Secure and Dependable Systems
Jacobs University Bremen
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Course: CO21-320203
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SADS 2019 Problem Sheet #3

Problem 3.1: *lamport clocks and vector clocks* (1+1+1 = 3 points)

Let $e \prec f$ (with $e, f \in E$) be the causal order relation on the set of events E with n concurrent processes. Let $\Theta_L : E \to \mathbb{N}$ denote a Lamport clock and $\Theta_V : E \to \mathbb{N}^n$ denote a vector clock.

a) Given two events $e, f \in E$ with $e \neq f$ and with $\Theta_L(e) < \Theta_L(f)$, which of the following statements are true or false? Provide a reasoning.

   (i) $\Theta_L(e) < \Theta_L(f) \implies e \prec f$

   (ii) $\Theta_L(e) < \Theta_L(f) \implies f \prec e$

b) Given two events $e, f \in E$ with $e \neq f$ and with $\Theta_V(e) < \Theta_V(f)$, which of the following statements are true or false? Provide a reasoning.

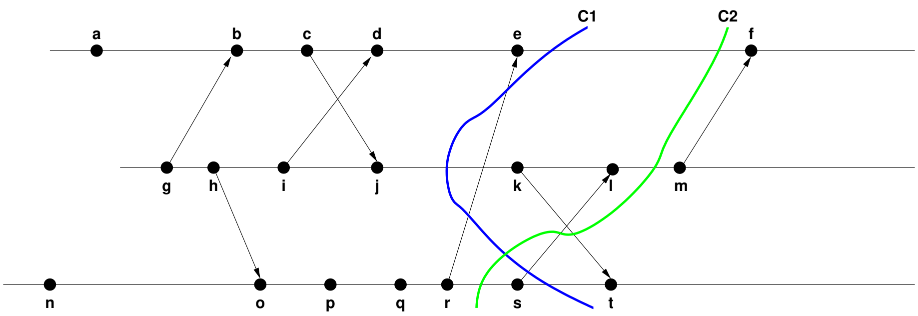
   (i) $\Theta_V(e) < \Theta_V(f) \implies e \prec f$

   (ii) $\Theta_V(e) < \Theta_V(f) \implies f \prec e$

c) Given two concurrent events $e, f \in E$ with $e \neq f$. How can one determine from the vector clock values $\Theta_V(e)$ and $\Theta_V(f)$ that e and f are concurrent?

Problem 3.2: *logical clocks and consistent cuts* (2+2+1 = 5 points)

Consider a distributed system with three processes that proceeds as shown below:



a) Determine the Lamport clock values for all events.

b) Determine the vector clock values for all events.

c) Are the cuts C_1 and C_2 consistent cuts? Explain why or why not.

Problem 3.3: *causal reliable broadcast algorithm* (2 points)

The lecture notes contain a definition of a reliable broadcast algorithm implementing the primitives $broadcast(R, m)$ and $deliver(R, m)$. Use these primitives to define a causal reliable broadcast algorithm implementing the primitives $broadcast(C, m)$ and $deliver(C, m)$.