Green Cloud computing- New Approach of Energy Consumption

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Abstract: Cloud computing is a highly scalable and cost-effective infrastructure for running HPC, enterprise and Web applications. However, the growing demand of Cloud infrastructure has drastically increased the energy consumption of data centers, which has become a critical issue. High energy consumption not only translates to high operational cost, which reduces the profit margin of Cloud providers, but also leads to high carbon emissions which is not environmentally friendly. Hence, energy-efficient solutions are required to minimize the impact of Cloud computing on the environment. Cloud green computing is the latest trend today. Balancing energy consummation and hibernating money from saving costs by leaving the purchase of servers, software, datacenter space or network equipment, make the businesses more efficient and attractive. Cloud computing can enable more energy-efficient use of computing power, especially when the computing tasks are of low intensity or infrequent. However, under some circumstances cloud computing can consume more energy than conventional computing where each user performs all computing on their own personal computer (PC). Thus, in this paper, we discuss various elements of Clouds which contribute to the total energy consumption and how it is addressed in the literature.

Keywords- Cloud computing, data centers, energy consumption.

I. INTRODUCTION

With the growth of high speed networks over the last decades, there is an alarming rise in its usage comprised of thousands of concurrent e-commerce transactions and millions of Web queries a day. This ever-increasing demand is handled through large-scale datacenters, which consolidate hundreds and thousands of servers with other infrastructure such as cooling, storage and network systems. Many internet companies such as Google, Amazon, eBay, and Yahoo are operating such huge datacenters around the world.

The commercialization of these developments is defined currently as Cloud computing [1], where computing is delivered as utility on a pay-as-you-go basis. Traditionally, business organizations used to invest huge amount of capital and time in acquisition and maintenance of computational resources. The emergence of Cloud computing is rapidly changing this ownership-based approach to subscription-oriented approach by providing access to scalable infrastructure and services on-demand. Users can store, access, and share any amount of information in Cloud. That is, small or medium enterprises/organizations do not have to worry about purchasing, configuring, administering, and maintaining their own computing infrastructure. They can focus on sharpening their core competencies by exploiting a number of Cloud computing benefits such as on-demand computing resources, faster and cheaper software development capabilities at low cost. Moreover, Cloud computing also offers enormous amount of compute power to organizations which require processing of tremendous amount of data generated almost every day.

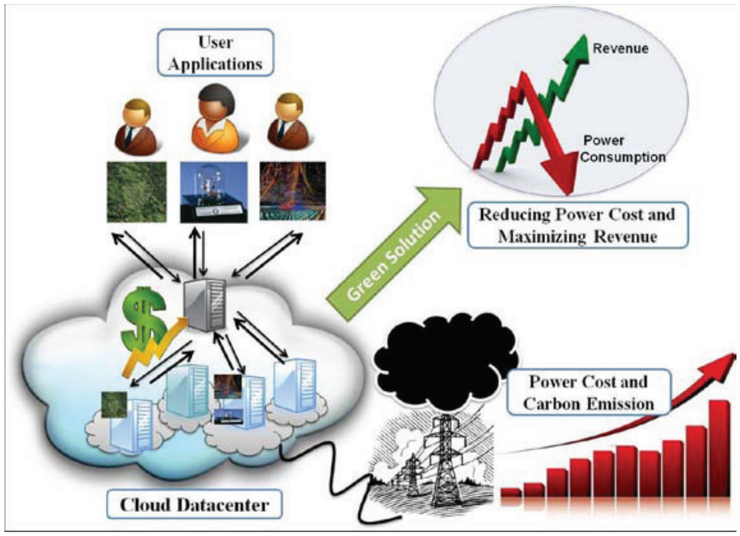

Figure1. Cloud and Environmental Sustainability

Clouds are essentially virtualized datacenters and applications offered as services on a subscription basis as shown in Figure 1. They require high energy usage for its operation [3]. Today, a typical datacenter with 1000 racks need 10 Megawatt of power to operate [4], which results in higher operational cost. Thus, for a datacenter, the energy cost is a significant component of its operating and up-front costs.

In addition, in April 2007, Gartner estimated that the Information and Communication Technologies (ICT) industry generates about 2% of the total global CO2 emissions, which is equal to the aviation industry [4]. According to a report published by the European Union, a decrease in emission volume of 15%–30% is required before year 2020 to keep the global temperature increase below 2 0C. Thus, energy consumption and carbon emission by Cloud infrastructures has become a key environmental concern.

Some studies show that Cloud computing can actually make traditional datacenters more energy efficient by using technologies such as resource virtualization and workload consolidation. The traditional data centres running Web applications are often provisioned to handle sporadic peak loads, which can result in low resource utilization and wastage of energy. Cloud datacenter can reduce the energy consumed through server consolidation, whereby different workloads can share the same physical host using virtualization and unused servers can be switched off. A recent research by Accenture [6] shows that moving business applications to Cloud can reduce carbon footprint of organizations. According to the report, small businesses saw the most dramatic reduction in emissions – up to 90 percent while using Cloud resources. Large corporations can save at least 30-60 percent in carbon emissions using Cloud applications, and mid-size businesses can save 60-90 percent.

Contrary to the above opinion, some studies, for example Greenpeace [5], observe that the Cloud phenomenon may aggravate the problem of carbon emissions and global warming. The reason given is that the collective demand for computing resources is expected to further increase dramatically in the next few years. Even the most efficiently built datacenter with the highest utilization rates will only mitigate, rather than eliminate, harmful CO2 emissions. The reason given is that Cloud providers are more interested in electricity cost reduction rather than carbon emission. The data collected by the study is presented in Table 1 below. Clearly, none of the cloud datacenter in the table can be called as green.

Table1. Comparison of Significant Cloud Datacenters [5]

Cloud datacenters	Location	Estimated power usage Effectiveness	% of Dirty Energy Generation	% of Renewable Electricity
Google	Lenoir	1.21	50.5% Coal, 38.7% Nuclear	3.8%
Apple	Apple, NC		50.5% Coal, 38.7% Nuclear	3.8%
Microsoft	Chicago, IL	1.22	72.8% Coal, 22.3% Nuclear	1.1%
Yahoo	La Vista, NE	1.16	73.1% Coal, 14.6% Nuclear	7%

Finally, we also propose and recommend a Green Cloud framework for reducing its carbon footprint in wholesome manner without sacrificing the quality of service (performance, responsiveness and availability) offered by the multiple Cloud providers.

II. CLOUD COMPUTING

A. What is Cloud Computing?

Cloud computing is an evolving paradigm which is enabling outsourcing of all IT needs such as storage, computation and software such as office and ERP, through large Internet. The shift toward such service-oriented computing is driven primarily by ease of management and administration process involving software upgrades and bug fixes. It also allows fast application development and testing for small IT companies that cannot afford large investments on infrastructure. Most important advantage offered by Clouds is in terms of economics of scale; that is, when thousands of users share same facility, cost per user and the server utilization. To enable such facilities, Cloud computing encompasses many technologies and concepts such as virtualization, utility computing, pay as you go, no capital investment, elasticity, scalability, provisioning on demand, and IT outsourcing.

The literary meaning of “Cloud computing” can be “computing achieved using collection of networked resources, which are offered on subscription”. Cloud computing is also called “Cloud” since a Cloud server can have any configuration and can be located anywhere in the world. Internet is a fundamental medium through which these Cloud services are made accessible and delivered to end user.

The growing popularity of Cloud computing has led to several proposal defining its characteristics. Some of the definitions given by many well known scientists and organizations include:

A) “A Cloud is a market-oriented distributed computing system consisting of a collection of interconnected and virtualized computers that are dynamically provisioned and presented as one or more unified computing resource(s) based on service-level agreements established through negotiation between the service provider and consumers.”

B) “Cloud computing is 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. This Cloud model promotes availability and is composed of five essential characteristics, three service models, and four deployment models.”

B. Cloud Computing Characteristics

The characteristics of Clouds include on-demand self-service, broad network access, resource pooling, rapid elasticity, and measured service. The available service models are classified as SaaS (Software-as-a-Service), PaaS (Platform-as-a-Service), and IaaS (Infrastructure-as-a-Service).

The key characteristics exhibited by Clouds are: Autonomic Elastic Market Oriented (Pay As You Go) Virtualized Service Oriented Dynamic (& Distributed) Shared (Economy of Scale) Cloud Computing.

C. Components Of Cloud Computing

Cloud computing is mainly composed of three layers which cover all the computing stack of a system. Each of these layers offers different set of services to end users as described in Figure 2.

At the lowest layer, Cloud offerings are named as Infrastructure-as-a-Service (IaaS) which consists of virtual machines or physical machines, storage, and clusters. Cloud infrastructures can also be heterogeneous, integrating clusters, PCs and workstations. Moreover, the system infrastructure can also include database management systems and other storage services. Even though IaaS gives access to physical resources with some software configuration, for designing new applications user requires advanced tools such as Map Reduce etc. These services constitute another layer called Platform as a Service (PaaS).

Platform as a Service (PaaS offering Cloud users a development platform to build their applications. Google AppEngine [7], Aneka [8], and Microsoft Azure [9] are some of the most prominent example of PaaS Clouds. In general, PaaS includes the lower layer (IaaS) as well that is bundled with the offered service. In general, pure PaaS offers only the user level middleware, which allows development and deployment of applications on any Cloud infrastructure.

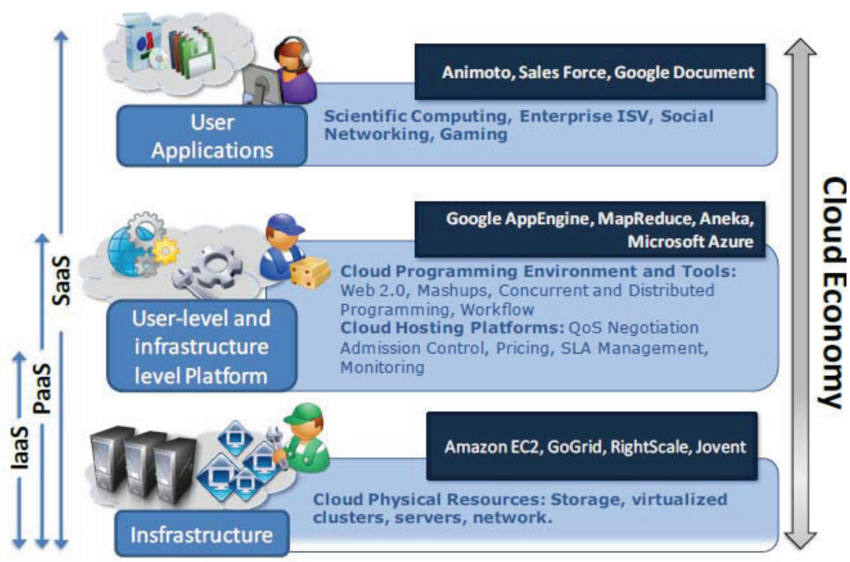

Figure2. Cloud computing Architecture

On topmost layer of Cloud computing Architecture, the Cloud services (Figure 2) are referred as Software as a Service (SaaS) which is a software delivery model providing on-demand access to applications. The most common examples of such service are CRM and ERPF applications that are commonly used in almost all the enterprises from small, to large business. 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. This scenario results in considerable reduction in upfront cost of purchasing new software and infrastructure.

D. Cloud Computing Deployment Models

Cloud computing is a paradigm of offering on-demand services to end users. Clouds are deployed on physical infrastructure where Cloud middleware is implemented for delivering service to customers. Such an infrastructure and middleware differ in their services, administrative domain and access to users. Therefore, the Cloud deployments are classified mainly into three types: Public Cloud, Private Cloud and Hybrid Cloud.

III. GREEN CLOUD COMPUTING

The cloud lifecycle can be divided into four stages, viz., designing, setup, using and disposal. Green computing in the cloud context can be achieved by ensuring minimum or no impact on environment during each of these cloud lifecycle stages. The objective is to reduce energy consumption and improve resource performance and efficiency. Green computing in a Cloud can be achieved by initiating a series of transformative actions such as improving Cloud data center design, increasing resource longevity, consolidating resources, and optimizing algorithms.

A. Cloud Data Center Design

Data center design plays a very important role and is essential for creating an energy efficient data center with energy saving configuration.
Creating a good data center design requires attention to be paid to the following:

• *Data center location:*
Decide data center location factoring the data center purpose as well as availability of resources for running the data center such as cheaper electricity and skilled resources.

• *Construction of the data center building:*
While designing the data center, electrical systems must consider the data center landscape and wherever possible leverage the natural lighting. Other factors to be considered are local availability of renewable energy, using outside air for cooling or locating the systems where the heat they produce may be used for other purposes.

• *Resources:*
The selection of a resource to be used in the data center must be based on lower energy consumption by the resource. This will help reduce the running costs. Other steps include using efficient air management, cooling and electrical systems while designing data centers. Terminal servers have also been used in green computing. Users connect from their terminal to a central server. Though all the computing is done at the central server, the user experiences the operating system on the terminal. Combining of terminal servers with thin clients that use about one-eighth of the energy of a normal workstation, result in decrease of both energy costs and consumption.

• *Configuration:*
Align all IT processes and systems with the core principle of sustainability. The IT systems should be designed from the cloud perspective and must help leverage the benefits of the cloud. Many operating systems provide Advanced Configuration and Power Interface (ACPI), an open industry standard that allows an operating system to directly control the power saving aspects of its underlying hardware. Data center must be designed so as to ensure appropriate cooling throughout the data center. It is crucial to use energy efficient cooling systems in the data center and intelligent systems for temperature control within the data center. One must also provide for alternative power supply for use in case of disaster, setup processes for regular system maintenance and conduct periodic checks to ensure that the systems are functioning properly. The above considerations will help arrive at a good design resulting in better space utilization and increased performance and efficiency.

B. Increasing Resource Longevity

Each resource has a lifespan. One can contribute to green computing by increasing the resource longevity by including upgradability and modularity. For example, it is said that manufacturing a new PC makes a bigger ecological footprint than making a new RAM module to upgrade an existing one.

C. Resource Consolidation

Another important factor that plays a major role in creating an energy efficient data center is resource consolidation. This can be achieved by virtualization, and consolidation of other resources that cannot be virtualized. This gives flexibility of sharing the available resources and allocating then depending on the business need. Resource consolidation by virtualization helps to reduce the quantum of energy consumed. Other ways by which resource optimization can be achieved are shutting down resources when not needed, reuse and recycling.

D. Optimization

The efficiency of an algorithm has an impact on the resources required for a computing function and at times one may need to do trade-offs while writing programs. Use efficient algorithms. For example, use fast search algorithms such as hashed or indexed search algorithms instead of slow linear search algorithms. Cost optimization can be achieved by using algorithms to route the data to data center where electricity is cheaper. In case data center is facing warm weather, traffic could be routed away to cut energy usage, allowing the servers to shut down and avoid using the air conditioning.

IV. GREEN CLOUD ARCHITECTURE

Cloud providers, being profit oriented, are looking for solutions which can reduce the power consumption and thus, carbon emission without hurting their market. Therefore, we provide a unified solution to enable Green Cloud computing. We propose a Green Cloud framework, which takes into account these goals of provider while curbing the energy consumption of Clouds. The high level view of the green Cloud architecture is given in Figure 3. The goal of this architecture is to make Cloud green from both user and providers perspective.

In the Green Cloud architecture, users submit their Cloud service requests through a new middleware Green Broker that manages the selection of the greenest Cloud provider to serve the user's request. A user service request can be of three types i.e., software, platform or infrastructure. The Cloud providers 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 current status of energy parameters for using various Cloud services from Carbon Emission Directory. The Carbon Emission Directory maintains all the data related to energy efficiency of Cloud service. This data may include PUE and cooling efficiency of Cloud datacenter which is providing the service, the network cost and carbon emission rate of electricity, Green Broker calculates the carbon emission of all the Cloud providers who are offering the requested Cloud service. Then, it selects the set of services that will result in least carbon emission and buy these services on behalf users.

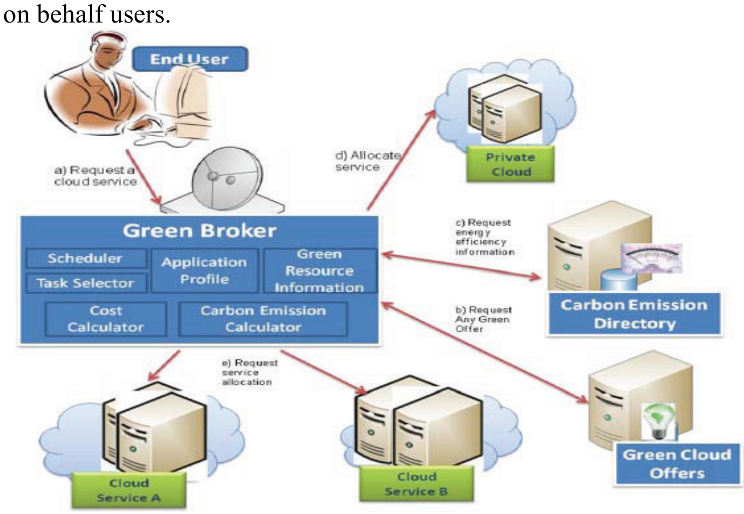

Figure3. Green Cloud Architecture

. The Green Cloud framework is designed such that it keeps track of overall energy usage of serving a user request. It relies on two main 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". From user side, the Green Broker plays a crucial role in monitoring and selecting the Cloud services based on the user QoS requirements, and ensuring minimum carbon emission for serving a user. In general, a user can use Cloud to access any of these three types of services (SaaS, PaaS, and IaaS), and therefore process of serving them should also be energy efficient. In other words, from the Cloud provider side, each Cloud layer needs to be "Green" conscious.

☐ SaaS Level: Since SaaS providers mainly offer software installed on their own datacenters or resources from IaaS providers, the SaaS providers need to model and measure energy efficiency of their software design, implementation, and deployment. For serving users, the SaaS provider chooses the datacenters which are not only energy efficient but also near to users. The minimum number of replicas of user‟s confidential data should be maintained using energy-efficient storage.

□PaaS level: PaaS providers offer in general the platform services for application development. The platform facilitates the development of applications which ensures system wide energy efficiency. This can be done by inclusion of various energy profiling tools such as JouleSort [4]. It is a software energy efficiency benchmark that measures the energy required to perform an external sort. In addition, platforms itself can be designed to have various code level optimizations which can cooperate with underlying complier in energy efficient execution of applications. Other than application development, Cloud platforms also allow the deployment of user applications on Hybrid Cloud. In this case, to achieve maximum energy efficiency, the platforms profile the application and decide which portion of application or data should be processed in house and in Cloud.

□ IaaS level: Providers in this layer plays most crucial role in the success of whole Green Architecture since IaaS level not only offer independent infrastructure services but also support other services offered by Clouds. They use 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. This information is advertised regularly by Cloud providers in Carbon Emission Directory. Various green scheduling and resource provisioning policies will ensure minimum energy usage. In addition, the Cloud provider designs various green offers and pricing schemes for providing incentive to users to use their services during off-peak or maximum energy-efficiency hours.

V. FEATURES OF CLOUDS ENABLING GREEN COMPUTING

Even though there is a great concern in the community that Cloud computing can result in higher energy usage by the datacenters, the Cloud computing has a green lining. There are several technologies and concepts employed by Cloud providers to achieve better utilization and efficiency than traditional computing. Therefore, comparatively lower carbon emission is expected in Cloud computing due to highly energy efficient infrastructure and reduction in the IT infrastructure itself by multi-tenancy. The key driver technology for energy efficient Clouds is "Virtualization," which allows significant improvement in energy efficiency of Cloud providers by leveraging the economies of scale associated with large number of organizations sharing the same infrastructure. Virtualization is the process of presenting a logical grouping or subset of computing resources so that they can be accessed in ways that give benefits over the original configuration [10]. By consolidation of underutilized servers in the form of multiple virtual machines sharing same physical server at higher utilization, companies can gain high savings in the form of space, management, and energy.

A. The benefits of green clouds usage: lower costs with high profit

Cloud computing is the way to save money and energy for your business. Speaking about cost savings, cloud computing users first of all emphasize *Infrastructure as a Service (IaaS)*. Using IaaS, users can improve their manageability and facilitate the maintenance of the resources. It means that benefit of business enterprises consists by avoiding spending on software and infrastructure resources, allowing business clients to focus on earning money rather than being weighted down with infrastructure concerns.

VI. CONCLUSION

Cloud computing business potential and contribution to already aggravating carbon emission from ICT, has lead to a series of discussion whether Cloud computing is really green. It is forecasted that the environmental footprint from data centers will triple between 2002 and 2020, which is currently 7.8 billion tons of CO_2 per year. There are reports on Green IT analysis of Clouds and datacenters that show that Cloud computing is "Green", while others show that it will lead to alarming increase in Carbon emission. Thus, we first analyzed the benefits offered by Cloud computing by studying its fundamental definitions and benefits, the services it offers to end users, and its deployment model. Then, we discussed the components of Clouds that contribute to carbon emission and the features of Clouds that make it "Green". Several research efforts and technologies that increase the energy efficiency of various aspects of Clouds can be used. Proposed Green Cloud Framework and presented some results for its validation. Even though our Green Cloud framework embeds 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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