Assignment 2, Embedded Systems II
Mälardalen University

Emil Broberg
School of Innovation, Design and Engineering
Mälardalen University, Västerås, Sweden
Email: ebg20007@student.mdu.se

I. Question 1

$$R_i^{n+1} = C_i + \sum_{\forall j \in hp(i)} \left\lceil \frac{R_i^n}{T_i} \right\rceil C_j$$

Task	Period (T)	Deadline (D)	Exec. time (C)
A	1000	20	3
B	100	100	10
C	50	50	20
D	57	10	5
E	33	33	1
F	7	7	1
G	30	5	2

Figure 1. Task set

Task	Semaphore	Length of critical section
A	S_1	2
	S_3	2
B	S_2	7
	S_3	5
	S_4	2
D	S_1	2
C	S_2	1
G	S_1	1

Figure 2. Task set

$R^0 = C_i$ iterate until $R^{n+1} = R^n$, or $R^{n+1} > D_i$. If $R^{n+1} > D_i$, the task set is not schedulable.

A. *Priorities*

The priority of each task is determined by the size of its deadline. The proirity is inversely proportional to the deadline, i.e. the smaller the deadline, the higher the priority. The following list shows the priorities of the tasks in the task set where the highest priority is 7 and the lowest proirity is 1:

- $P(A) = 4$
- $P(B) = 1 \leftarrow$ Lowest
- $P(C) = 2$
- $P(D) = 5$
- $P(E) = 3$
- $P(F) = 6$
- $P(G) = 7 \leftarrow$ Highest

The priority ceiling of each semaphore is the highest priority of the tasks that use the semaphore. The following list shows the priority ceilings of the semaphores:

- $ceil(S_1) = max(P(A), P(D), P(G)) = 7$
- $ceil(S_2) = max(P(B), P(C)) = 2$
- $ceil(S_3) = max(P(A), P(B)) = 4$
- $ceil(S_4) = P(B) = 1$

Using the Priority Ceiling Protocol (PCP), the priority of a task is the highest priority of the semaphores it is waiting for.

B. *Blocking time*

In this example we need to consider blocking time such that we can use the formula:

$$R_i^{n+1} = C_i + B_i + \sum_{\forall j \in hp(i)} \left\lceil \frac{R_i^n}{T_i} \right\rceil C_j$$

where B_i is the blocking time of task i. Since we are going to find the response times of task A and G we need to fint B_A and B_G.

$B_A = ?$
$lp(A) =$ all tasks that has lower priority than A.

- $lp(A) = \{B, C, E\}$
- B uses S_2, S_3 and S_4
  - $P(A) > ceil(S_2) = 4 > 2$? Yes $\rightarrow$ B with S_2 cannot block A.
  - $P(A) > ceil(S_3) = 4 > 4$? No $\rightarrow$ B with S_3 can block A.
  - $P(A) > ceil(S_4) = 4 > 1$? Yes $\rightarrow$ B with S_4 cannot block A.
- C uses S_2
  - $P(A) > ceil(S_2) = 4 > 2$? No $\rightarrow$ C with S_2 can block A.
- E uses no semaphore
  - $P(A) > P(E) = 4 > 3$? Yes $\rightarrow$ E cannot block A.
- $B_A = CS(B, S_3) = 5$

$B_G = ?$
$lp(G) =$ all tasks that has lower priority than G.
$lp(G) = \{A, B, C, D, E, F\}$

- A uses S_1 and S_3
  - $P(G) > ceil(S_1) = 7 > 7$? No $\rightarrow$ A with S_1 can block G.
  - $P(G) > ceil(S_3) = 7 > 4$? Yes $\rightarrow$ A with S_2 cannot block G.
- B uses S_2, S_3 and S_4
  - $P(G) > ceil(S_2) = 7 > 2$? Yes $\rightarrow$ B with S_2 cannot block G.
  - $P(G) > ceil(S_3) = 7 > 4$? Yes $\rightarrow$ B with S_3 cannot block G.
  - $P(G) > ceil(S_4) = 7 > 1$? Yes $\rightarrow$ B with S_4 cannot block G.
- C uses S_2
  - $P(G) > ceil(S_2) = 7 > 2$? Yes $\rightarrow$ C with S_2 cannot block G.
- D uses S_1
  - $P(G) > ceil(S_1) = 7 > 7$? No $\rightarrow$ D with S_1 can block G.
- E uses no semaphore
  - $P(G) > P(E) = 7 > 3$? Yes $\rightarrow$ E cannot block G.
- F uses no semaphore
  - $P(G) > P(F) = 7 > 6$? Yes $\rightarrow$ F cannot block G.
- $B_G = max(CS(A, S_1), CS(D, S_1)) = 2$

Conclusively, $B_A = 5$ and $B_G = 2$.

C. *Response Time Analysis (RTA)*

Doing the RTA of the tasks A and G we get the following results:
$R_A^{n+1} = C_A + B_A + \sum_{\forall j \in hp(A)} \left\lceil \frac{R_A^n}{T_j} \right\rceil C_j$
$j \in hp(A) = \{D, F, G\}$
$R_A^0 = C_A + B_A = 8$
$R_A^1 = C_A + B_A + \sum \left\lceil \frac{R_A^0}{T_j} \right\rceil C_j = 3 + 5 + \left\lceil \frac{8}{57} \right\rceil 5 + \left\lceil \frac{8}{7} \right\rceil 1 + \left\lceil \frac{8}{30} \right\rceil 2 = 3 + 5 + [1] * 5 + [2] * 1 + [1] * 2 = 17$
$R_A^2 = C_A + B_A + \sum \left\lceil \frac{R_A^1}{T_j} \right\rceil C_j = 3 + 5 + \left\lceil \frac{17}{57} \right\rceil 5 + \left\lceil \frac{17}{7} \right\rceil 1 + \left\lceil \frac{17}{30} \right\rceil 2 = 3 + 5[1] * 5 + [3] * 1 + [1] * 2 = 18$
$R_A^3 = C_A + B_A + \sum \left\lceil \frac{R_A^2}{T_j} \right\rceil C_j = 3 + 7 + \left\lceil \frac{18}{57} \right\rceil 5 + \left\lceil \frac{18}{7} \right\rceil 1 + \left\lceil \frac{18}{30} \right\rceil 2 = 3 + 5[1] * 5[3] * 1 + [1] * 2 = 18$
$R_A^3 = R_A^2 = 18$

$R_A = 18$

$R_G^{n+1} = C_G + B_G + \sum_{\forall j \in hp(G)} \left\lceil \frac{R_G^n}{T_j} \right\rceil C_j$
$j \in hp(G) = \{$No tasks with higher priority than $G\}$
Worst case scenario, $R_G = C_G + B_G = 2 + 2 = 4$

$R_G = 4$

II. Question 2

A. *Assignment A*

Message	**Maximum bit size**	**Transmission time (ms)**
Sense A	75	1.000
Sense B	95	1.267
Sense C	95	1.267
Act A	65	0.867
Act B	75	1.000
Act C	95	1.267

Figure 3. Maximum bit size and transmission time for each message

B. *Assignment B*

Node & CAN	**Load (percent)**
Node A	55.33
Node B	55.33
Node C	50.33
Node A	50.00
CAN	54.00

Figure 4. Load (utilization) of on each node and the CAN bus. Displayed in percetage.

C. *Assignment C*

Node/CAN	Task/Message	Priority
Node A	SenseA	2
	ActA	2
	P1A	1
	P2A	3
	P3A	4
Node B	SenseB	2
	ActB	2
	P1B	1
	P2B	3
	P3B	4
Node C	SenseC	2
	ActC	2
	P1C	1
	P2C	3
	P3C	4
Node D	CalcA	1
	CalcB	1
	CalcC	2
CAN	SenseA	1
	ActA	1
	SenseB	1
	ActB	1
	SenseC	2
	ActC	2

Figure 5. The priorities of the tasks and messages. Priority is set according to Rate Monotonic and 1 is the highest priority possible.

D. *Assignment D*