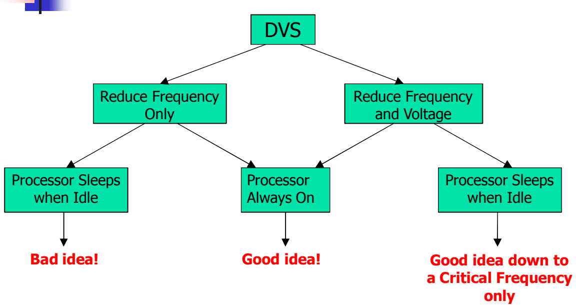
Energy

To Turn-off or not to Turn-off

Recap



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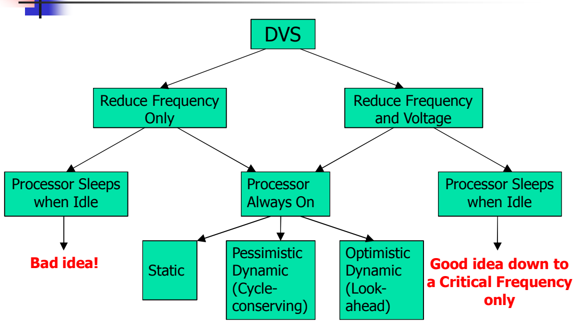

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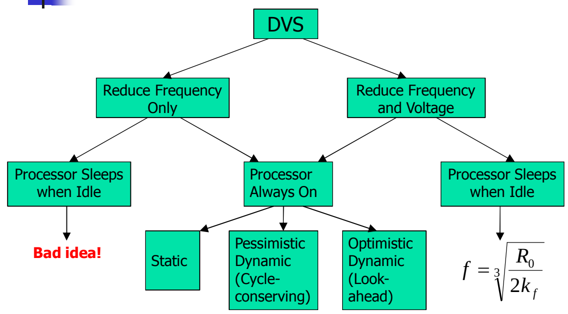

Turning Processors Off
The Cost of Wakeup

- Energy expended on wakeup, E_{wake}
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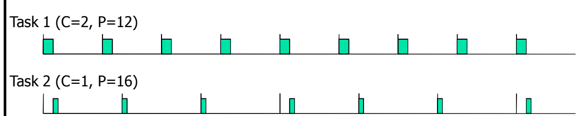
Minimum sleep interval

Dynamic Power Management

- DPM refers to turning devices off (or putting then in deep sleep modes)
- Device wakeup has a cost that imposes a minimum sleep interval (a breakeven time)
- DPM must maximize power savings due to sleep while maintaining schedulability

DPM and the Problem with Work-conserving Scheduling

- Example:



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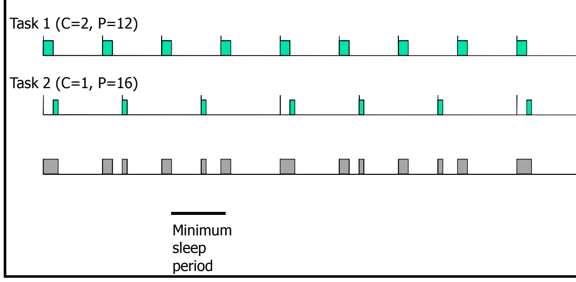

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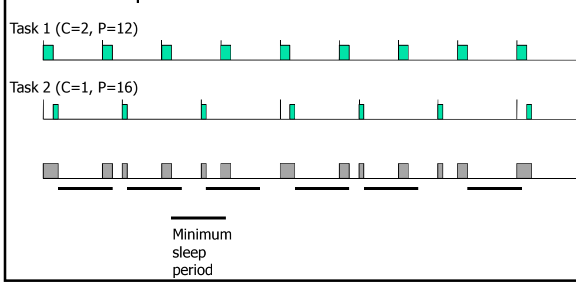

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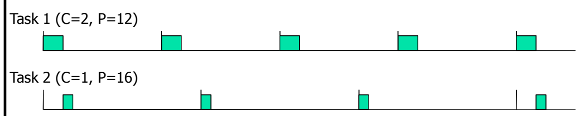

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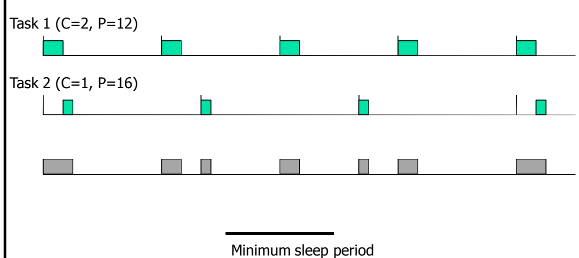

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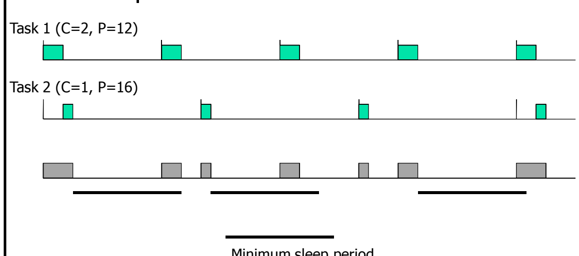
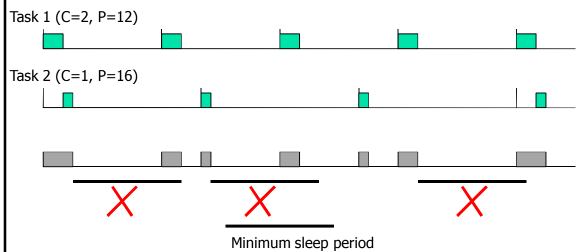


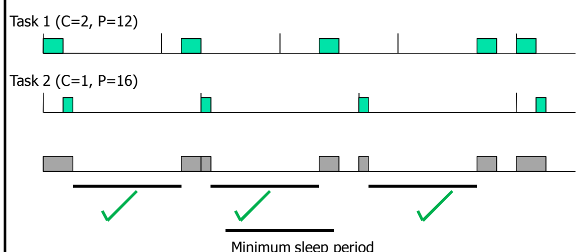
DPM and the Problem with Work-conserving Scheduling

- No opportunity to sleep ☹



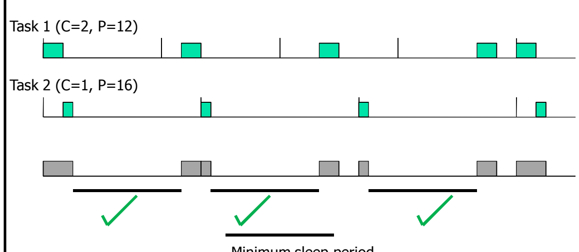
DPM and the Problem with Work-conserving Scheduling

- Must batch! ☺



A Schedulability Question:

How to Analyze Schedules with Sleep Periods?



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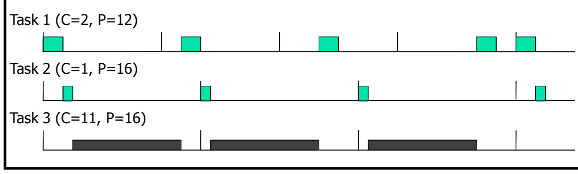
- Option 1: Treat sleep periods like a sporadic task. Use the Liu and Layland utilization bound for schedulability. Problems?



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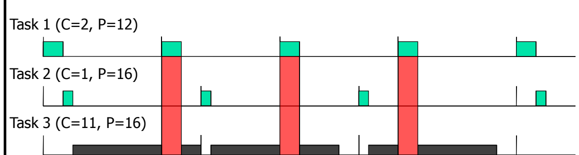
How to Analyze Schedules with Sleep Periods?

- Option 1: Treat sleep periods like a sporadic task. Use the Liu and Layland utilization bound for schedulability. Problems?
  - Does not work because the "sleep task" cannot be preempted, whereas the rest of the tasks are preemptible. The utilization bound works only for fully preemptive scheduling.



A Schedulability Question:

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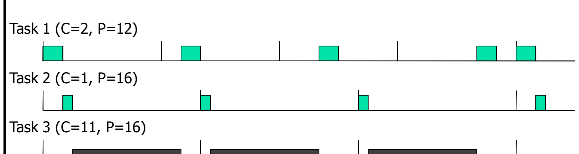
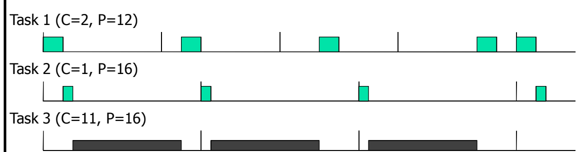


A Schedulability Question:
How to Analyze Schedules with Sleep Periods?

- Option 2: Treat sleep periods like the *highest-priority* sporadic task. Use the Liu and Layland utilization bound for schedulability. Problems?
  - Does not work because the "sleep task" may need to have a larger period than the actual top-priority task, which contradicts rate-monotonic scheduling. The bound does not work.



A Schedulability Question:
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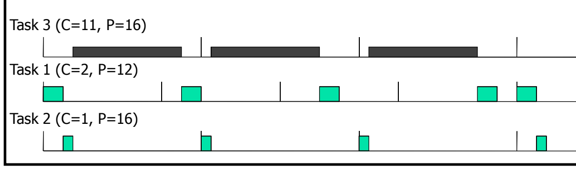
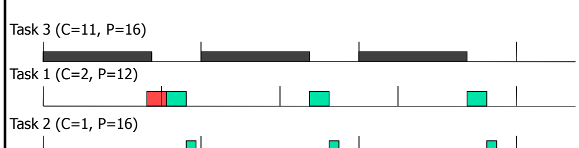
- Option 3: Treat sleep periods like the *highest-priority* sporadic task. Use *response time analysis* for schedulability. Problems?



Device Forbidden Regions

- Option 3: Treat sleep periods like the *highest-priority* sporadic task. Use *response time analysis* for schedulability. Problems?
  - A Valid solution, but pessimistic.

  (Called: Device Forbidden Regions. Published in RTAS 2008.)



DVS on Homogeneous Multiprocessors

- Consider a set of tasks, where task i has period P_i and total number of cycles C_i
  - Sort tasks from largest to smallest utilization C_i / P_i
  - Assign tasks one at a time (largest-first) to the least utilized processor
  - Apply one of the previous algorithms on each processor separately

Question

- From the perspective of minimizing energy, is it always a good idea to use up all processors?

How Many Processors to Use?

- Consider using one processor at frequency f versus two at frequency $f/2$
- Case 1: Total power for one processor
  - $k_f f^3 + R_0$
- Case 2: Total power for two processors
  - $2 \{k_f (f/2)^3 + R_0\} = k_f f^3 / 4 + 2 R_0$

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- What if n is not an integer?

Advanced Configuration and Power Interface (ACPI Standard)

- C-states (idle states)
- P-states (dynamic voltage and frequency scaling)

Turning a Processor Off