

CS60002: Distributed Systems  
Department of Computer Science & Engineering  
Indian Institute of Technology, Kharagpur  
Final Examination, Spring 2011

Total Marks: 100

Time: 3 Hours

Answer ALL questions.

Answers should be brief and to the point. Please try to answer all parts of a question consecutively as much as possible.

1. (a) What is the Byzantine General's problem? If there are  $n$  processes out of which at most  $f$  are faulty, exactly how many messages will the OM (oral message) algorithm of Lamport, Shostak, and Pease send in the worst case? How can a process distinguish between messages belonging to different recursive invocations of the OM algorithm? (2 + 3 + 2)  
(b) Define Unix semantics and session semantics in the context of DFS. Which of these two types does NFS enforce? No explanation is needed. (4 + 2)  
(c) What is the complexity of termination detection using Dijkstra-Scholten's algorithm? (2)  
(d) Describe what will happen if in the 2-phase commit protocol, the coordinator fails after sending some but not all COMMIT messages in the second phase. (Do not explain the entire protocol). (5)
2. (a) Show a scenario in which a node may get more than two messages with the same sequence number in Schneider et al.'s reliable broadcast protocol. You must mention the ordering between the different messages you use and the faults clearly. (5)  
(b) Consider a bidirectional ring with  $n$  nodes, each node having a distinct id. Let the maximum id node be  $p$  and the goal is to elect  $p$  as the leader. A single node other than  $p$  can crash at any time in the system, and the crashed node does not recover afterwards. Design a leader election algorithm based on the Hirschberg-Sinclair algorithm to elect  $p$  as the leader even in the presence of this single crash fault. You must show the states at each node, the type and content of all messages used, and the message sending/receiving rules clearly. Make any assumptions you may need (if any), but write them clearly at the beginning of your answer. (15)
3. (a) What kind of file access pattern and network environment is NFS best suited for? Justify your answer briefly and clearly. (4)  
(b) Describe the pros and cons of using sender-initiated versus receiver-initiated load balancing algorithms. (4)  
(c) Consider a system with 1000 machines belonging to three classes, Xeon servers running Linux, Sun servers running Solaris, and IBM servers running AIX. The CPU speeds and the memory sizes of the machines also vary. Moreover, some of the machines may temporarily fail, and then come up again.  
New jobs can come only at five predesignated machines, and each job specifies the type and speed of the CPU and the minimum memory size needed by the job. The five machines are expected to assign the jobs to a machine that matches its requirements, taking load balancing into account. The five machines themselves do not execute any job, they just allocate the jobs to other machines and give the response back to the user at the end of a job. Suggest a scheme that you will use for the job assignment. For every design decision you make, justify briefly and clearly the reason for the decision. Make any reasonable assumptions that you may need, but write them clearly at the beginning of your answer. (12)

4. (a) Company *A* with domain name *A.com*, headquartered in Singapore, has branches in 50 different countries in the world, with the branch name in country *X* having domain name *X.A.com* (for ex. *India.A.com*, *Taiwan.A.com* etc.). Each branch has at least two divisions – sales and technical support, and the people in the two divisions are separated into two domains *sales.X.A.com* and *techsupport.X.A.com*. However, tech support people in different countries may need to access each others' databases to search for similar technical problems that customers faced. The sales people in different countries do not need to communicate directly with each other.  
 Kerberos is used for all authentication in this system, with an AS/TGS for each domain. State clearly what keys need to be shared between the different AS/TGS's, if any, for the company to operate as above. Show clearly the sequence of Kerberos messages that will occur when a tech support person in India accesses the tech support database in Taiwan. (3 + 12)  
 (b) Describe the working of the distributed 2-phase locking protocol with an example. (5)
  
5. (a) Show an execution of Juang-Venkatesan's algorithm with 4 processes in which exactly 4 rounds are needed to find the recovery line during recovery of a process. Show first the space-time diagram clearly showing all application messages and the positions of the events for each of the processes first. Then for each round, show the control messages sent and the corresponding actions taken by the processes on receiving the messages. (10)  
 (b) Modify Koo-Toueg's protocol so that it checkpoints a strongly consistent state. Show all data structures used clearly. (7)  
 (c) Show an example of a sequence of events that are causally consistent but not sequentially consistent in the context of consistency models in replication. (3)