UNIVERSITY OF EDINBURGH

COLLEGE OF SCIENCE AND ENGINEERING

SCHOOL OF INFORMATICS

INFR11022 DISTRIBUTED SYSTEMS (LEVEL 11)

Thursday 28th April 2016

14:30 to 16:30

INSTRUCTIONS TO CANDIDATES

Answer any TWO questions.

All questions carry equal weight.

CALCULATORS MAY NOT BE USED IN THIS EXAMINATION

Year 4 Courses

Convener: I. Stark

External Examiners: A. Burns, A. Cohn, P. Healey, T. Field, T. Norman

THIS EXAMINATION WILL BE MARKED ANONYMOUSLY

1. (a) What is an overlay? Why are they useful in distributed systems? [*2 marks*]

   (b) Suppose you have processes $1, 2, \ldots n$ on different machines in a data centre and that the number n is known to all processes. Each process is allowed to communicate two messages in each round. Each process holds a value that changes with time. An application requires computing the average of these values periodically.

      i. What overlay structure will you use and why? [*2 marks*]

      ii. Describe the distributed algorithm to compute this overlay. What is its message complexity. [*6 marks*]

      iii. How will you compute the average? What will be the time complexity for each computation of the average? [*3 marks*]

   (c) Describe four problems that require the global state of a distributed system to be known, rather than the states of each of the nodes in isolation. For each problem highlight the information that would be lost if only local state information were available. [*8 marks*]

   (d) You are expected to implement a logging process in a distributed system. The process should receive messages from all processes in the system and write these to a file. The system should run continuously and the log file will be used to monitor the execution and determine the order of events. Describe a conceptual solution and its limitations. Focus on causality and synchronisation. [*4 marks*]

2. (a) Is communication in real life (e.g. by email or letter) synchronous or asynchronous? . [*2 marks*]

(b) Why do we often use synchronous communication as a model for developing distributed protocols even when there are no known bounds on communication time? [*3 marks*]

(c) Suppose a system has the following sequence of events and messages (an arrow such as $s \rightarrow a$ represents s sending a message to a):

$$\begin{aligned} s &\rightarrow a \\ s &\rightarrow b \\ a &\rightarrow c \\ a &\rightarrow d \\ b &\rightarrow c \\ d &\rightarrow e \\ d &: \text{idle} \end{aligned}$$

Draw the Dijkstra-Scholten termination detection graph with child counters for all nodes after this sequence of events. You can assume any message is received before the next message in the sequence is sent. [*6 marks*]

(d) Consider a graph G of n nodes. The Maximum Independent set is given by $MaxIS(G)$, and the Maximal Independent set is given by $MIS(G)$. What is the largest possible value of the ratio $\frac{|MaxIS(G)|}{|MIS(G)|}$? [*2 marks*]

(e) Describe two different ways of implementing total-order multicast using only b-multicast with no link-layer multicast support. Compare the two strategies. [*12 marks*]

3. (a) State a scenario where a directed graph may be a suitable way to represent a network. [*2 marks*]

   (b) What could be the difficulties of representing a conventional wireless network as a directed graph? [*2 marks*]

   (c) Give four reasons for choosing to elect the node with highest id as the leader. [*4 marks*]

   (d) What are the advantages of geographic routing over flood based protocols such as DSR or AODV? [*4 marks*]

   (e) A friend of yours has implemented a distributed mutual exclusion lock for a known, fixed number of processes. A process must acquire the lock before entering the critical section. The protocol is very simple; a process sends request and enters a state waiting for ok messages from all other processes. If it receives other requests while in the waiting state it will simply put them on hold until it has executed the critical section.

   Your friend has some problems with deadlocks, something he detects and handles with timeouts. Describe to him what the problem is and a simple way to at least handle the deadlock problem while preserving the distributed architecture. Also explain to him that although your simple solution will prevent deadlocks from occurring it might have other problems. Describe these problems and give your friend some hints on how to handle them. [*4 marks*]

   (f) Assume that you have four uniquely named processes communicating in an asynchronous system. Assume also that they will behave correctly, that no messages are lost and that we have all the time in the world; how can you then implement a consensus protocol? Assume that messages can get lost, how does this change the situation? Assume that we have a deadline to meet and that all processes have to decide what to do before the deadline, how does this change the situation? [*4 marks*]

   (g) A historian wants to investigate the origin of a brilliant idea: who actually was first to have the idea and how the idea evolved. As material to this investigation he has a set of articles, unfortunately without dates but of course with complete references (still no dates). Several papers describe the idea but they could of course be written independently from each other. How will he be able to trace the idea and determine the relationship? Assuming he is given two papers that describe the idea, how can he determine who was first without looking at the other papers? How does this relate to vector clocks?

QUESTION CONTINUES ON NEXT PAGE

QUESTION CONTINUED FROM PREVIOUS PAGE

Assuming that an author wrote articles one by one, and numbered them; could we show that two articles from two authors did happen in real-time order although we don't have dependences (through references) between the two articles? Assume we want to reward papers presenting original ideas. Design a very simple scheme that will allow us to reward a paper from a set of submitted papers so that we will never give a reward to a paper if there is another submitted paper with the same idea that the first paper depends on. [*5 marks*]