WIP: Response Time Bounds for Typed DAG Parallel Tasks on Heterogeneous Multi-cores

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Motivation

• Real-Time system becomes more computation-demanding
  • Hardware: Multi-core
    • Meet the rapidly increasing high performance computing requirements.
    • Lower the power consumption.

• Many modern multi-cores adopt heterogeneous architectures
  • CPU+DSP: Zynq-7000, OMAP1/OMAP2, etc.
  • CPU+GPU: Tegra processors
Modeling Typed Parallel Tasks

• Directed Acyclic Graph (DAG)
  • Model intra-task parallelism structures
    • Vertex: presents each task, $c(v)$ denotes the worst-case execution time (WCET) of each vertex $v$.
    • Edge: presents dependency between vertices
    • Type: $S$ is the set of core types and for each $s \in S$ there are $M_s$ cores of this type ($M_s \geq 1$). $\gamma(s)$ represents vertex $v$ must be executed on cores of type $s$.
    • $\text{len}(G)$ denotes the longest path of $G$
    • $\text{len}_s(\pi)$ denotes the total workload of $\pi$ typed with $s$
    • $\text{vol}(G)$ denotes the total workload of $G$
    • $\text{vol}_s(G)$ denotes the total workload of $G$ with type $s$
Schedulability Analysis

- OLD-B: $R(G) \leq \left(1 - \frac{1}{\max_{s \in S}(M_s)}\right)\text{len}(G) + \sum_{s \in S} \frac{\text{vol}_s(G)}{M_s}$
  - Pessimistic and Non-self-sustainable
  - Self-sustainable property: the increasing of $M_s$ would not increase $R(G)$

- NEW-B-1: $R(G) \leq \text{len}(\tilde{G}) + \sum_{s \in S} \frac{\text{vol}_s(G)}{M_s}$
  - $\tilde{G}$ is the scaled graph of $G$. The scaled graph $\tilde{G}$ of $G$ has the same topology ($V$ and $E$) and type function $\gamma$ as $G$, but a different weight function $\tilde{c}$: $\forall v \in V: \tilde{c}(v) = c(v) \times \left(1 - \frac{1}{M_{\gamma(v)}}\right)$.
  - More precise than OLD-B and self-sustainable with each $M_s$, but still pessimistic

- NEW-B-2: $R(G) = \max_{\pi \in G}\{\tilde{R}(\pi)\}$
  - $\tilde{R}(\pi) = \text{len}(\pi) + \sum_{s \in \pi} \frac{\sum_{v \in \text{ivs}(\pi,s)} c(v)}{M_s}$
  - For each vertex $v \in V$, $\text{par}(v)$ denotes the set of vertices that are in type $\gamma(v)$ but neither ancestors nor descendants of $v$. Let $\pi$ be a critical path, $\text{ivs}(\pi,s)$ is defined as: $\text{ivs}(\pi,s) = \bigcup_{v \in \pi \land \gamma(v) = s} \text{par}(v)$.
  - The problem of computing $\max_{\pi \in G}\{\tilde{R}(\pi)\}$ is strongly NP-hard.
  - If the number of types is a constant, we proposed an algorithm to compute $\max_{\pi \in G}\{\tilde{R}(\pi)\}$ with complexity of $O(|V|^{|s|+2})$. 
Evaluation

• Using normalized WCRT: NEW-B-1/OLD-B and NEW-B-2/OLD-B

• Randomly Generated Tasks
  • Different total utilization $U$
  • Different probability to number of tasks $|V|$
  • Different probability to number of edges $pr$
  • Different probability to number of types $|S|$