# Energy-Efficient Resource Scheduling In Cloud Computing

**Navjyoti Prakash[1], Ms. Naziya Anjum[2], Dr. Sifatullah Siddiqi[3]**

*[1]PG Student, Dept. Of Computer Science and Engineering, Integral University Lucknow, Uttar Pradesh, India*
*[2,3]Assistant Professor, Dept. Of Computer Science and Engineering, Integral University Lucknow, Uttar Pradesh, India*

---***---

**Abstract –** *Cloud computing is a popular computing paradigm which offers scalable on-demand access to computing services including processing power, storage and networking services. Nonetheless, the fast development of cloud services has dramatically consumed more energy at cloud data centers caused by the persistent usage of resources, the inefficiency of the distribution of tasks as well as the use of the computing infrastructure that is not fully used. This is because high energy usage is not only costly to the operations, but it has also been identified as a source of environmental issues and hence energy efficiency is a major concern in the cloud computing environments.*

*Resource scheduling that is energy efficient tackles the issue by assigning tasks to the computing resources in such a way that the resource minimizes the amount of power consumed without affecting the performance of the system, its reliability or the Quality of Service (QoS). The issue of energy usage of cloud computing systems and different energy-aware resource scheduling methods are discussed in the paper. It talks about techniques like dynamic voltage and frequency scaling, consolidation of virtual machines, scheduling of tasks with attention on power consumption, and load balancing plans that tend to maximize the use of resources and minimize the consumption of energy.*

*The strategies are based on enhancing the efficiency of a given system through reduction of idle resource power and ensuring that workload is optimally distributed across the available computing resources. The paper will also indicate some of the important performance metrics that would be used to gauge the effectiveness of the energy-efficient scheduling algorithms such as energy consumption, resource utilization, time taken to complete a task and compliance with service level agreement.*

*The paper highlights the relevance of smart and adaptive scheduling system with respect to realization of sustainable cloud computing infrastructure. Energy efficient planning that is effective in cost minimization, carbon emission and increasing the effectiveness of the system and resources utilization. Consequently, the creation of enhanced time management methods is needed to enhance the sustainability and efficiency of the contemporary cloud computing environments.*

**Key Words: Cloud computing, Energy-efficient scheduling, Resource allocation, Virtual machine consolidation, Power consumption optimization.**

## 1. INTRODUCTION

Cloud computing is a revolutionary computing model that offers on-demand access of shared computing resources in the form of processing power, storage and networking resources over the internet. It allows organizations and users to use a scalable and elastic computing infrastructure without incurring huge expenses by making substantial investments in physical infrastructures or upkeep [1].

The speed at which people are moving towards cloud computing in different fields such as business, health care, education and research has greatly surged the demand of the computational resources. This has seen cloud data centers grow at an alarming rate to facilitate the delivery of services in large scale and constant accessibility to resources. The popularity of cloud computing has increased the rate of energy consumption in cloud data centers even though cloud computing has its benefits. They are scaled-up physical server based data centers numbering in the thousands with networking devices and systems as well as cooling facilities that need to be used 24hours round the clock to accommodate dynamic work loads and user demands [2].

Running and inefficient use of resources are also some of the factors that make energy consumption excessive. Servers also consume a lot of power even when they are underutilized or idle which results in the wastage of energy. This high power usage adds to the cost of operations of cloud service providers and is also a source of environmental issues like carbon emissions and global warming. Thus, the enhancement of energy efficiency of cloud computing has emerged as a research topic of interest to academia and industry.

Inefficient management of resources is one of the key issues that influence the energy usage in cloud environments. Cloud systems should assign tasks, applications and services to computing resources at hand, in a manner that would maximize performance, and guarantee minimum wastage of resources [3].

Resource scheduling is an important part of this process whereby the allocation of tasks to virtual machines, processors, and storage units is done. Effective scheduling aids in better utilization of resources, minimization of processing delays and increased system performance. Nevertheless, conventional scheduling methods are primarily concerned with maximizing performance and do not pay much attention to energy efficiency concerns [4]. Resource scheduling that is eco-friendly is set to overcome this shortcoming by using power consumption as a key parameter when making decisions regarding resource allocation. Energy-efficient scheduling is aimed at the main objective of achieving minimum energy consumption with system performance, reliability and Quality of Service (QoS). It entails the selection of the proper computing resources, workload distribution, and bringing [5] down the number of the active servers when the demand is low. Energy-efficient scheduling will enable organizations to cut down on power consumption to a large extent without affecting service quality, since it will be achieved effectively through efficient allocation of the resources.

Several methods have been invented to enhance the efficiency of energy consumption in the cloud computing systems. These are dynamic voltage scaling and frequency scaling which scales the processor speed according to workload needs and virtual machine consolidation which cuts back on the number of running servers by moving workloads to fewer servers [6]. There are other methods such as power-conscious scheduling of tasks and load balancing techniques that allocate workloads effectively within the available resources. The methods are aimed at maximizing the performance of the systems and minimizing the consumption of unnecessary energy. Nevertheless, there are a number of difficulties in applying energy efficient scheduling in the cloud environment. The workloads in clouds are very dynamic and unpredictable and hence, they are hard to allocate resources efficiently on the fly. Moreover, energy saving and system performance tend to be traded off where minimizing the consumption of energy can impact the speed of processing and services delivery [7].

The scheduling decisions are also complicated by the fact that it is harder to manage resource heterogeneity and guarantee adherence to service level agreements. In this paper, attention is paid to the concept of energy-efficient resource scheduling in cloud computing and the discussion of different methods of minimizing energy consumption without affecting the performance of the systems [8]. It describes the necessity of energy-conscious scheduling tools, the various optimization strategies, and the major issues surrounding the concept of energy-efficient resource utilization. The research will seek to offer information regarding how to enhance the sustainability and efficiency of cloud computing systems with respect to efficient resource scheduling strategies.

## 2. Energy Consumption in Cloud Computing

A significant issue in the cloud computing setup is the use of energy because of the massive infrastructure and the constant running of the cloud data centers. Cloud service providers have thousands of "physical servers, networking equipment and storage to provide continuous services to users [9]. These units consume a lot of electrical energy to compute, process data and cool them down. With the ongoing rapid expansion of cloud services, control over energy usage has become a necessity in terms of decreasing the costs of operations, enhancing efficacy of the system, and lessening the effects on the environment [10]. Some of the major components that cause energy consumption in cloud environments are the areas of CPU processing, memory consumption, storage, and idle servers. Of these, CPU processing is the single greatest consumer of energy since most of the computational activities are performed by processors. When the CPU is used heavily, it consumes more power particularly when handling complex workload or using large scale applications. Power used by processors is determined by their working frequency, voltage at which they are operating [11] and the level of workload they are doing. With the rise in the demand, the processors run faster and hence consume more energy.

Another important source of energy consumed by the cloud systems involves the usage of memory. Even with a relatively low workload, memory modules actively use power both to save data and to access it. The use of cloud applications in large scale consumes a lot of memory capacity to process the data which is a source of total energy consumption [12]. Likewise, storage processes like access, transfer and maintenance of storage devices also demand a lot of power. Cloud data centers are based on large storage systems to store large volumes of data and when the data is subject to frequency input and output operations the energy demands go up. Idle servers are one of the biggest energy wasters in the cloud computing environment. Servers also consume a lot of power to be in operation even when they are not working on tasks [13]. Research indicates that nonproductive servers can use a high percentage of peak power consumption, which results in poor energy conversion. This is because servers have to be on standby to receive incoming work at any one time hence constant power use irrespective of the degree of work. In turn, the poor allocation of resources and overutilization of the servers contribute a lot to the total energy consumption in the cloud data centers.

Besides computer parts, other infrastructure equipment like cooling systems and network devices are also sources of energy consumption. Continuous use of servers in cloud data centers produces a lot of heat that may need sophisticated cooling systems in order to maintain optimal temperatures of the servers [14]. Cooling mechanisms also use more energy which further adds to the overall power usage of cloud infrastructure. Transmission and communication of data in networks are also done by network devices, which need to be powered constantly contributing to the total energy consumption. Power usage in cloud computing is often modeled mathematically in order to gain a better understanding and control of the use of energy. A basic energy consumption model is given as:

$E = P \times T$

In which the E is the total energy used, P is the power used by the computing resource and T is the time taken to run a task. According to this model, the amount of energy consumed by a system and the time period of operation of the system are the factors that determine the energy consumption. Thus, the decrease in either power usage or execution time can be used to reduce overall energy consumption. The energy consumption in cloud computing systems tends to grow as the resources are used but does not decline on an equivalent proportion when the utilization declines [15]. This non-linear association leads to the poor use of energy when workload is low. Consequently, there is a need to have an effective resource management strategy to achieve optimization of energy consumption and efficiency of the system.

Resource scheduling can be of great importance when it comes to minimizing the use of energy consumption, where a task is distributed among computing resources according to the workload needs and energy efficiency. The purpose of energy-aware scheduling methods is to reduce the count of active servers, the idle power consumption, and optimize the use of the resources [16]. Cloud systems can also use dynamic processing of workloads and task consolidation to minimize unnecessary energy consumption. In sum, it can be concluded that the sources and nature of energy consumption in cloud computing are necessary to create an efficient way of resources scheduling, which is energy-efficient. Cloud service providers can also ensure better system performance and lower the operation costs as well as increase the sustainability of cloud computing environments by determining significant contributors of power usage and employing optimized resource management strategies.

**Table -1:** Major Sources of Energy Consumption in Cloud Data Centers

| Component | Description | Energy Impact |
|---|---|---|
| CPU Processing | Executes computational tasks and workloads | Very High |
| Memory Usage | Stores and retrieves application data | High |
| Storage Operations | Data access, read/write operations | Medium |
| Network Equipment | Data transmission and communication | Medium |
| Idle Servers | Servers running without active workload | High |

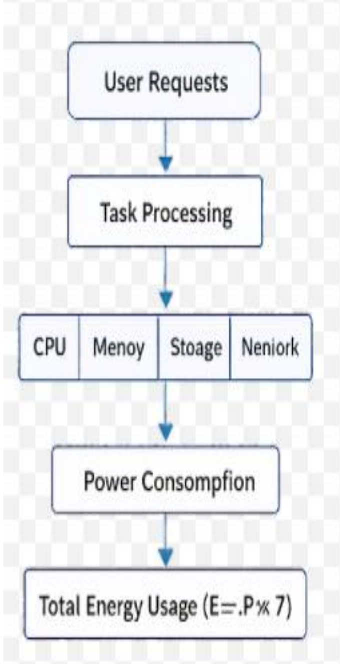


**Fig. 1.** Energy consumption model in cloud computing.

## 3. Energy-Efficient Resource Scheduling Techniques

Resource scheduling methods that can be used to lower power usage in cloud computing systems seek to deliver efficient use of energy without compromising the performance of the system or the quality of the services provided. The techniques aim at maximizing the usage of resources, reducing the amount of idle power, and enhancing the distribution of workloads among computing resources [17].

Various strategies have been devised in order to attain energy efficiency in cloud system among them being dynamic voltage and frequency scaling, virtual machine consolidation, power-aware scheduling, and load balancing. All the techniques have the contribution of cutting down on the energy consumption in terms of various mechanisms and strategies.

**Table 2:** Comparison of Energy-Efficient Scheduling Methods

| Technique | Main Idea | Advantages | Limitations |
|---|---|---|---|
| DVFS | Adjust processor voltage and frequency | Reduces processor power | May increase execution time |
| VM Consolidation | Migrate tasks to fewer | Reduces idle power usage | Migration overhead |

| | | | |
|---|---|---|---|
| | servers | | |
| Power-Aware Scheduling | Select low-energy resources | Improves energy efficiency | Requires energy monitoring |
| Load Balancing | Distribute workload evenly | Prevents overloading | Implementation complexity |

## A. Dynamic Voltage and Frequency Scaling (DVFS)

Dynamic Voltage and Frequency Scaling (DVFS) is the popular method of decreasing the energy of cloud computing system by modifying the operating voltage and the operating frequency of the processor as per the needs of the workload [18]. As the power consumption of any processor is directly proportional to the voltage and the frequency level, lowering these parameters when the computation load is low may lead to a dramatic reduction in power consumption. DVFS has allowed processors to run with reduced power when the workload demand is low and boost performance levels when the computational demands increase. Such dynamic adjustment is useful to maximize the use of energy without fully immobilizing system resources. DVFS decreases the amount of required power to process tasks by decreasing the operating frequency, thereby decreasing the heat generation and cooling demands. Nonetheless, DVFS can slow down the time taken to execute tasks in case processors run at lower speeds. Thus, there should be a proper balance between energy saving and system performance. In spite of this drawback, DVFS is still a useful method of enhancing energy efficiency, especially in systems whose workloads vary and systems that have different resource requirements.

## B. Virtual machine consolidation

Introduces the concept of virtual machine consolidation, a domain between hardware and software, which enables less expensive hardware by restricting the capacity of physical resources.

**Mintroduces** the notion of virtual machine consolidation, a realm between hardware and software, as such that allows less expensive hardware by limiting the power of physical resources.

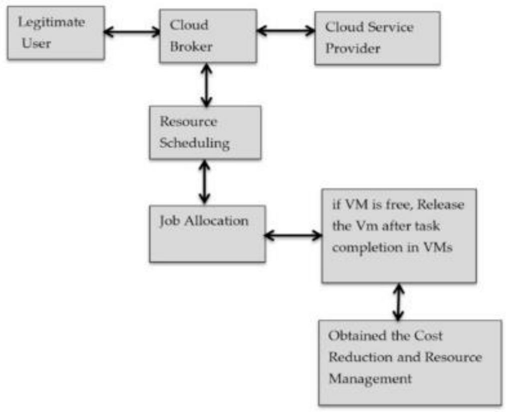


**Figure 2.** Resource Scheduling Techniques

Another technique that is of significance to enhance the energy efficiency of the cloud is virtual machine consolidation. It is a process that entails the migration of workloads across several underutilized servers to fewer active servers. With tasks being concentrated on fewer underlying machines, idle or underloaded servers can either be turned off or put into low power states, which helps to lower the overall amount of energy consumed [19]. Cloud computing is strongly dependent on the virtualization technology that enables the execution of several virtual machines using a single physical server. Using this feature, virtual machine consolidation maximizes resource usage and reduces unnecessary power consumption by idle servers. It is not only a good way of saving energy, but also better utilization of hardware, minimization of operational costs. Nonetheless, there is evidence of some challenges posed by virtual machine migration including migration overhead, temporary performance decrease and augmented network traffic [20]. Miscarriage of migration choices can also have an influence on service availability and system reliability. As such, effective workload monitoring mechanisms and migration strategies are required to see to it that virtual machine consolidation is well implemented.

## C. Power-Aware Scheduling

Power-aware scheduling is the task of assigning tasks to computing resources, using their energy consumption properties. In comparison to the conventional approaches to scheduling where performance is mostly the major focus, power-conscious scheduling takes into account the energy efficiency as one of the factors, in making decisions related to the allocation of resources. This method tests the resources available, and then the ones that require minimum power and satisfy the performance needs are selected. It seeks to reduce the total consumption by the system energy by cutting down the unnecessary resources activation and optimisation of workload distribution [21]. Other power-sensitive scheduling can include; choosing efficient servers, minimal switching of resources and system states in order to lower power consumption. The usefulness of the power-aware scheduling will be determined by proper estimation of the energy consumption of the resources and in-time tracking of system performance. Cloud systems can be more energy efficient and still service the quality and reliability of the services by incorporating energy metrics into the scheduling decisions.

### D. Load Balancing

Load balancing is a vital resource management strategy that allocates the workloads equally among the available computing resources to avoid overload of a particular server and underload of an alternative server. Equal distribution of workload enhances economical use of resources and eliminates energy wastage by having the computing resources run effectively [22]. Distribution of workload in cloud environments may result in overloading of some servers and idle ones. Servers with high loads also use too much power, produce too much heat, require more cooling and leave idle servers using unnecessary energy. Load balancing means solving this problem with the help of distribution of tasks dynamically on servers in accordance with their capacity and workload status. The use of effective load balancing has the effect of conserving energy, improving the system performance as well as reliability. It is also scaleable as the cloud systems are able to support the growing workload without over activating the resources. Load balancing, when used in combination with other power saving scheduling methods, is very important in enhancing the use of power and overall effectiveness of cloud computing systems.

## 4. Performance Metrics

Energy efficient resource scheduling techniques effectiveness in cloud computing is measured using numerous performance measures. These metrics can be used to gauge the efficiency of the scheduling algorithms in terms of minimizing the energy use without compromising system performance and service quality [23]. An effective assessment approach guarantees that cloud service vendors attain effective use of resources, lower operation expenses, and better Quality of Service (QoS). The key performance indicators applied in measuring energy-efficient scheduling are energy use, resource use, makespan, and adherence to Service Level Agreement (SLA).

**Table 3:** Performance Metrics for Evaluation

| Metric | Description | Objective |
|---|---|---|
| Energy Consumption | Total power used by system | Minimize |
| Resource Utilization | Percentage of resource usage | Maximize |
| Makespan | Total execution time | Minimize |
| SLA Compliance | Service performance level | Maintain |

### A. Energy Consumption

The most commonly used measure of energy efficient scheduling methods is energy consumption. It is the sum total of the electrical energy used by computing resources in the execution of tasks. The primary aim of energy efficient scheduling is to reduce total power consumption but without impairing the performance and reliability of the system [24]. The use of energy in the cloud systems is variable, which relies on CPU, memory, storage, and server operating conditions. The main goals of efficient scheduling methods are to minimize the energy consumption by minimizing idle server activity, optimal workload scheduling, and choosing energy-efficient resources. Less use of energy leads to a decrease in the cost of operation, sustainability of the system and environment. Consequently, the overall energy consumption can be measured to give a direct measure of the efficiency of the scheduling measures.

### B. Resource Utilization

Resource utilization is used to measure the degree of computing resources being used in executing tasks. Such resources are processors, memory, storage, and network bandwidth. High resource use implies that there is efficient use of available infrastructure whereas low use implies resources wastage and poor scheduling. Energy efficient scheduling is primarily meant to make the best use of resources in that it allocates the tasks efficiently and minimizes the idle or underutilized servers. With proper utilization of the resources, less number of servers is needed to carry out the same work and this reduces the amount of energy used. But, when used very heavily, it can overload the system and simultaneously lower its performance. As such, there should be an ideal level of resource consumption and system output. Resource utilization monitoring lets cloud providers understand the inefficiencies of resource allocation and better schedule decisions to increase efficiency in a system.

### C. Make span

Make span is the overall time it takes to accomplish a number of tasks or workloads within a cloud computing environment. It compares productivity of the tasks as regards the time of execution and productivity of the system. A reduced make span means that there will be increased speed in completing the task and the system will perform better. As much as energy efficient scheduling will aim at making sure that the amount of power used is minimal, it must not cause much time to be wasted in executing the tasks. In other situations, energy conservation by lowering the processor speed or even combining workloads can result in more execution time. Scheduling algorithms [25], therefore, should reduce the consumption of energy at an acceptable level and keep makespan at a reasonable level. Makespan is a significant performance indicator since it directly influences user satisfaction, system responsiveness and service quality. The effective scheduling solutions are intended to meet the goals of energy efficiency and the completion of tasks in time.

### D. Service level Agreement (SLA) Compliance.

Service Level Agreement (SLA) is a measurement of the capability of cloud systems to satisfy the predefined service performance requirements. SLAs stipulate particular performance criteria like response time, availability, throughput and reliability that cloud providers ought to provide to users. The methods of scheduling will have to be energy efficient, and the energy optimization will not need to go against the SLA conditions. As one example, when there is too much consolidation of workload or a low processing speed, it can cause delays in performing tasks and low quality of service. Service providers can face financial fines due to SLA breaches that can bring about adverse effects on the user [26]. Thus, it is important to maintain high levels of SLA compliance in applying energy efficient scheduling plans. The algorithms used in the scheduling of the energy saving should be closely balanced with the service performance to give dependable and stable cloud services.

## V. Challenges

The dynamic nature of cloud computing and the complexity of cloud computing exposes the resource scheduling in cloud computing to a number of challenges. Even though some methods have been devised to minimize the usage of energy and enhance the use of resources, the application of these methods in an effective manner necessitates that the challenge of resources variability in the workload, performance demands, resource heterogeneity and complexity are addressed. The key problems are the changes in the workload dynamically, the trade-offs between performance and energy efficiency, the heterogeneity of resources, and the complexity of scheduling. The workloads in the cloud computing environments are very dynamic and unpredictable. The user requests, application requirements, and system requirements keep on changing with time and thus, it is hard to allocate the resources effectively. The demand in workloads can be on a sudden increase during rush hours and on a heavy decrease during off-peak hours. These changes demand that scheduling algorithms be flexible in responding to changing conditions.

Changes in the workload dynamically complicate the process of energy-efficient scheduling since the allocation decisions of resources will always have to be done in real-time. Without the proper allocation of resources, it is possible to have servers becoming overloaded and still have idle servers thus resulting in poor utilization of energy and performance degradation. Thus, planning algorithms should be used to ensure that resources are dynamically allocated to constantly check the workload in the system and preserve its energy efficiency and performance. Balancing between energy savings or system performance is one of the greatest challenges in energy efficient scheduling. Other methods like slowing down the computer processor, workload consolidation or idle server shut down can reduce power usage but might impact negatively on processing speed, response time, and service quality.

Indicatively, reducing processor frequency to conserve energy can make execution of tasks take longer, whereas over consolidation of work can lead to delays or resource contention by the system. The providers of cloud services should be sure that energy optimization does not affect the Quality of Service (QoS) or breach Service Level Agreements (SLAs). To ensure a good balance between energy efficiency and performance, it is important to use intelligent schemes of scheduling that take into consideration both of these aspects. The environments of cloud computing have varied computing resources with varying processing capabilities, energy consumption properties, memory capacity, and performance. These nonuniform resources complicate the process of scheduling as different resources do not act in a similar manner to different workloads.

Efficient scheduling has to take into account the variant of hardware configurations, power consumption rates, and performance capabilities during the tasks allocation. The proper estimation of resource performance and energy used is essential to select the most suitable resource to use in the particular workload. The problem of resource hate organisation requires effective management to maximize the use of energy consumption and enhance the overall system efficiency. The size and scattered nature of cloud infrastructure makes the scheduling of resources energy efficient a complex decision-making process. Thousands of servers and virtual machines are stored in cloud data centers, and it takes considerable computational power to define the most efficient assignment of tasks to these resources.

Scheduling algorithms should take into account various aspects including the nature of the workload, availability of the resources, energy usage, execution time and performance needs. The more tasks and resources involved, the more the complexity of the scheduling decisions. It is also ensured by the fact that real-time scheduling can complicate this process even more because decisions have to be made fast without any impact on the system performance. One of the significant research problems is to develop scheduling algorithms that are efficient and scalable to operate in large-scale cloud environments, with energy-efficiency.

## 6. CONCLUSIONS

The complex and dynamic environments of cloud computing pose a number of challenges to energy efficient resource scheduling in cloud computing. Despite the development of different methods that will help minimize the amount of energy used and better manage resources, the application of the methodologies in practice presupposes the necessity to face the challenge of the variability of the workload, performance needs, resource heterogeneity, and computational complexity. Such challenges as the workload dynamism, performance and energy efficiency trade-offs, resource heterogeneity, and complexity of schedule are all the major issues. Cloud computing systems have extremely unpredictable and dynamic workloads. This is because the number of user requests, application demands and system requirements keeps on changing with time and it is hard to allocate resources efficiently. The demand workload can also suddenly rise at the peak time and reduce tremendously at the off-peak periods. Such changes mandate that scheduling algorithms be fast to adapt to the variations.

The nature of the dynamic workload variations leads to energy-attractive scheduling as, at the moment the resources are allocated, it should be determined in real time. Without proper allocation of resources, some of the servers might overload whereas others are underutilised and hence inefficient use of energy and wastage of performance. The scheduling mechanisms should thus be able to keep a constant check on the workload of the system and dynamically allocate resources to ensure energy efficiency and system performance. A major problem in energy efficient scheduling is striking a balance between the energy saving and performance of the system. Some of the techniques include slowing down processor speed, workload consolidation or decommissioning of idle servers which has the effect of reducing energy use at the expense of processing speed, response time and service quality.

At one time, an example of this is turning the processor frequency down to reduce energy consumption, raising the possibility of longer execution of a task, whereas too large a workload consolidation could lead to system slowing or sharing of resources. Service providers should make sure that the optimization of energy does not lead to the Quality of Service (QoS) or the violation of Service Level Agreements (SLAs). The only way to achieve a perfect compromise between performance and energy efficiency is to have a wise scheduling mechanism which takes both into consideration at the same time. Cloud computing environments are of heterogeneous computing resources of various processing capacities, energy consumption profiles, memory capacities and performance. These nonhomogenous resources complicate the scheduling process since different resources respond differently to different workloads.

Proper scheduling should be able to take into account the disparities in hardware settings, power consumption rates, and performance facilities when distributing work. To choose the most suitable resource to provide a particular workload, one has to estimate the resource performance and energy consumption properly. The management of heterogeneous resources is the key to resource optimization and the efficiency of the entire system. Scheduling of resources that are energy efficient entails complicated decision making processes owing to the scale and decentralization of the cloud infrastructure. Cloud data centers have thousands of computers, virtual machines, and it takes much computing power to figure out which tasks are best handled on which resources.

There are several factors that scheduling algorithms need to take into consideration and these are: workload characteristics, resource availability, energy consumption, execution time, and performance requirements. The more tasks and resources are involved, the more complicated a scheduling decision becomes. This complexity is further enhanced by real-time scheduling since decisions have to be made within a very short period of time without compromising on the performance of a system. A key research question is to come up with efficient and scalable scheduling algorithms capable of managing the operations of large-scale cloud environments with energy efficiency.

## REFERENCES

1. Vakilinia, S., Heidarpour, B., &Cheriet, M. (2016). Energy efficient resource allocation in cloud computing environments. IEEE Access, 4, 8544-8557.

2. Hua, W., Liu, P., & Huang, L. (2023). Energy-efficient resource allocation for heterogeneous edge–cloud computing. IEEE Internet of Things Journal, 11(2), 2808-2818.

3. Shrimali, B., & Patel, H. (2020). Multi-objective optimization oriented policy for performance and energy efficient resource allocation in Cloud environment. Journal of King Saud University-Computer and Information Sciences, 32(7), 860-869.

4. Dewangan, B. K., Agarwal, A., Venkatadri, M., & Pasricha, A. (2019). Self-characteristics based energy-efficient resource scheduling for cloud. Procedia Computer Science, 152, 204-211.

5. Singhal, S., Gupta, N., Berwal, P., Naveed, Q. N., Lasisi, A., &Wodajo, A. W. (2023). Energy efficient resource allocation in cloud environment using metaheuristic algorithm. Ieee Access, 11, 126135-126146.

6. Dhaya, R., Ujwal, U. J., Sharma, T., Singh, P., Kanthavel, R., Selvan, S., &Krah, D. (2022). Energy-efficient resource allocation and migration in private cloud data centre. Wireless Communications & Mobile Computing (Online), 2022.

7. Bitkuri, V., Kendyala, R., Kurma, J., Mamidala, J. V., Enokkaren, S. J., &Attipalli, A. (2023). Efficient Resource Management and Scheduling in Cloud Computing: A Survey of Methods and Emerging Challenges. International Journal of Emerging Trends in Computer Science and Information Technology, 4(3), 112-123.

8. Thein, T., Myo, M. M., Parvin, S., &Gawanmeh, A. (2020). Reinforcement learning based methodology for energy-efficient resource allocation in cloud data centers. Journal of King Saud University-Computer and Information Sciences, 32(10), 1127-1139.

9. Li, H., Zhao, Y., & Fang, S. (2020). CSL-driven and energy-efficient resource scheduling in cloud data center. Journal of Supercomputing, 76(1).

10. Akki, P., &Vijayarajan, V. (2020). Energy efficient resource scheduling using optimization based neural network in mobile cloud computing. Wireless Personal Communications, 114(2), 1785-1804.