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A Survey on Green Cloud Computing Strategies

Ajay Singh
Department of Information Science and Engineering, B.M.S College of Engineering, Bangalore, India
vsajay789@gmail.com

Anupriya Jain
Department of Information Science and Engineering, B.M.S College of Engineering, Bangalore, India
anupriyajain12@gmail.com

Naveen Kedilaya
Department of Information Science and Engineering, B.M.S College of Engineering, Bangalore, India
naveenkedilaya@gmail.com

Muskan Agarwal
Department of Information Science and Engineering, B.M.S College of Engineering, Bangalore, India
agarwalmuskan1211@gmail.com

Ashutosh G Shanbhogue
Department of Information Science and Engineering, B.M.S College of Engineering, Bangalore, India
ashutoshgs99@gmail.com

Heena Kousar B M
Department of Information Science and Engineering, B.M.S College of Engineering, Bangalore, India
heenamakandar24@gmail.com

Sheela S V
Department of Information Science and Engineering, B.M.S College of Engineering, Bangalore, India
ssv.ise@bmsce.ac.in

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ABSTRACT

Cloud computing, with its many services across the globe powering virtual resources, is one of the principal IT fields today. The future will be more inclined towards cloud computing, especially Green Cloud Computing (GCC). People nowadays prefer cloud services and storage instead of home-based systems as it is fast, dynamic and accessible from any part of the world. Also, people do not have to upgrade their systems and instead can use software available on the cloud that too at a very nominal fee. Cloud-based solutions save time, money, resources, and space, making it the first choice for businesses over individual hard drives. Due to its vast potential and many clients, resource management for better efficiency has become an enormous challenge. Data Centres (DC) consume exceedingly large amounts of electricity on any scale, making GCC's need even more crucial for minimized environmental impact. The complexity of a GCC system makes its implementation and management a daunting task. This paper provides an overview of various strategies proposed in existing literature for an environmentally sound cloud computing system.

Index Terms – Cloud Computing, Datacenter, Green Cloud Computing, Resource Management, Environmental Impact.

1. INTRODUCTION

Cloud computing facilitates easy network access to remote virtual computing resources that service providers can swiftly provision on-demand. It provides single-point access to data and applications to users anywhere globally, making it so popular across industries and individuals. Cloud computing provides services under three major domains, namely, Software as a Service (SaaS), Platform as a Service (PaaS), Infrastructure as a Service (IaaS), to attract business application owners to adopt and migrate the cloud services to their business app modules. Cloud-based DCs, platforms, servers, and other infrastructure services are elastic enough to supply the sudden demand for enormous resources from customers.

Many companies offer cloud services nowadays, like Amazon Web Services (AWS) by Amazon, Azure by Microsoft, and Google Cloud, to name a few. One can quickly build solutions, deploy and manage applications using the global network of DCs managed by these cloud service providers. Operating these colossal DCs 24/7 electricity supply and proper cooling mechanisms produces many Greenhouse Gases (GHGs) emissions leading to substantial carbon footprints. DCs accounted for nearly 1.3% of the world's total energy consumption in 2010, according to Koomey [1]. GHGs emissions have grown substantially in recent years.

Nowadays, software and hardware developers are giving importance to sustainability as energy consumption has increased. Cloud service providers face pressure from the government and peers to create more eco-friendly solutions and fall into environmental regulations set up by governments. The public is also showing considerable interest in environmental sustainability, which has led to the rise in the study of GCC, which is precisely the solution the providers need. It can be adopted to build green DCs. However, there are burdens associated with it, such as cost, lack of time, well-planned strategies, and cooperation between different stakeholders. The advantages offered by adopting the practice of GCC, whether in terms of electricity bills, resource management optimization, faster network, less wastage, and the like, outweigh the challenges.

The design organization can save energy in cloud computing and use cloud servers, services, and cloud nodes without impacting the environment. By utilizing virtualization, server consolidation, load balancing, storage management, and power management, energy conservation becomes one of the earliest obtained objectives in any cloud design and infrastructure [14]. Virtualization is an essential concept of cloud computing, enabling multiple Operating Systems (OS) and software applications to run on a single host, giving users the feeling that they are accessing independent resources. Server consolidation amalgamates multiple servers in the cloud and treats them as one single server, minimizing power consumption.

Load balancing distributes tasks evenly among servers, saving energy by ensuring that no server is over or underloaded. Management of practical storage and networking resources also conserves energy. Recognizing the advantages of GCC, the study by Karuppasamy et al. aims to provide the best resource provisioning method to maximize server utilization and avoid overhead. Consolidation is the process of implementing a variety of DCs related data processing applications on a single server using virtualization technology [9]. It is the main subtask derived from virtualization and is committed to implementing level load balancing, utilizing virtual systems, and reducing power consumption. The consolidation process is a resource incentive one and expects the intelligence support to reduce the server downtime to a minimum. Dynamic consolidation, Threshold-based consolidation, and consolidation process are the current trending topics in green cloud Virtual Machine (VM) consolidation [3].

This paper aims to study the existing literature to identify the critical issues, valuable strategies, research, and applications. It does not present new GCC solutions but highlights the interest and efforts of researchers in sustainable technological evolution.

2. RELATED WORK

Saurabh et al. explain that a detailed analysis of the cloud is required to determine its energy performance that helps achieve energy efficiency and how these solutions can warrant GCC [2]. The green cloud architecture, which considers provider's and user's aspects, enables GCC. The architecture chooses the most environment-friendly cloud provider through an intermediate middleware green broker to meet users' needs. Five policies were adopted to validate the framework's carbon emission efficiency.

- Greedy Minimum Carbon Emission (GMCE)
- Minimum Carbon Emission - Minimum Carbon Emission (MCE-MCE)
- Greedy Maximum Profit (GMP)
- Maximum Profit - Maximum Profit (MP-MP)
- Minimizing Carbon Emission and Maximizing Profit (MCE-MP)

Green policies reduce carbon emissions by 20% compared to policies based on the profit of providers. More efforts are needed to design software, understand the existing infrastructure of DCs, design solutions for scheduling and resource allocation to ensure it does not create health problems in humans. A cloud DC comprises lots of equipment like networked computers and their corresponding peripherals. Due to this, DCs consume vast amounts of electricity and have a large carbon footprint. DCs in the United States amounted to about 1.5% of the cumulative energy produced, which cost a whopping amount of 4.5 billion US dollars in 2007, according to a report by the US Environmental Protection Agency (EPA). This high usage of energy created about 80-116 Metric Megatons of carbon emissions each year. Typically, the cooling device in a DC (Computer Room Air-conditioning (CRAC), Chiller) amounts to 33 to 40%, Electrical Equipment (UPS, lighting, Power Distribution Units (PDUs)) about 28% and IT Equipment contributes about 30% to energy consumption.

Tram Truong Huu et al. propose algorithms comprising Linear relaxation-based randomized algorithm), exhaustive search algorithm and Green Greedy algorithm (or GGA) for optimizing energy consumption and resource allocation [3]. ESA and LRRA algorithms involve computing maximized users' bid value (total revenue) for using the cloud resources and is solved using linear programming by maximizing objective function, which computes the number of users utilizing the cloud resources and constraints involving bid values. When simulated for 15-20 users for four VM types, GGA serves 62% users compared to LRRA (54% users) and LSA (75% users). However, LRRA generates higher user utilities than GGA as GGA gives a higher bid value with fewer total users' utilities considering less energy consumption than the other two algorithms. Comparing the three algorithms, Green Greedy Algorithm effectively computes the highest revenue with less energy consumption of the resources.

Jean-Charles et al. proposed a new methodology for modelling, simulating, and deploying GCC DCs, which helps managers organize a GCC to save energy-related costs [4]. It is based on the Analysis-Specification-Design-Implementation (ASDI) concept and the System-Of-Systems (SOS) pattern. The approach deals with decision making on an in-system hierarchical basis to resolve and validate decision-making. It strengthens the collaboration and cooperation entities that affect the decision-making process. The design can be used as a generic form for different types of GCC as a library of components. We can develop simulation models to design decision-making tools. The energy performance of infrastructure in a Cloud Computing system can be evaluated using different simulation software and can be used to organize the data. The model's main advantage is that it improves GCC design in concert with the staff and engineers.

Er. Yashi Goyal et al. discovered an efficient strategy for relocating the VMs and host selection [5]. Initially, we contrast all migratable host VMs' utilization against the CPU and RAM utilization to select the most suitable candidates using a Hybrid VM Selection Policy Algorithm. The next step is to select a host to which the administrator can migrate the selected VMs. The most efficient way would be to choose the VMs as a host with the least CPU utilization. The reason being if VM migration takes over a host with high CPU utilization, the chances of the host being overloaded and crashing are too high. A Low Utilization Host Policy Algorithm takes these aspects into account to find an apt host. The approach minimizes energy consumption in cloud computing, which helps meet the energy efficiency requirements and ensures service quality. It also performs well in optimizing other parameters like VM migration, SLA degradation (%), SLA time per active host (%), and Standard deviation before the host shuts down.

Prasanna et al. discussed how Cloud Computing has led to increased electricity consumption for running DCs [6]. Dynamic provisioning, multi-tenancy, server utilization, and DC efficiency have proved to be significant factors that the system can implement to reduce power consumption and increase environmental sustainability. Increasing demands for DCs in the cloud have led to a boost in the amount of energy consumed to operate cloud infrastructure, which strictly opposes the concept of Cloud Computing as "Green." The energy consumption is high because a typical direct current can consume up to twice the power of a standard commercial building.

Jagadeeswara Rao. G et al. compare green cloud scheduling algorithms and other existing task scheduling algorithms [7]. There is a growing need for efficient scheduling in cloud services, task execution, NP-hard optimization problems, and real-time provisioning. They use Green Cloud Simulator, a small-scale DC, to simulate four task schedulers, Random, HEROS, Green cloud, and Round-Robin, in a preconfigured environment. From the observations, it was found that green cloud scheduling performed the best in terms of performance based on energy consumption. Compared to other algorithms, the energy consumption was less by almost 2%. The significance of this slight improvement grows proportionately with the scale of the DC.

Karuppasamy et al. talk about how cloud computing has drawbacks regarding energy consumption in remote servers, storage devices, and power requirements to cool the IT infrastructure load [8]. It also talks about increased carbon emission in the air due to them. The primary goal is to save energy and use it efficiently and effectively. Cloud computing, a variant of distributed computing, shares computers and resources to sustain user requests. The computing power can potentially turn into a compelling open resource framework alongside the elements like water, fire, and air in the future. The resource portion, distribution, assignment, and allocation in cloud networks play a significant role in GCC Algorithms. For productive registration of resources, the Power Utilization Effectiveness (PUE) factor computes the energy consumption and is given by

$$PUE = \frac{Total\ Power}{IT\ Equipment\ Power} \tag{1}$$

Resource utilization estimates computing resources spent working on a suitable job and its scheduled tasks. The actual resource usage depends on the amount and type of computing tasks to manage. Some tasks require heavy resource utilization time, while others require less utilization time based upon job and resource availability. The allocated resources utilization is measured as

$$CRU = \{CRUt_1., CRUt_2., \ldots. CRUt_n\} \tag{2}$$

$$CRE = \{CREt_1., CREt_2., \ldots. CREt_n\} \tag{3}$$

In equations (2) and (3),

CRU: Computing Resource Utilization,

CRUtn: CRU × Total time taken for nth user

CRE: Cloud Resource Energy

Finally, the Cloud Resources Energy Efficiency (CREE) is calculated as

$$CREE = \frac{CRU * CRE}{PUE} \tag{4}$$

The used Ant Colony Algorithm simulates the foraging process, finds the size of the arrival job and unallocated resources, and notes the time taken to utilize the resource in the cloud.

Mohammad Masdari et al. highlight the importance of VM Management (VMM) [9]. Effective VMM is a critical issue in cloud DCs that directly affects power consumption, cost, extensibility, and CO2 emissions. VM Placement (VMP) is a salient part of VMM. It can be categorized as reactive and proactive/predictive programs that attempt to improve the VMP results and place VMs in the most appropriate PMs considering various factors. VMMs facilitate the management of the resources shared by PMs and improve the security of VM. Proper VMP and dynamic management can significantly reduce DC power consumption, improve performance, and increase CSP benefits while preventing SLA Violation (SLAV). Various algorithms and techniques for predicting the VMP Scheme and their main features and limitations are described, where a majority of them apply regression methods, ANN, and exponential smoothing. One key issue many schemes overlook is DDoS attacks that malicious VMs can initiate by increasing the demand for resources and by initiating multiple needless VM migrations to put a heavy load on DC. Thus, it is crucial to integrate predictive VMP plans with detection of any intrusion and prevention systems to recognize genuine tampering requests and enhance the security of DCs.

Rashmi V Bhat et al. proposed that cloud computing has become an emerging technology for SaaS, PaaS, IaaS, and it has drawbacks involving maintenance cost of the DCs for hosting VMs, energy wastage, large energy consumption thus might hinder the quality of service [10]. We can overcome these drawbacks through Green Computing approaches comprising VM-based Cost Optimization techniques as follows. VM migration reduces power consumption and increases power usage. Server Consolidation of VMs where a trade-off between efficiency and performance leads to higher energy efficiency with a 30 percent decrease in performance. VMP method for minimizing energy consumption, optimal selection of resources, and carbon emission and prices. Energy-efficient algorithms are also used for cost optimization, which effectively uses the resources and turns idle modes in CPUs when the job queue is empty. Green Scheduling and Spatial task scheduling reduce energy consumption with resource optimization. Green architecture and optimized resource allocation for DCs also play an essential role in Green Computing.

Zhong Zong et al. claim that a fundamental piece of dynamic energy utilization of systems using cloud computing is the energy consumption by the cloud servers in task scheduling [11]. The paper aims to reduce energy consumption by optimizing the task scheduling with respect to its timings. A dynamic task scheduling algorithm is proposed by combining two algorithms: The Genetic Algorithm and the ant colony algorithm. The fundamental thought was to consolidate the Genetic Algorithm's global optimization capacity and the Ant Colony algorithm's ability of local optimization. On connecting the two algorithms, it found that the convergence speeds up, the task execution time is shortened dramatically, and the efficiency of the task execution is improved, all of which in turn helps reduce the energy consumption of the cloud systems.

Sambit Kumar et al. identify the direct proportionality between power consumption and resource allocation of computing tasks [12]. Conscientious management of resources can minimize the consumption of energy by the system and the makespan as well. The Adaptive Task Allocation Algorithm (ATAA) was proposed for a heterogeneous cloud environment to achieve this. It includes both the resource model and the task model. The execution rate achieved is way more in the proposed method, considering the urgent IO and CPU-bound tasks. Thus, a higher execution rate is achieved. The Expected Time to Compute (ETC) matrix accounts for the heterogeneity of tasks as well. The ATAA takes inspiration from the Hungarian method in the context of assignment problems. Upon evaluation, ATAA outperforms the Round-Robin algorithm under constraints, with the gap expanding with increasing VM count. The simulation results of ATAA conclude that it can lead to a dynamic approach for resource allocation that, according to supplied priority, can permit the preemption of tasks.

Dr. V Bindhu et al. propose a green cloud computing solution that addresses issues like reducing operational cost and reducing the carbon footprint and, subsequently, its impact on the environment [13]. They use data mining techniques and the approach of the model-driven engineering process to help reduce the carbon footprint and optimize the operational cost in GCC. The performance evaluation contrasts the average energy consumption (Joules/ Unit Workload) and CO2 emissions (Tons/ Unit Workload) with the traditional methods in GCC.

P. Geetha et al. propose an effective resource allocation scheme for cloud users by introducing two distinct layers- Cloud Manager Layer (CML) and Green Manager Layer (GML) [14]. The CML selects the appropriate resources from available ones, the GML chooses the best one among them. Grouping cloud servers by distance metrics makes the process of current status analysis of servers more effective. The approach used minimizes power consumption and service response time without compromising the Quality of service.

An enhanced two-phase VMP strategy is proposed by Rahimatu et al. using a prediction methodology [15]. The methodology is based on damped trend exponential smoothing, which is very effective for time-series analyses. It examines the objective function F (x, t) optimized and decides when to trigger the VMP reconfiguration (VMPr) phase for placement recalculation and reconfiguration. Temporal average costs were taken for benchmarking criteria. The results showed that the scheme best suits dynamic cloud environments due to the steady performance with increasing workload.

3. GCC STRATEGIES

Metric	Description	Formulation
PUE	Power Usage Effectiveness	$PUE = \frac{Total\ Power}{IT\ Equipment\ Power}$
CUE	Carbon Usage Effectiveness	$CUE = \frac{Total\ CO_2\ emissions\ caused\ by\ Total\ Data\ Center\ Energy}{IT\ Equipment\ Energy}$
WUE	Water Usage Effectiveness	$WUE = \frac{Annual\ Water\ Usage}{IT\ Equipment\ Energy}$
CREE	Cloud Resources Energy Efficiency	$CREE = (CRU * CRE)/PUE$
ERF	Energy Reuse Factor	$ERF = \frac{Reuse\ Energy\ outside\ of\ DC}{Total\ DC\ Source\ Energy}$
ERE	Energy Reuse Effectiveness	$ERE = \frac{Total\ Energy - Reuse\ Energy}{Total\ IT\ Equipment\ Energy}$
DCiE	Data Center Infrastructure Efficiency	$DCiE = \frac{IT\ Equipment\ Power}{Total\ Facility\ Power}$
DCP	Data Center Productivity	$DCP = \frac{Useful\ Work}{Total\ Facility\ Power}$
ERP	Energy-Response Time Product	$ERP^{\pi} = E[P^{\pi}] \times E[T^{\pi}]$, under control policy π
CF	Carbon Footprint	$CF = \frac{Annual\ Electricity\ usage \times CO_2\ national\ emission\ average \times 1\ metric\ ton}{2204.6\ lbs}$

Figure 1: Green DC

The first step to green data centers is to define specific green metrics based on which algorithms can be quantified and strategies devised. These metrics relate to multiple domains in cloud computing ranging from carbon emission to VMP. GCC strategies can take roots from various aspects factoring in GCC adoption/implementation. The strategies discussed can be categorized into the following categories

- Modelling Methodology
- VM Migration

- VMP
- Task Scheduling
- Resource Allocation

3.1 Modelling Methodology

When developing a cloud strategy to leverage platforms and capabilities efficiently, taking stock of internal resources and organizational design is of prime importance. Decision-making is perhaps an essential component of any organizational activity. It is essential for providing unity of action and being decentralized in concert. In [4], Jean-Charles et al. categorize all decisions in GCC into four classes:

- Supervising the system working
- Adapting GCC plans
- Changing GCC plans when necessary
- Managing breakdown cases

The core entity in their proposed model is the Decision-making Subsystem (DSS) which emphasizes that all parts of a GCC system can be functional in decision making from either a local scope or a global scope. A central decision center applies global strategies for system equilibrium. The distributed decision centers bring in hierarchical resolution and incremental approach for decisions. Modularization helps to make the strategy generic and reusable at multiple scopes.

3.2 VM Migration

Migration of virtual machines is gaining more importance today to improve utilization of resources, load balancing, isolation of applications, fault tolerance, portability of nodes, and to raise the cloud server efficiency. It refers to moving one virtual machine from one server to another with minimal disruption in the service.

In [5], Er. Yashi Goyal et al. highlight the importance of VM migration and propose a 2-phase strategy that minimizes the degree of SLA violation. The strategy results in performance on par with a complete Energy-efficient cloud. It leaves room for enhancement in other aspects of the cloud. Each phase implements its algorithm respective to its role:

- Hybrid VM selection policy Algorithm
- Low Utilization Host Policy Algorithm

Algorithm 1 selects migratable VMs on underutilized hosts who are migrated to hosts with minimum CPU utilization under Algorithm 2. The strategy ensures a minimized number of migrations which in turn results in minimum power consumption. Furthermore, this strategy is consistent with both live and inactive migration, making room for future enhancements.

3.3 VMP

VMP is a part of VM migration, and its practical implementation aims to improve performance, resource utilization with minimized energy consumption in DCs without SLA violation. While provisioning assets to VMs, a cloud supplier needs to augment asset usage by putting VMs over a minimal set of physical hosts. The VMP problem is dynamic, i.e., after the initial placement, new VMs with fluctuating resource requirements show up and existing VMs leave and the asset necessities change constantly. In this way, after completing the initial placement, scheduling decisions need to be taken intermittently at each scheduling cycle.

Mohammad Masdari et al. in [9] contrasted numerous VMP schemes for an extensive review across various factors. More than 30% of schemes used regression-based forecasting methods followed by ANN and exponential smoothing. They can be further improved to handle linear and non-linear loads. Additionally, more than half of them have applied heuristic algorithms. The review also strengthens the notion of dynamic power management in the future since static management is still adopted in most schemes. Another area of interest is context-aware VMP schemes which can predict patterns and resource requirements heuristically.

Rahimatu et al. proposed a two-phase VMP scheme with an enhanced damped trend exponential smoothing-based triggering method [15]. The scheme is divided into two phases, incremental (runtime/online) and reconfiguration (static/offline). This method would trigger VMPr with an optimized objective function, giving a more consistent temporal average cost than the distorted values in the existing two-phase scheme. The scheme addresses the uncertainty in the VMP problem with improved QoS.

3.4 Task Scheduling

Distributed cloud computing allows hundreds of online users to submit thousands of jobs either individually or in bulk for dynamic resources anytime, anywhere. Optimal Scheduling can be a critical problem in the cloud as many inbound tasks compete for resources due to subdividing these tasks. Optimization of task scheduling is essential in minimizing the response time and improving the service quality. However, in dynamic cloud environments, this becomes a nonlinear problem. The primary concerns being inherent uncertainty and conflicting objectives.

Jagadeeswara Rao. G et al. present a comparison of popular task scheduling algorithms in a small-scale DC environment [7]. The green scheduler comes out on top with the lowest power consumption and an average simulation time in the results. However, to achieve the same results with the green scheduler in a large-scale environment would require the scheduler to be already up and running and the peak load under the combined server tolerance at the time. Round Robin is another promising alternative and is adopted in a majority of the platforms in the market. It has an average power consumption with the best execution time.

In [11], Zhong Zong et al. propose a task scheduling algorithm that combines Genetic Algorithm (GA) and Ant Colony Optimization (ACO) to achieve quicker convergence and improved task scheduling, hence, lessening energy utilization. They combine GA's global and ACO's local optimization ability. In GA, a chromosome represents a feasible solution, i.e., compute node numbers corresponding to tasks. The chromosomes are encoded using an indirect coding method. A fitness function is used as a constraint to measure the optimality of the solution. Crossover and mutation operations are executed to produce chromosomes that have inherited superior genes of the parent. The fittest chromosome is set as the initial pheromone of ACO. Randomly arranged ants on resource nodes select the next assignable node of the next task. The scheduling improvement of the algorithm is reflected in the results, where it provides the best execution times with the lowest power consumption. Although the difference is not notable at a small scale, the gap becomes distinctive with increasing task count.

A task scheduling algorithm derived from the Hungarian method in assignment problems is proposed by Sambit Kumar et al. in [12]. The algorithm minimizes the makespan when VM count increases with growing input tasks making the rise in energy consumption gradual, not sudden. The algorithm directly results in an optimal solution instead of a feasible solution that must be optimized. However, the algorithm was devised with constraints like non-failing independent tasks and single-core VMs, which are not ideal for cloud computing. The algorithm best works with urgent CPU/IO-bound tasks where the task count will not spike erratically, and we can achieve heightened execution rates.

3.5 Resource Allocation

Resource Allocation (RA) is assigning available resources dynamically or statically to cloud applications over the internet. RA starves services if the assignment is not managed accurately, which is solved by resource provisioning by allowing service providers to manage respective module resources.

Among the three algorithms based on combinatorial auction by Tram Truong Huu et al. in [3], GGA is recommended for all cloud systems. It has the lowest execution time, highest user served percentage, and lowest energy consumption. The algorithm comprises two steps involving ordering and decision. We order the users' bid (resource requirement) based on a given criterion defined as the bid ratio to the total cost for energy consumption in the ordering step. The most feasible bid is determined as the winner. The payment is computed as the product of the energy cost factor and the bid. GGA is proven a truthful mechanism since a user will have to pay only the minimum value required to win the auction. To win the bidding, users must either have the highest bid or the lowest energy cost.

Karuppasamy et al. use an ant colony algorithm to optimize the resource allocation in [8]. Arrival task size, resources, and availability are identified initially to find feasible tasks. That task is assigned the resources using a fitness function, and the processing time is taken into the record. The processing time is considered as the pheromone for the next generation (allocation). The algorithm works well with dynamic resources and enhancing resource utilization. The algorithm works to reduce energy consumption and reduce the number of resources utilized without negatively affecting the performance.

In [14], P. Geetha et al. propose a scheme where a submitted request would go through the CML and GML layer for efficient resource allocation. The CML layer maintains a cloud resource table with multiple static and dynamic fields, the most important being Average Service Request (ASR) and Queue Length (QL). CML shortlists the table for machines with the least possible distance, ASR and QL. The GML employs the Lion Optimization Algorithm (LOA) to find the fittest resource for allocation. The fitness function is dependent on the utility degree factor, which is computed in percentage and ensures that the resources are not under or overloaded. The scheme outperforms similar approaches with respect to response time and power consumption. The utility degree factor ensures that the power consumption rate grows steadily and not in spikes. The scheme does not sacrifice the QoS, and by taking the sensitivity of a request into future consideration, it can be further enhanced and improved.

4. CONCLUSION

GCC is the amalgamation of environmentally sound technologies and organizational practices. In this paper, multiple GCC strategies were discussed across various aspects of cloud computing. Growing demand for cloud computing has led to an increase in DCs. This demand also contributes to climate change which is a severe environmental, economic, and social challenge. All the strategies surveyed lead to DC efficiency and reduced carbon footprint. The majority of the strategies still have room for improvement to make the DCs energy neutral. All future development must be with balanced performance and energy consumption trade-off.

REFERENCES

[1] Koomey. J, "My new study of data center electricity use in 2010" at https://www.koomey.com/post/8323374335, 2011, accessed on 13-April 2021.
[2] S.K. Garg., R. Buyya, "Green Cloud computing and Environmental Sustainability" in Harnessing Green IT: Principles and Practices, Wiley, 2012, pp. 315-340.
[3] Tram Truong Huu, Chen-Khong Tham, "An Auction-based Resource Allocation Model for Green Cloud Computing" in IEEE International Conference on Cloud Engineering, 2013, pp. 269-278.
[4] Jean-Charles Huet and Ikram El Abbassi, "Green Cloud Computing modelling methodology" in IEEE/ACM 6th International Conference on Utility and Cloud Computing, 2013, pp. 339-344.
[5] Er. Yashi Goyal, Dr. Meenakshi S. Arya Er. Sunil Nagpal, "Energy Efficient Hybrid Policy in Green Cloud Computing" in International Conference on Green Computing and Internet of Things (ICGCIoT), 2015, pp. 1065-1069.
[6] Prasanna N Balasooriya L.N, Santoso Wibowo, Marilyn Wells, "Green Cloud Computing and Economics of the Cloud: Moving towards Sustainable Future" in GSTF Journal on Computing (JOC), Vol. 5 No. 1, 2016, pp. 15-20.
[7] G. J. Rao and G. S. Babu, "Energy analysis of task scheduling algorithms in green cloud" in International Conference on Innovative Mechanisms for Industry Applications (ICIMIA), 2017, pp. 302-305.
[8] Karuppasamy M, Suprakash S Balakannan S P, "Energy-Aware Resource Allocation for an Unceasing Green Cloud Environment" in International Conference on Intelligent Computing and Control (I2C2), 2017, pp. 1-4.
[9] Mohammad Masdari & Mehran Zangakani, "Green Cloud Computing Using Proactive Virtual Machine Placement: Challenges and Issues" in J Grid Computing, Springer, 2020, pp. 727-759.
[10] Rashmi V Bhat, Sanjana M Moodbagil, Supreeta Anand Byatnal, Nalina V, "Survey on Energy and Cost Optimization Techniques using Green Cloud Computing" in Wutan Huatan Jisuan Jishu, 2020, pp. 337-345.
[11] Zhong Zong, "An Improvement of Task Scheduling Algorithms for Green Cloud Computing" in International Conference on Computer Science & Education (ICCSE), 2020, pp. 654-657.
[12] Sambit Kumar Mishra, Deepak Puthal, Bibhudatta Sahoo, Sajay Kumar, Mohammad S. Obaidat, "An adaptive task allocation technique for green cloud computing" in J Supercomput, Springer, 2017, pp. 370-385.
[13] Dr. V. Bindhu, C. Vijesh Joe, "Green Cloud Computing Solution for Operational Cost Efficiency and Environmental Impact Reduction" in Journal of ISMAC, Vol.01/ No. 02, 2019, pp. 120-128.
[14] P. Geetha, C. R. Rene Robin, "Power conserving resource allocation scheme with improved QoS to promote green cloud computing" in Journal of Ambient Intelligence and Humanized Computing, 2020, pp. 1-12.
[15] Rahimatu Hayatu Yahaya, Faruku Umar Ambursa, "Enhanced Two-Phase Virtual Machine Placement Scheme for Cloud Computing Datacenters" in 2019 15th International Conference on Electronics, Computer and Computation (ICECCO), IEEE, 2019, pp. 1-5.

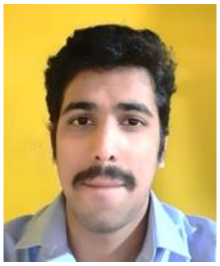
Authors

Ajay Singh is currently in his final year pursuing Bachelor of Engineering in Information Science and Engineering in B.M.S College of Engineering, Bengaluru, Karnataka, India affiliated with Visveswaraya Technological University. He is in constant pursuit of understanding and improving cloud technologies. His recent works have been in enhancing cloud service-broker platforms and overall DevOps workflow.

Anupriya Jain is currently serving as a Software Engineer Intern at Honeywell Technology Solutions Lab Private Limited. She is currently in her final year pursuing Bachelor of Engineering in information Science and Engineering from B.M.S. College of Engineering, Bengaluru, Karnataka, India affiliated with Visvesvaraya Technological University.

Naveen Kedilaya is currently in his final year pursuing Bachelor of Engineering in Information Science and Engineering in B.M.S College of Engineering, Bengaluru, Karnataka, India affiliated with Visveswaraya Technological University. He is a machine learning enthusiast and appreciates the challenge of questions with unequivocal answers.

Muskan Agarwal is currently in her final year pursuing Bachelor of Engineering in Information Science and Engineering in B.M.S College of Engineering, Bengaluru, Karnataka, India affiliated with Visveswaraya Technological University. She is a highly motivated, curious and creative person with skills in multiple IT principles.



Ashutosh G Shanbhogue is currently in his final year pursuing Bachelor of Engineering in Information Science and Engineering in B.M.S College of Engineering, Bengaluru, Karnataka, India affiliated with Visveswaraya Technological University. He is a conscientious team player with an enthusiasm for machine learning and artificial intelligence.

Heena Kousar B M is currently in her final year pursuing Bachelor of Engineering in Information Science and Engineering in B.M.S College of Engineering, Bengaluru, Karnataka, India affiliated with Visveswaraya Technological University. She is highly inspired by machine learning principles and is constantly expanding her skill-set.

Dr. Sheela S V has an experience of 21 years teaching courses in different facets of Information science. She has 17 publications to her credit. She is currently guiding three research scholars in the areas of biometric authentication. She has coordinated several workshops, industry visits and extension lectures including National level championships in association with IIT Kharagpur. She has actively participated in IEEE International Advance Computing Conference - IACC 2015. She is the member of IEEE.