Laboratory 1

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3.3.1 Periodic tasks in Ada

Format:

$$\tau(\phi, T, C, D)$$

Tasks:

$$\tau_1(T_1 = 900, , 300)$$

Task 2,3 and 5 are released at $t = 1.000$, task 2 finishes first, then task 6 so:

$$P_2 > P_6 > P_5$$

Task 3 is released at $t = 1.200$, pre-empting task 5.

$$P_3 > P_5$$

Task 2,6,3 and 5 seem to have a higher priority than task 4 since it finishes at $t = 1.396$ despite being scheduled to start at $t = 0.900$.

$$P_2 > P_6 > P_5 > P_4$$

Tasks 3 and 2 are scheduled to start at the same time at $t = 2.000$. Obviously task 3 has a higher priority than task 2.

$$P_3 > P_2 > P_6 > P_5 > P_4$$

Tasks 2 and 1 are scheduled to be released at the same time at $t = 3.500$. Task 2 seems to have higher priority since task 1 has to wait. Also task 1 has to wait for task 3 which starts at $t = 3.600$.

$$P_2 > P_1$$

$$P_3 > P_1$$

Task 1 and 6 are both scheduled to start at $t = 6.200$. In this case, task 1 starts first due to higher priority.

$$P_1 > P_6$$

Which leads to:

$$P_3 > P_2 > P_1 > P_6 > P_5 > P_4$$

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:

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

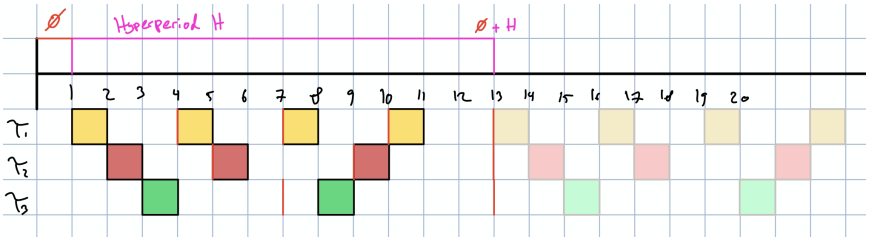
The hyperperiod H is defined as the least common multiplier from the set of task periods:

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

According to RMS the priorities should therefore be:

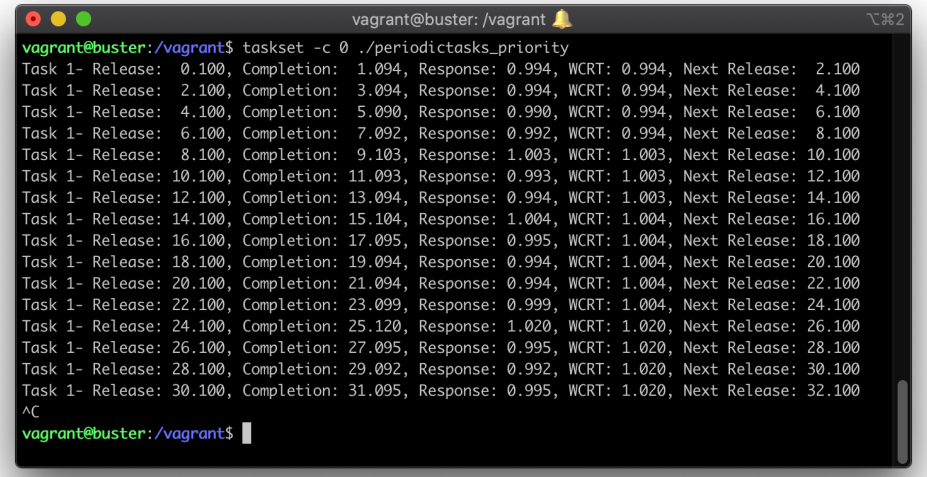
$$P_1 > P_2 > P_3$$

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:

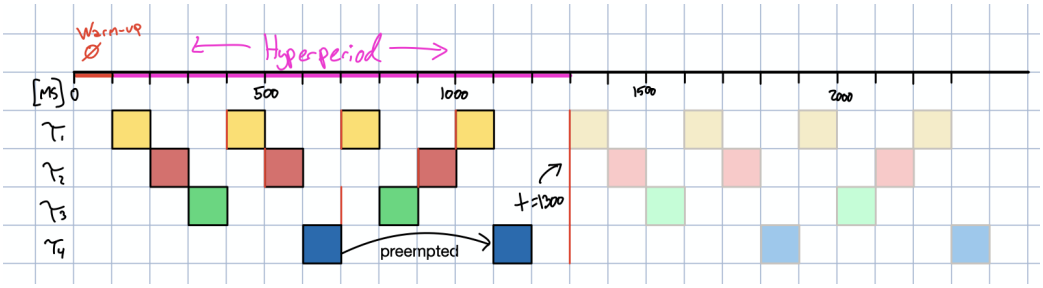


3) Implementing the periodic task set Γ_1

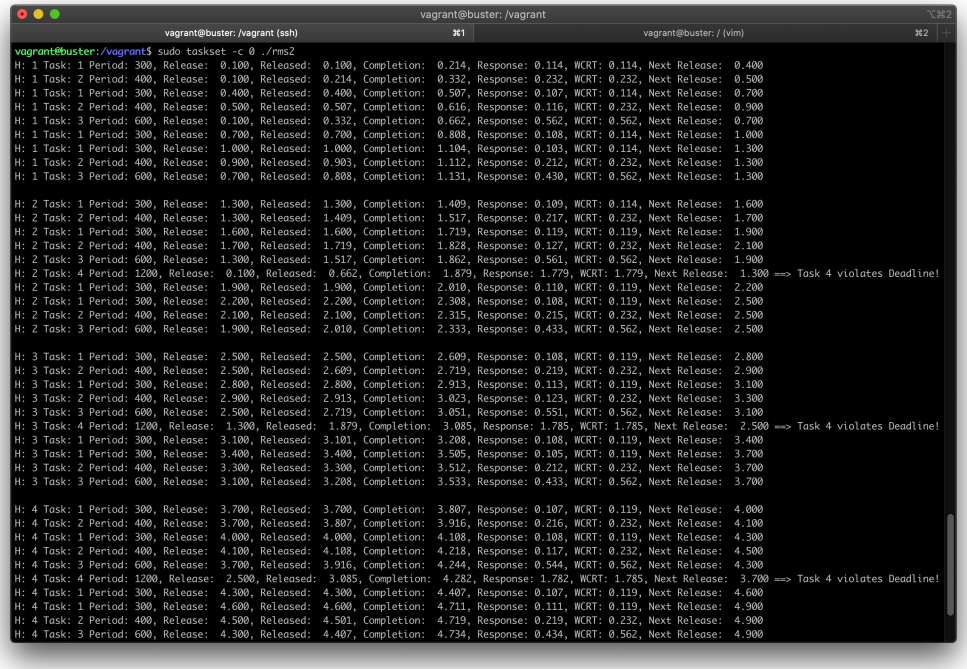
Running the rms on a single core produces the following output:

```
vagrant@buster: /vagrant
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:  1.600, 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
vagrant@buster: /vagrant (ssh)
⌘1
vagrant@buster: / (vim)
⌘2
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