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Cooling-Efficient Job Scheduling in a Heterogeneous Grid Environment

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Abstract

Electricity consumption typically forms the biggest portion of a Data Centre's operational cost, with the biggest consumers, in roughly equal proportion, being the servers and the cooling units. In an effort to reduce electricity consumption, in this paper, we propose a grid scheduling algorithm that takes advantage of a prior Gas-District Cooling Data Centre model to reduce the cooling energy consumption. The scheduling algorithm is an extension of a prior version that has been shown to perform with competitive average turnaround time, waiting time and maximum tardiness in heterogeneous grid environments. Experimental analysis shows that the proposed method was able to reduce cooling electricity consumption by 20%. Further, by increasing the maximum allowable temperature by 1 degree, the proposed method was able to save an additional 3%.

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1. Introduction

Data centres worldwide were projected to have consumed between 203 and 271 billion kilowatt hours of electricity in the year 2010¹. According to Greenpeace², unless steps are taken to save energy and go green, global data centres' share of carbon emission (CO₂) is estimated to rise from 307 million tons in 2007 to 358 million tons in 2020.

Koomey¹ showed that the DC electricity is spent mainly on cooling and on computing. Hence, these two areas have become the focal points for energy savings mechanism. The computing resources in DC consist of servers arranged in racks and chassis. The computing load includes processing jobs and other management and monitoring tasks. The cooling mechanism consists of installation and configuration of cooling units and the rearrangements of server racks in an attempt to reduce equipment failure due to temperature mismanagement^{3,4}.

Data centres have been spending huge amount on electricity for cooling and computing for long time^{1,7}. Any approach to reduce electricity usage will be more successful by minimizing the load on the cooling mechanism used to cool the computing mechanism. In this paper we focus on one driven by a Gas District Cooling (GDC) Centre. A GDC provides electricity and chilled water to facilities with relatively low running cost and has the potential to reduce CO₂ emission as it can makes effective reducing of wasted energy. As shown by Okitsu et al.⁵, the present GDC CO₂ emission tends to be higher than expected due to the chilled water supply-demand gap. Actually, the chilled water supply generated by the waste heat from gas turbine in GDC cannot satisfy the chilled water demand. This leads to the generation of additional electricity for the electric chillers to make up for the demand, further leading to an increase in CO₂ emission⁵.

Okitsu et al.⁵ proposed a Gas District Cooling Data Centre integrated (GDC-DC) model to efficiently manage the gap. However, it was not shown how a job scheduler can exploit the model.

Therefore, in this paper, we verify whether the effectiveness GDC-DC model is effective through a series of experiments, by running a job scheduler that distributes jobs in a heterogeneous grid environment using benchmark traces. The job scheduler is as per the description in⁶. However, it has been modified to shift heavy jobs execution to night time and small jobs execution to day time in a heterogeneous grid environment. Thus, this paper takes advantage of a prior GDC-DC model to reduce cooling energy consumption in data centre.

The rest of the paper is organized as follows. Section II discusses related works. While section III presents the experimental setups. Section IV explains the experimental results and discussions. Finally, Section V presents conclusion and future work.

2. Literature review

Researchers have proposed thermal management through cooperation between hardware and software^{8,9}. Tasks running on a microprocessor are indexed as to how hot the tasks are. This is calculated through regression analysis of the recent past and prediction of the possibility of a hotspot, and clock gating is used reactively to prevent the hot tasks from exceeding a maximum thermal threshold. Merkel et al.¹⁰, proposed a scheduling technique that creates a power-consumption-based profile for each task in the run queue of microprocessor cores and tries pre-emptively to balance the load by shifting tasks in the run queues. Choi et al.¹¹, proposed a proactive technique to execute jobs in a balanced manner among all cores. Deferring a hot job and executing a cool job or halting the processor temporarily and then continuing executing the hot job can keep the temperature lower with less overhead.

Arani¹² assigned more tasks to cooler cores than hotter cores and lowering the clock frequency of hot cores that have a shorter-length queue of tasks. Lowering the clock frequency of cores to ensures that all the cores finish the tasks in a time-balanced manner.

Moore et al.¹³, algorithm allocates a power budget to each server according to the current outlet temperature and reduces the power budget to keep the outlet temperature of each server within a uniform range from a reference temperature. Sharma et al.¹⁴ develop temperature-aware workload placement algorithms and present the first comprehensive exploration of the benefits from these policies.

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