# Green Computing: An Era of Energy-Efficient Computing Over Cloud

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***Abstract:*** **Cloud computing is the Buzzword in the ICT sector for high performance computing. It continues grabbing headlines as one of the biggest technology trends gains momentum. Cloud provides lots of benefits in the fields of Businesses and individuals, like high performance, convenience and cost savings, so they increasingly choose cloud services to stay competitive. Our main focus is on the capabilities of the cloud due to which we forget about the environmental impacts derived from the technology. In the business world Cloud computing contributes to the green computing movement through energy and resource efficiency. As energy costs are increasing while availability dwindles, so it is required to focus on optimisation of energy efficiency while maintaining high service level performance rather than optimising data centre resource management. This paper highlights the impact of Green Cloud computing model that accomplishes not just efficient processing and utilisation of computing infrastructure, but also reduce energy consumption. This paper exhibits the methods which increase the power efficiency and minimize power consumption of the data centers.**

***Keywords:*** **Cloud Computing; Data Centers; Energy Efficiency; Green Computing**

## I. INTRODUCTION

**Cloud Computing:** Cloud is an integrated, dynamic infrastructure that provides services either internally (private cloud) or externally (public cloud). Every cloud provide the three types of services like *Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS)*. So it is important to understand the trade-offs among ***SaaS, PaaS and IaaS***, and between *Public* and *Private* clouds. Find the possibilities for our organization to build virtualized environment into a fully automated, service-oriented infrastructure of pooled resources (server, storage, and network) that enables us to easily deliver IT Services to our internal users. To optimize the working of shared IT environment we focus on following three advantages:

- Tremendous agility
- Extreme efficiency
- Maximum Utilization

It consolidates your environment, saving power, cooling, and space, as well as money. Cloud offers a future-proof platform that can grow no disruptively as your business requires.

**Green Computing:** Energy efficient and eco-friendly use of computers and resources is known as green computing. It is the implementation of energy-efficient CPU, servers, peripheral devices as well as reduced resource consumption. The aim of "green computing" is to define such type of energy initiatives, so that it will help full to reduce the carbon footprints.

Day by day the amount of huge energy consumption is increase because generally we focus with data centers for providing high speed /performance without paying any attention about energy consumption. A 10 year's (2000-2010) report of energy consumption in world wide data centers is shown in fig 1.

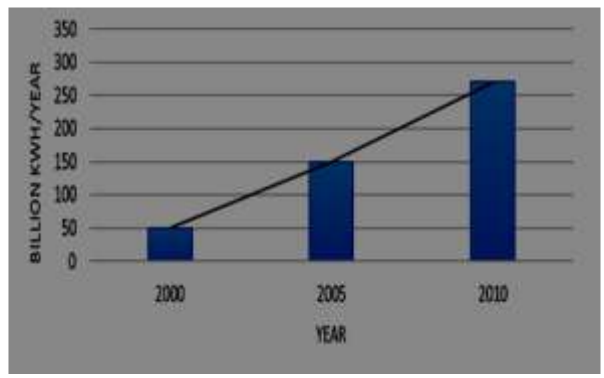


Fig 1: Energy Consumption Report of worldwide Data Center (2000-2010)

The different components of any server also consume high energy shown in fig 2:

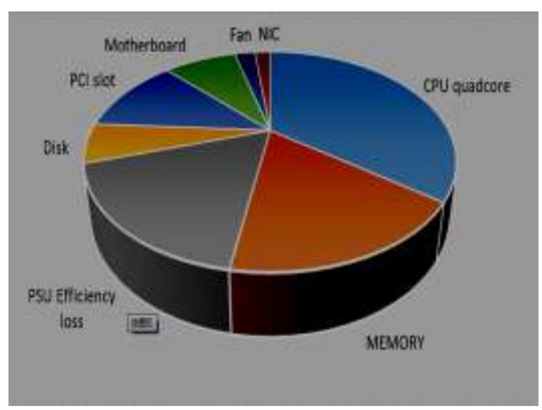


Fig 2: Pie chart of power consumption of Server's component

Fig.3 shows that any cloud computing environment is a large cyber-physical system consisting of electrical, mechanical and IT systems running a variety of tasks on a multitude of server pools and storage devices connected with multitier hierarchy of aggregators, routers and switches.

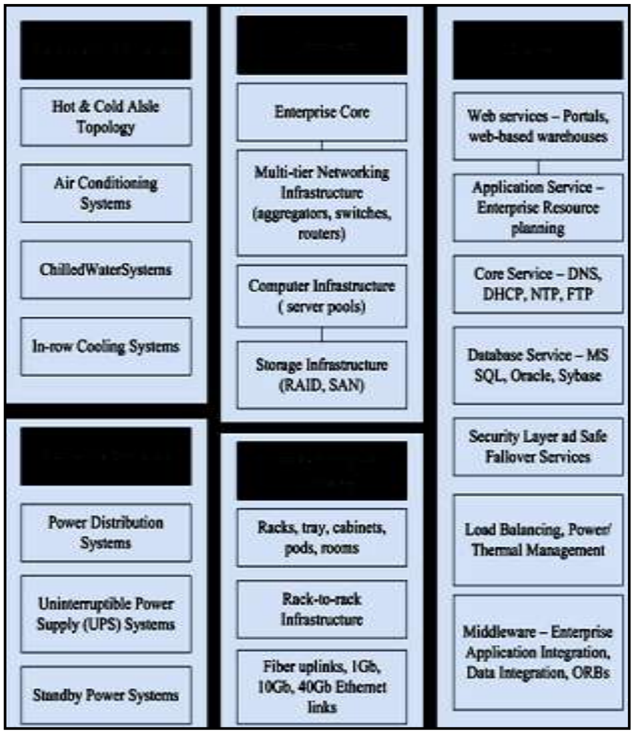


Fig3: High –level components comprising cloud computing environment

## II. NEED OF ENERGY EFFICIENT CLOUD ENVIRONMENT

Energy consumption is the key concern in content distribution system and most distributed systems (Cloud systems). These demand an accumulation of networked computing resources from one or multiple providers on datacenters extending over the world. This consumption is censorious design parameter in current data center and cloud computing environment. The power and energy consumed by the computer systems and the linked cooling system is a main constituent of these energy cost and excessive carbon emission.

Data centers in cloud applications use huge quantities of energy which contributes to increased operational costs and carbon emission. Some research shows that excluding the energy consumed by the cooling equipment for the server, a single 300-watt server running throughout a year can cost about $338, and can emit around 1,300 Kilos CO2 [1]. According to a McKinsey report, $11.5 billion was the total estimated energy bill for data centers in 2010 [2]

Cloud computing environment comprises thousands to tens of thousands of server machines, working to render services to the clients [4], [5]. Present servers are far from energy uniformity. Servers consume 80% of the peak power even at 20% utilization [6]. The power non-uniformity server is a key source to power inefficiency in cloud computing surroundings. Servers are often applied with between 10% to 50% of their top load and servers enjoy a common idle instance [7] which means that servers aren't working at their superior strength-performance tradeoff points normally, and idle mode of servers consumes huge portion of overall power.

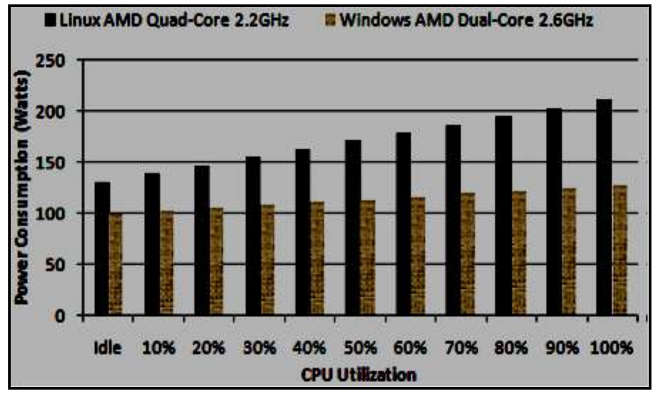


Fig 4: Power consumption under different workloads.

## III. CAUSES OF INEFFICIENCY

To improve the efficiency of data centre, it is important to identify the causes of inefficiency in the first place. The factors which we include for it are:

■ *Power equipment Inefficiencies:* Comprises of equipment such as Uninterruptible Power Supplies (UPS), transformers, transfer switches, and wiring. Efficiency is drastically affected when equipment is doubled for redundancy or operated well below its rated power. Cooling System cooled the heat generated by power equipment, using up even more energy.

■ *Cooling equipment inefficiencies:* Comprises of equipment such as air handlers, chillers, cooling towers, condensers, pumps, and dry coolers. When cooling equipment is doubled for redundancy or operating well below its rated power, efficiency falls dramatically. This is made more urgent as the waste heat of cooling equipment typically exceeds that of power equipment.

■ *Power consumption in light:* Lighting consumes electricity and generates heat, which must be cooled by the cooling system. Useless electrical intake consequences when lights remains turned on when there are no personnel within the data centre, or while unutilized areas of the data centre are lit.

■ *Size of power and cooling systems:* This is one of the largest drivers of energy waste. Sometime design of the power or cooling system increase the IT load, for the fast execution of IT Load. For example, the IT load may have been overestimated and the power and cooling systems were sized for too large a load. Or, the design of cooling system itself may have been poor, requiring analyzing the over-sizing of cooling equipment to successfully cool the IT load.

■ *Configuration Inefficiencies*: Poor configuration forces the cooling system to move more air and generate cooler air than the IT equipment requires. Poor configuration may also force various cooling units into conflict where one is dehumidifying while the other is humidifying.

## IV. ELEMENTS OF ENERGY EFFICIENT ARCHITECTURE

There are several key elements that will give rise to improved data centre efficiency. These elements will directly address the contributors to electrical inefficiency highlighted above.

■ *Scalable power and cooling:* Avoids over-sizing. Data centre efficiency decreases when IT loads decrease. Therefore, when the percentage of IT load actually being used is below the design value of a data centre, the data centre is considered to be over-sized for that IT load. This particularly affects power and cooling efficiency. To correct this problem, power and cooling equipment should be scalable to meet data centre needs over time. Not only does this increase efficiency, but also can help managers reduce capital investments and operating costs until additional capacity is required.

■ *Row-based cooling:* Improves cooling efficiency. Row-based cooling places air-conditioning within the rows of IT equipment, rather than at the perimeter of the room. Shortening the airflow path reduces the mixing of hot and cold air streams which improves the predictability of air distribution. Predictable air distribution to IT equipment allows for more precise control of variable airflow rates that adjust automatically to the needs of nearby IT loads. In addition, row-based cooling captures the hot air from IT load while it is still hot, before it has the chance to mix with ambient air as shown in fig 5.

■ *High-efficiency UPS:* Improves power system efficiency. According to a study by Lawrence Berkley National Labs [3], at 30% load, new, high-efficiency UPS systems are 10% more efficient when compared to the average UPS system. Actual wattage losses of high-efficiency UPS systems can be reduced by as much as 65%.

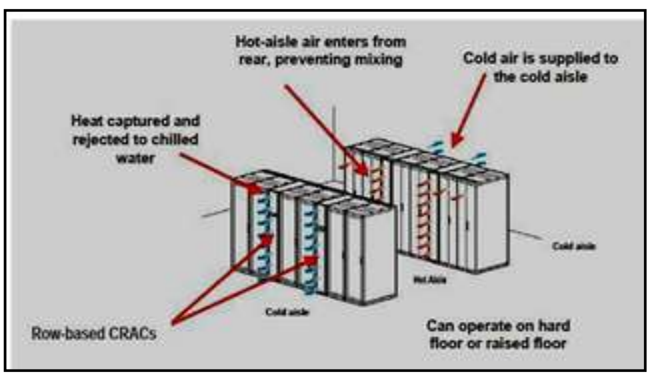


Fig 5: Representation of row-based cooling system

■ *Variable speed drives on pumps and chillers:* To Improves cooling efficiency, variable speed drives (VSDs) are used in data centers and appropriate controls can reduce their speed and energy consumption to match the current IT load and the current outdoor conditions. The power improvement varies relying on conditions, but may be as large as 10% or more, mainly for data centers that are not working at full rated IT load, or for data centers with chiller or pump redundancy.

■ *Capacity management tools:* Improves utilization of power, cooling, and rack capacity. Capacity management tools can help managers improve power utilization, cooling and rack capacity by monitoring energy consumption. These tools can identify and alert managers about specific conditions that create less than optimal electrical consumption, helping to identify opportunities for reduced electricity usage and improved energy efficiency.

■ *Room layout tools:* Optimizes room layout for cooling efficiency. A room optimized for efficiency is one in which-

- Airflow path lengths are minimized to reduce fan power
- Airflow resistance is minimized to reduce fan power
- IT equipment exhaust air is returned directly at high temperature to the air-conditioner to maximize heat transfer
- Air-conditioners are located so that airflow capacities are balanced to the nearby load airflow requirements.

## V. ARCHITECTURE OF A GREEN CLOUD COMPUTING

For supporting power-efficient service allocation in green cloud computing environment, a high-level architecture is suggested shown in fig 6. There are basically four main entities involved in this architecture:

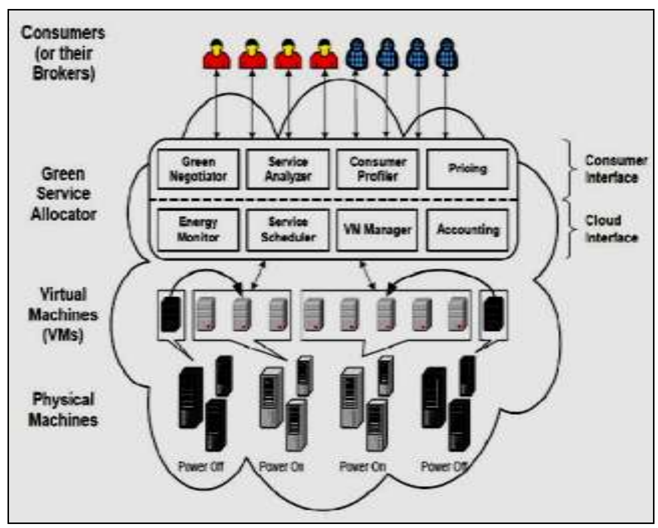


Fig 6: Eco Friendly Architecture of Cloud Computing

*a) Consumers:* Cloud consumers submit service requests from anywhere in the world to the Cloud. It is important to be aware that there can be a difference among Cloud consumers and users of deployed services. As an instance, a customer may be a company which deploying a Web application, which shows different workload according to the number of users accessing it.

*b) Allocator of green resource:* It like as the interface between the Cloud environment and consumers. It requires some components to support energy-efficient resource management as:

• *Negotiator*: It negotiates with the consumers/brokers to finalize the SLA with targeted prices and consequences (for violations of SLA) among the Cloud provider and customer relying on the customer's QoS requirements and energy saving schemes. In case of Web applications, for instance, QoS metric can be 95% of requests being served in less than 3 seconds.

• *Service Analyzer:* Interprets and analyses the service requirements of a submitted request before deciding whether to accept or reject it. As a result, it needs the latest load and energy information from VM Manager and Energy Monitor respectively.

• *Consumer Profiler:* Gathers precise characteristics of consumers so that essential consumers may be granted unique privileges and prioritized over different consumers.

• *Price:* It decides how service requests are charged to manage the supply and demand of computing resources and facilitate in prioritizing service allotment successfully.

• *Energy Observer:* It Observes and finds which physical machine's power can be on/off.

• *Service Scheduling:* Here service scheduler assigns requests to VMs and determines resource entitlements for allocated VMs. It also finds when we can add or remove VMs are to be added or remove according to demand.

• *VM Manager:* Keeps track of the availability of VMs and their resource entitlements. It is also in charge of migrating VMs across physical machines.

• *Accounting:* Maintains the actual usage of resources by requests to compute usage costs. Historical usage information can also be used to improve service allocation decisions.

*c) Virtual Machines:* Many Virtual Machines may be dynamically began and stopped on a single physical machine to fulfill accepted requests, for this reason , offering maximum flexibility to configure different partitions of resources on the same physical machine to different specific requirements of service requests. Multiple VMs also can concurrently run different applications based on different operating system environments on a single physical machine. In addition, via dynamically migrating VMs across physical machines, processes can be consolidated and unused resources can be put on a low-power state, turned off or configured to operate at low-performance levels (as:DVFS) in order to save energy.

*d) Physical Machines:* The underlying physical computing servers provide hardware infrastructure for creating virtualized resources to meet service demands.

*Making cloud computing more green*

Three approaches have been tried out to make cloud computing environments more environmental friendly. These approaches have been tried out in the data centers under experimental conditions. The methods are:

• *Dynamic Voltage frequency scaling technique (DVFS):-* Every electronic circuitry will have an operating clock associated with it. The operating frequency of this clock is adjusted so that the supply voltage is regulated. Thus, this method heavily depends on the hardware and is not controllable according to the varying needs. The power savings are also low compared to other approaches. The ratio of power savings to cost is low.

• *Resource allocation or virtual machine migration techniques:-*In a cloud computing environment, every physical machine hosts a number of virtual machines upon which the applications are run. These virtual machines can be transferred across the hosts according to the varying needs and available resources. The VM migration method focuses on transferring VMs in such a way that the power increase is least. The most power efficient nodes are selected and the VMs are transferred across to them.

• *Other approaches:-* Dynamic provisioning environment, multi-tenancy, green data center approaches are enabling cloud computing to lower carbon emissions and energy usage up to a great extent. Large and small organizations can reduce their direct energy consumption and carbon emissions through up to 30% and 90% respectively through moving certain on-premises applications into the cloud environment.

## VI. CONCLUSION

As large data centers emerge for media-rich Internet services and applications, their energy efficiency has become a central issue of both economic importance and environmental urgency. Cloud computing relies on the compute and storage infrastructure provided by these data centers and is becoming a highly accepted computing paradigm. The need for high availability and scalability in Internet computing has resulted in multi-layer, distributed and virtualized systems which make energy efficiency a more challenging problem. In particular, multimedia services are growing more and more popular in recent years. How to manage power and energy for multimedia services in data centers and cloud environment, therefore, is a subject of great practical value. The energy consumption of data centers has been skyrocketing. An estimate indicates that data centers in U.S. would consume 100 billion KWh by 2011 [1]. This can result in an increase in electricity cost and emission of more carbon dioxide.. In this paper, we identify some of the challenges in energy management and summarize design techniques for energy-efficient data centers.

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