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Environmental and Green Cloud Computing

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Abstract - Cloud computing is extremely scalable and profitable infrastructure for functioning High Performance Computing, enterprise and Web applications. Due to a rising demand of Cloud infrastructure has raised the energy consumption of data centers, which has become a crucial issue. Tremendous energy consumption not only converts to high operational cost, which reduces the profit margin of Cloud providers, but also leads to high carbon emission which is not eco-friendly. Energy efficient solutions are required to reduce the impact of Cloud computing on the environment. For designing the solution, deep study of Cloud is required with respect to their power efficiency. In this paper, we discuss about Cloud which contribute to the total energy consumption and how it is addressed in the literature

Key Words: ***Cloud Computing, Scalable, Infrastructure, Eco-friendly and Energy Consumption.***

I. Introduction

As we all know computers, smart phones and tablets plays a very important role in today’s world, with the growth of high speed network from last few years till now, up rise in its usage consist of multiple of simultaneous e-commerce transactions and thousands of web queries. This of all time raising demand is managing through large datacenters, which merge millions of servers with other infrastructure and network systems.

Earlier business firm spend large amount of capital and time for profit and conservation of computational modality. But now most of the work is done by E-commerce, there are many internet companies which are operating around the world. The commercialization of this development is delimitating presently as Cloud Computing [4], which is based on pay-as-you-go basis. Users can store, access and share any type of information in Cloud. There are different types of Cloud which are dissimilar from one another, enterprises/organizations do not have to incise about purchasing, configuring, administering, and sustain their own computing infrastructure. Cloud computing benefits such as on demand computing resources, faster and cheaper software development capabilities at low cost. Many financial firms and companies have to keep every day the dynamic information about their hundreds of clients, and manage huge data.

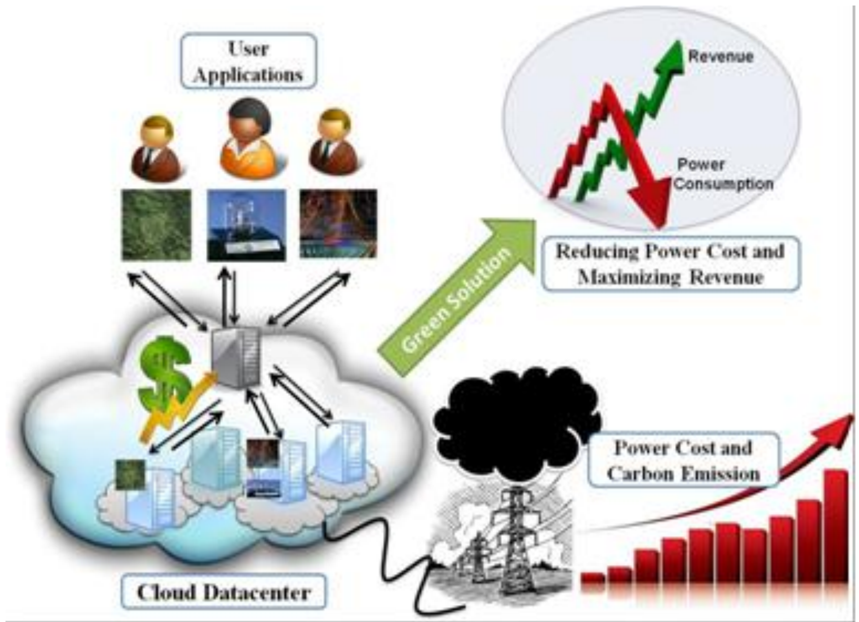


Figure1. Cloud and Environment Sustainability

II. WHAT IS CLOUD COMPUTING?

Cloud computing refers to applications and services that run on a distributed network using virtualized resources and accessed by common internet protocols and networking standards.

2.1 Components of Cloud Computing

Cloud computing is mainly composed of three layers which cover all the computing stack of system. Each of these layers different set of services to end users as described. At the lowest layer, Cloud offerings are named as Infrastructure –as-a-Service (IaaS) which consists of virtual machines, storage, and clusters. Cloud infrastructures can be heterogeneous, integrating clusters, PCs and workstation. The infrastructure is generally managed by an upper management layer that guarantees runtime environment customization, application, application isolation, accounting and quality of service

Even though IaaS gives access to physical resources with some software configuration, for designing new applications user requires advanced tools. This services constitute another layer called Platform as a Service (PaaS), offering Cloud users a development platform to build their applications. PaaS offers only the user level middleware, which allows development and deployment of applications on any Cloud infrastructure.

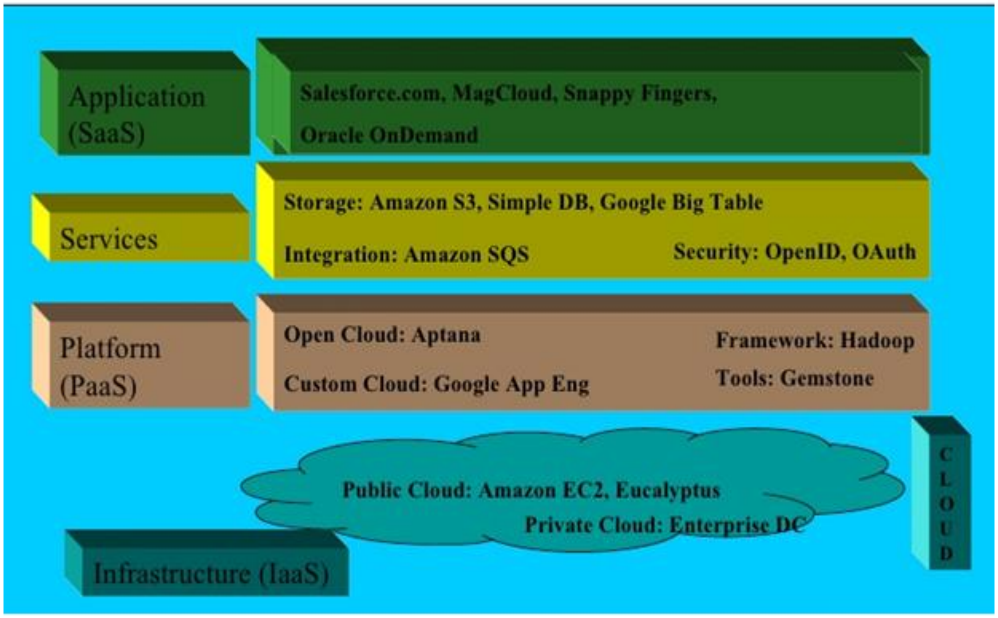


Figure2. Cloud Computing Architecture

On the topmost layer of Cloud computing Architecture, the Cloud services (fig 2) are referred as Software as a Service (SaaS) which is a software delivery model providing on-demand access to applications. In general SaaS providers also constitute other layers of Cloud computing and thus, maintain the customer data and configure the applications according to customer need. SaaS model is particularly appealing for companies who get access to software configured according to their specific needs and shared between multiple users

2.2 Cloud Computing Models

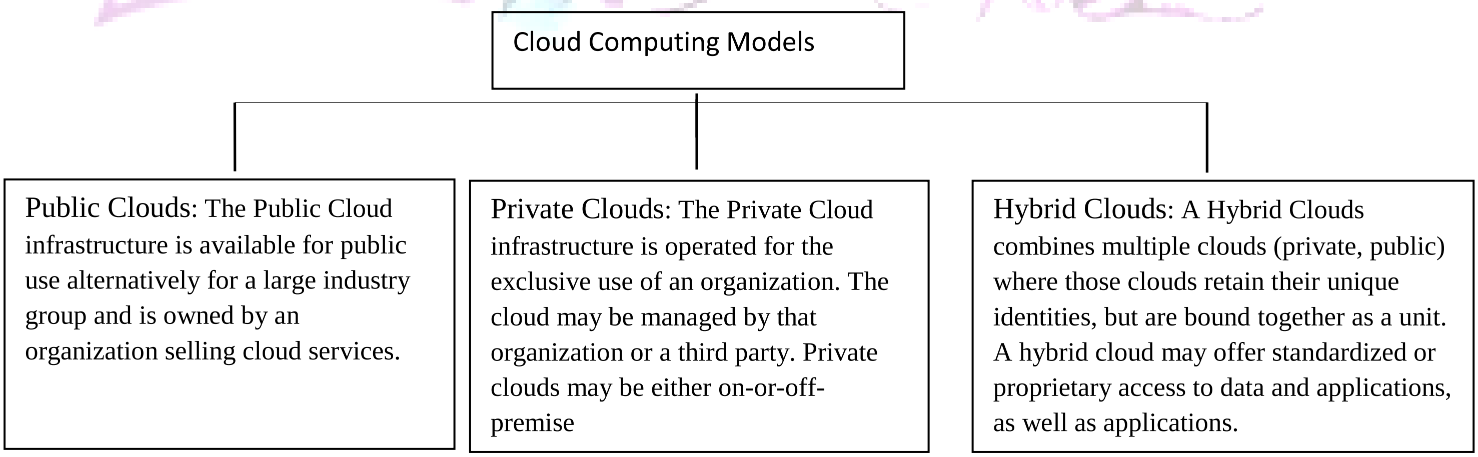


Figure3. Models for Cloud Computing.

III. Energy Usage Model of Cloud Computing

Through a typical Cloud Usage scenario we will consider various elements of Clouds and their energy efficiency. (Fig1) shows how an end user accessing Cloud services such as SaaS, PaaS, or IaaS over internet. User data pass from his own device through an Internet service provider's router, which in turn connects to a Gateway router within a Cloud datacenter. Network devices that are directly accessed to serve Cloud users contribute to energy consumption. In addition, within a Cloud datacenter, there are many other devices, such as cooling and electrical devices, that consume power. These devices even though do not directly help in providing Cloud service, are the major contributors to the power consumption of a Cloud datacenter.

3.1 Datacenter

A cloud datacenter could comprise of many thousands of networked computers with their corresponding storage and networking subsystems, power distribution and conditioning equipments and cooling infrastructure. Due to large number of equipments, datacenters can consume massive energy consumption and emit large amount of carbon

Table1. Percent of Power Consumption by Each Datacenter Device

Cooling device(Chiller, Computer Room Air Conditioning(CRAC)	32.8%+9.2%
IT Equipment	29.91%
Electrical Equipments (UPS, Power Distribution Units(PDUs), lighting)	28.01%

IV. DATACENTER LEVEL

The construction of large Datacenters which are running, commodity hardware has enabled cloud computing to gain traction. These datacenters gain access to low-cost electricity, high-network bandwidth pipes, and low-cost commodity hardware and software, which taken together, represents an economy of scale that allows cloud providers to amortize their investment and retain a profit. It has been estimated that costs around $100 million to create a datacenter with sufficient scale to be between 35% - 20% lower than pricing that is offered to medium-sized.

Table2. Comparison of significant Cloud Datacenters [5]

Cloud datacenters	**Location**	**Estimated power of usage effectiveness**	**% of Dirty Energy Generation**	**% of Renewable Electricity**
Google	Lenoir	1.22	50.5% Coal, 38.6% Nuclear	3.9%
Yahoo	La Vista ,NE	1.17	73.1% Coal, 14.6% Nuclear	6.9%
Apple	Apple, NC		50.5% Coal, 38.8% Nuclear	3.9%
Microsoft	Chicago, IL	1.23	72.8% Coal, 21.9% Nuclear	1.1%

4.1 Monitoring/Metering

It is necessary to construct power models that allow the system to know the energy consume by a particular device, and how it can be reduced. To measure the collective adaptability of a datacenter and improve its performance per watt, the Green Grid has proposed to specific metrics known as the Power Usage Effectiveness (PUE) and Datacenter Infrastructure Efficiency (DciE) [4]

- PUE = total facility power/ IT equipment power
- DciE =1/PUE=IT equipment power/ total facility power * 100%.

The total facility power is defined as the power measured at the utility meter that is dedicated to the datacenter power. The IT equipment power is defined as the power consume in the management, processing, and storage or routing of data within the datacenter. PUE and DCIE are the most common metrics designs to compare the efficiency of datacenters. To measure the power consume by a server (e.g. PowerEdge R610) the Intelligent Platform Management Interface (IPMI) [3] is proposed. This framework provides way to axis the power monitoring sensors available on recent server. This interface being independent of the operating system can be accessed despite of operating system failures and without the need of the servers to be powered on (that is connection to the power grid is more). Further, intelligent power distribution units (PDUs), traditional power meters (example watts Up Pro power meter) and ACPI enabled power supplies can be used to measure the power consumption of the whole server.

V. Green Cloud Architecture

From the above study of current efforts in making Cloud computing energy efficient, its shows that the researchers have made various component of Cloud efficient in terms of power and performance, still they lack a unified picture. Most of Cloud computing have missed the network contribution. If the file sizes are quit large, network will become a major contributor to energy consumption, thus it will be greener to run application locally than in Clouds. Many study focused on just particular component of cloud computing while neglecting effect of other which may not result in over all energy efficiency. For example, virtual machine consolidation may decrease number of active server but it will put excessive load on few servers where heat distribution can become a major issue. Cloud providers, being profit oriented, are looking for solutions which can reduce the power consumption and thus, carbon emission without hurting their market. There for we provide a unified solution to enable Green Cloud computing. The high level view of the green Cloud architecture is given in figure. The goal of this architecture is to make Cloud green from both user and providers.

In the green Cloud architecture, users submit their Cloud service request through middle ware green broker that manages the selection of the greenest Cloud provider to serve the users request. A user service request can be of three types that is software, platform or infrastructure. The Cloud provider can register their services in the form of ‘green offers’ to a public directory which is accessed by Green Broker. The Green offers consist of green services, pricing and time when it should be accessed for least carbon emission. Green broker gets the currents status of energy parameter for using various Cloud services from Carbon Emission Directory. The carbon emission directory maintains all the data related to energy efficiency of cloud services. Green broker calculate the carbon emission of the entire Cloud provider who are offering the requested Cloud service. It selects the set of services that will result in least carbon emission and by these services on behalf users.

The Green Cloud framework is designed such that it keeps track of overall energy usage of serving a user request. It depends mainly on two components, Carbon Emission Directory and Green Cloud offers, which keep track of energy efficiency of each Cloud provider and also give incentive to Cloud providers to make their service “Green”.

A) SaaS Level: Since SaaS providers mainly offer software offer software installed on their own datacenters or resources from IaaS providers. The SaaS provider chooses the datacenters which are not only energy efficient but also near to users. The minimum number of copies of user's confidential data should be maintained using energy-efficient storage.

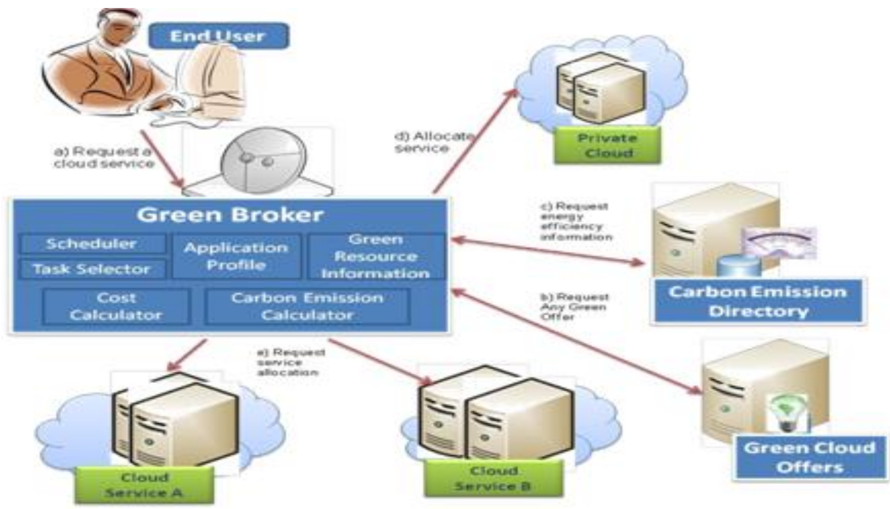


Figure4. Green Cloud Architecture

B) PaaS Level: PaaS level providers offer in general the platform services for application development. The platform facilitates the development of applications which ensures system wide energy efficiency. It is a software energy benchmark that measures the energy required to perform an external sort. This platform itself can be designed to have various code level optimizations which can cooperate with underlying compiler in energy efficient executions of applications.

C) IaaS Level: IaaS level not only offer independent infrastructure services but also support other services offered by Clouds. Use the latest technologies for IT and cooling systems to have most energy efficient infrastructure. By using virtualization and consolidation, the energy consumption is further reduced by switching-off unutilized server. Various energy meters and sensors are installed to calculate the current energy efficiency of each IaaS providers and their sites. Various green scheduling and resource provisioning policies will ensure minimum energy usage. The Cloud provider designs various green offers and pricing schemes for provide incentive to users to use their services during off-peak or maximum energy-efficiency hours.

Table3. Carbon Emission Related Parameter of a Datacenter

Parameter	**Notation**
Carbon emission rate	$r_i^{co_2}$
Average COP	COP_i
Electricity price (S/Kwh)	P_i^{c}
Data transfer price (S/GB) for upload/download	P_i^{dt}
CPU power	$P_{i=}$
CPU frequency range	$[f_i^{min}, f_i^{max}]$
Time slots (start time, end time, number of CPUs)	(t_s, t_c, n)

VI. Policies to achieve better efficiency in terms of carbon emission

Achieving better efficiency in terms of carbon emission, we have studied five policies (Profit oriented and Green) employed for scheduling by Green broker.

1. Greedy Minimum Carbon Emission (GMCE): In this, user applications are assigned to Cloud providers in greedy manner based on their carbon emission.

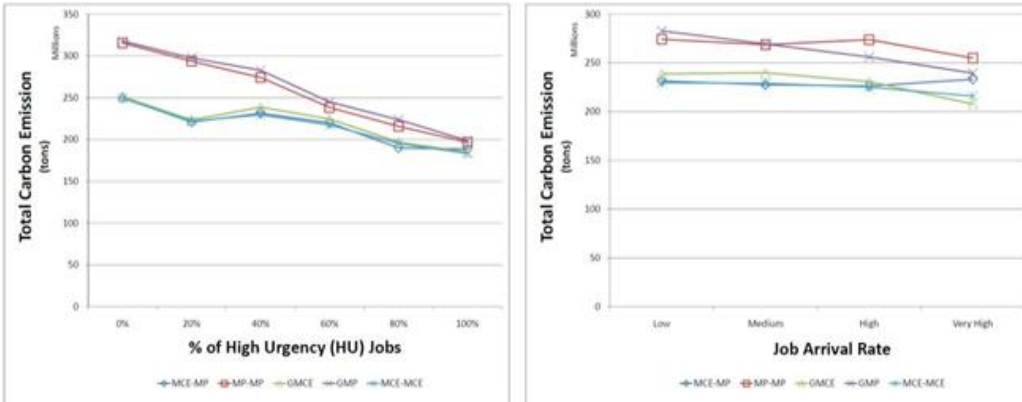
2. Minimum Carbon Emission- Minimum Carbon Emission (MCE-MCE): This is a double greedy policy where applications are assigned to the Cloud providers with minimum carbon emission due to their datacenter location and carbon emission due to application execution.

3. Greedy Maximum Profit (GMP): In this, user's applications are assigned in greedy manner to a provider who execute the application fastest and get maximum profit.

4. Maximum Profit- Maximum Profit: This is also a double greedy policy considering profit made by Cloud providers and application finishes by its deadline.

5. Minimising Carbon Emission and Maximising Profit (MCE-MP): In this the broker tries to schedule the applications to those providers which results in minimization of total carbon emission and maximization of profit.

GMCE, MCE/MCE and MCE/MP are "GREEN" policies while MP/MP and GMP are profit/oriented policies. A more extensive detail on modeling of energy efficiency of a Cloud datacenter, experimental data and result is available in above work [6]. Here, we present some important result to illustrate the validity of are presented framework.



(a) Carbon Emission VS Urgency (b) Carbon Emission VS Arrival Rate

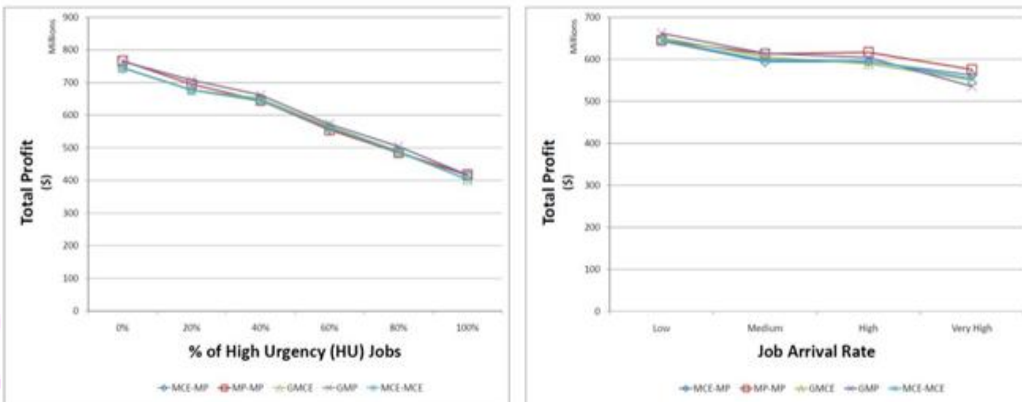


Figure5. Carbon Emission and Profit using Green Cloud Framework

Figure5. Shows the course of experiment conducted with varying user's urgency for executing his application and job arrival rate. The metrics of total carbon emission and total profit are used since the resource provider needs to know the collective loss in carbon emission and gain in profit across all datacenters. From these result three main inferences can be made.

1. Green policies reduce the carbon emission by almost 20% in comparison to profit based policies. This observation emphasis is the inclusion of overall carbon efficiency of all the Cloud providers in scheduling decisions.

2. With the increase in user's urgency to execute the application, the gain in carbon emission reduces almost linearly. This clearly shows how important is the role of users in making Cloud computing in general "Green". When the datacenters are running at higher energy efficiency, more energy and carbon gain can be made. In this we show the need of Green Cloud offers from provider.

The Green policies also have minimal effect on the provider's profit. This shows that by using energy efficient solution such as Green Cloud Framework both Cloud providers and user can benefit.

VII. CONCLUSION

It is forecasted that the environmental footprint from datacenters will triple in-between 2002-2020 which, is currently 7.8 billion tons of CO2 per year. There reports on Green IT analysis of Cloud and datacenters that show Cloud ”Green” while others show that it will need to increase in carbon emission . thus, in this , we first analyzed the benefits offered by Cloud computing by studying its fundamental definitions and benefits, the services it offers to end user , and its deployment model then, we discussed the component of Clouds that contribute to carbon emission and the feature of Cloud that make it” Green”. We also discussed several research efforts and technologies that increase the energy efficiency of various aspects of Cloud. We identified several unexplored areas that can help in maximizing the energy efficiency of Cloud. After analyzing the shortcoming of previous solution, we proposed a Green Cloud framework and presented some results for its validation. Even though our Green Cloud frameworks embed various features to make Cloud computing much more Green, there are still many technological solutions are required to make it a reality.

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