Scheduling Algorithm and Analysis

Interrupts and non-RM Tasks
(Module 31)

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Schedulability with Interrupts

- **Interrupt processing can be inconsistent with rate monotonic priority assignment.**
  - interrupt handler executes with high priority despite its period
  - interrupt processing may delay execution of tasks with shorter periods

- **Effects of interrupt processing must be taken into account in schedulability model.**

- **Question is: how to do that?**
Determining Schedulability with Interrupts

<table>
<thead>
<tr>
<th>Task(i)</th>
<th>Period(T)</th>
<th>Execution Time(C)</th>
<th>Priority(P)</th>
<th>Deadline (D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>τ₃</td>
<td>200</td>
<td>60</td>
<td>HW</td>
<td>200</td>
</tr>
<tr>
<td>τ₁</td>
<td>100</td>
<td>20</td>
<td>High</td>
<td>100</td>
</tr>
<tr>
<td>τ₂</td>
<td>150</td>
<td>40</td>
<td>Medium</td>
<td>150</td>
</tr>
<tr>
<td>τ₄</td>
<td>350</td>
<td>40</td>
<td>Low</td>
<td>350</td>
</tr>
</tbody>
</table>

τ₃ is an interrupt handler
UB Test with Any Fixed Priority

- Test is applied to each task.
- Determine effective utilization ($f_i$) of each task $i$ using when $d_i = p_i$

$$f_i = \sum_{j \in H_n} \frac{e_j}{p_j} + \frac{e_i}{p_i} + \frac{1}{p_i} \sum_{k \in H_n} e_k$$

Preemption from the tasks that can hit more than once (with period less than $p_i$)

Execution of a task under test

Preemption from tasks that can hit only once (with period greater than $p_i$)

- Compare effective utilization against bound, $U(n)$.

$$n = \text{num}(H_n) + 1$$

$$\text{num}(H_n) = \text{the number of tasks in the set } H_n$$
UB Test with Any Fixed Priority

- Test is applied to each task.
- Determine effective utilization \((f_i)\) of each task \(i\) using when \(d_i < p_i\) (\(e_i\) must be done within \(d_i\), not \(p_i\))
  \[
  f_i = \sum_{j \in H_n} \frac{e_j}{p_j} + \frac{e_i}{d_i} + \frac{1}{d_i} \sum_{k \in H_1} e_k
  \]
  - Preemption from the tasks that can hit more than once (with period less than \(d_i\))
  - Execution of a task under test
  - Preemption from tasks that can hit only once (with period greater than \(d_i\))

- Compare effective utilization against bound, \(U(n)\).
  \[
  n = num(H_n) + 1
  \]
  \[
  num(H_n) = \text{the number of tasks in the set } H_n
  \]
UB Test with Interrupt Priority: $\tau_3$

- For $\tau_3$, no tasks have a higher priority:
  \[ H = H_n = H_1 = \{ \}. \]

\[
f_3 = 0 + \frac{C_3}{T_3} + 0 \leq U(1)
\]

- Note that utilization bound is $U(1)$: $\text{num}(H_n) = 0$.

Plugging in numbers:
\[
f_3 = \frac{C_3}{T_3} = \frac{60}{200} = 0.3 < 1.0
\]
UB Test with Interrupt Priority: $\tau_1$

- For $\tau_1$, $\tau_3$ has a higher priority: $H = \{\tau_3\}; \ H_n = \emptyset$; $H_1 = \{\tau_3\}$.

  $$f_1 = \frac{C_1}{T_1} + \frac{1}{T_1} \sum_{k=3} C_k \leq U(1)$$

- Note that utilization bound is $U(1)$: $\text{num}(Hn) = 0$. Plugging in the numbers:

  $$f_1 = \frac{C_1}{T_1} + \frac{C_3}{T_1} = \frac{20}{100} + \frac{60}{100} = 0.800 < 1.0$$
UB Test with Interrupt Priority: $\tau_2$

- For $\tau_2$ : $H=\{\tau_1, \tau_3\}$; $H_n=\{\tau_1\}$; $H_1=\{\tau_3\}$;

$$f_2 = \sum_{j=1}^{\tau_2} \frac{C_j}{T_j} + \frac{C_2}{T_2} + \frac{1}{T_2} \sum_{k=3}^{\tau_2} C_k \leq U(2)$$

- Note that utilization bound is $U(2)$: $\text{num}(H_n) = 1$.

Plugging in the numbers:

$$f_2 = \frac{C_1}{T_1} + \frac{C_2}{T_2} + \frac{C_3}{T_3} = \frac{20}{100} + \frac{40}{150} + \frac{60}{150} = 0.867 > 0.828$$
UB Test with Interrupt Priority:

- For \( \tau_4 \): \( H = \{ \tau_1, \tau_2, \tau_3 \}; H_n = \{ \tau_1, \tau_2, \tau_3 \}; H_1 = \{ \}; \)

\[
f_4 = \sum_{j=1,2,3} \frac{C_j}{T_j} + \frac{C_4}{T_4} + 0 \leq U(4)
\]

- Note that utilization bound is \( U(4): \) \( \text{num}(H_n) = 3. \)

Plugging in the numbers:

\[
f_4 = \frac{C_1}{T_1} + \frac{C_2}{T_2} + \frac{C_3}{T_3} + \frac{C_4}{T_4}
\]

\[
= \frac{20}{100} + \frac{40}{150} + \frac{60}{200} + \frac{60}{350} = 0.882 > 0.756
\]
Supplementary Slides