

STOCHASTIC MODELING AND OPTIMIZATION FOR POWER AND PERFORMANCE CONTROL IN DVFS SYSTEMS

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KEYWORDS

Stochastic modeling; DVFS; Multi-Objective Optimization; Markov Chain; Performance; Power consumption analysis

ABSTRACT

The paper addresses the problem of performance-energy trade-off in DVFS (Dynamic Voltage Frequency Scaling) systems. We propose a stochastic hybrid model between hysteresis models and server block models. We provide a closed form for the steady-state distribution probability and we establish a "1st" type order to compare the performance measures. The fast computation of power and performance measures leads to a multi-objective optimization analysis in two forms: a scalarization method and a Pareto based method. For the two approaches, we propose fast and efficient approximate algorithms that construct progressively an optimal solution. To discuss results, the model is used to simulate a physical server hosting several VMs (Virtual Machines) where we investigate optimal thresholds for the performance-energy trade-off.

INTRODUCTION

High power consumption remains an issue in data centers, cloud systems, and more generally in information and communication technology (ICT). Moreover, the advent of Artificial Intelligence, Data Mining, IoT, High Performance Computing, Crypto-mining brings the issue of power consumption into focus. Server virtualization provides a major reduction impact on energy consumption due to on demand resource allocation through many techniques such as consolidation, virtual machine migration, scheduling, load balancing, dynamic frequency scaling. In this work, we focus on the Dynamic Voltage Frequency Scaling (DVFS) in virtualized context for power monitoring and Quality of Service (QoS) preservation. Many manufacturers of CPUs and GPUs (Intel, AMD, ...) implement the DVFS approach in their computing devices as processors or controllers. This mechanism operates the system at several frequencies and voltages denoted as "Pstates". The frequency and power increase in higher Pstates. The highest

Pstate runs the system at full rate and full voltage. But during off-peak periods, the clock can go down considerably, saving a significant portion of the power at full speed (AMD 2005).

This work is composed of two major parts. The first one consists on modeling the DVFS system by a Markov chain approach where we propose a closed form formula for steady-state distribution probability. Then we proceed with a numerical multi-objective analysis by proposing two fast and approximate algorithms for the performance and power consumption trade-off. To model DVFS system, most analytical methods are based on stochastic modeling as: in (He et al. 2020) a Petri Net model is proposed for dynamic scaling and VM migration in Energy-Aware cloud system; in (Dargie 2015) a random variable analysis is set for estimating the relationship between workload and power consumption in multi-core processor; while in (Nguyen et al. 2020) a Hidden Markov Model is used with a predicting algorithm for hidden states of the system applied to a multi-core DVFS for energy-time trade-off; Markovian Decision Process (MDP) also is proposed (Anselmi et al. 2021), for models with tasks deadlines and unbounded state space and speed rates. These models often suffer from the explosion of the set of states. However, queuing theory offers a range of models that can address this type of problems and solves systems efficiently with less concern for the quality of the solution or the scalability of the problem. In this regard one notes Ghandi's works, in particular, for the optimization of the distribution of energy in k-server Farm (using DVFS levels) (Gandhi, Harchol-Balter, et al. 2009). Some works also model the DVFS system as an $M/M/1$ (Basmadjian et al. 2016) or $GI/G/K$ (Kühn et al. 2019) queue for power management purpose. System modeling we propose is based on a threshold policy that is similar to Hysteresis models (Golubchik et al. 2002; Lai et al. 1999) but adapted to DVFS systems. Hysteresis models are based on two threshold vectors. When the number of tasks exceeds an activation threshold, a new server is added (instantaneously; Lai et al. 1999, or with non-negligible time; Golubchik et al. 2002) and when the number of tasks falls below an inverse threshold, a server is removed from the system. Similar approach can be found in Mitrani's model

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