Department Computer Science	**Distributed Systems**
Vrije Universiteit	**22.02.2012**

BE SURE THAT YOUR HANDWRITING IS READABLE

1a Explain Lamport's happened-before relationship and provide a distributed implementation of the associated logical clocks. *5pt*

1b Give an example of how Lamport's logical clocks can be used to realize distributed mutual exclusion. *5pt*

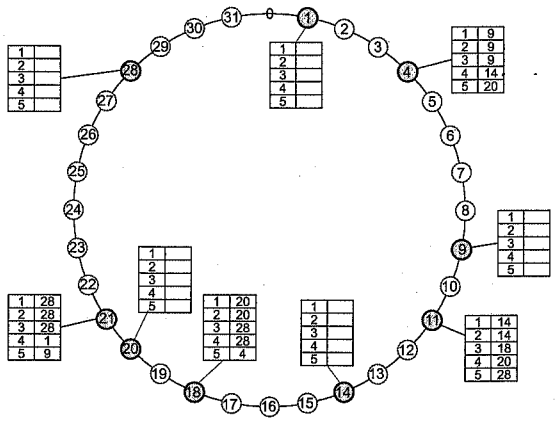
1c Show by an example that Lamport's clocks cannot generally capture causal relations. *5pt*

2a Explain how TCP-handoff works. *5pt*

2b Sketch a solution for an efficient, content-aware, TCP-handoff. *5pt*

2c How would you realize TCP handoff if the servers are placed in different autonomous systems? *5pt*

3



3a Fill in the missing Chord finger table for nodes 1, 9, 14, 20, 28. *5pt*

3b Show all hops for the following key lookups for the shown Chord-based P2P system: *5pt*

source	key
1	12
9	3
14	20
14	31
20	18

3c Explain how node 7 can join the Chord network, assuming it knows only node 21. *5pt*

4a Explain how a content-aware Web cache works by considering the processing of database queries. *5pt*

4b Web-hosting services such as Akamai redirect clients to a best replica server using DNS. Explain, by example, how this redirection works. *5pt*

4c Provide details on how Web clients can get redirected to a replica server in the case of a flash crowd. *5pt*

5 Consider an implementation of numerically bounded continuous consistency. Assume that each write $W(x) > 0$. Let $origin(W)$ denote the server S_i to which the write operation was submitted first, and $log(S_i)$ the log of server S_i. We assume there are N servers. For data item x, $TW[i,j]$ is defined as

$$TW[i,j] = \sum\{W(x) | origin(W) = S_j \& W \in log(S_i)\}$$

5a Give an expression for the value $v(x)$ of x assuming its initial value was 0. *5pt*

5b Give an expression for the value of $v_i(x)$ of x at server S_i. *5pt*

5c To be numerically bounded, we demand that $|v(x) - v_i(x)| < \delta$. What can a server do to guarantee this constraint? *5pt*

6a Consider a set of N replica servers. Show, by counter example, that for quorum-based replication, the write set needs to be larger or equal to $\lfloor N/2+1 \rfloor$. *5pt*

6b Assuming crash/performance failure semantics, how large must the write set be in the case of quorum-based replication in case we want to survive the failure of k servers? *5pt*

6c Consider the previous question. How large must the read set be? *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.*