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Performance Evaluation of Energy Efficient Power Models for Digital Cloud

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Abstract

Background: To improve quality of service energy-efficiency is one of the key parameters of Cloud service providers. Every year huge amounts of electrical energy consume by Cloud data center which leads to more expense in costs and emission of CO2 to the environment which is unhealthy for us. In this case the need of Green Cloud computing solutions to minimize emission of carbon footprints as well as operational costs is the utmost desire. **Objectives:** In our research work we have implemented four different power models such as linear model, cubic model, square model and square root model on an Infrastructure-as-a-Service (IaaS) Cloud environment to find out the best one. **Methods:** Here we considered the CPU utilization and power consumption by enabling virtual machine migration. Then to validate the accuracy of these power models R-squared, Mean Square Error (MSE) have been performed. **Finding:** We found out that the cubic polynomial model is the most efficient one and consume less power in comparison to the other three models. **Application:** Hence this model can be used in energy saving applications over Cloud data centers.

Keywords: Cloud Computing, CPU Utilization, Energy Efficiency, Energy-Aware Cloud Computing, Power Models

1. Introduction

Cloud data centers are the backbone of modern economy which supports server farms that run cloud computing services. These services are basically provided by Amazon, Facebook, Google, and others. The uses of online-digital contents, big data analytics, e-commerce applications, and Internet traffic are also making data centers to consume high electricity in developed countries like USA, UK etc. As per the Natural Resources Defense Council (NRDC)[1] survey data centers consume overall 1.3% of worldwide electricity used. It has been predicted that in US data centers has consumed 91 billion KW of electricity in 2013 and it will increase to 140 billion KW by 2020. Therefore the need of energy efficient power models over data centers is vital.

CPU (server), memory, bandwidth, disk storage and network interfaces are the key ingredients of power consumption over data centers. Among all these key factors CPU is the main source of consumption, and therefore the aim of this research work is to manage its power consumption and efficient usage. Moreover, the CPU utilization and power consumption by enabling VM migration is our first priority. Basically the task of virtual machine migration is to move a virtual machine hosted on a source server is migrated to another machine without first powering down the source VM.

2. Research Findings

This research work is totally focused on four energy aware power models: *linear model, cubic model, square model* and *square root model* on an infrastructure-as-a-service (IaaS) Cloud environment. Our research findings are the followings.

- Overall CPU-utilization in each model.
- Overall power consumption (in KW) in each case by enabling virtual machine (VM) migration.
- Relationship between CPU utilization and overall power consumption in each model.
- Based on total power consumption in a stipulated time period we find the best model out of these four and finally calculate the accuracy through R-squared and mean square error.

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3. Related Work

In[2,3] for virtualized Cloud data centers authors proposed energy efficient resource management system. This system effectively reduces the costs of operation and quality of service based on thermal optimization, network optimization and optimization over multiple system resources. For the single VM migration and dynamic VM consolidation problem authors in[4,5] proposed optimal online deterministic algorithms. In[6] authors have proposed an energy aware scheduling algorithm called Max-Max-Util. This algorithm consumes minimum energy in comparison to other task consolidation heuristic algorithms. In[7] authors have demonstrated an online provisioning approach for high performance computing applications on virtualized environment. In[8] authors investigated power-aware provisioning of virtual machines using DVFS (Dynamic Voltage Frequency Scaling) scheme for real-time services. Authors in[9] studied various green computing concepts for data center with and without power management techniques by using Green Cloud simulator. Authors in[10] investigated EnaCloud - a Cloud based platform which enables application live placement dynamically with consideration of energy efficiency. The basic idea behind EnaCloud is that virtual machine to encapsulate the application, which supports applications scheduling and live migration to minimize the number of running machines, so as to save energy. Authors in[11] proposed a power migration and management algorithm for Cloud. This algorithm uses resources in an effective and efficient manner ensuring minimum power consumption. This algorithm successfully reduces 30% of the power consumption to execute services. Authors in[12] presented a solution to the dynamic capacity provisioning problem. This solution reduces the total energy cost effectively while meeting the performance objective. Authors in[13] studied for two-tier, three-tier and three-tier high speed data center architectures over Green Cloud. This scheme demonstrates the effectiveness of power management schema such as voltage scaling, frequency scaling and dynamic shutdown of various data center network peripherals such as L3 switch, L2/L3 rack-switch, and computing server. In[14] they have also presented an energy-efficient scheduling approach called DENS (data center energy-efficient network-aware scheduling) for three-tier data center architecture. The basic idea behind DENS scheme is to balance the energy consumption of a data center, individual job performance and traffic demands. Authors in[15] outlined the rudimental ideas behind the services that compare the total cost of ownership of a physical machine with the cost of a virtual Cloud-based machine. In addition to that he has also analyzed the costs associated with Cloud Computing services for monitoring, estimating and analyzing. They have also investigated[16] the energy consumption patterns over Green Cloud Environments and verified the relationship between energy consumption and Cloud workload with system performance. Moreover in their another research effort[17] they are able to save 20% of energy consumption over Cloud data center which can be integrated to monitor energy conservation and support static and dynamic system level optimization. In[18] authors have improved the quality of service parameter of Cloud Computing by improving service response time and total throughput.

SPEC power is a standardize benchmark that evaluates servers based on power and performance characteristics[19]. It helps us to compare energy efficiency among different servers and to measure the power of computing systems under different workloads.

4. Experimental Setup

The large-scale implementation of different power models on a real-world infrastructure is very difficult and expensive so the tool Cloud Reports[20], an extensible simulation tool for energy-aware Cloud Computing is taken for simulation. It uses Cloud-sim in a plug-in fashion.

The simulation carried out over one data center and the data center consists of 100 heterogeneous computational nodes (hosts). Each node is modeled to have one CPU core with performance equivalent to 1000, 2000 or 3000 MIPS, 4 GB of RAM and 110 TB of storage capacity. The simulation is carried out for four different energy aware power models: cubic, linear, square and square root over an Infrastructure-as-a-Service (IaaS) Cloud platform for a period of 1 hour. The customers of the simulated IaaS platform are entirely customizable. After simulation was over in Cloud Reports environment we implemented the results of simulation in Matlab Neural Network Fitting Tool (NNFT) to create and train a network and evaluate its performance using MSE and Regression testing. Parameters regarding users and virtual machines (VMs) are set as per the given Table 1 and Table 2 respectively.

Table 1. Users Parameters

Parameters	Values
No of customers	5
Cloudlets sent per min	250
Avg. length of Cloudlets	50000
Avg. Cloudlet's file size	500
Avg. Cloudlet's file size	500

Table 2. Virtual Machines Parameters

Parameters	Values
No of VMs	5
Avg. image size	1000
Avg. RAM	512 MB
Avg. bandwidth	100000

5. Experimental Results

Figure 1 shows the overall power consumption for Cubic model. From simulation the highest value for power consumption in Cubic model is 1.4 KW during 25th minute. Average power consumption is about 0.75 KW.

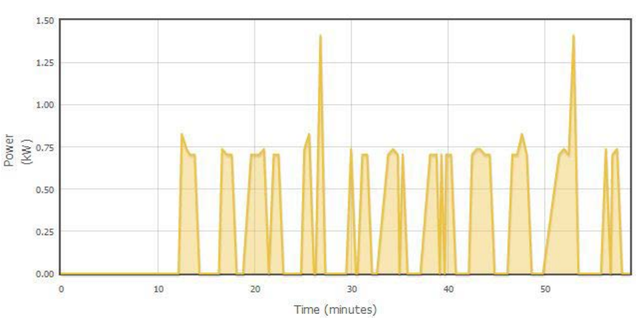

Figure 1. Overall Power consumption in Cubic model.

Figure 2 shows CPU utilization of Cubic model. From simulation result the highest resources utilization for Cubic model is 0.75 MIPS. Average CPU utilization is 0.5 MIPS.

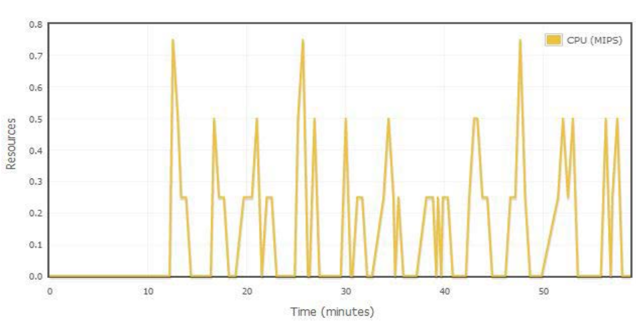

Figure 2. Overall CPU utilization in Cubic model.

Figure 3 shows the overall power consumption for Linear model. From simulation the highest value for power consumption in case of Linear model is 1.6 KW during 20th, 25th and 55th minutes. Average power consumption is about 0.8 KW.

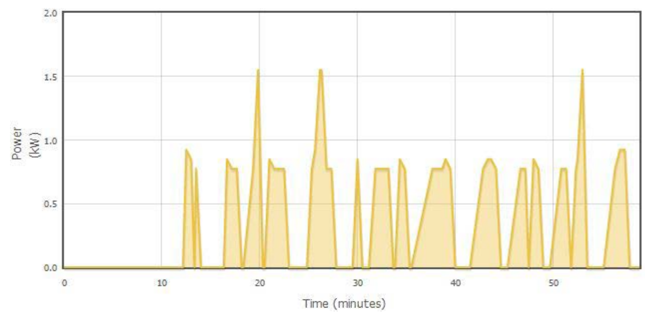

Figure 3. Overall Power consumption in Linear model.

Figure 4 shows the CPU utilization for Linear model. From simulation the highest resources utilization for Linear model is 0.75 MIPS. Average CPU utilization is 0.5 MIPS.

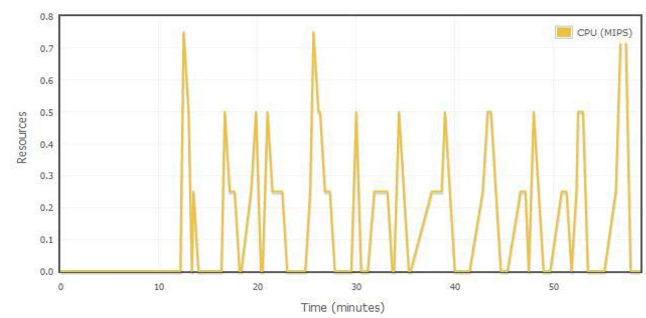

Figure 4. Overall CPU utilization in Linear model.

Figure 5 shows the overall power consumption for Square model. From simulation the highest value for power consumption for Square model is 1.6 KW during 26th minute. Average power consumption is about 0.75 KW.

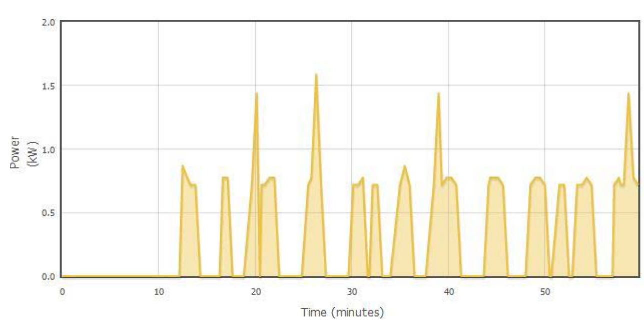

Figure 5. Overall Power consumption in Square model.

Figure 6 shows the overall CPU utilization for Square model. From simulation the highest resources utilization for Square model is 1.0 MIPS. Average CPU utilization is 0.5 MIPS.

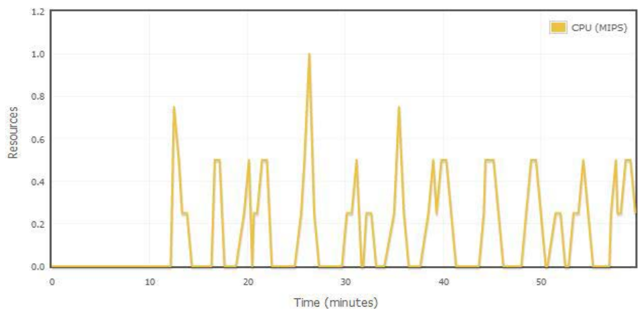

Figure 6. Overall CPU utilization in Square model.

Figure 7 displays the overall power consumption for Square root model. From simulation the highest value for power consumption in case of Square root model is 1.75 KW during 35th, 40th and 55th minutes. Average power consumption is about 0.8 KW.

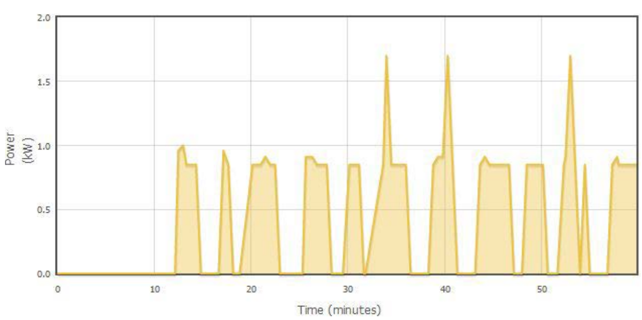

Figure 7. Overall Power consumption in Square root model.

Figure 8 shows the CPU utilization for Square root model. From simulation the highest resources utilization for Square root model is 1.0 MIPS. Average CPU utilization is 0.5 MIPS.

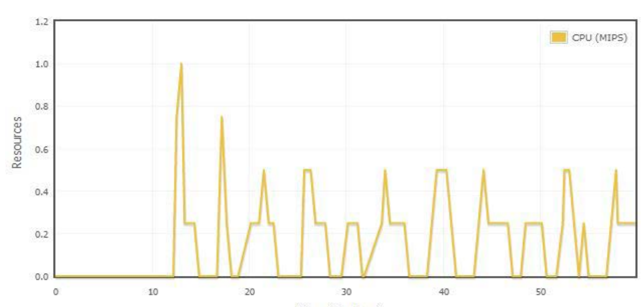

Figure 8. Overall CPU utilization in Square root model.

The below graph given in Figure 9 shows the relationship between power vs. CPU utilization. From this graph we identified that cubic model consumes near about 80% of CPU utilization while consuming 0.8 KW of power. Linear model consumes near about 80% of CPU utilization while consuming 0.9 KW of power. On the other hand square model takes 100% CPU utilization while consuming 1 KW of energy. At last square root model takes 100% CPU utilization while consuming 1.6 KW of energy.

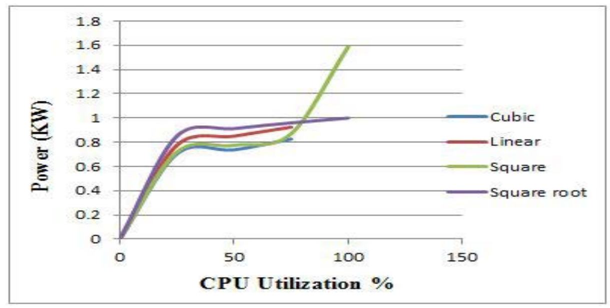

Figure 9. Power vs. CPU Utilization.

6. Performance Evaluation of Four Different Power Models

In this section we demonstrate performance through MSE and regression analysis of four different power models in MATLAB using NNFT. Here we took near about 70 samples of overall power values and 70 samples overall time in each four power models. This network will be trained with Levenberg-Marquardt back propagation algorithm. Finally we calculate the overall power consumption for four different power models in KWh.

The graphs given in Figure 10 and Figure 11 show the MSE and validation testing of cubic power model respectively. From Figure 10 best validation performance occurs at 41 epochs which is 0.0881 and from Figure 11 the value of regression R= 0.55.

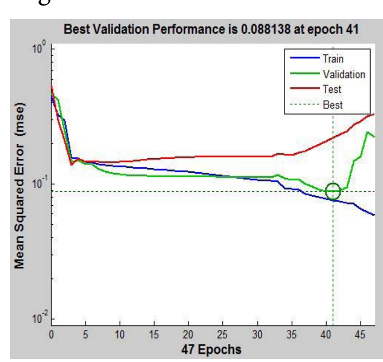

Figure 10. MSE of Cubic model.

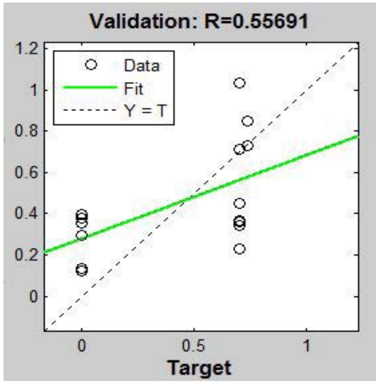

Figure 11. Validation testing of Cubic model.

The graph given in Figure 12 and Figure 13 show the MSE and validation testing of linear power model respectively. From Figure 12 best validation performance occurs at epoch 5 i.e. MSE is 0.0973. From Figure 13 the value of R for linear model is 0.64.

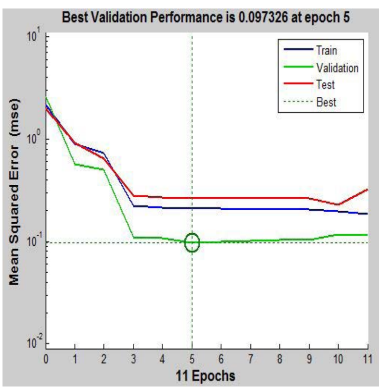

Figure 12. MSE of linear model.

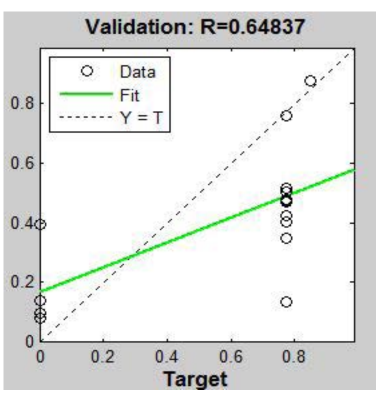

Figure 13. Validation testing of linear model.

The graphs given in Figure 14 and Figure 15 show the MSE and validation testing of square model respectively. From Figure 14 the best validation performance is 0.0419 which occurs at epoch 5. The value of R for square model from Figure 15 is 0.83.

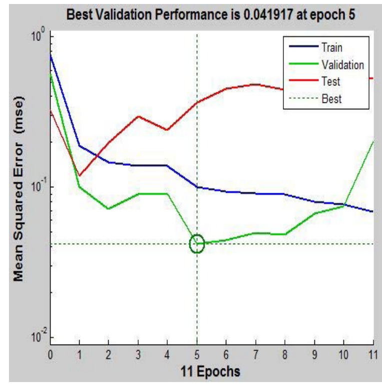

Figure 14. MSE of square model.

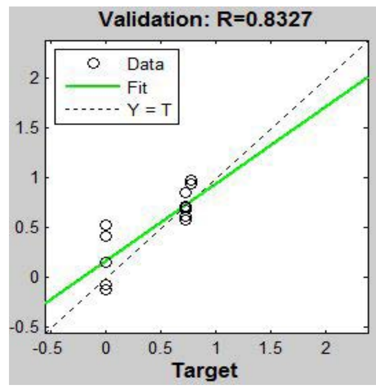

Figure 15. Validation testing of square model.

The graphs given in Figure 16 and Figure 17 show the MSE and validation testing of square root model respectively. From Figure 16 it is clear that the best validation performance for square root model is 0.1891 which occurs at epoch 2. From Figure 17 the value of regression analysis is 0.8.

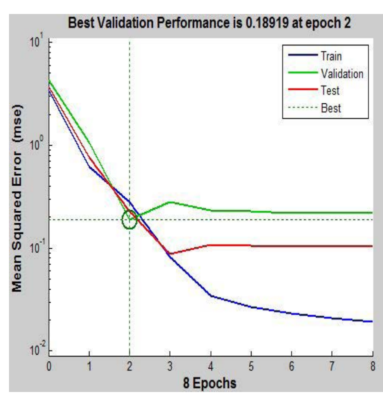

Figure 16. MSE of square root model.

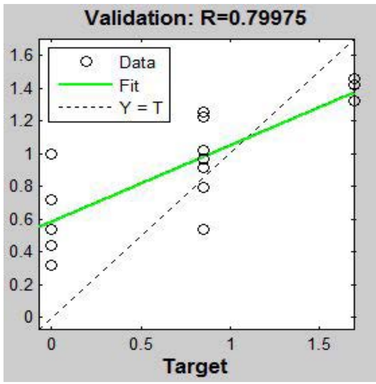

Figure 17. Validation testing of square root model.

In Table 3 we show comparison of four power models including overall power consumption (KWh) for a simulation of 1 hour, mean square error and finally compare R-square.

Table 3. Comparison of Different Models

Power Model	Overall Power Consumption (KWh)	Mean Square Error	R-Square
Cubic	33.85	0.0881	0.309
Linear	40.10	0.0973	0.41
Square	40.93	0.0419	0.68
Square Root	50.29	0.1891	0.64

7. Conclusion and Future Research Work

Energy efficiency have advanced as the cutting edge IT stage for facilitating applications in science, business, long range interpersonal communication, and media content conveyance. In this research paper we have evaluated the performance of four different power models over IaaS Cloud infrastructure. In addition to that we found the relationship between CPU utilization and power consumption in each case. Moreover we have experimentally verified that cubic power model consumes less power in comparison to linear, square and square root power models. In addition to that Cubic power model produce less mean square error and R-square. Therefore cubic power model is the efficient one in comparison to the other three energy efficient models.

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