Development of Real-Time Systems

July 3, 2016

Assignment 3

In this assignment we will focus a bit more on the theoretical side. We will have a look at verifying real-time system by using the cyclic structured construct handled in the course and a simulation environment to automatically schedule a full timeline. The main purpose of the assignment is to expose the student to several ways of planning and verifying a real-time system in practice.

1 Theory assignment

The following part of assignment is a purely theoretical task that requires no additional tools. The task is to find the largest possible frame size for the cyclic structured scheduler by following requirements 1, 2 and 3 for finding the largest frame size. The following three task sets should be used:

1. $T_1(15, 1, 14)$ $T_2(20, 2, 26)$ $T_3(22, 3)$
2. $T_1(4, 1)$ $T_2(5, 2, 7)$ $T_3(20, 5)$
3. $T_1(5, 0.1)$ $T_2(7, 1)$ $T_3(12, 6)$ $T_4(45, 9)$

1.1 Report 1

This report shows the results with the first data: $T_1(15, 1, 14)$ $T_2(20, 2, 26)$ $T_3(22, 3)$

- **Requirement 1**

  $f \geq 3$

- **Requirement 2**

  $f = \{22, 20, 15, 11, 10, 5, 4, 3, 2, 1\}$

- **Requirement 3**

	T_1	T_2	T_3
22	$44 - 1 \nleq 14$		
20	$40 - 5 \nleq 14$		
15	$30 - 15 \nleq 14$		
10	$20 - 5 \nleq 14$		
5	$10 - 5 \leq 14$	$10 - 5 \leq 26$	$10 - 1 \leq 22$

- **Results**

  The optimal frame size that fulfils the requirements is $f = 5$.

1.2 Report 2

This report shows the results with the second data: $T_1(4, 1)$ $T_2(5, 2, 7)$ $T_3(20, 5)$

- **Requirement 1**

  $f \geq 5$

- **Requirement 2**

  $f = \{20, 10, 5, 4, 2, 1\}$

- **Requirement 3**

	T_1	T_2	T_3
20	$40 - 4 \nleq 4$		
10	$20 - 2 \nleq 4$		
5	$10 - 1 \nleq 4$		
4	$8 - 4 \leq 4$	$8 - 1 \leq 7$	$8 - 4 \leq 20$

- **Results**

  In this case there is no frame size that fulfils the requirements since the candidate from the requirement 3 doesn't satisfies requirement 1. For making this system feasible, jobs from T_3, which have a execution time bigger than 4, should be split in smaller parts.

1.3 Report 3

This report shows the results with the third data: $T_1(5, 0.1)$ $T_2(7, 1)$ $T_3(12, 6)$ $T_4(45, 9)$

- **Requirement 1**

  $f \geq 9$

- **Requirement 2**

  $f = \{45, 15, 12, 9, 7, 6, 5, 4, 3, 2, 1\}$

- **Requirement 3**

	T_1	T_2	T_3
45	$90 - 5 \nleq 5$		
15	$30 - 5 \nleq 5$		
12	$24 - 1 \nleq 5$		
9	$18 - 1 \nleq 5$		
7	$14 - 1 \nleq 5$		
6	$12 - 1 \nleq 5$		
5	$10 - 5 \leq 5$	$10 - 1 \nleq 7$	
4	$8 - 1 \nleq 5$		
3	$6 - 1 \leq 5$	$6 - 1 \leq 7$	$6 - 3 \leq 12$

- **Results**

  In this case there is no frame size that fulfils the requirements since the candidate from the requirement 3 doesn't satisfies requirement 1. For making this system feasible, jobs from T_3 and T_4, which have a execution time bigger than 3, should be split in smaller parts.

2 Simulation assignment

The assignment is to use a real-time simulator to verify feasibility of a set of tasks.

The following task sets and scheduler should be used:

1. $T_1(2, 0.5)$, $T_2(3, 1.2)$, $T_3(6, 0.5)$ and the RM scheduler
2. $T_1(2, 0.5, 1.9)$, $T_2(5, 2)$, $T_3(1, 0.1, 0.5)$, $T_4(10, 5, 20)$ and the EDF scheduler

2.1 Report 1

- **What is the utilization factor of the system and what is the value for Urm(3)**

  Looking at the general tab, which is shown on figure 1, the total utilization has a value of 0.7410.

	Total load	Payload	System load
CPU 1	0.7410	0.7410	0.0000
Average	0.7410	0.7410	0.0000

Figure 1: General tab of results window in the first simulation

  This value is very similar with the theorical total utilization, which is calculated in the ecuation 1

$$U = \frac{0.5}{2} + \frac{1.2}{3} + \frac{0.5}{6} = 0.7333 \tag{1}$$

  $U_{RM}(3)$ has been calculated using the ecuation 2

$$U_{RM}(3) \ = \ 3(2^{\frac{1}{3}} - 1) = 0.7798 \tag{2}$$

- **What is the minimum/maximum/average response time of all tasks?**

  This data is shown on the task tab, which is presented on figure 2.

Task	min	avg	max	std dev
TASK T1	0.500	0.564	0.700	0.093
TASK T2	1.200	1.458	1.700	0.250
TASK T3	2.700	2.700	2.700	0.000

Figure 2: Task tab of results window in the first simulation

- **Is any task missing the deadline? Which task? Where?**

  There is no task missing its deadline. This can be seen in the log tab, which is presented on figure 3.

Date (cycles)	Date (ms)	Message
0	0.0	TASK T1_1 Activated.
0	0.0	TASK T2_1 Activated.
0	0.0	TASK T3_1 Activated.
0	0.0	TASK T1_1 Executing on CPU 1
500000	0.5	TASK T1_1 Terminated.
500000	0.5	TASK T2_1 Executing on CPU 1
1700000	1.7	TASK T2_1 Terminated.
1700000	1.7	TASK T3_1 Executing on CPU 1
2000000	2.0	TASK T1_2 Activated.
2000000	2.0	TASK T3_1 Preempted! ret: 200000
2000000	2.0	TASK T1_2 Executing on CPU 1
2500000	2.5	TASK T1_2 Terminated.
2500000	2.5	TASK T3_1 Executing on CPU 1
2700000	2.7	TASK T3_1 Terminated.
3000000	3.0	TASK T2_2 Activated.
3000000	3.0	TASK T2_2 Executing on CPU 1
4000000	4.0	TASK T1_3 Activated.
4000000	4.0	TASK T2_2 Preempted! ret: 200000
4000000	4.0	TASK T1_3 Executing on CPU 1
4500000	4.5	TASK T1_3 Terminated.
4500000	4.5	TASK T2_2 Executing on CPU 1
4700000	4.7	TASK T2_2 Terminated.
6000000	6.0	TASK T3_2 Activated.
6000000	6.0	TASK T2_3 Activated.
6000000	6.0	TASK T1_4 Activated.
6000000	6.0	TASK T1_4 Executing on CPU 1

Figure 3: Log tab of results window in the first simulation

- **If a deadline is missed, could it be avoided by changing the scheduler?**

There aren't missed deadlines in the simulation.

2.2 Report 2

- **What is the utilization factor of the system and what is the value for Urm(4)**

  Looking at the general tab, which is shown on figure 4, the total utilization has a value of 1.0000.

	Total load	Payload	System load
CPU 1	1.0000	1.0000	0.0000
Average	1.0000	1.0000	0.0000

Figure 4: General tab of results window in the second simulation

This value doesn't correspond with the theorical total utilization, which is calculated in the ecuation 3

$$U = \frac{0.5}{2} + \frac{2}{5} + \frac{0.1}{1} + \frac{5}{10} = 1.25000 \tag{3}$$

$U_{RM}(4)$ has been calculated using the ecuation 4

$$U_{RM}(3) \;=\; 4(2^{\frac{1}{4}} - 1) = 0.7568 \tag{4}$$

- **What is the minimum/maximum/average response time of all tasks?**

  This data is shown on the task tab, which is presented on figure 5.

Task	min	avg	max	std dev
TASK T1	0.600	0.600	0.600	0.000
TASK T2	2.800	3.100	3.400	0.300
TASK T3	0.100	0.100	0.100	0.000
TASK T4	20.000	20.000	20.000	0.000

Figure 5: Task tab of results window in the second simulation

- **Is any task missing the deadline? Which task? Where?**

  Yes there is. Task 4 only satisfies its deadline on the first job and then always fails it and abort its execution. This is shown on the log of the simulation, which is presented on figure 6. It can be seen that it execution exceeds the deadline at time 30.0 and successive.

27000000	27.0	TASK T2_6 Preempted! ret: 700000
27000000	27.0	TASK T3_28 Executing on CPU 1
27100000	27.1	TASK T3_28 Terminated.
27100000	27.1	TASK T2_6 Executing on CPU 1
27800000	27.8	TASK T2_6 Terminated.
27800000	27.8	TASK T4_2 Executing on CPU 1
28000000	28.0	TASK T1_15 Activated.
28000000	28.0	TASK T3_29 Activated.
28000000	28.0	TASK T4_2 Preempted! ret: 3800000
28000000	28.0	TASK T3_29 Executing on CPU 1
28100000	28.1	TASK T3_29 Terminated.
28100000	28.1	TASK T1_15 Executing on CPU 1
28600000	28.6	TASK T1_15 Terminated.
28600000	28.6	TASK T4_2 Executing on CPU 1
29000000	29.0	TASK T3_30 Activated.
29000000	29.0	TASK T4_2 Preempted! ret: 3400000
29000000	29.0	TASK T3_30 Executing on CPU 1
29100000	29.1	TASK T3_30 Terminated.
29100000	29.1	TASK T4_2 Executing on CPU 1
30000000	30.0	Job TASK T4_2 aborted! ret:2.5
30000000	30.0	TASK T4_4 Activated.
30000000	30.0	TASK T2_7 Activated.
30000000	30.0	TASK T1_16 Activated.
30000000	30.0	TASK T3_31 Activated.
30000000	30.0	TASK T3_31 Executing on CPU 1
30100000	30.1	TASK T3_31 Terminated.

Figure 6: Log tab of results window in the second simulation

- **If a deadline is missed, could it be avoided by changing the scheduler?**

  In this case it can't, because as has been calculated in the first point, the theorical total utilization is 1.2500, and this value is greater than 1.0000