Laboratory 1

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September 15, 2020

3.3.1 Periodic tasks in Ada

TODO

3.3.2 The rate monotonic schedule.

1) Calculating utilization

The utilization of a periodic task $\tau_i(T_i, C_i)$ is defined as:

$$u_i = \frac{C_i}{T_i}$$

The total utilization for a set of tasks is defined as:

$$U = \sum_{i=1}^{n} u_i$$

The 3 tasks given are:
$$\tau_i(\phi_i, T_i, C_i, D_i)$$

$$\tau_1(100, 300, 100, 300)$$

$$\tau_2(100, 400, 100, 400)$$
$$\tau_3(100, 600, 100, 600)$$

Their respective utilizations are:

$$u_1 = \frac{C_1}{D_1} = \frac{100}{300} = \frac{1}{3}$$

$$u_2 = \frac{C_2}{D_2} = \frac{100}{400} = \frac{1}{4}$$

$$u_3 = \frac{C_3}{D_3} = \frac{100}{600} = \frac{1}{6}$$

The total utilization U can thus be calculated:

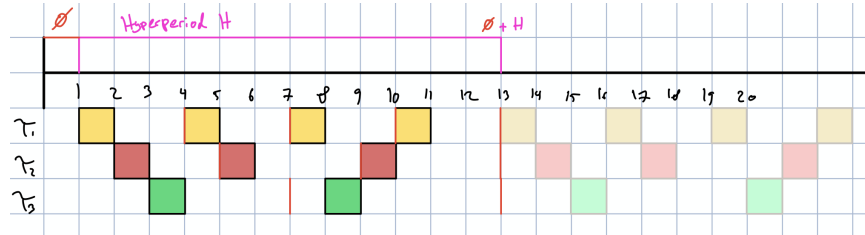$$U = \frac{1}{3} + \frac{1}{4} + \frac{1}{6} = \frac{9}{12} = \frac{3}{4} = 0.75$$

The hyperperiod H is defined as the least common multiplier from the set of task periods:

$$H = lcm(T_1, T_2, T_3) = lcm(300, 400, 600) = 1200$$

According to RMS the priorities should therefore be:

$$P_1 > P_2 > P_3$$

For one hyperperiod of 1200ms the schedule should look like this:

2) Calibrating execution time

Constraining the execution of the program to use only a single CPU core using taskset was made possible on a macOS system by using a virtual machine. The calibration parameter was set to **1208** which produced the following output:

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● ● ●                          vagrant@buster: /vagrant 🔔                        ⌥⌘2
vagrant@buster:/vagrant$ taskset -c 0 ./periodictasks_priority
Task 1- Release:  0.100, Completion:  1.094, Response: 0.994, WCRT: 0.994, Next Release:  2.100
Task 1- Release:  2.100, Completion:  3.094, Response: 0.994, WCRT: 0.994, Next Release:  4.100
Task 1- Release:  4.100, Completion:  5.090, Response: 0.990, WCRT: 0.994, Next Release:  6.100
Task 1- Release:  6.100, Completion:  7.092, Response: 0.992, WCRT: 0.994, Next Release:  8.100
Task 1- Release:  8.100, Completion:  9.103, Response: 1.003, WCRT: 1.003, Next Release: 10.100
Task 1- Release: 10.100, Completion: 11.093, Response: 0.993, WCRT: 1.003, Next Release: 12.100
Task 1- Release: 12.100, Completion: 13.094, Response: 0.994, WCRT: 1.003, Next Release: 14.100
Task 1- Release: 14.100, Completion: 15.104, Response: 1.004, WCRT: 1.004, Next Release: 16.100
Task 1- Release: 16.100, Completion: 17.095, Response: 0.995, WCRT: 1.004, Next Release: 18.100
Task 1- Release: 18.100, Completion: 19.094, Response: 0.994, WCRT: 1.004, Next Release: 20.100
Task 1- Release: 20.100, Completion: 21.094, Response: 0.994, WCRT: 1.004, Next Release: 22.100
Task 1- Release: 22.100, Completion: 23.099, Response: 0.999, WCRT: 1.004, Next Release: 24.100
Task 1- Release: 24.100, Completion: 25.120, Response: 1.020, WCRT: 1.020, Next Release: 26.100
Task 1- Release: 26.100, Completion: 27.095, Response: 0.995, WCRT: 1.020, Next Release: 28.100
Task 1- Release: 28.100, Completion: 29.092, Response: 0.992, WCRT: 1.020, Next Release: 30.100
Task 1- Release: 30.100, Completion: 31.095, Response: 0.995, WCRT: 1.020, Next Release: 32.100
^C
vagrant@buster:/vagrant$
```

3) **Implementing the periodic task set Γ_1**

Running the rms on a single core produces the following output:

```
vagrant@buster:/vagrant$ sudo taskset -c 0 ./rms
H: 1 Task: 1 Period: 300, Release:  0.100, Released:  0.101, Completion:  0.207, Response: 0.107, WCRT: 0.107, Next Release:  0.400
H: 1 Task: 2 Period: 400, Release:  0.100, Released:  0.207, Completion:  0.314, Response: 0.214, WCRT: 0.214, Next Release:  0.500
H: 1 Task: 1 Period: 300, Release:  0.400, Released:  0.401, Completion:  0.499, Response: 0.099, WCRT: 0.107, Next Release:  0.700
H: 1 Task: 2 Period: 400, Release:  0.500, Released:  0.501, Completion:  0.603, Response: 0.103, WCRT: 0.214, Next Release:  0.900
H: 1 Task: 3 Period: 600, Release:  0.100, Released:  0.314, Completion:  0.629, Response: 0.529, WCRT: 0.529, Next Release:  0.700
H: 1 Task: 1 Period: 300, Release:  0.700, Released:  0.703, Completion:  0.818, Response: 0.118, WCRT: 0.118, Next Release:  1.000
H: 1 Task: 2 Period: 400, Release:  0.900, Released:  0.900, Completion:  0.999, Response: 0.099, WCRT: 0.214, Next Release:  1.300
H: 1 Task: 1 Period: 300, Release:  1.000, Released:  1.000, Completion:  1.107, Response: 0.107, WCRT: 0.118, Next Release:  1.300
H: 1 Task: 3 Period: 600, Release:  0.700, Released:  0.818, Completion:  1.129, Response: 0.429, WCRT: 0.529, Next Release:  1.300

H: 2 Task: 1 Period: 300, Release:  1.300, Released:  1.300, Completion:  1.408, Response: 0.108, WCRT: 0.118, Next Release:  1.600
H: 2 Task: 2 Period: 400, Release:  1.300, Released:  1.409, Completion:  1.510, Response: 0.210, WCRT: 0.214, Next Release:  1.700
H: 2 Task: 1 Period: 300, Release:  1.600, Released:  1.699, Completion:  1.699, Response: 0.099, WCRT: 0.118, Next Release:  1.900
H: 2 Task: 2 Period: 400, Release:  1.700, Released:  1.702, Completion:  1.806, Response: 0.106, WCRT: 0.214, Next Release:  2.100
H: 2 Task: 3 Period: 600, Release:  1.300, Released:  1.510, Completion:  1.816, Response: 0.516, WCRT: 0.529, Next Release:  1.900
H: 2 Task: 1 Period: 300, Release:  1.900, Released:  1.900, Completion:  2.007, Response: 0.106, WCRT: 0.118, Next Release:  2.200
H: 2 Task: 2 Period: 400, Release:  2.100, Released:  2.100, Completion:  2.199, Response: 0.099, WCRT: 0.214, Next Release:  2.500
H: 2 Task: 1 Period: 300, Release:  2.200, Released:  2.201, Completion:  2.304, Response: 0.104, WCRT: 0.118, Next Release:  2.500
H: 2 Task: 3 Period: 600, Release:  1.900, Released:  2.007, Completion:  2.318, Response: 0.418, WCRT: 0.529, Next Release:  2.500

H: 3 Task: 1 Period: 300, Release:  2.500, Released:  2.500, Completion:  2.609, Response: 0.109, WCRT: 0.118, Next Release:  2.800
H: 3 Task: 2 Period: 400, Release:  2.500, Released:  2.609, Completion:  2.711, Response: 0.211, WCRT: 0.214, Next Release:  2.900
H: 3 Task: 1 Period: 300, Release:  2.800, Released:  2.800, Completion:  2.899, Response: 0.099, WCRT: 0.118, Next Release:  3.100
H: 3 Task: 2 Period: 400, Release:  2.900, Released:  2.902, Completion:  3.003, Response: 0.103, WCRT: 0.214, Next Release:  3.300
H: 3 Task: 3 Period: 600, Release:  2.500, Released:  2.711, Completion:  3.020, Response: 0.519, WCRT: 0.529, Next Release:  3.100
H: 3 Task: 1 Period: 300, Release:  3.100, Released:  3.100, Completion:  3.205, Response: 0.105, WCRT: 0.118, Next Release:  3.400
H: 3 Task: 2 Period: 400, Release:  3.300, Released:  3.301, Completion:  3.399, Response: 0.099, WCRT: 0.214, Next Release:  3.700
H: 3 Task: 1 Period: 300, Release:  3.400, Released:  3.402, Completion:  3.503, Response: 0.103, WCRT: 0.118, Next Release:  3.700
H: 3 Task: 3 Period: 600, Release:  3.100, Released:  3.205, Completion:  3.512, Response: 0.412, WCRT: 0.529, Next Release:  3.700

H: 4 Task: 1 Period: 300, Release:  3.700, Released:  3.703, Completion:  3.812, Response: 0.111, WCRT: 0.118, Next Release:  4.000
H: 4 Task: 2 Period: 400, Release:  3.700, Released:  3.812, Completion:  3.913, Response: 0.213, WCRT: 0.214, Next Release:  4.100
H: 4 Task: 1 Period: 300, Release:  4.000, Released:  4.003, Completion:  4.105, Response: 0.105, WCRT: 0.118, Next Release:  4.300
H: 4 Task: 2 Period: 400, Release:  4.100, Released:  4.105, Completion:  4.209, Response: 0.109, WCRT: 0.214, Next Release:  4.500
H: 4 Task: 3 Period: 600, Release:  3.700, Released:  3.913, Completion:  4.222, Response: 0.522, WCRT: 0.529, Next Release:  4.300
H: 4 Task: 1 Period: 300, Release:  4.300, Released:  4.300, Completion:  4.407, Response: 0.107, WCRT: 0.118, Next Release:  4.600
H: 4 Task: 2 Period: 400, Release:  4.500, Released:  4.500, Completion:  4.599, Response: 0.099, WCRT: 0.214, Next Release:  4.900
H: 4 Task: 1 Period: 300, Release:  4.600, Released:  4.601, Completion:  4.702, Response: 0.102, WCRT: 0.118, Next Release:  4.900
H: 4 Task: 3 Period: 600, Release:  4.300, Released:  4.407, Completion:  4.709, Response: 0.409, WCRT: 0.529, Next Release:  4.900
```

4) **Adding the additional task τ_4**

RMS2 output:

```
vagrant@buster:/vagrant$ sudo taskset -c 0 ./rms2
H: 1 Task: 1 Period: 300, Release:  0.100, Released:  0.100, Completion:  0.214, Response: 0.114, WCRT: 0.114, Next Release:  0.400
H: 1 Task: 2 Period: 400, Release:  0.100, Released:  0.214, Completion:  0.332, Response: 0.232, WCRT: 0.232, Next Release:  0.500
H: 1 Task: 1 Period: 300, Release:  0.400, Released:  0.400, Completion:  0.507, Response: 0.107, WCRT: 0.114, Next Release:  0.700
H: 1 Task: 2 Period: 400, Release:  0.500, Released:  0.507, Completion:  0.616, Response: 0.116, WCRT: 0.232, Next Release:  0.900
H: 1 Task: 3 Period: 600, Release:  0.100, Released:  0.332, Completion:  0.662, Response: 0.562, WCRT: 0.562, Next Release:  0.700
H: 1 Task: 1 Period: 300, Release:  0.700, Released:  0.700, Completion:  0.808, Response: 0.108, WCRT: 0.114, Next Release:  1.000
H: 1 Task: 1 Period: 300, Release:  1.000, Released:  1.000, Completion:  1.104, Response: 0.103, WCRT: 0.114, Next Release:  1.300
H: 1 Task: 2 Period: 400, Release:  0.900, Released:  0.903, Completion:  1.112, Response: 0.212, WCRT: 0.232, Next Release:  1.300
H: 1 Task: 3 Period: 600, Release:  0.700, Released:  0.808, Completion:  1.131, Response: 0.430, WCRT: 0.562, Next Release:  1.300

H: 2 Task: 1 Period: 300, Release:  1.300, Released:  1.300, Completion:  1.409, Response: 0.109, WCRT: 0.114, Next Release:  1.600
H: 2 Task: 2 Period: 400, Release:  1.300, Released:  1.409, Completion:  1.517, Response: 0.217, WCRT: 0.232, Next Release:  1.700
H: 2 Task: 1 Period: 300, Release:  1.600, Released:  1.600, Completion:  1.719, Response: 0.119, WCRT: 0.119, Next Release:  1.900
H: 2 Task: 2 Period: 400, Release:  1.700, Released:  1.719, Completion:  1.828, Response: 0.127, WCRT: 0.232, Next Release:  2.100
H: 2 Task: 3 Period: 600, Release:  1.300, Released:  1.517, Completion:  1.862, Response: 0.561, WCRT: 0.562, Next Release:  1.900
H: 2 Task: 4 Period: 1200, Release:  0.100, Released:  0.662, Completion:  1.879, Response: 1.779, WCRT: 1.779, Next Release:  1.300 ==> Task 4 violates Deadline!
H: 2 Task: 1 Period: 300, Release:  1.900, Released:  1.900, Completion:  2.010, Response: 0.110, WCRT: 0.119, Next Release:  2.200
H: 2 Task: 1 Period: 300, Release:  2.200, Released:  2.200, Completion:  2.308, Response: 0.108, WCRT: 0.119, Next Release:  2.500
H: 2 Task: 2 Period: 400, Release:  2.100, Released:  2.100, Completion:  2.315, Response: 0.215, WCRT: 0.232, Next Release:  2.500
H: 2 Task: 3 Period: 600, Release:  1.900, Released:  2.010, Completion:  2.333, Response: 0.433, WCRT: 0.562, Next Release:  2.500

H: 3 Task: 1 Period: 300, Release:  2.500, Released:  2.500, Completion:  2.609, Response: 0.108, WCRT: 0.119, Next Release:  2.800
H: 3 Task: 2 Period: 400, Release:  2.500, Released:  2.609, Completion:  2.719, Response: 0.219, WCRT: 0.232, Next Release:  2.900
H: 3 Task: 1 Period: 300, Release:  2.800, Released:  2.800, Completion:  2.913, Response: 0.113, WCRT: 0.119, Next Release:  3.100
H: 3 Task: 2 Period: 400, Release:  2.900, Released:  2.913, Completion:  3.023, Response: 0.123, WCRT: 0.232, Next Release:  3.300
H: 3 Task: 3 Period: 600, Release:  2.500, Released:  2.719, Completion:  3.051, Response: 0.551, WCRT: 0.562, Next Release:  3.100
H: 3 Task: 4 Period: 1200, Release:  1.300, Released:  1.879, Completion:  3.085, Response: 1.785, WCRT: 1.785, Next Release:  2.500 ==> Task 4 violates Deadline!
H: 3 Task: 1 Period: 300, Release:  3.100, Released:  3.101, Completion:  3.208, Response: 0.108, WCRT: 0.119, Next Release:  3.400
H: 3 Task: 1 Period: 300, Release:  3.400, Released:  3.400, Completion:  3.505, Response: 0.105, WCRT: 0.119, Next Release:  3.700
H: 3 Task: 2 Period: 400, Release:  3.300, Released:  3.300, Completion:  3.512, Response: 0.212, WCRT: 0.232, Next Release:  3.700
H: 3 Task: 3 Period: 600, Release:  3.100, Released:  3.208, Completion:  3.533, Response: 0.433, WCRT: 0.562, Next Release:  3.700

H: 4 Task: 1 Period: 300, Release:  3.700, Released:  3.700, Completion:  3.807, Response: 0.107, WCRT: 0.119, Next Release:  4.000
H: 4 Task: 2 Period: 400, Release:  3.700, Released:  3.807, Completion:  3.916, Response: 0.216, WCRT: 0.232, Next Release:  4.100
H: 4 Task: 1 Period: 300, Release:  4.000, Released:  4.000, Completion:  4.108, Response: 0.108, WCRT: 0.119, Next Release:  4.300
H: 4 Task: 2 Period: 400, Release:  4.100, Released:  4.108, Completion:  4.218, Response: 0.117, WCRT: 0.232, Next Release:  4.500
H: 4 Task: 3 Period: 600, Release:  3.700, Released:  3.916, Completion:  4.244, Response: 0.544, WCRT: 0.562, Next Release:  4.300
H: 4 Task: 4 Period: 1200, Release:  2.500, Released:  3.085, Completion:  4.282, Response: 1.782, WCRT: 1.785, Next Release:  3.700 ==> Task 4 violates Deadline!
H: 4 Task: 1 Period: 300, Release:  4.300, Released:  4.300, Completion:  4.407, Response: 0.107, WCRT: 0.119, Next Release:  4.600
H: 4 Task: 1 Period: 300, Release:  4.600, Released:  4.600, Completion:  4.711, Response: 0.111, WCRT: 0.119, Next Release:  4.900
H: 4 Task: 2 Period: 400, Release:  4.500, Released:  4.501, Completion:  4.719, Response: 0.219, WCRT: 0.232, Next Release:  4.900
H: 4 Task: 3 Period: 600, Release:  4.300, Released:  4.407, Completion:  4.734, Response: 0.434, WCRT: 0.562, Next Release:  4.900
```