A HYBRID GENETIC ALGORITHM WITH MAPREDUCE TECHNIQUE FOR CLOUD COMPUTING ENERGY EFFICIENCY

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To

my beloved and supportive parents,

Haliza binti Md. Yatim and *Ruzan bin Haji Masron,*

my loving sister, Izayu Nurfarha

and

my late lovely grandmother Hajah Masitah binti Haji Abdul Manan.

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ABSTRACT

Computer clouds generally comprise large power-consuming data centers as they are designed to support the elasticity and scalability required by customers. However, while cloud computing reduces energy consumption for customers, it is an issue for providers who have to deal with increasing demand and performance expectations. This creates the need for mechanisms to improve the energy-efficiency of cloud computing data centers while maintaining desired levels of performance. This research seeks to formulate a hybrid algorithm based on Genetic algorithm and MapReduce algorithm techniques to further promote energy efficiency in the cloud computing platform. The function of the MapReduce algorithm is to optimize scheduling performance which is one of the more efficient techniques for handling large data in servers. Genetic algorithm is effective in optimally measuring the value of operations and allows for the minimization of energy efficiency where it includes the formula for single optimization energy efficiency. A series of simulations were developed to evaluate the effectiveness of the proposed algorithm. The evaluation results show the amount of Information Technology equipment power required for Power Usage Effectiveness values to optimize energy usage where the performance of the proposed algorithm is 6% better than the previous genetic algorithm and 5% better than Hadoop MapReduce scheduling on low load conditions. On the other hand, the proposed algorithm improved energy efficiency in comparison with the previous work.

ABSTRAK

Pengkomputeran awan merupakan pusat-pusat data yang besar dengan penggunaan kuasa yang tinggi kerana ia direka bagi menyokong keanjalan dan skala yang diperlukan oleh pelanggan. Walaupun pengkomputeran awan dapat mengurangkan penggunaan tenaga di bahagian pelanggan, ia boleh menjadi satu isu kepada pembekal untuk berurusan dengan peningkatan tenaga ke atas permintaan dan jangkaan prestasi yang tinggi oleh pelanggan yang menggunakan pengkomputeran awan. Isu ini telah menjadi satu keperluan mekanisme bagi meningkatkan kecekapan tenaga pusat-pusat data pengkomputeran awan di samping memelihara tahap prestasi yang dikehendaki. Matlamat kajian ini adalah untuk menguji kira algoritma hibrid dengan menggabungkan dua teknik iaitu algoritma Genetik dan algoritma Pemetaan Pengurangan. Fungsi algoritma Pemetaan Pengurangan adalah untuk mengoptimumkan prestasi penjadualan yang cekap semasa pengendalian data besar di dalam pelayan. Algoritma Genetik dikenali sebagai salah satu teknik yang berkesan mengukur nilai operasi yang optimum, di dalam kajian ini ianya berfungsi untuk mengurangkan pengiraan pengoptimuman tunggal kecekapan tenaga. Simulasi ini telah dibangunkan secara bersiri untuk menilai keberkesanan algoritma yang telah dicadangkan. Hasil keputusan kajian penilaian menunjukkan bahawa jumlah kuasa peralatan teknologi maklumat untuk nilai Keberkesanan Penggunaan Kuasa bagi mengoptimumkan penggunaan prestasi tenaga algoritma yang telah dicadangkan adalah 6% lebih baik daripada algoritma genetik sebelumnya dan 5% lebih baik daripada penjadualan Hadoop Pemetaan Pengurangan pada keadaan beban rendah. Walaupun algoritma yang dicadangkan adalah kecil namun ia dapat meningkatkan kecekapan tenaga jika dibandingkan dengan kajian yang sebelumnya.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ANN	Artificial Neural Network
API	Application Program Interface
CCU	Close Control Unit
CMOS	Complementary Metal-Oxide-Semiconductor
CO_2	Carbon Dioxide
CPU	Central Processing Unit
CRAC	Computer Room Air Conditioner
DC	Data Center
DVFS	Dynamic Voltage and Frequency Scalling
DVFS-MODPSO	Dynamic Voltage and Frequency Scalling – Multi-objective Discrete Particle Swarm Optimization.
EDF-LRH	Earliest Deadline First - Least Recirculated Heat
EPA	Environmental Protection Agency
FCFS	First Come First Serve
FIFO	First In First Out
GA	Genetic Algorithm
GOC	Green Open Cloud
HPC	High Performance Computer
IaaS	Infrastructure as a Service
ICT	Information and Communication Technologies
IGA	Improve Genetic Algorithm
IT	Information Technology
MO-GA	Multi-Objective Genetic Algorithm
NIST	National Institute of Standards and Technology
PaaS	Platform as a Service
PTM	Power Thermal Management

PTM	Power Thermal Management
PUE	Power Usage Effectiveness
QoS	Quality of Service
SaaS	Software as a Service
SLO	Service Level Objectives
TUF	Time Utility Function
UPS	Uninterruptible Power Supplies
VM	Virtual Machine
XCP	Xen Cloud Platform

CHAPTER 1

INTRODUCTION

1.0 Overview

The disclosure of cloud computing has been much predictable by a world with an ever increasing computing evolution of on-demand information technology service and product. The term “cloud” has been predicted by researchers to a large expansion based on virtualized resources, also an analogy for the internet, that is based on business model infrastructure, whereby the user can access anytime at anywhere, wherever and whenever they wanted to, because cloud computing gives them the service in real-time from the internet. The creation of cloud has been a help for both hosting companies and consumers can have access to the internet, whereas cloud users can also access, store and share any amount of information online.

The use of cloud computing is expanding and for the system to be effectively utilized, massive storage facilities are required and consequently enormous amount of energy consumption is consumed to operate and support the system. All contents that are stored and shared in the data centres, which includes videos, photographs and texts, must be accessible to the users in real-time.

Furthermore, some example from Facebook on January 2010 gets the majority of its energy from coal-fired power stations (Green, 2010) which produce the cheapest electricity in many countries. Whereas nowadays Facebook are the

number one for the cloud users actively use and now Facebook has faces the same challenges like others cloud computing companies facing with, where they should build or placed their own data centers. Yahoo, however, obtained energy to power its data centers from hydro-electric power plants, and this greatly decreases its carbon footprint. In contrast, Google is provided with clean energy (Google, 2011) to power its data centers by engaging renewable energy providers to provide its energy requirements.

To address climate change, there is a necessity to move away from generating a large amount of electrical power using coal-fired power stations, especially which is needed to run cloud infrastructures such as data centers, backup power and cooling equipment. To move towards low carbon footprint, Information and Communication Technologies (ICT) equipment and cloud computing infrastructure should be powered by clean renewable energy.

The development in the utilization of cloud computing has led to the production and increase in the carbon footprint, which consequently contributes to the world's climate change. Although cloud computing has rapidly emerged as a widely accepted computing paradigm, research on cloud computing is still in its early stages, in which the related issues are as follows:

- Security: to make end users feel comfortable with "cloud" solution that holds their data, software and processes, there should exist assurances that service are highly reliable and available, as well as secure and safe, and that privacy is protected (Ivica and Larsson, 2002; Mladen, 2008; Bhadauria *et al*, 2014; Chen *et al*., 2010; Jensen *et al*., 2009; Jing *et al.*, 2013; Zissis and Lekkas, 2012).
- Software frameworks: handling varying and unpredictable loads and offering a highly available and reliable service in the face of hardware and software failures and evolution. These problems lead to the familiar challenges of constructing secure, reliable and efficient software (Zhang *et al.*, 2010; Jing *et al.*, 2013; Bykov *et al.*, 2010).

- Quality of service (QoS): capability of acquiring and releasing resource on-demand. This is the objective to satisfy its service level objectives (SLOs) while minimizing the operational cost. (Jing *et al.*, 2013; Ferretti *et al*., 2010; Fan *et al*., 2007).
- Standardization: the failure of comprehensive cloud computing standards to gain traction and lack of security standards addressing issues such as data privacy and encryption (Bhadauria *et al.*, 2014; Jing *et al.*, 2013; Somani and Chaudhary, 2009; Labes *et al.*, 2012).
- Power consumption: the use of Information and Communications Technologies (Cordeiro *et al.*, 2010) equipment is expected to rapidly increase the power consumed by ICT equipment and it is recognized that the power consumption of ICT equipment should be one of key issues, to stop the global growth emissions when it is now on top of priority issues (Jing *et al.*, 2013; Benini *et al.*, 2000; Jejurikar *et al.*, 2004; Kuribayashi, 2012).

1.1 Problem Background

The use of the Information and Communication Technologies (ICT) steadily leads to the increase in electricity rates. The amount of communications are rapidly growing, especially with the use of "smart" devices, peripherals, computers and data centers (Moreno and Xu, 2011). Driven by the increasing demand for data processing and storage to large number of equipment, data centers can consume large amount of energy and emit large amount of carbon (Garg and Buyya, 2012). There are two principle sources of energy consumption on data processing center, also known as data center, one of which comprises the information systems that include hardware, servers, data storage systems and network interface. The second source is associated with the cooling systems, which is essential to guarantee the proper performance of information system; the more the data centers is utilised, the more heat is generated and consequently, increases the cooling requirement.

Among the issues previously mention, energy management in cloud computing environment had received a great attention from researchers (Nathuji *et al.*, 2007; Buyya *et al.*, 2008; Berral *et al.*, 2010; Zhang *et al.*, 2010; Zikos and Karatza, 2011). The drastic development of on-demand upon cloud computing networks increases the energy consumption in the data center. This has become a critical issue and major concern for both industry and society (Armbrust *et al*., 2010; Moreno and Xu, 2011; Kansal and Chana, 2012; Lee and Zomaya, 2012). The system performance improved with more energy consumption from the hardware and this has caused the energy consumption to increase and indirectly gives negative pressure to the cloud environment. Recent report estimated data center consume 0.5% of the world's total electric energy consumption and if current demand continues, it could be quadruple by 2020 (Brown, 2008). Hence infrastructure providers are under enormous pressure to reduce energy consumption.

As aforementioned, many researchers recently have focused considerable attention on energy efficient cloud computing that can be approached from several directions. Among them is managing energy efficiency of servers through appropriate scheduling strategies that can be found in the operating system and the open source because both have a different finding. A key challenge in all the above methods is to achieve a good trade-off between energy savings and applications performance.

The scheduling methods used in cloud computing platform mostly to measure the optimizations of the power, some implemented in software application while others in hardware application. In this study, the scheduling method will be implemented in software application by focusing on the scheduler phase, which is scheduling and matching techniques genetic algorithm and MapReduce algorithm, a technique as put forward by previous researchers (Buyya *et al.*, 2010) for genetic algorithm whereas the MapReduce as put forward by previous researchers (Wang *et al.*, 2012). In general, using the technique would reduce the power consumption of the data center, but the key focus in this study is to calculate the amount of IT equipment power for PUE values to optimize energy usage.

One outcome from the green technology is the concept of Power Usage Effectiveness (PUE), developed by a company The Green Grid, which highlights the importance of energy consumption in data centers. Standard metrics have emerge from PUE, a measure how efficiently data center used its power, can be used as a benchmark on every research (Belady *et al.,* 2008). Recent measurements by researchers in Lawrence Berkley National Labs found that 22 data centers have PUE values in the range 1.3 to 3.0 (Greenberg *et al.,* 2006). Measuring power efficiency of data center will provide ways to improve its efficiency.

1.2 Problem Statement

Hence, in this research, the aim is to determine the optimal value from the amount of IT equipment power for PUE values to optimize energy usage using selected technique which is genetic algorithm MapReduce algorithm, in which the optimized values would be dependent on the type of situations the data center are under (Haupt and Haupt, 2004). The results obtained from experiments and simulation using the chosen optimization technique will be compared from previous studies conducted by other researchers (Wang *et al*., 2012). The key challenge that needs to be addressed is:

- How to optimally solve the trade-off between energy savings and delivered performance?

In (Wang *et al.,* 2012) works they have done and measured for genetic algorithm optimization and Hadoop MapReduce algorithm which they compared the result obtained together to achieve a good performance of clouds. The limitation from this works (Wang *et al*., 2012) is that, they have measured this two algorithm separately whereas in this research study the flow of the algorithm will be combined it together and become hybrid algorithm. In this research also will be made into three series of experiment to compare with the previous works of (Wang *et al*., 2012).

Many existing issues have not been fully addressed while new challenges continue to emerge from industry applications, and energy management is one of the challenging research issues (Zhang *et al.*, 2010). The problem is that cloud infrastructure is not only expensive to maintain, but also unfriendly to the environment. In addition, traditional Information Technology (IT) infrastructure issues need to deal with power consumption, heat dissipation and cooling provisioning (Moore *et al.*, 2005) leads to increase carbon dioxide (CO_2) emissions. Thus, the emerging Cloud Computing and Information Technology (IT) have resulted in high power consumption. These challenging issues have gained attention from researchers in attempting to find the best solution and the optimal value to reduce the power consumption.

1.3 Objective

The problem statement aforementioned has shown that the emerging cloud computing and information technology have resulted in high power consumption, which contribute to have a challenging issues to reduce the power consumption on cloud computing. From these issues the research has come out an objective which is:

i. To propose an optimal energy efficient scheduling algorithm while maintaining the computing performance.

1.4 Scopes

The scopes of this research are:

i. This research will be based on existing works (Wang *et al.*, 2012). Whereas this research is limited only on normal condition, low load condition and also heavy load condition scheduling which conducting with big data.

ii. The modeling of hybrid GA-MR is based on (Wang *et al.*, 2012) techniques of algorithm but in different flow of algorithm were measure, this techniques is called as genetic algorithm and MapReduce algorithm.

1.5 Thesis Organization

This research is organized into six chapters. Chapter 1 presents the background of the research, problem background, problem statement, objective and scopes of this research. Chapter 2 explain the details on the literature review regarding the technique has been done with the scheduling and cloud computing, also with the findings of the technique in the related works that have been found in this research. Chapter 3 explains the research methodology used in this research which in the following step follows to make the process work accordingly, and also it will be match with the objectives aim. The flows of the MapReduce algorithm will be explaining more in this chapter. Chapter 4 describes the scheduling proposed on hybrid genetic algorithm methods where it is including the operation of MapReduce algorithm with the formula of optimization energy efficiency. Chapter 5 describes the experiments conducted in the study, evaluation results obtained from the experiments and findings of the discussion on this research experiments under normal condition, low load conditions and heavy load conditions while Chapter 6 concludes the overall research, stating the recommendations for future works and also with the contribution of this research.

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