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# *A Review on Dynamic Consolidation of Virtual Machines for Effective Energy Management and Resource Utilization in Data Centres of Cloud Computing*

Nimmol P. John
School of Computer Sciences
Mahatma Gandhi University
Kottayam , India.
nimmolpjohn96@gmail.com

Bindu V. R
School of Computer Sciences
Mahatma Gandhi University
Kottayam, India.
binduvr@mgu.ac.in

*Abstract*— **Virtual Machine Consolidation (VMC) is one of the key instruments of structuring a dynamic energy effective management framework for cloud resources. It is established on the fact that migration of Virtual Machines (VMs) onto a lesser number of Physical Machines (PMs) can increase the use of servers and correspondingly decrease the energy utilization of the data centres. In any case, packing a bunch of VMs into an individual server may degrade the rate of Quality of Service (QoS), since VMs share the underlying resources of server. To rectify this issues VMC algorithms are developed for dynamic selection of VM for migration taking into account the QoS along with the objectives of optimization. VMC is one of the NP-Hard issues and henceforth a broad range of meta-heuristic and heuristic algorithms for VMC has been recommended whose main objective is to accomplish optimality. Since VMC is a prominent subject of research, plenty of scientists are currently working on it. This paper reviews some of their techniques that propose to manage energy effectively.**

***Keywords— Cloud computing; consolidation; virtual machines; resource utilization; energy consumption***

## I. INTRODUCTION

With extensive developments in the technology of storage and processing time along with the successful use of the internet, resource computation has turned out to be powerful, reasonable and available globally like never before. The workforces in the organizations are attempting to discover techniques to reduce expenses while keeping up similar performance guidelines. This has resulted in the realization of another model for computation referred to as cloud computing, in which the assets (for example network, CPU, etc.) are provided to the users via the internet as general utilities [1]. A formal definition of cloud computing was given by National Institute of Standards and Technology (NIST) as a model that has four models for deployment, three models for service and with five attributes. The four deployment models are public, private, hybrid and community clouds. The three service models are SaaS, PaaS and IaaS, Software as a Service, Platform as Service and Infrastructure as a Service respectively. The five essential attributes are on-demand self-service, board network access, resource pooling, rapid elasticity and metered service [2].

Cloud computing has reformed the industry of Information and Communication Technology (ICT) by empowering on-request provisioning of versatile resources of computing on the basis of pay as you go. But the data centres of cloud expend tremendous measures of electrical energy bringing about the high cost of operation and emissions of carbon dioxide ($CO_2$) into nature [4]. In spite of the enhancements in the equipments the overall utilization of energy keeps on growing because of expanding necessities for computing resources [5]. Currently virtualization is broadly utilized in data centres to minimize energy usage by reducing the total number of resources. The resources which are requested by the clients are packed in the form of VMs and after that are put in various hosts depending on particular criteria like meeting the prerequisites of Service Level Agreement (SLA) between the users and cloud providers, improving the resource usage and reducing the number of migration of VMs [7].

Virtualization assumes an imperative role in access management and coordination to the pool of resources by means of software layer referred to as Virtual Machine Monitor (VMM) or hypervisor. It conceals the subtleties of the physical resources along with providing virtualized resources for the higher level applications. In addition it virtualizes the majority of the resources in the given PM permitting the sharing of resources in the VMs [3]. A fundamental attribute for a VM is that the product running on it is restricted to the abstractions and resources given by the VM. Virtualization additionally permits assembling various VMs into a solitary physical server utilizing a method referred to as VMC. Consolidating the VM can give noteworthy advantages to cloud computing by encouraging better utilization of the accessible resources of the data centre. It can be carried out either dynamically or statically. In static consolidation of VM, the VMM designates physical resources to VMs depending on overprovision (demand for peak load). This results in wastage of resources on the ground that the remaining tasks at hand are not generally at the peak. On account of dynamic consolidation of VM, VMM changes the capacities of VM in accordance with the existing demands of the workload (resizing). This aids in using the resources of data centres proficiently [6]. In recent time many

cloud researchers have been attracted to the area of VMC and have developed effective algorithms. This paper presents a review of the techniques being proposed for dynamically consolidating VMs so that the energy and resources are utilized effectively in cloud data centres.

## II. Review of the existing Literature

The authors Buyya et al. [8] proposed a unique approach for the energy effective VMC based on the threshold with auto-modification of the values of threshold. Simulations were conducted on large-scale experimental setups for evaluating the developed algorithms. The exploratory outcomes demonstrate that the proposed strategy performed better than other policies of migration-aware with respect to the violation of SLA (< 1%) and various migrations of VM while giving a comparative degree of energy utilization. Besides, the conduct of the developed Dynamic Threshold (DT) algorithm can be balanced by changing its parameters, SLA can be loosened up prompting a further decrease in energy utilization. For augmenting the ROI (Return on Investment), the suppliers of cloud need to apply energy effective strategies of resource management, for example, the dynamic VMC and changing inactive servers to modes that save power. But, such consolidation is relatively significant, as it can bring about infringement of the SLA. Thus the study in [9] carried out an analysis of the single migration of VM and dynamic VMC problems. They found and demonstrated competitive proportions for the ideal online deterministic calculations for these issues. The authors concluded that it is important to create randomized or versatile algorithms to enhance the algorithm performance. As per the results obtained from examinations, they developed a versatile heuristics that depends on an investigation of chronicled information on the resource utilization for energy and effective dynamic VMC. Beloglazov et al. [10] introduced and assessed energy-aware algorithms for resource allocation using the dynamic VMC. The proposed energy-aware provisioning of heuristics to customer applications is in a manner that improves the data centres energy productivity, while conveying the arranged QoS. The test results have demonstrated that this methodology prompts a considerable decrease in energy utilization in Cloud server in contrast with static techniques of resource allocation. The authors aimed at placing a solid push on the challenges recognized in this paper so as to upgrade the energy effective administration of Cloud computing conditions.

The server overloads resulting in the shortage of resources and performance degradation which explains the impact on the QoS [11]. Existing solutions for the issue of the host overload identification are commonly based on heuristics or depend on the historical data analysis. The drawbacks of these methodologies are that they lead to imperfect outcomes and do not permit the unequivocal determination of a QoS objective. Consequently a unique methodology was proposed wherein for any known workload the state design ideally takes care of issues of detecting the host over-load by amplifying the time required for inter-migration under the predefined QoS objective dependent on the Markov chain model [11]. They heuristically adjust the calculation to deal with unknown workloads utilizing the Multisite Sliding Window estimation procedure. By simulating the workload from PlanetLab VMs, the authors demonstrated that the methodology performs better than the best benchmark calculation and gives roughly 88% efficiency of the ideal offline algorithms. In [12] Kaushar et al. attempt to research "SLA and Energy effective Dynamic VMC" which meets requirements of QoS and prerequisites of SLA. The examination of VMC algorithms depending on different heuristics on the real host is introduced as the primary highlight of this work. The authors also present the results of comparative analysis by carrying out an investigation of different existing VMC procedures utilizing CloudSim toolbox. The primary objective of this study was to help cloud providers evaluate power attributes of their own innovations along with the existing resources in identifying their favorability in migrating to new architectures of cloud that are energy effective. The outcomes likewise help in assessing the current systems and provide considerable savings in energy for effectively managing fixed QoS prerequisites of SLA.

Issue of optimizing the global operation in cloud computing with respect to the service providers of cloud (CSP) is considered in [13]. The main objective is providing CSP with an adaptable framework that can schedule and optimize while simultaneously maximizing the energy proficiency and fulfill all the deadlines of the users. The authors propose "Guided Migrate and Pack" (GMaP) as a framework that can schedule and optimize for the CSP that deals with these issues in a comprehensive manner. Also, GMaP is adaptable in controlling the run time of the algorithm and space sizing. Test results demonstrate that when CSP employs GMaP, the cost of energy utilization improves by over 23% for 30 - 50 clients, and over 16% in the case of 60 - 100 clients.

The authors Gao Y et al. in [14] proposed algorithms for dynamic VMC in cloud servers. The main objective is improvement in the usage of processing resources and decreasing the energy utilization under SLA requirements in regards to CPU, RAM, and transmission capacity. The productivity of the developed algorithm was verified by carrying out various simulations. The after effects of the assessment demonstrate that the developed algorithms considerably reduce the utilization in energy while giving an elevated level of responsibility to the SLA. In view of the recommended suggestions, 28% of energy utilization can be minimized and 87% SLA improvement is achieved when contrasted with the other benchmark algorithms. Beloglazov et al. propose an Enhanced Optimization (EO) policy as a unique process of managing the resources in data servers of the cloud [9]. Also, the authors present the main significance of optimizing various targets in data servers of the cloud including VM migrations, SLA violation and energy consumption simultaneously. This paper designs a holistic technique. For the process of managing the resources dependently on multi-criteria decision making for determining both the migrating VM placement and under loaded hosts. The simulation results utilizing CloudSim test system validated the relevance of the proposed strategies which appears at 46%, 7%, and 92% decrease in the energy utilization, violation of SLA, and various migrations of VM respectively, in contrast with the existing techniques.

Dynamic Cloud Resource Broker (DCRB) with VMC based Size Decision (VC-SD) technique for effectively managing energy effective resources is proposed in [15]. This methodology can lessen the productively energy utilization of servers without a considerable reduction in the performance by live relocation and execution of Dynamic Right Sizing (DRS) via a considerate model taking into account the overheads of

switching. The different outcomes from the experiments dependent on OpenStack stage validate that the developed algorithms should be used for common cloud centres. In addition, the unique strategy for prediction referred to as Self Adjusting Workload Prediction (SAWP) is proposed so as to enhance the precision of estimating future requests even under extraordinary changes in the workload. The authors in [16] developed another way to deal with the issue of dynamic VMC of VM in the environments of Cloud computing. They initially defined the cost of migration for all the VMs depending on their network usage, CPU and memory. The author's then develop a unique algorithm to choose the best VM for migrating depending on the cost of VM migration in case of a PM that is overloaded. The results obtained from such simulation show that the developed technique accomplishes good performance and considerably decreases the energy consumed in the data centre.

In the paper [17] authors Kaur A et al. developed an algorithm dependent on MBFD for placement of VMs. The primary objective is to decrease the number of dynamic servers and to get a steady host for all the VMs with the end goal that the unnecessary migrations and complete power utilization can be diminished. The presentation of the proposed calculation is contrasted with that of a current MBFD algorithm for VM placement. The outcomes from simulations demonstrate that the proposed system accomplished better outcomes when contrasted with the standard algorithm of MBFD. L.Ma et al. [18] proposed a Joint VM-Switch Consolidation algorithm (JVSC) for the efficiency of energy in data centres. JVSC could i) enhance the energy productivity of PMs by means of VMC ii) decrease the energy utilization of switches by consolidating them at the top, aggregation and core levels respectively and iii) decrease the energy utilized by the migration of VMs by a straightforward yet effective relocation choice system. Investigations on applications that are simulated and genuine traces of Google cluster showed that in comparison with the existing techniques, JVSC could enhance the effectiveness of energy in DCs at 60%. The outcomes likewise outlined that JVSC is less sensitive to the degree of VM and release time in comparison to state of the art techniques.

In paper [19] the authors Li.H Zhu G et al., proposed a unique energy effective algorithm for migrating and consolidating VMs dependent on a multiple resource energy effective models. It can restrict energy utilization with a guarantee of QoS. The authors develop a technique for double threshold with multiple resource use in triggering the VM migration. The Modified PSO strategy is brought into the VMC to abstain from falling into the local optima that is a typical deformity in conventional heuristic algorithms. In comparison with the prominent conventional heuristic algorithms MBFD, the developed algorithm decreased the dynamic physical nodes along with the migration of VM. It shows better productivity in cloud computing data centres. Nguyen et al. developed a VMC with Multiple Usage Prediction (VMCUP-M) for improving energy production of cloud data centres. In this situation, different uses allude to both horizons utilized in the future prediction and types of resources [20]. The proposed algorithm was executed during the VMC procedure to predict the long term usage of various types of resources dependent on the considered servers' local history. The combined utilization of current and anticipated resource usage takes into account a reliable portrayal of under and over loaded servers, consequently decreasing both the power and load utilization after consolidating. The examination assessed the technique via simulations on both real-world and engineered workloads. The outcomes obtained demonstrated that consolidating with various utilization predictions lessens the power utilized and the migration number of the servers while complying with the SLA.

Nhapi et al.,[21] proposed two VMC techniques that had the ability to reduce the energy utilization and enhance the QoS by a decrease in the migrations of VM. They utilized simulations along with real data for evaluating the introduced techniques. The outcomes from the simulations have demonstrated that the recommended techniques Sn and Qn have a superior performance in comparison to the existing techniques. Hence, this method can be utilized in huge data centres for productive and effective use of servers. Thus, providers of cloud service can cut down their power utilization, restrict the cost of operation, and increment return on investment (ROI). Besides the utilization of this strategy data centres can also decrease their CO2 emissions and in this manner adding to the initiative of the green data centre. Jararweh et al., [22] developed an algorithm for host prediction that depends on a model of logistic regression and median absolute deviation. The developed algorithm predicts the overloading of hosts resulting in the performance improvement for the process of managing resources in the data centre. It was assessed utilizing CloudSim and contrasted to five other algorithms of predicting host status. This algorithm was adaptable and can be utilized with any algorithms for placing and migrating VM. A broad assessment process was utilized with the dynamic workload to confirm the effectiveness of the algorithm developed. The outcomes demonstrated that the algorithm performed better than other techniques for predicting the status of hosts.

Ranjbari and Torkestani [23] developed an algorithm for effective allocation of resources dependent on learning automata for the cloud environments. This algorithm took into account the changes in the resources requested by users in predicting the PM that is overloaded. As a result of balancing among servers and prevention of their overloading and shutting down inert PMs, this algorithm reduces the consumed energy in the data centre. Additionally, this examination demonstrated that it is helpful in utilizing learning algorithms for predicting effective resource use and management in the cloud. This algorithm can be checked further to be applied for detecting the underutilized PMs with considerations of network topology, cooling systems and temperature of the server. Haghighi et al., in [24] did a study on energy-aware resource provisioning since the Data centres need large quantities of energy and hence emit CO2 that affects the natural environment resulting in global warming. The objective of this study is to accomplish a trade off among decreasing the energy used and maintaining the resource performance of the hosts under SLA imperatives. The authors via virtualization system proposed the hybrid approach for managing the resources. This procedure utilized k-means clustering to map and dynamic consolidation technique that was enhanced by the application of a micro-genetic algorithm. An exploratory assessment was performed on CloudSim 3.0.3 and the outputs were compared with other in Expert-Choice a different software tool. The results reveal that the proposed KMGA method could give a decent trade-off

between the effective reduction of energy utilization in Data centres and consistent service quality.

Shaw et al., [25] utilized real traces of workload for providing a comparison of the most broadly utilized forecast models and presented a unique Predictive Anti-Correlated Placement Algorithm (PACPA) that considered the resource consumption of both bandwidth and CPU. The observational outcomes showed how the proposed methodology reduced the energy by 18% along with reducing the violations in service by more than 34% contrasted with the most frequently utilized algorithms of placement. In general, the developed algorithm demonstrated the productive advantages of employing intelligent solutions of machine learning with the possibility to convey more prominent energy proficiency and improved execution over the existing approaches.

Shakya S. [36] introduced an optimal solution for securing data transfer in three stages. The first stage is the establishment of a socket layer among the sender and receiver nodes. In the second stage ticket for data migration is initiated with the least privilege. In the sender node data is encrypted using prediction based encryption, comprising shared and random keys. This reduces the time taken for encrypting, transferring and decrypting the data. This frame work can be adopted for all cloud storage providers.

## III. COMPARATIVE ANALYSIS

In this section, the existing techniques for VMC have been compared theoretically and numerically.

TABLE I. THEORETICAL COMPARISON OF THE EXISTING TECHNIQUES

| Reference number &Authors | Algorithm developed | Considered resources | Performance evaluation | Merits/demerits | Research gap |
|---|---|---|---|---|---|
| [26] Masoumzadeh &Hlavacs | Dynamic Fuzzy Q-learning (DFQL) | Disk storage, Bandwidth, RAM and CPU | CloudSim | Reduces the number of active PMs by VMC. with the help of energy aware migration, energy consumption also reduced. | To use continuous action set instead of discrete actions sets, in DFQL structure |
| [27] Salimian et al. | A power aware algorithm based on fuzzy logic and to detect under loaded hosts. | CPU | CloudSim | This technique reduces the consumption of energy by active PMs.VM migration is with better SLA. / Performance is not evaluated on real data. | To solve the host overloading detection sub problem and to present a new fuzzy algorithms for selection and placement of VMs |
| [28] Han et al., | PA/RUA | CPU | CloudSim | Simulation results shows reduced SLA violations and improved system performance by saving energy. | Intend to evaluate PA/RUA in a real cloud infrastructure and to help the providers to make better management policies. |
| [29] Arroba et al., | Freq-aware DVFS | CPU | CloudSim | 41.62%of energy is saved in dynamic load conditions /performance of memory is not been considered. | Further optimization by considering the integrated effect of temperature, DVFS and workload consolidation |
| [30] Hu et al., | MFD-MU-CABFD | Bandwidth, RAM and CPU | CloudSim | Keeping up SLA, reduced energy consumption. | The threshold value can be reduced further for dynamic adjustment depending on historical data of the various resources |
| [31] Xie et al., | Dynamic multi-thresholds (DMT) VMC technique | Bandwidth, RAM and CPU | CloudSim | Lower SLA violation and energy consumption /study considered only in limited number of servers. | Various parameters in DMT can be considered for exploring the effect of each parameter's weight. |
| [32] | DCV | CPU | CloudSi | 20%gain | |

| | | | | | |
|---|---|---|---|---|---|
| Thiam et al., | M algorithm | | m | of energy over basic algorithm / only one parameter is used for evaluation. | improvement of QoS |
| [37] Yong S and Kai.Q | LBMM algorithm | CPU | cloudsim | Decreases completion time and improves load balancing of resources and outperforms traditional algorithms | Can extend this work considering the parameters energy , memory and QoS. |

**Table II. Numerical comparison of the existing techniques**

| Reference Number&Authors | Energy usage (kWh) | Migration number | SLA violations (%) | ESV metric |
|---|---|---|---|---|
| [8] Beloglazov&Buyya | 1204 | 20577 | 0.96x10-2 | 11.55 |
| [34] Luo et al., | 87 | 16669 | 5x10-5 | 4.35 |
| [14] Arianyan et al., | 70.85 | 19913 | 119.5x10-5 | 84.72 |
| [33] Abdelsamea et al., | 34.57 | 1613 | 1.841 | 63.63 |
| [21] Nhapi et al., | 151.59 | 22236 | 393x10-5 | 595 |
| [23] Ranjbari and Torkestani, | 175.48 | 24624 | 3.26x10-5 | 5.72 |
| [24] Haghighi et al., | 0.623 | 100 | 0.06108 | 38.05 |
| [25] Shaw et al., | 5000 | 10000 | 8.7x10-5 | 435 |

From the theoretical comparison on different studies presented in table 1, it can be observed that the main resources considered for effective management are CPU, RAM, disk storage and bandwidth. All the studies utilized the CloudSim toolkit simulation for evaluating the performance of the developed techniques implying the popularity of the CloudSim toolkit.

The energy utilized by a PM relies upon the use of its CPU, network card, memory and disk. Most investigations demonstrated that CPU consumed more power. VM migration is an expensive activity that incorporates some measure of CPU handling on the source PM, the bandwidth of the link between the destination and source PMs, service downtime on migrating VM, and the complete time required for the migration. Hence many of the studies aimed at reducing the number of migrations and also reducing the energy consumed by the CPU. Consequently the table II presents the results of some of the studies with respect to energy usage, migration number, SLA violations and ESV (Energy and SLA Violation) metric. The lesser the parameters the higher is the performance of the system.

## IV. CONCLUSION

In spite of the fact that datacentres are the backbone of services based on cloud, the major issue is the huge amount of energy consumed by it. It is difficult to reduce the energy consumption if energy is not considered while structuring the modules that satisfy the functionalities. Virtualization additionally permits assembling various VMs into a solitary PM utilizing the method referred as VMC. Consolidating the VMs can give noteworthy advantages to cloud computing by encouraging better utilization of accessible resources of the data centre. This paper presented a review of VMC algorithms with varied viewpoints. Both the algorithms of static and dynamic VMC are pivotal for the efficiency of the energy of the data centre. Static VMC is the initial move towards constraining energy utilization, while dynamic VMC further limits the energy utilization while increasing the resources utilized. The main disadvantage of VMC is the violation of SLA that may emerge in light of forceful consolidation. The algorithms of dynamic VMC based on Static Threshold are unable to control the violations in SLA. Conversely, dynamic VMC based on adaptive threshold limit violations in SLA by prior VM migration from the possible PMs that are overloaded. But with respect to minimizing the energy consumption dynamic VMC algorithms based on adaptive threshold are less proficient and results in a higher number of migrations in VM. In virtualized Clouds the live and offline migration of VM offered by virtualization has empowered the system of dynamic VMC to leverage the variability in workloads. But migration of VM prompts performance and energy overheads requiring a cautious examination and intelligent methods for eliminating the migrations that are not productive.

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