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# A REVIEW ON ENERGY EFFICIENCY IN CLOUD DATA CENTER

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**Abstract:** In this paper we explore the energy efficient approaches inside data centers from the site and IT infrastructure perspective incorporating Cloud networking from the access network technologiesand network equipment point of view to give a comprehensive prospect toward achieving energyefficiency of Cloud computing. Traditional and Cloud data centers would by compared to figureout which one is more recommended to be deployed. Virtualization as heart of energy efficientCloud computing that can integrates some technologies like consolidation and resourceutilization has been introduced to prepare a background for implementation part. Finallyapproaches for Cloud computing data centers at operating system and especially data centre levelare presented and Green Cloud architecture as the most suitable green approach is described indetails. In the experiment segment we modeled and simulated Face book and studied the behavior in terms of cost and performance and energy consumption to reach a most appropriatesolution.

**Keywords: energy efficiency, cloud computing, data centre**

## I.INTRODUCTION

Cloud computing is a concept involving different issues, concerns, technologies. Reaching to a global comprehensive definition seems to be defined arbitrarily for each IT organization or company. We rather to skip debates about our definition and use global definition announced by NIST [1] as follows: "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." In simple words Cloud computing is a collection of hardware, networks, interfaces, services and storage providing feasibility to deliver everything such as social networks (Facebook) or collaboration tools (video conferencing, webinars, document management) as a service over internet whenever and wherever you need on-demand. [2]

### a) Cloud Computing Characteristics

There are some natural characteristics associated with Cloud computing that sustain IT from the environment or energy efficiency and economy perspective: [3,4,5 and 6] Cloud Computing and Sustainability: Energy Efficiency Aspects

**Centralization:** It means moving all computing for applications, storage and infrastructure to the Cloud in order to reduce cost and have a better resource management.
**Virtualization**: It corresponds to virtualizing any consisting component of IT (storage, network, desktop, server, switch and router, applications firewall). It will lead to lower cost, better performance, elasticity and dynamic provisioning and energy efficiency.
**Automation:** It is the use of IT to reduce the human interaction in producing things, e.g. provisioning the resources. Automation reduces the cost, improves quality, elasticity and provisioning.
**Broad Network Access:** Users can access Cloud services ubiquitously as soon as they have a device with capability to connect to the Cloud such as laptops, PDAs, mobile phones.
**Dynamic Movement of Resources:** It moves virtual machines and storage inside data center and across them as well due to more suitable conditions such as lower cost, daytime, power and consumption and maintenance concerns.
**Internet:** Cloud use internet as a main infrastructure to connect customers to it that is widely used.
**Self-service :** Users can access the Cloud services without interference of IT organization.
**Chargeback (Pay per Use) :** Users pay for Cloud service only when they use it and Cloud just charge them for that specific service.
**Simplification :** Running many applications inside one would make it simply understandable for user like Salesforce.com Company.
**Standardization:** In order to eliminate the complexity from Cloud, one vendor equipment's should be used inside Cloud like unique vendor switches and routers or all the operating systems belong to one company.
**Technology Convergence:** It is capable to unify all computing technologies such as storage, network, virtualization and servers in one platform to lower the cost and enhance the scaling of data center deployment.
**Federation:** It is about Bundling disparate Cloud computing data centers together via connecting their infrastructures to enable resource sharing.
**Multi-tenancy (Shared):** Multiple customers use the shared infrastructure. Resources are allocated to users on demand, they are not aware of location of services and whom the resources are shared with.
**Dynamic Provisioning (Elasticity):** Cloud responds rapidly to customer demand flexibly. This feature regards to dynamically adjusting the capacity and scaling up and down the resources such as network, storage and Cloud Computing and Sustainability: Energy Efficiency Aspects processing depending on customer demand requirements avoiding inessential energy and resource usage.
**On Demand:** As opposed to ordinary computing that resources are inside IT infrastructure, in case of Cloud computing we have access to any resources residing in the Cloud without having any dedicated ones to use internal services.

**Server Utilization:** Cloud computing can save energy by utilizing servers via distribution of resources, multi tenancy and virtualization.
**Data Center Efficiency:** It addresses Improving data center energy efficiency by optimizing cooling, air conditioning, design, power consumption and energy source to reduce the environmental impact of data centers.
**Service Oriented:** Cloud delivers computing as a service to users regardless of being software, application and infrastructure.

## b) Cloud Service Models

There are three major Cloud service models as mentioned below: [7]

**Software as a service (Saas):** In This model application is hosted on the Cloud and user has access to that through world wide web, web based email service of Google (Gmail) is an example of this kind of service. This model transfer the maintenance, troubleshooting, monitoring and management to the service provider. Salesforce.com is another famous company offering Saas.

**Platform as a service (Paas):** In this model customer can use the Cloud platform to deploy, run, and build his own application in this case users are no more concerned about the scalability of provided platform components. Google with its (App-Engine) is an example of this sort of service. Microsoft windows azure is another Paas Cloud provider that makes clients to create and start their services on that platform. [8]

**Infrastructure as a service (Iaas):** In this model the service provider supply different types of infrastructures such as network, storage and computing to users. Afterwards they can install operating system, applications, upload or download software or files into the Cloud. Elasticity is not the responsibility of Cloud provider but is the user. Therefore its user in charge of defining requirements needed for his career. Amazon is a leader in Iass by its handy tool so-called elastic Cloud computing Cloud (EC2).

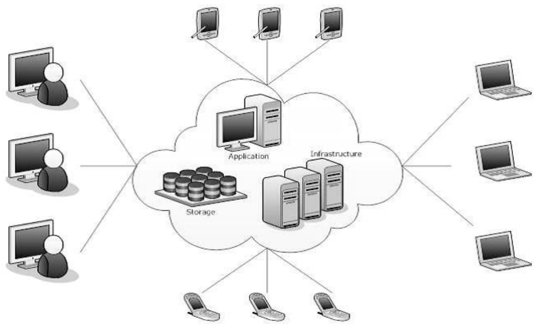


**Figure 1: Cloud service models**

### c) Cloud Deployment Models
Cloud can be categorized into four deployment models as follows: [1]
**Public Cloud:** It this model Cloud is disposable to public and all have access to its infrastructures.
**Private Cloud:** It is a model as Cloud services are limited to specific organization. Cloud provider can be organization itself or third party.
**Community Cloud:** It is model where Cloud infrastructures are shared among some organizations having same policies, issues like security. Cloud manager can be local organizations of external one.
**Hybrid Cloud:** Hybrid Cloud merges different Cloud models such as public, private or community. However they are identical models but they can collaborate with each other and create some useful techniques like load balancing. Hybrid Cloud can be the best applicable model as it adds up the advantages of its fundamental models.

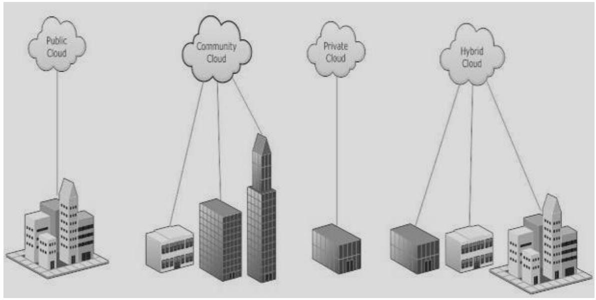


**Figure 2: Cloud deployment models**

IT businesses are free to elect Cloud model depending on their needs. Public Clouds provide rapid access to resources at low cost and suitable deployment for unpredictable and not frequently demands. On the other side private Clouds provide a platform for predictable and constant demand while delivering quality of service, security and enterprise class performance. To gain benefits of both public and private models, hybrid Cloud looks ideal as it enables portability between those in accordance with business requirements. Hybrid model has agility in response while supporting security, quality of service and control and performance. It hands over the right content at right place at right cost. Therefore hybrid Cloud seems the most economical model as it can reduce the cost up to 30% compared to legacy IT enterprises. This comes up with technologies such as virtualization, optimizing workload and rightsizing. Hybrid model is strategic because companies can deploy applications and adjust cost and service level agreement (SLA) according to their needs. [9]

### d) Cloud Computing Benefits
Here we mention some benefits of moving IT computing to Cloud: [10, 11, and 12]
**Time to Market:** Introducing and developing new services demanding new infrastructure is more efficient and faster through Cloud computing compare to traditional computing.
**Economics:** Without Cloud computing customer pays for everything including the required service while in case of using Cloud computing payment is done only for what he uses therefore is definitely more financial than the usual way.
**Flexibility:** Businesses are able to determine how much resources they need like storage and processing.
**Scalability:** Businesses are able to transition from processing a small quantity of data to large amount of data immediately without requiring extra requirement or buying additional devices.

**Simplicity:** Cloud computing makes it simple to connect IT staff to what they need easily at the lowest cost. Cloud Computing and Sustainability: Energy Efficiency Aspects

**Portability:** Cloud computing give the opportunity to businesses employees and users to access the computing resources remotely no matter where they are as soon as they have a web based access to Cloud, therefore this capability omit the geographical restrictions.

## II. ENERGY EFFICIENCY APPROACHES FOR CLOUD DATA CENTERS

As we mentioned before data centres are the most energy consumers inside the Cloud whereby they consume large amount of electrical power of Cloud, therefore decreasing energy consumption of Cloud data centre leads to a more sustainable and energy efficient Cloud computing. This chapter is an overview of effective approaches and aspects for energy efficient data centres. It will cover IT equipment, cooling systems (chillers, pumps and fans), air conditioning, power systems, and energy source. Energy consumption is classified into two categories as IT and site infrastructure where total amount of energy consumed in each is almost equal. Majority of energy consumed in site and IT infrastructure for cooling/air systems and powering servers respectively. Lighting has a very minor impact on energy usage compare to previous factors. [13]

This chapter talks about the energy efficient approaches for Cloud data centres at different levels with emphasize on data centre level. First of all, we need to have a comparison between traditional data centre and Cloud data centre to clarify whether it is beneficial to transit computing to a Cloud environment or not [14,15]

Traditional data center runs Thousands of different applications whereas Cloud data center does just by a few ones. It can be even one application running in data center like Facebook.

- Traditional data center is designed for complex and combined workload. On the other hand Cloud data center is operational for single workloads. But when a workload becomes optimized Cloud data center acts more efficiently and economically.
- Traditional data center uses multiple management tools as monitoring, testing or measuring services whereas Cloud data center has standard one.
- Traditional data center requires frequent maintenance such as software patching and updating, back up and system support. As opposed in Cloud data center service provider takes care of maintenance.
- Traditional data center holds several software architectures to offer different types of requests whereas Cloud data center uses single service oriented one to deliver every kind of request such as storage, software or network as a service.
- Traditional data center has heterogeneous hardware environment. In contrast Cloud data center uses homogenous hardware environment. It means it aggregates homogeneous resources to make them available to customers quicker than traditional data center can.
- Traditional data center suffer from limited capacity while Cloud data center is almost unlimited.
- Traditional data center is dedicated to single enterprise. In contradictory Cloud data centers is shared across multiple enterprises.
- Traditional data center can be mostly secure but Cloud data center is lacking from the top level of security.
- Traditional data center is fully controlled under enterprise surveillance nevertheless enterprises have partial control over Cloud data center.
- Traditional data center is proprietary and can be customized. Adversely Cloud data center is almost using standardized infrastructure.
- Traditional data center doesn't have economy of scale in case of enterprise expansion whereas Cloud data center has economy of scale when the number of enterprises increases.

It is quite clear that moving to the Cloud data centers is more cost effective and utilized than traditional one. It is simpler to organize and operate Cloud data centers. They are scalable as you gain lower cost per user if you expand Cloud data center.

There are many approaches regarding energy efficiency of Cloud datacentre at different levels such as hardware, operating system and data centre. Data centre level is the most important one and as a matter of fact addressing challenges about energy efficiency in this level sounds to be more complicated and comprehensive covering the other levels. [16]

Cloud computing gains energy efficiency naturally in following ways: [16]

- Scalability is economical due to redundancies removal.
- It enhances resource utilization.
- VMs can migrate to location having cheaper energy.
- Resources allocation is elastic depending on requirement.
- Cloud provider has efficient resource management.

In this part we try to survey some researches done on the operating system and data centre level of Cloud computing noticing that hardware level was discussed previously as DVFS and ACPI and sleep/standby modes. First we deal with operating system level and introduce some projects proposed as power management solutions in this level: [16]

**The Ondemand Governor :** OS adjusts the frequency and voltage based on the performance requirements by monitoring the CPU utilization level. It uses DVFS and the goal is minimizing power consumption and keeping good performance.

**ECOsystem:** The system calculates the required power. Then distribute that to applications according to their priorities. Afterwards application consumes the power by resource utilization and throttling method. The goal is reaching to battery lifetime on mobile systems.

**Nemesis OS :** In case of excess of threshold by applications in regard to their energy consumption, they must set their operation according to received signal from OS. Resource throttling is used here and the goal is getting to battery lifetime on mobile systems.

**GRACE :** Global, per application and internal are three levels of adaption which are coordinated to ensure effectiveness. Resource throttling and DVFS are used here and the goal is minimizing power and having acceptable performance.

**Linux/RK:** The system automatically chooses a unique DVFS out of four depending on the different system characteristics. DVFS is used as technique and the goal is minimizing power consumption and meeting good performance.

**Coda and Odyssey :** Coda signal application adaption via distributing a file to them whereas Odyssey does it allowing regulating the resource. Resource throttling is used here and the goal is minimizing energy consumption and application data degradation allowance.

**PowerNap:** It Leverages short sleep modes to utilize resources by using dynamically deactivating components of system. The goal is minimizing power consumption and satisfying performance.

## III. ENERGY EFFICIENT APPROACHES FOR NONE VIRTUALIZED CLOUD DATA CENTRES

**Load Balancing and Unbalancing for Power and Performance in Cluster-Based System :** The system keeps in mind acceptable performance; load monitoring is performed in specified intervals to shut down or on a system in order to achieve power consumption. Server power switching technique is used. The goal is minimizing power consumption and performance degradation.

**Managing Energy and Server Resources in Hosting Centres:** It concerns economy as system regulates the cost of a resource and usefulness of assigning that to a service to maximize profit. Recourses are marked by services from volume and quality point of view. There would be some servers elected to handle the service. Workload consolidation and server power switching is used as energy efficiency technique. The goal is minimizing power consumption and performance degradation.

**Energy Efficient Server Clusters :** The system predicts the amount of frequency needed to meet the reasonable response time. Afterwards it sub divides that to minor frequencies allocated to the number of nodes. Here a threshold determines when to turn on or off the nodes. Dynamic voltage frequency scaling and server power switching is used for this project. The goal is minimizing power consumption and meeting performance.

**Energy aware Consolidation for Cloud Computing :** Server's workload distribution is by means of heuristic for bin packing. If a request cannot serve, using the same heuristic another server powers on to handle the allocated requests. This Project uses server power switching and consolidation. The goal is minimizing power consumption and meeting performance.

## IV. ENERGY EFFICIENT APPROACHES FOR VIRTUALIZED CLOUD DATA CENTRES

**VirtualPower: Coordinated Power Management in Virtualized Enterprise Systems :**
Power management is being executed in two levels. At First level local policies for power management of VMs on physical server run whereas global policies are performed at the Cloud Computing and Sustainability: Energy Efficiency Aspects second level to coordinate the same responsibility among several physical servers, hence it should be aware of attributes and needs of racks. VM consolidation, DFVS, soft scaling, server power switching are techniques to save power. The goal of this approach is to minimize power usage while having expected performance.
Hint: soft scaling is hardware scaling emulation that uses the VMM scheduling ability to make VM have less time to utilize the resource.

**Coordinated Multi-level Power Management for the Data Center:** It is based on different power management trends treating dynamically across nodes to allocate power according to power budget. Server power switching, DVFS and VM consolidation are technologies helping this project. The goal is to meet power budget while considering performance and minimizing energy consumption.

**Resource Allocation using Virtual Clusters :** This research uses bin packing method to arrange request requirement for resources from most demanding to the least one. Resource throttling is its required technique in this project. Performance satisfaction and maximizing resource utilization are the goals.
Hint: Resource throttling is regulation of resources by means of algorithms.

**Multi-Tiered On-Demand Resource Scheduling for VM-Based Data Centre :** It happens in three scheduling levels: distributing requests across VMs at the application scheduler, depending on VMs priorities resources are allocated to VMs on a physical server at the local scheduler. Global level scheduler controls the flow of resource for applications. It uses resource throttling as energy saving method. Maximizing resource utilization and fulfilling acceptable performance are its goals.

**Shares and Utilities based Power Consolidation in Virtualized Server Environments :** Based upon a fact that quantity of resources allocated to a VM is specified and by use of a sharing technique the resources are distributed among VMs by Hypervisor. DFVS and soft scaling are energy efficient mechanisms and the goal is minimizing power consumption and meeting performance.

**Mapper: Power and Migration Cost Aware Application Placement in Virtualized Systems:** Three managers cooperate here, performance manager observes applications status and depending on SLA and resource requirements change the size of VMs. Migration manager is in charge of VMs live migration while power manager is responsible for DVFS and power states adjustment. Besides arbitrator decide for VMs migration and relocation of them. Server power switching, VM consolidation and DVFS are useful techniques here.

**Green Open Cloud: an Energy-aware framework for Clouds :** It works based on advanced reservation facility. This approach accumulates resource requests using negotiations to users and green offering to them thereby idle servers can turn off. Resources are monitored by energy sensors to help resource allocation efficiently. Server power switching and VM consolidation are used here. The goal is minimizing power consumption without degrading performance. It was forecasted that virtualized data centre approaches respond better rather than non-virtualized projects as they use one of the most energy efficient factors which is virtualization that uses server consolidation, resource provisioning and VM migration in addition to server power switching and DVFS to minimize power while satisfying performance [17][18].

## V.CONCLUSION

In this paper, we presented Cloud computing as a sustainable solution for IT businesses to deploy their applications upon that. Then we challenged issues regarding energy efficiency of Cloud computing as an important concern of IT industry to operate in a more sustainable manner from the aspects of economy and environment. Energy efficiency aspects were described in two parts. Data centre concluded to consume the largest amount of energy inside Cloud particularly in cooling and air conditioning equivalent to energy provided for servers to run services. Wide variety of techniques and approaches were introduced for IT and site infrastructure contributors to direct datacentre to a greener and economical design and deployment. A comparison between traditional data centre and Cloud data centre was proposed and recommended using Cloud data centre is more economical, scalable, and simpler to manage. We surveyed some approaches corresponding energy efficiency of Cloud data centres at different levels. Data centre level as an inclusive of hardware and operating system level was discussed in detailed at virtualized and non-virtualized level . Energy efficiency is not meant to be always reducing carbon footprint.

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