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# GREEN CLOUD COMPUTING: A REVIEW ON GREEN CLOUD COMPUTING AND VIRTUALIZATION IN GREEN COMPUTING

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## ABSTRACT

***Cloud Computing is an emerging technology and is being used by more and more IT companies due to its cost saving benefits and ease of use for users. But, it needs to be environment friendly also. Therefore, Green Cloud Computing is the requirement of the today's world. This paper reviews the efforts made by various researchers to make Cloud Computing more energy efficient, to reduce the carbon footprint rate by various approaches and also discusses the concept of virtualization and various approaches which use virtual machines scheduling and migration to show how these can help to make the system more energy efficient. The summary of the main features of the proposed work of different authors that we have reviewed is also presented in it.***

**Keywords**: Cloud Computing; Virtualization and techniques; Energy efficiency; Green Cloud Computing;

## I. INTRODUCTION ABOUT GREEN CLOUD COMPUTING

In last few decades the day to day demand and usage of cloud computing in IT areas makes it compulsory to think that the energy and power can not only be minimized but can also be used for the purpose of recycling. Generally, Cloud exhibits the huge amount of numerous data centres and servers to fulfil the need of customers .These resources are diffused in large area and consume big amount of power for networking devices, cooling technologies, monitors and farms of servers etc. thats'why to make these resources green by using Green technologies have become a primary purpose of government as well as industries. Here we also discuss various research issues and some significant results of this survey. Finally a concluding remark of this paper is given in last section.

## 2. INTRODUCTION ABOUT VIRTUALIZATION

large data storage and computational demand is growing day by day . Green Cloud Computing is known to be a broad and suitable area for research. To take advantage of various IT resources, Cloud computing has generated an ultimate and impressing way to virtualize servers and data centers and to make it energy efficient , its known as green cloud computing. It focuses on power management , energy efficiency , pollution control etc.

## 3. CLOUD COMPUTING

Cloud computing is a paradigm shift which provide computing over the internet . A cloud computing service consist of highly optimized datacenters. It provides energy efficient , price effective technologies which helps accessing , sharing of services and management of resources . Its provide various hardware , software's and information resources for useful needers. We have a three type of clouds ., these are … -Private cloud -Public cloud -Hybrid cloud The advantage of cloud computing is saving of costs reliability , flexibility , location autonomy etc.

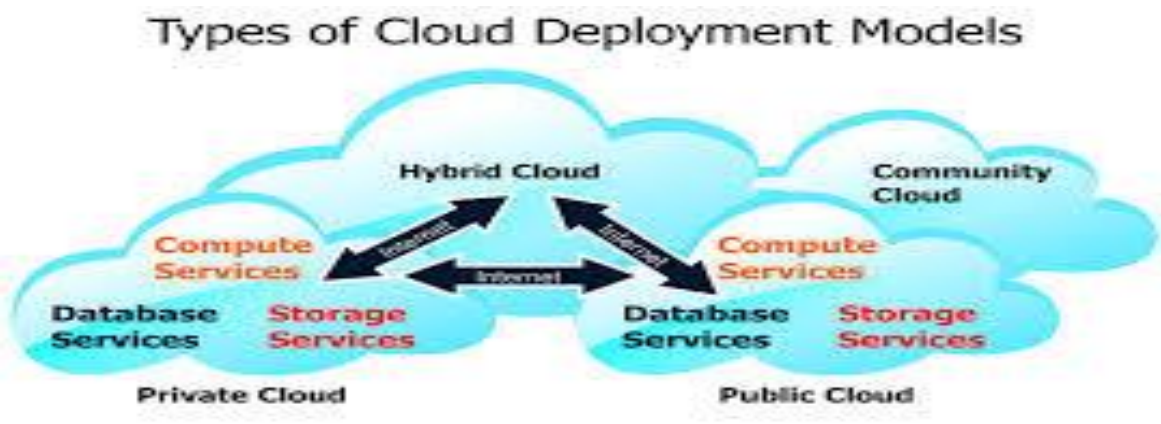
### A. Services of Cloud Computing

Cloud is referred to a pool of data centres. There are three types of services .. -SaaS(software as a service) Software as a service is a software Licensing and delivery model in which software is licensed on a subscription basis and is centrally hosted. -IaaS(infrastructure as a service)Infrastructure as a services refers to online services that provide high level APIs used to dereference various low-level details of underlying network like physical computing resources , location data , scaling , security etc. -Paas(Platform as a services)It includes services for deploying application.

### B. Deployment Models of Cloud Computing

The deployment of cloud computing is varied based on the requirements and based on these requirements the deployment models can be categorized into four types such as Private Cloud, Public cloud, Community cloud and Hybrid cloud . These models are described as follows:

i) Private Cloud: It is deployed, controlled and maintained for a particular organization or a company.
ii) Public Cloud: It is available for commercial basis which allows the users to build up and deploy a service the environment of cloud.
iii) Community Cloud: It is utilized by number of organizations which are having common needs and interests.
iv) Hybrid Cloud: It exhibits a number of clouds with different types but having the potentiality through their interfaces to allow and move applications or data between one to another cloud. It can be a combination of two or more clouds.




## 4. PARTS OF VIRTUALIZATION

Virtualization is nothing but known to be Green Cloud Computing. It focuses various areas such as power management, energy efficiency, virtualization of servers etc.

### A. GREEN COMPUTING

This section gives a brief discussion on origin, definitions, Green IT, applications of Green IT and need of Green IT as follows:

#### A1. Origin

The origin of Green Computing is started in 1987, when the report named "Our Common Future is issued by the World Commission. It basically stated the idea about "sustainable development . In 1992, one consumer Energy Star plan is launched by the U.S. Environmental Protection Agency (EPA) . The purpose of this is to minimize the consumption of energy it was primarily for computer products.

#### A2. Definitions

Green Computing refers to the efficient use of computers and other technologies with respect to environment so that the primary goals such as energy efficient peripherals, improve the consumption of resources and electronic waste can be satisfied. These goals will not only make the resources more efficient but also enhance the overall performance.
In the technical way, the Green Computing can have 2 aspects:
(i) For software technology the purpose is to create such methods that can enhance the efficiency of program, storage and energy.

While
(ii) In hardware aspect there is need of such technologies which can not only minimize the consumption of energy but also make it economically efficient
with the help of recycling .

**A3. Green IT**

Green IT, is a development and proposal of new computing models that used to make the IT resources more energy efficient both in terms of cost and power. While using the IT resources there are number of key areas that should be taken care. The Primary key areas of Green IT are discussed further.

**A4. Application Areas of Green IT**

Green IT spans a number of areas that are needed to be focused as shown in Fig. 3, such as:

i) power management of power
ii)virtualization of severs
iii)design od data Centres
iv)design of recycling methods
v)Eco labelling for it products
vi)Environment sustainability design
vii)Energy efficient resources

These areas are needed to be taken under consideration, while using the IT resources.

**A5. Need of Green IT for Cloud Computing**

In modern world, where the data centers and servers are remotely controlled under the Cloud Computing models there is a need of Green Computing to make these more energy efficient and economically reliable. While offering the Cloud services, the service provides should be ensured that they can provide energy efficient services with economical cost. But the challenging and complex task is to lower the usage of energy of data centres. As data are growing exponentially, the Green Cloud computing having issues related to infrastructures for computations that can not only minimize the consumption of energy but can also make the Cloud services reliable and economically efficient.

## B. REVIEW ON GREEN IT AREAS FOR CLOUD COMPUTING

There are number of authors who have worked in Green computing areas with respect to Cloud Computing. Table I represents the work done in terms of concern area of Green IT for Cloud computing. A year-wise study from 2009 to 2014 is given. It is shown with concern area of Green IT and Objectives which have focused to work towards the Green Cloud Computing. The Results of this survey are shown in the next section.

## C. ENERGY SAVING STRATEGIES

Energy consumption and performance of the system depend on many factors. Some simple techniques provide basic energy management for servers in Cloud environments, i.e. turning on and off servers, putting them to sleep. Other techniques for saving energy include use of Dynamic Voltage/Frequency Scaling (DVFS) and use of virtualization techniques for better resource utilization. Various researchers have put many efforts to reduce the energy consumption in clouds and data centres. In light of today's requirements for green computing, we present latest research efforts that attempt to deal with them.

## Calculating energy consumption by considering single task as a unit

In the authors had presented an energy consumption model, associated analysis tool and empirical energy analysis approaches to calculate total energy consumption in Cloud environments based on different runtime tasks. A single task was considered as a unit and energy produced by the task under various configurations was measured. The analysis tool had taken the energy consumption model as input and characterized energy consumed by each task based on the parameters like the number of processes, the size of data to be processed, size of data transmitted and system configuration. It helped to identify the relationship between energy consumption and running tasks in cloud environments, as well as system configuration and performance. The analytical results correlated system performance and energy consumed which can be important for developing energy efficient mechanisms.

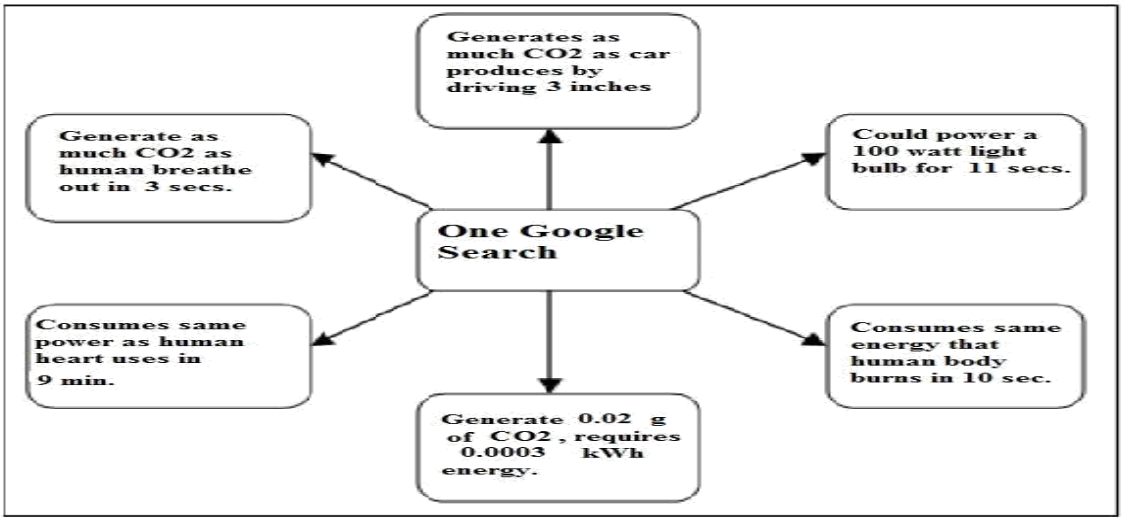



**Fig. 1 Energy consumption in one Google search [12]**

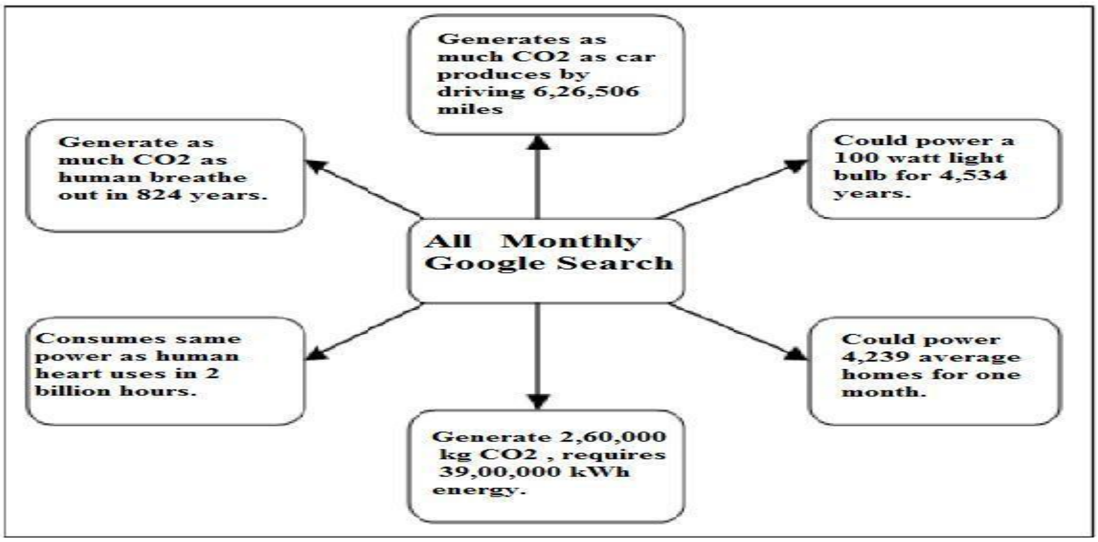



**Fig. 2 Energy consumption in monthly Google search [12]**

### Scheduling of workloads

Another approach presented in is to schedule workload across servers selected as a function of their cost to operate, in order to improve efficiency. The focus was to achieve the maximum utilization in a cost-efficient manner. The approach used queuing theory principles and also the relationship between packet arrival rate, service rate and response time. An exponential relationship between power cost and server utilization was found which was used for selection of the server to achieve maximum efficiency. It was also proposed that optimal efficiency can be achieved by maintaining server configuration with respect to the required utilization for handling the recommended workload.

### Efficient server allocation

The authors in had designed an algorithm for efficiently managing the network resources by allocating workload as a function of application traffic volume an speed of server. Efficiency was achieved by minimizing the packet loss and efficiently using the residual server capacity with respect to traffic patterns. It was proposed that by selecting the servers which can process the workloads at speed matching the packet arrival rate, optimization can be achieved. There is a point in server speed, at which optimal performance is achieved which cannot be achieved at speeds lesser or more than that. This is shown in the following graph in Fig. 3.

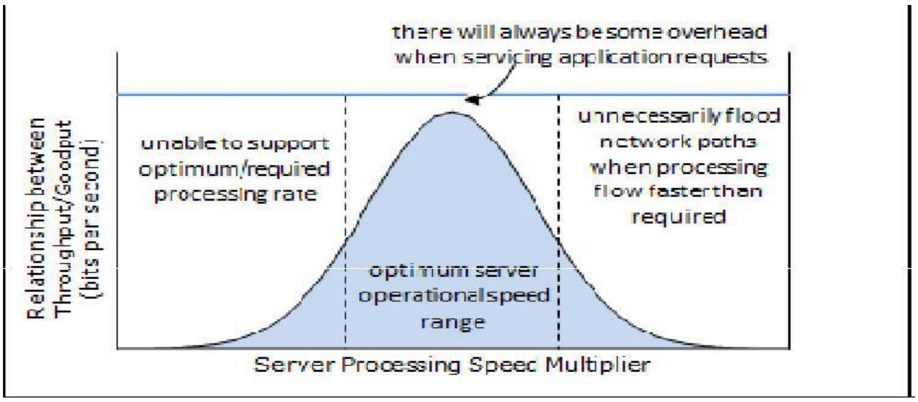



**Fig. 3 Server Selection Strategy as Function of Speed [17]**

## D. POWER MANAGEMENT IN DATACENTRES

Server virtualization empowers businesses to lower hardware spending, simplify administration and boost availability. It’s no surprise, then, that nearly 80 percent of server workloads supported by x86 hardware will be running on virtual machines (VMs) by 2016, according to analyst firm Gartner Inc.

For IT and facilities managers, however, server virtualization introduces both challenges and opportunities. In particular, while it makes preventing downtime during utility failures dramatically easier, provided your data center is equipped with the proper power management software, it also adds new complexities to the demands of avoiding data loss during electrical outages when shutting down servers is unavoidable.

This white paper discusses server virtualization’s impact on both maintaining business continuity and preserving data integrity during power outages, and then explains how state-of-the-art power management solutions can help virtualized data centers cope with utility failures more effectively

### Maintaining business continuity

Downtime is enormously expensive, so a truly comprehensive power protection environment must be designed to ensure that essential applications remain continuously available.

In principle, server virtualization makes preserving business continuity during electrical service interruptions significantly easier by enabling data centers to move virtual machines onto unaffected host servers elsewhere on the network. In reality, however, managing that process is harder than it sounds.

**The challenges**

VMware, Microsoft, Citrix and other server virtualization software vendors all offer "live migration" products that can swiftly transfer virtual machines from one host server to another for load balancing purposes or when the original server experiences operational problems or requires maintenance. However, none of those systems include built-in functionality for responding to power outages.
Furthermore, most power protection systems for virtualized server environments come with their own command console. As a result, technicians must use one tool for virtualization management and a separate one for power management. That weakens their productivity and can delay their response time during utility failures.

**The solution**
Deploying modern power management software significantly eases the complexities of keeping critical applications continuously available during power outages.
For starters, some such solutions integrate closely with leading virtualization management products, including VMware vCenter Server, Microsoft SCVMM and Citrix XenCenter. That enables technicians to view, monitor and administer not only physical and virtual servers but uninterruptible power systems (UPSs) and other power devices through a single console.

## E. TOWARDS ENERGY EFFICIENCY OF CLOUD COMPUTING

### E1 .Applications

SaaS model has changed the way applications and software are distributed and used. More and more companies are switching to SaaS Clouds to minimize their IT cost. Thus, it has become very important to address the energy efficiency at application level itself. However, this layer has received very little attraction since many applications are already on use and most of the new applications are mostly upgraded version of or developed using previously implemented tools. Some of the efforts in this direction are for MPI applications , which are designed to run directly on physical machines. Thus, their performance on virtual machine is still undefined.

Various power efficient techniques for software designs are proposed in the literature but these are mostly for embedded devices. In the development of commercial and enterprise applications which are designed for PC environment, generally energy efficiency is neglected. Mayo et al. presented in their study that even simple tasks such as listening to music can consume significantly different amounts of energy on a variety of heterogeneous devices. As these tasks have the same purpose on each device, the results show that the implementation of the task and the system upon which it is performed can have a dramatic impact on efficiency. Therefore, to achieve energy efficiency at application level, SaaS providers should pay attention in deploying software on right kind of infrastructure which can execute the software most efficiently. This necessitates the research and analysis of trade-off between performance and energy consumption due to execution of software on multiple platforms and hardware. In addition, the energy consumption at the compiler level and code level should be considered by software developers in the design of their future application implementations using various energyefficient techniques proposed in the literature.

### E2 .Cloud Software Stack: Virtualization and Provisioning

In the Cloud stack, most works in the literature address the challenges at the IaaS provider level where research focus is on scheduling and resource management to reduce the amount of active resources executing the workload of user applications. The consolidation of VMs, VM migration, scheduling, demand projection, heat management and temperature-aware allocation, and load balancing are used as basic techniques for minimizing power consumption. As discussed in previous section, virtualization plays an important role in these techniques due to its several features such as consolidation, live migration, and performance isolation. Consolidation helps in managing the trade-off between performance, resource utilization, and energy consumption . Similarly, VM migration allows flexible and dynamic resource management while facilitating fault management and lower maintenance cost. Additionally, the advancement in virtualization technology has led to significant reduction in VM overhead which improves further the energy efficiency of Cloud infrastructure.

Abdelsalam et al. proposed a power efficient technique to improve the management of Cloud computing environments. They formulated the management problem in the form of an optimization model aiming at minimization of the total energy consumption of the Cloud, taking SLAs into account. The current issue of under utilization and over-provisioning of servers was highlighted by Ranganathan et al. . They present a peak power budget management solution to avoid excessive over-provisioning considering DVS and memory/disk scaling. There are several other research work which focus on minimizing the over provisioning using consolidation of virtualized server . Majority of these works use monitoring and estimation of resource utilization by applications based on the arrival rate of requests. However, due to multiple levels of abstractions, it is really hard to maintain deployment data of each virtual machine within a Cloud datacenter. Thus, various indirect load estimation techniques are used for consolidation of VMs.

Although above consolidation methods can reduce the overall number of resources used to serve user applications, the migration and relocation of VMs for matching application demand can impact the QoS service requirements of the user. Since Cloud providers need to satisfy a certain level of service, some work focused on minimizing the energy consumption while reducing the number of SLA violations. One of the first works that dealt with performance and energy trade-off was by Chase et al. who introduced MUSE, an economy-based system of resource allocation. They proposed a bidding system to deliver the required performance level and switching off unused servers. Kephart et al. addressed the coordination of multiple autonomic managers for power/performance tradeoffs using a utility function approach in a nonvirtualized environment. Song et al proposed an adaptive and dynamic scheme for efficient sharing of a server by adjusting resources (specifically, CPU and memory) between virtual machines. At the operating system level, Nathuji et al proposed a power management system called VirtualPower integrating the power management and virtualization technologies. VirtualPower allows the isolated and independent operation of virtual machine to reduce the energy consumption. The soft states are intercepted by Xen hypervisor and are mapped to changes in the underlying hardware such as CPU frequency scaling according to the virtual power management rules.

In addition, there are works on improving the energy efficiency of storage systems. Kaushik et al. presented an energy conserving self-adaptive Commodity Green Cloud storage called Lightning. The Lightning file system divides the Storage servers into Cold and Hot logical zones using data classification. These servers are then switched to inactive states for energy saving. Verma et al proposed an optimization for storage virtualization called SampleReplicate-Consoidate Mapping (SRCMAP) which enables the energy proportionality for dynamic I/O workloads by consolidating the cumulative workload on a subset of physical volumes proportional to the I/O workload intensity. Gurumurthi et al. proposed intra-disk parallelism on high capacity drives to improve disk bandwidth without increasing power consumption. Soror et al. addressed the problem of optimizing the performance of database management systems by controlling the configurations of the virtual machines in which they run.

Since power is dissipated in Cloud datacenter due to heat generated by the servers, several work also have been proposed for dynamic scheduling of VMs and applications which take into account the thermal states or the heat dissipation in a data centre. The consideration of thermal factor in scheduling also improves the reliability of underline infrastructure. Tang et al. formulated the problem using a mathematical model for maximizing the cooling efficiency of a data center. Heath et al. proposed emulation tools for investigating the thermal implications of power management. Ramos et al. proposed a software prediction infrastructure called C-Oracle that makes online predictions for data center thermal management based on load redistribution and DVS. Moore et al. proposed a method for automatic reconfiguration of thermal load management system taking into account thermal behavior for improving cooling efficiency and power consumption. They also propose thermal management solutions focusing on scheduling workloads considering temperature-aware workload placement. Bash et al. propose a workload placement policy for a datacenter that allocate resources in the areas which are easier to cool resulting in cooling power savings. Raghavendra et al. propose a framework which coordinates and unifies five individual power management solutions (consisting of HW/SW mechanisms).

**E3 . Datacenter level: Cooling, Hardware, Network, and Storage**

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.

Another area of concern within a datacenter is its cooling system that contributes to almost 1/3 of total energy consumption. Some research studies have shown that uneven temperature within datacenter can also lead significant decline in reliability of IT systems. 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. Other than that, the outside temperature/climate can have direct impact on the energy requirement of cooling system. Some systems have been constructed where external cool air is used to remove heat from the datacenter.

Another level at which datacenter‟s power efficiency is addressed is on the deployment of new power efficient servers and processors. Low energy processors can reduce the power usage of IT systems in a great degree. Many new energy efficient server models are available currently in market from vendors such as AMD, Intel, and others; each of them offering good performance/watt system. These server architecture enable slowing down CPU clock speeds (clock gating), or powering off parts of the chips (power gating), if they are idle. Further enhancement in energy saving and increasing computing per watt can be achieved by using multi-core processors. For instance Sun‟s multicore chips, each 32-thread Niagara chip, UltraSPARC 1, consumes about 60 watts, while the two Niagara chips have 64 threads and run at about 80 watts. However, the exploitation of such power efficiency of multi-core system requires software which can run on multi-CPU environment. Here, virtualization technologies play an important role. Similarly, consolidation of storage system helps to further reduce the energy requirements of IT Systems. For

example, Storage Area Networks (SAN) allow building of an efficient storage network that consolidates all storage. The
use of energy efficient disks such as tiered storage (Solid-State, SATA, SAS) allows better energy efficiency.

The power supply unit is another infrastructure which needs to be designed in an energy efficient manner. Their task is to feed the server resources with power by converting the high-voltage alternating current (AC) from the power grid to a low-voltage direct current (DC) which most of the electric circuits (e.g. computers) require. These circuits inside Power Supply Unit (PSU) inevitably lose some energy in the form of heat, which is dissipated by additional fans inside PSU. The energy efficiency of a PSU mainly depends on its load, number of circuits and other conditions (e.g. temperature). Hence, a PSU which is labeled to be 80% efficient is not necessarily that efficient for all power loads. For example, low power loads tend to be the most energy inefficient ones. Thus, a PSU can be just 60% efficient at 20% of power load. Some studies have found that PSUs are one of the most inefficient components in today‟s data centers as many servers are still shipped with low quality 60 to 70 percent efficient power supplies. One possible solution offered is to replace all PSUs by ENERGY STAR certified ones. This certificate is given to PSUs which guarantee a minimum 80% efficiency at any power load.

**E4 . Monitoring/Metering**

It is said that you cannot improve what you do not measure. It is essential to construct power models that allow the system to know the energy consumed by a particular device, and how it can be reduced. To measure the unified efficiency of a datacenter and improve its' performance per-watt, the Green Grid has proposed two specific metrics known as the Power Usage Effectiveness (PUE) and Datacenter Infrastructure Efficiency (DciE) .

- **PUE = Total Facility Power/IT Equipment Power**
- **DciE = 1/PUE = IT Equipment Power/Total Facility Power x 100%**

Here, the Total Facility Power is defined as the power measured at the utility meter
that is dedicated solely to the datacenter power. The IT Equipment Power is defined as the power consumed in the management, processing, and storage or routing of data within the datacenter.
PUE and DCIE are most common metrics designed to compare the efficiency of datacenters. There are many systems in the marketplace for such measurements. For instance SunSM Eco
Services measures at a higher level rather than attempting to measure each individual device‟s power consumption. For measuring and modeling the power usage of storage system, Researchers from IBM have proposed a scalable, enterprise storage modelling framework called STAMP. It side steps the need for detailed traces by using interval performance statistics and a power table for each disk model. STAMP takes into account controller caching and algorithms, including protection schemes, and adjusts the workload accordingly. To measure the power consumed by a server (e.g. PowerEdge R610) the Intelligent Platform Management Interface (IPMI) is proposed. This framework provides a uniform way to access the power-monitoring sensors available on recent servers. 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 (i.e. connection to the power grid is enough). Further, intelligent power distribution units (PDUs), traditional power meters (e.g. Watts Up Pro power meter) and ACPI enabled power supplies can be used to measure the power consumption of the whole server.

**E5 . Network Infrastructure**

As discussed previously, at network level, the energy efficiency is achieved either at the node level (i.e. network interface card) or at the infrastructure level (i.e. switches and routers). The energy efficiency issues in networking is usually referred to as “green networking”, which relates to embedding energy-awareness in the design, in the devices and in the protocols of networks. There are four classes of solutions offered in literature, namely resource consolidation, virtualization, selective connectedness, and proportional computing. Resource consolidation helps in regrouping the under-utilized devices to reduce the global consumption. Similar to consolidation, selective connectedness of devices consists of distributed mechanisms which allow the single pieces of equipment to go idle for some time, as transparently as possible from the rest of the networked devices. The difference between resource consolidation and selective connectedness is that the consolidation applies to resources that are shared within the network infrastructure while selective connectedness allows turning off unused resources at the edge of the network. Virtualization as discussed before allows more than one service to operate on the same piece of hardware, thus improving the hardware utilization. Proportional computing can be applied to a system as a whole, to network protocols, as well as to individual devices and components. Dynamic Voltage Scaling and Adaptive Link Rate are typical examples of proportional computing. Dynamic Voltage Scaling reduces the energy state of the CPU as a function of a system load, while Adaptive Link Rate applies a similar concept to network interfaces, reducing their capacity, and thus their consumption, as a function of the link load. The survey by Bianzino et al. gives more details about the work in the area of Green networking.

**F. CASE STUDY:**

In this section, we describe a case study example to illustrate the working of the proposed Green Architecture in order to highlight the importance of considering the unifying picture to reduce the energy and carbon emissions by Cloud infrastructure. The case study focuses on IaaS service providers. Our experimental platform consists of multiple Cloud providers who offer computational resources to execute user‟s HPC applications. A user request consists of application, its estimated length in time and number of resources required. These applications are submitted to the Green broker who acts as an interface to the Cloud infrastructure and schedules applications on behalf of users as shown in Figure 7. The Green Broker interprets and analyzes the service requirements of a submitted application and decides where to execute it. As discussed, Green Broker‟s main objective is to schedule applications such that the CO2 emissions are reduced and the profit is increased, while the Quality of Service (QoS) requirements of the applications are met. As Cloud data centers are located in different geographical regions, they have different CO2 emission rates and energy costs depending on regional constraints. Each datacenter is responsible for updating this information to Carbon Emission Directory for facilitating the energy-efficient scheduling. The list of Energy_related_parameters_is_given_in_t able.

| Parameter | Notation |
|---|---|
| Carbon emission rate (kg/kWh) | $r_i^{CO_2}$ |
| Average COP | $COP_i$ |
| Electricity price ($/kWh) | $p_i^e$ |
| Data transfer price ($/GB) for upload/download | $p_i^{DT}$ |
| CPU power | $P_i = \beta_i + \alpha_i f^3$ |
| CPU frequency range | $[f_i^{min}, f_i^{max}]$ |
| Time slots (start time, end time, number of CPUs) | $(t_s, t_e, n)$ |

**Figure: carbon emission relateparameter of a datacentre**

## G. Conclusions and Future Directions

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, in this chapter, 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”. We also discussed several research efforts and technologies that increase the energy efficiency of various aspects of Clouds. For this study, we identified several unexplored areas that can help in maximizing the energy efficiency of Clouds from a holistic perspective. After analyzing the shortcoming 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:

1. 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. In addition, modeling tools are required to measure the energy usage of all

□the components and services of Cloud, from user PC to datacenter where Cloud services are hosted.

2. For designing the holistic solutions in the scheduling and resource provisioning of applications within the datacenter, all the factors such as cooling, network, memory, and CPU should be considered. For instance, consolidation of VMs even though effective technique to minimize overall power usage of datacenter, also raises the issue related to necessary redundancy and placement geo-diversity required to be maintained to fulfill SLAs with users. It is obvious that last thing Cloud provider will want is to lose their reputation by their bad service or violation of promised service requirements.

3. Last but not the least, the responsibility also goes to both providers and customers to make sure that emerging technologies do not bring irreversible changes which can bring threat to the health of human society. The way end users interact with the application also has a very real cost and impact. For example, purging of unsolicited emails can eliminates energy wasted in storage and network. Similarly, if Cloud providers want to provide a truly green and renewable Cloud, they must deploy their datacenters near renewable energy sources and maximize the Green energy usage in their already established datacenters. Before adding new technologies such as virtualization, proper analysis of overhead should be done real benefit in terms of energy efficiency.

4. In conclusion, by simply improving the efficiency of equipment, Cloud computing cannot be claimed to be Green. What is important is to make its usage more carbon efficient both from user and provider‟s perspective. Cloud Providers need to reduce the electricity demand of Clouds and take major steps in using renewable energy sources rather than just looking for cost minimization.