Universität Heidelberg
Wintersemester 18/19

Group Parallel and Distributed Systems (PVS)
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Problem Set 7 for lecture Distributed Systems I (IVS1)

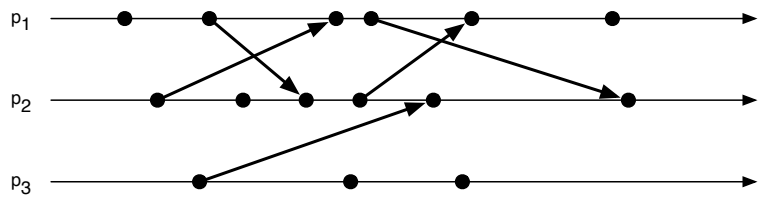
Due: 12.12.2018, 14:00 Uhr

Exercise 1 (2 Points)

By considering a chain of zero or more messages connecting events e and e' and using induction, show that $e \rightarrow e' \Rightarrow V(e) < V(e')$.

Exercise 2 (2 Points)

Consider vector clocks for determining logical time of events in processes. Denote every event in the figure below with a variable name and determine the vector timestamp for each event.



Exercise 3 (4 Points)

Consider a knock-out tournament among 32 teams in a team sport (like in the tournament phase of the FIFA World Cup). In the first round, the teams pair up to play 16 matches. The winners of these 16 matches pair up to play further 8 matches. The 8 winners of these play in the 4 quarter-final matches. Their winners compete in the 2 semi-final matches. Finally, the two remaining winners play in the final match for the cup. Additionally, the losers of the 2 semi-finals play a match for the „third place“.

For simplification, imagine each team has a constant „(playing) strength“. No two teams have the same strength. And whenever two teams are playing in a match, the „stronger“ team wins. That means, the teams' strengths induce a total ordering (linear ordering). This total ordering means that we have one strongest team, one second strongest team,... , one second-to-least strong team, and one least strong team.

Which of the following statements is true, and why?

1. The winner team w of the knock-out tournament is the strongest team w.r.t. its strength $s(w)$. If untrue, give a lower bound for his rank in the ordering.
2. The first, second and third place are in the correct order, w.r.t. to the teams' strengths $s(\_)$. If untrue, try to construct a counter-example.
3. The team on the second place is at least the fourth-strongest team. If untrue, give an alternative lower bound for its rank in the ordering.

- How many linear orderings of 32 teams are there? How many different combinations of outcomes are there (all matches in the tournament combined)? What does that imply for our ability to make statements about the real linear ordering, given the observed matches?
- How can you in principle use the logical clock formalism to reason about the strength of teams? What could the *happened_before* relation, processes, events and sending correspond to? How can you interpret the entries in the resulting clock vectors?

Exercise 4 (2 Points)

In the distributed system depicted below three processes p_1,p_2 and p_3 execute a series of computations. Two cuts C and C', attempt to capture the global state of the system. Are both C and C' considered consistent? Explain your answer based on the formal definition of consistent cuts and give two more examples of consistent and inconsistent cuts using the system below.

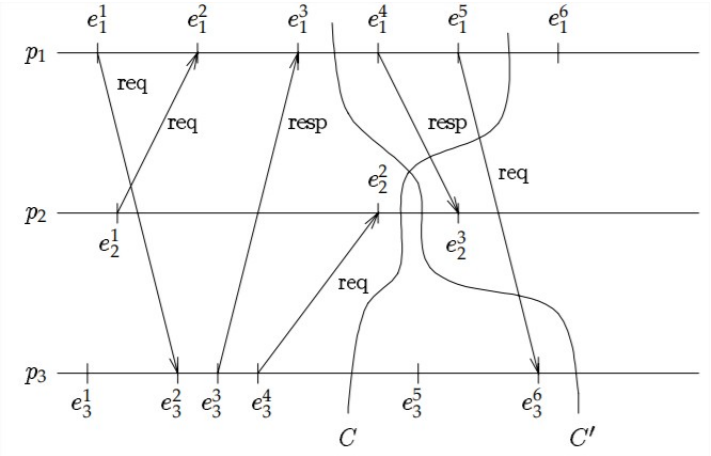


Figure 1: Cuts of a Distributed Computation