An Effective Green Computing Virtualization Model to Optimize the Computer Operating Process by Lessening Energy Consumption

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ABSTRACT

The goal of this dissertation is to facilitate a Green Computing Virtualization Model (GCVM), a technology which will provide energy efficiency to virtually monitored computer systems by utilizing Virtual Machines (VMs) through optimization of power consumption in idle periods. This proposed model will reduce the energy consumption by 33% if it is operated successfully. This Energy Efficient Model (GCVM) was constructed with three consecutive iterative phases which are monitoring phase, virtualization phase and termination phase. Initially, Monitoring phase starts the system as it monitors activities to establish a time frame for the virtualization phase. After monitoring phase, Virtualization process keeps the system ready to launch according to the time frame provided by Monitoring phase which is used in saving energy and utilizing resources. At the end, Termination phase terminates the virtualization process upon checking the time frame demand and then the system repeats these phases in order. The model is constructed utilizing virtual machines, an emulation of computing system that provides functions of an actual computer. The proposed model showed us that energy consumption can be reduced for idle periods on computers implementing this model. The outcome was certainly efficient compared with the data from existing technology which is elaborated in Data Collection. Our framework perhaps could become more effective if it is being assembled in a virtual environment.

Keywords

GCVM, Estimated energy consumption (EEC), Estimated cost (EC), Green computing, Monitoring phase, Virtualization phase, Termination phase, Time frame.

1. INTRODUCTION

The concept of green computing is gaining popularity as it has become the most essential weapon against global warming. Global warming is leading our planet towards eminent extinction and Green Computing is the safest path that leads towards earth's salvation from it. Temperatures around the world is increasing day by day due to greenhouse gas emission and toxic materials which results in Climate change. Production of electricity with thermal power plants, chemical plants and even nuclear power plants emits huge amount of carbon dioxide and many hazardous materials [1]. Without electricity, the entire ICT world will come to a stop, without ICT mankind cannot sustain in this world anymore. Also, ICT materials has proven to be harmful for the environment as most of raw materials for production does not dissolve in nature and has toxic effects. It is time to adopt Green Computing as it ensures earth's safety and builds towards a sustainable future.

The proposed method works by ensuring that ICT components are energy-efficient and eco-friendly. Energy efficiency is the initial motive of designing including cooling mechanism. Habit of using computers and other subsystems with reduced energy consumption and reusing and refurbishing old components and systems is adopted in this paper [1].

Green computing applies new computing paradigms like Cloud Computing which use virtualized server infrastructure through virtual machine (VM) instances which was the main motivation behind the proposed method. This paper incorporates the idea of virtual machine by proposing a virtual model. Rapid fluctuation of application demand occurs in broad range. Sometimes drastic load on the system may happen with a short response time, system may fall short of requirements even if it's automated. For handling such pressure pre-booted virtual instances can be allocated in periods of high demand which can also remain idle in low demands. In idle periods VM instances stand by in the queue, through auto scaling server utilization and decrease of idle time can be achieved which negates from wasted power consumption, increased cost for operation, increased demand for new system that require large investments. This also reduces emission of superfluous carbon dioxide [2].

The proposed green computing virtual model incorporates such mechanism that reduces consumption of power and mitigates high carbon emission has the potential for vast growth of ICT towards greener and sustainable technological development which is the actual objective of this paper.

Our primary concern was about the feasibility of this model. So, the first question did arise that if the model is feasible or not. Based on this question, we analyzed and developed a simulation of our model. Later it was compared by analyzing its' feasibility with respect to energy consumption rate and the cost.

Secondly, we worked on how efficient this GCVM is compared to other existing systems. We reviewed enough papers and found a model which have the pretty much same mechanism as our model. But from feasibility matrix analysis, a clear idea was improved that the existing model is expensive enough and runs on heavy hardware. Performance of our proposed model is discussed on the later section of the paper.

2. REVIEW OF RELATED LITERATURE

Governments, enterprises, societies, world organizations have started to adopt Green Computing as an environment friendly sound practice. Entire life cycle of a computer, from production, in use, and into its disposal has a severe impact on the environment. Green Computing negates the impact through designing for natural sustainability, energy-efficiency, optimal power management, server and data center virtualization, implementation of renewable energy, eco-labeling of ICT products. A holistic approach can be addressed, by focusing our efforts on Green Use, Green Disposal, Green Design and Green Manufacturing. Various measures like reducing energy consumption by PCs, enabling power management features, turning off system in idle phases, using screensavers and thin-client PCs, greener data center, energy conservation, virtualization, eco-friendly design, reuse, recycle, refurbish and many more [3]. The importance of green computing is increasing and this is gaining more popularity than ever. The paper focused on the environmental impact of IT operations and emphasis on the reduction of hazardous materials. The paper [1] does not talk about ways to improve energy efficiency but takes an abstract approach to address the necessity as to why improving this situation and adapting a greener approach is computing is important. Many non-technical and careful approaches could also be taken to make computing greener such as recycling in an eco-friendly way, refurbishing, reusing, using with care, to turn off when not in use. Also using hydrogen fuel cells as an alternative for conventional electricity. However, these are major advance technologies, which are not compatible for developing and under developing countries. Energy efficiency in developing and under developing countries require a more conventional and cheap way to save energy.

Manufacturers at large are using renewable, energy efficient & eco-friendly materials. Universities implementing various techniques like sleep mode, shut down when not in use, print only on demand, sharing files and documents through FTP, using virtualization of software instead of machines. With increasing population, computer use is increasing which results into high energy consumption. In order to reduce power consumption, measures like printing double sided, viewing documents on screen are adopted. Algorithm efficiency has a functional impact, Google search engine algorithm emits 0.2 grams of carbon-dioxide and Windows 7 OS + Office 2010 uses 70 times more memory space (RAM) than Windows 98 OS + Office 2000 in order to send a particular e-mail or write a particular text 10 years ago. Using the same model of equipment's help as the damaged equipment's parts can be used to fix a less damaged equipment. Using LED technology in monitors rather than CRT or LCD which uses more power than LED [4]. Though manufacturers of today are making components and devices that are efficient, but at the end of their life cycle, those products end up contributing to toxic e-wastes because of the materials used like lead, mercury, cadmium etc. This is especially applicable in developing countries. This quickens pollution. According to this paper [5], data center servers consume 50 times more the energy per square foot as in office and this is one of the main energy consuming area. Many major companies are building their data centers near seaside to use hydroelectric power and because it is more energy efficient and temperature near sea area remains about the same through put the year if not, gets colder and this helps with the cooling of components. Powerful equipment requires more cooling. However, not every data center can be built near seaside so other means of saving energy has to be adopted. This is what our software will do. This will shut down computers under the same network. Shutting down is important because according to a study [6], annual cost of standby is more than the annual cost of use. Software approach to make efficient use of energy and to save energy is the main focus of our paper which was not properly highlighted in author's paper.

Energy consumption occurs in various level of computers. This paper was concentrated on a specific area related to cloud computing that could be either under a private server or a public server and the consumption of energy occurs during switching and transmission as well as data processing and data storage [7]. The focus does not deal with saving energy but concentrates on the balance of server energy consumption and how it can be managed; this energy consumption is of server, network and end user energy consumption. Author works with three cloud computing services which are storage as a service, processing as a service and software as a service. However, one main drawback is that this system is only effective when the tasks are of low intensity and infrequent. If this is not the case then this system will end up consuming more energy than regular conventional systems and if the end user uses all the computing on their personal computer than this system will consume more energy. To improve cloud computing efficiency and for this system to be efficient it has to depend on a lot of variables and existing technology like the existing hardware based method of saving energy which is sleep scheduling, use of advanced cooling systems, consolidation of servers and virtualization of computing resources in cloud computing data centers. In addition, the power consumed by private servers is greater than power consumption of public servers. However most mid-range to big companies or institutions use their own private servers. Therefore, this system will not be effective. Now for the companies or institutions that use public server if their service of employee count exceeds 20 or if the frame rate of either uploading or downloading increases than public server will start consuming more energy than a regular mid-range PC. However, this role takes a 180 degree turn when transportation of data is included because then private server is more energy efficient that public server. The percentage of absolute energy saving from this service rather small than the conventional hardware approaches for optimization of energy consumption. Internet usage has grown exponentially and the size of data stored has also increased, in order to maintain demand modern data centers has upgraded. Data centers nowadays contain tens of thousands of servers providing 24 hours service to millions of clients [8]. Due to that power consumption has also increased, in 2006 datacenters and servers used in U.S. consumed 61 billion kilowatt hours of electricity which is 1.5% of consumed electricity of all US costing $4.5 billion [9]. 100 million videos are viewed and uploaded on YouTube servers a day, while almost 400 million active Facebook users upload 3 billion photos every month [10]. Such cloud based datacenters $9.3 million worth power per year [11]. It has been estimated that worldwide expenditure is more than $30 billion on enterprise power supply and cooling [12]. This is why, power management is of great importance to maintain a green ICT sector. A popular power management technique is Dynamic voltage and frequency scaling, where the clock frequency of a processor is dynamically adjusted to allow a corresponding reduction in the supply voltage to achieve power saving [13].

Dynamic Power management (DPV) techniques [14] that are discussed about also is applied at the hardware and firmware level. Dynamic Components Deactivation (DCD) is the process of transitioning from one state to another i.e. from active state to inactive state then back to active state. However, this transitioning consumes quite a lot of additional power. So, if the session of inactivity is short then the power consumed during transitioning from one state to another would be much greater than the power saved during inactive period. Another method was Dynamic Voltage and Frequency Scaling (DVFS). What this technique does is that it intentionally down- scales CPU performance when not fully utilized by down scaling voltage and frequency, resulting in cubic reduction of the dynamic power consumption. However, modern CPUs have a complex architecture so if DVFS is not carefully applied then this technique has a potential of failure.

In another paper, Dougherty proposed an Auto-scaling cloud computing model to make the response time faster. However, it also proposed the Smart Cloud Optimization of Resource Configuration Handling (SCORCH) to reduce the power consumption using an optimized auto-scaling queue [2]. And it successfully reduced a great amount of power consumption rate. Though response time was clearly not on the focus line in this paper. But the main goal was to reduce operating costs as well as response time. In this auto-scaling model, VMs are assigned to any applicant based on availability. But if required VM is not available, it may have a running VM configuration that can be modified to meet the requested configuration. However, research about making response time faster will be the subject of the further research of this model. But there are some limitations too. If there is auto scaling queue without an exact match, a running VM configuration may be present for modification in order to meet the desired configuration. But in that case sometimes may be modified VMs can't fulfill the user configurations in a correct way. Also, Manual requesting for VMs may take some response time than allocating VMs completely dynamically or automatically. Though automatically allocation may not provide VMs as demanding configuration but it will reserve more time than manual requesting.

However, in the modern world, energy consumption is the new hot topic in the recent research fields. Green technology has been proved enough effective in order to reduce energy consumption and emission of deadly gases. The Green Cloud Simulator [15] is a special type of simulator which is typically based on two effective models but that does not focus much on reducing energy consumption. Basically, it is used for simulation. A new model was proposed which was capable of reduce energy consumption saving several parameters such as total energy, servers energy etc. But this simulator model also contains some problem as well. In the time of transmitting least data, predictive data delivery may fail sometime to send the least amount of data. Also during the routing of the data, routing algorithm may not be correctly chosen sometime which may take more time than usual.

3. PROPOSED GREEN COMPUTING VIRTUALIZAION MODEL (GCVM)

This paper proposes a Green Computing Virtualization Model (GCVM) which mainly focuses on reduction of power consumption which is an aspect of green computing through distributed system. A university Computer laboratory system is recognized as the field for implementing the model that is proposed in this paper. GCVM model will centrally control the entire VMs system to automatically Idle the entire system by checking the time frame frequently. System administrator remotely will select the time frame according to their efficiency. GCVM model will thoroughly go under some process or system to generate an efficient result of energy consumption rate.

There are several reasons behind using GCVM. Some of them are mentioned below:

- GCVM will work with respect to Estimated Energy Consumption (EEC) which will allow to visualize the real-life impact on reserving energy directly.
- GCVM is less expensive so it can be assembled into any system without any complexity.
- The proposed model can be monitored by any single authority, so user complexity will decrease.

3.1 Active Phases of GCVM

Major activities are being categorized into three broad phases. Monitoring phase will look onto whether any VM matches with the time frame. If VM does match with its' time frame the model will automatically make the VM idle in the Virtualization phase. This idling process will stop automatically by the proposed model in the later phase.

1. *Observing in Monitoring Phase:* In this phase, the active system will monitor the VMs since the system will be on active mode. The process of monitoring activities of virtual machines in Computer laboratories will run at all time without any disruption. Monitoring will only be limited for a limited time being since the system will frequently check the time frame to starts idling the system.

2. *Idling VMs in Virtualization Phase:* Administrator will have soul authority to take input for the time frame (time input for the activeness of the PCs) since the system needs a time box for idling the VMs. Time checker will check given input from administrator and decide whether it is in allocated time frame or not. If it does not comply with the time frame, the process will go to the monitoring phase again.

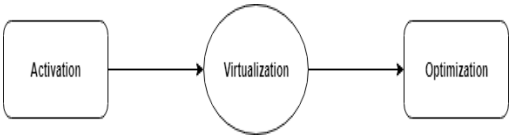

Fig 1: Virtualization Phase

On the other hand, if it does comply, the process will proceed to idling phase. In virtualization phase, virtual machines will be set to idle mode which will reduce the power consumption which will enable it the title of Green Computing.

3. *Expiring in Termination Phase:* After the virtualization phase, time frame checker checks whether the time has ended or not. If time is available, process will continue idling the virtual machines. If no more time available, the system will go to the Monitoring Phase again that means the system will start monitoring activities of virtual machines of the computer labs.

Pseudo code for Green Computing Virtualization Model is given below:

Green Computing Virtualization Model (GCVM)

1. Login
2. Give desired time as input
3. System monitors VMs activity
4. If (input time matches with the current time)
5. **Starts** idling VMs
6. Else
7. **Go** to line 3
8. System frequently checks when the time ends
9. If (time limit exceeds)
10. **Stop** idling VMs
11. Else
12. **Continue** idling VMs
13. End of GCVM activities

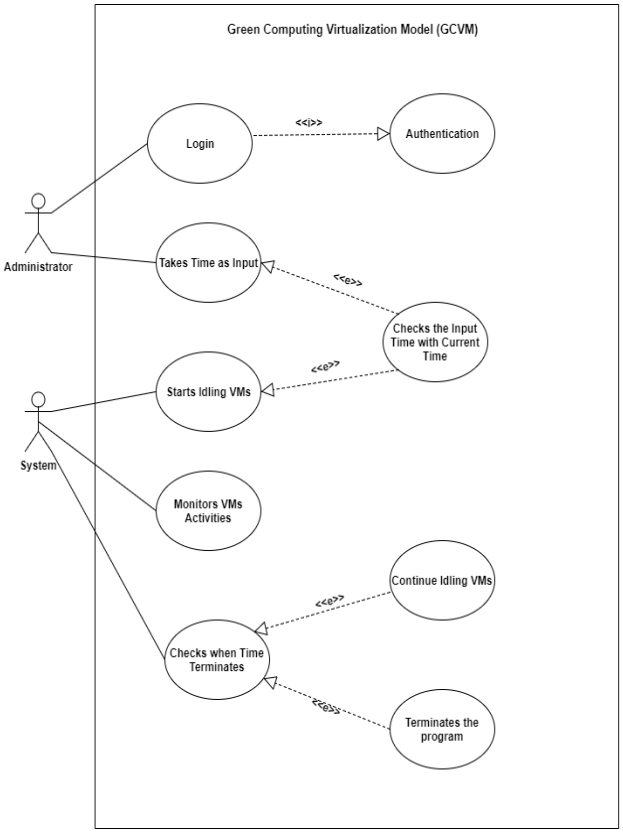

Fig 2: Use case diagram of the proposed GCVM

4. PERFORMANCE MEASUREMENT OF GCVM

Performance of GCVM is mainly measured in this proposed model with respect to Estimated Energy Consumption (EEC). EEC is used for comparing the model's performance which is described in the further sections of this paper.

4.1 Data Collection

The model is basically based on the energy consumption theory, so data related to power consumption were collected in a specific way and verified from the Bangladesh Power Development Boards' (BPDB) Circular (Bangladesh Energy Regulatory Commission, 2015). In our paper, we took the sample from our university (American International University Bangladesh) data and planned to apply on our model.

According to our collected data, Air conditioner costs about 2530KWH of power in total (1265 ton * 2KWH) and that's a huge amount of consumption.

Though we collected every electronic machines' data regarding power, but our main focus here was about computers.

Total number of PC we found is 1350 including Windows and MAC. In average, 280KW power is consumed per hour by all that devices.

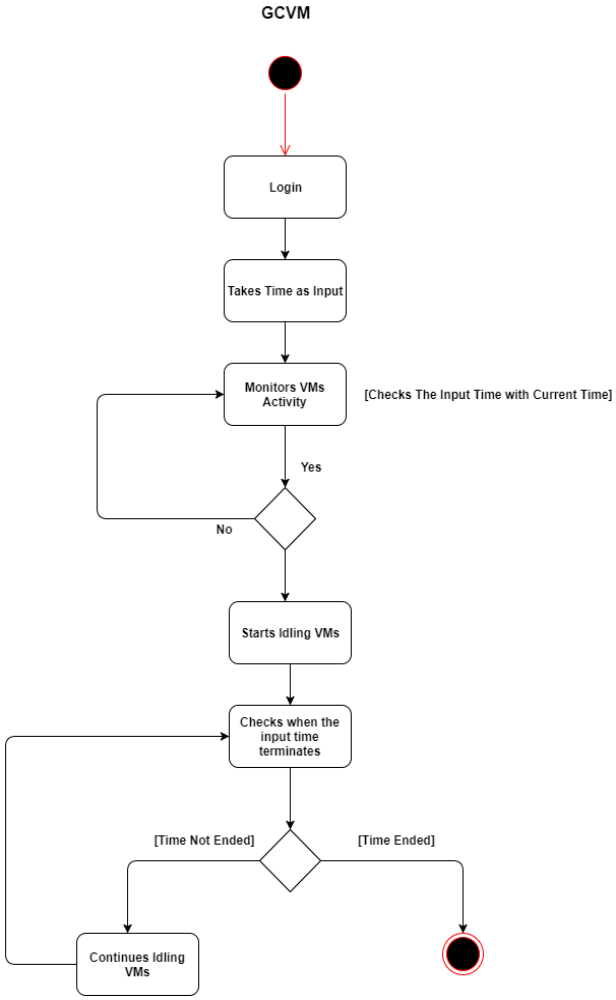

Fig 3: Activity diagram of the proposed GCVM

A short calculation is given below to have a quick idea about the costs:

Total cost for PCs only

*(per hour) = 280KWH*5.22BDT = 1461.6 BDT*

*(per day) = (1461.6*24) BDT = 35078.4 BDT*

*(per month) = (35078.4*30) BDT= 1052352 BDT*

*(per year) = (1052352*12) BDT = 12628224 BDT*

N.B. 5.22 BDT is the cost for per KW according to Bangladesh Power Development Boards' (BPDB).

4.2 Calculation with respect to EEC and EC

Without GCVM,

P_n = total power consumption for n number of PCs

E = individual PCs power consumption rate

$$P_n = \sum_{i=1}^{n} E1 + E2 + E3 + \cdots \qquad [n=1, 2, 3,..]$$

$$= \sum_{i=1}^{n} Ei$$

With GCVM applied,

G_n = total power consumption for n number of PCs

M = individual PCs power consumption rate

$$G_n = \sum_{i=1}^{n} M1 + M2 + M3 + \cdots \qquad [n=1, 2, 3,..]$$

$$= \sum_{i=1}^{n} Mi$$

Expected result, $V_n = P_n - G_n = \sum_{i=1}^{n} Ei - \sum_{i=1}^{n} Mi$

All the data we gathered, were processed through above equations to get the desired outcome of the model.

4.3 Performance Comparison

By applying GCVM model in this very same system, we could save 8 hours of power consumption per day and could minimized the consumption rate successfully.

Table 1. Performance Measurements with respect to EEC and EC

	Without GCVM	**With GCVM**
EEC in KWH	2.4 million (Approximately)	1.6 million (Approximately)
EC in BDT	12.6 million (Approximately)	8.4 million (Approximately)

The performance will be much lower as we can see it on the table1. For visualization, a chart of performance comparison would be more comfortable to analyze the power consumption rate which was our primary goal of this proposed model.

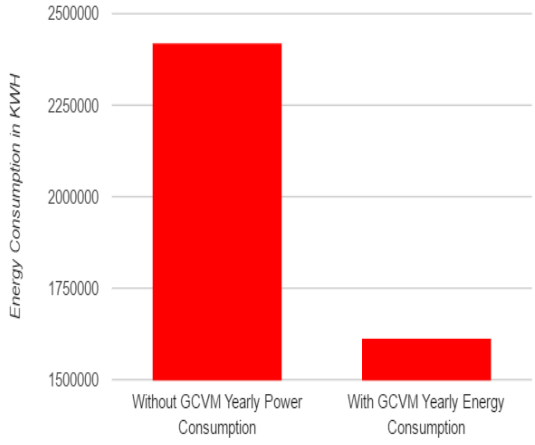

Fig 4: Energy consumption comparison chart with/without GCVM

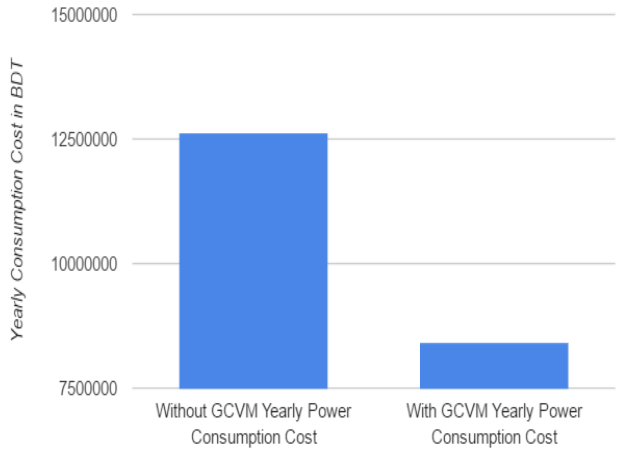

Fig 5: Cost comparison chart with/without GCVM

5. CONCLUSION AND FUTURE WORK

According to our knowledge gained, green computing is not very recognized in our environment in Bangladesh yet because of our system still lacks proper knowledge about it. But it can be proved to be essential because of its' easier flexibility and easier usability. Also, Green Computing can reduce the energy consumption in a very simple and efficient way. Proposed GCVM model can be very useful in an environment in which the number of VMs are large. It can control the whole system from a single or multiple central administrator PCs. In the system, time frame will be set for the automatic shutdown for the remaining entire number of PCs which time will match with the given time frame. After a certain amount of time, when the specific time period of the given time frame will end, the system will automatically turn on the VMs. The system will now start observing the VMs again until the new time frame will be set again. It will not only reduce the energy consumption but also it can make the environment green by limiting of emission of C02 during the idle time.

Our paper is about a proposal of a model which can reduce the energy consumption and save out a lot of assets and resources as well. For the shortage of time, just a virtual simulation of this model was created which was discussed before. But in near future, we are going to implement the whole model into a realistic one and assemble into a large infrastructure like our university. For this purpose, one laboratory will be taken for the observation and will be controlled by a central administrator PC. Another plan is to make the system an open source program which will be very helpful for the developing country like Bangladesh.

After a successful attempt of this model on the virtual machines, our plan is to work with other machines as well like air-conditioner, air-cooler and so on. And finally, for the future work, our aim is to develop a mobile application by which the whole system can be controlled. So that the accessibility and efficiency of the model may increase eventually.

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