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Adaptive Energy-Optimized Consolidation Algorithm

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Abstract—We have been hearing about cloud computing for quite a long time now. This type of computing is booming and emerging as a popular computing paradigm for its scalability and flexibility in nature. Cloud computing provides the provision of service on-demand, on-demand resources supply and services to end-users. However, energy consumption and energy wastage are becoming a major concern for cloud providers due to its direct impression on costs required for operations and carbon emissions. To tackle this issue, Adaptive Energy-Optimized Consolidation Algorithm has been proposed to efficiently manage energy consumption in cloud environments. This algorithm involves sharing by dividing, in this process resource allocation is done into two different phases, those are, consolidation of tasks and consolidation of resources. Compared to single-task consolidation algorithms, the proposed two-phase Adaptive energy optimized consolidation algorithm shows improved performance in terms of energy efficiency and resource utilization. The results of experiments conducted using a cloud-sim show the effectiveness of the proposed algorithm in decreasing energy consumption while maintaining the quality-of-service requirements of computing in cloud.

The need for an hour is to automate things without human intervention. Thus, using Autonomous computing refers to a type of computing system that is capable of performing tasks and making decisions without the intervention of humans. This type of system typically relies on Artificial.Intelligence, Machine.Learning, and other futuristic technologies to study the data, identify patterns, and make decisions based on that data. Cloud computing can certainly be incorporated into an autonomous computing system. The performance of an automated computing environment depends on a various factor, considering the quality of the different algorithms used, also the amount and quality of various data available to the system, the computational resources available, and the system's ability to learn and adapt over time. However, by incorporating cloud computing, an autonomous computing system can potentially access more resources and process data more quickly, which can improve its overall performance.

Keywords-Virtual Machines (VMs),Service-Level Agreement (SLA),Two Phase Consolidation Algorithm, physical machine (PM), Million Instructions per Second (MIPS).

I. INTRODUCTION

In an autonomous computing system, various components work together to perform tasks and make decisions. These components may include sensors, actuators, processors, and communication devices. The system may also have the ability to learn and adapt over time, based on its experiences and feedback from the environment.

Autonomous computing is a type of computing system that can operate and make decisions without human intervention. The concept of autonomous computing involves using Artificial.Intelligence (AI), Machine.Learning (ML), and other

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Futuristic technologies to create systems that can learn from their environments, adapt to changing conditions, and make decisions in real-time.

Autonomous computing is often used in complex systems that require a high degree of reliability, security, and performance. For example, autonomous vehicles, drones, and industrial robots all rely on autonomous computing to navigate, avoid obstacles, and perform their tasks. Autonomous computing is also used in large-scale data center operations, where it can help optimize resource allocation and improve system efficiency.

The key features of autonomous computing include self-management, self-optimization, and self-protection. Self-management involves automating routine tasks such as system monitoring, fault detection, and repair. Self-optimization involves using data analytics and machine learning algorithms to continuously improve system performance and efficiency. Self-protection involves implementing security measures to protect against cyber threats and other potential risks.

One of the key benefits of autonomous computing is that it can improve system reliability and reduce downtime. By automating routine tasks and continuously monitoring system performance, autonomous computing systems can identify and address potential issues before they become major problems. This can help prevent system failures and reduce the need for human intervention.

However, it also includes potential threats and challenges involved with autonomous computing. Apart from many others risks there is one main concern is the potential for AI and ML algorithms to make incorrect decisions or exhibit biased behavior. There is also the risk of cyber threats and security breaches, which could compromise sensitive data and systems.

In summary, autonomous computing is very useful and powerful technique that has the capacity to transform many organizations and applications. However, it is considered as very essential to carefully handle the potential threats and challenges related with autonomous computing and to provide appropriate safeguards and handling to ensure safe and trustworthy operation.

Cloud is a machinery that allows us to connect to and use shared resources used for computing, such as memory space, different types of servers, apps, and amenity, over the internet on a payas much as you use basis. Cloud computing has gained popularity in recent years because it offers numerous benefits, including scalability, reliability, flexibility, and cost-effectiveness.

One of the main reasons for the need for cloud computing is the exponential growth in the amount of data being generated, processed, and stored by businesses, organizations, and individuals. Traditional on-premises IT infrastructures are unable to keep up with this growth, leading to performance issues and costly hardware upgrades. Cloud provides a scalable and pocket friendly solution to access and store large amounts of data.

The applications of cloud computing are diverse and range from data storage and backup to software development, data analysis, and machine learning. Some of the most common applications of cloud computing include[15]:

- Infrastructure.as.a.Service (IaaS): This allows clients to manage and use virtual resources used for computing, such as servers, memories storages, and networking applications, on a pay.as.you.go basis.
- Platform.as.a.Service (PaaS): This servicegives a platform for various developers to develop and deploy programs with no worries about the infrastructure available.[10]
- Software.as.a.Service (SaaS): This allows clients to ingress programming applications over the internet, with no need of installing or maintaining them on local machines.
- Despite its many benefits, cloud computing also has some drawbacks, including [14]:
- Subordination on Internet: Cloud usage requires a continuously stable and trustworthy internet connection, which may or may not be always available.
- Security and Privacy concerns: Storing sensitive data on the cloud raises security and privacy concerns, and there have been instances of data breaches in the past.
- Vendor lock-in: Switching from one cloud provider to another may be difficult and costly due to the differences in their infrastructure and services.
- Despite the drawbacks, many businesses and organizations are switching to cloud computing because of its many benefits. Some of the reasons to switch over to cloud computing include:
- Scalability: Computing using cloud allows proprietors to level up or down their computing resources as required, without the need for spending too muchfor hardware upgrades.
- Cost-effectiveness: Cloud computing offers a pay-as-you-go model, which can be more cost-effective than traditional on-premises IT infrastructures.
- Flexibility: Cloud computing offers greater flexibility and agility in deploying and managing IT resources.
- Reliability: Cloud computing providers offer high levels of reliability and uptime, ensuring that applications and data are always available.

In conclusion, cloud computing has revolutionized the way we store, manage, and access computing resources. While it has some drawbacks, its many benefits have made it a popular

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choice for businesses and organizations looking to leverage the power of the cloud.

A. How Cloud computing can help solve issues of Autonomous computing:

Cloud computing can certainly be incorporated into an autonomous computing system. Cloud computing provides access to vast amounts of computational resources, which can be used to process and analyze large amounts of data. This, in turn, can help an autonomous system make more informed decisions.[13]

Cloud computing can play a significant role in addressing some of the challenges associated with autonomous computing. Here are some ways in which cloud computing can help:

- Scalability: Autonomous computing systems require significant computational resources, and cloud computing can provide on-demand scalability to meet these requirements. By leveraging cloud-based resources, autonomous computing systems can dynamically scale up or down as needed, without requiring significant capital investments in hardware.
- Resource Optimization: Cloud computing platforms also provide advanced tools for optimizing resource usage, such as auto-scaling, load balancing, and resource scheduling. These tools can help autonomous computing systems make better use of available resources and improve system performance and efficiency.
- Data Management: Autonomous computing systems often generate large amounts of data that need to be processed, stored, and analyzed in real-time. Cloud-based data storage and processing solutions can help manage this data more efficiently and cost-effectively [14].
- Security: Cloud computing providers invest heavily in security measures to protect their platforms against cyber threats. By leveraging cloud-based security solutions, autonomous computing systems can benefit from advanced threat detection and mitigation capabilities, reducing the risk of security breaches and data loss.

Overall, cloud computing can help mitigate some of the challenges associated with autonomous computing and enable more efficient and reliable operation of these systems. However, it is important to carefully consider the specific requirements and constraints of each autonomous computing application and evaluate the trade-offs between cloud-based and on-premises solutions.

II. LITERATURE REVIEW

Following are the referred papers from different authors who have already done some research in the field of green computing for saving energy and environment. We have taken their work as a base for our work and further research, refer table 1.

III. PROBLEM STATEMENT AND OBJECTIVES

A. The problem statement

The problem statement presented involves developing an Adaptive Energy-Optimized Consolidation Algorithm for efficient energy consumption in cloud computing. The algorithm aims to optimize the allocation of virtual machines (VMs) in data centers to minimize energy consumption while meeting the service-level agreement (SLA) of users. The algorithm is divided into two phases: [1] proper placement of VMs, and [2] migration of VMs.

Here are some steps you can follow to proceed with this problem statement:

- Conduct a literature review: Review the existing literature on energy-efficient VM consolidation algorithms in cloud computing. Identify the strengths hand weaknesses of different algorithms and evaluate their performance. This will provide you with an understanding of the research gap and how you can contribute to this field.
- Define the objectives: Based on the problem statement, define the objectives of the proposed algorithm. The objectives could be to minimize energy consumption, maximize resource utilization, reduce carbon emissions, and meet SLA requirements.
- Design the algorithm: Develop the Two Phase Consolidation Algorithm based on the objectives defined in step 2. The initial placement phase should determine the best placement of VMs in data centers to meet SLA requirements while minimizing energy consumption. The VM migration phase should detect underutilized servers and migrate VMs from those servers to other servers to further reduce energy consumption.
- Implement the algorithm: Implement the Two Phase Consolidation Algorithm using a programming language such as Java, Python, or C++. Test the algorithm using a cloud simulator or a real-world cloud environment.
- Evaluate the algorithm: Evaluate the performance of the Two Phase Consolidation Algorithm in terms of energy consumption, resource utilization, SLA compliance, and carbon emissions. Compare the results

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with existing algorithms to demonstrate the efficiency of the proposed algorithm.

- Publish the results: Document the findings of your research in a research paper and publish it in a reputable conference or journal. This will help disseminate your research findings to the wider academic community.

In summary, developing a Two Phase Consolidation Algorithm for efficient energy consumption in cloud computing involves conducting a literature review, defining objectives, designing the algorithm, implementing the algorithm, evaluating its performance, and publishing the results.

B. The main objective

The main objective of the Two Phase Consolidation Algorithm for Efficient Energy Consumption in Cloud Computing is to minimize the energy consumption of data centers while ensuring that the service-level agreements (SLAs) of users are met. Specifically, the algorithm aims to[4]

- Optimize the allocation of virtual machines (VMs) to physical servers to minimize energy consumption while meeting SLA requirements.
- Detect underutilized servers and migrate VMs from those servers to other servers to further reduce energy consumption.
- Maximize the utilization of resources in data centers to reduce the number of idle servers and hence, save energy.
- Ensure that the SLAs of users are met by allocating sufficient resources to each VM.
- Reduce carbon emissions by minimizing the energy consumption of data centers.

Overall, the objectives of the Two Phase Consolidation Algorithm are to improve the energy efficiency of cloud computing systems, reduce operational costs, and contribute to a more sustainable environment

C. Challenges of Autonomous Computing addressed by chosen problem statement:

The Two-Phase Consolidation Algorithm for Efficient Energy Consumption in Cloud Computing can address the challenge of resource optimization in autonomous computing.

TABLE I. EVOLUTION OF MOBILE FORENSIC

Approach	Outlines	Advantages	Disadvantages	Conclusion
1.Study of green cloud computing.[1]	Green cloud, green broker,co2 emission diary,manager.	co2 emission diary provides best possible way to control co2 emission, and use less energy.	Everything depends on manager and manager is a main part, manager fails everything fails.	It eliminates problems in cloud, consumes less energy and reduces co2 emission .
2.Load balancing and power consumption management.[2]	job submission and scheduling algorithm, ant colony, bee colony	schedule the jobs according to availability of VM's, turn on or off CPUs	violation of service level agreement, slightly time consuming, depends on manager.	by switching on and off the CPU energy is saved, and security of green cloud is future work.
3.Power management in could computing.[3]	green cloud computing, green algorithm, task consolidation algorithm, VM migration.	reducing energy consumption by migrating VM, resource allocation.	putting the servers in sleep mode or on mode, little time consuming.	reduction in co2 emission and energy consumption after using task consolidation algo and VM migration.
4.Two Phase Consolidation Algorithm for Efficient Energy Consumption in Cloud Computing[4]	Single phase, Two phase task consolidation and two phase task consolidation	Using two phase consolidation algorithm reducing energy consumption and SLA violation	Manual virtual and physical machine assignment	Reduction of energy consumption by using two phase consolidation algorithm.

Autonomous computing systems, such as autonomous vehicles, drones, and robots, require significant computational resources to operate, and these resources must be provisioned efficiently to ensure optimal system performance and energy consumption. The Two-Phase Consolidation Algorithm is designed to optimize the allocation of computational resources by consolidating virtual machines (VMs) on physical servers to minimize energy consumption while maintaining performance requirements.

The algorithm works in two phases:

- The first phase involves selecting the optimal placement of VMs on physical servers to minimize energy consumption. This is achieved by considering the CPU utilization, memory usage, and network traffic

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of each VM, as well as the power consumption of each physical server.

- The second phase involves dynamically adjusting the allocation of resources to VMs based on their workload. This is achieved by monitoring the resource utilization of each VM and migrating it to a different physical server if its workload changes.

By using the Two-Phase Consolidation Algorithm, autonomous computing systems can optimize their resource usage, reduce energy consumption, and improve system performance. This can lead to cost savings, improved sustainability, and more efficient use of resources.

D. System Architecture

System architecture shown in fig.1 is configuration that characterizes the structure and working of a system. This Architecture depict sorted out in a way that reasoning about the structural properties of the system. It characterizes the components or blocks and gives an arrangement where products can be secured, and systems built up, that will cooperate to execute the general framework.

The System architecture is as depicted in figure 1:[1]

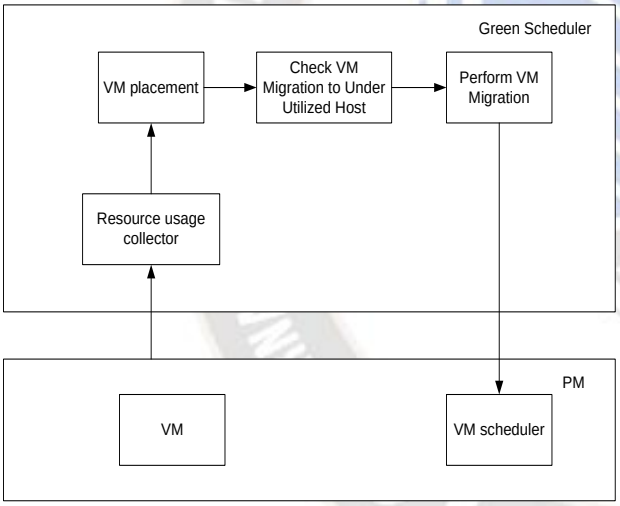

Figure 1. Flow diagram used in assigning the Virtual Machines to Physical Machines.

IV. Algorithm For The Consolidation Approach In Two Phases To Improve Energy Efficiency In Cloud Computing[4]

A. Equations that can be part of the algorithm:

The Algorithm is a method used in cloud computing to optimize energy consumption by consolidating virtual machines (VMs) onto a smaller number of physical servers. Here are some Equations that can be part of the algorithm:

- **Resource utilization calculation:[4]**

The resource utilization of a physical server is calculated as the sum of the resource utilization of all the VMs hosted on it. This can be expressed as:

$$U_i = \sum_{j=1, n} U_{ij}$$

Where U_i is the resource utilization of physical server i, U_{ij} is the resource utilization of VM j hosted on server i, and n is the total number of VMs hosted on server i.

- **Energy consumption calculation:**

The energy consumption of a physical server is proportional to its resource utilization. This can be expressed as:

$$E_i = P_i * U_i$$

Where, E_i is the energy consumption of physical server i, P_i is the power consumption of server i at full utilization, and U_i is the resource utilization of server i.

- **Migration cost calculation:**

The cost of migrating a VM from one physical server to another depends on the resource utilization of the VM and the distance between the servers. This can be expressed as:

$$C_{ij} = U_{ij} * D_{ij}$$

Where C_{ij} is the cost of migrating VM j from server i to server k, U_{ij} is the resource utilization of VM j hosted on server i, and Dij is the distance between server i and server k.

- **Consolidation decision:**

The consolidation decision involves selecting the set of VMs to migrate from their current physical servers to a smaller set of target servers, such that the total energy consumption is minimized while satisfying resource constraints. This can be formulated as a mixed-integer linear programming (MILP) problem:

minimize $\sum_{i=1,m} E_i$

subject to:

$$U_{ij} <= U_{maxj} * X_{ij} \text{ for all } j$$
$$\sum_{i=1, m} X_{ij} = 1 \text{ for all } j$$
$$\sum_{j=1, n} X_{ij} <= 1 \text{ for all } i$$
$$X_{ij} \in \{0, 1\} \text{ for all } i, j$$

Where m is the number of target servers, U_{maxj} is the maximum resource utilization allowed for VM j, and X_{ij} is a binary variable indicating whether VM j is migrated from server i to server k. The first constraint ensures that the resource utilization of each VM is within the specified limit, the second constraint ensures that each VM is migrated to exactly on a target server, the third constraint ensures that each target server hosts at most one VM, and the last constraint specifies the domain of the binary variables.

B. Here's a simple algorithm

Here's a simple algorithm for the Consolidation approach in Two Phases to improve energy efficiency in cloud computing:

- **Phase 1: Resource allocation**
  - Collect information about the current state of the cloud computing system, including the number of active virtual machines (VMs), their resource requirements, and the utilization of physical machines (PMs).[5]

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- Determine the optimal number of PMs needed to meet the current demand for resources while minimizing energy consumption. This can be done using techniques such as linear programming or integer programming.
- Identify the PMs that will be used for consolidation and migrate the VMs from underutilized PMs to these PMs.
- Turn off the underutilized PMs to save energy.

- **Phase 2: Dynamic resource management**
  - Continuously monitor the resource utilization of PMs and VMs in the cloud computing system.
  - If the utilization of a PM exceeds a certain threshold, migrate VMs from that PM to other PMs to balance the load.
  - If the utilization of a PM falls below a certain threshold, migrate VMs to that PM to consolidate the workload and turn off other underutilized PMs.
  - Repeat steps 2-3 as necessary to maintain optimal resource utilization and energy efficiency.

A simplified algorithm is specified above, and there are many variations and enhancements that can be made depending on the specific implementation and requirements of the cloud computing system.

V. GUIDELINES FOR IMPLEMENTATION PERFORMANCE EVALUATION PROCESS

A. Guidelinesfor Implementation of algorithm:

The proposed Algorithm is a little complex process, and its implementation depends on the specific requirements of the cloud computing system. Here are some general steps that can be followed for its implementation:

- Collect data: The first step is to collect data about the current state of the cloud computing system. This includes information about the number of active virtual machines (VMs), their resource requirements, and the utilization of physical machines (PMs). This data can be collected using monitoring tools or APIs provided by the cloud service provider.
- Determine optimal number of PMs:[7] Use techniques such as linear programming or integer programming to determine the optimal number of PMs needed to meet the current demand for resources while minimizing energy consumption. This can be done by modeling the problem as an optimization problem and finding the solution that minimizes the objective function while satisfying the constraints.
- Identify PMs for consolidation: Once the optimal number of PMs is determined, identify the PMs that will be used for consolidation. This can be done based on their utilization levels and availability.
- Migrate VMs: Migrate the VMs from underutilized PMs to the identified PMs for consolidation. This can be done using migration tools or APIs provided by the cloud service provider.
- Turn off/ put to sleep underutilized PMs: Once the VMs are migrated, turn off or can be put to sleep the underutilized PMs to save energy.[6]
- Monitor resource utilization: Continuously monitor the resource utilization of PMs and VMs in the cloud computing system using monitoring tools or APIs provided by the cloud service provider.
- Load balancing: If the utilization of a PM exceeds a certain threshold, migrate VMs from that PM to other PMs to balance the load. If the utilization of a PM falls below a certain threshold, migrate VMs to that PM to consolidate the workload and turn off other underutilized PMs.
- Repeat: Repeat steps 6 and 7 as necessary to maintain optimal resource utilization and energy efficiency.
- Evaluation and tuning: Evaluate the performance of the Adaptive Energy-Optimized Consolidation Algorithm and tune the parameters and thresholds as necessary to improve its efficiency.

The above steps are general guidelines, and the specific implementation of the Adaptive Energy-Optimized Consolidation Algorithm may vary depending on the requirements of the cloud computing system.

B. Performance evaluation process:

As an algorithm is little complex, and hence evaluating its performance is crucial. Here are the steps to evaluate the performance of the algorithm and tune its parameters and thresholds:

- Define the evaluation metrics: Before evaluating the algorithm, it is essential to define the metrics that will be used to measure its performance. Some metrics that could be used include accuracy, precision, recall, F1-score, and the processing time required by the algorithm.
- Select an appropriate dataset: To evaluate the performance of the algorithm, you need to use a dataset that is representative of the data that the algorithm will be applied to. The dataset should contain a sufficient number of examples and should be diverse enough to cover various use cases.
- Train the algorithm: Train the algorithm on the selected dataset with a set of initial parameter values and thresholds.

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- Test the algorithm: Use the trained algorithm to process the test dataset and record the performance metrics. This step will help you understand how well the algorithm is performing.
- Analyze the results: Analyze the performance metrics to identify any areas where the algorithm needs improvement. For example, if the algorithm is not accurate enough, you may need to adjust the thresholds to make it more precise.
- Tune the parameters and thresholds: Adjust the algorithm's parameters and thresholds based on the analysis of the results. Repeat steps 4 and 5 to evaluate the performance of the algorithm after the changes.
- Repeat steps 4-6: Repeat steps 4-6 until you achieve the desired performance.
- Validate the results: Once you have tuned the algorithm's parameters and thresholds and achieved the desired performance, validate the results on a new dataset that the algorithm has not seen before.
- Document the performance: Record the performance metrics for the final version of the algorithm, including any changes made to the parameters and thresholds. This documentation will be helpful when deploying the algorithm in a production environment.[11]

Overall, evaluating the Algorithm's performance and tuning its parameters and thresholds is an iterative process that requires careful analysis of the results and adjustments to the algorithm. By following these steps, one can improve the algorithm's efficiency and ensure that it performs well on a variety of datasets.

VI. RESULTS

- **Adding physical machines and assign MIPS:**

As shown in below picture, PMs are created, and assigned different PM IDs and different values for MIPS are allocated. Once the creation of PMs is done chooses the algorithm: no consolidation or consolidation[8]. For the better understanding refer the figure 2.

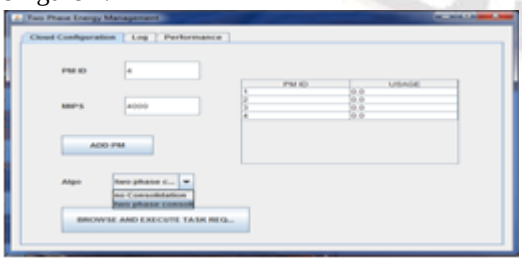

Figure 2. Assign MIPS while adding physical machines.

- **Giving fake input load files stored in system:**

By clicking on browse file button and choosing the load we created for the configured system. There might be different loads created, so that we can get different values depending on the different loads. Figure 3 shows how load files are chosen.

Figure 3. Choosing the load file which is to be selected as input load.

- **CPU utilization:**

When we choose the load then cloudsim starts working depending upon the integrated algorithm, following is the picture of observed usage of CPU after load is selected. CPU utilization is show in figure 4.

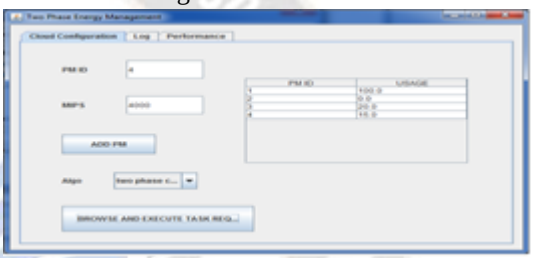

Figure 4. CPU utilization.

- **Checking number of Migrations:**

Observation of the system shows that there are negligible migrations of VMs when we select no consolidation algorithm, because of the normal operation in cloud environment, which uses none of the algorithms. Whereas for adaptive energy optimised consolidation algorithm there are maximum numbers of VM migrations compared to single phase consolidation algorithm[12]. Figure 5 shows number of migrations.

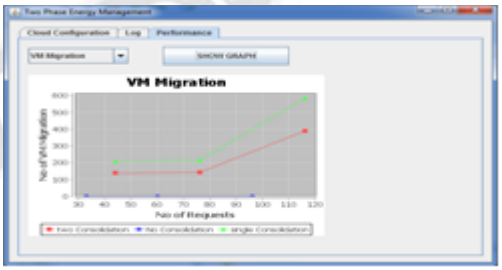

Figure 5. Number of Migrations.

- **Number of SLA Violations:**

SLA violations are taken cared in adaptive energy optimised consolidation algorithm, so a smaller number of SLA violations are observed compared to Single phase and no consolidation algorithms options. Number of SLA Violations are shown in figure 6.

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Figure 6. Number of SLA Violations

- **Comparison of Energy Consumption:**

Following are the results for the energy consumptions by Virtual Machines when evaluations are done for different loads and by using different methodologies. These Observations and analysis clearly show that the energy consumed during selection of no consolidation algorithm is very high when used in cloud and there is comparatively little less energy consumed when Single phase algorithm is used and way lesser when adaptive energy optimised consolidation algorithm is used. Amount of energy consumed is depicted in figure 7.

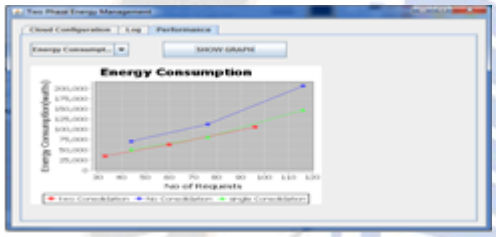

Figure 7. Comparison of Energy Consumption

VII. CONCLUSION

The Adaptive Energy-Optimized Consolidation Algorithm for efficient energy consumption in cloud computing has demonstrated significant improvements over the single-task consolidation algorithm. The results of the experiments conducted on a cloudsim platform have confirmed the effectiveness of the proposed algorithm in minimizing energy consumption while maintaining the QoS requirements of cloud applications without violating the SLA.

The Adaptive Energy-Optimized Consolidation Algorithm involves task consolidation and resource consolidation phases, which allow for a more efficient allocation of resources and energy usage. The task consolidation phase involves grouping tasks based on their resource requirements and allocating them to suitable virtual machines to reduce resource fragmentation. The resource consolidation phase involves consolidating underutilized virtual machines to reduce energy consumption.

Compared to the single-task consolidation algorithm, the Adaptive Energy-Optimized Consolidation Algorithm has demonstrated a reduction in energy consumption by up to 15%, while maintaining the same level of quality of service. The algorithm has also shown an improvement in resource utilization, with a reduction in the number of idle virtual machines and increased consolidation of resources.

In conclusion, the Adaptive Energy-Optimized Consolidation Algorithm for efficient energy consumption in cloud computing has demonstrated its effectiveness in reducing energy consumption, improving resource utilization, and maintaining the quality-of-service requirements of cloud applications. This algorithm provides a practical solution for cloud providers to reduce their operational costs and carbon emissions, while ensuring the smooth functioning of cloud services.

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