Parallel and Distributed Real-Time Systems
EDA420

Final exam, March 9, 2006 at 08:30 – 12:30 in the V building

Examiner:
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Content:
The written exam consists of 4 pages (including cover), containing 7 problems worth a total of 60 points.

Grading policy:
24–35 $\Rightarrow$ grade 3
36–47 $\Rightarrow$ grade 4
48–60 $\Rightarrow$ grade 5

Restrictions:
Books, notes or calculators are NOT allowed (only writing material and dictionaries)

Solution:
No solution provided.

Results:
Posted on the course home page on Monday, March 27, 2006 at 09:00.

Inspection:
Room 4128, Rännvägen 6 B, on Monday, March 27, 2006 at 13:00–15:00.

Language:
Your solutions should be written in Swedish or English.

IMPORTANT ISSUES

1. Use separate sheets for each answered problem, and mark each sheet with the problem number.
2. Mark the first sheet with your name and "personnummer".
3. Justify all answers. Lack of justification can lead to loss of credit even if the answer might be correct.
4. Explain all calculations thoroughly. If justification and method is correct then simple calculation mistakes do not necessarily lead to loss of credit.
5. If some assumptions in a problem are missing or you consider that the made assumptions are unclear, then please state explicitly which assumptions you make in order to find a solution.
6. Write clearly! If I cannot read your solution, it is wrong.

Good Luck!

PROBLEM 1

State whether the following propositions are TRUE or FALSE. For each correct statement, you will be given 1 point; for each erroneous statement you will be given -1 point; if you make no statement at all, you will be given 0 points. **Quality guarantee**: The total result for this problem cannot be less than 0 points. (6 points)

a) When there are mutual exclusion constraints in a system, it is impossible to find an optimal on-line scheduling algorithm (unless it is clairvoyant).

b) By *high precision* in a clock synchronization context, we mean a small deviation between clocks.

c) One of the so-called *Richard's anomalies* states that task completion times may decrease as a result of increasing the number of processors.

d) In a *negotiation scheme* for on-line task admission in a real-time system tasks provide primary and alternate constraint configurations so as to allow the systems to adjust task properties in case there is a risk for system overload.

e) A *necessary* feasibility test is one such that, if a given task set is schedulable, it always reports the answer "yes".

f) In the Fault-Tolerant Average algorithm for clock synchronization, the new clock value is the mean of the fastest and slowest remaining clock readings after excluding the t fastest and t slowest clocks.

PROBLEM 2

The following questions are related to estimation of worst-case execution times (WCET) of tasks.

a) Explain why is it preferred that WCET estimates for tasks in a real-time system are *pessimistic* as well as *tight*. (2 points)

b) Explain what the term *infeasible path* refers to in the context of WCET analysis and why it is useful to identify such paths. (2 points)

c) Explain why WCET for the, seemingly simple, program statement (here in the Ada programming language)

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X(1) := X(1) + 10/Y
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can be difficult to derive. (2 points)

PROBLEM 3

The following questions are related to the CAN (Controller Area Network) technique.

a) State whether communication medium access in CAN is token-based or contention-based. Motivate your answer. (1 points)

b) Describe the message format used in CAN. (1 points)

c) Describe the *binary countdown* algorithm as used in CAN. (3 points)

d) Describe how response-time-based schedulability analysis can be adapted to message scheduling in CAN. (3 points)

PROBLEM 4

Consider the Multiprocessor Scheduling decision problem — that is, the problem of determining schedulability for a set of independent tasks with a common deadline using a set of identical processors.

a) The Multiprocessor Scheduling decision problem is said to belong to class NP. Describe the formal characteristics of problem class NP. (4 points)

b) Describe the general procedure for proving that a decision problem, such as the Multiprocessor Scheduling problem, is NP-complete. (4 points)

c) Can the corresponding Multiprocessor Scheduling optimization problem also be proven to be NP-complete? Motivate your answer. (2 points)

PROBLEM 5

The following questions are related to p-fair scheduling (proportionate fairness).

a) Describe the difference between greedy and p-fair scheduling. (1 points)

b) Describe briefly the concept of *characteristic string* in p-fair scheduling. (1 points)

c) Describe briefly the concept of *lag* in p-fair scheduling. (1 points)

The following questions are related to global multiprocessor scheduling, where ready tasks are kept in a common queue and where a task can be dispatched to an arbitrary processor.

d) One well-known drawback with global multiprocessor scheduling is a dilemma referred to as *Dhall's effect*. Describe the basic features of Dhall's effect and also give an example of a task set that suffers from the effect. (4 points)

e) Describe a static-priority scheme for global multiprocessor scheduling that is guaranteed to circumvent Dhall's effect. (3 points)

PROBLEM 6

Consider a real-time system with periodic tasks and a run-time system that employs preemptive scheduling using the rate-monotonic (RM) priority assignment approach.

a) Describe Liu & Layland's sufficient schedulability test for RM scheduling. (2 points)

b) Describe under what assumptions the schedulability test in sub-problem a) applies. (2 points)

c) To prove the correctness of the schedulability test in sub-problem a), Liu & Layland took advantage of a special property of static priority scheduling. This property has since been useful for deriving a general schedulability analysis for tasks with static priorities. Describe the meaning of this property. (3 points)

Now assume that the given system consists of three tasks. For each task τ_i it applies that its deadline D_i is equal to the period T_i. All tasks arrive the first time at time 0. It is known that the tasks' utilizations $U_i = C_i/T_i$ are $U_1 = 0.60$, $U_2 = 0.15$, $U_3 = 0.10$.

d) If neither the tasks' execution times C_i, nor their periods T_i are known, is it possible to decide if the tasks are schedulable with RM? Motivate your answer. (3 points)

PROBLEM 7

Consider a real-time system with sporadic tasks and a run-time system that employs preemptive scheduling using the earliest-deadline-first (EDF) priority-assignment approach.

a) At a certain stage in the execution of the system, four sporadic tasks, τ_1, τ_2, τ_3 and τ_4, arrive according to the following scenario:

- At time $t = t_a$, task τ_2 arrives with an execution time $C_2 = 3$ and a relative deadline $D_2 = 7$.
- At time $t = t_a + 0.5$, task τ_4 arrives with an execution time $C_4 = 1.5$ and a relative deadline $D_4 = 9$.
- At time $t = t_a + 1.5$, task τ_3 arrives with an execution time $C_3 = 1.5$ and a relative deadline $D_3 = 6.5$.
- At time $t = t_a + 2$, task τ_1 arrives with an execution time $C_1 = 3$ and a relative deadline $D_1 = 4$.

Show, by constructing a timing diagram, that the task instances given above are schedulable using EDF. Assume, for simplicity, that the system is not currently executing any other task at $t = t_a$ and that no new instances of the four tasks arrive before $t = t_a + 15$. (4 points)

b) Show, by adding one more sporadic task arrival to the schedule, that EDF can yield a *cumulative value* of zero for the original four tasks if they are assumed to have hard deadlines. At the same time, give an example of another priority assignment that will yield a non-zero cumulative value for the original four tasks in the presence of the new sporadic task. (6 points)