Towards Green Cloud Computing: Impact of Carbon Footprint on Environment

Prof. Sanjeev Thakur
Amity University
Noida, India
sthakur3@amity.edu

Mr. Ankur Chaurasia
Amity University
Noida, India
achaurasia@amity.edu*

Abstract— **Latest research states that by the end of 2020 carbon emission footprints will increase by 20%. This emission is mainly taking place due to Data Centers used to achieve the cloud computing architecture. Data centers and new technology adoptions are mainly causing this carbon emission. These Data Centers uses cloud energy to serve the user generated request and this energy consumption is the basic cause of carbon emission. This paper is basically an attempt to look for the possible solutions which we can adopt to reduce the carbon footprints and produce a green cloud computing which will help the humanity in saving our environment.**

Keywords—cloud computing, cloud broker, SPI Model, Saas, Paas, Iaas

I. INTRODUCTION

The Cloud Computing can easily be explained as a variety of computing methodology that involves resource, rather than preparing local machines or personal machines to govern the requests and applications requested by the user.

Variety of Clouds:

A ***public cloud*** **(offsite location)** [2] describes a type of Cloud Computing in which cloud resources are provisioned dynamically on the web using web applications or web services, depending upon the request and demand.

A ***private cloud*** [2] generally belongs to an Organization. The organization might have a setup spread in a large amount of area. To share their resources among all the employees of that organization, we prefer to have a private cloud rather that making a public cloud. The public cloud can also be accessed outside the organization boundary. So a public cloud may work as a security breach for the organization.

A ***hybrid cloud*** [2] basically includes some properties of public cloud and some properties of private cloud i.e. it may contain some properties onsite and some offsite. By combining these properties we may we can make available those resources which are too costly to maintain. For example server backups like activities etc.

SPI Model

Software as a Service (SaaS) [1] SaaS is a cloud computing technology that enables us to provide software and other resources remotely over the web with an implementation of web based services.

- Calculation of bills depending upon the usage
- Follows multi tenant structure
- We can spread the structure up to wide extent

Accessing applications from the Internet (online banking, Gmail and Facebook etc.) – Used by End Customer comes under this umbrella.

Figure 1.1

Platform as a Service (PaaS) [1] enables us to share a platform on which the software and resources can run on. This platform will be shared among the users with the help of

Internet. Prime job of this sharing is to provide required facilities for various programs to help them to complete its life cycle.

- Platform based application should be developed
- Again it follows multi tenant structure

Infrastructure as a Service (IaaS) [1] is the phenomenon of sharing the infrastructure among the users. By infrastructure we mean like sharing hardware, storage media, networking hardware etc.

- Calculation of bills depending upon the usage
- Generally follows multi tenant virtual structure
- Efficiency of 24X7 up time.
- Prime property is easily can be embedded with Operating Systems to provide resourses

Figure 1.2

II. Cloud Computing and Environment Sustainability

Cloud computing is emerging as a technology which is helpful in providing cost efficiency, up to date software access, flexibility, potential and greener environment, and most important universal access. Apart from this, cloud computing also raising questions about the environmental sustainability. Due to resource sharing financial aspects are achieved a bit but still energy efficiency is still a matter of concern. [3] The problem can be resolved by using the Cloud computing implementing data centers which are largely shared but virtually. However this may cause few problems like data traffic over the Internet, day by day increase of information database etc. But this will also be helpful in terms of energy efficiency.

Energy Efficiency in Cloud Computing

Few technologies, in data center infrastructures, are investigated to solve problems occurring in Cloud computing, to make an energy efficient system without affecting the need and the environment. It was observed that how Cloud bases data centers are more effective and efficient in comparison with the traditional data center. As energy is a big factor these days hence an efficient solution for Cloud computing environment at various levels like Green Open Cloud [5, 6] and Green Cloud [4, 7] provides us a power efficient model which operates on data center level. Out of these, Green Cloud architecture is the most efficient not only in terms of energy efficiency, but also carbon emission aspect. To build an efficient data center infrastructure we need to understand the meaning of sustainability and the concept of cloud computing which is well efficient in decreasing the use of energy and the amount of carbon emission to provide a green environment provided the cost aspect should not be penalized.

Virtualization is a prime feature for Cloud computing to provide sustainability in terms of the energy efficiency and cost point of view. Virtualization enables us to perform the user request by reducing the number of working terminals or computer systems implementing it inside one computer with the help of software therefore this causes less energy consumption, less cost and less carbon emission as well. [9]

Virtualization technique is applicable for both cloud as well as traditional data centers. In case of traditional data center the concept of virtualization is optional hence we may or may not use it. But for Cloud computing virtualization the concept is highly significant in terms of energy efficiency, hence it's strongly recommended to use it. We have a freedom to virtualize each and every IT component like servers, switches, routers, LANs, storage media, desktops, applications, input and output modules and application delivery controllers (ADCs) and firewalls. Basically there are 3 main types of virtualization: i) server ii) desktop iii) appliances. All they are related among each other but we emphasis on server virtualization because it would be the most important form. The prime reason behind deploying this is cost efficiency and virtualizing machines dynamically among servers. [8]

Different Computing Models

- Traditional Application Server
- Virtual Server model
- Massively virtualized model (Cloud)

Merits

- Power and Space requirements are decreased drastically
- Server response time and performance is enhanced
- Eliminating incompatible application issues
- In terms of investments, returns are too fast
- Simplifying Backup and Recovery
- Enhancing Business Continuity
- Enabling Dynamic Provisioning
- Enhancing Security
- Providing a Logical IT Infrastructure

Data Centres

Data centers are the prime part of Cloud computing. In addition with this they are the most energy consumers within the cloud. Hence if we want to achieve our concept of Green Cloud Computing, we need to emphasize on the energy consumption held within the Data centers.

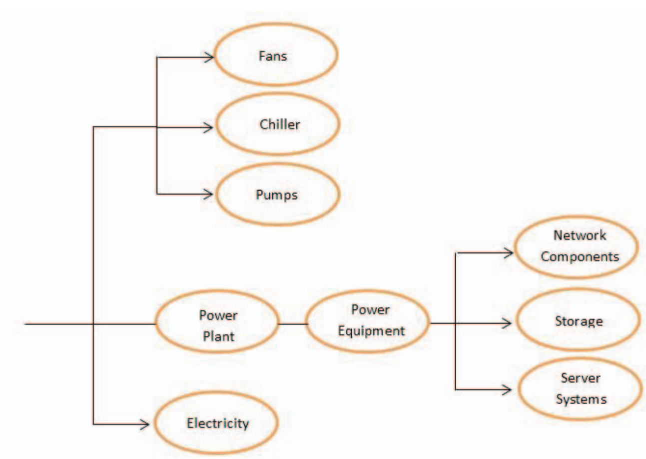

Figure 2.1

III. ARCHITECTURE FOR GREEN CLOUDS

The prime requirement for achieving green cloud architecture is to establish a balance between the power consumption and performance. These days cloud service providers are analyzing solutions through which they can reduce the power usage and obviously carbon emission as well. To achieve the target a new middleware is introduced naming "Green Cloud Broker". This Cloud Broker works as an intermediate tool between the Cloud users and providers giving facilities of the procedure in terms of managing, responding and providing services to end users. The cloud broker consists of information like the carbon emission level of a system and the greener cloud for the request service etc. A cloud broker involves following modules inside it:

- Scheduler: This module is responsible for scheduling the incoming requests in an organized and synchronized manner.
- Task selector: This module identifies that which kind of services is required to complete an incoming request.
- Cost calculator: This module keep track of the cost required to fulfill the posted request.
- Application profile: This module keeps track of information related with the applications available to complete the incoming requests.

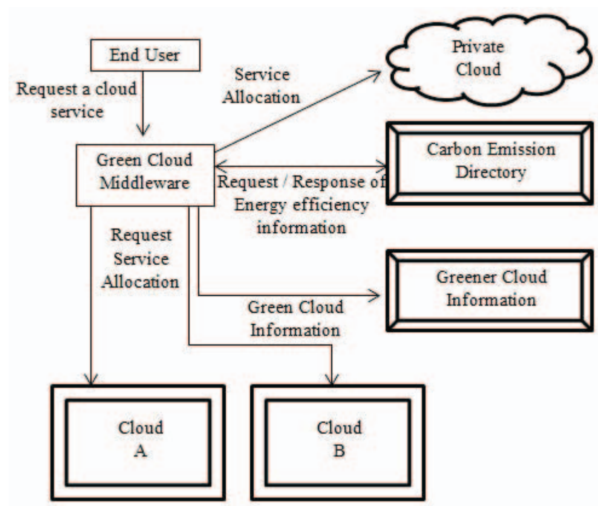

Figure 3.1 Green Cloud Broker

- Green Resource Information Database: This module maintains a database of all the available resources along with their green ability information. This module actually decides that to fulfill a request which of the cloud will perform greener.

- Carbon emission calculator: This module maintains information about the carbon emission quantity of all the available clouds. To fulfill a request, resources with least carbon emission will be selected by the Green Cloud Broker. [14]

IV. TOWARDS GREENER

Major Metrices used for measuring CO_2 emission

PUE (Power Usage Effectiveness) and its correlative DCiE (Data Center foundation Efficiency) are measurements presented in the February 2007 Green Grid whitepaper "Green Grid Metrics: Describing Data Center Power Efficiency". Truth be told, in the first paper DCiE was called Data Center Efficiency; then again, there was some disarray in respect to whether the metric surmised productivity of the IT hardware, and as it doesn't it was changed to DCiE. This highlights a vital point in that both PUE and DCiE are measurements that give a sign as to the supporting so as to compel utilization of force "base" just. All force coordinated to the IT load itself is expected to deliver 'helpful work'. PUE has turned into the true metric utilized as a part of server farms as for vitality utilization. PUE is ascertained by isolating the aggregate office power (i.e. All force devouring components that constitute the server farm biological community) by IT gear

Metric Acronym	Metric Name	Formula Detail	Unit
PUE	Power usage effectiveness	Total Data Center Energy and IT Equipment Energy	Unit-Less
CUE	Carbon usage effectiveness	CO2 emission caused by the total data center energy and IT equipment energy or CEF X PUE where CEF=kgCO2eq/kWh for the grid and/or on-site generation	Unit-Less
WUE	Water usage effectiveness (site)	Annual site water usage and IT equipment energy	L/kWh
WUE_{SOURCE}	Water usage effectiveness (site + source)	(Annual source water usage + Annual site water usage) / IT equipment energy	L/kWh

Table 1: The Green Grid x UE Metrices

power. The metric demonstrates how adequately or vitality effectively one is supporting the IT load. Vitality productivity is yet one point of view on a server farm's outline and operations, versatility and security being two others. In any case, the emphasis here is on the green measurements, notwithstanding the PUE the green framework has proposed a suite of XUE metrices, for example, carbon use effectiveness (CUE) and water use effectiveness (WUE) appeared in Table 1. [14]

Depending upon various scenarios given in technical report[15], we are considering the average PUE value as 1.92 and considering the average CUE value of 14 major countries, in carbon emission report 2014[16], we are calculating the Carbon Usage Effectiveness as per the table given below:

CO2 Emission Component	Range	Avarage CEF Value (kgCO2eq/kWh)	Average PUE Value	CUE = CEF X PUE
CO2 emission per server	Low range server	768.86	1.92	1476.21
	Medium range server	1794.14	1.92	3444.75
	High range server	20504.43	1.92	39368.50
CO2 emission per data center	Servers	1007.36	1.92	1934.13
	Storage	201.50	1.92	386.88
	Network	134.29	1.92	257.83
	Data center	2417.50	1.92	4641.60
CO2 emission per kWh from electricity generation, source IEA.	CO_2 Emission from Fuel Combustion Highlights [16] kg CO2 /kwH	0.49	1.92	0.94

V. CONCLUSION

In conclusion, we studied various models of cloud. In our study we discussed about how energy efficiency in cloud architecture can be achieved. We took reference from various reputed reports and calculated the carbon usage effectiveness (CUE). We discussed about the green broker structure which contains various modules dedicated to perform a special task. Such like scheduler (for scheduling incoming requests), task selector (for completing the incoming request), cost calculator (for the cost calculation), application profile (searches for the suitable application), green resource information database (contains all the data related with greener environment) and carbon emission calculator (maintains the information about the carbon emission quality). Collectively this architecture is termed as Green Cloud Middleware which is responsible for managing and serving the incoming requests following greener rules. Depending upon the services requested this architecture looks for the greener cloud and directs the request towards it. Along with this we studied "The Green Grid x UE Metrices". Here we discussed about the formula details and units of various factors which plays an important role towards greener cloud. Finally we calculated the value of CUE for servers and data centers. Here we found that value of CUE for low range server is 1476.21, medium range server is 3444.75 and for high range server is 39368.50. On the other hand value of CUE for data center servers is 1934.13, data center storage is 386.88 and data center network is 257.83.

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