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# A Comparative Analysis of Green Cloud Computing Mechanisms

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***Abstract— Due to the increasing number of Cloud applications, the demands for cloud data centres have raised exponentially. Cloud computing allows dynamic resource provisioning for erratic computational demands. Green Cloud Computing is used to reduce the effect of these data centres in terms of energy, temperature, carbon footprint and SLA violations. This paper presents a comprehensive survey on various mechanisms, falling under three categories: DVFS, VM Migration/Allocation and Green Algorithms, used for achieving Green Cloud Computing. The objective is to find the best mechanism to reduce overall energy consumption while avoiding SLA violations. A meticulous comparative analysis of the various mechanisms determines the power and thermal-aware VM allocation mechanism is better than the other methods, as it leads to the most reduction in both power usage and number of VM migrations in the data centre. The comparative analysis contains a detailed assessment of the strategy, reduced energy expenditure, advantages and limitations of various mechanisms.***

***Keywords— Cloud Computing; Virtual Machine; Power Consumption; Thermal aware; DVFS; Green Algorithms***

## I. INTRODUCTION

Cloud computing, often designated as simply, the cloud', is the delivery of on demand computing resources- everything from applications to data centres, over the internetwork on a pay-for-use foundation. To yield and deliver the services to users' devices, cloud makes use of a large number of data centres consisting of thousands of physical servers. Nowadays, cloud computing servers use massive amount of energy, which is followed by discharge of pollutants majorly CO2. According to statistics, one data centre can create one hundred seventy million metric tons of CO2 annually. The probable measure of CO2 produced by data centres by 2020 is approximately669 million metric tons per year. In addition to this, the energy consumption by data centres translates to high operational costs. The energy evaluated for data centres in the year 2013 was about 90 billion kWh [3]. Cloud service providers need to ensure that the profit mar gin isn't severely concentrated due to the high energy expenditure. Thus it is essential to lower the energy usage significantly and reduce the greenhouse gasses liberated during the process.

With its capability to provide a high performance environment for scientific applications [7], cloud can be optimized in such a manner that it offers green cloud computing solutions. Hence, this survey paper aims at inspecting and contemplating the various strategies proposed by distinguished authors to tackle the increasing energy consumption. The paper discusses alternatives typically focussing on these three aspects- Green Algorithms, Virtual Machine Migration and Dynamic Voltage and Frequency Scaling.

One of the many objectives of Green Algorithms is scheduling the tasks in a workflow (jobs) in order to cut down on the make span, thus enhancing the performance of each server. Exploration continues into prime areas such as formulating algorithms and systems for performance related computers [14]. With VM Migration between the cloud servers, consolidation of the workloads on fewer machines and enabling idle machines to operate in a low power mode is possible, hence reducing the carbon emissions [7]. DVS (Dynamic Voltage Scaling) and DFS (Dynamic Frequency Scaling) mechanisms are utilized for dynamic alteration in the performance of the server machine so as to lower the power consumption.

In a data centre a job scheduler is necessary to plan the execution of the processes in a workflow. This job scheduler needs to effectively make use of the resources for performing the jobs. An efficient job scheduler is capable of working with a lesser amount of time and fewer resources. If there is a little dependency between the tasks allotted to a server machine or any form of interconnection, there may be a lower consumption of the cloud resources [9]. Therefore, the paper puts forward the concept of task scheduling algorithms for cloud computing in order to raise energy savings. Optimal scheduling mechanisms show clear reductions in the total time taken to process a set of programmed jobs, this time duration is called as the make span [8].

With the increase of cloud users, incoming client requests per unit time and the obligation of being a faster server, the concept of Virtualization becomes a crucial aspect in IT domain. In cloud computing, virtualization is the technique of segregating server's resources [3]. Cloud typically employs Virtual Machine (VM) technologies for integration and atmosphere isolation. Along with this it restricts the guest OS from utilizing the original hardware. It improves CPU usage by up to 70%, by cutting down the count of server machines required to keep and compute data. This paper surveys VM Migration and placement algorithms [10].

Another mechanism used to cut down the energy expenditure in data centres is Dynamic Voltage Frequency Scaling (DVFS). This paper also analysis the scheduling algorithms that can be used to allot virtual machines to DVFS-enabled infrastructures along with dynamic scaling of the supplied voltage. Pengji Zhou has proposed a precedence constraint job schedule algorithm implemented on a DVFS enabled hardware [2]. Keqin Li [1] has suggested six innovative task scheduling algorithms typically executed on a DVS based machine. Whereas [3] presents a power aware algorithm that works along with DVFS mechanism to reduce power consumption and complies by the SLA. The techniques proposed in the paper are evaluated via simulation tools and their corresponding test results justify for the efficiency of that particular strategy.

The rest of this paper is structured as follows: In Section II, the literature survey and the related research work are presented.

## II. LITERATURE REVIEW

### *A. DVFS*

*1) Green Task Scheduling Algorithms with speed optimisation on heterogeneous cloud servers*: In [1] Luna and Yan-Qing have proposed a set of green algorithms to minimize the power utilization by the servers. The suggested algorithms first establish the maximum speed for all tasks allocated to a server machine. These are typically thought of for heterogeneous cloud servers with adjustable speeds and parameters to successfully reduce energy expenditure and terminate all tasks before the time limit. The simulation results indicate that the best heuristic among these is Shortest Task First for Computer with Minimum Energy algorithm. The name of the simulation method has not been mentioned.

*2) An Efficient Bi-objective Heuristic for Scheduling Workflows on heterogeneous DVS- Enabled Processors:* The approach used by Pengji Zhou and Wei Zheng in [2] works on DVFS based hardware. The aim is to schedule a DAG based workflow established on shortest completion time for a set of tasks. It allows the processors to operate at a lower voltage at the cost of cutting down the CPU speed. This heuristic helped in providing a desirable trade-off between energy utilized and QoS granted. The objective is to obtain a scheduled workflow, which generally is a precedence dependent application on a restricted amount of heterogeneous DVS-processors.

A faster and a more efficient heuristic is suggested named, EECS and is analysed using a simulation tool. It is a well competent bi-objective DAG scheduling heuristic established for the augmentation of energy conscience scheduling heuristic ECS. The proposed heuristic talks about minimizing make span and the net energy consumed along with the maintenance of a lower complexity. The results imply that EECS algorithm can notably surpass the existing algorithm on both the given basis. Also, EECS has a lower execution cost and hence is able to generate a schedule as a real time response.

*3) CloudSim: A toolkit for modelling and simulation of cloud computing environment and evaluation of resource provisioning algorithms:* A power-aware scheduling algorithm is given. It utilizes Dynamic Voltage Frequency Scaling (DVFS) method, which operates on special CPUs that can too function at discrete voltages and frequencies. It chooses from the given voltages and frequencies of the processors to play down power utilization without violation of SLA contract, depending on the VMs load. [3] Each VM is allotted to the First Fit server machine; every machine applies the DVFS methodology to accumulate the energy while agreeing to the SLA necessities. The output presents lessening in power expenditure without breaching the SLA contract and is set side by side with a non-power heuristic. The performance is evaluated by utilizing CloudSim Toolkit.

Typically, the power saved in during the algorithms that utilizes DVFS based infrastructure or hardware is low compared to other mechanisms [4]. The energy savings to cost spent ratio is again low.

*B. Virtual Machine Migration and Allocation*

Virtual Machine Migration refers to the process of moving a virtual machine running or not running from one host to another in a Cloud environment.

*1) Energy and Carbon Efficient VM Placement and Migration Technique for Green Cloud Data centers:* Engineers and Researchers have provided a range of solutions to make Cloud Computing energy efficient and minimizing the $CO2$ emissions. Switching the servers on and off according to usage load, putting the servers to sleep, use of DVFS are the majorly implemented techniques.

Virtualization techniques are implemented for better resource utilization and it does so by live migrating the resources and consolidating them. [7] The proposed method by the authors follows a distributed architecture where data centres are located over various locations. Each data centre has its own carbon footprint reliant on its energy utilization. The process of our proposed approach can be achieved using a two-step process-

- Placing the VM onto a suitable host from the data centre having minimum carbon footprint rate.
- Optimizing the current VM allocation inside every data centre.

This is the proposed technique by the authors which includes the VM migration and allocation in cloud data centre considering carbon footprint of various data centres.

*2) Energy-efficient CPU utilization based virtual machine scheduling in green clouds:* Energy efficiency can be attained by consolidating the VM's constantly considering the current utilization and thermal state of the nodes. The author focuses on managing, consolidating and migrating the virtual machines for achieving energy efficiency. Migration is done on the basis of workload management so that it will not exceed the power consumption or temperature of a host beyond a certain limit. The authors implement 3 techniques, namely: 1) Virtual Machine Consolidation 2) Live Migration Theory 3) Power Aware and Temperature Aware VM Migration in their algorithm [11]. We notice that, after the use of the algorithm, with migration, the number of required hosts in the cloud decreased by 1/5th, the Power Consumption decreased by 30% and the average temperature dropped by 9 degrees Celsius. The obtained results show that the technique of VM migration and switching off idle hosts makes the system energy efficient and saves the systems which are near their critical temperature from failure.

*3) Power and Thermal-Aware Virtual Machine Allocation Mechanism for Cloud Data Centres:* This study proposes an energy-aware and thermal-aware virtual machine migration and allocation mechanism. The aim is to reduce energy consumption and VM migrations while evading SLA violations. The proposed technique can be divided into 3 parts: (1) classifying the hosts into over-utilized or under-utilized; (2) selecting Virtual Machines for migrations and migrating them from an over-utilized host; (3) moving those VMs onto under-utilized hosts. The authors [12] carried out a series of experiments using a random workload, comprising of 50 hosts and 50 VMs, and a real-world workload, randomly choosing a day from the workload traces of an organization called PlanetLab which in our case comprised of 800 hosts and 1052 VMs, to analyse the efficiency of the proposed technique. In the random workload experiments, the authors observe that the number of migrations and overall energy consumption of the proposed mechanism outclasses the energy-based methods by 33% to 52%. In the real world workload, the overall energy consumption when compared to other methods is reduced by 30%. Also, the number of migrations while using the proposed method is around 50% less than its counterparts at all times. Both these examples also show that the SLA violations are only slightly higher than other methods. However, the proposed mechanism can effectively allocate proper hosts for the VMs, and can achieve reasonable interchanges among power consumption, temperature, and SLA violations. The proposed mechanism keeps the hosts working under optimal temperatures through VM migration and allocation. As a result, it enables better consolidations of VMs. Compared with the power-aware methods, the proposed mechanism shows reduced energy consumption; number VM migrations and SLA violations

*C. Green Algorithms*

*1) A Green Greedy Process Scheduler for Cloud Data Centres:* Green Algorithm mainly deals with assigning n tasks to r different resources without violating the various constraints of efficiency. Whenever there are tasks assigned to any server, the server needs to work at very high efficiency to ensure that the task is completed without any delays. The cooling system at any data centre needs to be very good so that it can handle the server. Whenever any task arrives at a data centre, it has its own number of resources that are required and that specifies how much power consumption will happen for that task. The power consumption can also be defined by the temperature load it has to concur due to that particular task. the way temperature load affects the power consumption of the system. The algorithm that is defined is based on which system is better suited to perform the task with bearing the least amount of temperature load. This algorithm performed better against the basic algorithm in which the tasks are assigned to the very first system wherever it can be completed. When the TSR (task to system ratio) was $\leqslant 4$, the temperature load factor was lower than the basic algorithm. But, when the value of TSR was > 4, the results were same for

Both the algorithms. Therefore, it can be said that when the TSR at any data centre is less than 4, it can use the proposed algorithm for power consumption.

*2) e-stab: Energy-efficient scheduling for cloud computing applications with traffic load balancing:* The e-STAB is another algorithm that provides the temperature load balancing which optimizes the power consumption by balancing the traffic flowing within the data centre network. e-STAB allocates jobs depending on the most available bandwidth on the network. e-STAB helps in improving the Quality of service of the cloud by decreasing the delays in communication and the packet losses that are related to congestion [6]. A group of S servers that are connected to the data centre network with the highest available bandwidth is selected such that at least one of those servers is able to put up with the computational demands of that job. The unused capacity of the link or the set of links that connects the group of servers to the rest of the data centre network is defined as the available bandwidth. Among the group of selected servers S, it selects the server which has the least computing capacity but it is enough for completing the task. [6]. For e-STAB the task completion delay stays constant at around 50 milliseconds whereas for Green algorithm, the delay keeps varying with an average of 78 milliseconds. Although there is 16% more power reduction in Green algorithm than the e-STAB.

## III. COMPARATIVE ANALYSIS

TABLE I
COMPARATIVE ANALYSIS OF VARIOUS GREEN CLOUD COMPUTING MECHANISMS

| Strategy | Performance measure | Power usage reduced | Algorithms/ Techniques used | Advantages | Limitations |
|---|---|---|---|---|---|
| Six discrete algorithms are proposed that set a similar optimal speed for the workflow and enhance the Usage under a deadline constraint. [1] | Energy Expenditure | 19% | STF-CME, LTF-CME, RT-CME, STF-RC, LTF-RC, RT-RC | High speed | Accuracy or efficiency might be less. No utilization of the idle time.(slacks) |
| DAG may also be used to model processes to optimize ECS using DVS. [2] | 1. Energy expenditure 2. Makespan. | 2% more than ECS | DAG | 1. Fast scheduling time. 2. Makespan optimization | Scheduling performance is often limited due to local optimum. |

| | | | | | |
|---|---|---|---|---|---|
| Implements DVFS to deliver an Equity amid energy usage and SLA. [13] | 1. Energy consumption 2. SLA violation | To be applied. | DVFS VM Migration | High Frequency processing. | Requires tighter over constraining of the input paths to the CPU interface. |
| e-STAB provides temperature load balancing optimizes power consumption by balancing traffic flow in data centre network | 1. Energy consumption 2. Load balancing | 16% | e-STAB | Reduces communication delays and congestion related packet losses | The power consumption is more than the Green Greedy Algorithm |
| Green Greedy Algorithm allocates a job to the system which has to bear the least load for running that job. [9] | 1. Power consumption 2. Task to System Ratio (TSR) | 16% more than e-STAB | Greedy Algorithm | Low power consumption | Number of cycles used for scheduling workflow is comparative-ly higher |
| Places the VMs initially to a host having minimum carbon footprint and optimizes current allocation of VMs in the data centre. [7] | 1. Energy efficiency 2. Carbon footprint 3. SLA violations | To be applied | 1. VM allocation to host in most carbon efficient data centre 2.MM Algorithm | 1. Carbon footprint & energy usage drops significantly. 2. Lower VM migration rate | Relatively lower energy efficiency is achieved. |
| Virtual machines are consolidated on a minimum number of active physical servers. VMs from overloaded hosts are live migrated to under loaded hosts. [11] | 1.Energy efficiency 2.CPU utilization & temperature. | 30% | 1. VM Consolidatio n 2.Live Migration | 1. Lower number of active servers in the datacentre 2. High CPU utilization and low temperature of hosts | Difficult to study utilization, temperature and power consumption together & balance their effects on large data centres for VM selection. |

| | | | | | |
|---|---|---|---|---|---|
| Overloaded and underutilized hosts are identified. VMs are selected to migrate from overloaded host onto underutilized host. [12] | 1.Energy efficiency 2.CPU utilization & temperature of hosts | >30% more efficient than other methods | 1.VM Selection 2.THR, IQR, MAD, LRR 3. TDR Best Fit Decreasing | 1.<50% VM migration than its counter parts 2. Low power usage and temperature of hosts. | Problematic to have a proper temperature control when only power or utilization of the host is considered. |

### IV. CONCLUSION AND FUTURE WORK

This paper performs comprehensive comparative analysis of various green cloud computing mechanisms. The analysis compares the mechanisms with respect to the reduction in energy usage and SLA violations. The comparison also compares different factors of the respective mechanisms. As a result of the analysis, we find that the power and thermal-aware VM migration mechanism is the best mechanism for Green Cloud Computing, as it showcases the most reduction in power usage, SLA violations as well as the number of VM migrations. The mechanism provides a spectacular >30% reduction in the power consumption. DVFS can only decrease the power usage by 19% and Green algorithms decrease up to 16%.

In the future, the power and thermal-aware VM migration and allocation mechanism can be improved to also consider the carbon footprint of the hosts and the data center. This will reduce the impact of the large data centers on the environment and make the cloud data center more energy efficient while reducing the release of greenhouse gases, such as, carbon-dioxide. Feasibility and practicability of the proposed future work.

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