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PAST, PRESENT, AND FUTURE TRENDS OF GREEN CLOUD COMPUTING

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ABSTRACT

Environmental issues are receiving global attention as man worries whether his activities will lead to his extinction. Concerns over carbon emission levels that eventually lead to climate change and global warming are ubiquitous. World leaders and environmental stakeholders have in present times concerned themselves with findings on the possibility of sustainability of the environment for future generations. Amidst these uncertainties, green computing was born as a way of ensuring that Information Technology maintains an eco-friendly operational environment. Since the inception of green computing, computing technologies have maintained a rapid trend towards its adoption. The paradigm shift of technology towards distributed computing architecture has propelled the adoption and use of green cloud computing which is presently being angled as among the most viable energy-saving technological inventions of our times. Researchers also view green cloud computing as the best channel through which operational costs can be lowered and environmental carbon footprints effectively checked. This paper examines green computing, settles on green cloud computing, and discusses the current and future trends of green cloud computing. This research work aims to create awareness and sensitize the public on the need to not only adopt green computing but to also move with the trends presented by green cloud computing. The paper discusses green cloud computing trends and groups them into environmental sustainability, power management techniques, e-waste management, and energy-efficient coding.

KEYWORDS: Green Computing, Green Cloud Computing, Rare Earth Elements, Power Usage Effectiveness, Virtualization, Data centers, Cloud Computing Services, Cloud Service Providers.

INTRODUCTION

It is an undoubted fact of modern life that today's business processes are driven by ICT (Airehrour et al., 2019). Presently, the world is grappling with the rapid and dynamic change in technology. The increase in demand for I.T. infrastructures and edge technologies such as cloud computing occurs daily (Jayalath

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et al., 2019). This brings about an increase in energy use and high carbon emissions.

Ahmed (2018) states, that the rise in the use of Information Technology, and the consumption of energy in the sector are among the top global challenges. Faria et al., add to this by stating that globally, 10% of all energy consumed is used by electronic and computing devices. 50% of this energy consumption is directly used by computing devices while the other 50% is used by Television sets and other electronic devices. Further to this, 50% of all the energy used in data centers is used for cooling (Faria et al., 2023). Shortages of power are rampant due to high usage by technological devices and companies (Jayalath et al., 2019) Research data estimates that wasted energy in computing costs about 212.5 billion dollars every year and this is the reason why many companies are struggling to adopt green computing in their operations to increase performance, reduce energy consumption and develop sustainable I.T operations. In an attempt to reduce energy costs and preserve the environment, giant corporations such as Microsoft, Yahoo, and Google have built their data centers in cities with renewable energy sources such as hydroelectricity, solar, and wind power (Ahmed, 2018).

On the other hand, the increment in carbon emissions has led to global warming challenges which have become a major concern for environmentalists (Jayalath et al., 2019). Statistics suggest that CO_2 emissions from I.T industries constitute of an average of 2% of global CO_2 emissions (Ahmed, 2018). Therefore, the goal of Information Technology stakeholders should be the provision of safe energy with low carbon emissions. This goal formed the foundation of green computing.

The green computing concept was laid out in 1987 and has its target laid in the provision of energy efficient I.T resources. Its main goal was to promote a safe and sustainable environment for technological development (Jayalath et al., 2019). The idea behind green computing is to reduce electronic waste while maximizing the use of energy through energy-efficient peripherals. This is known as green computing. Green computing is designed to enhance the performance of IT devices through software and hardware enhancements. Software is used to design methods that increase program efficiency and enhance energy and storage use. Hardware on the other hand helps promote economic efficiency and reduce energy consumption through given technologies (Jayalath et al., 2019).

2. METHODS

Researchers have yet to delve deeply into the area of green cloud computing, especially when matters relating to its technologies and trends are at play. Perhaps it is because cloud computing falls among the recent emerging disruptive technologies of the present. This research paper sought its foundation from existing research work in the field as presented by other researchers. The researcher applied different terms on strategic the following scientific databases: Science Direct, SSRN, Academia, TUWHERA, Research Square, Google Scholar, IEE Explore, and ProQuest.

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The key terms applied to these databases were such as "Green Cloud Computing", Trends in Green Cloud Computing", "Technological developments of Green Computing", and "The future of Green Cloud Computing". The search parameters were also defined to get refereed journals and conference papers on research done within the past ten years.

From the search databases, a total of forty-two research papers were derived. The researcher then began the process of scanning through to analyze relevance to the study in question. A critical analysis of the quality of research work done and the relevance of the papers left the researcher with 28 publications. The researcher then carried out an intensive study of the remaining papers to further determine relevance and coherence. As a result, eleven scholarly articles were deemed relevant and utilized in this research work. Research work from the eleven journals has been systematically analyzed and discussed, and relevant knowledge deductively drawn.

3. RESULTS

3.1 Green Computing Trends

In the ICT sector, the term 'Green' is used as a light for optimism as it gives new hope in saving the environment (Quraishi, 2022). By definition, green computing evolves around the procedures of developing, manufacturing, operating, recycling, and disposing of electronic devices in an environmentally friendly and environmentally sustainable manner in the ICT sector (Airehrour et al., 2019) and is composed of energy use, water use, use of renewable resources and the efforts to minimize computational waste which entails the necessary use of computational resources. (Faria et al., 2023).

Green computing was propelled into the limelight by environmental issues such as global warming, the e-waste explosion, and the need for energy conservation in the ICT Sector. The economic significance brought about by the adoption of green computing and the positive impacts it has on the sustainability of Information Technology also led to the spread and adoption of green computing advocacy (Airehrour et al., 2019; Wabwoba et al., 2014).

Green computing efficiently utilizes resources in the computing field as it increases social benefits and minimizes ICT-related environmental impacts. It ensures sustainability without compromising on the technological needs of ICT users and can significantly shift the economic expenditure of an organization by lowering operational costs and enforcing energy efficiency.

There exist four key areas of green computing that help in addressing environmental impacts as identified by Murugesan. These key areas of green computing are green design, green usage, green manufacturing,

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and green disposal of IT systems. The four areas encompass factors such as economic growth, environmental conservation, and the effects of social performance (Ahmed, 2018; Airehrour et al., 2019). The responsibility of every person is to ensure they use efficient computational resources with minimal negative environmental impact (Faria et al., 2023).

In the year 2007, the carbon emissions from the ICT sector were over four hundred metric tons. Most of these emissions came from a large number of personal computers and screen monitors. Research data indicates that the number of PCs in the year 2020 was close to four billion and is continuously rising as it becomes easier and cheaper to acquire PCs (Airehrour et al., 2019). This has led to a worrying rise in Carbon Emissions over the years.

The fundamental culprit in carbon emissions are compounds known as Rare Earth Elements (REE). There are 15 types of Rare Earth Elements used by ICT companies with some of these being cerium, neodymium, promethium, lanthanum, and praseodymium. REEs, though toxic, are useful for the development of display devices in ICT and are contained in gadgets such as smartphones, tablets, monitor screens, laptops, and many other IT devices with display units. In the year 2012, the yearly demand for Rare Earth Elements (REE) in the computing field was close to 180,000 against a supply of 124,000 tomes. However, carbon emissions have been declining since then with China being the biggest player in the proliferation of IT-related carbon emissions (Airehrour et al., 2019). Green computing advocates against the excessive use of Rare Earth Elements by ICT companies in the production and manufacture of their products. Green computing's main focus is the reduction of energy consumption while ensuring the efficient use of resources (Faria et al., 2023).

3.2 Green Computing Development Trends

3.2.1 Cloud Computing

Cloud computing is envisaged as a new model used to host resources out of the premises of a given company. It is defined by the National Institute of Standards and Technology (NIST) as a model for computing that enables convenient, on-demand network-based access to a shared pool of configurable resources such as servers, storage, applications, and services. These can be provisioned quickly and presented to users with minimal interactions (Prasanna et al., 2016).

Cloud computing stands among the current ICT trends and offers a paradigm that reduces ICT complexity through the effective assembly of self-organized virtual infrastructure on demand. The internet is the main medium through which cloud computing's resources such as data processing and storage are shared. Access to applications, data, and services from anywhere and on any device across the globe is made possible. Cloud computing comes with many features such as the ability to access and process information,

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resource configuration, service features, and subscription management via the internet network from all corners of the globe. Cloud computing services are provided by Cloud Service Providers (CSPs) who preserve the rights of clients using policies and procedures developed and tested within international standards (Alrabei, 2023).

Cloud computing presents four development models which are public cloud, private cloud, Hybrid Cloud, and community cloud. The public cloud allows users from any organization to deploy and build cloud services, the private cloud is maintained, controlled, and deployed for a specific organization, the hybrid cloud is a combination of the public and private cloud infrastructures while the community cloud allows access by users from specific organizations with shared concerns (Jayalath et al., 2019).

Cloud computing comes in three basic service types namely Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS). In the case of infrastructure as a service, Cloud Computing Service Providers (CSPs) offer access to resources for networking, storage, and servers to the users. Thus, instead of users purchasing hardware, they can pay for IaaS on demand and this saves them money and time. Likewise, Platform as a Service (PaaS) presents a platform where CSPs distribute hardware and software tools over the internet such that the user can develop and deploy his applications in the cloud. Common applications of PaaS Include business intelligence (BI) services, Database Management Systems (DBMS), Infrastructure networking, Development tools, and middleware among many others. Some CSPS providing PaaS include AWS, Google App Engine, and Windows Azure. Software as a Service (SaaS) is a model where CSPs make applications available to customers over the Internet. Such applications do not need installations on personal computers. This greatly reduces the expenses that can be incurred in the purchase of the needed hardware, licenses, maintenance, installation, and support. Real-world examples of SaaS include Google Apps, Dropbox, and Cisco WebEx (Jayalath et al., 2019)

In the realms of cloud computing, the service providers include Internet Service Providers, data centers, business operations, and telecommunication companies among numerous services availed to the consumers. There also exist cloud service brokers such as technology consultants who ensure that people can choose the best cloud computing services. Cloud resellers are also available and perform negotiations between CSPs and cloud users (Alrabei, 2023).

Cloud technology relies on the transfer of processors, operations, and storage of the computer to the cloud. The cloud is considered a server device accessible through the internet in such a manner that ICT programs are transformed into services (Alrabei, 2023). The technology is of great interest to companies, corporations, and other users from across the globe. Some of the distinguished CSPs include the Google

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Cloud Platform, IBM Cloud, Microsoft Azure, Adobe, Amazon Web Services, Red Hat, and Rackspace. These charge their customers for the services they offer as per usage (Jayalath et al., 2019).

Cloud computing has changed the way people collaborate and work. It has enhanced knowledge sharing from across the world despite the physical location of individuals (Prasanna et al., 2016). Mustafa states that cloud computing platforms present elasticity and rapid access to applications at flexible costs by ensuring that the user only pays for what he uses. The scalable nature of cloud computing services enables dynamic expandability of virtualized pools of resources (Jayalath et al., 2019). This has caused the rapid adoption of cloud computing platforms and ensured that cloud computing forms an integral part of the daily lives of people. This has roused the interest and concern of researchers on how its development and use impact the environment (Faria et al., 2023). This concern and interest led to the rise of Green Cloud Computing.

3.1.2 Green Cloud Computing

Green cloud computing is the new science of green informatics (Airehrour et al., 2019). Green cloud computing is defined as the study of how the use and design of digital technologies have smaller negative environmental impacts (Sailesh, 2023). The ICT sector, when tapped well, combined with mature ICT policies can play extremely key roles in environmental conservation. When green computing is blended with environmental science and electro-technology, precise decisions that can greatly advance green computing can be reached. Current trends have ensured that continuous environmental monitoring can be done through IoT and machine learning algorithms with precise predictive modes that can change the trajectory of environmental conservation as well as create a behavioral change (Airehrour et al., 2019; Wabwoba, 2019).

Traditionally, data centers needed high amounts of electricity to attain performance efficiency. However, the adoption of virtualization and cloud services by organizations has ensured that they can have a shared pool of remote computing resources to the benefit of green ICT. Companies such as Microsoft estimate that the adoption of cloud-based operations can reduce the carbon footprints of organizations by between 30-90% (Airehrour et al., 2019)

3.2.3 Green Cloud Architecture

Green computing evolves around the reduction of energy consumption, the rise of environmental awareness, environmental monitoring systems, and environmental issues communication to protect natural ecosystems (Airehrour et al., 2019; Wabwoba et al., 2014). Faria states that the choice of cloud infrastructure is changing and is no longer just about computational and cost reduction. Factors about energy efficiency in data centers and the use of renewable energy sources have also been factored in (Faria

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et al., 2023). Some know this as the green cloud architecture.

Green cloud architecture is concerned about energy waste in a day-to-day cloud computing environment. Green cloud architecture removes unrequired components to make the cloud computing process more eco-friendly. Thus, green cloud computing includes green services, packages, and tools in cloud computing that promote less waste of energy (Quraishi, 2022).

3.2.3 Data Center Design

At the heart of cloud computing lies the data centers. Data centers operate thousands of server-related workloads, storage, and processing operations. These data centers consume hundreds of megawatts of electricity. For this reason, the improvement of data center design is an area of huge concern for green cloud computing experts from across the globe. System design and analysis of power, water, and carbon use of the Massachusetts Green High-Performance Computing Center (MGHPCC) is used as a perfect example of a huge data center measuring 90,000 square feet but which has a highly advanced cooling system and energy efficiency (Jayalath et al., 2019).

A good operational procedure adopted by some companies is the relocation of their data centers to cold areas where the cooling and energy consumption are greatly reduced. Such data centers have power infrastructure that simulates the network in their energy grid distribution with feeders, substations, transformers, and switchboards that feed power to the computer and the cooling systems. The physical location of a data center is also an imperative consideration in the development of a green data center (Jayalath et al., 2019).

3.2.4 Servers Virtualization

Virtualization is the process of creating virtual resources such as the desktop, operating system, file system, storage, and network. The main types of virtualizations are server virtualization, application virtualization, desktop virtualization, network virtualization, hardware virtualization, and hardware virtualization. In the case of green cloud computing, server virtualization assists greatly by masking server resources (Jayalath et al., 2019).

3.2.6 E-Waste

Globally, in the category of dangerous solid waste materials, electronic waste, also known as E-Waste, is considered the fastest-growing type of waste. E-waste constitutes 1% of solid waste in developed countries and is discarded in huge amounts by such countries. Scant e-waste is recycled, reused, or shipped to developing countries. Global e-waste is estimated at between 20-50 million tons per year. Research data indicates that every year, E-Waste contributes huge irreversible harm to the environment. E-waste impacts

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computing by producing harmful REEs and carbon footprints which harm the environment and are detrimental to human health (Airehrour et al., 2019).

Further, E-Metals like tantalum used to make functional components of electronic devices have proven health impacts and social consequences for exposed communities. Further, e-waste disposed in landfills is from electronic discards and causes toxic emissions that pollute groundwater. To solve the problem of E-waste, international cooperation on sustainable business practices must be enforced within nations. Some countries have resorted to offering economic incentives for companies effectively handling E-Waste. A sustainable model of green computing that handles E-Waste can include structured support and debate on large-scale initiatives for E-Waste management and control (Airehrour et al., 2019).

3.3 Green Cloud Computing Adoption Trends

The increase in the adoption and use of cloud computing led to the rise in huge data centers and highly performing computers. This resulted in higher energy consumption rates leading to dissipation of extra energy into the environment and the rise in CO2 emissions. Data Center processor chips were also emitting more heat (Jayalath et al., 2019). These factors led to the serious consideration and adoption of green cloud computing.

In the year 2009, 34 countries signed the Declaration on Green Growth. This confirmed the need for the adoption, practice, and promotion of 'The Green Environment' which included ways into the reduction of carbon footprints. Since then, the use of green technologies has increased rapidly. Presently, global warming concerns and high-power consumption issues coupled with carbon dioxide emissions have led to increased worry over the preservation of the environment. As a result, many strategies and policies have been developed by national governments and international bodies in a bid to enforce green cloud computing. Many funding programs and initiatives by organizations with a bid to lower greenhouse gases, and reduce energy consumption have also been initiated. In the year 2016, 174 countries ratified the Paris Agreement to try and place the rising greenhouse gas emissions under control with their (GHGE) long-term goal being the reduction of risks associated with climate change by capping the global average temperature increment to 1.5 °C (Airehrour et al., 2019).

Presently, the ICT sector has been praised for creating efficient industry sectors capable of enforcing the Paris Agreement through green computing paradigms such as green cloud computing. Today, the world is serious about environmental conservation and major contributors to green computing are organizations such as Greenpeace, Climate Savers Computing Initiative, and the United States Environmental Protection Agency (EPA) (Ankita et al., 2023).

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Cloud computing presents a huge number of virtual machines running on top of the underutilized data centers and this leads to high energy and power consumption. To solve this problem, power hibernation and migration of virtual machines into other machines is employed. The rise of green cloud computing has presented an opportunity for the reduction of power bills from data centers (Jayalath et al., 2019). Thus, over the years, unlike traditional cloud computing, the green cloud has offered a much better avenue for saving energy through well-conceptualized cooling requirements and heat release systems. Today, green cloud computing contributes to the growth of the internet, data centers, social networks, and e-commerce without causing a proportional growth in power density. Green computing also offers lower server use rates for organizations ensuring that their expenses are within their budget capacities. Green cloud computing minimizes carbon footprints and promotes an eco-friendly ICT environment and is thus meant to enable the present generation to fulfill its desires without compromising the future generations (Airehrour et al., 2019).

4. DISCUSSIONS

Green cloud computing use has increased exponentially in recent times. Lots of research work is being performed on ways through which the application of green cloud computing can be integrated into real-life scenarios with the help of differing parameters. Despite their efficiency and capability in reducing carbon footprints, cloud data centers still use a lot of energy, and the perfect cooling systems for them are yet to be designed. NIST states that even though cloud computing's major objective is the maximization of shared resources, its unnecessary power consumption is its major undoing (Ankita et al., 2023).

For the calculation of energy efficiency, green cloud computing uses parameters such the Power Usage Effectiveness (PUE), Data Center Efficiency (DCE) metrics, and Thermal Design Power among many others. PUE is the most widely adopted and used measure of energy efficiency. PUE is an indicator that offers information on the amount of extra power needed for cooling ICT equipment. PUE was developed by the green grid as a metric measure to determine power consumption in data centers. With PUE, the effectiveness of data centers can be effectively determined (Ankita et al., 2023).

The cloud consists of thousands of data centers that process queries of millions of users from across the globe. Huge amounts of power are used for the processes and cooling of cloud data centers. The dream of green cloud computing is to reduce power consumption and provide better alternatives to reduction of carbon emission and power consumption. To achieve this, many techniques and algorithms have been employed and some are presently under research (Ankita et al., 2023).

Present research into green cloud computing is focused on energy reduction by computer servers, and dynamic server configurations for the reduction of the total power consumption. Researchers seek ways

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of effective load balancing through the utilization of only a subset of available resources. To achieve load balancing, companies have employed dynamic CPU clock frequency scaling to ensure that data centers can save power under different load conditions (Ankita et al., 2023).

Cloud computing has increased in popularity and usage. More and more people are adopting the use of cloud services. Researchers are in a race to devise cloud eco-friendly concepts for green cloud computing. The ultimate goal of green cloud computing is to facilitate the reduction of computing power and carbon emissions while minimizing e-waste in the process (Ankita et al., 2023).

The extraction, usage, and disposal of REEs in traditional computing ICT devices are the major factors of carbon emissions and also lead to huge consumption of non-renewable energy (Airehrour et al., 2019). A study done by Wabwoba F. on green ICT maturity for developing countries indicates that 41.7% of the respondents believed that their organizations did not have set policies to govern ICT use and carbon footprint reduction (Wabwoba, 2019).

It is unfortunate therefore that, most companies still rely on traditional computing procedures and maintain desktops and printers within their premises. Systems such as laser printers are huge energy users and may need some form of power down. Energy-efficient laptops can replace these devices. Systems with low power usage, help in saving energy in their idle time as compared to desktops (Airehrour et al., 2019). It is also good to note that when fewer resources are utilized, the lifespan of devices is prolonged, and companies get higher Returns on Investment and effectively lower carbon footprints.

5. CONCLUSION

This research has been able to look at the past, present, and future trends of green cloud computing. The research has uncovered the factors behind the rapid growth, development, and adoption of green cloud computing. As per the research findings, it is beyond doubt that green computing, specifically green cloud computing is the new norm of present and future ICT operations. Right from virtualized servers all through to data center cooling systems amongst many other current trends, green cloud computing is indeed on the right path to helping the world preserve its environment for future generations. As organizations struggle to implement green cloud computing, the dimensions of viability and the physical data center locations cannot be underestimated. Despite the challenges faced in the implementation of green cloud computing, the world has hope as edge technologies such as machine learning and IoT are presently being integrated into green computing. Should green cloud computing provide expected returns, the result will change the trajectory of green world preservation efforts and make the world a healthier planet to live in.

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