A Succinct Review Of Intelligent Computational Techniques In Green Cloud Computing

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***Abstract*—Green cloud computing (GCC) has various advantages and benefits, especially for power management and energy efficiency. Many techniques can reduce the consumption of energy to solve environmental problems caused by IT industries. An in-depth understanding of these techniques could have a positive impact on the development of GCC. This paper discusses the existing intelligent techniques applied to cloud computing and analyses them according to diversified parameters, such as resource utilization, response time, overhead, etc. A clear trend is that cloud computing is developing in a greener direction.**

***Index Terms*—Green cloud computing, Computing performance, Energy consumption, Carbon emission**

I. Introduction

Green cloud computing (GCC) has been used by both governments as well as industries. It is a virtual computing platform which is used to solve IT related environmental problems. According to the study of [1], using GCC brings unique advantages, including improving resources consumption, saving electronic energy, and enhancing computing performance. Green cloud computing becomes a research hotspot, gradually affecting technologies and environment. The increasing demand for large data storage and huge wastes of energy are challenging questions. People are paying more attention to pursue sustainability of cloud computing in order that we are able to efficiently use computing infrastructures and computer products. This article focuses on GCC and techniques related to cloud computing. It also analyzes the advantages and benefits of these techniques to think about the future development and challenges of GCC. Another objective is to explore the impacts of GCC on environmental protection, resource administration, and human life.

II. Literature Review

An in-depth analysis of cloud energy efficiency by surveying and establishing a classification of current articles on energy-efficient cloud pointed out that reducing power consumption at each level of cloud computing systems is difficult to achieve because energy-saving policies have been thoroughly studied. Combining multiple levels for decreasing consumption of power and implementing efficient data management are the key points to realize green cloud computing [15]. The key elements of achieving energy conservation and environmental

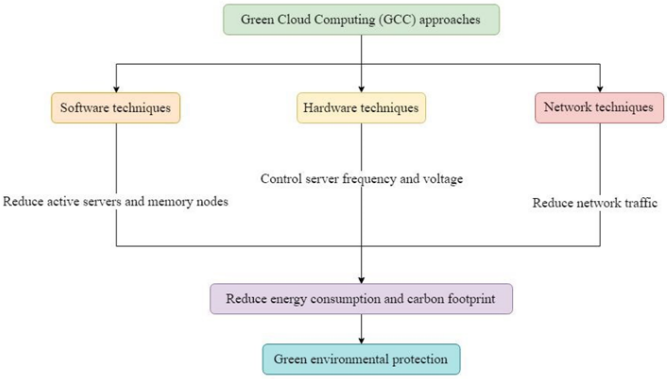

Fig. 1. Green cloud computing approaches.

sustainability are dynamic provisioning, multiple tenancies, resource utilization, and energy efficiency of data centers, etc. Adopting green cloud practices plays a vital role in the development and dissemination of green cloud computing services. Energy-efficient techniques and renewable energy sources promote environmental protection. They drew the conclusion that better energy saving, higher resource utilization, less carbon emission, and smarter power management contribute to accomplishing green cloud goals [14]. Furthermore, using cloud computing techniques have a better and greener performance by comparing traditional and cloud computing data centers. The experimental results showed that cloud computing DC was able to decrease the power consumption of a virtual machine by 51 % and the consumption of energy for storing one byte was lessened by 87 %. Optimizing data centers can improve the efficiency of energy and cut down carbon emission and e-waste. Cloud computing is considered as a green technique [5]. Analysis of ten techniques that reduce the power consumption of cloud systems based on the processing unit to determine whether these techniques can improve the efficiency of data centers pointed out that all of these techniques were mainly focused on virtualization. Servers' virtualization is one of the critical elements to reduce consumption and enhance the overall performance of green cloud computing [15]. The approaches of green cloud computing are outlined

and classified, that are hardware, software, and network techniques for optimizing resource utilization. Software techniques reduce active servers and memory nodes in order to save the energy of the server and memory. Hardware techniques decrease consumption by utilizing flexible hardware that controls server frequency and voltage. Network techniques can reduce network traffic between virtual machines for energy reduction [1]. These GCC techniques aim to reduce energy consumption and carbon footprint to protect the environment. In [16], authors introduced a fair and efficient method for green computing resource allocation using deep reinforcement learning to the users connected via a network. Their results show that the introduced method provides better allocation schemes compared to the conventional model. An approaches to GCC is shown in Figure 1.

III. Research data collection and methodology

A. Techniques Summary

This paper summarizes ten different techniques served for cloud computing, as shown in Table1 including technique names, their application environment, and research results.

- ***Split-new cloudlet allocation strategy [2]*** Shorten the host in the data center and better performance for completion time and make span.
- ***Central Load Balancing Policy for Virtual Machines [3]*** Distributed virtual machines (VMs) to isolated systems hosting multiple virtual machines.
- ***ENNEGCC[4]*** Control server state according to usage to reduce power consumption also reduces heat and carbon emissions.
- ***Honey bee behavior inspired load balancing [6]*** The mean execution time and the latency of tasks in the queue are significantly improved without additional overheads.
- ***Join-Idle-Queue [7]*** Remove jobs from the critical path to save the actual response time and effectively reduce the length of the queue and system load without any additional communication overhead
- ***Limited Redirection Rate (LRR) [8]*** provides better response times than Round Robin (RR) and Smallest Latency (SL).
- ***Ant Colony Optimization (ACO) algorithm [9]*** Improve data center efficient and increase revenue.
- ***Two-phase scheduling algorithm [12]*** Three-level cloud computing network maintains better load balancing of the system with better execution efficiency.
- ***(MA)-based VM allocation method [13]*** Reduces the energy cost of the system and migration cost.
- ***TVRSM[16]*** Provide more efficient virtual resource allocation and management.

B. Metrics for techniques in Clouds

These techniques aim to provide higher performance in terms of response time, make span and resource utilization, etc. Another major goal is to achieve greener cloud computing in order to realize energy efficiency and protect the environment. This article considers the following metrics to analyze these techniques.

According to the mentioned metrics, the existing techniques have been analyzed in TABLE 2

- ***Overall performance*** refers to the efficiency of the system. Good overall performance will provide more satisfactory services to customers.
- ***Response time*** is the time required for the virtual environment to finish the request. Less response time can effectively improve overall performance.
- ***Scalability*** refers to the theoretical ability to serve a certain number of users. Higher scalability allows the system to handle a great quantity of user application requests simultaneously.
- ***Overhead*** is any combination of additional or indirect computation time, communication, or other resources required to perform a particular task. This metric should be minimized for better efficiency.
- ***Fault tolerance*** is the characteristic that allows a system to keep running normally when certain components of the system fail.
- ***Resource utilization*** is the capacity to dynamically allocate and reallocate different physical and virtual resources according to consumer needs. Sufficient and reasonable utilization of resources is the pursuit of cloud computing.
- ***Energy Consumption*** refers to the energy consumed by all resources in cloud computing. Excessive energy consumption should be avoided to eliminate global energy overuse.
- ***Carbon Emission*** refers to the carbon emission produced by all resources in clouds. More carbon footprints will put a burden on the environment. In order to pursue green cloud computing, this metric needs to be minimized.

C. Comparison of technique capabilities

In order to provide better cloud services for users, these techniques have a positive impact on different metrics, including shortening response time, increasing scalability and fault-tolerance rate, avoiding overhead, and improving resource utilization. According to the analysis shown in Figure 2, of the ten techniques, 42.86 percent can reduce the response time and improve the efficiency of resources usage. 14.28 percent of techniques are used for better scalability, and 28.57 percent can reduce the additional overhead. This paper divides these technologies into two time periods for analysis. From 2010 to 2014, these techniques only consider improving overall performance. They do not have much ability to reduce carbon emissions and energy consumption. From 2015 to 2019, ten percent of techniques are able to decrease carbon emission and twenty percent focuses on higher performance. Eighty percent is dedicated to energy conservation. (See in Fig. 3)

IV. Result

Each of the ten techniques analyzed above has different advantages and benefits. Most of the techniques have a significant improvement in terms of resource utilization and response time. In the early stages of development, techniques were

TABLE I
ANALYSIS OF DIFFERENT GREEN CLOUD COMPUTING TECHNIQUES

No	Techniques	Environment	Results
T1	Join-Idle-Queue [7]	Data centers	1. Remove jobs from the critical path to save the actual response time 2. Effectively reduce the length of the queue and system load without any additional communication overhead
T2	Limited Redirection Rate (LRR) [8]	Internet distributed services	1. LRR provides better response times than Round Robin (RR) and Smallest Latency (SL), which is 31% shorter than RR and 32 % shorter than SL
T3	Central Load Balancing Policy for Virtual Machines [3]	Distributed virtual machines (VMs) or cloud computing environment	1. Compared to isolated systems hosting multiple virtual machines, improvement of performance was up to 20% in most cases 2. Improve overall performance without considering fault tolerance
T4	Two-phase scheduling algorithm [12]	Three-level cloud computing network	1. Maintain better load balancing of the system with better execution efficiency 2. Effectively utilize resources and improve work efficiency
T5	Honey bee behavior inspired load balancing [6]	Cloud computing environments or heterogeneous cloud computing systems	1. Both the mean execution time and the latency of tasks in the queue are significantly improved without additional overheads
T6	Split-new cloudlet allocation strategy [2]	Cloud Computing environment	1. Shorten the host in the data center 2. Better performance for completion time and make span 3. Raise the QoS of a cloud and system resource utilization
T7	ENNEGCC-3D energy efficient scheduling algorithm [4]	Cloud Computing environment	1. Control server state according to usage to reduce power consumption 2. Reduce heat and carbon emissions
T8	Ant Colony Optimization (ACO) algorithm [9]	Cloud Computing environment	1. Improve data center efficiency and increase revenue 2. Provide shorter execution time and lower energy consumption
T9	Distributed multi-agent (MA)-based VM allocation method [13]	Cloud computing systems	1. Greatly Reduce the energy cost of the system and migration cost 2. Excellent performance for resource management in cloud computing 3. Consume tolerable network traffic and minimize energy in real time
T10	Three-dimensional virtual resource scheduling method (TVRSM) [16]	Data centers	1. Provide more efficient virtual resource allocation and management 2. Effectively minimize energy consumption

TABLE II
METRICS CONSIDERED BY EXISTING TECHNIQUES IN CLOUD COMPUTING

Techniques	Overall performance	Response time	Scalability	Overhead	Fault tolerance	Resource utilization	Energy Consumption	Carbon Emission
T1	✓	✓	×	✓	×	×	×	×
T2	✓	✓	×	×	×	×	×	×
T3	✓	✓	×	×	×	✓	×	×
T4	✓	×	×	×	×	✓	×	×
T5	✓	×	✓	✓	×	×	×	×
T6	✓	×	×	×	×	✓	×	×
T7	×	×	×	×	×	×	✓	✓
T8	✓	×	×	×	×	×	✓	×
T9	×	×	×	×	×	✓	✓	×
T10	×	×	×	×	×	✓	✓	×

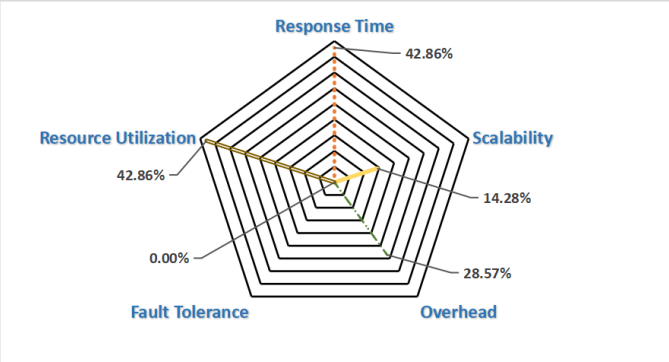

Fig. 2. The percentage of techniques that affects different metrics.

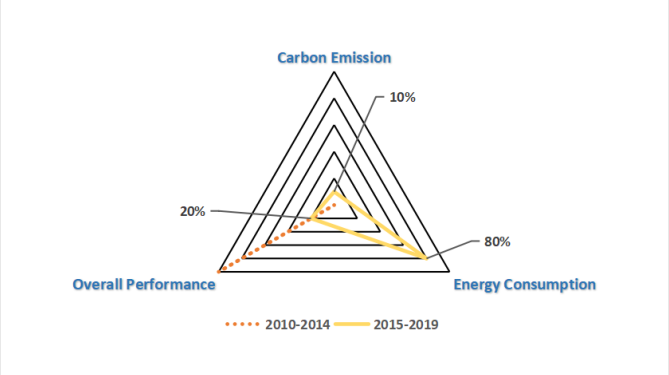

Fig. 3. The technical focus at different period.

focused on improving the performance and service quality of cloud computing. As the amount of energy consumption increases, techniques are being asked to be more energy-efficient and environmental. More and more techniques have been proposed to reduce energy consumption and carbon dioxide emissions. This phenomenon indicates that the development tendency of cloud computing is to be more efficient and greener.

V. Conclusion

Green cloud computing is more and more valued by people and needed by reality. With the help of different techniques, greener and more environmental cloud computing can be achieved. Although existing techniques improve the quality of cloud services, they still have limitations and shortcomings. In the future, the development of cloud computing should place emphasis on both environmental capabilities and higher performance. While ensuring efficient cloud services, reducing energy consumption and carbon emissions are the keys to implementing green cloud computing.

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