Green Cloud Computing: Balancing and Minimization of Energy Consumption

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Abstract -Cloud computing focuses on maximizing the effectiveness of the shared resources. The cloud model enables customers to access, from any computer connected to the internet (whether a desktop PC or a mobile device), a multitude of IT services rather than being limited to using locally installed software and being dependent on the storage capacity of their local computer network. This model of IT service provision is one that is growing exponentially. It is estimated that one third of all revenue generated in the software market today relates to the delivery of cloud computing services, and that the value of the UK cloud computing market could reach around £10.5 billion in 2014, up from £6 billion in 2010. Clouds can be classified as public, private or hybrid. Cloud computing is come forth as a new prototype of large-scale distributed computing. It is a model for enabling convenient, on-demand network access to a shared pool of computing resources. As cloud computing becomes more widespread, however, the development demands of Cloud infrastructure has drastically increased the energy expenditure of data centers, which turn into a decisive issue. High energy expenditure not only translates to high functional cost, which reduces the net profit margin of Cloud providers, but also extends to high carbon emissions which cause environmental damage. Hence, it is mandatory to find energy-efficient solutions to minimize the affect of Cloud computing on the environment. This is happening at a time when there is increasing attention being paid to the need to manage energy consumption across the entire information and communications technology (ICT) sector. There has been less attention paid to the energy expenditure of the transmission and switching networks that are key to connecting users to the cloud. In this paper, we present an analysis of energy consumption in cloud computing and how we can minimize the carbon emission. The analysis considers both public and private clouds, and includes energy consumption in switching and transmission as well as data processing and data storage. We show that energy consumption in conveyance and switching can be a significant percentage of total energy consumption in cloud computing. Cloud computing can enable more energy-efficient use of computing power, especially when the computing tasks are of low intensity or infrequent.

***Keywords* – Cloud computing, Energy efficiency, Green cloud computing, Energy consumption, public cloud, private cloud, hybrid cloud.**

I. INTRODUCTION

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. Cloud computing consists of three different types of service provision. In each case the services are hosted remotely and accessed over a network (usually the internet) through a customer's web browser, rather than being installed locally on a customer's computer. Firstly, SaaS (software as a service) refers to the provision of software applications in the cloud. Secondly, PaaS (platform as a service) refers to the provision of services that enable customers to deploy, in the cloud, applications created using programming languages and tools supported by the supplier. Thirdly, IaaS (infrastructure as a service) refers to services providing computer processing power, storage space and network capacity, which enable customers to run arbitrary software (including operating systems and applications) in the cloud. These three elements are together referred to as the

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cloud computing 'stack'. In cloud, the machines are running for providing web services and these machines also consumes some amount of energy for working. The cloud computing which focuses on reduction or minimization of energy consumption is known as Green Cloud computing. In data center, the physical machines emit heat and harmful gases. The green cloud computing can also be used for e-waste management. The reduction of energy consumption can be controlled on two basis: one is hardware and other is software. For controlling energy consumption on hardware basis, the hardware devices are used and likewise on software devices by using program and algorithms. The energy consumption controlled at software level is easy to maintain and less expensive. These techniques have to be implemented only once and used for data centers. In this paper we are using algorithm for minimizing the energy consumption. Cloud has virtual machines and machine has number of jobs for execution. There is a need for proper job scheduling because if there are three processes such as P1, P2 and P3. The amount of energy consumed by process P2 is less than the amount of energy consumed by P1 and the amount of energy consumed by P3 is less than P2 but if we follow FCFS (First Come First Serve) algorithm then P2 can't execute before completion of P1 and P3 can't execute before completion of P2. This method consumes much more energy when waiting. We have to reduce the waiting energy.

II. CLOUD COMPUTING DEPLOYMENT MODELS

Clouds are deployed on physical infrastructure where Cloud middleware is implemented for delivering service to customers. Such an infrastructure and middleware differ in their services, administrative domain and access to users. Therefore, the Cloud environment is subdivided into: Public Cloud, Private Cloud, Hybrid Cloud and community cloud.

a. Public Cloud:

Public Cloud is the most common deployment model where services are available to anyone on Internet. In public cloud a business rents the capability and pays for what is used on demand. The fundamental characteristic of public Clouds is its multi-tenancy, which is essentially achieved using sophisticated virtualization at various level of the software stack. Being public Clouds, Quality of Service and security are the main issues that need to be ensured in their management. Thus, a significant portion of the software infrastructure is devoted to monitor Cloud resources, to bill them according to the contract made with the user, and to keep a complete history of the Cloud usage for each customer.

b. Private Cloud:

Private Cloud is essentially a private network used by one customer for whom data security and privacy is usually the primary concern. The downside of this type of cloud is that the customer will have to bear the significant cost of setting up and then maintaining the network alone.

c. Hybrid Cloud:

Hybrid Clouds is the deployment which emerged due to diffusion of both public and private Clouds" advantages. Hybrid cloud environments are often used where a customer has requirements for a mix of dedicated server and cloud hosting, for example if some of the data that is being stored is of a very sensitive nature. In such circumstances the organization may choose to store some data on its dedicated server and less sensitive data in the cloud. Another common reason for using hybrid clouds is where an organization needs more processing power than is available in-house and obtains the extra requirement in the cloud. This is referred to as 'cloud bursting'. Additionally, hybrid cloud environments are often found in situations where a customer is moving from an entirely private to an entirely public cloud setup.

d. Community Cloud:

Community clouds usually exist where a limited number of customers with similar IT requirements share an infrastructure provided by a single supplier. The costs of the services are spread between the customers so this model is better, from an economic point of view, than a single tenant arrangement. Although the cost savings are likely to be greater in a public cloud environment, community cloud users generally benefit from greater security and privacy, which may be important for policy reasons.

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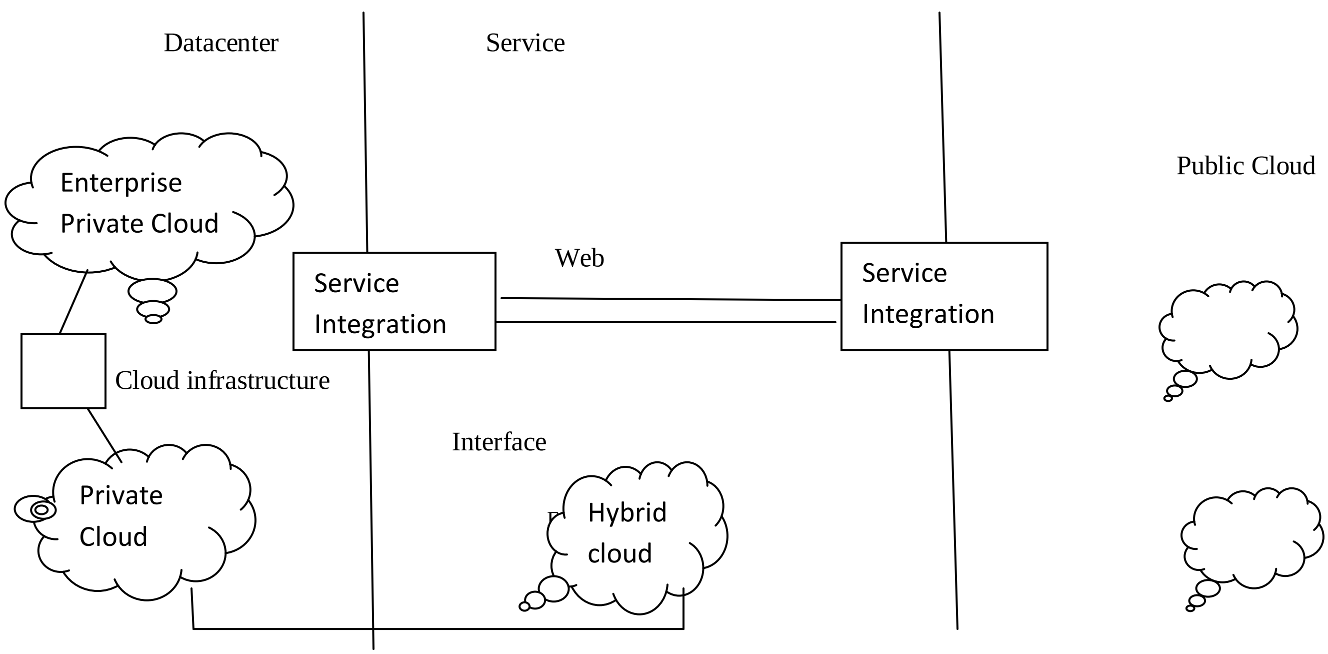

Fig 1. Private, public and hybrid cloud

III. Green Cloud Computing Architecture

From the above study of current efforts in making Cloud computing energy efficient, it shows that even though researchers have made various components of Cloud efficient in terms of power and performance, still they lack a unified picture. Most of efforts for sustainability of Cloud computing have missed the network contribution. If the file sizes are quite large, network will become a major contributor to energy consumption; thus it will be greener to run application locally than in Clouds. Furthermore, many work focused on just particular component of Cloud computing while neglecting effect of other, which may not result in overall energy efficiency. For example, VM consolidation may reduce number of active servers but it will put excessive load on few servers where heat distribution can become a major issue. Some other works just focus on redistribution of workload to support energy efficient cooling without considering the effect of virtualization. In addition, Cloud providers, being profit oriented, are looking for solutions which can reduce the power consumption and thus, carbon emission without hurting their market. Therefore, we provide a unified solution to enable Green Cloud computing. We propose a Green Cloud framework, which takes into account these goals of provider while curbing the energy consumption of Clouds. The high level view of the green Cloud architecture is given in Figure 2. The goal of this architecture is to make Cloud green from both user and provider's perspective.

In the Green Cloud architecture, users submit their Cloud service requests through a new middleware Green Broker that manages the selection of the greenest Cloud provider to serve the user's request. A user service request can be of three types i.e., software, platform or infrastructure. The Cloud providers can register their services in the form of

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„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 data centre 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.

- SaaS Level: SaaS providers mainly offer software installed in their own datacenters or resources leased from IaaS providers. Therefore, they require Power Capping component to limit the usage of software services by each user. This is especially important for social networking and game applications where users become completely unaware of their actions on environmental sustainability. SaaS providers can also offer Green Software Services deployed on carbon efficient datacenters with less replications.
- PaaS Level: PaaS providers in general offer platform services for application development and their deployment. Thus, to ensure energy efficient development of applications, relevant components such as Green Compiler to compile applications with the minimum carbon footprint and carbon measuring tools for users to monitor the carbon footprint of their applications.
- IaaS level: IaaS providers play the most crucial role in the success of Green Cloud Architecture since IaaS not only offers independent infrastructure services, but also support other services (SaaS and PaaS) offered by Clouds. They use the latest technologies for IT and cooling systems to have the most energy efficient infrastructure. By using virtualization and consolidation, the energy consumption is further reduced by switching off unutilized servers. Energy and Temperature Sensors are installed to calculate the current energy efficiency of each IaaS provider and their data centres. This information is advertised regularly by Cloud providers in the Carbon Emission Directory. Various green scheduling and resource provisioning policies will ensure minimum energy usage. In addition, IaaS providers can design attractive 'Green Offers' and pricing schemes providing incentives for users to use their services during off-peak or maximum energy efficiency hours.

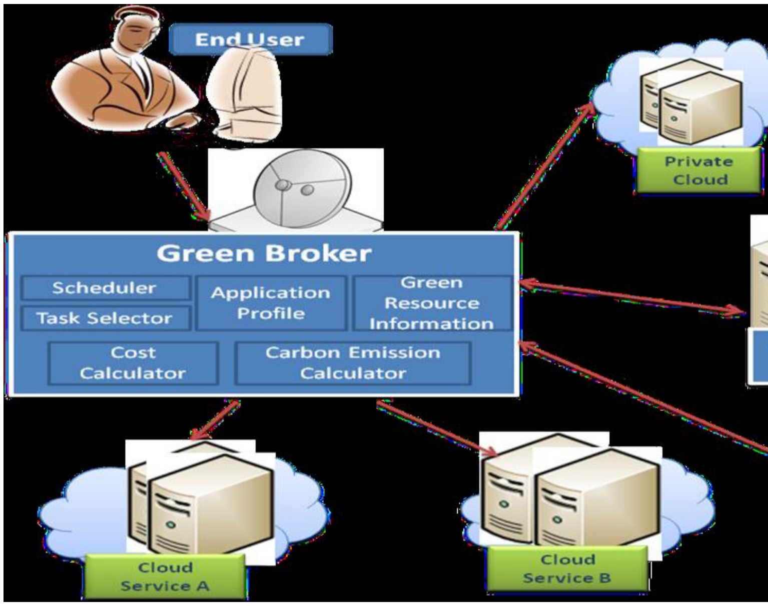

Fig. 2 Green cloud Infrastructure

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IV. Carbon Efficient Green Policy (CEGP)

We develop Carbon Efficient Green Policy (CEGP) for Green Broker to periodically select the Cloud provider with the minimum carbon footprint and initiate VMs to run the jobs (Algorithm 1). Based on user requests at each scheduling interval, Green Broker obtains information from Carbon Emission Directory about the current CO2 emission related parameters of providers. The QoS requirements of a job j is defined in a tuple
(dj;nj;ejfmj), where dj is the deadline to complete job j,nj is the number of CPUs required for job execution, andejis the job execution time when operating at the CPU frequency f^{m}_{j}.
CEGP then sorts the incoming jobs based on Earliest Deadline First (EDF), before sorting the Cloud datacenters based on their carbon footprint. CEGP schedule jobs to IaaS Clouds in a greedy manner to reduce the overall CO2 emission. For IaaS providers, CEGP uses three main factors to calculate the CO2 emission: CO_2 emission rate, DCiE, and CPU power efficiency. The carbon footprint of an IaaS Cloud is given by: $\mathbf{r_i^{Co}{}_{2\,*\,1/}I\,e\,f\,f_{\,i\,*\,1/}V\,M\,f\,f_i}$ where VMeffi can be calculated by Cloud providers based on the proportion of resources on a server utilized by the VM using tools such as Power Meter].If a VM consumes the power equivalent to a processor running at Fi frequency

1. while current time < next schedule time **do**
2. RecvCloudPublish(P);
   //P contains information of Cloud datacenters
3. RecvJobQoS(Q);
   //Q contains information of Cloud users
4. Sort jobs in ascending order of deadline;
5. Sort datacenters in ascending order of
   $\mathbf{r_i^{Co}{}_{2\,*\,1/}I\,e\,f\,f_{\,i\,*\,1/}V\,M\,f\,f_i}$
6. Foreach job j RecvJobQoS **do**
7. foreach datacenter i RecvCloudPublish
8. if is Initiated VM(i) **then**
9. if MaxIniVMlimitReached(i) **then**
10. Try to schedule the job j on already initiated VMs;
11. If job j is missing deadline **then**
12. continue;
13. break;
14. else
15. Initiate VM(i) and schedule job j;
16. break;

Algorithm 1. Carbon Efficient Green Policy (CEGP)

V. Less Energy consumption Methods

In data centers, if the physical machines consume more energy, these resources will also emit heat and harmful gases. This problem can be minimized by Green Cloud computing which provides the eco-friendly environment. The Green cloud computing reduces the energy consumption and also save energy.

A. Virtualization and Cooling technique

Another solution for greening the data centers is virtualization and cooling technique. First is cooling system which minimizes the energy consumption. Various companies uses river water for data center's cooling, open air data centers, air-conditioned system etc. This system is expensive and not efficient for minimizing energy consumption. Second is virtualization technique in which more than one virtual machine loaded on a single physical machine. The virtualization technique provides the abstraction because the internal working hidden from the user. The user only accesses the web services and does not aware about the virtual machines. The virtualization techniques realize that a single physical machine is provided to the single user. This reduces the energy consumption because of single physical machine running. But performance can be degraded; the reason behind the performance degradation is a unbalanced load. Third is nano data center technique which specifies that the large number of small sized data centers should be geographically distributed. Traditional data centers are of large size and few data

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centers are distributed and this technique consumes more energy because of long distance of data transmission. This nano data center technique reduces the energy consumption because of the short distance between client and data center. These all techniques are used for greening the data centers.

B. Energy management in public and private cloud

In cloud environment there are two basic clouds first is public cloud and second is private cloud. Public cloud is accessible from any user through internet but private cloud is only accessible by the particular organization. The analysis of energy consumption is performed on basic web services such as storage as a service, software as a service and processing as a service. Storage as a service provides a service in which user can store their data on cloud not on their personal machine. There is no need to buy any storage device such as hard disk, but the users have to pay according to the usage of the storage devices on cloud. Software as a service provides the latest software to the user through cloud for developing their own applications easily. Processing as a service is used for performing the computations on user's data and after all operations the result is provided to the user. There are various energy consumption models which consumes energy. First, user equipments such as processor, memory, display unit etc. these devices consumes energy but at user side. Second, data center consumes energy because there are number of devices used for providing the services to the users. The energy consumption can be reduced by consolidating the servers but for consolidation the servers which are idle and have no task to perform can be turned off. In this method the load is distributed to the few servers and performance can be degraded. This process requires more attention. The energy consumption analysis is performed on three web services such as storage as a service, software as a service and processing as a service. In case of storage as a service, the user creates their file and store on cloud. After some time if user wants to edit this file then the user must download the file form cloud and after providing the modifications again upload the file on cloud. This process consumes more energy because of uploading and downloading the files on cloud**.**

C. Job Scheduling

In, scheduler schedules the tasks by determining the temperature of the task and node. The tasks are generated by Task Generation System. This system determines the temperature of the task by specifying the parameters such as initial temperature of the task, per minute rise in temperature and execution time of the task. This specification is given manually. After determining the temperature of the task then the prediction method is used for determining the temperature of the node. This prediction method uses two parameters: 1) task specification and 2) energy consumption. In this scheduler FCFS (First Come First Serve) algorithm and priority algorithm is used for scheduling. The priority algorithm schedules tasks according to the temperature of the task and node. The task, which requires low temperature, has high priority and the high temperature task have low priority. In this algorithm, one additional parameter is used for comparison which is a critical temperature and if any task requires temperature up to critical temperature then this task will not be executed, otherwise system gets failure. System performance should not be impacted while energy consumption is being minimized. Power aware virtual machine scheduling is another technique for reduction of energy consumption. The virtual machines are scheduled according the power consumed by the virtual machines. This scheduling is provided for minimizing the performance overheads but with energy efficiency. But this technique does not providing the greenest data center which is the main aim of green cloud computing. The job grouping is another technique for efficient energy consumption. Jobs are scheduled according to the resource capability. Before the scheduling process, calculate the capability of each resource by selecting them. After calculating the capability resources then allocate the jobs to the resources according their capability. This scheduling technique is basically used for load balancing but with minimum reduction of energy consumption. In, the jobs are grouped together on the basis of similar resource requirement. This scheduling technique concentrates only on

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efficient resource management but with minimal reduction of energy consumption. This reduction is provided by reducing the waiting energy of the jobs.

VI. Conclusion

In this paper, we present a Carbon Aware Green Cloud Architecture to improve the carbon footprint of Cloud Computing taking into account its global view. Our architecture is designed such that it provides incentives to both users and providers to utilize and deliver the most “Green” services respectively. Therefore, it embeds components such as Green broker from user side to ensure the execution of their applications with the minimum carbon footprint. Similarly, from provider side, we propose features for next generation Cloud providers who will publish the carbon footprint of their services in public directories and provide ‘Green Offers’ to minimize their overall energy consumption. We also propose a Carbon Efficient Green Policy (CEGP) for Green broker which schedules user application workload with urgent deadline on Cloud data centres with more energy efficiency and low carbon footprint.

- 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 behaviour 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 tradeoffs can be managed.
- To enable the green Cloud data centres, the Cloud providers need to understand and measure existing data centre power and cooling designs, power consumptions of servers and their cooling requirements, and equipment resource utilization to achieve maximum efficiency. In addition, modelling tools are required to measure the energy usage of all the components and services of Cloud, from user PC to data centre where Cloud services are hosted.
- For designing the holistic solutions in the scheduling and resource provisioning of applications within the data centre, 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 data centre, also raises the issue related to necessary redundancy and placement geo-diversity required to be maintained to fulfil 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.
- 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 data centres near renewable energy sources and maximize the Green energy usage in their already established data centres. Before adding new technologies such as virtualization, proper analysis of overhead should be done real benefit in terms of energy efficiency.

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BIOGRAPHY

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