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EMERGING GREEN CLOUD AND EDGE COMPUTING – INNOVATIVE TECHNIQUES FOR A SUSTAINABLE DEVELOPMENT

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Abstract:
Cloud computing is a new technology that is being used by an increasing number of IT organisations because of its cost savings and user-friendliness. It must, however, be environmentally friendly. As a result, Green Cloud Computing is a necessity in today's environment. The cloud is an energy-intensive system that runs hundreds of hosts in a data centre. The energy consumption of cloud and edge computing is quite high. As a result, there is a need to investigate alternative strategies for lowering cloud energy use and develop an algorithm to do so. The goal of this research is to investigate developing energy-efficient cloud and edge computing approaches. Various energy-saving Green IT approaches are explored in this study. Because cloud computing is such a rapidly evolving technology these days, the study also discusses several energy-saving cloud computing strategies. The article also discusses virtual machine migration, a developing energy-conscious data centre technique. It also reviews the attempts made by different scientists to make Cloud and Edge Computing further energy efficient, to cut carbon footprint rate by various approaches.
Keywords: *Green Cloud, Technology, Sustainable Development, carbon footprint*

1. Introduction:

The field of communication and information technology has advanced rapidly as a result of tremendous technological advancements. From simple everyday activities like emails and cell phones to complicated applications like manufacturing and flight control, technology has become increasingly important in every area and arena of business and life. Failure to meet these ever-increasing demands, even for a short time, would result in massive losses and development stumbling blocks. Huge high-speed data centres have been built to address today's tremendous consumer needs, resulting in the rise of cloud computing, which has made processing and storing faster, cheaper, and more powerful as technology has advanced.

In the world of computation, cloud computing has become a standard. The goal of cloud computing is to have an architecture for applications that need to be dynamically scalable and are utilised to store data and files. The development of cloud computing has greatly lowered the cost of application hosting, data retention, and distribution, as well as the time required to do it. Common Internet protocols which are based on a decentralized system using a virtual server are used to access applications and services. It is rapidly expanding because it is simple to use and inexpensive, with appealing features like on-demand services and a pay-per-use structure. As the need for data centres grows, they consume an increasing amount of energy, resulting in increased power consumption and carbon emissions. [1][2]

For time-sensitive applications, edge computing greatly improves the user experience. Edge computing is a new paradigm that aims to fulfil the growing processing and connectivity needs of billions of edge devices. Edge computing has promise for a variety of application situations since it uses less network bandwidth and thus puts less strain on data centres, while also improving service timeliness and data privacy. Edge Computing is proving to be a viable solution for dealing with the data deluge at the network edge and gaining insights that aid in real-time strategic planning. Many devices in the edge computing ecosystem aren't as strong as traditional windows and server systems. Instead, they have limitations in terms of computer power, storage capacity, and network connectivity. Furthermore, because billions of edge devices are implemented in an edge computing

system, their energy consumption is critical for both edge node longevity and service quality assurance, particularly for battery-powered devices or power-constrained edge nodes. [3]

Green cloud computing is being developed by a number of researchers in order to reduce energy consumption and maximise the use of computing infrastructure. Green cloud computing is a new cloud computing innovation that focuses on how people can work in environmentally friendly environments, as well as how we can protect the climate and reduce load between data centres. Cloud service facilities are virtualized and geographically spread, providing applications and services at fast processing speeds and consuming a lot of energy in the process. As the use of cloud services has grown, several studies have been undertaken that have produced disturbing results in terms of their environmental impact. According to a study by Smith et al., one data centre can produce 170 million metric tonnes of carbon every year [4]. According to Rivoire et al., the communication and information technology sector emits an alarming quantity of CO2, which is similar to the amount produced by the aviation sector and accounts for 2% of total global emissions. [5] Microsoft's datacenter in Quincy, Massachusetts, consumes enough energy to power 40, 000 homes, according to the company. [6] Between 2005 and 2010, data centre electricity consumption climbed by 56% to meet consumer demands. According to the report the carbon footprint of data centres will rise by 20% by 2020, owing to the adoption of cloud computing designs. [7, 8] This sparked widespread worry in the computer industry, necessitating quick research and studies to dramatically cut greenhouse gas emissions and make the world more environmentally friendly, thus the phrase "green computing" or "green IT."

Green computing is a concept that is growing in value and importance as our reliance on technology grows. It includes environmentally friendly IT practises that have minimal negative effects on the environment in regard to e-waste generation, carbon emissions, energy usage, and recycling. It is being adopted in several IT fields since it minimises energy consumption, lowering costs and eliminating negative environmental effects. Green computing can be used in any aspect of IT and can have immediate impacts such as turning off computers, storage, and network devices when they are not in use, using flat screen PCs to save energy, and properly disposing and recycling gadgets to avoid the release of dangerous materials. Regular practise and adoption of these healthy behaviours can lead to increased and improved environmental sustainability. Green cloud technology has been used by numerous specialists [9] to minimise the use of energy-efficient, achieve competent preparing, and use the computing framework. Energy-efficient central processing units, servers, and peripherals have been used, and a reduction in resource consumption is required, as well as proper disposal of electronic waste [10]. Green computing disposes of, designs, and manufactures the computer, servers, as well as other systems that are involved with

Other efforts have been undertaken to make cloud services green, such as increasing the rate of energy usage, carbon emissions, and e-waste disposal in cloud environments by introducing resource virtualisation. [11] Based on the scale of the company, carbon emissions from cloud-based business apps can be greatly decreased. Small businesses lowered their carbon footprint the greatest, by 90 percent; mid-sized businesses reduced emissions by 60-90 percent; and large businesses reduced emissions by 30-60 percent. Greenpeace International (2010), on the other hand, claims that carbon footprint from cloud services may have even more disastrous consequences because service providers are more focused on economic effect of reducing energy use than with harmful emissions of Greenhouse Gases. [12]

The development of green cloud computing is closely related to the evolution of green data centres, because the data centres are the core of cloud computing. According to a study [13], the energy consumed by data centres in 2010 represented 1.3% of the total consumption. A report published by GeSI [14], which is considered one of the most comprehensive and well-recognized snapshots of the Internet’s energy demand at the global level, estimates an increase in the share of total carbon dioxide (CO_2) emissions from ICTs from 1.3% of global emissions in 2002 to 2.3% in 2020. [15]

2. Emerging strategies for green cloud and edge computing

2.1 Effective Power Management

Because green cloud computing pushes technology to be environmentally friendly, energy efficient, and cost effective, adequate power management in the cloud is critical. If the cloud provides all desired services, there is a chance that certain services may not be used to their full potential. This can result in an increase in carbon emissions, which can be quite detrimental in terms of air pollution. Rakshith and Sreenivas did a study on the power efficiency of green cloud computing in 2015, and they discovered that computers running at low utilisation in data centres might be a major source of energy inefficiency. Because there is a situation when the power consumed exceeds the power spent on utilisation, even though resource usage is lower. According to their findings, energy consumption is the primary driver of content distribution systems, which need the acquisition of networked computer resources from one or more service providers in data centres across the world. The amount of electricity and energy required by computer equipment and the related cooling system determines the high carbon emissions and energy costs [16]. To address these issues, a novel idea for improving data centre and cloud application power performance was developed. There are a number of technical algorithms that can be used to manage power consumption, but the most commonly used is the Agglomerative Hierarchical Clustering algorithm, which is a 'bottom up' approach in which each observation begins in its own cluster and combinations of clusters are combined as it moves up the hierarchy. When a user submits a job, it is placed in a queue and eventually allocated to Virtual Machines. Previously, each Virtual Machine (VM) was treated as a distinct cluster, with independent mechanics used to compute the energy efficiency of each VM and machine, with the same energy being pooled to make a single group. Small, medium, and large size clusters are the three basic cluster categories for virtual machines. Energy values will be lower while the power demand is low, and as the load grows, the cluster will be transferred to the Medium size cluster. This method aids in the reduction of CO2 emissions into the atmosphere. As a result of this optimal power consumption, CO2 emissions into the atmosphere are reduced.[16]

2.2 Renewable Energy Resources

All cloud data centres employ generators to provide power backup and to reduce CO2 emissions and greenhouse gas emissions. Instead, renewable energy such as hydro, wind, and solar energy must be used to produce electricity for data centres' power and cooling needs in order to conserve energy and protect the environment from pollution. Because only Google data centres throughout the world require almost 260 million watts of electricity, which is roughly a fourth of a nuclear power plant's output. [17]

2.3 Nano Data Centers

Because of the growing worry over energy usage in traditional data centres, a new distributed computing architecture known as Nano Data Centres (NaDa) is recommended. To establish a distributed information centre architecture, NaDa delivers compute and storage services and uses a controlled peer-to-peer paradigm. Instead of a few major data centres, there are a huge number of geographically scattered nano data centres that are smaller in size, networked, and distributed along network edges. Data access through NaDa saves at least 20% to 30% of energy when compared to typical data centres in terms of energy usage [18]. Figure 1 depicts the amount of energy utilised in various components of the data centre.

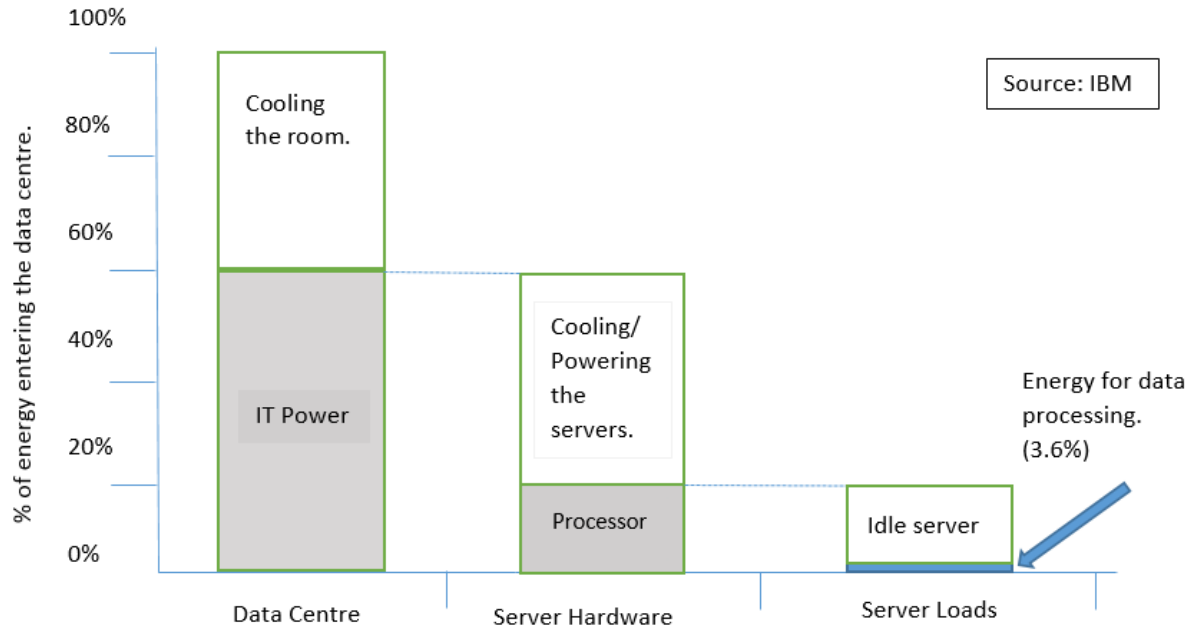

Fig 1: Energy Consumption in Different Sections of the Datacenter [17]

2.4 Employing Energy Efficient Storage

Cloud storage should be replaced with energy-saving storage components. Because a data center's lifespan is just 9 to 10 years, developers should employ energy-efficient memory, such as solid-state storage as well as other upgraded effective storage technologies, while upgrading older data centres. Because solid state storage does not have a moving mechanical component like a hard disc drive, it requires less cooling, resulting in lower cooling energy use.

2.5 Energy Conservation Plan for Software of System

This technique incorporates energy-efficient nuclear scheduling, equipment resource management, and operating system dynamic energy consumption control. In a poly nuclear system, the former represents an energy-efficient scheduling strategy. Wang Jing examined thread scheduling strategies and resource categorization mechanisms in order to reduce resource contention and suggested future research directions [19]. Equipment resource management ensures that all computer elements have the best possible environment. Dynamic energy consumption refers to the OS modifying the system unit in real time to accomplish the lowest possible power consumption without compromising the job at hand.

2.6 Energy Conservation for Computer Architecture and Compiling Technology

Cloud computing consists of a huge number of computers connected together. A heterogeneous computer is made up of several processors that are largely independent and of various types. The usage of common processors as the primary control module and other special purpose CPUs as the acceleration unit in such systems results in an effective energy consumption ratio. FAWN (Fast Array and Wimpy Nodes) is a low-power cluster technology suggested by David Andersen of Carnegie Mellon University for large-scale data-intensive applications [20]. Compiler technology optimization is also important for energy conservation. Better compilation technology optimises application technology and aids in the analysis of application programme behaviour in order to reduce system or processor operating power consumption. Zhao Rongcai suggested a concept in [21] that uses multithreading system structure to lower execution frequency and hence power consumption.

2.7 Network Environment Energy Conservation Strategy

A networked platform is cloud computing. As a consequence, a good outcome may be attained by implementing various energy management strategies. This method focuses on energy efficiency in

network algorithms and protocols. A vast number of communication protocols and algorithms fail to fulfil the energy-saving criteria. In wireless networks, CSMA/CD, TCP and CSMA/CA are examples of such protocols. Furthermore, there is research on adaptive link rate and sleeping modes in the literature. Adaptive link rate techniques modify the data rate of the connections dynamically based on traffic demands. Another option to save energy with the sleep mode strategy is to turn off the component or put a subgroup of idle components into sleep mode. Around the same time, the remaining active pieces must continue to meet the changing needs. Nevertheless, the QoS criteria must be met, and fault tolerance must be avoided at all costs. [17]

2.8 Virtual Machine Manager's Energy Efficiency Approach

Energy management in interfaces support, foundation and desk-top class virtual machines, and many other areas are included in this technique. Stoess suggested an energy management strategy for virtualized servers in [22]. Models of energy management and job planning approach across operating systems, virtual server manager, and higher application of hardware are some of the primary topics of research in cloud computing to control energy consumption.

2.9 Virtual Machine Migration in real time

Moving a live VM from one host to another is known as live migration. It offers data centres a variety of advantages, including load balancing, power control, and open IT maintenance. Some elements influence the cost of this type of live migration [23]. Resource utilisation of source and host systems are parameters connected to physical machines. A parameter in VM migration is the actual overall network bandwidth between the source and target hosts. In addition to live VM migration, green cloud architecture turns off underused servers to reduce power consumption while maintaining service quality.

Assignment of virtual machines with a focus on carbon and energy efficiency

Although VM allocation and migration can increase the energy efficiency of cloud systems, if the techniques are not employed correctly, they can result in excessive energy consumption and, as a result, significant CO2 emissions. The authors developed a VM placement algorithmic strategy for minimising power consumption and CO2 emissions in [24]. This method took into account data centres that are dispersed and have varying carbon footprints and energy sources. Different sorts of VM requests, data centre power use effectiveness (PUE), and physical server proportionate power utilisation were the key characteristics considered. When compared to other algorithms, the technique was proven to be capable of significantly lowering carbon footprints and electricity usage. Figure 2 depicts the system architecture created using this method.

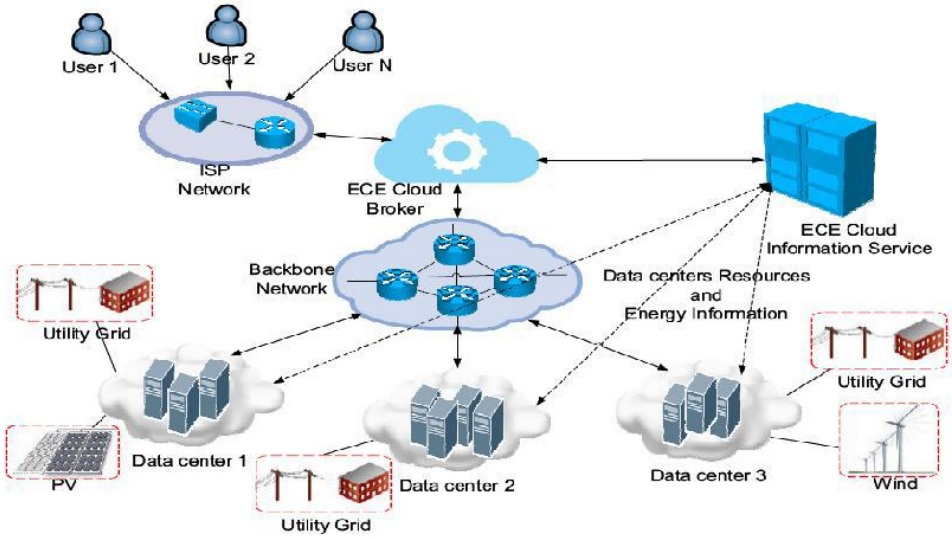

Fig 2: Cloud Architecture of Energy and Carbon-Efficiency [27]

By conducting an experimental investigation, the researchers in [25] concentrated on the power and energy usage in the process of migration for different kinds of workloads, finding that migration can result in a 10% increase in power consumption. In some cases, the power consumption can also be

lowered by shortening the migration time. Different sorts of workloads that are appropriate for migration and how to move them efficiently were also explored.

The energy-efficient green computing technologies presented in literature concentrate on virtual machine allocation and migrations. However, virtual machine migration and scheduling have costs that must be considered. Based on past work in this subject, the authors of [26] attempted to classify the migration costs involved and the factors that influence them. The migration costs were classified by the authors as shown in Figure 3.

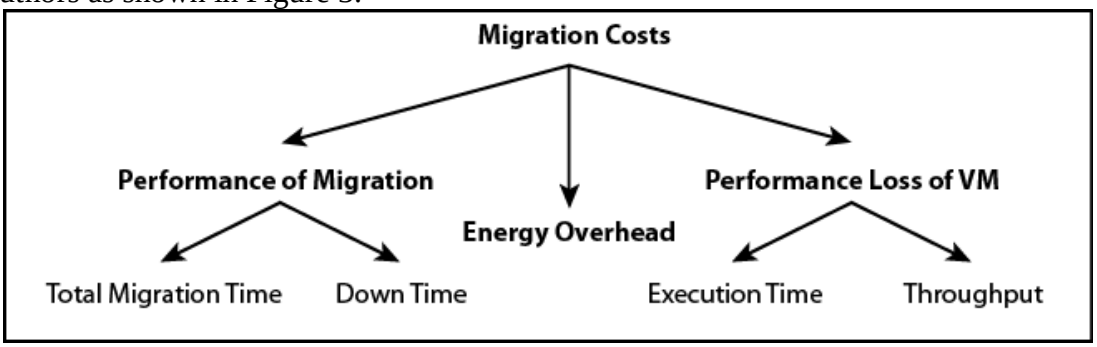

Fig3: Migration Cost Classification [27]

3. Future Scope

For us, becoming green is not a novel notion. Companies are putting forth effort to implement new and creative green computing methods. Cloud Computing is a novel concept that combines previously existing technologies to improve resource use efficiency. Green cloud computing is a new field with a lot of potential. Green cloud computing requires the exploration and implementation of new technologies. The services supplied by cloud computing and the processes that take place should be analysed in a methodical manner. There has been a great growth in clouds such as mobile, social clouds, and it will continue to develop exponentially in the future, therefore sustainable mobile communications will serve as a foundation for green cloud and edge computing. Companies must use renewable energy sources to provide cloud services in an environmentally sustainable manner. Before selling cloud services, cloud providers should examine the following factors: Companies that supply cloud services must adhere to green ICT standards in order to minimise unwanted consequences. The main aim while delivering cloud services is to limit carbon dioxide emissions, cut power consumption, and minimise the quantity of e-waste created.

4. Conclusion

In the cloud and edge computing environments, we investigated numerous energy-saving solutions. To make data centres more environmentally friendly, a variety of energy-efficient solutions should be employed. Only by reducing server energy consumption will cloud and edge computing be successful. Task consolidation, particularly in cloud computing, has become a popular method for reducing resource use and increasing energy efficiency. Energy-saving measures save a significant amount of energy while also reducing the cloud footprint. This document describes the methods that may be used to make clouds greener. This article discusses several popular green cloud computing technologies, such as producing electricity from renewable sources, controlling power usage, cluster computing, and so on. Green computing methods will only show positive results when they have been fully implemented over a period of time. However, because cloud computing is rapidly expanding, its negative consequences will become apparent in the near future. Green cloud computing nevertheless confronts security issues and connection requirements. Many people are still researching environmentally friendly and cost-effective computing techniques. However, despite the difficulties, there are several advantages to employing green cloud computing solutions.

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