Nov 6, 2024

CS 350 DISCUSSION 9

Real time scheduler

QUESTION 1

You have entered the CubeSat Developer's Workshop (it's real thing! See here: https://www.cubesat.org/) and you are progressing towards the design of your very own cube satellite. In terms of hardware, you are trying to settle on how many cores your main processor needs to handle all the software workload. The deployed software components need to collect data from the onboard sensors and to keep the satellite on the right orbit and 3D orientation.

You have computed that at the very minimum, you need three periodic components. These are (1) "star tracking" to identify the 3D pose of the satellite using the position of the visible stars in the field of view. Star tracking needs to be done every 19 ms, with each instance taking up to 4.5 ms processor time; (2) "orbit correction" to be done every 22 ms and that requires a worst-case computation time of 4.5 ms; and (3) ground-station radio link handling which takes up to 3 ms of CPU time and requires to be performed every 9 ms.

Now on to the workbench to figure out the following:

a) Can you conclude that you should be able to get away with a single-core CPU and RM scheduling? Motivate your answer and show your work.

Formula to check if RM holds: $$\sum_{i=1}^{m} \frac{C_i}{T_i} \leq m \cdot (2^{\frac{1}{m}} - 1)$$

Question 17.1 from the textbook

a) Can you conclude that you should be able to get away with a single-core CPU and RM scheduling? Motivate your answer and show your work.

Solution:

$$\sum_{i=1}^{m} \frac{C_i}{T_i} \leq m(2^{1/m} - 1)$$

$$\frac{4.5}{19} + \frac{4.5}{22} + \frac{3}{9} \leq 3 \times (2^{1/3} - 1) \Rightarrow 0.775 \leq 0.78$$

The inequality holds. Therefore, the taskset is schedulable under RM.

You have computed that at the very minimum, you need three periodic components. These are (1) “star tracking” to identify the 3D pose of the satellite using the position of the visible stars in the field of view. Star tracking needs to be done every 19 ms, with each instance taking up to 4.5 ms processor time; (2) “orbit correction” to be done every 22 ms and that requires a worst-case computation time of 4.5 ms; and (3) ground-station radio link handling which takes up to 3 ms of CPU time and requires to be performed every 9 ms.

Now on to the workbench to figure out the following:

b) To achieve better bandwidth on the radio link, it would be best to add an on-board atomic clock and the appropriate atomic time sampling task. Atomic clock sampling needs to be done every 6 ms but it takes only 1 ms to complete in the worst case. Can you still use RM and a single-core CPU? Motivate your answer and show your work.

Formula to check if RM holds: $\sum_{i=1}^{m} \frac{C_i}{T_i} \leq m \cdot (2^{\frac{1}{m}} - 1)$

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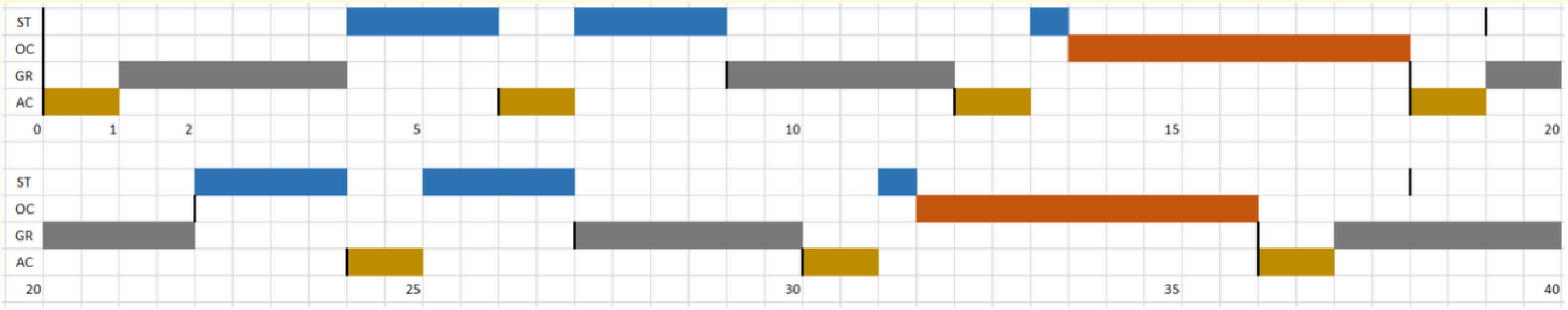
Solution:

$$\sum_{i=1}^{m} \frac{C_i}{T_i} \leq m(2^{1/m} - 1)$$

$$\frac{4.5}{19} + \frac{4.5}{22} + \frac{3}{9} + \frac{1}{6} \leq 4 \times (2^{1/4} - 1) \Rightarrow 0.94 \leq 0.76$$

The above inequality does not hold, and therefore it does not yield any conclusions. Hence, we need to draw the scheduling diagram to check if the taskset is schedulable or not.

The taskset is schedulable under RM, since no jobs miss deadlines.



c) You just got off the phone with your other friends at the CubeSat workshop. They want to create a mesh network where satellites can exchange information among themselves and relay messages to collaboratively increase their visibility from the ground. To perform inter-satellite communication, a new task with a WCET of 4 ms and a period of 15 ms needs to be added to all the ones considered so far. Can you still use RM and a single-core CPU? Motivate your answer and show your work.

Formula to check if RM holds: $$\sum_{i=1}^{m} \frac{C_i}{T_i} \leq m \cdot (2^{\frac{1}{m}} - 1)$$

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Solution:

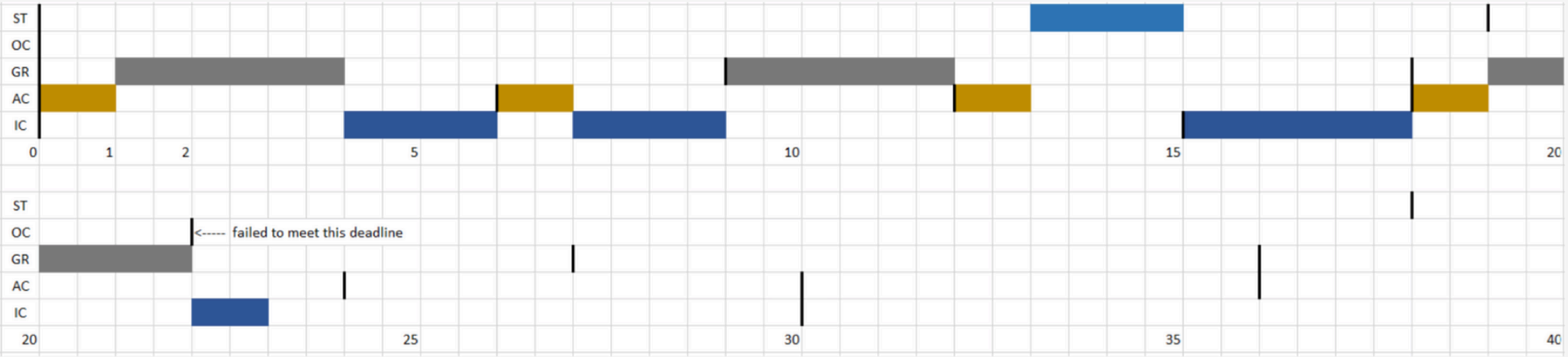
$$\sum_{i=1}^{m} \frac{C_i}{T_i} \leq m(2^{1/m} - 1)$$

$$\frac{4.5}{19} + \frac{4.5}{22} + \frac{3}{9} + \frac{1}{6} + \frac{4}{15} \leq 5 \times (2^{1/5} - 1) \Rightarrow 1.2 \leq 0.74$$

The above inequality does not hold, and therefore it does not yield any conclusions.

Hence, we need to draw the scheduling diagram to check if the taskset is schedulable or not.

The taskset is not schedulable because at least one task misses its deadline.



d) To ensure future upgradability and be able to comfortably schedule all the necessary workload, you are now considering using a processor with two identical CPUs. Use RM-FF to produce a task-to-CPU assignment for the considered tasks in taken in the following order: (1) star tracking, orbit correction, ground-station communication, atomic clock sampling, and inter-satellite communication.

Formula to check if RM-FF holds: $\sum_{i=1}^{m} \frac{C_i}{T_i} \leq N \cdot (\sqrt{2} - 1)$

d) To ensure future upgradability and be able to comfortably schedule all the necessary workload, you are now considering using a processor with two identical CPUs. Use RM-FF to produce a task-to-CPU assignment for the considered tasks in taken in the following order: (1) star tracking, orbit correction, ground-station communication, atomic clock sampling, and inter-satellite communication.

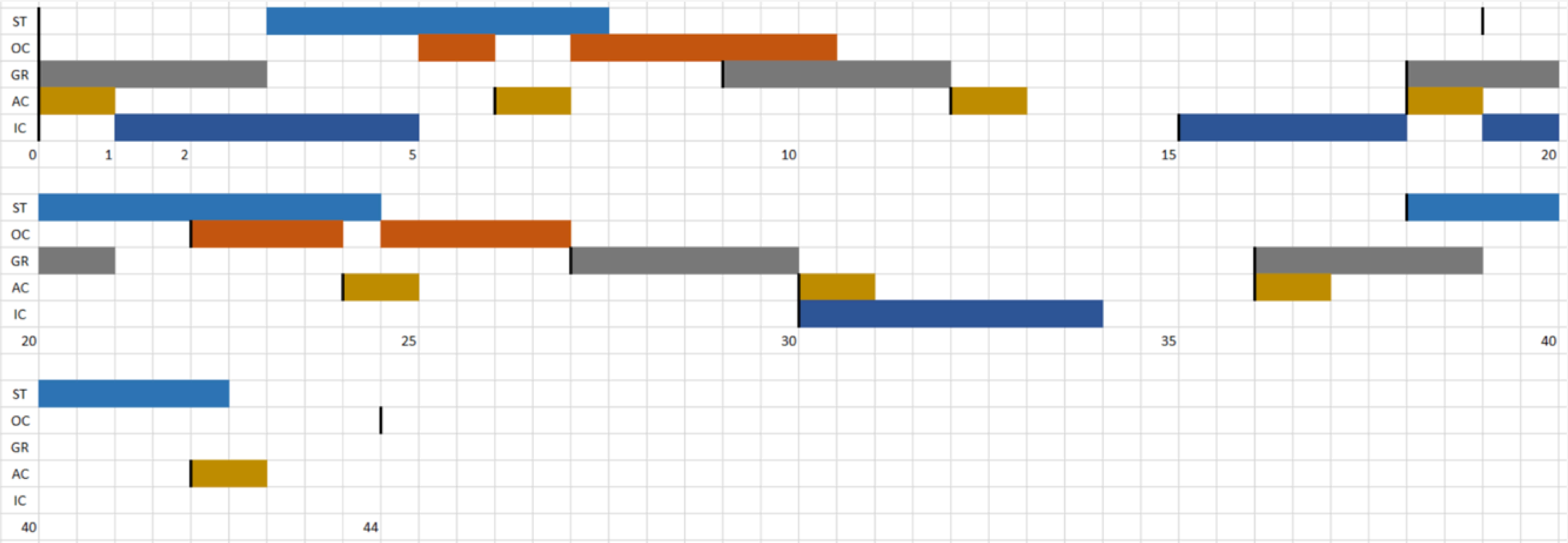
Solution:
We need to keep the utilization of each CPU less than $n(2^{1/n} - 1)$.

- CPU1: start tracking, orbit correction, ground-station communication.
- CPU2: atomic clock sampling, inter-satellite communication.

e) Would it be possible to schedule the system using Global EDF? If necessary, draw the resulting schedule up to time 44 ms.

Formula to check if EDF holds: $$\sum_{i=1}^{m} \frac{C_i}{T_i} \leq 1$$

e) Would it be possible to schedule the system using Global EDF? If necessary, draw the resulting schedule up to time 44 ms.



f) Having studied Global EDF, how would Global RM work? Provide a brief description of its policy and draw the schedule produced by Global RM on the considered system up to time 44 ms.

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