Exam Distributed Algorithms

Free University Amsterdam, 27 August 2003, 9:30-12:30

(At this exam, you may use the book Introduction to Distributed Algorithms by Gerard Tel, and copies of the slides without handwritten comments.)

(The exercises in this exam sum up to 90 points; each student gets 10 points bonus.)

1. Consider the Netchange and Merlin-Segall algorithms for computing shortest paths in a weighted, undirected graph (without cycles of negative length).

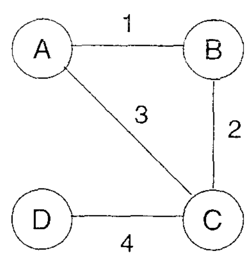
   (a) Explain why (or give an example to show that) the worst-case message complexity of the Netchange algorithm is exponential. (7 pts)

   (b) Explain why the worst-case message complexity of the Merlin-Segall algorithm is $O(|V|^2 \cdot |E|)$, where V is the set of nodes and E the set of edges. (5 pts)

2. Prove that there exists a deadlock-free controller, for packet switching on a cube, which uses only two buffers in each node, and allows packets to be routed via minimum-hop paths. (10 pts)

3. Consider the Gallager-Himblet-Spira (GHS) algorithm for computing a minimal spanning tree in a weighted graph (in which different edges have different weights).

   (a) Apply the GHS algorithm to the following weighted undirected graph:

   (12 pts)

   (b) Suppose that, at some point in an execution of the GHS algorithm, a process p in a fragment F sends a **connect** message over some edge pq directed towards a fragment F' having the same level as F. Argue that fragment F eventually either forms a new fragment with F' or else is absorbed into some fragment that includes F'. (8 pts)

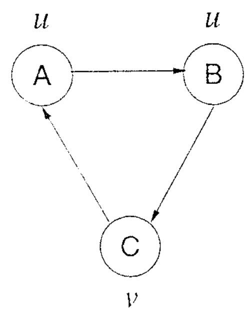
4. Consider the Dijkstra-Feijen-van Gasteren and Safra's algorithm for termination detection in a unidirectional network.

   (a) Explain in detail why the Dijkstra-Feijen-van Gasteren algorithm does not work in case of asynchronous communication. (4 pts)

   (b) Give an example to show that colouring *receiving* nodes black in the Dijkstra-Feijen-van Gasteren algorithm is incorrect. (4 pts)

(c) Explain (in your own words, i.e. do not copy the predicates from Section 8.3.2) why Safra's algorithm is correct. (8 pts)

5. Apply the Itai-Rodeh election algorithm to the following anonymous unidirectional ring, where initial random identities have been chosen.



Let $u < v$. Check that one of the upper two nodes becomes the leader. (10 pts)

6. Consider a *complete* network G (i.e., there is a channel between each pair of different processes) of five processes. Let three processes hold the value 0, while two processes hold the value 1.

   (a) Apply the Bracha-Toueg algorithm for 2-crash consensus to G. Give two scenarios: one scenario where all correct processes decide 0, and one scenario where all correct processes decide 1. (12 pts)

   (b) We adapt the Bracha-Toueg algorithm for t-Byzantine consensus by allowing a correct process to decide b if it receives *at least* (instead of more than) $\frac{N+t}{2}$ b-votes in one update round.

   Apply the adapted version of the Bracha-Toueg algorithm for 1-Byzantine consensus to G, and show that it can lead to inconsistent decisions. (10 pts)