Final Exam for Real Time Systems

2011 Oct 19, 8–13 (five hours!)

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Important Instructions:

1. No course material or computer/calculator are allowed, only a pen and a dictionary.
2. Please mark which course you are registered for:

◯ **5hp** (1DT063) You need to solve problems 1–4 only.	◯ **10hp** (1DT004) You need to solve *all* problems.

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Problem 1 (30 points)

1. Describe briefly three main features of RTOS.
2. Describe briefly three main features of an RT programing language like Ada.
3. Describe briefly three main differences between real-time and general-purpose computer systems.
4. Explain briefly how the arbitration mechanism of CAN works.
5. What are the essential difference between EDF and DMS? Are they optimal? If yes, why?
6. Give three reasons why it is difficult to design deterministic real-time systems.
7. Assume periodic tasks: A and B where B is released by A during its execution in each period. To reduce the release jitter of B, what will you do? Give two reasons why we should avoid jitters?
8. Explain the un-bounded priority inversion problem. Describe briefly two solutions.
9. Explain briefly the concept of Resource Reservation (RR). Which of the following statements are correct? (Please mark the correct one(s).)
   - ◯ RR is proposed to improve resource utilization in RT systems
   - ◯ RR allows modular design and analysis for RT systems
   - ◯ RR allows platform-independent design for RT systems
10. Describe briefly three periodic servers.

Problem 2 (20 points)

Assume a system with one processor and three periodic tasks:

Task	T_i	C_i	D_i
A	52	12	52
B	40	10	12
C	30	10	25

where T stands for period, C for WCET, och D for deadline.

1. Assume that $D_i = T_i$ (i.e. ignore the deadlines given in the table) and RMS is used to schedule the tasks:
   (a) What is the priority order?
   (b) Construct the run time schedule for the first 52 time units.
   (c) Is the task set schedulable? Motivate your answer.
2. Assume that DMS is used to schedule the tasks:
   (a) What is the priority order?
   (b) Construct the run time schedule for the first 52 time units.
   (c) Is the task set schedulable? Motivate your answer.
3. Assume that EDF is used to schedule the tasks:
   (a) Construct the run time schedule for the first 52 time units.
   (b) Is the task set schedulable? Motivate your answer.
4. Assume that task B is a polling server to run non-periodic requests whose total resource requirement is bounded by 10. The tasks may arrive sporadically but the next instance of each such task will not arrive before the current instance is computed. What are the worst-case response times for the non-periodic tasks when RMS and DMS are used respectively for the system?

Problem 3 (20 points)

Assume a CAN bus running at 1Mbits per second, connecting four stations (nodes) A, B, C and D.

1. On node A, there are two tasks. One is sending a message with identity 7 at most every 50ms and the other is sending a message with identity 9 at most every 60ms.
2. On node B, there are two tasks. One is sending a message with identity 10 at most every 100ms and the other is sending a message with identity 2 at most every 10ms.
3. On node C, there is a single task sending a message with identity 4 at most every 20ms.
4. On node D, there are five tasks sending messages with identity 1, 13, 20, 18, 25 at most every 15ms.

The transmitted messages are of fixed size (120 bits each). Assume that the CAN controllers have sufficient buffer capacity, no transmission errors, and no jitters. What is the worst case transmission delay (i.e. time from queuing to completed message transmission) for the messages with identity 9? Motivate your answer.

Problem 4 (20 points)

Assume a set of periodic tasks.

1. Describe briefly the RMS priority assignment and run-time behaviour.
2. Describe how the RMS sufficient schedulability test (i.e. using the utilization bound) works.
3. Describe how to calculate the worst case response times for each task. You should ignore jitters, overheads for context switch etc. Modify your calculation for non-preemptive tasks.

Problem 5 (20 points)

1. Describe briefly how partitioned scheduling works for multiprocessor systems using EDF and RMS. Describe briefly how to estimate the number of processors needed for each case.
2. Assume a set of 9 tasks with utilizations: $0.5, 0.7, 0.5, 0.2, 0.4, 0.2, 0.5, 0.1, 0.6$. Estimate the number of processors needed to run these tasks when EDF and RMS are used for partitioned scheduling. Explain your answers. For the case of RMS, you may use the worst-case utilization bound 69.3% as the capacity for each processor.
3. Describe an algorithm for partitioning a given task set onto a multiprocessor system. Assign the above set of tasks to the estimated number of processors for each of the two cases (i.e. EDF and RMS).

Problem 6 (20 points)

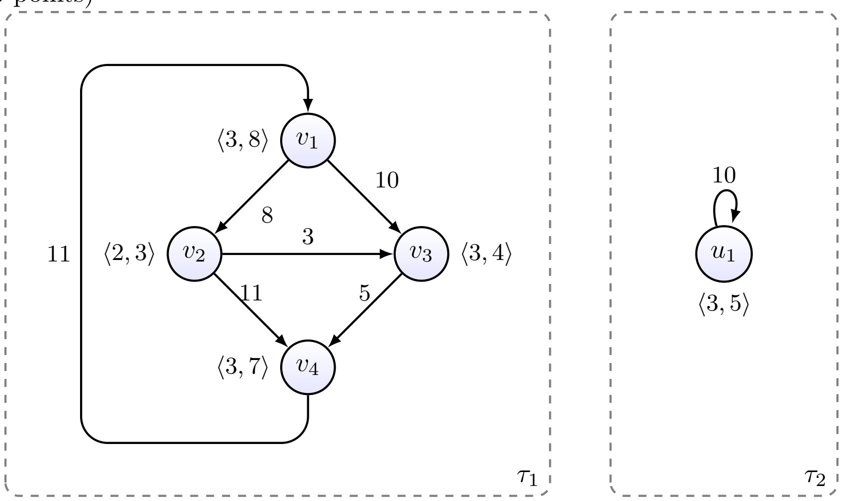
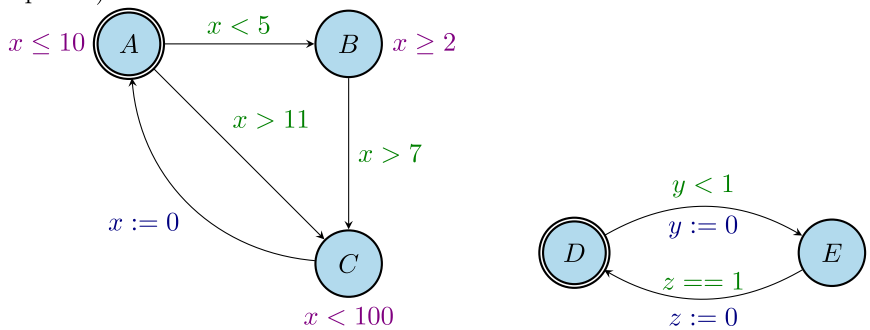


Figure 1: DRT task set $\tau = \{\tau_1, \tau_2\}$.

Take a look at DRT task set τ in Figure 1.

1. Which of the following is true? (Note that more than one option may be true.)
   - ◯ $\langle 5, 7 \rangle$ is a demand pair for τ_1.
   - ◯ $\langle 6, 7 \rangle$ is a demand pair for τ_1.
   - ◯ $dbf_{\tau_1}(7) \geqslant 5$
   - ◯ $dbf_{\tau_1}(7) = 5$
2. Is τ schedulable with EDF? Why/Why not?
3. Is τ schedulable with a fixed priority scheduler? Why/Why not?

Problem 7 (20 points)



(a) Timed automaton T_1

(b) Timed automaton T_2

Figure 2: Two timed automata in which x, y and z are clocks. Note that both automata are separate systems, they do *not* run together.

1. Take a look at the timed automaton T_1 in Figure 2(a).
   (a) Describe the set S of reachable states.
   (b) For each of the following properties, express it as a temporal formula and assess whether the property is satisfied.
      i. Is location B reachable?
      ii. Can x be below 5 at location C?
      iii. In each (infinite) trace, is x eventually at least 1?
   (c) Is there an edge that can be removed without altering S?
2. Take a look at the timed automaton T_2 in Figure 2(b). For each of the following properties, express it as a temporal formula and assess whether the property is satisfied.
   (a) Is it possible that T_2 deadlocks?
   (b) No matter what, will T_2 eventually deadlock?