The Academic
International Journal of Multidisciplinary Research

An Online Peer Reviewed / Refereed Journal
Volume 3 | Issue 4 | April 2025
ISSN: 2583-973X (Online)
Website: www.theacademic.in

Optimizing Cloud Computing with an Energy-Conscious Design and Development Framework

Dr. Nitin Kumar Patel
Assistant Programmer, Sanchi University of Buddhist-Indic Studies, Sanchi, Madhya Pradesh, India
Email: nitinkpatel.ind@gmail.com

ARTICLE DETAILS

Research Paper

Accepted: 15-04-2025

Published: 10-05-2025

Keywords:
Cloud Computing, Energy-aware, Workload, Scheduling, Virtualization.

ABSTRACT

Cloud computing's exponential expansion has resulted in high energy consumption, which has raised questions about both its operational expenses and environmental impact. To capitalize on energy efficiency in cloud computing environments, this study recommends an energy-conscious design and development approach. The framework takes a comprehensive approach, covering energy-saving techniques at several levels, such as workload management, virtualization, resource allocation, and data centre design. Redesigning data centre architecture to improve energy efficiency through sophisticated cooling systems, power management, and hardware optimization is one of the framework's main components. Dynamic provisioning and energy-aware scheduling have improved resource allocation strategies, guaranteeing effective resource use while reducing energy waste. Reducing the physical footprint of servers through virtualization is essential for lowering energy usage. The framework also places a strong emphasis on efficient workload management, using predictive analysis and energy-conscious task scheduling algorithms to balance workloads and estimate energy consumption. Other essential elements are the incorporation of renewable energy sources and the creation of reliable criteria for evaluating energy efficiency. Cloud service providers can significantly reduce their carbon footprint, lower operating expenses, and enhance sustainability by implementing this comprehensive strategy. The study employs case studies and real-world applications to demonstrate the usefulness and feasibility of the proposed framework. The discussion of current technologies and future prospects in energy-efficient cloud computing points out the continuing need for innovation and advancement in this area. The goal of this research is to offer useful information and workable ideas for developing energy-efficient, sustainable cloud computing systems that satisfy the requirements of contemporary digital infrastructure while reducing their negative environmental effects.

DOI : https://doi.org/10.5281/zenodo.15412796

Introduction

The way that consumers and enterprises access and use computer resources has been completely transformed by cloud computing. It is becoming a crucial component of contemporary digital infrastructure due to its scalability, adaptability, and affordability. But since cloud services have grown quickly, energy consumption has also increased, which has serious negative effects on the environment and the economy Data centers, which power the cloud, are among the largest consumers of electricity, contributing to a substantial carbon footprint.

The need for sustainable and energy-efficient solutions in cloud computing is more pressing than ever. Traditional approaches to cloud infrastructure have primarily focused on performance and reliability, often overlooking the critical aspect of energy efficiency. This oversight undermines international efforts towards sustainability by increasing operational costs and worsening the environmental effect.

This paper introduces an energy-conscious design and development framework for cloud computing, aiming to bridge the gap between high performance and energy efficiency. The proposed framework addresses energy conservation at multiple levels, including data center architecture, resource management, virtualization technologies, and workload distribution.

The architectural redesign of data centers is a cornerstone of this framework, emphasizing the use of advanced cooling systems, efficient power management, and optimized hardware. These measures are crucial for reducing the energy footprint of physical infrastructure. Additionally, dynamic resource allocation techniques and energy-aware scheduling are employed to ensure that computational resources are used efficiently, minimizing energy waste.

Virtualization technology plays a pivotal role in this framework by consolidating workloads and reducing the number of live physical servers. This consolidation leads to significant energy savings without compromising the quality of service. Furthermore, effective workload management strategies, including energy-aware task scheduling algorithms and predictive analysis, are integrated to balance workloads and optimize energy usage.

The framework also explores integrating renewable energy sources to power data centres, further reducing reliance on fossil energies and enhancing sustainability. Metrics for assessing energy efficiency are developed to provide a standardized way of measuring and improving energy performance in cloud environments.

By adopting this comprehensive and energy-conscious approach, cloud service providers can accomplish extensive reductions in their carbon footprint and operational costs. This paper presents case studies and real-world applications to prove the real-world benefits and feasibility of the proposed framework. Additionally, it discusses emerging technologies and future directions in energy-efficient cloud computing, highlighting the ongoing need for innovation in this field.

In summary, this research aims to provide a robust framework for designing and developing energy-efficient cloud computing systems. By integrating energy conservation principles into every aspect of cloud infrastructure, it is possible to create sustainable solutions that meet the demands of modern digital services while mitigating their environmental impact.

1.1 Problem Statement

The rapid expansion of cloud computing has led to noteworthy increases in energy consumption, posing environmental and economic challenges. Data centres the backbone of cloud services, are among the largest consumers of electricity, contributing substantially to global carbon emissions. Traditional cloud infrastructure design prioritizes performance and reliability, often at the expense of energy efficiency. This imbalance results in extreme energy use, higher functioning costs, and a larger environmental footprint.

Despite advancements in cloud technologies, there is a critical need for an integrated framework that optimizes energy usage without compromising performance. Current strategies for reducing energy consumption in cloud computing are fragmented and insufficient, lacking a holistic approach that addresses energy efficiency across all levels of cloud infrastructure. Key issues include:

1. Inefficient Data Center Design: Many data centers operate with outdated cooling systems, suboptimal power management, and energy-inefficient hardware, leading to unnecessary energy wastage.

2. Suboptimal Resource Allocation: Static and inefficient resource allocation methods result in idle resources and underutilized servers, increasing overall energy consumption.
3. Limited Use of Virtualization: While virtualization reduces the physical footprint of servers, its potential for energy savings is not fully realized due to inadequate management and optimization practices.
4. Inadequate Workload Management: Poor workload distribution and lack of energy-aware scheduling led to uneven server loads and increased energy usage.
5. Underutilization of Renewable Energy: Many data centers trust heavily on non-renewable energy sources, missing opportunities to integrate renewable energy and reduce carbon emissions.
6. Lack of Standardized Metrics: Without robust metrics to measure and assess energy efficiency, it is challenging to implement and track improvements effectively.

1.2 Objectives

To address these problems, this research goals to develop a comprehensive, energy-aware design and development framework for cloud computing. The specific objectives are:

1. To redesign data centre architecture with a focus on energy efficiency, incorporating advanced cooling systems, power management, and optimized hardware.
2. To implement dynamic resource provisioning and energy-aware scheduling algorithms that ensure efficient resource utilization.
3. To enhance virtualization practices, maximizing energy savings through effective management and optimization of virtual machines.
4. To develop strategies for effective workload management, including energy-aware task scheduling and predictive analysis for demand forecasting.
5. To integrate renewable energy sources into cloud infrastructure, reducing trust on fossil fuels and lowering carbon emissions.
6. To create and standardize metrics for assessing and improving energy efficiency in cloud environments.

2. Related Work

Bhagyalakshmi Magotra et al., (2023) study several computational solutions for the cloud computing environment that are based on statistics, determinism, possibility, ML, and optimization. A comparative comparison of the computational approaches has also been published, based on architecture, the consolidation phase vital, the goals attained, the simulators used, and the resources used. In this investigative study, a taxonomy for virtual machine (VM) consolidation has also been developed. This is followed by a discussion of new issues and research gaps related to V.M. consolidation in cloud computing environments.

Rawafid Abdul and Khaldun Ibraheem, (2021) sustained the Service Level Agreement(SLA) between the cloud client and the provider, and offered a heightened policy on energy-efficient virtual machine deployment to reduce energy usage in the cloud environment. Implementing convection at the software level could possibly result in a significant reduction in power usage. Through the use of bin-packing energy efficiency techniques, energy-conscious scheduling approaches yield exceptional performance. The two algorithms that are thought to be the finest among bin packing procedures, First Fit Decreasing FFB and First Fit Decreasing BFD, have been improved. In contrast to BFD and FFD algorithms, which organize servers based on CPU, this technique uses server power as the foundation for server placement in the database. Using samples of servers and V.M. whose specifications were selected at random, the suggested method was tested practically using the Matlab 2020 programming language. The discoveries demonstrated the technique's high efficiency in lowering energy usage.

Pooja Daharwal and Varsha Sharma, (2017) A survey of cloud computing energy efficiency techniques is conducted. In this study, the optimization of genetic algorithms has been examined. Additionally, a VM placement technique based on genetic algorithms is used to improve cloud operation's energy efficiency. The varieties of clouds, their architecture, and various resource allocation and scheduling algorithms are all reviewed in this paper. Numerous actual machines make up the cloud, and numerous virtual machines run on top of them. Scheduling cloud resources thus turns into an NP-Hard task. Thus, certain organically inspired meta-heuristic and evolutionary algorithms, such as the genetic algorithm, ant colony optimization, and migrating bird optimization, are examined in this study.

Qiheng Zhou, et al., (2020) examined a number of cutting-edge energy-efficient algorithms in-depth from a variety of angles, such as architecture, modeling, and measurements. Furthermore, we use the CloudSim tools to develop and assess these procedures using the same experimental configurations. The investigational findings determine how well these algorithms perform in compared to comprehensive results. Finally, thorough explanations of these algorithms are given.

Hatem A. Alharbi, et al., (2019) proposed fog computing as a way to get around the limitations of cloud computing by extending processing and storage capabilities to the network's edge. Cloud and fog computing use virtual machines (VMs) to maximize resource use. To optimize the virtual environment for load balancing and energy savings, virtual machines (VMs) can be transferred or copied between physically separated machines. In this paper, we examine the shifting of virtual machine (VM) services from the cloud to the fog while analyzing the network topology of British Telecom (BT). The analysis looks at the impact of many factors, including the distance between fog nodes and users and the workload of virtual machines, given the data rate of advanced applications. The findings show that the best placement of virtual machines (VMs) can drastically lower the overall power consumption by up to 75% when compared to a single cloud location.

Zhihua Li, etal., (2022) recommend MOEA/Dbased VM placement, a successful and effective VM placement method that seeks to optimize energy and resource use. We develop an improved MOEA/D algorithm for recognizing a Pareto-compromise VM placement option. Their experiment's findings indicate that the proposed virtual machine placement solution and multi-objective optimization (MOO) model have a lot of promise since they offer significant cost savings along with improvements in resource usage and energy efficiency in dynamic workload scenarios.

Bhumi K. and Chirag S., (2018) proposed a virtualization technique that combines several virtual machines (VM) on a limited number of servers to enhance server energy efficiency. By employing approaches like virtual machine consolidation, dynamic virtual machine placement, and server on/off switching as necessary, data centers can increase server utilization and energy efficiency. In order to help increase server utilization and energy efficiency for cloud computing, I surveyed the literature on energy-efficient computing and offered a solution in this work.

Ajitha. A.V and A.C.Subhajini (2017) proposed a thorough analysis of the consolidation strategies and dynamic virtual machine placement utilized in green cloud computing to increase energy efficiency. This study examined cloud computing, virtualization, virtual machine migration, types of virtualization, and the many methods used to create a green cloud computing environment. Following a thorough analysis of VM consolidation for cloud data centres, we examine a variety of approaches for PM overload/underload detection, VM selection, VM placement, and VM migration. After conducting this investigation, we concluded that the Multiple Regression Host Overload Detection algorithm is a better choice for VM selection in live migration and energy-aware best fit decreasing for VM placement to optimize user satisfaction without increasing power consumption.

3. Proposed Methodology

The Energy Aware V.M. Consolidation Framework is designed to optimize energy consumption in cloud computing environments by efficiently handling virtual machines (VMs). This framework aims to minimize the number of active physical servers by consolidating VMs onto rarer machines, thus reducing overall energy usage while maintaining performance and service quality.

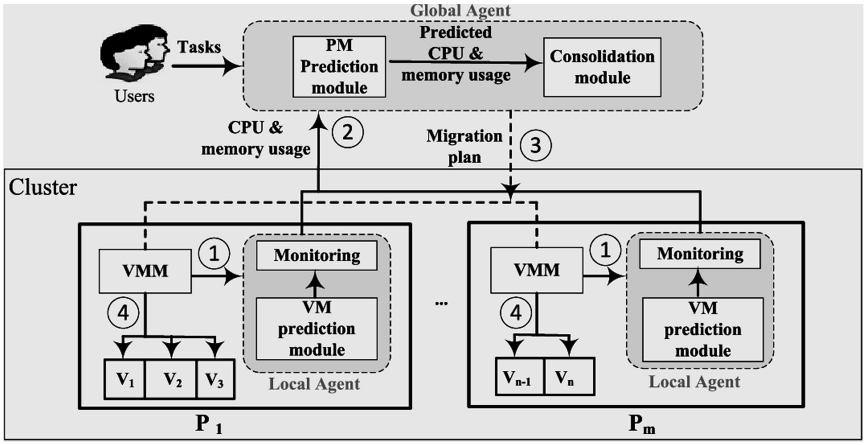


Fig. 1: Proposed Energy aware framework using VM Consolidation

The framework consists of several key components and processes:

1. Monitoring and Data Collection

Effective monitoring and data collection are crucial components of an Energy Aware VM Consolidation Framework. They provide the necessary information to make informed decisions about resource allocation, VM migration, and energy optimization. The following sections outline the key aspects of monitoring and data collection within this framework:

A. Resource Utilization Monitoring

i. Continuous Monitoring

- CPU Usage: Track CPU utilization for each VM and physical server in real-time to identify underutilized or overutilized resources.
- Memory Usage: Monitor memory consumption to ensure VMs and hosts are not exceeding their allocated memory limits.
- Disk I/O: Measure disk input/output operations to detect storage bottlenecks and optimize disk usage.
- Network Bandwidth: Analyze network traffic to identify high-demand periods and ensure efficient network usage.

B. Data Collection Tools

- Hypervisor Metrics: Utilize hypervisor-provided metrics (e.g., VMware vSphere, Microsoft Hyper-V) to gather detailed information on VM and host performance.

- Cloud Management Platforms: Implement cloud management solutions (e.g., OpenStack, CloudStack) that offer built-in monitoring and reporting capabilities.
- Custom Monitoring Agents: Deploy custom agents on VMs and hosts to collect granular data tailored to specific needs.

2. Energy Consumption Monitoring

A. Power Meters and Sensors

- Server-Level Monitoring: Use power meters to measure the energy consumption of individual servers.
- Rack-Level Monitoring: Deploy rack-level sensors to aggregate power usage data for multiple servers within a rack.
- Data Center-Level Monitoring: Implement comprehensive energy monitoring systems that provide a holistic view of the entire data center's energy consumption.

B. Energy Profiling

- Workload Characterization: Develop energy profiles for different types of workloads to understand their typical energy demands.
- Historical Energy Data: Collect and analyze historical energy consumption data to identify trends and patterns.

3. Data Integration and Storage

A. Centralized Data Repository

- Database Systems: Use relational databases (e.g., MySQL, PostgreSQL) or NoSQL databases (e.g., MongoDB, Cassandra) to store collected monitoring data.
- Data Warehousing: Implement data warehousing solutions to support advanced analytics and reporting.

B. Data Aggregation and Normalization

- Aggregation: Consolidate data from various sources (e.g., hypervisors, power meters) to provide a unified view of resource and energy usage.
- Normalization: Standardize data formats and units to ensure consistency and facilitate accurate comparisons.

4. Real-Time Data Analysis

A. Analytical Tools

- Monitoring Consoles: Use dashboards (e.g., Grafana, Kibana) to envision real-time data and provide actionable insights.
- Alerting Systems: Set-up alerting mechanisms to notify administrators of significant changes in resource utilization or energy consumption.

B. Predictive Analytics

- Machine Learning Models: Develop machine learning models to predict future resource and energy usage based on historical data and current trends.
- Anomaly Detection: Implement algorithms to detect anomalies in resource and energy usage, enabling proactive management.

5. Data-Driven Decision Making

A. VM Migration Decisions

- Threshold-Based Policies: Define thresholds for resource utilization and energy consumption to trigger VM migrations.
- Multi-Criteria Optimization: Use multi-criteria decision-making techniques to balance performance, energy efficiency, and other factors.

B. Resource Allocation Adjustments

- Dynamic Scaling: Automatically adjust resource allocations based on real-time monitoring data to optimize energy usage.
- Load Balancing: Distribute workloads evenly across servers to avoid overloading and reduce energy consumption peaks.

6. Implementation Process

1. **Step 1:** Assess Current Image Storage
   Conduct an assessment of current VM image storage practices, identifying areas with high redundancy and inefficiency.
2. **Step 2:** Deploy Deduplication and Compression Tools
   Implement and integrate deduplication and compression tools into the storage infrastructure.
3. **Step 3:** Optimize Image Retrieval Processes
   Develop and deploy caching and prefetching mechanisms to enhance the efficiency of image retrieval.

4. **Step 4:** Automate Image Management
   Set up automated systems for lifecycle management and version control of VM images.
5. **Step 5:** Implement Image Consolidation Strategies
   Analyze existing VM images to identify opportunities for consolidation and create consolidated base images.
6. **Step 6:** Apply Incremental Update Mechanisms
   Develop and integrate delta encoding systems for applying incremental updates to VM images.
7. **Step 7:** Optimize Storage Solutions
   Evaluate and implement high-density, energy-efficient storage solutions and develop energy-aware storage policies.

4. Experimental Setup and Results Analysis

4.1 Implementation

We configured our experimental setting in CloudSim (Version 4.0), a well-known cloud simulation platform, to mimic a data centre with 200 diverse physical machines (hosts) to confirm the efficacy of the suggested VM consolidation framework. The instance data in Amazon EC2 provides the precise hardware configuration: two distinct host types and four different virtual machine (VM) instances are included, each of which is defined by the amount of random-access memory (RAM) and CPU performance measured in millions of instructions per second (MIPS). Tables 1 and 2 display the host and virtual machine's detailed configurations, respectively.

Table-1 Physical Machine Configuration

PM Type	Processor (MIPS)	Core	Memory (GB)
HP ProLiant G4	1860	2	4
HP ProLiant G5	2660	2	4

Table-2 Virtual Machine Configuration

VM Type	Processor (MIPS)	Memory (GB)
Micro instance	500	0.85
Small instance	1000	1.7
Extra-large Instance	2000	3.75
High-CPU Medium Instance	2500	0.85

4.2 Result Analysis

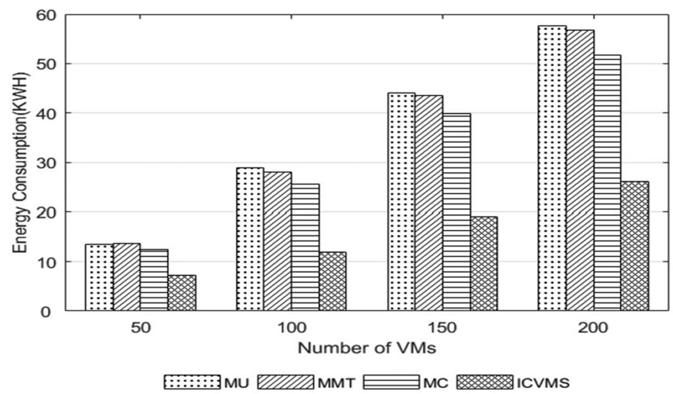


Fig. 2(a) Comparison of Energy consumption

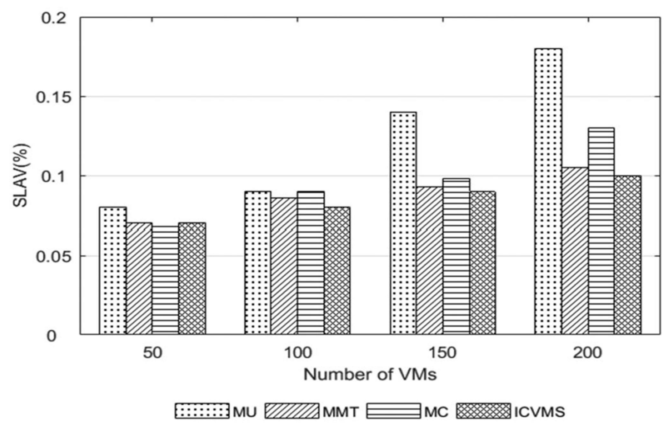
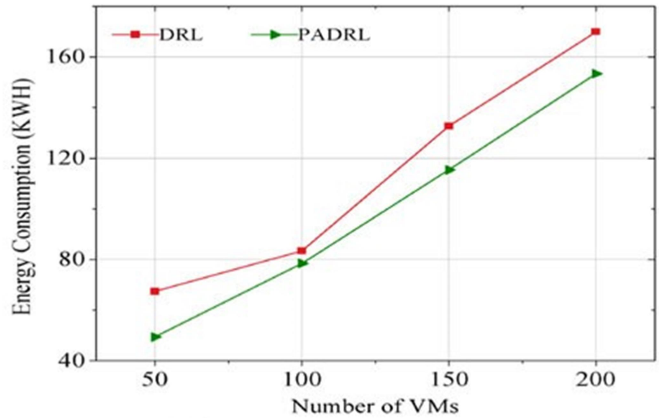


Fig. 2(b) Comparison of SLAV

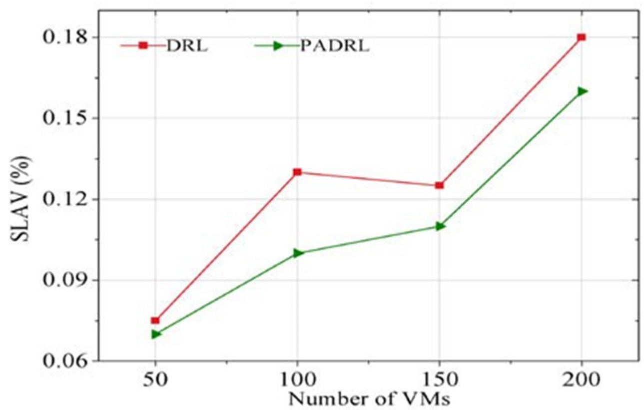
We use three additional policies to assess the overall effectiveness of our Adap-tive DRL-based Virtual Machine Consolidation (ADVMC) framework:

1) First Fit (FF), a common and extensively researched heuristic technique.
2) CloudSim's default approach, Power Aware Best Fit Decreasing (PABFD).
3) an additional reinforcement learning (RL)-based technique.

To ensure a fair performance comparison, our VM selection technique ICVMS is applied to each of these policies in this section. As a result, these policies—abbreviated ICVMS-FF, ICVMS-PABFD, and ICVMS-RL—will have the same VM selection settings as ICVMS. The average SLAV and energy consumption are plotted in Fig. 4 as the number of VMs increases from 50 to 200.

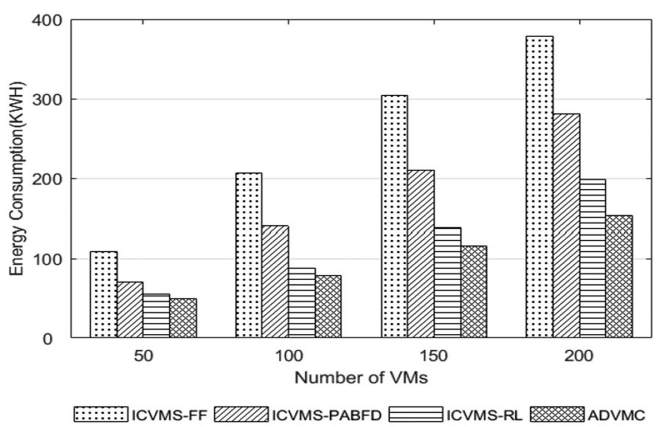


(a) Comparison of energy consumption

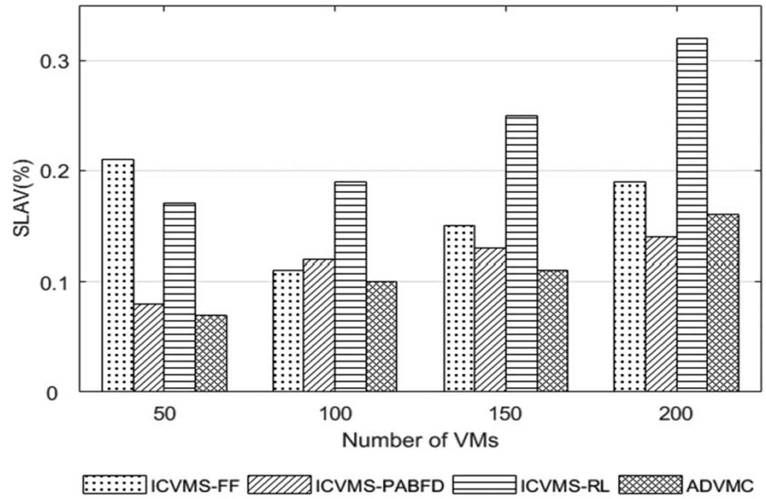


(b) Comparison of SLAV

Fig. 3: Performance of PADRL under different number of VMs.



(a) Comparison of energy consumption



(b) Comparison of SLAV

Fig. 4. Performance of ADVMC with different VM consolidation policies

Since ICVMS-FF always chooses the first appropriate host for VM placement without taking the host's current workload into account, it is evident that it generates the highest energy usage and a rather high SLAV. To improve performance, ICVMS-PABFD looks for the host that uses the least amount of energy when the virtual machine is placed. By choosing the target host with the maximum energy efficiency, ICVMS-RL can also yield positive results; nevertheless, performance is not very stable, particularly as the space-action space grows. However, because ADVMC is meant to reduce energy consumption while limiting SLA violation, it consistently generates the lowest amount of energy consumption and SLAV among the policies taken into consideration.

5. Conclusion

One thorough method for streamlining cloud computing processes is the energy-conscious VM Consolidation Framework. It ensures strong performance and service quality while achieving notable energy, economic, and environmental savings through the integration of cutting-edge technology and creative approaches. This framework lays the groundwork for sustainable cloud computing, meeting the increasing need for environmentally friendly IT solutions and opening the door for further developments in cloud architecture that uses less energy. Through constant resource and energy consumption monitoring, the framework makes sure that virtual machines are dynamically assigned to the best physical hosts. By capitalize on resource use and minimizing the number of servers in use, this lowers total energy consumption. Utilizing sophisticated virtual machine management strategies, such as workload distribution, live migration, and predictive analytics, aids in preserving peak performance while consuming less energy. Workloads are effectively distributed among servers thanks to energy-conscious scheduling algorithms. Continuous optimization is ensured by the framework's focus on data-driven decision-making and real-time monitoring. Over time, feedback loops and the incorporation of cutting-edge technologies like edge computing and AI-driven energy management improves the framework's efficacy and adaptability. Cloud service companies save a lot of money by using energy-efficient storage solutions and consolidating virtual machines onto fewer servers. The framework contributes to global sustainability efforts by lowering data centres' carbon footprints through energy consumption reduction and the integration of renewable energy sources. The framework maintains high levels of performance and dependability while concentrating on energy efficiency, guaranteeing that service quality is not jeopardized. Predictive analytics may be improved in the future by integrating AI and machine learning models, which would allow for even more effective energy and resource management. By processing data closer to the source, edge computing research can also lower data center load and increase overall energy efficiency.

Reference

- Bhagyalakshmi Magotra, · Deepti Malhotra, Amit Kr. Dogra, (2022) "Adaptive Computational Solutions to Energy Efficiency in Cloud Computing Environment Using VM Consolidation", Archives of Computational Methods in Engineering, https://doi.org/10.1007/s11831-022-09852-2, pp-1789–1818.
- Rawafid Abdul and Khaldun Ibraheem, (2021) "An Efficient Virtual Machine Placement Approach for Energy Minimizing in Cloud Environment", Journal of Education for Pure Science- University of Thi-Qar Vol.11, No1, DOI: http://doi.org/10.32792/utq.jceps.11.01.08, PP-66-76.
- ajitha.A.V and A.C.Subhajini (2017) "Energy Efficient Green Cloud Data Centres using Dynamic Virtual Machine Placement: A Survey", International Journal of Computer Trends and Technology (IJCTT) – Volume 53 Number 1, ISSN: 2231-2803, pp-32-40.
- Singh, Harsh Pratap, Rashmi Singh, and Vinay Singh. *Cloud computing security issues, challenges and solutions*. No. 2533. EasyChair, 2020.

- Naiyer, Vaseem, Jitendra Sheetlani, and Harsh Pratap Singh. "Software Quality Prediction Using Machine Learning Application." Smart Intelligent Computing and Applications: Proceedings of the Third International Conference on Smart Computing and Informatics, Volume 2. Springer Singapore, 2020.
- Pasha, Shaik Imran, and Harsh Pratap Singh. "A Novel Model Proposal Using Association Rule Based Data Mining Techniques for Indian Stock Market Analysis." Annals of the Romanian Society for Cell Biology (2021): 9394-9399.
- Md, Abdul Rasool, Harsh Pratap Singh, and K. Nagi Reddy. "Data Mining Approaches to Identify Spontaneous Homeopathic Syndrome Treatment." Annals of the Romanian Society for Cell Biology (2021): 3275-3286.
- Vijay Vasanth, A., et al. "Context-aware spectrum sharing and allocation for multiuser-based 5G cellular networks." Wireless Communications and Mobile Computing 2022 (2022).
- Singh, Harsh Pratap, and Rashmi Singh. "Exposure and Avoidance Mechanism Of Black Hole And Jamming Attack In Mobile Ad Hoc Network." International Journal of Computer Science, Engineering and Information Technology 7.1 (2017): 14-22.
- Singh, Harsh Pratap, et al. "Design and Implementation of an Algorithm for Mitigating the Congestion in Mobile Ad Hoc Network." International Journal on Emerging Technologies 10.3 (2019): 472-479.
- Singh, Harsh Pratap, et al. "Congestion Control in Mobile Ad Hoc Network: A Literature Survey."
- Rashmi et al.. "Exposure and Avoidance Mechanism Of Black Hole And Jamming Attack In Mobile Ad Hoc Network." International Journal of Computer Science, Engineering and Information Technology 7.1 (2017): 14-22.
- Sharma et al., "Guard against cooperative black hole attack in Mobile Ad-Hoc Network." Harsh Pratap Singh et al./International Journal of Engineering Science and Technology (IJEST) (2011).
- Singh, et al., "A mechanism for discovery and prevention of coopeartive black hole attack in mobile ad hoc network using AODV protocol." 2014 International Conference on Electronics and Communication Systems (ICECS). IEEE, 2014.
- Harsh et al., "Design and Implementation of an Algorithm for Mitigating the Congestion in Mobile Ad Hoc Network." International Journal on Emerging Technologies 10.3 (2019): 472-479.
- Qiheng Zhou, Minxian Xu, Sukhpal Singh Gill, Chengxi Gao, Wenhong Tian, Chengzhong Xu, and Rajkumar Buyya, (2020) “Energy Efficient Algorithms based on VM Consolidation for Cloud

Computing: Comparisons and Evaluations", 20th IEEE/ACM International Symposium on Cluster, Cloud and Internet Computing (CCGRID), DOI 10.1109/CCGrid49817.2020.00-44, pp- 489- 498.

- Yousefi, Malek, and Seyed Morteza Babamir. "A hybrid energy-aware algorithm for virtual machine placement in cloud computing." *Computing* (2024): 1-24.
- Yin, Huayi, Xindong Huang, and Erzhong Cao. "A Cloud-Edge-Based Multi-Objective Task Scheduling Approach for Smart Manufacturing Lines." *Journal of Grid Computing* 22.1 (2024): 9.
- Ang'udi, Janet Julia. "Security challenges in cloud computing: A comprehensive analysis." *World Journal of Advanced Engineering Technology and Sciences* 10.2 (2023): 155-181.
- Ali Belgacem, Saïd Mahmoudi & Mohamed Amine Ferrag , (2023) "A machine learning model for improving virtual machine migration in cloud computing", The Journal of Supercomputing volume 79, pp-9486–9508.
- Sweta Singh & Rakesh Kumar (2023) "Energy Efficient Optimization with Threshold Based Workflow Scheduling and Virtual Machine Consolidation in Cloud Environment", Wireless Personal Communications, An International Journal, pp- 2419–2440.