WALAILAK JOURNAL
http://wjst.wu.ac.th MiniReview

A Survey on Various Problems and Techniques for Optimizing Energy Efficiency in Cloud Architecture

Sanjeevi PANDIYAN and Viswanathan PERUMAL*

School of Information Technology and Engineering, VIT University, Vellore 632014, India

(*Corresponding author's e-mail: viswatry2003@gmail.com)

Received: 11 August 2015, Revised: 21 May 2016, Accepted: 30 June 2016

Abstract

Cloud computing offers variety of resources and provides flexible services to users. The major issue ominous cloud computing is that it consumes servile amount of energy for providing a valuable computing services. Many attempts were taken to decrease the energy consumption of the data center yet the endeavors make less satisfaction. In this paper, a survey of energy consumption in the cloud computing is described a) Problems in the existing methods and energy reduction constraint used by various algorithms b) Comparison of various techniques with their findings emphasizing their advantages and disadvantages. Resource allocation in cloud is another issue in which energy can be reduced, and if a server is in idle it menaces enormous amount of energy and many algorithms were attempted to make the idle server to use in an efficient manner. Cooling of data center is also another enticing issue, because during heat the server consumes more energy and the stability of the system is reduced. Finally, the objective is to decrease the amount of energy consumed in data center leading to enhancement of Quality of Services (QoS).

Keywords: Energy consumption, data centers, DVFS, cloud computing

Introduction

Cloud data centers acts as a backbone of extensive assortment of cloud services obtainable via the network boast. The application caters various areas of ecommerce, social interacting, and a variety of services such as Software as a Service (SaaS), Platform as a service (PaaS), and Infrastructure as a Service (IaaS) [1]. Green cloud signifies data center's energy competence, and creates it greener through restricting the usage of energy in cloud data centers though executing confined workloads. It depends on 2 key modules: green cloud agreements and CO_2 discharge that centrist energy productivity of each cloud provider and cloud user, besides give enticement to providers to create their cloud service. Cooling of hosts in cloud data center is one of the servile characteristics that can restraint the energy consumption of the cloud data centers and is restraint through cooling administrator, and by cooling of cloud data center the heat is being decreased to normal promotes decreases the energy consumption of single host [2]. Decreasing the usage of energy in cloud data centers is an ambitious and difficult issue for computing jobs and data are developing contingently that progressively larger hosts and disks are required to ally them between the prerequisite times. Green computing is planned to attain not only the utilization of resource in a computing frame, but also bequeath to restraint the consumption of energy. This is vital for pleasantries that the future development of cloud computing is maintainable. Cloud with progressively general frontend client policies networking with backend cloud data centers will have a servile rise of energy utilization. To deal this problem and initiative green cloud, data center resources must to be sycophantic in a proficient method. In specific, cloud resources need to be assigned not only to fulfill QoS necessities stated by cloud users through Service Level Agreements (SLAs), but also trail to decrease energy utilization. To understand the prospective of cloud data center, cloud service providers must warrant that they can compromise in their provision distribution to satisfy various user requests, though keeping the users quarantined from the underlying IaaS infrastructure. Multi- tenancy Virtualized Public Cloud in IaaS is shown in **Figure 1**. Until lately, high performance stayed the solitary concern in cloud data center placements, and this request has been satisfied without reimbursing much consideration to consumption of energy. Though, a typical data center fulminates energy as 25,000 homes [3]. Usually, the cloud infrastructure is sycophantic through a third party, who extends computing resources accessible to users through network. With the development of innovative computation standards in data center it has been used to resolve complex problems related to workload proficiency in processing substantial amounts of records. Alternatively, given the controlling constraint to decrease the carbon footprint of environment, substantial research attempts have been focused concerning simulation centered energy utilization with its general aim to restraint energy consumption [4].

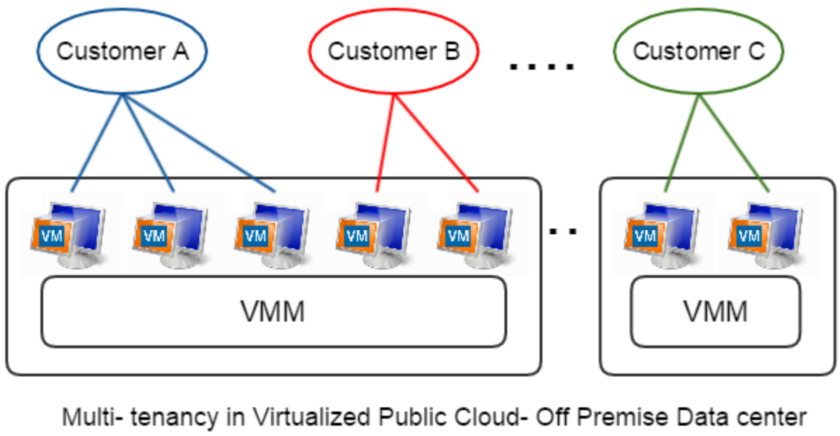

Figure 1 Multi- tenancy Virtualized Public Cloud in IaaS.

Energy usage analysis

PUE (Power Usage Effectiveness) is a standard to efficiently express of how energy is reused in cloud data center, and how significantly energy is in engaged via computing kit. PUE is calculated as;

$$PUE = Total\ Facility\ Energy / IT\ Equipment\ Energy \quad (1)$$

Data Center Infrastructure Efficiency (DCIE) a performance advancement metric job used to campaign energy efficiency of cloud data center [5]. DCIE is calculated as;

$$DCIE = 1 / PUE = IT\ Equipment\ Power / Total\ Facility\ Power \times 100\ \% \quad (2)$$

Background motivation to optimize energy in Cloud

In Beloglazov *et al*. [6], an architectural background and ideologies for energy effectual cloud computing is described, and they considered resource provisioning systems that blunts data center resources to user applications in an approach that increases the energy adeptness of a data center, deprived of violating SLAs. Their proposed Minimization of Migrations (MM) strategy chooses the lowest number of Virtual Machines (VMs) required to transfer from a host to eloquence the CPU utilization to decrease the power consumption of servers. In Wu *et al*. [7], they used Dynamic Voltage Frequency Scaling (DVFS) method for data center with scheduling process and arranges to idle mode to confine the energy consumption of the hosts. There are 2 methods in their proposed work. First is to deliver the realistic arrangement or scheduling a task. Second is to offer the suitable voltage and frequency resource for the hosts through DVFS method. Almost 5 - 25 % of energy is being condensed through their experimentation results.

In Sampaioa and Barbosa [8], they deliberated private cloud and created virtual clusters for cloud user workloads with energy efficiency by piloting arbitrary synthetic workloads of Google cloud trace records. About 12.9 % of energy is conserved and 15.9 % to State-of-the-art systems. They also investigated their energy consumption is less than other systems by measures ≥ 25 %. Studies in [9-11] uses various energy aware technique to decrease the consumption of energy in distributed systems. However, in these studies, the performance is boasted. Optimizing energy in cloud data centers takes computing in a different level of computation. Gradually cloud computing develops and its waves to the environment also gets distressed through its cost aspects. The key benefits of using cloud computing is that it rises the utilization of hardware tools. The purpose of IaaS supplier is to restraint the cost of cloud data center, in a way that it must not patchy the cloud users.

There are 2 details which ensued in more energy ingesting in data center. The first factor is hasty growing of CPUs in addition to the amount of cloud customers, which consequences in a substantial extent of energy spent in data center because of their enormous sizes. Secondly, resources distribution is not realistic in cloud. Resources (such as CPU, disk, memory, and bandwidth) provision suits an important problem which needs to be fixed, as arbitrary resources provision can lead to additional energy consumption in data center which is an important aspect of research in the arena of cloud.

Study and analysis

Problems and techniques in existing methods

One of the worldwide current thoughtfulness is to reduce power consumption in data centers and restraint greenhouse gas productions. Many approaches aftermaths to restraint the energy consumption in data centers, but the most efficient one is to also reduce the energy consumption of systems i.e. distribution of power and cooling system. With PUE of total energy expended by data center is 1.7, and loss of power dispersal is 8 %. This means even with improved technology the energy reduction will not surpass 8 %. To decrease the energy intake of cooling system, Google uses free cooling mode. Reducing heat is one of the main problems in servers, consequently many cloud providers eliminate the heat from servers through disappearing water or reducing temperature air. Although this method is useful, the economic and practical strength should be higher for providers to run data centers through worldwide and backup data is one of the privileged task of computational loads. Many companies are being focused to improve their hardware components to save energy but there are still many reforms possibility to save energy on system operation also. The energy consumption of the single data center costs up to $9.2 billion in a year [12]. In servers, power metrics is more common due to energy consumption, since extent of that one VM in server consumes more energy and the power meters' problem remains constant [13]. Integrating the power measurement is being followed by many vendors in order to monitor the server consumption, by doing this mechanism the power consumption of the total system can be measured, but the aim of measuring the power consumption of a single VM cannot be billed is considered as a disadvantage [14].

Encourage of the previous investigates, the scheming of energy ingestion in a single VM is very problematic due to the following explanations. Integrated power meters for the sampling intervals lies between 1 and 0.1 s [15]. However, the interval taken for centrist is very short oscillating through few hundred microsecond or in milliseconds, hence it is very agonized to scale the setting-up, and measurement is difficult to recognize the energy consumption of a single VM because there are bulky number of VM that are opposing to the processor. According to State of the cloud, 94 percent of establishments measured are consecutively claims or straddle with IaaS [16].

Idle hosts consume more power, so turning off hosts when not in usage is assessed as alternative way to restraint the consumption of power. Several explanations are embraced which fundamentally classified into devious energy capable network or moreover launching hosts by energy aware virtualization. Virtualization procedures can be extremely valuable in developing high-level application because virtualization techniques hook the hardware necessities, and it is functioned in an aggressive manner however, in case of low level application assets can execute in a single hardware. Later, idle hosts can turn off to preserve energy. Subsequently, VMs are relocated, produced, and terminated from one host to another deregulates enormous extent of energy [17,18]. To advance the energy proficiency of hosts, the agreement of scheduling job with data assignment is engaged first and execution to the modification of the network state and multi job programming is taken into account to protect energy in hosts [19].

Placement of VMs is moreover a major assessment in servile the energy. Observing the energy and the VMs assignment is a substantial concern in the cloud data center. A scheduling technique is presented to decrease the consumption of energy in cloud data center without decreasing client performance. RESCUE (an energy aware Scheduler) is being presented in private cloud. The RESCUE is the connotation between the software, energy efficiency, and the hardware. Grade of nodes is made in the cloud centered on their relation between their hardware, energy efficiency and the software. The Same performance is also well-maintained and RESCUE allocates the workloads to improve the energy efficiency. RESCUE is instigated in the varied because of the below reasons: 1) Hardware elements cannot be resolute because it is identified to fail. 2) Scalability is one of the identified term in data center and if the workload rises the new servers is being added. This is uncertainty in its nature. To describe the uncertainty in the cloud computing environment servile the number theory and its intermissions to describe the uncertainty bearing and a scheduling architecture is being introduced for enlightening the quality of scheduling task in the cloud data center. Based on the combativeness to enlarge resources properly and to improve the energy efficiency they proposed 3 approaches for scaling computing resources. DVFS and machine virtualization are the most commonly used techniques than many other scheduling algorithms in Energy-aware. The power and performance of processor in trade off are frequently used to lessen energy ingestion in data centers by using the DVFS procedure.

The uncertainty-aware scheduling architecture

An interval number theory is familiarized to define the uncertainty of the cloud environment and a scheduling framework to lessen the effect of uncertainty on the job scheduling feature in a data center. Based on this framework, they contemporary a novel scheduling algorithm named Proactive and Reactive Scheduling (PRS) [20] that manipulates active and responsive scheduling approaches, for scheduling real-time and independent tasks. The benefits are given below:

- Prohibited of notion of the algorithm, if the number of task in the waiting queue rises it shrinks reliability of the system. Since the errands are directed in the VM, it becomes loaded and consume more energy, so lessening the count of task that are waiting to escape uncertainties.
- The system manner is measured in a way that as soon as the task that are in the waiting queue has finished its process next task is scheduled routinely, and the fresh task delay is omitted. In this scheduling method VM can straightly take the task from the waiting queue. This scheme saves the computational time and traction between them has become inveterate to improvement the performance of scheduling. When there is a requirement to voyage VMs, the transmission of task midst the host is reduced in overheads. When VM is being pooled, the waiting task present in the present VM is also wandered to the migrated VM which is the main motive of triggering overheads.

The power must be obtainable in an ample quantity to the cloud infrastructure, regular energy consumption does not have much influence, but the greatest power consumption can affect cost and constancy of system, the greatest consumption of power is more concerned than the servers. To make more energy efficient each VM is being deliberate to the physical servers' combativeness to advance energy, and the mapping techniques reductions the overall energy consumption but does not able to controller energy consumption of each VM. The software approach that is used to extent the energy consumption is the Joule meter [21] in which apiece VM energy ingesting is energetically pragmatic by using 2 energy estimate models. The first model calculates the energy consumption by thriving the average influence ingesting of the processor time, using this process it artworks a deprived accuracy. In second model, power ingesting of the entire system is being analyzed through integrated power consumption. Every time a new VM is formed the estimation is considered statically.

The important objective of detailed mapping research is to recognize the factors of cloud computing energy reduction aspects, which are given below:

DVFS: DVFS is commonly used as power handling method, where the clock regularity of a CPU is reduced to permit an equivalent decrease in the supply voltage. To employ the resources in a well-organized way, and to decrease the consumption of energy in data center DVFS method is commonly used. Several scheduling methods are executed using DVFS method for decreasing CO_2 discharge to achieve green computing. Various green cloud method is projected to decrease CO^2 discharge. Several characteristics like VM migration, and placement of VMs are projected in green cloud using DVFS [35].

DVFS is authorized in the core of Linux ever since 2001 [36]. It is capable to be recycled by involving the *cpufrequtils* policy, and its accounts gives complete statistics about all performance. The DVFS division authorizes the technique to regulate between the 5 different means for every handler's correctness, by choosing their administrator.

Load balancing: A load balancing system efforts to increase the response time of cloud user's submitted workloads by straddling utmost utilization of offered resources. Load balancing method is a procedure in which no node of a host residues in idle state while others are over employed. Significant goals of load balancing system are cost efficiency, flexibility, and ranking resources.

VM scheduling is maintained in Cloudsim [37] at 2 levels i.e. host level and the VM level. Between all the modules in cloud environment, load balancing is a certainly significant one. Load balancing retains a distinct resources provision policy subsequently to have a determined throughput. Data center manager practices VM load balancer to regulate which VM must be assigned (Cloudlet) for execution. Load balancers, additionally, utilize an effectual load balancing system with the intention to show the demand for the best appropriate VM. A desirable scheduling method is the substantial key to achieve load balancing among dissimilar mechanisms, and rises the placement of computing resources.

Virtualization: The key characteristic of cloud is the usage of virtualization. VM runs over the offered hardware to deal the customer requests. VM administration forms a vital part of this perception, and is achieved through a loyal part termed as hypervisor. Due to several benefits of virtualization many organizations including Amazon EC2 [38] employ on virtualization.

The assortment of VMs when the jobs are executed is done through the load balancer, whose goal is to allocate the job in a way that no VM is swamped by customer requests formerly, while enduring idle at other times. Beyond this stage lies alternative abstraction called the cloud broker, which is the transitional among the cloud users of the cloud provider. It utilizes the prevailing broker strategies akin to conditioning the customer demand to the best suitable data center. Consequently, assortment of the best strategy chooses the response time of a specific request and competence of usage of data center. Similarly, the hardware maintains on altering time to time conferring to the user necessity [39,40].

Resource allocation: Resource allocation is an essential, sycophantic part of several data center administration problems such as VM assignment in data centers, network virtualization, and multi-path network routing. Resource finding recognizes the appropriate physical resources wherein the VMs are to be produced identical to the user's demand. Resource scheduling picks the centrist resource from the corresponding physical resources.

Comparison of existing methods

The existing techniques are lacked in various aspects in energy reduction which is compared and illustrated with their findings in **Table 1** and with their metrics in **Table 2**.

Table 1 Comparison of existing energy reduction techniques in cloud.

Techniques	Findings	Advantages	Disadvantages
Cloud Workload Management Framework (CWMF) [22]	i. Over K-means the workload of the cloud is acknowledged and clustered. ii. Through the assistance of cloud workloads, QoS and efficient management is achieved.	i. CWMF is established on Decision tree based arrangement that permits the mapping and implementation of cloud assignment conferring to cloud user requests. ii. Associated to the existing scheduling algorithms the agenda is being done in a way that it shrinks the energy and cost.	CWMF fails to analyze the decision tree which is used to choose the precise scheduling strategy established on user workload details.
Depth-First Search (DFS) [23]	At the runtime expending the DFS the clash of offloading is deliberated.	i. The no-partitioning algorithm and static partitioning algorithm is associated to advance energy. ii. The authority of the energy in separating and stationary is improved by 0 - 1 ILP.	The major disadvantage of transfer based partitioning technique is that at advanced graph complexity their performance decreases.
Link selection [24]	i. By preserving constancy of the mobile device the energy consumption of the scheme is organized and lessened. ii. Using Eco Plan, WIFI, and SALSA systems are scrutinized and outlined.	i. The problematic of energy consumption is verbalized and the stability restriction of the mobile devices is preserved. ii. Eco Plan wheels the rulings on the fly without subjective dealings.	While selection may service to lessen the computing and storing limitation of mobile devices, it statically facades great experiment in real-world application (e.g., amplified authenticity and isolated healthcare) because of energy deficiency in mobile devices.
Smart Energy-Aware Task Scheduling (SEATS) [25]	To lessen the energy level in the host by means of the VM scheduling algorithm	Approximately 60 % of the energy consumption of a cloud is abridged and acquiescent the task which is long and attractive tiny deadlines.	The responsibility of a VM manager is to control the storage constraint every time, and it fails to warranties that each VM running on its extreme MIPS on its assigned server based on the requirement.
Vertical handoff algorithm [26]	The mobile device energy consumption is abridged and the exploiting the service handiness to users.	The handoff algorithm is used to find the construction time and the reserve announcement.	The energy requisite for handling and conveying workloads have direct relation with consumption of energy, the association time is allied to accessibility of service fails to convey the delay time which has effect on consumption of energy in addition to accessibility of service.

Techniques	Findings	Advantages	Disadvantages
Priced timed automaton [27]	The path energy ingesting is lessened by using the projected algorithm.	Traditional scheduling algorithms is associated to the proposed algorithm to lessen the energy consumption.	When additional VM is being administered task is transferred into the confined cloud server, which is on sleep state, and they fail to analyze the migration into local cloud server.
Window-K [28]	i. Diminish the row time, response time, and vitality ingesting. ii. Make the most of the complete system positioning.	The performance is predictable by 3 metrics (queue time, response time, and slowdown ratio) and integrated the energy effectiveness.	The finishing time and consumption of energy in the machine is diminished and fails to analyze the workload parameters considered for task deadline.
MAPE-K [29]	For constructing the data padding amenities, the virtual devices are pondered and to squelch SLA damages.	By consuming the concrete connotations, the linkage reputes the cloud as part is managed.	MAPE-K explains the cloud storage services as “virtual” sensors that frequently discharges monitoring data, but fails to encounter SLAs associated with cloud users formerly using the service.
Overload Decision Algorithm (ODA) [30]	i. To diminish and maximize the utilization strategy to expand power ingestion. ii. SLA destruction is also supervised to take conclusion.	i. 21 to 34 % of tradable in the energy consumption. ii. 63 % of lessening in the accomplishment time.	ODA maintenances both system and performance modeling of cloud system modules but fails to analyze resource provisioning strategies for energy-efficient administration in cloud.
Utilization and Minimum Correlation (UMC) [31]	The QoS aware VMs consolidation technique is casted off to contrivance based on the submission of the virtual mechanism history.	i. The number of VM relocation is reduced. ii. SLAV and total conveyed data are coordinated to the existing algorithms to advance the energy ingesting.	They choose random variables to represent the CPU usage but in reality the random variable fails to meet the QoS requirement of users.
Task Scheduling Algorithm based on Similar Tasks (TSAST) [32]	They designed a scheduling model based on vacation queuing model to heterogeneous cloud system.	They evaluated the prospects of assignment vacation time and energy consumption in cloud to compute nodes	Scheduling is incorporated in similar tasks to monitor system performance.
Approximate Dynamic Programming Algorithm (ADP) [33]	i. They framed the problem as stochastic dynamic program (SDP) that targets to increase energy consumption and throughput of the system. ii. To explain the framed SDP, they then intended a mountable ADP process that does not demand the indicators of data arrival	Virtual reality studies illustrates that their anticipated ADP algorithm can decrease the regular energy spent for providing a packet by an extreme of above 40 % matched to unusual SDP strategies.	Unlike typical reluctant programming, it forwards over time and depends on estimated value utility for decision-making.

Techniques	Findings	Advantages	Disadvantages
EARH Scheduling model [34]	i. To address task adapted environment they propose a novel rolling-horizon arrangement exemplary model for virtualized clouds. ii. Based on their scheduling, they developed an algorithm termed EARH for real-time tasks.	They established strategies aimed at VM creation, relocation and termination to enthusiastically regulate the balance of cloud, real-time necessities and motivated to protect energy.	EARH holds both new tasks and waiting tasks to be executed but fails to implement the urgent tasks which is an important constraint in QoS metric

Table 2 Metrics considered in existing energy reduction techniques in cloud.

Techniques	Performance	Scalability	Resource utilization
T1 [22]	✓	×	✓
T2 [23]	✓	×	✓
T3 [24]	✓	×	×
T4 [25]	✓	×	✓
T5 [26]	✓	✓	✓
T6 [27]	×	×	✓
T7 [28]	✓	×	✓
T8 [29]	✓	×	✓
T9 [30]	×	✓	×
T10 [31]	✓	×	✓
T11 [32]	✓	×	✓
T12 [33]	✓	✓	✓
T13 [34]	✓	×	✓

Conclusions

In this paper we scrutinized and survey about the various energy consumption problems and techniques to save the energy consumption by using methods like DVFS, Rescue, and uncertainty. Cloud computing provides the perfect services to both the cloud earners and the cloud users. The ambiguity aware scheduler is also analyzed and various algorithms are inspected that affords the better performance, efficiency, encounter the essential SLA, and gloomy the power consumption. Resource management stages and the hardware level that shelters the hybrid approaches requests to be progressive to deliver the capable energy management in virtualized cloud data centers. We hope that this paper will arouse researches to verbalize new demonstrations on several energy reduction methods in cloud.

Acknowledgments

A special note of thanks to Vellore Institute of Technology (VIT) University for providing necessary infrastructure facilities to carry out the research work and my friends who has helped me to complete this study. Comments from anonymous reviewers were very supportive in improving the organization and presentation of the paper.

References

[1] K Kant. Data center evolution: A tutorial on state of the art, issues, and challenges. *J. Comput. Netw.* 2009; **53**, 2939-65.
[2] Anusuya and Krishnapriya. Green cloud: A pocket-level simulator with on-demand protocol for energy-aware cloud data centers. *Int. J. Sci. Res*. 2014; **3**, 10-6.
[3] A Beloglazov, R Buyya, YC Lee and A Zomaya. A taxonomy and survey of energy-efficient data centers and cloud computing systems. *Adv. Comput*. 2010; **82**, 47-111.
[4] I Petri, H Li, Y Rezgui, Y Chunfeng, B Yuce and B Jayan. A HPC based cloud model for real-time energy optimization. *Enterp. Inform. Syst.* 2016; **10**, 108-28.
[5] PT Jaeger, J Lin and JM Grimes. Cloud computing and information policy: Computing in a policy cloud. *J. Inform. Tech. Polit.* 2008; **5**, 269-83.
[6] A Beloglazov, J Abawajy and R Buyya. Energy-aware resource allocation heuristics for efficient management of data centers for cloud computing. *Future Generat. Comput. Syst.* 2012; **28**, 755-68.
[7] CM Wu, RS Chang and HY Chan. A green energy-efficient scheduling algorithm using the DVFS technique for cloud data centers. *Future Generat. Comput. Syst.* 2014; **37**, 141-7.
[8] AM Sampaioa and JG Barbosa. Towards high-available and energy-efficient virtual computing environments in the cloud. *Future Generat. Comput. Syst.* 2014; **40**, 30-43.
[9] P Raycroft, R Jansen, M Jarus and PR Brenner. Performance bounded energy efficient virtual machine allocation in the global cloud. *Sustain. Comput. Inform. Syst.* 2014; **4**, 1-9.
[10] Q Zhang, G Metri, S Raghavan and W Shi. RESCUE: An energy-aware scheduler for cloud environments. *Sustain. Comput. Inform. Syst*. 2014; **4**, 215-24.
[11] J Cao, K Li and I Stojmenovic. Optimal power allocation and load distribution for multiple heterogeneous multicore server processors across clouds and data centers. *IEEE Trans. Comput.* 2014; **63**, 45-58.
[12] A Greenberg, J Hamilton, A David and P Patel. The cost of a cloud: Research problems in data center networks. *ACM SIGCOMM Comput. Commun*. 2009; **39**, 68-73.
[13] N Kim, J Cho and E Seo. Energy-credit scheduler: An energy-aware virtual machine scheduler for cloud systems. *Future Generat. Comput. Syst.* 2014; **32**, 128-37.
[14] Enhanced Power Monitoring for Dell PowerEdge Servers, Available at: www.dell.com/downloads/global/power/ps3q08-20080174-Bhadri.pdf, accessed July 2015.
[15] Architecture (DESA) for 11G Rack and Tower Servers, Available at: www.dell.com/downloads/global/products/pedge/en/poweredge-11g-desa-white-paper.pdf, accessed July 2015.
[16] SE Dashti and AM Rahmani. Dynamic VMs placement for energy efficiency by PSO in cloud computing. *J. Exp. Theor. Artif. Intell.* 2016; **28**, 97-112.
[17] A Tchana, ST Giang and L Broto. Two levels autonomic resource management in virtualized IaaS. *Future Generat. Comput. Syst.* 2013; **29**, 1319-32.
[18] RN Calheiros, AN Toosi, C Vecchiola and R Buyya. A coordinator for scaling elastic applications across multiple clouds. *Future Generat. Comput. Syst.* 2012; **28**, 1350-62.
[19] X Wang, Y Wang and Y Cui. A new multi-objective bi-level programming model for energy and locality aware multi-job scheduling in cloud computing. *Future Generat. Comput. Syst.* 2014; **36**, 91-101.
[20] H Chen, X Zhu, H Guob, J Zhu, X Qin and J Wud. Towards energy-efficient scheduling for real-time tasks under uncertain cloud computing environment. *J. Syst. Softw.* 2015; **99**, 20-35.
[21] A Kansal, F Zhao, J Liu, N Kothari and AA Bhattacharya. Virtual machine power metering and provisioning. *In*: Proceedings of the 1st ACM Symposium on Cloud Computing, New York, USA, 2010, p. 39-50.
[22] S Singh and I Chana. QRSF: QoS-aware resource scheduling framework in cloud computing. *J. Supercomput.* 2015; **71**, 241-92.
[23] V Pandey, S Singh and S Tapaswi. Energy and time efficient algorithm for cloud offloading using dynamic profiling. *Wirel. Pers. Commun.* 2014; **80**, 1687-701.

[24] X Xiang, C Lin and X Chen. EcoPlan: Energy-efficient downlink and uplink data transmission in mobile cloud computing. *Wirel. Netw.* 2014; **21**, 453-66.
[25] S Hosseinimotlagh, F Khunjush and R Samadzadeh. SEATS: Smart energy-aware task scheduling in real-time cloud computing. *J. Supercomput.* 2015; **71**, 45-66.
[26] A Ravi and SK Peddoju. Handoff strategy for improving energy efficiency and cloud service availability for mobile devices. *Wirel. Pers. Commun.* 2014; **81**, 101-32.
[27] Z Deng, G Zeng, Q He, Y Zhong and W Wang. Using priced timed automaton to analyse the energy consumption in cloud computing environment. *Cluster Comput.* 2014; **17**, 1295-307.
[28] AA Chandio, K Bilal, N Tziritas, Z Yu, Q Jiang, SU Khan and CZ Xu. A comparative study on resource allocation and energy efficient job scheduling strategies in large-scale parallel computing systems. *Cluster Comput.* 2014; **17**, 1349-67.
[29] R Dautov, I Paraskakis and M Stannett. Towards a framework for monitoring cloud application platforms as sensor networks. *Cluster Comput.* 2014; **17**, 1203-13.
[30] Z Cao and S Dong. An energy-aware heuristic framework for virtual machine consolidation in Cloud computing. *J. Supercomput.* 2014; **69**, 429-51.
[31] A Horri, MS Mozafari and G Dastghaibyfard. Novel resource allocation algorithms to performance and energy efficiency in cloud computing. *J. Supercomput.* 2014; **69**, 1445-61.
[32] C Cheng, J Li and Y Wang. An energy-saving task scheduling strategy based on vacation queuing theory in cloud computing. *Tsinghua Sci. Tech*. 2015; **20**, 28-39.
[33] X Xiang, C Lin and X Chen. Energy-efficient link selection and transmission scheduling in mobile cloud computing. *IEEE Wirel. Commun. Lett.* 2014; **3**, 153-6.
[34] L Yang, X Zhu, H Chen, J Wang, S Yin and X Liu. Real-time tasks oriented energy-aware scheduling in virtualized clouds. *IEEE Trans. Cloud Comput.* 2014; **2**, 168-80.
[35] P Chauhan and M Gupta. Energy aware cloud computing using dynamic voltage frequency scaling. *Int. J. Comput. Sci. Tech.* 2014; **5**, 195-9.
[36] T Guerout, T Monteil, GD Costa, RN Calheiros, R Buyya and M Alexandru. Energy-aware simulation with DVFS. *Simulat. Model. Pract. Theor.* 2013; **39**, 76-91.
[37] R Kumar and G Sahoo. Cloud computing simulation using cloudSim. *Int. J. Eng. Trends Tech.* 2014; **8**, 82-6.
[38] P Sanjeevi, V Perumal, MR Babu and PV Krishna. Study and analysis of energy issues in cloud computing. *Int. J. Appl. Eng. Res.* 2015; **10**, 16961-9.
[39] D Bhatt. A revolution in information technology: Cloud computing. *Walailak J. Sci. & Tech.* 2012; **9**, 107-13.
[40] P Sanjeevi and P Viswanathan. A green energy optimized scheduling algorithm for cloud data centers. *In*: Proceedings of the IEEE International Conference on Computing and Network Communications, Trivandrum, India, 2015, p. 941-5.