

# EINDHOVEN UNIVERSITY OF TECHNOLOGY

Department of Mathematics and Computer Science

*Examination Real-time Architectures (2IN20)*

*on Wednesday, June 28<sup>th</sup> 2006, 14.00h-17.00h.*

First read the entire examination. There are 6 exercises in total. Grades are included between parentheses at all parts and sum up to 11 points. Good luck!

1. The so-called *hyperbolic bound* for a set of  $n$  tasks is given by

$$\text{HB}(n) = \prod_{1 \leq i \leq n} (U_i + 1) \leq 2.$$

- (a) (0.5) What does this bound represent?

**Answer** A *sufficient* schedulability test for rate monotonic scheduling (RMS).

- (b) (0.5) Give at least three assumptions that need to hold to use this bound.

**Answer** See assumptions for RMS in book.

- (c) (1.0) Give an example of a task set  $\mathcal{T}$  that satisfies this bound, and has the additional property that an increase of the computation time of any task of  $\mathcal{T}$  will make  $\mathcal{T}$  unschedulable.

**Answer** Let  $\mathcal{T}$  consist of 2 tasks, with  $C_1 = 2$ ,  $T_1 = 5$ ,  $C_2 = 3$ , and  $T_2 = 7$ . These values for the tasks satisfy the conditions for a minimal total utilization, i.e.  $T_1 < T_2 < 2T_1$ ,  $C_1 = T_2 - T_1$ , and  $C_2 = 2T_1 - T_2$ ; see book p. 89. Now  $U_1 = \frac{2}{5}$ ,  $U_2 = \frac{3}{7}$ ,  $\prod_{1 \leq i \leq 2} (U_i + 1) = 2$ , and the hyperbolic bound is therefore satisfied. Increasing either  $C_1$  or  $C_2$  will make the task set unschedulable, as becomes immediately clear when drawing a timeline with a simultaneous release at time zero.

This exercise has been taken from sheet 30 of ‘RTA.B5-Analyse-1’.

2. (2.0) Using a sporadic server with capacity  $C_S = 2$  and period  $T_S = 5$ , schedule the following tasks, (i.e. draw a timeline for the tasks and the capacity of the server as a function of time):

periodic tasks			aperiodic tasks		
	$C$	$T$		$a$	$C$
$\tau_1$	1	4	$J_1$	2	2
$\tau_2$	2	6	$J_2$	5	1
			$J_3$	10	2

Assume rate monotonic scheduling, and a simultaneous release of the periodic tasks at time zero.

**Answer** See book Exercise 5.6.

3. Consider the periodic tasks and the sporadic server given in the previous exercise, and assume rate monotonic scheduling.

- (a) (0.5) Determine whether or not the periodic tasks and the sporadic server are schedulable.

**Answer** From a timeline with a simultaneous release at time zero and a complete utilization of the sporadic server, we see that  $\tau_2$  misses its deadline. Hence, the periodic tasks and the sporadic server are not schedulable under worst-case conditions.

- (b) (0.5) Describe how to determine the minimal period  $T_2^{\min}$  for task  $\tau_2$  for which the periodic tasks and the sporadic server are schedulable under worst-case conditions. Also determine the value of  $T_2^{\min}$ .

**Answer** Given the timeline constructed for item (a), we immediately see that extending the period to 8 will make  $\tau_2$  schedulable, hence  $T_2^{\min} = 8$ .

4. Consider three periodic tasks  $\tau_1$ ,  $\tau_2$ , and  $\tau_3$  (having decreasing priority), which share three resources,  $A$ ,  $B$ , and  $C$ . Compute the maximum blocking time  $B_i$  for each task for the following two protocols, knowing that the longest duration  $D_i(R)$  for a task  $\tau_i$  on resource  $R$  is given by the following table (there are no nested critical sections):

	$A$	$B$	$C$
$\tau_1$	2	0	2
$\tau_2$	2	3	0
$\tau_3$	3	2	5

- (a) (1.5) Priority Inheritance Protocol.

**Answer** See book Exercise 7.2.

- (b) (1.5) Priority Ceiling Protocol.

**Answer** See book Exercise 7.3.

5. One of the motivations for resource reservation is to prevent temporal interference between applications.

- (a) (0.5) Explain the notion of *temporal interference*.

- (b) (1.0) Explain the concept of *resource reservation*, including the four elements on which it is based.

- (c) (0.5) Explain how temporal interference between applications can be prevented by resource reservation.

**Answers** See slides of ‘RTA.D8-Resource reservation’.

6. Consider two different activation paradigms, *time triggered* (TT) and *event triggered* (ET).

- (a) (0.5) Explain both paradigms in your own words.

- (b) (0.5) Give two relative merits of TT compared to ET.

**Answers** See slides of ‘TT-ET+offline’.