A Study on Green Cloud Computing and its Challenges

Dr N Neelima Priyanka, Professor, Department of IT, SRK Institute of Technology

Abstract

Cloud computing has emerged as an effective way to tackle the storage and processing challenges associated with large amounts of data. It offers cost-effective, fast, flexible, and scalable solutions. Despite significant advancements in cloud computing and its services, the development of environmentally-friendly "green clouds" is still in progress. This is largely due to limited research and various implementation barriers. Green clouds aim to be eco-friendly, energy-efficient, resource-efficient, low in carbon emissions, and sustainable. Cloud service providers are continually striving to meet the increasing demands of enterprise data storage and processing. To address the environmental implications associated with cloud computing, these providers are actively implementing innovative technologies such as Green Cloud Computing in their architectural designs. The goal is to minimize power consumption, water usage, reliance on physical hardware peripherals, overall infrastructure, and the release of harmful carbon emissions. In order to protect our environment, service providers must adopt and enhance their cloud infrastructure to align with green computing principles. Extensive research in this field focuses on the development of efficient cloud systems that possess green characteristics, including load balancing, virtualization, power management, computing, high performance green data centers, and promoting reusability and recyclability. This analysis report aims to provide a detailed overview of green cloud computing and its key features. It delves into the previous accomplishments in green computing, explores current trends in the field, and outlines future research challenges. This comprehensive analysis report serves as a valuable resource for aspiring green researchers, offering insights into green cloud topics and the upcoming challenges in the field.

Keywords: *Energy Efficiency, Virtualization, Multi-Tenancy, Consolidation, Eco-friendly, SaaS, PaaS, IaaS etc*

I. Introduction

Cloud computing has gained popularity as a computing platform for businesses over the past decade. It allows entrepreneurs to focus on their core business operations instead of investing time and money in managing infrastructure. According to the National Institute of Standards and Technology (NIST), cloud computing provides different services such as Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS). These services are designed to attract business application owners to adopt and migrate their applications to the cloud. Cloud-based data centers, platforms, servers, and other infrastructure services are highly flexible and can easily meet the sudden resource demands of customers. According to Heininger's research in 2012, the availability of various deployment models, a charging policy based on actual usage, flexible connectivity options, fast networks, and cost-effective resources have all contributed to the increasing adoption of cloud technology by organizations, ranging from large multinational corporations to smaller businesses.

Today, a vast array of devices such as smart phones, tablets, smart watches, healthcare devices, and sensors are utilizing cloud technology for the purpose of storing their private data. Various software applications, including email services, messaging apps, enterprise applications, social media networks, online shopping platforms, audio and video streaming services, broadcasting, and entertainment platforms, are also relying on cloud services to securely store, process, and share their data. An example of this is the well-known search engine company Google, which hosts its services such as Gmail, Google Earth, Google Drive, Google Play, and YouTube on its dedicated cloud platform known as GCF, enabling it to provide high-quality services to its customers worldwide. According to a survey conducted by Forbes and Gartner in September 2018, it was found that the current value of worldwide public cloud revenue is $175.8 billion. The revenue is expected to reach $206.2 billion in 2019, with a growth rate of 17.3%. This signifies the rapid growth of cloud utilization on a global scale. Leading vendors in the cloud market include Amazon Web Services (AWS), Microsoft's Azure, Google Cloud Platform, and IBM Cloud.

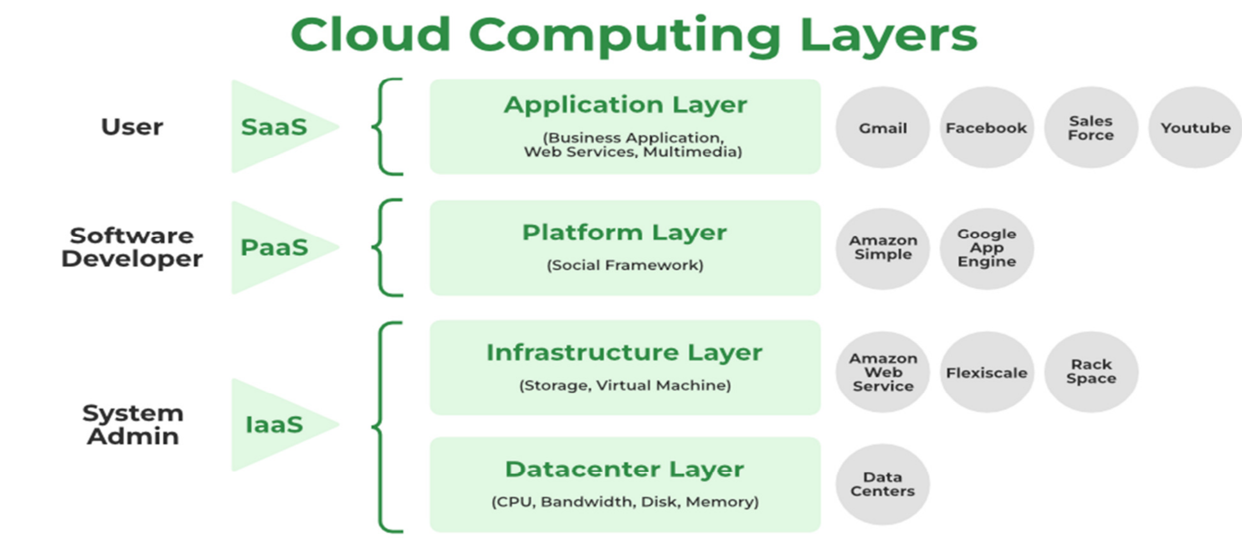

Fig.1-CloudComputingServiceLayersArchitecture

Though the cloud's elastic nature satisfies the needs of cloud service users, service providers suffer from having to put up with data centers' massive power consumption, which further drives up operating costs, increases carbon emissions, and reduces profits. Most of the issues that modern business organizations face are being addressed by clouds, but they still have some significant drawbacks, such as high power consumption, increased CPU idle times, the requirement to deploy resources at maximum capacity, carbon gas emissions, and large amounts of electronic waste (e-waste) material produced. Thus, it is necessary to develop modern cloud environments that are environmentally friendly, such as "Green Cloud Computing." While general cloud computing focuses primarily on data processing and storage, green cloud computing is a new cloud computing reform that aims to make the cloud environment more environmentally friendly (Hilty M.L., & Arnfalk P, et al., 2006). Energy efficiency, virtualization, multi-tenancy (high-end utilizable), consolidation, automation, resilience, recycle ability, and sustainability of cloud resources are the primary features of green clouds. It is imperative that naïve innovations like cloud computing do not compromise the world's green nature. As such, experts strongly advise that "cloud computing must consider the ecology gaining along with economy."

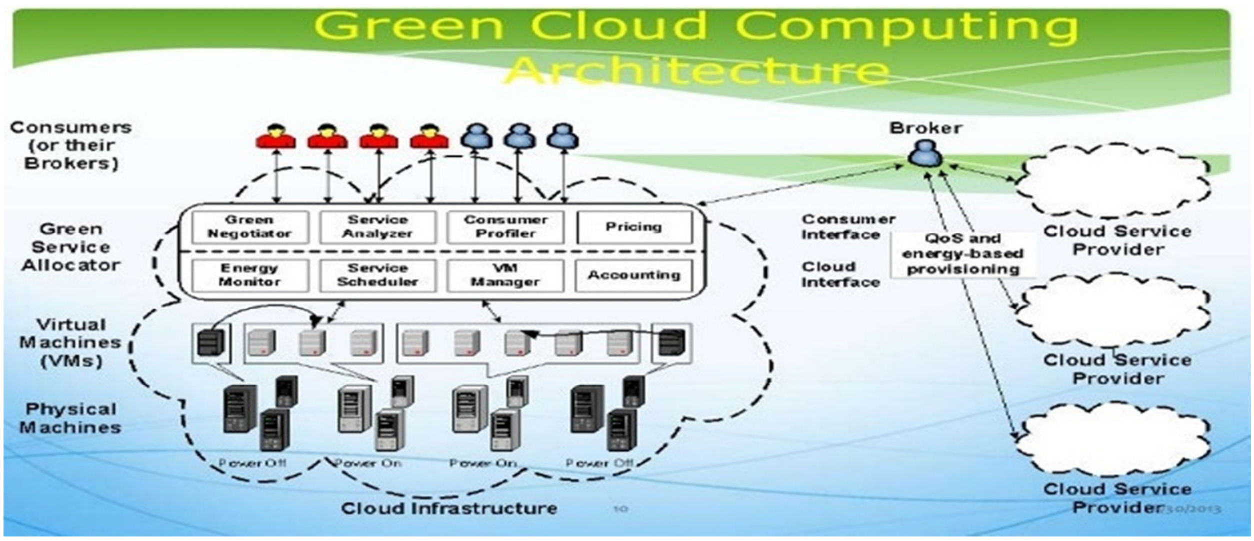

Fig.2-Green Cloud Computing Architecture

The goal of green cloud computing is to create an environmentally friendly cloud environment, which means that the cloud shouldn't take advantage of nature's greenery in any way. For instance, even though a cloud environment strictly adheres to energy-efficient power management standards and policies in order to save energy, the fact that it gets its power from coal-based thermal stations causes indirect environmental harm. Therefore, it is imperative that green cloud policies and standards take into account the adverse effects that clouds have on ecology, both directly and indirectly. To design the green cloud architecture, a number of technologies and monitoring tools are needed in addition to the policies and standards. The key instruments and technologies utilized in the architecture design of the green cloud computing system are shown in Figure 2.

The previously mentioned green cloud computing architecture was created in collaboration with cloud providers, cloud users, and cloud data centers (cloud-A, cloud-B, and cloud-C). Cloud data centers are typical cloud environments that are made to provide cloud services such as SaaS, PaaS, and IaaS. In order to certify the related clouds as green, the Green Cloud Provider (GCP) is designed as a cloud service broker module. This module is authenticated and permitted to monitor the cloud infrastructure and activities. GCP installs energy consumption meters at the module level to monitor power management at each cloud tier as part of its job description. Following the receipt of power consumption data from monitors, GCP applies analytics to the consumption details and makes recommendations for energy-efficient power management solutions. In order to process incoming requests accurately and quickly, a scalable process scheduler builds cloud virtual instances during runtime. By making the most use of them, these virtual instances are used to improve the capabilities of hardware infrastructure. In order to enable parallel processing, this process scheduling makes use of custom job scheduling algorithms. The majority of cloud clients, with the exception of a select few well-known large corporations, are in small- to medium-sized businesses. They are turning to the clouds to deploy their apps for data processing and storing because they are unable to set up their own IT infrastructure with large capital expenditures. In this scenario, public clouds need to be built with security in mind, enabling a group of cloud users to share resources and host their apps on a single cloud instance. In the world of cloud computing, this procedure is known as multi tenancy.

Another crucial cloud monitoring tool is the GCP module's resource calculator, which is installed at the level of each cloud instance and records the memory, CPU, storage, bandwidth, and time utilization values. Using the appropriate resource calculation algorithms, this recorded data will be analyzed to determine future resource demand, resource availability, resource underutilization, etc. Reutilization monitor is a high-level analyzer created to suggest potential cloud resource repurposing options in order to reduce costs and save time. In a similar vein, the load balancing module works to ensure seamless processing by distributing the load (of memory and CPU) among the several cloud instances. The third party policy preparation groups are carbon emission directories and green cloud policies. Their standards and policies help build green clouds from regular cloud environments. Last but not least, the end user is an IT manager from any company who can get in touch with GCP to talk about hosting their apps on green clouds and to plan the process of migrating their apps based on service level agreements (SLA).

II. Literature Review

In order to obtain the most highly reliable information about green cloud computing and its attributes, we extensively checked a large number of journals, conferences, white papers, and online sources as part of our research analysis on "Green Cloud Computing." With the aid of pertinent earlier research publications, we present the review of the literature on green cloud computing in this section. A brief analysis of each significant study project in the field of green cloud computing is provided, along with author information. This data aids novice researchers in comprehending the assessment of green cloud computing and its advancements since inception.

In 2002, Pat Boher at el (Pat Bohrer, Elmootazbellah et al.) studied the best power management strategies while running the web servers at a low utilization level with no impact on performance. They used the system logs as their primary source of information in order to calculate a web server's energy consumption at different utilization levels. An effective power simulation mechanism was implemented to track the energy values consumed by the CPU and other resources, aiding in the prediction of future energy needs. The "Dynamic Thermal Management" approach was created by David Brooks (D. Brooks, M. Martonosi et al. 2001) using CPU level clock gating techniques. This aids in operating the main processor at maximum low power, but research using this technique found that it has a negligible effect on CPU performance. The "energy-conscious provisioning" method was proposed by Jeffrey (J. Chase et al., 2001) in order to distribute the load of incoming requests to idle servers, conserve energy, and use resources equitably. In order to finish the operations quickly, this method evenly distributes the load of a request across all instances that are feasible (as committed in SLA). In this instance, the resources are pooling their actual processes in order to overcome the issue of underutilization. A study on the power consumption of data centers in the United States as well as other computational devices was carried out by Jonathan G. (J.G. Koomey, 2007). Using this information, he calculated that by 2005, data centers' power consumption would account for 0.65% of all power generated in the United States.

In a white paper on energy efficiency, John Judge atel(John Judge, Jack P, Anand E, & Sachin Dixit,2008) outlined how data center power consumption can be decreased without compromising server availability or performance. Lastly, he recommended that the best practices for designing energy-efficient clouds include the use of potentially low-voltage resistant processors, the installation of power management tools (to monitor and automatically manage power), virtualization techniques (to increase processing power with the same resources), the design of blade servers, and effective cooling mechanisms. In order to save power and speed up processing, Eduardo (Pinheiro Eduardo, Bianchini Ricardo et al., 2001) wrote a paper on the application of load balancing and unbalancing techniques in cluster-based systems. They included a "on & off mechanism" in the design of the cluster-based system to automate the turning on and off of operations in response to power demands. This technique was put into practice at the server and operating system levels, and positive outcomes in resource optimization were noted. The study by Luca Benni et al. (L. Benini, A. Bogliolo & G.D. Micheli, 2000) examined system level design approaches for enhancing cloud dynamic power management (DPM) procedure performance. They extensively revised the earlier studies on various system level dynamic power management techniques as part of their survey. This information aids in their comprehension of the limitations of the power management strategies in use today and the design of the dynamic strategies that will be used in the future to achieve higher performance. They included detailed descriptions of power management at the system component, system, and network levels as well as some noteworthy dynamic power management strategies.

2010 saw the creation of an NS-2 based simulator by Dzmitry (D. Kliazovich, P. Bouvry, Y. Audzevich & S. U. Khan, 2010) to track power usage at green cloud data centers. Using that simulator, he conducted some tests to record the cloud's power consumption values with an Intel

Xeon 4-core processor, 8MB DDR3 RAM, and a cache frequency of 3.33GHz. They calculated the power consumption at each entity level by simulating and keeping an eye on the servers, routers, links, switches, and workloads. This simulation environment gathered various cloud component-related critical power consumption statistics, such as the average power usage of the component, the power usage at idle state, and the extreme high/low power usage values at each component. Their simulations revealed that the various cloud components that use the most energy are the CPU (130W), memory (12%), disks (12W), peripherals (17%), motherboards (8%) and others (16%).

According to the "ICT electricity consumption and carbon emissions by 2020" survey report (Green Peace International article, 2010), both carbon emissions and electricity consumption are expected to grow at an annual rate of 9 to 9.6%. They listed the following three critical factors regarding the state of current clouds: i) clouds are growing but not contributing to provider economic growth as anticipated; ii) a strong emphasis on the design of energy-efficient cloud data centers; and iii) well-known cloud providers are building extremely large data centers to compete. On the other hand, this article on green peace poses some important queries to data center owners in order to encourage the use of green IT. These include high energy consumption, carbon emissions, and effective resource management. Energy production sources include wind, hydraulic, coal, and nuclear power. Following a thorough analysis, we determined that energy efficiency, scalable resource management, low operating costs, and environmental friendliness are the four main pillars of green cloud computing.

III. Green Cloud Computing and its Current Trends

Green cloud computing is a business model that benefits both the environment and cloud service providers. By using resources effectively, green cloud not only helps the environment but also boosts service provider profits. We can make the current cloud environment green certified by enforcing certain management policies and features. Energy efficiency, virtualization, multi-tenancy, consolidation, recycling, and environmental friendliness are among the main features of green cloud. This section will cover the basic definitions, implementation process, specific information, and current trends related to each green cloud character.

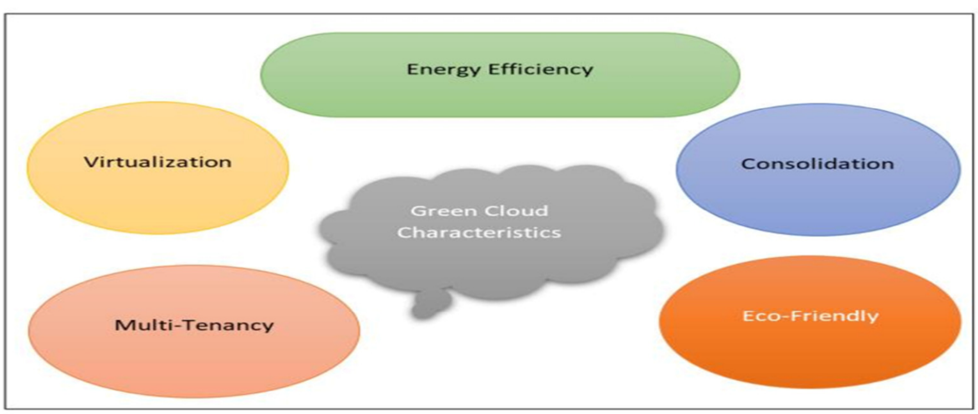

Fig.3-Essential Characteristics of Green Cloud Computing

Energy Efficiency

One of the fundamental components of green cloud computing, energy efficiency is essential to the development of environmentally friendly green clouds. Utilizing effective power management strategies to lower power consumption at every cloud object (servers, data centers, disks, routers, processors, etc.) level is what is meant by "energy efficiency in the cloud." Anton Beloglazov published a survey in 2011 on cloud computing systems and energy-efficient data centers (Anton Beloglazov, Rajkumar Buyya, Young Choon Lee & Albert Zomaya). The sources of power consumption, modeling of power consumption, static and dynamic power consumption techniques, and high power consumption issues were all thoroughly covered in this survey. In addition, since the primary power-consuming components of cloud computing architecture are the operating systems, data centers, virtualization, and hardware, they talked about the taxonomy of power management at each level. Static power management systems turn on all related cloud resources without realizing when they are needed for processing, and they provide the same voltage of power under both high and low utilization requirements.

Dynamic power management (DPM) systems were proposed in recent research (L. Benini, A. Bogliolo & G.D. Micheli, 2000; D. Kliazovich & P. Bouvry, 2010) to prevent the needless use of enormous amounts of energy in cloud environments. This system only launches the necessary cloud resources at first, calculates how much power is needed, and adjusts the power voltage to meet demand. Any cloud resource that is supplied with more power than necessary—that is, voltage—will be detected and fixed right away using dynamic power management techniques. The process is known as dynamic power optimization. We also had a thorough discussion of the subject of energy efficiency in section 2, as well as the insights provided by previous research scholars.

The current trends observed in this field include component level power management (resource power optimization), working on power utilization monitoring tools, designing power utilization simulators, designing decision making algorithms in DPM, and creating mixed work environments.

Virtualization

The idea of virtualization is to use the abstraction process to run multiple logical (virtual) computers on a single physical computer (hardware device). As far as we are aware, the idea of virtualization (Flavio Lombardi & Roberto Di Pietro, 2011) permits the creation of numerous virtual machines that can carry out a few tasks at once. The system software known as a hypervisor functions as an operating system (or abstraction layer) for virtual machines, coordinating with the underlying hardware in accordance with the instructions provided by the virtual machine. The concept of virtualization is not new to the field of information technology;

it was first applied to our magnificent Main Frames, which are considered to be second-generation computing devices.

Typically, high-end configuration components like RAM, processors, drives, routers, switches, and other components are used in the design of cloud systems. When using traditional (sequential) processing techniques, the running task(s) will receive all of the resources before they start. A task's allotted resources cannot be swapped for those of any other active tasks. In this manner, the assigned resources are not fully utilized, are obstructed by certain tasks, and the execution process takes longer to finish. Hypervisor-based virtual machines (VMs) are later designed to run multiple jobs in parallel on the same machine with resource sharing facilities in order to overcome the sequential processing limitations. In his study on cloud virtualization, Sabahi (2012) examined three alternative approaches to virtual machine creation: hypervisor-based virtualization, operating system-based virtualization, and application-based virtualization. He talked about designing virtual machine activity monitoring systems (VSEM, VREM) and the privacy and security of virtual machines. According to an article on cloud virtualization by tech-savvy Indian Jayabalan Subramanian from Net Magic Solutions, cloud virtualization helps to use the resources available at a high rate and decreases the amount of time required to perform a single task, which indirectly causes to save a significant amount of power over the cloud's lifetime. Vincent Motochi et al. presented their experimental analysis of cloud virtualization to illustrate how the virtualization techniques reduced the power consumption of the physical computer hardware (Vincent Motochi, Samuel Barasa, Patrick Owoche & Franklin Wabwoba, 2017). He saw that the hyper vision selection process had an impact on power consumption values and that starting the right number of virtual machines in accordance with workload also contributed to a significant reduction in consumption.

Taking Out The main benefits of virtualization are high resource performance, less frequent infrastructure investments, and effective resource utilization. Virtualization has produced high-speed processing, low power consumption, advanced resource utilization, and cost savings. It also greatly aids in the design of green clouds. The newest developments in green cloud computing include dynamic work load balancing with virtual machines (VMs), resource sharing amongst VMs, secure VM design, and energy optimization techniques for virtualization.

Multi Tenancy

In order to minimize costs (starting a new cloud instance for every tenant) and make effective use of the resources at hand, multi-tenancy refers to a cloud instance that serves several tenants of the same category. The majority of the time, multi-tenancy became a contentious topic in cloud news because of privacy and security concerns that arose during implementation (R. Ashalatha & J. Agarkhed, 2016). Multi-tenancy is a key feature of green cloud computing, according to NIST (Peter Mell and Tim Grance, 2011), since it greatly reduces resource consumption by supporting multiple tenants on a single cloud instance. Multi-tenancy was also identified by the Cloud Security Alliance (CSA) as a key component of green cloud infrastructure (CSA guide.v3.0).

Because multitenancy is implemented at two layers of the cloud—SaaS and PaaS—it is frequently difficult for listeners and novice cloud users to understand. Applications that fall under the line-of-business category, such as Sales Force CRM, which is a single instance that provides its services to multiple organizations, are shared among multiple tenants at the SaaS level. Although every customer is associated with a different organization, they all store their data in the same database tables provided by the CRM program. The phrase "multitenancy" at the PaaS level refers to the implementation of resource sharing across multiple clients using cloud infrastructure hardware (processor, disk, RAM, etc.) and software (virtual machines) in order to minimize processing costs and maximize resource utilization. In a multi-tenant cloud environment, Mayang Zou et al. (2016) described how to implement access controls to handle security issues while distributing resources among various users. My research revealed, after a thorough examination of the cloud multi-tenancy process, that multi-tenancy increases profits for cloud service providers by allowing them to service multiple applications on a single cloud instance. However, the majority of service users are afraid to interact in this multi-tenancy setting because they have security and privacy concerns. To gain acceptance from cloud service users, multi-tenancy must demonstrate that it is a secure environment for processing and storing data. Trending developments in this field of green cloud research include secure multi-tenancy development, multi-tenancy optimizations, and privacy-preserving secure access to multi-tenancy clouds.

Consolidation

Consolidation is defined as "the process of deploying different data centers related data processing applications on a single server with virtualization technology" in the context of green cloud computing. This is the primary side project that came about as a result of virtualization, and it aims to implement process-level load balancing, improve virtual system utilization, and also lower power consumption. In-depth discussions were held by Anton Beloglazov et al. (Anton Beloglazov & Rajkumar Buyya, 2012) regarding the necessity of consolidation, the steps involved in dynamic virtual machine consolidation, and its benefits. They discussed the consolidation of multiple virtual machines on a single physical server (the one-many approach) and multiple physical servers on multiple machines (the many-many approach). They suggested both deterministic and non-deterministic online algorithms to describe the cloud virtual machine migration process. In a different study, Anton Beloglazov and Rajkumar Buyya (2010) suggested an IaaS platform threshold-based method for VM consolidation in order to effectively balance the load and prevent resource underutilization issues. In addition to their previous threshold-value-based methods, they also introduced the dynamic threshold-value determination method, which takes into account the needs of the current virtual machine as well as historical usage data.

While working on the virtual machine consolidation process, scholar Hosseini brought up current issues (Mirsaeid Shirvani, Amir Rahmani & AmirSahafi, 2018). The goal of the consolidation process is resource optimization, with the expectation that intelligence support will minimize server downtime. He suggested the DVFS (Dynamic Voltage Frequency Scaling) based virtual machine consolidation technique to get around the limitations of the consolidation process and save energy by operating the servers at different voltage frequencies. The current hot topics in green cloud virtual machine consolidation are threshold-based consolidation, dynamic consolidation, and process optimization.

Eco-Friendliness

The management of everyone's safe lifestyle depends equally on the economy and the environment. However, in actuality, environmental restrictions become barriers to economic growth, while economic growth ruins the environment. Using cutting-edge technologies, green computing's eco-friendliness proposal closes the gap between the environment and the economy. The phrase "green cloud computing" suggests that these are environmentally friendly clouds that are specifically created to reduce activities that harm the environment (in the name of development) and guarantee that ecological elements are not disturbed. In this essay, we primarily addressed energy efficiency from beginning to end since it helps control greenhouse gas emissions to the atmosphere because it reduces the need for power generation. In order to meet our energy needs, the energy sector of today heavily relies on nuclear reactors and coal-based power generation, both of which emit harmful monoxides into the atmosphere.

The Green Peace International organization provided comprehensive statistics and projections in an article (Green Peace International article, 2010) that explains how cloud computing and its components are affecting the environment. They hinted that because the information and communication technology (ICT) sector is expanding quickly in both China and India, these two nations will soon have to deal with the consequences of their carbon footprints. They forecasted the electricity consumption by 2020 and showed the total amount of cloud power consumed in 2007. Their data gives information regarding the amount of carbon ($MtCO_2$) released into the atmosphere in order to generate sufficient electricity for the consumption of cloud objects.

An article on developing software applications that are energy-efficient was written in 2013 by Nitin Singh Chauhan and Ashutosh Saxena from the Infosys organization. They anticipated that the executing software application should be cognizant of energy efficiency in addition to the energy-efficient cloud environment. They looked closely at the software development life cycle (SDLC) and determined which important software application areas needed to be designed with the environment in mind. The newest developments in the eco-friendliness of green cloud computing are the creation of carbon emission directories and green cloud policies.

IV Green Cloud Future Challenges

Energy Efficiency: Since multi-core CPUs are being used in today's clouds, power optimization and management techniques must be developed to support multi-core CPU power management. The data center, which consists of a collection of data management software and data storage components, is another extremely power-hungry aspect of the cloud. The research challenges in this area include developing an effective power consumption monitoring system, a dynamic power management system, and an intelligent power supply decision making system. Given the current speed of IT, we require a thorough and sophisticated system to address all cloud architecture level energy optimization concerns.

Virtualization: Although a lot of earlier research focused on developing an effective cloud virtualization process, there are still certain high-end optimization-related virtualization-related limitations. Creating innovative approaches using cutting-edge technologies to maximize the virtualization process throughout its whole life cycle is a significant research challenge (Tadapaneni, N. R., 2018). The other significant research challenges in virtualization are automated optimal virtual machine creation with substantial resources and dynamic resource allocation & sharing facilities without affecting cloud performance.

Multi-tenancy: While this is a fundamental feature of green cloud, multi-tenancy is currently plagued by privacy and security issues. Future research challenges include designing secure multi-tenant architectures and providing privacy-preserving secured access to multi-tenant modules.

Consolidation: Future research challenges in this field will include the design of intelligence support for virtual machine consolidation, multi-aspect based threshold value calculation, leveraging of critical resources, and server downtime management.

Eco-Friendliness: This field focuses primarily on designing tools that are environmentally friendly, such as carbon emission calculators that assess how the cloud affects the environment. It is necessary to create a thorough framework based on several Green Cloud Computing factors in order to certify clouds and assign rankings.

V. Conclusion

We included a review of the green cloud computing literature in this paper as part of our research analysis. We quickly reviewed the idea of cloud computing and the necessity of creating green clouds. The literature review revealed that earlier researchers conducted extensive searches on green clouds, identifying constraints and suggesting potential solutions. We went into great detail about the architecture of green cloud computing and its corresponding modules. This paper's primary goal was to examine the noteworthy aspects of green cloud computing by examining previous research discussions, current trends, and upcoming research challenges. The authors have designed this paper to serve as a concise guide for scholars studying green cloud computing, explaining its features, current trends, and upcoming research challenges.

REFERENCES

[1] Pat Bohrer, Elmootazbellah N.Elnozahy, Tom Keller, Michael Kistler, Charles Lefurgy, Chandler Mc Dowell, RamRajamonyetal. (2002). The case for power management in web servers. IBM Research, Austin TX 78758, USA. http://www.research.ibm.com/arl

[2] Heininger,R.(2012). IT Service Management in a Cloud Environment: A Literature Review. In Proceedings of the 9th Workshop on Information Systems and Services Sciences, München, Germany, 8–10 May -12; pp. 1–12. https://www.forbes.com/sites/louiscolumbus/ 2018/09/23/ roundup-of-cloud-computing-forecasts-and-market-estimates-2018/#727f7b5b507b.

[3] J.Chaseetal.(2001). Managing energy and server resources in hosting centers. Proceeding SOSP'01 Proceedings of the eighteenth ACM symposiumon Operating systems principles Pages 103 - 116.

[4] Peter Mell and Tim Grance (2011). "The NIST Definition of Cloud Computing" Version15, 10-7-09, National Institute of Standards and Technology, Information Technology Laboratory.

[5] J.G.Koomey (2007). Estimating Total Power Consumption by Servers in the US and the World, Analytics Press, Oakland, CA. http://www-sop.inria.fr/mascotte/Contrats/ DIMAGREEN/ wiki/ uploads/Main/svrpwrusecompletefinal.pdf

[6] D.Brooks, M.Martonosietal. (2001). Dynamic thermal management for high-performance microprocessors. Proceedings HPCA Seventh International Symposiumon High-Performance Computer Architecture, Monterrey, Nuevo Leon, Mexico, pp. 171-182.

[7] Hilty, M.L., Arnfalk, P, ErdmannL, GoodmanJ, Lehmann M&WagerA.P (2006). The relevance of information and communication technologies for environmental sustainability—A prospective simulation study. Environmental Modelling & Software, Volume 21, Issue 11, Pages 1618-1629.

[8] L.Benini, A.Bogliolo, G.D.Micheli, (2000) A survey of design techniques for system-level dynamic power management, IEEE Trans. VLSI Syst. 8-3-299–316. D.Kliazovich, P. Bouvry, Y. Audzevich and S. U. Khan.(2010).

[9] Green Cloud: A Packet-Level Simulator of Energy-Aware Cloud Computing Data Centers. 2010 IEEE Global Telecommunications Conference GLOBECOM2010, Miami, FL, 2010, pp.1-5.

[10] Anton Beloglazov, Rajkumar Buyya, Young Choon Lee And Albert Zomaya(2011)" A Taxonomy and Survey of Energy-Efficient Data Centers and Cloud Computing Systems" Advances In Computers, vol. 82, issn: 0065-2458/doi: 10.1016/b978-0-12-385512-1.00003-7.

[11] John Judge, Jack P, Anand E, and Sachin Dixit (2008). Reducing Data Center Energy Consumption. Ashrae Journal.50. http://ashraephilly.org/images/downloads/ CTTC_ Articles/ 1503_cttc.pdf

BL Publications DOI:10.5072/FK26H4PV9J.2024.02.02.001

[12] Flavio Lombardi, Roberto DiPietro, (2011). Secure virtualization for cloud computing, Journal of Network and Computer Applications, Volume 34, Issue4, Pages1113-1122, ISSN 1084-8045.

[13] Tadapaneni, N.R. (2018). Cloud Computing: Opportunities And Challenges. International Journal of Technical Research and Applications. SSRN Electronic Journal.10.2139/ssrn.3563342

[14] N. Neelima Priyanka, B. Sukumar Babu, Enhanced EDF Scheduling Model for Resource Allocation in Cloud Computing, Jour of Adv Research in Dynamical & Control Systems, 09-Special Issue, December 2018

[15] Farzad Sabahi, Member, IEEE (2012). Secure Virtualization for Cloud Environment Using Hypervisor-based Technology. International Journal of Machine Learning and Computing, Vol. 2, No. 1. https://www.netmagicsolutions.com/blog/virtualization-and-green-computing

[16] Green Peace International article (2010)“ Make IT green: Cloud computing and its contribution to Climate Change”, http://www.ictliteracy.info/rf.pdf/make-it-green-cloud-computing.pdf.

[17] Pinheiro Eduardo, Bianchini Ricardo, Enrique V.Carrera, Heath Taliveretal. (2001). Load Balancing and Unbalancing for Power and Performance in Cluster-Based Systems. 2nd Workshop on Compilers and Operating Systems for Low Power, At Barcelona, Spain, Volume: 1.

[18] Ant on Beloglazov and Rajkumar Buyya. (2012). Optimal Online Deterministic Algorithms and Adaptive Heuristics for Energy and Performance Efficient Dynamic Consolidation of Virtual Machines in Cloud Data Centers. Concurrency Computation: Practices & Experiments- 2012; 24:1397–1420.

[19] Vincent Motochi, Samuel Barasa, Patrick Owoche, Franklin Wabwoba(2017). The Role of Virtualization towards Green Computing and Environmental Sustainability.

[20] International Journal of Advanced Research in Computer Engineering & Technology (IJARCET) Vol6, Issue6, June2017, ISSN:2278–1323. https://downloads.cloudsecurityalliance.org/ assets/ research/ security-guidance/csaguide.v3.0.pdf

[21] Nitin Singh Chauhan and Ashutosh Saxena. (2013). A Green Software Development Life Cycle for Cloud Computing. In IT Professional,vol.15, no.1, pp.28-34, Jan.-Feb. http://fac.comtech.depaul.edu/yhwang1/Articles_KHU/article_8.pdf.

[22] R. Ashalatha and J.Agarkhed. (2016). Multitenancy issues in cloud computing for SaaS environment, 2016 International Conference on Circuit, Power and Computing Technologies (ICCPCT), Nagercoil, pp. 1-4.

[23] M.Zou, J.Heand Q.Wu. (2016). Multi-tenancy access control strategy for cloud services. 10th International Conference on Software, Knowledge, Information Management & Applications (SKIMA), Chengdu, pp. 258-261.