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COMPLEXITY AND ENERGY SAVING IN CLOUD LOAD BALANCING ALGORITHMS: A STUDY

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ABSTRACT: Based on the idea of pay-per-use and on-demand access to shared IT resources, cloud computing is rapidly emerging as a computing model of choice. It holds ample promises for individual users and organizations as well as impacts significantly the IT industry as a whole. Consequently, there is a pertinent demand for large, high performance and efficient data centers. These data centers necessitate energy efficient cloud computing algorithms to reduce energy consumption and diffusion of carbon dioxide. This paper follows a systematic approach to review energy consumption algorithms used in cloud data centers. Although several studies are available in the literature, it is felt that more exhaustive study is required to present the stat-of-the-art in the field. Further, the paper identifies the most common factors such as the technique used by the researchers, resources on which they focused, strength, weakness, the complexity of algorithm and percentage of energy saving resulted by the algorithms and presents a comparative assessment of some select algorithms. This will certainly help the new researchers for a comprehensive understanding of the issues in cloud computing energy saving algorithms and set path for further study.

Keywords: Carbon Dioxide (CO2), Complexity of algorithm, Data Center, Emission, Pay-per-use, Energy Efficient Cloud Algorithm

I. INTRODUCTION

The increasing demand for computing technology in the last few years lead to emerge a new technology in the computing era known as Cloud Computing. In traditional computing expensive supercomputers were used for high-end computing. Still, it had a limitation of infrastructure cost, non-optimal resource utilization, and maintenance cost. Cloud computing is an alternative to the traditional system. As it consists of large data centers equipped with high-end technology to fulfill the demands of the clients. Within any botheration of the limitation of resources, the user can opt for any requirements and pay for the number of services they availed. There is a tremendous change in cloud environments. Cloud providers are merged to provide the best services. Some service providers are focused on cloud infrastructure and some of them are focused on services. As a result, clients are getting maximum benefits out of cloud services.

Some of the major benefits of cloud computing are cost-saving, elastic capacity, latest technology, mobility, no maintenance, easy access, increased security, and the illusion of infinite resources, etc. On the other hand, the cloud computing system encounters challenges like security, downtime, data privacy, high power consumption, etc. As per the demands of the clients, the size of the data center is increasing day by day and consuming more energy. This leads to the diffusion of carbon dioxide into the environment in the time of global warming. The energy-efficient algorithm is required to optimize costs while maintaining QoS and SLA.

This paper is divided into various sections, which start with the background study of cloud computing. The next section describes the need for energy-efficient load balancing in the cloud. The third section will brief about the taxonomy in energy-efficient algorithms, Section IV presents a review of the select algorithm used in energy-efficient cloud computing data centers. Section V describes different issues and challenges in cloud computing data centers. Section V describes a comparison of the different energy-efficient algorithms, Section VI presents some of the findings and the last section presents the future work and conclusion of the paper. The prime objective of this paper is to identify various existing energy-efficient cloud data center algorithms and prepare a comparative study on the select algorithm.

II. BACKGROUND

The setting of IT infrastructure by any organization required huge investment, manpower, 24X7 securities, 24x7 power supplies, and many more. This was necessary and very common in the traditional computing system. In a traditional computing system, different Operating systems (OS) and application services are installed on different physical servers. These servers are mainly connected with a switch and available on the organization premises.

Different physical servers are used to access different services in traditional systems in which most of the servers are underutilized and the efficiency of the system is always less than its capacity. These servers required separate high skilled manpower to manage and access the servers. The rapid change in IT infrastructure needs more investment in IT Infrastructure. Again security is a major challenge in the traditional computing system [22].

In the current business, companies are more inclined to their core business than IT infrastructure of their own. As a need and necessity, most organizations are moving onto the cloud platform to get the best services. With the help of technology and popularity, the organization is presenting itself in e-commerce, social networking, video streaming, search engine, digital marketing, business intelligence, data analytics, and many more. All these technologies including scientific workflow required a high-end computing system that includes servers, storage, memory, high networking, and parallel computing and these are available in cloud computing [1]. Looking into the demands, companies like Amazon, Microsoft Azure, Microsoft Office 365, Salesforce, Oracle Cloud, Google Apps, Digital Ocean, and others are providing different services/facilities in the form of Clouds [2].

2.1 Cloud computing

It is the practice of storing and accessing of data available over the internet. Cloud delivers different services like storage, servers, networking, databases, software, analysis, intelligence, and many more based on pay per usage. Cloud computing allows business organizations to access shared resources as per their needs. There is no physical dedicated server available in cloud computing which will be accessed by the clients. A technique like Virtualization is used to manage the physical resources in the cloud.

2.2 Virtualization

In virtualization, the physical hardware system of the computer is layered to create and run the systems as the virtual instances. Virtualization abstracts the physical systems of the data center as a virtual resource and a single physical server can be virtualized into no services. Virtualization helps to create virtual instances of computer hardware, storage devices, memory, data, and network resources. Software like Hypervisor or the virtual monitor is used to manage the virtualization in the cloud. The benefits of virtualizations are like maximum resource utilization, support multiple OS and applications, flexibility, scalability, security [24].

2.3 Hypervisor

In virtualization, different resources are installed or configured in one or more physical servers. Typical software is used in virtualization to separate the physical resources of the servers available in the data center to the virtual environments. The software is known as Hypervisor.

There are two methods available to use in virtualization as hosted and bare-metal. In hosted service, all the guest OS and applications are installed on top of the underlying OS. It takes the help of a hypervisor or virtual machine monitor to do the installations. In bare-metal architecture, the hypervisor is directly installed on the hardware. Users interact and run their computations within the virtual environments and different services assigned to the clients are executes as per their requirements [8].

Cloud computing is a completely new architecture in comparison to the traditional computing system. As the resources are available in different VMs and several of clients are accessing the cloud concurrently, there is a need for effective and more reliable load balancing to balance the loads among the VMs [3]. A huge no of physical servers is used in data centers that consume high energy. To minimize the power consumption in the data center server consolidation is used.

2.4 Server consolidation

The main purpose of the consolidation of the server is to minimize the number of servers and maximize available resources. Server consolidation reduces the energy consumption of computer resources by managing them efficiently.

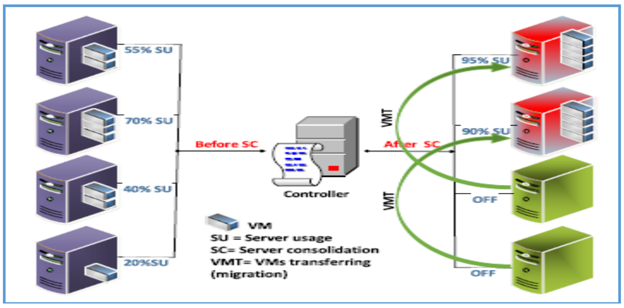

Figure 1: Sever Consolidation [Source: [10]

2.5 VM scheduling

Based on constraints like resource constraints or time constraints, the scheduler will assign the task to the VMs. The cloud datacenter will classify the tasks according to the SLA and availability of requested services. Once the server performs the task it transmits the response back to the client. The primary objective of the scheduler is to balance the scenario for processing the task by spreading

the load of the processor and minimize the total task execution time [2].
The scheduling algorithm works based on finding of PM by the VMs, proper provisioning scheme, and scheduling of tasks on the VMs

To provide the different services to the clients three models are available in a cloud computing system as Software as a Service (SaaS), Platform as a Service (Paas), and Infrastructure as a Service (IaaS) [11].

A. SaaS is available to the clients based on the distribution model. This avoids the pain of software installation in each client system. The software will be available to the clients in their web browser. It is independent of any specific hardware installation or available in the client system and it is based on software subscription.

B. PaaS provides the necessary environment for the clients to create, host, and deploy different applications. Software development and deployment control by clients with fewer efforts. In this type of service, the client gets the benefit of Operating Systems (OS), middleware like JRE, and .NET, Database services. It also provides services like Business Intelligence (BI), security, and scheduling.

C. In IaaS the clients will get the benefit of virtualized resources over the net. It manages the creation of virtual machines and enables VM migration. It may scale up and down as per the requirement of the clients. It helps to purchase huge cost infrastructure to run the OS and different application software.

These services are available in different types of cloud-like i) Private cloud, ii) Public cloud, iii) Hybrid cloud, and iv) community cloud [2][20]. Each model is having its own merits and demerits.

A. A private cloud is mainly used for data security. It is of two types as a) on-premise private cloud and off-premises/ externally hosted private cloud. In the on-premises private cloud, the services are hosted within one data center. In off-premises/ externally hosted private cloud the services are hosted externally or outside with a cloud provider [21]. It is usually not exposed to the public. One of the major drawbacks is it is managed by the business organization. The company is fully responsible to manage the cloud as a whole. This type of cloud is highly secure, high energy efficient, low complexity, and less risky, but it is costly.
B. The public cloud is meant for the public, where any organization can avail of the services and pay as per the usage. This type of cloud is mainly based on the virtualization technique. It is accessible to the clients through the internet. It may be hosted inside the country or outside the country. It supports no of high computing applications like big data processing, business intelligence, etc. As the users are considered as untrustworthy, privacy and security is a concern in the public cloud. [22].
C. A hybrid cloud is a combination of private cloud and public cloud in which confidential information will be in the private cloud and the rest of the common information will be in the public cloud. Sensitive data or application is kept inside the private cloud and other applications in the public cloud. It is accessible from the private network of the organization as well as a public network. This type of cloud is often used for backup purposes. [22].
D. In the community cloud, employees from different organizations work on a common platform. It mainly focused on the specific needs of different communities available in the cloud. The infrastructure is shared among the specific community with the same or similar concerns like compliance, jurisdiction, security, etc. A community cloud is a variant of the private cloud. In this type of cloud software tools are used to meet the needs of the community. Community cloud cost is less as the cost-shared with organizations but has a limitation of sharing of storage needs. The best

As cloud computing providing on-demand sharing of different computing resources with very little effort by the organization, it is necessary to realize the provisioning of the resources. Cloud computing data centers may be over-utilized or underutilized. When the capacity of the host is less than the demands on the host, it will be over-utilized. As a result, some (sometimes all) VMs on the host are not able to meet Service Level Agreements. Thus decreasing the number of over-utilized hosts results in fewer SLAVs [4].

There is a tradeoff between SLAV and the number of PMs as when no PMs are minimized there is an increase in SLAV [7]. There are two major reasons for SLAV as a) Overutilization of VMs and b) migration of live VMs [7]. VM migration could be based on bandwidth, communication speed, the distance between cloud nodes, and the client to resource location distance [9]. Bandwidth consumption on the link between the client and the nodes has to be based on a minimum no of hops to minimize the network power consumption.

III. NEED OF ENERGY EFFICIENT ALGORITHMS

Energy consumption in the data center is very high; it is due to the different resources used in cloud data centers. Researchers revealed that energy consumption will be 10300 TWh per year in 2030 based on 2010 efficiency levels and energy consumption [9]. The main challenge in the cloud data center is energy efficiency and eco-friendly cloud computing. In the age of global warming, it is not acceptable to use high energy computing devices and emission of high Carbon Dioxide [23] devices in data centers.

The main devices which consume more energy in datacenters are CPU, disk storage, memory, and network devices. At the same time, cooling and distribution of jobs also consume energy in the datacenter. It is found that excess energy consumption diffuse more carbon dioxide, decreases system performance, and increase monetary expenses [10]. As per a Google study, an idle server consumes around 50% energy in comparison with energy consumption of the server in peak hours [21], Therefore a novel technique is required to monitor the servers and needs to decide when to put on sleep mode effectively in the clouds physical servers. An effective energy-efficient algorithm will consume less energy and produce low diffusion of carbon dioxide. This will save the total expenditure of a data center

CPU energy consumption can be managed by shifting the overloaded VMs to the underutilized VMs based on different load balancing algorithms used in cloud computing. While moving the load from one VM to another it is necessary to minimize the level of SLA violation, which is one of the essential requirements of any data center. A proper load balancing system with the minimum number of resources will increase efficiency and decrease power consumption [6]. Further researchers revealed that power consumption in a cloud data center can be minimized by using less energy consumed, effective, and powerful hardware devices like DVFS based CPU, flash memory, etc. [12].

Energy cost varies from geo-location to geo-location which leads to focus more on the data center systems location where energy cost is cheap in comparison to other locations. This will not only minimize the expenditure of cloud computing and decrease carbon diffusion but also increase user satisfaction. Energy efficiency is the biggest challenge in cloud computing. This can be managed by maximum resource utilization with limited resources. The challenges in the cloud data center with energy efficiency are a) selection of workload type, b) provisioning of resource allocation, c) asset utilization, and d) performance increase [4].

Alternate to the general source of energy, a cloud data center may use renewable energies, but it is unpredictable and depends on nature. The best practice is to use a multi-sources power supply in a cloud data center [14].

In the majority of cases, it is observed that the researchers have focused on different algorithms based on energy utilization in CPUs and ignore the energy consumption in the cooling system, network resources, storage devices, and other resources.

Limited of researches has been done by the researchers on load balancing, server consolidation, and task scheduling. Based on the outcomes of the research they shared that cloud computing facing load balancing as the major issue in energy efficiency.

Irrespective of the situation cloud providers have to provide continuous power supply to the data centers to avoid the SLA violation with the best energy-efficient systems. Therefore, there is a need for more research on energy-efficient cloud algorithms to increase the efficiency of the cloud data center by decreasing energy consumption and diffusion of carbon dioxide without violation of service level agreement (SLA).

IV. THE TAXONOMY OF ENERGY MANAGEMENT TECHNIQUE IN CLOUD COMPUTING

There are two basic ways to save energy in any data center. The first one is by reducing energy wastage and the second one is by increasing the efficiency of the data center. The energy in a data center can be managed in four ways first at the hardware level, second by using optimized resource management techniques, third based on geo-location and a fourth one is using different software technology or algorithms.

A. HARDWARE

Energy wastage can be minimized by using a different technique like star ranked devices related to CPU, storage, memory, network resources, etc. Hardware and equipment design plays an important role in energy saving at a semiconductor level by using advanced level designs, outlined time with track and framework level [14]. Some of the technique like Multi-Speed Disk, Solid State Disk is popularly known as SSD Disk [18], DVFS enabled CPU, DVFS based CPU and DVFS based flash memory may be used in the cloud data center which will increase the energy efficiency of the data center and decrease the power consumption[13][17]. DVFS decreases the power consumption by CPU frequency which may be scaled up and down depending on the task given to the CPU [14]. Multi-speed disks are available for commercial applications. These devices are designed based on the Intelligent Power technique. This technique adjusts the speed of the motor and the transfer rate to reduce disk power consumption [19]. Flash-based solid-state disk or SSD is used in cloud systems as they are non-volatile, consume less energy, resist shock, and excellent in the read operation. The systems can design it in such a way when they are not in use, they will be in sleep mode

B. OPTIMIZE RESOURCE MANAGEMENT

Cloud infrastructure plays an important role in energy saving. Without the change or upgrade of cloud infrastructure, it is difficult to achieve QoS in cloud computing. Therefore there is a need for optimized resource management. In a data center, the energy consumption is about 40% of the total energy used. It is including communication links, aggregation elements, and servers [16]. The use of more infrastructures fulfills the requirements of the users but consumes more energy and on another side, fewer infrastructures may lead to SLAV, so an appropriate and optimize resource management policy is required in a cloud data center to achieve energy consumption objectives.

C. LOCATION LEVEL

The location level data center plays an important role in energy saving in the cloud data center. It may be based on the cost of energy or based on the clustering of data centers. Each type has its own merits and demerits in energy saving.

a) Energy Cost

The cost of energy plays an important role to set up any cloud data center. Energy cost varies from geo-location to geo-location. The power consumption cost of a data center is about 40% of the cost of the data center as a whole. Based on the cost, a company may set up a data center. Production of renewable energy will decrease the expanses up to some extent, but it depends on the locality and environmental situation of the data center.

b) Clustering

A technique in which nodes holding a similar type of data will be grouped is known as a cluster. When data were available in different geo-location, it makes sense to cluster the nodes for the saving of energy. Energy efficiency in cluster computing is based on operational cost and system reliability. Static power management (SPM) saves energy by utilizing a low power component. Dynamic Power Management (SPM) saves energy by utilizing software and scalable components.

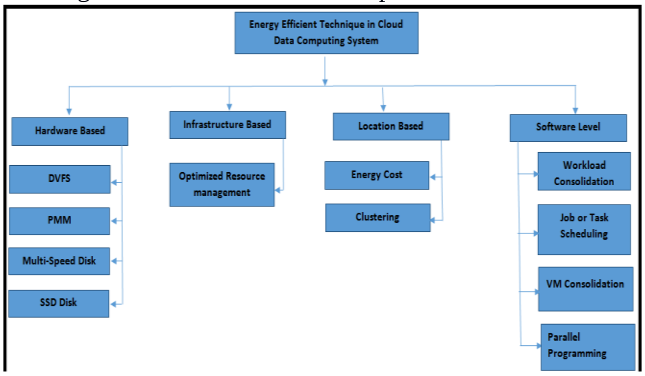

Figure 2: Taxonomy of power management techniques

D. SOFTWARE LEVEL

Software technique or algorithm is necessary to increase the efficiency of the data centers as they play a major role in the cloud computing data center. Algorithms help in workload consolidation, task scheduling, VM migration, etc. This will not only save energy but also increase efficiency, maintain QoS in the system, and avoid SLA violation.

a) Workload Consolidation

It decreases the usage of energy by changing the state of the system from idle mode to turn off mode. It balances the performance of the system and avoids overloading. Dynamic workload consolidation reduces energy consumption by shifting the workload to fewer servers

b) Job/Task Scheduling

In task scheduling tasks will be scheduled to get the CPU depending on different algorithms like First in First Out (FIFO), Shortest Job First (SJF), Round Robin, etc. as a result load on the system will decrease and there will be an increase in energy efficiency.

c) VM Consolidation

In VM consolidation several virtual machines gather together into a single PM. By placing a VM in a selected PM or moving VM from one PM to another. This is done by using the logic when to migrate, which VM to migrate and when the VMs migrate. It helps to decrease energy usage by the migration of the VMs from underutilized PMs to other resources. VM placement is a part of VM Migration in which the system finds out the best Physical Machine (PM) to host the VMs.

d) Parallel Programming

In parallel programming execution of multiple tasks performed simultaneously. It breaks the large problems into smaller tasks or statements to process simultaneously. A technique like MapReduce can be used to develop a high-performance cloud application. As it saves time of computing and increases the efficiency of the systems, as a result, it maintains QoS and decreases energy wastage.

V. REVIEW OF ALGORITHMS

[25] In the proposed method the upcoming task dispatch to the minimum no of available servers by adjusting the execution frequency. Again there is a processor level migration in which the remaining tasks of the individual server will be dynamically balanced the workload for total ECR. They show that the performance of the system increase and saves energy. The proposed algorithm maintains QoS, by maintaining the principle task in time. To get it the system will estimate the workload of each input task before it gets to execute. The algorithm is based on two methods as local task migrations and energy-aware task allocation.

[26] The proposed algorithm is to determine the data center is imbalanced or not and then it will redistribute the workload among all the hosts. They used a mathematical model in which VMs will be reassigning to the data centers' hosts. Energy consumption of the data center is minimized by using a mathematical model in which they reassign the VMs to the data center hosts. It is consists of two algorithms as a) clustering process to organize the nodes into cluster heads and b) Matching method to minimize migration costs and energy consumption. This algorithm is based on parameters like Computing Balance Factor, Detecting overload, selecting particular VMs to migrate if there are under loaded hosts. They compared their method LBBMC with Local Robust Regression Minimum Migration Time (LRRMMT) and show that in LBBMC energy consumption is lesser than the LRRMMT algorithm. This is happening due to the balance factor computing time but it was not considered in LRRMMT.

[27] The proposed algorithm used a virtual machine migration technique to solve major issues of cloud data centers like load balancing and power consumption. The migration scheme is named as eeadoSelfCloud. They used a technique called Bee Lion Optimization. They used parameters like VM allocation, utilization of data center, average node utilization (ANU), hop count, etc to overcome the migration issue. The BLO algorithm finds out the best VMs based on three values as Residual Power, Previous Allotted Counter, and CPU utilization. The BLO will group the results into four different groups a) Critical Group, b) Active Group, c) Selfish Group, and d) Overflow Group. The VMs will be in an Active state

at first and then change to other groups. The algorithm was tested with two experiments. In the first case, performance is measured based on request propagation, and in the second case based on power consumption. The result shows that it is autonomous and energetic.

[28] The proposed algorithm is based on Particle Swarm Optimization (PSO) to solve the complex resources required for scientific workflows. To solve the problems they have divided into two phases as Preparation of the tasks list and schedule of the task. In the first phase, the algorithm will process the bottleneck tasks and reduce the execution time. In the second phase, the algorithm will schedule the task to reduce cost and execution time. The proposed system monitors the load balance for effective uses the cloud resources. Workflows are represented in directed acyclic graphs. The vertices represent the tasks and dependencies of the tasks in the edges. They tested the algorithm with the different dataset and show that the proposed algorithm will reduce the energy consumption when compared with other algorithms

[29] The algorithm is focused on the VM selection technique. The technique selects the required VMs from the overloaded servers. The algorithm is based on two steps. In the first step it will determine the overloaded server and in the second step selection of the VMs from the server for migration in an intelligent way. The proposed algorithms maintain the level of QoS while saving power. It was tested with the CloudSim simulator and show that the algorithm will minimize power consumption and several VMs migration.

[30] The proposed algorithm Greedy based solution (GreenGLB) is based on real-world workload traces and the cost of electricity. Workload and electricity charges are not considered by the researchers in the algorithm. They compared their algorithm with the standard benchmark algorithms. The findings of the algorithms show that the proposed algorithm is superior in performance and total energy costs, especially for geographically distributed data centers.

[31] This algorithm is based on the threshold of resource utilization. It is based on a minimum migration policy and ensures to lowest VM migration to maintain SLA. The algorithm solved the NP-Hard of VM placement. The method is based on three parts. a) The algorithms consider Resource utilization and the threshold value of the PMs, b) Measure the Euclidian distance between the PMs which helps to select the VMs to be migrated, c) used IGAVP for effective VM placement. This algorithm also supports the bin-packing problem which occurred in the cloud data center.

[32] The algorithm is based on a forecasting model to predict the energy demand and offer minimum usage-based prices for the data center. It co-ordinates the data center workload for power supply, generator, battery backup, and other renewable sources. It forecast based on electricity price day ahead which helps to save energy cost. The algorithm simulated with real data set.

[33] The proposed algorithm combines three models to get the maximum energy saving and minimize the SLA violation. The gradient descent-based regression (Gdr) method is an adaptive energy algorithm based regression to detect the overloaded hosts. The maximum correlation percentage (MCP) is a regression model that will set an upper threshold based on the correlation coefficient. The bandwidth-aware selection policy (Bw) is the VM selection algorithm which will minimize the migration of VMs. Them VMs are selected based on CPU, Network traffic, and Memory. The algorithm reduces energy consumption in the cloud.

[34] KnEA (knee point-driven evolutionary algorithm) is based on many objective virtual machine placement models. It considers different resource utilization, energy consumption, load balancing, and robustness of the VMs while designing the algorithm. It can be used for many-objective problems. They solved the virtual machine placement problem by improving the algorithm and named as EEKnEA. Though the algorithm is many-objective algorithms but has not focused on abnormal load including overload and under load.

[35] This paper is based on scheduling load between servers instead of dependent on the centralized system. They shifted the distributed responsibilities across the heterogeneous servers.
Considered each server will manage its own VMs. The VMs will migrate from lightly loaded servers to powerful servers. If any server is in idle mode means the server without VM, will move to sleep mode to save energy consumption. They compare their LACE algorithm with existing DVFS (dynamic voltage-frequency scaling), energy-aware scheduling, and minimum utilization policy to show that the energy consumption in LACE is less. They used resource allocation management, task scheduling, and VM migration policy in the algorithm.

[36] The researchers have focused on VMs allocation. The algorithm is considering the ratio of reservation of resources and allocation of resources in a dynamic model. It maintains resource utilization within a range. Then it fragments the resources for future use. It satisfies the maximum resource requests. They compare the algorithm with RUAEE and the result shows that the proposed algorithm reduces the risk of system overload and also improves the stability of the systems

[37] They proposed the algorithm to cluster the VMs based on the strengths K-means clustering with weight parameter and PSO (Particle Swarm Optimization) algorithms using the weight parameter. The proposed algorithm is named KPSOW (K-means with particle swarm optimization using weights). The algorithm focused on low complex tasks to low performance and high complex tasks to high-performance tasks. They compared the result with PSO and FCFS. The result shows that there is a considerable change in resource utilization and an increase in energy efficiency.

[38] The VM consolidation algorithm is based on resource utilization at present and future. Future resource utilization is predicted using the regression-based model. It predicts Memory and CPU utilization of the PMs and VMs. It is tested with PlanetLab and Google cluster real-world traces. The VM consolidation problem of the cloud is addressed with the Utilization Prediction Aware Virtual Machine Consolidation (UP-VMC) technique. The result shows that there is a substantial growth in power saving in the algorithms.

Comparison of different algorithms based on different methods, resources on which they focused and limitation in the algorithms.

Ref	Algorithms	Technique	Resources	Strength	Weakness	Complexity of Algorithm	Energy Saving
[25]	A DVFS Based Energy-Efficient Tasks Scheduling in a Data Center	DVPS	CPU	Dynamic Work load, Cost Saving And Response Time	Service allocation may not attain	O(n)	23%
[26]	Energy-Efficient Resource Allocation and Provisioning Framework for Cloud Data Centers	Dynamic Provisioning and Resource Optimization	CPU , RAM, Network	Tested with Google traces and cluster. SLA	Workload prediction model need to improve for best performance. Guaranty on CPU workload only	O(n)	substantial energy savings
[27]	Energy Efficient Adaptive Depth Optimized Self Cloud Mechanism for VM Migration in Data Centers	VM Migration	CPU	Improve resource efficiency, reduce allocation time	Based on static resource allocation	$O(n^2)$	Consume less energy
[28]	A Hybrid Algorithm for Scheduling Scientific Workflows in Cloud Computing	DVFS	CPU	Consume less time and save money. Without changing the load balance	May not guarantee QoS	$O(n^2)$	Consume less energy
[29]	Energy And SLA-Aware VM Selection Algorithm For Resource Allocation In Cloud Data Centers	VM Consolidation and Migration	CPU	Power efficiency, resource allocation and SLA	Selection of VM for migration	O(n)	Improved
[30]	Energy Efficient Indivisible Workload Distribution in Geographically Distributed Data Centers	Workload distribution	dynamic electricity prices	guaranteed QoS	batch workload and bandwidth cost	O(n)	Reduce
[31]	Energy-Efficient Virtual Resource Dynamic Integration Method in Cloud Computing	PM/VM Selection and VM Placement	PM and VM	Solved the bin-packing problem	QoS, Impact of network resources	$O(n^2)$	Reduce
[32]	A Robust Optimization Technique for Energy Cost	Cost forecasting	Energy Cost	Minimize data center cost	Uncertainty on electricity cost and natural calamites	$O(n^2)$	Improve

	Minimization of Cloud Data Centers						
[33]	Adaptive Energy-Aware Algorithms for Minimizing Energy Consumption and SLA Violation in Cloud Computing	VM Selection and Migration	Network traffic, CPU, Memory	analyzed the impact of PM type and task execution time on power consumption	May leads SLA violation	$O(n^2)$	Improve
[34]	Energy-Efficient Many-Objective Virtual Machine Placement Optimization in a Cloud Computing Environment	VM Placement	PM	energy saving, robustness	abnormal load	$O(n^3)$	Reduce
[35]	A Locust-Inspired Scheduling Algorithm to Reduce Energy Consumption in Cloud Datacenters	DVFS and workload aware	CPU	fault tolerance under heavy workloads, SLA	network traffic of datacenter components and clustering	O(n)	Reduce
[36]	Server Consolidation Energy-Saving Algorithm Based on Resource Reservation and Resource Allocation Strategy	Resource reservation and resource allocation ratio for VM Allocation. Predictive analysis	CPU	Prevent SLA violation	migration costs, communication costs	$O(n^2)$	Reduce
[37]	Cluster based Hybrid Approach to Task Scheduling in Cloud Environment	K-means clustering and PSO with weight	Task schedulin g	Improve utilization of resources	May leads SLA violation	$O(n^2)$	Reduce
[38]	Energy-Aware VM Consolidation in Cloud Data Centers Using Utilization Prediction Model	VM Consolidat ion	CPU, Memory	Based on regression for forecasting the future usage and minimize violation of SLA	Scalability issue	$O(n^3)$	Substantial ly Reduce

Table I: Comparison of Energy Efficient Cloud Computing Algorithm

VI. OBSERVATIONS AND FINDINGS

Even though plenty of algorithms are proposed and implemented in cloud computing some of the major drawbacks identified are:

- QoS and SLA are necessary while VM migration.
- More focus on network devices, cooling systems power consumption.
- Network Bandwidth will play a major role in SLA during VM migration
- More focus on VMs migration based on overloaded and under loaded VMs.
- MSD Disk, SSD Disk, DVFS enabled CPU, DVFS enabled Flash memory will minimize energy consumption.
- Data centers set up based on energy costs will reduce total energy costs.
- Workload based server may be used instead of multiple underutilized servers.

VII. CONCLUSION AND FUTURE WORK

Energy efficiency in the cloud is one of the important issues in the cloud data center and it will continue as a challenge due to high operational cost and diffusion of CO_2. In the era of global warning diffusion of CO_2 to the environment is not acceptable. To reduce the operational cost and carbon diffusion there is a need for further research in this area. In this paper, we studied select energy-efficient algorithms categorized them. The taxonomy will provide in-depth knowledge of energy-efficient algorithms and challenges to continue future research work. The outcome of the study was categorized based on energy efficiency, the complexity of the algorithm, technique, resources used, strength, and weakness of the select algorithm. More research work may be carried out by the researchers on energy-efficient infrastructure and algorithms to solve the power consumption issue in the cloud data center. In future research work, we investigate more energy-efficient algorithms and develop an algorithm that will increase the energy efficiency of the cloud data center and reduce the data center cost as a whole.

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