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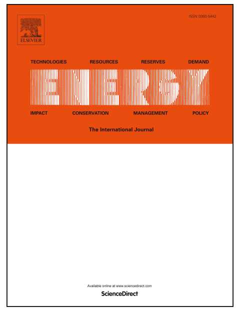

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Energy-Aware Stochastic Scheduler for Batch of Precedence-constrained Jobs on Heterogeneous Computing System

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Abstract-The problem of optimal scheduling of precedence-constrained jobs as well as finding the Pareto-optimal sets for multi objective scheduling problem have been proven to be nondeterministic polynomial time (NP)-complete. The growing consumption of energy has compelled the researchers to consider energy consumption as an important parameter along with other parameters in multi-objective scheduling problem. Accordingly, many energy-aware precedence-constraints scheduling algorithms have been reported in the literature. Most of the algorithms have a limitation of treating this problem as a single objective optimization problem modelling with deterministic execution times rather than stochastic execution times. This work proposes energy-aware stochastic scheduler to schedule the batch of precedence-constrained jobs on dynamic voltage frequency scaling-enabled processors in order to optimize the energy consumption and the turnaround time. The execution and inter-communication times are stochastic which are drawn from independent probability distributions. A novel encoding for batch of precedence-constrained jobs, stochastic turnaround time and energy models are also proposed. Experimental results show that, compared with other algorithms, the proposed scheduler offers reduced turnaround time and reduced energy consumption.

Keywords- Heterogeneous Computing System, Stochastic Scheduling, Dynamic Voltage and Frequency Scaling, Precedence-constrained jobs, Multi-objective optimization, Energy, Turnaround Time.

1. Introduction

The two important issues encountered in many real-world scheduling problems are higher energy consumption of computing servers and a certain degree of uncertainty about the execution times. The issue of higher energy consumption of computing servers is consistently gaining prominence. It is confirmed by the fact that the three million data centres in United States having 12 million computing servers consumed an estimated 91 billion kilowatt-hours of electricity in 2013. Expectedly, the energy consumption will reach to 140 billion kilowatt-hours by 2020, which leads to \$13 billion per year cost and emission of nearly 150 million metric tons of carbon pollution annually [1]. The high energy consumption of computing servers has become an unavoidable issue due to high monetary cost, reduced reliability of computing devices and negative effects on the environment. These statistics encourage the development of energy-efficient hardware, software and scheduling algorithms. The second issue is the stochastic execution time of jobs and inter-communication times. This issue is adequately addressed by stochastic scheduling where the execution times of jobs are not known beforehand but the probability distributions of execution times are known [2]. The actual execution time becomes known only after the job has finished its execution. For stochastic scheduling, shortest expected processing time first (SEPT), weighted shortest expected processing time first (WSEPT) and longest expected processing time first (LEPT) policies are very popular scheduling policies. These policies work based on expectation of execution times of the jobs, however, Möhring; Schulz and Skutella; Uetz pointed out that the performance of the stochastic scheduling is affected by the expectation as well as variance of the jobs [3]. Moreover, these policies are single objective that optimize the expected makespan without considering the energy consumption of processors. Therefore, it is required to develop the algorithms that deal with multi-objective optimization as well as randomness of execution times to optimize energy consumption and expected execution time.

The successfulness of multi-objective optimization methods in various domains inspires its use to develop multi-objective scheduler to minimize energy consumption and execution time [4]. Instead of offering single solution, the multi-objective optimization method offers multiple solutions with different trade-off of the objectives [5]. Further, to reduce the energy consumption of computing servers, the energy aware management of jobs on dynamic voltage and frequency scaling (DVFS)-enabled processors have been proven to be effective