Execution Right Delegation Scheduling Algorithm for Multiprocessor

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Agenda

• Introduction
• ERD (Execution Right Delegation) Algorithm
• ERD for Multiprocessor (mERD)
• Evaluation
Introduction ... Scheduling in Operating System

273 Processes
3367 Threads

These tasks are scheduled by OS
Introduction ... Scheduling in Operating System

• Windows/Linux ... Time sliced scheduling
Introduction ... RT Scheduling Algorithm

• What is Real-Time Scheduling Algorithm?
  • Schedule many tasks effectively and efficiently
  • Deadline is given each task
Introduction ... RT Scheduling Algorithm

• What is Real-Time Scheduling Algorithm?
  • Schedule many tasks effectively and efficiently
  • Deadline is given each task

• Task (a.k.a. process / thread)
  • Model in scheduling algorithm
  • Computation that is executed by CPU
  • Release infinite sequence of jobs periodically
  • Priority is given
Introduction ... Task

• Denoted as $\tau_i$
• Has period $T_i$, worst case execution time (WCET) $C_i$
  • Execution has to be finished until deadline ($\tau_i$ = period)
• $ex: \tau_1 = (C_1, T_1) = (2, 5)$
Introduction ... Task Set

• Task set, denoted as $\Gamma = \{\tau_1, \tau_2, \ldots, \tau_n\}$
  • $ex : \Gamma = \{\tau_1, \tau_2, \tau_3\}$
    • $\tau_1 = (1, 4)$
    • $\tau_2 = (1, 5)$
    • $\tau_3 = (2, 8)$
Introduction ... Rate Monotonic (RM)

• Task whose period is shorter has higher priority
  • $\tau_1 = (1, 4)$
  • $\tau_2 = (1, 5)$
  • $\tau_3 = (2, 8)$

Priority: $\tau_1 > \tau_2 > \tau_3$
Introduction ... Rate Monotonic (RM)

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ERD (Execution Right Delegation)

• In RM,
  • Task whose period is shorter has higher priority
  • Priority is assigned regardless it’s importance

• In ERD,
  • Introduces high priority server VS to task set
  • Important, but longer period task $\tau_p$ is executed instead of VS
ERD ... VS Algorithm

- Candidate of high priority server $VS = (C_s, T_s)$ is given by:

$$C_s = \begin{cases} 
C_p, & \text{if } R_p \leq T_{p-1} \\
idle'(T_s), & \text{otherwise}
\end{cases}$$

where

$$T_s = \begin{cases} 
T_h, & \text{if } R_p \leq T_{p-1} \\
t \in \Psi, & \text{otherwise}
\end{cases}$$

$$\Psi = \{T_1, T_2, ..., T_{p-1}\}$$

$$T_h = \min(\{t \mid t \in \Psi, R_p \leq t\})$$

$$idle'(t) = t - \sum_{j=1}^{p-1} \left\lfloor \frac{t}{T_j} \right\rfloor C_j$$
ERD ... Example

• $\Gamma = \{\tau_1, \tau_2, \tau_3\} = \{(1, 5), (2, 6), (4, 13)\}$

• $\tau_p = \tau_3$
ERD ... Example

\[ T_1 = 5 \]
\[ T_2 = 6 \]
\[ R_p = 10 \leq T_2 \]

\[ T_s = 5 \]

\[ C_s = \begin{cases} 
C_p, & \text{if } R_p \leq T_{p-1} \\
idle'(T_s), & \text{otherwise}
\end{cases} \]

\[ T_s = \begin{cases} 
T_h, & \text{if } R_p \leq T_{p-1} \\
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\end{cases} \]

where
\[ \Psi = \{T_1, T_2, \ldots, T_{p-1}\} \]
ERD ... Example

\[ C_s = \begin{cases} 
C_p, & \text{if } R_p \leq T_{p-1} \\
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\[ T_s = \begin{cases} 
T_h, & \text{if } R_p \leq T_{p-1} \\
t \in \Psi, & \text{otherwise}
\end{cases} \]

where

\[ \Psi = \{T_1, T_2, ..., T_{p-1}\} \]

\[ \text{idle}'(t) = t - \sum_{j=1}^{p-1} \left\lceil \frac{t}{T_j} \right\rceil C_j \quad (t \in \Psi) \]

- \( T_s = 5 \)
- \( C_s = 2 \)

\( \text{idle}'(5) = 2 \)
ERD ... Example

\[ C_s = \begin{cases} 
  C_p, & \text{if } R_p \leq T_{p-1} \\
  \text{idle}'(T_s), & \text{otherwise}
\end{cases} \]

\[ T_s = \begin{cases} 
  T_h, & \text{if } R_p \leq T_{p-1} \\
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\[ T_s = 5 \]
\[ C_s = 2 \]

\[ VS = \{C_s, T_s\} = \{2, 5\} \]
ERD ... Example

\[ \tau_p = \tau_3 \]

\[ VS = \{2, 5\} \]
ERD ... Example

- $\tau_p = \tau_3$
- $VS = \{2, 5\}$

Response time has shortened: 10 → 7
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System Model

• Based on partitioned Fixed Task Priority (pFTP)

• Only $\tau_p$ can be migrated
  -> mERD is semi-partitioned scheduling

• Each processor $P_i$ has $VS_i$
System Model

- Based on partitioned Fixed Task Priority (pFTP)
- Only $\tau_p$ can be migrated
  - $\rightarrow$ mERD is semi-partitioned scheduling
- Each processor $P_i$ has $VS_i$
mERD Scheduling Rule

- **Primary Processor**...
  - A processor which $\tau_p$ is assigned
  - Must has $VS_p$

- **None-primary Processor**...
  - Has $VS_i$ if idle time is available

idle time...
A period which any job is not executed until
$t \in \{T_1, T_2, \ldots T_n\}$
mERD Scheduling Rule

• $\tau_p$’s job is executed in primary when released

• Migrate to $P_i$ ...
  • If $P_i$ is idle (no job is executed)

  • If $VS_i$ is in the highest in ready que
Example of mERD

Two processors \(\{P_1, P_2\}\), and two task sets \(\Gamma_1 = \{\tau_1, \tau_2\}, \Gamma_2 = \{\tau_3, \tau_4\}\)

pFTP \(\Rightarrow\) Response time of \(\tau_2\) is 7
Example of mERD

Let $\tau_2$ be a $\tau_p$ and $P_1$ is a primary processor

$VS_1 = \{2, 4\}, VS_2 = \{1, 6\}$ is derived by Definition 7
Example of mERD

Response time
7 -> 3
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Evaluation Environment

• Following scheduling algorithm are evaluated:
  • pFTP_RM (Partitioned RM) = Baseline
  • pFTP_DM (Deadline Monotonic)
  • pERD
  • mERD
  • gFTP

• With two processors
Results

Ratio of task sets with shortened WCRT.
Results

Average WCRT normalized to RM
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