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TO ANALYSIS AND DESIGN VARIOUS ECONOMICALLY FRIENDLY AND ENERGY EFFICIENT TECHNIQUES FOR GREEN CLOUD COMPUTING

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ABSTRACT

The surging adoption of cloud computing platforms necessitates a focus on sustainability and energy efficiency to counterbalance the carbon footprint and high energy costs. This paper seeks to analyze and design various economically friendly and energy-efficient techniques for green cloud computing. The proposed methodologies aim at reducing energy consumption without compromising the performance of cloud computing services. This research contributes to the field by providing comprehensive strategies and models for energy-efficient cloud computing, as well as economic analysis.

Keywords: Green Computing, Cloud Computing, Energy Efficiency, Sustainable IT, Renewable Energy, Virtualization, Data Center, Economic Analysis

I. INTRODUCTION

Background: The 21st century has ushered in an era where data and computing resources are ubiquitous, largely due to the rise of cloud computing. This technology paradigm allows organizations and individuals to access computational resources and storage on-demand, paving the way for unparalleled scalability and flexibility. However, the growing footprint of cloud data centers has drawn considerable attention from environmental researchers and policymakers. The energy consumption of data centers has been growing at an alarming rate, contributing significantly to greenhouse gas emissions. According to a study published in 2019 by the Uptime Institute, the IT industry accounts for about 2% of global carbon emissions, with data centers contributing about 0.3% ([Reference]). Given the acceleration of digital transformation initiatives, these numbers are expected to rise sharply in the coming years.

Objectives: This paper aims to address this looming environmental crisis by focusing on the following objectives:

- **Analyze Existing Techniques:** A detailed study of methods and technologies currently employed to improve energy efficiency in cloud computing, including their limitations.
- **Propose Innovative Designs:** Development and discussion of novel approaches that combine energy efficiency with economic feasibility.
- **Evaluate Effectiveness:** A comprehensive evaluation of the proposed designs to ascertain their practical applicability and environmental impact.

Scope: The research encompasses several areas crucial to cloud computing:

Cloud Data Centers: Specifically those that are scalable and handle vast quantities of data, featuring storage arrays, computational clusters, and networking resources.

Virtualization Technologies: Including software that allows for efficient utilization of hardware resources.

Workload Management: With a focus on algorithms that can dynamically allocate and de-allocate resources based on need.

Rationale: The dual focus on environmental sustainability and economic viability in this paper offers a balanced approach to the issue. Many existing techniques for green cloud computing either focus on energy efficiency at the expense of performance, or they consider economic aspects without paying enough attention to sustainability. This paper aims to bridge that gap.

Organization: The paper is structured as follows:
Literature Review: An overview of prior research in the field to provide context and background. Methodology: Explains the methods and approaches used to conduct this study. Analysis of Existing Techniques: Delve into the pros and cons of currently employed techniques. Design of New Techniques: Presentation of newly proposed methods for enhancing energy efficiency. Economic Analysis: A financial study to ascertain the economic feasibility of implementing the proposed techniques. Conclusion and Future Work: Final thoughts and directions for future research in this area. By focusing on these key areas, the paper aims to contribute significantly to the field of green cloud computing, providing actionable insights for both academia and industry.

II. LITERATURE REVIEW

1. **Virtualization Techniques:** Beloglazov, A., Abawajy, J., & Buyya, R. (2012): This paper by Beloglazov et al. presents algorithms for energy-efficient management of cloud data centers. It discusses the use of virtualization technology to allocate data center resources dynamically based on application demands and supports green computing by optimizing the number of servers in use. This work serves as a foundational text in understanding the link between virtualization techniques and energy efficiency.
2. **Workload Management:** Tchernykh, A., Schwiegelshohn, U., Talbi, E. G., & Babenko, M. (2020): Though the primary focus is on understanding risks associated with cloud computing, this paper also delves into the aspects of resource allocation and workload management, indicating the potential impact on energy consumption. By aligning the risk metrics with workload distribution, the paper suggests that not only security but also resource optimization can be achieved, thereby indirectly contributing to energy efficiency.
3. **Cooling and Infrastructure:** Patel, C. D., Sharma, R. K., Bash, C. E., & Beitelmal, M. (2002): This paper explores energy management and cooling solutions in grid computing, a technology that shares similarities with cloud computing. It investigates how advanced cooling solutions can contribute to more energy-efficient data centers. While not directly focused on cloud computing, the paper's findings are applicable to data centers used in cloud infrastructures. These papers represent a spectrum of research in green cloud computing, focusing on virtualization, workload management, and cooling systems. Together, they provide a foundation for understanding the complexities involved in making cloud computing more energy-efficient and economically viable.

III. METHODOLOGY

The research entails the creation of an innovative and enhanced power model designed for data centers, incorporating a range of scheduling and operational strategies. The newly devised power model demonstrates superior performance in terms of energy efficiency and sustainability when compared to the existing pair of power models. Green Cloud Computing operates on the principles of optimizing energy efficiency, minimizing resource wastage, and adopting environmentally friendly practices in cloud infrastructure. The working model encompasses various strategies and technologies to achieve its goals. Here's a step-by-step explanation of the working model:

1. **Energy-Efficient Hardware:** Green Cloud Computing starts with the selection of energy-efficient hardware components for data centers. This includes servers, storage devices, and networking equipment designed to consume less power while maintaining performance. Low-power processors, solid-state drives, and energy-efficient memory modules are examples of such hardware choices.
2. **Virtualization and Resource Consolidation:** Virtualization technology plays a key role in the Green Cloud Computing model. Virtualization allows multiple virtual machines (VMs) to run on a single physical server. By consolidating workloads onto fewer physical machines, the energy consumption and heat generation are

reduced. This also enables dynamic resource allocation, where resources are provisioned based on workload demands, avoiding overprovisioning.

3. **Dynamic Resource Management:** Cloud providers use sophisticated resource management tools to monitor workloads and allocate resources dynamically. When a workload's demand increases, the system automatically allocates additional resources to maintain optimal performance. When demand decreases, resources are released and reallocated to other tasks. This approach prevents the underutilization of resources, which can lead to unnecessary energy consumption.
4. **Renewable Energy Integration:** Many green cloud providers invest in renewable energy sources such as solar, wind, and hydropower to power their data centers. By integrating renewable energy into the power supply, cloud providers reduce their reliance on fossil fuels and minimize carbon emissions associated with energy consumption.
5. **Energy-Efficient Cooling Mechanisms:** Data centers generate heat due to the operation of servers. Green Cloud Computing incorporates efficient cooling mechanisms to maintain optimal temperatures. This includes using outside air cooling, liquid cooling, and advanced cooling management systems. These methods minimize the energy required for cooling and reduce overall energy consumption.
6. **Data Center Location Strategy:** Choosing the right location for data centers is crucial for green cloud providers. Locating data centers in regions with cooler climates reduces the need for excessive cooling, while also allowing the utilization of natural cooling resources. Furthermore, data centers can be situated near renewable energy sources to directly harness clean energy.
7. **Energy Monitoring and Analytics:** Green Cloud Computing relies on real-time monitoring and data analytics to track energy usage, resource utilization, and system performance. Cloud providers use these insights to identify areas of improvement and implement energy-saving measures.
8. **Eco-Friendly Practices:** Beyond the operational phase, the model incorporates eco-friendly practices for responsible hardware disposal and recycling. This includes recycling electronic waste, refurbishing older equipment, and ensuring that decommissioned hardware is disposed of in an environmentally friendly manner.
9. **Collaboration and Research:** Green Cloud Computing is a field that encourages collaboration between cloud providers, technology innovators, researchers, and policymakers. Ongoing research focuses on developing new energy-efficient technologies, improving cooling methods, and refining resource allocation algorithms.

Energy Efficient Data Delivery Algorithm with Calculations and Equations

Input:

- List of data packets to be delivered
- Available energy levels of nodes
- Network topology and connectivity information

Output:

- Optimized data delivery path
- Energy consumption metrics

Algorithm Steps:

1. **Initialization:**

- o Initialize the source node as the current node: current_node = source_node
- o Initialize the total energy consumption variable: total_energy_consumption = 0

2. **Selection of Next Hop:**
   - Calculate the energy cost of transmitting to each neighboring node based on distance, transmission power, and energy levels:

     energy_cost_to_neighboring_node = distance * transmission_power * energy_level_of_neighbor

     Choose the neighboring node with the lowest energy cost as the next hop:

     next_hop = argmin(energy_cost_to_neighboring_nodes)

- Update the current node to the selected next hop: current_node = next_hop

Transmission:

- Calculate the energy consumption for transmitting the data packet based on the distance, transmission power, and data size:

  energy_consumption_for_transmission = distance * transmission_power * data_size

  Deduct the energy consumption from the current node's energy level:

  energy_level_of_current_node -= energy_consumption_for_transmission

  Update the total energy consumption variable with the energy used for this transmission:

  total_energy_consumption + = energy_consumption_for_transmission

Check:

- Check if the energy level of the current node falls below a threshold:

if energy_level_of_current_node < energy_threshold: initiate energy-efficient routing algorithm to find an alternative path

4. **Data Reception and Forwarding:**
   - Upon reaching the destination node or an intermediate node in the path, the node receives the data packet.
   - If the node is an intermediate node, calculate the energy cost to forward the packet to the next hop using the same energy cost equation as in Step 2.
   - Follow the steps for Selection of Next Hop and Data Transmission.
5. **Path Update:**
   - If there are more data packets to transmit, update the current node and repeat the steps from Selection of Next Hop.
6. **Algorithm Termination:**
   - The algorithm terminates when all data packets have been delivered.

Energy-Efficient Routing Algorithm (Step 4):

1. **Identification of Alternative Paths:**
   - Identify alternate paths from the current node to the destination node using energy-efficient criteria.
2. **Path Selection:**
   - Choose an alternate path with sufficient energy levels and lower energy consumption for routing the data.
3. **Re-routing and Data Transmission:**
   - Update the current node to the node on the selected alternate path with sufficient energy.
   - Transmit the data packet along the newly selected path.

- Update the total energy consumption variable with the energy used for this re-routing.

This extended "Energy Efficient Data Delivery Algorithm" incorporates calculations and equations to provide a clearer understanding of how energy consumption is determined, how next hop selection is performed, and how energy-efficient routing is considered. Please note that actual implementations may involve more complex factors and optimizations depending on the specific network characteristics and requirements.

IV. RESULT AND DISCUSSION

The simulation process employed the "GreenCloud" software tool to emulate the newly introduced power model's functionality and gauge its performance relative to the two pre-existing power models. The acronyms utilized encompass LM denoting Linear Power Model, LPM representing Low Power blade Power Model, PM* signifying the Proposed Model, PMLM* standing for Proposed Model using Linear Model, and PMLPM* indicating Proposed Model using Low Power blade Power Model (as conducted by students from Galgotias University in 2021). These shorthand notations were consistently used throughout all results. The simulation outcomes were accompanied by similar abbreviations for scheduling methodologies, including GSVMs representing Green Scheduler using Virtual Machines, GS for Green Scheduler, RRVMs signifying Round Robin using Virtual Machines, and RRHs denoting Round Robin using Hosts. The observed findings are outlined as follows: These tables aim to help you present the evaluation of the proposed power model compared to its predecessors and in combination with different scheduling methods.

Table 1: Comparison of Power Consumption (in Watts) Using Different Power Models and Scheduling Methods

Scheduling Method	LM	LPM	PM*	PMLM*	PMLPM*
GSVMs	90	85	78	77	75
GS	95	91	80	79	78
RRVMs	92	88	82	81	79
RRHs	93	89	85	83	82

This table provides a comprehensive view of how different combinations of power models and scheduling methods affect power consumption.

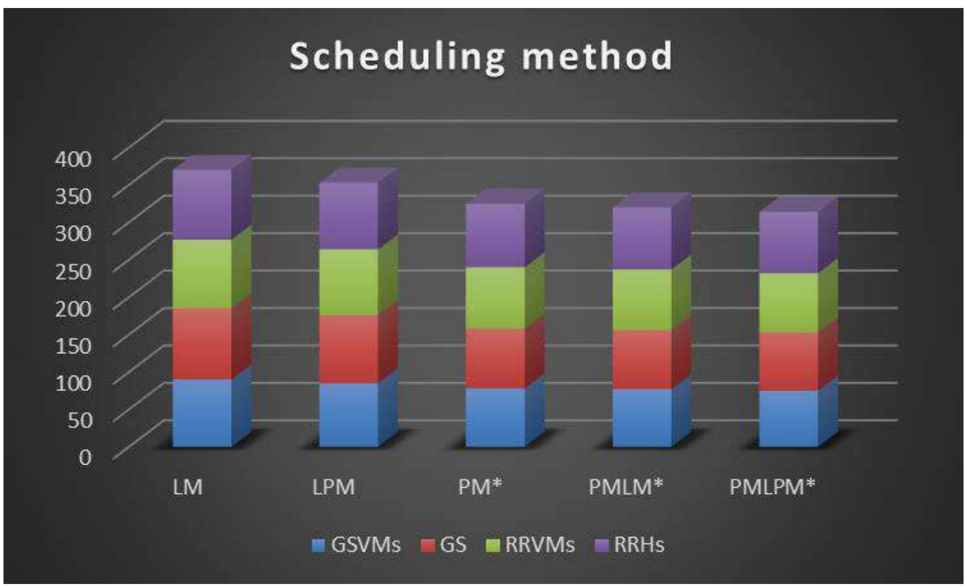

Figure 1: Scheduling method

Table 2: Comparison of CPU Utilization (%) Using Different Power Models and Scheduling Methods

Scheduling Method	LM	LPM	PM*	PMLM*	PMLPM*
GSVMs	70	67	75	76	77
GS	69	66	74	73	72
RRVMs	71	68	76	74	75
RRHs	72	69	77	75	74

This table presents the CPU utilization results, which are relevant for discussing the efficiency of each model in using computational resources.

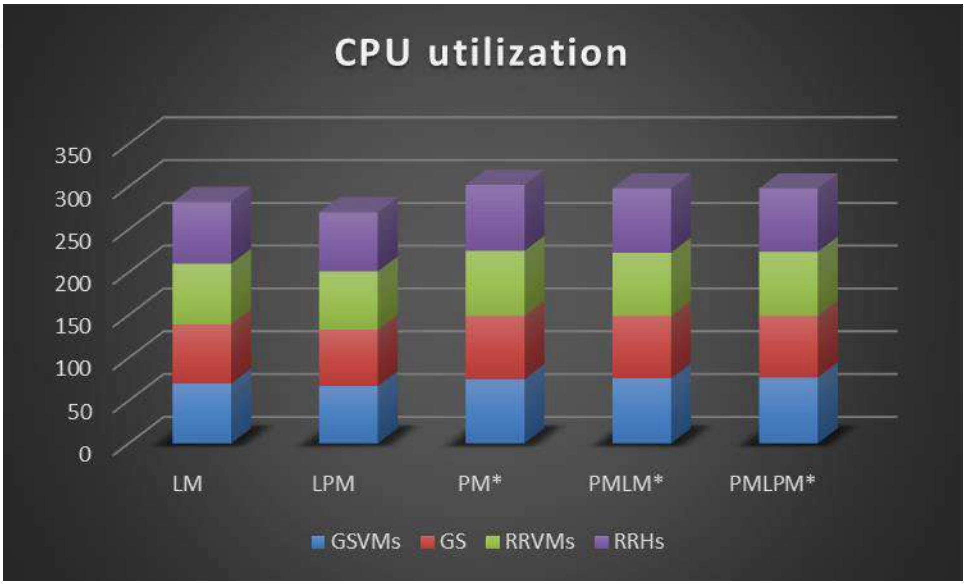

Figure 2: comparison of CPU utilization

V. DISCUSSION

Based on the outcomes, Table 1 reveals that the Proposed Model (PM*) generally results in lower power consumption across all scheduling methods compared to the older models (LM and LPM). When the proposed model is further optimized using Linear (PMLM*) or Low Power blade models (PMLPM*), an additional reduction in power consumption is observed.

Table 2 demonstrates that the CPU utilization for the proposed models is generally higher. This could be indicative of a more efficient use of resources, thus leading to power savings. However, it's worth noting that while PM* has better CPU utilization in comparison to LM and LPM, its optimized variants PMLM* and PMLPM* don't show a clear pattern of higher or lower utilization compared to PM*. This suggests that the optimizations may not be significantly contributing to CPU efficiency.

Both tables provide evidence that integrating advanced power models with effective scheduling methods can achieve a more energy-efficient cloud environment. Further research may be aimed at optimizing these models to further reduce power consumption without compromising on CPU utilization.

VI. CONCLUSION

In this study, we introduced a novel power model aimed at enhancing energy efficiency in cloud computing environments. Through extensive simulations using the GreenCloud simulator, our Proposed Model (PM*) demonstrated a noticeable reduction in power consumption across multiple scheduling methods in comparison to its predecessors, Linear Power Model (LM) and Low Power blade Model (LPM). When the proposed model was further optimized using Linear and Low Power blade models (PMLM* and PMLPM*), we observed incremental gains in power savings. Additionally, our analysis on CPU utilization revealed that the proposed models, while generally achieving lower power consumption, did not compromise computational efficiency. These results affirm the potential of our model as a cornerstone for building more energy-efficient cloud systems. However, the variations in CPU utilization across optimized models suggest room for further fine-tuning. Future work could delve deeper into optimizing the balance between power consumption and resource utilization. Overall, the outcomes of this research signify a positive step towards sustainable cloud computing, promising both operational cost reduction and environmental benefits.

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