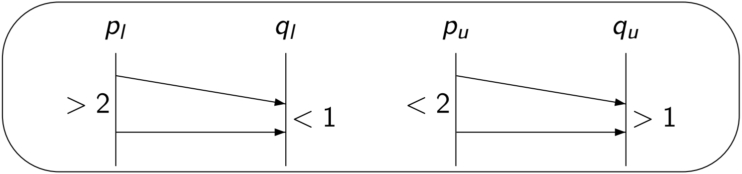
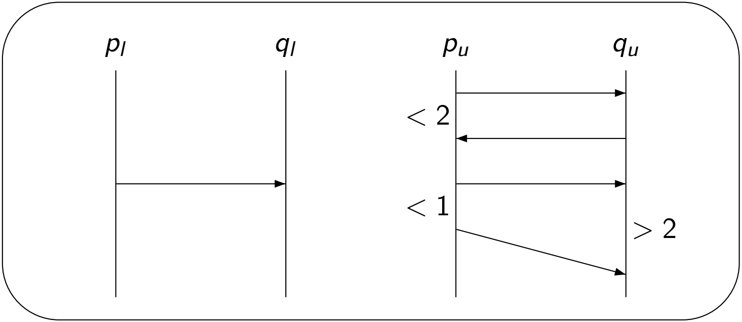


Open interval ...

Check for 0



More Undecidability – 2

What about the reachability problem for channel bounded TC-MSGs?

More Undecidability – 2

What about the reachability problem for channel bounded TC-MSGs?

The reachability problem for channel bounded TC-MSGs is also undecidable.

Single process as a time keeper

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Even with the restriction that constraints across nodes are permitted only on a fixed process, the reachability and boundedness problems for TC-MSGs remain undecidable.

More Undecidability – 3

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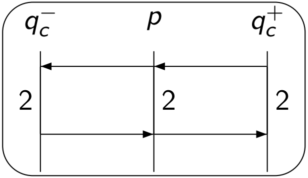
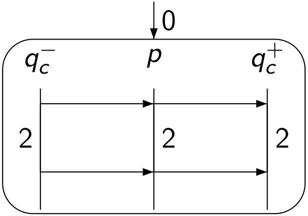
1. The time difference between the last events in p and q^- is a lower bound on the value of the clock.
2. The time difference between the last events in q^+ and p is an upper bound on the value of the clock.

More Undecidability - 3

Initialize

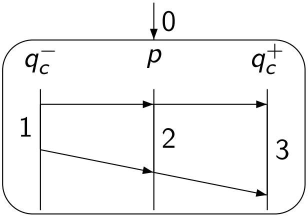


Freeze

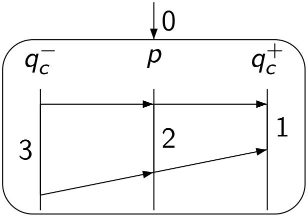


More Undecidability – 3

Increment

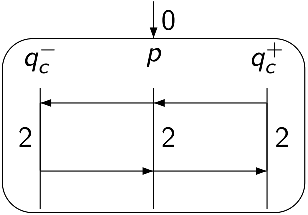


Decrement



More Undecidability – 3

Check for Zero



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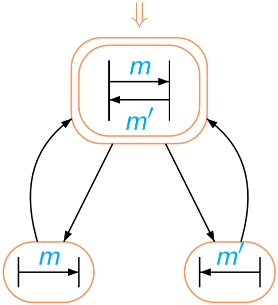

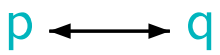

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  - Works like an event-clock automaton (upto some extra labelling).

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Thank you.

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