A Study of Efficient Energy Management Techniques for Cloud Computing Environment

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Abstract—The overall performance of the development of computing systems has been engrossed on enhancing demand from the client and enterprise domains. But, the intake of ever-increasing energy for computing systems has commenced to bound in increasing overall performance due to heavy electric payments and carbon dioxide emission. The growth in server’s power consumption is increased continuously; and many researchers proposed, if this pattern repeats continuously, then the power consumption cost of a server over its lifespan would be higher than its hardware prices. The power intake troubles more for clusters, grids, and clouds, which encompass numerous thousand heterogeneous servers. Continuous efforts have been done to reduce the electricity intake of these massive-scale infrastructures. To identify the challenges and required future enhancements in the field of efficient energy consumption in Cloud Computing, it is necessary to synthesize and categorize the research and development done so far. In this paper, the authors discuss the reasons and problems associated with huge energy consumption by Cloud datacentres and prepare a taxonomy of huge energy consumption problems and its related solutions. The authors cover all aspects of energy consumption by Cloud datacentres and analyze many research papers to find the better solution for efficient energy consumption. This work gives an overall information regarding energy-consumption problems of Cloud datacentres and energy-efficient solutions for this problem. The paper is concluded with a conversation of future enhancement and development in energy-efficient methods in Cloud Computing.

Keywords—Energy-efficiency; Virtualization; DVFS; VM-Consolidation; VM-Migration; Cloud Datacentres; VM-Allocation.

I. INTRODUCTION

Cloud Computing is the uprising model in ICT that makes computing trustworthy, dynamic, convenient, and rapidly fast. Cloud Computing has merited over traditional computing as it possesses nimbleness, device undependability and ascendable characteristic [1][2][3]. A Datacenter is like a farmstead that holds huge number of servers which provide data management, networking, data storage, backup and recovery [4]. Half of the energy supplied to a datacenter is used by cooling system at the infrastructure level and a lot of energy is being used by systems when they are in the idle state [5]. Both the providers and users get financial loss from such type of wastes. As per the report by Gartner [6], the cloud datacenters having the electricity consumption, that will be increased to the 0.1202 Billion kWh by 2020. By considering the complications related to datacenters, energy efficiency and the trustworthiness are the two major challenges in today’s scenario. With the growing capabilities of datacenters, if efficient power management tactics are not applied, then power consumption of datacenters will be increased continuously. The report [7] says, the total worldwide power consumption by the datacentres in 2015 was almost 416.2 terawatt which is more than the energy consumption of the United Kingdom. The Cloud Computing infrastructure is one of the major importers to carbon emission. Cloud vendors like Google, Amazon have been working so as to produce the cloud services that are eco-friendly and efficient [8]. In response to these, several researchers around the world have suggested many algorithms architectures and different policies build the cloud computing environment trustworthy and power efficient. This paper gives the overview and classification of enormous energy consumption problems and its related solutions also it suggests various energy efficiency techniques to improve resource utilization and power consumption in cloud datacenters.

Rest sections of the paper are as follows. In section II, related works have been discussed. Section III gives a taxonomy of various energy efficient techniques and discussion on these techniques are mentioned in section IV. Section V concludes the paper.

II. RELATED WORKS

Cloud computing has changed the IT industry by providing an elastic on-demand allocation of computational resources comprising processors, storage & networks which is accompanied by creation, modification, and enhancement of large-scale systems consisting of cluster, grids and Cloud datacenters. This system leads to a lot of energy consumption and significant CO₂ emissions. Due to the increased quantity of computational resources, the energy bills come as the second largest items in the budgets of Cloud service providers. Many researchers have been worked to enhance the effective energy utilization in Cloud datacenters and proposed many algorithms related to virtual machine migration, consolidation, and VM allocation. Various task scheduling parameters in Cloud Computing have been discussed in the paper [9], energy-efficiency is more concern parameter of today’s research community. In paper [10], the author gives an absolute review
of currently alive techniques for energy regulation and reliability. To improve the availability for the cloud services, energy-aware resource provisioning strategy is identified simultaneously minimizing its energy consumption. Several challenges and research gaps for future research and developments for a trade-off between energy regulation and reliability are also identified. Another review paper [11] summed up with a few existing energy scheduling algorithms taken up in a cloud environment also the energy saving percentage in present energy-efficient scheduling algorithms. The results reveal the best energy saving proportion level can be attained by using DVFS and DNS both. In paper [12], the author discussed the double role of Cloud Computing as a huge power consumer and as an energy saving method with compare to traditional computing systems. This paper gives a comprehensive and relative study of several energy efficient methods in Cloud Computing. The power consumption of ICT equipment is discussed in the paper [13]. The authors give a classification of power and system performance based efficient methods for grid, cluster and Cloud datacenters. This survey is different from other surveys because it discussed both aspects of power consumption and system performance of ICT equipment. In this paper, the author also presents a taxonomy of energy-efficient techniques and discussed various methods, concerning energy efficiency and other related parameters of Cloud Computing.

III. TAXONOMY OF ENERGY-EFFICIENT TECHNIQUES

Energy conscious scheduling such as DVFS, energy efficient load balancing, virtualization, resource consolidation, and migration are mostly reviewed for knowledge and practical implementations. Many researchers worked for efficient power consumption in Cloud Computing. In this paper author categories, these techniques in different ways and describes the method, improvements, and limitation of these techniques.

Figure-1 presents the taxonomy of various energy efficient techniques. The author further discusses all these techniques one by one and give a detailed description and study of these algorithms in table-1.

A. Virtual Machine (VM) Selection Methods

- Random VM selection: A uniform distributed discrete random variable is used to select the virtual machine from the overloaded server for migration [14].
- Minimum migration time: Migration time of the virtual machine is considered as the ratio of the quantity of RAM utilization of virtual machine to the server’s bandwidth that hosted virtual machine. In this method of VM selection for migration, a VM having minimum migration time is select for migration in comparison to other VMs [15] [16].
- Minimum utilization: Physical resource utilization by the virtual machine is considered as the ratio of the volume of resource utilized by the virtual machine due to user’s tasks allocated to that VM and total MIPS allocated to that VM. And in this method [15] a VM which has minimum utilization has to be select for migration.
- Least VM in CPU utilization first: In this method of VM selection [17], a VM which has share least CPU time with other virtual machines (VMs) allocated to the same server has been selected for migration.
- Maximum correlation: Multiple correlation coefficient [18] is used to calculate the correlation among the virtual machines hosted on the same server. In this method [15] [19] a VM with a maximum correlation of CPU usage with the others VMs has been selected for migration.

B. Virtual Machine (VM) Placement Methods

For developing Cloud datacentres, energy consumption is the main concern. Several methods and techniques have been proposed to reduce energy consumption but these techniques are mainly having more VM migration and less resource utilization.

In paper [20] the authors proposed a VM placement technique based on a heuristic greedy algorithm. In this algorithm, the author develops a VM deployment and live migration model to improve resource utilization and decrease power consumption. The heuristic algorithm predicts the workload and mapped CPU-intensive workload and memory-intensive workload to the same physical server to reduce energy usage by the different servers and balancing the workload.

In paper [21], the author developed a statistical mathematical framework for VM placement, which integrates complete virtualization expenses in the dynamic migration process. The proposed dynamic virtual machine placement method enables VM request scheduling and lives migration to
reduce the active server participation so as to reduce the power
consumptions in Cloud datacentres.

The author proposed a VM allocation method [22], based
on minimum virtual machine migration. Three strategies
named fixed double threshold, double resource threshold and
dynamic double threshold are developed and two phases in
each strategy are used. In the first phase, VM selection is made
and selected VM is placed on a physical datacentre in the
second phase. The result shows that these lower and upper
bound resource utilization threshold policies are better than the
single threshold technique. These methods determine less
power consumption, a smaller number of SLA violations and a
minimum number of VM migration.

The main concern of Cloud service provider is to answer
two questions, where to place VMs initially and where to
transfer VMs, when VM-migrations are required. VM
migration is helpful to reduce datacentre overloading and
reduce active servers’ involvement for effective resource
utilization and power saving. It is important to detect
overloaded servers efficiently for better performance and
minimum service cost of Cloud system. In [23], a logistic
regression and median absolute derivation methods are used to
proposed a general detection algorithm for the overloaded
server. Any VM placement and migration algorithms can
detect overloaded server with this detection algorithm.

In [24], the authors have presented an algorithm which is
task-based virtual machine placement algorithm, in which tasks
are mapped to the VMs according to their demand and VMs
are placed to physical machine accordingly. The algorithm
reduces the number of active servers involved in serving VMs
to reduce energy consumption. It also reduces the task rejection
rate and makespan of the Cloud system.

C. Virtual Machine (VM) Migration Methods

An energy consumption model is proposed in paper [25]
which is based on the statistical method and can estimate the
VM power consumption with the error rate of 3%-6%. In this
method, a workload threshold is set for each server, and if a
server exceeds its workload threshold then the VM will be
migrated from that overloaded server to another server to
reduce the energy consumption by the overloaded server. This
method can achieve an effective reduction in power
consumption without violating the QoS.

A linear integer programming model and bin packaging
model are used in [26], to develop two exact algorithms for
VMs placement and consolidation for reducing power consumption and VM migration cost and compared with the
heuristic based best-fit algorithm. The results show that the
combination of these two algorithms contributes to a
significant reduction in power consumption.

In the paper [22], the authors have proposed three policies
for VM placement and migration. When the number of VM
placement increased o server then due to overload the VM
migration is required. Which server has to be select for VM
migration is dependent on these policies named FDT, DRT,
and DDT. These are three different methods for selection of the
server for migration according to the threshold set by these
policies.

D. DVFS-Aware Consolidation Methods

More than 43 million ton of CO2 emission per year and
about 2% of the world’s power production has been consumed
by the Cloud datacentres. In paper [27], the author proposed
two methods, one for efficient power consumption based on
DVFS technique and second for VM consolidation. The first
method is used to determine performance degradation with
power consumption and gives a DVFS-aware workload
management which saves energy up to 39.14% for dynamic
workload situations. The second VM consolidation method is
also determined dynamic frequency while allocating workload
to achieve QoS.

There are different types of physical machines are available
in Cloud datacentres. This machine heterogeneity consumes
more energy when workloads have been scheduled on them. A
job consolidation algorithm with DVFS technique is proposed
in paper [28], for efficient resource utilization in heterogeneic
Cloud physical machines. The proposed algorithm will replace
jobs efficiently to reduce energy consumption.

E. Virtual Machine (VM) Scheduling Methods

In this paper [29], the author proposed an online scheduling
algorithm for IaaS Cloud model for reduction in energy
consumption. The algorithm works for heterogeneous
machines and different workload scenario to achieve a better
quality of service.

One way to reduce energy consumption in Cloud
datacentres is to shut down physical servers which are idle. In
paper [30], an energy-aware virtual machine scheduling
algorithm has been proposed named as dynamic round robin
algorithm. The results showed that the algorithm saves 43.7%
energy and 60% of physical machine usage compared with
other scheduling algorithms.

The authors suggest a model [31] for energy consumption
estimation, which considered the running tasks created by
virtual machine for estimation of each VM’s power
consumption. The suggested model also schedules the VMs to
confirm the energy cost of each VM.

Most of the energy efficient methods use VM migration
technique but in the paper [32], the author proposed an energy-
aware virtual machine scheduling algorithm EMinTRE-LFT,
which is based on the concept i.e., decrease in power
consumption is directly equivalent to minimization in the
completion time of all physical servers. The author used
OpenStack Nova scheduler for simulation and compare it with
other algorithms.

The Cloud scheduling algorithms face many challenges due
to the dynamic and unpredictable nature of Cloud user’s
request. In this paper [33], the author proposed an algorithm
which does not require any prior knowledge of user’s request.
The author conducted a mathematical analysis to find the
balance between energy consumption and system performance.
A real-time dynamic scheduling algorithm is proposed in paper [34], which schedule distributed application in a distributed system to reduce the power consumption. The proposed algorithm uses heuristics and resource allocation techniques to get the optimal solution. It minimizes the power consumption and task execution time with order dependent setup between tasks for VM and power setup for different Cloud designs.

### F. Virtual Machine (VM) Allocation Methods

The authors proposed an interior search based virtual machine allocation algorithm for efficient energy consumption and proper resource utilization in the paper [35]. The model and simulation of the proposed algorithm are tested on CloudSim and compared the amount of energy consumption with the Genetic Algorithm (GA) and Best-fit Decreasing (BFD) algorithm.

Cloud provider allocates VMs to the customer’s application according to their demand, and these VMs are assigned to the physical machines. Many resource allocation methods use VMs resource utilization history for efficient resource allocation. In paper [36], the author proposed a QoS-aware virtual machine allocation method based on resource utilization history to improve the level of quality of services and reduce energy consumption.

Cloud datacentres provide services to Cloud applications which consume a huge amount of energy and produce carbon emission. To overcome from this issue, the author proposed an energy-aware VM allocation algorithm in [14], that provision and schedule Cloud datacentre resources to the user’s tasks in an efficient manner that reduces energy consumption level of datacentres and improve the quality of service.

Many researchers worked for energy efficiency in Cloud Computing but some researchers are working for energy efficiency in a specific type of Datacentres. In paper [37], the author proposed an efficient power consumption algorithm for video streaming datacentres. They proposed a method for VM management with the power-law feature. It predicts the future resource usage of VM, according to the popularity of video and arranges sufficient resources for that VM and shut down the idle servers on the datacentres to reduce power consumption. The results showed that this algorithm reduced more power consumption compared with Nash and Best-fit algorithm.

| Energy Efficient Algorithm | Techniques | Findings | Parameters Improved | Experimental Tool | Environment |
|----------------------------|------------|----------|---------------------|-------------------|-------------|
| Energy-aware resource allocation heuristic algorithm [14] | VM-Selection | Uniform Distributed Discrete Random Variable is used for VM-Selection | Maintain QoS and reduce power consumption | CloudSim toolkit | Cloud |
| | VM-Allocation | | | | |
| Optimal online deterministic algorithm [15] | VM-Selection | For VM-selection minimum migration time of VM has been used | Reduce energy consumption and high level of observance to SLA | CloudSim | Cloud |
| Energy efficient resource utilization algorithm [17] | VM-Selection | Least CPU utilization first VM is selected | Reduce CO₂ emission and energy consumption, resource utilization | CloudSim toolkit | IaaS Cloud Model |
| Energy-aware resource allocation algorithm [20] | VM-Placement | The heuristic greedy algorithm is used for workload prediction | Reduce SLA Violation, Energy wastage, Balance Workload and provide Scalability | PowerEdge blade servers are used for experiments | Cloud |
| Dynamic virtual machine placement algorithm [21] | VM-Placement | The statistical mathematical framework is used | Workload handling, reduce power consumption | Self-designed Simulator | Cloud |
| Efficient allocation of VMs in servers [22] | VM-Placement | Three VM-Placement policies FDT, DRT, and DDT are used | Less power consumption, a smaller number of SLA violations and reduce VM migration | CloudSim Simulator | Cloud |
| Energy efficient dynamic resource management [23] | VM-Placement | Logistic regression and median absolute derivation models are used for detection algorithms | Minimize power consumption of the datacentre and avoid SLA violations. | CloudSim | Cloud |
| Energy-Efficient VM-Placement [24] | VM-Placement | Demand-based VM and Physical machine mapping algorithm is developed | Reduce energy consumption, makespan, and task rejection rate | CloudSim | Cloud |
| An Energy-Saving Virtual-Machine Migration [25] | VM-Migration | Statistical based energy consumption algorithm | Efficient power consumption and provides QoS | PowerEdge blade servers are used for experiments | Cloud |
| Exact allocation and migration algorithms | VM-Migration | Linear integer programming model | Minimize energy consumption and | A dedicated simulator is developed based on | Cloud |
| [26] | DVFS-Aware consolidation for energy-efficient clouds [27] | DVFS-Aware VM-Consolidation | Two methods are developed, one for efficient power consumption based on DVFS technique and second for VM consolidation | Energy efficient, maintain QoS and improve system performance. Save energy up to 39.14% for dynamic workload situations | CloudSim | Cloud |
| Towards energy-aware job consolidation scheduling [28] | DVFS-Aware VM-Consolidation | Job consolidation algorithm with DVFS technique | Reduce energy consumption, supports physical machine heterogeneity | CloudSim | Cloud |
| Energy-aware online scheduling [29] | VM-Scheduling | Online VM Scheduling algorithm is developed | Maintain QoS, reduce energy consumption, supports a heterogeneous environment | Self-designed Simulator | Cloud |
| Energy-aware virtual machine dynamic provision and scheduling [30] | VM-Scheduling | Dynamic round robin algorithm is proposed for power-aware VM scheduling | Reduce energy consumption and physical machine usage | Eucalyptus: An open-source Cloud middleware | Cloud |
| Energy-based accounting and scheduling of virtual machines [31] | VM-Scheduling | In-processor tasks generation model for energy efficiency | Reduce energy consumption, energy-credit scheduler | Xen Hypervisor | Cloud |
| Energy-efficient Scheduling of Virtual Machines in IaaS clouds [32] | VM-Scheduling | Proposed an energy-aware virtual machine scheduling algorithm EMinTRE-LFT | Reduce completion time and power consumption of physical machine | OpenStack Nova Scheduler | Cloud |
| Energy efficient scheduling and management for large-scale services computing systems [33] | VM-Scheduling | Lyapunov optimization technique based distributed the online algorithm | Energy efficiency, prior knowledge of user’s request is not required, improved system performance | Numerical experiments and real trace-based simulation | Cloud |
| Dynamic energy-aware scheduling for parallel task-based application [34] | VM-Scheduling | Multi-heuristic resource allocation (MHRA) is proposed | Minimize energy consumption and task execution time | Implement a Scheduler using COMPS programming model | Cloud |
| Energy-Efficient virtual machine allocation technique using interior search algorithm [35] | VM-Allocation | An interior search based virtual machine allocation algorithm | Reduce energy consumption, and efficient resource utilization | CloudSim | Cloud |
| Novel resource allocation algorithms to performance and energy efficiency [36] | VM-Allocation | Proposed UMC and VDT algorithms | Efficient energy consumption and resource utilization, maintain QoS | CloudSim | Cloud |
| An energy efficient VM management scheme with power-law characteristic [37] | VM-Allocation | Proposed a power consumption algorithm for video streaming datacentres | Energy efficiency, efficient resource utilization, video streaming datacentres | CloudSim with Python (pyCloudSim) | Cloud |

### IV. DISCUSSION

Increment in power utilization is the emerging problem in today’s computing world. Hike of applications related to complicated data have introduced the establishment of big datacenters which raised the energy need. From the above study of energy efficient techniques, we can say that, most of the work to reduce energy consumption in datacenters are done using VM-migration and VM-scheduling methods. Some researchers proposed multi-objective algorithms, which are mostly cover SLA, QoS and resource utilization with efficient energy consumption in Cloud datacenters. Less work has been done for heterogeneous physical machines, which needs some attention from research community.

### V. CONCLUSION

In this paper, the author presents a taxonomy of energy efficient techniques for Cloud Computing. Various algorithms have been studied and their finding and improved parameters are listed in the table. This paper can help readers to find merits and limitations of proposed energy efficient algorithms present in the literature.

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REFERENCES

[1] Foster, I., Zhao, Y., Raicu, I., & Lu, S. (2008, November). Cloud computing and grid computing 360-degree compared. In Grid Computing Environments Workshop, 2008. GCE'08 (pp. 1-10). IEEE.

[2] Buyya, R., Yeo, C. S., & Venugopal, S. (2008, September). Market-oriented cloud computing: Vision, hype, and reality for delivering IT services as computing utilities. In High Performance Computing and Communications, 2008. HPC2008. 10th IEEE International Conference on (pp. 5-13). IEEE.

[3] Wang, L., Von Laszewski, G., Younge, A., He, X., Kunze, M., Tao, J., & Fu, C. (2010). Cloud computing: a perspective study: New Generation Computing, 28(2), 137-146.

[4] Mell, P., & Grance, T. (2011). The NIST definition of cloud computing.

[5] Orgerie, A. C., Assuncao, M. D. D., & Lefevre, L. (2014). A survey on techniques for improving the energy efficiency of large-scale distributed systems. ACM Computing Surveys (CSUR), 46(4), 47.

[6] Anderson, E., Lam, L. L., Eschinger, C., Cournoyer, S., Correia, J. M., Wurster, L. F., & Swinehart, H. H. (2013). Forecast overview: Public cloud services, worldwide, 2011-2016, 4Q12 Update. Gartner Inc., February.

[7] Data centres to consume three times as much energy in next decade, experts warn. http://www.independent.co.uk/, 2016. [Online; accessed 3-Aug-16].

[8] Reiss, C., Wilkes, J., & Hellerstein, J. L. (2011). Google cluster-usage traces: format+ schema. Google Inc., White Paper, 1-14.

[9] Ali, S. A., & Alam, M. (2016, December). A relative study of task scheduling algorithms in cloud computing environment. In Contemporary Computing and Informatics (IC3I), 2016 2nd International Conference on (pp. 105-111). IEEE.

[10] Sharma, Y., Javadi, B., Si, W., & Sun, D. (2016). Reliability and energy efficiency in cloud computing systems: Survey and taxonomy. Journal of Network and Computer Applications, 74, 66-85.

[11] Atewi, S., Yussof, S., Ezaani, M., & Almiani, M. (2016, April). A review energy-efficient task scheduling algorithms in cloud computing. In Systems, Applications and Technology Conference (LISAT), 2016 IEEE Long Island (pp. 1-6). IEEE.

[12] Kaur, T., & Chana, I. (2015). Energy efficiency techniques in cloud computing: A survey and taxonomy. ACM Computing Surveys (CSUR), 48(2), 22.

[13] Zakarya, M. (2018). Energy, performance and cost efficient datacenters: A survey. Renewable and Sustainable Energy Reviews, 94, 363-385.

[14] Beloglazov, A., Abawajy, J., & Buyya, R. (2012). Energy-aware resource allocation heuristics for efficient management of data centers for cloud computing. Future generation computer systems, 28(5), 755-768.

[15] Beloglazov, A., & Buyya, R. (2012). Optimal online deterministic algorithms and adaptive heuristics for energy and performance efficient dynamic consolidation of virtual machines in cloud data centers. Concurrency and Computation: Practice and Experience, 24(13), 1397-1420.

[16] Lee Rodgers, J., & Nicewander, W. A. (1988). Thirteen ways to look at the correlation coefficient. The American Statistician, 42(1), 59-66.

[17] Verma, J. K., Katti, C. P., & Saxena, P. C. (2014). MADLVF: An energy efficient resource utilization approach for cloud computing. International Journal of Information Technology and Computer Science, 6(7), 56-64.

[18] H. Abdi, “Multiple correlation coefficient”, In Encyclopedia of Measurement and Statistics, Salkind NJ (ed.), The University of Texas at Dallas, pp. 648 – 651, 2007.

[19] Verma, A., Dasgupta, G., Nayak, T. K., De, P., & Kothari, R. (2009, June). Server workload analysis for power minimization using consolidation. In Proceedings of the 2009 conference on USENIX Annual technical conference (pp. 28-28). USENIX Association.

[20] Wang, J., Huang, C., He, K., Wang, X., Chen, X., & Qin, K. (2013, November). An energy-aware resource allocation heuristic for VM scheduling in cloud. In High Performance Computing and Communications & 2013 IEEE International Conference on Embedded and Ubiquitous Computing (ECC/IEUC), 2013 IEEE 10th International Conference on (pp. 587-594). IEEE.

[21] Zheng, X., & Cai, Y. (2014, September). Dynamic virtual machine placement for cloud computing environments. In Parallel Processing Workshops (ICCPPW), 2014 43rd International Conference on (pp. 121-128). IEEE.

[22] Dad, D., & Belalem, G. (2017, October). Efficient allocation of VMs in servers of data center to reduce energy consumption. In Cloud Computing Technologies and Applications (CloudTech), 2017 3rd International Conference of (pp. 1-6). IEEE.

[23] Jararwah, Y., Issa, M. B., Daraghmeh, M., Al-Ayyoub, M., & Alsmirat, M. A. (2018). Energy efficient dynamic resource management in cloud computing based on logistic regression model and median absolute deviation. Sustainable Computing: Informatics and Systems.

[24] Mishra, S. K., Puthal, D., Sahoo, B., Jayaraman, P. P., Jun, S., Zomaya, A. Y., & Ranjan, R. (2018). Energy-Efficient VM-Placement in Cloud Data Center. Sustainable Computing: Informatics and Systems.

[25] Wu, K., Du, R., Chen, L., & Yan, S. (2013, December). An Energy-Saving Virtual-Machine Scheduling Algorithm of Cloud Computing System. In Information Science and Cloud Computing Companion (ISCC-C), 2013 International Conference on (pp. 219-224). IEEE.

[26] Ghribi, C., Hadji, M., & Zeghlache, D. (2013, May). Energy efficient vm scheduling for cloud data centers: Exact allocation and migration algorithms. In Cluster, Cloud and Grid Computing (CCGrid), 2013 13th IEEE/ACM International Symposium on (pp. 671-678). IEEE.

[27] Arroba, P., Moya, J. M., Ayala, J. L., & Buyya, R. (2015, October). Dvfs-aware consolidation for energy-efficient clouds. In Parallel Architecture and Compilation (PACT), 2015 International Conference on (pp. 494-495). IEEE.

[28] Sanjeevi, P., & Viswanathan, P. (2016, August). Towards energy-aware job consolidation scheduling in cloud. In Inventive Computation Technologies (ICICT), International Conference on (Vol. 1, pp. 1-6). IEEE.

[29] Tchernykh, A., Lozano, L., Bouvy, P., Peercy, J. E., Schieweckshohn, U., & Nechamchow, S. (2014, July). Energy-aware online scheduling: ensuring quality of service for IaaS clouds. In High Performance Computing & Simulation (HPCS), 2014 International Conference on (pp. 911-918). IEEE.

[30] Lin, C. C., Liu, P., & Wu, J. J. (2011, July). Energy-aware virtual machine dynamic provision and scheduling for cloud computing. In 2011 IEEE 4th International Conference on Cloud Computing (pp. 736-737). IEEE.

[31] Kim, N., Cho, J., & seo, E. (2011, August). Energy-based accounting and scheduling of virtual machines in a cloud system. In Proceedings of the 2011 IEEE/ACM International Conference on Green Computing and Communications (pp. 176-181). IEEE Computer Society.

[32] Quang-Hung, N., & Thoui, N. (2016). Minimizing Total Busy Time with Application to Energy-efficient Scheduling of Virtual Machines in IaaS clouds. arXiv preprint arXiv:1609.05767.

[33] Chen, Y., Lin, C., Huang, J., Xiang, X., & Shen, X. (2017). Energy efficient scheduling and management for large-scale services computing systems. IEEE Transactions on Services Computing, (1), 1-1.

[34] Juarez, F., Ejarque, J., & Badia, R. M. (2018). Dynamic energy-aware scheduling for parallel task-based application in cloud computing. Future Generation Computer Systems, 78, 257-271.

[35] Usman, M. J., Samad, A., Chizari, H., & Aliyu, A. (2017, May). Energy-Efficient virtual machine allocation technique using interior search algorithm for cloud datacenter. In Student Project Conference (ICT-ISPCC), 2017 6th ICT International (pp. 1-4). IEEE.

[36] Horri, A., Mozafari, M. S., & Dastghaibyfard, G. (2014). Novel resource allocation algorithms to performance and energy efficiency in cloud computing. The Journal of Supercomputing, 69(3), 1445-1461.

[37] Tseng, H. W., Yang, T. T., Yang, K. C., & Chen, P. S. (2014, September). Dynamic energy-aware scheduling for parallel cloud application. In High Performance Computing and Communications Environments Workshop, 2014 (pp. 1-14). IEEE.

[38] Jararwah, Y., Issa, M. B., Daraghmeh, M., Al-Ayyoub, M., & Alsmirat, M. A. (2018). Energy efficient dynamic resource management in cloud computing based on logistic regression model and median absolute deviation. Sustainable Computing: Informatics and Systems.