

Introduction to Distributed Systems WT 19/20

Assignment 4 – Part I

Submission Deadline: Monday, 16.12.2019, 08:00

- *Submit the solution in PDF via Ilias (only one solution per group).*
- *Respect the submission guidelines (see Ilias).*

1 Global State

[13 points]

Figure 1 shows a distributed system consisting of two processes P_1 and P_2 . P_1 has the events e_1^1 through e_1^5 and P_2 has the events e_2^1 through e_2^3 . Each event in P_1 and P_2 changes the value of local variables x_1 and x_2 , respectively. Figure 2 depicts the corresponding lattice of global states for the distributed system shown in Figure 1.

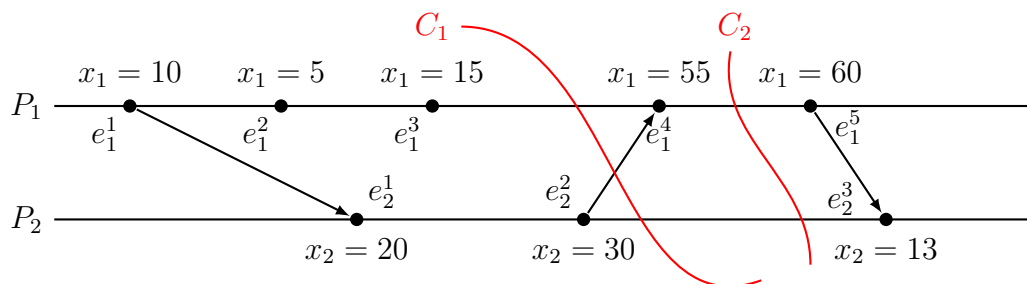


Figure 1: Distributed System with Processes P_1 and P_2

- a) [2 points] C_1 and C_2 represent two cuts of the system history. Mention all events that belong to C_1 and C_2 . Are C_1 and C_2 consistent cuts? Justify your answer.
- b) Take a look at the criteria to discover reachable states on slide 42 of chapter "6-Global State".
 - i. [2 points] Why is the inequality in the box not sufficient to prove that state S' is Level $L + 1$ reachable from S ? What else has to be put in consideration?
 - ii. [3 points] Now state and prove using the inequality and your additional criteria whether S_{31} , S_{32} and S_{42} are Level $L + 1$ reachable states from state S_{30} . For the inequality the final result (**true** or **false**) is enough, but show why one can be sure that it is a Level $L + 1$ reachable state.
- c) [2 points] Complete Figure 2 by adding the values of local variables x_1 and x_2 for all states.
- d) Assuming the following two predicates,
 - $\phi_1 = (x_2 - x_1) = 5$
 - $\phi_2 = (x_2 - x_1) \leq 5 \text{ and } (x_1 - x_2) > 0$

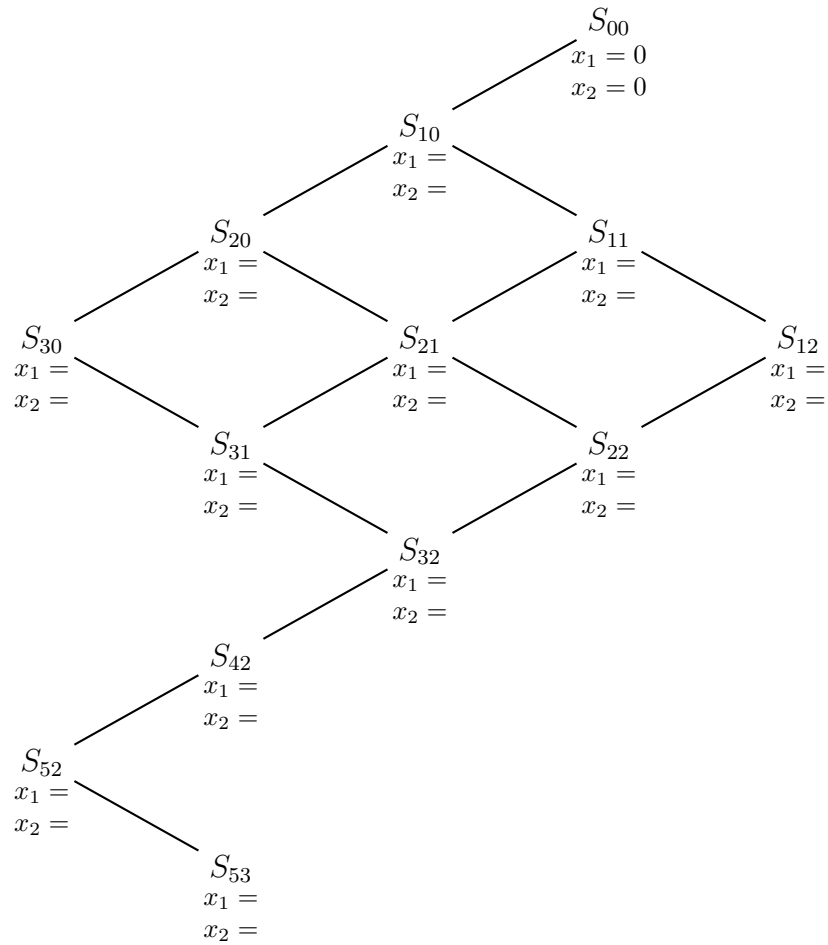


Figure 2: Lattice of global states

- i. [2 points] Assume $(\neg\phi_1)$ is a safety condition. Is this condition fulfilled? Justify.
- ii. [2 points] Assume (ϕ_2) is a liveness condition. Is this condition fulfilled? Justify.

2 Transaction Processing**[6 points]**

- a) [2 points] Assume three transactions T1, T2 and T3 as shown in Figure 3. Find all pairs of conflicting operations between these transactions.

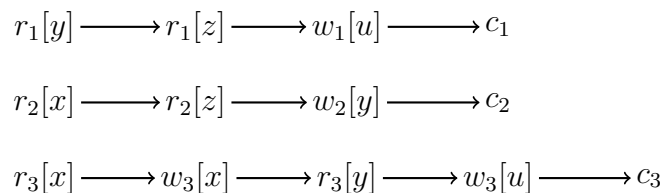
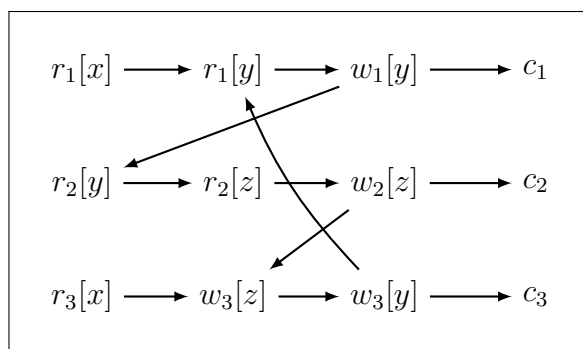
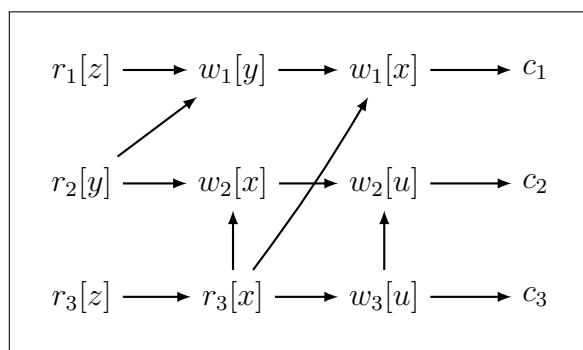


Figure 3: Transactions T1, T2 and T3

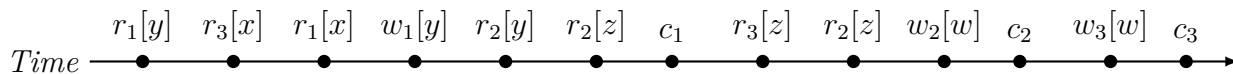
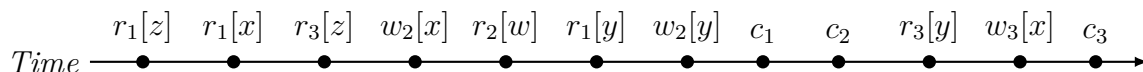
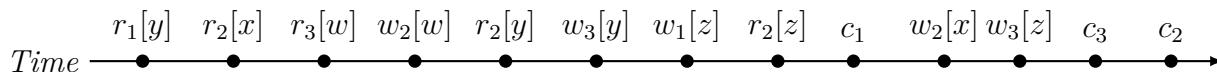
- b) [4 points] For each of the following histories (Figure 4 and Figure 5) construct a serialization graph and determine whether the history is serializable.

Figure 4: History H_1 Figure 5: History H_2

3 Two-Phase Locking

[6 points]

Figures 6 to 8 show the total order of operations that occurred during a parallel execution of three transactions. Determine whether each of these executions could have been generated by 2-phase-locking. Assume that locks are requested as late as possible, i.e. on the first use of the respective variable. Justify your answer.

Figure 6: Execution of History H_1 Figure 7: Execution of History H_2 Figure 8: Execution of History H_3