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Research Article

Energy-Efficient Cloud Computing: A Survey

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ENERGY-EFFICIENT CLOUD COMPUTING: A SURVEY

Abstract. This comprehensive assessment examines the rising energy usage and environmental risks linked with the rapid growth of cloud computing. It investigates a variety of technologies and tactics targeted at enhancing cloud computing's energy efficiency and sustainability. The research looks at the complexities of cloud computing, examining how diverse applications, workloads, and server designs affect performance and energy consumption. It emphasizes virtualization and consolidation as major strategies for optimizing energy utilization. The notion of "green cloud computing", which

combines server virtualization, liquid cooling, and renewable energy sources, is investigated for its ability to minimize carbon emissions and promote sustainability. The review also goes into software-level strategies to improve energy efficiency, such as power-awareness, bio-inspired methodologies, and thermal management. The study underlines the growing importance of energy efficiency in information technology, as well as the role of cloud computing in lowering overall energy usage. It describes numerous energy-saving solutions, particularly those optimized for integrated systems that include both computer systems and networks, with the potential to minimize software and hardware expenses across data centers running cloud applications. Improving load balance is also stressed for improved service quality and performance. However, implementing energy-efficient solutions in cloud computing systems is not without its difficulties. Infrastructure management becomes more complicated, certain strategies may necessitate additional resources, and switching to energy-efficient technologies can be intimidating, particularly for organizations with existing infrastructures. Integrating new energy-saving technologies into existing systems and networks can take time, since rigorous trade-off analysis is required to balance energy efficiency with performance and service quality. In conclusion, this paper provides a thorough overview of the cloud computing energy-efficiency landscape, emphasizing the importance of energy-efficient solutions in mitigating environmental issues and promoting sustainability within the cloud computing sector while acknowledging the complexities and challenges associated with their implementation.

Keywords: Cloud computing, Efficiency, Energy.

INTRODUCTION

The rapid growth of cloud computing has led to increased energy demand and environmental concerns in data centers. Researchers are exploring various technologies and methodologies to make cloud computing more energy-efficient and sustainable. This review explores data centers, where cooling infrastructure is a significant portion of energy budget. It discusses the heterogeneity of cloud computing, its performance and energy consumption characteristics across applications, workloads, and server architectures. Virtualization and consolidation techniques are crucial for optimizing energy usage. Green cloud computing, incorporating server virtualization, liquid cooling, and renewable energy sources, is explored for reducing carbon emissions and promoting sustainability. The review also examines software-level techniques for energy efficiency, including power awareness, bio-inspired methodologies, and thermal management.

LITERATURE SURVEY

A complete evaluation of current best practices and literature on energy-efficient computer hardware and network infrastructure is performed.
The study begins by emphasizing importance of energy efficiency in information and communication technologies (ICT) and the potential of cloud computing to improve energy consumption.

The report addresses significant research problems as well as areas in which energy-saving approaches should be expanded for usage in cloud computing systems.

In this article, Contributions and research efforts in the field of energy-saving measures for integrated systems, such as computer systems and networks, are examined. The study proposes that cloud computing, in conjunction with virtualization, can be used to identify the primary sources of energy usage as well as trade-offs between performance, quality of service (QoS), and energy efficiency. The study suggests that specific plug-ins and energy-control centers be implemented for networked large-scale devices and software.According to the study, energy-saving measures can result in lower energy costs for both software and hardware in single or federated data centers running 'cloud' applications. Energy-efficient techniques can improve load balancing, which improves QoS and performance in single and federated data centers. Furthermore, energy-efficient solutions may result in lower energy consumption connected with data center communications. It can reduce greenhouse gas (GHG) and carbon dioxide (CO_2) emissions from data centers and networks while also providing environmentally friendly computing power. According to the report, these can be used in data centers and networks, potentially lowering energy use in transportation and encouraging 'green' ICT-based solutions for e-work, e-learning, and home climate control. Implementing energy-efficient solutions in cloud computing systems may complicate infrastructure management and maintenance. Some energy-saving strategies may result in higher prices. Transitioning to more energy-efficient systems may be difficult, in businesses with existing infrastructure. Integrating new energy-saving technologies with existing systems and networks can be difficult and time-consuming. Balancing energy economy with performance and service quality may necessitate trade-offs that enterprises must carefully examine. (Andreas Berl, 2009)

The study starts by emphasizing the significance of energy efficiency in data centers and the need for energy-aware resource management systems to solve energy waste in IT equipment. The thesis focuses on three methods for increasing energy efficiency: scaling virtual machine (VM) and server processing capabilities, workload consolidation, and leveraging resource heterogeneity. In addition, the thesis provides energy-saving models, algorithms, and strategies such as VM scaling, VM sizing for CPU and memory, CPU frequency adaptation, and hardware power capping. Based on the presented models, controllers are created to dynamically identify power-efficient resource allocations while minimizing performance penalties. To improve resource utilization and energy efficiency in data centers, methods for resource overbooking and workload consolidation are presented. Furthermore, the thesis takes into account resource heterogeneity and proposes heterogeneous-aware scheduling algorithms (e.g., FPGAs) and use variances in server energy footprints. Furthermore, virtualization overheads are evaluated using four popular virtualization systems: XEN, KVM, LXC, and Docker. Benchmarks are used to evaluate CPU, memory, disk I/O, and network performance. In this study, metrics for quantifying virtualization overheads in terms of performance, resource usage, and power consumption are presented. It calculates and numerous instances.

Using several benchmarks, the study objectively assesses virtualization overheads in four virtualization systems. It provides information about each platform's performance, resource usage, and power overheads. The findings show

that no single virtualization strategy provides excellent outcomes across all parameters. Each platform has advantages and disadvantages, and certain limitations can be handled with existing solutions. The report also assesses cloud-related issues such as resource isolation, over-commitment, start-up time, and density (the number of instances supported per physical machine). According to the findings, techniques that combine the best features of several platforms into a single solution offer a potential way for enhancing virtualization in cloud environments. Introducing complexity into data center management and decision-making by using energy-efficient resource allocation strategies and analyzing virtualization overheads. Some energy-saving strategies may necessitate additional resources, which could result in higher operational expenses. Transitioning to more energy-efficient systems and virtualization platforms may be difficult, particularly for enterprises with established infrastructure. Balancing energy economy with performance and service quality may necessitate trade-offs t. In conclusion, the thesis investigates several approaches and technologies for increasing energy efficiency in data centers. It also assesses virtualization overheads in major platforms, highlighting trade-offs and the possibilities for integrating the benefits of several platforms for optimal results. The findings are useful for data center and cloud environment management. (Tesfatsion, 2018)

The study begins by addressing the issue of balancing high system The paper covers contemporary approaches and techniques for improving energy efficiency in cloud computing. SaaS, PaaS, IaaS, and so on. performance with low power consumption in cloud data centers. It gives an overview of cloud computing, emphasizing the pay-as-you-go approach and the importance of virtualization in delivering computer resources. The importance of data centers as the foundation of cloud computing, where corporate information is stored and applications are hosted, is emphasized in the article. Furthermore, it discusses the emphasis on energy efficiency in cloud computing, as well as the advent of numerous strategies and algorithms to accomplish efficient energy consumption. The document makes no clear reference of the survey's precise conclusions or findings are effective or how they affect the balance of system performance and energy usage. The study provides a broad. However it lacks specifics on methodologies and results. In summary, the study discusses the difficulty of balancing system performance and power usage in cloud data centers. It discusses the significance of energy efficiency in cloud computing as well as the existence of numerous techniques. However, it does not specify the outcomes or downsides of these strategies. The exact methodology and results will most likely be published in the complete publication or study. (Mohamed Deiab, 2019)

The article discusses the issue of increased energy usage in cloud computing as a result of virtualization adoption, as well as the necessity for energy management approaches. The paper discusses current research on cloud energy management approaches such as ballooning, virtual machine migration, resource allocation, Energy Efficiency Heuristic with Virtual Machine Consolidation (EEEHVMC), and three-way decision (VMM-3WD).According to the report, each strategy is systematically analyzed, with strengths, flaws, and future prospects highlighted. The

document, it is stated, offers light on the requirements and criteria that cloud enterprises and data centers must adhere to.The article discusses the issue of increased energy usage in cloud computing as a result of virtualization adoption, as well as the necessity for energy management approaches. The paper discusses current research on cloud energy management approaches such as ballooning, virtual machine migration, resource allocation, Energy Efficiency Heuristic with Virtual Machine Consolidation (EEEHVMC), and three-way decision (VMM-3WD). (Riakshi Routray, 2023)

According to the report, each strategy is systematically analyzed, with strengths, flaws, and future prospects highlighted. The document, it is stated, offers light on the requirements and criteria that cloud enterprises and data centers must adhere to.The paper presents a broad review of the study on energy management approaches in cloud computing, but does not go into detail on the studies' outcomes or findings. While the paper briefly highlights the benefits, flaws, and future possibilities of the described methodologies, it does not dive into detailed details or the amount to which they are effective. In summary, the abstract discusses the issue of growing energy consumption in cloud computing as well as research on energy management approaches. It mentions a thorough analysis of various strategies, a comparison chart, and energy optimization issues. However, it lacks precise outcomes and detailed information regarding the methodology used in these studies. The complete publication or study will most likely provide more detailed information. (Riakshi Routray, 2023)

Primary studies are gathered from a variety of sources, including databases (Springer, Scopus, ScienceDirect, IEEE Xplore, Wiley, ACM Digital library) and prestigious publications and conferences.

The study discusses the issue of high energy usage in data centers, as well as the environmental impact of such elements as global warming and CO_2 emissions. The goal of this, study is to conduct a systematic mapping analysis to understand the environmental impact of excessive energy usage in cloud data centers. search of six databases as well as consideration of ten prestigious publications and six conferences are considered as main process. Snowballing was employed to improve search efficiency. A pool of 119 primary studies (PSs) was chosen for further analysis after meticulous screening and quality assessment. The mapping of primary studies reveals a constantly thriving study topic connected to the environmental impact of excessive energy usage in cloud computing. The paper gives an overview of cloud energy-efficiency approaches, stressing their importance in lowering energy usage for a more sustainable environment.The mapping of selected primary papers revealed a continually expanding research field in cloud computing about the influence of excessive energy usage on the environment, according to the report. virtualization-based strategies, consolidation techniques, bio-based optimization processes, temperature control, and non-technical procedures are used as techniques. (Salil Bharany, 2022)

This analysis of green computing via cloud and IT research on sustainability compiles data on energy-saving tools and techniques. It evaluates the efficiency of server virtualization, cooling techniques, and renewable energy sources in lowering

energy consumption and carbon emissions. Data were acquired for the study from a number of sources including cloud service providers.

According to the study, green cloud computing can drastically lessen the environmental impact of IT operations. The combination of server virtualization and water cooling may be able to cut energy use and carbon emissions by as much as 50%. Solar and wind power are examples of renewable energy sources that can support sustainability. However issues like high initial costs, specialized maintenance skills, and the availability of renewable energy sources based on geography still exist. The report recommended that firms perform a thorough review of their IT operations in order to understand energy consumption and carbon emissions. It is recommended that energy-efficient technology and procedures be identified. And the formulation of a long-term sustainability strategy that includes investments in renewable energy sources, which can vary depending on the organization's location, was advocated. According to the survey, despite the potential advantages, the adoption of green cloud computing may be hampered by high upfront costs, the requirement for specialized knowledge and experience, and the location-dependent nature of renewable energy sources. save energy, there may be upfront fees connected with its adoption and upkeep. Discuss the potential obstacles associated with integrating the notion into existing business processes and IT infrastructure. (Dr. Tarun Kumar Vashishth, 2023)

The researchers conducted a thorough analysis of the available literature on Green IT, cloud computing, and business environmental sustainability. Investigate prior studies on cloud architecture and energy efficiency. For this study's data Gather information on existing business apps and cloud architectures, including technical and business characteristics. Obtain information on the energy usage and costs of various cloud architecture configurations. It clearly explains the dilemma of increasing environmental effects while remaining profitable in businesses. And, as a remedy, identify the need for energy-efficient cloud design. (Salama, 2012)The study investigates the relationships between selected features and appropriate cloud architectures. And Identify links between attribute patterns and energy-efficient structures using statistical approaches. Create a recommender system that recommends energy-efficient cloud designs based on attribute-architecture correlations. Create algorithms to deliver recommendations depending on the individual properties of an application. The document Displays the recommender system's output, which includes recommended cloud designs for various sorts of applications. Highlight the proposed architectures' energy efficiency and environmental benefits. It also includes case studies of organizations that have used the approach, highlighting their environmental gains and financial savings. Describe how the recommended architectures are used in real-world applications. And show how the recommended architectures correspond with the organizations' technical and business requirements. Demonstrate how the notion assists firms in meeting their goals while remaining environmentally conscious. The study emphasizes the need for ongoing maintenance and upgrades while acknowledging the difficulties of implementing a cloud computing concept, such as the time-consuming task of collecting data for attribute recognition and correlation analysis and the possibility

that its applicability may vary depending on individual applications and organizations. And Mention that, while the proposal intends to Green cloud computing projects need specialized skills for handling and upkeep of infrastructure, which some businesses may not have, and are dependent on local environmental laws, energy sources, and geography. (Salama, 2012)

A thorough study of existing literature on the environmental impact of ICT, cloud computing, and the developing topic of green cloud computing was conducted. Investigated numerous approaches and technologies relating to energy-efficient and environmentally friendly cloud computing. Data on the environmental impact of traditional data centers and cloud computing activities, such as energy usage, carbon emissions, and resource utilization, was most likely acquired. Traditional cloud data center architectures were compared to green cloud computing standards. The potential benefits of green cloud computing, such as energy efficiency, resource optimization, and lower carbon footprints, were examined. (Bharani Dharan G, 2020) Green cloud computing has the ability to lessen the environmental impact of ICT and cloud computing operations. Benefits such as energy efficiency, resource utilization, lower carbon footprints, and reduced electronic waste were highlighted. They've talked about how CSPs need to modernize their data center infrastructure and reduce negative environmental impacts. The emphasis is on how CSPs may play a critical role in promoting green cloud computing. Green cloud computing approaches and technologies such as containerization, creating eco-friendly data center infrastructure, virtual machine (VM) placement, server consolidation, green network protocols, and sustainable software development were discussed. The report acknowledged that enterprises may have challenges in shifting to green cloud computing, particularly in terms of modifying current infrastructure and procedures. The potential initial costs involved with using green cloud technology were mentioned, which may be a barrier for some enterprises. Recognized that not all organizations and IT workloads may be fit for all parts of green cloud computing approaches, requiring businesses to select the best strategies depending on their individual needs. It should be noted that converting existing data centers to meet green standards can be a complex and time-consuming procedure. (Bharani Dharan G, 2020)

The paper emphasizes the internet's quick development and the rising need for computational capacity. It talks about how moving to the cloud from small data centers affects energy consumption. Hardware elements, network and server groupings, and adaptive power management are techniques for lowering the amount of energy used in data centers. With a focus on data center power efficiency, the study examines more than 100 green cloud computing strategies. For lowering power consumption, energy-efficient algorithms are essential. The paper emphasizes the internet's quick development and the rising need for computational capacity. It talks about how moving to the cloud from small data centers affects energy consumption. Hardware elements, network and server groupings, and adaptive power management are techniques for lowering the amount of energy used in data centers. With a focus on data center power efficiency, the study examines more than 100 green cloud computing strategies. For lowering power consumption, energy-efficient algorithms

are essential. The research assesses more than 100 green cloud computing strategies without providing any concrete approaches, findings, or recommendations. Without going into the techniques covered or their effects, it gives a broad overview of the subject. Although the report doesn't give particular outcomes or findings from the survey, it does emphasize the need for data centers to be more energy efficient as cloud computing expands. (Avita Katal, 2022)

The article discusses the issue of high energy usage in data centers hosting cloud applications, as well as the environmental and financial ramifications. Its goal is to propose a vision and solutions for energy-efficient cloud computing administration. The methodology entails the creation of dynamic resource provisioning and allocation algorithms that take into account varied data center infrastructures, as well as comprehensive strategies for enhancing data center energy efficiency and performance. A performance evaluation study utilizing the CloudSim tools validates the technique.The findings show that the Cloud computing model has a substantial potential for enhancing performance in terms of reaction time and cost savings, especially in dynamic workload circumstances. And The research promotes the field of Cloud computing by lowering the cost of data center energy use, making Cloud computing more competitive. It also aligns with environmental goals and policies by targeting greenhouse gas emissions reduction.

While the report indicates potential performance increases and contributions, no precise quantitative results or findings from the performance evaluation The paper discusses energy consumption in cloud data centers, proposes solutions, and suggests architectural concepts and methods for energy-efficient management. It highlights the importance of this research in Australia's expanding data center sector and environmental concerns. However, the abstract lacks specific findings and findings, which can be found in the complete report. (Arindam Banerjee, 2013)

A survey of existing literature on Green Cloud computing, energy efficiency, and data center management was conducted. It defined the issue of data centers hosting Cloud applications in terms of energy usage and operational costs. Developed architectural ideas for energy-efficient cloud computing management. This most likely entailed creating a framework for resource allocation optimization. Energy-efficient resource allocation principles and scheduling algorithms were developed. These restrictions most likely took into account device power consumption and quality-of-service expectations. A revolutionary software technology is proposed that is specifically specialized for energy-efficient management of Cloud settings. To evaluate the suggested approach, a performance test was carried out using the CloudSim toolbox. Simulating alternative workload scenarios and data center architectures to analyze performance benefits in terms of reaction time and cost savings was most likely included. The Architectural concepts for energy-efficient Cloud management are presented, taking into account the synergy between various data center infrastructures such as hardware, power units, cooling, and software. The resource allocation strategies and scheduling algorithms that consider quality-of-service expectations and device power utilization characteristics were discussed. In addition, an innovative software solution for energy-efficient Cloud administration was introduced. Cloud computing has been shown through comprehensive

performance assessments utilizing CloudSim to have tremendous promise for boosting performance in terms of response time and lowering operational costs in dynamic workload scenarios. Due to upfront expenditures, resource allocation guidelines, and maintaining a variety of equipment, power units, and cooling solutions, adopting energy-efficient management techniques in data centers can be difficult. Heterogeneity may make it difficult for innovative technologies to be sustainable over the long term.y and scalability of energy-efficient data center management systems. Adoption and implementation of new architectural concepts and software The essay examines the demand for energy-efficient cloud computing solutions, suggests a design method, and then uses performance evaluations to verify the approach. Under dynamic workload conditions, it illustrates the potential for improving performance and lowering costs, but it also points out drawbacks such as complexity and early outlays. (Rajkumar Buyya, 2010)

CONCLUSION

Finally, the studies presented highlight the critical need of improving energy efficiency and promoting environmental sustainability in the arena of cloud computing and data centers. These studies shed light on a plethora of approaches and technologies aimed at reducing energy usage and carbon emissions, mainly in the context of cloud computing. Energy-saving strategies such as server virtualization and liquid cooling, as well as resource management and virtualization approaches, are key areas of study. These solutions provide concrete benefits in terms of cost savings and reduced environmental impact, but they require careful management and trade-off evaluation.

Furthermore, comprehensive mapping analysis and architectural techniques highlight the importance of environmental concerns in cloud computing. While these studies identify and emphasize the value of energy-efficient practices, they frequently fall short of presenting particular quantitative conclusions. Furthermore, energy-efficient cloud design suggestion systems and performance enhancement studies reveal the potential for significant increases in resource efficiency and operating cost reduction. However, these techniques recognize the complexities and challenges of implementation, such as upfront expenses and the requirement for specialized expertise. Addressing these difficulties and optimizing energy use is critical for a more sustainable and eco-conscious IT infrastructure as cloud computing evolves. More study is needed to fine-tune these approaches and provide useful insights to enterprises and data center operators.

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