A Systematic Evaluation on Energy-Efficient Cloud Data Centers with Reduced SLAV

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Abstract.

In cloud computing, cloud data centers are looking for ways to improve the services they offer to their customers. So, with the exponential rise of cloud computing applications, data centers are becoming more energy-intensive, capable of delivering performance assurance, and service level agreements. It offers instant services to computer resources, pay-as-you-go services through a global network of data center sites. Cloud servers are consuming a lot of electricity and leaving a lot of carbon footprint on the environment. The goal of cloud computing services is to deliver seamless services via the Internet utilizing virtualization technologies to meet the QoS (Quality of Service) demands of end-users. This review article focuses to identify the research done in Energy Consumption (EC), Quality of Services, and Service Level Agreement Violation (SLAV) by different techniques using statistical, machine learning, heuristic, and metaheuristic method. Host CPU utilization prediction, Underused or Overused detection, VM selection and migration, and VM placement were applied to manage the resources. Researchers have used different algorithms using the PlanetLab and Bitbrains workload and had performed experiments on different environments i.e., CloudSim, Matlab, Java, OpenStack, etc and the work done basis on performance metrics are evaluated.

Keywords. Cloud Computing, Energy Consumption, SLAV, Quality of Service, Data Center, Performance Assurance.

1. Introduction

The industry has used the term "Cloud Computing" to describe a powerful service and application that is integrated and packaged on the web [1]. It has developed as a novice flexible, efficient and powerful computational technology that offers customized, reliable, and dynamic computing environments to users. Remote data centers host, high-capacity servers and storage systems, which are used to host cloud applications. Rapid growth in requests for cloud-based facilities necessarily involves the development of bulky amounts of data centers, consuming huge amounts of electrical power [2].

Optimizing energy can be accomplished by uniting resources based on current utilization, well-organized virtual network structures, and the thermal position of computing equipment and nodes. An approach to cost-effective VM migration based on erratic electricity prices significantly decreases the energy costs associated with the cloud service operation.

A quick introduction to cloud computing has been given in section I. In Section II definition of cloud computing, Virtualization, Energy Consumption, service level agreement, VM migration, CloudSim, and Workload data is defined. Section III provides the importance of the paper. Section IV outlines the analysis, and evaluation of existing relevant work for the resource management, performance, and comparisons of approaches with their benchmark algorithm considering energy consumption, and SLAV. Conclusion of the paper is summarised in section V.

2. CLOUD COMPUTING

Cloud computing offers computational resources as well as on-demand resources, scalability, flexibility, and greater availability to consumers anywhere and at any time by utilizing virtualization technology [3]. It is distributed in nature and is a group of independent resources which are spread in remote locations. National Institute of Standards and Technology (NIST) has a widely recognized definition, “Cloud Computing is a model for providing ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources that can be rapidly provisioned and issued with minimal management effort or interaction from service providers" [4].

Cloud computing is based on three service models IaaS (Infrastructure as a Service), PaaS (Platform as a Platform), and SaaS (Software as a Service). Cloud computing delivers IT infrastructure and utilities depending on a service model. Based on the their deployment, clouds are categorized as: Public, Private, Community and Hybrid Cloud[5].

A. Virtualization

Virtualization technology allows many separate operating systems, software, and applications to operate on a single Host, allowing massive data centers to be handled more effectively, dividing hardware resources into logical units called virtual machines (VMs). VMware, Xen, and KVM are commonly used virtual environments in cloud DCs [6].

B. Energy Consumption, Service Level Agreement and VM Migration

Cloud computing may be a step forward in analyzing, recognizing and implementing global energy reductions in a system to achieve true energy-efficient computing services while lowering costs [7]. Uniting hardware and reducing repetition can help us to save energy. Services should be able to be moved to other locations, if necessary, as well as virtualized and managed within a data center. Machine-readable accounting of the demands and characteristics of applications, networks, servers, or even entire locations must be accessible to enable energy efficiency in the future [8]. The most significant challenges are task scheduling, load balancing, Quality of Service (QoS), resource management, energy efficiency, and service level agreement (SLA). An effective management is required to optimize power utilization and maximize performance. In addition to energy consumption and SLAV, financial cost and CO2 emission from data centers, cooling systems also affects the environment significantly [9].

Virtual machine placement and migration have a significant influence on QoS and energy consumption. VMs are moved to different hosts, when existing host is either overburdened or underburdened based on power conservation considerations. VM allocation procedure will be in control of selecting suitable hosts for the designated VMs. Virtual Machine Migration is divided into three stages [10].

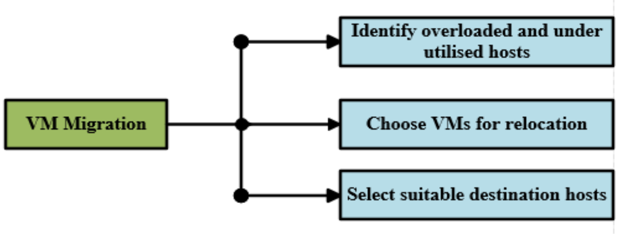

Figure 1: Stages of VM Migration

Computer resources are distributed to VMs constructed for users. To advance the QoS and management of power, VM scheduling has been done in such a way so that minimum numbers of Hosts are running. This method is known as Dynamic Consolidation of Virtual Machine (DCVM). Predicting host utilization is an ongoing research work and a variety of solutions have been proposed. A single Host can host several VMs, and VMs utilize the resources of hosts based on user requests. VM migration technique is suitable to control power consumption. To shrink the VM migrations, appropriate VM selection and VM placement methods must be created. When a VM from an overloaded host is in migration, then both source and destination host consume power without delivering any services, which should be minimized without affecting QoS and hence reducing energy utilization.

C. *CloudSim and Workload Data*

CloudSim [11] is the preferable simulation tool for research where workload data is used for input to test the algorithm. PlanetLab data given in table 1 and Bitbrains workload traces given in table 2 are used frequently for the simulation in experimental environment[12].

3. PURPOSE OF SURVEY

Cloud DCs are the backbone of cloud computing, consisting of networked computers, cables, power supplies, and other components that host and store data. Cloud Data centers demand a lot of energy, which results in significant operational expenses and carbon emissions. The main challenge is to establish a balance between system performance and energy consumption [13]. In this survey, balance between energy efficiency, SLA assurance, VM placement, VM selection and migrations are evaluated performed by different researchers [14].

4. RELATED WORK

Many researchers have applied different techniques for VM management and effective resource management approach to reduce energy utilization, and SLA Violation in cloud computing data centers. Details of their research work are described below.

Beloglazov and Buyya, (2010) [15] used Single Threshold (ST), Minimization of Migration (MM) procedures, and bin packing heuristics for VM consolidation. Random data and CloudSim simulator were used for VM allocation and live migration in an energy-aware resource scheduling system. In terms of energy conservation, the findings showed that dynamic VM consolidation with adaptive criteria is far superior to static thresholds. The MM algorithm outperformed ST, DVFS, and NPA by 23 %, 66 %, and 83 %, respectively.

Z. Cao et al. (2012) [16] proposed strategies for dynamically consolidating VMs (DCVM) to lower energy consumption and SLAV. Host overburden detection, VM selection, and allocation strategy were proposed by the authors. The authors employed standard deviation and mean CPU utilisation metrics to discover overloaded hosts. The Extension of Maximum Correlation (MCE) policy was utilised to select VMs for migration. Mean and variance computations were done for VM allocation on CloudSim utilising Planet Lab traces.

Farahnakian et al. (2013) [17] presented a DCVM in which the active number of hosts is minimised based on current and historical usage. The K-Nearest Neighbour (KNN) approach is used to forecast each Host's CPU use. The goal of their prediction approach is to detect Host overloading and underutilization to optimise dynamic VM consolidation.

A. Nadjar et al. (2015) [18] illustrates a decentralised scheduling strategy for DCVM fitted with an Auto-Regressive Integrated Moving Average (ARIMA) method to progress distribution of resources by predicting VM resource utilisation in future. In their model three types of controller Global Manager (GM) apply First Fit Decreasing (FFD), Cluster Manager (CM) performs Max Load VMP (ML-VMP) and Local Manager (LM) used ARIMA model.

Duggan et al. (2016) [19] presented an energy-efficient solution based on Reinforcement Learning (RL) to choose VMs for relocation from overburdened hosts using local regression approach. The Learning agent selects the best VM for migrating from an overloaded host while balancing energy consumption and migration. The experiments indicate an autonomous VM selection approach that can deduct energy cost and VM migration count.

M.A. Khoshkholghi et al. (2017) [20] projected a cost-effective energy-efficient supervision of VMs by developing an algorithm for overloading the detection of host using the iterative weighted linear regression (IWLR), which consider SLA constraints for data centers.

Wang and Tianfield (2018) [21] by introducing Space-Aware Best Fit Decreasing (SABFD) technique for VM placement, researchers focused on using efficient energy utilization by DCVM. They also created a policy called High CPU Utilization-based Migration VM Selection (HS) for VM selection. Using the CloudSim andPlanet Lab workload, the results showed that DCVM included SABFD and HS produced the greatest results.

A. Aryania et al. (2018) [22] proposed an Ant Colony System (ACS) method for resolving the Virtual Machine Consolidation (VMC) challenge and reduces data center energy consumption. Simulation findings showed that Energy-aware Virtual Machine Consolidation (EVMC-ACS) enlarged the number of sleeping host by 16 % as compared to ACS-VMC. Furthermore, in various circumstances, the suggested algorithm minimizes the number of migrations by 89 %, the energy utilisation during relocation by 91 %, the amount of SLAV by 79 %, and total energy utilization by 25 %when compared to ACS-VMC.

F.F. Moges et al. (2019) [23] proposed the OpenStack Neat framework's VM placement algorithm to address the problem of consolidation by modifying bin-packing heuristics to account for host power efficiency. The proposed algorithms improve energy proficiency up to 67 % with reference to PABFD and MBFD. They also defined an innovative bin-packing method termed as medium-fit power-efficient decreasing (MFPED) which reduces SLAV and VM relocations by up to 78 % and 46 %, respectively, when compared to MBFD, depending on the cloud scenariousing CloudSim on PlanetLab and Bitbrains cloud traces.

Mehran Tarahomi et al. (2020) [24] proposed a useful micro-genetic approach for selecting appropriate VM destinations among physical hosts. In comparison to other ways, their simulations revealed that the micro-genetic method gives significant enhancements in relations of power consumption. They used CloudSim to test the suggested approach and relate it to reference algorithms (genetic and Power-Aware BFD VM provision algorithms) in a variety of scenarios and PlanetLab datasets that improved power consumption.

V. Barthwal et al. (2021) [25] projected a VM placement process built on ACO meta-heuristic Predicted Utilization (AntPu) for dynamically placing VMs in the data center to minimise Energy Utilization (EU) and SLAV. Using CloudSim and the PlanetLab dataset the projected method offers a significant enhancement in energy usage and service level agreement comparing with other alternatives.

Garg et al. (2021) [26] approached LATHR (Load Aware three-gear THReshold) and MBFD algorithms to reduce overall energy utilization improving service quality. When used with a dynamic workload and a flexible number of virtual machines (range from 1–290) on each host, produces promising results. The proposed technique was found to reduce SLA defilements (26 %, 55 %, and 39 %) as well as energy utilization (12 %, 17 %, and 6 %) when related to inter quartile range, median absolute deviation, and double threshold overload recognition strategies, respectively.

Most of the Researchers have used PlanetLab (table 1) or Bitbrains (table 2) workload traces for simulation in CloudSim, or other environments, whose number of VMs are given below.

Date	***No. of VMs***	***Date***	***No. of VMs***
03/03/2011	**1052**	*03/04/2011*	**1463**

Table 1: Number of VMs in PlanetLab workloads traces [24]

06/03/2011	**898**	*09/04/2011*	**1358**
09/03/2011	**1061**	*11/04/2011*	**1233**
22/03/2011	**1516**	*12/04/2011*	**1054**
25/03/2011	**1078**	*20/04/2011*	**1033**

Table 2: Number of VMs in Bitbrains workloads traces [24]

Date	*No. of VMs*	*Date*	*No. of VMs*
01/08/2013	**1238**	*06/08/2013*	**1231**
02/08/2013	**1237**	*07/08/2013*	**1218**
03/08/2013	**1234**	*08/08/2013*	**1209**
04/08/2013	**1233**	*09/08/2013*	**1207**
05/08/2013	**1232**	*10/08/2013*	**1205**

A brief description of the above literature review, algorithms developed using different methods, comparison of Energy Consumption and SLAV reduction with Benchmark algorithm, workload data, experimental environment, and performance metrics is given in Table 3. The authors have already discussed setting of implementation; the host, virtual machine, datasets, simulators, and other criteria for comparing the proposed method to their benchmark algorithm.

Table 3: Management of Resources using different Methods in Cloud Data Center

S. No.	*Author/ Year*	*Algorithm / Method*	*Benchmark Algo*	*Reduction in EC%*	*Reduction in SLAV%*	*Data set/ Workload*	*Experiment Environment*	*Work Done*	*Performance Metrics*
1.	A. Beloglazav et al. [15], 2010	MM Bin Packing	ST	23	1.1	Random data	CloudSim	VM Consolidation	Energy Savings, SLAV
2.	Z. Cao et al. [16], 2012	EV_MCE	LR_MMT_1.2	-13	70	PlanetLab	CloudSim	Host Overload Detection, VM Selection	Energy Consumption, QoS, SLAV, VM Migrations
3.	F. Farahnakian et al. [17], 2013	DC-KNN	THR	9.2	19.9	PlanetLab	CloudSim	Utilization Prediction	SLAV, Energy Consumption
4.	A. Nadjar et al. [18], 2015	ARIMA MSV_ML	MAD_MMT_2.5	5.4	90	PlanetLab	CloudSim	DCVM	Energy Savings, Migration count, SLA
5.	M. Duggan et al. [19], 2016	AI tech RL RLLM	Lr-Mmt	3	48	PlanetLab	CloudSim	VM Migration	Energy Consumption, VM Migration, SLAV

6.	M A Khoshkholghi et al. [20], 2017	IWLR	LR_MMT	26	85	PlanetLab	CloudSim	Utilization Prediction, VMConsolidation	Energy Utilization, VM Relocation, SLAV
7.	H. Wang et al. [21], 2018	SABFD HS	DVMC	72	69	PlanetLab	CloudSim	VMPlacement VM Migration	Energy Efficient
8.	A. Aryania et al. [22], 2018	EVMC-ACS	ACS-VMC	25	79	Random Workload	Java	VM Consolidation	Energy Consumption, SLAV
9.	F F Moges et al. [23], 2019	MFPED	MBFD	67	78	Planet Lab Bitbrains	CloudSim	VMPlacement	Energy Consumption, SLAV, VMMigrations
10.	M. Tarahomi et al. [24], 2020	Micro-GA	GA	7.68	2.44	PlanetLab	CloudSim	VMPlacement	Power Consumption
11.	V. Barthwal et al. [25], 2021	AntPu	PABFD	24.59	53.19	PlanetLab	CloudSim	VMPlacement PM Overloading	Energy Consumption, SLA Violations, QoS
12.	V. Garg et al. [26], 2021	LATHR - MBFD	IQR	12	26	HPG4 100 hosts 290 VM	Matlab	Overload Detection, VM Migration	Energy Consumption, QoS, IER, No. of Migration

5. CONCLUSION

Since cloud data centers consume a lot of power, produce a lot of invoices, and are very expensive. So, energy consumption, and SLA violations have become major concerns in the previous decade. As a result, energy conservation and QoS are focused and are the most important study fields in Cloud computing.Many academia's are focusing on data center infrastructures' energy utilization, SLAV, and QoS. This article looks at virtual machine and physical machine consolidation strategies using various methodologies in the context of energy-efficient VM migration and SLA assurance. The approaches discussed by different researchers using many methods focusses at global energy conservation, effective VM migration, SLA assurance, and resource management. When comparing with their benchmark method we have seen that energy consumption and SLAV decreases with considerable percentages which has been given in table 3. So, the future scope of reducing these parameters is still in research of cloud computing. Effective VM consolidation techniques reduce power consumption during service provisioning. They also proposed SLA and Energy Aware policy for real-time VM consolidations in Cloud data centers to optimize the power and guarantee the service performance. As a result, resource utilisation increases, while total energy consumption, and SLAV decreases in cloud data centers.

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