

Green Cloud Computing

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Abstract

Green computing is defined as the study and practice of designing, manufacturing, using, and disposing of computers, servers, and associated subsystems-such as monitors, printers, storage devices, and networking and communications systems-efficiently and effectively with minimal or no impact on the environment. The goal of green computing is to reduce the use of hazardous materials, maximize energy efficiency during the product's lifetime, and promote the recyclability of outdated products and factory waste. Green computing can be achieved by either Product Longevity Resource allocation or Virtualization or Power management. Power is the bottleneck of improving the system performance.

Power consumption is causing serious problems because of excessive heat. As circuit speed increases, power consumption grows. Data centers working with Cloud computing model have many applications that require on-demand resource provisioning and allocation in response to time-varying workloads that are statically allocated based on peak load characteristics, in order to maintain isolation and provide performance guarantees without paying much attention to energy consumption. Cloud service providers need to adopt measures to ensure that their profit margin is not dramatically reduced due to high energy costs. There is also increasing pressure from governments worldwide to reduce carbon footprints, which have a significant impact on climate change.

As energy costs are increasing, while availability dwindles, there is a need to shift focus from optimizing data center resource management for pure performance alone to optimizing for energy efficiency while maintaining high service level performance. In this research paper I will focus on these policies which enable us to cut down data centre

energy costs, thus leading to a strong, competitive cloud computing industry. End users will also benefit from the decreased energy bills.

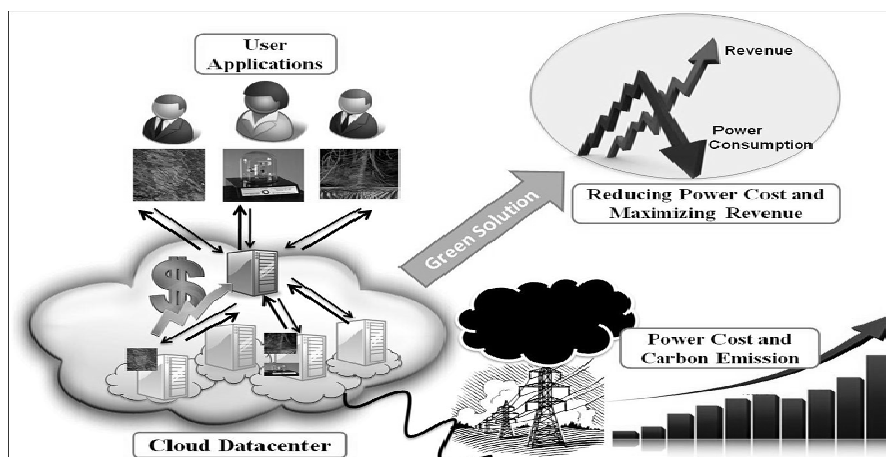
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1. Introduction

The depletion of fossil energy has become one of the major challenges for mankind to sustain the civilization. In addition, overindulgent energy consumption causes over emission of green-house gas, which, according to expert consensus, is a root cause for the current global warming. It is, therefore, vital for mankind to seek *green technologies*, i.e., technologies that can reduce energy consumption. As Internet has penetrated into our daily lives, cloud computing has emerged as a new kind of “utility” that gets delivered through wired or wireless networks. The increasing availability of high-speed Internet and corporate IP connections is enabling the delivery of new network-based services both to corporate and individual end users generically called “cloud computing” services.

The cloud computing service model involves the provision, by a service provider, of large pools of high performance computing resources and high-capacity storage devices that are shared among end users as required. To be successful, the cloud service model also requires a high-speed network to provide connection between the end user and the service provider’s infrastructure.

Cloud computing potentially offers an overall financial benefit, in that end users share a large, centrally managed pool of storage and computing resources, rather than owning and managing their own systems. Cloud service providers invest in the necessary infrastructure and management systems, and in return receive a time-based or usage-based fee from end users. Energy consumption and carbon emission by Cloud infrastructures has become a key environmental concern.



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2. Cloud Computing Deployment Models

Cloud computing is a paradigm of offering on-demand services to end-users. The Cloud deployments are classified into three types: Public Cloud, Private Cloud and Hybrid Cloud.

2.1 Public Cloud

A public cloud is hosted on the internet and designed to be used by any user with an internet connection to provide services. The famous public clouds are Amazon Web Services (AWS), Google AppEngine, and Microsoft Azure. In this deployment, Cloud services are made available to the public in a pay-as-you-go-manner. A public cloud can offer any of the three kinds of services: IaaS, PaaS and SaaS. For example, Amazon EC2 is a public cloud providing infrastructure as a service, Google AppEngine is a public Cloud providing an application development platform as a service, and Salesforce.com is a public cloud providing Software as a Service. The main characteristics of public clouds are its multitenancy, quality of service and security.

2.2 Private Cloud

A Private cloud is hosted within an enterprise, behind its firewall, and intended only to be used by that enterprise by investing and managing its own cloud infrastructure, but gains benefits from pooling a smaller number of centrally maintained high-performance computing and storage resources instead of deploying large number of lower performance systems. The private cloud services offer greater control over the infrastructure, improving security and services resilience because its access is restricted to one or few organizations.

2.3 Hybrid Cloud

Hybrid Clouds is the deployment which emerged due to diffusion of both public and private clouds' advantages. In this model, organizations outsource non-critical information processing to the public cloud, while keeping critical services and data in their control.

Three cloud computing services are considered, including storage as a service, processing as a service, and software as a service. Storage as a service allows users to store data in the cloud. Processing as a service gives users the ability to outsource selected computationally intensive tasks to the cloud. Software as a service combines these two services and allows users to outsource all their computing to the cloud and use only a very-low-processing-power terminal at home.

3. Cloud Service Models

3.1 Software as a Service

Consumer software is purchased with a fixed upfront payment for a license and a copy of the software on appropriate media. This software license typically only permits the user to install the software on one computer. When a major update is applied to the

software and a new version is released, users are required to make a further payment to use the new version of the software. Users can continue to use an older version, but once a new version of software has been released, support for older versions is often significantly reduced and updates are infrequent.

Software developers are trying to provide Software as a Service, clients are charged a monthly or yearly fee for access to the latest version of software. The software is hosted in the cloud and all computation is performed in the cloud. The client's PC is only used to transmit commands and receive results. Typically, users are free to use any computer connected to the Internet. One example of software as a service is Google Docs. In this scenario, data storage and processing is always performed in the cloud and we are thus able to significantly reduce the functionality, and consequently, the power consumption, of the client's PC.

3.2 Storage as a Service

In storage as a service, users can outsource their data storage requirements to the cloud. All processing is performed on the user's PC, which may have only a solid state drive, and the user's primary data storage is in the cloud. Files stored in the cloud can be accessed from any computer with an Internet connection at any time. For modifying any file it must first be downloaded, edited using the user's PC and then the modified file uploaded back to the cloud. One example of storage as a service is the Amazon Simple Storage Service.

3.3 Processing as a Service

Processing as a service provides users with the resources of a powerful server for specific large computational tasks which are uploaded to the cloud, processed in the cloud, and the results are returned to the user. The processing service can be accessed from any computer connected to the Internet. One example of processing as a service is the Amazon Elastic Compute Cloud service.

4. Features of Clouds Enabling Green Computing

Cloud Infrastructure has become a key environmental concern keeping in view of energy consumption and carbon emission. The key driver technology for energy efficient Clouds is "Virtualization", 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.

The following are the four key factors that have enabled the Cloud Computing to lower energy usage and carbon emissions from ICT. In this way, organizations can reduce carbon emissions by at least 30% per user by moving their applications to the cloud.

4.1 Dynamic Provisioning

In traditional settings, IT companies end up deploying far more infrastructure than needed. It is very difficult to predict the demand at a time and to guarantee availability

of services and to maintain certain level of service quality to end users. 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.

4.2 Multi-tenancy

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, which can minimize the need for extra infrastructure. The smaller fluctuation in demand results in better prediction and results in greater energy savings.

4.3 Server 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%. Even though high utilization of servers results in more power consumption, server running at higher utilization can process more workload with similar power usage.

4.4 Datacentre Efficiency

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 Power Usage Effectiveness (PUE) of their datacenters. 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. Green Cloud Architecture

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 green 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 to make their service clean by keeping track of overall energy usage of serving a user request. It relies on two main components, Carbon Emission Directory and Green Cloud offers. 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.

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. Platforms itself can be designed to have various code level optimizations which can cooperate with underlying compiler in energy efficient execution of applications.

IaaS level: Providers in this layer plays most crucial role in the success of whole Green Architecture. 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. 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.

6. Conclusion

The management of power consumption in data centres has led to a number of substantial improvements in energy efficiency. Cloud computing infrastructure is housed in data centres and has benefited significantly from these advances. Techniques such as sleep scheduling and virtualization of computing resources in cloud computing data centres improve the energy efficiency of cloud computing.

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