Scrutiny of Energy Efficiency for Green Cloud Computing

Kriti Agrawal
National Institute of Technical Teachers' Training and Research, Bhopal

Abishi Chowdhury
National Institute of Technical Teachers' Training and Research, Bhopal

Priyanka Tripathi
National Institute of Technical Teachers' Training and Research, Bhopal

ABSTRACT
Cloud computing is very common today due to its various characteristics and benefits. It is cost efficient and thus very popular, but has great impact on environment such as increase in pollution, climatic changes and shortage of energy resources. Green cloud computing is important issue at present time. In this paper, the author have made critical observations of energy efficiency in all fields of cloud computing and briefly describe about various research that have been done for green cloud computing. The power and energy consumption of cloud services is also discussed.

Keywords
Green computing, Cloud computing, Datacenter, Power consumption, Energy efficiency;

1. INTRODUCTION
Cloud computing is the technology which provide resources as a service. The resources can be of any form i.e. networks, storages, servers and applications. It is based on pay-as-you-go model. There are various characteristics of cloud [1] –

1. On demand self –service
2. Broad network access
3. Resource pooling
4. Rapid elasticity
5. Measured service

There are three types of service models that cloud composed of –

1. Software as a service
   This service allows the users to control only limited user-specific application configuration settings.
2. Platform as a service
   This service allows the users to control over deployed applications and its hosting environmental configurations. To build applications it provides programming languages, APIs, and tools.
3. Infrastructure as a service
   This service provides users the infrastructure including storages, servers and networking in the form of virtual machine.

The deployment of cloud can be done in four ways. First is Public cloud in which services are available for everyone and anyone on internet. As it is for general public, it is known as public cloud. The services available can be free or can be purchased. Second is Private cloud in which services are available for single organization. It can be operated by only internal users. Third is Hybrid cloud which is the combination of the private and the public clouds. Fourth is Community cloud in which services are available for group of organization who share their infrastructure.

2. GREEN COMPUTING
Green computing [2] refers to environmentally sustainable computing whose goals are mainly to maximize the energy efficiency and reduce the use of hazardous material. According to Murugesan, green computing is the study of designing, manufacturing, using and disposing of computers, servers and peripherals efficiently with minimal impact on the environment.

The methods used for green computing are data center designing, algorithm optimization, virtualization and power management. In data center designing the energy efficiency can be improved by using energy-efficient equipments, enhanced cooling techniques, recycling of waste heat and on-site electrical generation. Algorithm optimization can be done by changing search algorithms from linear to binary, indexed or hashed to reduce resource usage and improve algorithm efficiency. Virtualization reduces energy demand by hosting multiple VM on small number of servers. Power management software controls power management by automatically switching off components such as hard drives and monitor screens after set period of idleness.

3. ENERGY EFFICIENCY
When we relate cloud with green computing, the question arises that whether cloud is green or not.

The research by Accenture [3] in 2010 has shown that moving business application to cloud can reduce carbon footprints of organizations. According to the report – Small business saves up to 90 % carbon emission. Mid-size business saves 60 to 90 % carbon emission. Large business saves at least 30-60 % carbon emission.

On contrary, in same year Greenpeace [4] observed that cloud lead to increase in problem of carbon emission and global warming and the reason given is collective demand of computing resources increases in few years and cloud providers are interested in electricity cost reduction than carbon emission reduction. The data collected is shown in Table 1 below and no datacenter can be said as energy-efficient by this report.

Table 1. Comparison of Cloud Datacenters

Datacenter	Effective Power Usage	Dirty Energy	Renewable Energy
Google	1.21	50.5% coal, 38.7% Nuclear	3.8%
Apple	1.21	50.5% coal, 38.7% nuclear	3.8%
Microsoft	1.22	72.8% coal, 22.3% nuclear	1.1%
Yahoo	1.16	73.1% coal, 14.6% nuclear	7%

The growth of cloud computing is increasing with time in IT sector. Thus impact of it on environment is important research field today.

4. LITERATURE SURVEY

4.1. Energy Management

Zhang et al. [5], presented the various research challenges in cloud computing. One of which is energy management in cloud computing. The energy efficient datacenters design is main concern. The directions to approach this are first energy efficient hardware architecture which consists of energy aware job scheduling and server consolidation. Second energy efficient network protocols and infrastructures.[6] [7] [8].

The key challenge in above methods is to achieve good trade-off between energy saving and application performance.

4.2. Green Cloud Computing and Environment Sustainability

Garg et al. [9], discussed various elements of cloud which contribute to the energy consumption and solutions for future research directions to lead towards green cloud computing. The elements in cloud consist of user device which pass data through internet service provider’s router, which is connected to gateway router within a cloud datacenter. Within datacenter, data goes through local area network and are processed on VM, hosting cloud services which may access storage server.

The Green Cloud architecture was proposed in which user submit their requests through a new middleware. It keeps the track of overall energy usage of serving user requests. It manages the selection of greenest cloud provider to serve the user requests.

Several unexplored areas that can help to increasing energy efficiency are –

1. Designing software at various levels that facilitate system wide energy efficiency.
2. Need to measure existing datacenter power and cooling design, power consumption of servers and cooling requirements and resource utilization to achieve greater efficiency.
3. Effective consolidation of VMs to minimize overall power usage of datacenter.

In conclusion, by simply improving efficiency, cloud will not turn green. It is important to make cloud usage more energy efficient both from user and provider’s perspective.

4.3. Metrics of Green Cloud Computing

Priya et al. [10], describes various metrics of cloud computing which makes it greener. The significant amount of energy and power is consumed by datacenter and some devices are responsible for carbon emission. The explored measures for energy efficiency:

Device utilization: % of computational load relative to the peak load specified.

CPU utilization: Ratio of time CPU is busy to the total time.

Power usage effectiveness (PUE):

PUE = Total facility power / IT equipment power

Green power usage effectiveness (GPUE):

GPUE = G * PUE, where G is weighted sum of energy sources and their life cycle.

Carbon usage effectiveness (CUE):

CUE = Total CO_2 emission / IT equipment energy

Datacenter infrastructure efficiency (DCIE):

DCIE = 1/PUE

4.4. Analysis of Energy Consumption

Baliga et al. [11], presented the analysis of energy consumption in data processing, data storage and transmission that consider both public and private cloud. The estimated per-bit energy consumption of transmission for private cloud is 0.46µJ/b and estimated per-bit energy consumption of transmission for public cloud is 2.7µJ/b. The conclusion is data transmission leads more significant energy cost in public cloud services than in private cloud. The energy consumed in processing is significant when both nature and frequency of data processing task show that there will be fewer users per server. Processing as service does not include long term storage in the cloud.

Table 2 provides a summary of the conditions in which energy consumption is significant in processing, storage and transmission for both private and public cloud services.

Using this approach author, shown that cloud computing can enable more efficient use of the computing power, especially when users computing tasks are infrequent and low in intensity. However, when each user perform whole computing on personal computer it will be more energy efficient than cloud computing. Even with advance cooling system and server virtualization, cloud is not always greenest computing technology.

Table 2. Conditions for Significant Energy Consumption

Energy Component	Transport		Storage		Processing	
	Public	Private	Public	Private	Public	Private
Software as a Service	high frame rates	never	never	never	few users per server	few users per server
Storage as a Service	always	high download rates	low download rates	low download rates	Never	high download rates
Processing as a Service	medium to high encodings per week	never	-	-	medium to high encodings per week	medium to high encodings per week

4.5. Overall Energy Consumption

Kaur et al. [12], discussed that the cloud infrastructure in which node refers to general multi-core server along with its parallel processing units, network topology, storage capacity and power supply unit. The overall energy consumption of cloud environment can be classified as follows:

$E_{cloud} = E_{node} + E_{switch} + E_{storage} + E_{others}$

Consumption of energy having n nodes and m number of switching elements expressed as:

$E_{cloud} = n(E_{CPU} + E_{memory} + E_{disk} + E_{mainboard} + E_{NIC}) + m(E_{chassis} + E_{linecard} + E_{ports}) + (E_{NASServer} + E_{storageController} + E_{diskArray}) + E_{others}$

One of the main things to reduce carbon footprints and electric bill of IT infrastructure is to increase energy awareness to providers and users.

4.6. Task-based Energy Consumption

Chen et al. [13], conducted experiment to analyze energy consumption in cloud computing based on three types of tasks: (i) Computation-intensive, (ii) Data-intensive and (iii) Communication-intensive.

The various test sets were made to analyze the energy consumption for each task mentioned above. The conclusion is for a specific type of task, many configuration parameters are associated like, the number of processes, the size of data to be processed, the size of data to be transmitted and all parameters affect the energy consumption of task. These parameters are linked to system configurations. Even with the same resource allocation, different system configuration results in different energy consumption.

4.7. Energy Analysis Tool for Cloud Applications

Chen et al. [14], present StressCloud which can automatically generate load tests and profile system performance and energy consumption data. The demonstration consists of the impact of system resource allocation strategies on system performance and energy consumption by creating heterogeneous VMs in the cloud system.

The correctness of the tool is evaluated by comparing result of StressCloud to manually obtained test result presented in [13].

StressCloud can be used by performance engineer to model an application workload. It can generate and run extensive tests and obtain energy and performance data for specific application model.

4.8. Energy Efficiency in Datacenters

Buyya et al. [15], presented the architectural elements for management of energy efficiency in cloud computing environment. The proposal consists of:

1. Architectural principles for energy-efficient management of cloud
2. Energy efficient resource allocation policies and scheduling algorithms that consider quality of service expectations and power usage characteristics of device
3. Novel software technology for energy management of clouds

The result demonstrated that cloud computing has potential as it offers significant gain in performance with respect to response time and cost saving under the dynamic workload.

4.9. Green Cloud Architecture

Beloglazov et al [16], presented the high level architecture for supporting energy efficient service allocation. The green cloud computing infrastructure [15] comprises of four entities

1. Broker/consumer
2. Green service allocator
    1. Green negotiator
    2. Service analyzer
    3. Consumer profiler
    4. Pricing
    5. Energy monitor
    6. Service scheduler
    7. VM manager
    8. Accounting
3. Virtual machine
4. Physical machine

Figure 1 shows the architectural framework of green cloud and process model is defined as:

$P(u) = k.P_{max} + (1-k).P_{max}.u$,

Here, P_{max} is the maximum power consumed when server is idle and u is CPU utilization.

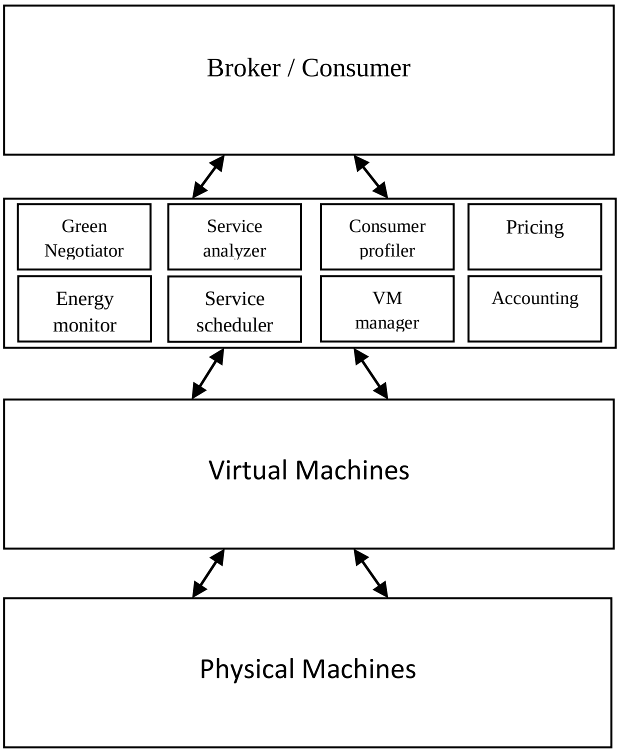

Figure 1.Green Cloud Architectural Framework

4.10. Mobile Device Perspective

Namboodiri et al. [17], presents an analytical model that help to characterize energy consumption of mobile devices under both cloud and non cloud applications. The author also presented a GreenSpot algorithm that can help mobile device determine whether it should run a cloud or non cloud version of any application, if the choice is available. The three applications used to compare cloud and non cloud environment are word document, multimedia and gaming. The results for all three types of applications is that cloud based applications consume more energy than non cloud based applications.

5. CONCLUSION

The author have discussed briefly about the energy efficiency of cloud computing. The survey of energy management of cloud computing, metrics of green cloud, overall energy consumption model and green cloud architecture is also done. Various researches have been there for green cloud computing and the work on reducing power consumption in datacenters is still in progress but cloud cannot be claimed as green. Cloud computing is accepted worldwide due to its cost efficiency but is it worth risking the environment.

In future the comparison of energy consumption should be done before switching from conventional to cloud computing. As it is said to improve something first we need to measure it. Thus there is need to focus on the energy investment caused by enduring cloud computing.

6. REFERENCES

[1] Mell, P. and Grance, T. 2009. The NIST Definition of Cloud computing, National Institute of Standards and Technology.

[2] Murugesan, S. (2008): Harnessing Green IT: Principles and Practices. IT Professional 10(1): pp. 24-33.

[3] Accenture Microsoft Report. 2010. Cloud computing and Sustainability: The Environmental Benefits of Moving to the Cloud,http://www.wspenvironmental.com/media/docs/newsroom/Cloud_computing_and_Sustainability_-_Whitepaper_-_Nov_2010.pdf.

[4] Greenpeace International. 2010. Make IT Green http://www.greenpeace.org/ international/en/publications/reports/make-it-green-Cloudcomputing/

[5] Zhang, Qi, Lu Cheng, and Raouf Boutaba. "Cloud computing: state-of-the-art and research challenges." *Journal of internet services and applications* 1.1 (2010): 7-18.

[6] VasicNetal(2009)Makingclusterapplicationsenergy-aware.In: Proc of automated ctrl for datacenters and clouds.

[7] Srikantaiah S et al (2008) Energy aware consolidation for cloud computing. In: Proc of HotPower.

[8] IEEE P802.3az Energy Efficient Ethernet Task Force, www. ieee802.org/3/az

[9] Garg, Saurabh Kumar, and Rajkumar Buyya. "Green cloud computing and environmental sustainability." *Harnessing Green IT: Principles and Practices* (2012): 315-340.

[10] Priya, Bhanu, Emmanuel S. Pilli, and Ramesh C. Joshi. "A survey on energy and power consumption models for Greener Cloud." *Advance Computing Conference (IACC), 2013 IEEE 3rd International*. IEEE, 2013.

[11] Baliga, Jayant, et al. "Green cloud computing: Balancing energy in processing, storage, and transport." *Proceedings of the IEEE* 99.1 (2011): 149-167.

[12] Kaur et al., International Journal of Advanced Research in Computer Science and Software Engineering 4(9), September - 2014, pp. 818-821.

[13] Chen, Feifei, et al. "Experimental analysis of task-based energy consumption in cloud computing systems." *Proceedings of the 4th ACM/SPEC International Conference on Performance Engineering*. ACM, 2013.

[14] Chen, Feifei, et al. "Automated analysis of performance and energy consumption for cloud applications." *Proceedings of the 5th ACM/SPEC international conference on Performance engineering*. ACM, 2014.

[15] Beloglazov, Anton, Jemal Abawajy, and Rajkumar Buyya. "Energy-aware resource allocation heuristics for efficient management of data centers for cloud computing." *Future generation computer systems* 28.5 (2012): 755-768.

[16] Buyya, Rajkumar, Anton Beloglazov, and Jemal Abawajy. "Energy-efficient management of data center resources for cloud computing: A vision, architectural elements, and open challenges." *arXiv preprint arXiv:1006.0308* (2010).

[17] Namboodiri, Vinod, and Toolika Ghose. "To cloud or not to cloud: A mobile device perspective on energy consumption of applications." *World of Wireless, Mobile and Multimedia Networks (WoWMoM), 2012 IEEE International Symposium on a*. IEEE, 2012.