Green Cloud Computing: A Review

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ABSTRACT
Cloud computing has revolutionized the way large data is stored and handled by the virtualization of servers and data centers to make them more efficient. However, these IT resources consume huge amounts of power and energy, ultimately becoming a vital source of CO2 emission. This has brought upon the need for Green Cloud Computing to make IT resources both energy efficient and operating at a low cost. In order to reach optimal solutions for green cloud computing, the power efficiency of the Cloud needs to be thoroughly analyzed. The aim of this review is to underscore some of the most effective ways to achieve green cloud computing such as scheduling, clustering, virtualization, proportional computing, and other energy conserving methods. Although the environmental impact is high for green cloud computing, it still faces challenges with regards to security and connectivity.

General Terms
Green Cloud Computing, Cloud Computing, Clustering, Data Virtualization, Proportional Computing

Keywords
Approaches, Advantages, Disadvantages

1. INTRODUCTION
Cloud computing is a nascent technology that encourages productivity by enabling institutions to outsource different Information Technology services such as data storage services, computational services, and Enterprise Resource Planning services. The successful adoption of cloud computing depends on the efficiency of utility computing, the scalability of the processes, and the scope of IT outsourcing. It was reported by MacAfee, the antivirus company, that the transmission of the trillions of spam e-mails received everyday needs as much electricity as needed to power two million homes in the Unites States. This produces greenhouse gas emissions equivalent to that generated by three million cars. The increasing demand for environment-friendly operations and business procedures has seen a number of innovations that focus on the development of technologies that provide services that not only boost the performance but also ensures the environmental sustainability. The development and adoption of green cloud computing help in the reduction of institutional carbon footprint and improve the image and public profile of the organization. Therefore, from the economic point of view, most of the consumers who are concerned with the conservation and management of natural resources would want to associate themselves with products that preserve the environment. This would allow the individuals to act as brand ambassadors of such products, thereby boosting the sales and profitability of the company [1].

This review provides a brief background on cloud computing and green cloud computing followed by approaches` to achieve green cloud computing. The advantages and disadvantages of green cloud computing are also highlighted in this paper. Finally, the conclusion offers a recap of the approached and focal points of the review.

2. BACKGROUND
The increasing computational demand coupled with the massive growth in the demand for data storage requires the use of green computing systems, which produces ultimate and pressing ways of virtualizing different servers along with data centers to execute energy efficient processes. Green cloud computing systems also offer solutions to other forms of Information Technology (IT) Systems. For example, IT systems that rely on the manual and dialogue operational platforms to execute different managerial as well as administrative functions help in enhancing the productivity of the institution [2]. The use of green cloud computing is an improvement on the analog cloud-based infrastructure, which was previously used in reducing the carbon footprint of companies.

Green cloud computing functions focus on providing energy utility efficiency, resource efficiency, clean energy sources, and product lifecycle management. These quality services are achievable through a number of procedures and operational strategies such as the virtualization of the institutional resources. This allows the institutions to run and manage their resources from a single physical server that runs multiple operating systems and digital interfaces across different departments of the organization. The adoption of virtual resources help in reducing the physical server footprint and encourages the inherent of eco-friendly benefits. For instance, the reduction in the number of equipment, which is needed in running different institutional activities proactively, cuts down the data center space. This leads to the eventual reduction in electronic-waste footprint [3].

Green cloud computing also promotes multitenancy, which allows different branches or departments within the organization to access and use a common cloud-based system simultaneously. This boosts the performance of the institution while eliminating the potential wastages that may arise during working hours. In addition to that, it helps in the realization of energy-efficiency along with achieving sustainability goals, which are critical in the management of natural environmental resources. The usage of such a technology also improves the social well-being of the workers as they no longer have to work long hours and in confined workstations since most of the operations are done virtually. This is a boost in the workforce morale which translates to increased productivity [4].

3. GREEN CLOUD COMPUTING APPROACHES

The importance of data processing and storage has increased during the past decade. Companies and individuals have integrated their storage and work functions with cloud services. Cloud computing depends on sharing computing resources rather than having to build and maintain local servers. Unfortunately, the prevalence of cloud computing raises the global energy consumption and CO2 emissions. Which brings the need for energy efficient Cloud Computing to reduce CO2 emissions known as green cloud computing. Below are a few techniques to do that.

3.1 Scheduling of Workloads

Scheduling of workload is an approach that applies queuing theory principles. Workload across servers is allocated to a server as a function of their cost to operate. This method uses the relationship between three factors: packet arrival rate, service rate and response time to reach the maximum utilization. An exponential relationship was developed between power cost and server to select which server improves efficiency. This mechanism is presented to manage and allocate jobs between servers to achieve server utilization [5].

3.2 Clustering

Another approach to green cloud computing that provides energy efficiency is to embed a cluster computing system. A cluster system is made up of independent computers connected together via networks with high-speed. Clusters are able to handle complex and large computations by simultaneously working on multiple computers on the same problem or a portion of it [6] [7]. Cluster systems are capable of competing with the performance of supercomputers at lower costs [8].

3.3 Data Virtualization

Cloud computing uses a set of flexible technologies which can serve well with the presence of virtualization; however, cloud computing is possible without virtualization although extremely complex [9]. Virtualization is a common technique that utilizes resources efficiently. It is a software used to run multiple applications by operating systems on a single server in parallel. This method helps to minimize the physical infrastructure and therefore the operating cost. Virtual Machine (VM) migration allows the ability to adapt the placement of VMs and move the VM from one physical server to another for the purpose of increasing efficiency. There are several techniques for applying VM migration with the major one being Pre-copy which is composed of three phases: Pre-Copy Phase, Pre-Copy Termination Phase and Stop-and-Copy Phase. This mechanism is done in multi-rounds as shown in figure 1 [10].

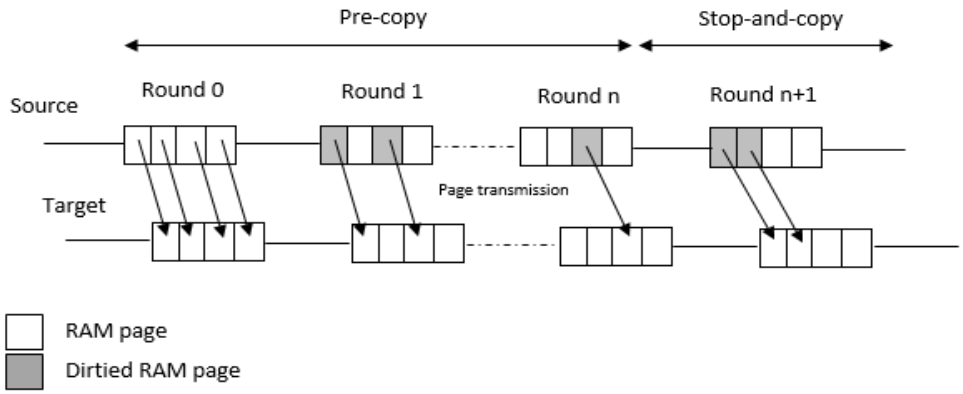

Figure 1: Live Migration algorithm performs memory transfer page wise in several rounds

3.4 Proportional Computing

Proportional computing takes into account the power consumed in relation to the entire system to find the rate that ensures its optimal productivity. This can be applied to the network protocols in addition to the system and its components to achieve better performance and utilization [11]. An example of proportional computing is Dynamic Voltage Scaling which is a management technique that increases or decreases the voltage based on the components' requirements. Another example of proportional computing is Adaptive Link Rate which has the potential to save substantial energy by dynamically changing data rate of links based on the traffic level.

3.5 Renewable Energy and Power Consumption

Using renewable energy produced from natural resources such as wind, hydropower, or solar is a promising approach for reducing CO2 emission. The data center is both supplied with electricity to run its functions as well as cooling its system components [12]. On the other hand, the cooling system and lighting equipment used in data centers exhaust around 35% of the power produced by the data center. This emphasizes the need for a change in methods of temperature distribution as well as efficient methods to reduce the waste generated by airflow [11].

4. ADVANTAGES AND DISADVANTAGES OF GREEN CLOUD COMPUTING

Among the highest priority objectives at companies are to reduce cost and minimize the size of its data centers without affecting the efficiency of services or the security of data. This can be achieved by using Green Cloud Computing technique which allows the ability to access applications and data without the need to purchase equipment or built data centers. Moreover, large organizations and companies that spread over many countries have information which needs to be available at all times throughout their offices. The only way to achieve this is by keeping many copies of the data at many servers which will ultimately cause the duplication of data; this can be avoided by using green cloud computing. Another benefit of Green Cloud Computing is that it will reduce power consumption and carbon dioxide emission by the reutilization of energy in an efficient way [13]. Finally, green cloud computing reduces the environmental impact by storing the information in digital format on the Cloud which will eliminate the physical counterparts and the storage devices since all the data will be available all the times on the Cloud with data centers using green cloud computing methods [14].

Green cloud computing faces a number of challenges which compromise its adoption among users from different backgrounds. The first challenge is that many public and private institutions are concerned over the security of cloud-based services. This, in turn, discourages them from strengthening their data in such platforms. In addition to that, the reliability along with the availability of green cloud computing services is heavily dependent on connectivity with the internet and its steady power supply. Any interruption in connectivity or outages in power source may result in downtimes jeopardizing the productivity of business operations and exposing the system to hackers particularly if the cloud is private [15].

5. CONCLUSION

The purpose of this review is to emphasize the necessity of altering current cloud computing methods to achieve green cloud computing for the objective of reducing greenhouse emission gasses, conserving power, and reducing cost. There are multiple ways to achieve that; some of which are scheduling to reach optimal utilization, virtualizing to attain minimal cost and hardware usage, and proportional computing for maximum productivity. Other general approaches include generating electricity using renewable energy, cluster computing, and managing power consumption. Despite the advantages of green cloud computing, it still encounters challenges of security and the need for connectivity. The search for new cloud computing methods continue to prevail the world of data centers. Methods not mentioned in this review include algorithmic approaches that utilize resources more efficiently causing less power consumption and increased productivity.

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