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Survey of State-of-Art in Green Cloud Computing

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ABSTRACT

Cloud computing is witnessing tremendous growth at one time when climate change and reducing emissions from energy use is gaining attention. With the growth of the cloud, however, comes an increase in demand for energy. There is growing global awareness about reducing greenhouse gas emissions and healthy environments. Green computing in general aims to reduce the consumption of energy and carbon emission and also to recycle and reuse the energy usage in a beneficial and efficient way. Energy consumption is a bottleneck in internet computing technology. Green cloud computing related technology arose as an improvement to cloud computing. Cloud data centers consume inordinate amounts of energy and have significant CO2 emissions as they have a huge network of servers. Furthermore, these data centers are tightly linked to provide high performance services, outsourcing and sharing resources to multiple users through the internet. This paper gives an overview about green cloud computing and its evolution, surveys related work, discusses associated integrated green cloud architecture – Green Cloud Framework, innovations, and technologies, and highlights future work and challenges that need to be addressed to sustain an eco-friendly cloud computing environment that is poised for significant growth.

KEYWORDS

Cloud Computing, Eco-Friendly, Green Cloud Computing

1. INTRODUCTION

To know what Green Cloud Computing is let's split the words and understand the meaning of each word. The word "Green" implies living friendly to the environment and contributing towards maintaining ecological balance and preserving the planet and its natural resources. The word "Cloud" is used as an analogy for network of

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servers accessible over the internet that provides a service to its users. So green cloud computing refers to use of computers and relevant resources in an environmentally responsible manner through implementing energy efficient computer systems and their peripherals (Rouse, 2010).

It is known that global warming emitting greenhouse gases and other toxic gases are harmful to mankind and the environment. Moreover, human activities like burning of coal, natural gas and oil causes emission of more greenhouse gases results in change in climate and average temperature of the atmosphere. On the other hand, IT technology keeps advancing and is extensively used globally due to the tremendous growth of the internet in the past decades. Industries like medical, telecommunication, business, and financial are predominantly dependent on applications that are developed and serviced by information technology systems.

The demand for internet bandwidth has been accelerated by the advent cloud computing technology. Cloud computing is helpful in providing services like software, infrastructure, and platform to its clients in an efficient manner. The cloud computing network provides a shared infrastructure which includes large data centers to store and service the client's data. Energy consumption is the key concern in distributed cloud computing systems. This cloud's cooling system consumes more energy and power and results in major energy costs and high carbon emission.

It makes sense to save energy and recycle or reuse as much as possible for the wellness and preservation of the environment. Lot of research is going on in every field to make the environment pure and healthy. Safety measures have also been taken by many organizations to support eco-friendly environment. Nowadays industries and companies in various fields like science and technology, medical, manufacturing, research etc. have started transforming their innovations and developments towards green technology. Because of the utilization of inordinate amount of energy in cloud computing, it has become a necessity to find a way for reducing energy consumption and promote reusability. Green cloud computing technology has evolved to fill this need.

Green cloud computing aims in reducing energy utilization and promote a sustainable and eco-friendly environment in cloud computing field. This paper discusses how green cloud computing plays a vital role in reducing energy usage and carbon-di-oxide emissions in the cloud data-center setting.

The remaining sections in the paper are organized as follows, Section 2 will discuss about the introduction to cloud computing technology Section 2.1 is about green cloud computing and section 2.2 is its relevant terminologies. Section 3 is about Literature Survey. Section 4 describes about the list of organizations that supports Green Cloud Technology. Sections 5, 6, 7 and 8 will discuss about the study of the latest architecture – Integrated Green Cloud Computing, simulators, and algorithms of green cloud computing technology, benchmarks and the challenges it faces towards sustainability in environment. Lastly, Section 9 will discuss the conclusion and future work that can be done to improve this technology to a greater extent.

2. CLOUD COMPUTING

The ideas and concepts behind cloud computing have existed for many years. It was started in 1950's along with mainframe computing. In the 1970's virtualization concept was created in which one or more operating systems can execute simultaneously in an isolated environment. In the early 1990's, telecommunication companies were offering virtualized private network services to its users. In the late 1990's the term "cloud" signifies the computing space among provider and end user. Later on the cloud providers like salesforce.com, amazon.com, Google gained the major internet marketplace and proved the power of cloud computing to the real world.

According to United States National Institute of Standards and Technology, Cloud Computing is defined as "A model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction". Cloud computing is used in one's personal as well as business life. It is widely used by major corporations like Amazon, Google, IBM, Sun, Cisco, Oracle etc., Social networking websites, email services, backup services, banking and financial services, health care and governmental agencies all use cloud computing.

Cloud computing is offered as different types of services like Software as a Service is commonly represented as SaaS, where the end user applications run on a set of pooled hardware resources and are accessed over the network; Platform as a Service is commonly represented as PaaS, a set of application components is offered by the service providers are used by developers put together into applications; Infrastructure as a Service is commonly represented as IaaS which subcontract the equipment that comprises of hardware, servers, storage, and networking components to support operations.

Cloud computing systems are characterized by on request self -service computing capabilities, wide network access on different platforms, multi-tenant model to serve multiple customers with hardware and simulated resources that are dynamically allocated and reallocated based on customer request, elasticity to scale up or down the services, and automatically optimized and which control the resource usage through measured service capability. Many IT companies and global brands like Amazon, Facebook, and Google are rapidly transforming their way of work, communication, sharing pictures, watching television, listening music to "cloud" systems in order to benefit the great services cloud offers. The cloud development and investment scale is very significant and it is been estimated that almost a 50-fold growth in digital data by 2020 and almost half a trillion in investment in the future years, all these are evident to generate and nourish our need for abundant access to endless information from our computers, laptops and mobile devices, rapidly (Cook, 2012).

2.1. Green Cloud Computing

The cloud data center consists of thousands of servers to store and manage the rapidly growing data and these consume tremendous amount of electricity equivalent to the

electricity consumption of nearly 180,000 homes. For example, the datacenters in Amazon on a 3-year amortization-schedule estimated to be about 53% of the total budget on cost and operation payment of the servers, 42% on energy related costs, approximately 19% through power usage and cooling infrastructure and amortized over a 15 year period estimated to be about 23% on cooling infrastructure (Hamilton, 2009). Thus, we need to increase energy efficiency in cloud data centers to contribute to greater environmental sustainability. With the advent of Green Cloud technology it is possible to achieve better energy efficient and eco-friendly environment.

Green cloud computing is facing lot of challenges these days and research is going on in at various levels to attain energy efficiency and reduce power consumption in cloud computing architecture. The application level (SaaS) is focused on deploying the software on accurate infrastructure to ensure it executed efficiently, less energy consumption and good performance on many platform and hardware. The infrastructure level is focused on planning and resource management to reduce the workload that execute the user applications of active resources. Virtualization technique plays a vital role in this level.

At the datacenter level, many fine practices are proposed to improve efficiency by building energy effective datacenters. Many best practices has been recommended to improve efficiency from electrical to processor level of individual device (Garg and Buyya, 2012). It includes constructing the data center by selecting a smart location, cooling systems to consume only 33.33% of overall energy consumption, power efficient servers and processors to be deployed in the datacenter and to design energy efficient power supply unit. At the monitoring/metering level, to construct a power model to determine the energy consumed by a particular device and to reduce the consumption. Green Grid proposed two metrics called Datacenter Infrastructure Efficiency (DciE) and Power Usage Effectiveness (PUE) (Rawson et al., 2008) to measure efficiency and improve performance of the datacenter's. At the network infrastructure level, the focus is on either node level or infrastructure level to achieve energy efficiency.

2.2. Relevant Terminology

This section lists the common terminology used in cloud or green cloud computing technology.

- **Computer Recycling:** A process in which equipment is broken into smaller pieces to recycle back the computer components easily. Recycling components include leaded glass from the cathode ray tubes, gold, copper, silver, tin ores and wires.
- **Green Computing:** It aims in reducing the usage of hazardous materials in computers, lower the energy consumption, maximize the new computers output, and recycle older computer parts to keep them out from landfills.
- **Electronic Waste:** It consists of discarded computer / electrical equipment. These wastes need to be recycled as they are harmful to environment.

- **Hibernate:** It is a feature of the operating system where the RAM is written to non-volatile storage before system power is turned off. The system can be restored without any break with exactly the programs that was left as before to work. Hibernating and restoring from hibernation is usually faster than normal system shutdown and reboot.

3. RELATED WORK – LITERATURE SURVEY

Saurabh et al in (2012) discuss that to achieve energy efficiency a detailed analysis on cloud related to their power efficiency is required and how these solutions draws a conclusion that directs to enable green cloud computing. Green cloud computing was enabled to provide solution to network contribution via Green Cloud Architecture which considers user's and provider's aspect to make green. In this architecture the greenest cloud provider is selected through a middleware green broker to service user's request. The framework's efficiency is validated using 5 policies including Greedy Minimum Carbon Emission, Minimum and Minimum Carbon Emission, Green Maximum Profit, Maximum Profit Maximum Profit and Minimizing Carbon Emission and Maximizing Profit and proved to be efficient with carbon emission. It is inferred that green policies reduces almost 20% of carbon emission and the usage of energy efficient solutions benefits both users and cloud providers. The paper concludes towards future direction to make green cloud reality with still many technological solutions like designing software at various levels, understanding the existing datacenter's cooling, power designs, energy consumption and resource utilization, design complete resulted in planning and resource provisioning for applications, and emerging technologies do not bring irreversible change and threat to human health society are required.

Qilin et al in (2011) discusses about finding a unifying abstraction in managing the tasks of hardware abstraction, resource allocation and operating system that needs energy awareness being integrated. Three major things approached in green networking are Re-engineering is to design more energy efficient components in network architecture. Dynamic adaptation aims in modulating the capacities of network device resources. The third approach Sleeping/Standby is used to select the idle portions to minimal standby mode and wake it up whenever necessary in the network. The paper concludes that in future many issues like metrics, benchmarking standards, green data and abstraction layers control; redundant devices support and management; virtualization and equipment in networks all requires investigation.

Mazedur et al in (2013) addresses and classifies the energy saving issues and challenges in mobile clouds and computing, reviews the current research techniques and outputs, examines their strengths and weaknesses, and identifies open issues for future research. The energy consumption issue during computation task is addressed by offloading computation to cloud and derive the amount of energy saved. In ad-hoc mobile cloud framework only small portion of task is executed locally and remaining is delegated to nearby mobile which already runs the same task. The cellular data rates are monitored periodically at a chosen interval in order to minimize the significant

usage of device energy. Catnap, an energy saving strategy accumulates the small intervals between packets to form large intervals when the device is sent to sleep mode without changing packets actual delivery time. EnaCloud approach uses energy aware heuristic algorithm to generate the application assignment and schemes scheduling in response to workload entry and exit, and alter the events size. The paper concludes that technology only focus on specific issues from one perspective and lacks saving energy with well-defined frameworks and solutions to address diverse green computing issues and needs in mobile clouds. The future research focus is on developing an innovative energy-saving infrastructure based on real-time analysis and intelligent decision-making.

4. ORGANIZATIONS

This section lists some of the organizations that help in regulating green computing in today's world-wide markets.

- **TCO Certification:** A series of accreditations and principles fixed up and maintained by TCO Development. These accreditations refer to monitors and high standards for computer equipment's, mobile phones, furniture's and additional electrical office tools.
- **Climate Savers Computing Initiative:** It comes under non-profit organization (NPO) consisting of customers, businesses, and other maintenance organizations are helpful in refining power efficiency, consuming less energy, and promoting smart technologies in computers.
- **Green Computing Impact Organization (GCIO):** It is a non-profit organization to support end clients and more responsibility towards environment with their products. It provides special services in auditing to help their users.
- **Green Electronics Council:** On the basis of 28-point criteria, different systems and components are evaluated to measure the efficiency of the product and its attributes.

5. INTEGRATED GREEN CLOUD COMPUTING ARCHITECTURE

The Green Cloud Framework was proposed as an integrated solution with the intention to reduce energy consumption in green clouds. Cloud is made green by considering users and providers aspect. With the help of green broker middleware, the software type cloud service request is submitted by the users. The greenest cloud provider is selected by the middleware broker to service user's request. The services are registered by cloud providers as green offers which need the access time for least carbon emission to a public directory and time being retrieved by green broker.

By using different cloud services and carbon emission directory, the present energy parameters status are received by green brokers (Kawade and Kapse, 2013). The entire data associated to energy efficiency is maintained in Carbon Emission Directory which

also includes Power Usage Effectiveness (PUE), network cost, cooling efficiency for datacenters, and emission rate of carbon in electricity. The carbon discharge value is calculated for all cloud providers and the service with the least value is selected by Green Broker and buys it as a representative of users.

To make the requested service "Green" the complete energy utilization and efficiency of each cloud provider that depends on carbon emission directory and green providers components are kept track by Green Cloud Framework. In the cloud providers aspect each cloud layer should be conscious about "green" and in user's aspect serving a user is a crucial role where the cloud services are selected and monitored on the basis of Quality of Service (QoS) requirements by Green Broker to ensure minimum carbon emission.

It becomes essential to ideal and amount the efficiency of energy design, operation and software deployment on behalf of SaaS service level providers. While serving users, only the least figure of copies of user private data should be retained by energy proficient storage. At the PaaS platform service level the developed applications should confirm wide energy efficiency in system by addition of energy profiling tools like JouleSort, a scale to measure vital energy to do external sort. The IaaS infrastructure service level providers offers both infrastructure and other support services and plays an important part in accomplishment of green architecture. They design various green offers and incentives to users using the service throughout the off-peak hours of energy efficiency.

6. STUDY ON GREEN CLOUD SIMULATORS

These simulators were developed in recent years to make cloud data centers energy efficient. This study discusses the features of different energy efficient green cloud simulators available namely, GreenCloud, iCanCloud, CloudSim and Cloud Reports.

The *GreenCloud Simulator* is an extension to packet-level network simulator Ns2 and offers a finely tuned energy consumption model by the elements like server, switches and links of the data center. The user demands need to be satisfied by transforming the received power to computing work. Server element uses varied job scheduling mechanisms extending from simplest round-robin to advanced Dynamic Voltage and Frequency Scaling and DNS supported, preset processing power limit and memory or storage resources size to implement single core nodes. The execution of workload is performed by delivering the load to one of the computing servers through interconnection fabric in an appropriate way using switches and links elements of data center. Each workload object execution requires the computational and communicational components for its successful completion. The comparison study done on different data center architecture based on setup composed of 1536 computing nodes employed energy-aware "green" scheduling policy for the incoming workloads arrived in exponentially distributed time intervals (Kliazovich et al., 2010). The policy aimed at grouping the workload together on a least possible set of computing servers allowing idle servers to be put into sleep. The dynamic shutdown showed effective result on both servers and switches energy efficiency.

iCanCloud is a new simulator with features such as elasticity, performance and scalability of cloud infrastructures. It is made based on the following design principles: target to conduct large experiments from literature, offers stretchy and wholly modifiable universal hypervisor for incorporating any cloud brokering rule, creation of instance type replica's as delivered by cloud setup, and lastly, it has a user-friendly GUI for organizing and initiating simulations (Nunez et al., 2012).

CloudSim is a popular simulator for cloud parameters, free and open source software based on Java code library. It provides the features like, an autonomous platform for service brokers, provisioning policies and model large-scale clouds; support and maintenance for simulation of computing environments and network connections; ability for simulation of combined cloud environment and experimentation studies linked to Cloud-Bursts and spontaneous application scaling (Calheiros et al., 2010).

CloudReports, a realistic tool to simulate scattered computing settings created using Cloud Computing pattern which uses CloudSim's simulation engine and offers easy access of graphical user interface, providing report information and design of extension plugin (Gupta, 2013).

7. STUDY ON GREEN CLOUD ALGORITHMS

This section lists some of the algorithm studied related with green cloud computing.

- *Green Genetic Algorithm* is a search heuristic based on genetic operations used for generating solutions to optimization and search problems. Two algorithms Critical Path Genetic Algorithm to minimize total execution time and Task Duplication Genetic Algorithm to deal with load balance satisfaction and to overcome communication overhead was developed. The Improved Genetic Algorithm was developed to make use of the computing resources to complete the tasks in shorter time period and reduced costs. It includes chromosome encoding and decoding, production of the initial population, fitness function, and genetic operations: selection, crossover and mutation (Nirubah and John, 2014).
- *Improved Clonal Selection Algorithm (ICSA)* will regulate the complete distribution of resources. As a pre-process, relationships are mapped into binary codes as a set of initial population X (0) and every individual i.e., antibody represent a binary series of characters of bits among tasks and resources. The length of the bits is used to get solution for the problem. The resource allocation process in ICSA evaluates the attraction of each antibody and the one with higher attraction is taken for subsequent generation. The selected antibodies are multiplied and replicated in the current population and then executed to mutation operation which produces a mutant individual. By this way, the worst antibodies are replaced best antibodies from the clonal library (Shu et al., 2014).
- *Green Scheduling Algorithm* used neural network predictor to address the shortage of energy problem and global climate change. It uses four different running modes

namely, optimal, conventional, prediction and prediction plus 20% additional servers mode to predict the future load demand.

Six new algorithms, namely Shortest Task First for Computer with Minimum Energy and Random Computer, Longest Task First for Computer with Minimum Energy and Random Computer, Random Task for Computer with Minimum Energy and Random Computer are developed to reduce the pollution and lower energy consumption.

Two traditional heuristic task scheduling algorithms - Shortest and Longest Task First for Computer with Minimal Energy First with Maximum Speeds and two new green task scheduling algorithms – Shortest and Longest Task First for Computer with Minimum Energy First with Speed Adjustment are evolved to minimize energy consumption in multi-task scheduling problem. Six energy-efficient task scheduling algorithms with continuous speeds, discrete speeds and hybrid algorithms are developed to conserve maximum energy (Nirubah and John, 2014).

- *Green Algorithm* is an effective way used for short and long terms to consolidate the tasks to manage clouds. In short term, the volume flux is handled by decreasing the live resources count and inordinate to a power saving mode or switching off systematically and in long term, cloud providers create an improved model to facilitate power and resources to lower the burden due to excess of provisioning. The two energy conscious algorithms used in power management are Maximum Utilization, and Energy and Task Consolidation (Yamini, 2012).

8. BENCHMARKS

This section lists the benchmarks used in green cloud computing that are helpful to make the cloud performance easy.

Perfkit is a living benchmark framework intended to develop through cloud technology variations and measures the latest workloads and makes knowledgeable decisions that matches infrastructure needs. New design tools, patterns and providers arise to keep it up-to-date (Google Cloud Platform Performance Team, 2015).

Grid'5000 similar to a benchmark is a large-scale, versatile test bed used to perform research experiments focusing on parallel and distributed computing which includes Cloud, High-Performance Computing (HPC), and Big Data (Grid'5000).

9. CONCLUSIONS AND FUTURE WORK

Cloud Computing has made tremendous impact to how business and companies leverage on computing technology. Green Computing has been evolving and makes amends on improving technology. There have been innovations, changes in architecture, simulators and other energy-efficient algorithms that are trying to help computing

environment friendly. Green Cloud is one such, where it makes cloud computing friendly to our ecosystem.

The future of Green cloud is still evolving, with more work towards green computing and efficient algorithms. Green cloud is not a distant reach, new techniques will come out which is not only energy efficient but also efficient carbon emission usage. Cloud providers should reduce the demand of electricity in clouds and shift to using renewable energy sources for servicing.

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