Limited-Preemption Scheduling on Multiprocessors

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Outline

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Motivation

Limited-preemption scheduling is an alternative to fully-preemptive scheduling and non-preemptive scheduling.

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<th>Fully-preemptive</th>
<th>Non-preemptive</th>
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<td>Schedulability</td>
<td>Better schedulability</td>
<td>Higher priority jobs may be blocked by lower priority jobs</td>
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<td>WCET and Run-time overheads</td>
<td>Larger and harder to determine</td>
<td>The system model is closer to the real system</td>
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<td>Access to shared resources</td>
<td>Non-trivial synchronization protocols needed</td>
<td>Synchronization protocols are simpler to implement</td>
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<td>(multiprocessors)</td>
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In limited-preemption scheduling a job executes preemptively until it needs to execute non-preemptively.
Limited-Preemption Sporadic Task Model

- Each task $\tau_i$ is characterized by four parameters:
  - $C_i$ - preemptive worst-case execution time
  - $L_i$ - non-preemptive worst-case execution time
  - $T_i$ - minimum inter-arrival separation (period)
  - $D_i$ - deadline (implicit or constrained)
- Utilization, $U_i = (C_i+L_i)/T_i$
- A task set $\tau$, consists of $n$ tasks
Schedulability Test

- In this work we propose a schedulability test for \textit{limited-preemption sporadic task sets} on \textit{m identical processors} under \textit{Global Earliest Deadline First} (GEDF)

- Prior work*: A schedulability test has been proposed for fully-preemptive sporadic task sets $\tau$, $\tau_i = \{C_i, T_i, D_i\}$, on \textit{m identical processors} under GEDF

  - The analysis is based on computing the total execution demand of all jobs over a certain \textit{interval t}

- Our Contribution: Extension to limited-preemption sporadic task sets $\tau$, $\tau_i = \{C_i, L_i, T_i, D_i\}$

  - We compute the \textit{maximum blocking} a job can experience over a certain \textit{interval t} due to the non-preemptive execution of lower-priority jobs

* S. Baruah, “Techniques for Multiprocessor Global Schedulability Analysis”, RTSS 2007
Properties

- **Pseudo-polynomial time** for all task sets for which total utilization is bounded by a constant strictly less than $m$
- Sufficient and necessary for uniprocessors
- Sufficient for multiprocessors
- *Sustainable* with respect to all parameters; $\{C_i, L_i, T_i, D_i\}$
Application to Multi-GPU Systems

• Recent work has been done towards incorporating GPUs (Graphical Processing Units) as a shared processing unit in real-time systems

• Multi-GPU system model:
  • \( m \) identical CPUs and \( g \) identical GPUs
  • Each task \( \tau_i \) may execute on the CPU and GPU. Consider that a task makes a single request to a GPU, and may execute on the GPU for a total of \( G_i \) time units
  • On GPUs execution is non-preemptive
• When a job executes non-preemptively on a GPU, the job *busy-waits non-preemptively* on a CPU. Other options: suspension, busy-wait preemptively

A synchronization approach* is used to access GPUs

• For the given *synchronization approach*, given values of $g$ and $m$, and $G_i$, for each task $\tau_i$, we compute $L_i$ (*worst-case non-preemptive busy-waiting*) for use in our schedulability test

Experimental Evaluation

• Schedulability experiments: randomly generated task sets and determined the percentage of task sets that are schedulable under the proposed schedulability test

• Compared schedulability under different platform configurations:
  
  • Limited-preemption + Multi-GPU system with $g = m$ (LPE)
  
  • Limited-preemption + Multi-GPU system with $g = m/2$ (LPL)
  
  • Full-preemption with $g = 0$ (FP)
• For each total effective utilization, 1000 sets each with \( n \) effective utilization values \( \{u_1 \ldots u_n\} \), were generated using the \textit{UUnifast-Discard} algorithm.

• For a set of \( n \) effective utilization values, \( \{u_1 \ldots u_n\} \), \textit{3 corresponding task sets} were generated.
Results

- LPE has better schedulability than FP for higher values of total effective utilization.

- LPE has significantly better schedulability than LPL.

- For the same total effective utilization:
  - for smaller values of SP, the length of $L_i$ increases and schedulability decreases.
  - for smaller values of $n$, schedulability in all 3 cases decreases. However, the trends observed in the graphs are consistent.
Summary

- We proposed a schedulability test for limited-preemption scheduling under GEDF

- Applied the schedulability test to a Multi-GPU system model with non-preemptive busy-waiting

- Performed schedulability experiments and compared schedulability under different platform configurations

Thank you!
For a set of $n$ effective utilization values, \{ sets were generated with the following task parameters:

- **FP**: $g = 0$
  - $T_i$
  - $D_i$
  - $G_i$
  - $C_i$
  - $L_i$

- **LPE**: $g = m$
  - $g_i$
  - $G_i$
  - $C_i$
  - $L_i$

- **LPL**: $g = m/2$
  - $L_i$

$m = 4, n = 40, SP = 30$