Energy Consumption Evaluation for Different VM Allocation Policies

Han Chen, Xiaoling Tang, Songjie Cai, Yiliang Tang
Department of Computer Science and Engineering
Santa Clara University
Santa Clara, California, USA
hchen3@scu.edu, scai@scu.edu, xtang@scu.edu, ytang@scu.edu

Abstract—**This paper analyzes the working principle of CloudSim simulation. In order to improve the host energy consumption, the energy-saving technology based on virtual machine migration was further studied, and the CloudSim platform was extended to implement four algorithms: the commonly used Round Robin algorithm, Dynamic Voltage and Frequency Scaling (DVFS) algorithm based on the frequency adjustment of CPU, Single Threshold (STH) algorithm based on the static threshold for virtual machine migration and the Non Power Award (NPA) as a comparison algorithm. Finally, after a specific cloud simulation scenario is configured, the proposed algorithm is simulated and analyzed. The results show that Round Robin and DVFS have stable service availability and comparatively low energy cost. the dynamic algorithm STH based on virtual machine migration has less energy consumption than DVFS algorithm, but it causes a small number of SLA violations and reduces the execution performance.**

Keywords—Cloud Computing, VM Allocation, Scheduling, DVFS, Round-robin, Single Threshold

I. INTRODUCTION

As an emerging computing model, cloud computing has always been the hottest research area at present, and it is considered as the commercialization of grid computing based on scientific research. At present, there is still no consensus on the definition of cloud computing. A representative view is that resource pools of types of services such as IaaS, SaaS, and PaaS can be provided. Resources in a resource pool can be dynamically configured according to load changes. The way to use resources is to adopt a pay-as-you-go approach. This definition emphasizes the characteristics of ultra-large-scale, virtualization, scalability, versatility, and on-demand services of cloud computing environments. At present, major manufacturers have successively launched cloud platforms such as Google's App Engine, Amazon's Amazon EC2, IBM's Blue Cloud and MicroSoftware's Azure OS.

Modern resource-intensive enterprise and scientific applications create growing demand for high performance computing infrastructures. This has led to the construction of large-scale computing data centers consuming enormous amounts of electrical power. Despite of the improvements in energy efficiency of the hardware, overall energy consumption continues to grow due to increasing requirements for computing resources. For example, in 2007 the cost of energy consumption by IT infrastructures in US was estimated as 4.5 billion dollars and it is likely to double by 2012 [1]. Apart from the overwhelming operational costs, building a data center leads to excessive establishment expenses as data centers are usually built to serve infrequent peak loads resulting in low average utilization of the resources. How to balance the workload and reduce the energy cost by using an energy efficiency algorithm becomes a very important issue in cloud computing. **To invest the issue and evaluate the energy consumption of cloud hosts, four different VM allocation policies were conducted and compared by using the CloudSim.**

The simulation-based approach allows the user to test the user's services repeatedly without the need for significant capital expenditures, and can adjust performance bottlenecks before deployment. As an emerging Internet computing model, there are not many current cloud simulation tools. Typical examples are CloudSim, SimCloud, and cloud computing platforms.

CloudSim is an open source simulation toolkit developed by the University of Melbourne to quantify scheduling performance for different application types and different service models. SimCloud is an enterprise-grade cloud platform that integrates resources such as engineering numerical simulation software and configures dynamic resource scheduling policies to provide enterprise users with unified, convenient, and powerful cloud computing services. "Cloud Computing Platform" is a new network simulation platform proposed by Li Bohu. The platform is based on the concept of cloud computing and can be applied in the engineering and non-engineering fields to achieve multi-user on-demand collaborative interoperability and scheduling of online resources. The "Cloud Simulation Platform" aims to improve the capabilities of the simulation grid for multi-users in on-demand sharing, collaboration, and fault-tolerant migration of multi-granular resources, and then establish a new modeling simulation mode "cloud simulation."

Given CloudSim's open source and widespread use, and the provision of a virtual engine, it helps to create and manage multiple independent and collaborative virtual machine services on a single data center node. This article examines the energy-efficient nature of cloud computing in the CloudSim environment. Based on the virtual machine deployment algorithm, four energy-saving algorithms were proposed, and these four algorithms were implemented in CloudSim, and specific cloud computing scenarios were configured for simulation experiments and performance analysis.

- Round Robin and DVFS have stable service availability and comparatively low energy cost.
- the dynamic algorithm STH based on virtual machine migration has less energy consumption than DVFS algorithm, but it causes a small number of SLA violations and reduces the execution performance.

By extending the related classes of CloudSim, simulation experiments were performed on the four algorithms, Round Robin algorithm, Dynamic Voltage and Frequency Scaling (DVFS) algorithm, Single Threshold (STH) algorithm and Non-Power Award (NPA). Simulation results show that the algorithm can effectively save energy.

A. CloudSim

CloudSim is an open source simulation engine based on GridSim and discrete event drivers that can simulate the creation of entities in a variety of cloud computing environments, including cloud data centers, physical hosts and virtual machines, messaging between components, and clock management. And, CloudSim, as a common scalable simulation framework, supports the simulation of emerging cloud computing infrastructure and management services. Figure 1 is the CloudSim architecture.

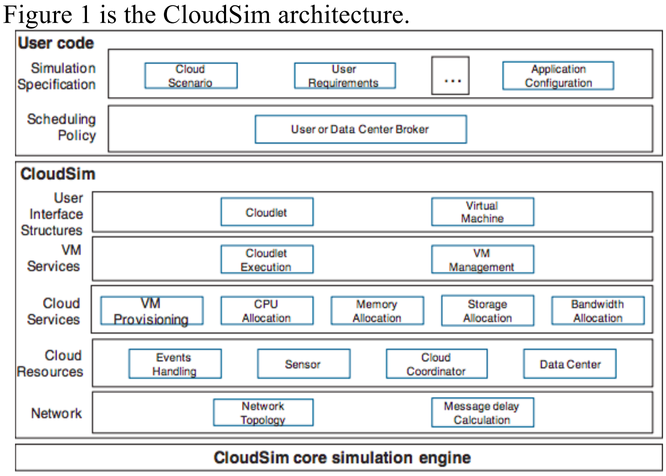

Figure 1 CloudSim Architecture

The user code layer is responsible for providing basic cloud entities, including user codes related to host (multiple machines, multiple specifications), applications (tasks and their requirements), virtual machines, configuration of many users and their application types and the scheduling policy of the agent. Cloud application developers can develop a variety of user demand distribution, application configuration requests, and cloud availability scenarios at the same layer for reliability testing, thus implementing custom cloud application scheduling algorithms.

B. Four VM Allocation Policies

Implement four energy-saving algorithms in CloudSim: RR, DVFS, STH, and NPA algorithms.

- **Round Robin**, a commonly used and popular algorithm.
- **DVFS (Dynamic Voltage Frequency Adjustment),** the algorithm idea is: Considering the insufficient CPU utilization when performing tasks, reducing CPU power supply voltage and clock frequency to achieve the purpose of reducing CPU performance, this method can not only greatly reduce The CPU's power consumption also guarantees service performance.
- **STH algorithm**. By setting a CPU utilization threshold, its utilization is always kept within this threshold during the scheduling process. Its purpose is to reserve part of the processing power for the CPU to meet the dynamically increasing demand for resources and to avoid SLA violations caused by VM consolidation. If the CPU utilization during the scheduling process is higher than the threshold, call the VM migration algorithm to reduce the utilization to within the threshold.
- **Non-Power Award (NPA) algorithm**. Keep the host's maximum power consumption status for task execution. The NPA algorithm serves as a comparison algorithm for performance analysis.

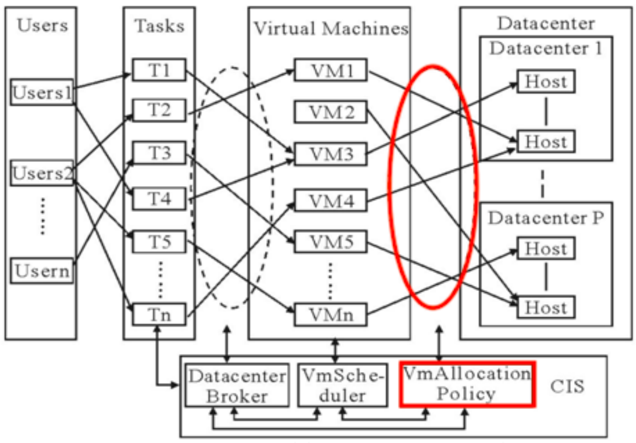

Figure 2 VM Allocation Policy in Cloud

II. Problem Analysis and Proposed Solution

The high energy consumption of the data center has become a major benefit because of the increasing demand for resources and services for enterprises and scientific applications. As a result, the data center infrastructure is not only expensive but also disadvantageous to the surrounding environment because of its huge carbon emissions. Therefore, the energy saving virtual machine allocation technology is needed to overcome the high energy consumption caused by the improper allocation of resources in the data center.

Previously comparing with different cloud simulation tools and adjusting with our research need, Cloudsim is our best choice to implement our process. Also, with the background knowledge of cooperation between data center and cloud will help to locate on which session of working step can be improved and effectively saving energy consumption.

C. System Architecture

Figure 3 shows the energy-saving architecture of virtual machine distribution in cloud data centers. It shows how the broker handles user requests to the cloud and finally to the data center. The user request is submitted to the cloud broker first, and then the broker will return the result to the user according to the demand capacity and performance management of the available data center of the subscription to the broker.

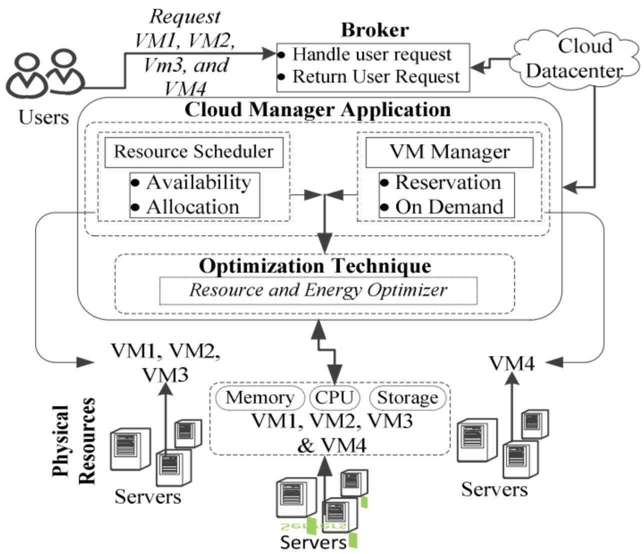

Figure 3. Energy-saving Architecture

When a broker's request arrives at the data center, the cloud manager will now check the request and make a decision under the comparison of the requests on the VM manager module and the resource scheduler module. Both modules will identify the characteristics of the resource, including reservations, on-demand, availability, and allocation. The cloud manager determines the acceptance of any request through system availability. This method has not solved the problem of low efficiency of resource allocation strategies, resulting in poor resource utilization and energy management in cloud data centers. Our research can test the energy consumption of different algorithms and filter out the relative energy-saving algorithms.

D. Workflow - main process

Cloud providers provide users or customers with different levels of virtual machines for user selection. These classes are different from the specification of memory, CPU unit and the storage of each computing resource. Therefore, the VM of each request is allocated on the PM of the data center resource. The system model processing request sent by the user is based on the following assumptions.

- **Cloudlet**: Tasks run in VM.
- **Datacenter**: A group of physical machines that VM can run on.
- **Datacenter Broker**: An agent to handle VM request.
- Host: Manages the VMs using hypervisor.
- **VM**: A software that representation as a physical machine.
- Every VM must be allocated by the host.
- Each VM and host are independent.

Since CloudSim is cloud simulation toolkit, these assumptions are provided by CloudSim. For our research which requires the information of the energy consumption, we still need the power base assumptions to implement our program.

- **PowerMonitor:** Monitor the energy consumption which can set the maximum consumption.
- **PowerHost:** PowerHost class enables simulation of power-aware hosts.
- **PowerHostUtilizationHistory:** The class of a host that stores its CPU utilization history. The history is used by VM allocation and selection policies.
- **PowerDataCenterNonPowerAware:** Represents a non-power aware data center in the context of power-aware simulations.
- **PowerDataCenterExtra:** It can support power aware VM allocation policy.

Bases on CloudSim library and our assumption class, our main process is split into three main sections.

Part 1: Create a monitor list for each non-NPA allocation policies. Each power monitor contains energy consumption data, SLA data.

Part 2: Get the energy consumption from different allocation policies by getting power function. Only the ST allocation policy need to preset the value of the threshold.

Part 3: Print out the result from monitor list.

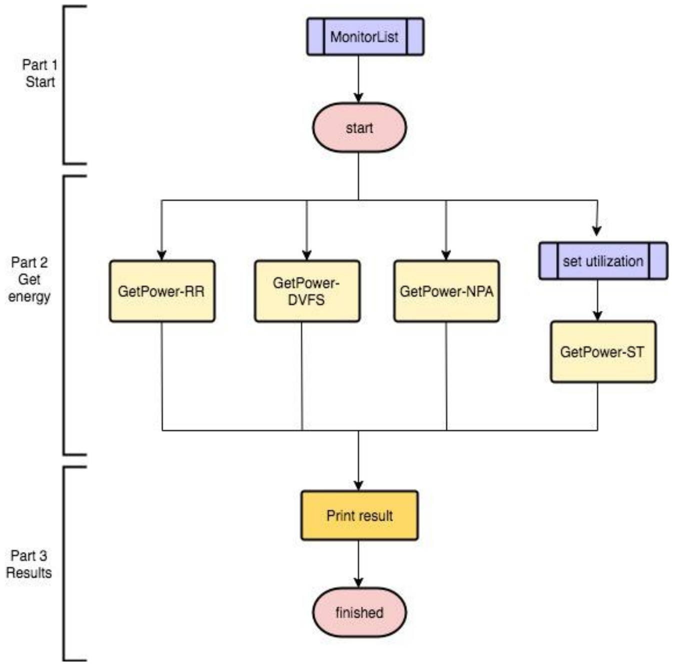

Figure 4. Main process

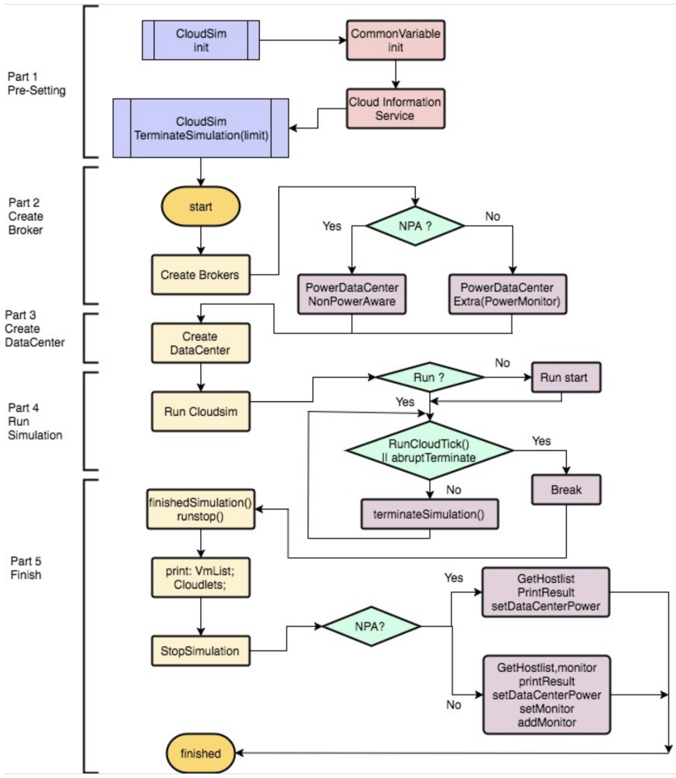

Figure 5. GetPower Function

E. Workflow - Get energy consumption process

In the main process, the most important is part 2 which collects the energy consumption data from different VM allocation policy. In GetPower function contains five parts, pic shows the detail of each step.

Part 1: To set the CloudSim environment by Initializing the CloudSim library, and create a cloud information service entity. The CIS provides cloud resource registration, indexing and discovery services. And then set up the terminate simulation time, which can terminate the simulation at a given time.

Part 2: A broker acting on a behalf of a user. Bases on NPA or non-NPA allocation policy, creating different power data center.

Part 3: Creating datacenter using the pre-step parameter. A datacenter is a CloudResource whose hostList are virtualized. It contains Datacenter characteristics, VM list, VM allocation policy, storage list.

Part 4: When the cloud environment is ready, to run the CloudSim simulation. Check if the CloudSim is running or not, if not then start the simulation first. Then processing the tasks till one of the conditions are reached. RunCloudTick returns true only finished all the cloudlet tasks. Or reach the terminate time will break the process of executing cloudlets.

Part 5: Simulation is finished then stop running. Print out the result and stop the simulation. non-NPA need to set the monitor and add to the monitor list which we mention in the main function.

III. IMPLEMENTATION AND EVALUATION

By extending CloudSim and expanding simulation toolkits, the VM allocation policies are implemented. Also, we analyzed energy consumption and SLA violation of each allocation policy.

In this work, we create a data center which has 4 types of Cloudlets, 4 types of virtual machines, and five types of hosts. The specific parameter settings are shown in table 1, 2 and 3.

Table I. Table of Cloudlets

Cloudlet Type	Length (MI)	Input file size (byte)	Output file size (byte)
0	4,000,000	300	300
1	16,000,000	300	300
2	20,000,000	300	300
3	60,0000,000	300	300

Table II Table of VMs

VM type	MIPS	Cores	Ram	Bandwidt h	Storage
0	750	1	512	1000	25000

1	1000	1	512	1000	25000
2	1500	1	1024	1000	25000
3	2000	1	1024	1000	25000

Table III Table of Hosts

Host type	MIPS	Cores	Ram	Bandwidth	Storage	Max power
0	1500	1	24GB	1,000,000	1TB	80
1	2000	1	24GB	1,000,000	1TB	120
2	2500	2	24GB	1,000,000	1TB	150
3	4200	4	24GB	1,000,000	1TB	130
4	6000	4	24GB	1,000,000	1TB	160

Virtualization Technology can solve the high energy consumption problem of the data center by instantiating multiple virtual machines on a physical host, thereby improving resource utilization and increasing return on investment. In the cloud computing environment, it is also indispensable to provide users with reliable QoS services defined by service level agreement (SLA). Therefore, for cloud resource providers, energy efficiency and high performance must be balanced to solve energy consumption. The problem is at the same time providing high reliability QoS guarantee.

To simulate the cloud environment and evaluate energy consumptions, we conduct the following tasks. The number of hosts is 60, the number of virtual machines varies from 20 to 60. And other settings follow above tables. For the benchmark policies we simulated a Non Power Aware policy (NPA).

A. *Power Model*

Computing servers account for the major part of energy consumption in data centers. The power consumption of a computing server is proportional to the utilization of the CPU utilization. Although an idle server still consumes around two-thirds of the maximum consumption just to keep memory, disks, and I/O resources running. The remaining one-third increases almost linearly with an increase in the load of the CPU:

$$\mathrm{P}(u) = P_{max} \times k + (1-k) \times P_{max} \times u$$

where P_{max} is maximum load consumption, k is consumption ratio in idle time, u is utilization of CPU.

In the cloud environment, however, the load execution is dynamically changing, so u is usually expressed as $u(t)$, so the total energy consumption can be defined as:

$$\mathrm{E} = \int_{t_0}^{t} P(u(t))\, dt$$

B. *SLA Violation*

A service-level agreement is defined as an official commitment that prevails between a service provider and a client. Particular aspects of the service – quality, availability, responsibilities – are agreed between the service provider and the service user.

In cloud environment, SLA is an essential part to ensure maximum availability of service for customers. With a violation of SLA, the cloud service provider has to pay penalties. Therefore, it is desirable to minimize the SLA violations. In this paper, we calculate the SLA violation per active host using the following equation:

$$\mathrm{SLAV} = \frac{\sum_{j=1}^{M} \int_{t_0}^{t} [U_{j,r}(t) - U_{j,a}(t)]dt}{\sum_{j=1}^{M} \int_{t_0}^{t} [U_{j,r}(t)dt}$$

where $U_{j,r}(t)$ is the total MIPS requested by virtual machines, $U_{j,a}(t)$ is the actual assigned MIPS, M is the total number of virtual machines.

IV. Results And Discussion

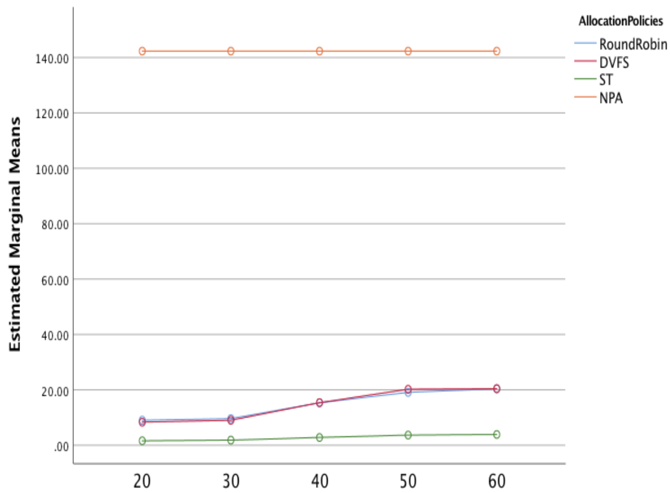

Figure 6. Energy consumption in different number of VMs

Figure 6 shows the energy consumption by using different allocation policy. Assume we use the same number of host and number of virtual machines, as we can see from the result, Single threshold algorithm has the lowest energy cost among the four algorithms, and NPA has the highest energy cost. The reason is that Single threshold algorithm reduces the number of physical nodes used based on current resource requirements through VM migration, thus decreasing the total energy consumption. The power consumption of the host for NPA algorithm has been kept at a maximum, so the energy consumption is also the largest. DVFS algorithm can adjust the CPU frequency adaptively according to task requirements, which greatly reduces CPU power consumption.

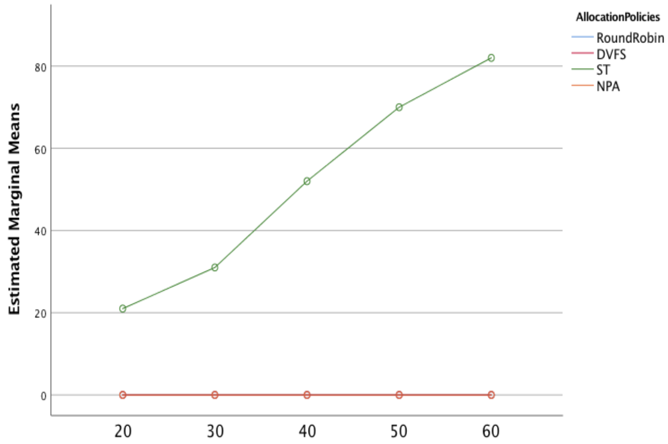

Figure 7. VM migration number

Figure 7 shows that only Single Threshold algorithm involves VM migration and the others don't. With the increasing number of cloudlets, ST algorithm tends to have a linear trend of increasing number of VM migrations.

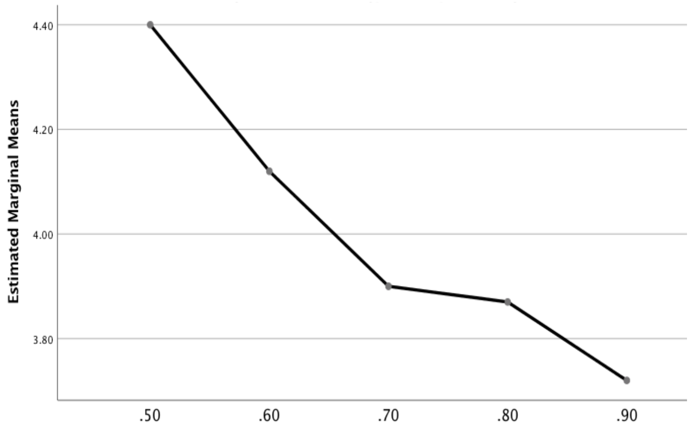

Figure 8. SLA violation number

Figure 8 shows the relationship between utilization threshold and energy cost for ST algorithm. With the higher utilization threshold, the energy consumption becomes smaller.

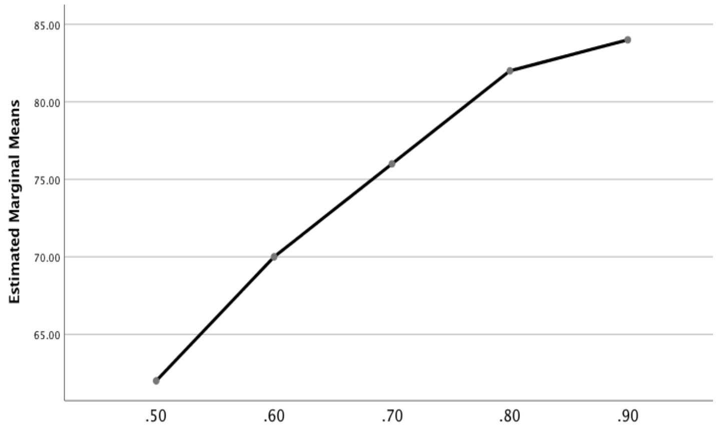

Figure 9. VM migration number of STH

Figure 9 shows that as number of utilization threshold increases, VM has higher probability to migrate and reduce the physical nodes used depending on resource requirement and therefore reducing the total energy cost.

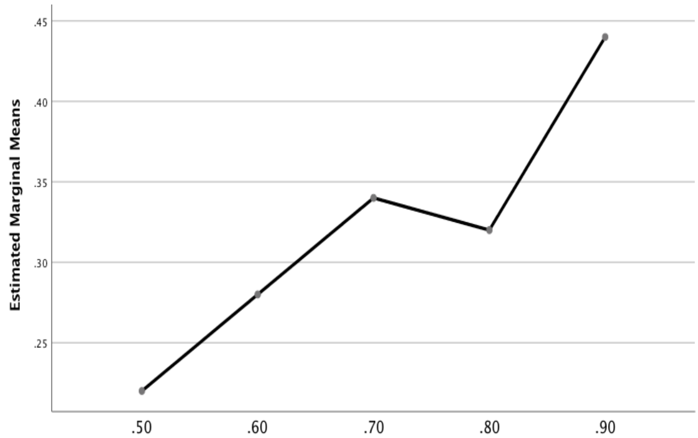

Figure 10. SLA violation number of STH

However, there is a tradeoff between performance and energy cost for Single Threshold algorithm. From Figure 10, we can see that with the increase of utilization threshold, although the energy cost is reduced, the violations of SLA gets higher, which means that the performance is getting worse. It can be seen that the selection of the threshold value requires a trade-off, because the energy consumption and performance need to be balanced. One thing to mention is that the other three algorithms all have zero violation, which means that they have a stable performance.

V. Conclusion And Future Work

With our exploration and analysis of working principle of CloudSim and its simulation mechanism, we have designed and implemented four different VM allocation algorithms which are Round Robin, Single Threshold, Dynamic voltage and frequency scaling, and Non Power Aware. After testing, we figure out that DVFS and Round Robin have stable service availability and comparatively low energy cost. Single

Threshold has the lowest energy cost but worse performance as the utilization threshold goes up.

Originally, we planned to conduct a deeper research on the performance of these scheduling algorithms. However, with the limitation of time, we are only able to use SLA violations as the only one criteria to evaluate the performance. So, future works can explore more on other criteria like the workload balance on the server and efficiency of the VMs with different allocations to execute assign tasks.

References

[1] Rajeshkannan, R., and M. Aramudhan. "Comparative Study of Load Balancing Algorithms in Cloud Computing Environment." Indian Journal of Science and Technology, vol. 9, no. 20, 2016, doi:10.17485/ijst/2016/v9i20/85866.

[2] Beloglazov, Anton, and Rajkumar Buyya. "Energy Efficient Resource Management in Virtualized Cloud Data Centers." 2010 10th IEEE/ACM International Conference on Cluster, Cloud and Grid Computing, 2010, doi:10.1109/ccgrid.2010.46.

[3] Mohammed, Maysoon A., et al. "Queueing theory study of round robin versus priority dynamic quantum time round robin scheduling algorithms." *2015 4th International Conference on Software Engineering and Computer Systems (ICSECS)*, 2015, doi:10.1109/icsecs.2015.7333108.

[4] Balogh, Tomáš, et al. "Performance of Round Robin-Based Queue Scheduling Algorithms." *2010 Third International Conference on Communication Theory, Reliability, and Quality of Service*, 2010, doi:10.1109/ctrq.2010.34.

[5] Pawar, C. S., & Wagh, R. B. (2012). "Priority Based Dynamic resource allocation in Cloud computing", International Symposium on Cloud and Services Computing, IEEE, 2012 pp 1-6

[6] Patil, Shital, et al. "Performance improvement in cloud computing through dynamic task scheduling algorithm." *2015 1st International Conference on Next Generation Computing Technologies (NGCT)*, 2015, doi:10.1109/ngct.2015.7375090.

[7] Jaspreet Kaur, "Comparison of load balancing algorithm in a Cloud", International Journal of Engineering Research and Applications (IJERA), vol. 2, Issue 3, May- June 2012, pp. 1169- 1173.

[8] X. Bai, M. Li, B. Chen, W.-T. Tsai, and J. Gao, "Cloud testing tools," in Service Oriented System Engineering (SOSE), 2011

[9] IEEE 6th International Symposium on, 2011, pp. 1–12.

[10] B. Santosh Kumar1 and Dr. Latha Parthiban2 , "An Implementation of Load Balancing Policy for Virtual Machines Associated with a Data Centre", International Journal of Computer Science & Engineering Technology (IJCSET), volume 5 no. 03, March 2014, pp. 253- 261.

[11] "Energy efficiency in the cloud," Google Official Bloge. [Online]. Available:http://googleblog.blogspot.com/2012/06/energy-efficiency-in-cloud.html.

[12] Calheiros, Rodrigo N., et al. "CloudSim: A Toolkit For Modeling And Simulation Of Cloud Computing Environments And Evaluation Of Resource Provisioning Algorithms." Software: Practice and Experience 41.1 (2011): 23-50.

[13] Monica Gahlawat, Priyanka Sharma (2013) "Analysis and Performance Assessment of CPU Scheduling Algorithm in CloudSim" International Journal of Applied Information System(IJAIS)-1SSN: 2249-0868 Foundation of Computer Science FCS, New York, USA Volume5- No 9, July 2013

[14] R. Buyya, R. Ranjan, and R. N. Calheiros, "Modeling and simulation of scalable Cloud computing environments and the CloudSim toolkit: Challenges and opportunities," in High Performance Computing & Simulation, 2009. HPCS'09. International Conference on, 2009, pp. 1–11.

[15] D. Kliazovich, P. Bouvry, and S. U. Khan, "Simulating communication processes in energy-efficient cloud computing systems," 2012

[16] Mohammed Joda Usman, Abdul Samad Ismail, "Energy-Efficient Virtual Machine Allocation Technique Using Interior Search Algorithm for Cloud Datacenter"

[17] Calheiros, R.N., R. Ranjan, A. Beloglazov, et al. CloudSim: A Toolkit for Modeling and Simulation of Cloud Computing Environments and Evaluation of Resource Provisioning Algorithms[J]. Software-Practice & 290 Experience, 2011, 41(1):23-50.

[18] Buyya, R., R. Ranjan, R.N. Calheiros. Modeling and Simulation of Scalable Cloud Computing Environments and the CloudSim Toolkit: Challenges and Opportunities[C]. In International Conference on High Performance Computing & Simulation, HPCS'09. 2009: p.1-11.

[19] SimCloud Platform. http://simcloud.com/.

[20] Bohu Li, Baocun Hou, "A Networked Modeling and Simulation Platform Based on Cloud Computing Concept - Cloud Simulation Platform" ; Journal of system simulation, 2009,21 (17): 5292-5299.