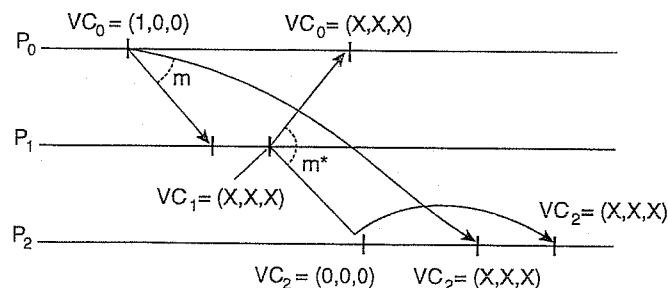


- 1a Give five examples of policies that have been separated from mechanisms in distributed systems. 5pt
- 1b Explain what is meant by geographic scalability problems and give an example how such a problem can be solved. 5pt
- 1c Web sites are often organized as a multi-tiered client-server system consisting of a Web server, and application server, and a database server. What are the advantages of such a scheme? 5pt
- 2a What is the major disadvantage of using RPCs in comparison to messaging as in message-queuing systems? 5pt
- 2b Explain what subject-based routing means and how message brokers can be used to implement it. 5pt
- 2c Consider a worldwide overlay network of many message brokers connected through IBM MQ series. Sketch a straightforward solution for supporting multicasting in such an environment. 5pt
- 3a When using DNS in the following way, the user apparently is getting inconsistent answers. Explain this difference. 5pt
- ```
seuss > host flits.cs.vu.nl; host 192.31.231.65
flits.cs.vu.nl has address 192.31.231.65
65.231.31.192.in-addr.arpa domain name pointer flits.few.vu.nl.

seuss > host entry.van-steen.net; host 213.10.169.34
entry.van-steen.net has address 213.10.169.34
34.169.10.213.in-addr.arpa domain name pointer ipd50aa922.speed.planet.nl.
```
- 3b User maarten in domain van-steen.net has a forwarding mail address to steen@cs.vu.nl. Show which messages are exchanged between a user agent sending a message to maarten@van-steen.net, DNS, mail servers, and the recipient user agent. 10pt
- 4a Explain how Lamport timestamps work and show by example that they do not necessarily capture (potential) causality. 5pt
- 4b Vector timestamps can be used for capturing potential causality. Fill in the vector clocks in the following figure and explain why the delivery of message  $m^*$  at process  $P_2$  is delayed. 5pt



- 5a Explain what is meant by sequential consistency. Be precise! 5pt
- 5b What is the essence of demanding that the set of synchronization variables adheres to sequential consistency when considering weak consistency models? 5pt
- 5c Is it possible to have write-write conflicts in client-centric consistency models? Explain your answer. 5pt

- 6a Explain what is meant by a virtual synchronous multicast. 5pt
- 6b In virtual synchrony we can separate the ordering of message delivery at a single recipient from the fact that messages are subject to total-ordered delivery. What is the difference between the two? 5pt
- 7a What is the difference between two-phase locking and two-phase commit? 5pt
- 7b Two-phase commit (2PC) is said to be a blocking protocol for which reason three-phase commit was devised (3PC). How can this blocking happen? 5pt

**Grading:** The final grade is calculated by accumulating the scores per question (maximum: 90 points), and adding 10 bonus points. The maximum total is therefore 100 points.