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A CRITICAL ANALYSIS ON ENERGY EFFICIENT AND ECO-FRIENDLY APPROACHES FOR GREEN CLOUD COMPUTING

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Abstract
With features like low cost, quick speed, on-demand, and pay-per-use, cloud computing has evolved into an excellent option for addressing the issues of high-capacity data processing and storage. Despite tremendous growth in the age of cloud computing and related services, the adoption of environmental clouds is still in the early stages due to a lack of fieldwork and several obstacles. To reduce the need for physical hardware components, architecture, and harmful greenhouse gas emissions, green cloud computing is used in cloud environments. Research in green computing focuses on creating effective clouds with eco-friendly features like energy monitoring, virtualization, high efficiency computing, balancing the burden, green data centres, as well as extensibility and recycling, among others.
Cloud computing is a widely used, economical infrastructure. Due to the increasing need for data centres, energy consumption has significantly increased. As the guardians of nature, we humans must use energy wisely. Therefore, green computing is launched in the IT industry, which aids in reducing excessive energy usage and enables users to take use of cloud storage benefits with little to no environmental impact. Green cloud helps businesses save money on operating expenses in addition to electricity. This paper discusses green computing, including its current state, upcoming difficulties, and various application domains. The goal of this article is to conduct a thorough, systematic mapping analysis of the GCC's energy-efficient and environmentally friendly practises.
Keywords: *Green computing, Energy efficient, Eco-friendly, Cloud computing, Global environment.*

1. Introduction

The surge in data usage and the number of computing devices can be attributed to the computing technology's transformation over the previous few decades into an indispensable component of the global infrastructure. The utilisation of computing resources in an environmentally beneficial manner is made possible by green computing. It can also be described as the study of creating, utilising, and disposing of computing systems in a way that lessens their impact on the environment. Power management and energy efficiency are the main goals of green computing, but it also covers the choice of ecologically friendly hardware and software through recycling material to extend the product's life. The phrase "green cloud computing" was originally used in 1992 with the introduction of the Energy Star Program. By achieving economically viable, ecologically sustainable production techniques, disposal and recycling procedures, and energy-efficient resources, green computing enhances the way computing equipment are used (Banumathy, Khalaf, Romero, Indra, & Harma, 2022).

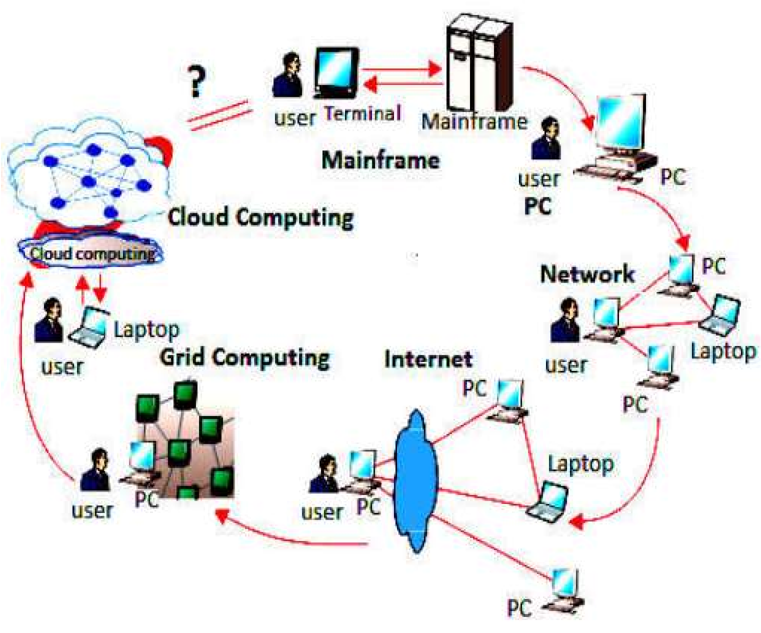
Green cloud computing focuses on improving energy efficiency in computing and promoting environmentally friendly computer technologies. Green cloud computing leverages digital space to lessen the technology's influence on the environment during production and design. Green cloud technology helps businesses save money on operations as well as energy. Organizations have a significant need for green cloud technology since it includes scalability, security, and cost-effectiveness aspects. Increased energy consumption as a result of market expansion has increased environmental pollution from carbon emissions. As a result, environmentally friendly monitors, printers, and storage devices have been produced and designed thanks to green cloud technology. The term "GREEN CLOUD" describes the advantages that information technology (IT) brings to society in terms of the environment.

According to a recent study, if the rate of power consumption increases, it will even exceed the cost of the hardware supporting the data centre architecture. Additionally, this will increase CO_2 emissions, which have an immediate impact on the environment. Green computing enters the scene at this point (l-Saleh, et al., 2022). In order to reduce the energy consumption of computers, servers, data centres, networks, and cooling systems, green computing makes environmentally friendly use of computers and related resources. Since data centres consume a large portion of the world's energy, they play a key role in green computing. As a result, there is a need for strategies that reduce the infrastructure and carbon emissions and properly install energy-efficient technologies in data centres.

1.1. Cloud Computing

The distribution of reconfigurable computing resources, such as networks, storage, servers, services, and applications, via ubiquitous, convenient on-demand network access that may be made available rapidly with little management labour or service provider involvement, is referred to as cloud computing.

Figure: 1. Six phases of evolution from mainframe to cloud computing



1.1.1. Benefits of cloud computing for Business

Benefits of cloud computing for businesses include cost savings on hosting, instantly expandable resources and pay-as-you-go pricing, a competitive strategic edge, high availability, lightning-fast performance with flexible working hours, and faster running apps with better security (Ibtehaj AlMusbahi, 2020).

1.1.2. Different Types of Cloud Computing Models

With tens of thousands of servers and storage devices, cloud computing is becoming more and more popular. These models for deploying cloud services vary depending on where they are deployed and can be divided into the following categories:

- **Private Cloud:** It is a cloud-based computing solution used by independent businesses that is accessible via the public internet or a secure internal network. These clouds offer excellent security and are suitable for businesses with stringent management and availability requirements.
- **Public Cloud:** the cloud services made available via the open internet by third-party suppliers. It is well-liked by companies and organisations of all sizes, whose needs for webmail, applications, and non-sensitive data storage change with time.
- **Community Cloud:** It is a cloud computing deployment service model that is managed and hosted either internally or by a third-party vendor between companies that are owned by a small number of people or entities, such as banks, governmental bodies, or commercial firms.
- **Hybrid Cloud:** To create the finest infrastructure possible, this architecture combines both private and public clouds. For simple and non-computing jobs, the combination makes use of the public cloud's adaptability and processing capacity. An enterprise that uses the private cloud to secure its data and uses the public cloud to communicate with its clients is the ideal illustration of this scenario.

1.1.3. Cloud Computing Service Model

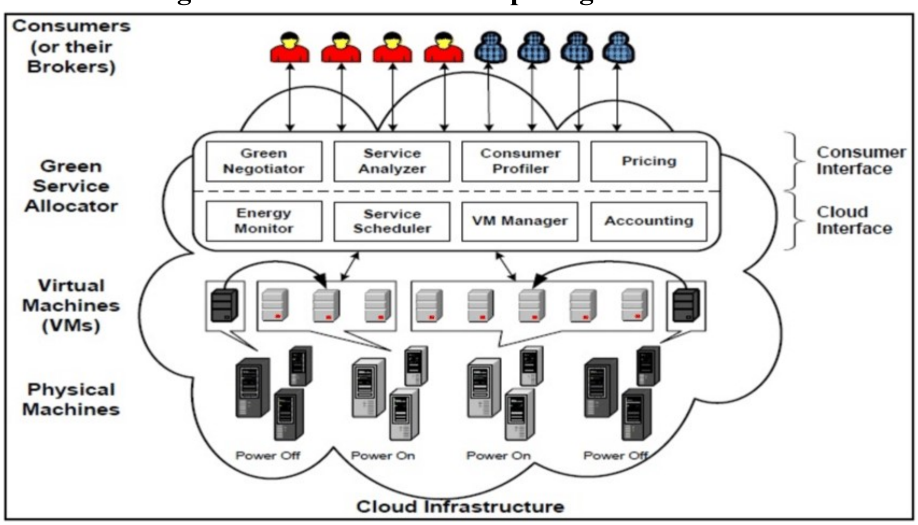
IAAS	SAAS	PAAS
Access to computational and hardware resources like servers, storage, and networking are made available to the user.	The provider offers the user cloud-based software that can be accessed via the web via an API.	The user is given access to a cloud environment with a variety of prebuilt tools and included development, management, and delivery applications.
Infrastructure is expandable in terms of processing and storage requirements, saving users' hardware and maintenance expenditures.	The vendor manages, instals, or upgrades software, and resource usage is scaled according to service needs.	It offers a setting that supports the development, testing, and hosting of apps.

Location independence and physical security are features of this concept.	This model has easier administration and patches management and is accessible worldwide.	This architecture includes a server-side scripting environment, tools for planning and creating applications, and database management system support.

1.2. Green cloud computing

Green computing is the efficient use of resources in computing (Jacob John, 2020). The objectives of green cloud computing are similar to those of chemistry; they include minimising the use of hazardous materials, maximising energy efficiency throughout the product's lifetime, and promoting the recyclability of outdated items and manufacturing waste (bid data analytics 2021).

Figure: 2. Green Cloud computing architecture



1.2.1. Benefits Of Going Green

In order to reduce energy consumption by huge data centres, green cloud computing seeks to incorporate energy-efficient technologies, employ environmentally friendly production methods, and enhance trash recycling.

- **Green Computing Works on Reduced Paperwork:** A secure cloud platform is provided by green cloud computing in the servers that house the data. The use of cloud storage platforms has improved the ability to store important documents in a secure location away from prying eyes. Google Drive, DropBox, OneDrive, and SharePoint are a few examples of these storage choices. With just a few mouse clicks, any operation can be carried out using these alternatives without printing the document (K. Nazeer and N. Banu, 2021). The certainty of data backup ensures that your data is still available even in the unforeseen case of a disc drive failure or serious room failure. Files can be viewed at any time and from any location. In going paperless, you have to guarantee you have effective administration and governance across cloud servers. Carbon footprints have decreased due to green cloud computing.

- **Decrease in Stuff Members:** A benefit of using cloud computing is that organisation can reduce their employees. Such firms ought to have user-friendly cloud capabilities that enable their employees to access data from a variety of platform devices. Given that green clouds have superior properties and are linked to increased productivity, they are relevant in this situation. Since it allows remote employees to work on-site and from their homes, green cloud is an environmentally responsible solution. Due to the decrease in the number of cars in the work area, the decrease in employees has also resulted in a decrease in fuel emission discharge.
- **Works on Energy conservation:** Organizations reduce the amount of energy used by switching from one software package to another. Using less fuel when switching produces better power usage, which lowers energy costs. Green cloud computing persistently regulates the running servers, resulting in the continual cooling of features (Mishal R, 2021). An analysis of the energy use and carbon footprints of cloud computing, funded by Google in 2013, found that companies could cut their overall energy consumption by 87% if they moved their most popular software applications to the cloud. Constant energy delivery to the servers is required to maintain server cooling.
- **Cost-cutting:** The use of green computing is incredibly economical and helps people save money. Green computing not only saves money, but also a lot of energy. Long-term financial benefits of green computing outweigh its high starting costs.
- **Process of Recycling:** Recycling is promoted by going green by reusing technology waste. Several parts of the PCs are built of eco-friendly materials rather than plastic to have a smaller environmental impact. This makes it possible to sort all electronic waste effectively. As a result, businesses that use green computing solutions can increase their overall recyclability.

1.2.2. Disadvantages of Green Cloud Computing

The first deployment is expensive since building up organisational infrastructure involves a significant outlay of funds for the acquisition of gadgets. Organizations must be more adaptable and update as technology evolves due to the constant changes brought on by digitalization. The firms tend to upgrade with the varying degrees of technology, which results in significant costs over time (Khalaf, Romero, Hassan, & Iqbal, 2022).

People are burdened more by green IT since they have to pay for the infrastructure needed to access the internet. People must pay a lot of money to buy computers since they are expensive. In terms of system efficiency and network usage, green businesses are frequently thought to be weak. This is mostly true when it isn't put into practise properly. This could result in a notable drop in employee productivity for businesses that rely on sophisticated computers, which could have a negative impact on sales. Furthermore, more than one person cannot ensure the survival of green technologies. It is focused on the efforts and preferences of each employee. They'll have to adapt their rules to the new paradigm. The implementation plan might be scrapped if even one participant objects. Because of those people, businesses should switch to green technologies.

Adverse safety hazards when implementing a green computer infrastructure are another drawback. Employees who work for green technology companies routinely switch their workstations and other equipment. This ultimately points to a lot of security flaws, including hacking. Companies must therefore implement the necessary safety measures to reduce these issues. Additionally, to run the green IT architecture, IT specialists with in-depth knowledge of the field should be hired. These geniuses are hard to come by, and if they are, they must be paid well. If you don't hire someone, your gadgets can eventually have technical issues as well as downtime (Mohapatra SK, 2021).

2. Literature Review

According to researchers (S. Kumar and R. Buyya), a complete analysis of cloud computing's electrical efficiency is necessary to achieve energy efficiency; these solutions lead to the conclusion that green computing should be enabled.

Internet contribution now has a greener option thanks to technology that takes into account both the client's and the provider's perspectives. In this concept, a middleware green broker selects the greenest cloud provider to handle clients' queries. Five policies—Greedy Minimal Carbon Emission, Least Carbon Emission, Green Maximum Profit, Minimizing Carbon Emission, and Maximizing Profit—were used to gauge the effectiveness of the framework. Energy-efficient technologies benefit both consumers and cloud providers, and green regulations are projected to cut carbon emissions by roughly 20%. The paper comes to the conclusion that many technological solutions, including software design, knowledge of current datacenter cooling, power spend, and resource utilisation, design absolute resulted in planning, and resource provisioning for apps, and new innovations do not bring about irreversible change and threat to human health society, are still needed to make green clouds a reality (Puhan, Panda, & Mishra, 2020).

The need of incorporating energy awareness into the tasks of managing system resources, dedicating hardware, and allocating resources is emphasised by the researcher. The main facets of green technology are divided into three categories. Re-engineering aims to make network infrastructure more environmentally friendly by influencing several elements. Dynamic adaptation aims to alter how well active network services operate. The third technique, napping, finds network nodes that are only somewhat idle and wakes them up when necessary. The report notes that further study is needed to address a number of upcoming challenges, including metrics, grading norms, green statistics, hidden layer control, redundant device administration and implementation, virtual approaches, and network hardware.

Mazedur's (K. Nazeer and N. Banu) analysis of current methodological approaches and findings, evaluation of their benefits and drawbacks, and assistance in identifying open-ended research questions enable to identify and address energy conservation concerns and issues in remote clouds and computing. The issue of energy consumption during calculation tasks is resolved by offloading computing to the internet and determining the amount of energy saved. In an ad-hoc wireless cloud architecture, just a small portion of a work is accomplished locally; the remaining portion is delegated to a nearby mobile that has already been carrying out the same task (Qi, Wang, & Psaraftis, 2021). In order to reduce the energy consumption of the computer, the mobile data frequencies are measured on an ongoing basis at a predetermined period. The power-saving method gathers the little time gaps between packets to create larger time gaps when the device is turned off. The EnaCloud technique uses an energy-efficient routing heuristic algorithm to adjust the event size while creating programme allocation and method scheduling with regard to task input and outflow. The essay concludes that technology tends to focus on specific issues from a single angle and requires well defined structures and solutions to handle a variety of green computing settings that call for portable clouds. The goal of continuous research will be to create a cutting-edge energy-saving architecture based on practical analysis and wise choices (LD., 2021).

2.1. Need of Energy-Efficient Techniques

Data centres were predicted to use 1.4% of all EEC (power consumption), with a 12% annual growth rate. A recent field that has captured the interest of scholars all over the world is green cloud computing. Such technology is necessary nowadays to resolve trade-offs between performance and energy. One of the key goals of the cloud is to properly distribute workloads while retaining performance by giving users access to services anywhere, at any time. The SLA (Service Level Agreement) may be broken by reducing energy use; however SLA breaches may result in penalties for cloud service providers, so we should prevent any SLA violations when thinking about energy-efficient systems (Ramasamy, Alotaibi, Khalaf, Samui, & Jayabalan, 2022).

The advantages of cloud computing for environmental conservation are also more pronounced if data centres are built according to the green computing philosophy. Massive data centres are often built for cloud computing services, connected to several high-speed networks and virtual servers, and equipped with amenities like climate control, power systems, and others.

Energy drop is the term used to describe energy that is transferred to a process but is not used by any subsystem (such as D1), such as electricity that is lost during transfer or conversion. The support system's overhead costs (D2), such as cooling or lighting in data centres that are predominantly supplied by cloud service providers, are a secondary reason for the decline. When a system is abandoned (L1), such as when it is operating but inactive, energy that was consumed for its primary purpose is lost (Rawat, Alghamdi, Kumar, Alotaibi, Khalaf, & Verma, 2022). Over-the-limit or redundant usage (L2), such as keeping the system as cool as possible at night when the temperature is already low, is another reason for loss (Ruby. G, 2022). The difficulty of reducing power usage in cloud data centres and cloud computing systems has drawn researchers' attention over time and is currently a popular study area.

2.2. Role of Energy Efficiency in Cloud Data Centres

The growth of cloud computing has made it a key paradigm. It offers an effective and dynamic way to use a computer to fulfil all IT requirements, including those for computer storage and software. Through virtualization, a cloud data centre may provide a potent and effective computing environment. This idea has received a lot of attention and piqued the curiosity of businesses looking to spend less on hardware and software. When thousands of users use the same resources and pay only for what they use, tremendous scalability, and dynamic provisioning are made possible.

Grid computing, parallel computing, virtualization, containerization, and distributed computing are fundamental concepts in cloud computing. The newest rising topics are microservice architecture and SOA (service-oriented architecture). Massive computers housed in these data centres need additional computing resources including storage, cooling equipment, and backup system support. Additionally, the data center's thousands of servers occupy a large amount of space and use a lot of electricity. These servers generate heat, thus they need to be kept in a completely air-conditioned space that is especially made for data centres. Data centres are also anticipated to use more energy quickly.

The design and operation phases of these data centres do not yet follow the optimal energy management patterns. However, the industry has made significant progress in this area. As a result, finding ways to make a server in a data centre more energy efficient is now a major factor in the possibility of increasing data centres' energy efficiency (Rubyga. G, 2021).

2.3. Research Gap

From the literature that has been reviewed thus far, it can be inferred that although not many, a sizable number of research have attempted to analyse the energy efficient and eco-friendly approaches for green cloud computing. The cloud computing platform includes cutting-edge computing models that allow for the web-based sharing of resources including web-based apps, computing control, capacity, and arrangement assets. For customers whose demand for virtual assets fluctuates over time, the widely applicable utility prepared computing demonstrations done by the majority of cloud computing providers are a possible highlight. Online applications' expansive potential results in workloads with a wide variety and enormous scale. Numerous organisations' computing and information processing power has been growing quickly.

In substance dissemination frameworks and most distributed frameworks, energy consumption is the primary problem (Cloud frameworks). These ask for an accumulation of organised computing resources from one or more suppliers for datacenters expanding around the globe. In the frameworks for advanced information centres and cloud computing, this utilisation is a restricted plan parameter (S. K. Mishra “t al., 2020). This energy consumption and high carbon outflow may be primarily caused by the control and energy used by the computer and the related cooling system. Due to the lack of relevant study on energy efficient and eco-friendly techniques for GCC, this research endeavour attempts to take a thorough look at the problem and come up with workable solutions to the current gaps.

2.4. Objectives of the study

The main objectives of this paper are:

1. In order to investigate green cloud computing.
2. To research green cloud energy-efficient methods
3. To examine green cloud computing environmentally friendly methods.

3. Proposed Method

In the study, a new and improvised power model that makes use of several scheduling and operating techniques for data centres has been constructed. In terms of energy efficiency and sustainability, the proposed power model performs better than the two current power models.

3.1. Green Cloud Computing

The green cloud is favourable to the environment. Reduce the energy consumption of computer resources during peak operation and store energy during idle operation as well as reduce the harmful possessions of computing resources and computing wastes (Saleh Atiewi, 2020).

3.2. Utilization Based Energy Model

A multi-layered hardware stack made up of physical devices, hubs, switches, bridges, gateways, network interface cards, and modems exists in a typical virtualized network. The energy components as $N = \{"Hubs, Switch, Bridge, Gateways, Network\ Interface\ Cards, Modems"\}$ are commonly formatted in the virtualized network's hardware framework for the convergence of representation.

$$\boldsymbol{E_{NC} = E_{static} + a(DNE\ n + UNE\ n)} \tag{1}$$

Where E_{NC} represents the energy used by network components, when there is no workload on it, ecstatic energy consumption is fixed. UNE Is the utilisation of each type of network component. DNE is the dynamic energy coefficient (hirvani, Rahmani, & Sahafi, 2020). A network's energy model can be revised when it is virtualized as

$$\boldsymbol{E_{NC} = E_{static} + a\ M\ ENCi} \tag{2}$$

Where M is the total number of active network components (NC) on the network and $ENCi$ is the dynamic energy consumption of NCi (network components). The actual energy consumption of the network components (NC), which cannot be connected by a hardware energy metre, should be assessed indirectly. The following is the network component energy model.

$$\boldsymbol{ENCi = \frac{E_{static}}{M} + W_i \times a(DNE\ n + UNE\ n)} \tag{3}$$

3.3. Energy Efficient Data Delivery Algorithm

Energy consumption is one of the main issues with cloud network communications. The energy-efficient data distribution method can be employed in the green cloud network to reduce unused network resources and boost bandwidth usage (Shivam Singh, 2022). The primary goal of a green cloud network is to take into account using high data rates (bandwidth) for the application and to constantly check the network's components for energy conservation. The following are the steps of an energy-efficient data delivery algorithm:

Step 1: Determine the resources that are available.

Step 2: Determine the sources and the destination.

Step 3: Find the shortest route

Step 4: Find the size of the arrival task.

Step 5: Decide the arrival job size.

Step 6: Use the fitness function "Bandwidth" > "Bandwidth" to assign the work to the specific resources (a requirement for individual tasks)

Step 7: Reallocate the resources based on the time it takes to complete the task.

Step 8: Unused resources will be turned off. Step 9: Steps 1 through 9 should be repeated for more allocation.

The suggested energy-efficient data distribution algorithm can be used to improve green cloud network bandwidth utilisation and lower the amount of underutilised network resources. The goal of limiting the number of active cloud network components, upgrading the cloud network components, and lowering power consumption has been accomplished by energy-efficient data transport. The least quantity of active cloud network components and the turning off of the inactive cloud network components are required to provide data in an energy-efficient manner.

4. Results and Analysis

"GreenCloud" is the simulator used to simulate the proposed power model and evaluate its performance in comparison to the two power models that came before it. LM stands for Linear Power Model, LPM for Low Power blade Power Model, PM* for Proposed Model, PMLM* for Proposed Model using Linear Model, and PMLPM* for Proposed Model using Low Power blade Power Model (Students of Galgotias University, 2021). These abbreviations are used for all outcomes. Also included in the simulation results are abbreviations for the scheduling methods, such as GSVMs for Green Scheduler using Virtual Machines, GS for Green Scheduler, RRVMs for Round Robin using Virtual Machines, and RRHs for Round Robin using Hosts. The outcomes are as follows:

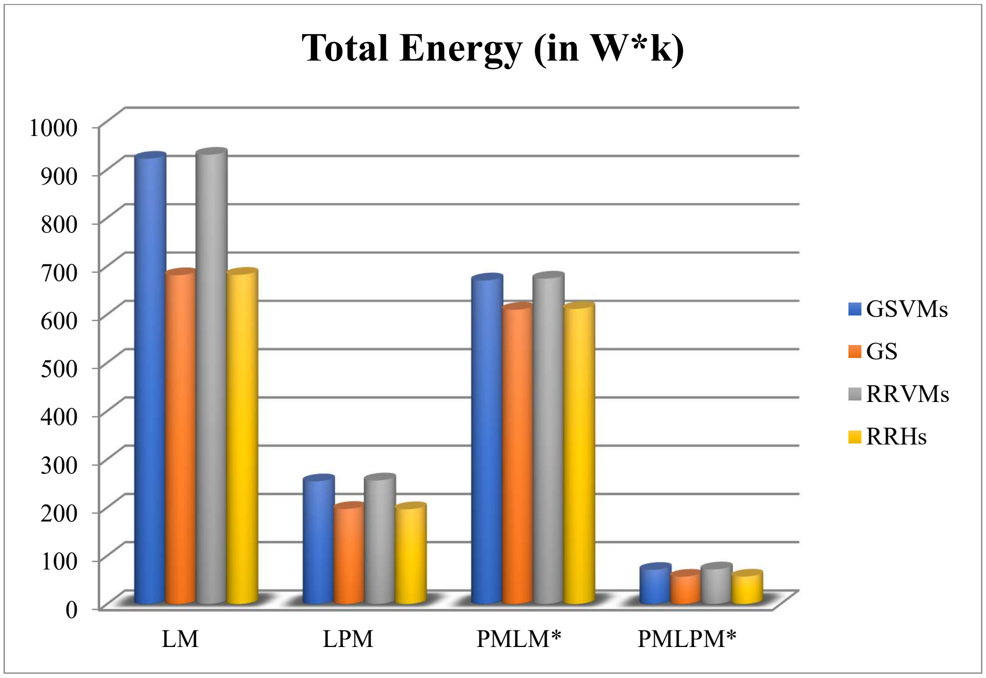
4.1. Total energy

Total energy is the amount of electrical energy or power used by all of the IT hardware in a system, including servers, switches, and other devices. It is expressed as W*k. As a formula

Total Energy =Server Energy + Network Switches Energy

The proposed power model's total energy consumption is shown in Figure 3 as follows:

Figure: 3. Comparison of Total Energy consumed by proposed power model (*) with the existing models



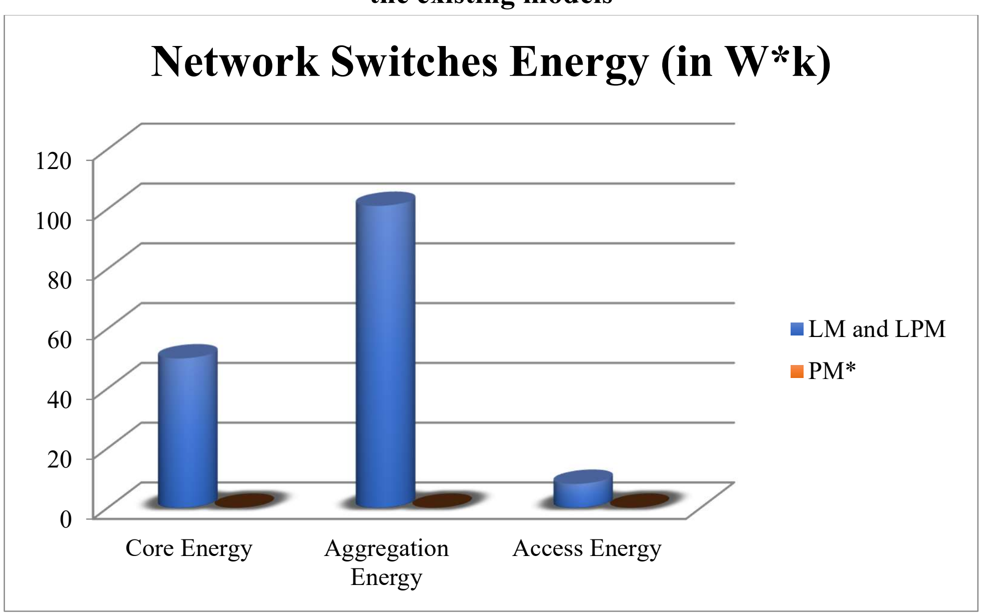
4.2. Network Switches Energy

Energy used by network switches is a proportionate part of the total electrical power or energy used by the switches only for proper operation. W*k is the unit of measurement for it.
In a formula,

Switches Energy = Core Energy + Aggregation Energy + Access Energy

Switches Energy is decreased in the suggested model to 0 W*k.
As shown in Figure 4, this contrasts the proposed power model's use of switching energy with the models already in use.

Figure: 4. Comparison of Network Switches Energy in Proposed Power Model (*) with the existing models



4.3. Server Energy

The fraction of the total electrical energy or electricity used by the servers just for proper operation is known as server energy. W*k is the unit of measurement for it.

In a formula,

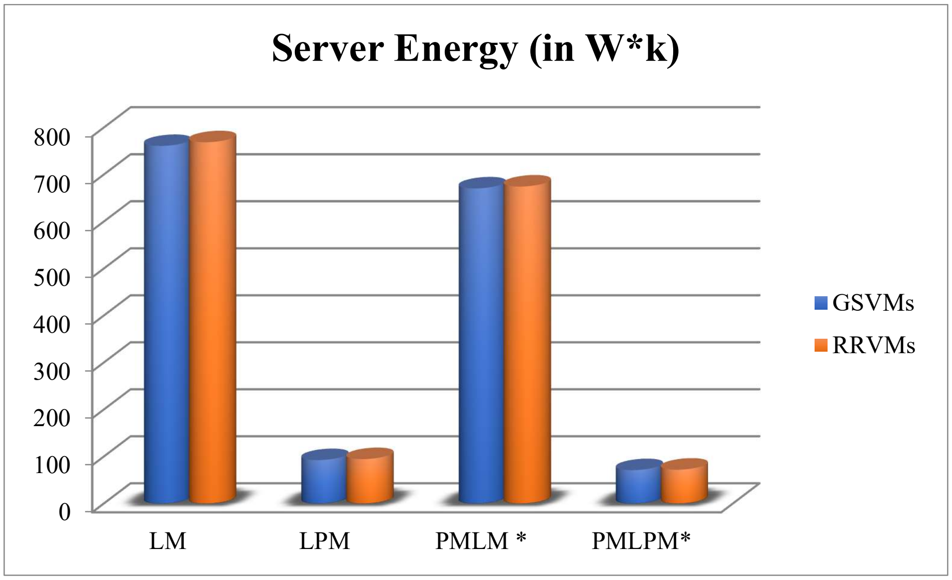
Server Energy = Total Energy – Switches Energy,

Where Switches Energy = 0

Thus, Server Energy = Total Energy

As shown in Figure 5 below, the suggested power model uses less server energy than the current models.

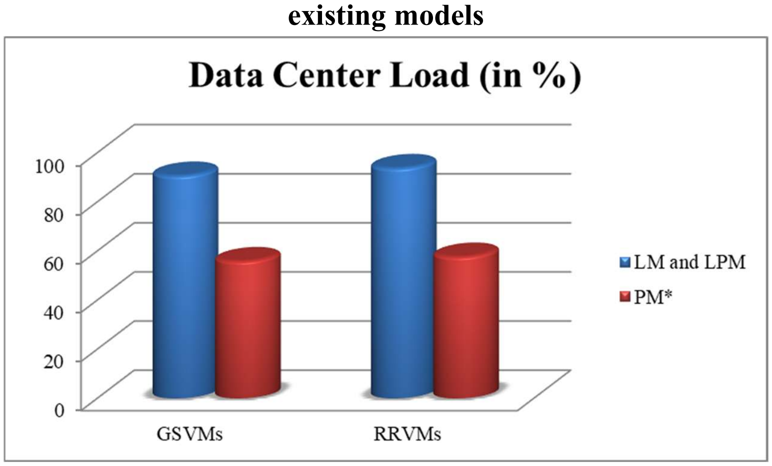
Figure 5: Comparison of Server Energy consumed by proposed power model (*) with the existing models



4.4. Data Centre Load

The term "data centre load" refers to the quantity of requests running through each DC, or how busy or unoccupied it is (Tribid Debbarma, 2022). It's expressed as a percentage (out of 100). Figure 6 compares the parameters used in the proposed power model with those used in the current models as follows:

Figure: 6. Comparison of Data Centre Load in Proposed Power Model (*) with the existing models



Following the comparison results, the following are some proposed model discussion points:

- Compared to the other two models, the total energy consumption and server energy consumption are significantly lower.
- In the 3-tier architecture's core, aggregation, and access layers, network switches' energy consumption is lowered to zero.
- Switch energy is lowered to zero, making total energy equal to server energy.
- The decreased data centre load further demonstrates its superior performance to the other two.
- There were fewer tasks that were declined and failed.
- Virtual Machine Migration approaches for server consolidation and load balancing are more effective than those of the other two types.

5. Conclusion

In this technocratic world of technological enthusiasts, green cloud computing is an emerging technology and study area. These days, IT organisations are moving toward cloud computing because of the rise in computational and huge data storage requirements, which has led to the expansion of cloud infrastructure with an ecological and economical balance. A top-notch strategy to virtualize servers and data centres with optimal energy efficiency has been created and developed for cloud computing (Tseng, 2020). The report comes to the conclusion that the government views energy efficiency and power management as major goals with clear guidelines as it moves toward the green revolution in the near future. Green cloud operating features lessen plastic usage and carbon footprints. Popular technology behemoths like Microsoft and Google have processes set up to handle environmentally friendly components on a regular basis.

The number of users is increasing in the current environment, which has a significant impact on the overall computing requirements. The natural world is running out of important energy sources as well. All of these factors are related, work together, and demand the creation and usage of energy-efficient solutions that help to lower the energy consumption of the massive and widely used data centres used for cloud computing. Additionally, these data centres produce excessive heat, toxic fumes, and dangerous carbon compounds. After addressing all of the drawbacks of the conventional cloud technology, green computing has thus been demonstrated to be a superior technology. Two built-in power models are available in the Green Cloud Simulator, which is intended for modelling and does not place a lot of emphasis on energy conservation (Wang, et al., 2022).

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