Second Labs on Real-Time Scheduling

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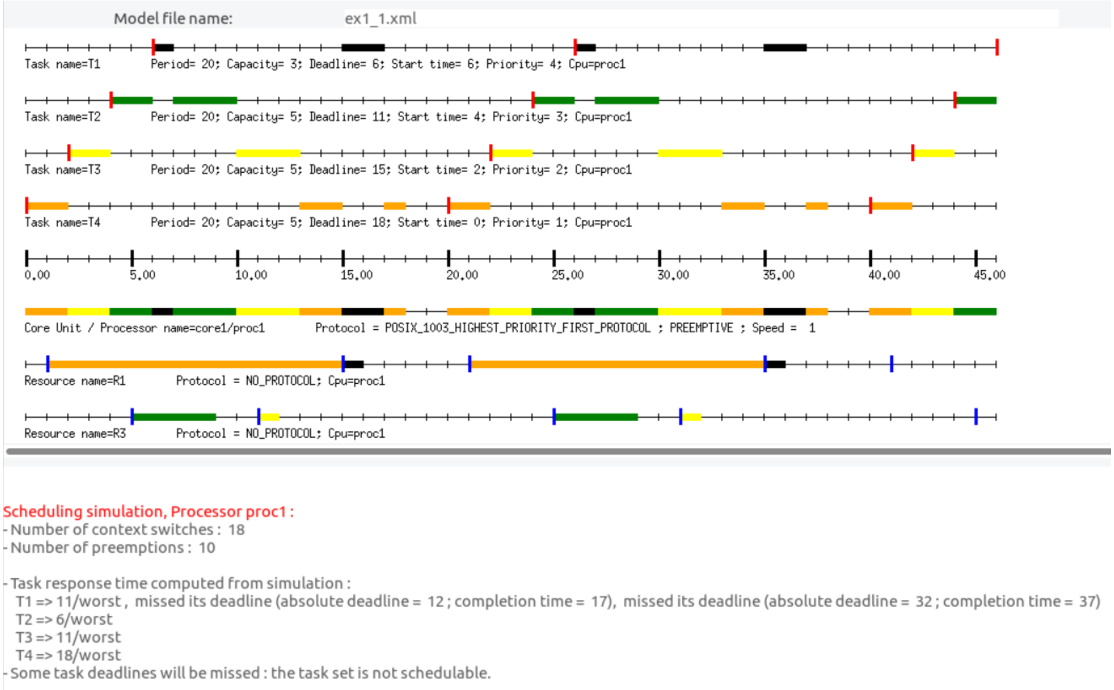
Exercise 1

Let’s assume the following task sharing resources R_1, R_2 and R_3:

	First release	WCET	D	P	Priority
T_1	6	3 : $\boxed{}\boxed{R_1}\boxed{}$	6	20	4
T_2	4	5 : $\boxed{}\boxed{R_3}\boxed{R_3}\boxed{\ R_3\ }\boxed{}$	11	20	3
T_3	2	5 : $\boxed{}\boxed{R_2}\boxed{R_2}\boxed{R_2 R_3}\boxed{}$	15	20	2
T_4	0	5 : $\boxed{}\boxed{R_1}\boxed{R_1}\boxed{R_1 R_2}\boxed{}$	18	20	1

1. The Simulation of this configuration without a specific protocol for resource allocation is ***not schedulable***. Because T_1 missed its deadline twice: (absolute deadline = 12; completion deadline = 17) and (absolute deadline = 32; completion deadline = 37).

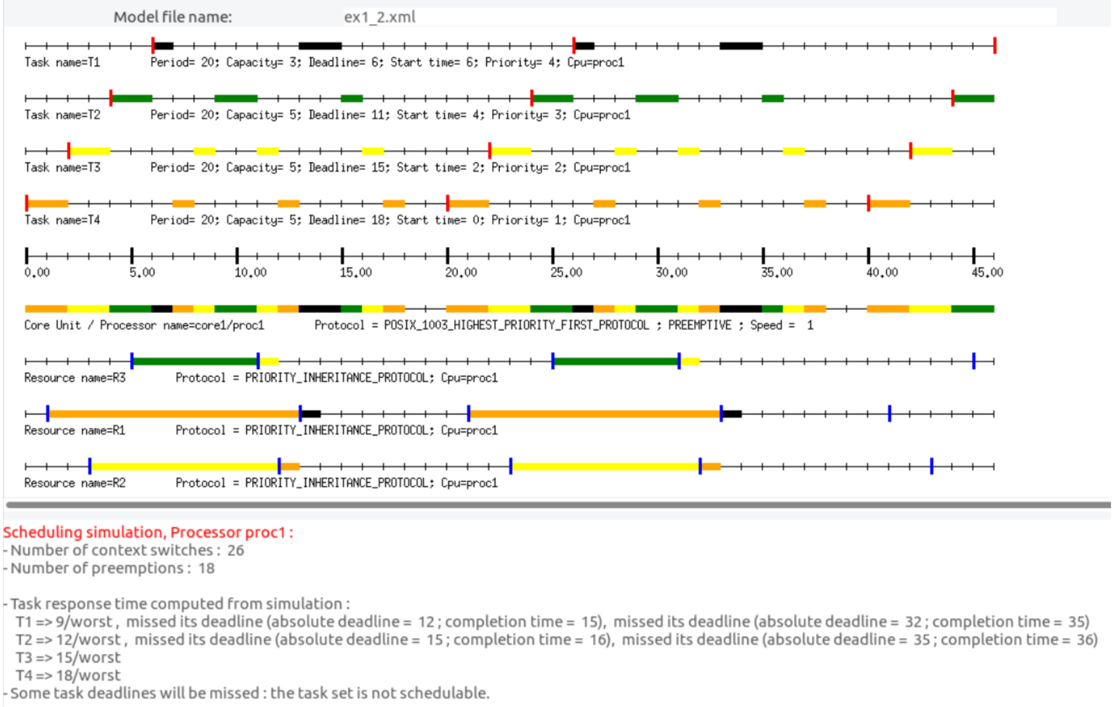


Model file name: ex1_1.xml

```
Task name=T1        Period= 20; Capacity= 3; Deadline= 6; Start time= 6; Priority= 4; Cpu=proc1
Task name=T2        Period= 20; Capacity= 5; Deadline= 11; Start time= 4; Priority= 3; Cpu=proc1
Task name=T3        Period= 20; Capacity= 5; Deadline= 15; Start time= 2; Priority= 2; Cpu=proc1
Task name=T4        Period= 20; Capacity= 5; Deadline= 18; Start time= 0; Priority= 1; Cpu=proc1
Core Unit / Processor name=core1/proc1        Protocol = POSIX_1003_HIGHEST_PRIORITY_FIRST_PROTOCOL ; PREEMPTIVE ; Speed =  1
Resource name=R1        Protocol = NO_PROTOCOL; Cpu=proc1
Resource name=R3        Protocol = NO_PROTOCOL; Cpu=proc1
```

```
Scheduling simulation, Processor proc1 :
- Number of context switches :  18
- Number of preemptions :  10

- Task response time computed from simulation :
   T1 => 11/worst ,  missed its deadline (absolute deadline =  12 ; completion time =  17),  missed its deadline (absolute deadline =  32 ; completion time =  37)
   T2 => 6/worst
   T3 => 11/worst
   T4 => 18/worst
- Some task deadlines will be missed : the task set is not schedulable.
```

2. The Simulation of this configuration with the Priority Inheritance protocol for resource allocation is ***not schedulable***. Because T_1 and T_2 both missed its deadline twice:
   - T_1: (absolute deadline = 12; completion deadline = 15) and (absolute deadline = 32; completion deadline = 35).
   - T_2: (absolute deadline = 15; completion deadline = 16) and (absolute deadline = 35; completion deadline = 36).

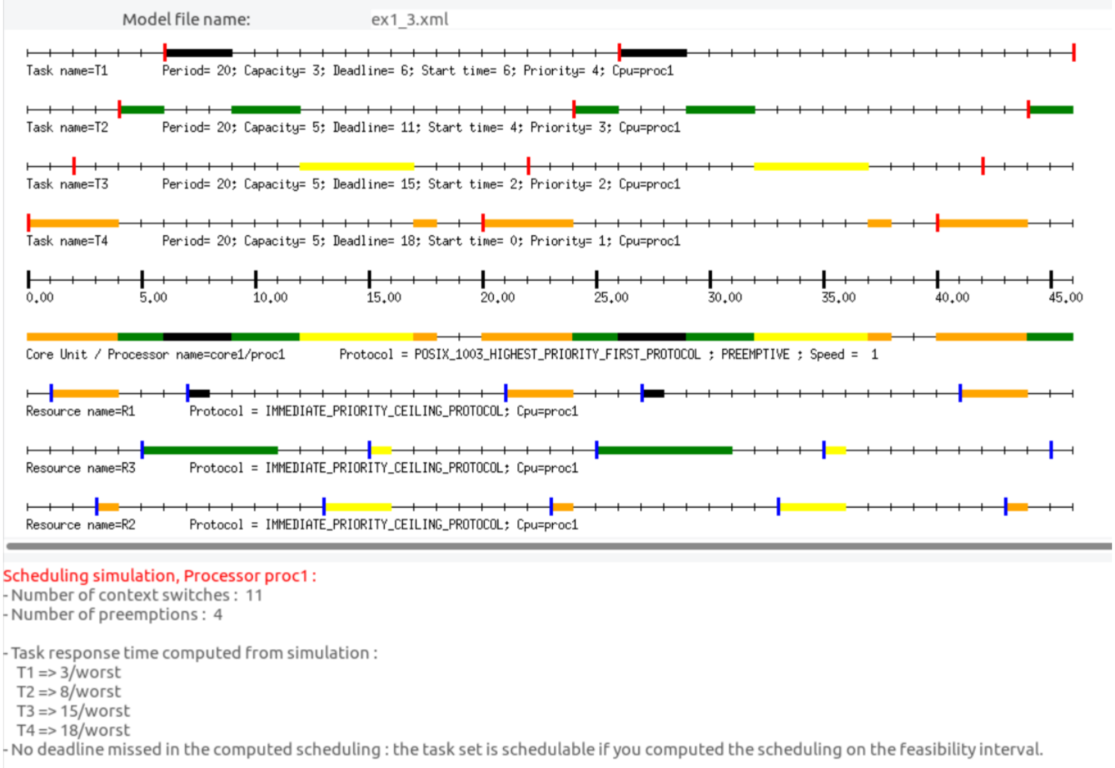


Model file name: ex1_2.xml

```
Task name=T1        Period= 20; Capacity= 3; Deadline= 6; Start time= 6; Priority= 4; Cpu=proc1
Task name=T2        Period= 20; Capacity= 5; Deadline= 11; Start time= 4; Priority= 3; Cpu=proc1
Task name=T3        Period= 20; Capacity= 5; Deadline= 15; Start time= 2; Priority= 2; Cpu=proc1
Task name=T4        Period= 20; Capacity= 5; Deadline= 18; Start time= 0; Priority= 1; Cpu=proc1
Core Unit / Processor name=core1/proc1        Protocol = POSIX_1003_HIGHEST_PRIORITY_FIRST_PROTOCOL ; PREEMPTIVE ; Speed =  1
Resource name=R3        Protocol = PRIORITY_INHERITANCE_PROTOCOL; Cpu=proc1
Resource name=R1        Protocol = PRIORITY_INHERITANCE_PROTOCOL; Cpu=proc1
Resource name=R2        Protocol = PRIORITY_INHERITANCE_PROTOCOL; Cpu=proc1
```

```
Scheduling simulation, Processor proc1 :
- Number of context switches :  26
- Number of preemptions :  18

- Task response time computed from simulation :
   T1 => 9/worst ,  missed its deadline (absolute deadline =  12 ; completion time =  15),  missed its deadline (absolute deadline =  32 ; completion time =  35)
   T2 => 12/worst ,  missed its deadline (absolute deadline =  15 ; completion time =  16),  missed its deadline (absolute deadline =  35 ; completion time =  36)
   T3 => 15/worst
   T4 => 18/worst
- Some task deadlines will be missed : the task set is not schedulable.
```

3. The Simulation of this configuration with the Stack-based Protocol (Immediate Ceiling Inheritance Protocol) for resource allocation ***is schedulable***.



Model file name: ex1_3.xml

```
Task name=T1        Period= 20; Capacity= 3; Deadline= 6; Start time= 6; Priority= 4; Cpu=proc1
Task name=T2        Period= 20; Capacity= 5; Deadline= 11; Start time= 4; Priority= 3; Cpu=proc1
Task name=T3        Period= 20; Capacity= 5; Deadline= 15; Start time= 2; Priority= 2; Cpu=proc1
Task name=T4        Period= 20; Capacity= 5; Deadline= 18; Start time= 0; Priority= 1; Cpu=proc1
Core Unit / Processor name=core1/proc1        Protocol = POSIX_1003_HIGHEST_PRIORITY_FIRST_PROTOCOL ; PREEMPTIVE ; Speed =  1
Resource name=R1        Protocol = IMMEDIATE_PRIORITY_CEILING_PROTOCOL; Cpu=proc1
Resource name=R3        Protocol = IMMEDIATE_PRIORITY_CEILING_PROTOCOL; Cpu=proc1
Resource name=R2        Protocol = IMMEDIATE_PRIORITY_CEILING_PROTOCOL; Cpu=proc1
```

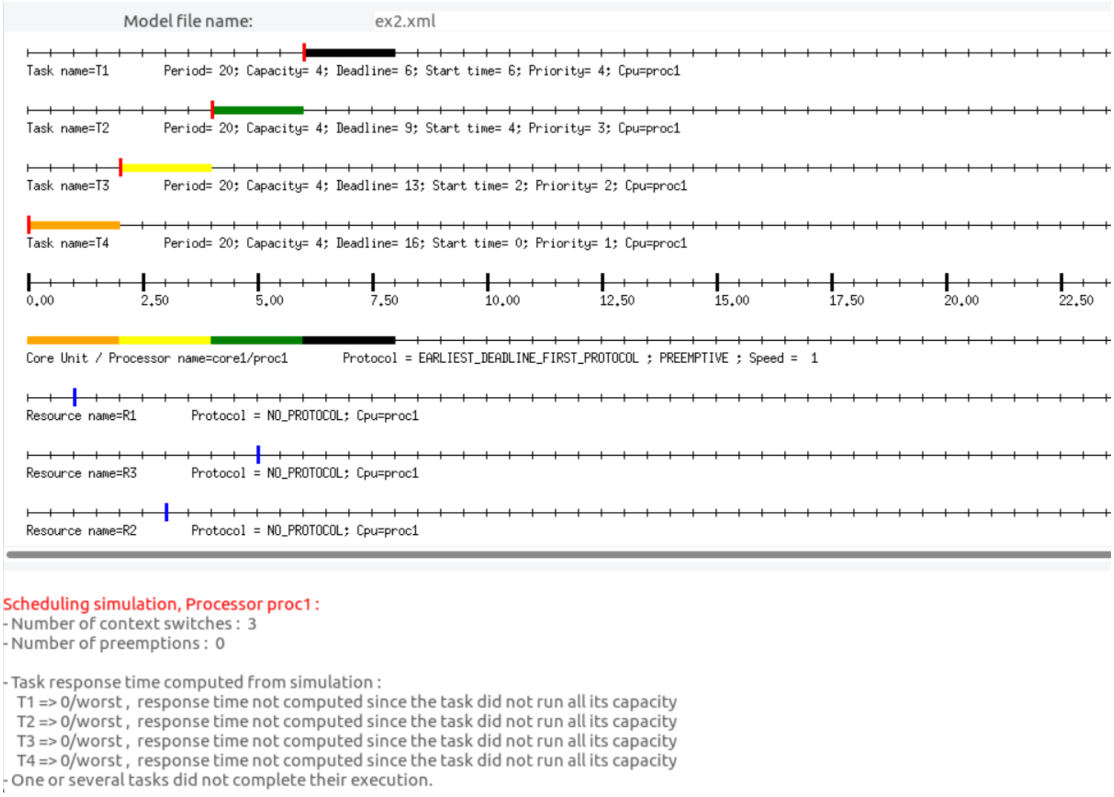
```
Scheduling simulation, Processor proc1 :
- Number of context switches :  11
- Number of preemptions :  4

- Task response time computed from simulation :
   T1 => 3/worst
   T2 => 8/worst
   T3 => 15/worst
   T4 => 18/worst
- No deadline missed in the computed scheduling : the task set is schedulable if you computed the scheduling on the feasibility interval.
```

Exercice 2

Let's assume the following task sharing resources R_1, R_2, R_3 and R_4:

	First release	WCET	D	P	Priority
T_1	6	4 : R_4 R_4R_3	6	20	4
T_2	4	4 : R_3 R_3R_4	9	20	3
T_3	2	4 : R_2 R_2R_1	13	20	2
T_4	0	4 : R_1 R_1R_2	16	20	1

- The Simulation of this task configuration is ***not schedulable*** because of every task's WCET(capacity).



Model file name: ex2.xml

```
Task name=T1        Period= 20; Capacity= 4; Deadline= 6; Start time= 6; Priority= 4; Cpu=proc1
Task name=T2        Period= 20; Capacity= 4; Deadline= 9; Start time= 4; Priority= 3; Cpu=proc1
Task name=T3        Period= 20; Capacity= 4; Deadline= 13; Start time= 2; Priority= 2; Cpu=proc1
Task name=T4        Period= 20; Capacity= 4; Deadline= 16; Start time= 0; Priority= 1; Cpu=proc1
```

```
Core Unit / Processor name=core1/proc1        Protocol = EARLIEST_DEADLINE_FIRST_PROTOCOL ; PREEMPTIVE ; Speed =  1
Resource name=R1        Protocol = NO_PROTOCOL; Cpu=proc1
Resource name=R3        Protocol = NO_PROTOCOL; Cpu=proc1
Resource name=R2        Protocol = NO_PROTOCOL; Cpu=proc1
```

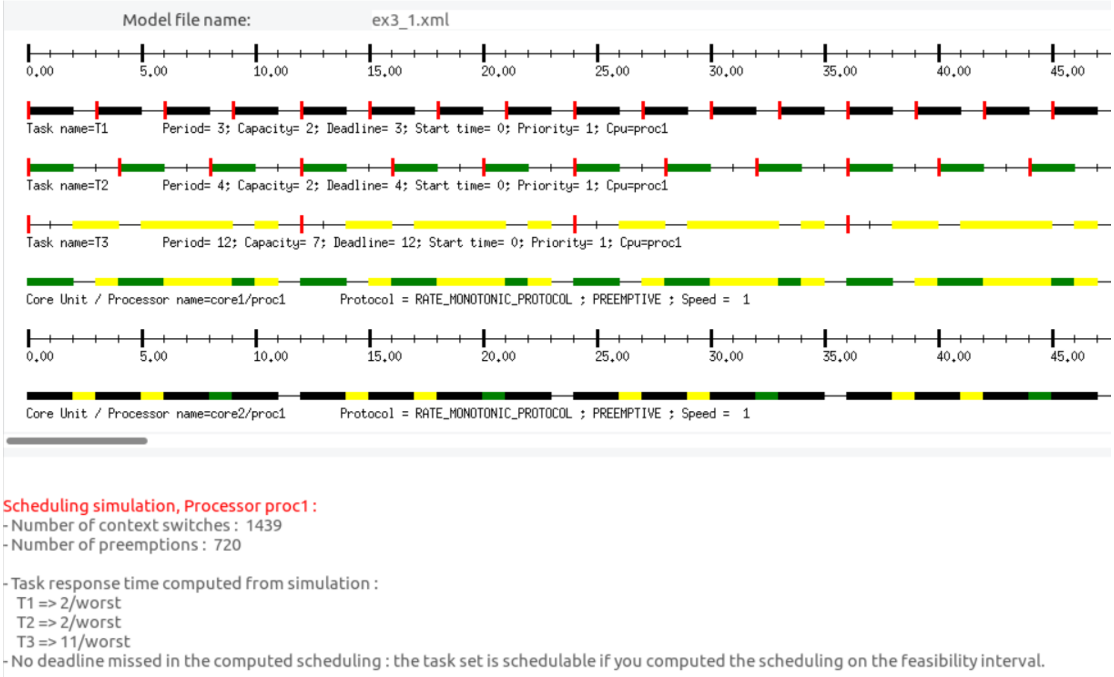
```
Scheduling simulation, Processor proc1 :
- Number of context switches :  3
- Number of preemptions :  0

- Task response time computed from simulation :
  T1 => 0/worst ,  response time not computed since the task did not run all its capacity
  T2 => 0/worst ,  response time not computed since the task did not run all its capacity
  T3 => 0/worst ,  response time not computed since the task did not run all its capacity
  T4 => 0/worst ,  response time not computed since the task did not run all its capacity
- One or several tasks did not complete their execution.
```

Exercice 3

1. Is the following task configuration schedulable on one processor with two cores using a fully global Rate Monotonic scheduler?

	First release	WCET	D	P
T_1	0	2	3	3
T_2	0	2	4	4
T_3	0	7	12	12

- This task configuration schedulable on one processor with two cores is using a fully global Rate Monotonic scheduler: "No deadline missed in the computed scheduling: the task set is schedulable if we computed the scheduling on the feasibility interval. "



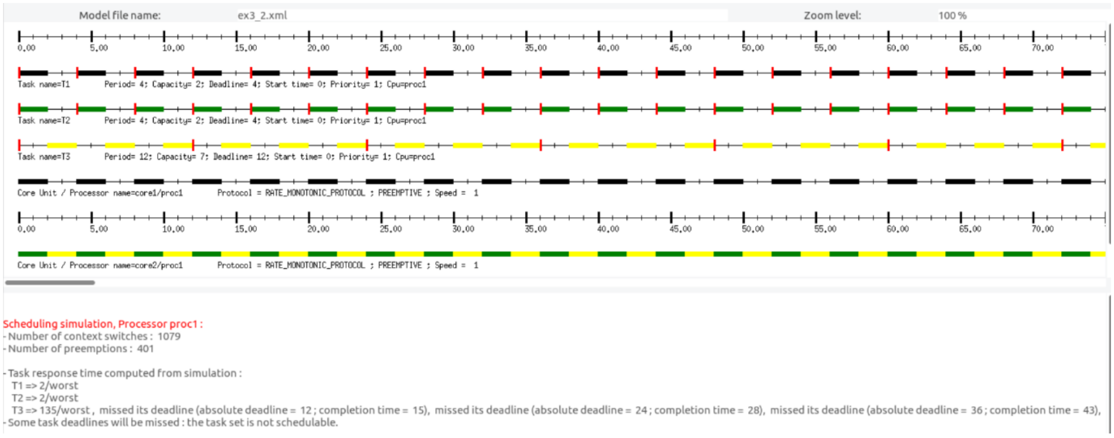
```
Task name=T1        Period= 3; Capacity= 2; Deadline= 3; Start time= 0; Priority= 1; Cpu=proc1
Task name=T2        Period= 4; Capacity= 2; Deadline= 4; Start time= 0; Priority= 1; Cpu=proc1
Task name=T3        Period= 12; Capacity= 7; Deadline= 12; Start time= 0; Priority= 1; Cpu=proc1
Core Unit / Processor name=core1/proc1        Protocol = RATE_MONOTONIC_PROTOCOL ; PREEMPTIVE ; Speed =  1
Core Unit / Processor name=core2/proc1        Protocol = RATE_MONOTONIC_PROTOCOL ; PREEMPTIVE ; Speed =  1
```

```
Scheduling simulation, Processor proc1 :
- Number of context switches :  1439
- Number of preemptions :  720

- Task response time computed from simulation :
   T1 => 2/worst
   T2 => 2/worst
   T3 => 11/worst
- No deadline missed in the computed scheduling : the task set is schedulable if you computed the scheduling on the feasibility interval.
```

2. Is the following task configuration schedulable on one processor with two cores using a fully global Rate Monotonic scheduler?

	First release	WCET	D	P
T_1	0	2	4	4
T_2	0	2	4	4
T_3	0	7	12	12

- The simulation of this configuration with the Priority Inheritance protocol is not schedulable, because T_3 missed its deadline three times: (absolute deadline = 12; completion deadline = 15), (absolute deadline = 24; completion deadline = 28) and (absolute deadline = 36; completion deadline = 43).



```
Task name=T1        Period= 4; Capacity= 2; Deadline= 4; Start time= 0; Priority= 1; Cpu=proc1
Task name=T2        Period= 4; Capacity= 2; Deadline= 4; Start time= 0; Priority= 1; Cpu=proc1
Task name=T3        Period= 12; Capacity= 7; Deadline= 12; Start time= 0; Priority= 1; Cpu=proc1
Core Unit / Processor name=core1/proc1        Protocol = RATE_MONOTONIC_PROTOCOL ; PREEMPTIVE ; Speed = 1
Core Unit / Processor name=core2/proc1        Protocol = RATE_MONOTONIC_PROTOCOL ; PREEMPTIVE ; Speed = 1
```

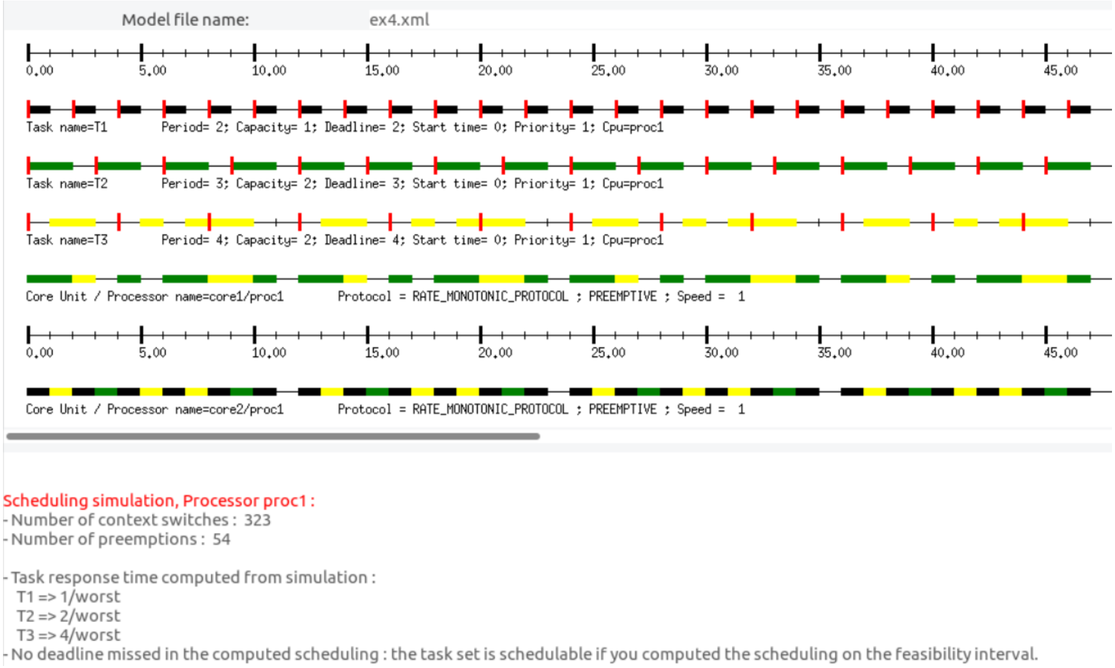
```
Scheduling simulation, Processor proc1 :
- Number of context switches : 1079
- Number of preemptions : 401

- Task response time computed from simulation :
  T1 => 2/worst
  T2 => 2/worst
  T3 => 135/worst , missed its deadline (absolute deadline = 12 ; completion time = 15), missed its deadline (absolute deadline = 24 ; completion time = 28), missed its deadline (absolute deadline = 36 ; completion time = 43),
- Some task deadlines will be missed : the task set is not schedulable.
```

3 . The conclusion is that if 2 tasks have the same periods and are synchronized, then for a dual-core processor, both cores will execute both tasks simultaneously. For the third task T_3, it does not perform well. Compared to the second simulation, the first simulation performs task T_3 better.

Exercice 4

Let's assume the following configuration of tasks.

	First release	WCET	D	P
T_1	0	1	2	2
T_2	0	2	3	3
T_3	0	2	4	4



```
Task name=T1        Period= 2; Capacity= 1; Deadline= 2; Start time= 0; Priority= 1; Cpu=proc1
Task name=T2        Period= 3; Capacity= 2; Deadline= 3; Start time= 0; Priority= 1; Cpu=proc1
Task name=T3        Period= 4; Capacity= 2; Deadline= 4; Start time= 0; Priority= 1; Cpu=proc1
Core Unit / Processor name=core1/proc1        Protocol = RATE_MONOTONIC_PROTOCOL ; PREEMPTIVE ; Speed = 1
Core Unit / Processor name=core2/proc1        Protocol = RATE_MONOTONIC_PROTOCOL ; PREEMPTIVE ; Speed = 1
```

```
Scheduling simulation, Processor proc1 :
- Number of context switches : 323
- Number of preemptions : 54

- Task response time computed from simulation :
  T1 => 1/worst
  T2 => 2/worst
  T3 => 4/worst
- No deadline missed in the computed scheduling : the task set is schedulable if you computed the scheduling on the feasibility interval.
```

Exercice 5

Let’s assume the following configuration of tasks.

	WCET	D	P
T_1	2	6	6
T_2	4	8	8
T_3	3	10	10
T_4	12	20	20
T_5	1	50	50
T_6	20	50	50
T_7	5	100	100
T_8	1	100	100

1. Is it schedulable on three processors with a partitioned First-Fit Rate Monotonic scheduler?
2. Same question with a partitioned First-Fit Earliest Deadline First scheduler.

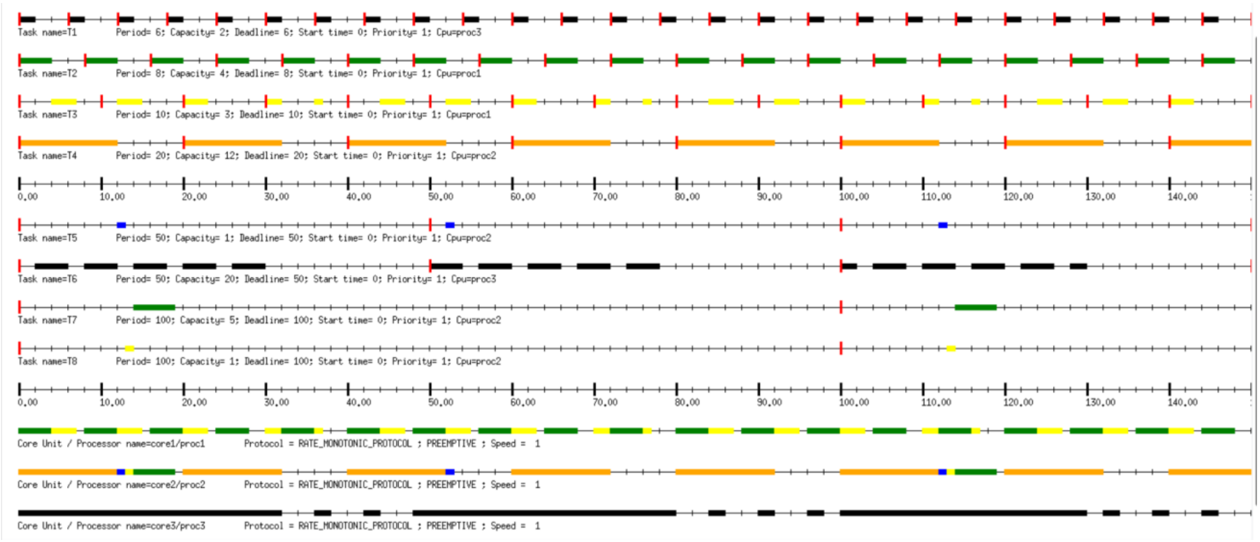
ANSWER:

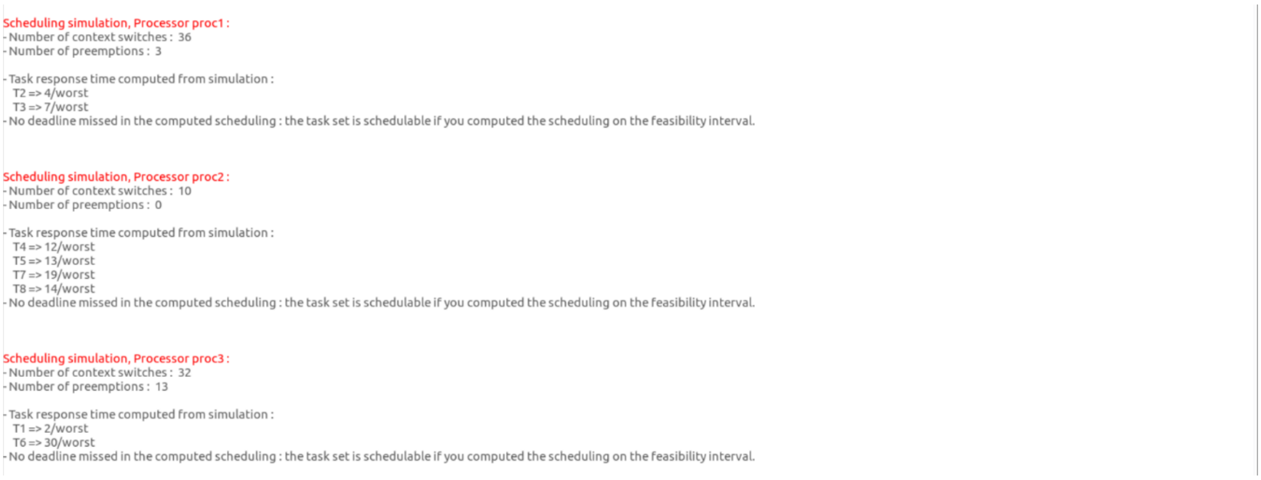
Firstly, we calculate the processor utilization rate of each task :

Task 2	$U_2 = \frac{C_2}{P_2} = \frac{4}{8}$	Task 4	$U_4 = \frac{C_4}{P_4} = \frac{12}{20}$	Task 1	$U_1 = \frac{C_1}{P_1} = \frac{2}{6}$
Task 3	$U_3 = \frac{C_3}{P_3} = \frac{3}{10}$	Task 5	$U_5 = \frac{C_5}{P_5} = \frac{1}{50}$	Task 6	$U_6 = \frac{C_6}{P_6} = \frac{20}{50}$
		Task 7	$U_6 = \frac{C_6}{P_6} = \frac{5}{100}$		
		Task 8	$U_8 = \frac{C_8}{P_8} = \frac{1}{100}$		
$U = \sum U_i = 0.8$		$U = \sum U_i = 0.608$		$U = \sum U_i \approx 0.733$	
Processor 1		**Processor 2**		**Processor 3**	

The tasks are **schedulable** on three processors with a partitioned First-Fit Rate Monotonic scheduler and First-Fit Earliest Deadline First scheduler.

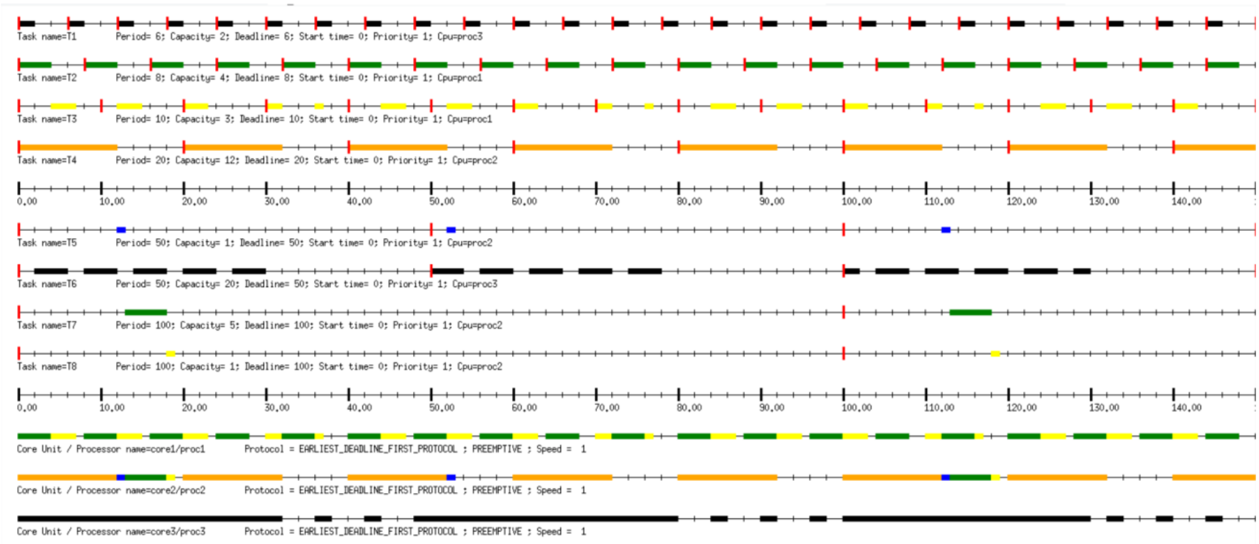
First-Fit Rate Monotonic scheduler:

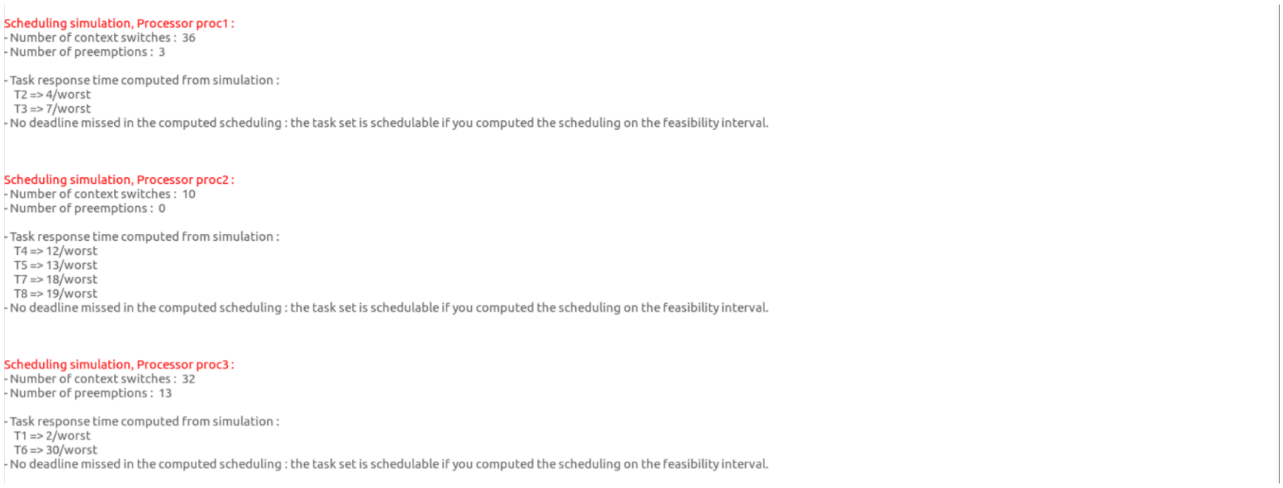




```
Scheduling simulation, Processor proc1 :
- Number of context switches :  36
- Number of preemptions :  3

- Task response time computed from simulation :
   T2 => 4/worst
   T3 => 7/worst
- No deadline missed in the computed scheduling : the task set is schedulable if you computed the scheduling on the feasibility interval.


Scheduling simulation, Processor proc2 :
- Number of context switches :  10
- Number of preemptions :  0

- Task response time computed from simulation :
   T4 => 12/worst
   T5 => 13/worst
   T7 => 19/worst
   T8 => 14/worst
- No deadline missed in the computed scheduling : the task set is schedulable if you computed the scheduling on the feasibility interval.


Scheduling simulation, Processor proc3 :
- Number of context switches :  32
- Number of preemptions :  13

- Task response time computed from simulation :
   T1 => 2/worst
   T6 => 30/worst
- No deadline missed in the computed scheduling : the task set is schedulable if you computed the scheduling on the feasibility interval.
```

First-Fit Earliest Deadline First scheduler:





```
Scheduling simulation, Processor proc1 :
- Number of context switches :  36
- Number of preemptions :  3

- Task response time computed from simulation :
   T2 => 4/worst
   T3 => 7/worst
- No deadline missed in the computed scheduling : the task set is schedulable if you computed the scheduling on the feasibility interval.


Scheduling simulation, Processor proc2 :
- Number of context switches :  10
- Number of preemptions :  0

- Task response time computed from simulation :
   T4 => 12/worst
   T5 => 13/worst
   T7 => 18/worst
   T8 => 19/worst
- No deadline missed in the computed scheduling : the task set is schedulable if you computed the scheduling on the feasibility interval.


Scheduling simulation, Processor proc3 :
- Number of context switches :  32
- Number of preemptions :  13

- Task response time computed from simulation :
   T1 => 2/worst
   T6 => 30/worst
- No deadline missed in the computed scheduling : the task set is schedulable if you computed the scheduling on the feasibility interval.
```