# EXAM–2 Fault Tolerant Systems 11/30/2005

## READ CAREFULLY BEFORE BEGINNING

1. This exam comprises 25% (400 level) or 20% (500 level) of your total grade. Points are indicated for each question/section.
2. This is an **in-class, open book** exam (which includes open notes and papers).
3. On-campus: You have **50** minutes to finish.
4. Video: You have **60** minutes to finish.
5. Make sure your copy has **5** questions.
6. Read each question completely before answering. Be sure you understand all assumptions and constraints.
7. **Show all work and state all assumptions**. Partial credit can not be given for work not shown. Use the back of the page, if necessary.

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| REG MAXIMUM | 100 |
| DEDUCTIONS | − |
| **TOTAL SCORE** | |

PRINTED NAME _____

1. (20 pts) With respect to clock synchronization:

   (a) Given the convergence function $CF(p, x_1, x_2, ..., x_n) = CF(2, 4, 6, 6, 3, 100, 1, 3, 5, 4, 5, 4, 4)$, $\delta = k = 3$, what are the results for the following conversion functions? Note that the values $x_i$ are not sorted and note that this is the function executed at processor 2, whose own value is 6 (as can be seen). Use the definitions of the paper by Fred Schneider for the algorithms.

      i. egocentric average:

      ii. fast convergence algorithm:

      iii. fault-tolerant midpoint:

      iv. fault-tolerant average:

   (b) We have discussed what initiated the agreement research, i.e. clock synchronization problems originally observe in SIFT. Given three clocks $A, B$ and $C$ describe how the clocks can be forced by a malicious clock, say $A$, to drift appart if each clock uses the median value in each round of the synchronization algorithm.

2. (30 pts) Answer the following questions with respect to fault models:

   (a) Give a proof that, in general, for an oral message algorithm ,e.g., $OM(m)$, there cannot be agreement for $N \leq 3m$ processors, where $m$ is the number of asymmetric faults. Make sure you explain where the *interactive consistency conditions* are violated.

   (b) Assume the Lamport bound of $N = 3m+1$, with $r = m+1$ rounds. In a simplex scenario, i.e. we have a single general, how many messages does a **single** processor (lieutenant) receive? Derive the general expression as a function of $N$ and $r$. Hint: this is directly related to the number of vertices of a processor's value tree.

(c) Now consider the system as a whole executing in a simplex scenario. What is the total number of messages sent in the system.

(d) Next, consider the multiplex scenario. How many messages are now send system wide?

3. (20 pts) Draw the Petri-Net describing the reliability (or unreliability) for the following RAID systems. You may omit the inhibitory arcs that halt each timed transition upon failure, if applicable. Assume that *each* disc drive has a fail-rate $\lambda$. The repair/recover rate is indicated by $\delta$, which accounts for repair and reconfiguration with recovery.

   (a) A RAID-0 (level 0) system consisting of $N$ drives total.

   (b) A simple RAID-5 (level 5) system consisting of $N$ drives total.

(c) Now assume a RAID-1 system which contains $2N$ drives. The $2N$ drives are configured as a RAID-1, with $N$ disks for each mirror.

(d) Now the RAID-1 system with $2N$ drives is configured in such a way that each of $N$ drives is "locally" mirrored, i.e. there are $N$ pairs of drives, each pair constitutes a two-drive RAID-1 configuration. You may assume the special case where $N = 3$.

4. (20) Answer the following questions with respect to reliable broadcast.

   (a) Describe the essential properties of *reliable broadcast*.

   (b) What is the difference between reliable broadcast and atomic broadcast?

   (c) What is the difference between atomic broadcast and causal broadcast?

   (d) With respect to the 1990 paper by Melliar-Smith assume that the following sequence occurs: $A - Ba - Cb - D\bar{b}c - Ba - Edb$. Describe briefly the chain of events.

      i. first:

      ii. second:

      iii. third:

      iv. ...

5. (10 pts) Answer the following question with respect to agreement and synchronization.

   (a) In Lamport's paper the oral message algorithm $OM(m)$ and the signed message algorithm SM(m) are discussed.

      i. What is the main advantage of using $SM(m)$ compared to $OM(m)$?

      ii. What is the main disadvantage of $SM(m)$?

   (b) Consider the *Probabilistic Approach to Distributed Clock Synchronization* presented by F. Cristian.

   Let $C_Q(t) \in [T+\min, T+2D-\min]$ describe the interval for clock values under the assumption that there is no clock drift at all, based on the interval from the paper by F. Cristian. Given this new inerval $C_Q(t)$, derive an expression for the clock value that should be selected to minimize possible errors.

Extra Workspace