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ACHIEVING A SUSTAINABLE ENVIRONMENT USING GREEN CLOUD COMPUTING

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ABSTRACT
With the rising use of IT infrastructure around the world, the rise in energy consumption and carbon emissions is a reason of concern for everyone because of the direct impact on the environment. The growing usage of information technology infrastructure and its waste is endangering the environment. To meet the ever-increasing enterprise data storage and processing needs, cloud service providers are developing cutting-edge technologies such as Green Cloud Computing in cloud architecture design to reduce massive power consumption, water consumption and harmful carbon emissions, among other things. To preserve our environment from the harmful effects of cloud computing, service providers must embrace and update their cloud architecture to support green computing. By detecting energy emission reductions, CO2 removal, assisting in the development of greener transportation networks, monitoring deforestation, and anticipating extreme weather events, green cloud computing has the ability to expedite global efforts to safeguard the environment and conserve resources. As part of our study on green clouds, this article provides a full analytical report on green cloud computing and its properties.

KEYWORDS: *Cloud Computing; Green clouds; Virtualization; Multi Tenancy; Global Environment*

1. INTRODUCTION

"Unfortunately, the world is currently in a critical position in terms of the effects of global warming and climate change, and there is a need to take action to adopt ecologically friendly and sustainable products" [1], [2]. Furthermore, environmental degradation along with climate change is one of the complex environmental concerns that necessitate smart and novel solutions [3]. Cloud services have become a fundamental component of modern software applications across various domains such as -

Email: Email services like Gmail, Outlook, and Yahoo Mail use cloud storage to store users' emails, attachments, and contacts. This enables users to access their emails from any device with an internet connection.

Messengers: Messaging applications like WhatsApp, Facebook Messenger, and Slack often rely on cloud services to store and sync conversations across multiple devices. Cloud infrastructure helps ensure real-time messaging and availability.

Workplace Apps: Cloud-based productivity suites like Google Workspace (formerly G Suite) and Microsoft Office 365 enable collaborative document editing, file sharing, and real-time communication among team members.

Social Web Networks: Social media platforms such as Facebook, Twitter, and Instagram leverage cloud services for data storage, content delivery, user authentication, and processing user interactions like posts, comments, and likes.

E-commerce Apps: E-commerce platforms like Amazon, eBay, and Shopify employ cloud services for product catalogs, inventory management, order processing, secure payment transactions, and scalable infrastructure to handle high traffic during peak times.

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Audio and Video Streaming Apps: Services like Spotify, Netflix, and YouTube stream audio and video content from cloud-based servers. Cloud storage and computing power enable fast access, seamless streaming, and personalized recommendations.
Broadcasting and Entertainment Services: Cloud services are used by media companies and broadcasters to distribute live events, video-on-demand (VoD), and streaming services. They leverage the cloud's scalability and reliability for high-quality content delivery.
Data Safeguarding: Cloud services often provide data backup, redundancy, and security measures to protect user data from loss, unauthorized access, and hardware failures. These measures include encryption, access controls, and disaster recovery solutions.
Consumption by data centres leads to higher operational costs, increased carbon emissions, and lower earnings. The majority of the issues facing today's businesses are addressed by clouds, but they have some notable drawbacks, such as high power consumption, prolonged CPU idle times, the requirement to deploy resources at the upper bound, the emission of carbon gases, and the production of a lot of electronic waste (e-waste). Therefore, it is necessary to create a cloud environment that is eco-friendly, such as 'Green Cloud Computing'. Living in an environmentally responsible manner that contributes to the preservation of the earth's natural balance and resources is referred to as being 'green'. The term 'cloud' refers to a network of accessible servers that provide services to their users. Therefore, green cloud computing refers to the installation of energy-efficient computer systems and peripherals [4]. It also refers to the environmentally sustainable utilisation of hardware, software, and related resources. Because of the internet's phenomenal recent growth, IT technology is constantly evolving and is used widely around the world. Green IT seeks to reduce energy consumption and develop an environmentally friendly and sustainable cloud computing environment.

2. CLOUD COMPUTING

"The concept of cloud computing has been around for a long time. Cloud computing is a new communication technology that facilitates communication. It contributes to the creation of a healthy and digital society based solely on knowledge-based services, as well as its promotion" [5], [6]. Cloud computing is concerned with three areas of importance: application, storage, and connectivity. It is constantly dependent on various types of internet and network-related services, depending on the needs of the users [7]. Grid Computing and Virtualization Technology are critical components of the Cloud Computing platform [8]. Cloud computing is useful in a variety of fields, including business, government, education, and transportation. Similarly, the use of Cloud Computing systems is noticeable in the Environment and Ecological areas. Information is a driving force in any industry, and Cloud Computing allows for more effective solutions and systems [7]. Because of the importance of cloud computing, governments from various countries are making efforts, providing assistance, and promoting it in a variety of areas [9], [10].

2.1. Green Cloud Computing: Fostering Environmental Sustainability

In order to store and handle the rapidly expanding amounts of data, the cloud data centre uses millions of computers, each of which consumes an enormous amount of power, equivalent to that needed by almost 180,000 homes [4]. For instance, Amazon's datacenters are anticipated to cost just over 53% of the total spend on the data centres' price and deployment over a 3-year repayment plan, 42% of the cost of energy-related costs, about 19% of the cost of electricity usage and deployment purchase of the data centres over a 3-year repayment plan, 42% on energy associated expenses, approximately 19% across electricity usage and thermal architecture, and approximately 20% on thermal subsystem computed over the course of several years [4],[11]. In such cases, green cloud computing can make it feasible to create a more power and environmentally friendly atmosphere. Cloud service providers have been increasingly focusing on adopting renewable energy sources such as solar, wind, and hydroelectric power to minimize the environmental impact of their operations. By relying on renewable energy, cloud providers can reduce greenhouse gas emissions and contribute to a more sustainable computing environment. However, it is true that not all cloud providers have transitioned to renewable energy sources. In some cases, they may still rely on traditional energy sources such as coal-based thermal stations, which can contribute to indirect environmental damage due to the carbon emissions associated with fossil fuel-based energy production. To address this issue, it is important for cloud service

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providers and organizations to prioritize sustainability in their operations [12]. This includes making conscious choices about the energy sources used to power their cloud infrastructure. By transitioning to renewable energy and supporting initiatives that promote clean power generation, cloud providers can align their operations with the principles of green cloud computing and minimize their environmental footprint. "The term general cloud computing focuses on efficiently storing and processing data, whereas green cloud computing is a novel reform in cloud computing that is introduced with the main goal of transforming the cloud environment into an eco-friendly environment" [13].
Green cloud computing advantages include-

- Reduced energy consumption.
- Global remote work helps to keep the environment clean.
- Going paperless by utilising green technologies and cloud computing.
- E-waste production is declining.
- Preserves the environment by conducting business without paper.

2.1.1. Energy Efficiency

Energy efficiency is a fundamental component of green cloud computing, which is essential in the development of environmentally friendly green clouds. To reduce power consumption at the level of each cloud item (servers, data centres, discs, routers, CPUs, etc.), efficient power management strategies must be implemented. "An analysis of cloud computing and energy-efficient data centres was released in 2011. In this study, a detailed analysis of the sources of power consumption, power consumption modelling, static and dynamic power consumption techniques, and excessive power consumption issues was provided. It also talked about the classification of power management at the hardware, operating system, virtualization, and data centre levels, which are the major power-consuming components of cloud computing architecture" [14]. According to recent studies, the dynamic power management (DPM) technology can stop cloud environments from wasting a lot of energy. "This system starts only the cloud resources that are necessary at first, anticipates energy requirements, and provides the appropriate power voltage based on demand. If any cloud resource is supplied with more power (voltage) than it should, this will be promptly detected and fixed utilising dynamic power management techniques [15]. This approach is known as dynamic power optimization".

2.1.2. Virtualization

The virtualization concept uses an abstraction mechanism to permit the operation of several logical (virtual) computers on a single physical computer (hardware device). Considering that several virtual computers can be created and run simultaneously according to the idea of virtualization, a number of things going on at once. The system software, known as a hypervisor, serves as a kind of operating system (abstraction layer) for virtual machines [16], [17]. Extracting the key benefits of virtualization include high resource performance, a decrease in the frequency of infrastructure investments, and effective resource usage. "Virtualization has achieved high performance processing, low power consumption, high-end resource utilisation, and cost savings, which greatly aid in the construction of green clouds. The hottest trends in green clouds are dynamic workload balancing with virtual machines, resource sharing between virtual machines, the design of safe virtual machines, and energy-saving strategies for virtualization" [16].

2.1.3. Multi Tenancy

"In order to save money and effectively use the available resources, multi-tenancy refers to the use of a single cloud instance to serve several tenants belonging to the same category. Due to various privacy and security concerns associated with its deployment, multi tenancy has frequently become a contentious topic in cloud news" [18]. Multi-tenancy is a key component of green cloud, because it significantly reduces resource consumption by allowing numerous tenants to use a single cloud instance [17], [19].

2.1.4. Consolidation

The practise of installing various data center-related data processing applications on a single server using virtualization technology is referred to as consolidation in green cloud computing [20]. It is

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committed to implementing process level load balancing, better utilising virtual systems, and lowering power consumption. This is the principal subtask resulting from virtualization. In depth discussions of the advantages, the process of dynamic virtual machine consolidation, and the need for consolidation were conducted in 2012 by researchers [21]. “They discussed how to combine several physical servers with numerous computers as well as a single physical server with multiple virtual machines (one-many approach) (many - many approach). To describe the procedure of VM migration in the cloud, they provided online deterministic and non-deterministic methods. In a different study, they proposed a threshold-based method for IaaS platforms to consolidate VMs effectively balance the load and prevent resource underutilization issues. In addition to their previous threshold value-based methodologies, they also introduced the concept of dynamic threshold value determination based on the requirements of the current VM and past usage records” [21].

2.1.5. Eco-Friendliness

The management of a secure way of life for everyone depends on both the economy and the environment. However, in reality, as the economy expands, the environment deteriorates, and environmental regulations become obstacles to economic growth. Green Computing's proposed eco-friendliness bridges the economic and environmental gaps by utilizing cutting-edge technologies. In order to avoid activities that hurt the environment (in the name of progress) and ensure that ecological features are not disrupted, "green cloud computing" implies that green clouds are environmentally friendly clouds. We can manage the amount of carbon dioxide released into the environment by lowering the demand for energy production [22]. Currently, the energy sector is highly relying on nuclear and coal-based power generation technologies, which release damaging carbon monoxide into the environment, to meet our energy needs.

3. UTILISING CLOUD COMPUTING TO PROTECT THE ENVIRONMENT

3.1. Climate change

According to a survey, there were 772 weather- and disaster-related events in 2016—three times as many as there were in 1980. This is because the earth is becoming warmer every day, and the climate is also changing. Around 20% of the species are already having issues as a result of this change, and researchers predict that by the year 2100, that number will have increased to about 50%. Additionally, the earth's temperature can increase by 3 C from pre-industrial levels. Here, computing systems can help control climate change and save the environment. Cloud computing is valuable for storing data from every significant time and context, as well as for communication and networking between meteorological and climate management stations. The ecology is greatly benefited by the clouds' greater energy efficiency as a result of fewer carbon emissions. The typical corporate data centre, in the words of AWS, "has a dirtier power mix than the typical large-scale cloud provider." The energy mix used by AWS and other cloud service providers is 28% less carbon-intensive. This has an effect on climate management costs as well because it is substantially more expensive to operate equipment at its most effective levels in optimum conditions. The cloud eliminates this wasteful spending as it employs energy-efficient machinery and produces less carbon emissions.

3.2. Natural disasters

Natural catastrophes result in considerable loss of life, destruction of infrastructure, and significant economic impact on the affected communities. By computationally simulating these complicated occurrences, geospatial scientists seek to reduce or control these risks, and information and communication technology (ICT) facilitates the use of diverse models addressing various facets of disaster management. With nearly unlimited capacity for compute, storage, and networking, cloud computing can address problems. It is now more feasible than ever to provide natural hazard modelling systems as end services [20], [24].

3.3. Energy management

Traditional data hardware systems are heavy maintenance since they need a lot of electricity, cooling, and uninterruptible power sources. Moving simple software applications to the cloud can save a ton of electricity. On a national level, migrating business applications to the cloud can save enough electricity

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annually. This suggests that the cloud would reduce these software applications' overall energy consumption by 87%.

3.4. Urban and rural areas

The goal of the "smart city" concept is to improve quality of life by collecting data from interconnected sensors, technologies, and people. Using data to increase efficiency, ongoing urban challenges like security, waste management, and traffic may be addressed. To do this, all of the data must be kept in a location that is easily accessible and usable by all parties, both governmental and private. To answer this need, the Smart Connected Digital Platform was developed. The cloud service will aid in removing the intergovernmental storage problem, which is considered as a major barrier to the implementation of smart cities since it prevents different departments from communicating clearly and understanding the databased goals of other departments. Because of the ongoing maintenance of the "internet of things," which has (and will continue to have) verifiable security risks, security is also a key component of the new product [25]. “Cloud-based solutions in infrastructure, platforms and applications (IaaS, PaaS, SaaS), services using cloud platforms, barriers and enablers in employing cloud technologies, and adjustments to applications and e-services during their migration to cloud environments can all be beneficial to smart cities” [26]. IaaS enables organisations to scale up provisioning based on current demand while also eliminating the procurement and administrative load of handling the real hardware, whether it be storage, network infrastructure, or virtualization environments.

3.5. Agriculture

With the help of their databases and intelligence systems, machine learning-based systems are capable of recommending good locations for tree planting, and here is where cloud computing-based systems are valuable and crucial [7]. Intelligent sensors play a crucial role in the collection of real-time data on temperature systems, soil composition, and crop moisture. As a result, it aids in environmental management and monitoring both directly and indirectly. Reduced water, fertiliser, and pesticide consumption is beneficial in various contexts as well as higher efficiency and improved yields in agricultural management [10], [27]. Farmers can benefit from real-time processing, data access, and storage provided by cloud computing without having to be concerned about the system's physical location or setup. In order to assist farmers manage their crops more effectively, cloud computing in agriculture can be used to combine data from technologies like soil sensors, satellite photos, and weather stations. The analytical capabilities of the cloud also help farmers comprehend their production environment.

3.6 Ocean management

The usage of cloud computing is quite significant and worthwhile in terms of data management and real-time data collection [7]. IaaS, PaaS, and SaaS are commendable in this context for managing data and information. “Scientists now have new tools for observing and forecasting the status of the ocean thanks to cloud platforms and the services and APIs, they offer. High-performance mass storage of observational data, on-demand computing to run model simulations near to the data, tools to manage processes and an exchange and interaction framework provide a more adaptable and flexible observation and prediction computing architecture” [27].

3.7. Transportation

Cloud, robotics, and related technologies are becoming crucial for developing better and healthier transportation systems. Sensor and camera integrated vehicles are becoming more common in traffic, along with automated vehicles, etc. Agencies can combine numerous data points for a more precise and dynamic picture by directly connecting transportation devices to the cloud. By not having 10 different personnel monitor 10 different dashboards with data on ridership, delays, or vehicle safety, operational efficiencies are also obtained [25]. The data is also made much more swiftly and almost instantly available through the cloud, enabling managers to make immediate changes for better service.

4. CONCLUSION

This research has found that using cloud computing, a number of doable recommendations can be made to make the earth greener. The green cloud architecture tries to reduce server energy consumption. The idea of "clean computing" has already been researched as a means of protecting the environment.

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Despite the fact that the idea is evolving, it is crucial for reducing carbon footprints in the atmosphere of the world. The field of green computing has evolved and increased. There have been advancements, architectural changes, simulators, and other energy-efficient technologies to make computers more ecologically friendly. An instance of cloud computing that has been made ecologically friendly is called Green Cloud. This essay explored the salient features of green cloud computing.

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