A Brief Survey on Benchmarks and Research Challenges for Green Cloud Computing

Yashwant Singh Patel
Dept. of Computer Science
CDGI, Indore, Madhya Pradesh, India

Kalash Jain
Dept. of Computer Science
CDGI, Indore, Madhya Pradesh, India

Surendra Kumar Shukla
Dept. of Computer Science
CDGI, Indore, Madhya Pradesh, India

ABSTRACT
With the fastest escalating development of large data storage and high performance computational demands raise the necessity of Green Cloud Computing. The green cloud computing has produced lots of solutions that can not only make the cloud resources energy efficient but also minimize the cost during operations. It refers to the learning of techniques and practices to make the efficient use of computing resources in an economical and effectual way. To measure the performance of green cloud computing has led the requirement of performance metrics in the form of benchmarking. In this article a survey is presented on the key research challenges for assimilation of benchmarking techniques in the area of green cloud computing. To measure the performance, taxonomy of benchmarks is also represented.

General Terms
Cloud Computing, Green Computing etc.

Keywords
Cloud Computing, Green Computing, Benchmarking, Performance Evaluation, Green-cloud, and Energy-saving.

1. INTRODUCTION
In the last few decades Cloud computing is named to be an emerging technology to provide the data centers and servers to satisfy the huge demand of customers. Its pay-per-use model is not only satisfying the demands of cloud users but also benefiting the small and medium enterprises while using the faster cloud resources in cheapest rate. It exhibits the numerous data centers that are deployed in different geographical areas around the world. To deliver the services of cloud computing the various big IT companies like Amazon, Google, eBay operates the large number of data centers. To run these data centers a huge amount of power is needed. Therefore to reduce the consumption of power and to make the energy-efficient cloud resources the use of green technology is become a primary purpose for both the government as well as for the well developed IT industries. The purpose of green computing is to provide a large amount of practices and methodologies to deal with the IT related environmental issues in an efficient manner. To measure the efficiency of cloud computing resources like data centers, farms of servers, networking devices, cooling technologies etc. the different kinds of benchmarks are defined and given by the various researchers.

Therefore, the purpose of this paper is to review the benchmarks for green cloud computing. Apart from the study of benchmarks it also reviews the key challenges and the application areas to create the green cloud computing environment. This study will not only help the eminent researchers to identify the key challenges and areas but also provide a proper list of benchmarks to identify the efficiency of cloud resources.

The rest part of this paper is structured as follows: In next section an overview and framework is presented on Green Cloud Computing. In section 2 the key research challenges are discussed to make a suitable environment for green cloud computing. In section 3, a survey is presented on the study of benchmarks to identify the performance of cloud resources. Finally, the conclusions are drawn in the last section of this paper.

2. GREEN CLOUD COMPUTING
To keep the momentum of on demand computing, the IT industry has now focusing on efficient development and deployment of services and resources. In this global era, the most promising technology i.e. Green computing defines to the efficient use of IT resources to satisfy the goals of energy saving. These goals will not only make the IT resources more efficient but also enhance the overall performance of system. The prime motivations behind the Green Technology are:

1) In software aspect the prime motivation is to improve the efficiency of a program.
2) In hardware aspect the secondary motivation is to reduce the energy consumption by using the methodology of recycling [1] [2].

2.1 Adoption of Green Computing Practices
With the digital growth, the IT industry has focused on the growth and use of IT products and services to satisfy the raising demands of business consumers. Due to this the following factors are impacting the IT industry and coercing the adoption of Green Computing practices [3]:

1) Rapid growth in the size and scale of data centers
2) Advancement in CPUs
3) Energy Cost
4) Server utilization
5) Impact on the environment.

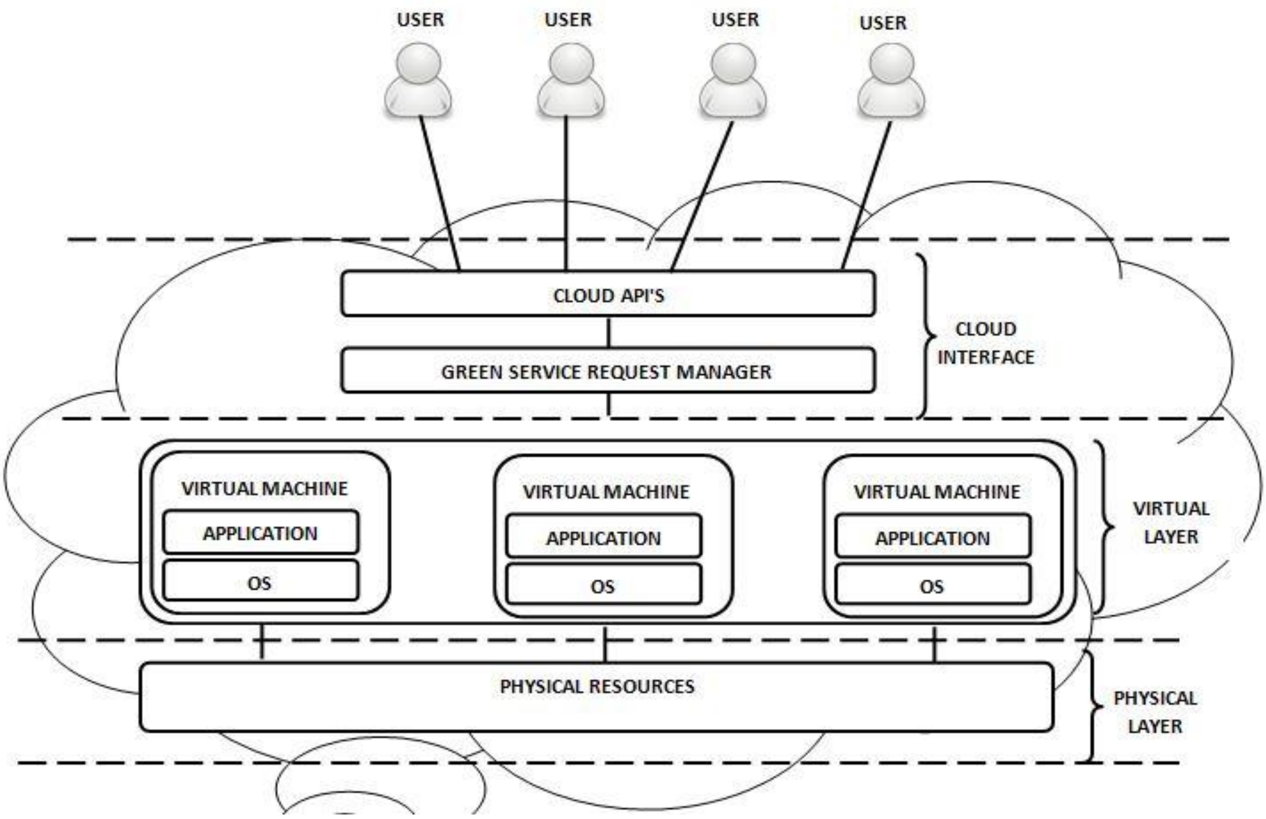

Fig 1: The Green Cloud Computing Framework

2.2 Framework for Green Cloud Computing

Fig.1 depicts the basic Green cloud computing framework [4][5][6][7] to provide energy efficient services to the cloud users. There are mainly four components as described below:

a. Users/Brokers: At uppermost layer the cloud users/brokers request for services from anywhere around the world. APIs provides the facility to store VM images and source files for web server components.

b. Green Service Request Manager: It provides an interface between the cloud users and cloud infrastructure. It handles all the requests generated by the cloud users and supports the energy efficient resources. It also uses various scheduling schemes [8] for distribution of virtual machines [9].

c. Virtual Machines: Commonly known as Virtual appliances it includes software to create and deploy the applications. VMs are used to handle the service requests at the virtual machine layer.

d. Physical Machines: The lowest layer exhibits the physical objects or resource instances to map the services to particular machine so that the computation of the particular task can be performed.

3. RESEARCH CHALLENGES FOR GREEN CLOUD COMPUTING

High-performance parallel and distributed computing environment not only consume substantial power but also entails the need of system cooling by air conditioning mechanism. Such exponential growth in computing is rapidly increasing the utilization of valuable natural resources which will soon the lift up the shortage of energy resources. In recent times, the researchers have indicated their impact and measurement. But still there are many areas are yet needed to be explored.

In this section some key research challenges are discussed in Table I.

4. GREEN CLOUD COMPUTING BENCHMARKS

With the advancement of technology, where the cloud computing resources are being remotely controlled by the service providers It is necessary to provide the energy efficient services while maintaining the cost. To keep such performance tradeoffs various benchmarks were introduced previously to measure the rate of power consumption, energy efficiency, resource utilization etc. at the level of system, data centre and server.

These benchmarks are listed with their brief formulation, level of usage and application discipline in Table II.

5. CONCLUSION

From the past few decades, to sustain the IT resources has been a major research area for IT organizations. With the increasing demand of large data storage, the new challenges are coming with the future computing innovations and applications. Each and every research challenge comes with a new requirement of efficient computing in different areas. Therefore, it is necessary to use a good strategy so that the cloud computation devices can be made energy efficient. Here comes the need of benchmarks for green cloud computing. This study gives a brief discussion on the benchmarks and research challenges for green cloud computing. Firstly, a taxonomy of various performance metrics are explored in Table I to analyze the performance of Cloud Computing resources of benchmarks Secondly, a brief assessment on the key research challenges is given for a planning of sustainable IT approach in Table II. In all over the world many researchers are engaged to design and develop green cloud computing resources and protocols. Therefore, It is to be believed that the research on this area will show a great support to improve the environmental and economical aspects while designing the energy efficient cloud resources.

Table 1. Key Research Challenges for Green Cloud Computing

Research Challenges	Description
Requirement of New Optimization Technique[10,11]	To achieve the objective of high performance, necessary tradeoffs between Energy and Temperature is required.
Minimize Architecture Complexity[12]	To reduce the dependency between the components so that the start-up power can be minimized.
Requirement of Efficient Data Centers [13]	Use of less IT equipments so that much more energy can be saved through large data centers.
Designing of Green Maturity Indexes [14]	To improve the degree of greenness there is a requirement of maturity indexes for IT equipments.
Cooling of Data Center [15]	To handle the power consumption rate of data centers, the sensor network can play a major role.
Green IT [16]	With the growth of IT industries the green software movement has become a wide research area. But still the organizations are needed to work together and take some good initiatives.
Performance deprivation [17]	Degradation in servers performance will increase the energy throughput and power consumption rate.
Platform management [18][19]	To deploy and maintain the applications in the scalable environment.
Server density	In data centers, more server density is required to run the cloud applications that higher the operating cost with respect to energy.
24 X 7 Cloud Services [20]	Due to global users, consistent power is required by Data centers
High Reliability [20]	Demands the reliable power supply
Dynamicity [20]	Automatic Power supply among multiple power sources
Cost-Efficiency[21,19]	To build less costly computation techniques
Virtualization of Servers [21,22,23,24]	To create measures for efficiency improvements and reduce the energy consumption by virtualization techniques.
Power Management [21,25]	Use of renewable energy in the resources of cloud.
Energy Efficiency [21,26]	To minimize the overall energy consumption rate
CO_2 Emissions [21][27]	Reduce the Co_2 emission rate from the cloud resources

Table 2. Taxonomy of Benchmarks for Green Cloud Computing

Benchmarks	Description	Formulation	Level	Domain
PUE [28][29][31]	Power usage Effectiveness	$\frac{Totaldatacenterenergy}{TotalITenergy}$	Data Center	Enterprise
CUE[28][29] [34]	Carbon usage Effectiveness	$\frac{Total\ Co2\ emission\ from\ data\ center\ energy}{IT\ equipment\ energy}$	Data Center	Enterprise
WU[28][29] [34]	Water usage Effectiveness	$\frac{AnnualWaterUsage}{ITequipmentenergy}$	Data Center	Enterprise
ERF[28][34]	Energy Reuse Factor	$\frac{ResuedEnergy}{TotalEnergyConsumed}$	Data Center	Enterprise
ERE[28]	Energy reuse effectiveness	$\frac{Total\ Energy - Reuse\ Energy}{IT\ equipment\ energy}$	Data Center	Enterprise
DCi[28][29] [31]	Data Center Infrastructure Efficiency	$\frac{IT\ equipment\ \ power}{Total\ \ facility\ \ Power}$ x 100%	Data Center	Enterprise
DCP[28][29] [33]	Data Center Productivity	$\frac{Usualenergy}{ITequipmentenergy}$	Data Center	Enterprise
ERP[28]	Energy Response time Product	Avg. Power Consumption Rate X Mean Customer Response Time	Data Center	Enterprise
ITEU [29]	IT Equipment Utilization	$\frac{TotalenergyofIT}{TotalspecificationenergyofIT}$	Data Center	Enterprise
TDP [30]	Thermal Design Power	Maximum amount of power needed for cooling of processor	Processor/ Data Center	Enterprise
PPW [32][37]	Performance per Watt	$\frac{Rate\ of\ Computation}{Power\ Consumption\ Rate}$	Any	Any
CPE [33]	Compute Power Efficiency	$\frac{IT\ equipment\ Utilization}{PUE}$	Data Center	Enterprise
GEC [34]	Green Energy Coefficient	$\frac{EnergyConsumed}{TotalEnergyConsumed}$	Data Center	Enterprise
DCEP[33]	Data Center Energy Productivity	$\frac{Usefulworkdone}{Totalresourcesused}$	Data Center	Enterprise
EDP [37]	Energy Delay Product	Energy X Delay	Data Center	Enterprise
Green Grid DCiE [37]	Data Center Infrastructure Efficiency	Percent of power that reaches IT equipment	Data Center	Enterprise
Green Grid DCPE [37]	NA	$\frac{Workdone}{Totalfacilitypower}$	Data Center	Enterprise
Energy Star: Workstations [37]	NA	Certify if “typical” power is less than 35% of “maximum” power	System	Enterprise
Energy Star: Other	NA	Certify if below a predefined threshold for the	System	Mobile, Desktop,

systems [35][37]		system class		Server
Energy Bench [35] [37]	NA	Throughput per Joule	Processor	Embedded
SWaP [36][37]	Space, Wattage and Performance	$\frac{Performance}{Space\ X\ Watts}$	System	Enterprise
TPC [37]	Total Power Consumption	$ cost of power consumed Kilowatts used	Data Center	Enterprise
JS[37]	Joule Sort	Records sorted per Joule	System	Mobile, Enterprise
Green Grid PUE [38,39]	NA	$\frac{Facility\ Power}{IT\ Equipment\ Power}$	Data Center	Enterprise
Carbon footprint Environmental Impact [40,41]	NA	Amount of CO2 emissions per product, service, process, facility, or organization	Any	Any
Device Utilization [42]	NA	Percentage of Computational Load beard by a device	Server/ Network	Any
CPU Utilization [42]	NA	Busy Clock Cycles/Total Clock Cycles	Processor	Any

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