Green Computing : An Integrated Approach to Cloud Computing Architecture

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Abstract:-
Today we live in a world which is full of constraints. Energy consumption is a bottleneck for Information computing and communication. Internet has provided an unlimited potential with access to eBooks, multimedia content, news, new ideas, and information access in general but, due to poor broadband infrastructure and available grid power to support the Internet and ICT growth the, developing regions have actually been left even further behind. The basic requirements in any developing region are a reliable electric power grid, network infrastructure, education, jobs, and a stable government and banking system. Nothing works without the electric and network infrastructure in place. The saddest part is diesel generators are used to power everything instead a stable power grid and the other is most of these countries have tremendous amount of wind or solar energy that can be used in place of imported fossil fuels.

Many articles are been released on how Cloud Computing helps the developing world by just lowering ICT costs but, here we introduce Green computing aiming to reduce energy cost and **C**O2 emissions as well as to effectively reuse and recycle power usage making the world *go-green*. This paper presents an approach for a low energy use data centers using cloud computing designed for developing regions, powered with renewable energy.

***Key Words**: Cloud Computing, green Computing, ITC, Data Centre*

I. Introduction

Most developing countries face financial, geographical, infrastructure, and power constraints that have largely prohibited development of reliable communications networks,data centers, and local ICT-related activity—all of which could be contributing to socio-economic growth and development.This situation is particularly unfortunate since emerging economies stand to gain a great deal from the benefits associated with telecommunications and related ICT advances that make distance obsolete. Yet ICT-related development cannot move forward unless the energy to power the technology is sufficient, affordable, and reliable. In many developing regions, diesel generators are widely used for power in the absence of a stable electrical power grid. Yet this expensive, stop-gap measure hampers economic growth, keeps developing economies dependent on volatile world oil prices, and increases pollution.

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.

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. For instance, financial companies have to maintain every day the

dynamic information about their hundreds of clients, and genomics research has to manage huge volumes of gene sequencing data.

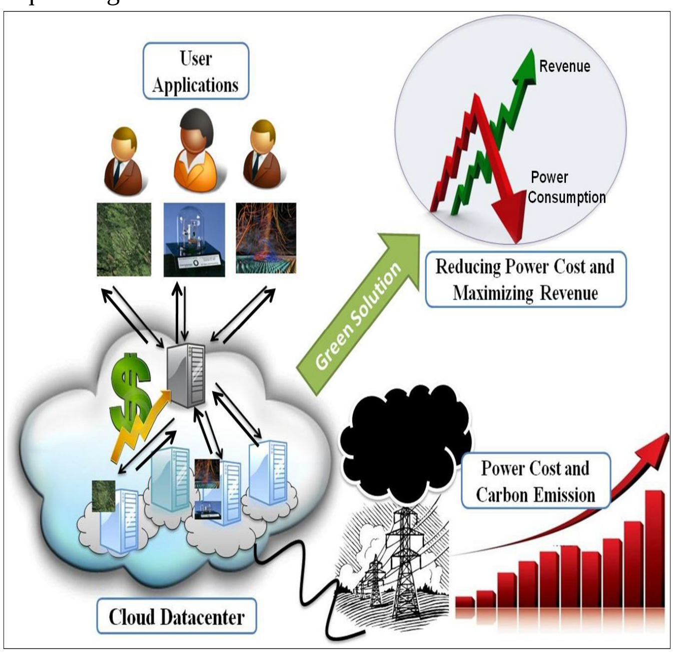


Figure 1. Cloud and Environmental Sustainability

II. Green Data Center Approach

Ultra energy-efficient computing and networking cannot be achieved without integration between computer science, electrical engineering, mechanical engineering, and environmental science. Designing data centers for high performance and extreme low energy usage requires a vertically and horizontally integrated effort to drive key energy-efficient technologies in computing (cloud computing) , electronics (low power CPUs and systems), and building systems (spot rack cooling, higher ambient temperatures, and natural convention cooling). Collectively, these existing and cutting edge technologies address very significant near-term and long-term energy and computing challenges and environmental issues. The approach we proposed for UCAD is a “Green Data Center in a Rack,” which incorporates cloud computing using low power CPUs, servers, renewable energy, and most importantly, keeping all of this close to the end user. By contrast to the Western model, the Green Cloud Computing approach uses a specialized, environmentally closed 42 unithigh rack specifically designed for use with low energy usage equipment. With little heat waste, this solution does not require all the special air conditioning of the modern data centers: these racks have their own air climate control units. By employing cloud computing in these data center racks, we can maximize the server utilization, which then facilitates a smaller number of active servers and energy usage to meet the constraints of the local circumstances. Cloud computing saves energy by employing: 1. Workload diversification: Because many different sorts of users will be availing themselves of diverse cloud resources – different applications, different feature set preferences and different usage volumes – this will improve hardware utilization and therefore make better use of power that is being used anyway to keep a server up and running. 2. Power-management flexibility: It is easier to manage virtual servers than physical servers from a power perspective. If hardware fails, the load can automatically be deployed elsewhere. Likewise, in theory, all virtual loads could be moved to certain servers when loads are light and power-down or idle those that are not being used. Low power CPUs have recently come to market thanks to a design for developing regions, the OLPC XO laptop. The OPLC project was based on development of a laptop using a low power CPU and low cost components to meet the price point and educational needs of the developing world. From this project, a whole netbook market was born and with it, the development of low power CPUs such as the Intel Atom, AMD Nano, and ARM based processors. These processors use 5% of the energy of a normal server CPU while still delivering 60% of the performance. The other advantage these processors offer is that they have been designed to run at higher ambient temperatures, so normal "meat locker" style air conditioning for data centers is not required when these processors are used in servers. Today's low power CPUs offer compute abilities that greatly exceed servers of even five years ago.

III. 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 [20]. 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.

According to Accenture Report [7], there are following four key factors that have enabled the Cloud computing to lower energy usage and carbon emissions from ICT. Due to these Cloud features, organizations can reduce carbon emissions by atleast 30% per user by moving their applications to the Cloud. These savings are driven by the high efficiency of large scale Cloud data centers.

1. **Dynamic Provisioning:** In traditional setting, datacenters and private infrastructure used to be maintained to fulfill worst case demand. Thus, IT companies end up deploying far more infrastructure than needed. There are various reasons for such over-provisioning: a) it is very difficult to predict the demand at a time; this is particularly true for Web applications and b) to guarantee availability of services and to maintain certain level of service quality to end users. One example of a Web service facing these problems is a Website for the Australian Open Tennis Championship [21]. The Australian Open Website each year receives a significant spike in traffic during the tournament period. The increase in traffic can amount to over 100 times its typical volume (22 million visits in a couple of weeks) [21]. To handle such peak load during short period in a year, running hundreds of server throughout the year is not really energy efficient. Thus, the infrastructure provisioned with a conservative approach results in unutilized resources. Such scenarios can be readily managed by Cloud infrastructure. The virtual machines in a Cloud infrastructure can be live migrated to another host in case user application requires more resources. Cloud providers monitor and predict the demand and thus allocate resources according to demand. Those applications that require less number of resources can be consolidated on the same server. Thus, datacenters always maintain the active servers according to current demand, which results in low energy consumption than the conservative approach of over-provisioning.

2. **Multi-tenancy:** Using multi-tenancy approach, Cloud computing infrastructure reduces overall energy usage and associated carbon emissions. The SaaS providers serve multiple companies on same infrastructure and software. This approach is obviously more energy efficient than multiple copies of software installed on different infrastructure. Furthermore, businesses have highly variable demand patterns in general, and hence multi-tenancy on the same server allows the flattening of the overall peak demand which can minimize the need for extra infrastructure. The smaller fluctuation in demand results in better prediction and results in greater energy savings.

3. **Server Utilization:** In general, on-premise infrastructure run with very low utilization, sometimes it goes down up to 5 to 10 percent of average utilization. Using virtualization technologies, multiple applications can be hosted and executed on the same server in isolation, thus lead to utilization levels up to 70%. Thus, it dramatically reduces the number of active servers. Even though high utilization of servers results in more power consumption, server running at higher utilization can process more workload with similar power usage.

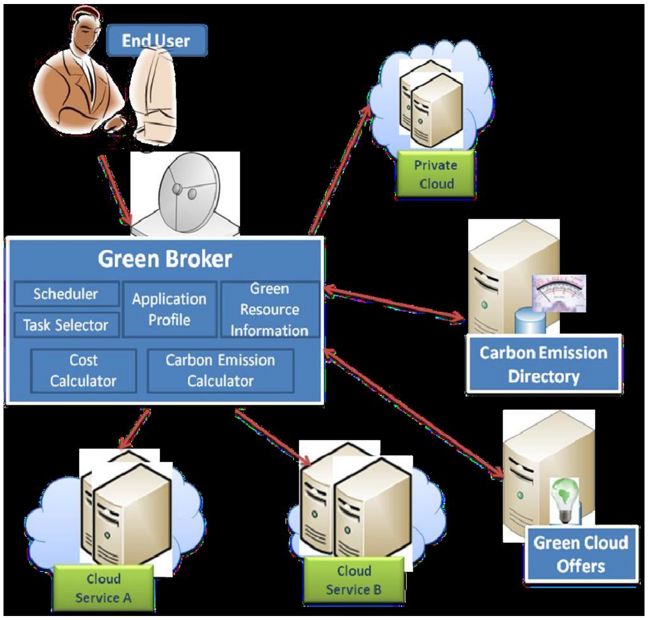
4. **Datacenter Efficiency:** As already discussed, the power efficiency of datacenters has major impact on the total energy usage of Cloud computing. By using the most energy efficient technologies, Cloud providers can significantly improve the PUE of their datacenters. Today□s state-of-the-art datacenter designs for large Cloud service providers can achieve PUE levels as low as

1.1 to 1.2, which is about 40% more power efficiency than the traditional datacenters. The server design in the form of modular containers, water or air based cooling, or advanced power management through power supply optimization, are all approaches that have significantly improved PUE in datacenters. In addition, Cloud computing allows services to be moved between multiple datacenter which are running with better PUE values. This is achieved by using high speed network, virtualized services and measurement, and monitoring and accounting of datacenter .

5. Energy Efficiency :

The rising energy costs, cost savings and a desire to get more out of existing investments are making today□s Cloud providers to adopt best practices to make datacenters operation green. To build energy efficient datacenter, several best practices has been proposed to improve efficiency of each device from electrical systems to processor level.

First level is the smart construction of the datacenter and choosing of its location. There are two major factors in that one is energy supply and other is energy efficiency of equipments. Hence, the datacenters are being constructed in such a way that electricity can be generated using renewable sources such as sun and wind. Currently the datacenter location is decided based on their geographical features; climate, fibre-optic connectivity and access to a plentiful supply of affordable energy. Since main concern of Cloud providers is business, energy source is also seen mostly in terms of cost not carbon emissions. In datacenter cooling, two types of approaches are used: air and water based cooling systems. In both approaches, it is necessary that they directly cool the hot equipment rather than entire room area. Thus newer energy efficient cooling systems are proposed based on liquid cooling, nano fluid-cooling systems, and in-server, in-rack, and in-row cooling by companies such as SprayCool.



IV.**Green Cloud Architecture**

Fig : Green Cloud Architecture

Still in the market there is lack a unified picture. Most of efforts for sustainability of Cloud computing have missed the network contribution. If the file sizes are quite large, network will become a major contributor to energy consumption; thus it will be greener to run application locally than in Clouds. In addition, 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 provider□s 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.

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 [5]. 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.

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 $CO2$ per year.

After analyzing theshortcoming of previous solutions, we proposed a 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:

First efforts are required in designing software at various levels (OS, compiler, algorithm

and application) that facilitates system wide energy efficiency. Although SaaS providers may still use already implemented software, they need to analyze the runtime behavior of applications. The gathered empirical data can be used in energy efficient scheduling and resource provisioning. The compiler and operating systems need to be designed in such a way that resources can be allocated to application based on the required level of performance, and thus performance versus energy consumption tradeoff can be managed.

To enable the green Cloud datacenters, the Cloud providers need to understand and measure existing datacenter power and cooling designs, power consumptions of servers and their cooling requirements, and equipment resource utilization to achieve maximum efficiency

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